A STUDY OF SEX/AGE RATIOS IN WILD UNGULATE POPULATIONS - AN APPROACH TO DESIGNING AN APPROPRIATE SAMPLING STRATEGY FOR ESTIMATING THE STRUCTURE OF WILD UNGULATE POPULATIONS ON ROOIPOORT NATURE RESERVE.

Sarah-Jane Laubscher

Thesis presented in partial fulfilment of the requirements for the degree of Master of Science at the University of Stellenbosch

Supervisors:

Prof. H.J. van Hensbergen and Dr M.P.S. Berry

March 2000

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DECLARATION

I, the undersigned, hereby declare the work contained in this thesis is my own original work and that I have not previously in its entirety or in part submitted it at any university for a degree.

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ABSTRACT:

A STUDY OF THE SEX/AGE RATIOS IN WILD UNGULATE POPULATIONS - AN APPROACH TO DESIGNING AN APPROPRIATE SAMPLING STRATEGY FOR ESTIMATING THE STRUCTURE OF WILD UNGULATE POPULATIONS ON ROOIPOORT NATURE RESERVE.

This thesis investigates the population structure of a number of ungulate species occurring within Rooipoort private reserve. Specifically the study serves to make estimates of the ratio of males to females and calves to cows within each species population under observation, based on the data collected.

Data were also analysed to ascertain the distribution patterns of the species in question, in relation to vegetation type and habitat. Distribution data were additionally compared to distribution data collected at an earlier period on Rooipoort, to determine whether any change has occurred in distribution patterns of the ungulates concerned.

Through analysis of both sex/age data and distributional data, one of the main objectives of the study was to determine the most appropriate time of the year, length of time and managment costs involved to undertake sex/age counts on Rooipoort. Results of the study were also compared to existing population models of ungulates on the reserve.

Results obtained from data concluded that a single monthly sex/age count or, in some cases, even three consecutive monthly counts, to determine age ratios, would be insufficient to deliver a reliable estimate of population structure. A number of counts would have to be carried out throughout the year in order to make reliable estimates. Distribution data revealed that all habitat/vegetation types on Rooipoort would have to be covered in order to effectively sample all of the species in question.

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OPSOMMING

N' STUDIE VAN GESLAGS/OUDERDOM VERHOUDINGS IN HOEFDIER BEVOLKINGS – N' BENADERING NA DIE ONTWERPING VAN N' MONSTER STRATEGIE OM DIE STRUKTUUR VAN WILD HOEFDIER BEVOLKINGS TE BEPAAL OP ROOIPOORT PRIVAAT RESERVAAT

Die tesis ondersoek die bevolkings struktuur van n' aantal hoefdierspesies wat op Rooipoort privaat reservaat voorkom. Hierdie studie se spesefieke doelwit was om beramings van die verhoudings van mannetjie: wyfie en kalf: koei in elke spesiebevolking te maak.

Gegewens is ook ontleed om die verspreidingspatrone van hoefdiersoorte te bepaal met betrekking tot plantegroeitipe en habitat. Die verspreidingsdata is ook vergelyk met vorige studies wat op Rooipoort gedoen is om te bepaal of enige veranderings in die verpreidingspatrone van die hoefdiere onder bespreking plaasgevind het.

Een van die hoof doelwitte van die studie was om, deur ontleding van beide die geslags/ouderdom data en die verspreidingsdata, die mees geskikte tye van die jaar, die tydsduur en bestuurskoste te bepaal, om geslags/ouderdomstellings op Rooipoort uit te voer. Resultate van die studie is ook met vertroude populasiemodelle op die reservaat vergelyk.

Die dataontledings het aangedui dat 'n enkele maandlikse geslags/ouderdoms telling, of , in sekere gevalle, selfs drie agtereenvolgende maandlikse tellings, om ouderdomsverhoudings te bepaal, nie voldoende sal wees om 'n vertroubare beraming van die bevolkings struktuur te maak. n' Aantal tellings moet gedurende die yaar uitgevoer word om vertroubare beramings te kan doen. Verspreidingsdata het bevestig dat alle habitate en plantegroeitipes op Rooipoort bemonster moet word om alle spesie effektief te bemonster.

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CONTENTS **PAGE**

DECLARATION i

ABSTRACT iii

ACKNOWLEDGEMENTS iv

SECTION 1: INTRODUCTION

1.1. Objectives of study 1
1.2 Literature review 2

1.2.1. The relevance of sex/age ratios in wildlife management 2
1.2.2. Sex/age counts 3
1.2.3. Sampling 10

SECTION 2: STUDY AREA

2.1. Location and Area 16
2.2. Climate 16
2.3. Geology 18
2.4. Vegetation 21
2.5. Herbivore species 29
2.6. Historical background 31

SECTION 3: MATERIALS AND METHODS

3.1. Introduction 33
3.2. Sampling method 33
3.3. Sampling procedure 33
3.4. Data 37
3.5. Statistical data analysis 39

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SECTION 4: SEX/AGE RATIO ESTIMATES FOR UNGULATES ON ROOIPOORT 40

4.1. Introduction 40

4.2. Results from individual species sex/age counts on Rooipoort 42

SECTION 5: RESULTS 68

5.1. Effect of seasonal conditions on the present distribution of wild ungulates on Rooipoort 68

5.1.1 Overall Seasonal Distribution 68

5.1.2. Individual species distribution patterns in the 1997 to 1998 period 74

5.2. Comparisons between overall, seasonal and individual ungulate species distribution patterns in the presents study period (1997 to 1998) and those from the period of 1982 to 1984 (Mark Berry) on Rooipoort 90

5.2.1. Analysis of distribution data using correspondence analysis 90

5.2.2. The use of Shannon and Simpson indices to give an indication of Species niche width 91

5.2.3. Comparisons between overall yearly and seasonal distribution patterns on Rooipoort 92

5.2.4. Comparisons between individual species distribution patterns 95

5.2.5. Discussion of results of variance- and multiple range analysis 109

SECTION 6: MANAGEMENT RECOMMENDATION FOR POPULATION MONITORING

6.1. Introduction 110

6.2. Discussion 111

6.2.1. Discussion of sex/age ratio results 111

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6.2.2. Discussion of ungulate distribution results 113

6.3. Conclusion and management recommendations 115

6.3.1. Estimated expenditure of the study in terms of fuel consumption and labour 117

REFERENCES 121

APPENDIX A: Sex/age classification and previously recorded sex/age ratios 130

APPENDIX B: Sex/age ratio Data 145

APPENDIX C: Species Distribution Data 164

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SECTION 1

INTRODUCTION

1.1. OBJECTIVES OF THE STUDY:

The objective of the study is to determine an appropriate cost-effective sampling regime for Rooipoort, in order to determine the population structure of certain of the larger ungulate species occurring within the reserve.

An annual census is conducted, in February/March of each year, to determine the population size of each of the large ungulate species occurring within the reserve. These censuses do not, however, give an indication of population structure.

In recent years, sex/age counts have been carried out once a year. The timing of these counts, however, has varied considerably, and although they give some indication of composition, it is difficult to compare results of counts from one year to the next, due to the differences in the timing of counts.

The study will be used to determine the most appropriate time(s) of the year to conduct a sex/age count(s), the number of counts required to obtain an accurate estimate, the most appropriate method, and the costs involved.

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1.2. LITERATURE REVIEW:

1.2.1. The relevance of sex/age ratios in wildlife management:

A population usually contains individuals of a range of different ages and both sexes. In order to study a population, its age structure must be determined, as must its rate of growth or decline. The relative proportions of the two sexes must also be determined. A study of the population structure as a whole involves the study of both its age and its sex structure. A prerequisite for the study of population structure is the identification and definition of those age and sex categories which can be distinguished (Bigalke, 1968).

It is rarely possible to determine the structure of an entire population and usually the structure of a sample must be determined, the results of which are extrapolated to the whole population.

Sex and age ratios of a population of animals are one of the most common statistics collected for the management of wildlife populations. These statistics provide information on productivity and mortality rates (Gilbert 1978) and are sometimes used to determine population size (Samuel *et al.* 1992) using the change-in-ratio method (Paulik & Robson, 1969), and are also useful in indicating population density (Dasmann & Taber, 1956). Sex ratio values may also be used to assess the effects of sport hunting (Bowden *et al.* 1984) or to determine the potential harvest of animals. By grouping animals into age classes, determining ratios and graphic presentation of the results, some understanding of population dynamics can be gained.

According to Caughley (1974) the age ratios, provided in papers on wildlife populations, are seldom interpreted. Also, the reasons for the collection and explanations of what they reveal about a population is usually left unsatisfied by the author (Caughley, 1974). Caughley (1974) proceeds to determine what age ratios reveal about the dynamics, as opposed to the statistic's, of a population. He uses population models to examine the effect on age ratios of abruptly changing the rate of increase. The fecundity and survival schedules of a simulated population with stationary age distribution and zero rate of

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increase are modified in four ways to effect rapid increase in numbers. Age ratios are monitored across the demographic change.

Results from longer-lived animals indicated that although the four increasing populations grew at about the same rate, the trends of their age ratios were very different. A change in survival affecting all age classes equally has no effect on the age distribution, and a manager using only age ratios to monitor a population, would be unaware of large population fluctuations if a massive increase or decrease in numbers was brought about by a general change in rate of survival (Caughley, 1974).

Not only can a massive increase or decrease in numbers go completely unnoticed by monitoring of only age ratios, but the same change in rate of increase can produce quite different age-ratio trends according to how increase was brought about (Caughley, 1974).

Caughley (1974) concludes that only when age ratios are supported by estimates of rate of increase and of survival or fecundity can they be interpreted critically. Age ratios are not adequate substitutes for accurate estimates of relative or absolute density from which rate of increase can be measured, but can be used in the calculation of this rate (Caughley, 1974).

1.2.2. Sex/age counts:

The most commonly used method for determining relative numbers of males, females and juveniles in a population of wild animals is a 3-category count. Such counts classify individuals as adult males, adult females, or juveniles, and are often taken as the basis for estimations of reproductive success. A major problem arising with such classification is that the female category is comprised of both adult and sub-adults, which are usually difficult to differentiate. Because the sub-adult component is usually non-productive, such a method often results in incorrect inferences regarding the reproductive performance of an animal population (Dasmann & Taber 1959).

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To avoid such error it is therefore necessary to distinguish between adults and sub-adults, resulting in a 5-category (Dasmann & Taber. 1959) or 3-age-class (Hanson 1963) herd composition, the categories being: adult males, sub-adult males, adult females, sub-adult females and juveniles. Hanson (1963) defines juveniles as those individuals less than 1 year old, sub-adults are 1 to 2 years old with the majority of their cohort not having reached sexual maturity, and adults as those individuals that have reached sexual maturity.

In order to acquire reliable estimates of sex and age composition for a population, 2 major problems must be overcome:

1) How to accurately identify the sex and age classes, and
2) how to obtain a representative sample of the population.

Some of the most general characteristics of a good sample, according to Simpson *et al.* (1960) are as follows: "The ideal representation of a population is a sample that is homogenous, adequate and unbiased, three requirements that mean:

1) All individual observations in a sample belong to a single defined population,
2) these observations include all the essential variations within a population, and
3) these variations occur in the sample with about the same relative frequency as in the population.

The more nearly a sample meets these 3 requirements the better it is and the more reliable are the inferences based on it."

To fulfil the second and third requirement, the sample must be random and fairly large. A random sample is one in which each animal (or group of animals) has the same probability of being counted. It is important to realise that behaviour is often a major source of bias in sampling mammal populations (Downing *et al.* 1977). Bias is likely to occur because of the complexity of the dispersion of individuals within a population, due to the difference in social organisation of these sex and age classes at different times of the year (Bigalke 1968).

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Differential visibility may occur between individuals of many ungulate species for a number of reasons. Different sized groups may be more easily visible and animals may be segregated according to different sex or age classes. Different habitats may also influence visibility (Gasaway *et al.* 1985) as may observers, weather conditions, equipment and sampling methods (Samuel *et al.* 1992). The resultant visibility bias must be taken into account and incorporated into sex/age ratio estimates (Samuel *et al.* 1992). It is important to sample in such a way that all animals in a population have an equal probability of being classified (Connolly, 1981), but unfortunately this is not always possible. The accuracy of sex/age ratio estimates may be greatly improved by selecting an appropriate season for carrying out counts. Downing *et al.* (1977) showed that seasonal observability in white-tailed deer (*Odocoileus virginianus*) might have dramatic influence on the accuracy of age and sex ratio estimates. Many deer workers in the Western United States consider the rut to be the optimum time to conduct sex/age counts (Leopold *et al.* 1951). During this time, however, adult males are usually active and conspicuous and family groups tend to be disorganised. The result is that counts tend to favour males and under-estimate juveniles. According to Dasmann and Taber (1959), counts are most accurate during the seasons when deer are found in family groups and no single class is unusually conspicuous or retiring.

Because social animals usually occur in groups (Samuel *et al.* 1992), and the age or sex composition of individuals within the groups is unlikely to be randomly distributed, it is believed that groups are the smallest sampling unit appropriate for wildlife surveys. Making the assumption that all groups have equal sampling probabilities will produce biased estimates and variances when differential observability of age or sex classes exists (Samuel *et al.* 1992).

Classification may be further affected by weather and time of day. Dasmann and Taber (1956) found that early morning sunlight on clear days gave excellent visibility, not only because of the air being relatively free of dust, but also because light from the sun was reflected from an animals coat directly back to observer, causing the animal to stand out conspicuously. Strong winds may cause deer (Dasmann & Taber, 1956) to seek sheltered areas, and unless such locations are visible from the observation point, calm days are

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preferable for observations, whereas overcast or rainy conditions were seen to result in restricted visibility (Dasmann & Taber, 1956).

The maximum range at which classifications can be made, on any given day, should not exceed the distance at which the antlers (Dasmann & Taber, 1956) (or horns) of a yearling can be distinguished. Undisturbed deer (Dasmann & Taber, 1956) which may be observed long enough to re-check first judgements, are seen to be classified more accurately than disturbed deer, which may not remain in sight long enough for re-examination (Dasmann & Taber, 1956).

In many cases one cannot be sure that data is reliable, in spite of precautions taken in collecting it. Increasing the sample size or the number of sample counts carried out, will help to minimise this sampling error. In order to determine whether or not results are in fact erroneous, one can compare observed sex/age ratios with expected ratios for each species.

1.2.2.1. Characteristics used to distinguish between different sex and age classes in the field:

Dasmann and Taber found that the principal objection to using the five category sex/age counts is that yearlings cannot be distinguished from adults with adequate accuracy. They discovered, nevertheless, various characteristics within each category, which served to separate classes successfully. Distinguishing criteria are size, conformation, coloration, and behaviour (Dasmann & Taber, 1956) (See Table 1.1. & Appendix A: section 1).

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TABLE 1.1. : CHARACTERISTICS USED IN THE STUDY FOR THE CLASSIFICATION OF DIFFERENT SEX AND AGE CLASSES IN UNGULATE SPECIES ON ROOIPOORT

SPECIES	CHARACTERISTICS FOR CLASSIFYING AGE CLASSES	CHARACTERSITICS FOR CLASSIFYING SEX CLASSES
BLACK WILDEBEEST	Coat colouration: juveniles have fawn-coloured coats Horns: the horns of juveniles rise straight up from the head and only start to curve at about 1 year of age.	Body size: the female is smaller and lighter than male Horns: horns of the female are thinner and less robust than those of the bull. Boss: the mature bull can be distinguished from the cow by the 'boss' formed from the horn base, over the top of its head.
BLESBOK	Body size: calves are much smaller in stature than adults or subadults Colouration : calves are a pale fawn to creamy colour Horns : calves can be distinguished from adults and subadults by their horn shape and size.	Body size: females are smaller and lighter than males Horns: those of the female are more slender than those of males and hardly thicked at the base The ridges of horns are also more prominent in males. Colouration: the ram has a darker coat colour than the female Neck thickness: the neck of the ram is thicker than the ewe's. Penal sheath: present in the ram
BLUE WILDEBEEST	Body size: calves are much smaller in stature than adults or subadults Colouration : very young individuals are fawn coloured all over, with a a darker face and dark stripe along the back. Horns: horn shape and size can be used to distinguish between different age classes.	Body size: females are smaller and lighter than males Colouration : males are almost black in colour whereas females are more brown in colouration. Horns: those of the cow are less robust than the bull's

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TABLE 1.1: Continued

ELAND	Body size: calves are much smaller in stature than adults or subadults Dewlap: older bulls typically develop a large dewlap on the throat Horns: horn shape and size can be used to distinguish between calves and adults.	Body size: Males are much larger and heavier than females Horns: those of the males are much heavier than those of the female and have a very prominent spiral ridge. Hair: adult bulls develop a patch of fairly long, dark, coarse hair on the forehead.
GEMSBOK	Colouration: newly born are fawn coloured or reddish brown. This is replaced in 4 to 6 months by adult pelage. Horns: horn size can be used to distinguish between different age classes.	Body size: females are slightly lighter than males Horns : those of the females are lighter than the males, but longer. Those of the males are shorter and thicker.
HARTEBEEST	Body size: calves are much smaller in stature than both adults and subadults. Colouration: calves are much lighter in colour than adults Horns: shape and size of horns can be used to differentiate between different age classes.	Body size: females are slightly smaller than males Colouration: adult males have a saddle of darker colouration than the rest of the body, which is less obvious in females. Horns: those of the male are heavier in build than the female's.
KUDU	Horns: in males, the horns can be used to differentiate between different age classes Body size: can be used to differntiate between calves, subadults and adult animals	Body size: the females are distinctly smaller than males Horns: horns are absent in the females Hair: the bull has a prominent mane from the neck to beyond the shoulders, and also a fringe on the throat and lower neck.
SPRINGBOK	Horns: the shape and size of horns can be used to differentiate between different age classes	Body size: males are slightly heavier than females. Horns: the female's are distinctly smaller and thinner than the male's Those of the male are also more heavily ridged.

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TABLE 1.1.: Continued

WARTHOG:	Body size: sucklings are generally much smaller than yearlings, which themselves are shorter and have a more slender build than adults.	Body size: females are slightly smaller and lighter than males Facial warts: males have two pairs of these, whereas females only have one pair Tusks: in old adult females the tusks curl over the top of the snout more than in the males.
ZEBRA	Body height: shoulder height can be used to differentiate between foals and yearling individuals (which may have reached adult body height). Subadults are lighter in stature than adults.	Because zebra lack sexual dimorphic characteristics such as horns, pelage differences, or a constantly visible penis sheath, differntiation between the sexes is often difficult. The only differentiating characteristics than are apparent are: Neck: the adult stallion has greater muscular development in the neck region than the female. The shape of the perineal region: In the stallion, the black perineal skin forms a long thin band running from the anus to the scrotum. In the mare, the same a is widened by the vulva, which gives the area totally different shape when viewed from the r This are is, however, not always easily viewed. especially in herds that are moving.

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No method applicable in the field will yield complete accuracy. Abnormal individuals, such as horned does or fawns born out of season introduce a certain amount of error. Additional error is introduced by mis-classification of normal animals (Dasmann & Taber, 1956).

1.2.2.2. Previously recorded sex, age and population ratios in wild ungulate species:

Many ungulate populations in tropical and temperate habitats have adult sex ratios biased toward females. In several African species, this bias has been ascribed to greater predation on males (Owen-Smith, 1982) (See Table 1.2. for summary data of previously recorded sex/age and population ratios in wild ungulate populations, and Appendix A: section 2).

1.2.3. Sampling:

Sampling consists of selecting some part of a population to observe, so that one may estimate something about the population as a whole (Thompson, 1992). In the basic sampling set-up, the population consists of a known, and finite number of N units (animals, etc.). A value (sometimes called a y-value) of a variable of interest is associated with each unit, and this value is viewed as a fixed, if unknown, quantity - not a random variable. The units in a population are identifiable and may be labelled with numbers $1,2,\ldots,N$.

The data collected in the sampling procedure consists of the y-value for each unit in the sample, together with the unit's label. The procedure by which the sample of units is selected from the population is called the sampling design.

The usual inference problem in sampling is to estimate some summary characteristic of the population, such as the mean or the total of the y-values, after observing only a

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TABLE 1.2.: SEX/AGE RATIOS PREVIOUSLY RECORDED IN WILD UNGULATE SPECIES

SPECIES	ADULT SEX RATIO (SAMPLE SIZE)	CALF SEX RATIO (SAMPLE SIZE)	REPROD. RATE	LOCATION	REFERENCE
BLACK WILDEBEEST		1 male:1 female		Pretoria Zoo	Brand (1963)
	1 male: 1.37 females	1 male:2.40 females	72.9 to 85.7 %	South Africa (S.A. Lombard NR)	Von Richter (1971b)
	1 male: 1.67 females		79.1 to 79.7 %	South Africa (Willem Pretorius GR)	Von Richter (1971)
	1 male: 0.79 females			South Africa (Giants Castle NR)	Von Richter (1971b)
	1 male: 0.87 females		76.9 to 92.8 %	Coleford NR	Von Richter (1971b)
	1 male: 1.09 females			South Africa (E.Cape, Mt Zebra NP)	Mentis (1972)
			84.20%	South Africa (E.Cape, Mt Zebra NP)	Von Richter (1971b)
BLESBOK		1 male: 1.12 females		Pretoria Zoo (Pretoria)	Brand (1963)
		1 male: 1.08 females		South Africa (Percy Fyfe NR)	Kettlitz (1967)
	1 male: 0.70 females to (10 year period)				
	1 male: 3.33 females			S. Africa (Rietvlei)	Du Plessis (1972)
	1 male:1 female (bontebok)			S. Africa (Bontebok NP, W. Cape)	David (1969)
BLUE WILDEBEEST	1 male: 1.57 females			Namibia (Etosha)	Berry (1981)
	1 male: 1.49 females			S. Africa (Zululand)	Atwell (1982)
	1 male: 2.60 females			S. Africa (Kruger NP))	Braack (1973)
		1 male: 1.07 females		Kenya (Serengeti)	Berry (1981)
		1 male: 1.17 females		Namibia (Etosha)	Berry (1981)
	1 male: 0.93 females	1 male: 0.52 females		Western Masailand	Talbot & Talbot (1963)
			96%	Kenya (Serengeti)	Watson (1969)
ELAND		1 male: 0.74 females		Pretoria Zoo	Brand (1963)
		1 male: 1.61 females		S. Africa (Loteni NR, Natal)	Stainthorpe (1972)
	1 male: 0.16 females			Kenya (Nairobi NP)	Mentis (1972)
	1 male: 3.02 females			S. Africa (Natal)	Natal Pks. Board
GEMSBOK		1 male: 1.14 females		Albuquerque zoo	Roth & Bowman (1967)
	1 male: 3.22 females			Namibia (Kalahari Gemsbok NP)	Mentis (1972)
					Mentis (1972)
HARTEBEEST	1 male: 2.20 females			S. Africa (Willem Pretorius NR)	Kok (1975)
KUDU	1 male: 1.60 females	1 male: 0.66 females		Zimbabwe (Rhodesia)	Simpson (1968)
	1 male: 2.40 females			Zimbabwe (Rhodesia)	Wilson (1965)
	1 male: 2.22 females	1 male: 0.70 females		Zambia (Northern Rhodesia)	
			19%	S. Africa (Agricultural areas)	Du Plessis (1986)
			11%	S. Africa (Andries Vosloo Kudu Reserve)	Allen-Rowlandson (1980)
	1 male: 1.50 females			S. Africa (Zululand)	Mentis (1970)
	1 male: 2.59 females			S. Africa (Loskop Dam NR)	Underwood (1978)

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TABLE 1.2. Continued...

SPRINGBOK		1 male: 1 female		Fairall et al (1990)
		1 male: 1.15 females	Pretoria Zoo	Brand (1963)
	1 male: 2.00 females		Etosha and Kruger NPs (S. Africa & Namibia)	
	1 male: 1.86 females		Botswana (Nxai Pan)	Bednekoff & Ritter (1997)
	1 male: 1.60 females		S. Africa (Rooipoort, N. Cape)	Crowe & Liversidge (1978)
	1 male: 1.18 females		S. Africa (Bontebok N.P., W. Cape)	David (1987)
	1 male: 1.01 females		S. Africa (SA Lombard NR)	Skinner et al (1971)
	1 male: 0.75 females		S. Africa (Mt Zebra NP, E. Cape)	Penzhorn (1974)
WARTHOG		1 male: 0.81 females	Chobe NP	Child (1968)
	1 male: 1.12 females		Nagupande	Mentis (1970)
	1 male: 2.13 females,			
	1 male: 0.90 females,			
	1 male: 2.12 females		Zimbabwe (Rhodesia)	Dasmann & Mossman (1962)
ZEBRA		1 male: 1.18 females	East Africa	Klingel (1965)
		1 male: 1 female	S. Africa (Kruger NP)	Smuts (1976)
	1 male: 3.32 females		Kenya (Nairobi National Park)	Foster & Kearney (1967)
	1 male: 1.22 females		S. Africa (Umfolozi NP, Natal)	Mentis (1970)

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sample. In addition to this, in most sampling and estimation situations, one would like to be able to assess the accuracy or confidence associated with the estimate; this assessment is very often expressed with a confidence interval (Thompson, 1992).

The uncertainty of estimates obtained by sampling stems from the fact that only a portion of the population is observed. While the population characteristic remains fixed, its estimate depends on which sample is selected. If, for every possible sample, the estimate is quite close to the true value of the population characteristic, then there is little uncertainty associated with the sampling strategy. It is possible, using a suitable sampling design and estimation method, to obtain estimates that are unbiased for population quantities. An unbiased estimate is one that has an expected value, over all possible samples that might be selected, equal to the actual population value. In addition to this, the random selection of samples removes the recognised and unrecognised human sources of bias. A probability design such as simple random sampling can thus provide unbiased estimates of the population mean or total and also an unbiased estimate of variability, which is used to assess the reliability of the survey result (Thompson, 1992).

A problem faced by all investigators contemplating sampling is whether to locate samples in a random or a systematic manner. In random sampling, the location of each unit/plot is independently determined, while in systematic sampling the location of each sample is subject to the placement of the initial plot (Bergerud, 1968). In a spatial setting, a systematic sample primary unit may be composed of a collection of plots in a grid pattern over the entire study area (Thompson, 1992).

Randomised sampling has the distinct advantage in that an estimation of the precision of the mean can be secured and confidence levels calculated between estimates from different habitats, years and populations. Random sampling is, however, frequently impractical as more work and cost may be involved in moving between random plots than travelling systematic routes. Additionally, systematic sampling can provide more representative results per sampling intensity if the animals show a clumped distribution (Bergerud, 1963).

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Most sampling schemes make the assumption that observations are independent. Essentially this means that the probability of a specific animal being included in a sample should not be affected by the fact that another specified animal has already been included. For highly social animals, however, this is unlikely and if one group member is in a sample, other group members will be as well. Such a violation of basic assumptions may result in a biased estimate, or at least a decrease in precision of estimates (Van Hensbergen & White, 1993).

Unless a knowledge of the actual number of animals of each species occurring within a reserve, is required, it is preferable to make precise, rather than accurate counts. An accurate count is one that gives an estimate very close to the actual number of animals present in an area. With the assumption of constant bias, precise counts give the same results on a number of different sampling occasions, whether they under- or overestimate animal numbers (Bothma, 1995).

Through precise estimates, one is able to obtain reliable information on the tendencies of a species population. Most managerial and ecological problems can be addressed by looking at tendencies, determined by precise counts of constant bias (Bothma, 1995).

A fairly recent approach to parameter estimation is based on resampling the sample (Manly, 1991). The sample of size n is considered to be an accurate representation of the population, and many further samples of size n are drawn from the sample, with replacement (Van Hensbergen & White, 1993). The mean and the variance of parameter estimates derived from replications are used as estimates for the population. This method has been used to estimate sex ratios in clumped populations (Zucchini & van Hensbergen, 1986), to estimate population size (Minta & Mangel, 1989) and for the estimation of variance in sample size in line transect estimation (Buckland *et al*, 1993; Van Hensbergen & White, 1993).

The Bootstrap (Efron, 1982) and jackknife methods are two commonly used resampling methods of parameter estimation (Thompson, 1992). The jackknife

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estimate (Quenouille, 1949), is obtained by systematically deleting one transect at a time from the sample. $X(i)$ is the estimate obtained from the n - 1 remaining transects in the sample after deleting the ith transect. For each of the n jackknife samples, each consisting of n - 1 transects, the whole process of making a pooled estimate of the parameter of interest, is repeated (Thompson, 1992).

The bootstrap (Efron, 1982) is conceptually the simplest of all resampling techniques. For this method, the sample of n transects is treated as a population itself. A bootstrap sample is obtained by selecting n of these transects from the sample, with replacement, and a bootstrap estimate is computed from the bootstrap sample. Note that the bootstrap sample may differ from the original sample because of the with-replacement sampling. The procedure is repeated to obtain M independent bootstrap values.

A simple point estimate of some parameter of interest, however, does not contain sufficient information to help a decision-maker. An estimate has no value without knowing how precise our estimate of that parameter is (Van Hensbergen & White, 1993).

Having selected a sample and used the sample data to make an estimate of the population mean or total, it is desirable, therefore, in addition, to make an assessment regarding the precision of the estimate. Constructing a confidence interval within which one is sufficiently sure that the true population parameter value lies most often does this. A confidence interval procedure uses the data to determine an interval with the property - that viewed before the sample is selected - the interval has a given "high" probability of containing the true population value (Thompson, 1992).

Under simple random sampling, a 95 % confidence interval procedure has the interpretation that for 95 % of the possible samples of size n, the interval covers the true value of the parameter (Thompson, 1992).

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SECTION 2:

STUDY AREA:

2.1. LOCATION AND AREA

Rooipoort is a privately owned reserve in the Northern Cape Province of South Africa, and is situated approximately 60 km west of Kimberley (28 40'S, 24 10'E) on the R64. The Vaal River forms the western border of the reserve for about 29 km. Rooipoort is approximately 42 500 ha in extent, making it one of the largest privately owned game reserves in Southern Africa.

The reserve has been divided into two main areas; the Waterkolk area, situated to the north-east of the reserve, and the Rooipoort area which consists of approximately 34 500 ha of land.

2.2. CLIMATE

Rooipoort is characterised as having a semi-arid climate with a late-summer rainfall, winters being typically dry and cold.

Rain occurs mainly in the summer months, with the wettest months being January through March. There is a tendency towards either dry years or wet years rather than "normal" years (See Fig. 2.1 (a)).

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Figure 2.1. (a):

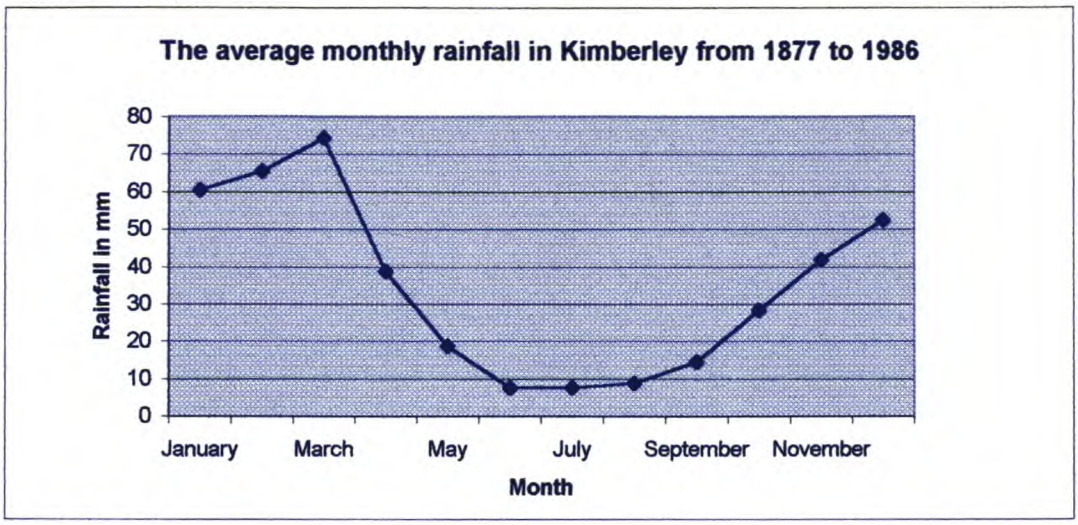


Figure 2.1. (b):

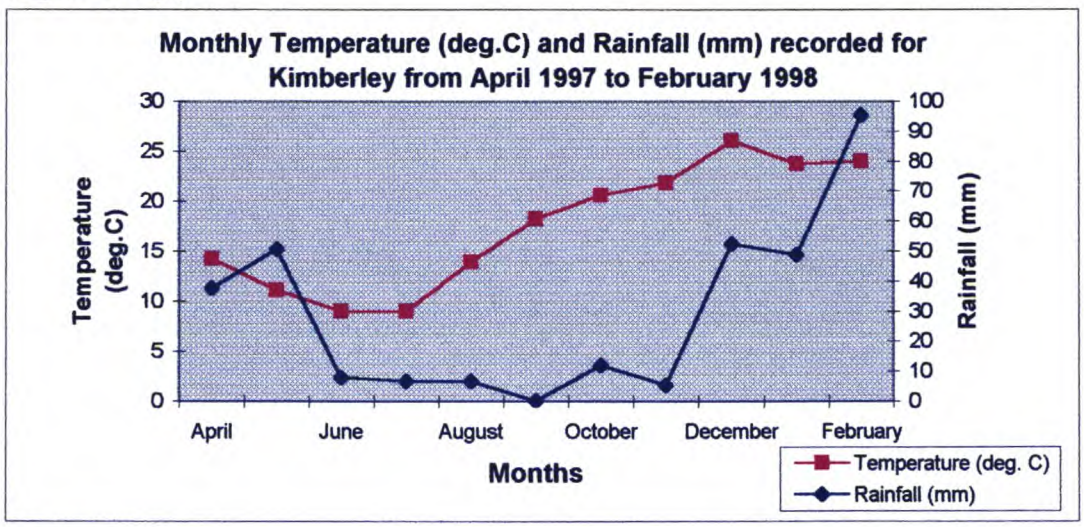
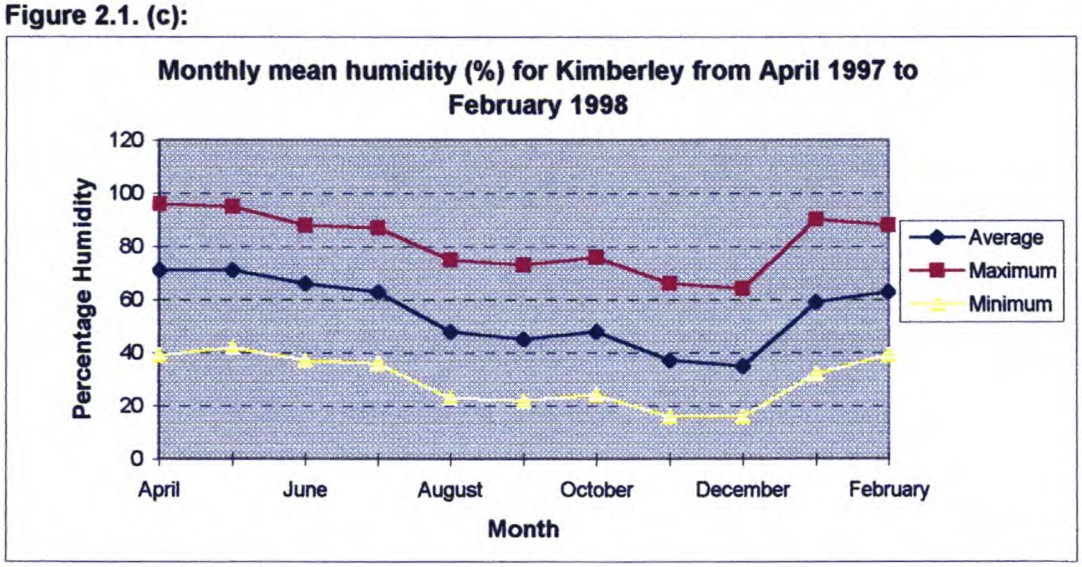


Figure 2.1. (c):



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Kimberley is subject to large seasonal fluctuations in temperature. Summers are generally hot with maximum temperature often exceeding 35 °C. The winters are cold often with sub-zero minimum temperatures (See Fig. 2.1. (b) and (c)).

2.3. GEOLOGY

Rooipoort lies at the base and to the east of the Ghaap plateau. The geological map of the area can be seen in Figure 2.2. As indicated on the map, the area of Rooipoort is underlain by several geological formations/types. These are labelled on the map as Qc, Qs, Ra, Vv, and C-pd (Geological Survey, Map: 2824 Kimberley) (Bosch, 1993) (See Fig. 2.2), and a brief description of each is given below.

a) Qc : calcrete, calcified pandune and surface limestone:

The geology of these areas is of the Quaternary period. The surface calcrete occurs as irregular layers and bodies on low lying areas and in cracks in the mudstone, shale, tillite, dolerite, dolomite and limestone, Ventersdorp lava and alluvial gravels. Calcrete is grey-white, light-grey- or cream coloured and three types can be distinguished in the area.

Calcified pandune reaches an average thickness of 3 m. Tuber-like calcrete underlies the calcified pandune in places.

This geological type underlies most of the "Calcrete savanna" areas of Rooipoort.

b) Qs : Sand - red and grey aeolian dune sand:

This geological type is also of the Quaternary period. Sand is mostly blown in from the Kalahari and is to a lesser degree from local origin. The colour of the sand varies from red/brown to grey. The red colour is ascribed to the precipitate of iron-oxides occurring in the quartz granules and/or in the cracks in the quartz granules. Adjacent

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to pans and floodplains, the ironoxides around the sand grains have been absorbed and a greater percentage of limestone is present. As a result of this, the sand is lighter in colour.

This geology type underlies the "Sandveld grassland" and "Sandveld savanna" areas of Rooipoort.

c) **Ra : andesite, in places amygdaloidal and/or porphorytic, quartzite and conglomerate lens near the bottom:**

This geological type is of the Allenridge formation in the Platteberg Group, which itself belongs to the Ventersdorp Supergroup. The Allanridge formation consists mainly of andesitic lava with outliers of dolomite and makes up the greatest outcrop area (up to 90 % of the Ventersdorp Supergroup). There are also several low ridges of quartzite to be found. The outcrop forms fairly prominent hills and a rugged hilly landscape.

This geology typically underlies all of the "koppieveld" areas of Rooipoort.

d) **Vv : Siltstone shale, quartzite, gritstone and conglomerate:**

This geological type is in the Boomplaas member of the Schmidtsdrift Formation of the Griqualand West sequence.

The typical formation of the Boomplaas member is dark, manganese rich dolomite with a thickness of 2.75 m at the base, followed by siltstone of 2.1 m (pavestone type) with three thin lenses of grey-white quartzite; middlegrain, mangenese-rich dolomite of 1.5 m; and siltstone of 1.2 m. A prominent layer of medium-grained, dark-grey dolomite with giant stromalites follows the siltstone later. Single dark-green shale layers occur between the layers of dolomite at the base.

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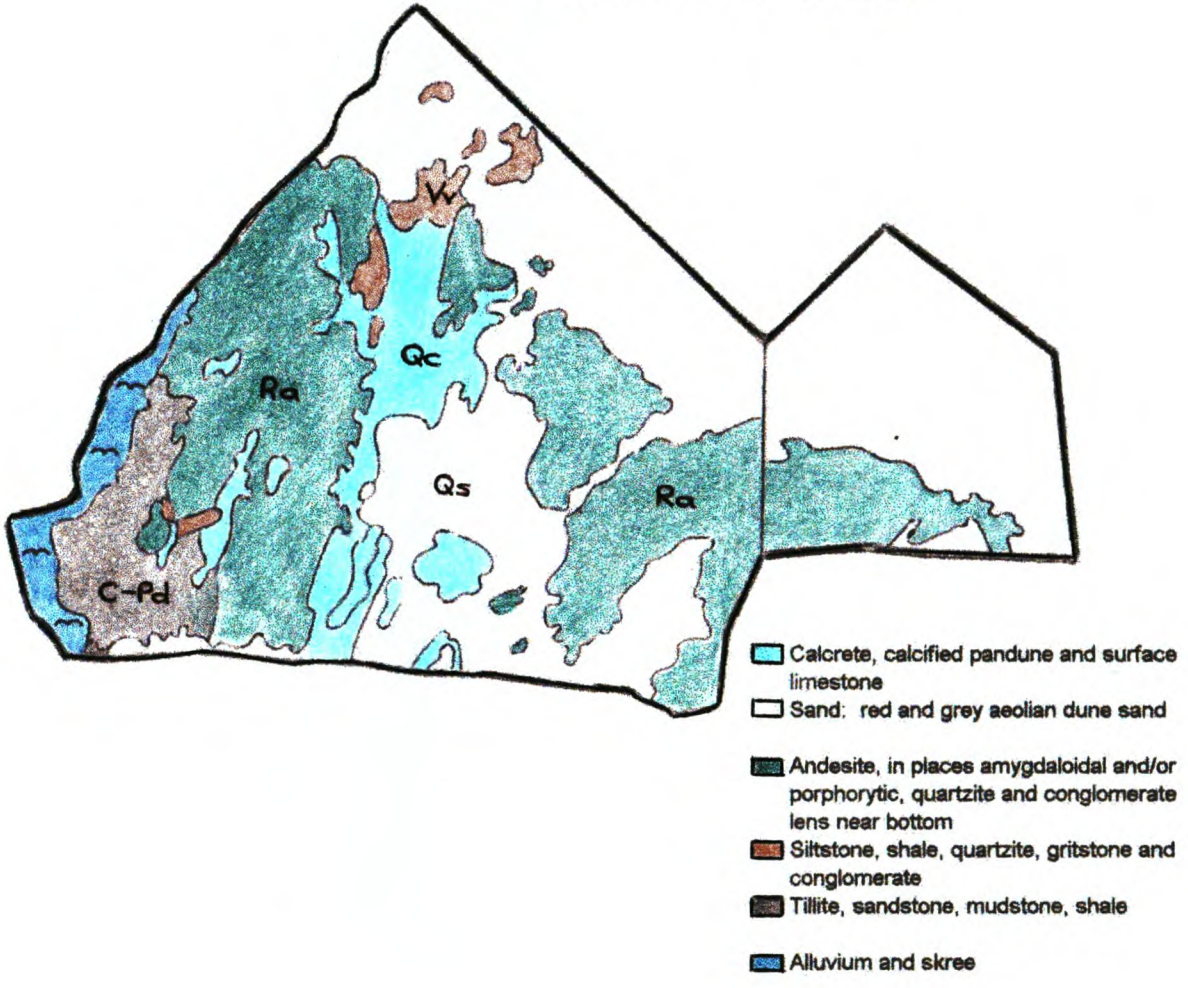
Figure 2.2. : GEOLOGICAL MAP OF ROOIPOORT



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e) C-pd: Tillite, sandstone, mudstone and shale:

This is a member of the Dwyka group in the Karoo Sequence. In general, the Dwyka group consists of massive areas of tillite at the base, and in places thin-layered tillite. This is followed by erratic shale containing interbedded fluvioglacial deposits and erratic shale that gradually proceeds into shale of the Prince Albert Formation. Rhythmites and rhythmitic shale is developed in places at the top of the Dwyka Group. The tillite shows considerable variation in appearance over short distances. The thickness of the rock formation varies from only a fraction of a metre, to single metres.

f) Alluvium and Scree:

Alluvium occurs along the banks of the Vaalriver on Rooipoort and consists of a mixture of sand, clay and silt. It can reach a thickness of 10 m. On the surface of the alluvium there is often a thin layer of surface limestone.

This geology, together with the previous; C-Pd type, underlies the "High-Lying Alluvial vegetation" type on Rooipoort.

2.4 VEGETATION

The reserve falls broadly within the False Orange River Broken Veld (40), with patches of Kalahari Thornveld invaded by Karoo (17) vegetation types (Acocks 1975). It is said to embrace 11 major vegetation types (Bigalke & Leistner, 1962; Bigalke unpublished report, 1974) which encompass or comprise many of the available habitats in the northern Cape Province (See Table 2.1. and Fig 2.3.).

Crowe *et al.* (1981) and Berry and Crowe (1985) have also classified the area according to habitat types. Both of these classifications identify 4 major habitat types on the reserve.

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2.4.1. Vegetation Classes of Bigalke and Leistner (1962):

i) Riverine Vegetation:

Three main habitats can be distinguished within the riverine vegetation. These are:

a) The lower banks, including the waters edge with hygrophylous communities. The vegetation consists mainly of perennial grass and *Cyperaceae*.

b) The gallery forest, of trees and shrubs, but little undergrowth, and

c) The flood plains, with a fairly open vegetation and few trees and shrubs. It is characterised by *Salsola glabrescens* and *Pentzia* species.

ii) Vegetation of the high-lying alluvial deposits:

Bigalke and Leistner (1962) describe this as the most diversified vegetation type, consisting of a heterogeneous mosaic of communities on a fairly uniform substrate. The vegetation shows signs of considerable disturbance in past times. Some of the communities are consequently considered to be of a secondary nature.

The vegetation is essentially open and *Rhigozum trichotomum* is the characteristic shrub, found in more or less circular patches. Clearings within this vegetation support varied plant communities. In their most severe form, patches of bare ground (in some areas with a gravel pavement) are not uncommon.

iii) Sandveld - Perennial grassveld:

Perennial grasses are the dominant plants in this vegetation type. Locally, shrubs, principally *Grewia flava* and occasionally *Tarchonanthus camphoratus* and *Rhus ciliata* and in some areas *Acacia giraffae* trees, are co-dominant.

The most common perennial grasses are *Eragrostis lehmanniana*, *Schmidtia pappophoroides* and *Eragrostis pallens*. The latter grass is characteristic of this vegetation type, and confined to it.

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iv) Sandveld - Annual grassveld:

This vegetation type comprises a flat area of sparse, open vegetation on red loamy sand. It shows signs of severe disturbance in the past, the most probable cause being overgrazing or even cultivation. The annual grassveld is in some ways a transitional vegetation between the perennial grass sandveld and the riverine alluvium.

Trees and shrubs are virtually absent here, but there are stunted *Acacia tortilis* and *heteracantha* shrubs in some areas.

The dominant grasses are annuals and weak perennials with *Aristida barbicollis* being the most common species.

v) Sandveld - Tarchonanthus savanna:

In a sense, this vegetation type is an intermediate between the perennial grassveld occurring on deep sand, and Tarchonanthus savanna on Calcrete. It differs from the former, in that it occurs in shallow sands and the presence of a sand layer overlying the subsurface calcrete, distinguishes it from the latter.

This vegetation is a bush savanna dominated by *Tarchonanthus camphoratus*, growing about 2 m high. *Acacia tortilis*, subspecies *heteracantha*, is co-dominant in certain areas, and *Grewia flava* is a common species. Other important shrubs include *Rhus ciliata*, which is locally abundant, often occurring in circular communities, *Acacia mellifera, subsp. detinens*, *Ehretia rigida* and *Diospyros lycoides*.

vi) Clearings in sandveld:

This is a fairly heterogeneous vegetation category and includes several fairly small areas of markedly open vegetation. Clearings are differentiated from calcrete clearings largely because one or other of the types of sandveld vegetation surrounds them and they have more soil than calcrete clearings. They are also much richer in grasses. Clearings are all somewhat low-lying.

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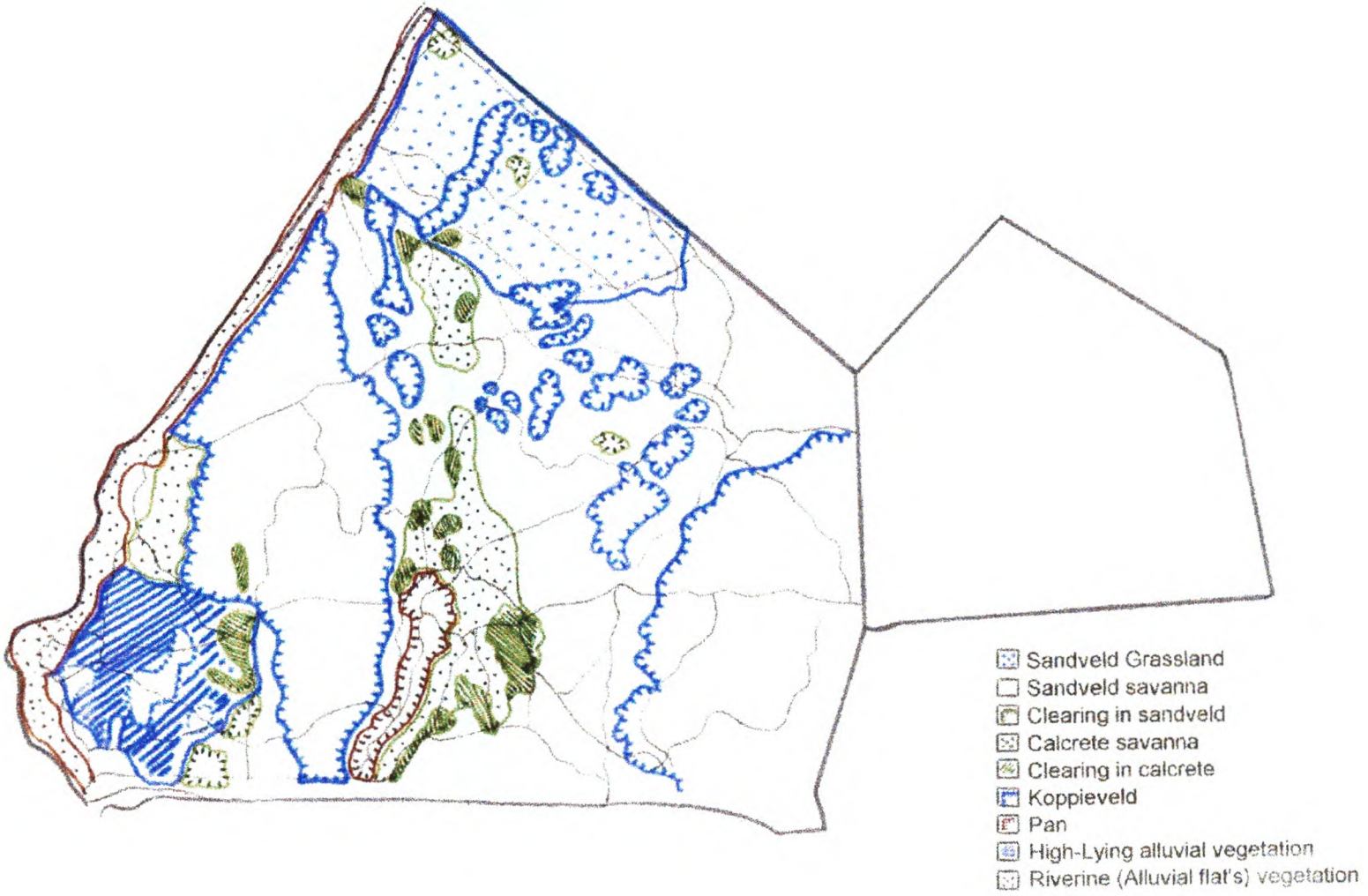
FIGURE 2.3. : VEGETATION MAP OF ROOIPOORT (Bigalke, 1974)



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vii) Calcrete vegetation - Hoffman's pan:

Hoffman's Pan is treated separately from the rest of the calcrete vegetation for a number of reasons. It is botanically related to other open vegetation types in the calcrete, but it is clearly distinguished by a greater preponderance of perennial grasses. These are presumably present as a result of deeper soil. The pan is also the single most important feeding area for a great number of the game on Rooipoort.

viii) Calcrete vegetation - Tarchonanthus savanna:

Tarchonanthus is the most well developed vegetation form in the calcrete areas. It occurs where a thin layer of dark brown sandy loam overlies the lime deposits. This vegetation type is dominated by *Tarchonanthus camphoratus* shrubs (which generally show a more stunted growth than those occurring in sandy soils), spaced about 2 to 2.5 m apart. Other shrub species occurring in these areas include; *Grewia flava, Diospyros sycioides, Acacia mellifera, subspecies detinens, Ehretia rigida* and, in sandier areas, *Rhus ciliata*. Trees occur only where there is adequate water, in the vicinity of pans and depressions and *Zizyphus mucronata* and *Rhus lancea* are the only trees of importance.

A mixture of perennial grasses and chamaephytes dominates the herbaceous layer and perennial grasses of greatest importance are *Eragrostis lehmanniana, Aristida vestita, Fingerhuthia africana, Schmidtia pappophoroides* and, locally, *Cymbopogon plurinodis.*

ix) Clearings in the Calcrete vegetation:

Open areas are characterised by very shallow, dark brown loam over calcrete or surface calcrete. The vegetation is typically sparse, with a few species of karroid shrubs and short grasses. Trees and shrubs are unimportant and restricted to a few stunted *Acacia tortilis* subspecies *heteracantha* or *Zizyphus* shrubs.

x) Koppieveld - on andesite or dolerite:

This vegetation type is an open shrub savanna. *Acacia mellifera*, subspecies *detinens* as a short or tall shrub, is the dominant species, with *Acacia tortilis*, subspecies *heteracantha*, being subdominant. On a few slopes, *Tarchonanthus camphoratus* is a conspicuous shrub.

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Table 2.1. :

Vegetation types classified by Bigalke and Leistner (unpublished report, 1972):

Vegetation Type	Area (ha)
1) Riverine vegetation	1282.6
2) Vegetation of high-lying alluvial deposits	1943.0
3) Sandveld - perennial grassveld	4314.0
4) Sandveld - annual grassveld	155.5
5) Sandveld - Tarchonanthus savanna	10612.2
6) Clearing in the Sandveld	145.8
7) Calcrete veld - Hoffman's Pan	608.2
8) Calcrete veld - Tarchonanthus savanna	1908.2
9) Clearings in the Calcrete Veld	839.0
10) Koppieveld on andesite or dolerite	12321.0
11) Koppieveld on quartzite	355.4

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xi) Koppieveld - on quartzite:

In the north-western part of the reserve are a range of quartzite koppies. The soils here are rather loose and sandy and the vegetation shows similarities with that occurring in the sandveld areas.

Shrubs and trees are less abundant than in other koppieveld areas and are also more sparsely distributed. The important species in this vegetation type are *Tarchonanthus camphoratus*, *Grewia flava* and *Rhus ciliata*.

The dominant perennial grasses, which are a prominent feature of this vegetation type, include *Eragrostis lehmanniana*, *Aristida vestita*, *Schmidtia pappophoroides*, *Brachiaria nigropedata* and *Rhynchelytrum villosum*.

2.4.2. Habitat Classes of Crowe *et al.* (1981) and Berry and Crowe (1985):

Berry and Crowe have identified four major habitat types on Rooipoort which are termed Pan, Clearing, Riverine and Koppie-savanna habitats (see Table 2.2.). The Koppie-savanna habitat may be further divided into four sub-habitats, i.e. koppieveld, annual grass savanna, sandveld savanna and *Tarchonanthus* savanna vegetation types (Berry & Crowe, 1985).

According to Crowe *et al.* (1981) there are at least 4 major habitat types within Rooipoort nature reserve. The pan habitat is characterised by mainly short, highly palatable grasses which can grow on seasonally moist soil (eg. *Agrostis grequensis* and *Sporobolus albicans*) and other signs of heavy use by animals. All pan areas are situated within Bigalke and Leistner's calcrete veld vegetation type. The second, Clearing habitat, is characterised by medium to highly palatable plant species, which have broad habitats or are adapted to unstable/overgrazed conditions (e.g. *Cynodon dactylon* and *Enneapogon desvauxii*). Most areas comprising this habitat were situated in segments dominated by Bigalke-Leistner clearings in calcrete vegetation type. Riverine habitat is seen as the 3rd major habitat type, and is situated along the banks of the Vaal River. It is characterised by tree and grass species adapted to alluvial soil conditions (e.g. *Salix mucronata* and

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Table 2.2. :

VEGETATION CLASSIFICATION ON ROOIPOORT:

Bigalke & Leistner (1962)			Berry & Crowe (1985)
Broad unit Vegetation	**Vegetation communities**	**Area (ha)**	
Riverine	Lower Bank communities	1282.6	Riverine
	Gallery forest		Riverine
	Flood plains		Riverine
High-lying Alluvial		1943	Koppie-savanna
Sandveld	Perennial grassveld	4314	Sandveld savanna (Koppie-savanna)
	Annual grassveld	155.5	Annual grassland savanna (Koppie-savanna)
	Tarchonanthus savanna	10612.2	Koppie-savanna (Koppie-savanna)
	Clearings	145.8	Clearing
Calcrete vegetation	Pan (Hoffman's)	608.2	Pan
	Tarchonanthus savanna	1908.2	Tarchonanthus savanna (Koppie-savanna)
	Clearings	839	Clearing
Koppieveld	on Andesite or dolerite	12321	Koppieveld
	on Quartzite	355.4	Koppieveld

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Hemarthria altissima). Areas comprising this habitat type fall within segments dominated by Bigalke and Leistner's riverine vegetation type (vegetation of the alluvial flats). The fourth and final habitat type termed Koppie-Savanna Habitat, is characterised by grasses (e.g. *Cymbopogon plurinoides* and *Sporobolus fimbriatus*), shrubs (e.g. *Boschia albitrunca*), and trees (e.g. *Acacia erioloba* and *A. mellifera*) which are adapted to dry, rocky and/or sandy conditions, and which are of varying palatability; high values for drainage; high values for bush and tree cover, poor access to drinking water; and low usage by animals, i.e. low values for trampling, dung heaps and dust baths. Most areas comprising this habitat fall within Bigalke and Leistner's koppie veld and savanna vegetation types.

2.5. HERBIVORE SPECIES

At the turn of the century seven large herbivore species were to be found on the reserve, and, in 1903, when the first recorded census was carried out, the numbers of large herbivores were estimated at 400 ostrich (*Struthio camelus*), 500 red hartebeest (*Alcelaphus buselaphus*), 1500 springbok (*Antidorcas marsupialis*) and 3 kudu (*Tragelaphus strepsiceros*).

In the 1950's a programme was initiated to reintroduce to Rooipoort other herbivores previously occurring in the area. The first successful translocation took place in 1958 when blesbok *(Damaliscus pygargus phillipsi*) (R.C. Bigalke, pers comm) were introduced. This was followed by eland (*Taurotragus oryx*) (1959), black wildebeest (*Connochaetes gnou*) (1959), gemsbok (*Oryx gazella*) (1961), warthog (*Phacochoerus africanus*) (1961), Burchell's zebra (*Equus burchelli*) (1963), giraffe (*Giraffa camelopardalis*) (1964) and blue wildebeest (*Connochaetes taurinus*)(1969) (Berry, 1991). More recently, sable and roan antelope have also been introduced to Rooipoort (specifically to Waterkolk).

Today 17 herbivore species occur on the reserve, and include black wildebeest, blesbok, blue wildebeest, duiker, eland, gemsbok, giraffe, red hartebeest, impala, kudu, roan and sable (occurring only on Waterkolk), springbok, steenbok, tsessebe, warthog, zebra and

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TABLE 2.3.: RECENT GAME CENSUS FIGURES RECORDED ON ROOIPOORT:

SPECIES	TOTAL 96	TOTAL 97			TOTAL 98		
	TOTAL	WKOLK	RPT	TOTAL	WKOLK	RPT	TOTAL
BLACK WILDEBEEST	208	0	174	174	0	210	210
BLESBOK	307	77	175	252	74	151	225
BLUE WILDEBEEST	685	113	623	736	154	612	766
ELAND	329	99	396	495	97	334	431
GEMSBOK	1319	106	982	1088	157	881	1038
HARTEBEEST	874	178	712	890	173	750	923
KUDU	393	18	233	251	25	323	348
SPRINGBOK	1958	244	1413	1657	221	1488	1709
WARTHOG	248	19	129	148	-	-	-
ZEBRA	459	0	537	537	0	522	522

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also mountain reedbuck. Herbivore numbers have increased considerably since 1960 and more recent game census figures are given in Table 2.3.

2.6. HISTORICAL BACKGROUND AND MANAGEMENT:

The properties comprising Rooipoort were acquired by the present owners, De Beers Consolidated Mines Limited, in 1893 for their alluvial diamond deposits. These deposits were never exploited and the area has been maintained as a private nature reserve up to the present day. As early as 1909, De Beers gave public notice that Rooipoort was to be established for conservation purpose. From its inception to 1930, the reserve was maintained mainly as a recreational hunting preserve, for the exclusive use of Company directors, their families and friends. It was used primarily for the hunting of gamebirds, including the helmitted guineafowl (*Numida meleagris*), the namaqua sandgrouse (*Pterocles namaqua*) and the spotted sandgrouse (*Pterocles burchelli)*, and also of springbok. At the turn of the century seven large herbivore species were to be found on the reserve.

Between 1930 and 1947, the estate was leased for domestic stock farming, mainly of horses, goats and cattle, and much of it was heavily overgrazed. Since 1947, the estate has reverted to a hunting preserve (Berry and Crowe, 1985). At this time, Professor J. Phillips made suggestions to the management of the farm, to discontinue the irrigation scheme, improve the Vaal River banks, control thorn shrubs and control veldfires more effectively.

Since the early 1950's, Rooipoort has been developed as a private nature reserve (Berry & Crowe, 1985).

The earliest recorded census on Rooipoort was carried out in 1903 and in 1973 aerial censuses re-commenced and were, thereafter, repeated every two years until 1984. Since 1984 an aerial census has been carried out annually (Berry, 1991).

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In 1974 Professor R.C. Bigalke, being well acquainted with the estate, was asked to draw up a management plan for Rooipoort. He proposed a scientifically based management plan, integrating game and cattle farming. In 1981 commercial trophy hunting was permitted for the first time on Rooipoort.

Today Rooipoort is managed as a game farm, the main activities being the live capture and the sale of game, venison production, trophy hunting by overseas hunters, company shoots and also selected hunting trips by the local population.

Further management aims include:

* The conservation of indigenous fauna and flora;
* the preservation of bushman paintings;
* the reintroduction of indigenous species;
* the development of the wildlife potential of the estate by maintaining an optimum number/balance between various species;
* the enhancement of the recreational aspects of the estate; and
* the renovation and preservation of the historical shooting box.

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SECTION 3 :

MATERIALS AND METHODS

3.1. INTRODUCTION

3.2. SAMPLING METHOD

Due to the size of the study area, it was necessary to use a sampling method that would cover a large, representative proportion of the area in a minimum period of time.

Systematic sampling was chosen over a randomised sampling method as it used time more efficiently. A systematic method of sampling is also seen to provide more representative results per sampling intensity if the animals show a clumped, rather than homogenous distribution pattern (Bergerud, 1963). Of the ten herbivore species being studied on Rooipoort Nature Reserve, only two were seen to have an homogenous distribution pattern, namely red hartebeest and gemsbok., and a systematic method was therefore seen to be more appropriate.

Fixed routes were chosen, therefore, rather than random quadrats as sampling units.

3.3. SAMPLING PROCEDURE

The entire study area was traversed each month by motor vehicle. The area was covered by means of 7 different road routes, which corresponded roughly to routes previously utilised in sex/age counts by the management of the reserve (See Fig. 3.1.). If possible, each route was sampled twice each month. Routes were chosen in such a way as to sample all of the representative vegetation and topographical areas within the study area. In some

FIGURE 3.1. : MAP OF ROUTES USED TO CARRY OUT SEX/AGE COUNTS ON ROOIPOORT:

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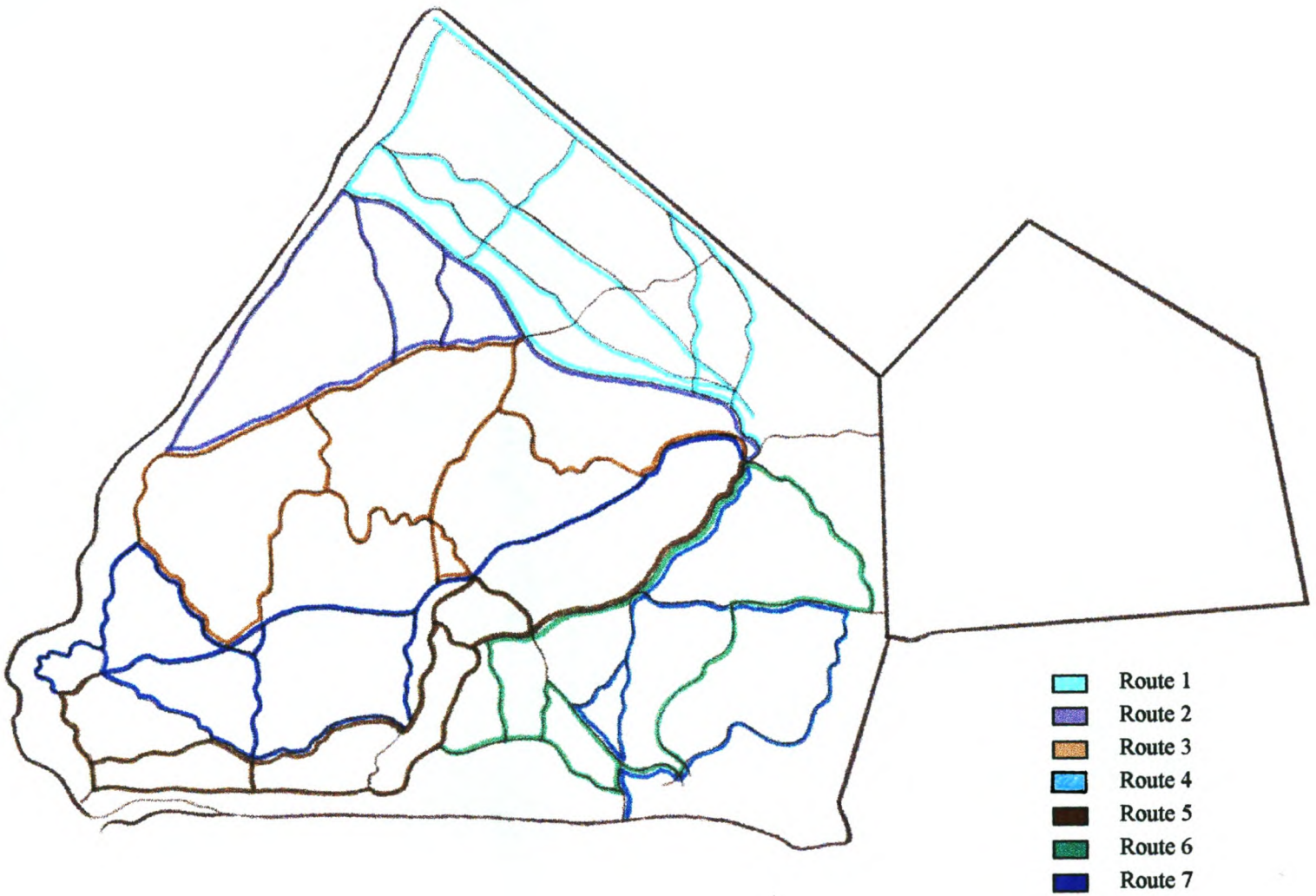
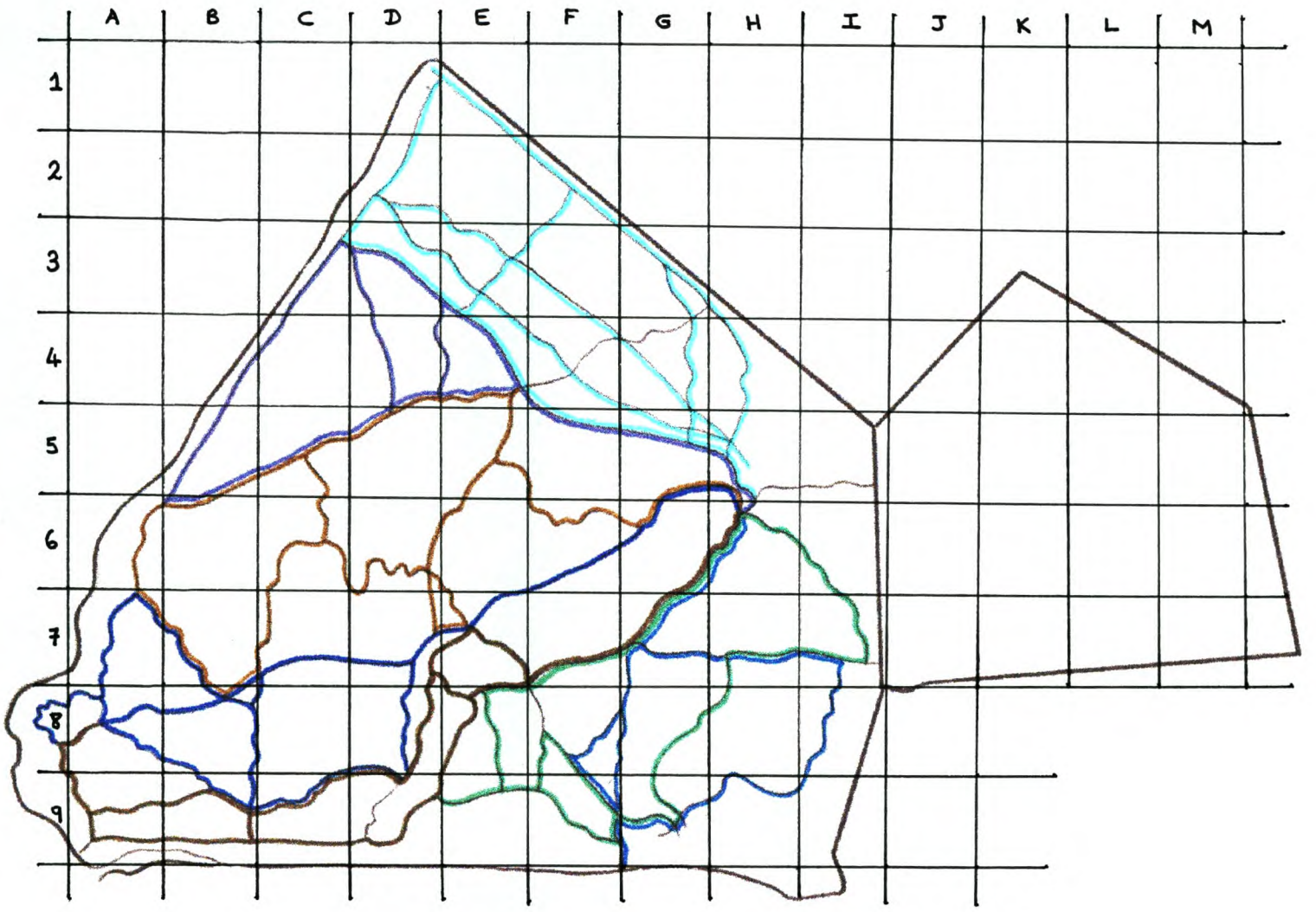


FIGURE 3.2. : GRIDDED MAP USED FOR SEX/AGE COUNTS ON ROOIPOORT



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cases a single road will be covered by more than one route and, in effect, a duplication sample of that area would be taken.

At a later stage, the reserve was divided into 3x3 km quadrats using a grid system (See Fig. 3.2.). The location of each herd or individual animal was then recorded according to quadrat number. Recording the location of each group/individual accordingly served to minimise the error of recounting groups/herds of animals. By gridding the reserve it was also possible to correlate animal observations with vegetation habitat, and thereby determine monthly or seasonal distribution patterns.

3.3.1. **Number and timing of sampling periods**

A total of 15 sex/age counts were carried out on Rooipoort each month, from April 1997 to May 1998 and, weather permitting, it was attempted to undertake sampling on consecutive days each month.

Wherever possible, two counts were undertaken on each day, one in the morning and one during the afternoon. The average duration of a sample count was 3 hours. The timing of counts showed seasonal variation. During the summer months counts were restricted to the early morning and late afternoon periods, as this was the time when animals were feeding and most active (they tend to retire in the midday heat). This was also the time when visibility was optimal. During the winter months animals fed irregularly all day and counting periods were not as restricted.

3.3.2. **Classification of animals**

Animals observed along routes were recorded and classified according to a sex and age class, the classes being; adult male, adult female, sub-adult (yearling) male, sub-adult (yearling) female, and juvenile. Animals that had not yet reached sub-adulthood were only classified by age.

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Criteria used for field classification of animals, according to age, body size, coat colour and horn shape and size. Sexes were differentiated on the basis of behaviour and morphological characteristics, such as body size, horn-thickness, presence or absence of horns, presence or absence of penal sheath, and neck thickness (Refer to Table 1.1., and Section 1 in Appendix A).

3.3.3. **Tools**

Classification of animals was made using a pair of binoculars (7x50 magnification), and a spotting telescope (30x70 magnification). A note pad and dictaphone were used for the recording of data. When available, a four-wheel-drive vehicle (Toyota landcruiser) was used to carry out counts, alternately a Mazda Hustler was used.

3.4. **DATA**

3.4.1. Ungulate data

The data collected was in the form of species name, group/herd size, group/herd composition i.e. the number of adult males, adult females, sub-adult males, sub-adult females, and juveniles (and undetermined individuals) in each group, and the quadrat number. Due to the fact that most of the large herbivore species are gregarious by nature, the 'group', or herd, was seen to be the smallest sampling unit, except in the case of solitary territorial male animals.

A record was also kept of the area covered in the counts. (See Fig. 3.3. for example of data sheet).

3.4.2. Weather data

In addition to animal data, a record was also kept of the time of day at which each count was conducted and the weather conditions at the time of each count.

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Figure 3.3. :

EXAMPLE OF DATA SHEET:

Date: 15-Jul-97
Time: 14h30
Area: Rooipoort Rd/pan/river rd/Kudu poort/Stone Dam
Weather: Cold, clear, SE wind blowing

Species	Group size	Group Composition						
		Adult M	Adult F	Sub M	Sub F	Juv	Undeterm	Block
Blck wilde	1	1						F7
	1	1						E8
	14	1	4	1		4		E8
	8	1	2	1		2		E8
	8	8						E8
	6	1	3			2		E7
	1	1						E7
	1	1						E7
	1	1						E7
Blesbok	3	1	2					F7
	7	1	3			3		F7
	16	1	5			4	6	E8
	1	1						E7
Blue wilde	1	1						E7
	17	2	6			6	3	C5
Eland	4	1	3					G7
Gemsbk	7		7					E7
Hartebst	11	2	5			4		G7
Kudu	5	5						G7
Springbk	1	1						G7
	1	1						F7
	3	1	2					E8
	8	1	3		1	3		E8
	6	3		3				E8

DISTANCE: 64 km

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The only quantitative weather data available from Rooipoort itself was rain data, which was obtained from rain gauges situated at various locations within the study area. During the study period, daily weather conditions were recorded for each sampling occasion, and included wind direction and strength (gentle/ moderate/ strong), sunshine/cloud cover and relative temperature (hot/warm/cool/cold). Supplementary weather data for Rooipoort had to be obtained from its closest weather station in Kimberley. This included wind, air pressure, humidity, temperature, sunshine, and rain data.

3.4.3 Distances

After each sampling occasion, a note was made of the distance travelled. This record was kept in order to estimate the potential fuel cost involved in such a study.

3.5. STATISTICAL DATA ANALYSIS

Sex and age data recorded over the study period was statistically analysed by means of the resampling method, known as the Bootstrap (Efron 1982) (See Section 1.2.3). The group was regarded as the smallest sampling unit. Monthly, quarterly and overall female/male ratios and calf/cow ratios were estimated using this method, which generates repeated sex and age ratios for the period/s in question. Population counts of each species were resampled 1000 times, using the Bootstrap method, in each of the time periods under observation, to give 1000 different estimates of sex and calf/cow ratios. The recalculated values were used to calculate an average sex/age ratio and the upper and lower confidence levels of these estimates. Confidence intervals were calculated at the 95 % confidence level. For monthly and quarterly estimates, 95 % confidence intervals were used to determine whether estimates differed significantly from one another and from the expected value for the estimate (taken from the "overall" estimate of sex/age ratios - see Tables 4.1. to 4.9.).

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SECTION 4

SEX/AGE RATIO ESTIMATES FOR UNGULATES ON ROOIPOORT

4.1. INTRODUCTION

Sex/age ratios (proportions) were estimated using the bootstrap method (See Section 3.5.). For a number of species, monthly sex ratio (female proportion) estimates show a great deal of similarity and do not differ significantly (using the 95 % confidence levels) from the expected ratio value (taken from "overall" sex/age ratios - see Tables 4.1. to 4.9. - for each species). These species include black wildebeest, blesbok, gemsbok, hartebeest and springbok (See Figure 4.1. and 4.7). For certain other species; for example eland, kudu and blue wildebeest, there would appear to be no similarity in monthly adult sex ratio estimates, and a lot of variation is observed (see Figure 4.3 and 4.4). Monthly calf/cow ratio estimates show much more variation than sex ratio estimates (See Figure 4.9 and 4.6). Only one species, namely blesbok, shows a pattern of monthly calf/cow ratio estimates that could be expected from the biology of the species. In the graphic representation of blesbok monthly calf/cow ratio estimates, ratio estimates show a high degree of similarity for the first half of the study period (April to October 1997). Thereafter, there is a sudden drop in calf/cow ratio, as is expected with the initiation of the calving season in November, at which time older calves become classified as yearlings. Calf/cow ratios then show an increase up until January (the end of the calving season), after which time they remain fairly constant at 60 to 70 % (See Figure 4.2).

For most species in the study, the confidence intervals (at 95% confidence level) for monthly estimates were very wide. Quarterly estimates yielded narrower confidence intervals for both sex and calf/cow ratios. For most species, however, only overall sex

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and age ratio estimates for the entire study period yielded confidence intervals that were sufficiently narrow to be considered useful.

Results were further analysed to determine whether there was any relationship between the width of the confidence intervals and the number of groups (sample size) encountered each month and also in each season (quarter). Results have been plotted graphically using linear regression to show the relationship between the sample size and the confidence interval widths.

A descending regression line indicates a negative (desirable) relationship between sample size and confidence interval width. In other words, if an increase in sample size corresponds to a decrease in confidence interval width, then the regression line will show a descending trend from left to right, on the graph. An example of a negative correlation can be seen in the graphic representation of "Monthly calf/cow ratio confidence interval widths for Zebra on Rooipoort", in Figure 4.10.

Alternately, a positive (undesirable) correlation exists if an increase in sample size corresponds to an increase in confidence interval width. In such cases, the regression will show an ascending trend from the left to the right hand side of the graph. An example can be seen in Figure 4.5. : "Eland - correlation between quarterly calf/cow ratio confidence interval widths and the number of groups seen".

A regression line running horizontal to the x-axis of the graph, indicates no correlation between an increase in sample size and the width of confidence intervals. Figure 4.8. shows an example of this in the graphic representation of Springbok quarterly female proportion confidence interval widths as plotted against the number of groups seen.

In addition to the graphic analysis of group size vs. confidence interval widths, results of regression analysis are given in Table 4.10. The coefficient of correlation values give an indication of whether there is a negative or positive correlation between confidence interval widths and the number of groups seen. Coefficient preceded by a minus sign have a negative correlation, and those without have a positive correlation.

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P-values give an indication of the significance of the correlation. P-values less than, or equal to 0.05 indicate a significant correlation between group size and confidence interval widths, whereas those greater than 0.05 show no correlation.

4.2. **Results from individual species sex/age counts on Rooipoort**:

4.2.1. Black Wildebeest

a) Monthly sex/age data from April 1997 to May 1998:

Monthly adult sex ratio estimates are fairly constant; with each month giving a value of approximately 1 male: 1 female (ranging from 50 to 60 % females) black wildebeest (see Table 4.1.). The estimate for February 1998, does deviate from the other months, at showing 90 % females in the population. Except for February, all monthly sex ratio estimates fall within 95 % confidence intervals of the previous month's estimate.

There is considerable variation in the estimated monthly calf/cow ratios (see Fig. 1, Appendix B). Most months, however, give values in the range of a 50 to 75 % calving rate (See Table 4.1).

There would appear to a negative correlation between the confidence interval widths for both adult sex ratios and calf/cow ratios, and the number of sightings made each month; with a decrease in confidence interval width corresponding to an increase in the number of animals sightings (See Fig 1 (iii) and (iv), Appendix B). P-values obtained from regression analysis, however, show this correlation to be not significant.

b) Quarterly sex/age data results:

As with the monthly sex ratio estimates, quarterly sex ratios approach parity, giving an estimate ranging from 50 to 57 % females in the population. Quarterly calf:cow ratios show still show a considerable degree of variation, but there does appear to be a definite drop in calving rate from 1997 to 1998. The 1997 estimates range between 57

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Table 4.1.

BLACK WILDEBEEST : Monthly, quarterly and overall sex and calf/cow ratios, including upper (UCL) and lower (LCL) confidence levels:

	MONTHLY					
	Proportion females			**Calf/cow**		
Month	**Average**	**UCL**	**LCL**	**Average**	**UCL**	**LCL**
April	**0.51**	0.71	0.25	**0.5**	0.71	0.36
May	**0.51**	0.64	0.31			
July	**0.52**	0.62	0.39	**0.41**	0.44	0.36
August	**0.49**	0.63	0.25	**0.49**	0.67	0.33
September	**0.6**	0.71	0.35	**0.66**	0.82	0.53
October	**0.52**	0.66	0.24	**0.71**	0.85	0.58
November	**0.52**	0.68	0.26	**0.69**	0.85	0.54
December	**0.54**	0.64	0.37	**0.21**	0.34	0.08
January	**0.54**	0.67	0.28			
February	**0.89**	0.97	0.41	**0.07**	0.72	0.02
March	**0.57**	0.69	0.38	**0.61**	0.74	0.48
April	**0.51**	0.63	0.41	**0.51**	0.63	0.41
May	**0.51**	0.66	0.3	0.5	0.7	0.32

	QUARTER					
	Proportion females			**Calf/cow**		
	Average	**UCL**	**LCL**	**Average**	**UCL**	**LCL**
Autumn	**0.5**	0.63	0.3	**0.57**	0.73	0.43
Winter	**0.52**	0.6	0.42	**0.63**	0.72	0.53
Spring	**0.57**	0.66	0.46	**0.69**	0.77	0.61
Summer	**0.54**	0.63	0.45	**0.46**	0.58	0.35
Autumn	**0.55**	0.63	0.44	**0.54**	0.62	0.47

	OVERALL					
	Sex Ratio			**Calf/cow**		
	Average	**UCL**	**LCL**	**Average**	**UCL**	**LCL**
	0.54	0.58	0.49	**0.55**	0.6	0.49

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and 69 %, while the 1998 estimate is only about 46 to 55 % (See Appendix B, Fig 1 (v) and (vi)). Here again, a negative (desirable) correlation exists between the number of sightings made each quarter, and the estimated adult sex ratio and calf/cow ratio confidence interval widths (See Fig 1 (vii) and (viii), Appendix B), although, according to P-values, this correlation is not significant.

c) Overall sex/age data results:

The overall adult sex ratio estimate for black wildebeest, over the entire study period was 1 male: 1.17 (54 %) females. The calving rate for the 1997/1998 calving season (December 1997/January 1998) was estimated at 55 %. This would appear to be lower than the 1996/1997 calving rate, estimated at around 65 to 70 %.

4.2.2. Blesbok

a) Monthly sex/age data from April 1997 to May 1998:

Monthly adult sex ratio (female proportion) estimates show a very limited degree of variation, ranging from 1 male: 1.51 females to 1 male: 1.97 females (See Figure 4.1., Table 4.2). By converting these ratios to percentages there is very little difference between most monthly averages. Estimates range from 60 to 66 % females, in all months.

As in Black wildebeest, all estimates fall inside the 95 % confidence levels and differences are therefore perceived as not significant.

There does appear to be a definite negative (desirable) correlation between the number of groups seen each month, and the size of adult sex ratio confidence interval widths. The greater the number of group sightings, the narrower the confidence intervals, as is expected (see Fig 2 (iii), Appendix B). P-values confirm this significance.

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Table 4.2.:

BLESBOK: Monthly, quarterly and overall sex and calf/cow ratios, including upper (UCL) and lower (LCL) confidence levels:

	MONTHLY					
	Proportion females			**Calf/cow**		
Month	**Average**	**UCL**	**LCL**	**Average**	**UCL**	**LCL**
April	**0.66**	0.76	0.49	**0.84**	0.93	0.77
May	**0.61**	0.74	0.39	**0.6**	0.7	0.49
July	**0.64**	0.77	0.43	**0.64**	0.8	0.52
August	**0.65**	0.83	0.37	**0.78**	0.94	0.62
September	**0.66**	0.82	0.38	**1**	1.01	0.91
October	**0.64**	0.77	0.45	**0.88**	1	0.81
November	**0.65**	0.83	0.3			
January	**0.61**	0.77	0.38	**0.66**	0.73	0.52
February	**0.63**	0.74	0.42	**0.68**	0.77	0.6
March	**0.63**	0.75	0.44	**0.59**	0.72	0.35
April	**0.61**	0.75	0.39	**0.7**	0.78	0.61
May	**0.6**	0.78	0.34	**0.61**	0.74	0.42

	QUARTER					
	Proportion females			**Calf/cow**		
	Average	**UCL**	**LCL**	**Average**	**UCL**	**LCL**
Autumn	**0.64**	0.73	0.52	**0.74**	0.81	0.66
Winter	**0.64**	0.76	0.48	**0.67**	0.79	0.56
Spring	**0.65**	0.74	0.52	**0.73**	0.89	0.54
Summer	**0.64**	0.72	0.54	**0.73**	0.8	0.68
Autumn	**0.63**	0.72	0.51	**0.63**	0.71	0.55

	OVERALL					
	Proportion females			**Calf/cow**		
	Average	**UCL**	**LCL**	**Average**	**UCL**	**LCL**
	0.64	0.67	0.6	**0.66**	0.74	0.7

Figure 4.1.:

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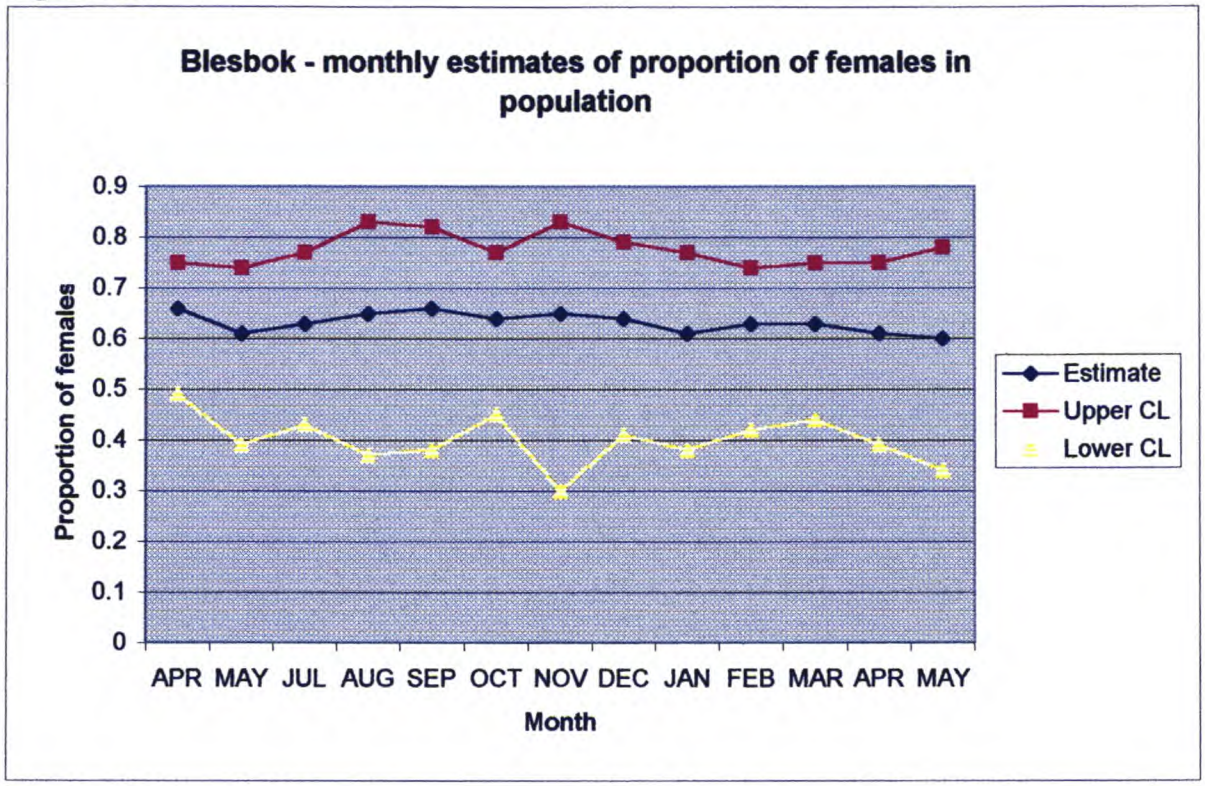
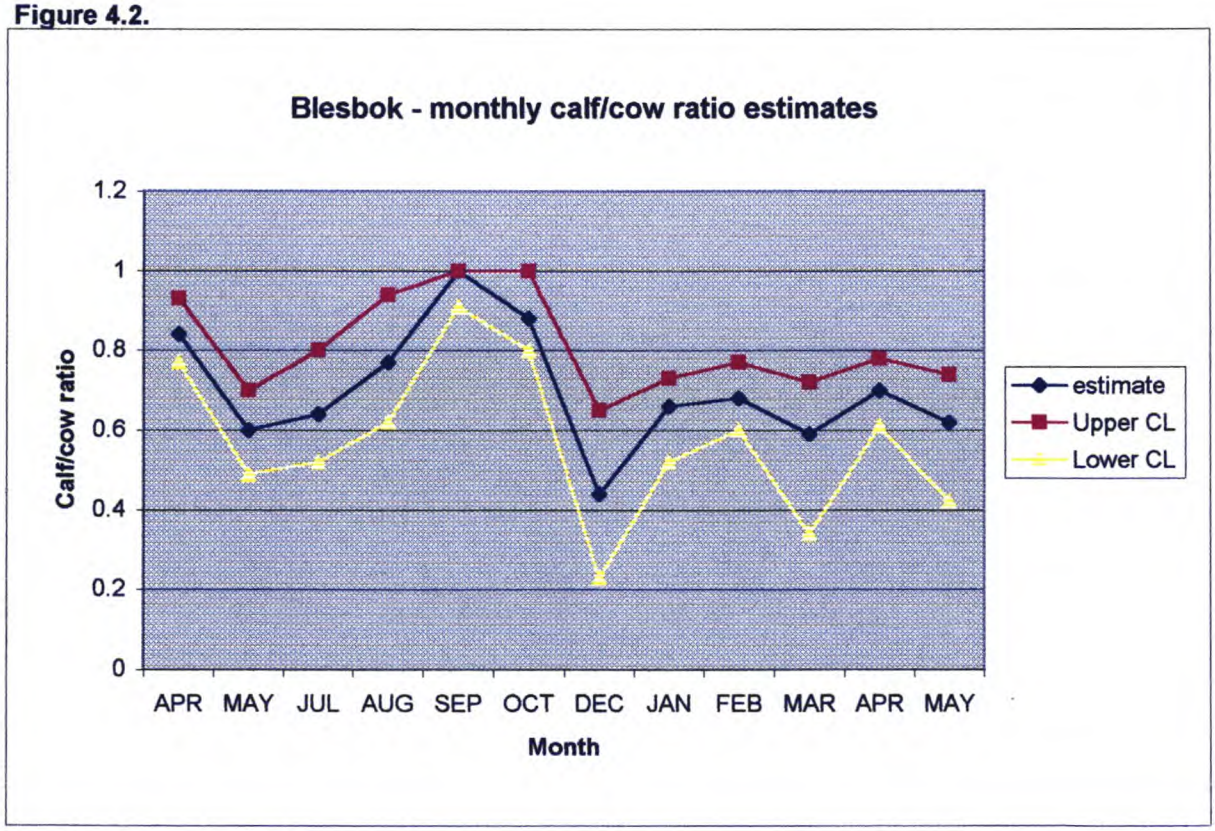


Figure 4.2.



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Monthly calf:cow ratios show considerable variation, ranging from a 60 to a 100 % calving rate (see Figure 4.2). As in black wildebeest, however, the calving rate for 1997 would appear to be slightly higher than that estimated for 1998 (See Table 4.2). Here too, there is a negative correlation between calf:cow ratio confidence interval widths and the number of group sightings (See Appendix B, Fig 2 (iv)), although it is seen as not significant.

b) Quarterly/Seasonal sex/age data results:

Quarterly sex ratio estimates show very little variation, ranging from 1 male: 1.72 (63 %) females to 1 male: 1.85 (65%) females. All estimates fall within 95 % confidence levels and differences between quarterly estimates are seen as insignificant. The width of the confidence intervals, as was the case above, appears to be related tot he number of groups seen (See Fig 2 (vii), Appendix B), although P-values indicate an non significant relationship.

Average estimates for quarterly calf:cow ratios vary from a 63 to a 74% calving rate. Although there would appear to be a desirable correlation between the width of the confidence intervals (Fig 2 (iv), Appendix B) and the number of groups seen in each season (See Fig 2 (viii), Appendix B), P-values suggest that this correlation is not significant.

c) Overall sex/age data results:

Overall blesbok data gave an average sex ratio estimate of 1 male: 1.81 (64%) females. The overall calving rate for the study period was estimated at 69 %.

4.2.3. Blue wildebeest

a) Monthly sex/age ratio data from April 1997 to May 1998:

Monthly adult sex ratios estimates vary from 1 male: 1.2 (55%) females, to 1 male: 2 (67%) females (See Table 4.3 and Figure 4.3). The width of confidence intervals

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would appear to be negatively (desirably) correlated to the number of group sightings each month (See Fig. 3(iii)). This correlation is perceived as not significant however.

There is considerable variation in monthly calf:cow ratio estimates for blue wildebeest, ranging from a 48 to a 86 % calving rate over the study period (See Example 4.5). Here again there is a negative correlation between interval width and number of groups seen (See fig. 3 (iv), Appendix B).

b) Quarterly sex/age ratio data results:

Quarterly sex ratio estimates show very limited variation, ranging from 1 male: 1.56 (61%) females, to 1 male: 1.73 (63%) females (See Fig. 3 (v), Appendix B). Calving rate estimates range from 60 and 78 %, and there would appear to be an increase in calving rate from the 1996/1997 to 1997/1998 period (See Fig. 3 (vi), Appendix B)..

Confidence interval widths, for female proportion and calf:cow ratio estimates, are negatively correlated with the number of groups observed, although P-values suggest that only the correlation between calf/cow ratio confidence interval widths and the number of groups, is significant (See Fig 3 (vii) and (viii), Appendix B).

c) Overall sex/age ratio data results:

The overall adult sex ratio estimate is 1 male: 1.62 (62%) females. The calf:cow ratio for the 1997/1998 calving period was estimated at 0.72, translating to a 72 % calving rate.

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Table 4.3.

BLUE WILDEBEEST: Monthly, quarterly and overall sex and calf/cow ratios, including upper (UCL) and lower (LCL) confidence levels:

	MONTHLY					
	Proportion females			**Calf/cow**		
Month	**Average**	**UCL**	**LCL**	**Average**	**UCL**	**LCL**
April	0.6	0.74	0.37	**0.48**	0.69	0.13
May	**0.67**	0.77	0.51	**0.78**	0.89	0.66
July	**0.64**	0.75	0.45	**0.61**	0.76	0.45
August	**0.55**	0.74	0.23			
September	**0.66**	0.78	0.47	**0.66**	0.79	0.51
October	**0.57**	0.75	0.2			
November	**0.6**	0.74	0.34	**0.82**	1	0.54
December	**0.55**	0.75	0.21			
January	**0.58**	0.76	0.23	**0.65**	0.82	0.47
February	**0.64**	0.8	0.42	**0.86**	0.95	0.72
March	**0.66**	0.77	0.44	**0.81**	0.9	0.71
April	**0.62**	0.73	0.39	**0.75**	0.91	0.49
May	**0.61**	0.78	0.28	**0.76**	0.84	0.69

	QUARTER					
	Proportion females			**Calf/cow**		
	Average	**UCL**	**LCL**	**Average**	**UCL**	**LCL**
Autumn	**0.63**	0.72	0.5	**0.63**	0.75	0.45
Winter	**0.61**	0.71	0.45	**0.6**	0.72	0.4
Spring	**0.61**	0.71	0.49	**0.76**	0.86	0.64
Summer	**0.61**	0.72	0.47	**0.72**	0.83	0.59
Autumn	**0.63**	0.71	0.51	**0.78**	0.85	0.69

	OVERALL					
	Proportion females			**Calf/cow**		
	Average	**UCL**	**LCL**	**Average**	**UCL**	**LCL**
	0.62	0.66	0.57	**0.72**	0.75	0.67

Figure 4.3.: Stellenbosch University http://scholar.sun.ac.za

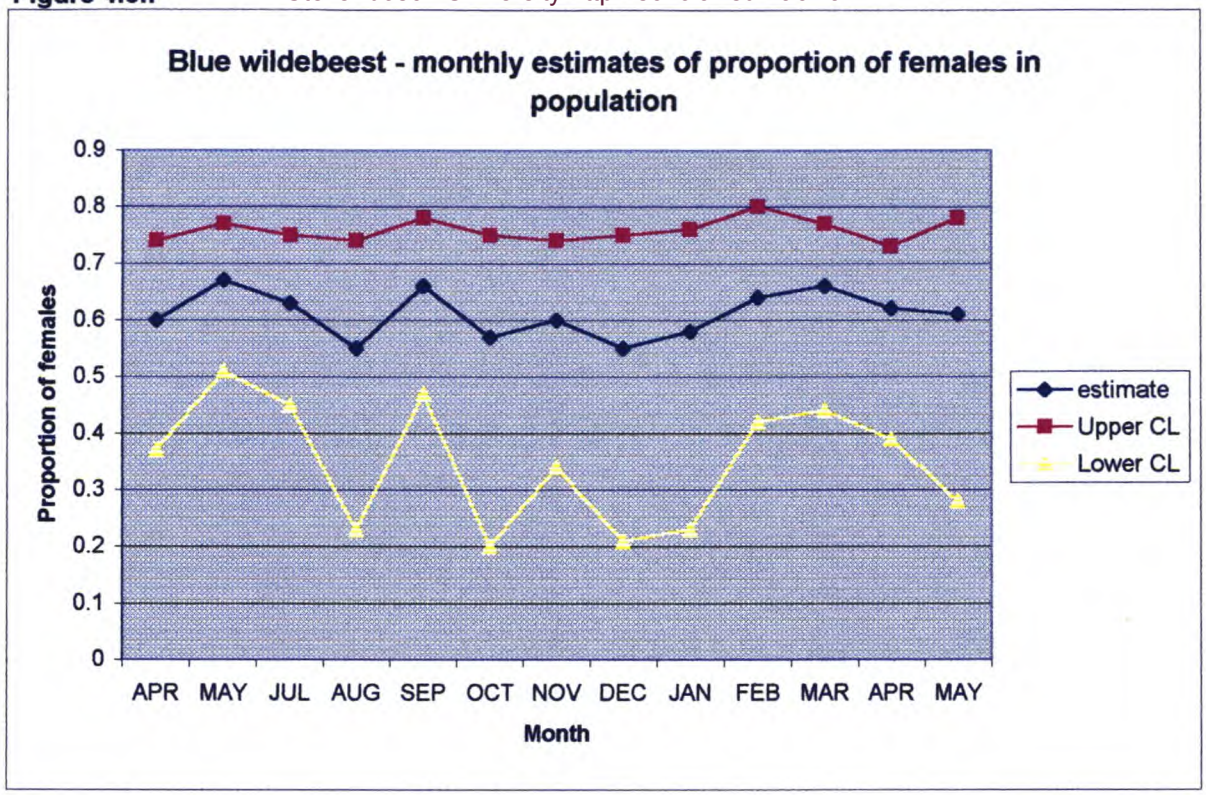
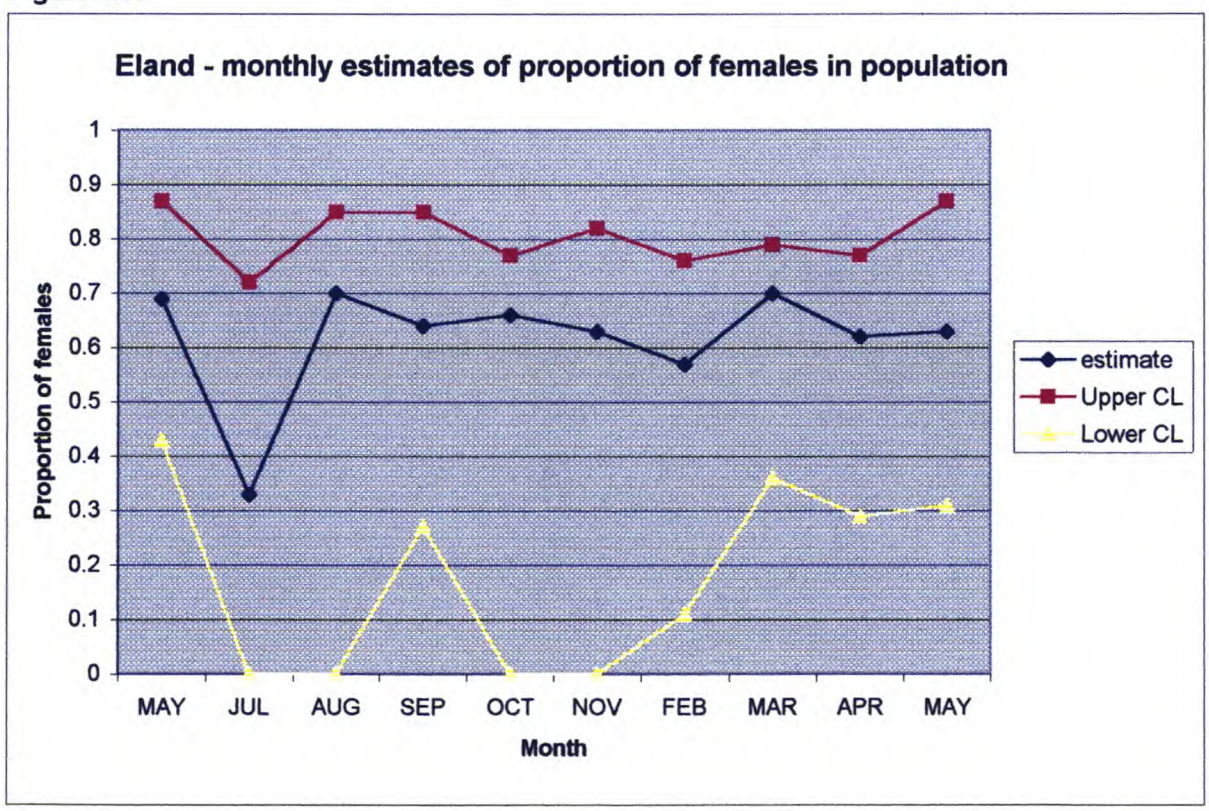


Figure 4.4:



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4.2.4. Eland

a) Monthly sex/age data from April 1997 to May 1998:

A large degree of variation is seen to exist between monthly sex ratio estimates. Ratios range from 1 male: 0.50 (33 %) female, to 1 male: 2.38 (70%) females. Except for 1 month within the study period, namely July 1997, estimates range from 57 to 70% females (See Table 4.4 and Figure 4.4). Estimated confidence intervals are very wide for eland at the 95 % confidence level and this is possibly due to very low sample sizes for many of the months. Sex ratio confidence interval widths are negatively correlated with the number of groups seen each month (See Fig. 4 (iii), Appendix B).

As in monthly sex ratio averages, calf:cow ratios also show a large degree of variation and very wide confidence intervals at the 95 % confidence level (see Fig. 3 (ii), Appendix B). There appears to be negative, although not significant, correlation between the width of calf/cow ratio confidence intervals and the number of groups seen each month (See Fig. 3 (iv), Appendix B).

b) Quarterly sex/age data results:

Of the 5 quarterly adult sex ratio estimates calculated, 4 (namely autumn, spring and summer of 1997, and autumn 1998) estimates give a female proportion of between 59 and 67 %. Winter 1997 shows a significantly lower percentage of females. Calf:cow ratios estimated for the 5 quarters show considerable variation (see Fig. 3 (v) & (vi), Appendix B).

Confidence intervals for both sex ratio and calf:cow ratio estimates are very wide at the 95 % confidence level. There would appear to be a positive, although not significant, (undesirable) correlation between the width of the calf/cow ratio confidence intervals and the number of groups observed in each quarter of the study period (See Fig. 3 (vii), Appendix B and Figure 4.5), but a negative correlation with the female proportion estimates.

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Table 4.4.

ELAND: Monthly, quarterly and overall sex and calf/cow ratios, including upper (UCL) and lower (LCL) confidence levels:

	MONTHLY					
	Proportion females			**Calf/cow**		
Month	**Average**	**UCL**	**LCL**	**Average**	**UCL**	**LCL**
May	**0.69**	0.87	0.43	**0.33**	0.49	0.07
July	**0.33**	0.73	0			
August	**0.7**	0.85	0	**0.48**	0.13	0
September	**0.64**	0.85	0.27	**0.22**	0.64	0
October	**0.66**	0.77	0	**0.51**	0.54	0
November	**0.64**	0.82	0			
January						
February	**0.57**	0.76	0.11	**0.29**	1	0.11
March	**0.7**	0.79	0.36	**0.64**	0.73	0
April	**0.62**	0.77	0.29	**0.49**	0.51	0
May	**0.63**	0.87	0.31	**0.28**	0.53	0

	QUARTER					
	Proportion females			**Calf/cow**		
	Average	**UCL**	**LCL**	**Average**	**UCL**	**LCL**
Autumn	**0.64**	0.8	0.45	**0.26**	0.43	0.08
Winter	**0.33**	0.75	0			
Spring	**0.67**	0.77	0.36	**0.52**	0.72	0.16
Summer	**0.59**	0.76	0.28	**0.24**	0.36	0
Autumn	**0.66**	0.75	0.51	**0.52**	0.71	0.09

	OVERALL					
	Proportion females			**Calf/cow**		
	Average	**UCL**	**LCL**	**Average**	**UCL**	**LCL**
	0.62	0.71	0.55	**0.42**	0.54	0.26

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c) Overall sex/age data results:

The overall sex ratio for eland was estimated at 1 male: 1.79 (62 %) females, while the overall calf:cow ratio was estimated at 0.42.

4.2.5. Gemsbok

a) Monthly sex/age data from April 1997 to May 1998:

Monthly adult sex ratio averages for gemsbok show limited variation, with the majority of estimates ranging from 1 male: 1.18 (54%) females, to 1 male: 1.55 (61 %) females (See Fig 5 (i), Appendix B). Calf:cow ratio estimates show a somewhat greater variation ranging from a 13 % calving rate (around the beginning of the calving season) to a high 38 % calving rate (see Table 4.5 and Figure 4.6).

Graphic representation of regression shows a negative correlation between both the sex ratios and monthly calf:cow ratio confidence interval widths and the number of monthly group observations (See Fig. 5 (iii) & (iv), Appendix B). P-values suggest that this correlation is not significant.

b) Quarterly sex/age data results:

Quarterly sex ratio estimates show seasonal estimates ranging from 1 male: 1.19 (54%) females to 1 male: 1.48 (60%) females. Calf:cow estimates range from a 23 to a 31 % calving rate, excluding a low of 16 % at the start of the calving season (See Fig. 5 (v) & (vi), Appendix B).

There would appear to be a negative, although insignificant (see P-values, Figure 4.10), correlation between the number of groups encountered each quarter, and the width of the confidence interval widths for both sex ratio and calf:cow ratio estimates (See Fig. 5 (vii) & (viii), Appendix B). An increase in the number of groups encountered would appear to correspond to a decrease in confidence interval widths.

Figure 4.5.: Stellenbosch University http://scholar.sun.ac.za

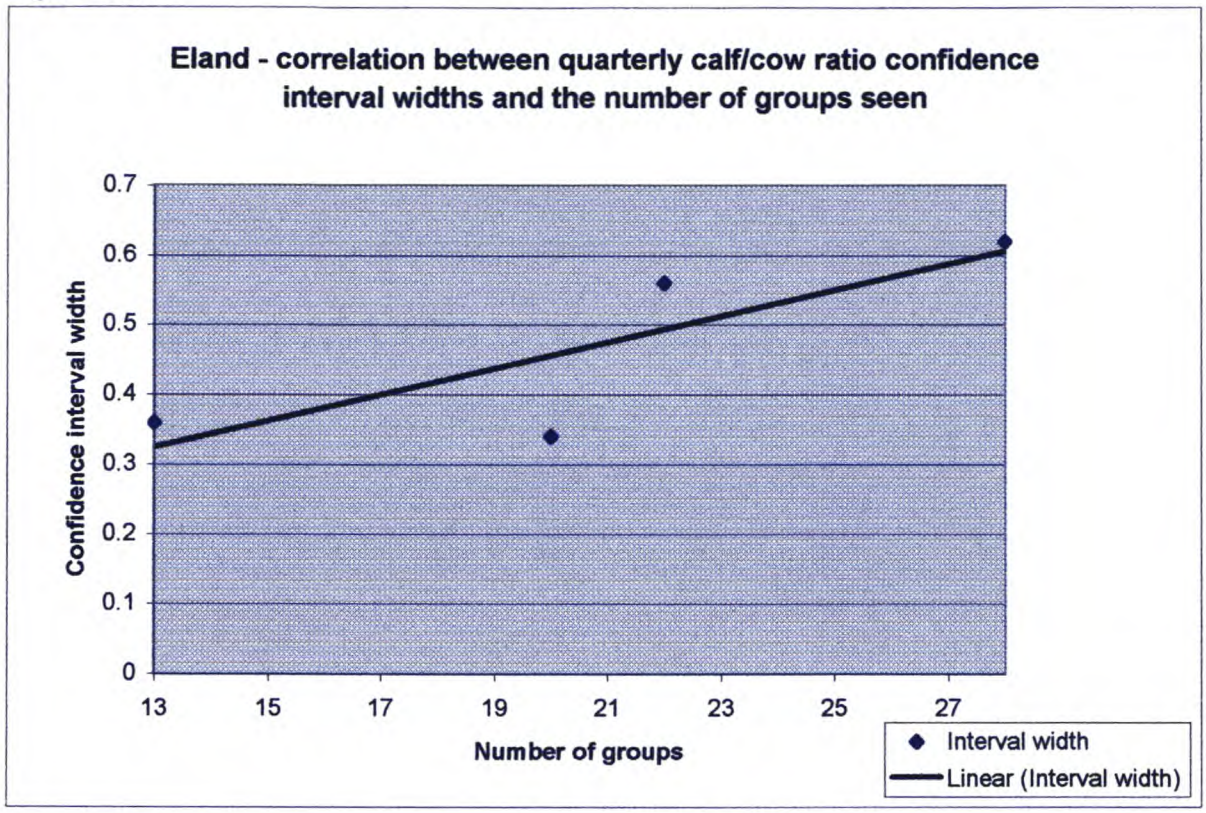

Figure 4.6.:

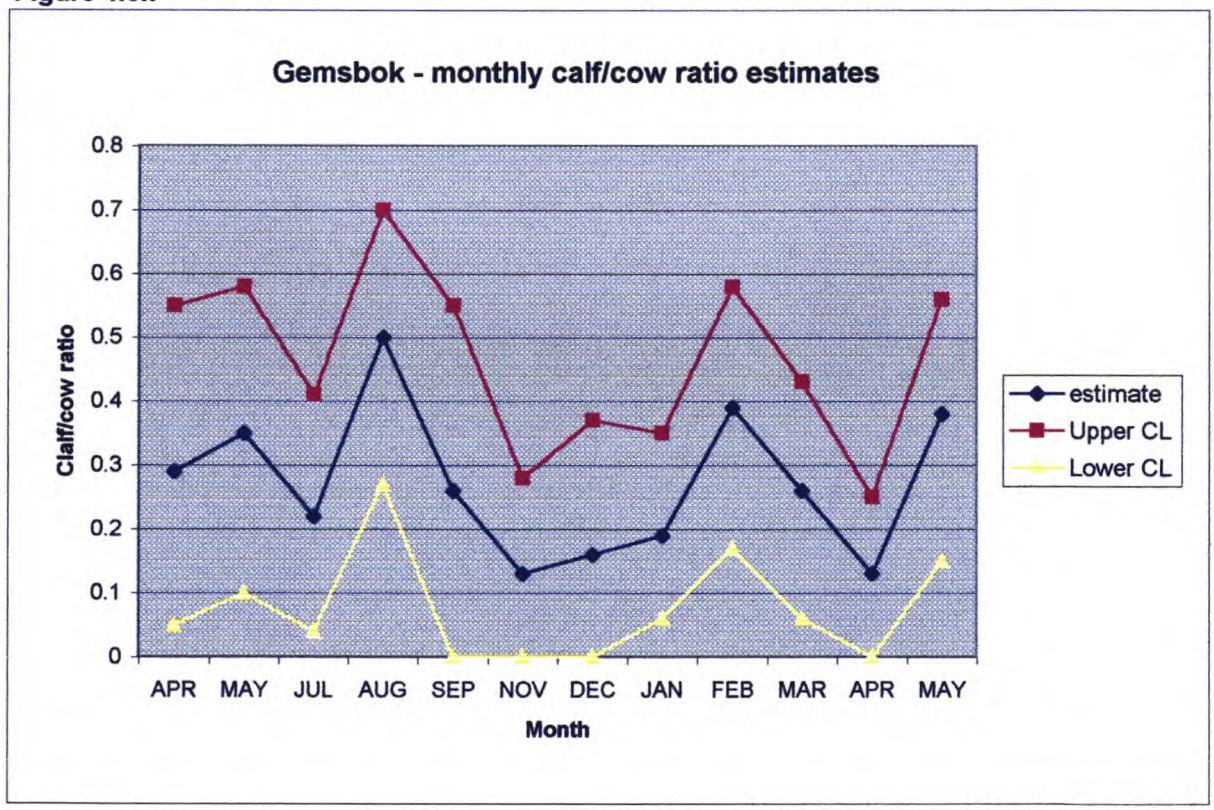

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Table 4.5.

GEMSBOK: Monthly, quarterly and overall sex and calf/cow ratios, including upper (UCL) and lower (LCL) confidence levels:

	MONTHLY					
	Proportion females			**Calf/cow**		
Month	**Average**	**UCL**	**LCL**	**Average**	**UCL**	**LCL**
April	**0.47**	0.65	0.3	**0.29**	0.55	0.05
May	**0.6**	0.71	0.44	**0.35**	0.58	0.1
July	**0.57**	0.73	0.37	**0.23**	0.41	0.04
August	**0.56**	0.7	0.35	**0.5**	0.7	0.27
September	**0.57**	0.73	0.3	**0.26**	0.55	0
October	**0.56**	0.74	0.27			
November	**0.54**	0.73	0.26	**0.13**	0.28	0
December	**0.49**	0.67	0.28	**0.16**	0.37	0
January	**0.61**	0.73	0.42	**0.19**	0.36	0.06
February	**0.58**	0.71	0.32	**0.39**	0.58	0.17
March	**0.58**	0.7	0.39	**0.26**	0.43	0.06
April	**0.59**	0.72	0.38	**0.13**	0.25	0
May	**0.55**	0.67	0.36	**0.38**	0.56	0.15

	QUARTER					
	Proportion females			**Calf/cow**		
	Average	**UCL**	**LCL**	**Average**	**UCL**	**LCL**
Autumn	**0.54**	0.66	0.42	**0.31**	0.5	0.14
Winter	**0.6**	0.7	0.48	**0.29**	0.45	0.14
Spring	**0.58**	0.68	0.44	**0.16**	0.27	0.09
Summer	**0.56**	0.65	0.45	**0.23**	0.35	0.14
Autumn	**0.57**	0.64	0.47	**0.26**	0.37	0.15

	OVERALL					
	Proportion females			**Calf/cow**		
	Average	**UCL**	**LCL**	**Average**	**UCL**	**LCL**
	0.57	0.62	0.53	**0.25**	0.31	0.19

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c) Overall sex/age data results:

The overall adult sex ratio estimate for gemsbok was 1 male: 1.34 (57%) females. The overall calf:cow ratio was calculated at a very low 0.25 (25% calving rate). Due to the fact that gemsbok calved twice during the study period (in September 1997 and March/April 1998), with each period giving a calving rate of approximately 25 %, the actual calving rate can be accepted as 50 and 60 %, provided that only half of the adult females calved at each period.

4.2.6. Hartebeest

a) Monthly sex/age data from April 1997 to May 1998:

Monthly data gives sex ratios estimates ranging from 1 male: 1.32 (57%) females to 1 male: 1.94 (66 %) females (See Table 4.6 and Fig. 6 (i), Appendix B). Monthly calf:cow estimates show slightly more variation than do sex ratio estimates, but most months give a moderate to high calving rate of between 69 and 84 % (See Fig. 6 (ii), Appendix B). There would appear to be a negative correlation between the number of monthly groups sightings and the width of the confidence intervals for both sex and age ratios (See Fig. 6 (iii) & (iv), Appendix B), although this correlation is perceived as not significant (see Figure 4.10).

b) Quarterly sex/age data results:

Quarterly sex ratio estimates are extremely similar ranging from 1 male: 1.52 (60 %) females and 1 male: 1.80 (64 %) females (See fig. 6 (v), Appendix B). The widths of quarterly female proportion confidence intervals show a negative correlation with the number of groups observed (See Fig. 6 (vi), Appendix B).

Calf:cow ratio estimates give a calving rate of between 54 to 81 % (See fig. 6 (vi), Appendix B). Here again there would appear to be a negative (desirable) correlation between calf:cow ratio confidence interval widths and the number of groups sighted in each quarter (See Fig. 6 (viii), Appendix B). P-values indicate a non significant

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Table: 4.6.:

HARTEBEEST: Monthly, quarterly and overall sex and calf/cow ratios, including upper (UCL) and lower (LCL) confidence levels:

	MONTHLY					
	Proportion females			**Calf/cow**		
Month	**Average**	**UCL**	**LCL**	**Average**	**UCL**	**LCL**
July	**0.62**	0.71	0.5	**0.75**	0.86	0.6
August	**0.58**	0.72	0.39	**0.71**	0.84	0.56
September	**0.57**	0.72	0.33	**0.59**	0.73	0.42
October	**0.62**	0.72	0.47	**0.5**	0.67	0.31
November	**0.62**	0.74	0.46	**0.54**	0.74	0.36
December	**0.65**	0.75	0.52	**0.71**	1	0.48
January	**0.65**	0.73	0.5	**0.72**	0.81	0.6
February	**0.65**	0.72	0.55	**0.69**	0.77	0.61
March	**0.64**	0.72	0.54	**0.79**	0.89	0.7
April	**0.63**	0.72	0.51	**0.84**	0.92	0.76
May	**0.66**	0.75	0.55	**0.83**	0.9	0.73

	QUARTER					
	Proportion females			**Calf/cow**		
	Average	**UCL**	**LCL**	**Average**	**UCL**	**LCL**
Winter	**0.6**	0.68	0.51	**0.73**	0.83	0.63
Spring	**0.6**	0.68	0.5	**0.54**	0.63	0.43
Summer	**0.65**	0.7	0.58	**0.71**	0.79	0.62
Autumn	**0.65**	0.7	0.59	**0.82**	0.87	0.77

	OVERALL					
	Proportion females			**Calf/cow**		
	Average	**UCL**	**LCL**	**Average**	**UCL**	**LCL**
	0.62	0.65	0.59	**0.71**	0.74	0.66

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correlation between sample size and both sex- and calf/cow ratio confidence interval widths.

c) Overall sex/age data results:

The overall sex ratio estimated for hartebeest was; 1 male: 1.66 (62%) females. The overall calf:cow ratio is estimated at 0.71; that is 71% of all adult cows calved.

4.2.7. Kudu

a) Monthly sex/age data from April 1997 to May 1998:

There is some variation between monthly sex ratio estimates (See Figure 4.4). Ratios range from 1 male: 1.73 (63%) females to 1 male: 2.67 (73%) females, but the majority of estimates lie between 67 and 73 % females (see Table 4.7).

Calf:cow ratio estimates show a great deal of monthly variation, ranging from a 14 to a 80 % calving rate. Confidence intervals are very wide (See fig. 7 (ii), Appendix B). There is a definite negative correlation between confidence interval widths for sex and calf:cow ratios and the number of groups sighted each month (See fig. 7 (iii) & (iv), Appendix B). P-values (Table 4.10) suggest that only the calf/cow ratio correlation is significant.

b) Quarterly sex/age data results:

Sex ratio estimates, calculated from quarterly data, are very similar, giving a female proportion of between 0.66 to 0.72 (66 to 72 %) (See Table 4.7 and fig. 7 (v), Appendix B).

Quarterly estimates of calf:cow ratios show considerable variation, probably due to small sample sizes (See fig. (vi), Appendix B). There is a negative (desirable) correlation between the number of groups seen and the sex and calf:cow ratio confidence interval widths (See fig. 7 (vii) and (viii), Appendix B), although only the sex (female proportion) ratio correlation is seen as significant (See Table 4.10).

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Table 4.7.

KUDU: Monthly, quarterly and overall sex and calf/cow ratios, including upper (UCL) and lower (LCL) confidence levels:

	MONTHLY					
	Proportion of females			**Calf/cow**		
Month	**Average**	**UCL**	**LCL**	**Average**	**UCL**	**LCL**
April	**0.73**	0.89	0.47	**0.8**	1	0.47
May	**0.68**	0.89	0.25			
July	**0.67**	0.88	0.41	**0.68**	1	0.24
August				**0.55**	0.8	0
September						
October				**0.53**	0.79	0.22
November	**0.68**	0.84	0.47	**0.42**	0.65	0.16
December						
January				**0.22**	0.6	0
February	-	-	-	**0.14**	0.35	0
March	**0.67**	0.81	0.47	**0.25**	0.47	0.1
April	**0.67**	0.77	0.5	**0.5**	0.8	0.18
May	**0.63**	0.82	0.37	**0.48**	0.79	0.24

	QUARTER					
	Proportion of females			**Calf/cow**		
	Average	**UCL**	**LCL**	**Average**	**UCL**	**LCL**
Autumn	**0.72**	0.86	0.52	**0.62**	0.86	0.41
Winter	**0.68**	0.86	0.48	**0.62**	0.91	0.29
Spring	**0.69**	0.8	0.57	**0.5**	0.66	0.34
Summer	**0.69**	0.86	0.53	**0.31**	0.51	0.12
Autumn	**0.66**	0.76	0.55	**0.41**	0.55	0.27

	OVERALL					
	Proportion of females			**Calf/cow**		
	Average	**UCL**	**LCL**	**Average**	**UCL**	**LCL**
	0.68	0.75	0.62	**0.47**	0.57	0.38

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c) Overall sex/age data results:

The overall estimate for adult sex ratio in kudu was 1 male: 2.17 (68%) females. Overall calf:cow ratio was estimated at 0.47 (47 % of all adult females calved) for the 1997/1998 calving period.

4.2.8. Springbok

a) Monthly sex/age data from April 1997 to May 1998:

All monthly sex ratio estimates are very similar, ranging from 1 male: 1.77 (64%) females, to 1 male: 2.22 (69%) females (See Table 4.8 and Figure 4.7), and all fall within the previous months 95 % confidence levels.

Monthly lamb: ewe ratio estimates, unlike sex ratios, show considerable variation, ranging from a 11 % to a 68 % lambing rate. Lambing rates do appear to be fairly low, but this could be due to the fact that there are 2 to 3 lambing seasons within a 12 month period and not all ewes lamb at each season.

There would appear to be a negative correlation between monthly sex ratio confidence intervals widths and the number of groups encountered each month, but a positive correlation with the calf/cow ratio confidence interval widths (See fig. 8 (iii) & (iv), Appendix B). P-values suggest that both correlation's are not significant.

b) Quarterly sex/age data results:

Quarterly sex ratio estimates for springbok are very similar, ranging from 1 male: 1.84 (65%) females, to 1 male: 1.98 (66%) females (See fig. 8 (v), Appendix B).

Lamb:ewe quarterly estimates are also fairly similar, ranging from a 34 % to a 43 % lambing rate (see Fig. 8 (vi), Appendix B).

Figure 4.7.: Stellenbosch University http://scholar.sun.ac.za

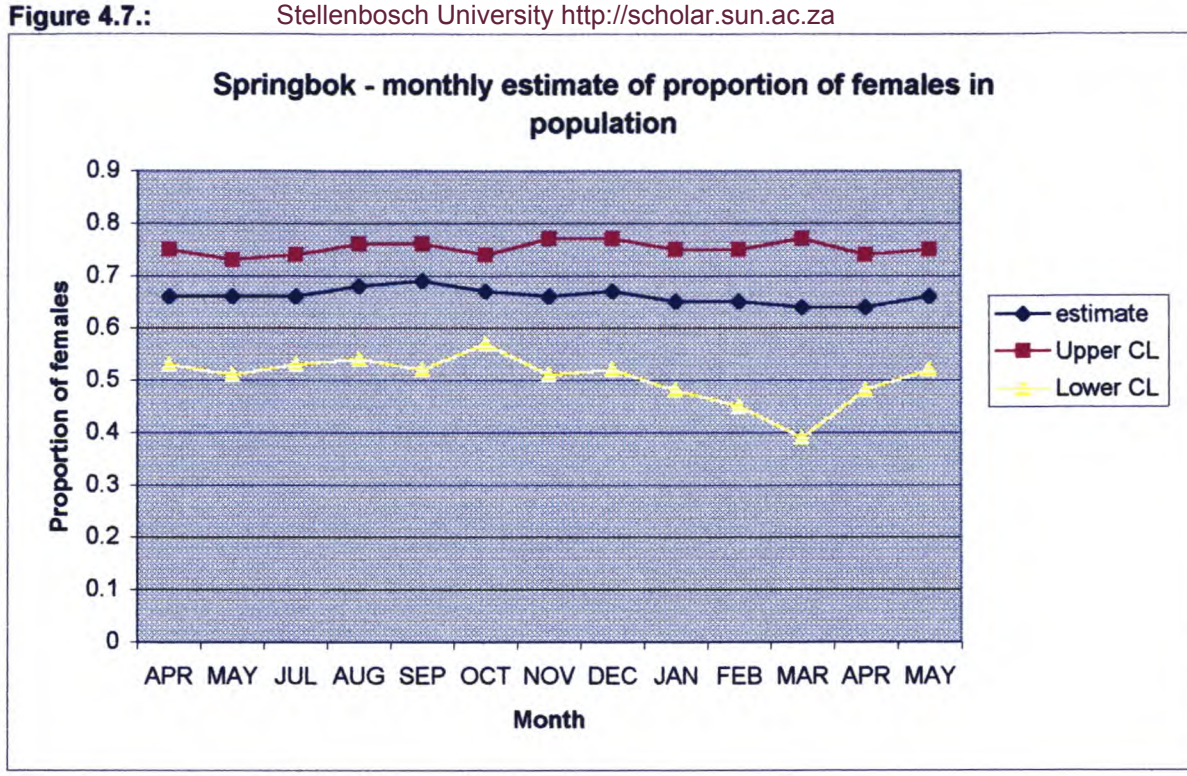

Figure 4.8.:

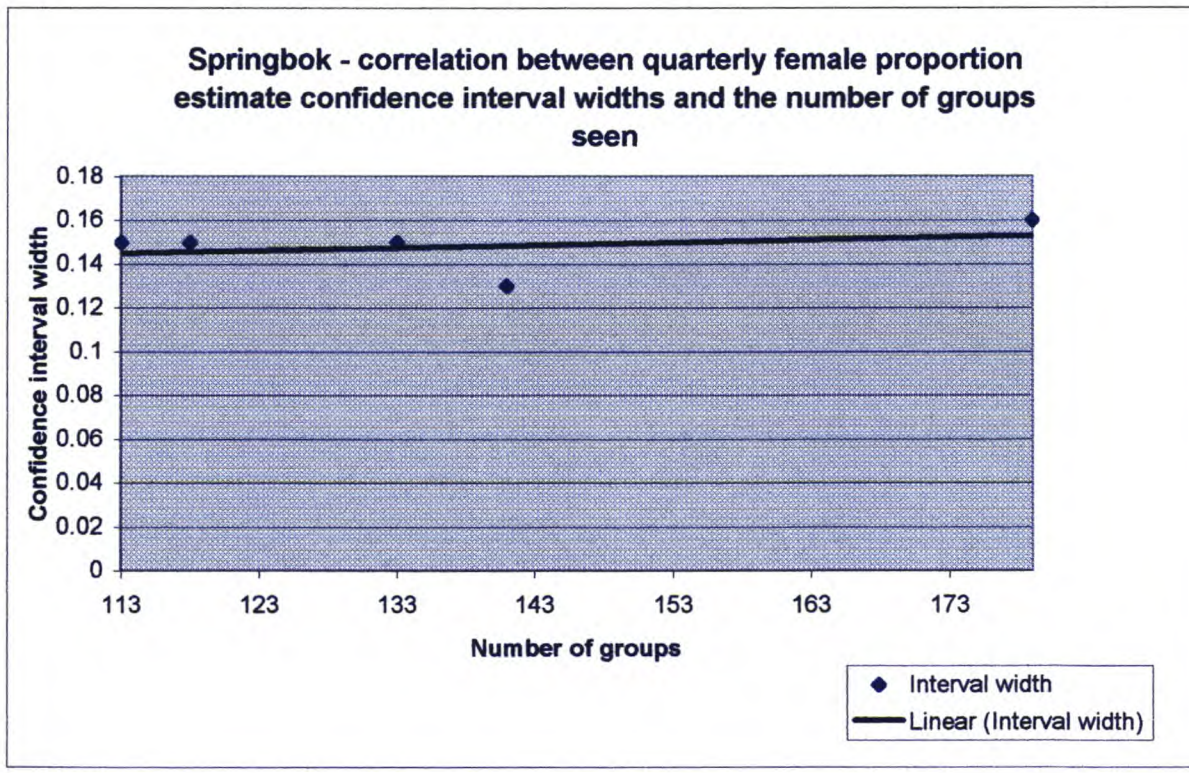

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Table 4.8.

SPRINGBOK: Monthly, quarterly and overall sex and calf/cow ratios, including upper (UCL) and lower (LCL) confidence levels:

	MONTHLY					
	Proportion of females			**Calf/cow**		
Month	**Average**	**UCL**	**LCL**	**Average**	**UCL**	**LCL**
April	**0.66**	0.75	0.53	**0.11**	0.25	0.03
May	**0.66**	0.73	0.51	**0.59**	0.74	0.39
July	**0.66**	0.74	0.53	**0.32**	0.48	0.15
August	**0.68**	0.76	0.54	**0.37**	0.52	0.22
September	**0.69**	0.76	0.52	**0.28**	0.42	0.19
October	**0.67**	0.74	0.57	**0.38**	0.52	0.22
November	**0.66**	0.77	0.51	**0.51**	0.68	0.35
December	**0.67**	0.77	0.52	**0.68**	0.84	0.45
January	**0.65**	0.75	0.48	**0.34**	0.43	0.24
February	**0.65**	0.75	0.45	**-**	-	-
March	**0.64**	0.77	0.39	**0.34**	0.44	0.19
April	**0.64**	0.74	0.48	**0.3**	0.44	0.16
May	**0.66**	0.75	0.52	**0.56**	0.67	0.43

	QUARTER					
	Proportion of females			**Calf/cow**		
	Average	**UCL**	**LCL**	**Average**	**UCL**	**LCL**
Autumn	**0.66**	0.72	0.57	**0.42**	0.55	0.27
Winter	**0.66**	0.73	0.58	**0.34**	0.45	0.22
Spring	**0.66**	0.72	0.59	**0.42**	0.5	0.33
Summer	**0.65**	0.72	0.57	**0.43**	0.55	0.32
Autumn	**0.65**	0.72	0.56	**0.41**	0.49	0.32

	OVERALL					
	Proportion of females			**Calf/cow**		
	Average	**UCL**	**LCL**	**Average**	**UCL**	**LCL**
	0.66	0.69	0.62	**0.4**	0.45	0.35

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There would appear to be a definite positive correlation between sex ratio confidence interval widths (Figure 4.8), and a negative correlation between lamb:ewe ratio confidence interval widths, and the number of group sightings each quarter of the study period (See fig. 8 (viii), Appendix B).

c) Overall sex/age data results:

The overall adult sex ratio was calculated at 1 male: 1.94 (66 %) females. The calf:cow ratio was estimated at 0.40 (41 % of adult females lambed). This is a fairly low lambing rate, but due to the fact that springbok lambed two or more times within the year study period, the lambing rate can perhaps be taken as 0.8 (80 % of all adult females lambed), as not all females lambed at each lambing season.

4.2.9. Zebra

a) Monthly sex/age data from April 1997 to May 1998:

Most monthly sex ratio estimates show females to make up between 63 and 74 % of the population. Only 2 months report lower female proportions of 0.54 and 0.59 (54 and 59 %) (see Table 4.9 and fig. 9 (i), Appendix B). There would appear to be a negative correlation between the number of group sightings and the sex ratio confidence interval widths (See Figure 4.10), although P-values suggest that this correlation is not significant.

There is considerable variation in the monthly foal: mare ratio estimates, ranging from 14 % (the start of the foaling season) to 62 % of mares with foals (See Figure 4.9). The foaling rate would appear to be fairly low (50 %). Although most foals appear to be dropped in the summer months of December, January and February, foaling can take place at any time of the year, and it is therefore not feasible to look at any one period of the study period, when determining foaling rate.

Figure 4.9.: Stellenbosch University http://scholar.sun.ac.za

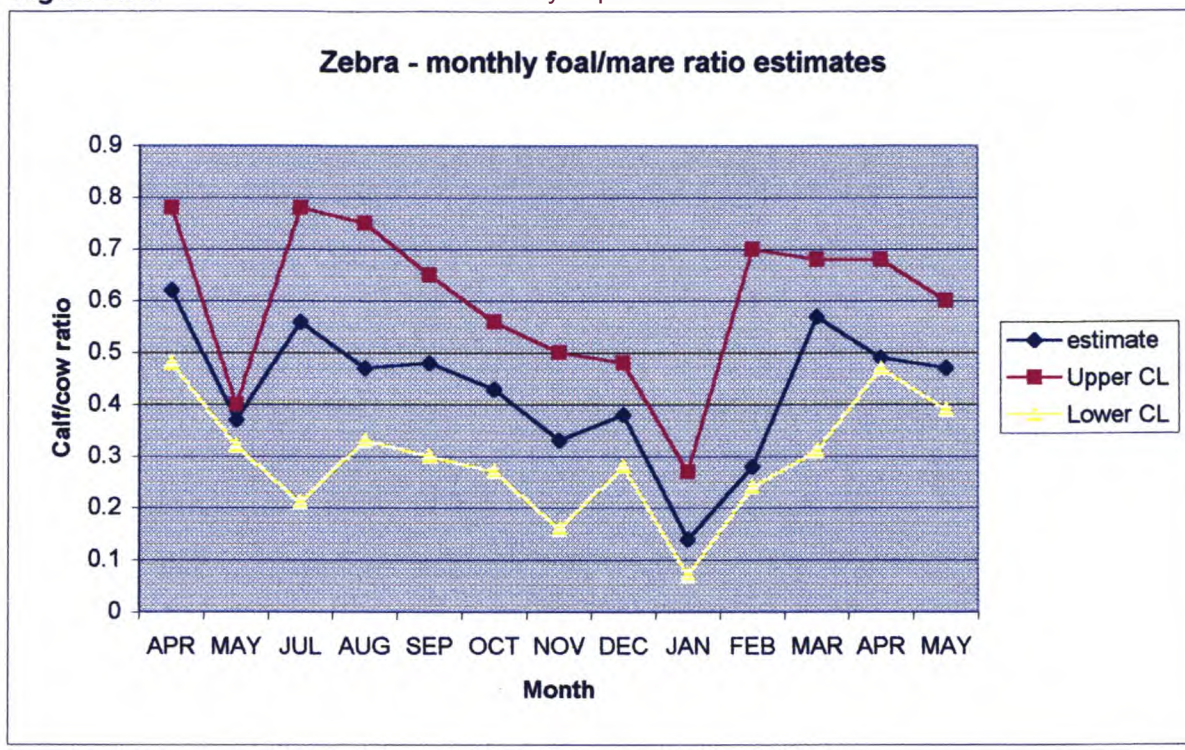
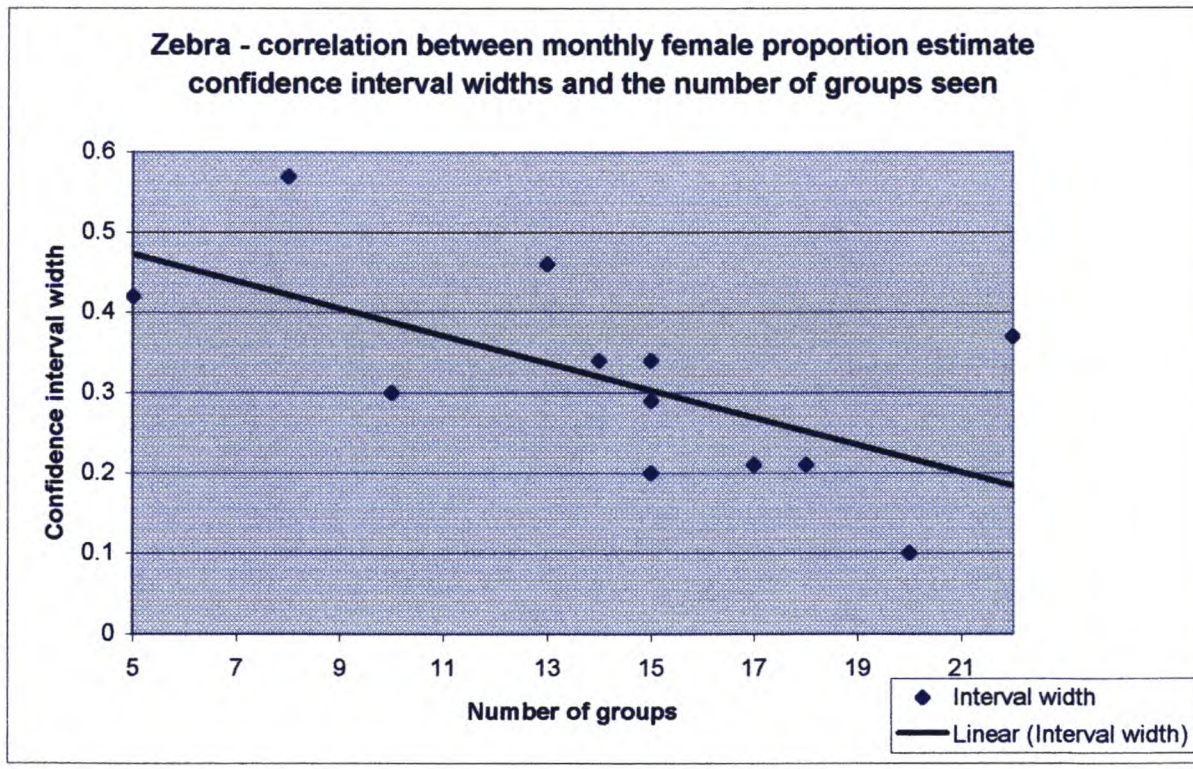


Figure 4.10.:



Stellenbosch University http://scholar.sun.ac.za

Table 4.9.:

ZEBRA: Monthly, quarterly and overall sex and calf/cow ratios, including upper (UCL) and lower (LCL) confidence levels:

MONTHLY

	Proportion of females			**Calf/cow**		
Month	**Average**	**UCL**	**LCL**	**Average**	**UCL**	**LCL**
April	**0.7**	0.77	0.55	**0.62**	0.78	0.48
May	**0.67**	0.77	0.52	**0.37**	0.4	0.32
July	**0.69**	0.81	0.45	**0.56**	0.78	0.21
August	**0.65**	0.86	0.39	**0.47**	0.75	0.33
September	**0.66**	0.77	0.49	**0.48**	0.65	0.3
October	**0.7**	0.81	0.49	**0.43**	0.56	0.27
November	**0.67**	0.8	0.48	**0.33**	0.5	0.16
December	**0.64**	0.79	0.47	**0.38**	0.48	0.28
January	**0.59**	0.75	0.51	**0.14**	0.27	0.07
February	**0.54**	0.76	0.45	**0.28**	0.7	0.24
March	**0.68**	0.75	0.53	**0.57**	0.68	0.31
April	**0.63**	0.78	0.48	**0.49**	0.68	0.47
May	**0.74**	0.79	0.51	**0.47**	0.6	0.39

QUARTER

	Proportion of females			**Calf/cow**		
	Average	**UCL**	**LCL**	**Average**	**UCL**	**LCL**
Autumn	**0.68**	0.74	0.6	**0.57**	0.66	0.46
Winter	**0.67**	0.78	0.42	**0.48**	0.66	0.31
Spring	**0.67**	0.73	0.58	**0.41**	0.51	0.31
Summer	**0.67**	0.73	0.56	**0.28**	0.38	0.19
Autumn	**0.66**	0.73	0.56	**0.53**	0.63	0.42

OVERALL

Proportion of females			**Calf/cow**		
Average	**UCL**	**LCL**	**Average**	**UCL**	**LCL**
0.67	0.71	0.62	**0.46**	0.52	0.4

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Table 4.10.: Regression Analysis: test for significant correlation between monthly and quarterly group numbers and estimated sex- (female proportion estimate) and calf/cow ratio estimate confidence interval widths:

Species	Monthly				Quarterly			
	F/M ratio		C/C ratio		F/M ratio		C/C ratio	
	Coefficien	P-Value	Coefficien	P-Value	Coefficien	P-Value	Coefficien	P-Value
Black Wildebeest:	-0.002	7.50E-02	-0.004	0.24	-0.002	0.23	-0.001	0.41
Blesbok:	-0.008	5.00E-03	0.001	0.77	-0.002	0.44	-0.006	1.67E-01
Blue wildebeest:	-0.005	0.24	0.005	0.5	-0.008	0.26	-0.003	0.03
Eland:	-0.048	0.002	-0.004	0.24	-0.022	0.017	0.019	0.178
Gemsbok:	-0.003	3.70E-01	-0.003	0.58	-0.001	0.127	-0.002	0.271
Hartebeest:	-0.004	1.00E-01	-0.002	0.572	-0.001	0.384	-0.001	0.292
Kudu:	-0.009	0.211	-0.012	0.05	-0.004	0.04	-0.006	0.09
Springbok:	-0.002	1.34E-01	0.001	0.453	0.0001	0.63	-0.001	0.09
Zebra:	-0.005	1.20E-01	-0.017	0.02	-0.004	0.194	-0.003	0.22

Coefficient: coefficient of correlation values indicate whether results show a negative or positive correlation. Coefficients preceded by a minus sign indicate a negative correlation, whereas those without have a positive correlation

P-values: those values less than or equal to 0.05 indicate a significant correlation between confidence interval widths and the number of groups seen.

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Here too, there would appear to be a significant (see P-value in Table 4.10) negative (desirable) correlation between foal:mare confidence interval widths and the number of monthly group sightings.

b) Quarterly sex/age data results:

Quarterly sex ratio average estimates for zebra are very similar, ranging from 1 male: 1.96 (66 %) females, to 1 male: 2.12 (68%) females (see Fig. 9 (v), Appendix B).

Quarterly foal:mare ratio estimates still show considerable variation and lie between 28 % and 57 % foaling rate for adult females (See fig. 9 (vi), Appendix B). There does appear to be a correlation, although not significant, between the width of confidence intervals, and the number of groups sighted quarterly, for both sex ratios and foal/mare ratio estimates (See fig. 9 (vii) & (viii), Appendix B).

c) Overall sex/age data results:

The overall sex ratio was estimated at 1 male: 2.04 (67%) females. The overall foal:mare ratio was estimated at 0.46 (46 % of all adult mares foaled). This is a fairly low foaling rate and is perhaps due to the fact that many zebra foaled prior tot he main birthing peak in December/January/February, and it is therefore considered that actual the foaling rate may in fact be considerably higher.

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SECTION 5

THE DISTRIBUTION PATTERNS OF WILD UNGULATE SPECIES ON ROOIPOORT

5.1. EFFECT OF SEASONAL CONDITIONS ON THE PRESENT DISTRIBUTION OF WILD UNGULATES ON ROOIPOORT:

5.1.1. Overall Seasonal Distribution:

In order to facilitate the determination of distribution patterns among the large ungulates on Rooipoort, the reserve was divided into 8 different vegetation/habitat types, as discussed in section 2.4.1. These are namely:

- Sandveld grassland
- Sandveld savanna (Tarchonanthus)
- Calcrete savanna (Tarchonanthus)
- Koppieveld
- Riverine vegetation
- Clearings
- Pan
- High lying alluvial areas

The period of study was divided into 4 seasons (refer to section 2.2), namely a "cool-wet" season, from March to May (Autumn); a "cold-dry" season from June to August (Winter), a "hot-dry" season from September through to November (Spring) and finally a "hot-wet" season from December to February (Summer). The following observations of seasonal distribution of animals were obtained (Monthly results are given in Table 5.1).

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a) Autumn

The distribution patterns of animals were very similar for all three months of the season. The highest percentage of sightings in all months occurred in the pan area of the calcrete vegetation type. The area showing the second highest percentage of sightings was the Koppieveld vegetation type. Sandveld grassland areas delivered the third highest percentage of sightings in March, whereas in April and May, it was the cleared areas. The areas showing the next highest percentage of sightings was reversed, being cleared areas for March, and sandveld grassland areas, in April and May.

Looking at the season in its entirety, it is apparent that, collectively, the pan, koppieveld, cleared-, and sandveld areas of Rooipoort accounted for over 75 % of all animal sightings (See Fig 5.1.).

b) Winter

June gave substantially different results to both July and August, which themselves showed very similar results to those of the Autumn months. The June deviation is probably due to insufficient data being collected for this month, as only 2 counts were undertaken on Rooipoort.

For both July and August, the pan area accounted for the highest percentage of sightings, followed by the Koppieveld areas. As in Autumn, clearings accounted for the next highest percentage of sightings, although here the percentage of clearing sightings were substantially lower. Sandveld savanna vegetation accounted for the fourth highest percentage of sightings in this instance, and not the sandveld grassland (as in autumn).

The pan, koppieveld, cleared-, and sandveld areas delivered up to 80 % of all animal sightings (Fig 5.2).

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Figure 5.1.

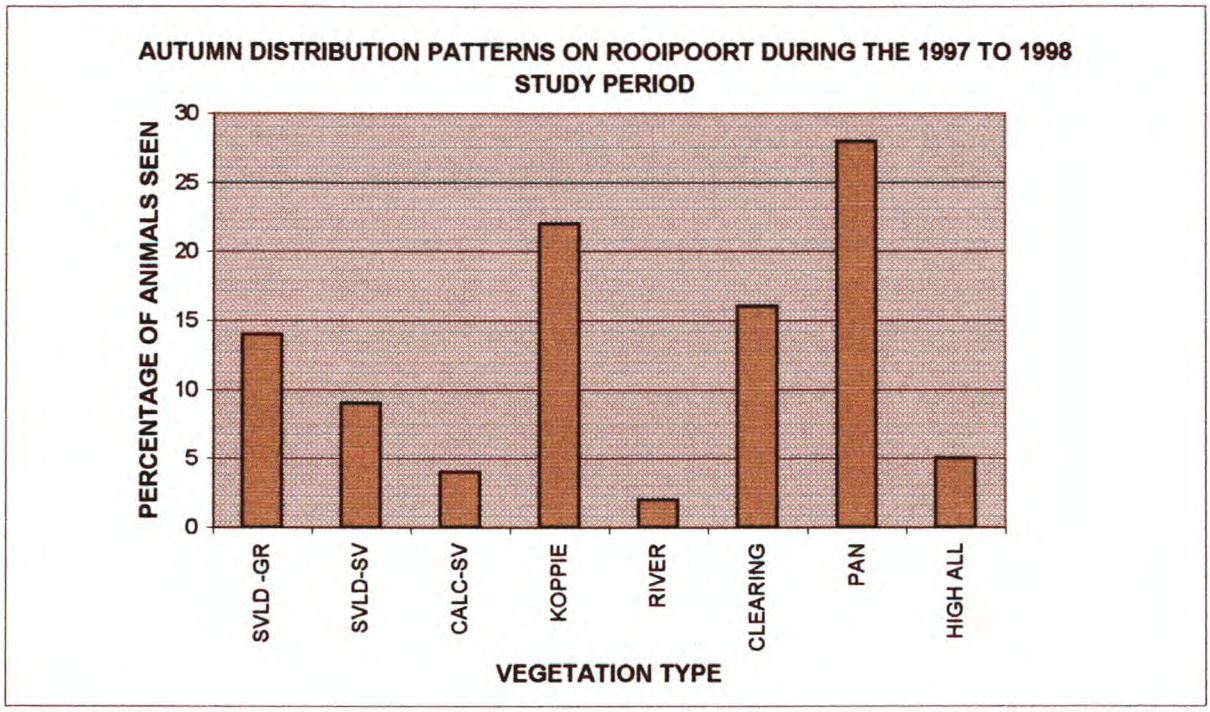
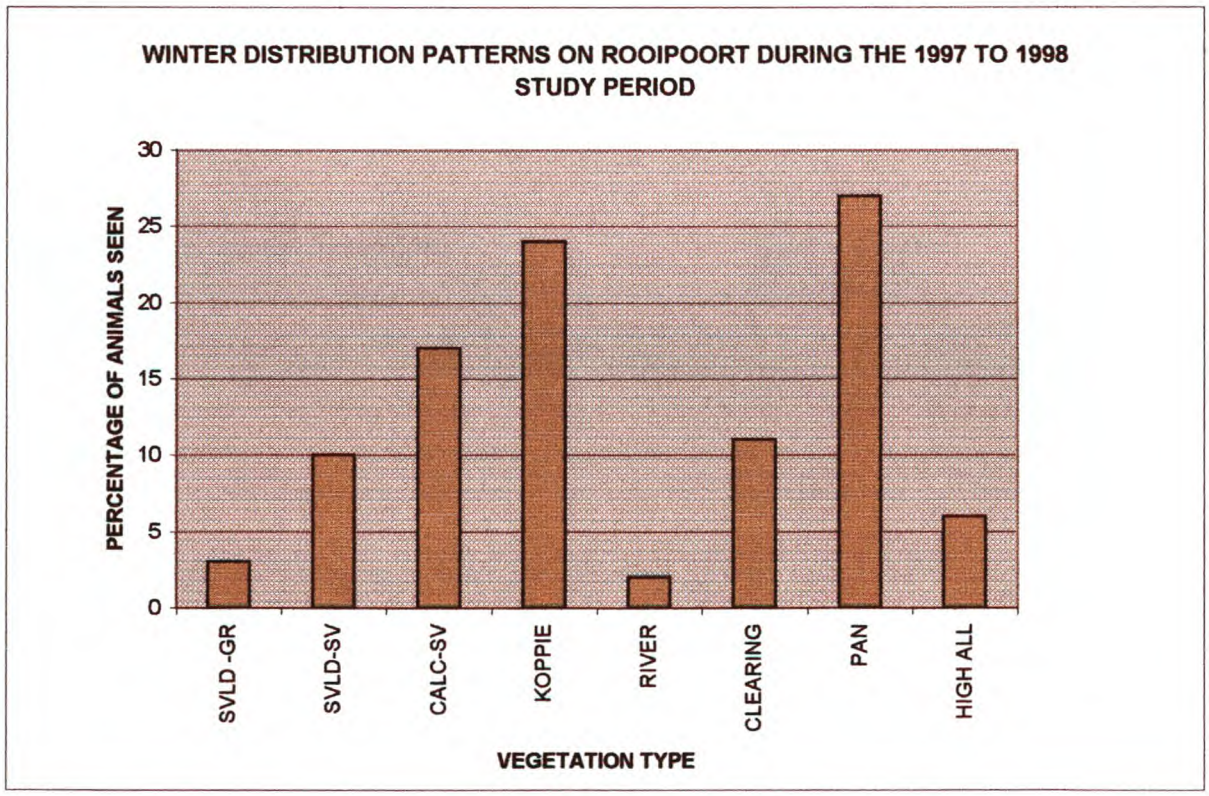


Figure 5.2.:



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c) Spring

As in the previous two seasons, distribution patterns follow the same trend, with pan, sandveld, cleared- and koppieveld areas accounting for the highest percentage of sightings. There are slight monthly differences, however.

In September, the highest percentage of sightings occurred on the pan, followed quite distantly by the Koppieveld areas. The sandveld savanna and 'clearings' delivered an equal, third highest, percentage of sightings, followed closely by the sandveld grassland areas.

The distribution in October was very similar, with the pan area delivering the highest figures, followed by the koppieveld, sandveld savanna and -grassland areas.

In November the pan and sandveld grassland areas delivered an equal percentage of sightings (25%), followed by the calcrete savanna and koppieveld area, both at 15 %. The sandveld savanna and cleared areas showed the third highest percentage of sightings, at 9 % each.

Together, the pan, sandveld, cleared- and koppieveld areas delivered over 80 % of all sightings made (Fig 5.3).

d) Summer

In December the koppieveld areas delivered the highest percentage of sightings, followed very closely by the pan. The area with the third highest percentage of sightings was the sandveld savanna areas and following that, the cleared areas.

The pan had the highest percentage of sightings in January, followed closely by cleared areas and koppieveld, respectively. The sandveld savanna shows the next highest percentage of sightings.

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Figure 5.3.:

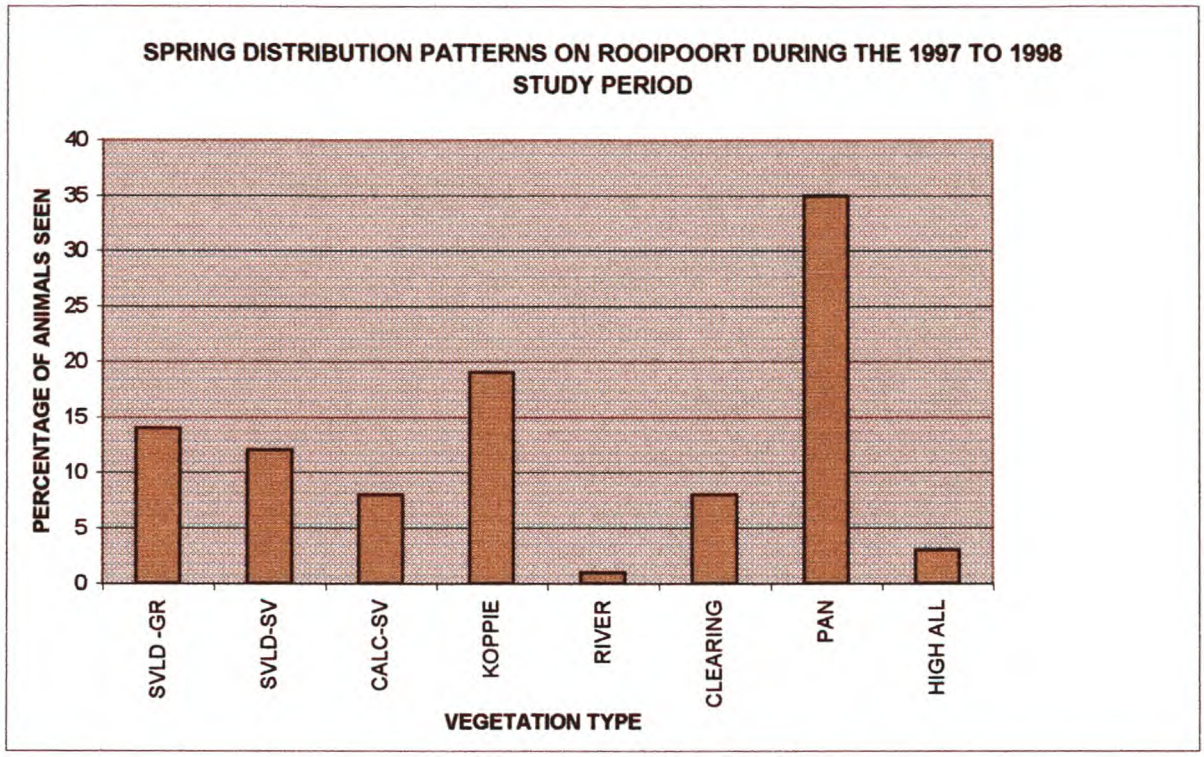

Figure 5.4.:

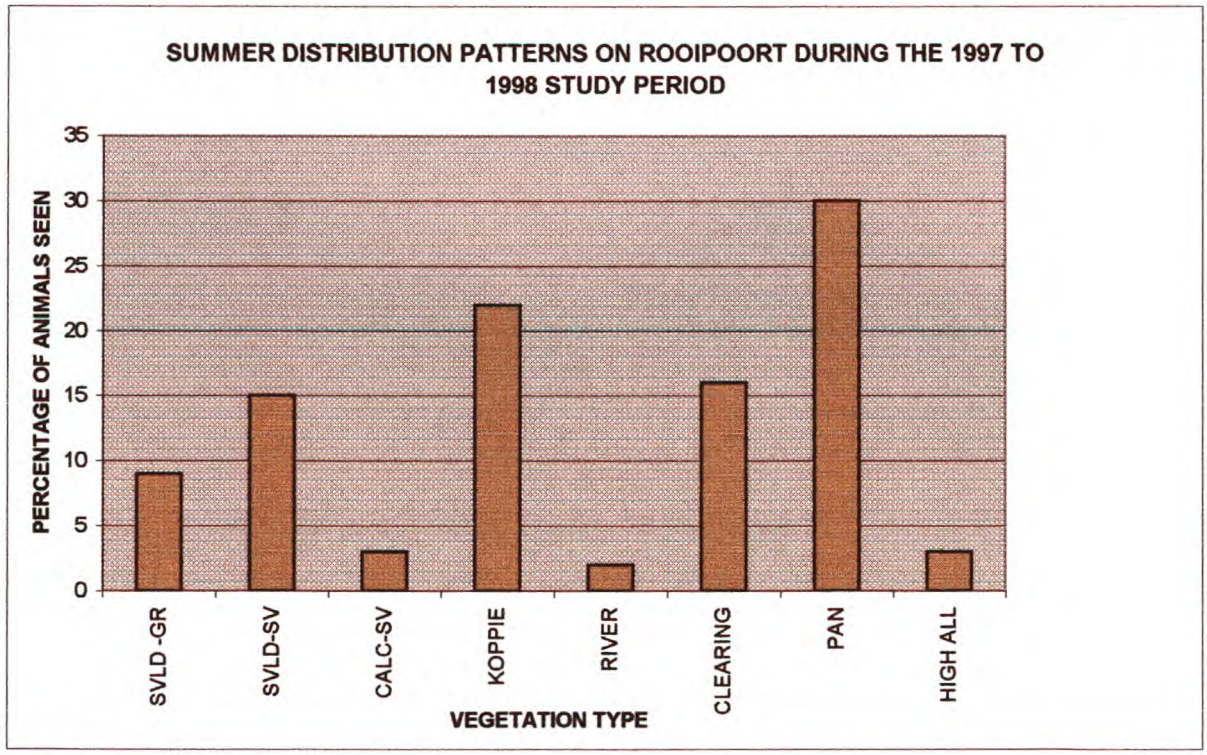

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Table 5.1. : Monthly distribution patterns on Rooipoort:

Month	Percentage of animal sightings:							
1997	**Svld-grass**	**Svld-sav**	**Calcr-sav**	**Koppievld**	**Riverine**	**Clearing**	**Pan**	**High-alluv**
June	0	12	41	34	1	10	0	2
July	9	10	6	15	1	10	42	7
August	1	9	5	23	1	13	39	9
September	8	10	5	20	1	10	45	1
October	9	18	5	20	1	6	34	7
November	14	12	8	18	3	8	34	3
December	7	18	2	27	4	10	26	6
1998								
January	11	14	4	21	0	23	26	1
February	9	12	3	19	1	16	37	3
March	19	10	6	21	2	14	26	2
April	13	10	3	22	3	18	26	5
May	11	8	3	24	1	17	28	8

KEY:
Svld-grass Sandveld grassland
Svld-sav: Sandveld savanna (Tarchonanthus)
Calcr-sav: Calcrete savanna (Tarchonanthus)
Koppievld Koppieveld vegetation
High-Alluv High-lying Alluvial vegetation

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In February the pan accounted for 40 % of all sightings, a much higher percentage of sightings than any other area. The koppieveld and cleared areas gave the next highest percentages, respectively, after which followed the sandveld savanna areas.

As expected from trends in the last three seasons, the pan, koppieveld, cleared-, and sandveld areas, together, accounted for up to 80 % of all sightings (Fig 5.4).

The high-lying alluvial areas, riverine vegetation areas, and calcrete savanna areas accounted for only a negligible percentage of the total number of sightings recorded each month. These areas may constitute a high percentage of sightings for individual species, however, and should, therefore, not be overlooked. Individual species distribution patterns will be discussed below.

5.1.2 **Individual species distribution patterns in the 1997 to 1998 study period:**

Distribution data for 1997 and 1998 was analysed using simple correspondence analysis (SIMCA) (Greenacre, 1986) and results are displayed graphically in Figure 5.5. This graph represents data, in the form of a 48-dimensional data matrix, condensed into a 2 dimensional space, using correspondence analysis. The total inertia (variance) value is a measurement of the proportion of variance accounted for by each axis of the graph. In this case, the inertia of axis 1 was calculated at 40.48 % and the inertia of axis 2 was 31.88 %. These 2 axes therefore account for 76 % of the total variance. The variance accounted for by the remaining axes is, therefore, fairly minimal and does not supply much more information.

Table 1A in appendix C gives the correlation coefficients for each species in each season, with each axis of the graph in Figure 5.5. The correlation coefficients in Table 1A correspond with the cosine of the angle between the axis origin and the point (species) of interest on the graph. The higher the correlation coefficient, the stronger the correlation between that point and the graph axis. Table 1A (Appendix C) gives correlation coefficients for species in 3 axes, while the graph only shows 2 axes.

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Species showing a strong correlation with axis 3 will, in reality, lie above the plane of the 2-dimensional graph.

Table 1 B (Appendix C) gives the correlation coefficient for each vegetation type with each axis of the graph in figure 5.5. By studying the graph and correlation coefficients it is possible to determine the correlation between species/season and vegetation type. Species are most strongly correlated with those vegetation types showing high correlation's to the same axes and occurring in the same directional plane of the graph.

Figures 1 to 10 in Appendix C give a graphic representation in the form of histograms, of individual species distribution, according to season and the percentage of sightings in each vegetation/habitat type on the reserve.

Maps 1 to 10 give an indication of individual species abundance in each of the vegetation/ habitat types on Rooipoort.

The following observations were made on the distribution of individual species during the study period.

a) Black Wildebeest

Figure 5.5 shows black wildebeest to have a strong association with the Pan area of Rooipoort, for all seasons during the study period (Figure 5.5).

The black wildebeest show a very narrow distribution range for both 1997 and 1998 on Rooipoort. Animal distribution would appear to be limited to Hoffman's pan and the cleared areas of the calcrete, and high-lying alluvial vegetation types. By far the highest percentage of sightings occurred on the pan, in all four seasons, and in every month of the study period (See Fig 1; Appendix C).

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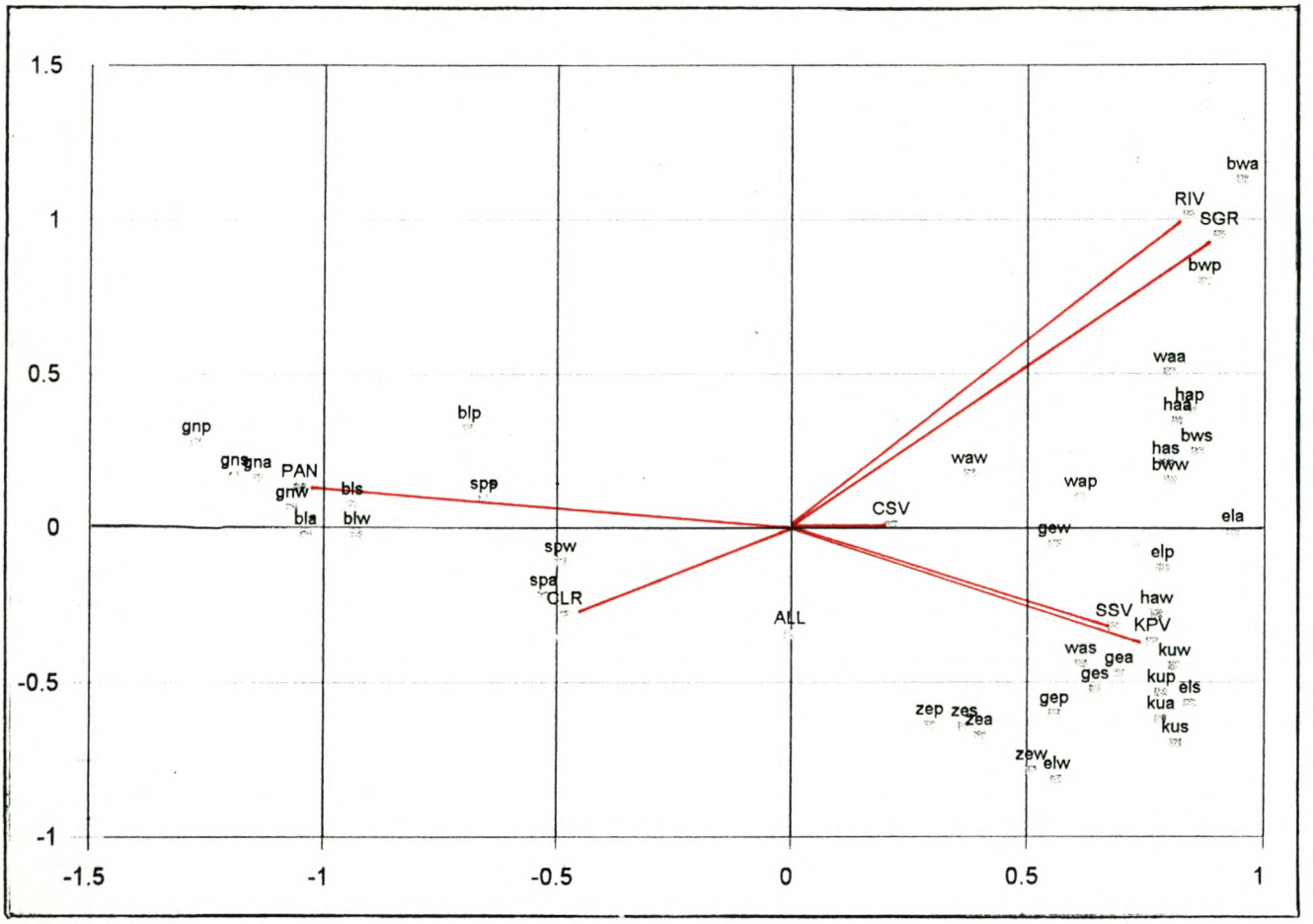
FIGURE 5.5. :



KEY:

Vegetation types:

SGR - Sandveld grassland
SSV - Tarchonanthus sandveld
CSV - Tarchonanthus calcrete
KPV - Koppieveld
RIV - Riverine vegetation
CLR - Clearings in calcrete
PAN - Hoffman's Pan
AL - High- lying alluvial areas

Suffixes:

p: spring
s: summer
a: autumn
w: winter

Species:

gn: black wildebeest
bl : blesbok
bw: blue wildebeest
el: eland
ge: gemsbok
ha: hartebeest
ku: kudu
sp: springbok
wa: warthog
ze: zebra

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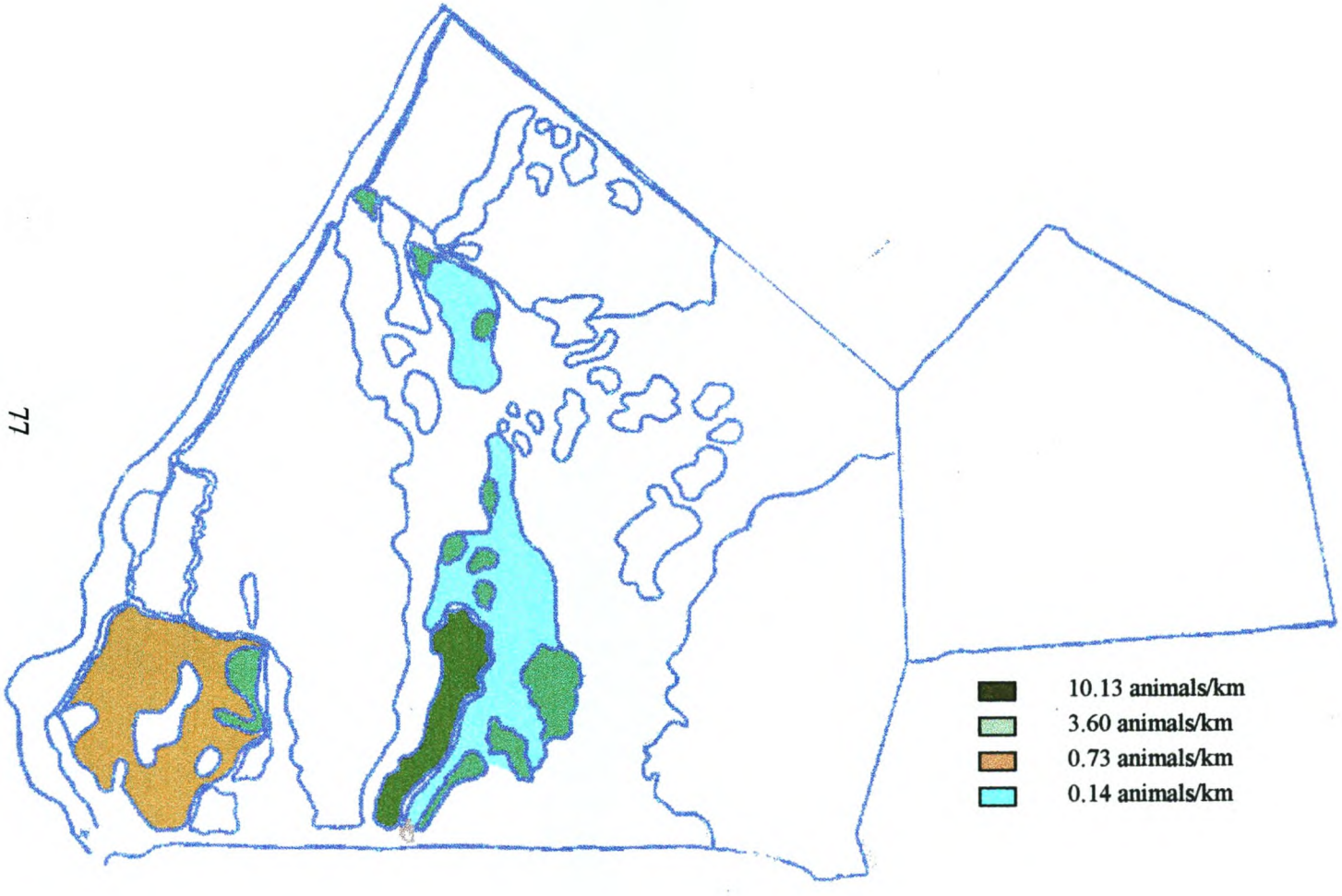
Map 1: Black wildebeest abundance patterns on Rooipoort (1997 to 1998):



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b) Blesbok

Blesbok show a strong association with the pan area during the summer months, while winter and autumn distribution shows a stronger association with the cleared areas of the calcrete savanna. Spring distribution is most strongly associatied with the Pan area of Rooipoort.

The distribution patterns of blesbok are, to a large extent, the same as those of black wildebeest, with the highest percentage of sightings found to be on Hoffman's pan and in the cleared areas of the calcrete, and high-lying alluvial areas of Rooipoort. Blesbok show a strong negative correlation with the sandveld savanna and koppieveld areas of Rooipoort (Also see Fig. 2; Appendix C).

c) Blue wildebeest

During both winter and summer the strongest association is with the sandveld grassland vegetation type of Rooipoort. Spring and autumn distribution shows a weaker association with the sandveld grassland and riverine areas (Figure 5.5).

Blue wildebeest showed a much wider distribution range than both black wildebeest and blesbok; and, according to Figure 3 (Appendix C), occur in almost every vegetation type within the study area. In this graph, the highest percentage of sightings were seen to occur in the sandveld grassland (and sometimes sandveld savanna) and koppieveld areas of Rooipoort. Riverine, clearing, pan and high-lying alluvial areas showed the lowest percentage of sightings for all seasons within the study period.

d) Eland

The autumn distribution data for eland shows the strongest association with the sandveld savanna vegetation type on Rooipoort (Table 5.1). Both spring and summer distribution data show a correlation with the koppieveld and sandveld savanna vegetation types. Winter distribution is strongly associated with the high-lying alluvial areas (Figure 5.5).

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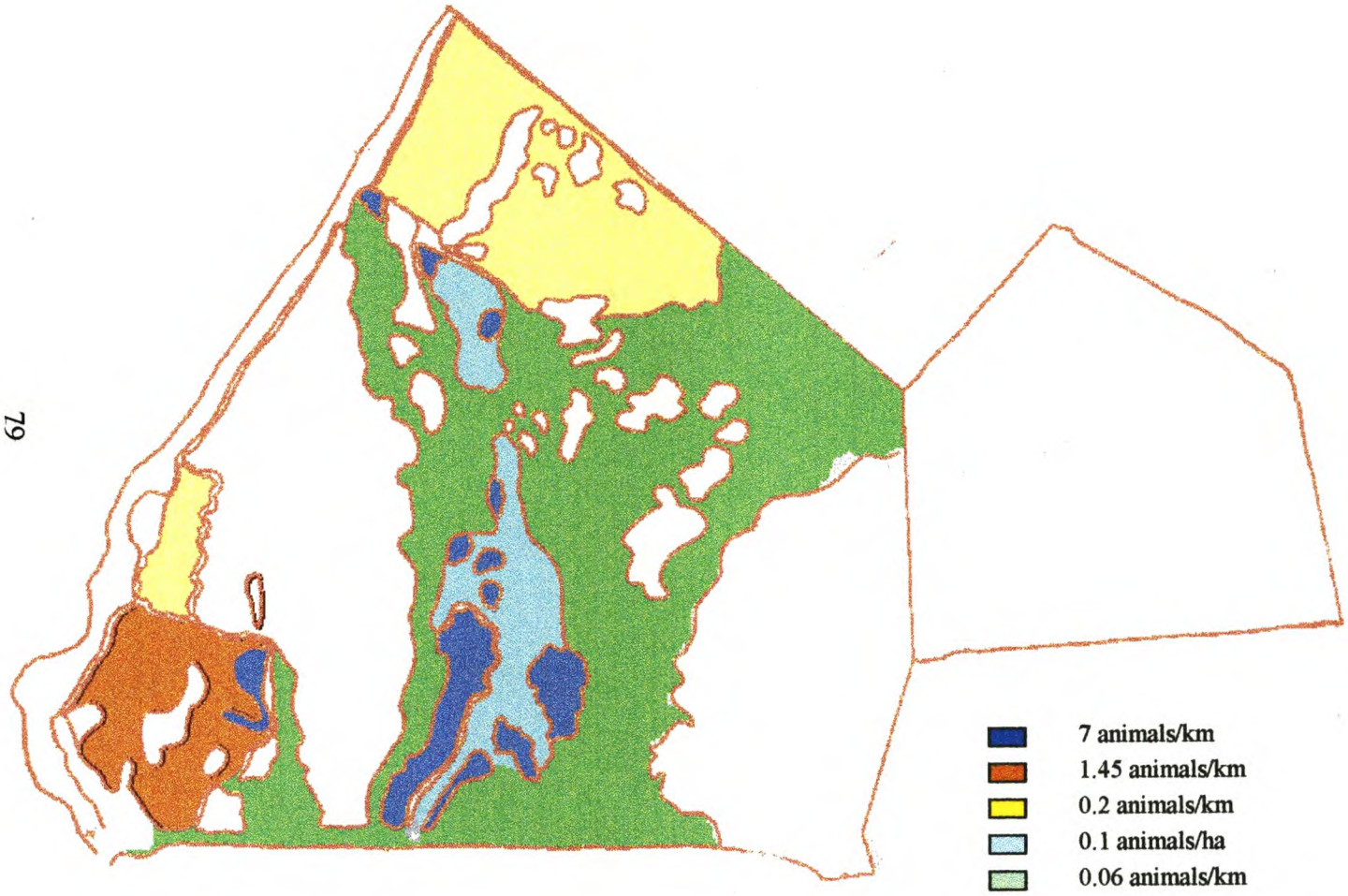
Map 2: Blesbok abundance patterns on Rooipoort (1997 to 1998):



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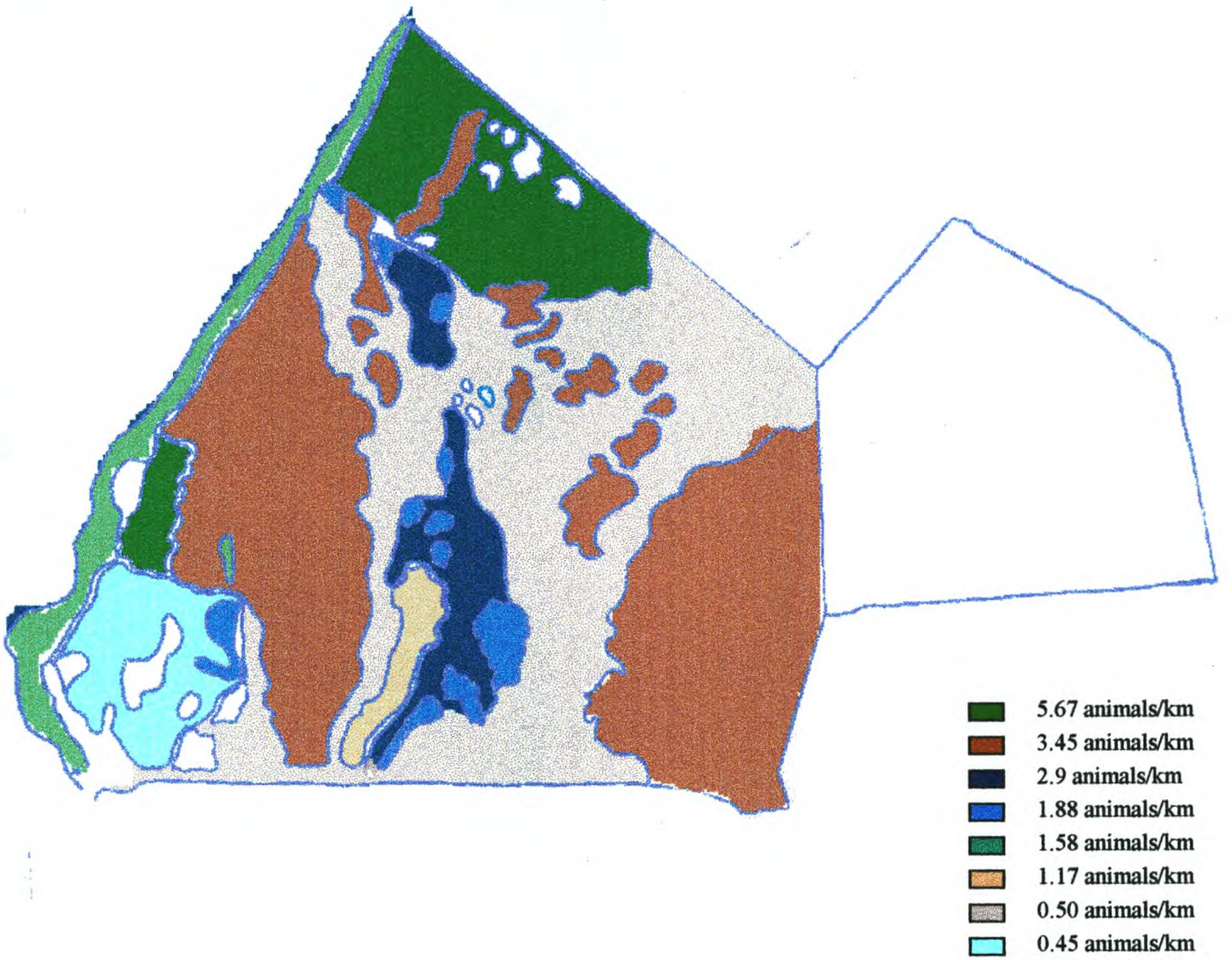
Map 3: Blue wildebeest abundance patterns on Rooipoort (1997 to 1998):



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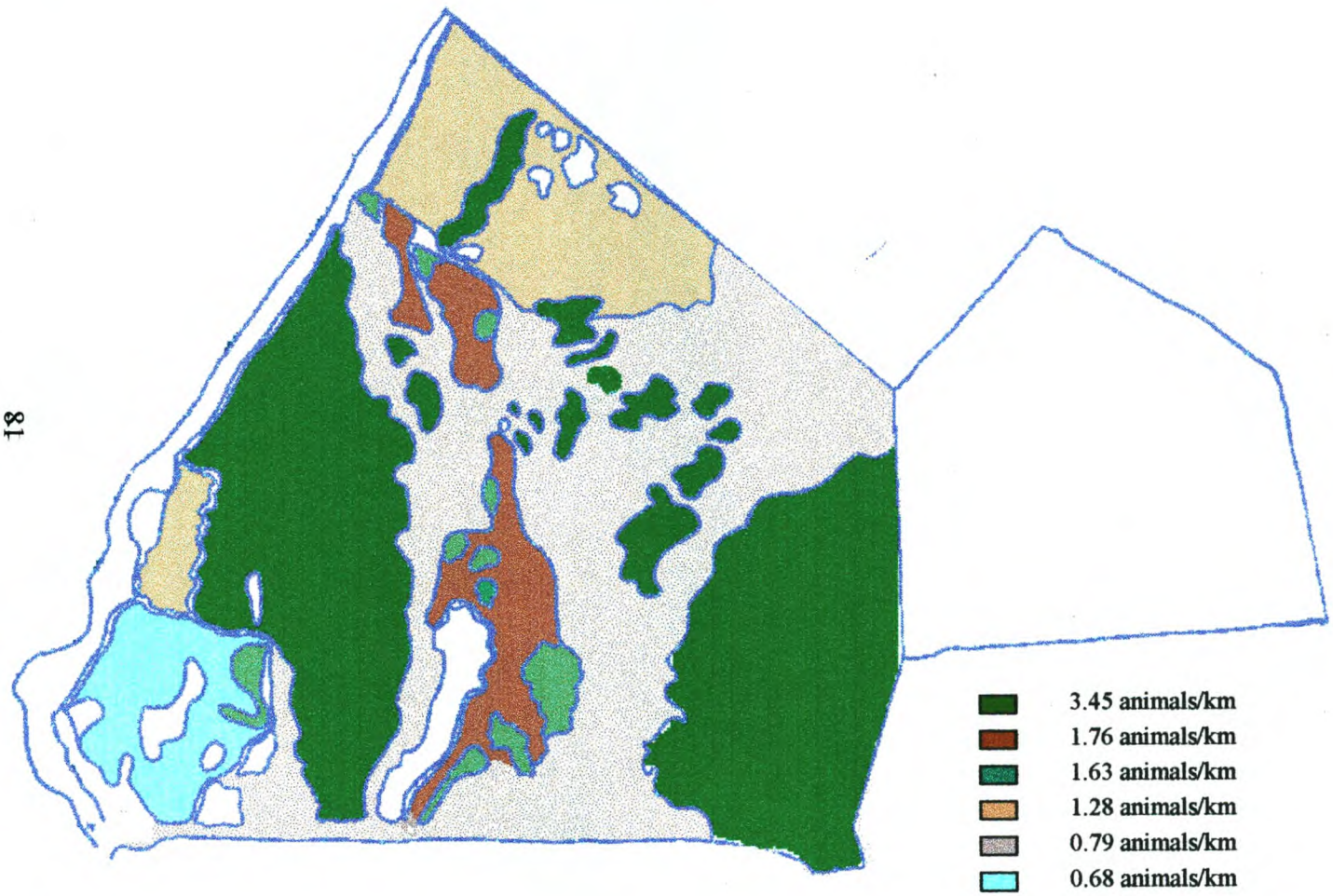
Map 4: Eland abundance patterns on Rooipoort (1997 to 1998):



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e) Gemsbok

Gemsbok are strongly associated with the sandveld savanna areas of Rooipoort during the winter months, whereas in summer and autumn there would appear to be a stronger association with the koppieveld areas of Rooipoort (Figure 5.5). During spring there is a stronger association with the high-lying alluvial vegetation type. Gemsbok show a strong negative correlation with the pan areas of Rooipoort.

According to Figure 5 (Appendix C) gemsbok have a widespread distribution. Most seasons during the study period gave the highest percentage of sightings to occurring in the koppieveld habitat of Rooipoort. Besides koppieveld areas, sandveld savanna also delivered a substantial percentage of gemsbok sightings each month. Areas showing virtually no gemsbok sightings were the high-lying alluvial and riverine habitat types on Rooipoort. The pan also had a very low gemsbok coverage for the majority of months during the study period

f) Hartebeest

Hartebeest are most strongly associated with the sandveld grassland vegetation, whereas in winter they show a strong association with the sandveld savanna and koppieveld vegetation types of Rooipoort (See Table 5.1 and Figure 5.5).

g) Kudu

Kudu are most strongly associated with the sandveld savanna and koppieveld vegetation types during all seasons of the study period (Figure 5.5).

h) Springbok

Springbok show the strongest association with pan area of Rooipoort during spring and summer. Winter and autumn results indicate a stronger correlation with the cleared areas of the calcrete vegetation type.

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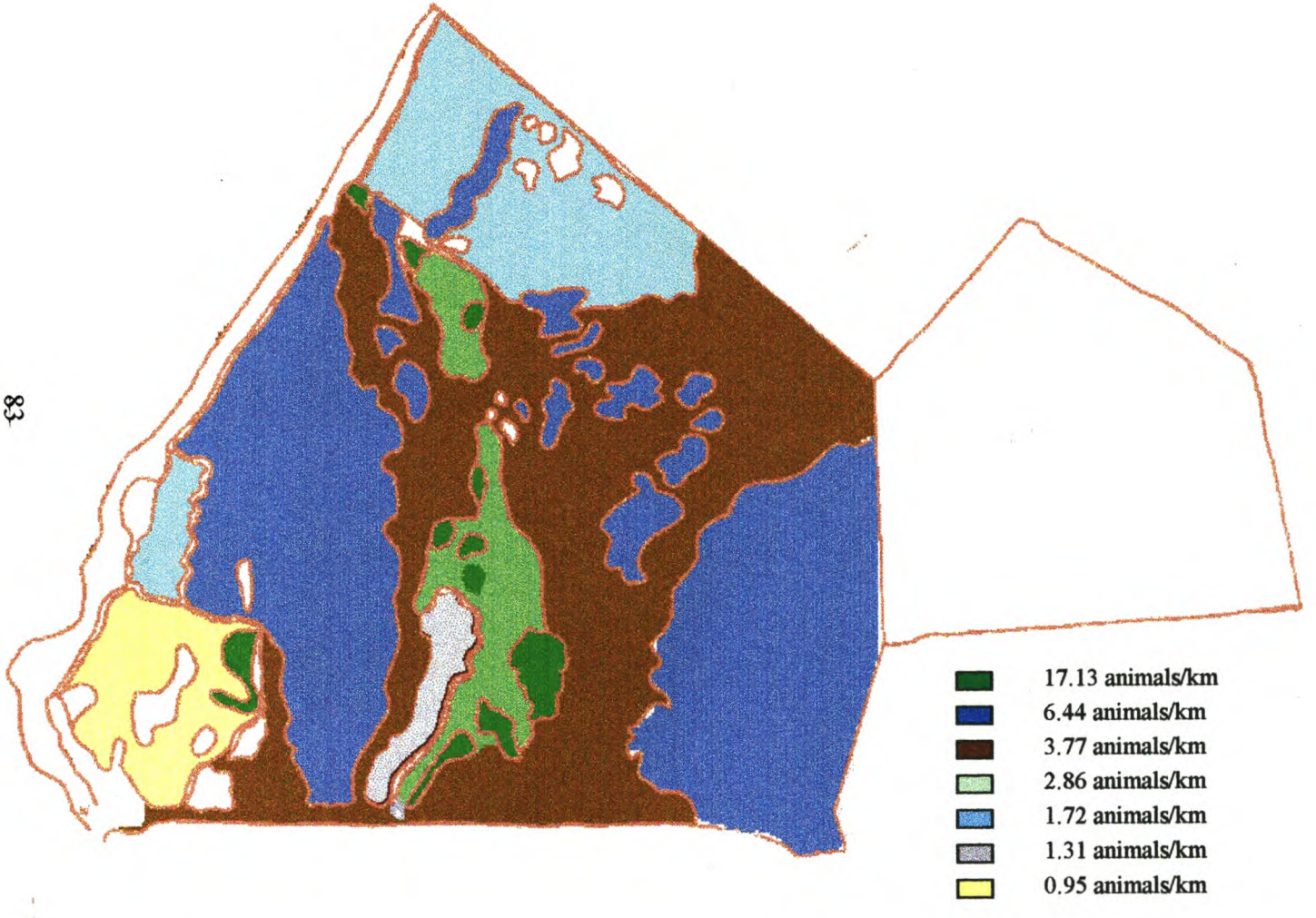
Map 5: Gemsbok abundance patterns on Rooipoort (1997 to 1998):



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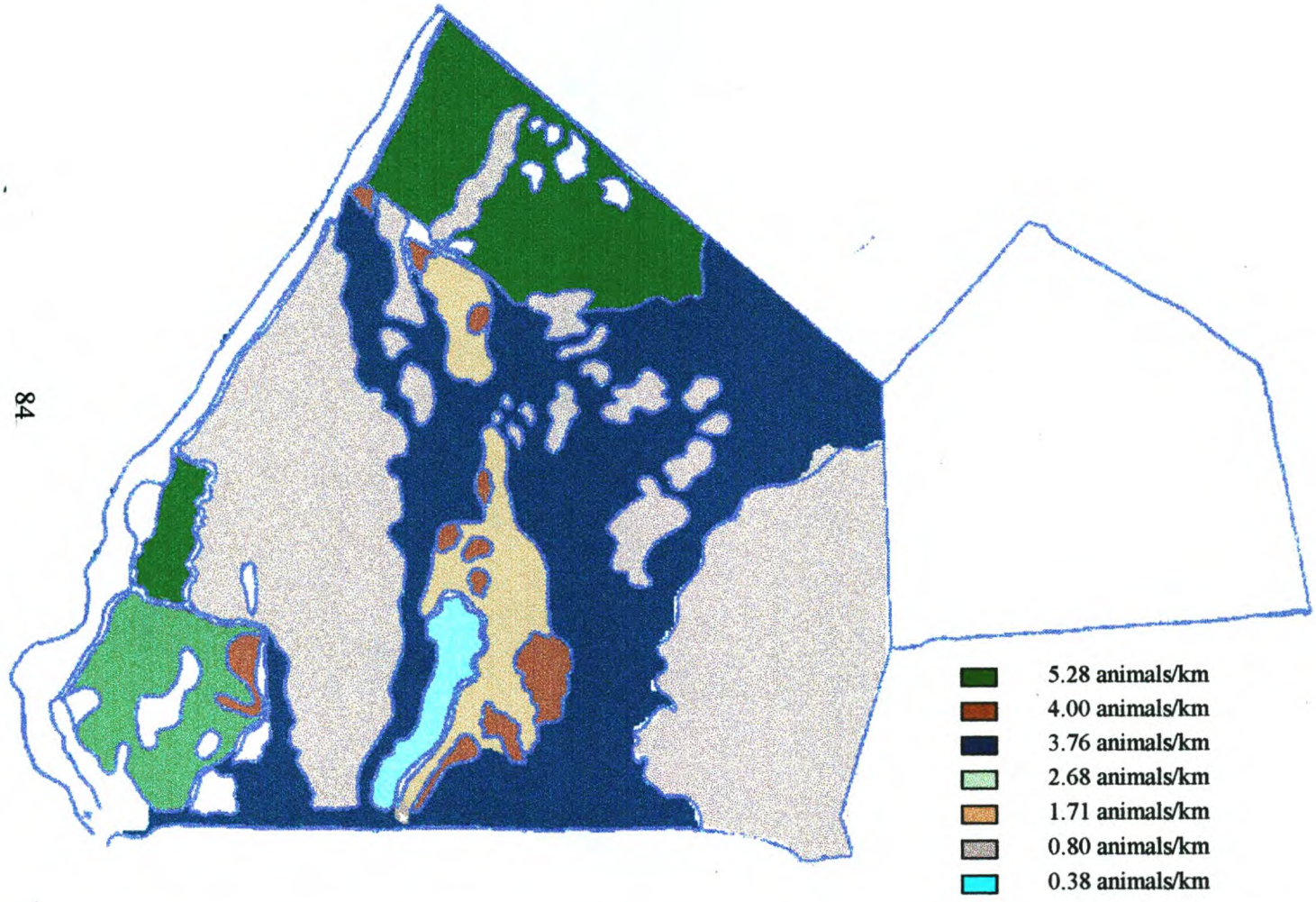
Map 6: Hartebeest abundance patterns on Rooipoort (1997 to 1998):



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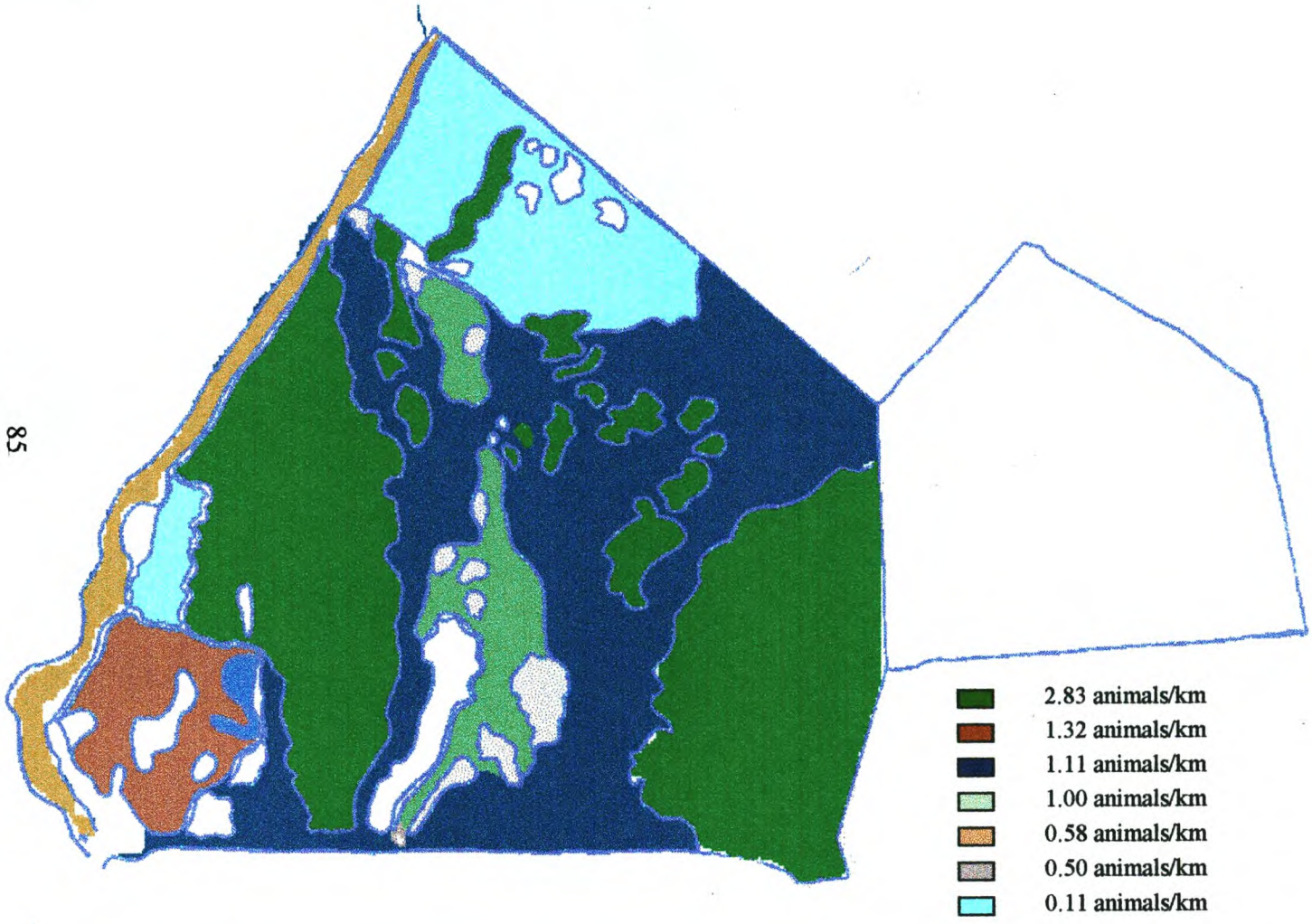
Map 7: Kudu abundance patterns on Rooipoort (1997 to 1998):



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i) Warthog

Looking at Figure 5.5 it is clear that warthog distribution is most strongly associated with the calcrete savanna vegetation type for both spring and winter. In Summer the strongest association is with the sandveld savanna and koppieveld areas of Rooipoort, whereas in autumn the association is stronger with the sandveld grassland areas. Warthog distribution is negatively correlated with the pan and cleared areas of the calcrete savanna.

Results illustrated in Figure 9 (Appendix C), show warthog to occur in every habitat in the study area at some time within the study period. The highest percentage of observations were seen to occur in the sandveld savanna habitats on Rooipoort for all seasons in the study period. This graph also shows a low percentage of sightings to occur in calcrete savanna areas.

j) Zebra

Figure 5.5 shows zebra to be associated with both the high-lying alluvial and koppieveld habitat types throughout the study period. Zebra appear to be weakly correlated with the koppieveld areas of Rooipoort (Figure 5.5) during the 3 other seasons.

The histogram respresentation of zebra distribution in Figure 10 (Appendix C), shows the highest percentage of sightings to occur in the koppieveld areas of Rooipoort, with a very low percentage of sightings in the high-lying alluvial areas.

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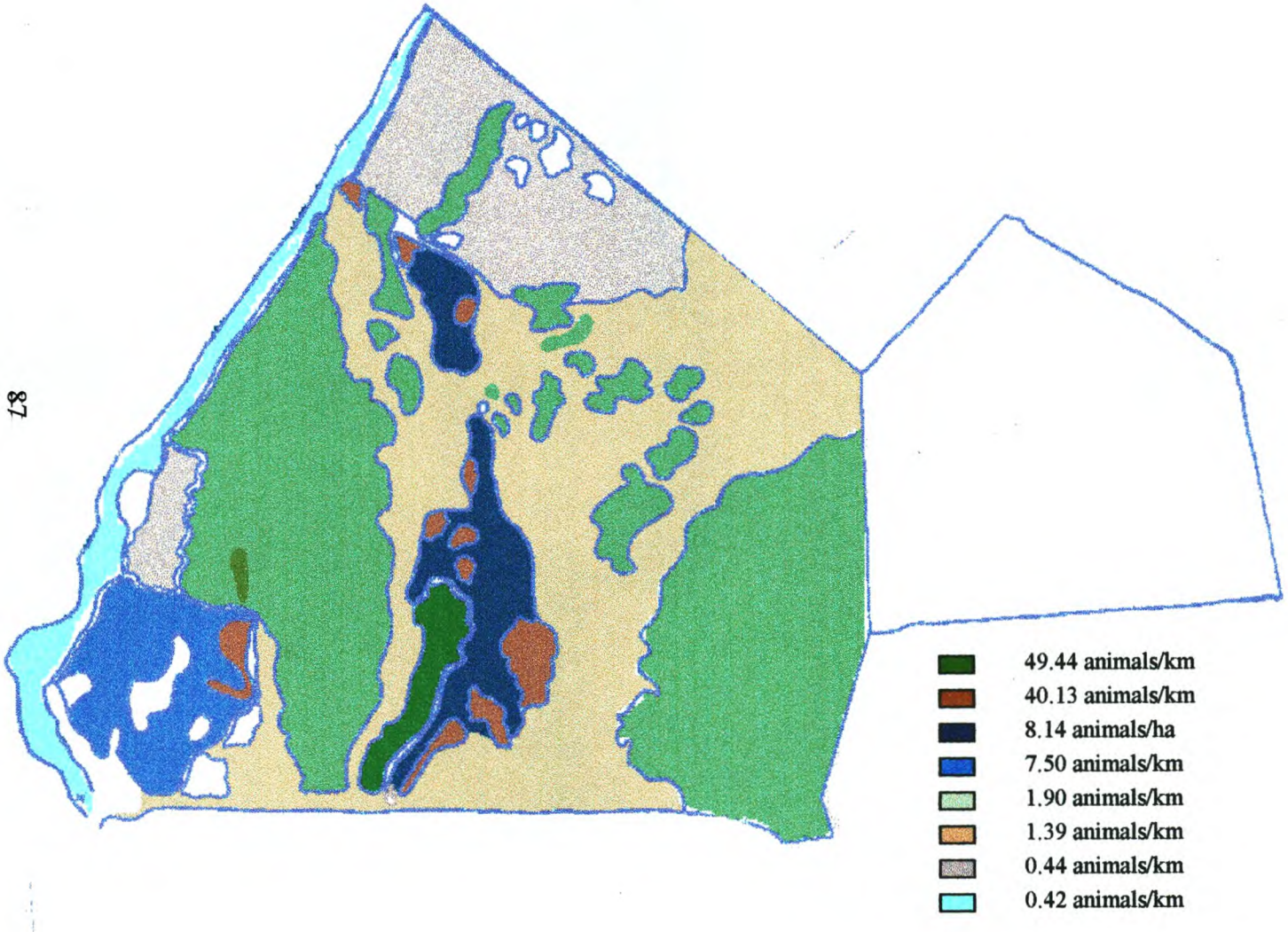
Map 8: Springbok abundance patterns on Rooipoort (1997 to 1998):



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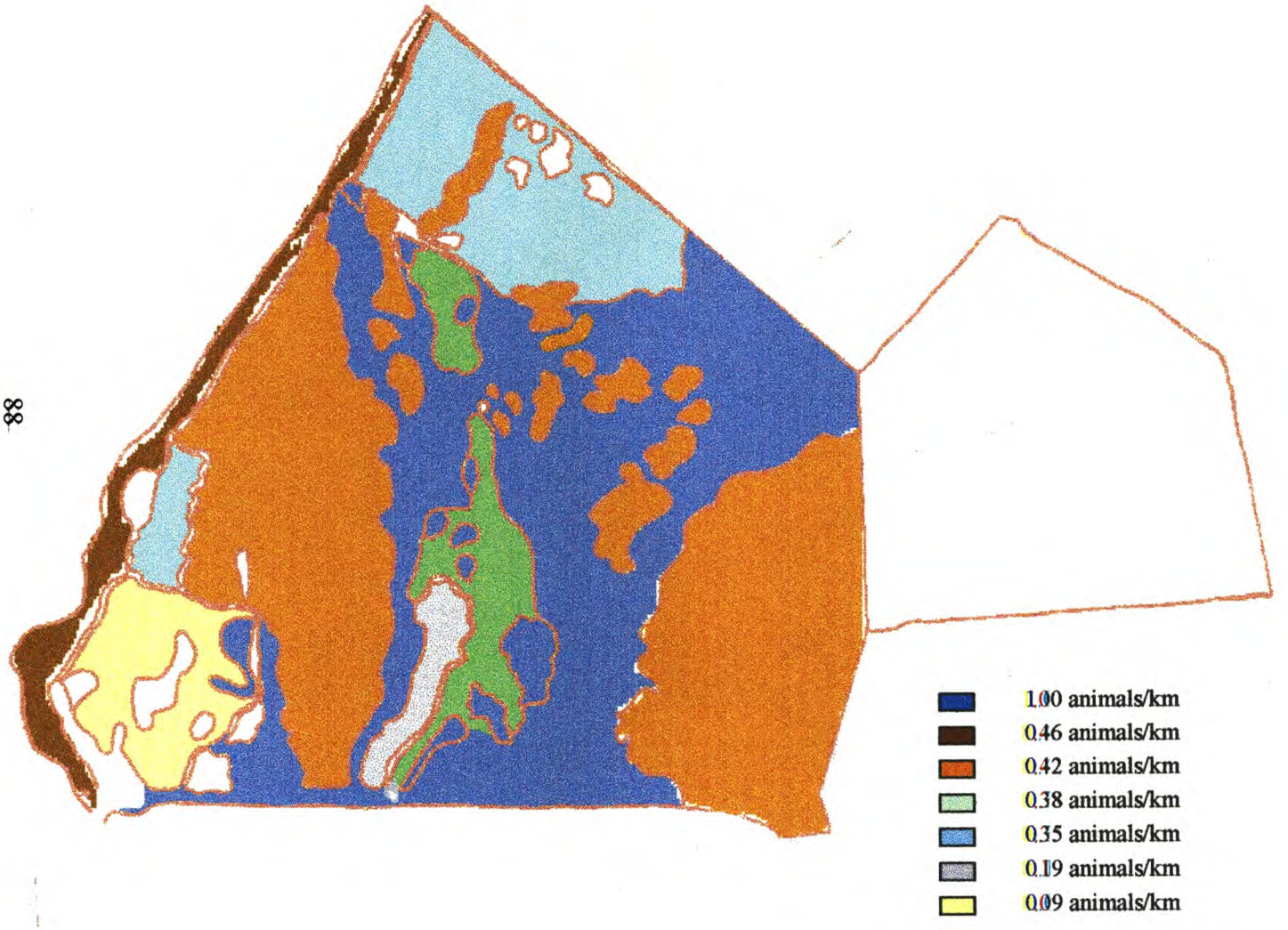
Map 9: Warthog abundance patterns on Rooipoort (1997 to 1998):



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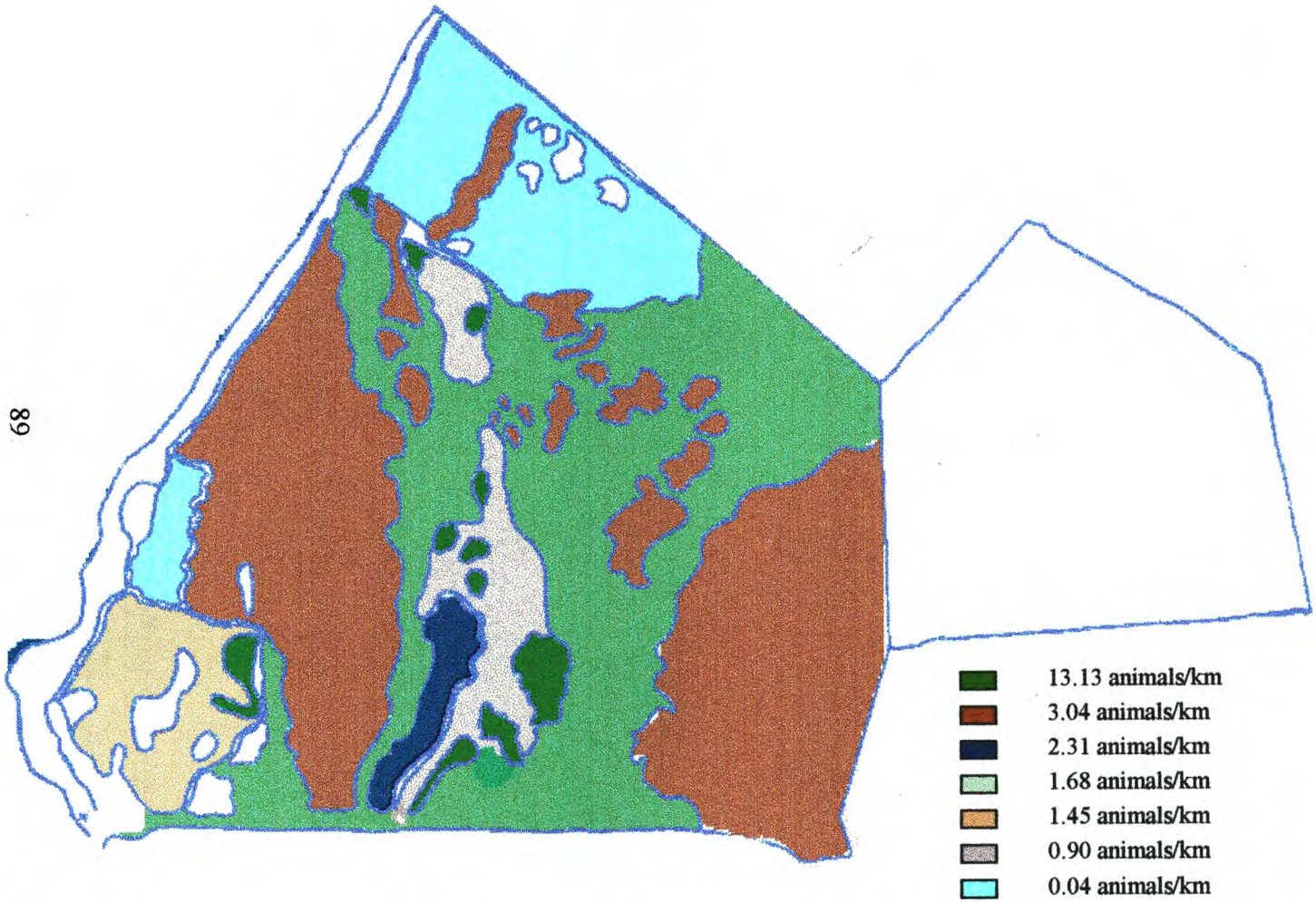
Map 10: Zebra abundance patterns on Rooipoort (1997 to 1998):



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5.2. Comparisons between overall, seasonal and individual ungulate species distribution patterns in the present study period (1997 and 1998) and those from the period of 1982 to 1984 (Mark Berry) on Rooipoort:

A study was undertaken by Mark Berry in the period from August 1982 to December 1984. This study comprised road counts traversing the area of Rooipoort, which were undertaken on an average of 1 day/month of the study period. All animals encountered along these routes were classified according to sex and age and a record was kept of the vegetation type in which they were observed. Vegetation types used in this study differ to a degree from the present study, in that pan counts were excluded. The vegetation types used here (with present classification in brackets) were:

- SV - Sandveld (Sandveld grassland)
- TS - Tarchonanthus sandveld (Sandveld Savanna)
- TC - Tarchonanthus calcrete (Calcrete savanna, including Clearings)
- KP & TK - Koppieveld and Tarchonanthus Koppieveld (Koppieveld)
- AL - Alluvium (High-lying alluvial areas)

5.2.1. Analysis of distribution data using correspondence analysis:

Distribution Data, in the form of a 55-dimensional data matrix is condensed into a 2 dimensional space (Figure 5.8.), using correspondence analysis. The total inertia (variance) value is a measurement of the proportion of variance accounted for by each axis of the graph. In this case, the inertia of axis 1 was calculated at 40.48 % and the inertia of axis 2 was 31.88 %. These 2 axes therefore account for 72.36 % of the total variance. The variance accounted for by the third and fourth axes is fairly minimal and does not supply much more information.

Table 2 A (Appendix C) gives the correlation coefficients for each species in each year, with each axis of the graph in Figure 5.8. The correlation coefficients in Table 5.2 correspond with the cosine of of the angle between the origin axis and the point (species) of interest on the graph. The higher the correlation coefficient, the stronger the correlation between that point and the graph axis. Table 2 A (Appendix C) gives

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correlation coefficients for species in 3 axes, while the graph only shows 2 axes. Species showing a strong correlation with axis 3 will actually lie above the plane of the 2-dimentional graph.

Table 2 B (Appendix C) gives the correlation coefficient for each vegetation type with each axis of the graph in figure 5.8. By studying the graph and correlation coefficients it is possible to determine the correlation between species/year and vegetation type. Species are correlated with vegetation types showing high correlations to the same axes and in the same directional plane.

Figures 21 to 30 in Appendix C give a graphic representation of the overall yearly distribution of each species on Rooipoort, according to the percentage of animals seen in each vegetation/habitat type.

5.2.2. The use of Shannon and Simpson indices to give an indication of species niche width:

In addition to the graphic analysis of distribution data, the distribution of each species for the 2 study periods, was compared using Shannon and Simpson indices to give an indication of changes in niche width.

The Shannon index H' is calculated from the equation:

$$H' = \Sigma p_i \ln p_i,$$

Where p_i is the proportion of individuals of a species (p) observed in the ith vegetation/habitat type. The higher the Shannon index (H'), the wider the species niche width.

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The Simpson index D, is calculated from the equation:

$$D = \Sigma \left(\frac{n_i\ (n_i - 1)}{N\ (N - 1)} \right),$$

Where n_i is the number of individuals (of a species) in the ith habitat/vegetation type, while N is the total number of individuals of a species observed (Magurran, 1988). The lower the Simpson index (D), the wider the niche width of a species.

Shannon and Simpson indices were calculated for each of the species under observation in each of the years in question, and are given in Table 5.2.

Analysis of variance was used to test for significant differences in Shannon and Simpson indexes, both between species and within species. This gives an indication of changes in niche width. Duncan's Multiple Range Analysis – a comparison procedure for obtaining all pairwise comparisons among a number of sample means (Ott, 1993) - was used to determine which species showed significantly different niche widths. Results of these analyses are given in Table 5.3, and discussed in Section 5.2.3

5.2.3. **Comparisons between overall yearly and seasonal distribution patterns on Rooipoort**:

The most apparent difference between seasonal distribution patterns in the two study period is the greater percentage of animal sightings in the Tarchonanthus sandveld vegetation type in the present study period. The Alluvium areas show a decrease in percentage of species sightings in the present study period, but the difference is only significant in two, out of the four seasons (See Fig 5.6 (a), (b), (c) & (d)).

Looking at Fig 5.7. it is apparent that the major difference in yearly distribution patterns occurs within the Sandveld grassland, Tarchonanthus calcrete and Alluvium vegetation types on Rooipoort. For all of the years in question, the Koppieveld areas show a high abundance of animals. The Sandveld grassland vegetation type shows a decrease in the percentage of animal sightings from the earlier to latter study period, whereas the

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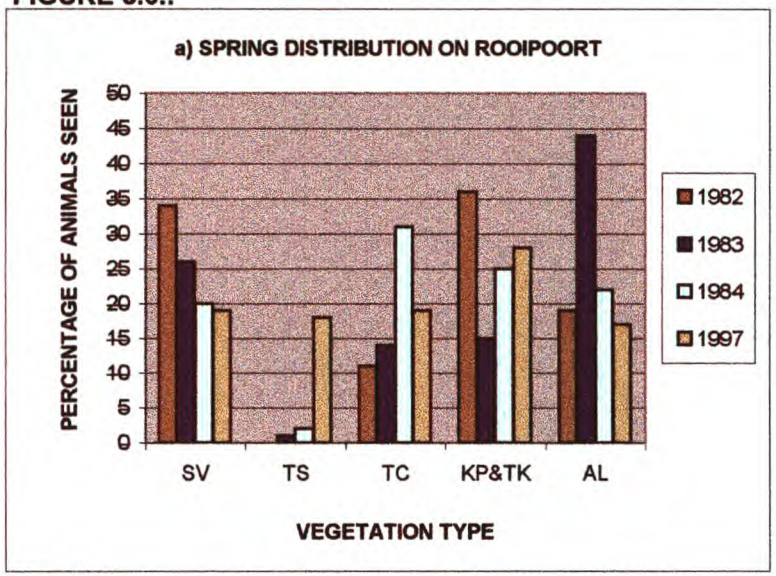
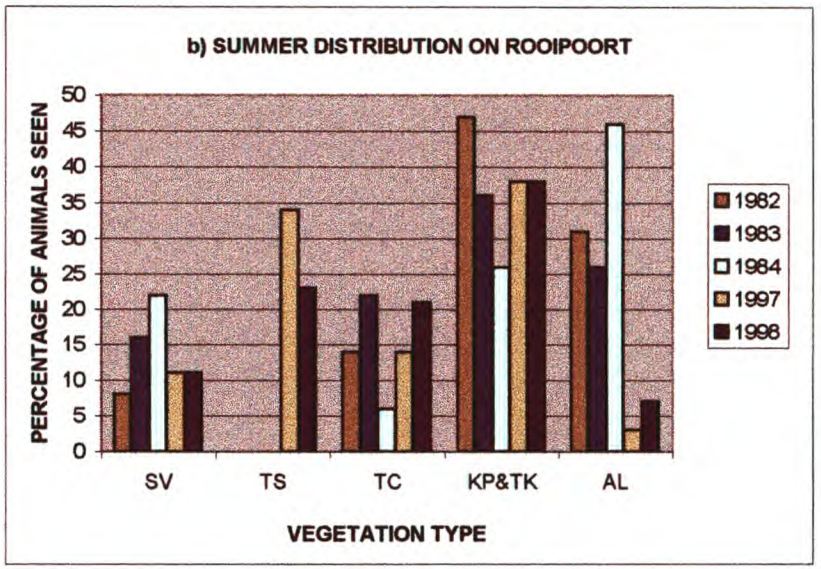
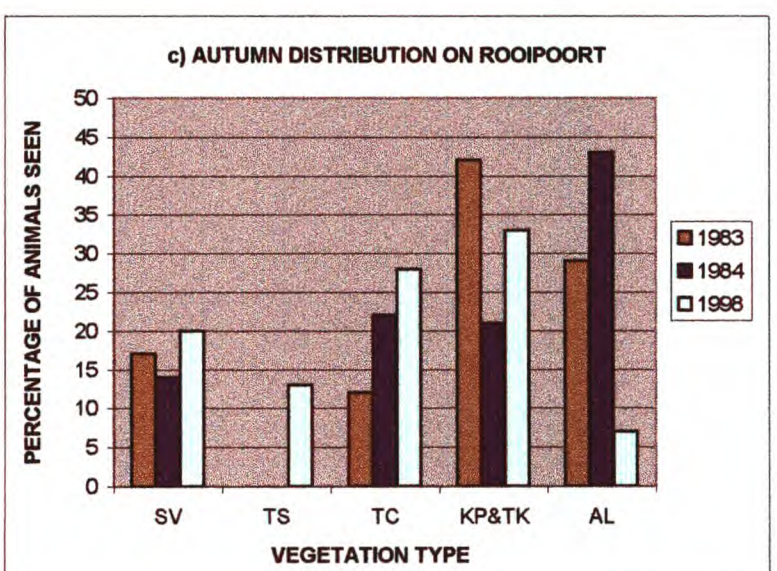
FIGURE 5.6.:







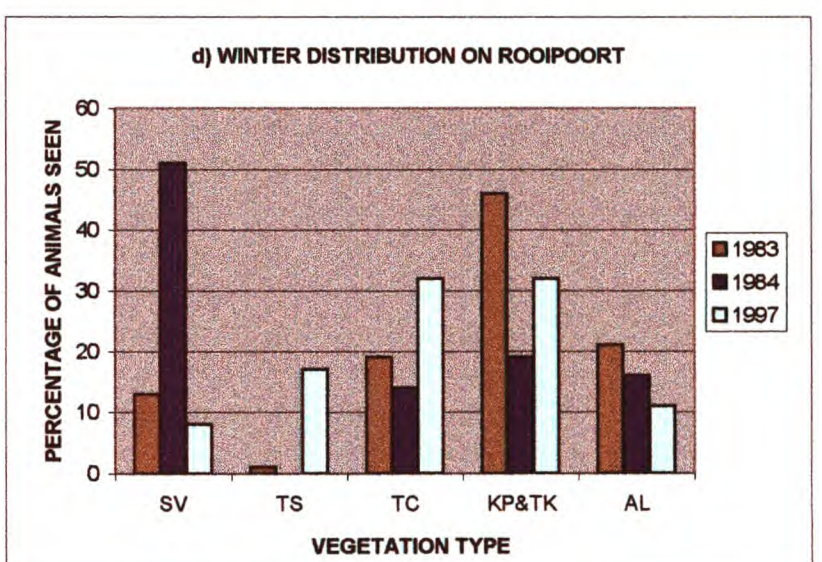


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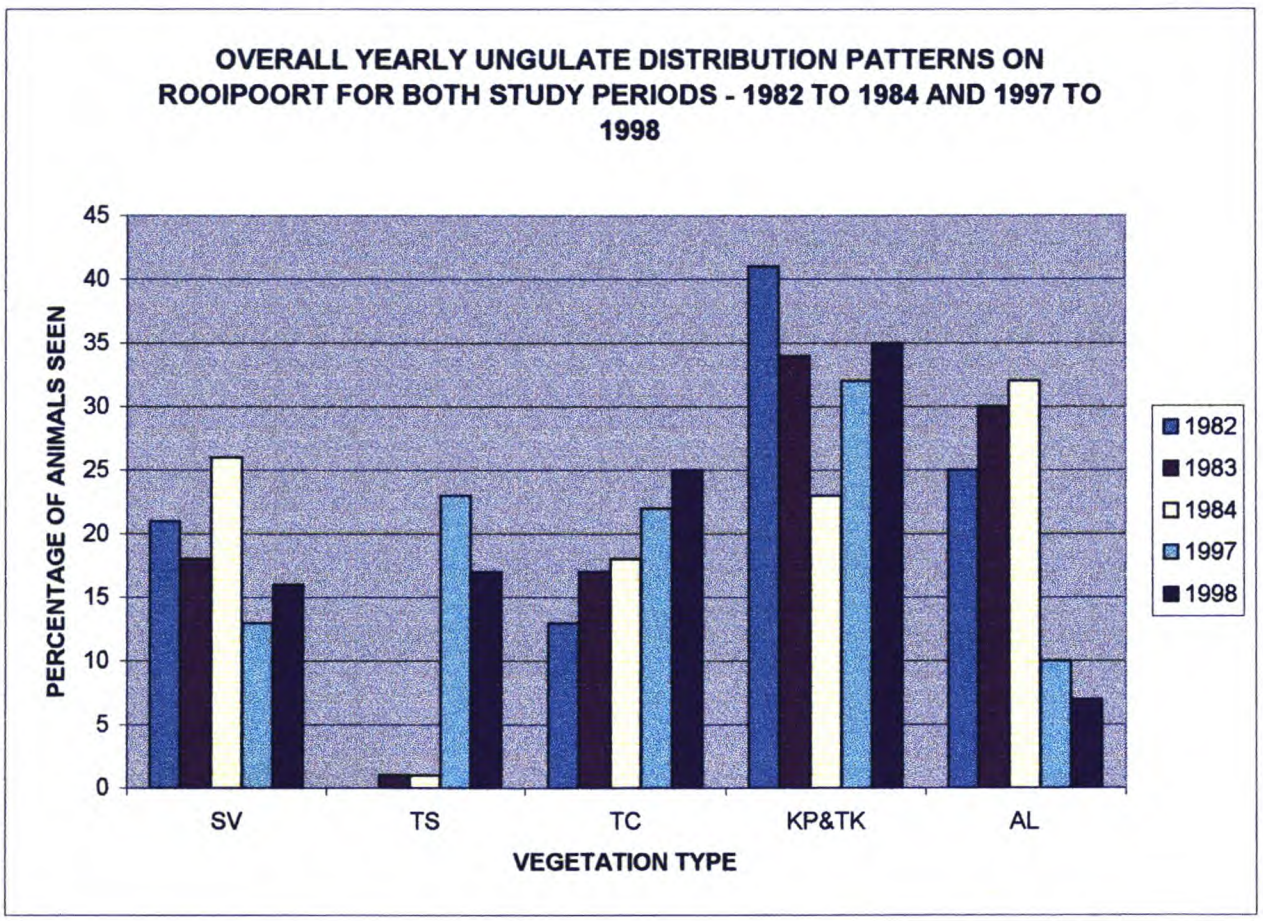
FIGURE 5.7. :



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Tarchonanthus sandveld vegetation type shows a very great increase in animal sightings. The Tarchonanthus calcrete areas show a considerable increase in percentage of species sightings in the present study period as compared with 1982 to 1984 data. Lastly the Alluvium vegetation type shows a higher percentage of sightings in the earlier study period.

5.2.4. **Comparisons between individual species distribution patterns:**

a) Black Wildebeest:

Shannon and Simpson indices calculated for black wildebeest for both study periods suggest a definite contraction of niche width from the former to latter study period (See Table 5.2.). Present distribution patterns show black wildebeest restricted to the Tarchonanthus calcrete (TC) vegetation type (mainly clearings), with a very small number being observed in the Alluvium vegetation type. Past distribution patterns showed a much greater number of observations in the Alluvium vegetation type, a limited number in the Sandveld (SV on graph) and, in 1983, a considerable number in the Koppieveld vegetation (KP on graph) type. As in present distribution patterns, past distribution also showed a high number of observations in the Tarchonanthus Calcrete (TC) vegetation type (See Fig. 21 and Fig. 31 in Appendix C) (see Figure 5.9.)

The correspondence analysis graph in Figure 5.9 shows black wildebeest to have a stronger association with the high-lying alluvial areas in the 1982 to 1984 study, while in 1997 and 1998 there is a very definite association with the Tarchonanthus calcrete areas of Rooipoort. In 1984 black wildebeest showed a slight association with the Tarchonanthus sandveld vegetation type on Rooipoort.

b) Blesbok:

During 1982 and 1984 blesbok did not show a very strong association with any vegetation type, but appeared to be most strongly associated with the Tarchonanthus calcrete areas. The 1983 data shows a strong association with the Tarchonanthus sandveld vegetation

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Table 5.2. : Shannon and Simpson indices as an indication of species niche width:

SPECIES	YEAR	SHANNON	SIMPSON
BLCK-WB	1982	0.92	0.38
	1983	1.16	0.33
	1984	1.28	0.25
	1997	0.25	0.84
	1998	0.15	0.93
BLESBK	1982	0.69	0.50
	1983	0.63	0.64
	1984	0.66	0.51
	1997	0.92	0.41
	1998	0.74	0.85
BLUE-WB	1982	1.05	0.39
	1983	0.95	0.47
	1984	1.16	0.38
	1997	1.30	0.30
	1998	1.14	0.38
ELAND	1982	1.16	0.33
	1983	1.12	0.43
	1984	1.20	0.45
	1997	1.29	0.36
	1998	1.13	0.40
GEMSB.	1982	0.68	0.53
	1983	0.81	0.49
	1984	0.91	0.47
	1997	1.30	0.31
	1998	1.30	0.30
HARTEB	1982	1.10	0.37
	1983	1.19	0.37
	1984	1.29	0.31
	1997	1.46	0.25
	1998	1.43	0.27
KUDU	1982	1.15	0.60
	1983	1.04	0.44
	1984	1.05	0.42
	1997	1.16	0.39
	1998	0.89	0.53
SPRGBK	1982	1.29	0.30
	1983	1.17	0.38
	1984	1.16	0.44
	1997	1.31	0.29
	1998	1.03	0.45
WARTHO	1982	0.63	0.57
	1983	0.89	0.33
	1984	0.92	0.44
	1997	1.22	0.34
	1998	1.31	0.32
ZEBRA	1982	0.25	0.85
	1983	1.08	0.32
	1984	0.47	0.65
	1997	1.24	0.32
	1998	1.28	0.32

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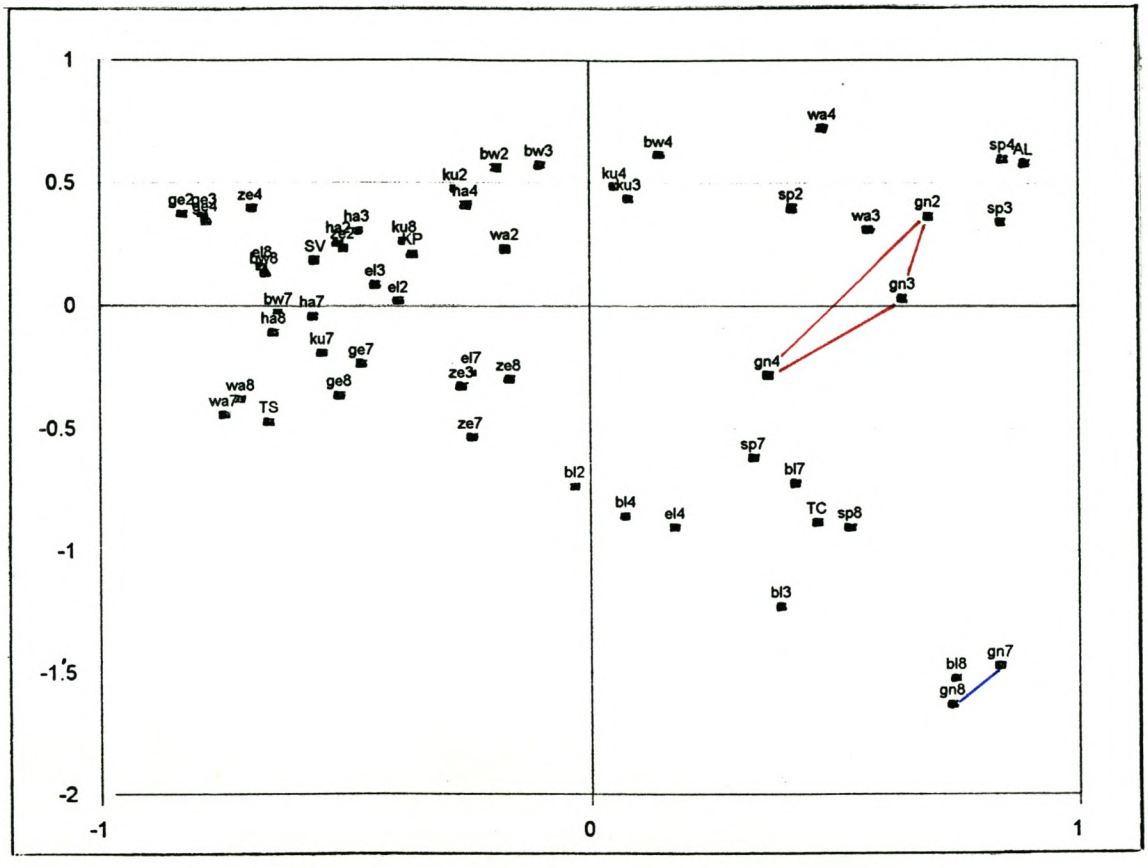
Figure 5.9.: Comparisons between black wildebeest distribution in the 1984 and 1997 study periods:



1982 to 1984 distribution

1997 to 1998 distribution

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type. For the latter, 1997 to 1998, period there is a strong correlation for blesbok with the Tarchonanthus calcrete vegetation type of Rooipoort (See Figure 5.8.).

Blesbok distribution patterns have not undergone any major changes, and data shows a consistently high percentage of blesbok observations in the Tarchonanthus calcrete vegetation type. Other areas showing a considerable percentage of observations in both periods were the Sandveld grassland areas, although this is lower for the 1997 to 1998 period. The high-lying alluvium vegetation types shows a higher percentage of sightings in the latter study period (see Fig. 32 in Appendix C). In no season were any observations made in the Tarchonanthus Sandveld vegetation and Koppieveld sightings were negligible (See Appendix C, Fig. 22, for seasonal distribution patterns).

The Shannon and Simpson indices for both study periods suggest a moderate niche width for blesbok (Table 5.2).

c) Blue Wildebeest:

Figure 5.10. shows blue wildebeest to be strongly associated with the sandveld grassland and Tarchonanthus sandveld areas in 1997 and 1998, whereas in 1982 to 1984 there was a weak association with both the high-lying alluvial and koppieveld areas of Rooipoort (also see Figure 5.10.)

Figure 33 (Appendix C) shows a consistently high percentage of sightings in the Koppieveld vegetation type for both study periods. For most seasons (See Fig. 23, Appendix C for seasonal distribution patterns) there is also a rather high percentage of observations in the Sandveld grassland areas. Vegetation types showing consistently low observations for blue wildebeest are the Tarchonanthus Sandveld and Tarchonanthus Calcrete. Sightings in the Alluvium vegetation type appear to have decreased substantially in the present study period, to what was the case in the 1982 to 1984 study period (See Fig. 33 in Appendix C).

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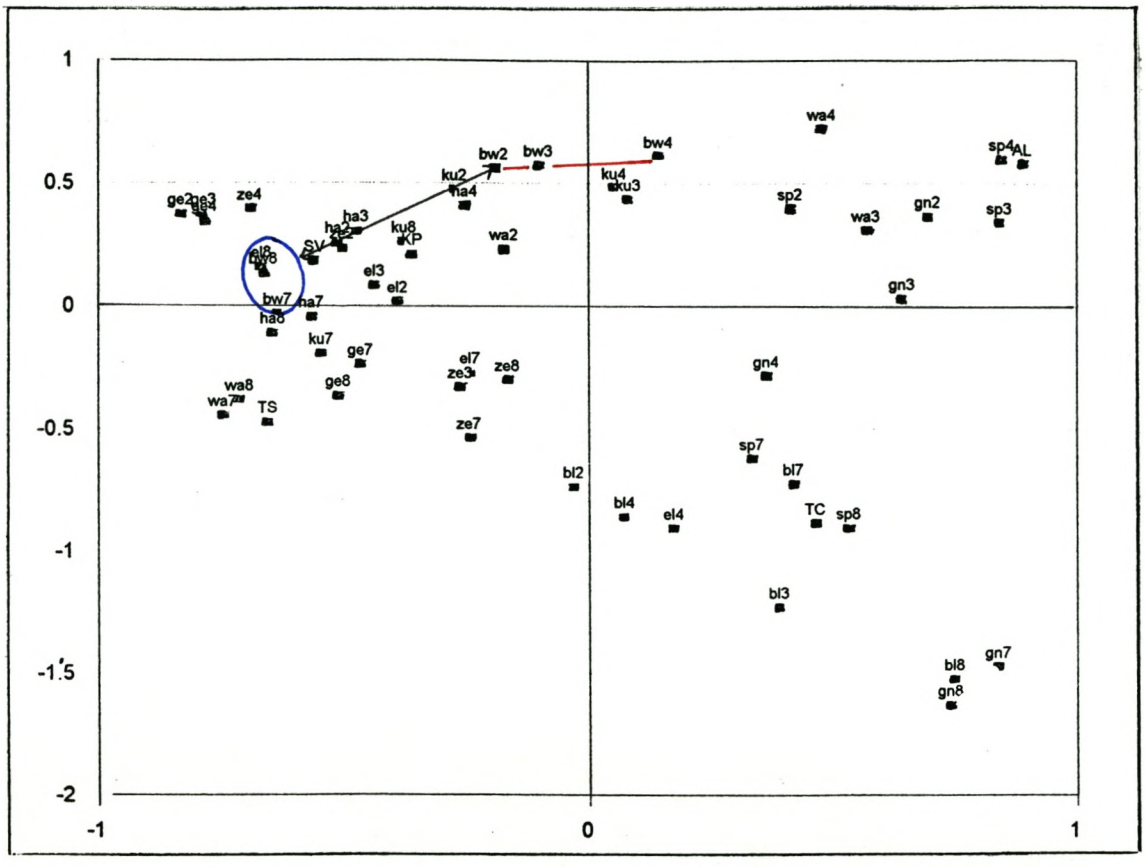
Figure 5.10.: Comparisons between blue wildebeest distribution in the 1984 and 1997 study periods:



1982 to 1984 distribution

1997 to 1998 distribution

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Shannon and Simpson indices indicate a very similar and fairly large niche width for blue wildebeest, for both study periods (Table 5.2).

d) Eland:

Looking at Figure 5.8 it is clear that, in 1984, eland were strongly associated with the Tarchonanthus calcrete vegetation types, whereas those of 1983 and 1982 were strongly associated with the sandveld grassland and koppieveld areas of Rooipoort. In 1998, eland are strongly associated with the sandveld grassland and koppieveld areas, while in 1997 they are more strongly correlated with the Tarchonanthus sandveld vegetation type.

For both study periods eland appear to be most strongly associated with the sandveld and koppieveld areas of Rooipoort. Distribution patterns do not appear to have changed much from the earlier to later study periods.

Shannon and Simpson indices indicate a fairly large niche width for eland for both study periods (Table 5.2).

e) Gemsbok:

Looking at Figure 5.11 it is apparent that in 1982, 1983 and 1984, gemsbok were strongly associated with the sandveld grassland and koppieveld areas of Rooipoort. In 1997 and 1998 the association is strongest with the Tarchonanthus sandveld vegetation type.

There would appear to have been a shift from the sandveld grassland (1982 – 1984) to the Tarchonanthus sandveld areas in the present study period (See Fig 25 and Fig. 35 in Appendix C).

Shannon and Simpson indices indicate a considerable increase in niche width from the earlier to latter study period (Table 5.2).

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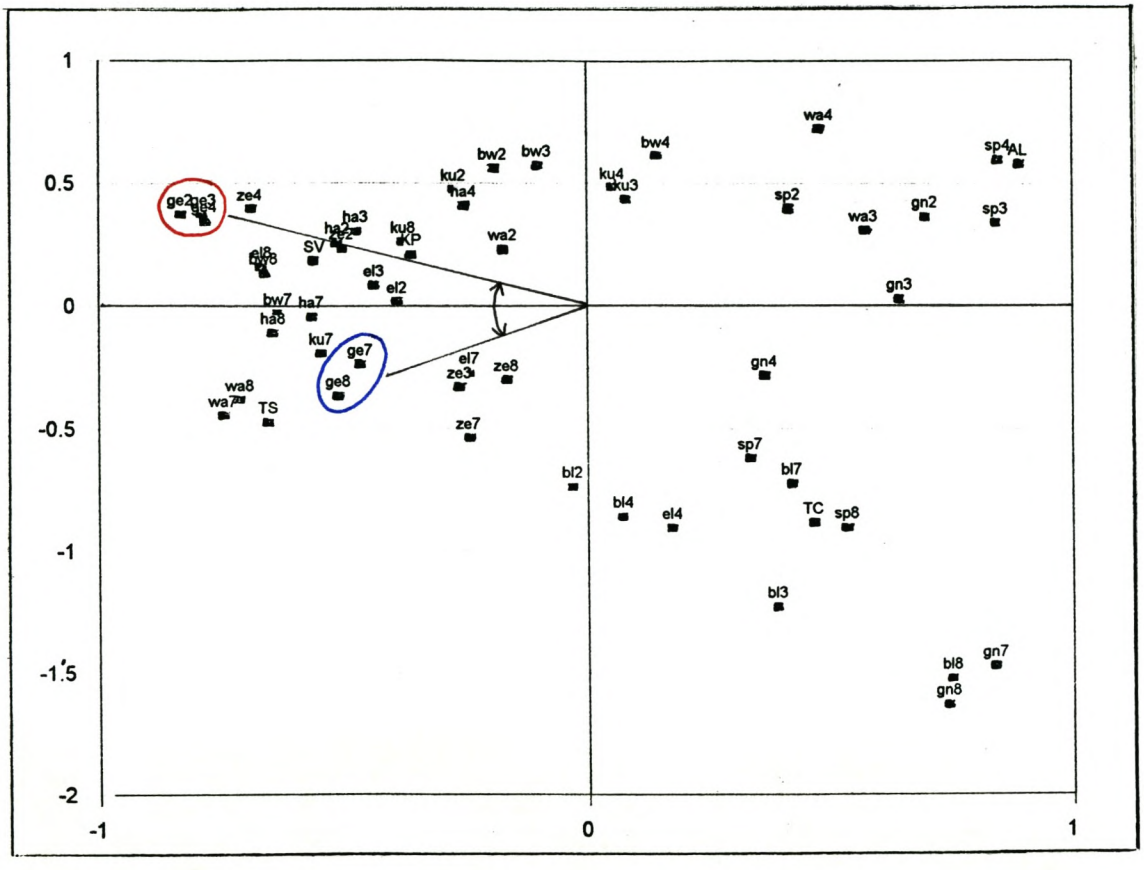
Figure 5.11.: Comparisons between gemsbok distribution in the 1984 and 1997 study periods:



1982 to 1984 distribution

1997 to 1998 distribution

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f) Hartebeest:

In the 1982 to 1984 study period, hartebeest showed the strongest correlation with the Koppieveld and sandveld grassland areas and possibly also the Tarchonanthus calcrete areas for 1984. In 1997 and 1998 the strongest correlation is with the Tarchonanthus sandveld and sandveld grassland areas of Rooipoort.

Hartebeest show a fairly wide distribution for both of the study periods. Both periods have the highest percentage of sightings in the Koppieveld and the Sandveld grassland vegetation types. The 1997 to 1998 study period does, however, reveal a much higher percentage of sightings in the Tarchonanthus sandveld vegetation type than in the earlier study. The Alluvium and Tarchonanthus calcrete areas also show a fairly high percentage of sightings for both study periods (See Fig. 26 and Fig. 36 in Appendix C).

Shannon and Simpson indices indicate a wide niche width for hartebeest for both study periods (Table 5.2).

g) Kudu:

During the 1997 to 1998 period, kudu show the strongest association with the koppieveld, sandveld grassland and Tarchonanthus sandveld areas, while the 1982 to 1984 period showed a weak correlation with the koppieveld and high-lying alluvial areas of the reserve.

According to Figure 37 (Appendix C) the koppieveld areas appear to be the dominant vegetation preference for Kudu in both study periods.

Shannon and Simpson indices indicate a similar and wide niche width for kudu for both study periods (Table 5.2).

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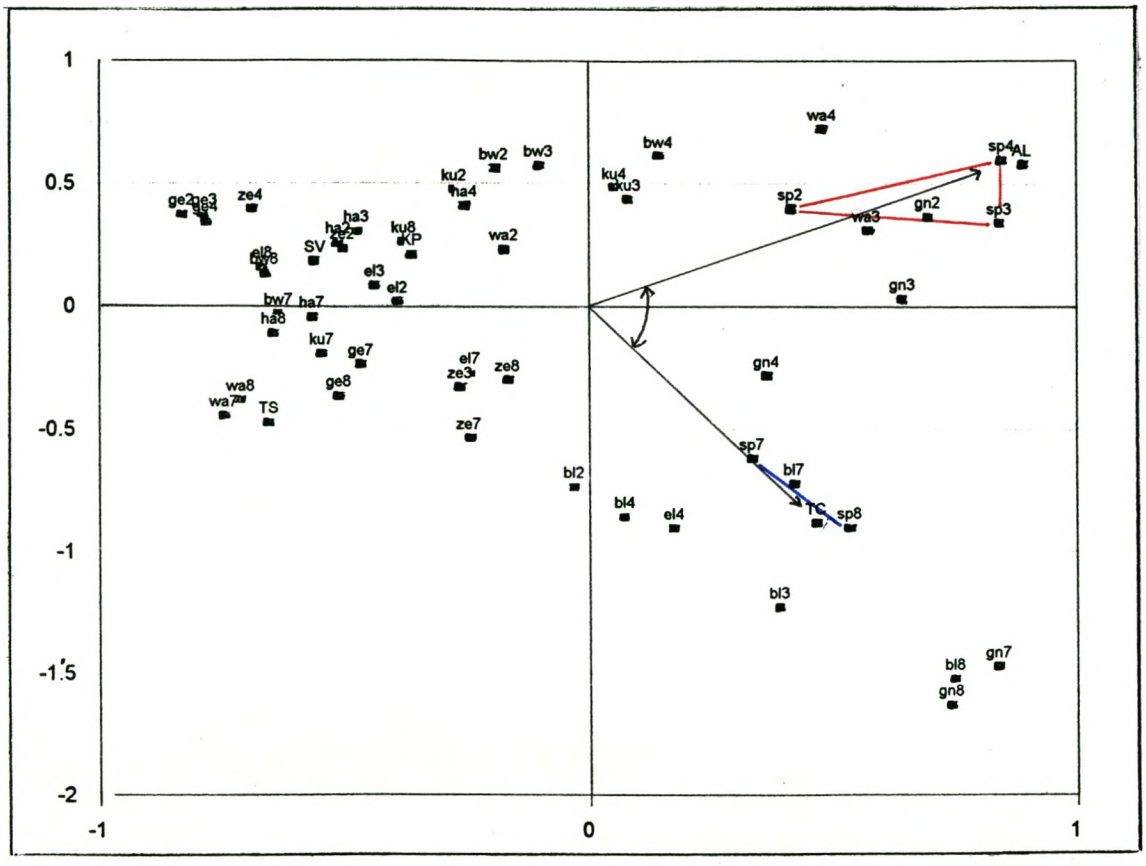
Figure 5.12.: Comparisons between springbok distribution in the 1984 and 1997 study periods:



1982 to 1984 distribution

1997 to 1998 distribution

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h) Springbok:

Figure 5.8 shows springbok to have been most strongly associated with the high-lying alluvial vegetation type in the 1982 to 1984 period. There is clearly a negative correlation in the

1982 t0 1984 data, with the Tarchonanthus sandveld vegetation. In the 1997 to 1998 study the strongest association is with the Tarchonanthus calcrete vegetation type of the reserve, with a negative association with the koppieveld and sandveld grassland areas (see Figure 5.12).

There would appear to be a definite change in distribution patterns of springbok from the 1982 to the 1997 study period. Springbok are concentrated in the high-lying alluvial areas in the earlier study and in the Tarchonanthus calcrete areas during the 1997 to 1998 period.

Shannon and Simpson indices reveal a fairly high niche width for springbok for both study periods (Table 5.2).

i) Warthog:

In the 1997 to 1998 period, warthog show a strong association with the Tarchonanthus sandveld areas of Rooipoort. The 1983 and 1984 data showed the strongest association with the high-lying alluvial areas, while the 1982 springbok were strongly associated with the Koppieveld areas of Rooipoort (Figure 5.8 and Figure 5.13).

The general distribution trend in warthog, has been a decrease in the percentage of Koppieveld and Alluvium sightings and an increase in the percentage of Tarchonanthus sandveld and Sandveld grassland sightings, from the earlier to the present study (See Fig 29. and Fig. 39 in Appendix C).

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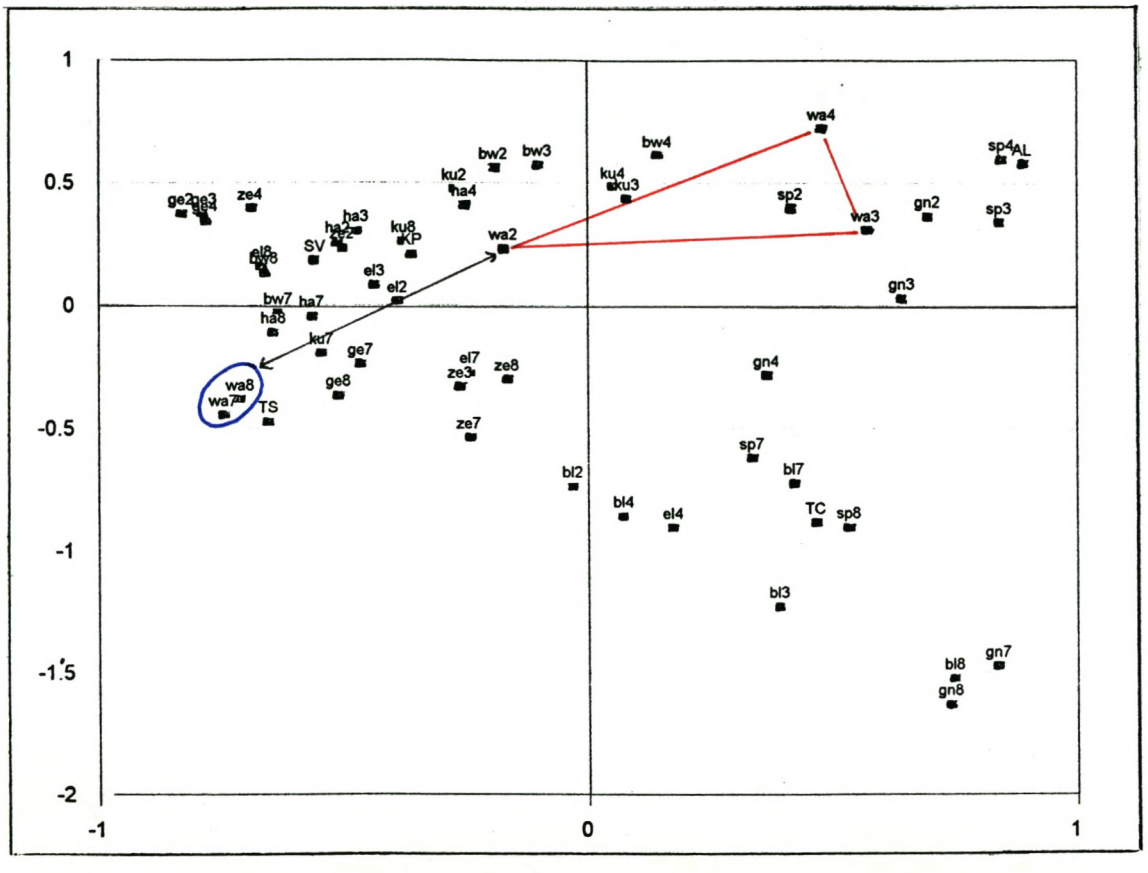
Figure 5.13.: Comparisons between warthog distribution in the 1984 and 1997 study periods:



1982 to 1984 distribution

1997 to 1998 distribution

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Shannon and Simpson indices show an considerable expansion in niche width from the early to latter study periods, although even the 1982 to 1984 period shows a fairly large niche width for warthog (Table .5.2).

j) Zebra:

Zebra showed a strong association with koppieveld and sandveld savanna vegetation types for 1982 and 1984. In 1983, 1997 and 1998 the strongest association is with the Tarchonanthus sandveld areas. For the years 1983, 1997 and 1998 zebra show a strong negative association with high-lying alluvial areas of Rooipoort.

Distribution patterns described above are not in agreement with the histogramatic representation of distribution in Figure 40 (Appendix C). The histogram supports the 1982 and 1984 distribution patterns, but shows the highest percentage of zebra sightings to occur in the koppieveld areas, followed by Tarchonanthus calcrete and Tarchonanthus sandveld areas in 1983, 1997 and 1998. For all years in question, zebra show a low percentage of sightings in the high-lying alluvial areas of the reserve.

There would appear to be a clear difference in zebra distribution in spring/summer of the present study as compared with autumn/winter. In the earlier two seasons, there is a more homogenous distribution, with a fairly similar percentage of sightings occurring in Koppieveld, Tarchonanthus calcrete and also Tarchonanthus sandveld vegetation types on Rooipoort. In Autumn and winter, however, the Koppieveld vegetation type boasts the highest percentage of sightings, followed by the Tarchonanthus calcrete and then Tarchonanthus sandveld and then Alluvium areas of Rooipoort. For all seasons in the present study period zebra were absent from Sandveld grassland areas.

In the 1982 to 1984 study period, however, the consistently highest percentage of observations occurred in the Koppieveld areas, followed by the Sandveld grassland areas of Rooipoort. No observations were made in the Alluvium and Tarchonanthus sandveld areas, and only the spring distribution data shows any record of zebra observations in the Tarchonanthus calcrete areas of Rooipoort (See Appendix C).

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Table 5.3 (a) : Results of Analysis of variance for Shannon Simpson indices:

	Source of Variation	Significance level
Shannon:	Species	0.0256
	Year	0.3588
Simpson:	Species	0.2012
	Year	0.5848

Table 5.3 (b) : Results of Duncan's Multiple Range analysis for Shannon indices:

Contrast		Difference (* denotes a statistically significant difference)
Black wb	Blesbok	0.024
Black wb	Blue wb	-0.368
Black wb	Eland	-0.428 *
Black wb	Gemsbok	-0.248
Black wb	Hartebst	-0.542 *
Black wb	Kudu	-0.306
Black wb	Springbok	-0.44 *
Black wb	Warthog	-0.242
Black wb	Zebra	-0.112
Blesbok	Blue wb	-0.392
Blesbok	Eland	-0.452 *
Blesbok	Gemsbok	-0.272
Blesbok	Hartebst	-0.566 *
Blesbok	Kudu	-0.33
Blesbok	Springbok	-0.464 *
Blesbok	Warthog	-0.266
Blesbok	Zebra	-0.136
Blue wb	Eland	-0.06
Blue wb	Gemsbok	-0.12
Blue wb	Hartebst	-0.174
Blue wb	Kudu	0.062
Blue wb	Springbok	-0.072
Blue wb	Warthog	0.126
Blue wb	Zebra	0.256
Eland	Gemsbok	0.18
Eland	Hartebst	-0.114
Eland	Kudu	0.122
Eland	Springbok	-0.012
Eland	Warthog	0.186
Eland	Zebra	0.316
Gemsbok	Hartebst	-0.294
Gemsbok	Kudu	-0.058
Gemsbok	Springbok	-0.192
Gemsbok	Warthog	0.006
Gemsbok	Zebra	0.136
Hartebst	Kudu	0.236
Hartebst	Springbok	0.102
Hartebst	Warthog	0.3
Hartebst	Zebra	0.43 *
Kudu	Springbok	-0.134
Kudu	Warthog	0.064
Kudu	Zebra	0.194
Springbok	Warthog	0.198
Springbok	Zebra	0.328
Warthog	Zebra	0.13

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Shannon and Simpson indices reveal a definite expansion in niche width in the 1997 study period, from a rather narrow niche width in the 1982 to 1984 period (Table 5.2).

5.2.5. **Discussion of Results of Variance- and Multiple Range Analysis**

The analysis of variance for Shannon and Simpson indices indicates whether a significant difference exists between niche widths of individual species, and also between years within a certain species. A significance level greater than or equal to 0.05 indicates a significant difference. Results (Table 5.2 (a)) of analysis for Shannon indices indicate a significant difference between species, but not between years within an individual species. There has therefore been no significant change in any individual species niche width from the earlier to later study period. Results for Simpson indices indicate that no significant differences exist either between species or between years, within species.

Results of Duncan's Multiple Range Analysis do indicate significant differences in the niche width of certain species. Only black wildebeest, blesbok and eland show statistically significant differences in niche width to any other species. The niche widths of both black wildebeest and blesbok species differ significantly to that of Eland, Hartebeest and Springbok (Table 5.2 (b)), while hartebeest's niche width differs significantly to that of zebra.

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SECTION 6 :

CONCLUSION : MANAGEMENT RECOMMENDATIONS FOR POPULATION SAMPLING:

6.1. INTRODUCTION

A number of factors can be used to determine the season or month in which sex/age counts should be conducted. These include weather conditions, animal distribution patterns and ultimately seasonal/monthly results obtained from the sampling.

Weather conditions may affect the reliability of counts. Unfavourable conditions, such as those where dense cloud cover, high precipitation and strong winds prevail, will affect counts negatively by either impairing observer visibility or by affecting animal behaviour and thereby reducing observability, or both. Unfavourable weather conditions should therefore be avoided when conducting sex/age counts.

Animal distribution may be influenced by seasonal variation. The most appropriate time to undertake counts will be when species distribution minimises time expenditure for counts and thus also minimises the costs involved. Certain seasons may also facilitate animal classification. During the calving season, for example, new born calves are easily distinguished from the previous years recruitment; now classified as sub-adults in most large ungulate species, and from the adult animals.

Comparisons between monthly/seasonal results obtained on Rooipoort and overall sex/age ratios as given by existing research data, can be used as an indication of the most appropriate month to carry out counts.

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6.2. DISCUSSION :

6.2.1. Discussion of sex/age ratio results:

For most species in the study, the confidence intervals (at 95% confidence level) for monthly estimates were wide. The April 1997 estimate for black wildebeest shall be used to illustrate this (See Table 4.1). In April 1997, the adult sex ratio estimate for black wildebeest was 1.03 (translating to 1 male: 1.03 females, or 51 % females), the upper confidence level (UCL) was 2.45 (71 % females) and the lower confidence level (LCL) was 0.34 (25 % females). At the 95 % confidence level, this means that the adult sex ratio for black wildebeest can lie anywhere between 2.45 and 0.34 with a 95 % certainty. This information is not considered very useful as it really doesn't tell a wildlife manager much about the population.

For all species in the study the monthly sex/age ratio confidence interval widths are considered too wide to be of any use to a wildlife manager in determining population structure.

For quarterly sex ratio (female proportion) estimates, confidence intervals are narrower, but, for most species, still too wide to be considered useful. The only exceptions are hartebeest and springbok, whose quarterly sex (and calf/cow ratio in the case of hartebeest) ratio confidence interval widths are considered sufficiently narrow to be useful in determining population structure. For quarterly calf/cow ratio estimates, confidence interval widths are still fairly wide.

Although quarterly confidence intervals are still fairly wide, sex ratio estimates for most species show very minimal seasonal variation, and do not differ from overall estimates for those species. These quarterly estimates of sex ratio may be a reliable indication of this parameter. All species except Eland show very similar seasonal estimates. All overall sex ratio (proportion of females in population) estimates had sufficiently narrow confidence intervals to render them of use in determining the population structure of each species.

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Table 6.1.: Comparisons between seasonal sex/age ratio estimates and overall estimates:

Species	Season	Prop. Females	Overall	Calf/cow ratio	Overall
Black-wb	Autumn	0.5		0.57	
	Winter	0.52		0.63	
	Spring	0.57		0.69	
	Summer	0.54	0.54	0.46	0.55
Blesbok	Autumn	0.64		0.74	
	Winter	0.64		0.67	
	Spring	0.65		0.73	
	Summer	0.64	0.64	0.73	0.66
Blue wildebeest	Autumn	0.63		0.63	
	Winter	0.61		0.6	
	Spring	0.61		0.76	
	Summer	0.61	0.62	0.72	0.72
Eland	Autumn	0.64		0.26	
	Winter	0.33		0.52	
	Spring	0.67		0.24	
	Summer	0.59	0.62	0.52	0.42
Gemsbok	Autumn	0.54		0.31	
	Winter	0.6		0.29	
	Spring	0.58		0.16	
	Summer	0.56	0.57	0.23	0.25
Hartebeest	Autumn	0.65		0.82	
	Winter	0.6		0.73	
	Spring	0.6		0.54	
	Summer	0.65	0.62	0.71	0.71
Kudu	Autumn	0.72		0.62	
	Winter	0.68		0.62	
	Spring	0.69		0.5	
	Summer	0.69	0.68	0.31	0.47
Springbok	Autumn	0.66		0.42	
	Winter	0.66		0.34	
	Spring	0.66		0.42	
	Summer	0.65	0.66	0.43	0.4
Zebra	Autumn	0.68		0.57	
	Winter	0.67		0.48	
	Spring	0.67		0.41	
	Summer	0.67	0.67	0.28	0.46

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For most species quarterly calf/cow ratio estimates still show a fair amount of variation. The only species showing very similar seasonal calf/cow ratio estimates are blesbok, blue wildebeest and springbok (Table 6.1 shows comparisons between seasonal sex/age ratio estimates and overall estimates for each species).

For most species in the study, only the overall calf/cow ratio estimates yield confidence intervals that are considered narrow enough to be of use to a wildlife manager. For eland, however, even overall calf/cow ratio confidence interval widths are considered to be too wide to be of use.

6.2.2. Discussion of ungulate distribution results:

A summary of the overall percentage of sightings in each vegetation type and for each species on Rooipoort is given in Table 6.2. By looking at this table it is clear that certain vegetation types have a very low overall abundance of species. These include the high-lying alluvial areas, the riverine areas. Areas showing a high overall percentage of species sightings include the koppieveld, the Tarchonanthus sandveld for many species and, for a few species, the sandveld grassland and "clearing" areas.

Blue wildebeest, eland and hartebeest show similar distribution patterns, and all three species show the highest abundance in the koppieveld, sandveld grassland, and Tarchonanthus sandveld areas of Rooipoort. Similarly, gemsbok and zebra show the highest abundance in the koppieveld and Tarchonanthus sandveld areas of the reserve.

Springbok, blesbok and black wildebeest all show the highest abundance on Hoffman's pan. Blesbok and springbok also show a high abundance in the "clearing" areas, and springbok are also fairly abundant in the Tarchonanthus calcrete and high-lying alluvial areas.

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Table 6.2. :

Vegetation/habitat types including 80 % of sightings for each species:

Species	**Vegetation/habitat types**
Black wildebeest:	Hoffman's Pan
Blesbok:	Hoffman's pan "clearings" in calcrete
Blue wildebeest:	Sandveld grassland Koppieveld (near river) Tarchonanthus sandveld
Eland:	Koppieveld Tarchonanthus sandveld Sandveld grassland
Gemsbok:	Koppieveld Tarchonanthus savanna "Clearings" in calcrete
Hartebeest:	Sandveld grassland Koppieveld Tarchonanthus sandveld
Kudu:	Koppieveld Tarchonanthus sandveld Tarchonanthus calcrete
Warthog:	Tarchonanthus sandveld Sandveld grassland Koppieveld Pan
Zebra:	Koppieveld Tarchonanthus savanna "clearings" in calcrete

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Kudu and warthog distributions do not show a great deal of similarity to the other species. Kudu distribution is similar to that of eland, blue wildebeest and hartebeest in that they show a high abundance in the koppieveld and Tarchonanthus savanna areas, but differ in showing a high abundance in the Tarchonanthus calcrete areas.

Warthog show the highest abundance in the Tarchonanthus sandveld areas, followed by the sandveld grassland, koppieveld and high-lying alluvial areas.

6.3. CONCLUSIONS:

Due to the considerable variation in monthly sex/age ratio estimates (and the width of confidence intervals) within species of ungulates on Rooipoort, it is impractical to allocate one specific month or season to carrying out sex/age counts.

From results it is clear that for most species, seasonal sex ratio (proportion of females in population) estimates may be sufficient in determining population structure, but only the **overall** (yearly) calf/cow ratio estimates are precise enough to render them of any practical use to a wildlife manager.

Looking at the seasonal and overall sex ratio estimates of the ungulate species in the study, it is apparent that for the majority of species (for black wildebeest and gemsbok this ratio approaches parity) there is a greater proportion of adult females than males in the population (See Table 6.1.). A number of game studies in Northern America indicate a higher natural mortality rate for males and suggest this to be due to vigorous, condition-depleting rutting activities, which may have an adverse effect on the survival of males during the winter months (Robinette *et al.* 1957). This higher proportion of females also agrees with many observations on African ungulates, which suggest that territorial males might be more vulnerable to predation due to their exposed way of living (Von Richter, 1971b), although this is not applicable to Rooipoort populations (except perhaps springbok).

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As is the case with sex ratios, calving rates also show a great deal of monthly and seasonal variation. Overall calving rates show a lot of interspecies variation, but it is apparent, although possibly just coincidental, that those species with unrestricted breeding seasons have the lowest estimated calving rates. These species include gemsbok, springbok, zebra and eland. It is possible that not all adult females calve/lamb at one time and calving rates taken at any one time, or even averaged over a long time period, would therefore appear lower than they actually are (See Table 6.1.).

In order to facilitate the sampling procedure on Rooipoort, it is suggested that certain areas/vegetation types might be left out during the sampling process. This may be impractical, however, due to the large number of species that require sampling on Rooipoort, each with their own different/varying distribution patterns. By leaving out certain areas of the reserve in the sampling procedure, it is inevitable that certain species will not be sampled efficiently, resulting in a consequent small sample bias in estimates for these species.

If sampling is targeted at specific species, however, it may be possible to omit certain vegetation/habitat types in the sampling procedure. Table 6.2. gives an indication of which areas one should concentrate on for sampling of individual species. Vegetation/habitat types given in the table include 80 % of all sightings for each species.

From the above discussion it is clear that the greater the number of sampling occasions, the more reliable the estimates of sex/age ratio will be. For most species a seasonal (3-month) count may be sufficient to determine the sex ratio (proportion of females) in a species population, although a reliable calf/cow ratio estimate may require additional sampling. It is recommended that as many counts be carried out as possible each year. It is desirable for at least 5, but preferably 10, days to be used each month to sample the entire reserve, although the extensive hunting season on Rooipoort, may make this impossible. It is therefore suggested that at least 3 months

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of sampling be carried out, comprising 10 sex/age (30 counts) counts each month. Ideally, the entire reserve should be sampled at least twice each month.

Table 6.3. shows what effect an increase in the number of sampling occasions will have on the variance of the estimates for sex and calf/cow ratio for certain species. By increasing the number of sampling occasions (and thus the sample size) the variance of sex/age ratio estimates may be decreased. An increase in sampling occasions from 30 (3-month) to 60 (6-month) decreases the variance of estimates by a minimum of 1, to as much as 19 %. An increase from 30 to 120 (year) sampling occasions may decrease the variance by between 5 and 25 %.

Due to the interspecies variation in the number of groups observed each month/season, an alternative would be to increase the sample size, rather than the number of sampling occasions. By increasing the sample size from, say, 50 to 100/150 groups for each species, the sample variance may be decreased by between 3 and 20 percent (See Table 6.4. for examples). At a sample size of 100 to 150, the variance is sufficiently narrow, for most species, to render the estimate of use to a wildlife manager.

For most species, a seasonal sampling period of 3 months (or alternatively 30 counts) will be sufficient to obtain sample sizes of 100 to 150 groups. The only species which may require a longer sampling period are eland, kudu and, possibly, zebra.

6.3.1. **Estimated expenditure of study in terms of fuel consumption**:

The estimated cost of such a study may be quite substantial. In order to effectively sample species populations on Rooipoort, at least 30 sex/age counts will be required, but optimally sex/age counts should be carried out at least once a month, over a 5 day period. Counts will most probably be carried out using a Toyota Landcruiser, which has a fuel consumption of approximately 3.84 km/l and a running cost of R1-50/hour.

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Table 6.3.: Examples illustrating how the number of sampling occasions affects the variance of an estimate:

	The percentage decrease in varaince with an increase in the number of sampling occasions:			
	an increase from 30 to 60 occasions:		an increase from 30 to 120 occasions:	
Species	**% females**	**Calf/cow ratio**	**% females**	**Calf/cow ratio**
Black wildebeest	6	0	11	5
Blesbok	9	6	13	8
Blue wildebeest	8	12	16	17
Eland	14	0	19	7
Gemsbok	8	19	15	24
Hartebeest	1	2	2	9
Kudu	8	9	11	11
Springbok	2	4	9	13
Zebra	3	3	8	11

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Table 6.4. : Examples illustrating how sample size affects the variance of an estimate:

	The percentage decrease in variance with an increase in sample size from 50 to 100 groups of animals:		The percentage decrease in variance with an increase in sample size from 50 to 150 groups of animals:	
Species	**% females**	**Calf/cow ratio**	**% females**	**Calf/cow ratio**
Black wildebeest	16	13	20	12
Blesbok	11	6	10	7
Blue wildebeest	12	4	4	3
Gemsbok	8	19	11	19
Hartebeest	3	3	6	9
Kudu	8	9	11	13
Zebra	7	12	10	13

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(R2-50, Automobile Association rates).

With a fuel cost/l of R2.57 and the average distance of a sex/age count being 50 km, this calculates to approximately R33.50 per sex age count. The total fuel cost of a study comprising 30 sex/age counts will be approximately R1005. With the average length of a sex/age count being 3 hours, the running cost of a landcruiser for the study is estimated at R135.

In addition to vehicle costs, someone will need to be employed to carry out sex/age counts. A salary of R150/hour was quoted. For a study comprising 30 sex/age counts, and involving approximately 90 hours of sampling work this calculates to R13 500-00.

The total cost of a study comprising 30 sex/age counts will be:

R 1 005-00	-	Fuel consumption
R 135-00	-	Running cost
R13 500-00	-	Salary
R14 640-00		

For most of the species under observation, a study comprising approximately 30 sex/age counts should deliver fairly precise sex/age ratio estimates. Sex (percentage of females) ratio estimates should have a precision of about 10 %, whereas calf/cow ratio estimates will have a precision of between 15 and 20 % for most species.

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APPENDIX A

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APPENDIX A: Section 1:

Characteristics used to distinguish between different sex and age classes in the field:

a) Black Wildebeest (*Connochaetes gnou*)

According to Skinner and Smithers (1990), the male wildebeest stands about 1,2 metres at the shoulders and weighs approximately 180 kg, whereas the female is smaller and lighter.

The general colouration of the wildebeest is a buffy-brown, with older males being darker, almost black. Juveniles have shaggy, fawn-coloured coats and horns that rise straight up from the head and only start to curve at about a year old (Skinner and Smithers, 1990).

The horns of the cow are thinner and less robust than those of the bull. The mature bull can also be distinguished from the cow by the 'boss' formed from the horn base, over the top of its head (Stuart and Stuart, 1991). Von Richter (1971b) uses dentition to distinguish between different age classes of animals, although this method of ageing is not applicable to field identification.

b) Blesbok (*Damaliscus pygargus phillipsi*)

Blesbok (Bontebok) males stand about 0,9 metres at the shoulder and have a mean mass of 61 kg. The females are slightly smaller and lighter. It is difficult to recognise the sexes in the field, except that the horns of the female are more slender than those of the males and hardly thicken up at the base (Skinner and Smithers, 1990; and Kettlitz, 1967). According to Kettlitz (1967), the circumference of the horn at its base is about 1 inch more in the ram than in the ewe, also the base of the horn in the adult ram is straw coloured, whereas in the female it is a dull black colour (Kettlitz, 1967). The ridges of the horns are also more prominent in the rams (Du Plessis, 1972).

From the side, a mature ram may also be distinguished from the female by its darker colour and thicker neck. In the ewe, the midline between the vulva and the udder is dark and devoid of

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hair, whereas the midline of the ram is covered with white hair. This difference is visible from behind, while the udder of a pregnant or lactating ewe is visible at a distance both from behind and from the side. To the experienced observer, the ewe my also be distinguished by the more slender, feminine conformation of the head and neck. In early November, mature ewes are heavily pregnant, thus facilitating sexing and the seperation of immature 2-year-old ewes (Du Plessis, 1972).

Calves are a pale fawn to creamy colour and much smaller in stature than adults or subadults (Skinner and Smithers, 1990). Juveniles may be easily distinguished by size, colour, and horns up to the age of about 13 months (Du Plessis, 1972).

Rowe-Rowe and Bigalke (1972) gave ageing criteria based on known-age animals in Queen Elizabeth Park. According to them, calves from 0 - 2 months of age have a cream body colour, a black facial blaze, and, at two month, horns emerge. At 6 - 7 months of age horns are about two-thirds the length of the ear, and no annuli (rings) are visible. At 8 months, the horn annuli are first observed, and by 9 months the horns are approximately ear length. At this time the horns have started to; curve inwards, but not backwards. By 12 - 14 months the body colour has darkened but is still much lighter and redder than the adult animals. The blaze is almost entirely white at this time and the horns begin to curve backwards, with five annuli already developed. At 16 - 18 months, the blaze is entirely white. The body has darkened to a rich chocolate colour by the time blesbok are 21 - 24 months old, but a reddish tinge is still obvious. In males, at this time, testis are still small and not conspicuous. By the time blesbok reach 30 - 36 months of age, they have a normal adult appearance. The body colour is a dark chocolate and the coat is short and shiny. In males the testis is conspicuous, but smaller than in males of over four years.

Olivier and Greyling (1991) also used horn annulation (in addition to cementum growth layers and tooth eruption) as a means of ageing blesbok, as did Watson et al (1991). They found that in free roaming herds it was impossible to distinguish blesbok older than 18 months from adults, but in animals younger than 18 months, horn shape, horn length and horn base

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circumference were useful parameters. By using all three variables it was possible to estimate age of subadults fairly accurately (Watson et al. 1991).

c) Blue Wildebeest (*Connochaetes taurinus*)

Adult male blue wildebeest stand about 1,5 metres at the shoulder and have a mass of about 250 kg, whereas the females are smaller (1,35 metres) and lighter at 180 kg.

Adults are dark grey in colour, tinged brown, with a silvery sheen and look almost black at a distance. In adult males the face from the top of the head to the nostrils is black, often, however, with a russet tinge on the forehead. The sides of the face are greyish, lighter in colour than the body, and are often tinged russet. In juveniles and females the bodies are browner than in adult males and they have more of a russet colour on the forehead, which may exten broadly from the forehead to between the eyes. Very young individuals are fawn-coloured over-all, with a darker face and a dark stripe along the back (Skinner and Smithers, 1990).

Both sexes have horns, but those of the cow are less robust (Stuart and Stuart, 1991). Kingdon (1982) uses horn shape and size to distinguish between the different age classes of animals. Talbot and Talbot (1963) also used horn development to distinguish between the age classes of the closely related Western White-bearded Wildebeest.

d) Eland (*Tragelaphus oryx*)

Adult male eland stands about 1.7 metres at the shoulder and at an age of six years, has a mass of up to 700 kg. They are the largest African antelope. The female is noticably smaller at about 1,5 metres, with a mass of up to about 460 kg (Posselt, 1963).

Both sexes carry horns, but those of the male are much heavier than those of the female, they are nearly always straight, slightly diverging, with a heavy spiral ridge at the base. The horns of the male are normally fairly even, while those of the female are often uneven, curving

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backwards or splayed broadly outwards and lacking the heavy spiral ridge seen in the horns of the male (Skinner and Smithers, 1990).

At birth the horn buds are visible in both sexes, growing rapidly up to about 7 months of age and thereafter more slowly. At about 15 months the horns of the male shows the appearance of the spiral ridge, at the base. This ridge is still poorly defined in the female. At 18 months the horns have reached a length of about 0.75 m. From this time onwards the horns of the male grow progressively heavier, especially at the bases (Skinner and Smithers, 1990).

Adult bulls develop a patch of fairly long, dark, coarse hair on the forehead, and older bulls typically develop a large dewlap on the throat (Stuart and Stuart, 1991).

e) Gemsbok (*Oryx gazella*)

Male gemsbok stand about 1,2 metres at the shoulder and have a mass of up to about 240 kg, whereas the females are slightly lighter at about 210 kg.

The newly born are fawn or reddish-brown in colour, which is replaced at about four to six months by the pale fawn-grey adult pelage.

Both sexes carry horns, those of the adult being straight and cylindrical and ringed for about one third of their length, the remainder being smooth. The horns of the female are lighter in build, but longer than those of the male (Skinner and Smithers, 1990), which are short and more robust (Stuart and Stuart, 1991).

f) Hartebeest (*Alcelaphus buselaphus*)

Adult male red hartebeest stand about 1,25 metres at the shoulder and have a mass of about 150 kg. The females are slightly smaller and have a mean mass of 120 kg.

Adult animals have a saddle of a darker colour than the remainder of the body, which extends on the mid-back from the shoulders to the base of the tail, broader towards the tail than on the

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shoulders. This saddle is less obvious in the female than in the males and in some females it is barely perceptible.

Both sexes carry horns, those of the male being heavier in build than those of the female (Skinner and Smithers, 1990). Kok (1975) used horn shape and size to distinguish between the various age classes of animals.

g) Kudu (*Tragelaphus strepsiceros*)

The adult kudu stands about 1,4 metres at the shoulder with a mass of up to 250 kg. The females are distinctly smaller with a maximum mass of 200 kg and shoulder heights of about 1,25 metres (Skinner and Smithers, 1990).

Simpson (1966 and 1972) showed that it was possible to classify immature male kudu into three categories based on the development of the horns. At five to six months the horn buds of the calves first appear. Horn growth starts at about five to six months. At first the horns are mere short spikes that swing outward from the head. The first curve starts to show as an inward curve at about 14 to 17 months old and is completed by about 21 months. The second outward curve shows by about 30 months. Horn growth continues throughout life and is used to distinguish between a total of 7 age classes in the male kudu (Simpson, 1966). Usually only the males carry horns, but rarely females do as well. These are very thin and twisted, however, and often curl in front of the eyes or form irregular shapes across the muzzle. They are nothing like the stately horns of the male (Rowland Ward, 1986, vide Skinner and Smithers, 1990).

The bull has a prominent mane from the neck to beyond the shoulders and a fringe of longer hair on the throat and lower neck (Stuart and Stuart, 1991).

h) Springbok (*Antidorcas marsupialis*)

Springbok stand about 750 mm at the shoulder. The males are slightly heavier than the females and weigh about 41 kg (the females; 37 kg). In the female the horns are distinctly smaller,

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wider apart at the base, lightly ridged and much thinner than in the male (Skinner and Smithers, 1990).

Ansell (1966, vide Mason, 1976) uses height classes relative to the adult female to classify springbok in the different ages. Mason used this method, along with horn development (Rautenbach, 1971), to classify springbok. Other criteria used by Mason included behaviour, and general physical appearance. Since horn growth in males commences at birth whereas in females horn only appear at about 3 months, age determination is very difficult if animals cannot be sexed (Mason, 1976).

i) Warthog (*Phacochoerus africanus*)

Adult boar warthog stand about 0,7 m at the shoulder and have a mass of up to 100 kg, whereas females are slightly smaller at 0,6 m and have a lighter mass of up to 70 kg (Skinner and Smithers, 1990). At birth the two sexes are very nearly the same size, but males grow faster and for longer, so that adult males are appreciably bigger. Sucklings are generally much smaller than yearlings, which are shorter in the body and have a more slender build than older animals (Child et al. 1965).

The face has distinctive facial warts. The males have two pairs of these, a very large pair, rising just below the eyes on the side of the face, and a second, much smaller pair, on the cheeks. The females have just one pair just below the eyes, but smaller than those of the male. The cheek warts are absent (Skinner and Smithers, 1990; Stuart and Stuart, 1991).

Warthog have characteristic tusks; canine teeth growing out sideways from the jaws. In old adult females the tusks tend to curl over the top of the snout more than in the males (Skinner and Smithers, 1990).

j) Zebra (*Equus burchelli*)

Adult zebra stand about 1,36 m at the shoulder, with a mass of about 320 kg and there is no difference between stallions and mares in the southern part of their distribution (Skinner and

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Smithers, 1990). Because zebra lack sexual dimorphic characters such as horns, a constantly visible penis sheath or size and pelage difference, they remain one of the most difficult species to sex in the field. In addition to the fact that the penis of the stallion is only visible when urinating or when in a state of erection, the testicles are inconspicuous and only evident in a few individuals (Smuts, 1974).

Sexing zebra is simplified by understanding their social behaviour (Klingel, 1965). Smuts used the shape of the perineal region to distinguish between the stallion and the mare from a posterior view, while the greater muscular development of the adult stallion's neck helped him to identify the stallion from the lateral aspect (Smuts, 1976 and 1975). In the Stallion, the black perineal skin forms a long thin band running from the anus to the scrotum. In the mare the same area is widened by the vulva, which gives the region quite a different shape when viewed from the rear (Smuts, 1974). The thickness of the neck cannot be used effectively to distinguish between the sexes during routine field counts (Smuts, 1974).

Shoulder height as indicated by Von Bertalanffy growth curves can be used to differentiate between foals and yearling individuals. By one year of age adult body height may be reached (Smuts, 1975). Smuts (1974) also used dentition to distinguish between different age classes, but this is not applicable in the field.

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APPENDIX A: Section 2:

Previously recorded sex, age and population ratios in wild ungulate species:

a) Black Wildebeest (*Connochaetes gnou*)

A sample of 63 calves from a captive population at Pretoria Zoo delivered a male to female ratio of 1:1 (Brand, 1963), whereas a sample of 17 calves in the S.A. Lombard Nature Reserve, delivered a ratio of 1 male: 2.40 females (Von Richter, 1971).

In the S.A. Lombard Nature Reserve (1971), an adult sex ratio of 1 male: 1.37 females was found in a sample of 173 animals. This ratio is attributed to the capture and removal of some animals in the reserve (Von Richter, 1971). According to Von Richter, the sex ratio of adults in the Willem Pretorius Game Reserve was 1 male: 1.67 females in August 1970, but that this ratio changed seasonally depending on whether it was calculated before or after the catching operations, as generally more males than females were removed.

In Giants Castle Game Reserve an adult sex ratio of 1 male: 0.79 females found, while similar ratio of 1 male: 0.87 females was found in Coleford nature Reserve (Von Richter, 1971b). In the Mountain Zebra National Park in the Eastern Cape, the adult sex ratio also approached parity, with a ratio of 1 male: 1.09 females (Mentis, 1972).

Reliable records of annual calf crop in the S.A. Lombard Nature Reserve from 1964 to 1969, show a reproductive rate that varied between 72,9% and 85,7% for adult females older than two years (the difference being insignificant). In the Willem Pretorius Game Reserve the rate was 79,7% in 1964 and 79,3% and 79,1% in 1968 and 1969 respectively (Von Richter, 1971b). In the Coleford Nature Reserve the percentage of adult cows (introduced in 1964) calving in a four year period ranged from 76,9% in 1966 to 92,8% in 1969. The Mountain Zebra National Park showed a reproductive rate of 84,2% for adult cows, in May 1970 (Von Richter, 1971b).

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b) Blesbok (*Damaliscus pygargus phillipsi*)

In a sample of 53 captive blesbok, Brand (1963) recorded a calf sex ratio of 1 male: 1.12 females. In the Percy Fyfe Nature Reserve (Kettlitz, 1967), calves showed a sex ratio of 1 male: 1.08 females. Both these ratios do not differ significantly from the expected 1 to 1 ratio.

On Rietvlei the adult sex ratio of blesbok ranged from 1 male: 0.70 females to 1 male: 3.33 females, over a 10 year period from 1956 to 1967. The average ratio was 1 male: 1.80 females (Du Plessis, 1972). David (1969) found a 1 to 1 sex ratio in the closely related bontebok in the Bontebok National Park in Swellendam. In the Percy Fyfe Nature Reserve in Natal (Kettlitz, 1967) a population sex ratio of 1 male: 1.30 females was observed, but this was expected to be higher than the ratio in the adult population, due to the inclusion of calves and juveniles.

c) Blue Wildebeest (*Connochaetes taurinus*)

A study of blue wildebeest was carried out in Etosha by Berry (1981). The structure of the population was established by taking the mean of three years of ground counts (1976 - 78). These ground counts were considered to be more detailed and accurate than aerial counts, except in the case of lone, territorial bulls, where aerial counts were used. The data collected showed fewer adult bulls in the population with a ratio of 1 male: 1.57 females. A study done by Atwell (1982) in Zululand gave an adult sex ratio for blue wildebeest, of 1 male: 1.49 females, and this suggests that the bulls in Etosha were subjected to a higher mortality rate, this is also supported by skulls collected in Etosha with a ratio of 1 male: 0.38 females (Berry, 1981). In the Kruger National Park adult sex ratios were more disparate at 1 male: 2.60 females, and this indicates an even greater mortality in bulls probably due to a high rate of predation (Braack, 1973). Lone, territorial bulls, in particular may be vulnerable to predation.

In both the Serengeti and Etosha (Namibia), blue wildebeest were found to have a calf sex ratio approaching parity (Berry, 1981). The ratios for these two areas were, respectively, 1 male: 1.07 females and 1 male: 1.17 females. Talbot and Talbot (1963) found a preponderance of males in a sample of 27 calves of the closely related White-bearded wildebeest, taken in Western Masailand. Here the ratio was found to be 1 male: 0.52 females. In the same study,

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the sexes of 5,907 adult wildebeest were identified, the sample being spread relatively throughout the 1959-1961 period. The average monthly ratio of males to females, however, ranged from 1male: 2.56 females to 1male: 0.67 females. This data reflects an irregular distribution of males and females in the study area throughout the year, and differences in the distribution patterns of the two sexes (Talbot & Talbot, 1963). It was concluded from this study that it would not be valid to determine sex ratios in the wildebeest population of the study area from samples taken at any one time or in any one location, and physically impracticable to determine sexes of individuals in herds of 10 to 50 thousand wildebeest when concentrated on open plains. The most valid sampling method, under these circumstances, was seen to be one that took in as much of the study area as possible and covered the whole year, in order to level out seasonal and local inequalities in distribution. When sex ratio samples from each month were averaged the result obtained was 1 male: 0.93 females. Ratios obtained from periodic aerial sampling averaged at 1 male: 0.82 females (Talbot & Talbot, 1963).

In a study of blue wildebeest in the Serengeti a reproductive rate of 96% was reported for females (Watson, 1969)

d) Eland (*Tragelaphus oryx*)

A sample of 54 calves from a captive population of eland at Pretoria Zoo, showed a sex ratio of 1 male: 0.74 females (Brand, 1963), whereas at Loteni Nature Reserve in Natal the calf sex ratio, from a sample of 47 individuals, was given as 1 male: 1.61 females (Stainthorpe, 1972). Both of these ratios do not show a significant departure for the expected 1: 1 ratio.

In the Nairobi National Park in Kenya, a sample of 172 animals delivered an adult sex ratio of 1 male to 0.16 females (Mentis, 1972), whereas at Giants Castle in Natal, a sample of 1009 individuals gave an adult sex ratio of 1 male: 3.02 females, showing a definite preponderance of females (Natal Parks Board records, vide Mentis 1972).

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e) Gemsbok (*Oryx gazella*)

Roth and Bowman (1967, vide Mentis 1972) found, from a sample of 14 births, a calf ratio of 1 male: 1.14 females, a ratio not departing significantly from the expected 1: 1 ratio.

In the Kalahari Gemsbok National Park, a sample of 97 animals delivered an adult sex ratio of 1 male: 3.22 females (Mentis, 1972).

f) Hartebeest (*Alcelaphus buselaphus*)

No information has, as yet, been located on the calf sex ratios of Red hartebeest, but a study undertaken by Kok (1975), in the Willem Pretorius Nature Reserve, showed a sub-adult ratio of 1 male: 1.50 females. The same study revealed an adult sex ratio of 1 male: 2.20 females (Kok, 1975).

g) Kudu (*Tragelaphus strepsiceros*)

In Zimbabwe (Rhodesia) a sample of 20 animals, delivered a calf sex ratio of 1 male: 0.66 females; not significantly different from the expected 1: 1 ratio (Simpson 1968). A study in Zambia (Northern Rhodesia) showed a calf sex ratio of 1 male: 0.70 females, from a sample of 34 individuals (Wilson, 1965). Du Plessis found a calf:cow ratio of 0.19 calves: 1 cow in South African agricultural areas, which agrees with findings of 0.11 calves: 1 cow in the Andries Vosloo Kudu reserve (Allen-Rowlandson, 1980).

Most studies that have been undertaken, reveal an adult sex ratio favouring females. In Rhodesia, a sample of 190 individuals delivered an adult sex ratio of 1 male: 1.60 females (Simpson, 1968), while Wilson (1970) found an adult sex ratio of 1 male: 4.00 females from a total of 180 animals, in Kyle National Park, Rhodesia. Wilson (1965) found a ratio of 1 male: 2.40 females in adult individuals in Northern Rhodesia (Zambia) and believes that this high percentage of females can be attributed to the hunting of the species in the area over a 20-year period.

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In Zululand females are also more abundant, showing a 1 male: 1.50 female ratio (Mentis, 1970). Du Plessis (1986) found the ratio of adult kudu in agricultural areas in South Africa to be 1 male: 2.22 females, which is lower than that found in conservation areas (he attributed this to hunting in these areas). A ratio of 1 male: 2.59 was recorded, however, at Loskop Dam Nature Reserve in the Eastern Transvaal (Underwood, 1978). This low ratio in a conservation area is believed to be due, in part, to the removal of a number of adult bulls during the study. Taking these into account the sex ratio would be calculated at 1 male: 1.83 females.

The general trend appears to be a lower male: female sex ratio in areas where hunting takes place and a higher ratio in conservation areas.

h) Springbok (*Antidorcas marsupialis*)

Springbok are born in an approximately even sex ratio (1:1) (Fairall *et al.* 1990). In a captive population of springbok at Pretoria zoo, the calf sex ratio approached parity, at 1 male: 1.15 females (Brand, 1963).

The skewed sex ratio observed in adult springbok is seen to reflect a much higher mortality rate of males than females. It is also believed that male dispersal could have an effect (Bednekoff & Ritter, 1996). Male mortality in springbok is influenced by the fact that males establish and hold territories. Crowe & Liversidge (1977) found that 83 % of male skulls collected, were from 1 to 30-month old individuals. This corresponds to the age at which males establish territories. Deaths of males from fighting have been observed (Estes, 1991). In areas where predators are present, males carry a greater predation risk than herd-living females, due to their territorial lifestyle (Jackson *et al.* 1993). Although territorial males join herds that are near their territories, they spend most of their time alone or in very small groups. They also spend a considerable amount of time maintaining territories and chasing females and less time on anti-predator vigilance (Bednekoff & Ritter, 1996).

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In Etosha and the Kruger National Park, Bigalke (1970) observed an adult sex ratio of 1 male: 2 females, from a sample of 3673 individuals. From this he concluded that this was the ratio to be expected under fairly natural conditions. Bednekoff and Ritter (1997) found a similar ratio of 1 male: 1.86 females at Nxai Pan in Botswana. Crowe and Liversidge (1978) found a ratio of 1 male: 1.60 females on Rooipoort Nature Reserve near to Kimberley. Populations in the Bontebok National Park in Swellendam, however, showed a ratio closer to parity at 1 male: 1.18 females (David, 1978), as did the ratio of 1 male: 1.01 females from a sample of 1633 individuals in the S.A. Lombard Nature Reserve (Skinner, Von La Chevallerie and van Zyl, 1971). In the Mountain Zebra National Park, however, a sample of 620 adult springbok showed a sex ratio 1.3 : 1 favouring males (Penzhorn, 1974).

i) Warthog (*Phacochoerus africanus*)

In Chobe National Park the calf sex ratio of a sample of 78 individuals approached parity at 1 male: 0.81 females (Child, 1968).

The sex ratio of a sample of 273 adult individuals in Chobe National Park favoured females at 1 male: 1.75 females (Roth and Kerr, 1968), but at Nagupande the ratio obtained from a kill revealed a sex ratio near parity of 1 male: 1.12 females (Mentis, 1970). In southern Rhodesia, Dasmann and Mosssman (1962) reported a ratio of 1male: 2.13 females from a sample of 45 individuals, 1 male: 0.90 females from a sample of 27, and a ratio of 1 male: 2.12 females from a sample of 72 individuals. There seems to be quite a lot of variation within and between areas, ranging from parity to a 1male: 2 female ratio.

j) Zebra (*Equus burchelli*)

Smuts (1976) undertook a study on zebra from various parts of the Kruger National Park. Chi-square tests were undertaken on sex ratio data from the skulls collected in each district and from the whole Kruger National Park and showed that the ratio deviated significantly from the expected 1 : 1 ratio. It indicated that stallions had a higher mortality rate than mares. In terms of behaviour, adult stallions take on a protective role during

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disturbance and may approach and investigate a potential source of danger. In support of this, adult stallions are more susceptible to hunter selection than adult mares.

It was also found that within isolated undisturbed herds of zebra, stallion groups tended to be located on the periphery of herds. When herds were on the move, it was observed that stallion groups took up their position at the rear of the herd or some distance away, and only under extreme conditions did they integrate with it (Smuts, 1976).

A calf sex ratio of 1 male: 1.18 females was obtained from a sample of 170 individuals in East Africa (Klingel, 1965). This is more or less at parity. Smuts (1976) observed a sex ratio of 1male: 1 female for zebra under 2 years of age in the Central District of the Kruger National Park. After this age, however a differential mortality favouring females became apparent. He attributes this mortality to lion predation, and areas of the park with a low kill index show a ratio closer the parity. Foster and Kearney observed an adult sex ratio of 1 male: 3.32 females. Mentis (1970) found a population sex ratio of 1 male: 1.22 females for Unfolozi Game Reserve in Natal.

Sexes would appear to occur in equal numbers up to about 2 to 3 years of age, after which a differential mortality rate produces a distorted sex ratio favouring adult mares. To date distorted sex ratios in favour of adult mares have been found in all populations of Burchell's zebra studied (Smuts, 1976).

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APPENDIX B

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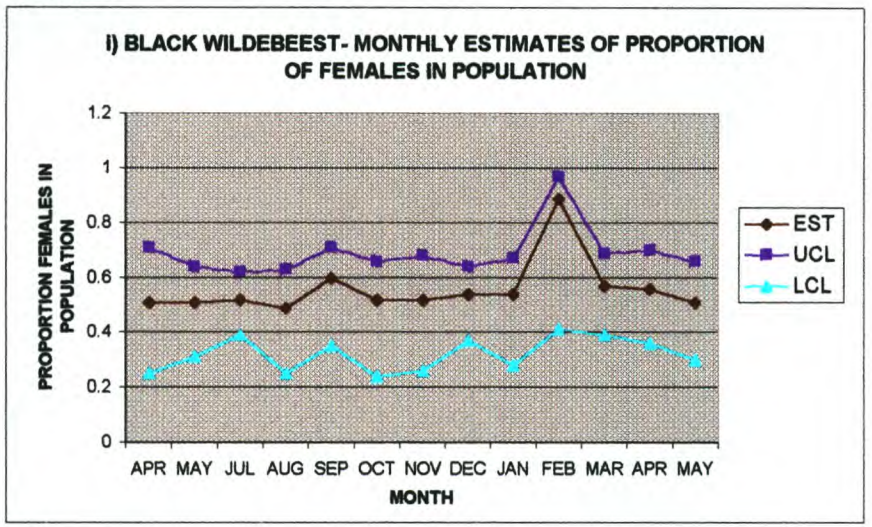
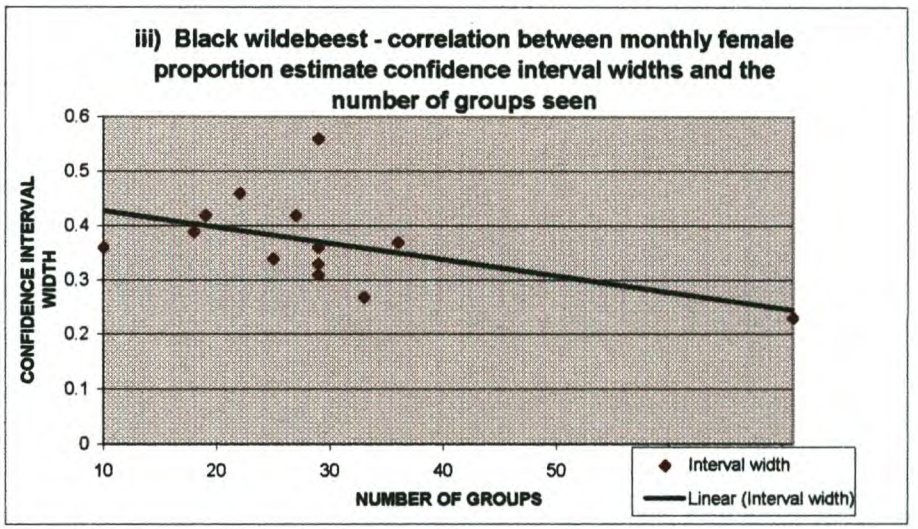
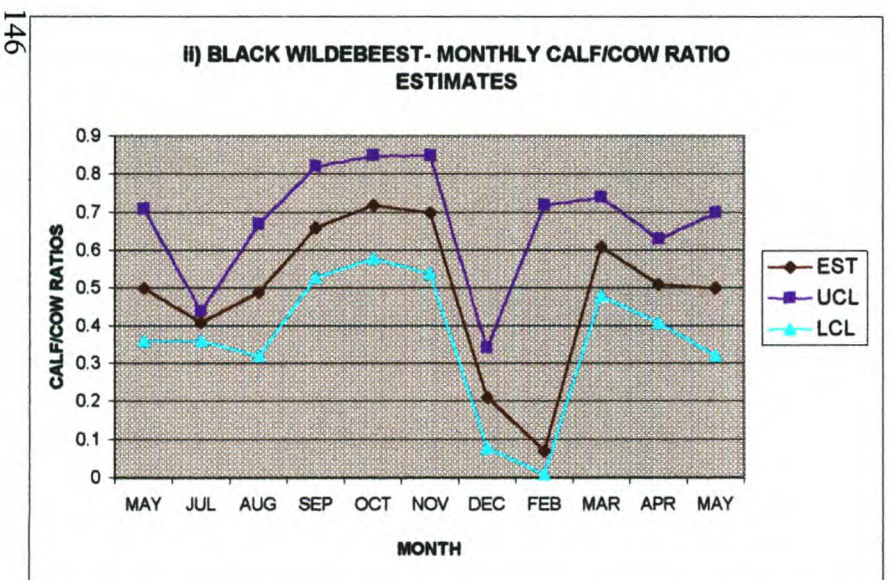
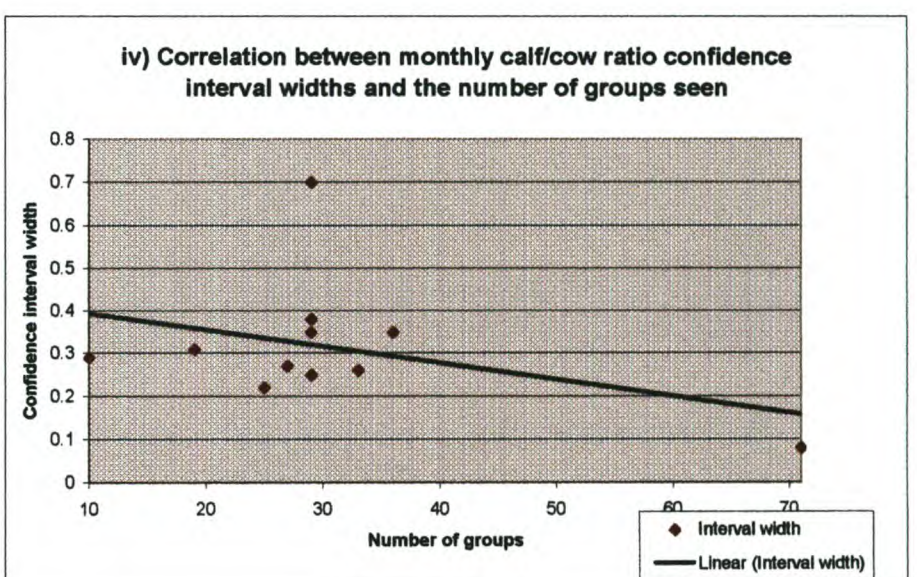
FIGURE 1:









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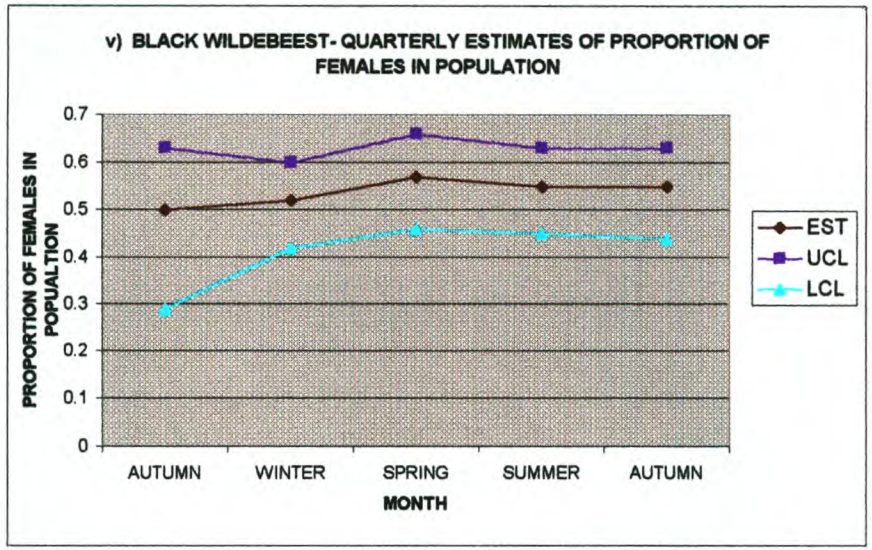

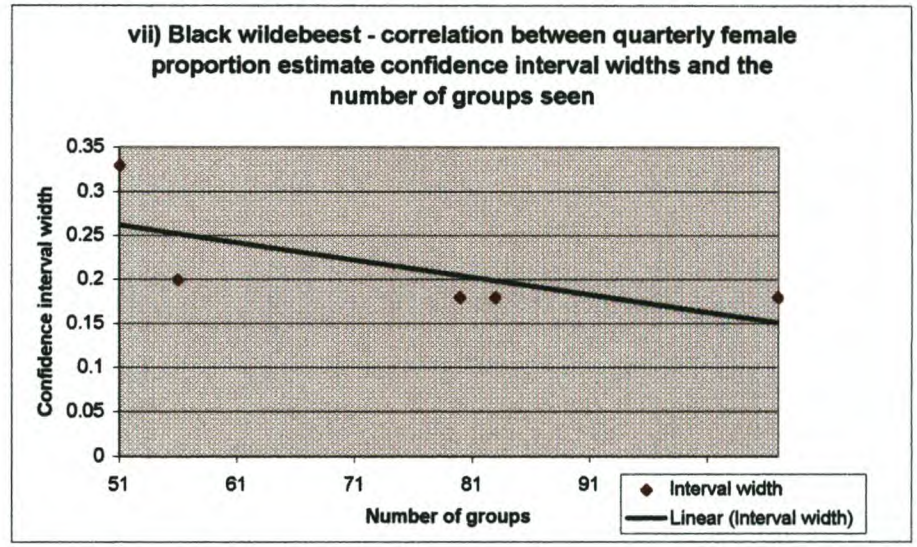

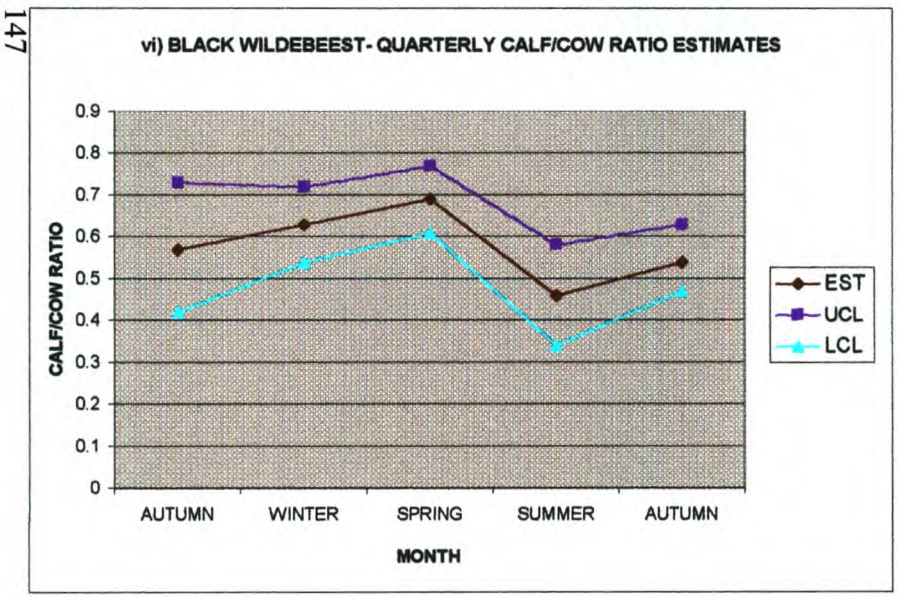

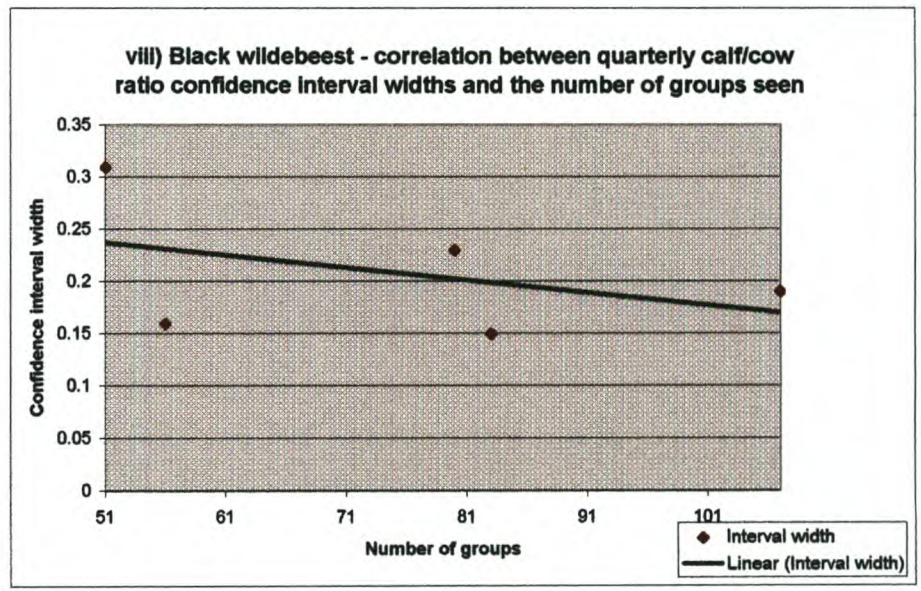

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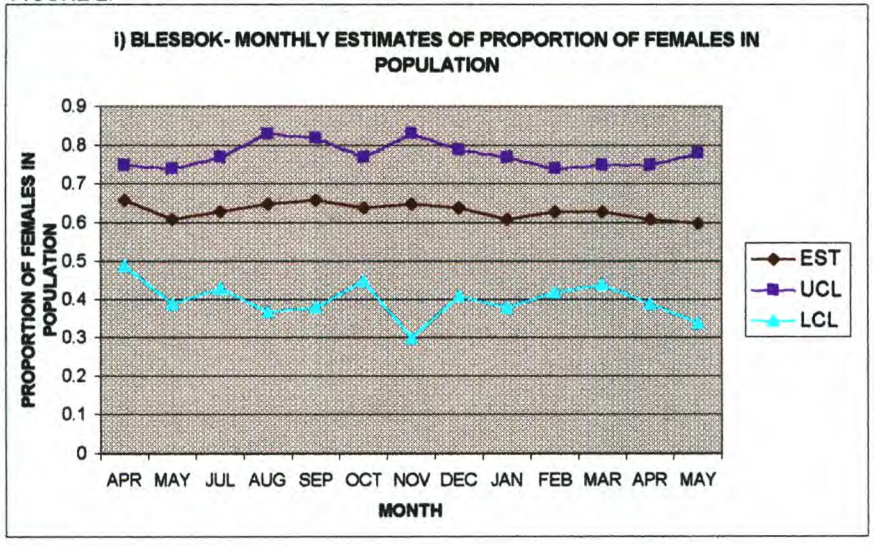

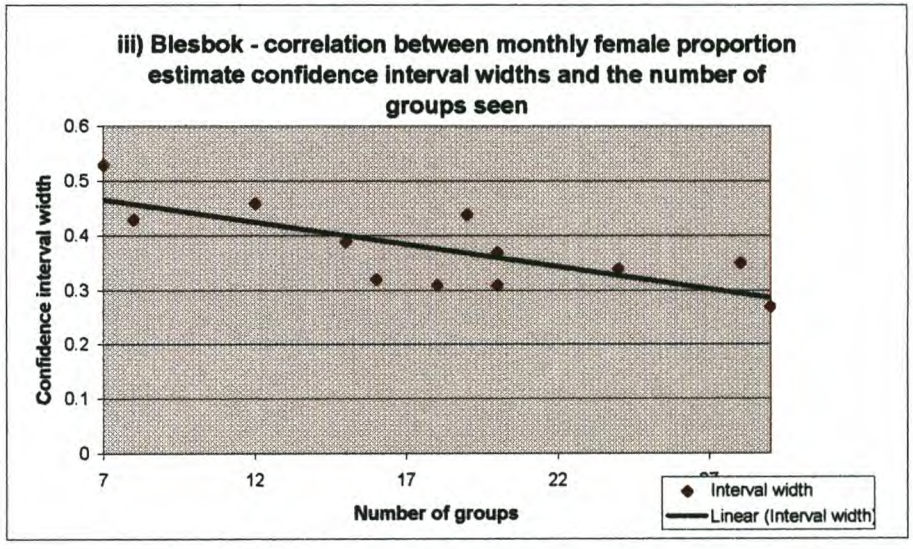

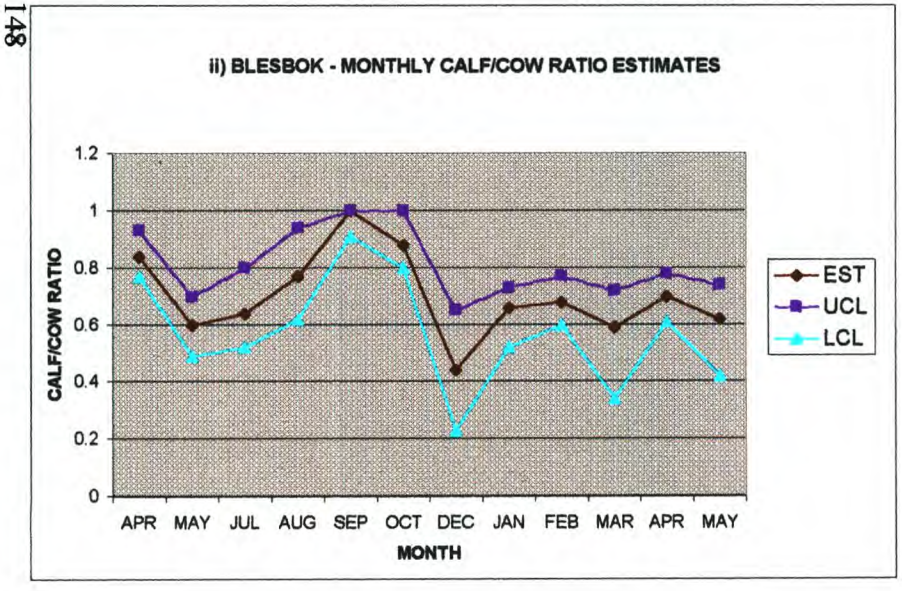

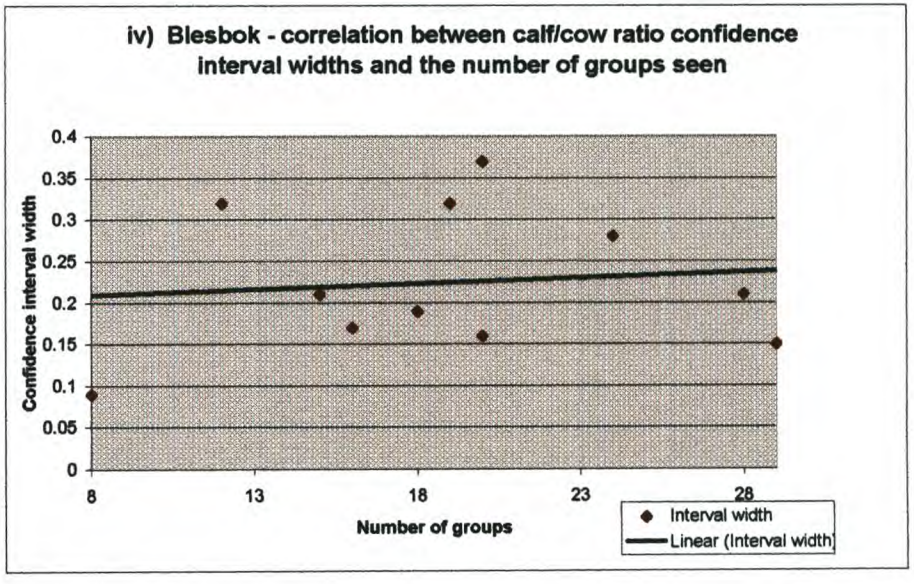

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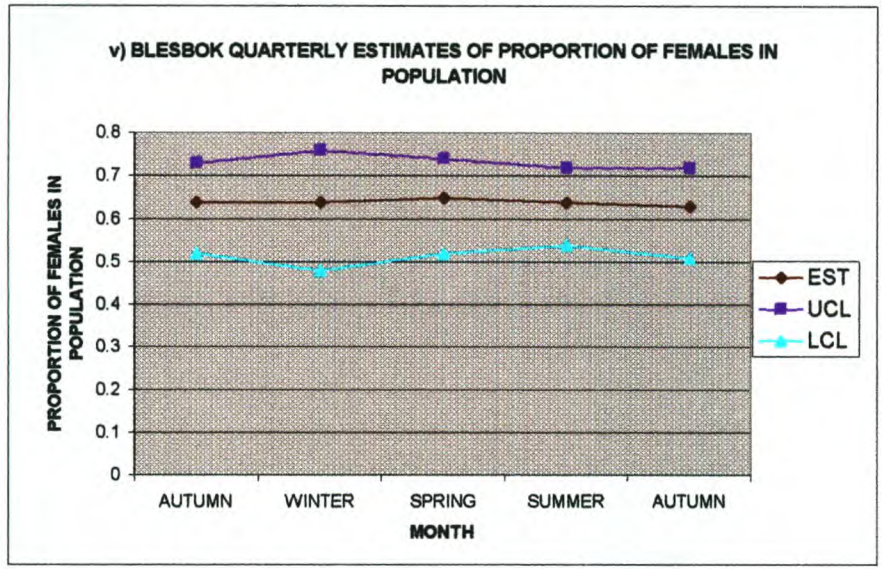

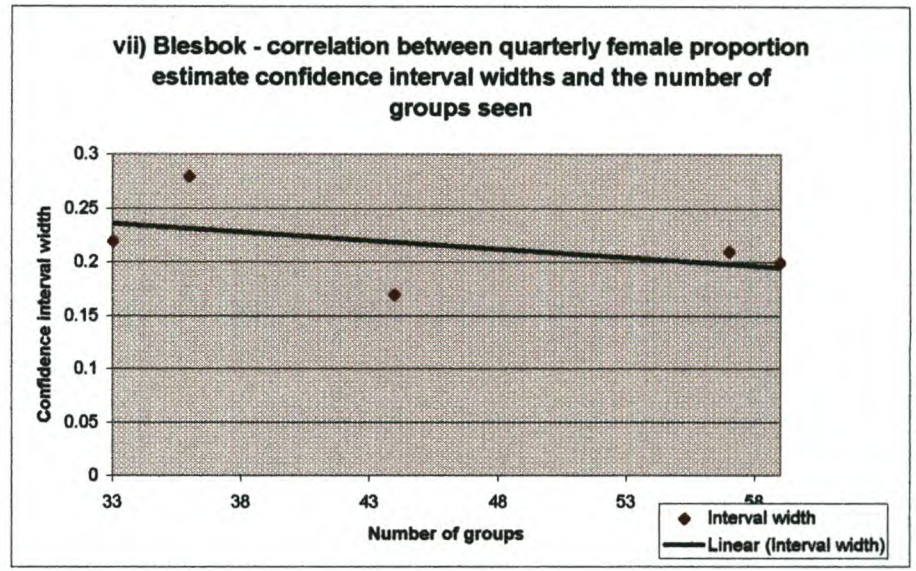

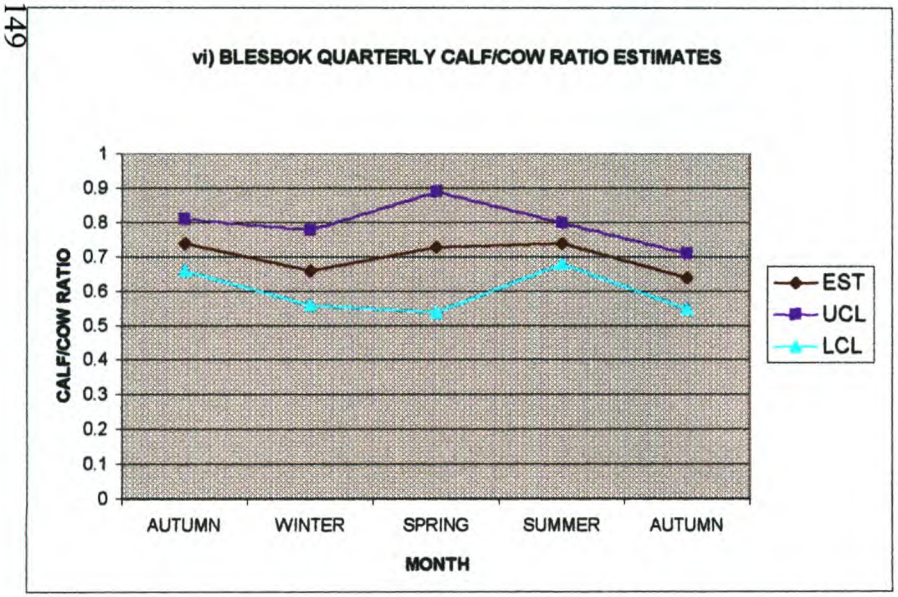

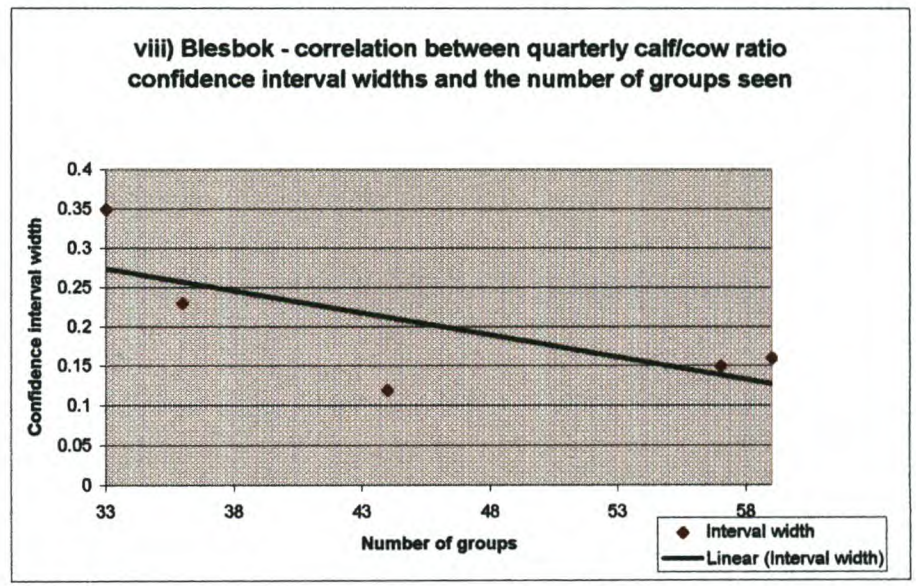

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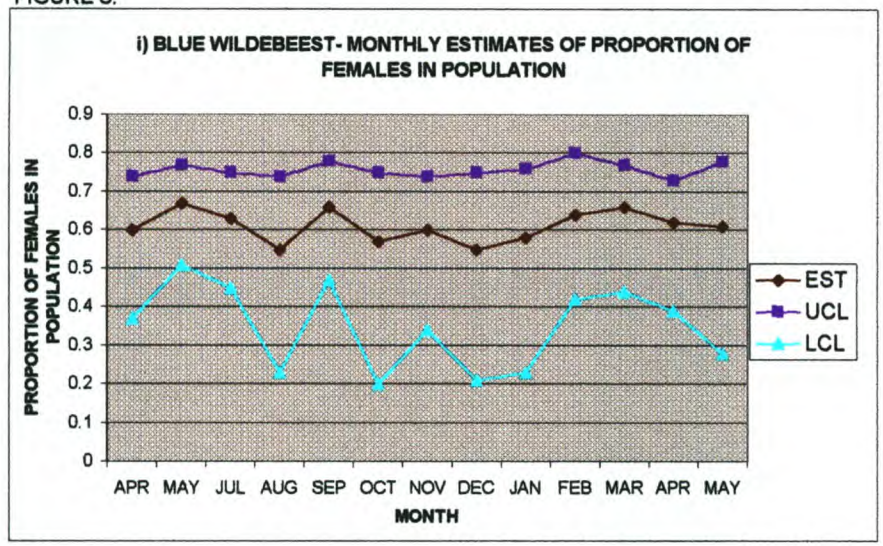
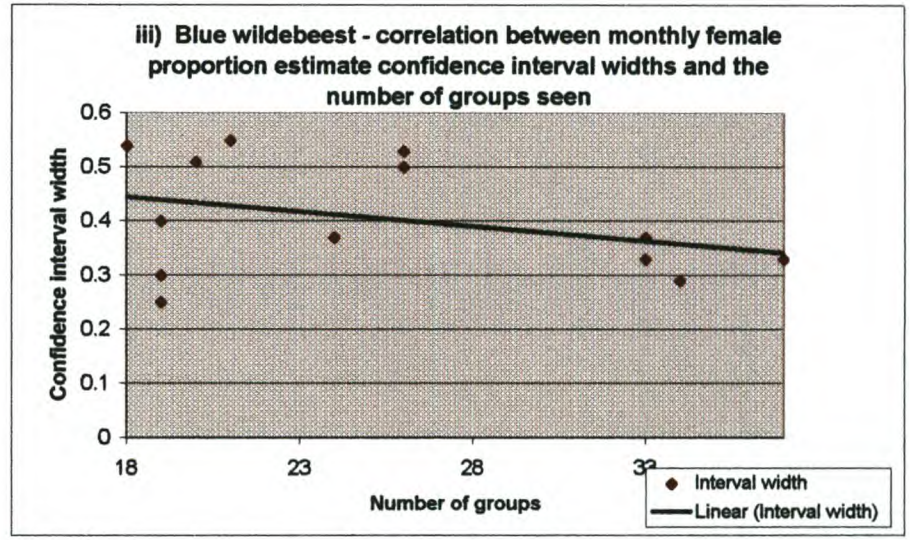
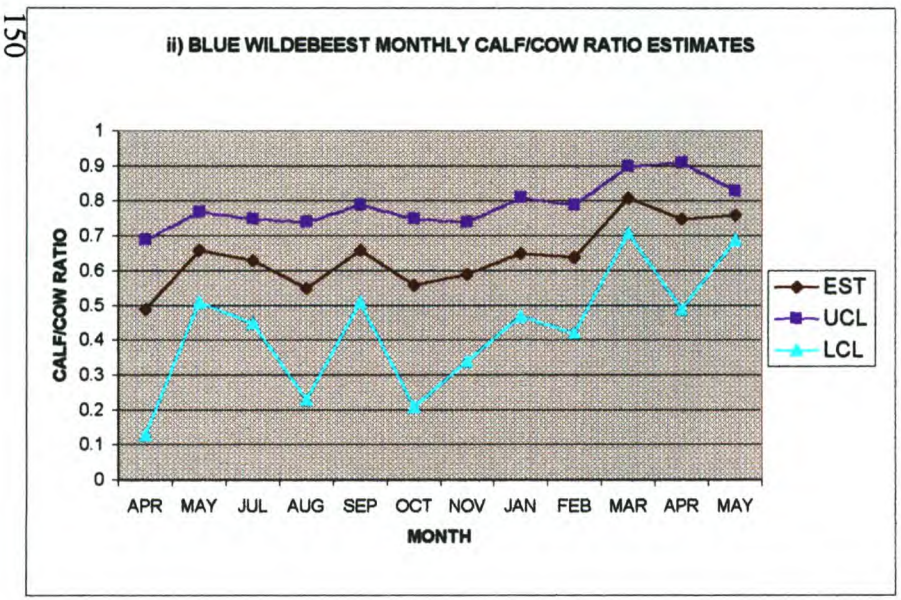
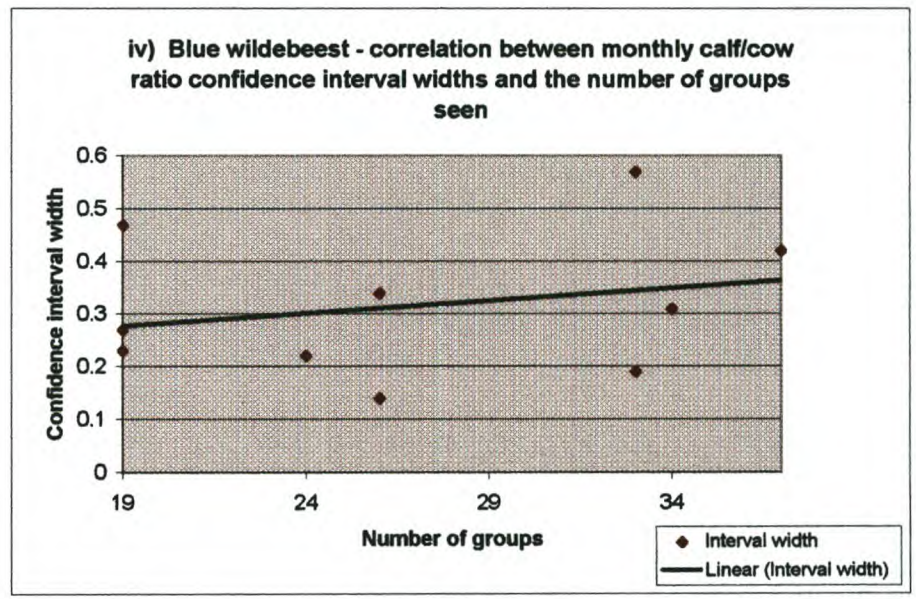
FIGURE 3:









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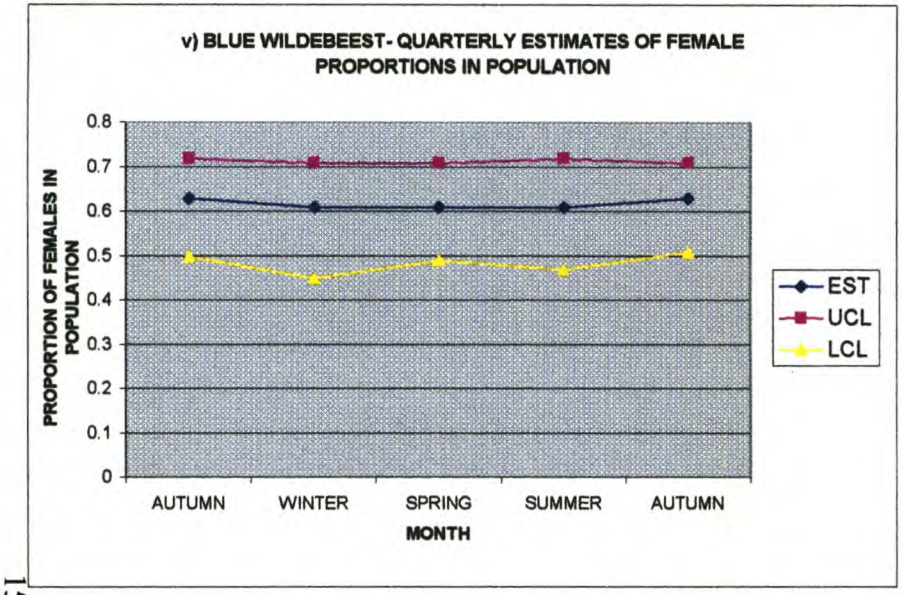

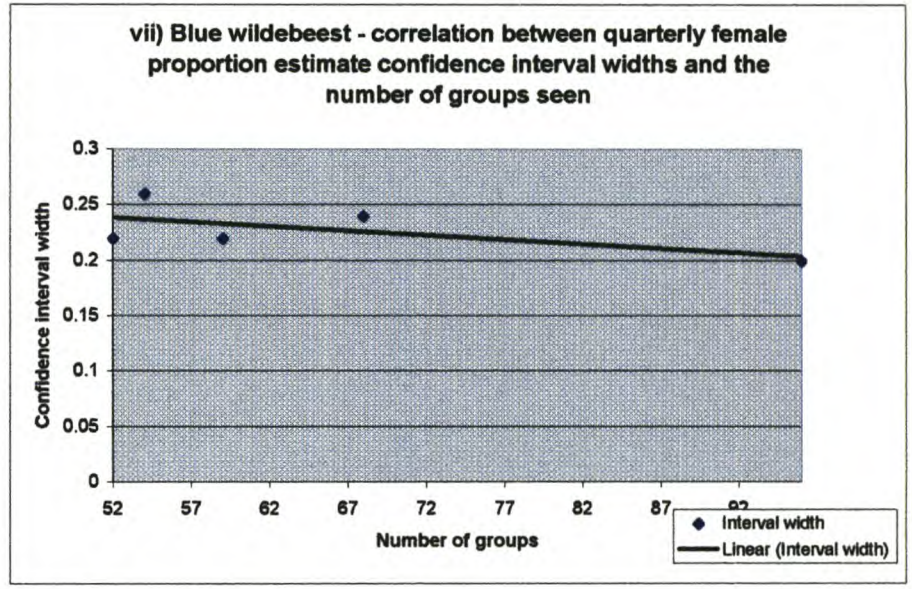

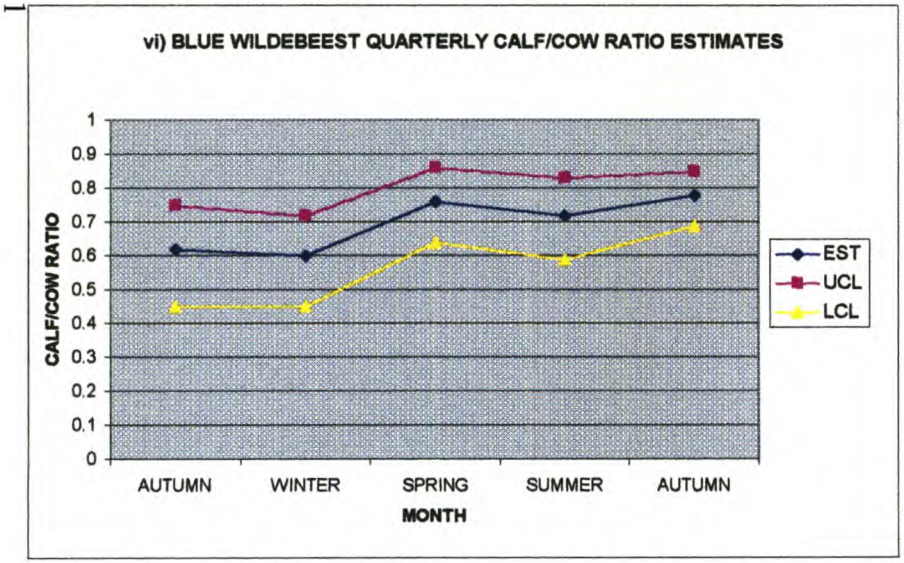

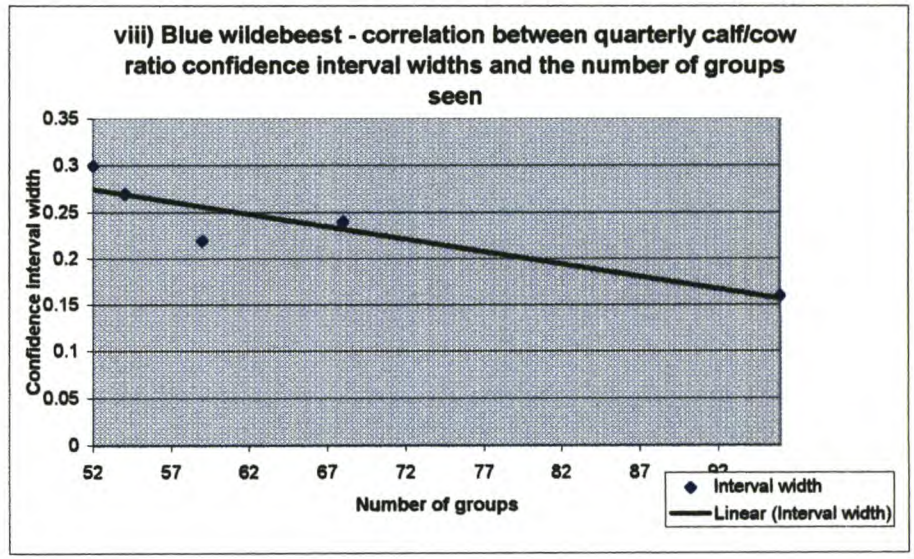

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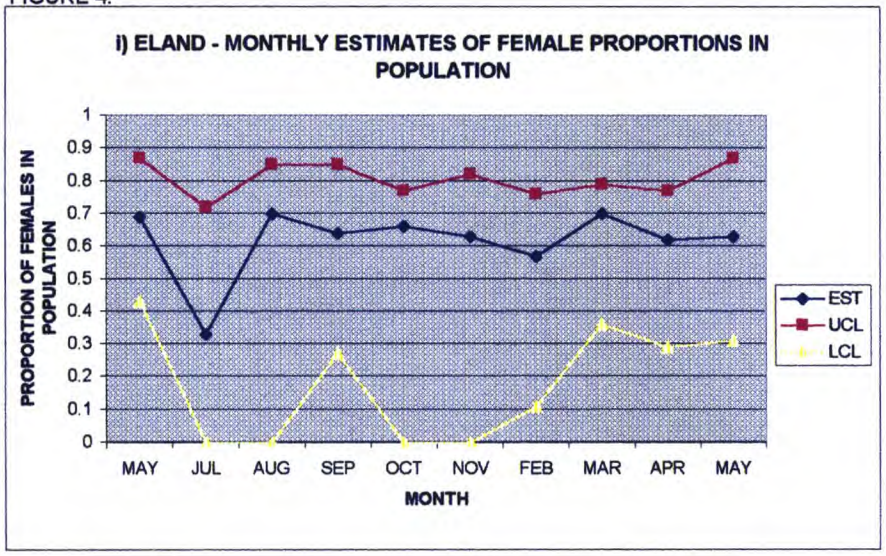

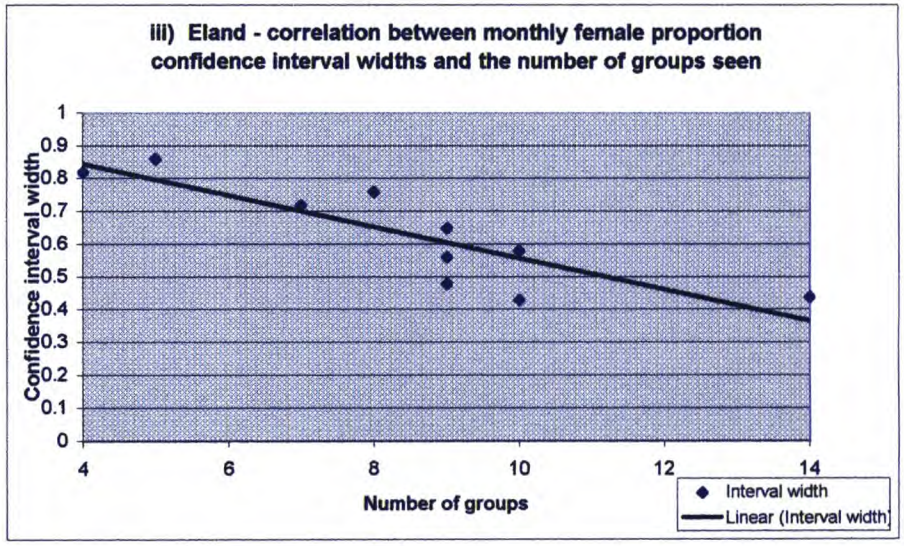

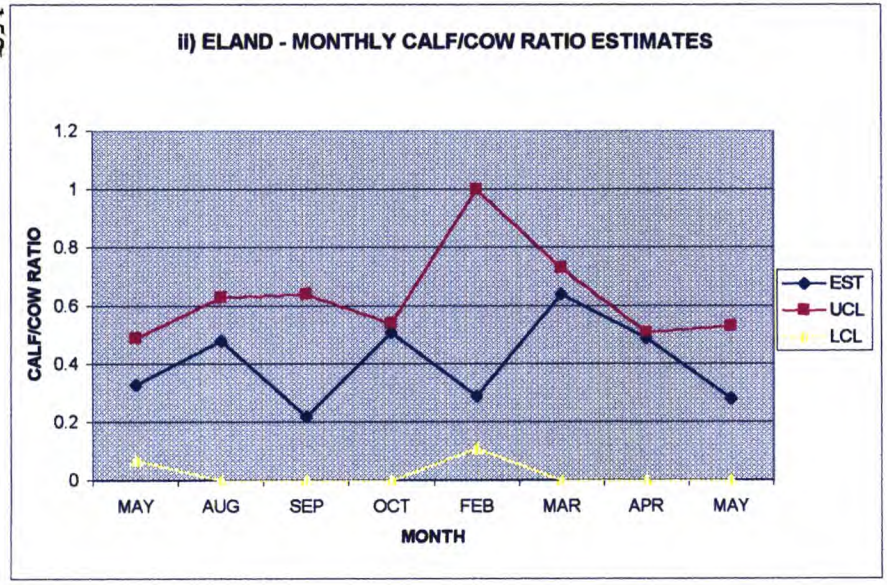

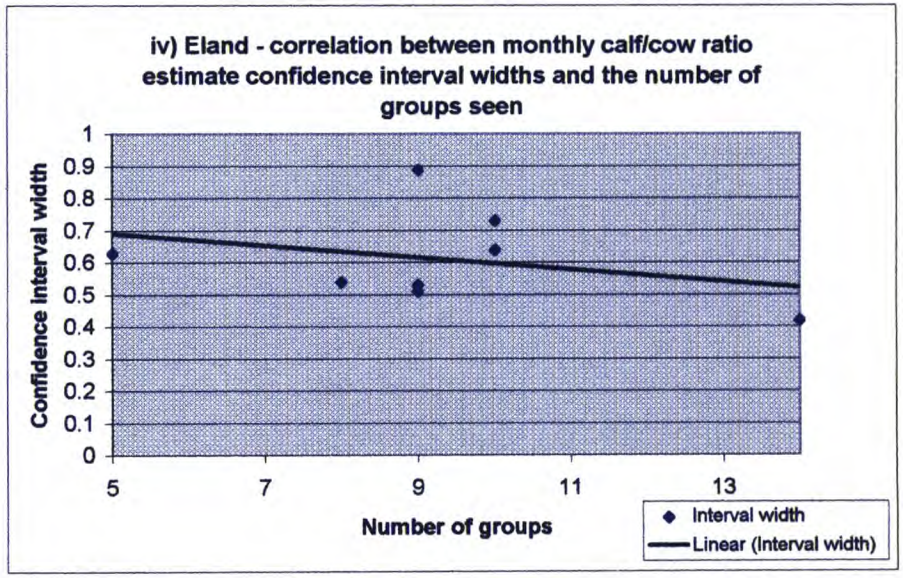

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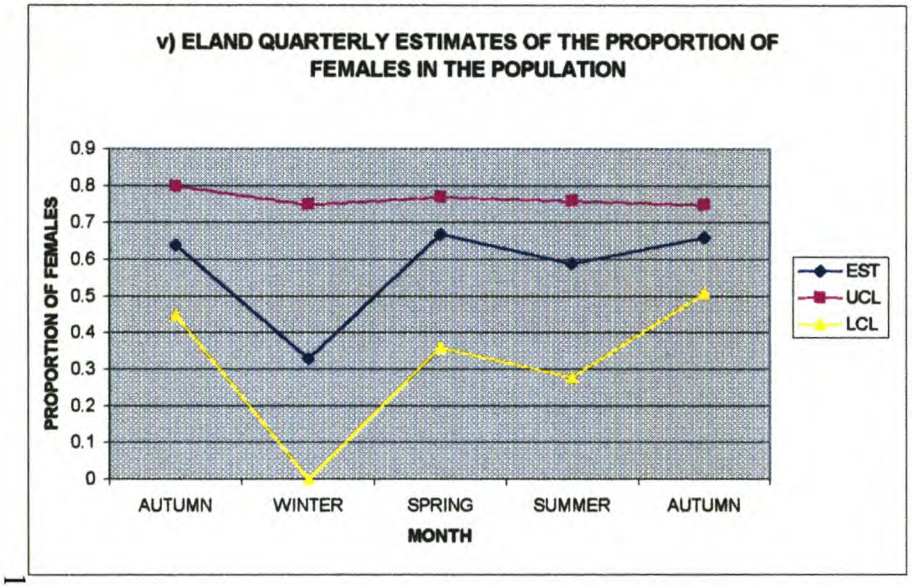

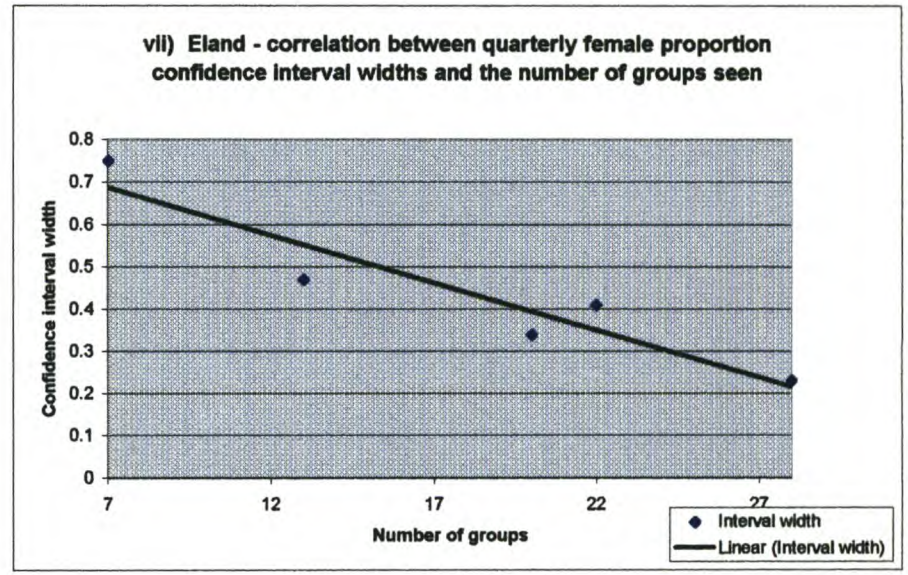

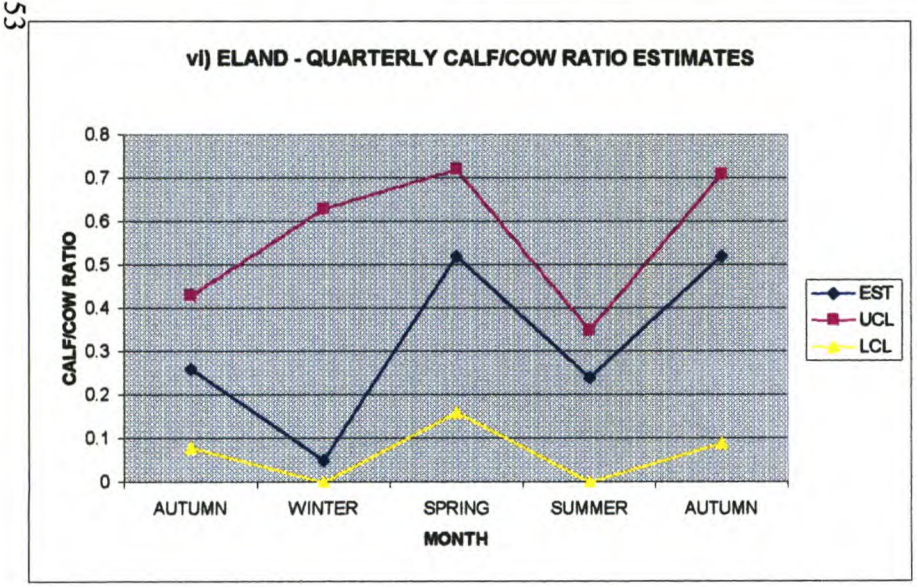

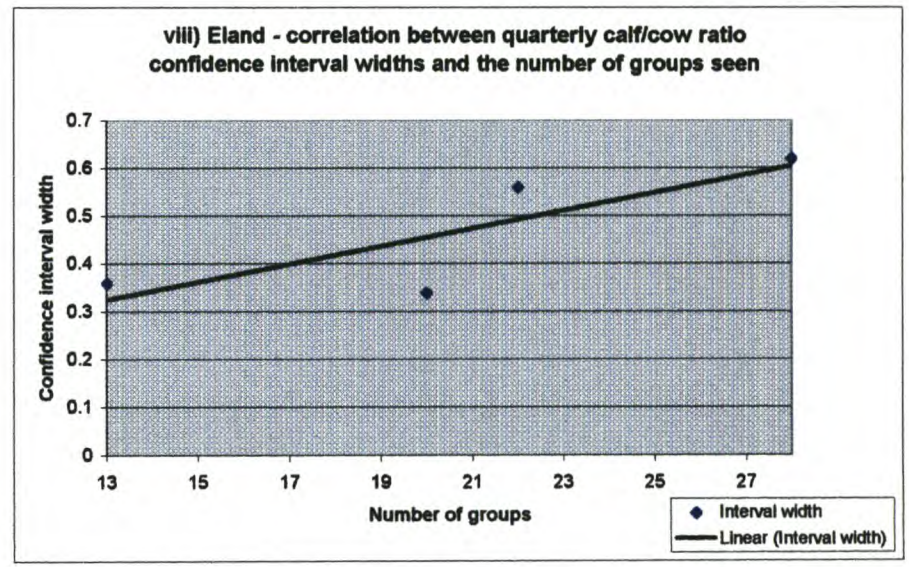

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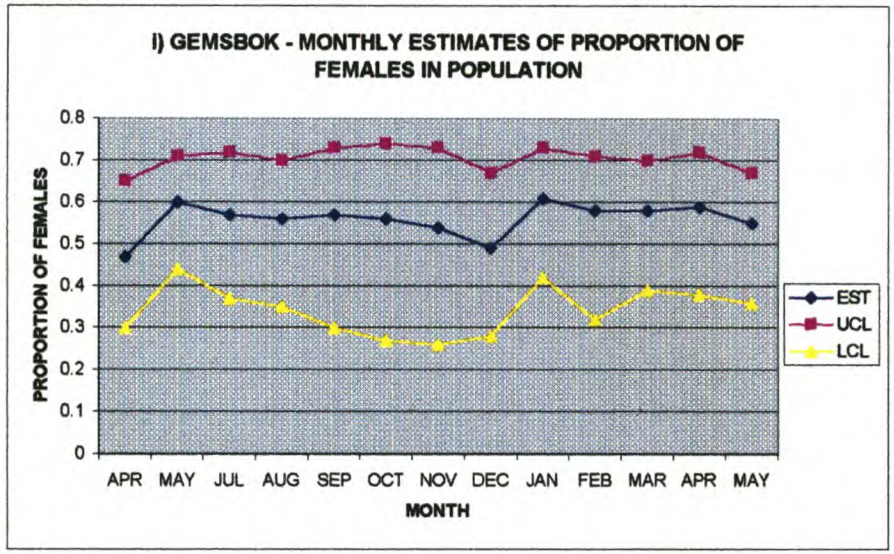

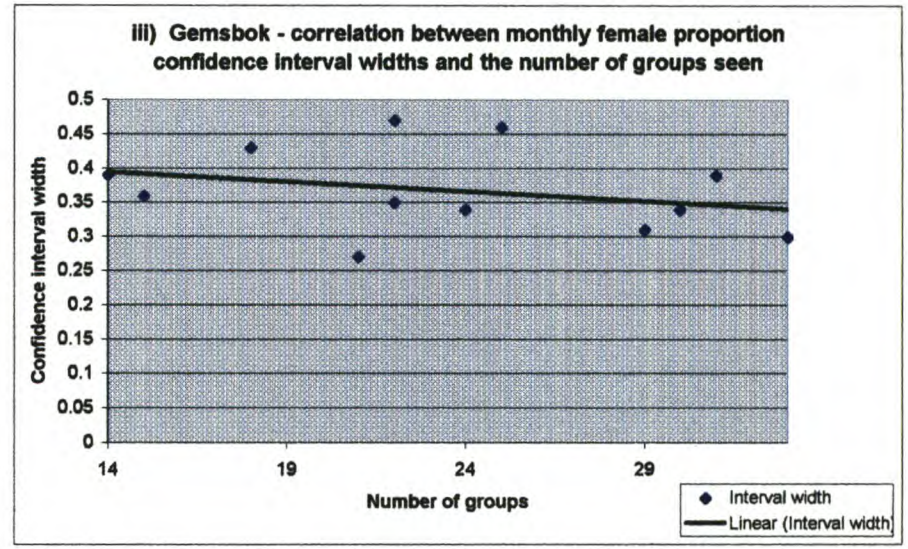

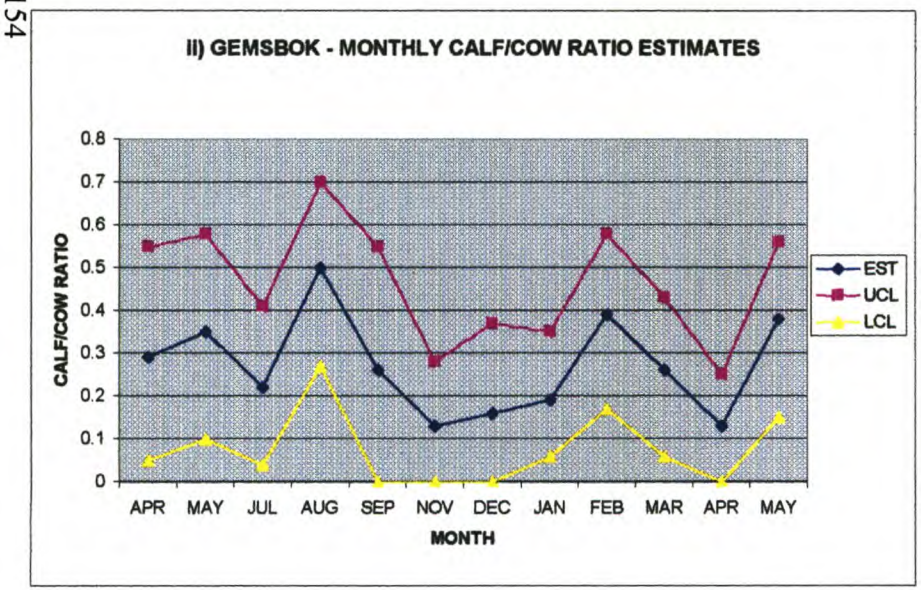

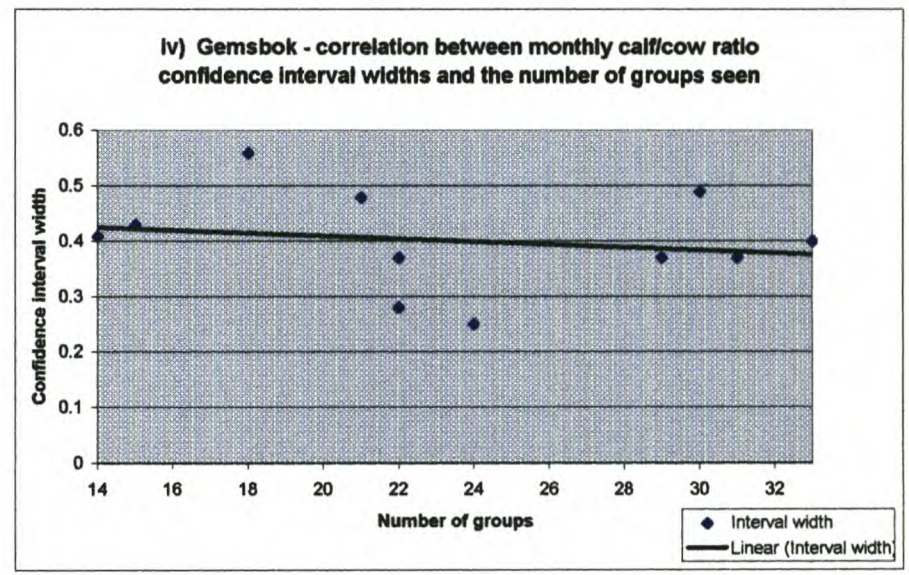

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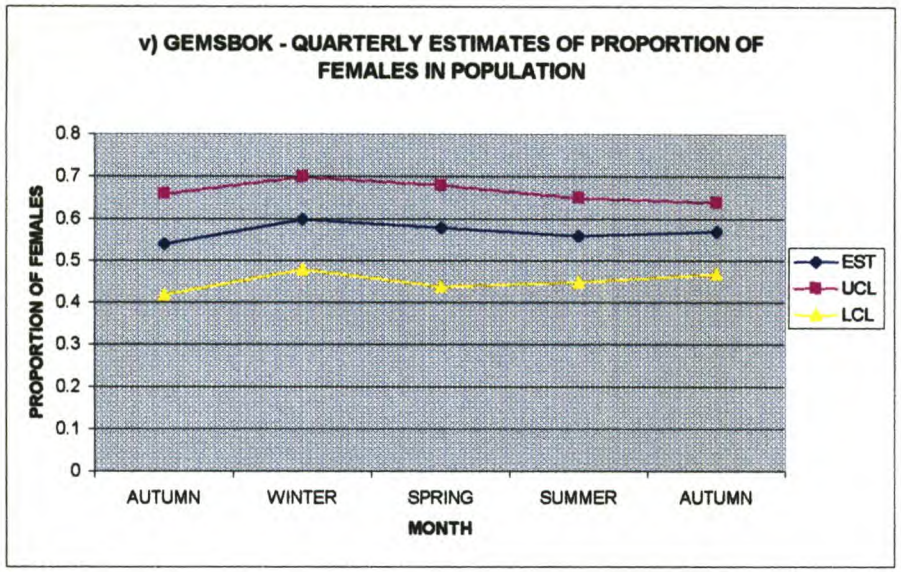

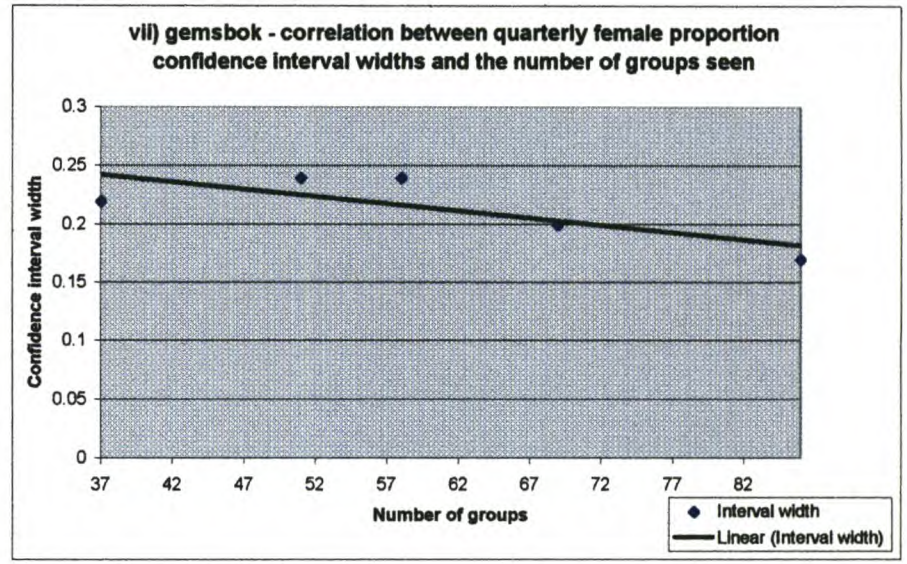

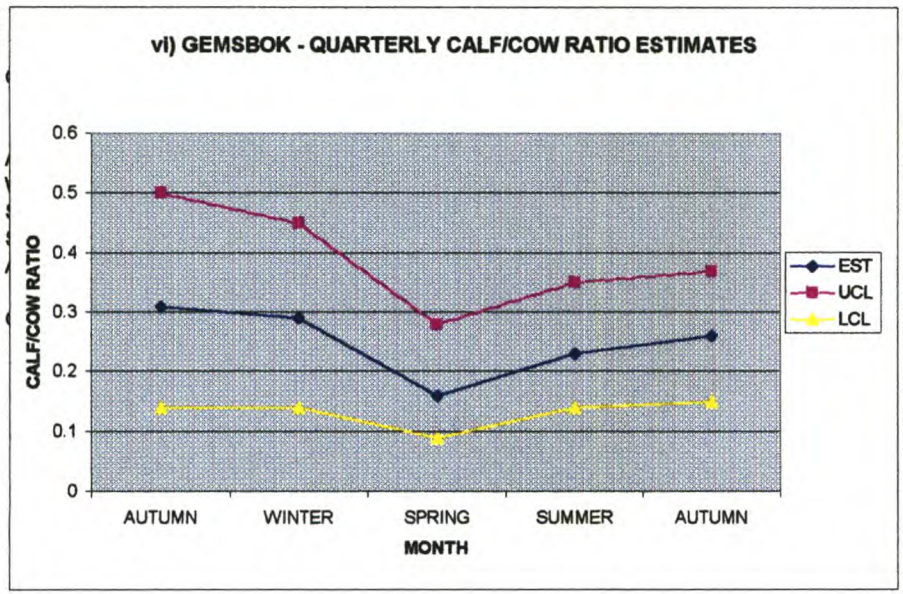

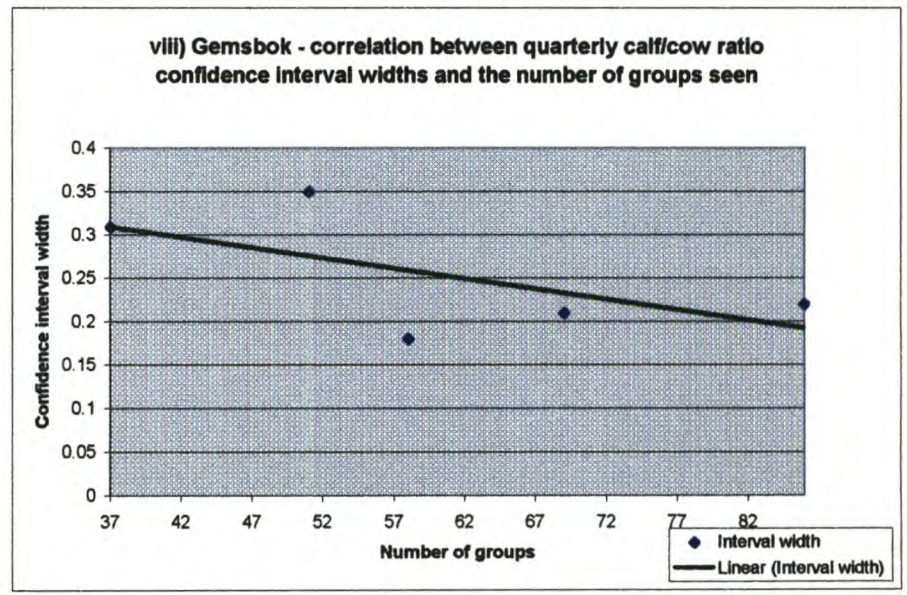

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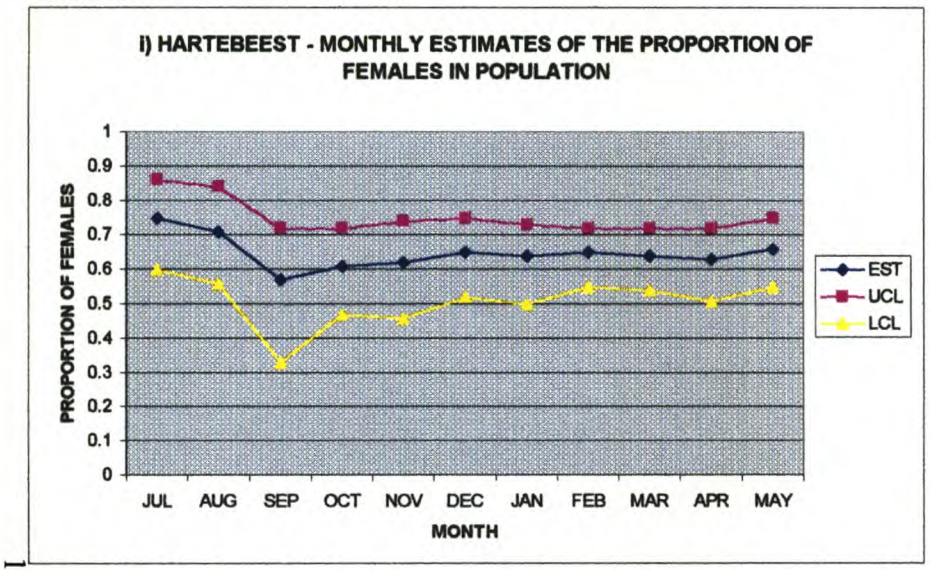

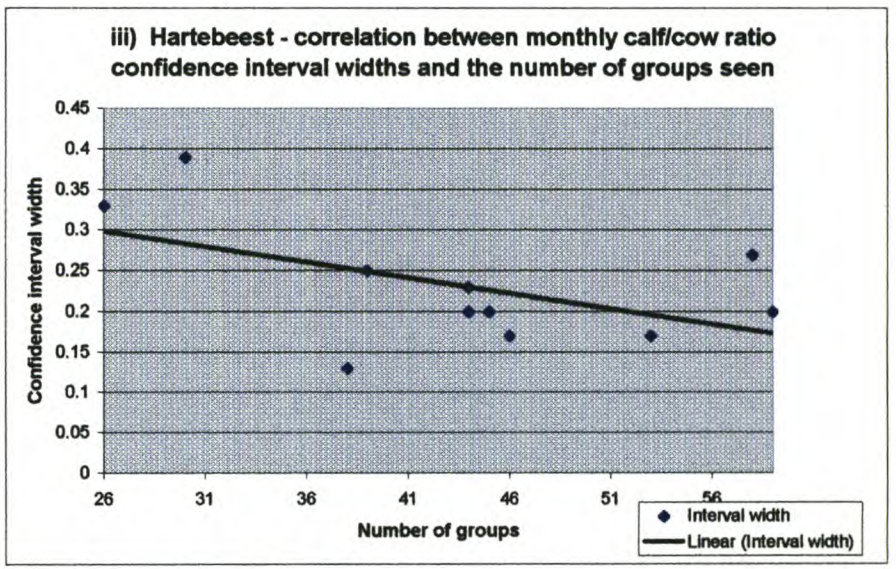

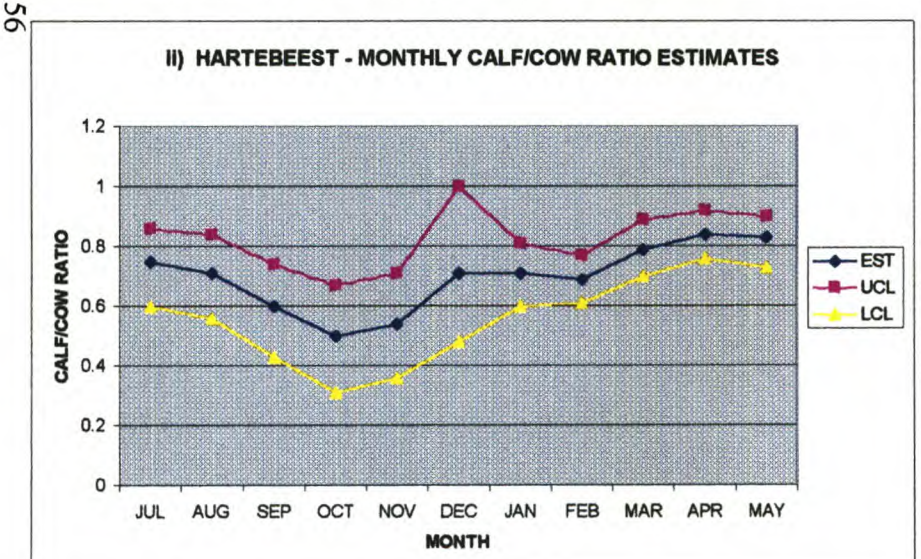

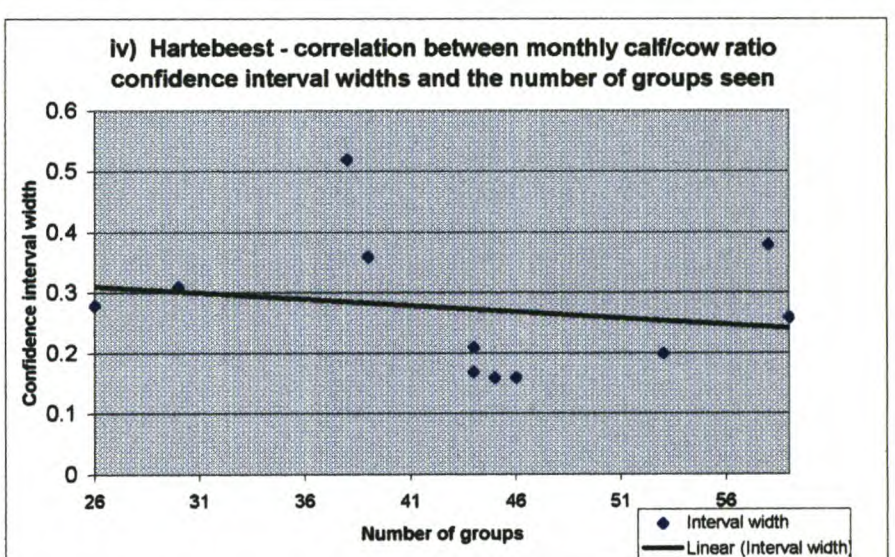

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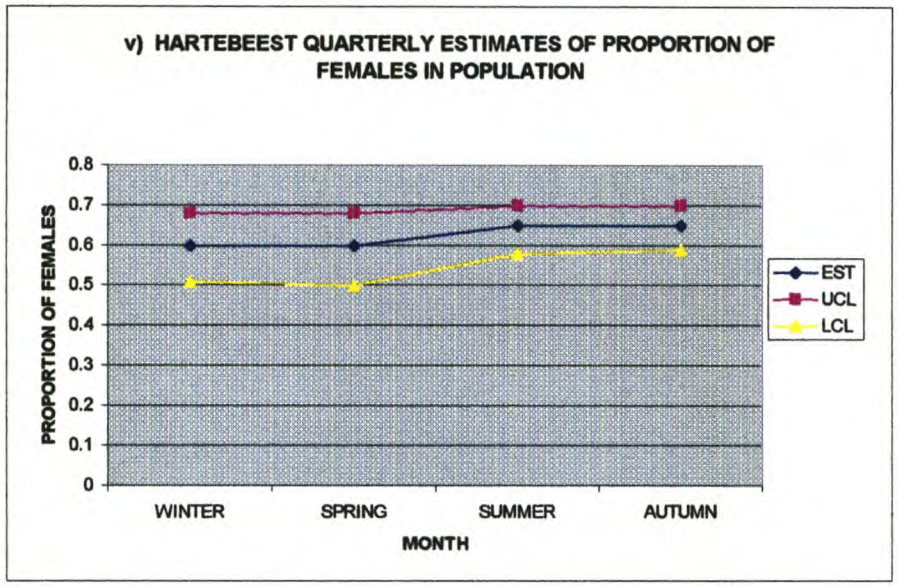

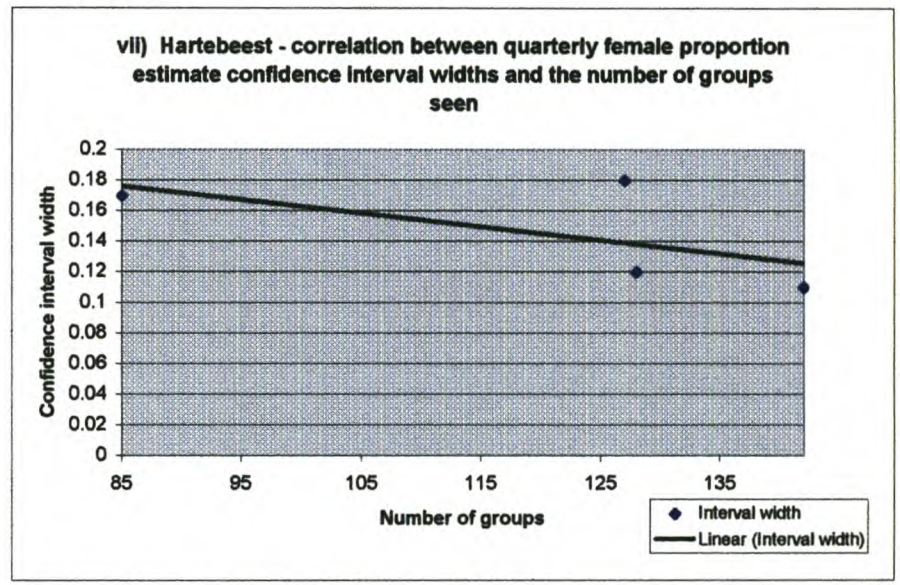

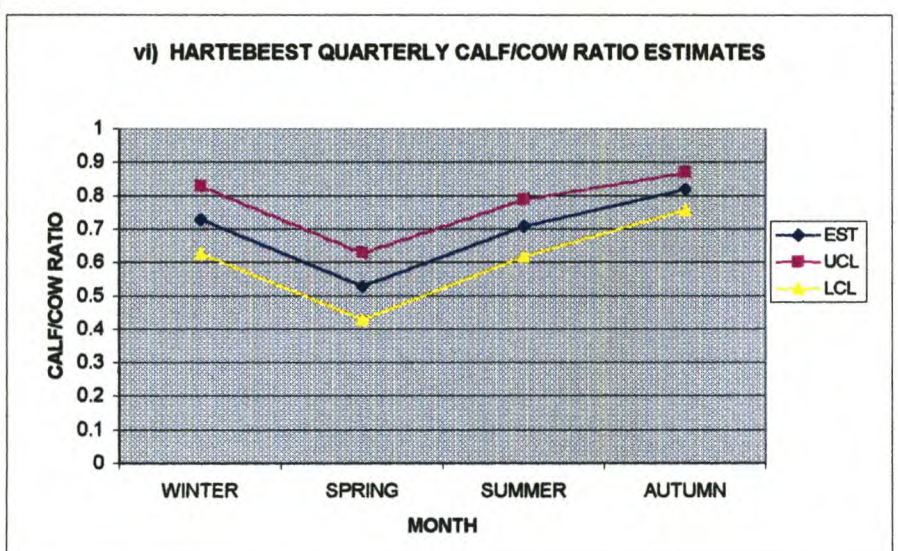

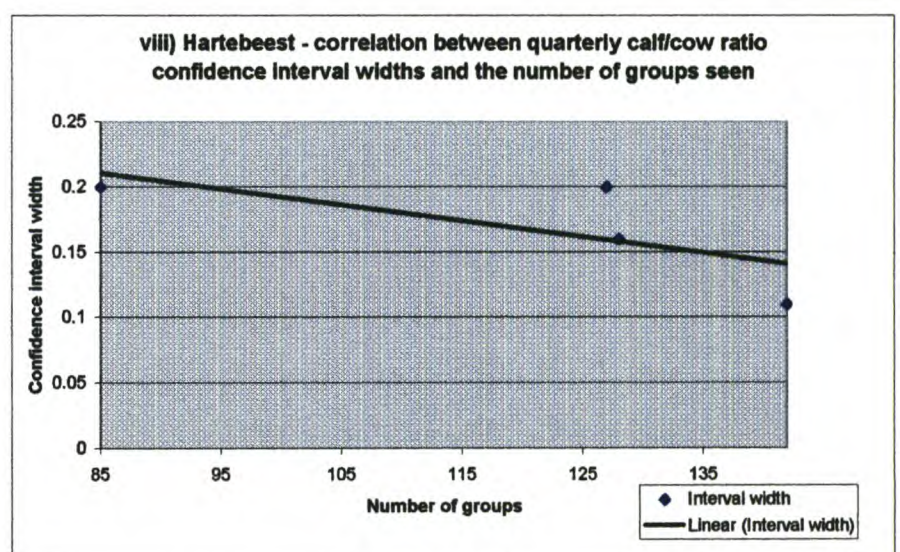

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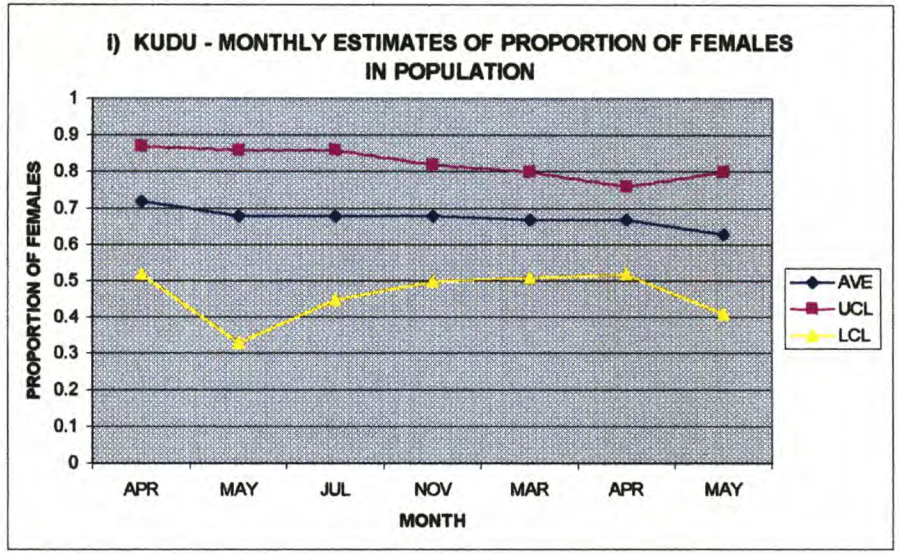

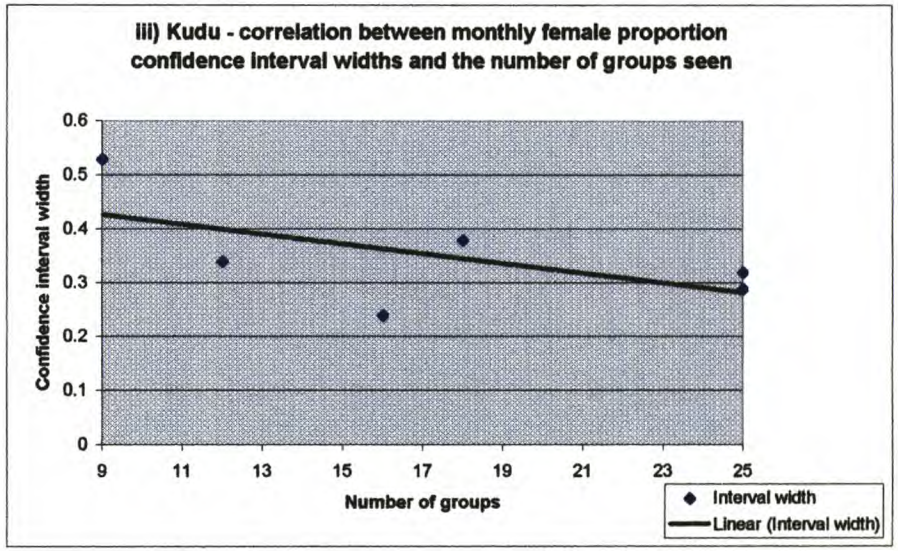

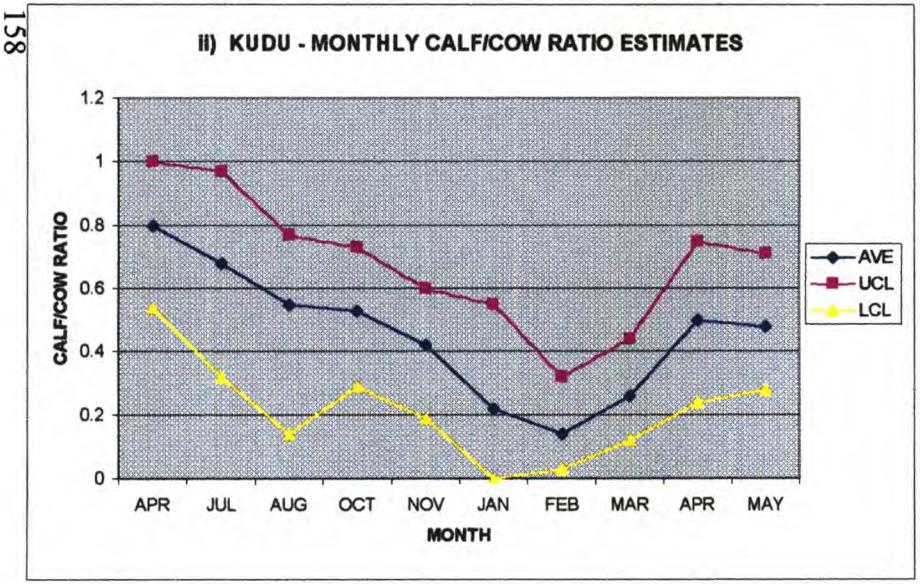

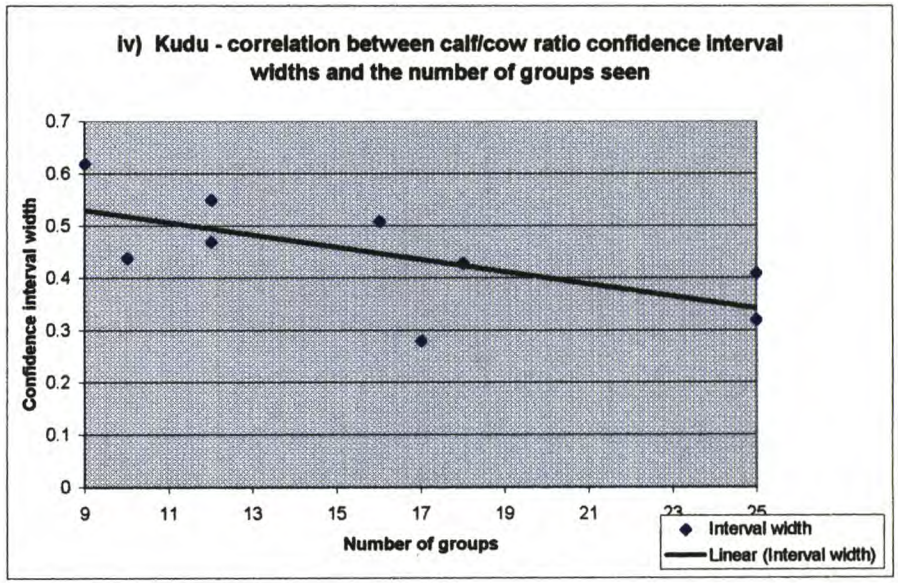

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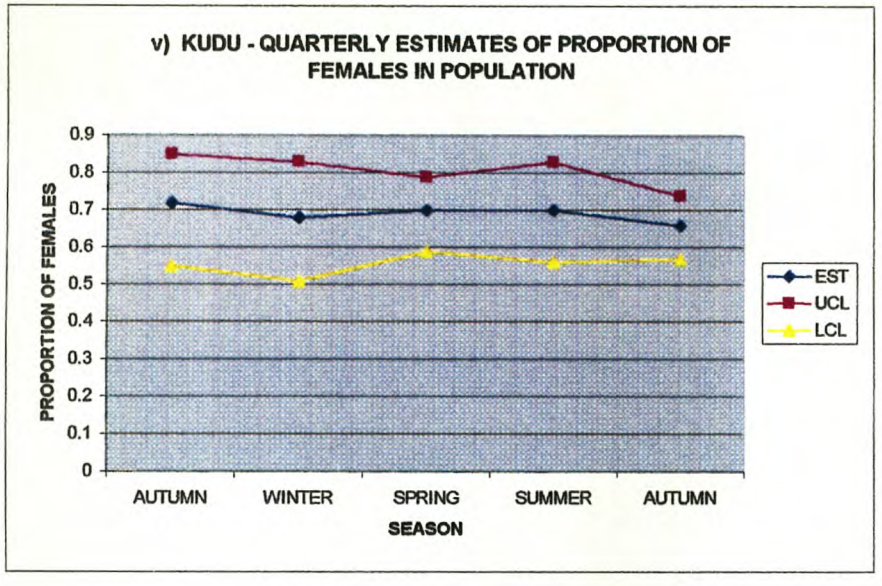

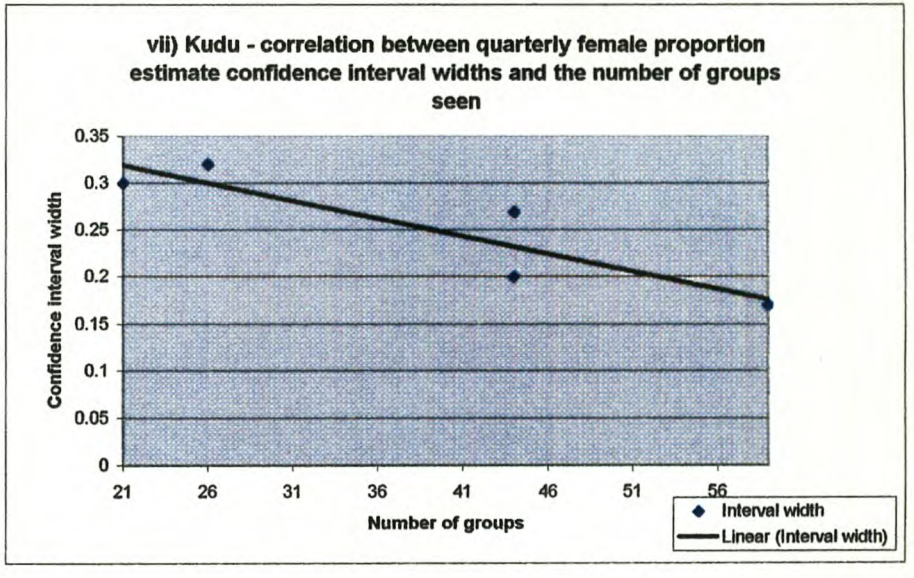

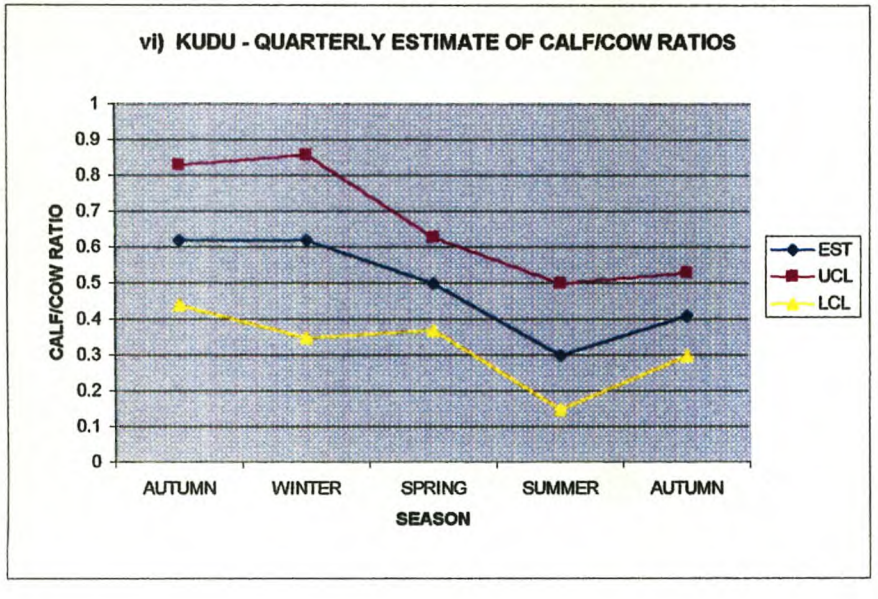

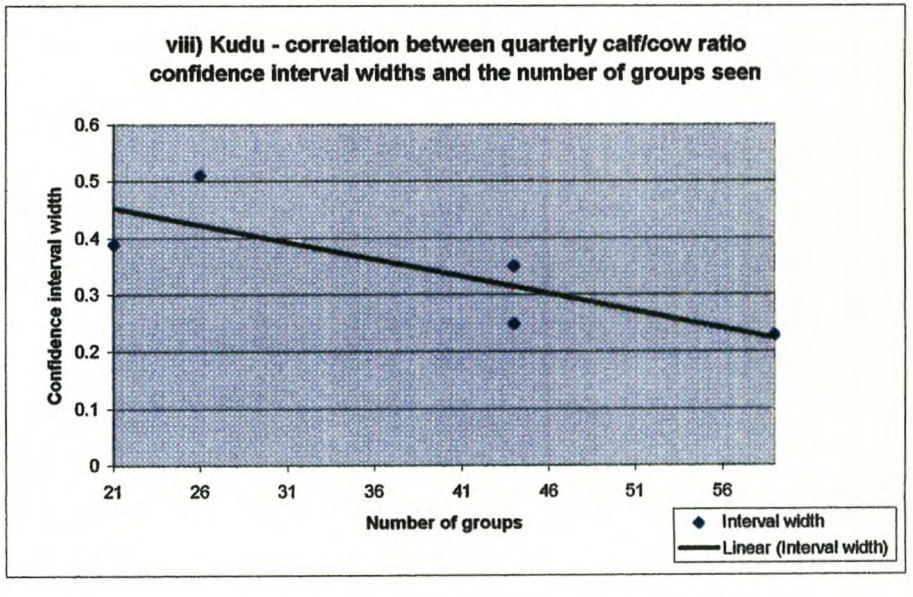

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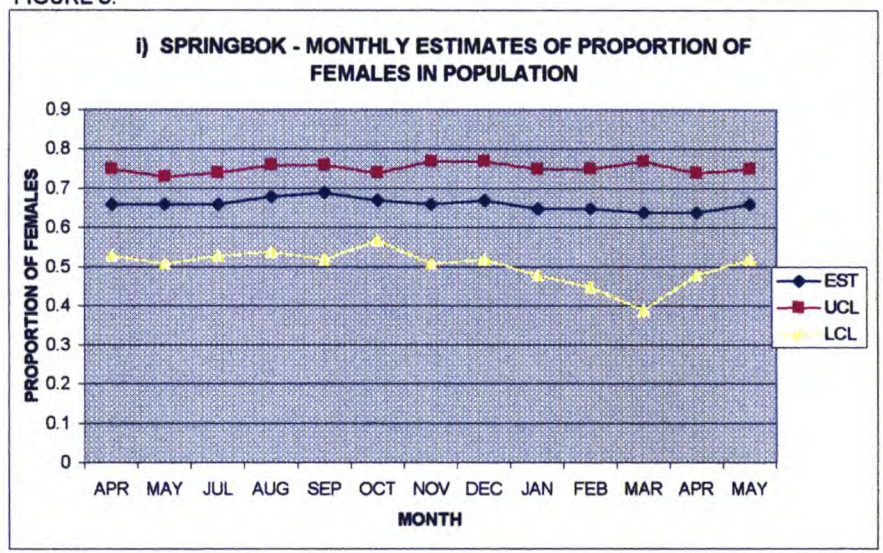

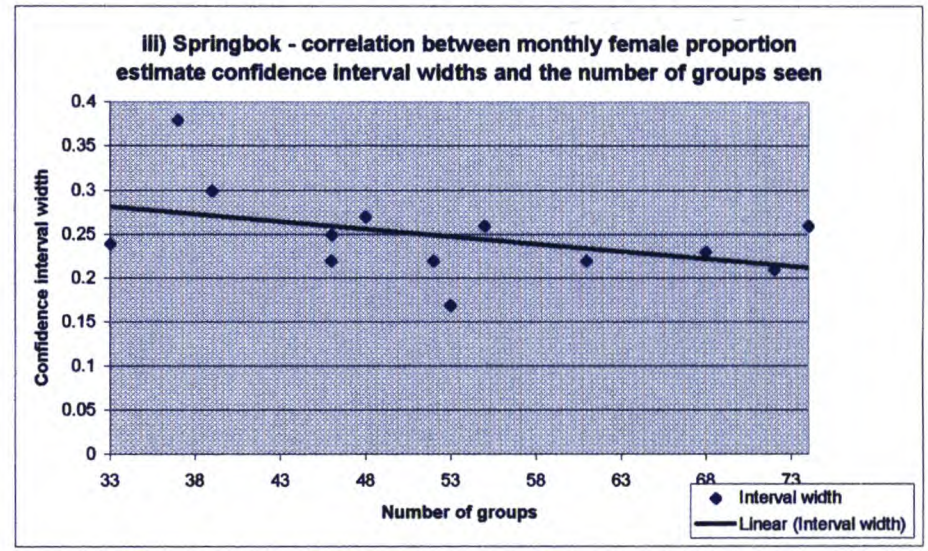

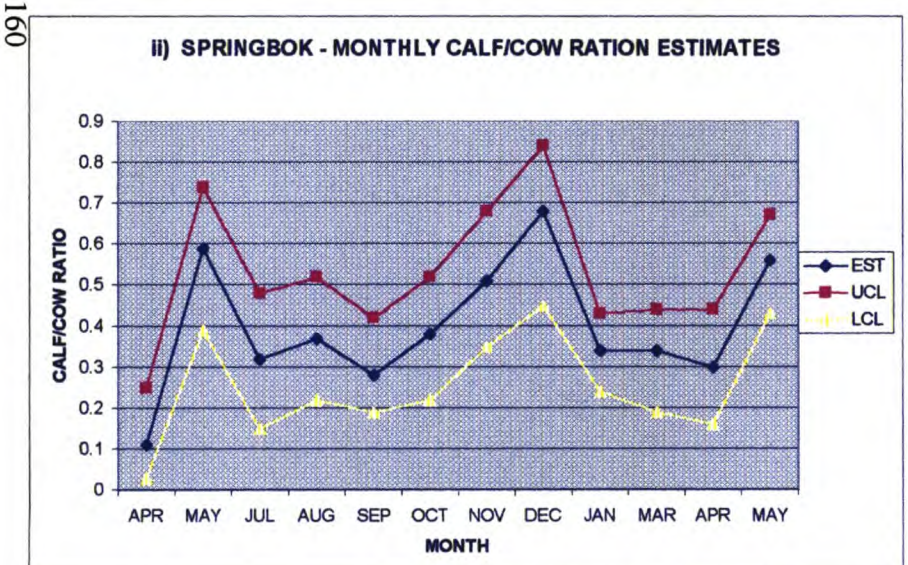

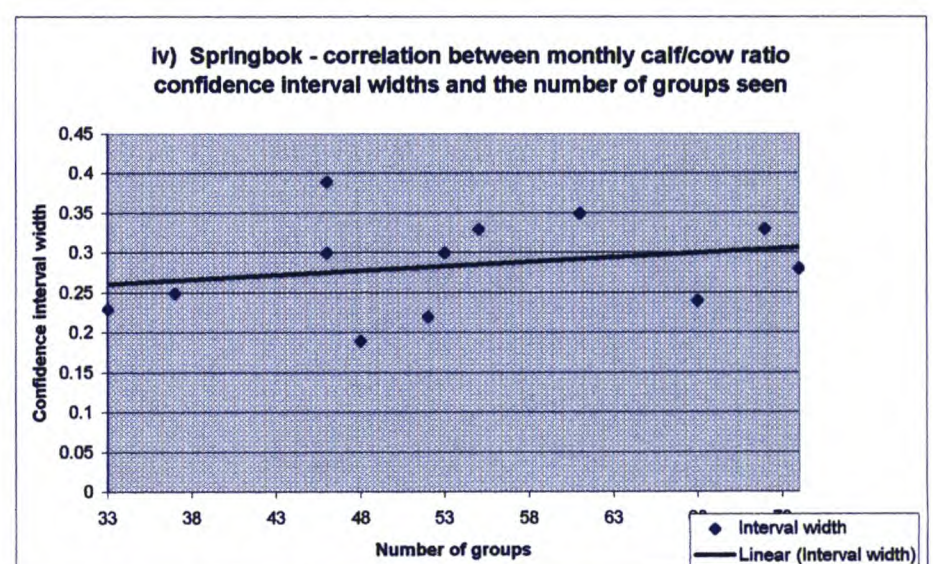

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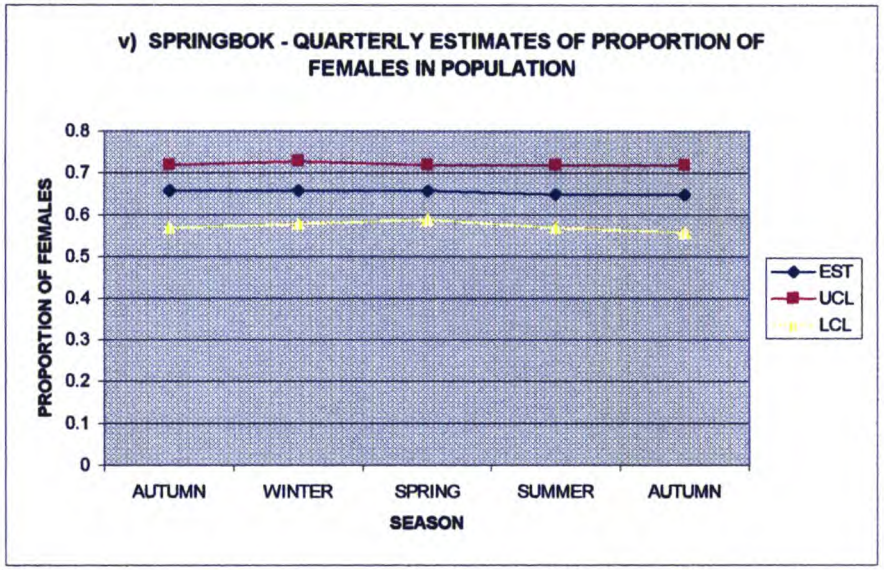

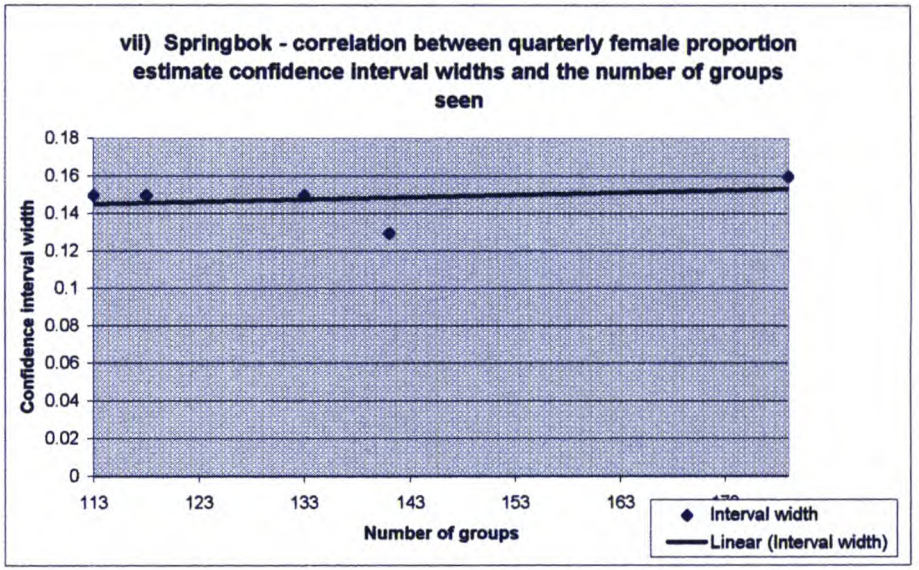

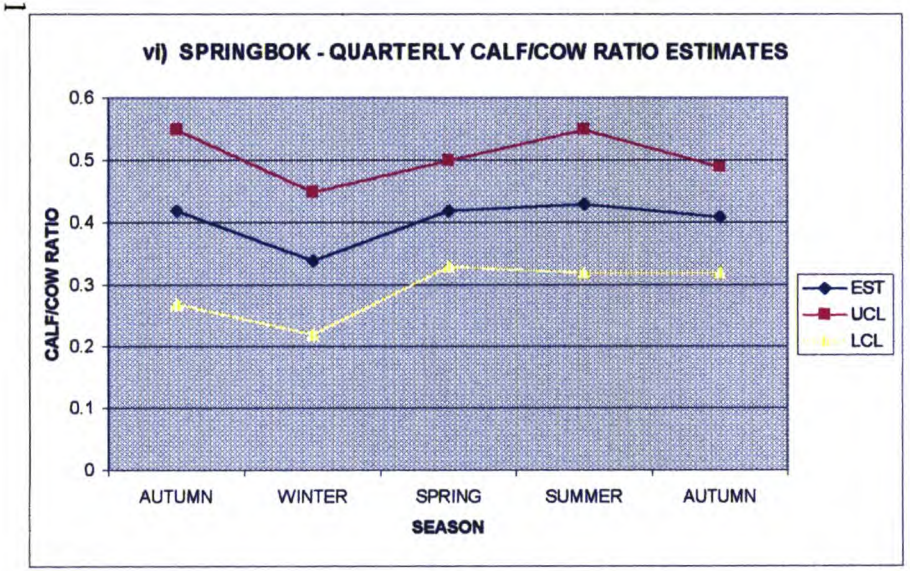

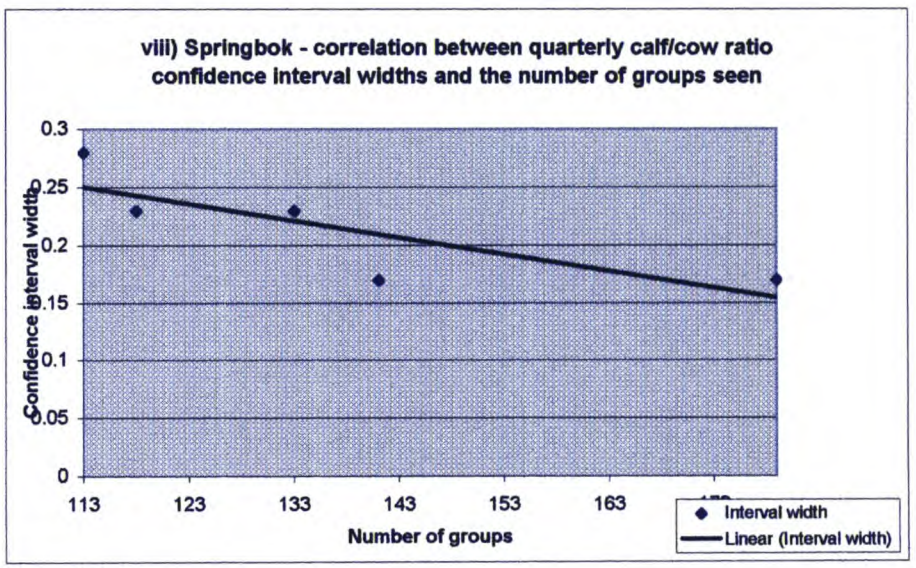

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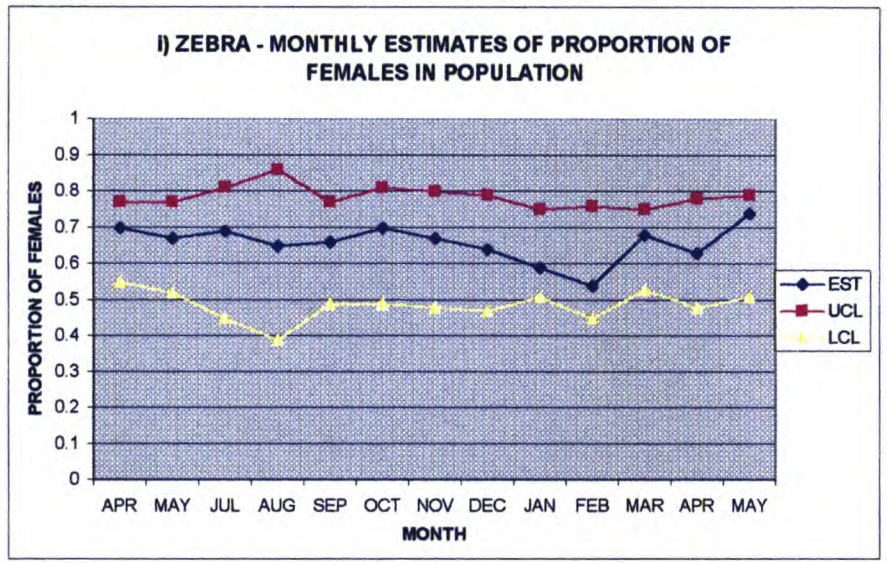

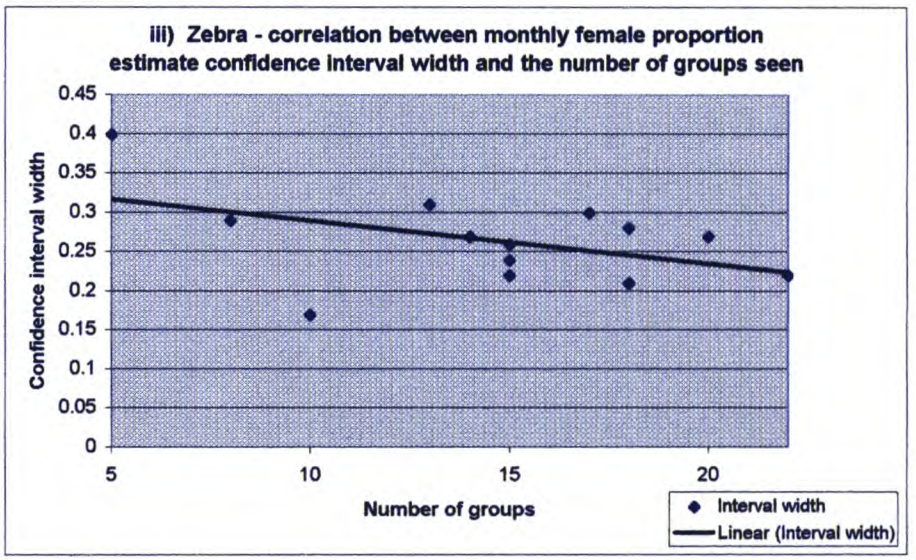

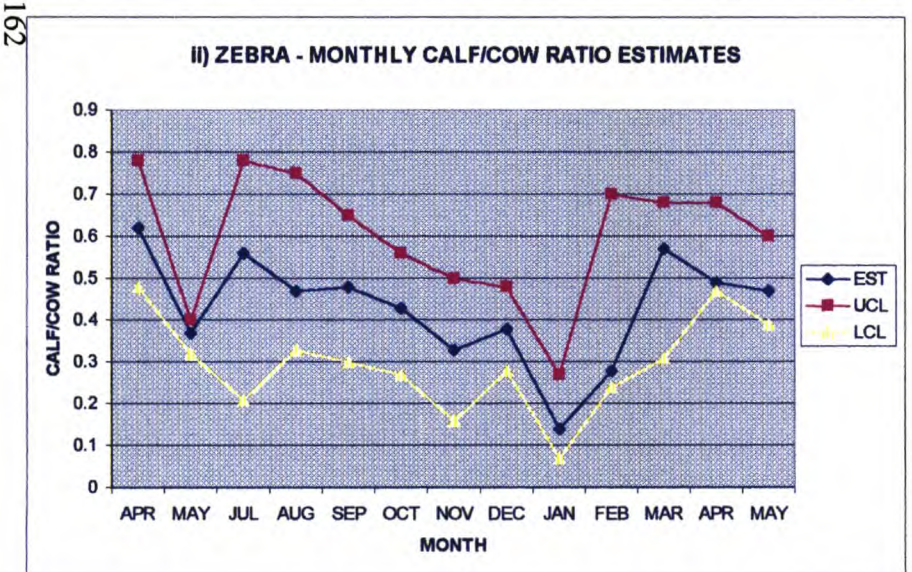

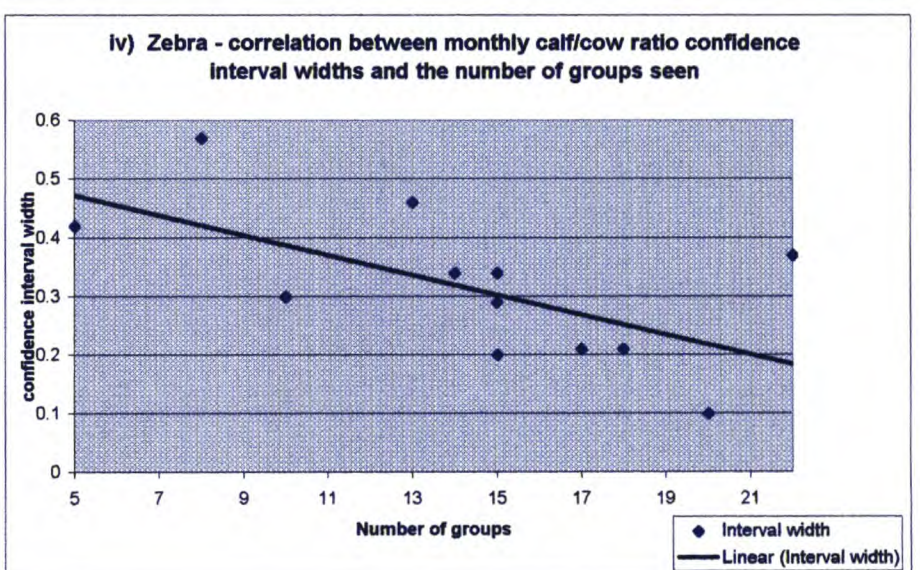

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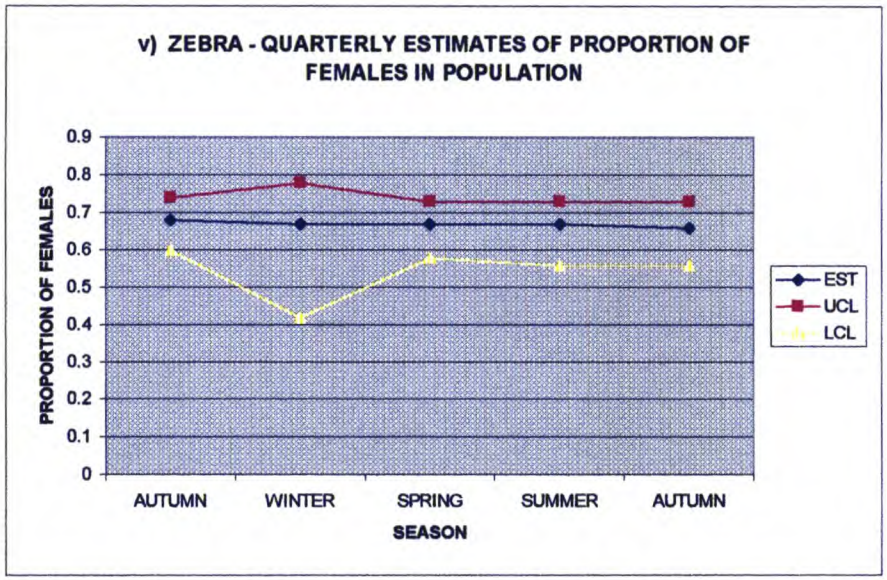

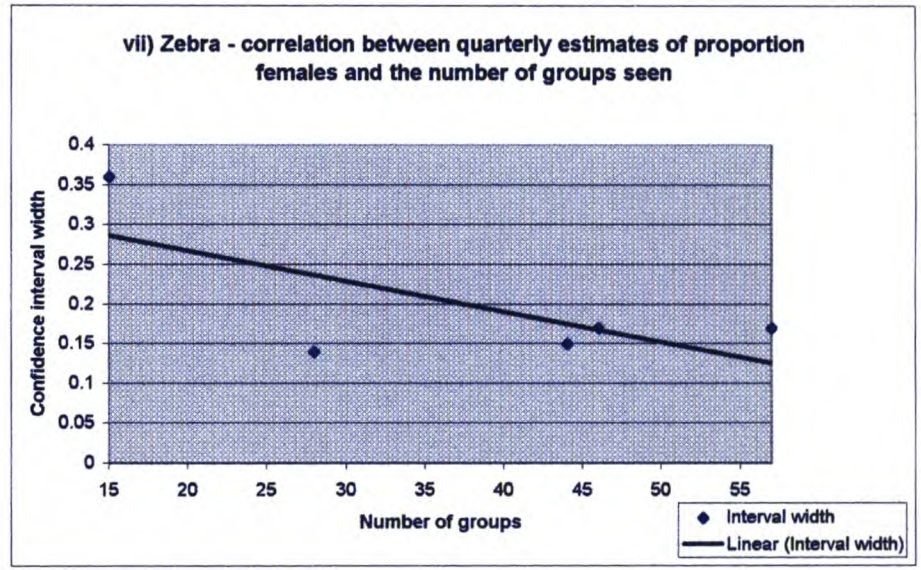

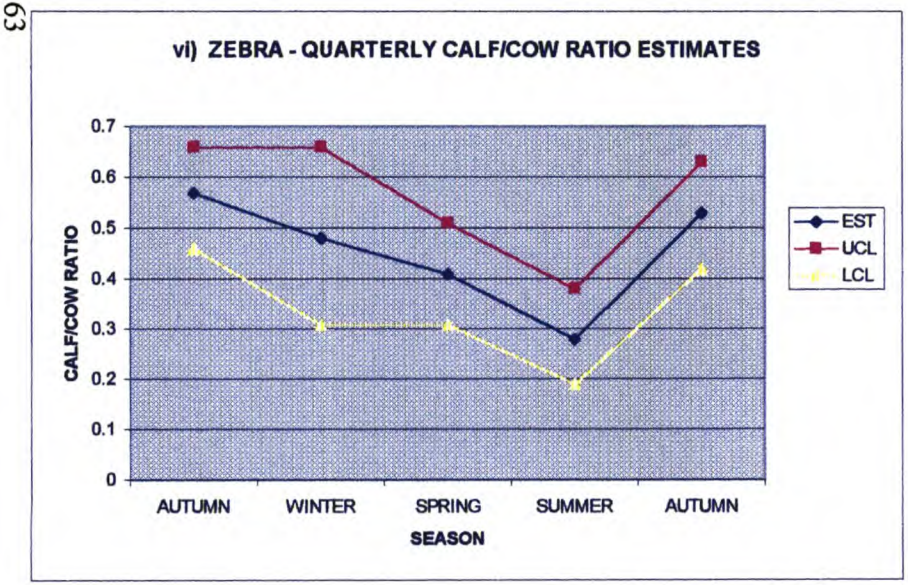

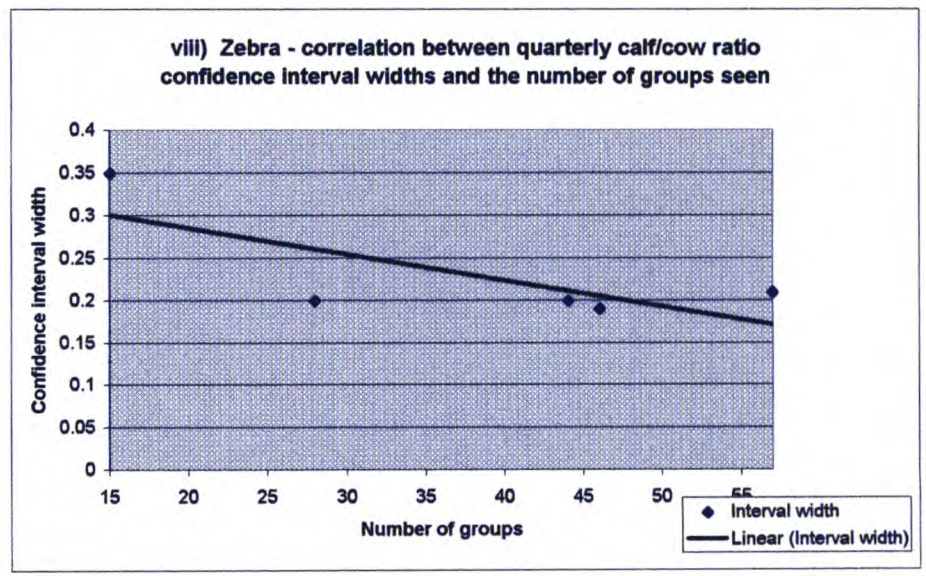

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APPENDIX C

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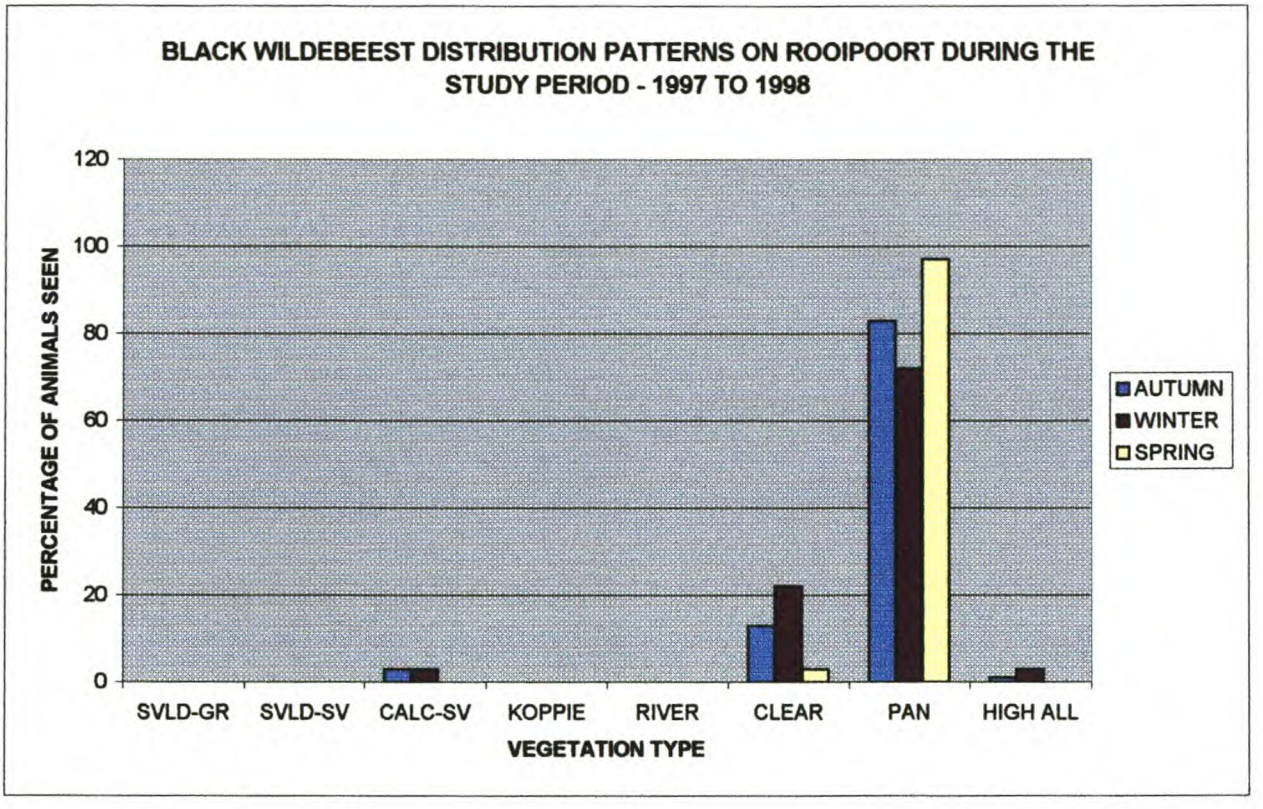
FIGURE 1 :



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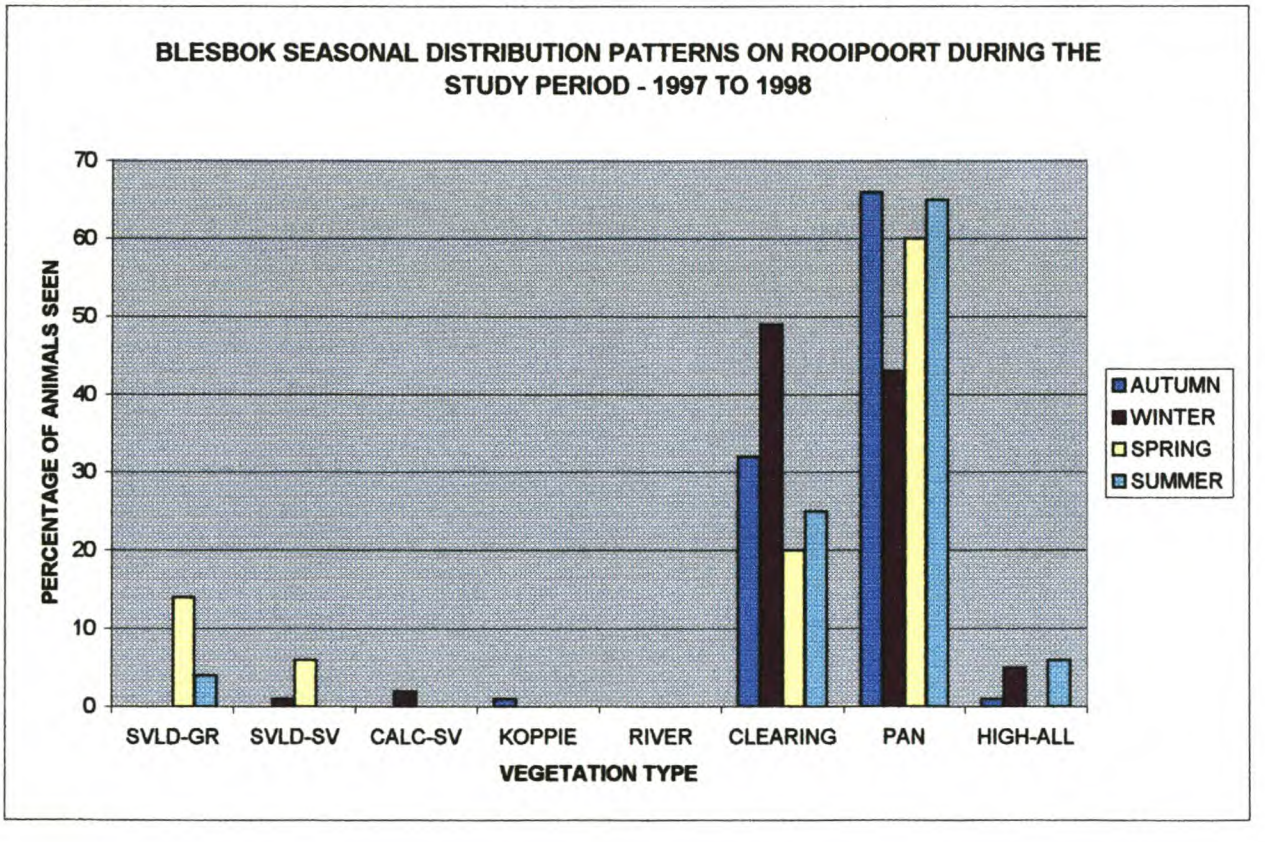

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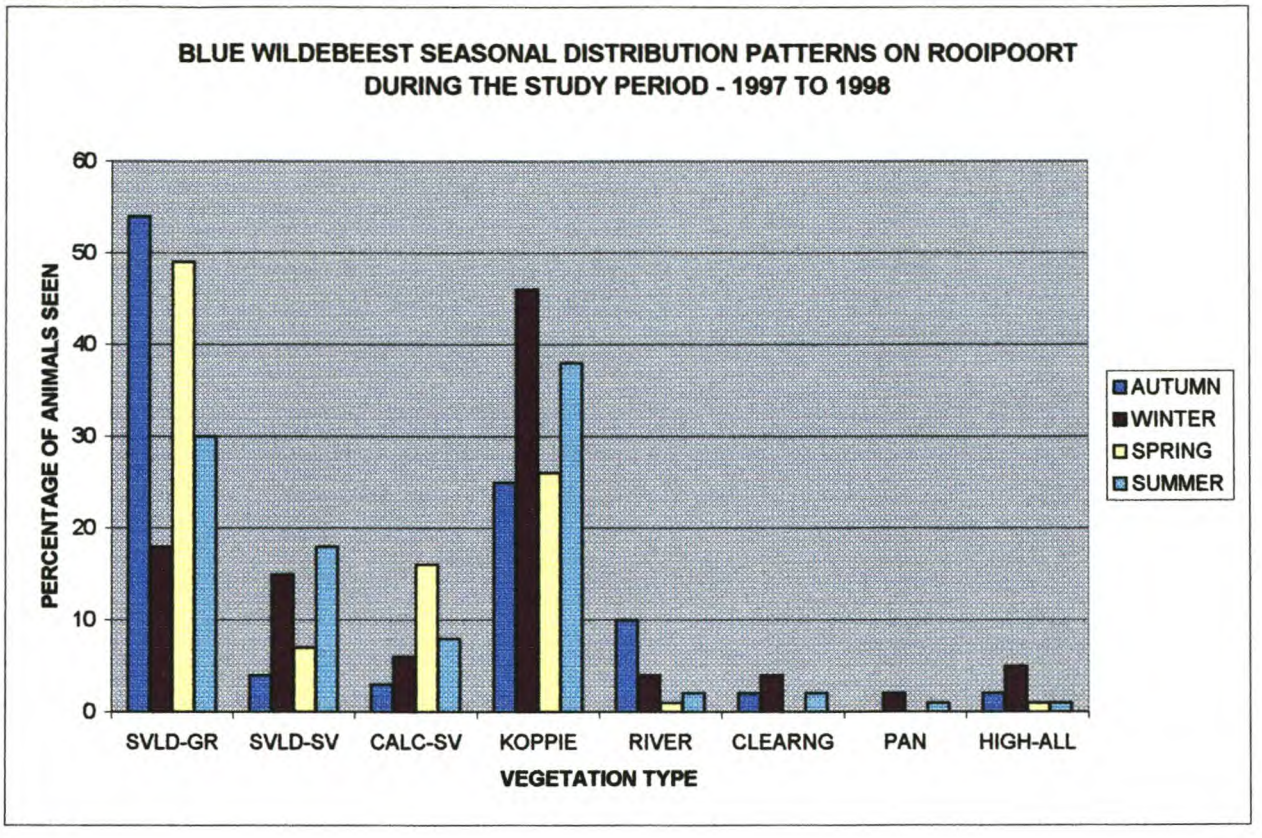

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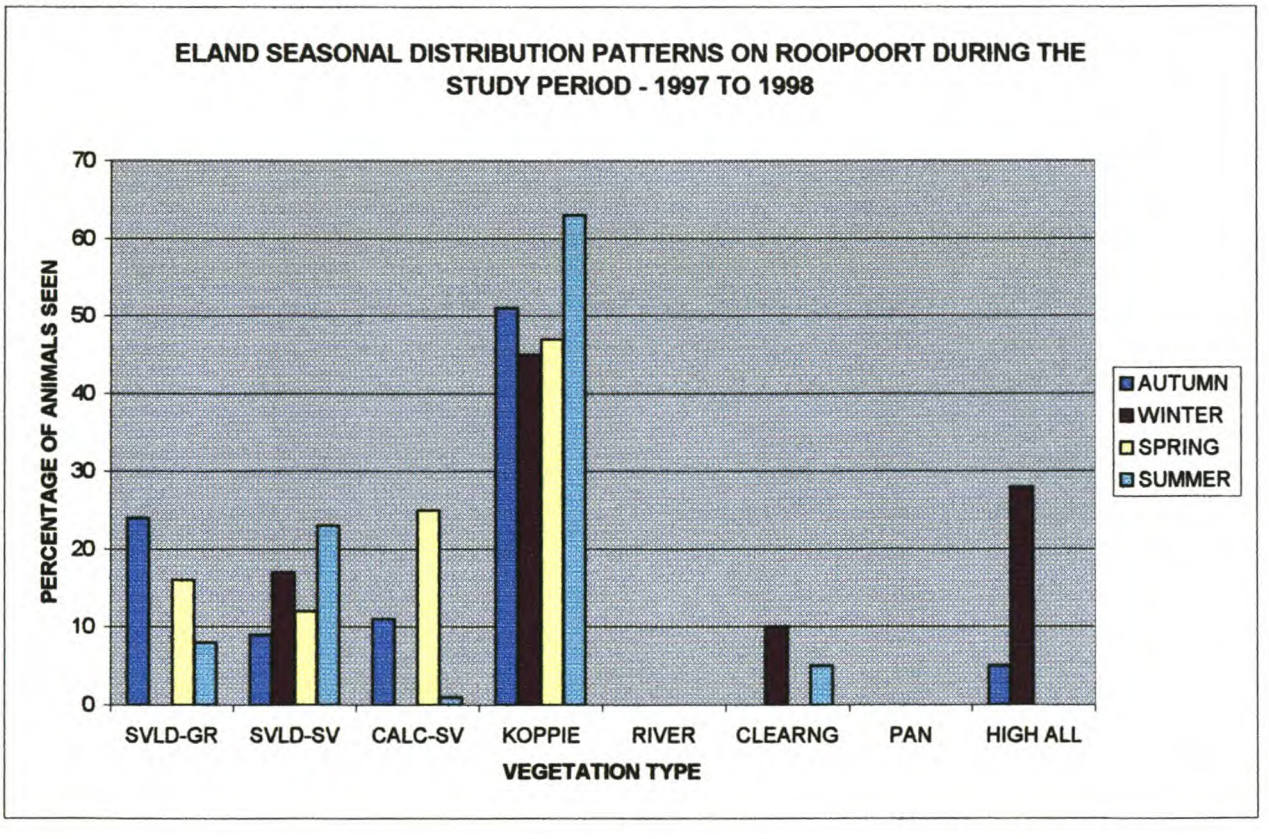

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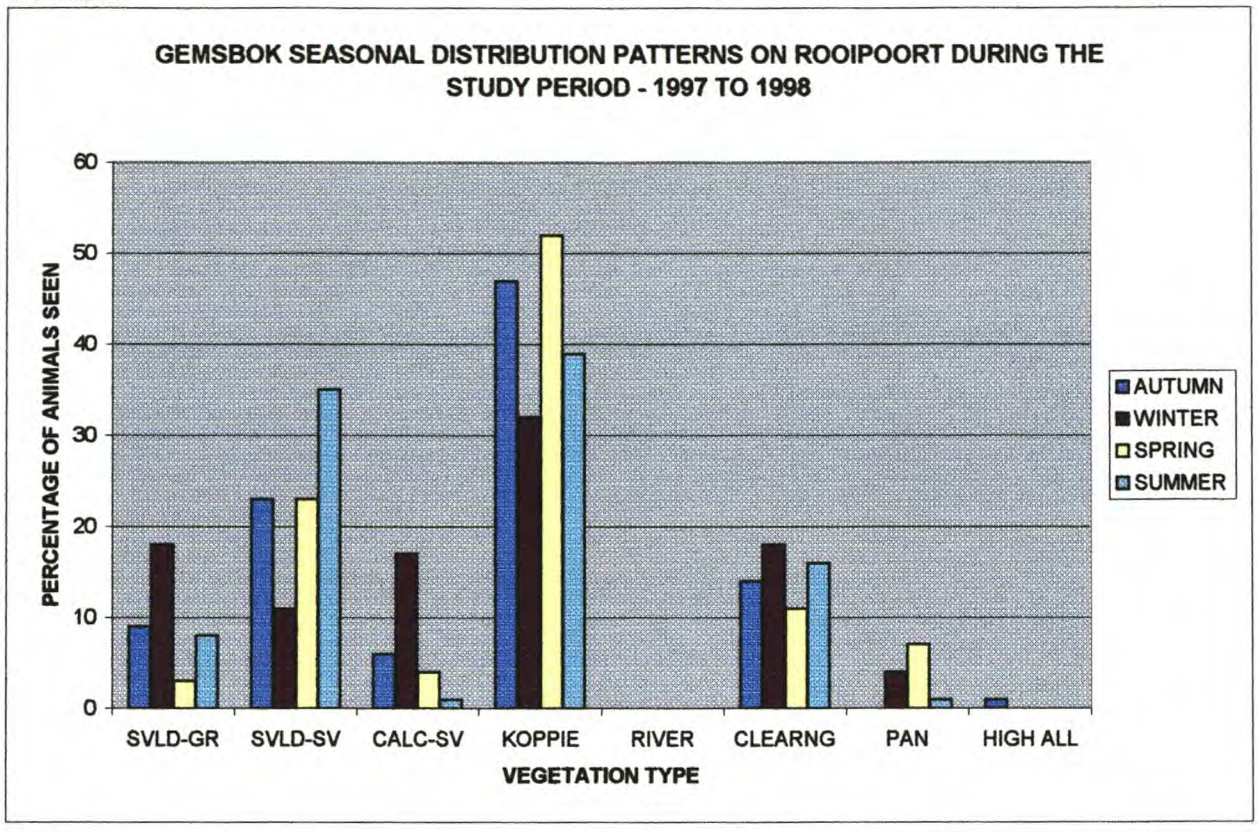

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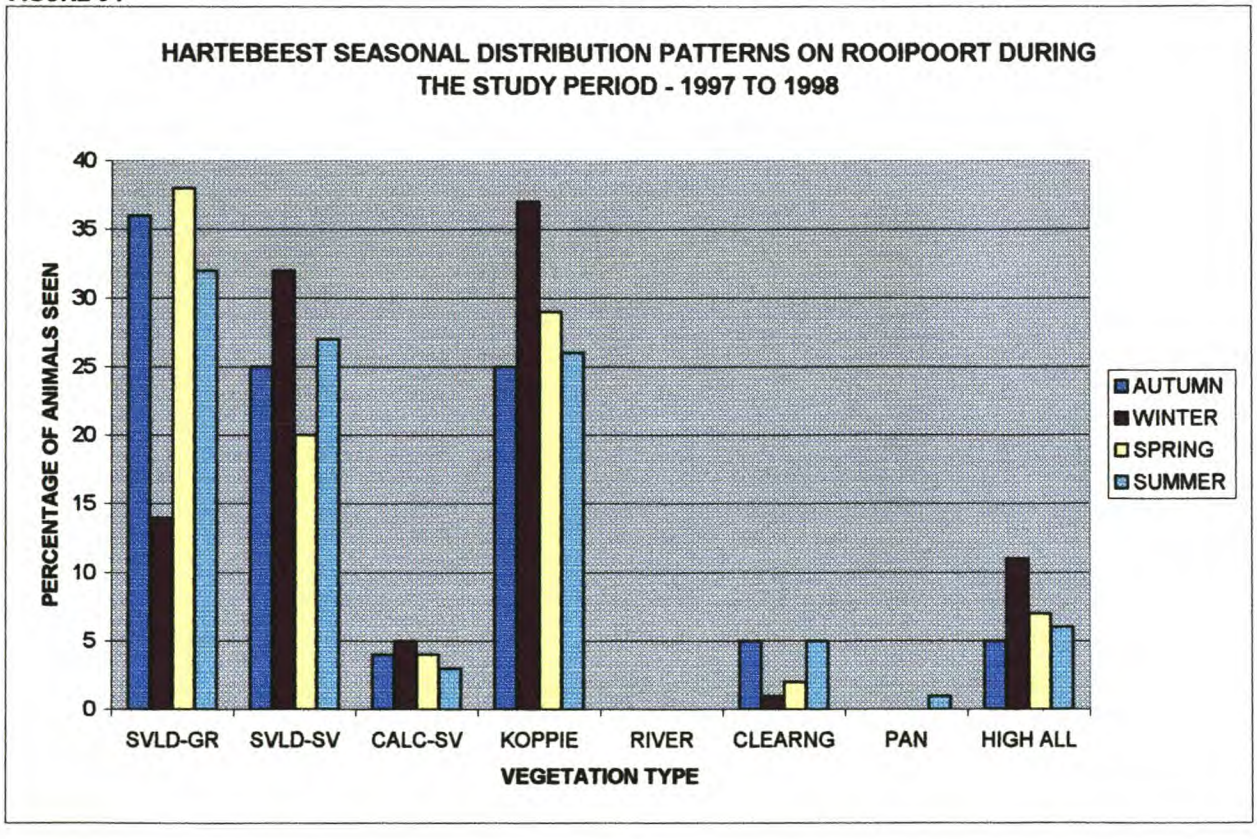

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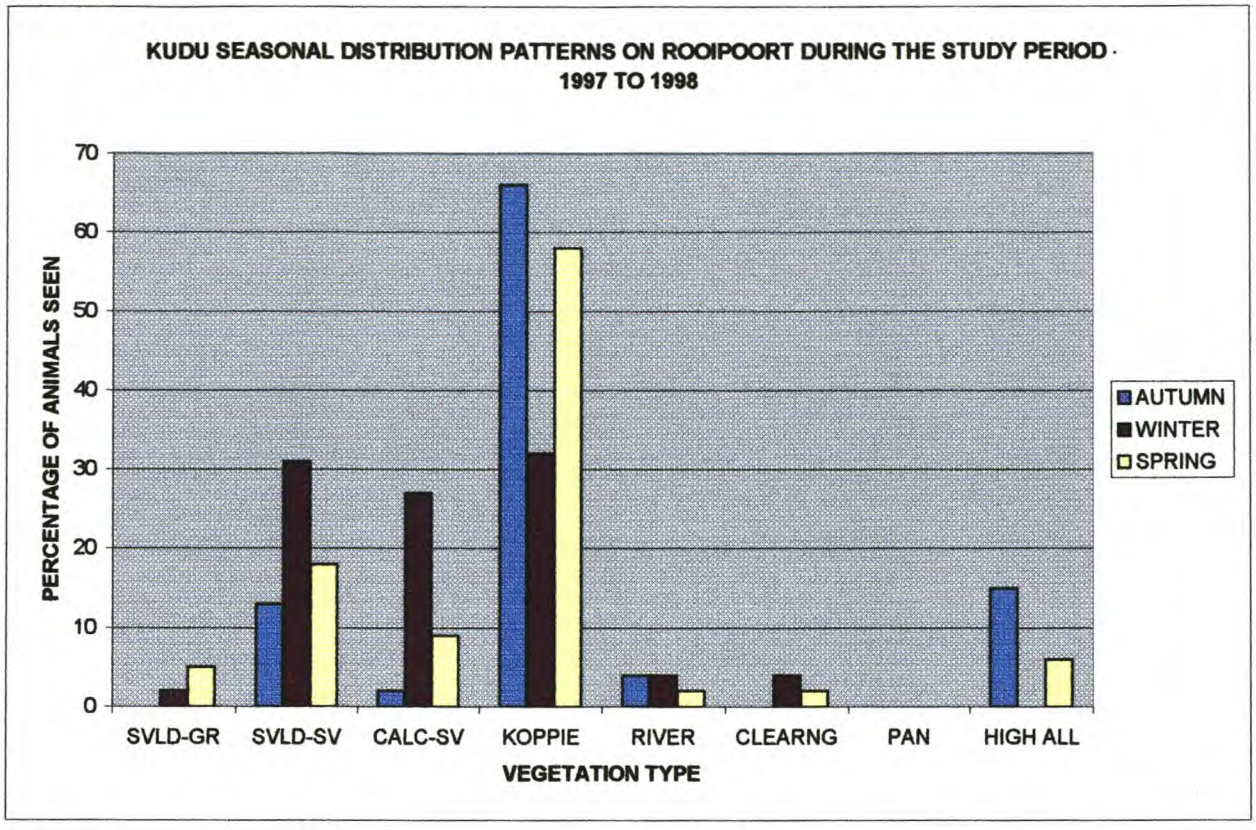

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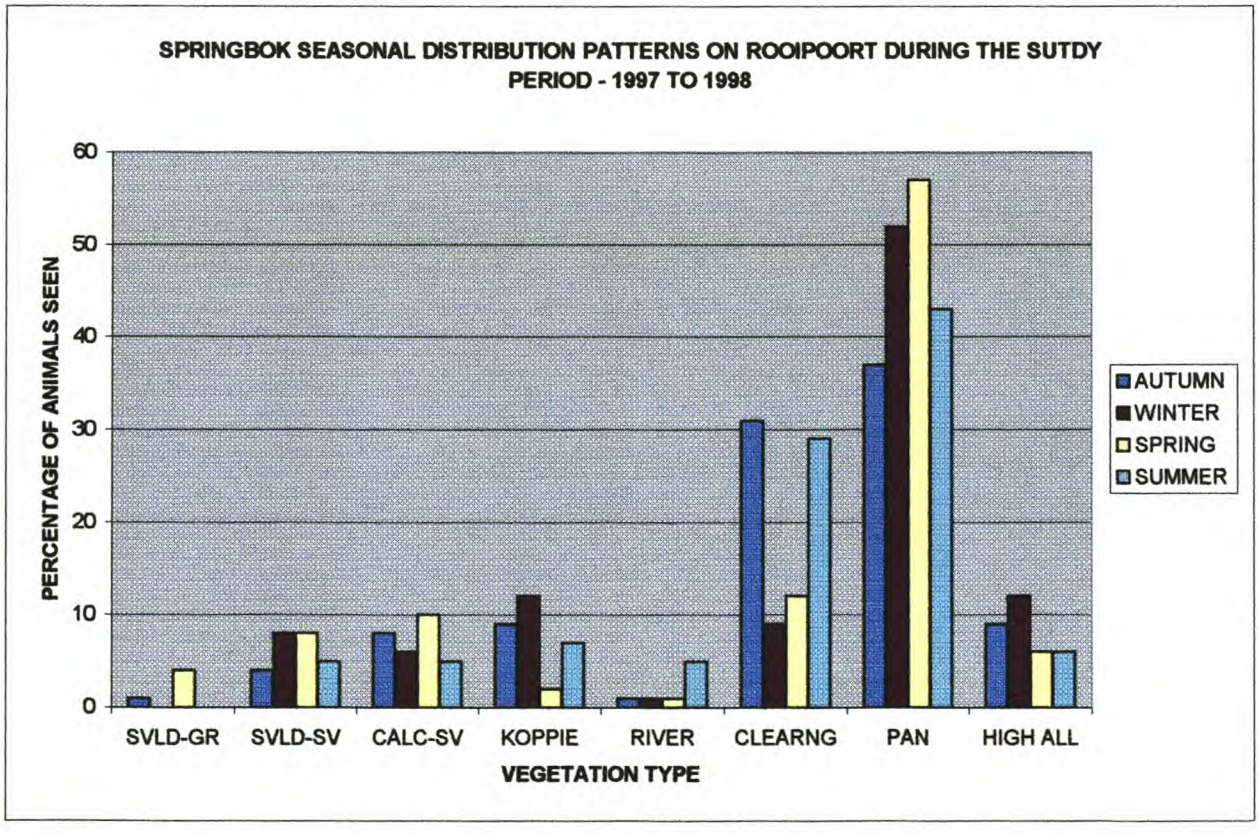

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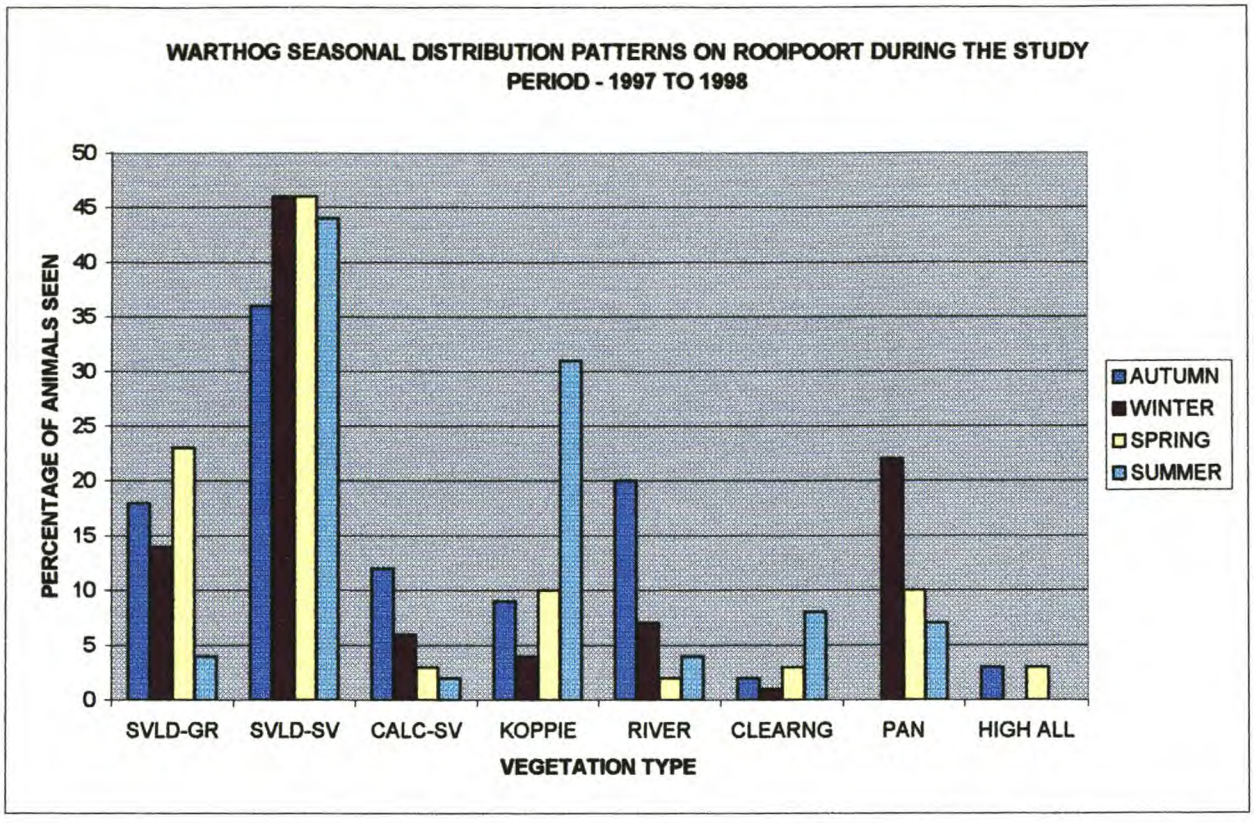

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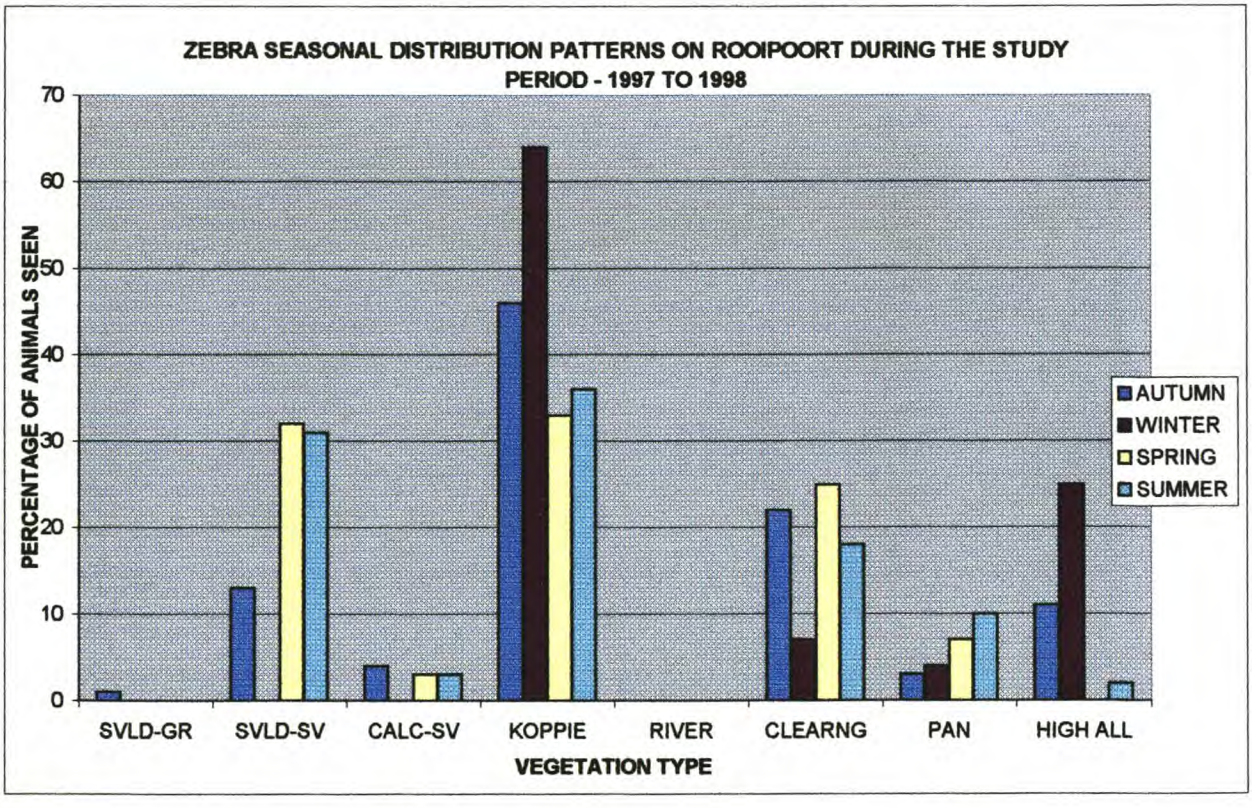

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Table 1A:

Species	Season	Correlation coefficient/Axis 1	Correlation coefficient/Axis 2	Correlation coefficient/Axis 3
Black wildebeest	winter	0.98	0.004	0.001
	spring	0.778	0.038	0.02
	summer	0.912	0.019	0.016
	autumn	0.919	0.019	0.009
Blesbok	winter	0.934	0	0.019
	spring	0.682	0.152	0.076
	summer	0.894	0.006	0.001
	autumn	0.847	0	0.005
Blue wildebeest	winter	0.852	0.031	0.042
	spring	0.455	0.379	0.052
	summer	0.883	0.073	0
	autumn	0.372	0.52	0.011
Eland	winter	0.193	0.4	0.217
	spring	0.415	0.011	0.115
	summer	0.541	0.243	0.009
	autumn	0.629	0	0.061
Gemsbok	winter	0.542	0.005	0.04
	spring	0.404	0.462	0.014
	summer	0.43	0.282	0.256
	autumn	0.616	0.283	0.013
Hartebeest	winter	0.642	0.083	0.033
	spring	0.697	0.141	0.001
	summer	0.722	0.05	0.063
	autumn	0.658	0.118	0.071
Kudu	winter	0.494	0.15	0.002
	spring	0.558	0.258	0.05
	summer	0.47	0.343	0.057
	autumn	0.334	0.208	0.129
Springbok	winter	0.431	0.021	0.137
	spring	0.798	0.017	0.006
	summer	0.798	0.017	0.006
	autumn	0.458	0.078	0.126
Warthog	winter	0.109	0.023	0.501
	spring	0.291	0.008	0.475
	summer	0.313	0.16	0.4
	autumn	0.153	0.061	0.021
Zebra	winter	0.11	0.255	0.355
	spring	0.11	0.512	0.222
	summer	0.197	0.591	0.188
	autumn	0.207	0.573	0.16

Table 1B:

Vegetation type	Correlation coefficient/Axis 1	Correlation coefficient/Axis 2	Correlation coefficient/Axis 3
SGR - sandveld grassland	0.461	0.507	0
SSV - Tarchonanthus sandveld	0.48	0.105	0.346
CSV - Tarchonanthus calcrete	0.052	0	0.226
KPV - Koppieveld	0.701	0.162	0.028
RIV - riverine	0.128	0.187	0.002
CLR - clearings in calcrete	0.342	0.115	0.001
PAN - Hoffman's Pan	0.958	0.015	0.003
ALL - High-lying alluvail area	0	0.107	0.357

FIGURE 11:

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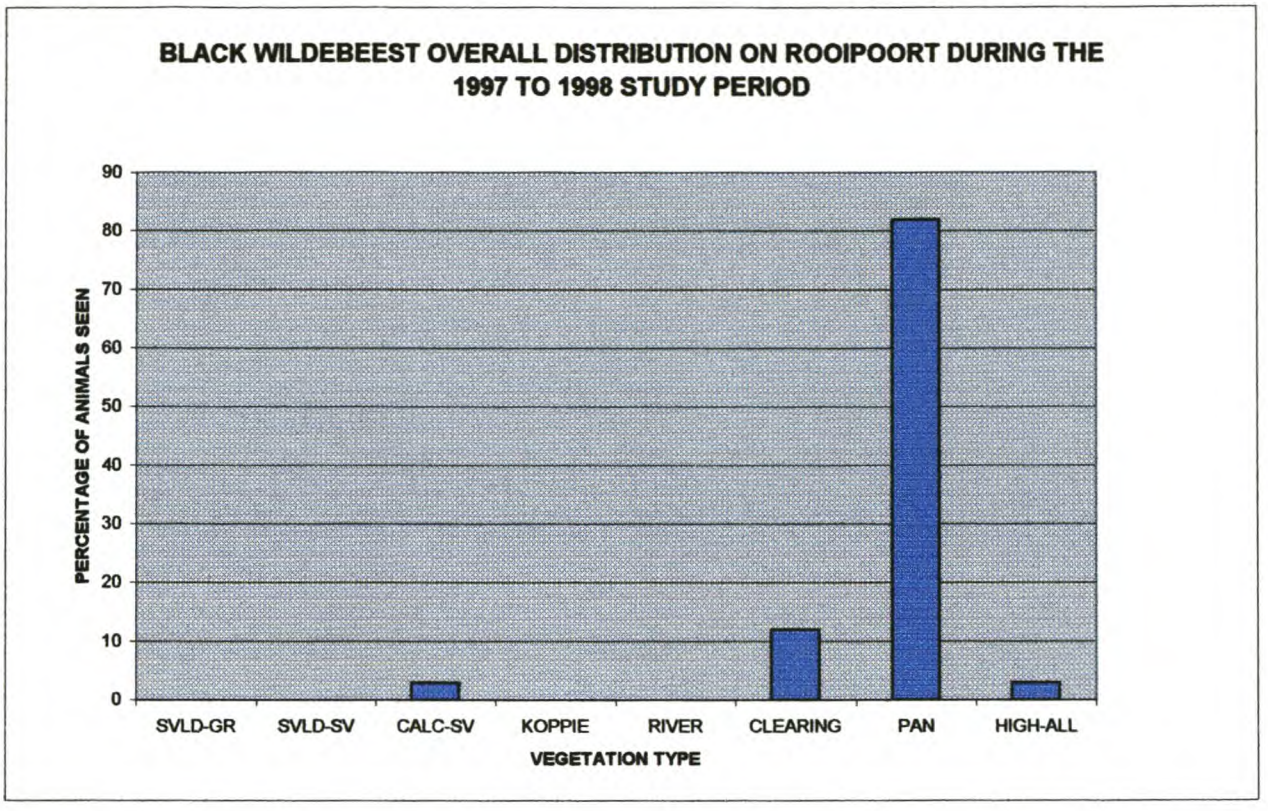

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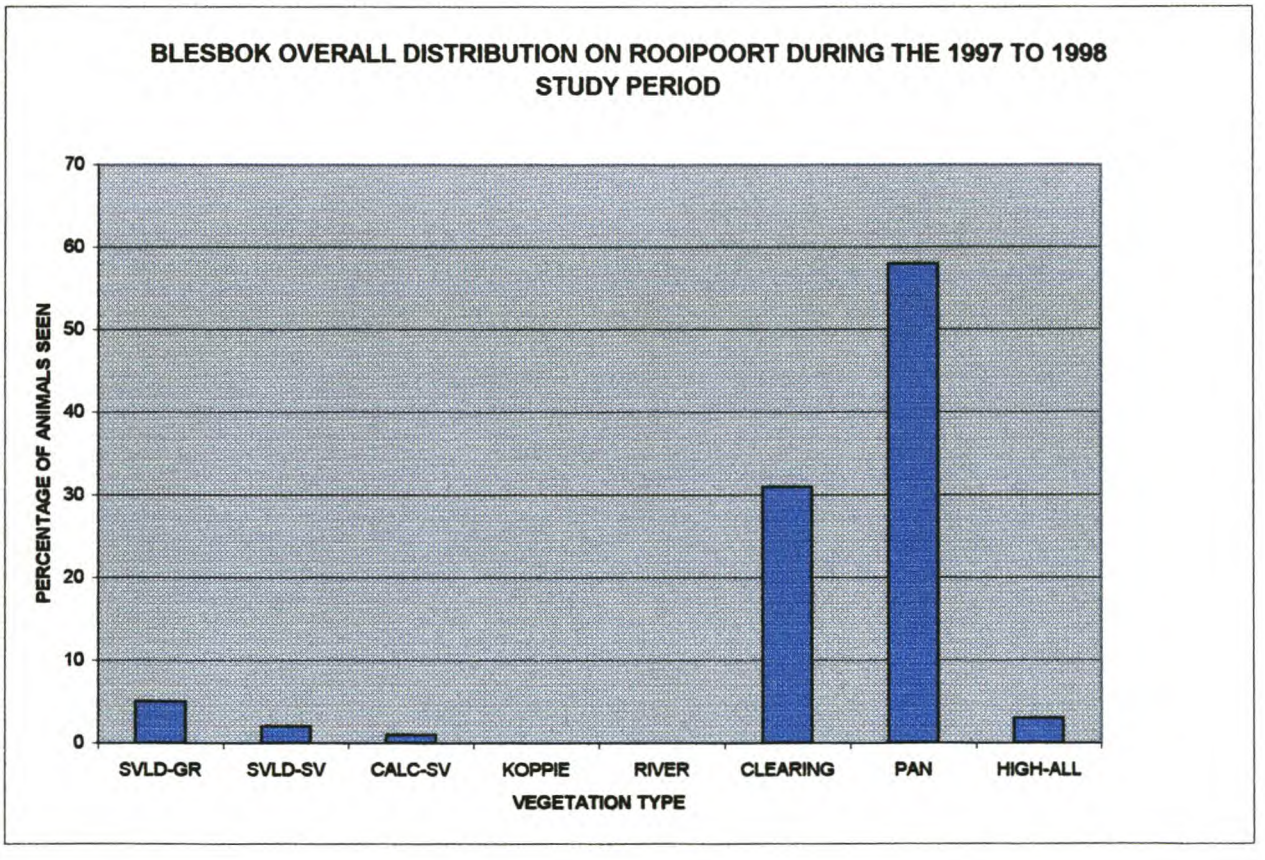

FIGURE 13:

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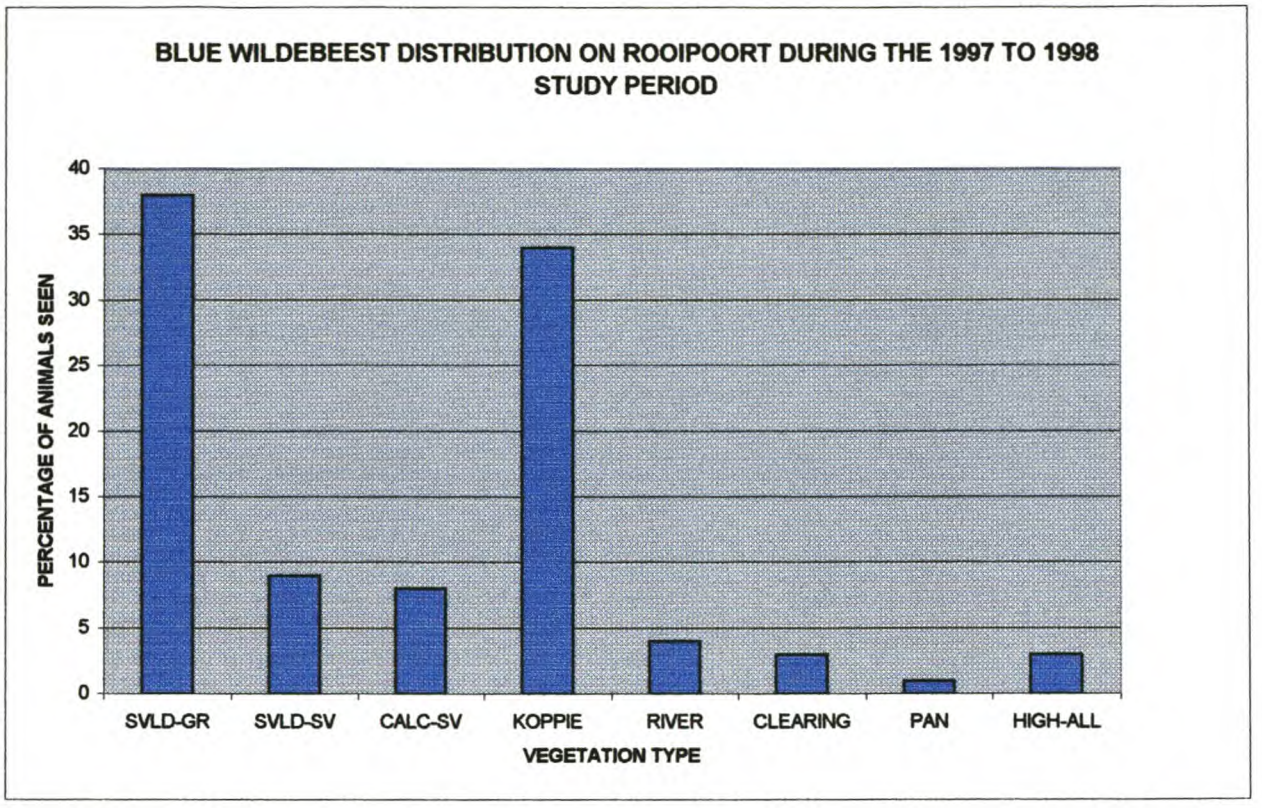

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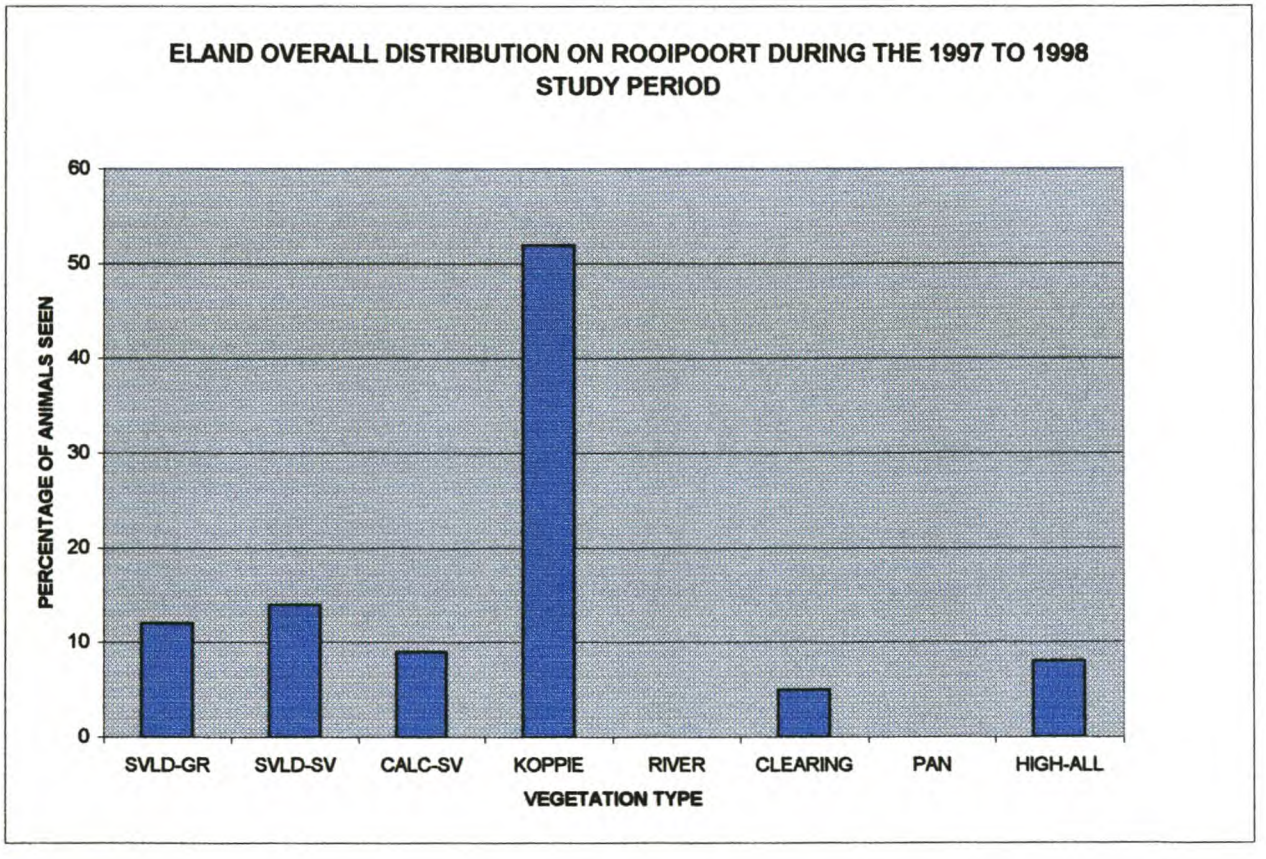

FIGURE 15:

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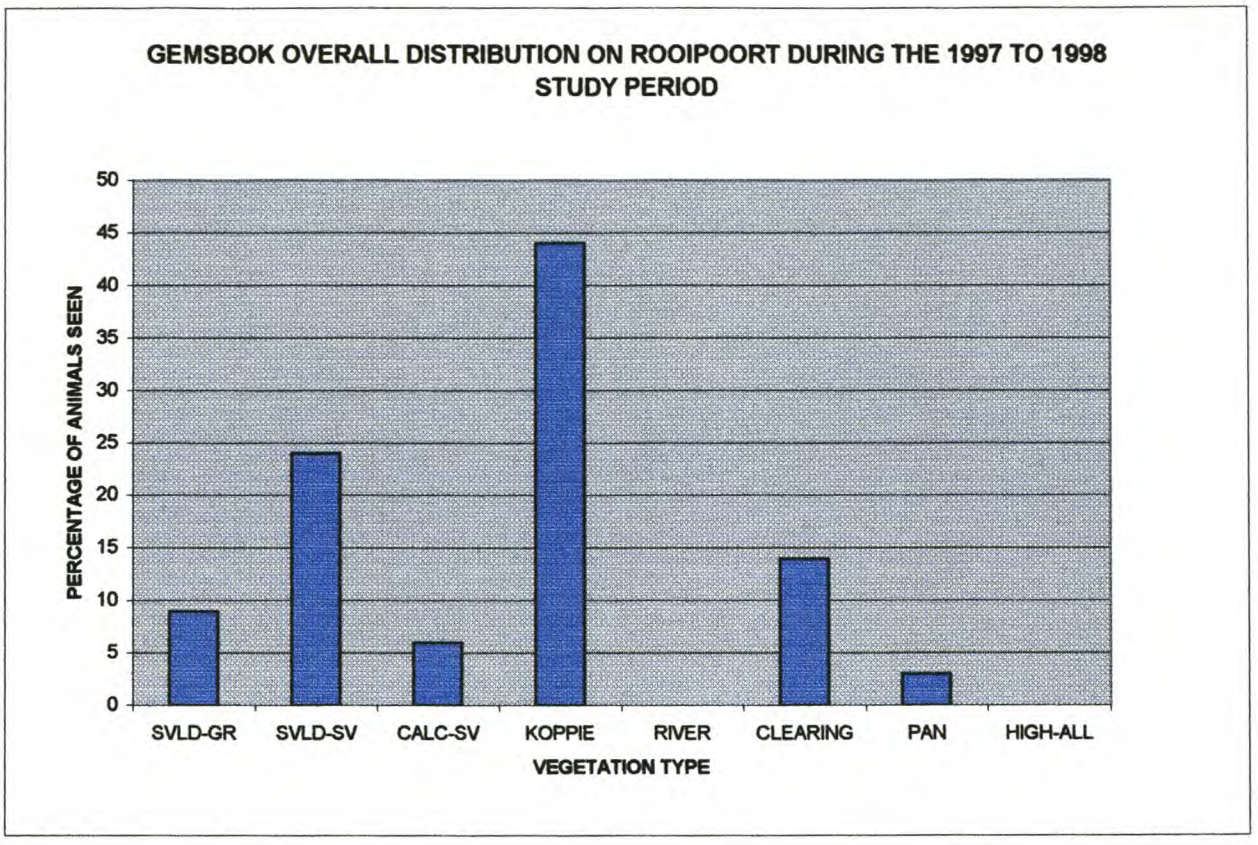

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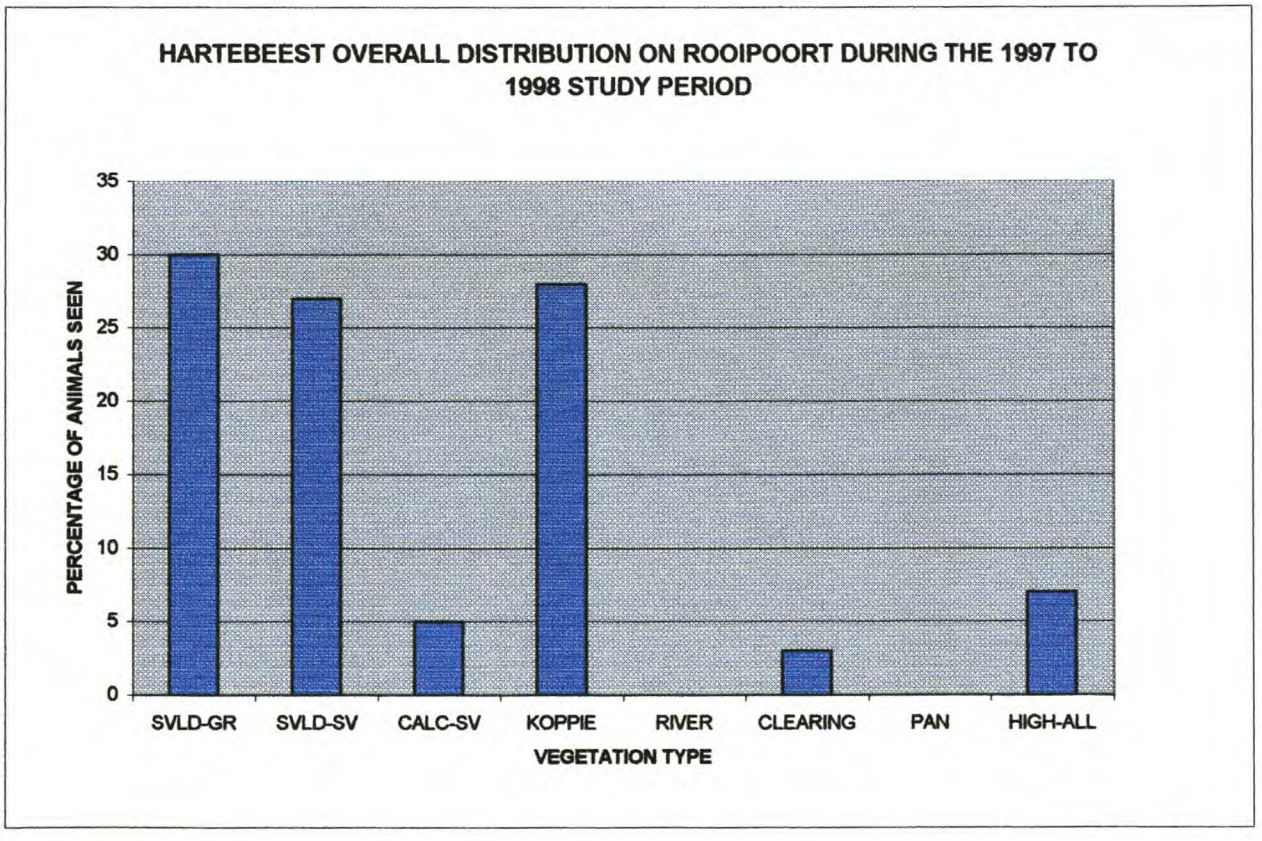

FIGURE 17 :

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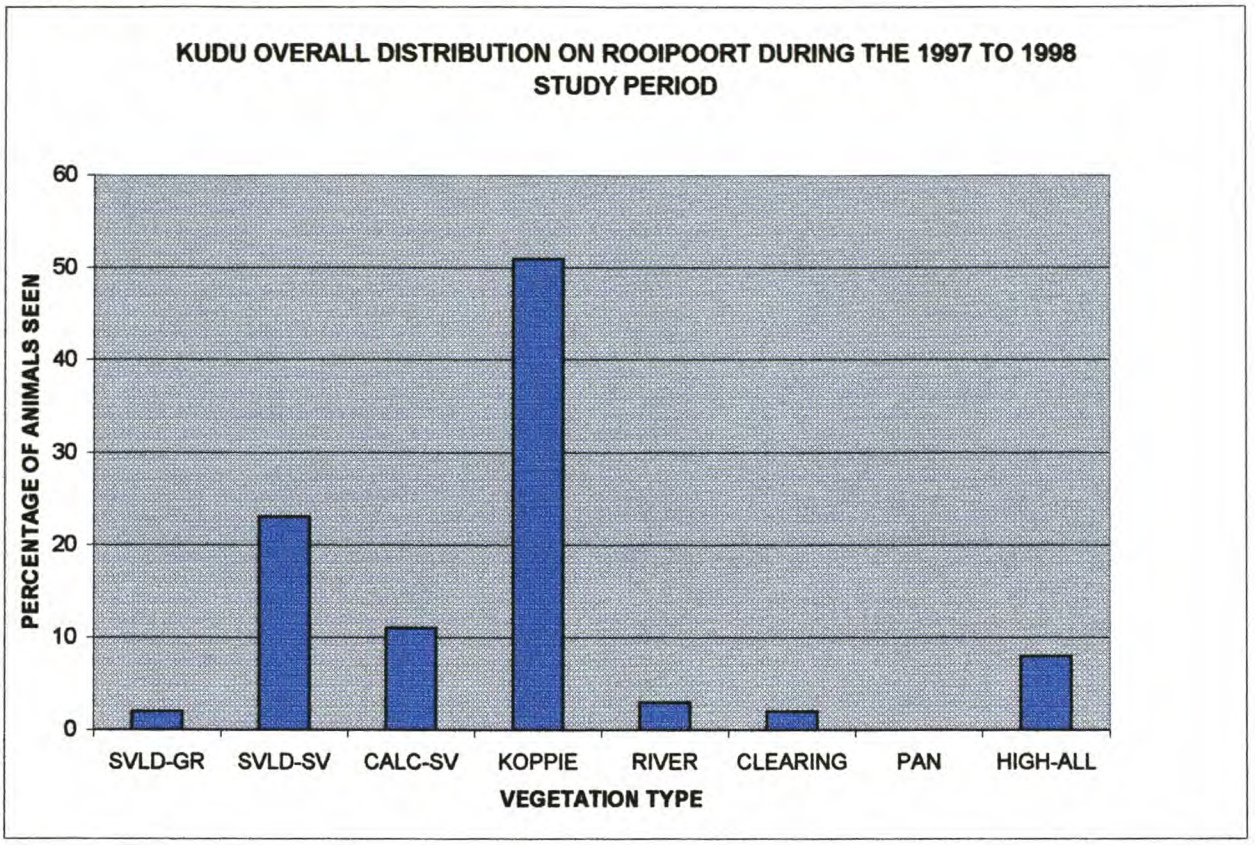

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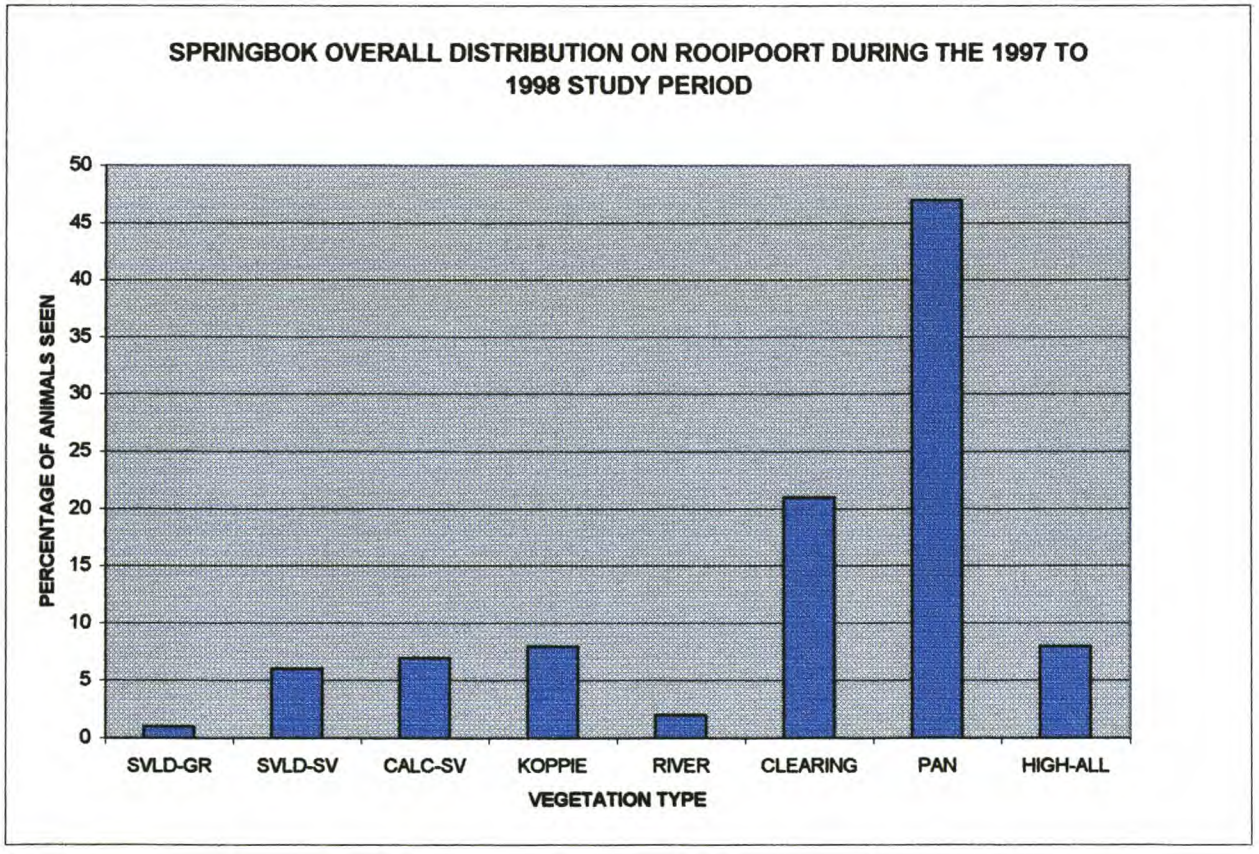

FIGURE 19:

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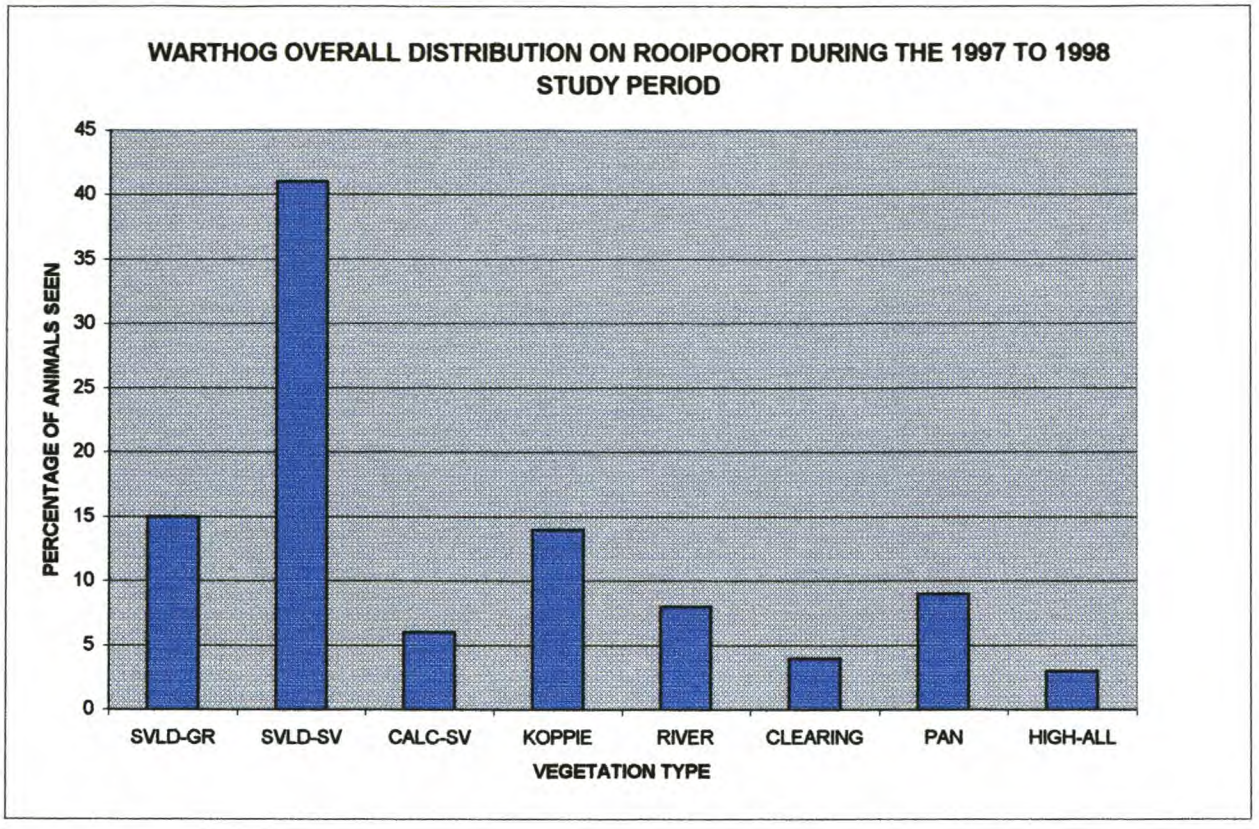

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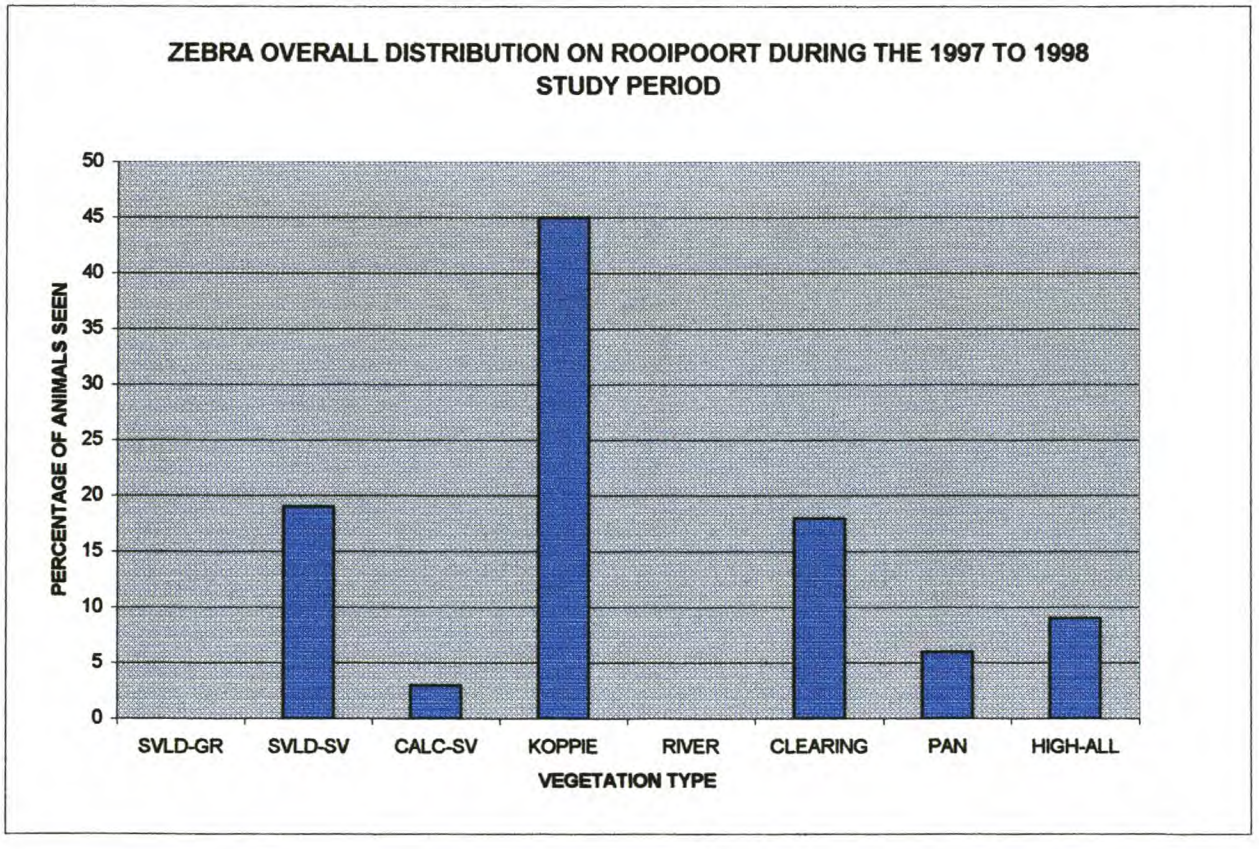

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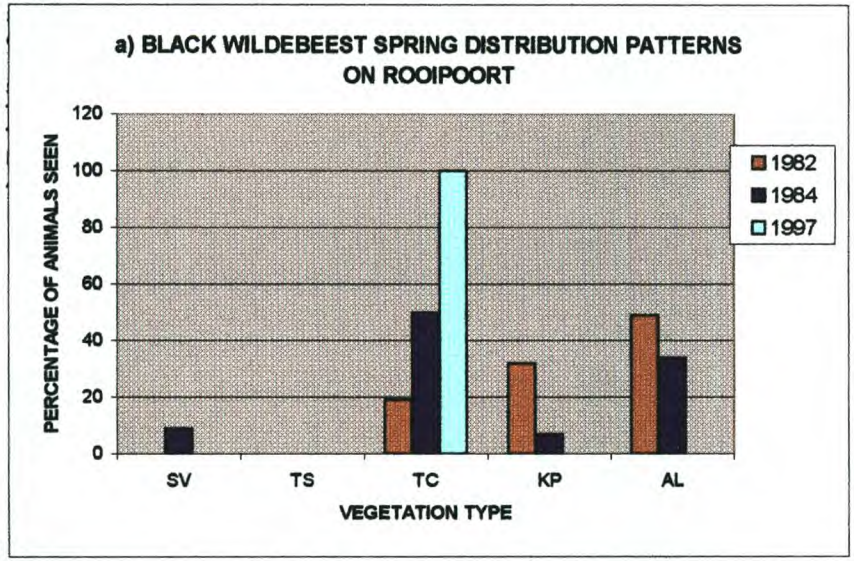
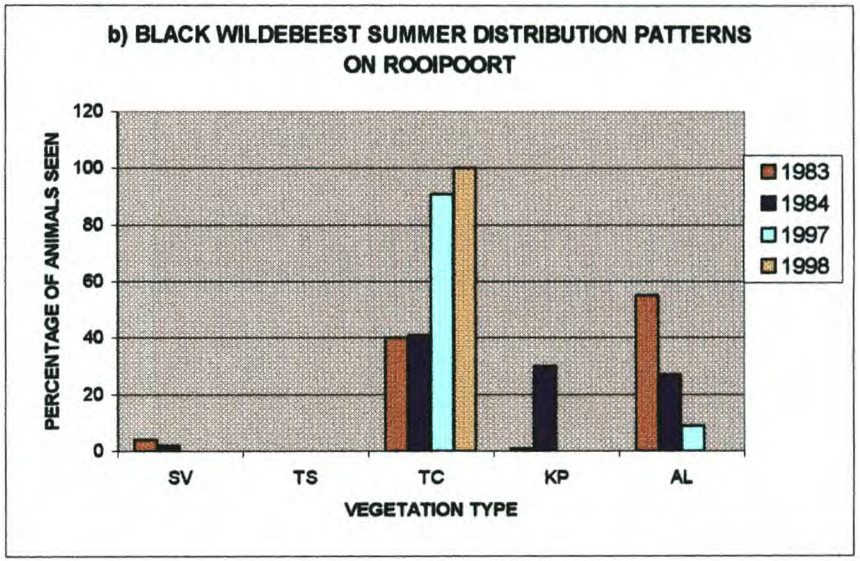
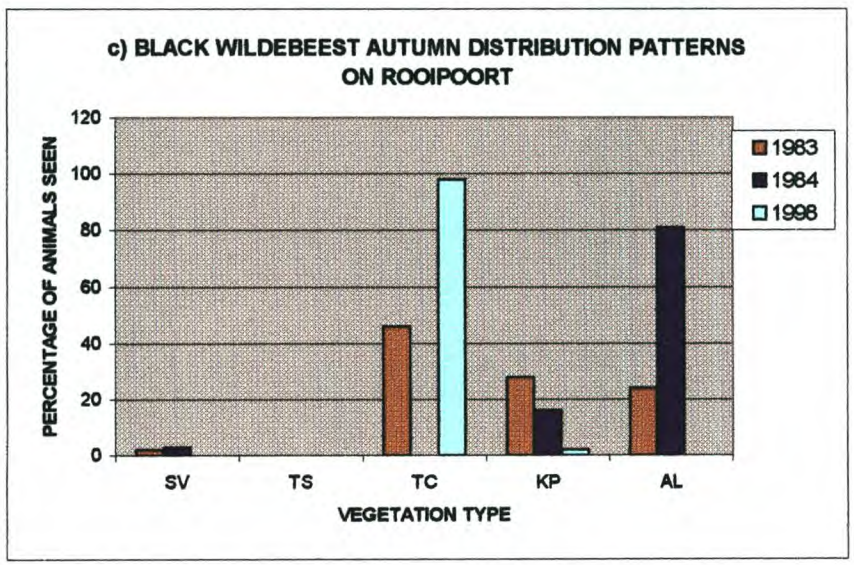
FIGURE 21: BLACK WILDEBEEST DISTRIBUTION PATTERNS:







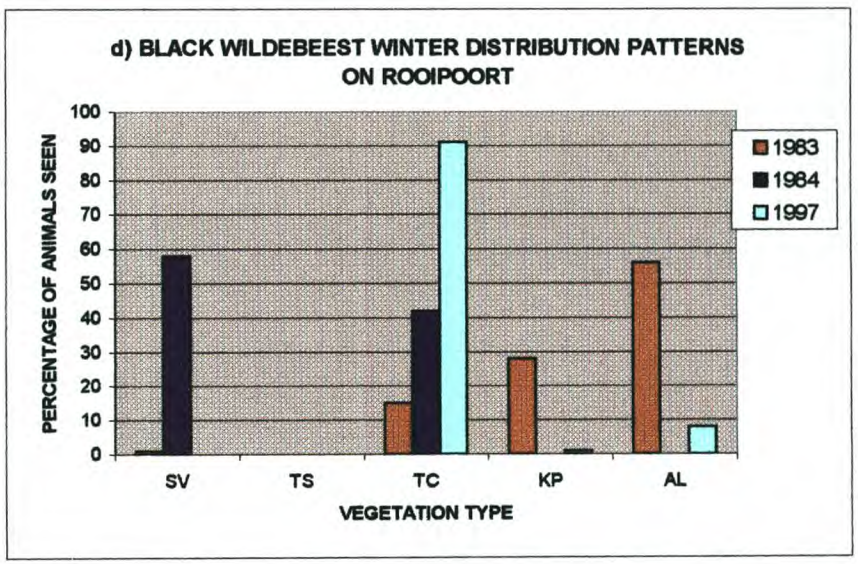


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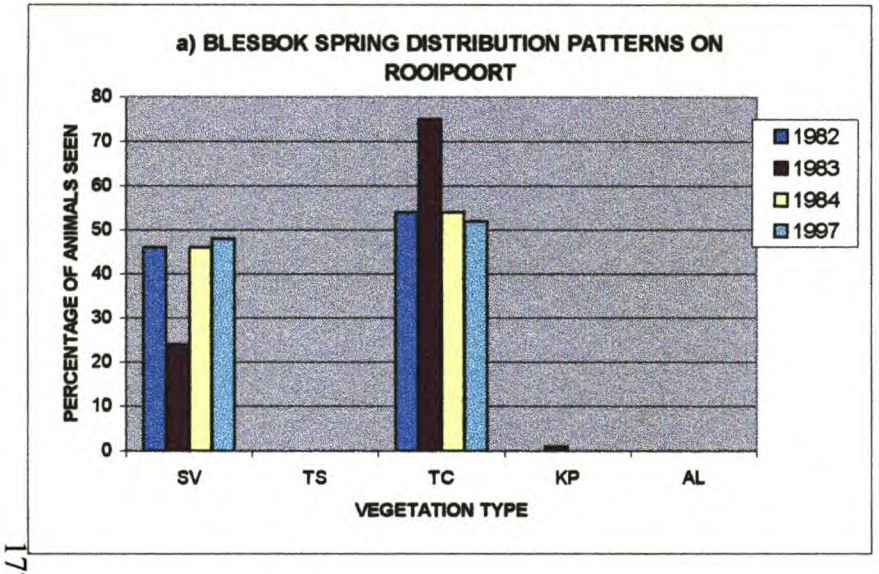
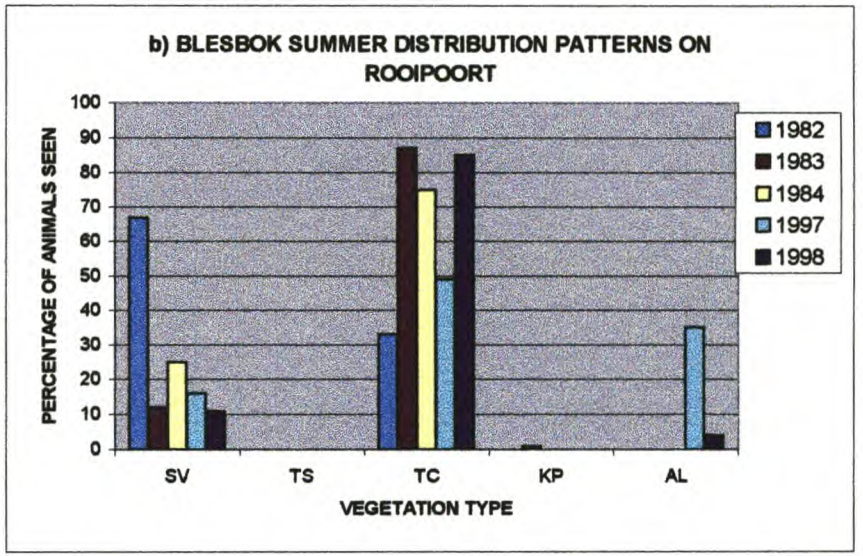
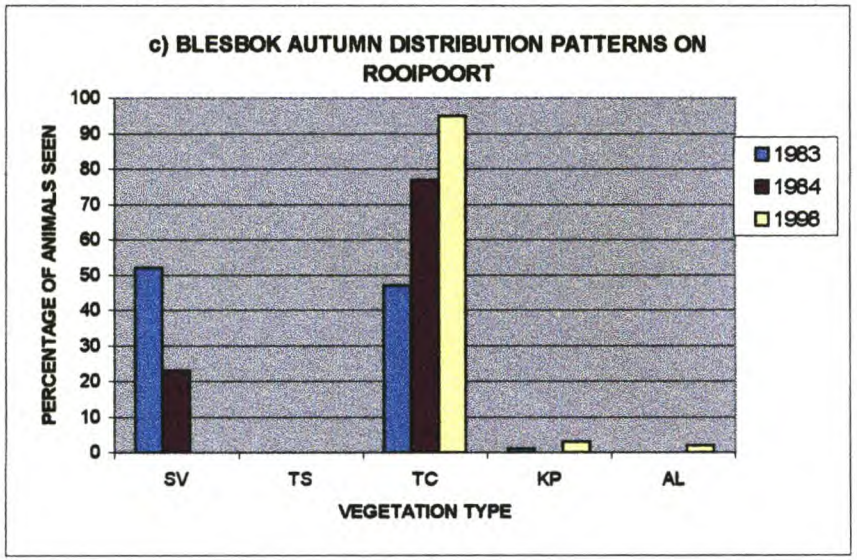
FIGURE 22 : BLESBOK DISTRIBUTION PATTERNS ON ROOIPOORT







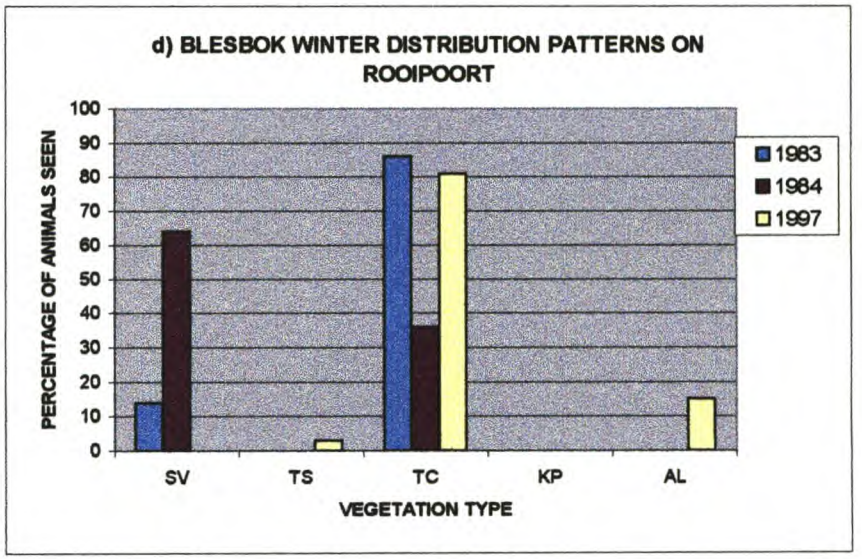


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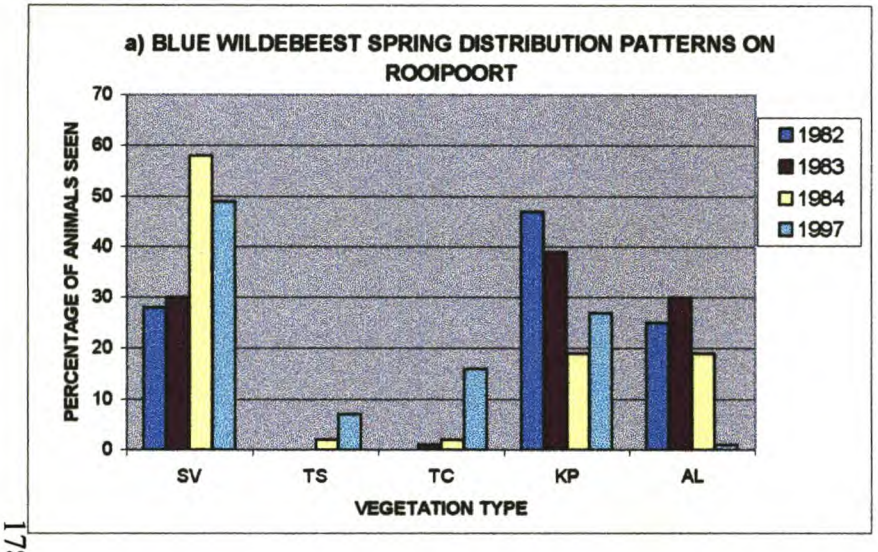
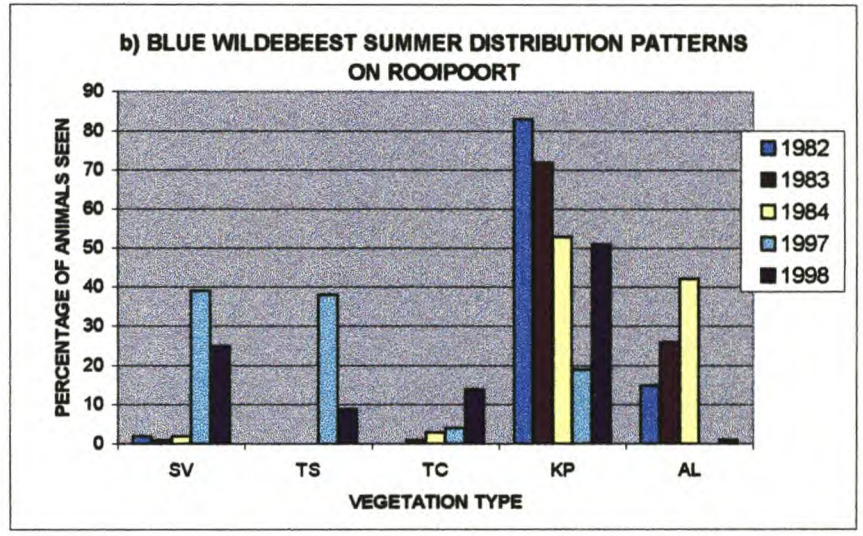
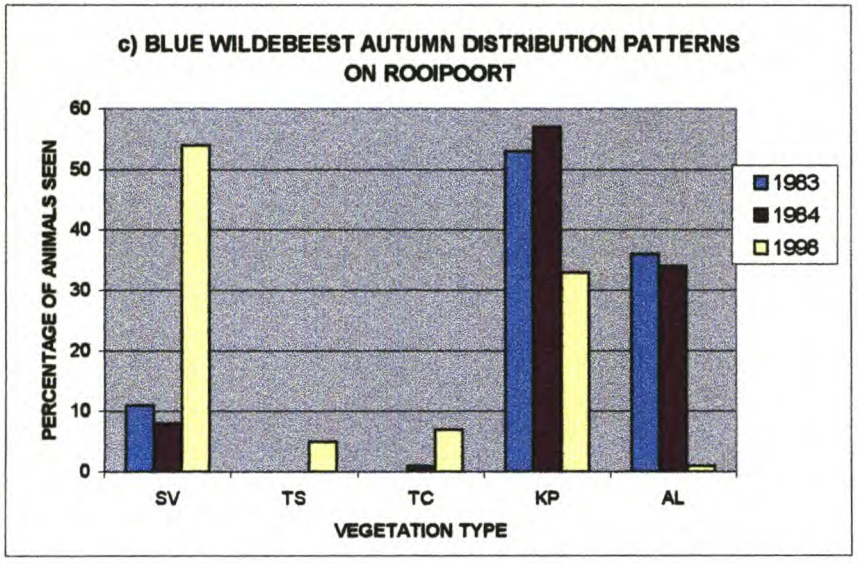
FIGURE 23 : BLUE WILDEBEEST DISTRIBUTION PATTERNS ON ROOIPOORT:







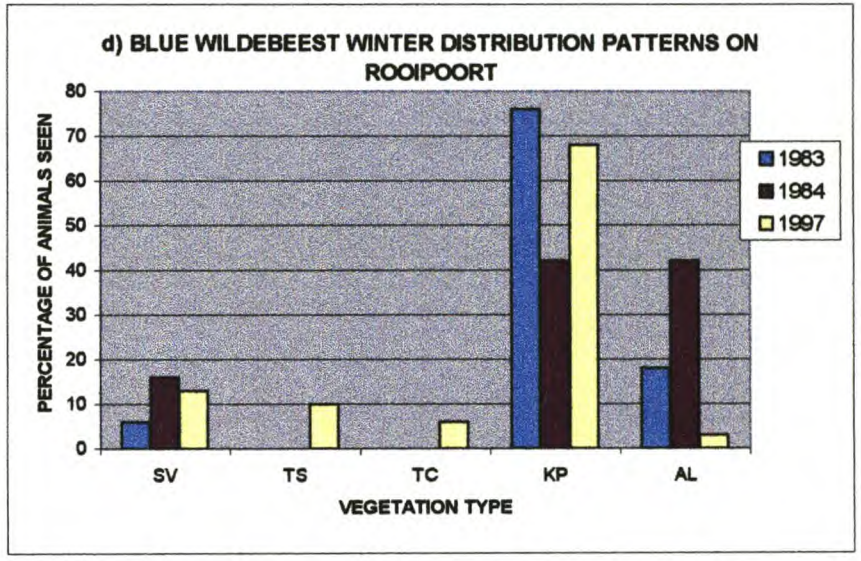


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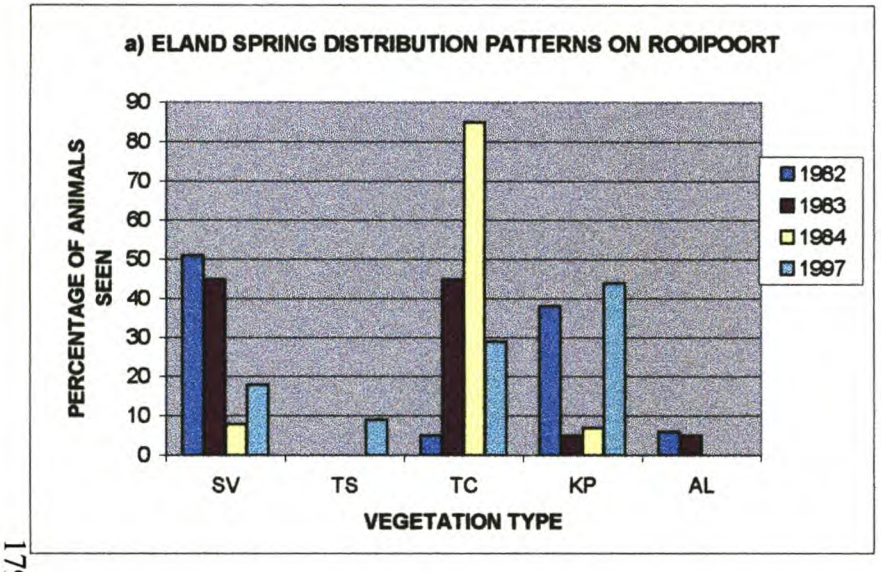
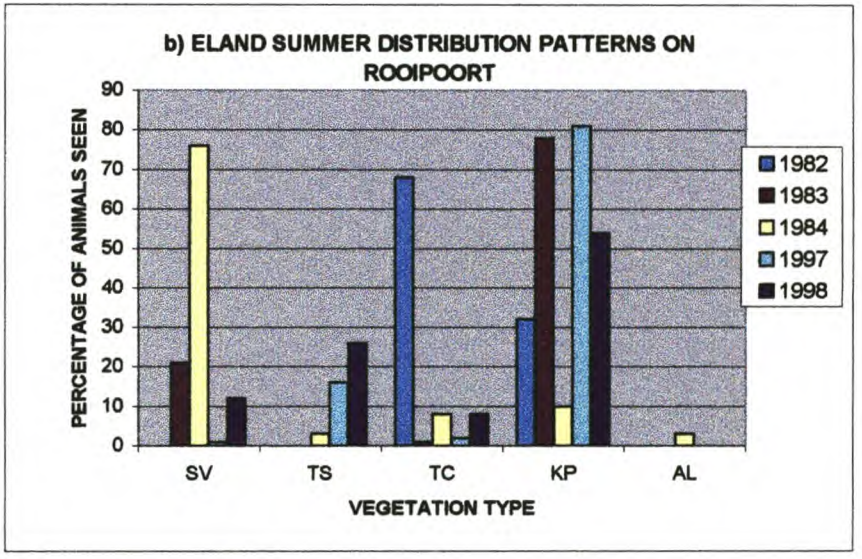
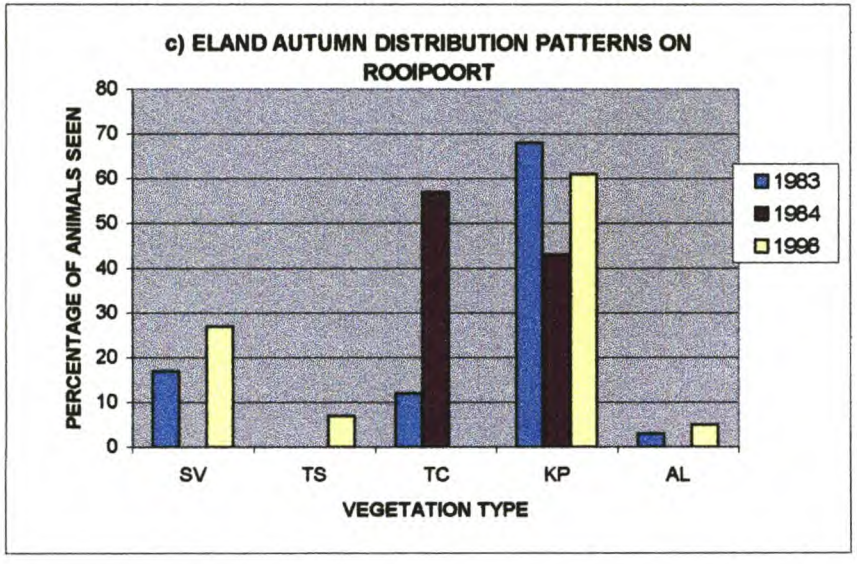
FIGURE 24 : ELAND DISTRIBUTION PATTERNS ON ROOIPOORT:







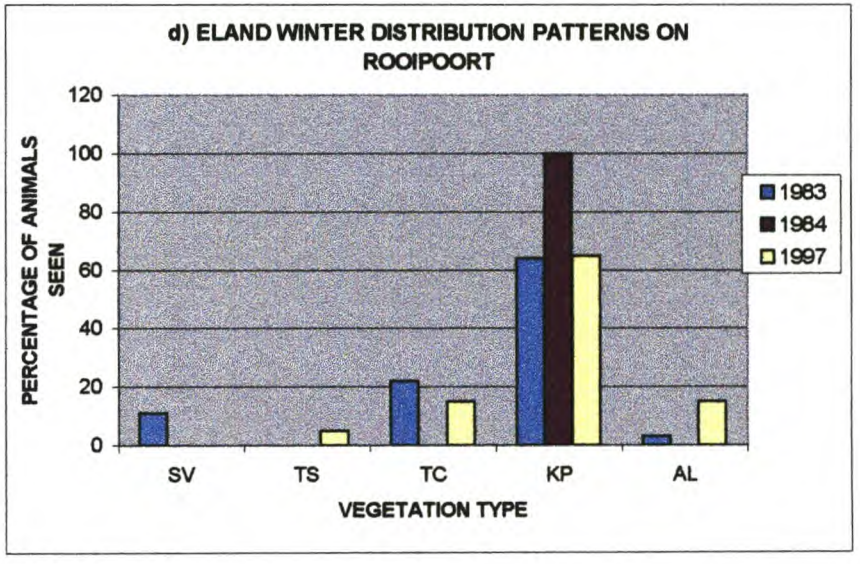


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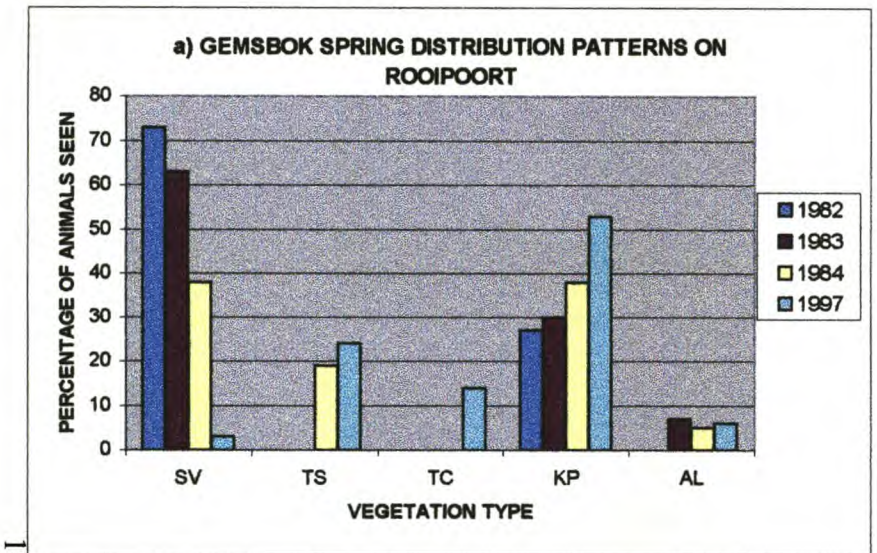
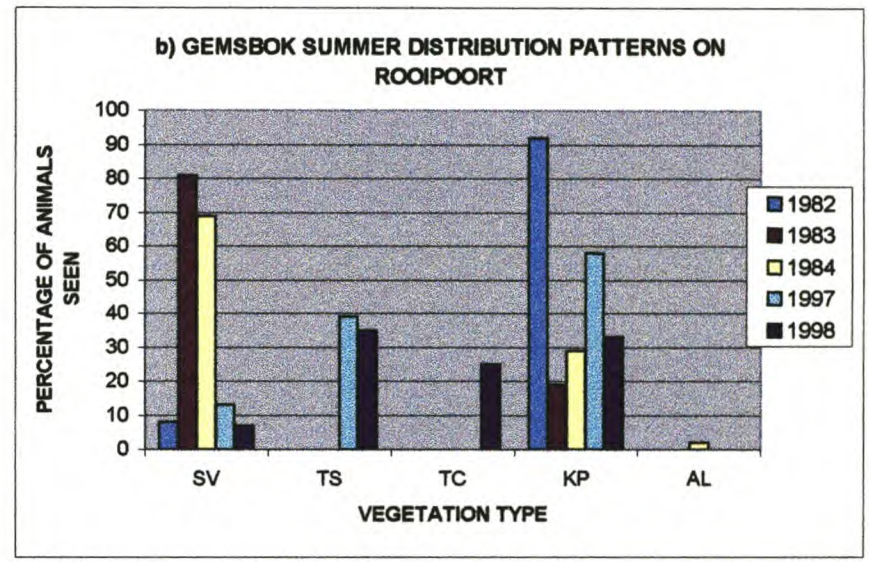
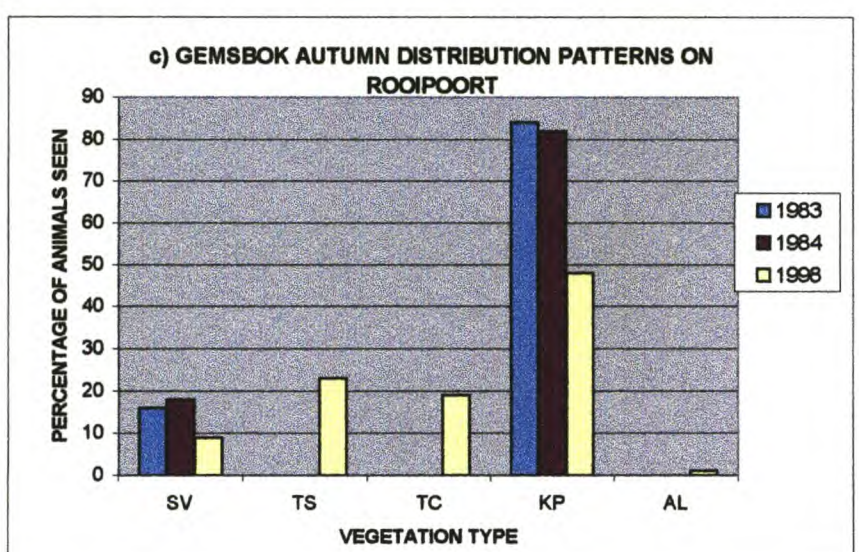
FIGURE 25 : GEMSBOK DISSTRIBUTION PATTERNS







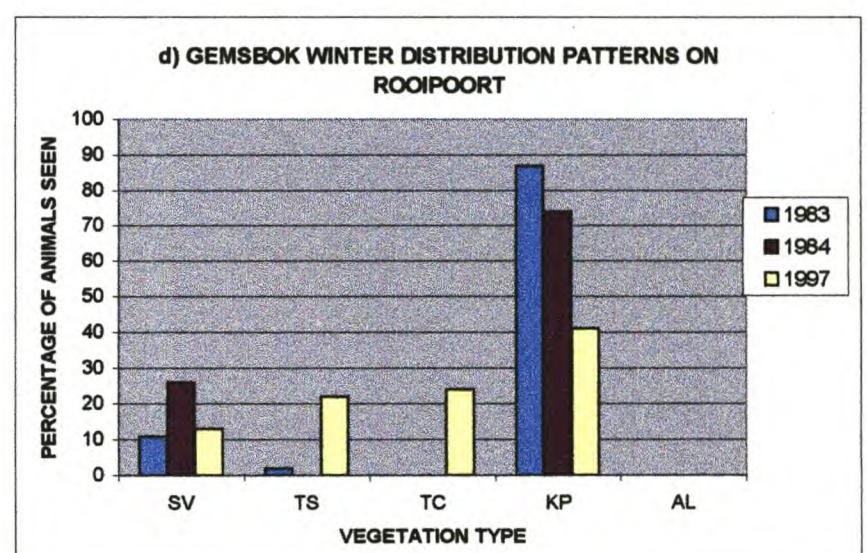


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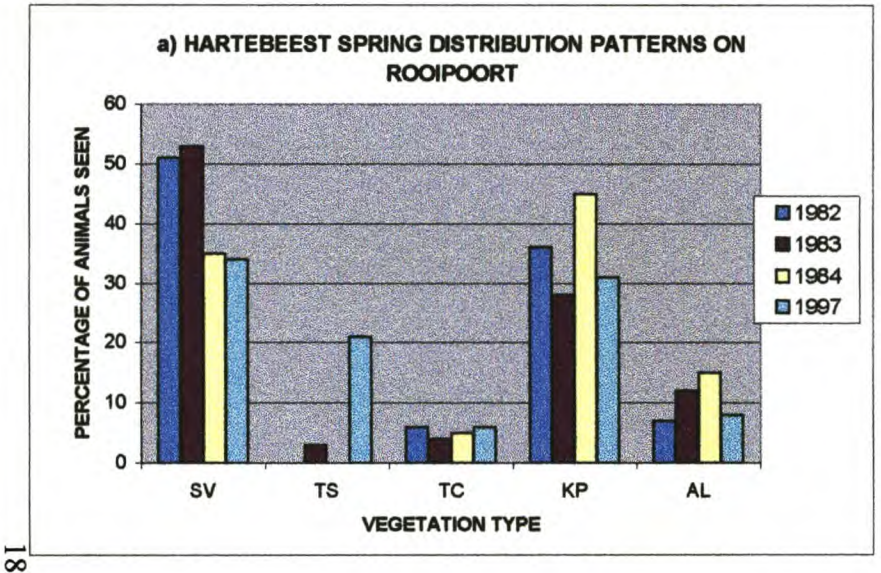
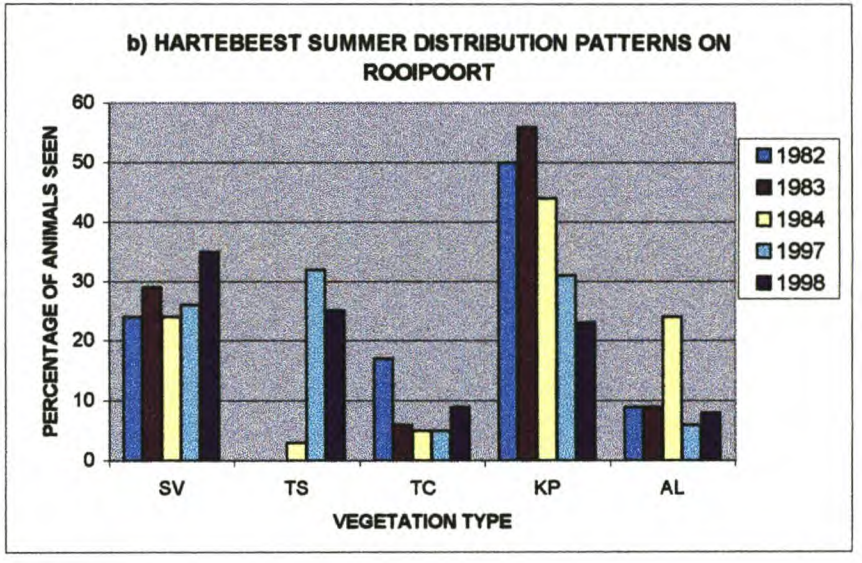
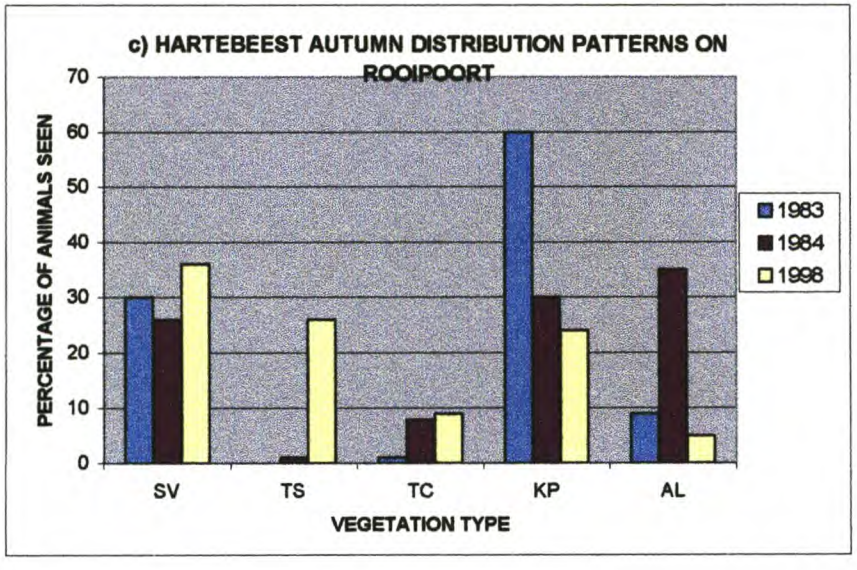
FIGURE 26 : HARTEBEEST DISTRIBUTION PATTERNS ON ROOIPOORT:







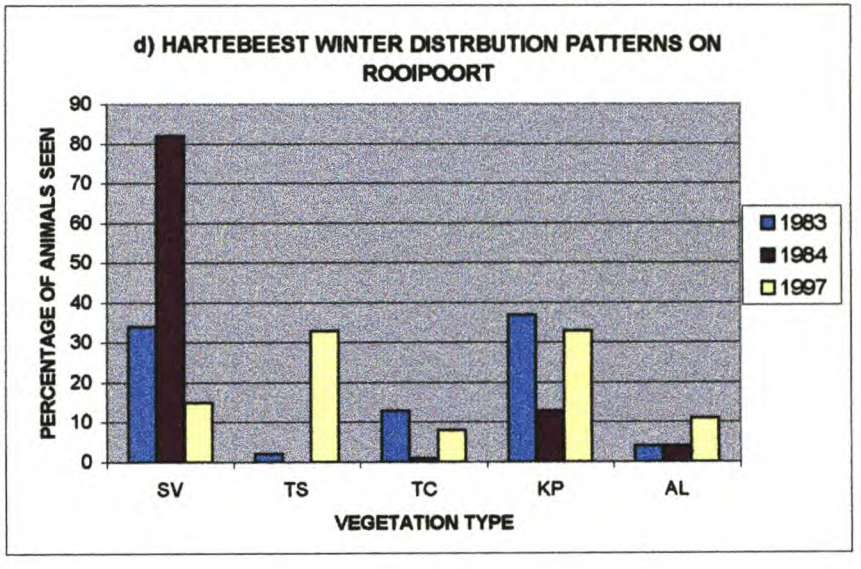


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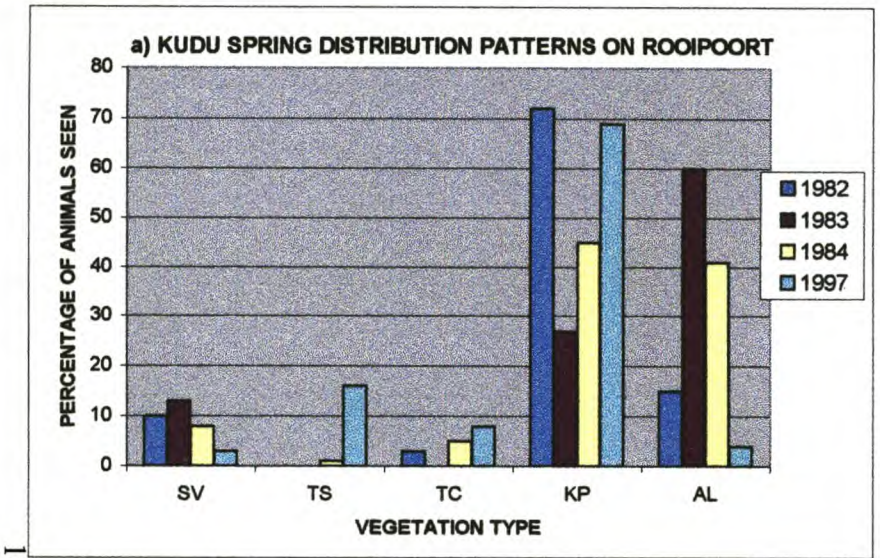
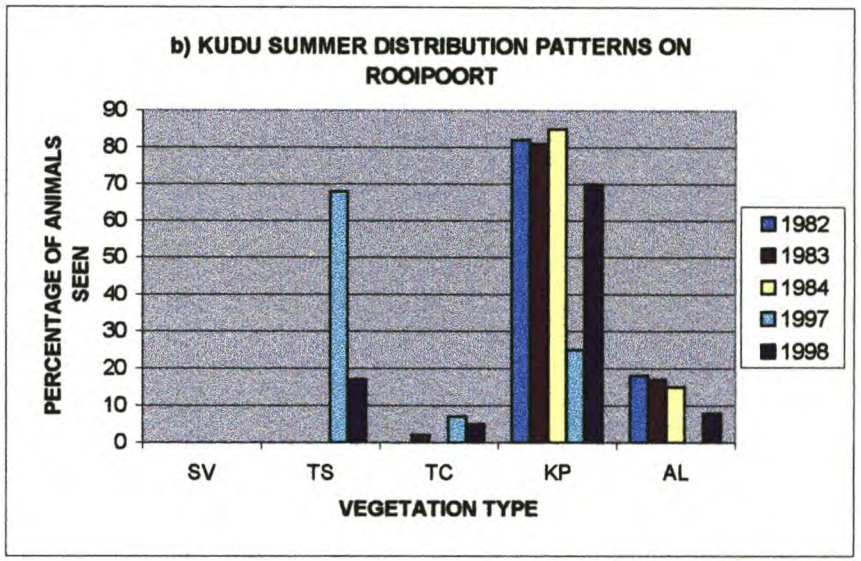
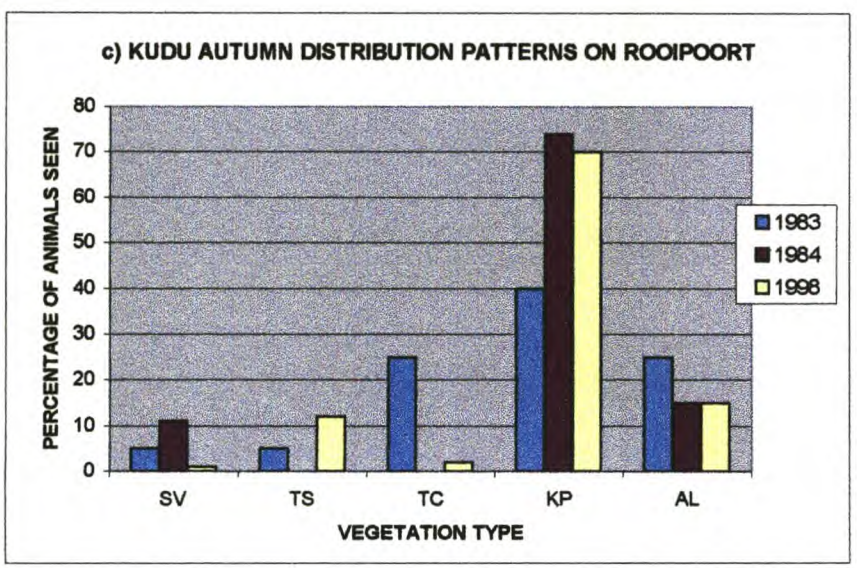
FIGURE 27 : KUDU DISTRIBUTION PATTERNS ON ROOIPOORT:







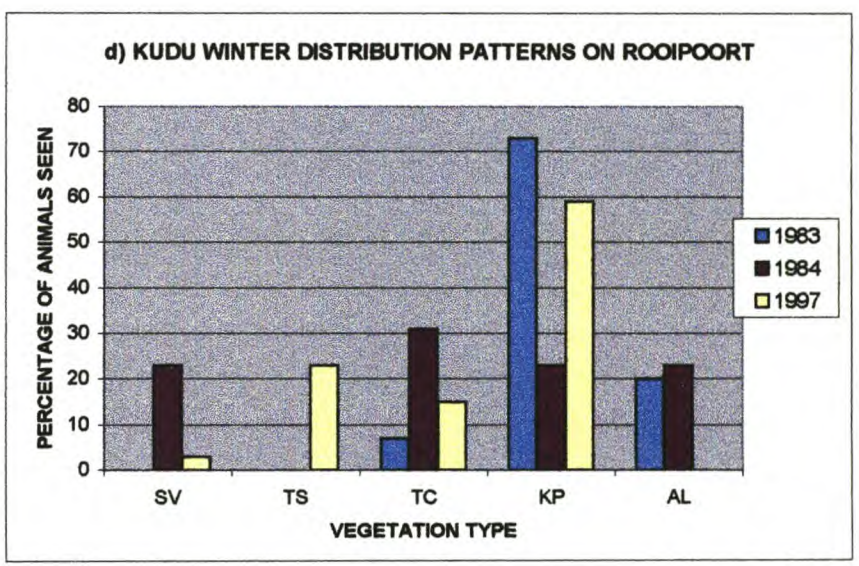


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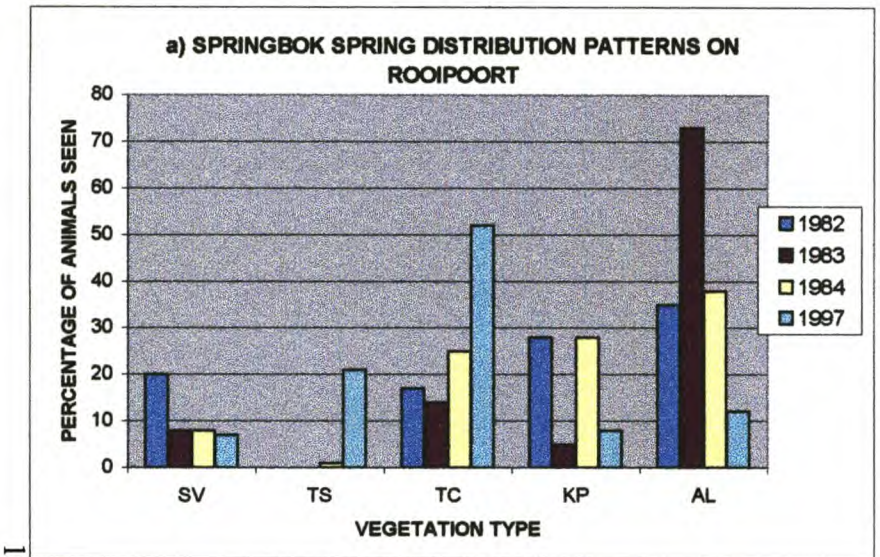
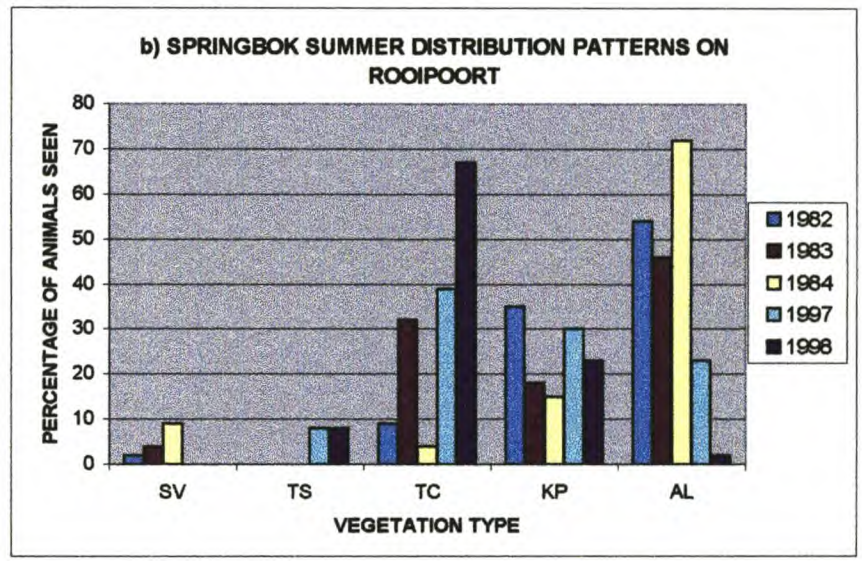
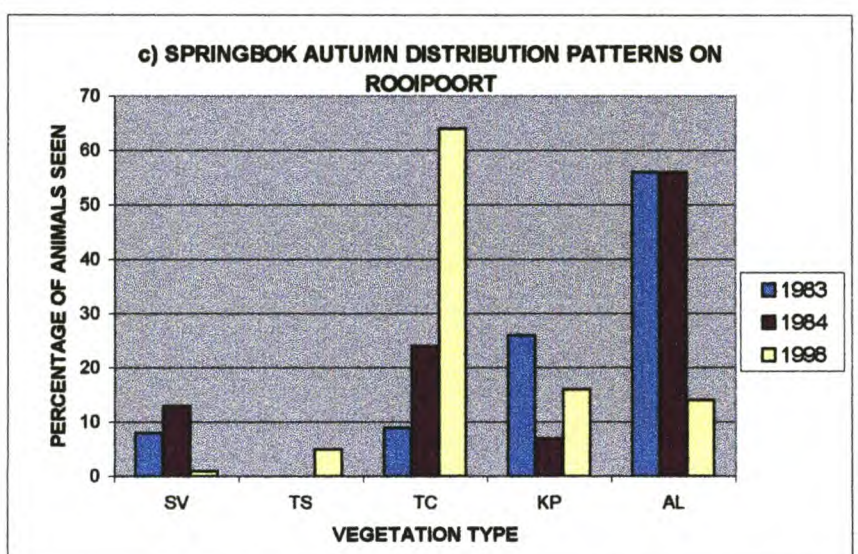
FIGURE 28 : SPRINGBOK DISTRIBUTION PATTERNS ON ROOIPOORT:







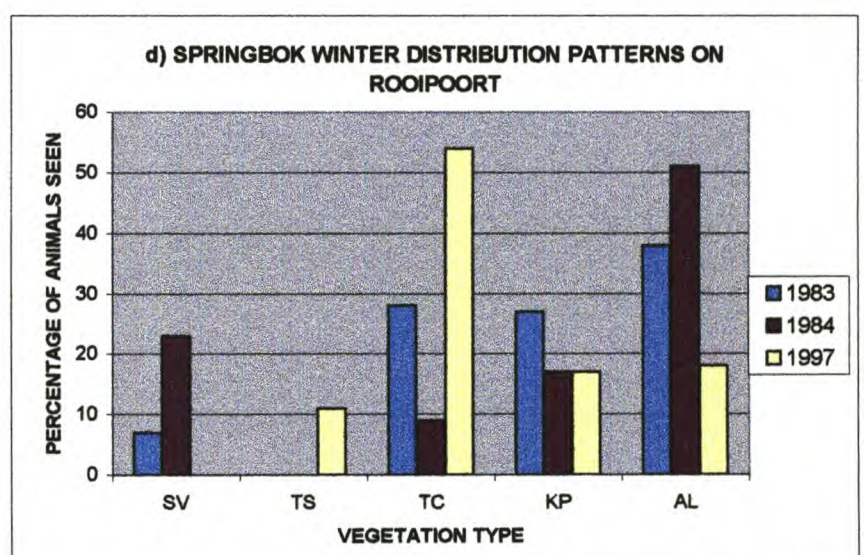


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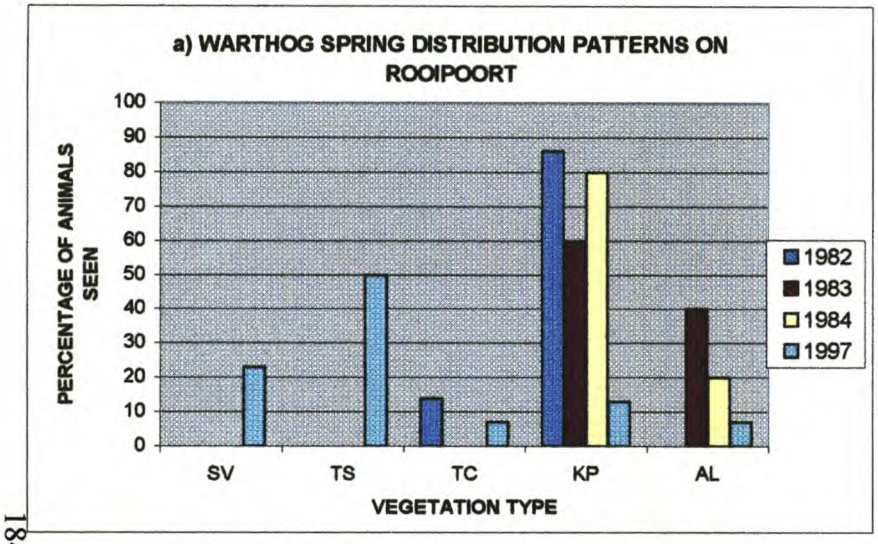
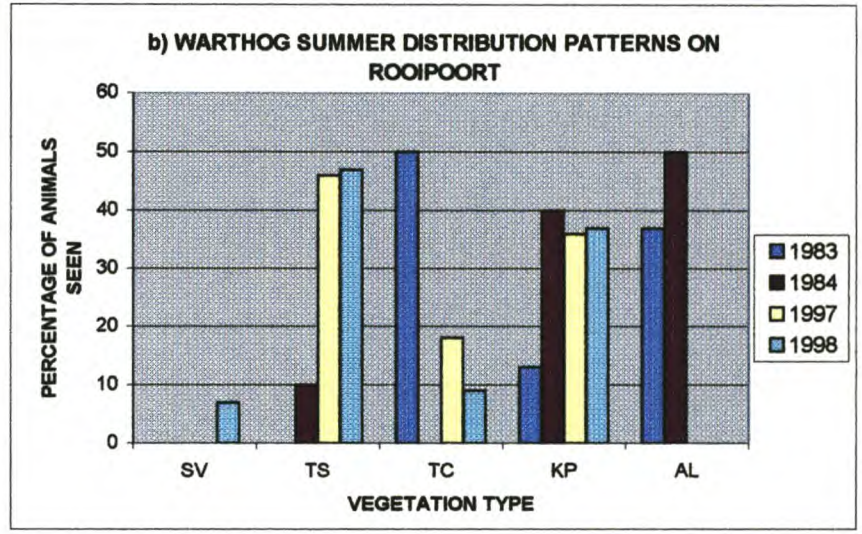
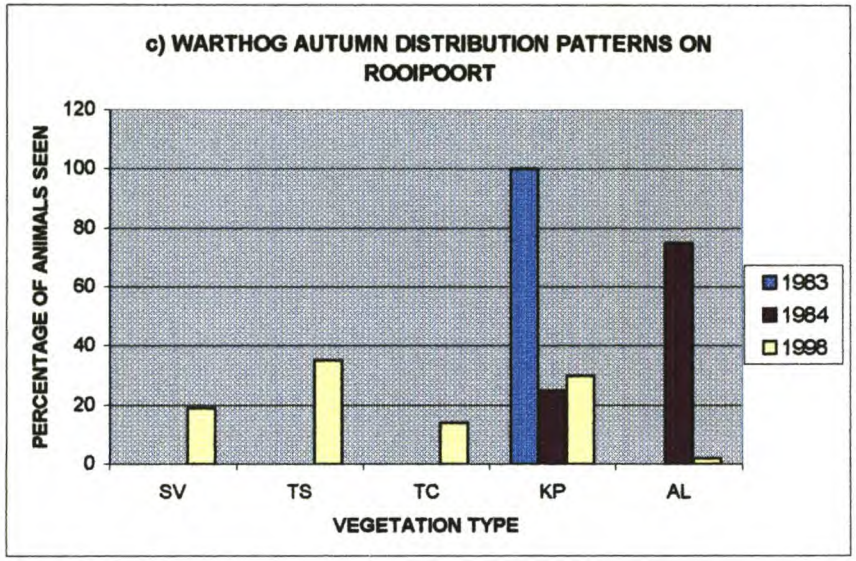
FIGURE 29 : WARTHOG DISTRIBUTION PATTERNS ON ROOIPOORT:







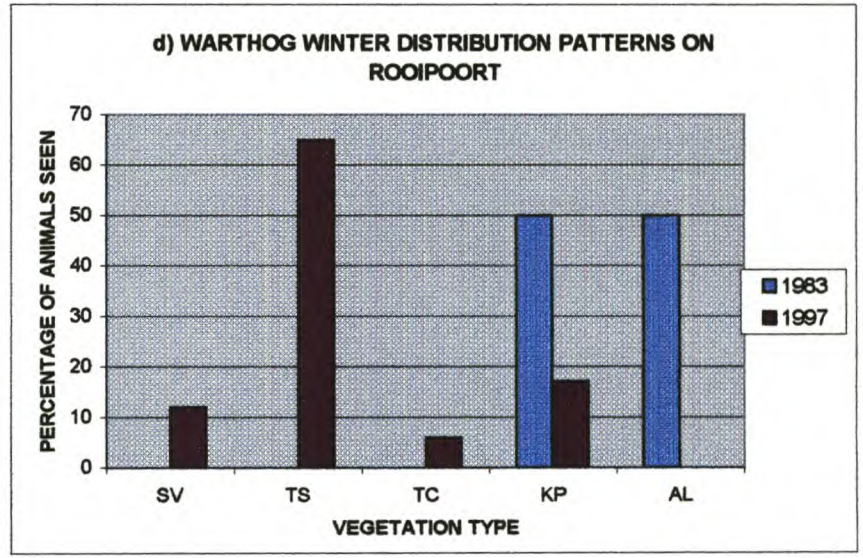


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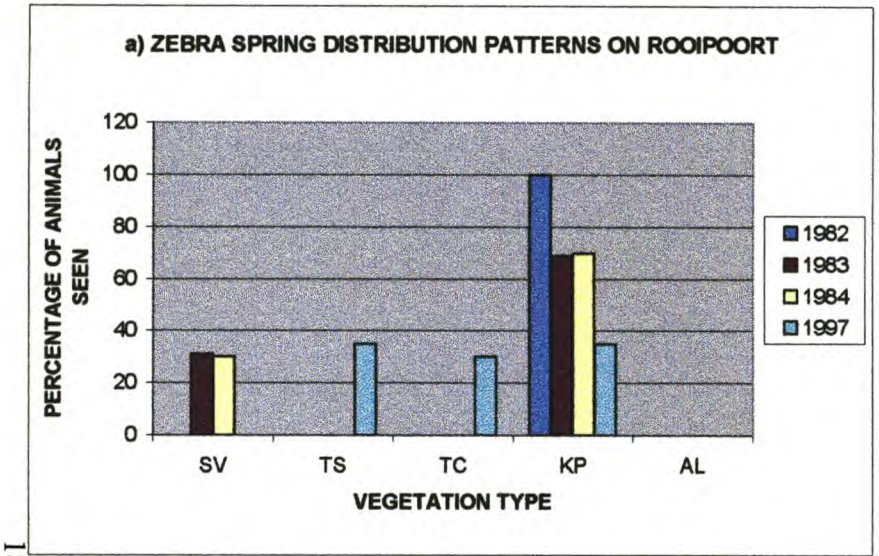
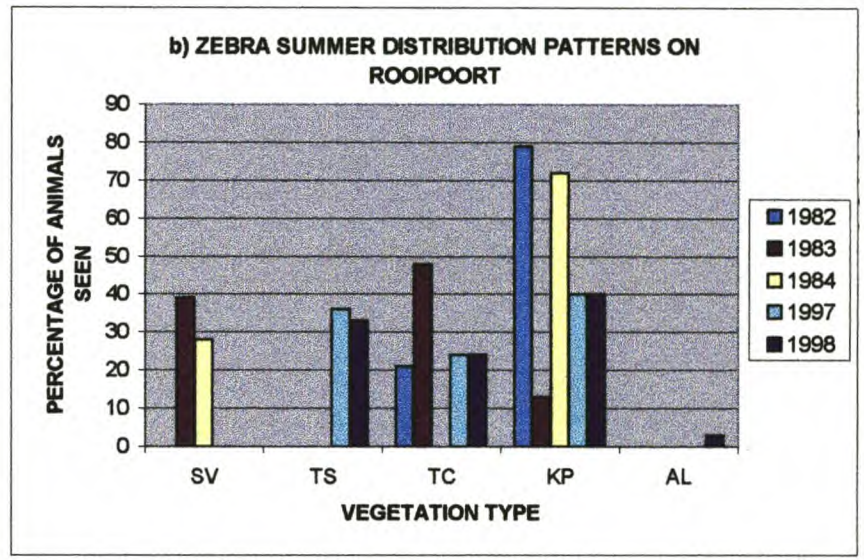
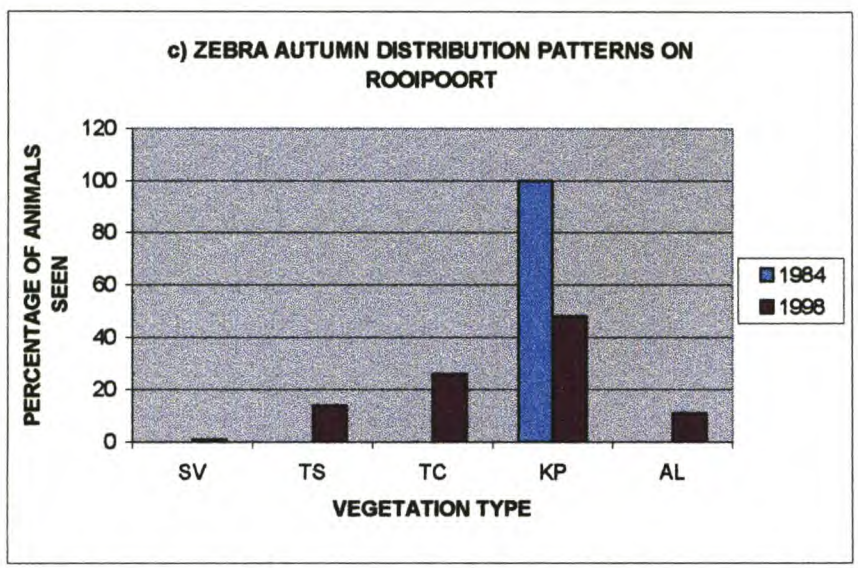
FIGURE 30 : ZEBRA DISTRIBUTION PATTERNS ON ROOIPOORT:







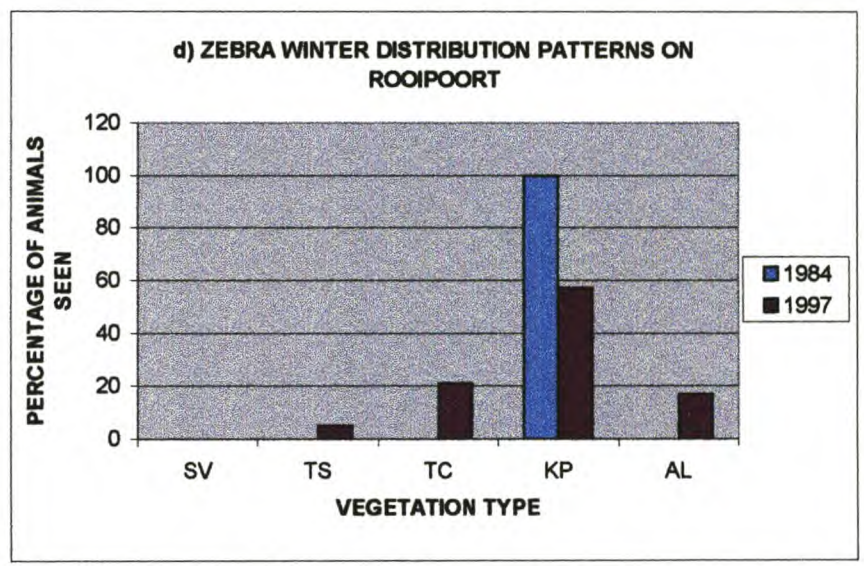


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Table 2A:

Species	Year	Correlation with Axis 1	Correlation with Axis 2	Correlation with Axis 3
Black wildebeest	1982	0.702	0.194	0.043
	1983	0.89	0.002	0.004
	1984	0.33	0.198	0.287
	1997	0.229	0.704	0.054
	1998	0.158	0.76	0.058
Blesbok	1982	0.001	0.363	0.534
	1983	0.071	0.712	0.215
	1984	0.003	0.476	0.458
	1997	0.17	0.505	0.266
	1998	0.179	0.739	0.067
Blue wildebeest	1982	0.084	0.719	0.021
	1983	0.016	0.519	0.017
	1984	0.043	0.78	0.014
	1997	0.889	0.002	0.008
	1998	0.652	0.027	0.293
Eland	1982	0.357	0.001	0.64
	1983	0.379	0.014	0.104
	1984	0.026	0.707	0.265
	1997	0.167	0.211	0.039
	1998	0.745	0.043	0.126
Gemsbok	1982	0.468	0.095	0.394
	1983	0.596	0.137	0.261
	1984	0.523	0.104	0.31
	1997	0.406	0.107	0.455
	1998	0.346	0.176	0.478
Hartebeest	1982	0.417	0.108	0.469
	1983	0.502	0.208	0.233
	1984	0.175	0.466	0.333
	1997	0.495	0.003	0.319
	1998	0.539	0.015	0.07
Kudu	1982	0.077	0.239	0.026
	1983	0.012	0.344	0.07
	1984	0.006	0.475	0.041
	1997	0.309	0.038	0.6
	1998	0.158	0.077	0.358
Springbok	1982	0.511	0.475	0.002
	1983	0.847	0.142	0.004
	1984	0.637	0.319	0.004
	1997	0.176	0.61	0.202
	1998	0.249	0.715	0.006
Warthog	1982	0.032	0.058	0.036
	1983	0.597	0.178	0.049
	1984	0.236	0.539	0.178
	1997	0.217	0.077	0.514
	1998	0.279	0.079	0.552
Zebra	1982	0.148	0.033	0.024
	1983	0.132	0.214	0.65
	1984	0.413	0.135	0.008
	1997	0.075	0.368	0.527
	1998	0.06	0.198	0.544

Table 2B:

Vegetation type:	Correlation with Axis 1	Correlation with Axis 2	Correlation with Axis 3
SV - Sandveld grassland	0.429	0.047	0.396
TS - Tarchonanthus sandveld	0.223	0.115	0.56
TC - Tarchonanthus calcrete	0.207	0.754	0.035
KP - Koppieveld	0.43	0.148	0.036
AL - High-lying alluvial vegetation	0.678	0.289	0.017

FIGURE 31:

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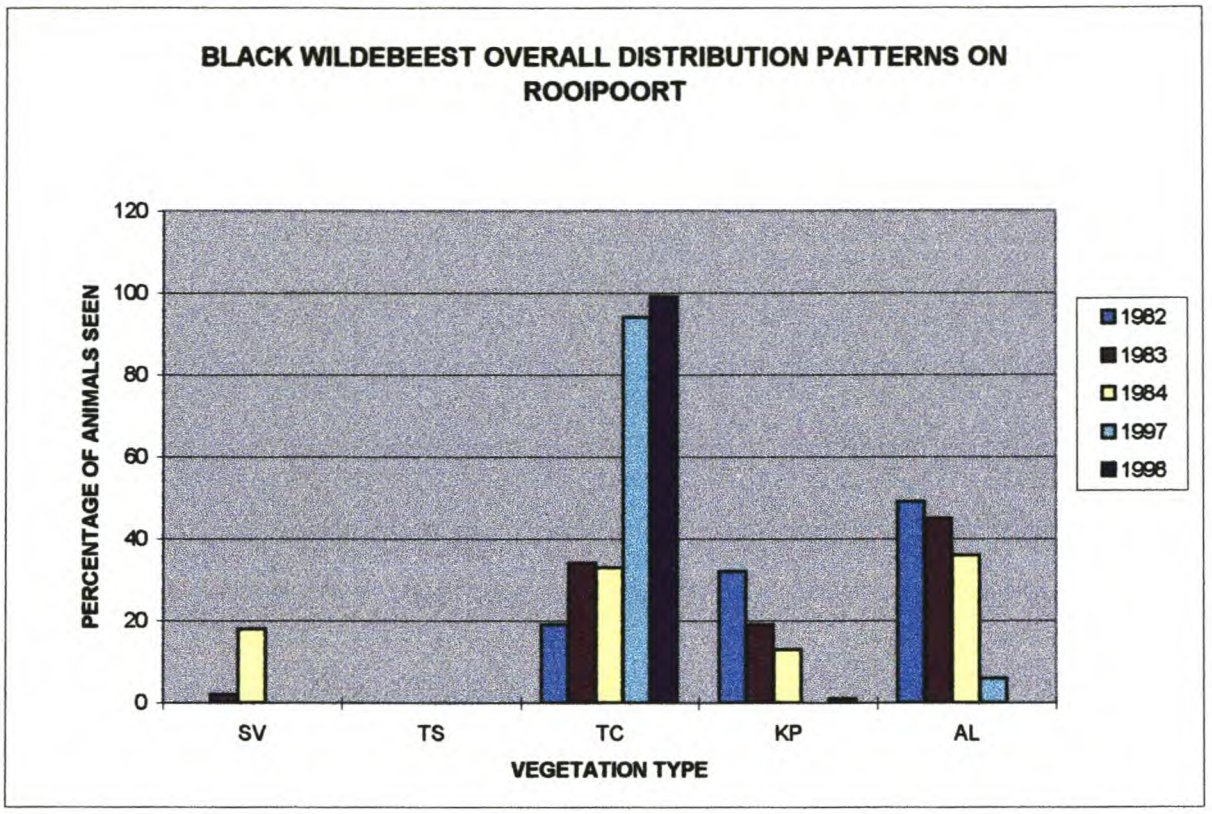

FIGURE 32:

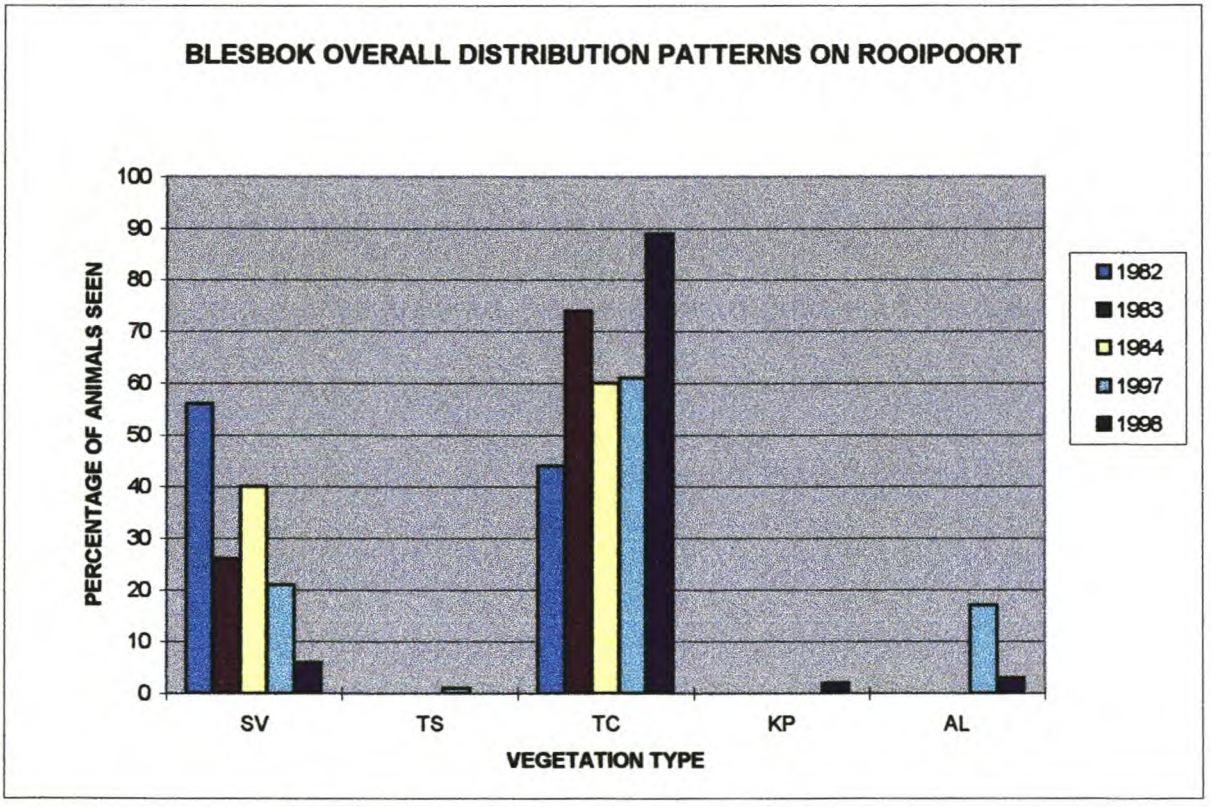

FIGURE 33:

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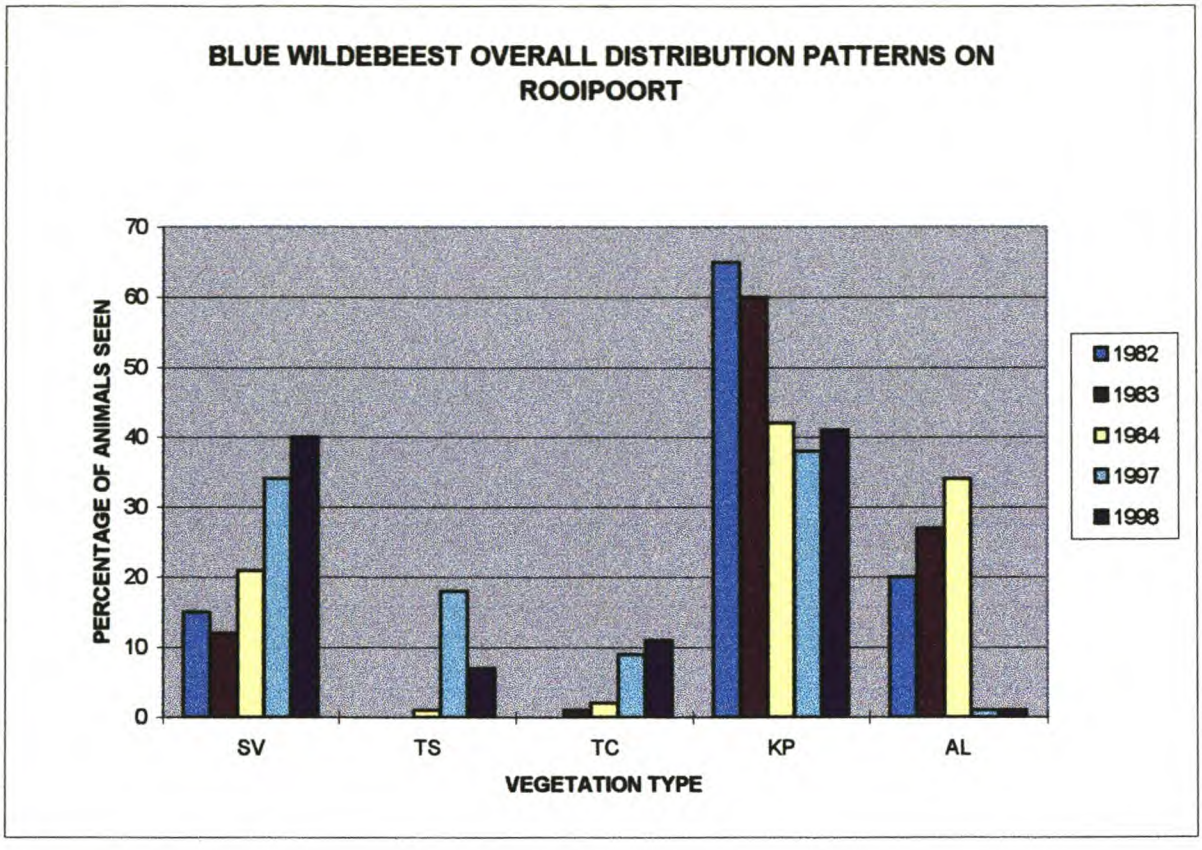

FIGURE 34:

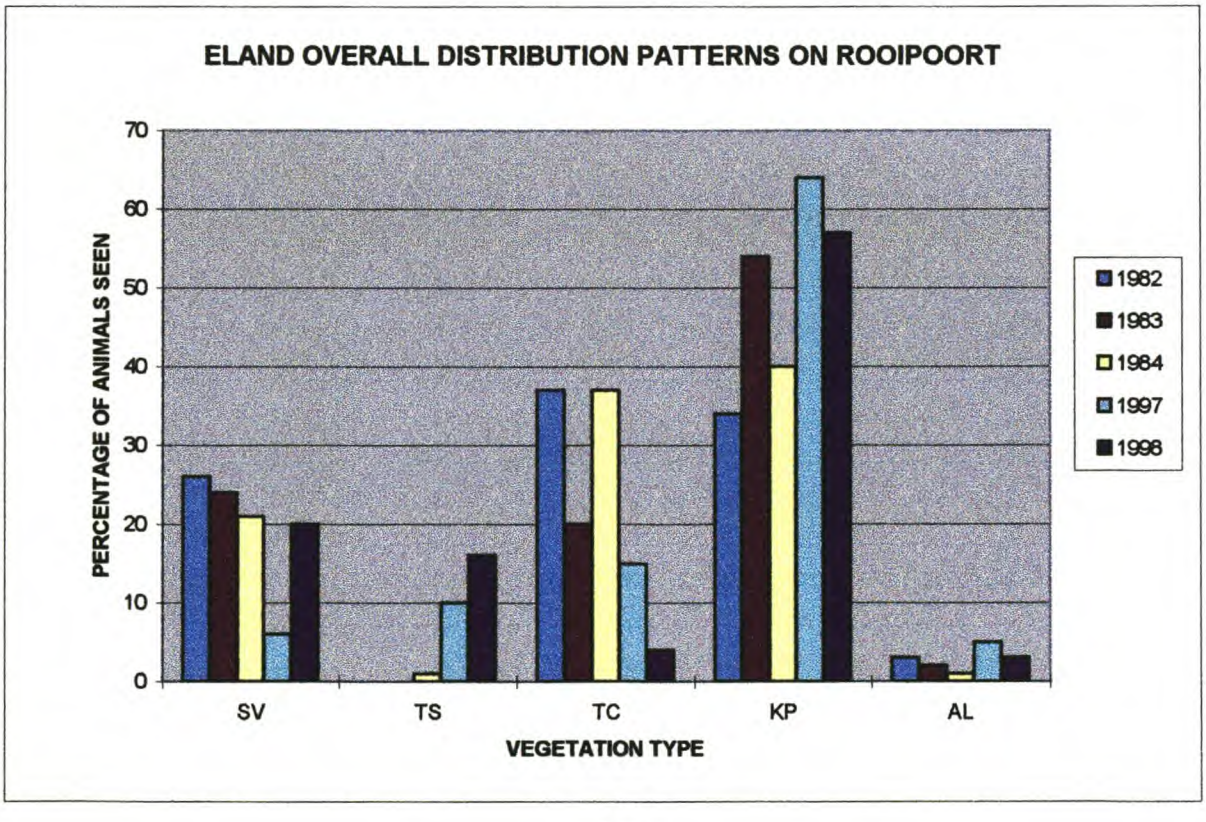

FIGURE 35:

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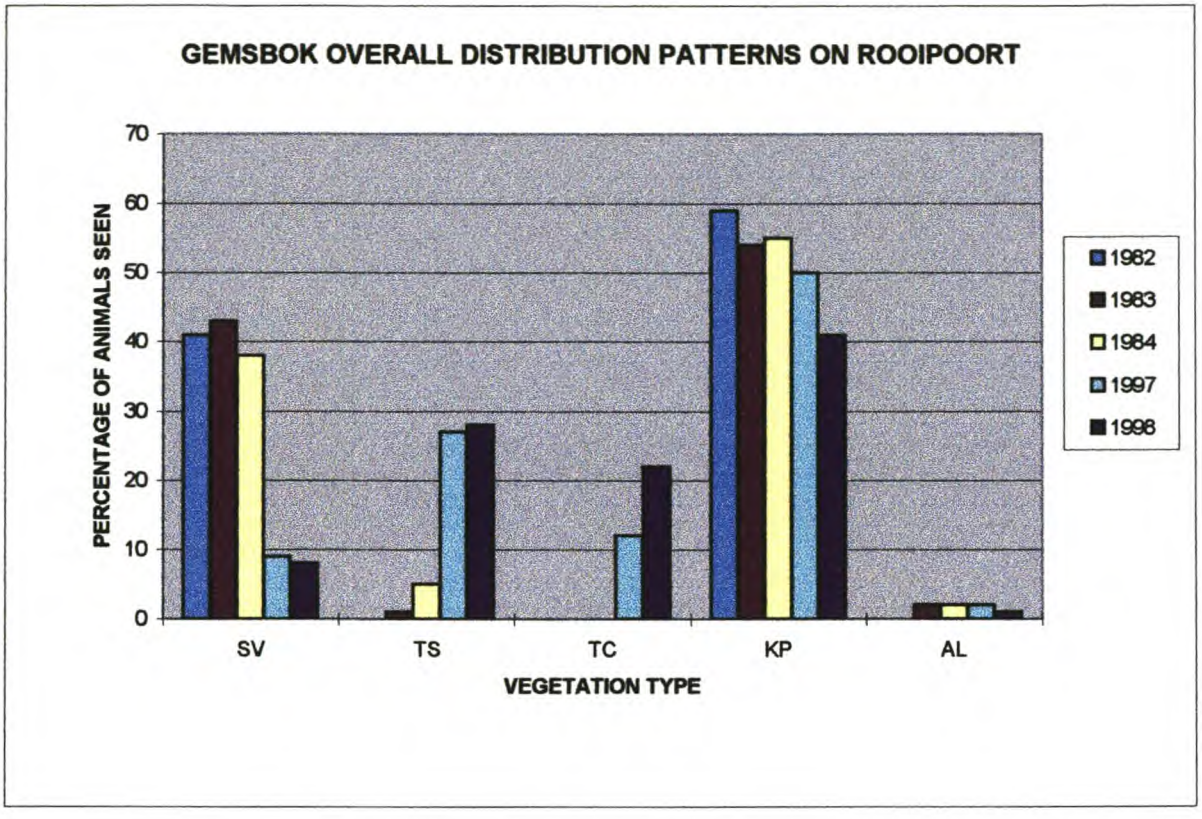

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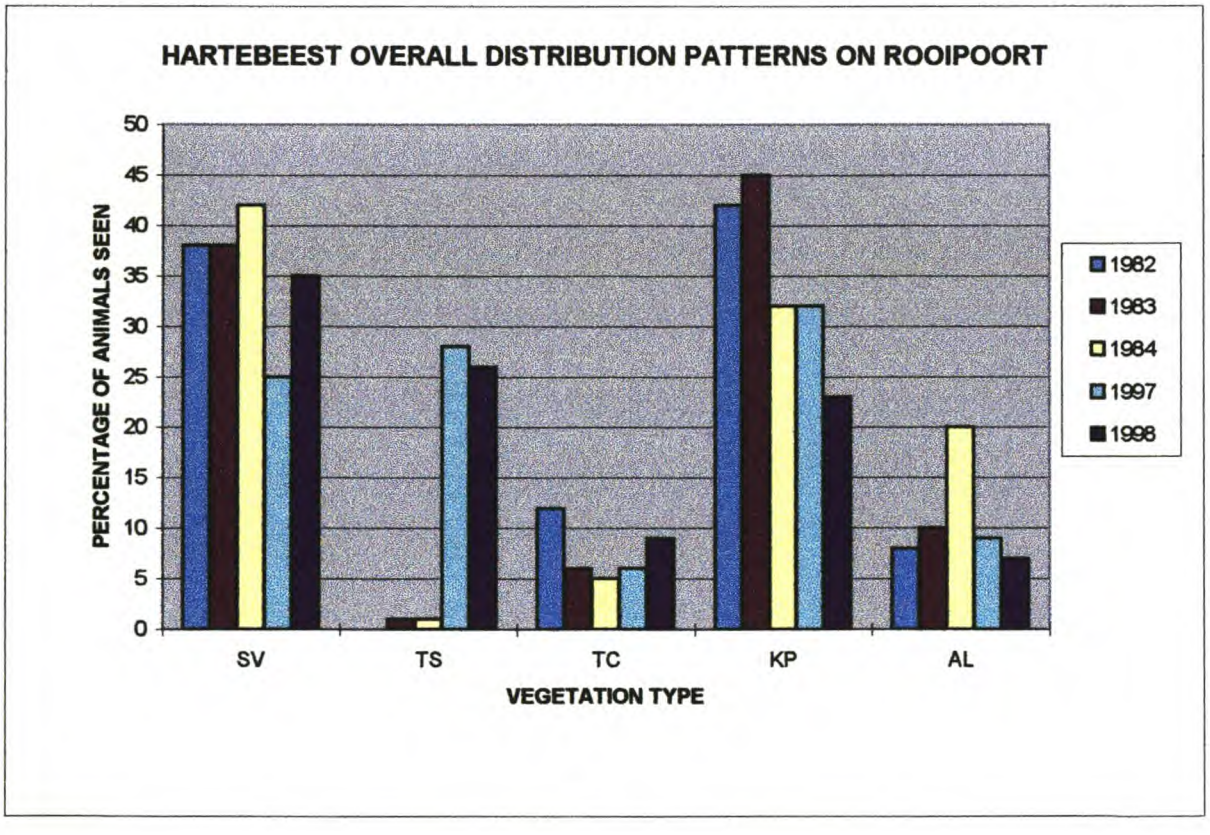

FIGURE 37:

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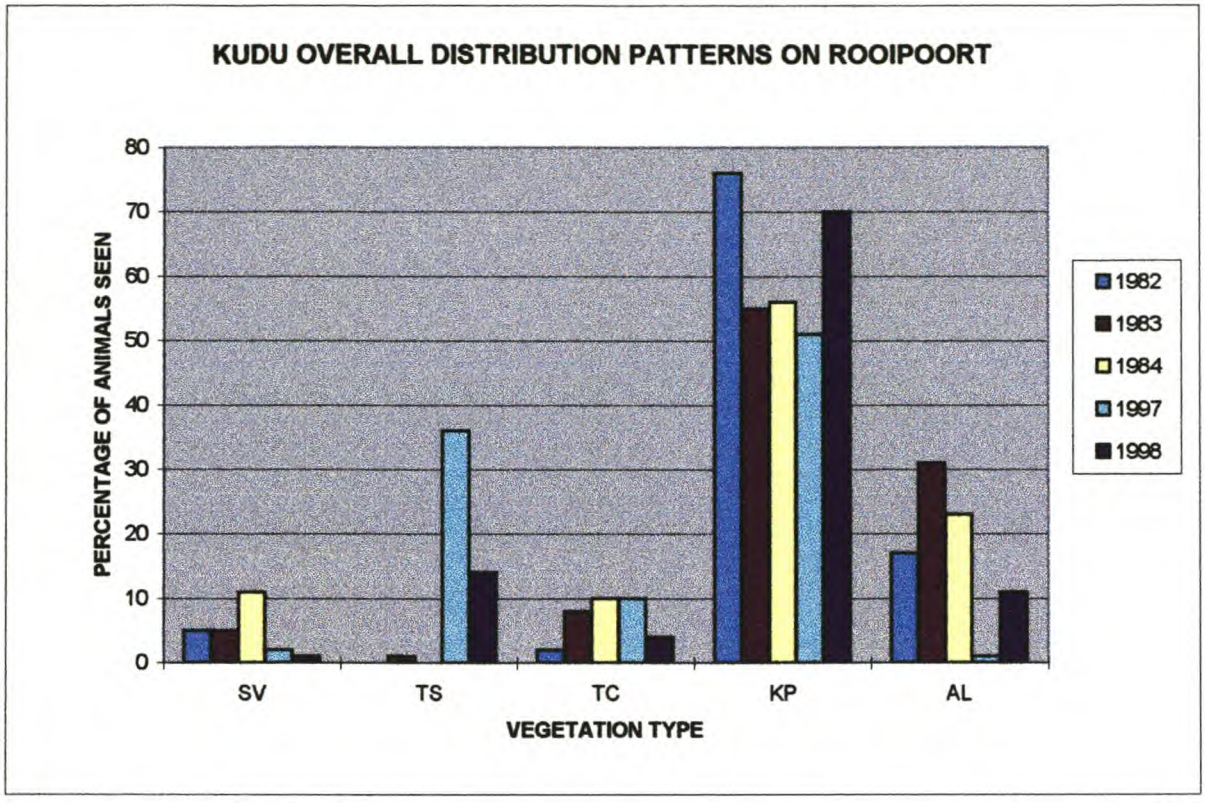

FIGURE 38:

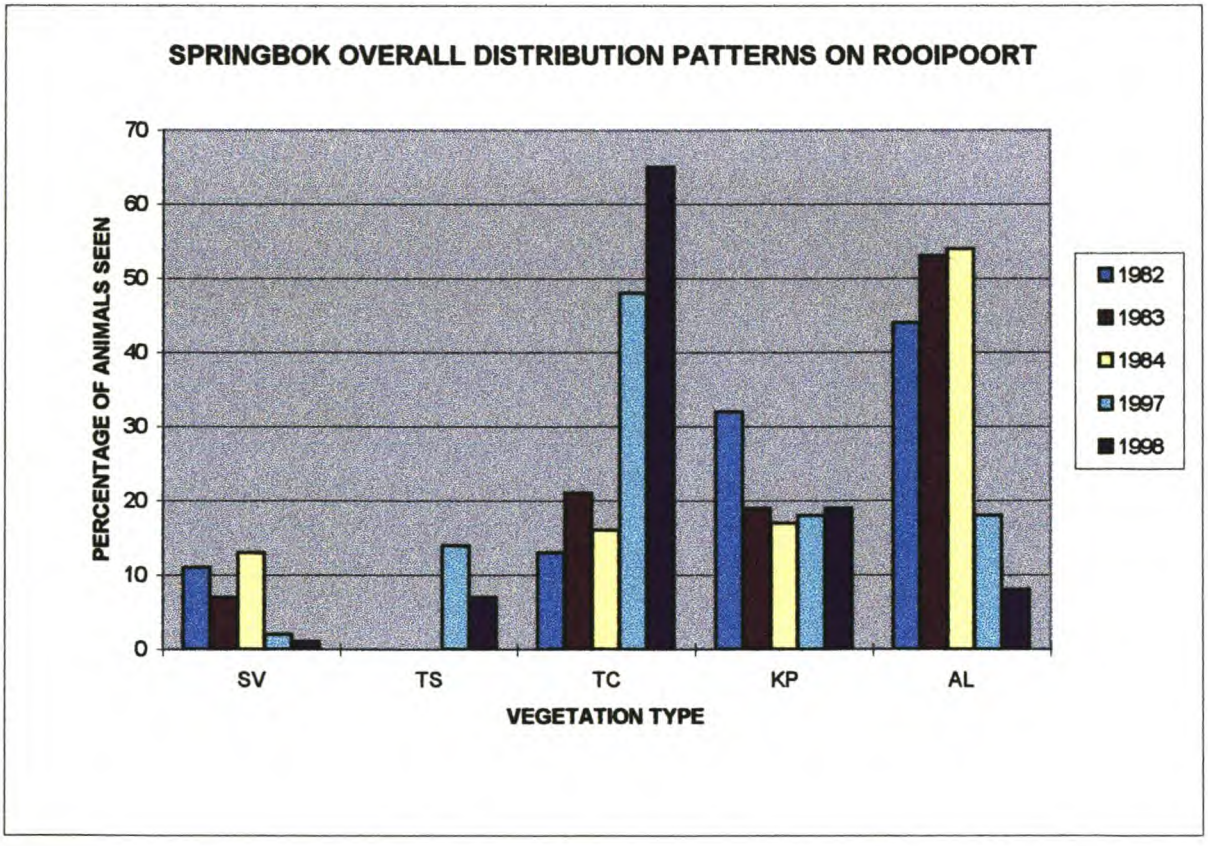

FIGURE 39:

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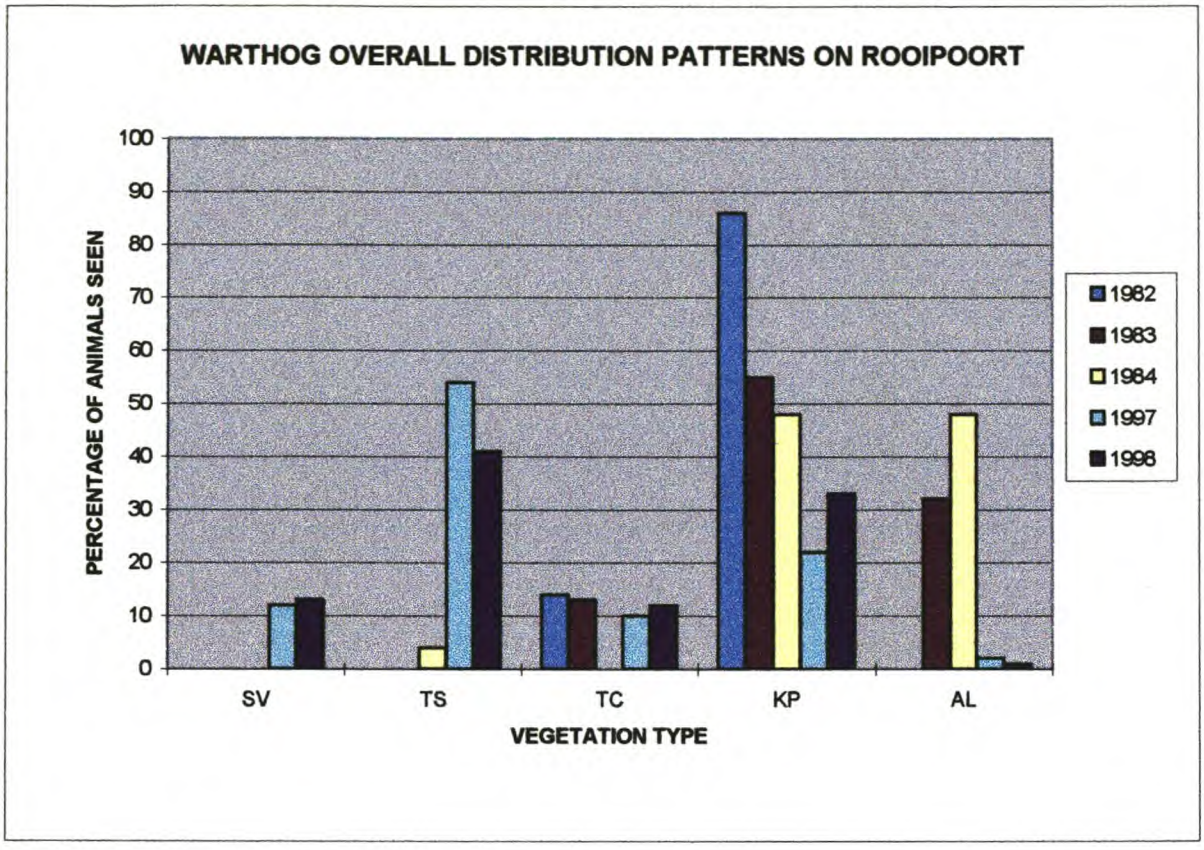
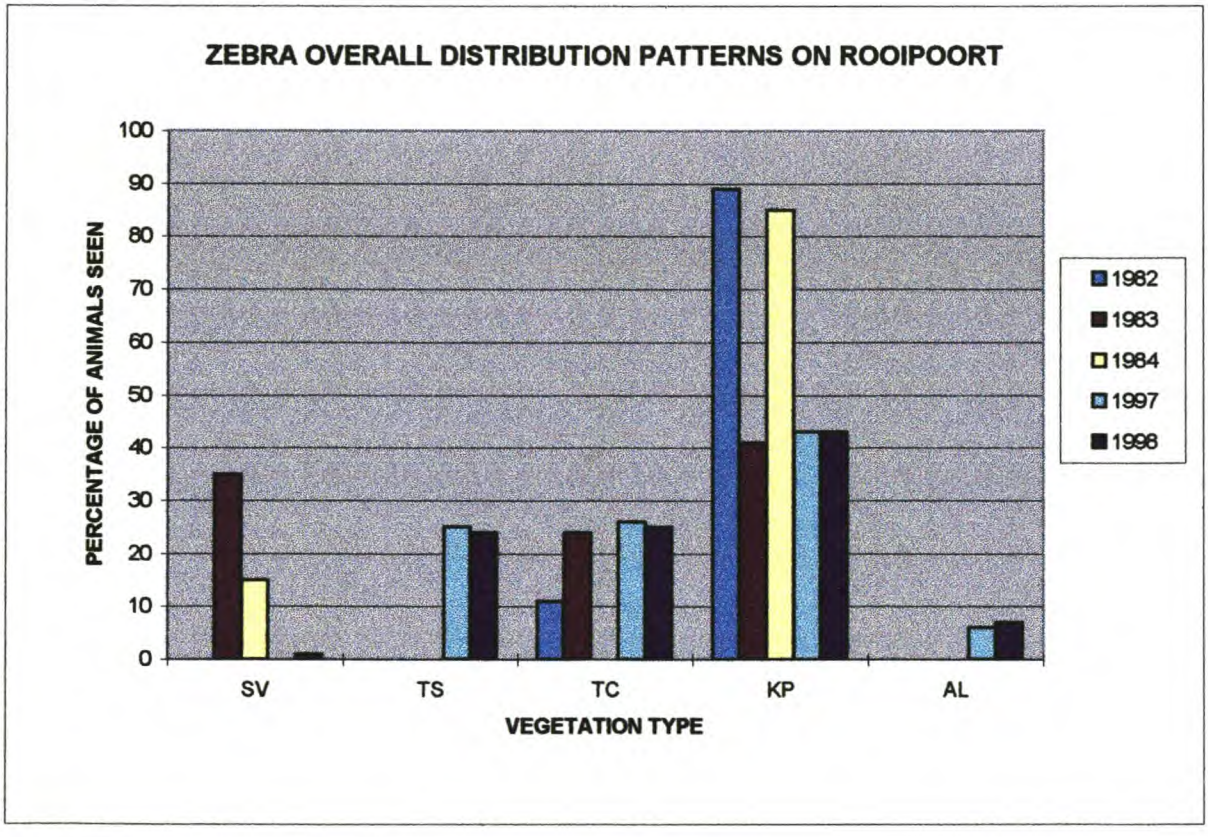
FIGURE 40: