The ecology of the Tsessebe, *Damaliscus lunatus lunatus*, in Borakalalo National Park, North West Province.

by

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ABSTRACT

Tsessebe are now considered rare antelope, which once occupied much of sub-Saharan Africa. Population numbers of tsessebe in Borakalalo National Park have shrunk from 43 to 13 in just 10 years. Causing great concern for park management and creating a need to determine distribution of these animals.

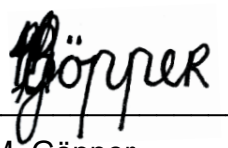
Five vegetation communities were identified within the tsessebe's home range. Step point method was used to determine the veld condition index for each of the identified communities. Height classes and density of woody species was determined per community. The five communities could be grouped into four major community types with two variants for community four. Veld condition index values ranged from 43.1% to 67.8%.

Data downloaded from GPS/GSM collars was used to determine home ranges, distribution patterns and spatial movements within the park. Mean home range was 248 ± 49 hectares. Core ranges occurred around and along temporary water points and drainage lines.

Cross-species microsatellites were used to assess genetic diversity among the tsessebe in Borakalalo National Park. In total, 36 alleles using 12 cross-species microsatellite makers were identified. The average number of alleles was 2.71 ± 1.2. The average expected heterozygosity was 0.446 ± 0.067 and average observed heterozygosity was 0.482 ± 0.047.

Declaration

I, Byron Malcolm Göpper, declare that the dissertation hereby submitted to the University of Limpopo, Medunsa Campus, for the degree of Master of Science in Biology has not previously been submitted by me for a degree at this or any other university; that this is my work in design and in execution, and that all material contained herein has been duly acknowledged.



B.M. Göpper

16 March 2012

Date

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List of abbreviations and symbols

BNP	Borakalalo National Park
CSV	comma-separated values
DNA	Deoxyribonucleic acid
dsDNA	double stranded Deoxyribonucleic acid
EDTA	Ethylenediaminetetraacetic acid
EtOH	Ethanol
F	inbreeding coefficient
GPS	Global Positioning System
GSM	Global System for Mobile Communications
H_e	Expected Heterozygosity
H_o	Observed Heterozygosity
HW	Hardy Weinberg
ind/ha	Individuals per hectare
IUCN	International Union for Conservation of Nature
KDE	Kernel Density Estimator
kg	kilogram
KNP	Kruger National Park
k-NNCH	k-Nearest Neighbour Convex Hull
LoCoH	Local Convex Hull
LSCV	Least Square Cross Validation
m	metre
MCP	Minimum Convex Polygon
MCSH	Minimum Covering of Spurious Holes
mg	milligram
$MgCl_2$	Magnesium chloride
min	minutes
mℓ	millilitre
mm	millimetre
mM	millimolar

ng	nana-gram
NWP&TB	North West Parks and Tourism Board
PCR	Polymerase Chain Reaction
PDOP	Position Dilution of Precision
PIC	Polymorphic Information Content
rcf	relative centrifugal force
rpm	revolutions per minute
sec	seconds
SMS	Short Message Service
SPIZE	species size
ssDNA	single stranded Deoxyribonucleic acid
SSR	Simple Sequence Repeats
STR	Short Tandem Repeats
USA	United States of America
VCI	Veld Condition Index
VHF	Very High Frequency
VIS	Very Important Species
µg	micro gram
µℓ	micro litre
°C	degrees Celsius

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Chapter 1

Introduction

1.1 Study problem

Since 1986, populations of rare antelope have noticeably declined (Grant & van der Walt 2000). Nicholls *et al*. (1996) estimated that the tsessebe population in the Kruger National Parks (KNP) could become extinct in approximately 69 years. According to North West Parks' modelling and census reports, for Borakalalo National Park, there has been a constant decrease in tsessebe numbers from 43 in 1999 to only 13 individuals in 2008. Crucial information needs to be obtained to determine the reasons for this decline and how it can be turned around.

1.2 Problem overview

Tsessebe numbers in the Kruger National Park (KNP) have dropped from 1163 in 1986 to 419 in 1993 (Grant & van der Walt 2000). According to Dunham *et al.* (2004) KNP used to have the largest population of tsessebe in South Africa. Several factors have been associated with the reduction of the tsessebe population including, habitat changes, alterations in rainfall patterns, hunting, land use changes and disease (Dunham *et al.* 2003).

Tsessebe are almost exclusively grazers, they also favour an abrupt ecotone between open grasslands and woodland (Child *et al*. 1972). Child *et al*. (1972) also noted that tsessebe utilise burnt areas more than un-burnt areas. This is confirmed by the findings of Gureja & Owen-Smith (2002) in the comparative study of rare antelope and the use of burnt grasslands where they found that

tsessebe moved onto burnt grasslands within two to three weeks after the burn occurred. Due to their social organization, tsessebe bulls are territorial and herms have a fixed home range. Tsessebe have an inclination for a particular habitat type, in the KNP individual herds may be observed in the same area for many years (Joubert & Bronkhorst 1977). Several lines of evidence have indicated that high density grazers such as zebra bring about changes to the grazing areas of associated rare antelope causing a decline in their numbers (Grant & van der Walt 2000). Due to changes in rainfall patterns and low rainfall the number of tsessebe in KNP declined because there was a decline in the food availability during the dry season (Dunham *et al.* 2004).

According to Dunham *et al.* (2003), another factor that needs to be considered is the susceptibility of young tsessebe to diseases such as pneumonia, especially after being exposed to prolonged wet and windy conditions associated with bad weather. Tsessebe population decline has not been found to be associated with diseases due to severe tick infestations (Dunham *et al.* 2003).

Genetic diversity provides the basis for adaptability (through natural selection) as environmental conditions change. If a population lacks genetic diversity, it is in great danger of not having the resources to survive environmental change. Low levels of genetic diversity may also lead to the expression of deleterious recessive alleles. In practice, loss of genetic diversity (or “inbreeding”) may result in reduced survival, reproductive abnormalities, juvenile mortalities, physical deformities and reduced growth in populations. It is therefore important to conserve representative levels of genetic diversity in artificially managed populations (Simberloff 1988). Genetic diversity may be lost through events such as (1) genetic bottlenecks, which occur when a population is reduced to a few reproducing individuals whose offspring then increase in numbers to re-establish the population; (2) founder events, when a population is started (or founded) using a small number of individuals which may not contain the full range of variation that occurs in the species; (3) isolation and lack of migration; and (4)

small population size (Amos & Harwood 1998). Currently, the level of genetic diversity among tsessebe in Borakalalo National Park has not been reported.

1.3 Significance

Statistics from Mésochina *et al.* (2009) show the current state of antelope world wide. Of the 91 species of antelope in the world, 25 of them are threatened by extinction.

The antelope population trends worldwide (Figure 1.1) shows that 62% of antelope species are on a decreasing trend, while 31% remain stable. Only a single antelope species, the Springbok (*Antidorcus marsupialis*), has an increasing population trend (Mésochina *et al.* 2009).

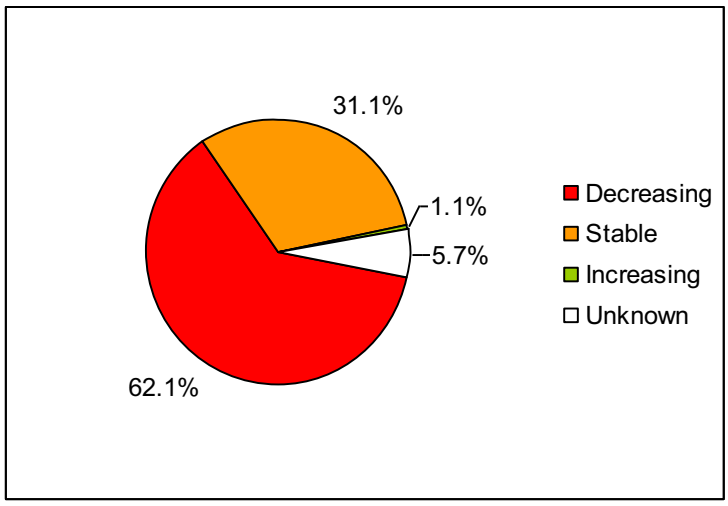

Figure 1.1: Current antelope population trends adapted from Mésochina *et al.* (2009).

Figure 1.2 gives an indication as to the conservation status of antelope in the world. Currently, approximately 58% of antelope fall into the Least Concern category. However ten sub-species are considered vulnerable, five sub-species

endangered and five sub-species are critically endangered (Mésochina *et al.* 2009).

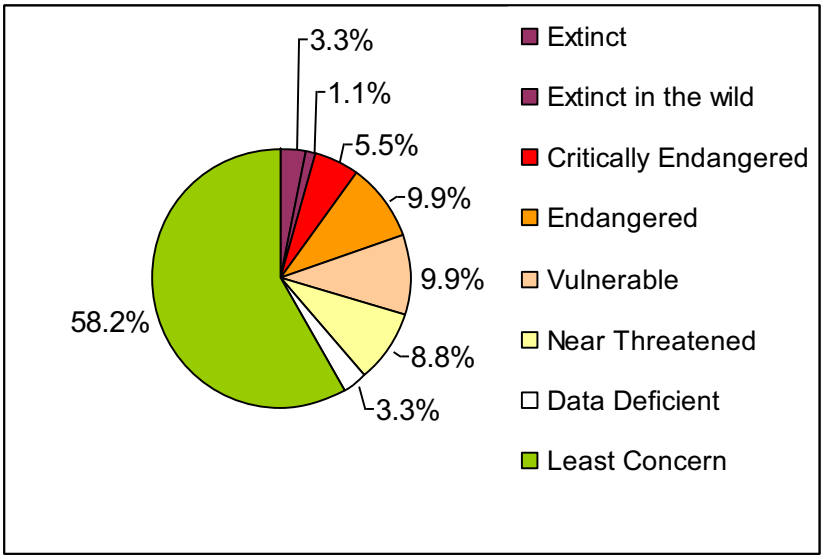

Figure 1.2: Current antelope conservation statuses adapted from Mésochina *et al.* (2009).

According to the IUCN Red List (2011) the total world population number of tsessebe is estimated at around 30 000 with 40% being on protected areas and 20% being on privately owned land.

On a global scale tsessebe are categorised as Least concern Conservation dependant (IUCN 2011). Least Concern as defined by IUCN criteria (version 3.1, 2011) when a taxon has been assessed according to the IUCN criteria and does not meet the requirements for Critically Endangered, Endangered, Vulnerable or Near Threatened. The taxon is widespread and abundant when it is included in this category.

Tsessebe are listed as endangered in the Red Data Book of the Mammals of South Africa (Friedmann & Daly 2004) with an estimated total population in South Africa sitting at around 1 100 individuals.

Endangered as defined in the Guidelines for using the IUCN Red List Categories and Criteria, (Version 9) (IUCN Standards and Petitions Subcommittee 2011) would be when a taxon meets any of the criteria of: (A) population reduction; (B) reduction in geographic range; (C) small population size and decline in population size; (D) very small or restricted population or (E) quantitative analysis where a extinction time is calculated. In this category the taxon if facing a very high risk of becoming extinct in the wild.

Principal threats to tsessebe, as listed in the Red Data Book, for the North West Province include high juvenile mortality, predation, competitors, deliberate fires and poor dispersal (Friedmann & Daly 2004).

1.4 Project aims

This study was conducted from April 2009 until June 2011 with the following aims in mind:

- Determine the habitat preference of tsessebe in Borakalalo National Park.
- Determine if tsessebe make use of micro-habitats within the current plant communities.
- Determine seasonal habitat selection of tsessebe in the southern section of the reserve
- Determine the population's genetic diversity and genetic status within Borakalalo National Park using microsatellite markers.
- Investigate factors associated with tsessebe decline in Borakalalo National Park.
- Establish broad management guidelines for tsessebe in Borakalalo National Park.

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Chapter 2

Literature Survey

2.1 Tsessebe overview

2.1.1 Historical background

The tsessebe was first described by Burchell in 1824 in his book; *Travels to the interior of Southern Africa*, where a single antelope was shot near the Matlhwareng River, Kuruman district (Burchell 1824). He named it "*Antilope lunata*" (Burchell 1824) due to the crescent shape of its horns (Burchell 1824). Harris (1838) in his book *Narrative of an expedition into Southern Africa* entered a description of the "sassaby of the Matabili and Beckuana" (Harris 1838) from a male and female and called it "*Acronotus lunata*" (Harris 1838). Smith (1849) described the "Sassaby of the Bechuanna" referring to it as "*Bubalus lunatus*" (Smith 1849).

2.1.2 Taxonomy

A taxonomic overview of the tsessebe according to Skinner & Chimimba (2005):

Order: Ruminantia
Suborder: Pecora
Super-family: Bovoidea
Family: Bovidae
Subfamily: Antilopinae
Tribe: Alcelaphini
Genus: *Damaliscus*

Species: *lunatus*

Subspecies: *lunatus*

jimela

topi

tiang

korrigum

Tsessebe (*Damaliscus lunatus lunatus*) occurs in the southern part of Africa. The Topi (*Damaliscus lunatus jimela*) are from East Africa and Democratic Republic of Congo. The Coastal Topi (*Damaliscus lunatus topi)* from southern Somalia and Kenya. The Tiang (*Damaliscus lunatus tiang*) can be found in Chad, the Central African Republic, Sudan, Ethiopia and northern Kenya and the Korrigum, (*Damaliscus lunatus korrigum*) can be found in parts of West Africa (Cotterill 2003 a).

2.1.3 Geographical distribution

An excerpt taken from *Narrative of an Expedition into Southern Africa* described the bounty of game in the past: *"Every open glade abounds with the more common species of game, such as the Brindled Gnoo, Hartebeest, Sassayby, and Quagga"* (Harris 1838). See Figure 2.1, with regards to the zoogeographic distribution of *Damaliscus lunatus* throughout Africa.

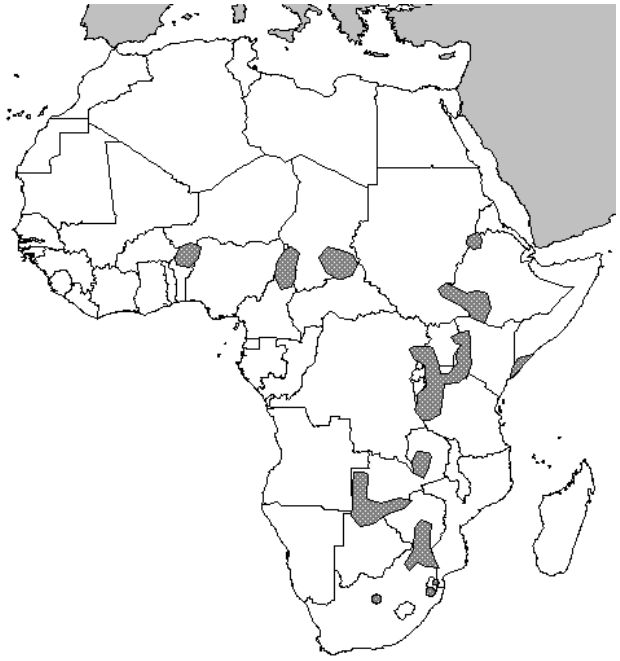


Figure 2.1: Zoogeographic distribution of *Damaliscus lunatus* throughout Africa adapted from Skinner & Chimimba (2005).

Damaliscus lunatus occupied much of the African continents sub-Saharan region. They ranged from Senegal, in the West African Region to the eastern parts of Ethiopia in Northern Africa and southwards through the East African Region to South Africa in the Southern African Region. Nonetheless the species has suffered a grave reduction in its range, mainly due to cattle taking over their distribution range and over utilization of the areas by humans. *Damaliscus lunatus korrigum* (Korrigum) previously ranged from Senegal to Cameroon but is now constrained to five countries (Skinner & Chimimba 2005). Likewise with the distribution of *Damaliscus lunatus lunatus* (Tsessebe) where the historical range has also shrunk a great deal (Cotterill 2003 b).

In Namibia tsessebe occurred in the extreme North Eastern Region as well as the Caprivi Strip. Currently they occur in small areas within their previous range as well as parts of the Central and Northern farming districts, where they were introduced onto private lands (Skinner & Chimimba 2005).

In Botswana they occurred throughout the Northern Region and were found in scattered populations in the Eastern Region (Skinner & Chimimba 2005). Currently they only occur in the Northern Regions of Botswana, within the Okavango Delta, the Moremi Game Reserve and the Chobe National Park (Skinner & Chimimba 2005). However, smaller numbers of tsessebe occur along the border of Zimbabwe in the North East as well as in the Tuli Block farm in the east (Skinner & Chimimba 2005).

In Zimbabwe they originally occurred in the North Western Regions and were scattered through the central parts of the country, but currently they occur in small numbers within protected areas such as the Chiarira National Park (Skinner & Chimimba 2005). Large numbers of tsessebe occurred within private lands but these numbers have decreased substantially due to habitat change and poaching that has come with political unrest in Zimbabwe since the year 2000 (Skinner & Chimimba 2005).

In Mozambique there were eight areas that were recorded to have tsessebe populations, however currently tsessebe are extinct in Mozambique (Skinner & Chimimba 2005).

Within South Africa the former ranges were the Limpopo Province, the North West Province, the Northern Cape, no further south than the Vaal River, Mpumalanga and the northern parts of KwaZulu-Natal (Skinner & Chimimba 2005). These former geographical ranges have been greatly reduced and current geographical ranges are depicted in Figure 2.2.

Figure 2.2: Zoogeographic distribution of *Damaliscus lunatus lunatus* through South Africa adapted from Friedmann & Daly (2004).

The current range in South Africa occurs within the Kruger National Park, north of the Letaba River (Skinner & Chimimba 2005). Isolated populations occur in Vaalbos in the Northern Cape; Pilanesberg, Madikwe and Borakalalo in the North West Province; Itala in KwaZulu-Natal and on private lands (Friedmann & Daly 2004).

2.1.4 Description

Male and female tsessebe are very much alike and distinguishing between the two sexes is difficult in the field. The general body colour is dark reddish-brown with a distinct iridescent purplish sheen and a dark, almost black tint on the top of the head and muzzle. The lower parts of the shoulder and the upper parts of the forelegs, both inside and outside, are darker than the general colour of the body, often nearly black. The thighs and upper parts of the hind legs are also noticeably darker (Figure 2.3). The tail is basally yellowish-white with black or dark brown tassels of long hair towards the tip. The back of the ears, the rump, the inside of the hind legs and the abdomen are yellowish-white. There is a patch of yellow-white above the darker part of the inside of the front legs. The lower parts of the legs are brownish-yellow and the front legs have a narrow band of

dark brown on the front. Juveniles are yellowish-red at birth and only acquire the same pelage colouration as adults when they are 9-11 weeks old (Skinner & Chimimba 2005).

The average total length for tsessebe are 2 160 mm for males and 2 130 mm for females, whereas the shoulder height for males are 1 260 mm and for females 1 250 mm (Skinner & Chimimba 2005).

Both sexes have horns, the horns bend in a consistent curve, forming a crescents shape. They are ringed for much of their full length, with only the tips being smooth. Sexual dimorphism is limited mainly to the thickness of the horn base, although this can be difficult to determine in the field (Skinner & Chimimba 2005). Generally, males have longer horns than females, although adult male horn length decreases with age probably due to wearing away from soil-horning (Anthony & Lightfoot 1984).

Figure 2.3: Tsessebe, *Damaliscus lunatus lunatus.*

2.1.5 Tsessebe biology

The successful establishment of surviving young is the biggest contribution towards the growth and preservation of a population (Bothma 2002). Environmental pressures put stress upon the reproductive success of animals, by being able to monitor the animal's reproductive success; measures can be put into place to limit the effects of harmful environmental factors that may cause deterioration in a population (Bothma 2002). Therefore the following reproductive aspects should be known: Mating and birthing seasons, the age at which a mature female will give birth for the first time and the period of time between successive births (Bothma 2002).

In the Kruger National Park the rut commences in mid-December and peaks in late January (Joubert 1972). Mating occurs from January to April, with a gestation period of 235 - 245 days. The birthing season falls around September to December with the peak period being October - November (Bothma 2002).

Males are sexually mature from the age of 36 - 42 months, while females become sexually mature from 18 - 24 months. First mating occurs when males reach 54 months and females from 24 - 36 months, resulting in females being between 24 - 36 months when they give birth to their first calf (Bothma 2002).

Calves weigh from 10 - 12 kg at birth. The successive time between births for tsessebe is 12 months, with an average life expectancy of 15 years in the wild (Bothma 2002). The females make no attempt to hide their young, even in the early stages of their lives, and shortly after birth they join their mothers. While their mothers forage, the young form nursery herds of two to five, which bed down in slight depressions. Females have one pair of inguinal mammae (Skinner & Chimimba 2005).

2.1.6 Habitat and food

Tsessebe's historical distribution occurred within the Lowveld, Mopane veld, Sweet and Mixed Bushveld and the Kalahari (van Rooyen 2002). The habitat requirements for tsessebe are adequate palatable grasses, surface water and shelter (Skinner & Chimimba 2005). Tsessebe are water dependant antelope, requiring up to five litres of water a day (du Toit *et al.* 2002), they make use of areas where there is water available in seasonal water pools, as these water pools dry up they leave these areas (Skinner & Chimimba 2005). Ben-Shahar (1990) found that tsessebe were associated with flat areas and moderate slopes and areas with sandy and acidic soils with a low rock cover. During the rainy season they will move from plains to more woody vegetation to make use of the palatable grasses found there (Skinner & Chimimba 2005). Tsessebe are exclusively grazers preferring grasses up to 600 mm high, they are bite selectors, selecting parts of a plant rather than selecting for grass patches such as site selectors do. Gureja & Owen-Smith (2002) found tsessebe had utilized grasses such as *Pogonarthria squarrosa, Eragrostis gummiflua, Eragrostis rigidior* and *Tricholaena monachne,* which are considered unpalatable to cattle. Tsessebe were also impartial to the selection of *Urochloa mosambicensis* and *Heteropogon contortus* (Gureja & Owen-Smith 2002).

2.1.7 Social structure

The social organisation of tsessebe includes a territorial male, breeding group of females and bachelor herds. Tsessebe occur in small herds, in the Kruger National Park the mean number in a herd being 7.7 (du Toit *et al.* 2002) and bachelor herds having a mean number of 3.0 in a herd (du Toit *et al.* 2002). Aggregations of herds do occur on preferred grazing ground (Skinner & Chimimba 2005). Territorial males create territories and then maintain them by regularly patrolling the area (Skinner & Chimimba 2005). Both sexes mark with their preorbital glands, they also horn the soil. Tsessebe also have interdigital

glands on their front feet which are also used for marking territory by pawing the ground (Skinner & Chimimba 2005). Herms remain with the territorial male indefinitely (Garstang 1982). Male yearlings are evicted from the herd by the territorial male once the calving season begins in October (Skinner & Chimimba 2005). These yearlings then join existing bachelor herds or form new ones (Skinner & Chimimba 2005). Bachelor herds do not have permanent areas of activity (Skinner & Chimimba 2005).

2.1.8 Past research

Since the 1960s the tsessebe became a matter of scientific enquiry (Garstang 1982) with the focus on their distribution, conservation status and general habitat as can be seen in Table 2.1. The 1970s saw a wider focus on other aspects of tsessebe biology. Both Child *et al.* (1972) and Grobler (1973), respectively, produced papers on tsessebe that dealt with their biology in large detail. However aspects of home range and management were essentially lacking (Garstang 1982). Garstang (1982) incorporated home range and habitat preferences in his work on tsessebe. Since the 1980s research on the other subspecies of *Damaliscus lunatus* were pronounced. Presently very little has been done in terms of genetics of tsessebe, and the use of GPS/GSM collars on tsessebe has not been found in literature.

Table 2.1: Research conducted on *Damaliscus lunatus* from 1962 to 2010 adapted and updated from Garstang (1982).

Year	Author/s	Sub-species	Distribution	Status	Taxonomy	Anatomical Data	Reproduction	Behaviour	Habitat	Management	Capture	Rumen flora	Genetics
1962	Kettlitz, W.K.		X	X									
1963	Pienaar, U. de V.	*Tsessebe*	X	X					X				
1964	Child, G. & Savory, C.R.		X	X					X				
1968	Child, G.		X						X				
1969	du Plessis, S.F.		X										
1971	Palmer, A.S., Best, E. & Shepherd, T.		X	X									
1971	Smithers, R.H.N.		X	X	X	X							
1972	Ansell, W.F.H.				X								
1972	Child, G., Robbel, H. & Hepburn, C.P.	*Tsessebe*	X	X		X	X	X	X				
1972	Huntley, B.J.								X				
1972	Joubert, S.C.J.	*Tsessebe*						X					
1972	Young, E.										X		
1973	Grobler, J.H.	*Tsessebe*				X	X	X	X	X			

Table 2.1 continued:

Year	Author/s	Sub-species	Distribution	Status	Taxonomy	Anatomical Data	Reproduction	Behaviour	Habitat	Management	Capture	Rumen flora	Genetics
1973	Huntley, B.J.	*Tsessebe*				X							
1974	Joubert, S.C.T.	*Tsessebe*							X	X			
1974	Lamprechts, A. von W.		X	X									
1975	van Hoven, W.	*Tsessebe*										X	
1976	Smithers, R.H.N. & Tello, J.L.P.L		X	X									
1977	Joubert, S.C.T. & Bronkhorst, P.J.L.	*Tsessebe*											
1979	Smithers, R.H.N. & Wilson, V.J.		X	X									
1980	Parris, R & Smith, J.M.	*Tsessebe*											
1981	Yoaciel, S.M. & van Orsdol, K.G.	*Topi*											
1982	Garstang, R.	*Tsessebe*							X	X	X		
1982	Sayer, J.A.	*Korrigum*		X									
1984	Anthony, A.J. & Lightfoot, C.J.	*Tsessebe*				X							
1987	van der Veen, H.J. & Penzhorn, B.L.	*Tsessebe*											X

Table 2.1 continued:

Year	Author/s	Sub-species	Distribution	Status	Taxonomy	Anatomical Data	Reproduction	Behaviour	Habitat	Management	Capture	Rumen flora	Genetics
1988	Ben-Shahar, R. & Skinner J.D.	*Tsessebe*							X				
1990	Ben-Shahar, R.	*Tsessebe*											
1991	Gosling, L.M.	*Topi*					X						
1994	Bartels, P.	*Tsessebe*					X						
1996	Nicholls, A.O., Viljoen, P.C., Knight, M.H. & van Jaarsveld, A.S.	*Tsessebe*		X									
1996	Bartels, P.	*Tsessebe*					X						
1997	Ito, A., Arai, N., Tsutsumi, Y. & Imai, S.	*Tsessebe*										X	
1999	Arctander, P., Johansen, C. & Coutellec-Vreto, M.A.	*Topi*											X
2000	Grant, C.C. & van der Walt, J.L.									X			
2003	Dunham, K.M., Robertson, E.F. & Swanepoel, C.M.	*Tsessebe*		X						X			

Table 2.1 continued:

Year	Author/s	Sub-species	Distribution	Status	Taxonomy	Anatomical Data	Reproduction	Behaviour	Habitat	Management	Capture	Rumen flora	Genetics
2003a	Cotterill, F.P.D.	*Tsessebe*			X								
2003b	Cotterill, F.P.D.	*Tsessebe*			X								
2003	Bro-Jørgensen, J.	*Topi*					X	X					
2003	Bro-Jørgensen, J. & Durant, S.M.	*Topi*					X	X					
2003	Dunham, K.M., Robertson, E.F. & Swanepoel, C.M.	*Tsessebe*		X						X			
2004	Dunham, K.M., Robertson, E.F. & Grant, C.C.	*Tsessebe*		X						X			
2006	Dörgeloh, W.G.	*Tsessebe*							X				
2007	Bro-Jørgensen, J.	*Topi*					X	X					
2008	Bro-Jørgensen, J.	*Topi*					X	X					
2010	Bro-Jørgensen, J. & Pangle, W.	*Topi*					X	X					

2.2. Study area

2.2.1 Borakalalo National Park

Borakalalo National Park (BNP) is situated about 70 km north-north east of Pretoria. Situated between latitudes S 25°04' and S 25°12', and longitudes E 27°42' and E 27°54'. Figure 2.4 depicts the position of BNP in the North West Province in South Africa. Topography of BNP can be seens in Figure 2.5.

The park lies in the Moretele River Valley. The Moretele River originates as the Morelettaspruit in Pretoria, which then becomes the Pienaars River. The Pienaars River, within the park's boundary, in known as the Moretele River. The river returns to its former name, the Pienaars River, upon leaving the park. The river continues to flow for about 20 km where it enters the Crocodile River about 9 km north-north east of Assen, North West Province.

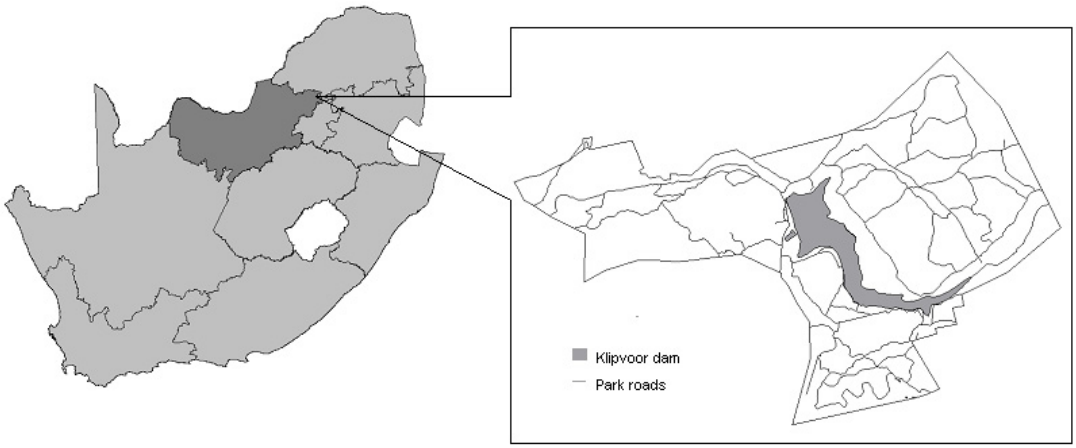


Figure 2.4: Borakalalo National Park situated in the North West Province, South Africa.

The Klipvoor dam, that was built in 1969 (Matthews 1991) falls within the boundaries of the park. The dam was primarily used for irrigation purposes (Greyling & Huntley 1984). The dam has a length of 10 km, at its widest point it

measures 1 km (Greyling & Huntley 1984). The dam is now used for recreational fishing. No private boating or swimming is permitted in the dam.

Figure 2.5: Topographical map of Borakalalo National Park, adapted from maps 2527BA and 2527BB.

2.2.1.1 History of the park

Borakalalo National Park was established in 1970 and comprised of land formerly managed by the Transvaal Provincial Administration's Nature Conservation and the South African Defence Force (Matthews 1991). After the independence of Bophuthatswana in 1977, the park became Bophuthatswana Department of Agriculture's responsibility (Matthews 1991). On 1st September 1983 the reserve was handed over to the Bophuthatswana National Parks Board (HO operations manual 1999).

A large extent of the terrain had, up to that time, been used as cattle farms and as a result, leaving the veld degraded (HO operations manual 1999). Factors such as over-grazing and erosion were very apparent; the occurrence of invasive alien plants and trees was also a sign of this over utilization. Major clean up ensued and on the 1st April 1984 Borakalalo National Park was proclaimed a National Park of Bophuthatswana and was re-opened on 2nd November 1984 to the public.

2.2.1.2 Restocking of animals

Restocking occurred during the restoration of the park, and animals that had previously occurred in the area were reintroduced (HO operations manual 1999). Most of the re-introduced species came from Pilanesberg National Park and now Borakalalo National Park is home to more than 30 large mammal species (Table 2.4).

2.2.2 Climate

Climate largely determines the geographic dispersion of species and distribution of vegetation types (Tainton & Hardy 1999). A more direct relation to this is to look on a smaller scale at the microclimate of a particular region, which is significantly affected by the topography of that region (Tainton & Hardy 1999).

The study area is situated in a region characterised by summer rainfall, which ranges from between 350 mm to 650 mm per year. The temperatures vary between -8°C and 40°C, with an average of 21°C (van Rooyen & Bredenkamp 1998). Climatic data for Borakalalo National Park was obtained from the South African Weather Bureau.

2.2.2.1 Rainfall

Water is essential for plant growth and development. Rainfall is the most important factor that governs the distribution and growth of plant communities in South Africa (Tainton & Hardy 1999). South Africa is generally considered a dry country (Tainton & Hardy 1999).

Jericho weather station (Station number: 0549530 4; S -25.3320 E 27.8000; Altitude: 1065 m above sea level) was the nearest station that could provide rainfall data and was considered appropriate to Borakalalo National Park as it is situated approximately 16 km south-south west of Borakalalo National Park . The rainfall is divided into two separate data sets, namely: short-term and long-term rainfall data (Table 2.2).

The short-term rainfall (Table 2.2) was determined for the three rainfall seasons from July 2008 to June 2011. The long-term rainfall (Table 2.2) was determined from July 1991 to June 2011. The mean annual rainfall for the short-term was 718 mm. The mean annual rainfall for the long-term was 555 mm. The highest mean monthly short-term rainfall of 172 mm occurred during January, and the lowest mean monthly short-term rainfall of 0 mm occurred during August. The highest mean monthly long-term rainfall of 146 mm occurred during January and the lowest mean monthly long-term rainfall of 1 mm occurred during August.

Figure 2.6 graphically depicts Table 2.2 showing short and long term rainfall patterns for this area.

Table 2.2: Rainfall data for the Jericho weather station (Station number: 0549530 4; S -25.3320 E 27.8000; Altitude: 1065 m above sea level).

Month	Short-term rainfall (mm) Monthly mean	Long-term rainfall (mm) Monthly mean
July	4	4
August	0	1
September	11	11
October	53	54
November	64	66
December	123	77
January	172	146
February	26	67
March	112	72
April	115	40
May	25	10
June	14	6
Total	**718**	**555**

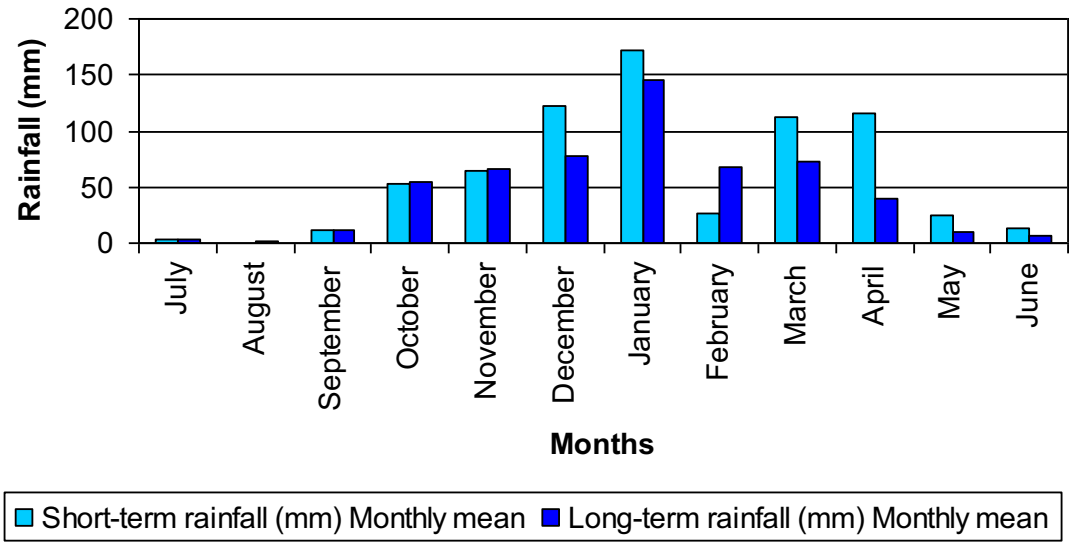


Figure 2.6: Short and long term rainfall patterns for Jericho.

2.2.2.2 Temperature

Jericho weather station only recorded daily rainfall data. Temperature data was thus taken from the next nearest weather station which was Pilanesberg weather station (Station number: 0548375A4; S -25.2610 E 27.2280; Altitude: 1085 m above sea level)(Table 2.3). Pilanesberg weather station is situated approximately 63 km west by south-south west of Borakalalo National Park. The mean annual temperature over a period of 20 years (1991 - 2011) was 20°C. The amplitude between the highest mean monthly temperature of 25°C and the lowest mean monthly temperature of 12°C is 13°C. The average maximum daily temperatures over 20 years were recorded during December and the minimum daily temperatures during July.

Table 2.3: Temperature data for the Pilanesberg weather station (Station number: 0548375A4; S -25.2610 E 27.2280; Altitude: 1085 m above sea level).

Month	Mean monthly maximum Temperature (°C)	Mean monthly minimum Temperature (°C)	Mean monthly Temperature (°C)
July	22	3	12
August	25	6	16
September	29	11	20
October	31	16	23
November	30	17	24
December	31	18	24
January	31	19	25
February	31	18	25
March	30	16	23
April	27	12	20
May	25	7	16
June	22	3	13

Figure 2.7 graphically depicts Table 2.3 showing the mean monthly temperatures over a 20 year period (1991 – 2011). The line indicates the trend of the mean temperature for this period.

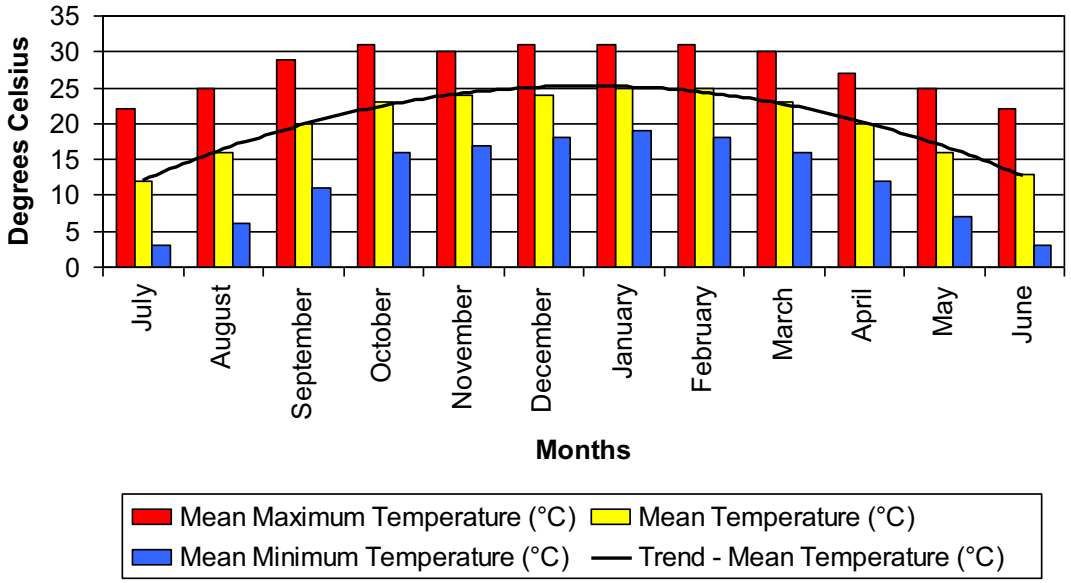
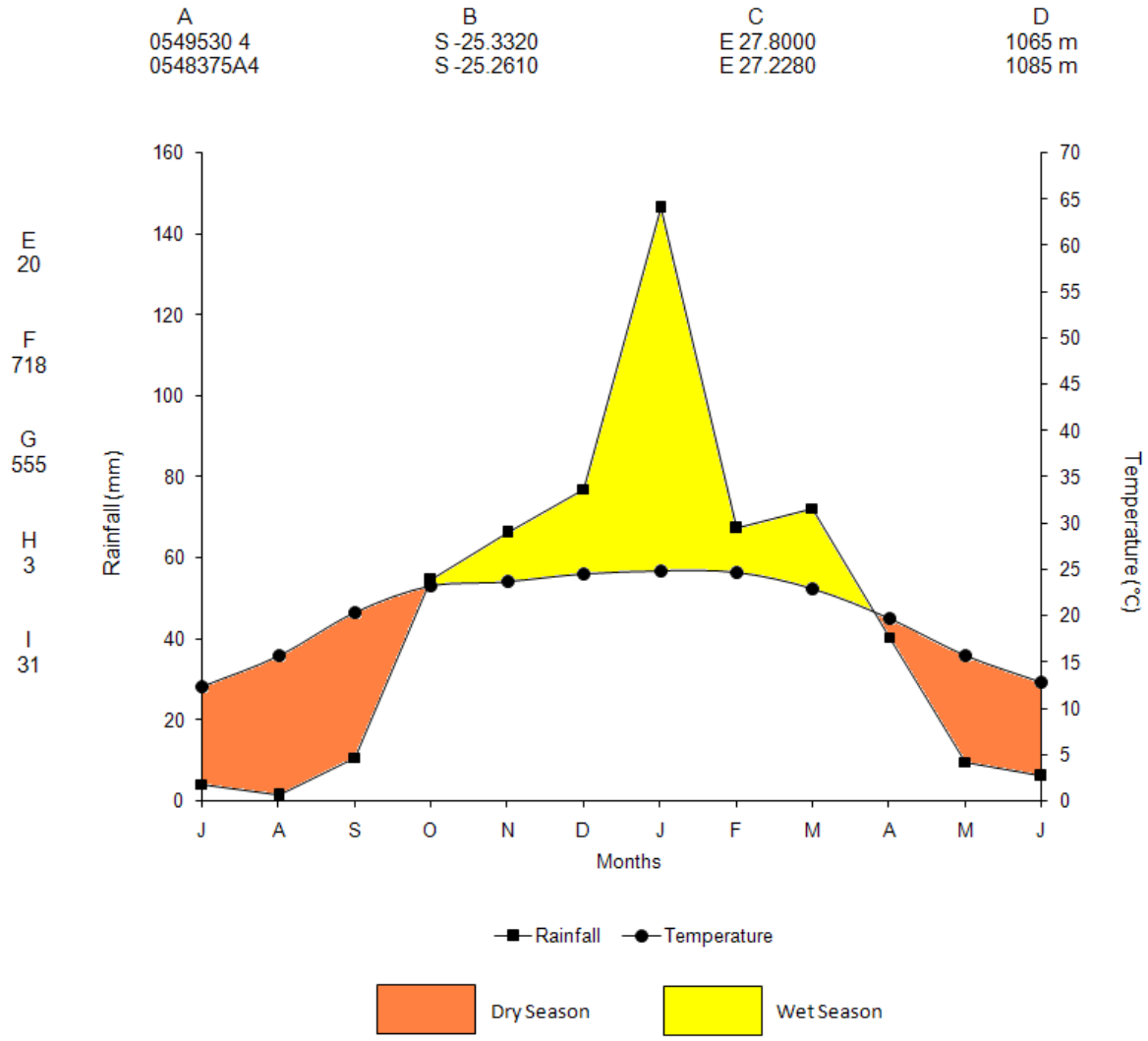


Figure 2.7: Mean temperatures from the Pilanesberg weather station.

The climatic data, rainfall and temperature, representative of Borakalalo National Park was diagrammed according to Walter & Lieth (1960) convention (Figure 2.8). This climate diagram indicates that the dry season extends from late April through to early October and the wet season extends from late October to early April.



A = Station number
B = Latitude
C = Longitude
D = Altitude (m)
E = Mean annual temperature (°C)
F = Mean annual short-term rainfall (mm)
G = Mean annual long-term rainfall (mm)
H = Mean daily minimum temperature (°C)
I = Mean daily maximum temperature (°C)

Figure 2.8: Climatic diagram for temperature (°C) and rainfall (mm) as determined from data of the Jericho and Pilanesberg weather stations following Walter & Lieth (1960).

2.2.3 Fauna

Table 2.4 lists most of the large mammals that can be found in Borakalalo National Park. Over 30 large mammals occur in the park, some of which are thriving within the park. There are no large resident predators, however Leopard do enter the reserve at times, but predators such as the Brown hyena, black-backed jackal and caracal are resident in the park.

Table 2.4: Large mammal species that occur in Borakalalo National Park.
List obtained from NWP&TB web site. Common names from Skinner & Chimimba (2005).

Scientific Name	English	Afrikaans	Setswana
Aepyceros melampus	Impala	Rooibok	Phala
Alcelaphus buselaphus	Red Hartebeest	Rooihartbees	Kgama
Canis mesomelas	Black-backed Jackal	Rooijakkals	Phokobjê
Caracal caracal	Caracal	Rooikat	Thwane
Ceratotherium simum	Square-Lipped (White) Rhino	Witrenoster	Tshukudu
Connochaetes taurinus	Blue Wildebeest	Blouwildebees	Kgôkông
Damaliscus dorcas phillipsi	Blesbok	Blesbok	Nônê
Damaliscus lunatus	Tsessebe	Baster hartbees	Tshêsêbê
Equus burchelli	Burchell's Zebra	Bontkwagga	Pitse
Giraffa camelopardalis	Giraffe	Kameelperd	Thutlwa
Hippopotamus amphibius	Hippopotamus	Seekoei	Kubu
Hippotragus equinus	Roan Antelope	Bastergemsbok	Kwalata
Hippotragus niger	Sable Antelope	Swartwitpens	Kukurugu
Kobus ellipsiprymnus	Waterbuck	Waterbok	Motomuga
Oreotragus oreotragus	Klipspringer	Klipspringer	Kololo
Oryx gazella	Gemsbok	Gemsbok	Kukama

Scientific Name	English	Afrikaans	Setswana
Panthera pardus	Leopard	Luiperd	Nkwê
Papio hamadryas	Chacma Baboon	Kaapse Bobbejaan	Tshwêne
Parahyaena brunnea	Brown Hyena	Bruin hiëna	Phiritshwana
Phacochoerus africanus	Warthog	Vlakvark	Kalobê
Potamochoerus larvatus	Bushpig	Bosvark	Kolobê yanaga
Proteles cristatus	Aardwolf	Aardwolf	Mmabudu
Raphicerus campestris	Steenbok	Steenbok	Phudufudu
Redunca arundinum	Common Reedbuck	Rietbok	Sebogata
Redunca fulvorufula	Mountain Reedbuck	Rooiribbok	Phele
Sylvicapra grimmia	Grey/Common Duiker	Duiker	Photi
Syncerus caffer	Cape Buffalo	Kaapse Buffel	Nare
Taurotragus oryx	Eland	Eland	Phôfu
Tragelaphus angasii	Nyala	Njala	Tsama
Tragelaphus scriptus	Bushbuck	Bosbok	Serôlôbotlhoko
Tragelaphus strepsiceros	Kudu	Koedoe	Thôlô
Vulpes chama	Cape Fox	Silwevos	Lesiê

Priority species, also referred as Very Important Species (VIS), are identified by the North West Parks and Tourism Board (NWP&TB) as rare, and are constantly monitored by park officials and NWP&TB Honorary Officers. Species such as the white rhinoceros, brown hyena, sable, roan antelope, tsessebe and buffalo are monitored to some degree. All the VIS mentioned above occur in Borakalalo National Park.

Borakalalo has a large biodiversity of bird life, with over 320 recorded species of bird inhabiting the park. Many waterfowl inhabit the shores of the Klipvoor dam and the riverine bush along the Moretele River.

The Klipvoor dam houses a variety of fish species. Five edible species occur in the dam, they include indigenous fish *Clarias gariepinus* (Sharp tooth catfish), *Schilbe intermedius* (mackerel), *Oreochromis mossambicus* (Mozambique tilapia) and *Barbus marequensis* (yellowfish) and the exotic *Cyprinus carpio* (carp) (Matthews 1991).

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Chapter 3

Vegetation Description of Tsessebe Home Range in Borakalalo National Park

3.1 Introduction

Plant species that grow together in a certain environment typically have similar needs for light, temperature, water, soil and geology (Bredenkamp & Brown 2002). Plants that are associated and located in a distinct habitat are referred to as a plant community (Bredenkamp & Brown 2002). Plant communities can be distinct and easily separated into vegetation units that are associated with particular environmental conditions, or vegetation can occur in gradients where one plant community grades into another without any sharp boundaries (Bredenkamp & Brown 2002). Plant communities encapsulate the whole floristic diversity, which includes, environmental fluctuations, the dispersal and existence of rare and endangered species, animal habitats and the impact of humans (Bredenkamp & Brown 2002). The study of plant communities as ecological units is fundamental to environmental and conservation management plans. A detailed record of plant communities and their species compositions provide valuable information for managers to make scientifically based decisions (Bredenkamp & Brown 2002).

The environment and its vegetation form habitats that animals use. Because of the relationship between plants, animals and the environment, the distinctive combinations of plant communities determine whether specific animal species occur in such habitats or not (Bredenkamp *et al.* 2001).

Grasses have distinct growth conditions that they are adapted to and if these change, their density could be affected. According to van Oudtshoorn (2004), grasses are regarded as good indicators of veld condition due to their sensitivity, and are used to determine the condition of the veld.

The veld condition index denotes the physical condition of the veld in terms of features such as forage, fuel production, plant species composition and the susceptibility to soil erosion (van Rooyen 2002). In essence a veld condition assessment focus is on the herbaceous layer, and more particularly on grasses within a defined vegetation community (van Rooyen 2002). The step point method (Evans & Love 1957) is used to determine the plant species composition and the percentage frequency of each species (van Rooyen 2002). Grasses are classified by their ecological status or grazing value. The ecological status is determined by a species' response to grazing pressure (van Rooyen 2002). Grazing pressure is determined by the palatability of the grass species and the preference to it by grazers (van Rooyen 2002). Ecological classes (Table 3.1) are used to determine the ecological status of a grass species.

Table 3.1: Description of the veld condition index ecological classes (adapted from van Oudtshoorn 2004).

Group	**Description**
Decreasers -	Grasses that are plentiful in good veld, in veld that is over- or undergrazed they decrease in number. Palatable climax grasses.
Increaser 1 -	Grasses that is plentiful in underutilized veld, usually unpalatable, robust climax species that grow without any defoliation by grazers.

Increaser 2 -	Grasses that are plentiful in overgrazed veld, they increase because of the disturbance caused by overgrazing. Include mostly pioneer and subclimax species. Many viable seeds are produced allowing these grasses to rapidly establish new shoots on bare ground. In lower rainfall areas, this group is common.
Increaser 3 -	Grasses that are frequently found in overgrazed veld, and are typically unpalatable, dense climax grasses. They increase because they are strong competitors and overgrow the palatable grasses that are weakened due to overgrazing. In higher rainfall areas this group is common.

Studies done by Brown & Bredenkamp (1994) had described the phytosociology of the southern section of Borakalalo, Brown *et al*. (1995) had described the phytosociology of the western section of the reserve, and Brown *et al*. (1996) had described the phytosociology of the northern section. Brown (1997) had also determined veld conditions and grazing capacities as well as structural species size (SPIZE) classes for the entire park.

The following objectives were set for this study:

- Determine the vegetation composition within a tsessebe's home range.
- Assess the different height classes of trees within the tsessebe's home range.
- Determine the veld condition of the tsessebe's home range.

3.2 Methods

Based on the floristic methods of studies previously done in Borakalalo National Park (Brown & Bredenkamp 1994, Brown *et al*. 1995, Brown *et al*. 1996), and for consistency, it was decided that the Braun-Blanquet method (Mueller-Dombois &

Ellenberg 1974) would be used for this study. According to Du Preez (1991), the phytosociological approach proposed by Braun-Blanquet has been successfully used to classify plant communities in South African vegetation biomes since 1969.

3.2.1 Plot samples

Using a 1:50 000 aerial photograph and the vegetation map produced by Brown (1997), as well as waypoints collected from collared tsessebe, a total of 26 sample plots were placed in astratified random manner within the home range of the tsessebe. The co-ordinates of the selected plots were recorded and the corresponding points were located in the field using a GPS. In the general area of each GPS point, a plot of 20m x 20m (400m^2) was demarcated (Figure 3.1). A waypoint was taken at a corner marker for each plot so that the plots could be relocated if need be.

Figure 3.1: A 20m X 20 m plot demarcated for the vegetation survey.

3.2.2 Veld Condition Index (VCI)

Within each plots' boundary, the step point method was used to determine the veld condition index. Using a steel rod as a marker, the rod's tip was placed on the ground after every two step interval (Figure 3.2 a), recording a "hit". The vegetation that was either directly under the rod's tip or the first closest species

to the rod was recorded (Figure 3.2 b). A total of 200 hits were recorded in each plot. For each hit either a grass or forb species was noted on a data collection sheet for later analysis. Grasses were identified using the Guide to Grasses of South Africa (van Oudtshoorn 2004).

a) **b)**

Figure 3.2: Step point method: a) The marker tip being placed on the ground after two steps. b) Nearest vegetation species to the marker was identified.

Table 3.2 indicates the grass species that occurred within the study area, grouped in their ecological classes along with their grazing values as obtained from van Rooyen (2002).

Table 3.2: Grasses found in the study area during this study, in their respective ecological groups and with their assigned grazing values (van Rooyen 2002).

Group	Grass species	Grazing value
Decreaser	*Brachiaria nigropedata*	10
	Digitaria eriantha	10
	Panicum maximum	10
	Schmidtia pappophoroides	10
	Themeda triandra	10
Increaser 1	*Cymbopogon pospischilii*	2
Increaser 2	*Urochloa mosambicensis*	7
	Eragrostis superba	5
	Heteropogon contortus	5
	Chloris virgata	4
	Eragrostis curvula	4
	Eragrostis lehmanniana	4
	Sporobolus nitens	4
	Tricholaena monachne	4
	Dactyloctenium aegyptium	2
	Eragrostis rigidior	1
	Perotis patens	1
	Pogonarthria squarrosa	1
Increaser 3	*Aristida congesta* subsp. *barbicollis*	1
	Aristida congesta subsp. *congesta*	1
	Aristida stipitata	1
	Cynodon dactylon	1
	Melinis repens	1

3.2.3 Structural analysis

Within the boundary of each plot, all tree species were identified using the Field guide to trees of South Africa (Van Wyk & Van Wyk 1997). Following Emslie (1991) and Brown (1997), each tree was classed into one of three height classes:

- Lower class - less than one metre high (< 1 m.).
- Middle class - one metre to three metres high (1 - 3 m.).
- Upper class - higher than three metres (>3 m).

A three-metre telescopic pole marked with one-metre increments was used to measure tree height. The pole was placed next to each tree and the height class was recorded (Figure 3.3).

Figure 3.3: Determination of height classes for trees.

3.2.4 Data analysis

Floristic data was captured into the floristic database TURBOVEG (Hennekens 1998). The data was then exported to JUICE (Tichý 2002) and analysed using the modified Two-way indicator species analysis multivariate classification technique (TWINSPAN) (Hill 1979). This classification technique numerically classifies the recorded vegetation data into an initial approximation of the main

plant communities occurring in the study area (Hill 1979). Further refinement was achieved by following Braun-Blanquet procedures. Plant communities were recognised by using diagnostic and/or characteristic species as defined by Kent & Coker (1992).

The densities of the different woody species in each height class were converted to individuals per hectare and are represented in bar charts for each community. All the veld condition data belonging to a plant community were grouped together, and the Veld Condition Index was determined for each of the different plant communities identified using the Ecological Index Method (Foran *et al*. 1978). This data was incorporated into a model called Graze (Brown 1997), that is used to calculate the grazing capacity for each plant community.

3.3 Results

3.3.1 Plant communities

A detailed vegetative analysis of the study area resulted in the identification of five plant communities (Figure 3.4).

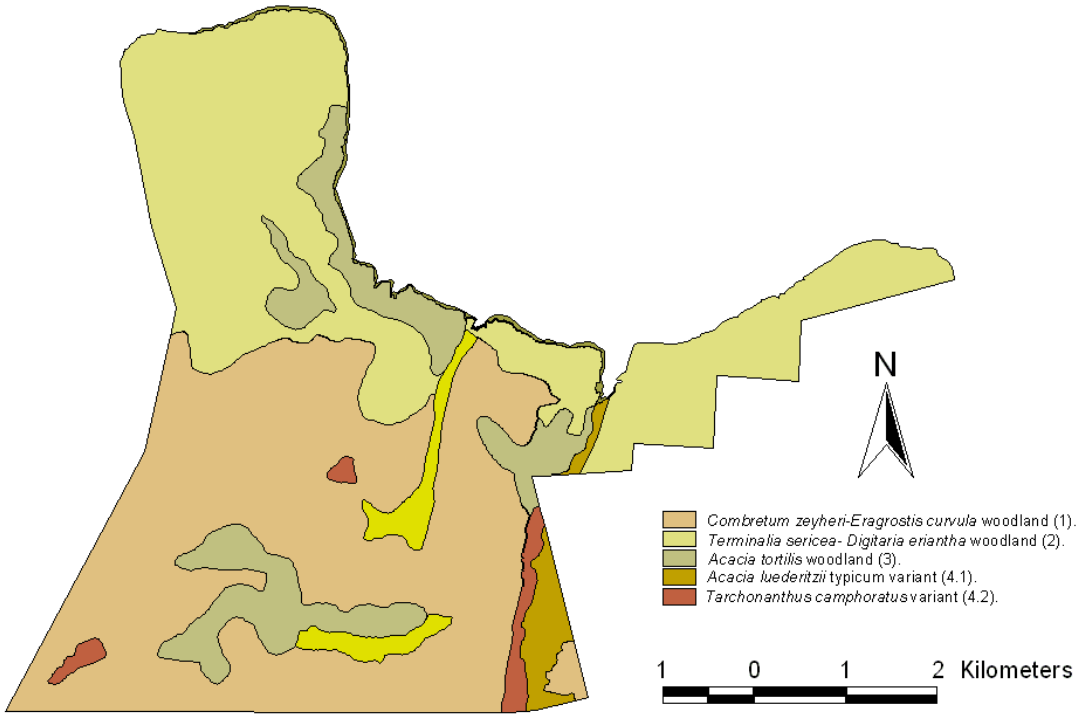

Figure 3.4: Vegetation map for the southern section of Borakalalo National Park.

The five communities can be grouped into four major community types with two variants for community four (Table 3.3):

1. *Combretum zeyheri-Eragrostis curvula* woodland
2. *Terminalia sericea-Digitaria eriantha* woodland
3. *Acacia tortilis* woodland
4. *Acacia luederitzii* woodland

4.1 *Acacia luederitzii* typicum variant

4.2 *Tarchonanthus camphoratus* variant

1. *Combretum zeyheri-Eragrostis curvula* woodland.

This woodland was associated with coarse-grained granite soil. Large boulders were found in some places. Little or no erosion was evident and the area was mostly level with a slight northern slope. This community covered 1 119 ha and comprised of approximately 37% of the study area.

This community was characterized by species from species group A (Table 3.8). The woody layer was dominated by the tree *Combretum zeyheri* (species group A), while the herbaceous layer was dominated by the grasses *Panicum maximum* (species group G) and *Eragrostis curvula* (species group A). The shrubs *Grewia flava* (species group D), *Dichrostachys cinerea* (species group G), and the grasses *Eragrostis rigidior* (species group G), *Pogonarthria squarrosa* (species group D) were locally prominent, while *Melinis repens* (species group D) was present throughout this community.

The species composition of this community was similar to that found by Brown & Bredenkamp (1994), who classified it as *Combretum apiculatum-Clerodendrum ternatum* woodland, the major difference being the absence of the tree *Combretum apiculatum* within the survey plots for this community. Brown & Bredenkamp (1994) did however also find areas within this community where *C. apiculatum* was absent, but similar to this study the rest of the species corresponded to the larger classification.

The woody layer covered 5% - 15%, the grass layer covered 5% - 15% and forbs covered 30% of the plots. *Terminalia sericea* covered up to 70% of the total plots and *Digitaria eriantha* covered up to 15% of the total plots.

Density distribution was determined and represented in Figure 3.5. This community had a total density of 454 individuals per hectare (ind/ha) (Table 3.3).

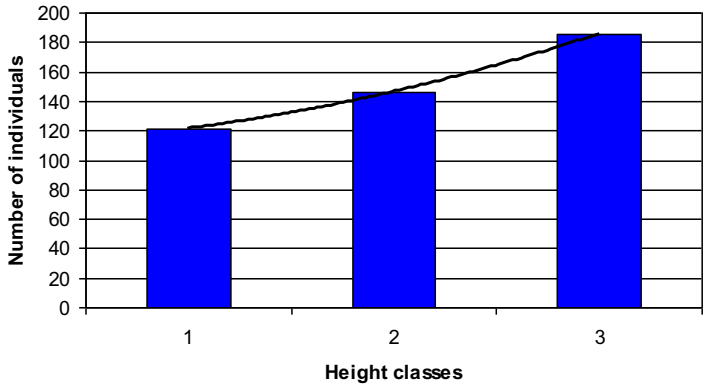

Figure 3.5: Density distribution of the various height classes in community 1.

1 = lower class, 2 = middle class, 3 = upper class.

Table 3.3: Quantitative data for woody species for community 1.

Woody species (1)	**Lower class** ind/ha	**Middle class** ind/ha	**Upper class** ind/ha	**Total ind/ha**
Terminalia sericea	82	68	157	307
Dichrostachys cinerea	14	39	18	71
Combretum apiculatum	0	25	0	25
Acacia tortilis	14	4	4	22
Acacia mellifera	7	4	4	15
Grewia flava	4	7	0	11
Peltophorum africanum	0	0	4	4
Total	**121**	**146**	**186**	**455**

Veld condition score for this plant community was 43.1 %.

2. *Terminalia sericea-Digitaria eriantha* woodland.

This woodland was associated with deep sandy soil. Surface erosion was evident in places. The area was mostly level with a slight northern slope. This community covered 854 ha and comprised of approximately 28% of the study area.

This community was characterized by species from species group B (Table 3.8). The woody layer was dominated by the trees *Combretum apiculatum* (species group B) and *Terminalia sericea* (species group B), while the herbaceous layer was dominated by the grasses *Digitaria eriantha* (species group G) and *Perotis patens* (species group G). The grasses *Brachiaria nigropedata* (species group B), *Pogonarthria squarrosa* (species group D), *Eragrostis rigidior* (species group G) and *Panicum maximum* (species group G) were locally prominent.

The species composition of this community was similar to that found by Brown & Bredenkamp (1994), who classified it as the *Eragrostis pallens-Terminalia sericea* woodland, having two variants namely *Eragrostis pallens-Terminalia sericea-Burkea Africana* woodland variants and *Eragrostis pallens-Terminalia sericea-Cleome maculate* mixed woodland variant. These two variants had a mosaic distribution.

The woody layer covered 15% - 30%, the grass layer covered 5% - 20% and forbs covered 25% of the plots. *Dichrostachys cinerea* covered up to 30% of the total plots and *Eragrostis rigidior* covered up to 20% of the total plots.

Density distribution was determined and represented in Figure 3.6. This community had a total density of 475 ind/ha (Table 3.4).

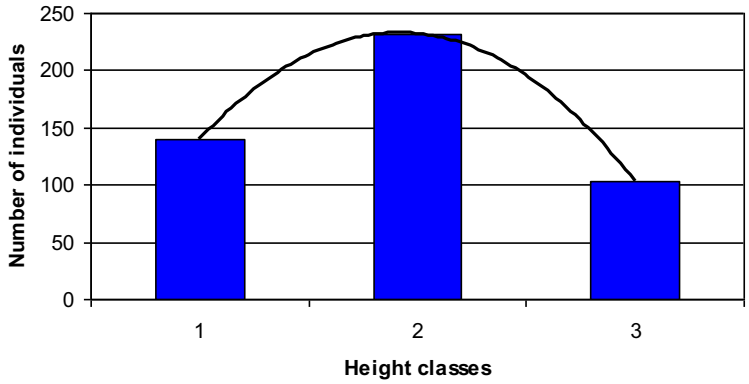

Figure 3.6: Density distribution of the various height classes in community 2.
1 = lower class, 2 = middle class, 3 = upper class.

Table 3.4: Quantitative data for woody species for community 2.

Woody species (2)	**Lower class** ind/ha	**Middle class** ind/ha	**Upper class** ind/ha	**Total ind/ha**
Dichrostachys cinerea	36	86	11	133
Combretum apiculatum	86	14	7	107
Grewia flava	4	100	4	108
Acacia tortilis	0	7	54	61
Terminalia sericea	11	18	21	50
Acacia caffra	0	0	7	7
Tarchonanthus camphoratus	4	4	0	8
Peltophorum africanum	0	4	0	4
Total	**139**	**232**	**104**	**478**

Veld condition score for this plant community was 53.3 %.

3. *Acacia tortilis* woodland.

This woodland was associated with coarse-grained soil derived from granite. Mild surface erosion was evident in places and the slope was slightly northern. This community covered 271 ha and comprised of approximately 9% of the study area.

This woodland was characterized by the species belonging to species group C (Table 3.8). The vegetation was dominated by the tree *Acacia tortilis* (species group C). The herbaceous layer was dominated by the grass *Panicum maximum* (species group G), while *Eragrostis rigidior* and *Cynodon dactylon* (species group G) were locally prominent.

The woody layer covered 10% - 20%, the grass layer covered 5% - 15% and forbs covered 30% of the plots. *Dichrostachys cinerea* covered up to 40% of the total plots and *Panicum maximum* covered up to 30% of the total plots.

Density distribution was determined and represented in Figure 3.7. This community had a total density of 545 ind/ha (Table 3.5).

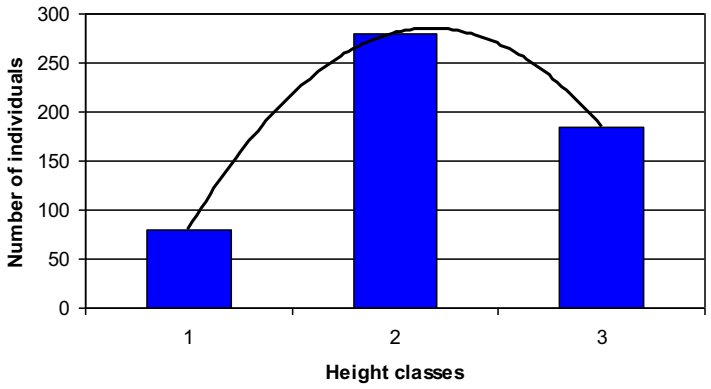

Figure 3.7: Density distribution of the various height classes in community 3.
1 = lower class, 2 = middle class, 3 = upper class.

Table 3.5: Quantitative data for woody species for community 3.

Woody species (3)	**Lower class** ind/ha	**Middle class** ind/ha	**Upper class** ind/ha	**Total ind/ha**
Dichrostachys cinerea	35	90	105	230
Acacia luederitzii	10	70	35	115
Acacia tortilis	5	75	15	95
Acacia mellifera	10	10	30	50
Grewia flava	20	15	0	35
Peltophorum africanum	0	10	0	10
Tarchonanthus camphoratus	0	5	0	5
Opuntia ficus-indica	0	5	0	5
Total	**80**	**280**	**185**	**545**

Veld condition score for this plant community was 49.9 %.

4. *Acacia luederitzii* woodland.

This woodland was characterized by species belonging to species group E (Table 3.8). The vegetation was dominated by the tree *Acacia luederitzii* (species group E), while *Acacia mellifera* (species group E) was locally prominent. The herbaceous layer was dominated by the grass *Digitaria eriantha* (species group G). The grasses *Eragrostis rigidior* (species group G) *and Panicum maximum* (species group G) were locally prominent. The shrub *Dichrostachys cinerea* (species group G) and the grass *Urochloa mosambicensis* (species group C) were locally present.

Veld condition score for this plant community was 58.3 %.

This woodland could be divided into two variants namely the *Acacia luederitzii* typicum variant (4.1) and the *Tarchonanthus camphoratus* variant (4.2).

4.1 *Acacia luederitzii* typicum variant.

Soil in this sub-community had sandy to course grained soils. Slight erosion was evident in places and the slope was slight. This sub-community covered 45 ha and comprised of approximately 2% of the home range.

The prominence of *Acacia luederitzii* (species group E) and *Acacia mellifera* (species group E) in the woody stratum is characteristic. *Searsia lancea* (species group E) and *Ziziphus mucronata* (species group E) were locally present.

This sub-community corresponds to the *Eragrostis gummiflua-Terminalia sericea* woodland described by Brown & Bredenkamp (1994), who described *Terminalia sericea* and *Dichrostachys cinerea* as dominant.

The woody layer covered 10% - 20%, the grass layer covered 10% - 20% and forbs covered 20% of the plots. *Acacia luederitzii* covered up to 30% of the total plots and *Eragrostis rigidior* covered up to 30% of the total plots.

Density distribution was determined and represented in Figure 3.8. This community had a total density of 733 ind/ha (Table 3.6).

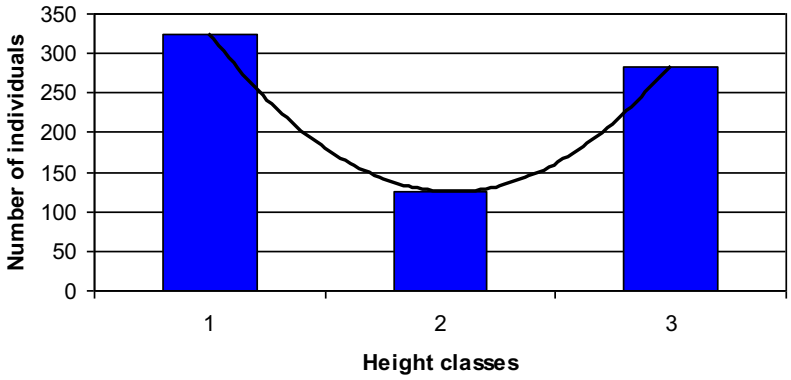

Figure 3.8: Density distribution of the various height classes in community 4.1.
1 = lower class, 2 = middle class, 3 = upper class.

Table 3.6: Quantitative data for woody species for community 4.1

Woody species (4.1)	**Lower class** ind/ha	**Middle class** ind/ha	**Upper class** ind/ha	**Total ind/ha**
Acacia luederitzii	100	8	108	216
Dichrostachys cinerea	75	33	50	158
Acacia mellifera	8	25	100	133
Grewia flava	67	25	0	92
Acacia tortilis	42	8	17	67
Searsia lancea	17	8	0	25
Ziziphus mucronata	8	17	0	25
Acacia karroo	8	0	8	17
Total	**325**	**125**	**283**	**732**

The veld condition score for this sub-community was 48.8 %.

4.2 *Tarchonanthus camphoratus* variant.

Soil in this sub-community had a sandy to clayish texture, with clayish soils having sodic properties. Erosion and slope were minimal. This sub-community occurred within or close to dry river beds. This sub-community covered 39 ha and comprised of approximately 1% of the home range.

This sub-community was characterised by the presence of species from species group F and was dominated by the shrub *Tarchonanthus camphoratus* (species group F).

This community corresponded to the *Tarchonanthus camphoratus-Acacia luederitzii* woodland described by Brown & Bredenkamp (1994), who also found that *Tarchonanthus camphoratus* had a mosaic distribution and was absent in some areas.

The woody layer covered 10% - 30%, the grass layer covered 5% - 10% and forbs covered 25% of the plots. *Acacia luederitzii* covered up to 30% of the total plots and *Digitaria eriantha* covered up to 30% of the total plots.

Density distribution was determined and represented in Figure 3.9. This community had a total density of 983 ind/ha (Table 3.7).

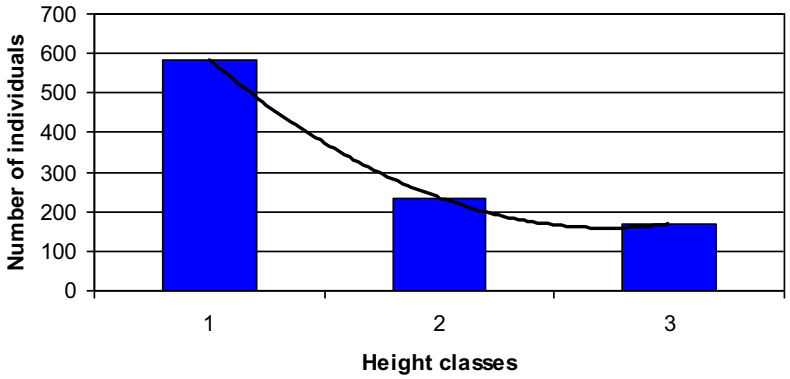

Figure 3.9: Density distribution of the various height classes in community 4.2.

1 = lower class, 2 = middle class, 3 = upper class.

Table 3.7: Quantitative data for woody species for community 4.2.

Woody species (4.2)	**Lower class** ind/ha	**Middle class** ind/ha	**Upper class** ind/ha	**Total ind/ha**
Acacia luederitzii	267	8	8	283
Tarchonanthus camphoratus	250	0	0	250
Dichrostachys cinerea	50	117	33	200
Grewia flava	0	67	33	100
Acacia mellifera	0	8	58	66
Combretum zeyheri	0	0	25	25
Acacia karroo	8	8	0	16
Searsia lancea	0	8	8	16
Acacia tortilis	0	8	0	8
Searsia pyroides	0	8	0	8
Ziziphus mucronata	8	0	0	8
Total	**583**	**233**	**167**	**980**

The veld condition score for this sub-community was 67.8 %.

Table 3.8: Phytosociological table of the vegetation for the study area.

Community number	**1**							**2**							**3**					4						
																				4.1			**4.2**			
Relevé number	**1**		**1**	**1**	**1**	**2**	**2**	**1**	**2**		**1**	**1**	**1**		**1**	**2**	**2**	**2**								**1**
	1	**6**	**5**	**7**	**9**	**0**	**1**	**6**	**4**	**8**	**9**	**0**	**3**	**4**	**2**	**2**	**3**	**5**	**7**	**1**	**2**	**3**	**4**	**5**	**8**	
Species Group A																										
Aristida stipitata	+	.	+	.	1	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Combretum zeyheri	1	.	1	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Eragrostis curvula	.	b	a	.	b	1	.	.	+	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.
Searsia pyroides	.	.	r	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Aristida congesta subsp. *congesta*	.	.	.	1	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Species Group B																										
Combretum apiculatum	.	.	.	.	.	.	.	.	.	a	.	1	a	.	.	.	.	.	.	.	.	.	.	.	.	.
Peltophorum africanum	+	.	.	.	.	.	.	.	r	r	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Terminalia sericea	b	.	.	.	.	.	.	.	.	1	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.
Heteropogon contortus	+	.	.	.	.	.	.	.	+	.	+	r	1	+	.	.	.	.	.	.	.	.	.	.	.	.
Tricholaena monachne	.	.	+	.	.	.	.	1	.	.	+	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Opuntia ficus-indica	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Brachiaria nigropedata	.	.	.	.	.	.	.	a	+	.	.	+	1	+	.	.	.	.	.	.	+	+	.	b	1	.

Table 3.8 continued:

Species Group C																															
Acacia tortilis	.	.	.	1	.	.	.	.	.	.	.	.	.	.	r	b	3	1	4	1	.	+	+	.	.	.					
Chloris virgata	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	1	.	.	.	.	.	.	+	.	.	.					
Urochloa mosambicensis	.	.	.	.	.	.	.	.	.	.	.	+	.	+	.	3	+	1	.	.	.	.	+	.	.	.					
Dactyloctenium aegyptium	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.					
Aristida congesta subsp. *barbicollis*	.	.	.	.	.	.	.	.	1	+	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.					
Species Group D																															
Grewia flava	.	1	1	1	.	.	.	.	+	r	.	.	+	.	r	1	a	.	+	+	.	.	.	.	.	.					
Melinis repens	+	+	+	+	+	1	+	1	+	+	+	+	.	+	.	.	1	.	.	.	.	.	+	.	.	+					
Pogonarthria squarrosa	+	+	.	1	+	.	b	.	+	+	+	1	+	b	.	.	.	.	.	.	.	.	+	.	.	.					
Species Group E																															
Acacia luederitzii	.	1	.	+	.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	.	1	+	r	+	3	+					
Acacia mellifera	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	1	.	+	+	.	a					
Searsia lancea	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	+	.	.	.	.	+					
Ziziphus mucronata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	r	r	.	.					
Species Group F																															
Tarchonanthus camphoratus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	r	.	.	r	.	.	.	1	3	a					
Schmidtia pappophoroides	.	+	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	r	1	.	.					
Cymbopogon pospischilii	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	+	.	.	.	1	b	.					
Eragrostis superba	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.					

Table 3.8 continued:

Sporobolus nitens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	a	.
Combretum hereroense	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r
Acacia karroo	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	r	r	.	.
Eragrostis lehmanniana	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	+	1	.	.	.	.	.	1	1	.
Acacia caffra	.	.	+	.	.	.	.	.	.	r	.	.	.	.	.	.	+	.	.	.	.	.	.	.	a
Themeda triandra	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.
Species Group G																									
Eragrostis rigidior	.	.	.	3	+	b	a	.	a	+	b	.	+	r	+	1	b	a	b	b	1	3	.	.	1
Dichrostachys cinerea	+	r	1	a	.	.	.	.	+	+	.	a	1	+	+	+	1	+	+	.	r	r	+	.	.
Panicum maximum	1	+	+	1	+	1	1	1	a	1	.	r	1	+	b	a	a	3	+	.	1	1	.	.	1
Digitaria eriantha	.	.	1	a	.	a	1	a	.	b	+	a	3	1	.	.	.	+	+	1	+	b	3	a	1
Perotis patens	.	.	+	.	+	.	+	1	+	1	+	1	.	a	.	.	.	1	.	.	1	r	a	.	.
Cynodon dactylon	.	.	.	.	.	+	.	.	a	1	1	1	.	.	.	1	1	1	.	a	1	.	.	.	.

3.3.2 Veld Condition Index (VCI)

Veld condition was calculated for each vegetation community. Table 3.9 depicts the values for each ecological group. A total VCI presented as a percentage is represented bellow.

Table 3.9: Veld Condition Index values for each of the plant communities.

Plant community	**1**	**2**	**3**	**4**	**4.1**	**4.2**
Decreasers	319	478	323	478	188	290
Increasers 1	0	7	11	64	0	64
Increasers 2	620	506	353	392	222	170
Increasers 3	269	242	219	140	134	6
Forbs	192	167	94	126	56	70
Total	1400	1400	1000	1200	600	600
Veld Condition Index %	**43.1**	**51.3**	**49.9**	**58.3**	**48.8**	**67.8**

3.4 Discussion

VCI values calculated in Table 3.9 were compared to VCI values calculated for the same plant communities in a previous study done by Brown (1997). VCI values for plant community 1 in the current study were 43.1 %, compared to 35.2 % for Brown (1997); there was an increase. VCI for community 2 was 51.3% compared to 34.2 % (Brown 1997), which showed an increase in condition. VCI for community 3 was 49.9% which showed an increase from 23.0% found by Brown (1997), which is just more than double the index value in a period of approximately 13 years. Community 4 obtained the highest index score with 58.3% when both sub communities were combined. Sub community 4.1 had a value of 48.8 % increasing from 36.0 % (Brown 1997) and Sub community 4.2 had a value of 67.8 % increasing from 33.3 % (Brown 1997). The increases that were obtained may have been as a result of the good rains during the years and thus increased veld production. Rainfall for the period when Brown (1997) conducted vegetation surveys was below the average rainfall of 540 mm (Brown 1997).

Generally a veld condition score of 40% or less suggests a poor veld, while a score of 40% to 60% suggests a veld in moderate condition and a score of 60% or more suggests a veld in good condition (van Rooyen 2002). Overall the veld conditions for the plant communities identified were in a moderate condition.

Community 1 was dominated by 41% of woody species in the upper class, while community 2 and 3 was dominated by 49% and 51% of woody species in the middle class respectively. Community 4.1 and 4.2 was dominated by 44% and 59% of woody species in the lower class respectively.

Community 1 was dominated by the woody species *Terminalia* sericea and the grass species *Digitaria eriantha*. Community 2 was dominated by the woody species *Dichrostachys cinerea* and the grass species *Eragrostis rigidior*. Community 3 was dominated by the woody species *Dichrostachys cinerea* and the grass species *Panicum maximum*. Community 4.1 was dominated by the woody species *Acacia luederitzii* and

the grass species *Eragrostis rigidior*. Community 4.2 was dominated by the woody species *Acacia luederitzii* and the grass species *Digitaria eriantha*.

The woody species densities of the plant communities identified, are all lower than the threshold of 1 800 ind/ha (Brown 1997), where after veld condition will deteriorate. Optimum grass production, under normal rainfall conditions, would deteriorate in these areas if densities increased above this threshold. Although denser areas exist within these communities as described by Brown (1997), it seems as though tsessebe prefer less dense areas.

Results from this study made it possible to obtain a greater knowledge of the vegetation composition in a tsessebe herd's home range within Borakalalo National Park. This study also determined the height classes for trees within these ranges and established the current veld condition in these ranges. These findings may indicate preferences tsessebe had to certain communities and are discussed in Chapter 4.

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Chapter 4

Tsessebe Home Ranges in Borakalalo National Park

4. 1 Introduction

Home range was defined by Burt (1943) as “that area traversed by the individual in its normal activities of food gathering, mating, and caring for young.” Home range estimation is a common type of spatial analysis ecologists employ because home range estimation may be a useful tool when looking at the associations animals have with their habitats. Home range estimates may also be used to determine the effects ecological constraints have on individuals or the phytosociological needs individuals place on an area (Johnson 1980, White & Garrott 1990, Aebischer *et al*. 1993, McLoughlin & Ferguson 2000, Girard *et al.* 2002).

“Utilization distribution is used to refer to the relative frequency distribution for the points of location of an animal over a period of time” (Van Winkle 1975). By quantifying the utilization distribution of an individual animal’s home range, density estimations may be made, thus Kernel density estimators make use of data points to create a smoothed surface of the animal’s utilization distribution (Downs & Horner 2007).

Naef-Daenzer (1993), Worton (1995), Seaman& Powell (1996) and Swihart & Slade (1997) had shown that the kernel method proved to have greater accuracy than either the harmonic mean or the Minimum Convex Polygon (MCP) as a home range estimator (Seaman *et al*. 1999).

Since the introduction of Global Positioning System (GPS) telemetry to wildlife monitoring, wildlife managers and researchers have been able to collect a larger

amount of spatial data sets with better accuracy than prior telemetric technology allowed (Cagnacci & Urbano 2008).

Using GPS telemetry allows for the improvement of complex ecological models (Cagnacci & Urbano 2008). Being able to understand and predict flora and fauna populations' habitat requirements ensures better management of these populations (Dörgeloh 1999). Therefore, according to Girard *et al.* (2002) it is important to gain accurate estimates for home range sizes so that they coincide with an animal's behaviour, as well as provide guidelines that may be used as a supplementary assessment between an individual, a population and even between different species.

GPS/GSM (Global System for Mobile Communications) collars make use of a cellular network to transmit GPS coordinates. This enables researchers to gather a great deal of datawithout the possible interference of humans when using Very High Frequency (VHF) radio tracking (Rahimi & Owen-Smith 2007) which requires the researchers to be within a certain range of the transmitter to obtain data.

The GPS/GSM collars are fitted with a HAWK105 device which sends the GPS coordinates at scheduled intervals. The readings are sent by SMS (short message service), and received by YRless (YRless International). These are saved on a database, and can be accessed via the internet; the data can be downloaded using Hawk Software.

A current prevalence exists in the use of kernel density estimation for utilization distribution estimates and home range studies (Kernohan *et al.* 1998) but recent studies have been using local convex hulls as an alternative (Getz & Wilmers 2004, Getz *et al.* 2007, Huck *et al.* 2008). Both kernel density estimation and local convex hulls make use of spatial coordinate data obtained from animal locations, and both can identify a range of space utilization patterns (Litchti & Swihart 2011).

Huck *et al.* (2008) found that convex hulls performed better than either kernels or MCPs when used to estimate the utilization of habitat by an animal. However it is the recommendation of Huck *et al.* (2008),that because convex hulls tend to generate smaller approximations on home range sizes compared to other methods, they should be used in conjunction with other methods to estimate the total home range.

Little information is known about tsessebe movements in Borakalalo National Park (BNP). Therefore the following objectives were set for this study:

- Determine individual home ranges for each collared tsessebe from GPS/GSM collar data.
- Determine if seasonal changes occur in the home ranges.
- Determine if tsessebe favour a particular vegetation community.
- Determine tsessebe distribution within BNP.
- Determine if tsessebe have particular movement patterns within BNP.
- Determine if the parks burn regime has an effect of on the areas utilised by the tsessebe.
- Make use of remote cameras to obtain possible behavioural information.

4.2 Methods

4.2.1 Collaring

One at a time an animal was selected to be darted. It was herded by a helicopter into a safe area (Figure 4.1). A qualified wildlife veterinarian darted an individual tsessebe from the helicopter with a mixture of ± 4 mg M99 and 25 mg Azaperone to anesthetize it (Figure 4.2). The dosages changed depending on the weight estimation of the antelope. Once the animal had fallen to the ground in was immobilized by the ground team by holding the antelope by the horns and covering the eyes with a cloth to calm the animal (Figure 4.3).

Figure 4.1: Helicopter used in the darting process.

Figure 4.2: Darted tsessebe with the anesthetising drugs taking effect.

Figure 4.3: Immobilized tsessebe with the eyes covered to minimize stress levels.

A GPS/GSM collar, custom made for the tsessebe, was attached around the neck allowing enough space for comfort and ease, and to lessen the possible stresses that the individual may endure from it. While the anesthetized animal was being collared, body measurements were taken as well as blood, tissue and hair samples were collected for genetic analysis (Figure 4.4). All of this was done in as short a period of time as possible to minimise stress put on the antelope.

Figure 4.4: Tsessebe after samples were taken and collar put on.

After all the necessary samples were collected and the collar secured, the antelope was given ± 4 mg M5050 IV as a reversal drug to allow the animal to regain consciousness (Figure 4.5). The tsessebe was observed from a short distance to ensure that it returned to a normal state and then left to return to the herd on its own accord.

Figure 4.5: The tsessebe was allowed to regain its senses and rejoin the herd.

As the darting was out of the control of the researcher the onus was upon the veterinarian to dart the requested genders. Two male and two female tsessebe were to be darted and collared. The two male bulls were meant to be territorial males and one female cow from each of the two herds. This would have served the purpose of determining if differences existed in ranges between the sexes. However because of the difficulties in determining the sex of the animals from the air during the darting of these antelope, opportunistic darting had to be done, resulting in the collaring of only the four females.

4.2.2 Satellite telemetry

Tsessebe were fitted with GPS/GSM collars from African Wildlife Tracking, Pretoria, South Africa. Table 4.1 indicates each collar with its identification code, deployment and operation information. Collar AG 55 was deployed on 24th April 2009 but subsequently

failed two months after deployment due to technical malfunction. A further four collars were then deployed on 12th September 2009. Collars weighed approximately 650 g each. Collared tsessebe were monitored for varying lengths of time, depending on collar battery life.

Table 4.1: Details for each collar used in this study.

Tsessebe	Collar ID code	Date deployed	Date stopped receiving fixes	Reason for collar stopping	No. of GPS fixes	No. of missing fixes
Female	AG 55	24/04/2009	08/06/2009	Ceased	180	3
Female	AG 81	12/09/2009	20/02/2010	Battery	2161	19
Female	AG 93	12/09/2009	20/04/2011	Poached	3248	25
Female	AG 242	12/09/2009	12/01/2011	Battery	1901	41
Female	AG 243	12/09/2009	06/08/2010	Battery	1279	13

Because collar AG 55 failed after only two months, data collected from it was not used in this study.

Initially all collars were set to download one GPS fix in the morning (06h00), one at mid-day (12h00) one in the evening (18h00) and one at mid-night (00h00). After a period of two months the collar AG 81 was changed to take a GPS fix every hour and collar AG 93 was changed to take a GPS fix every four hours. Collars AG 242 and AG 243 remained on six hourly GPS fixes.

All collars were equipped with a VHF transmitter, which allowed for periodic manual tracking of the collared tsessebe in the reserve. Manual tracking allowed the researcher to observe the individual tsessebe and to check on their condition.

Data obtained from the collars included date, time, latitude, longitude, travelling speed of the collar at time of the GPS fix, measured in kilometres per hour, direction of travel, temperature of collar, altitude and PDOP (Position Dilution of Precision) which indicated

the accuracy of the GPS location. The higher the PDOP value the less accurate the GPS fix is. An acceptable value for PDOP was three or less.

Missing fixes were as a result of not being able to establish connection with the cellular network in the allotted time of two minutes, with this short space of time it saves on battery power when the collar attempts to connect to the network. Cellular network coverage is limited in Borakalalo National Park, and therefore if tsessebe were in an area with little or no signal it was unable to send the location.

4.2.2.1 Data collection

Data was downloaded from the website www.yrless.co.za. Each collars data was downloaded in CSV (comma delimited) format for windows excel. The data was then saved as a text document and opened in ArcView 3.2

4.2.3 Spatial movements

Spatial movement diagrams were constructed from GPS fixes for each month of the study period, commencing from September 2009 until the last of the collar fixes in April 2011. The fixes were joined by a line in chronological order of day and time. The resulting line represented the monthly movements of the tsessebe in time and space. However, the time intervals were in hours and it is not presumed that each animal moved in a straight line. Lines indicate the overall average movement of the animal and can be used to draw general conclusions for assessing movement patterns within the study area.

4.2.4 Patterns of daily movements

To determine whether tsessebe made use of specific areas in their home range at specific times, data from hourly fixes obtained from AG 81 were used. One week per month from November 2009 to February 2010 was randomly chosen. Each hour of the

24 hour day was given a unique marker. Groupings of the same markers would have indicated areas utilized at the same time of day.

4.2.5 Home range estimation

Home ranges were calculated using two ArcView 3.2 (ESRI, Redlands, CA, USA) extensions i.e. Home Range Extension (Rodgers & Carr 1998) and LoCoH (Getz & Wilmers 2004). The year was split into four periods namely the late wet season (January - March), early dry season (April - June), late dry season (July - September) and early wet season (October - December).

4.2.5.1 Kernel estimates

Fixed kernel home range was selected from Home Range Extension (Rodgers & Carr 1998). 95% and 50 % isopleths were selected. The Least Square Cross Validation (LSCV), (ad hoc default) was used to calculate the smoothing factor (H). Values for each of the kernels constructed can be found in Table 4.2.

Table 4.2: LSCV values used to construct Kernels.

Period	AG 81	AG 93	AG 242	AG 243
Oct - Dec 2009	0.003128	0.004411	0.004696	0.003343
Jan - Mar 2010	0.002268	0.003566	0.001797	0.001589
Apr - Jun 2010		0.002242	0.001452	0.002323
Jul - Sep 2010		0.002645	0.001556	0.001668
Oct - Dec 2010		0.002465	0.002572	
Jan - Mar 2011		0.00152		

4.2.5.2 Local Convex Hull (LoCoH)

The Local Convex Hull (LoCoH) home range generator Arcview extension (Getz & Wilmers 2004) was used to generate home ranges for each of the four tsessebe.

LoCoH is based on the k-Nearest Neighbour Convex Hull (k-NNCH) method. Getz & Wilmers (2004) proposed a “Minimum Covering of Spurious Holes” (MCSH) rule to select the k value that covered most of the animal area of use and would minimize the areas unlikely to have been used by the animal. To determine the best k value a number of nearest neighbours was run ranging from 10 to 25. An area vs. k chart was the output thereof. Using the charts to find discontinuities in the histogram would imply possible values that would satisfy the MCSH rule. From the charts k values for each of the LoCoH analysis was selected (Table 4.3). A k value was selected that best fits the MCSH rule, that value was used to run the LoCoH homerange generator. Isopleths of 10% through to 100% with a 10% interval was selected. Isopleths were capped when they were greater or equal to the Nth% point and all hulls were used to create the last isopleth. Duplicate points were randomly displaced by 0.1.

Table 4.3: k values used to construct each LoCoH.

Period	AG 81	AG 93	AG 242	AG 243
Oct - Dec 2009	20	20	20	20
Jan - Mar 2010	15	20	18	18
Apr - Jun 2010		21	19	19
Jul - Sep 2010		18	2	16
Oct - Dec 2010		21	18	
Jan - Mar 2011		18		

Getz & Wilmers (2004) explain that compared to methods such as Minimum Convex Polygon (MCP) and kernel methods for home range calculation, that the k-NNCH has a number of advantages making it appropriate for use in areas that have abrupt features such as fences, water bodies or steep terrain which may result in having sharp boundaries like corners or corridors. In such cases k-NNCH isopleths have been shown to be better at representing the true area than either kernel or alpha-hull methods (Getz & Wilmers 2004).

4.2.6 Remote cameras

Three remote cameras were set up within tsessebe core home ranges. The cameras were placed against a tree trunk roughly 60 cm above the ground and camouflaged as best as possible. These cameras were used with the intention of determining how regularly tsessebe made use of these particular areas.

4.3 Results

4.3.1 Park utilization

The total utilization of the four collared tsessebe within BNP shows that their distribution is confined to the southern section of the reserve (Figure 4.6). The southern section has an approximate surface area of 3000 hectares.

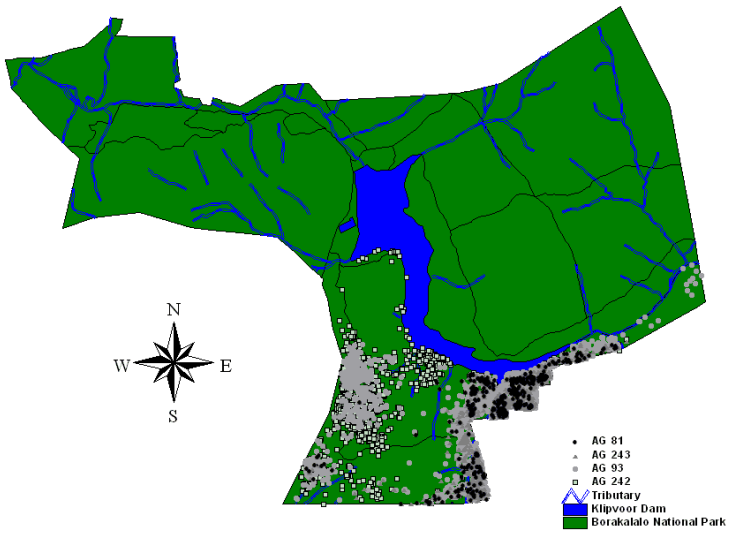


Figure 4.6: Total utilization of Borakalalo National Park by the collared tsessebe.

Figure 4.7 depicts features that are referred to in the subsequent sections. This Figure enables the reader to visibly identify with the features that have been indicated in subsequent sections.

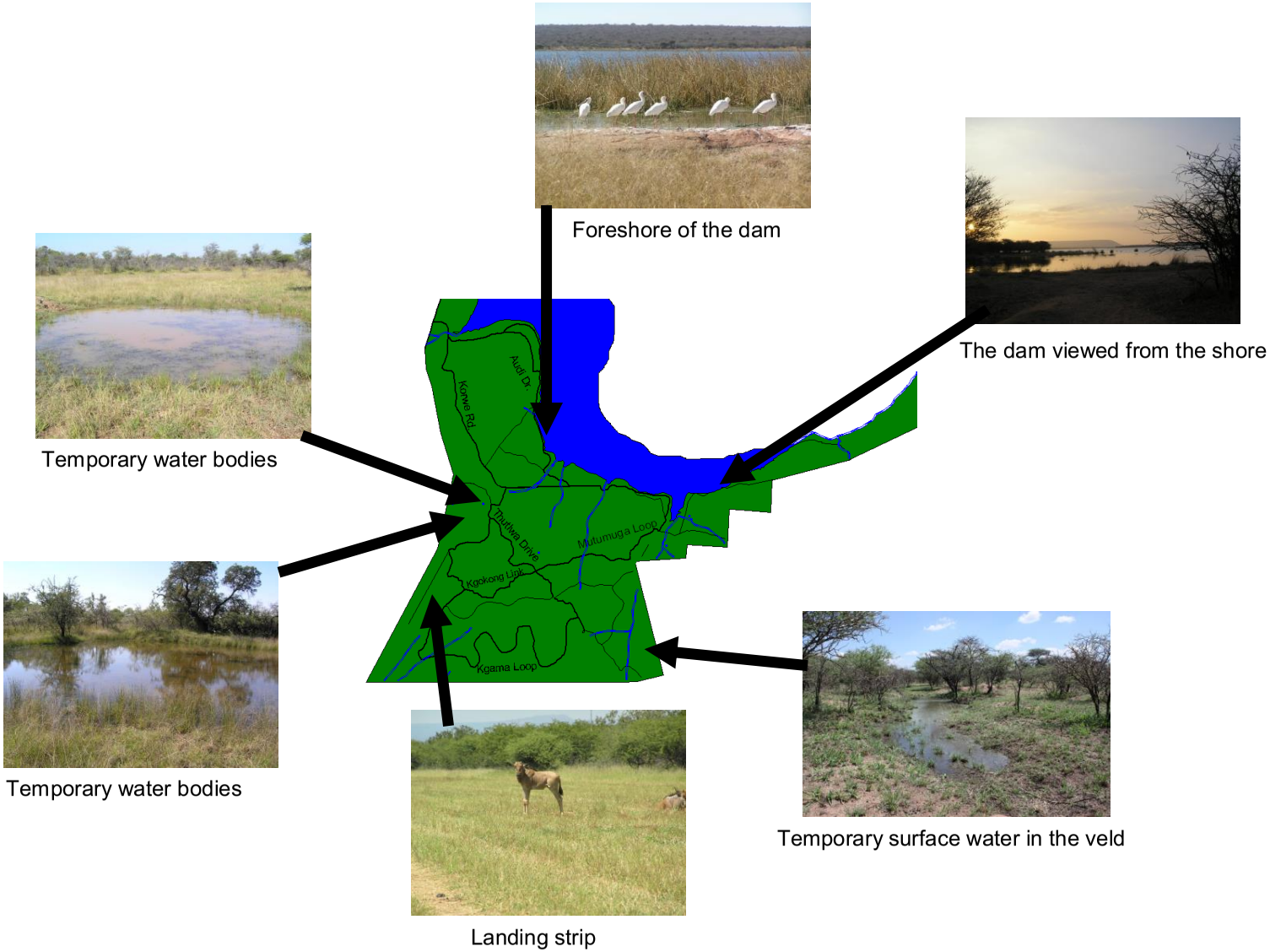


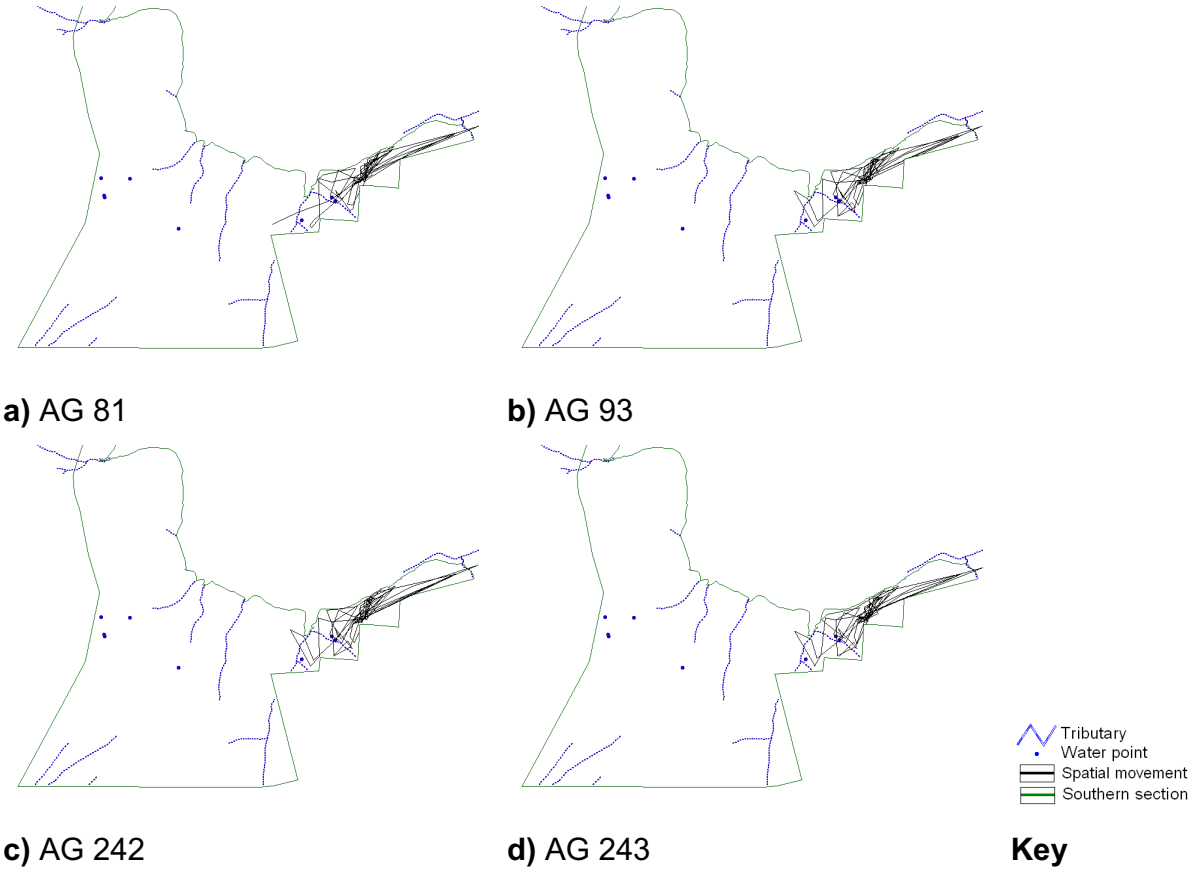
Figure 4.7: Features referred to in Borakalalo National Park.

4.3.2 Spatial movements

When collar identification is indicated in the descriptions below it is indicative of the herd associated with that individual animal.

During September, October and November 2009 all four the collared tsessebe roamed around in one herd.

In September 2009 (Figures 4.8 a-d) the herd made use of the narrow passage between the reserve fence and the dam on the eastern side of the study area.

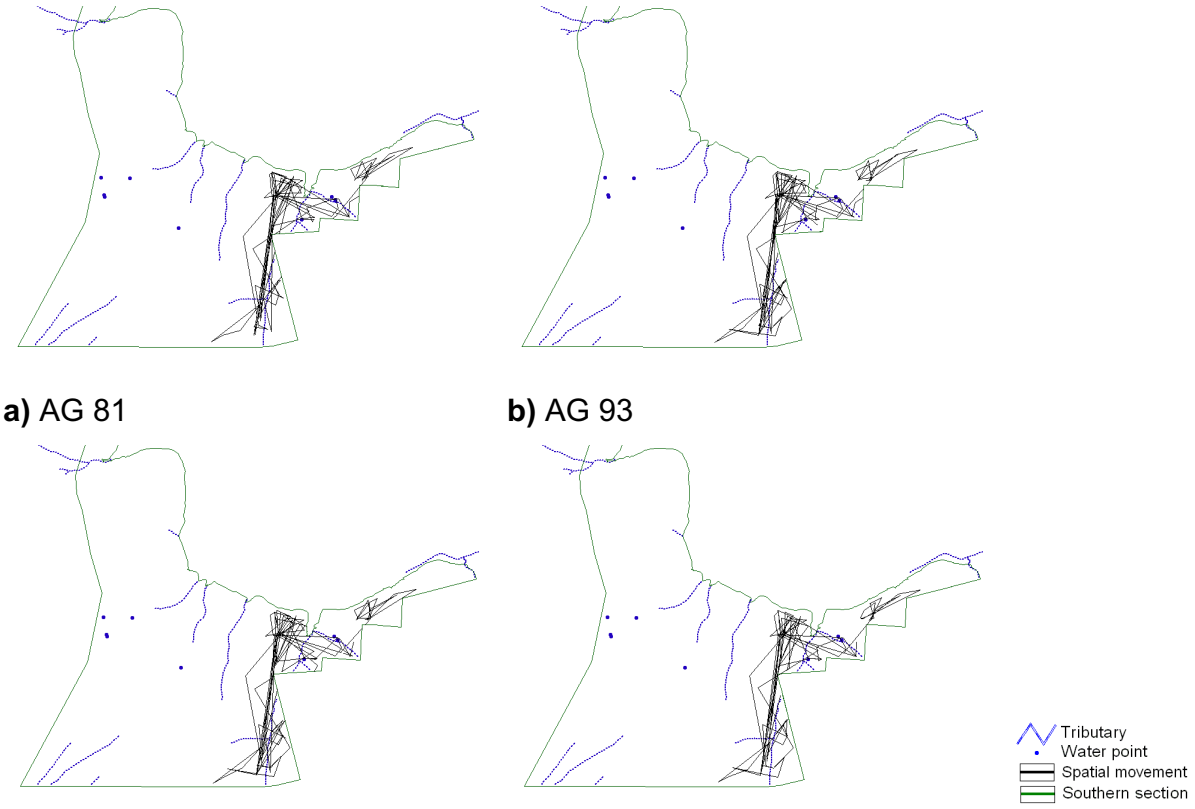


a) AG 81 **b)** AG 93

c) AG 242 **d)** AG 243 **Key**

Figure 4.8: Spatial movement patterns for September 2009.

During October 2009 (Figures 4.9 a-d) the herd made excessive use of the drainage line that runs along the eastern side of the study area.

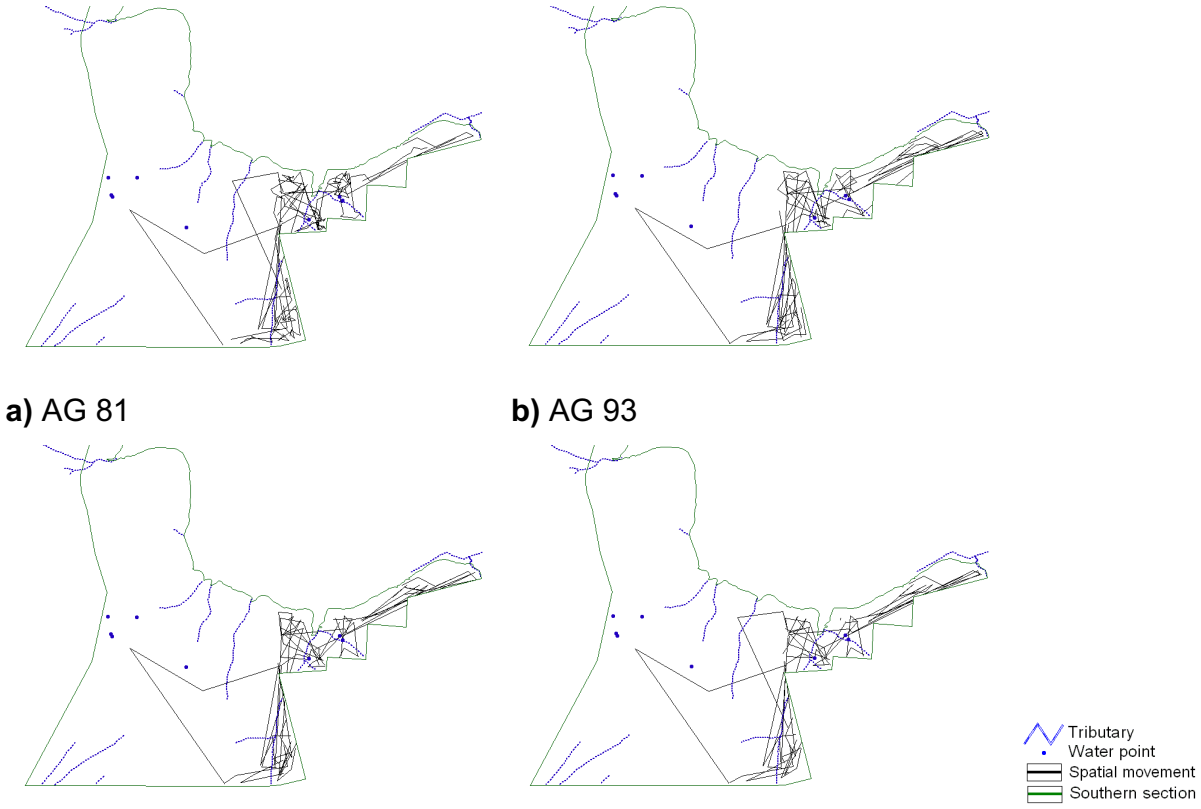


a) AG 81 **b)** AG 93

c) AG 242 **d)** AG 243 **Key**

Figure 4.9: Spatial movement patterns for October 2009.

From the collar data it was evident that AG 81 and AG 243 roamed together (Figures 4.10 a & d), therefore during mid November 2009 the period for AG 81 to obtain fixes was changed to hourly intervals. Thus a comparison could be made between fixes obtained at a six hour interval and fixes obtained at one hour intervals. Difference could beseen from the considerably more detailed movement paths of AG 81 (Figures 4.10 a & 4.11 a) as compared to the movement paths of AG 243 (Figures 4.10 d & 4.11 d). However the six hour interval fixes allow for sufficient information for movement purposes.

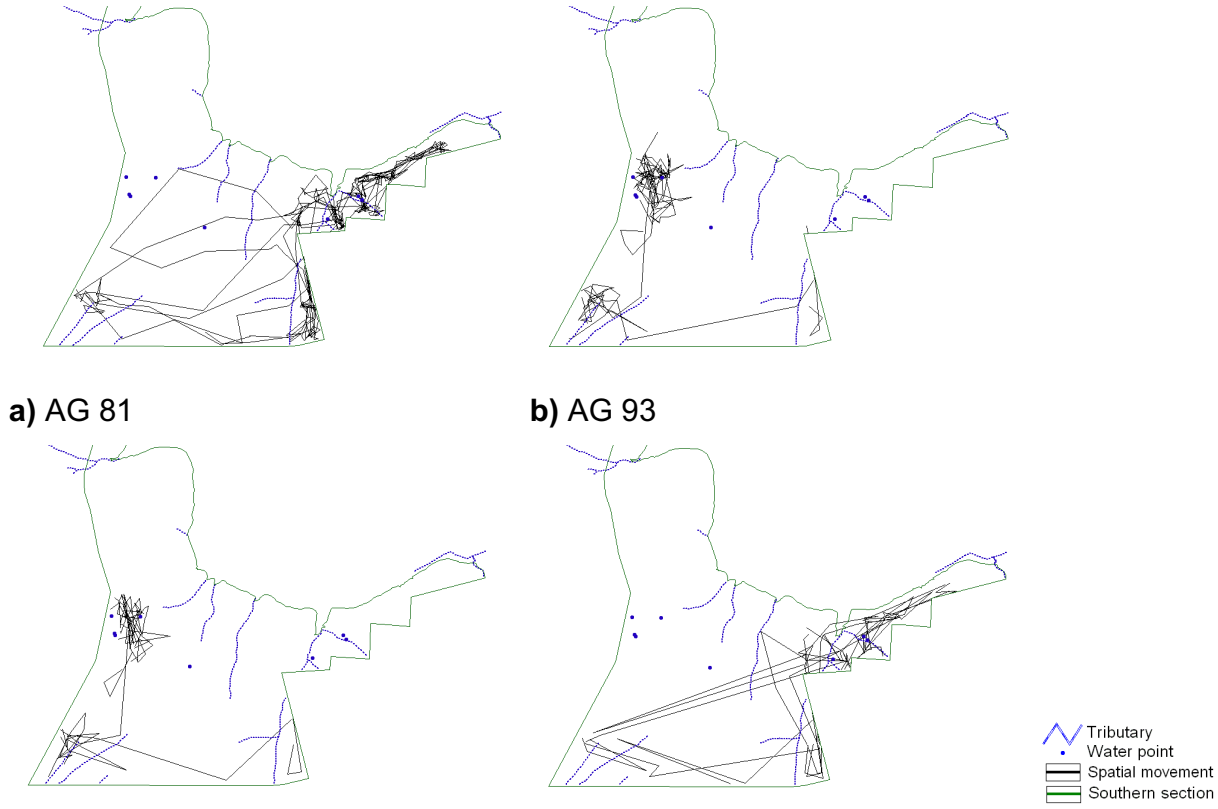


a) AG 81 **b)** AG 93

c) AG 242 **d)** AG 243 **Key**

Figure 4.10: Spatial movement patterns for November 2009.

During December 2009 the herd split up. AG 93 (Figure 4.11 b) associated with AG 242 (Figure 4.11 c), and moved over to the western side of the study area. AG 243 (Figure 4.11 d) and AG 81 (Figure 4.11 a) made several expeditions to the landing strip during this period. As the landing strip forms an open grassland area, it is assumed that these expeditions were for grazing purposes as they did not remain in the area for more than a day at a time.

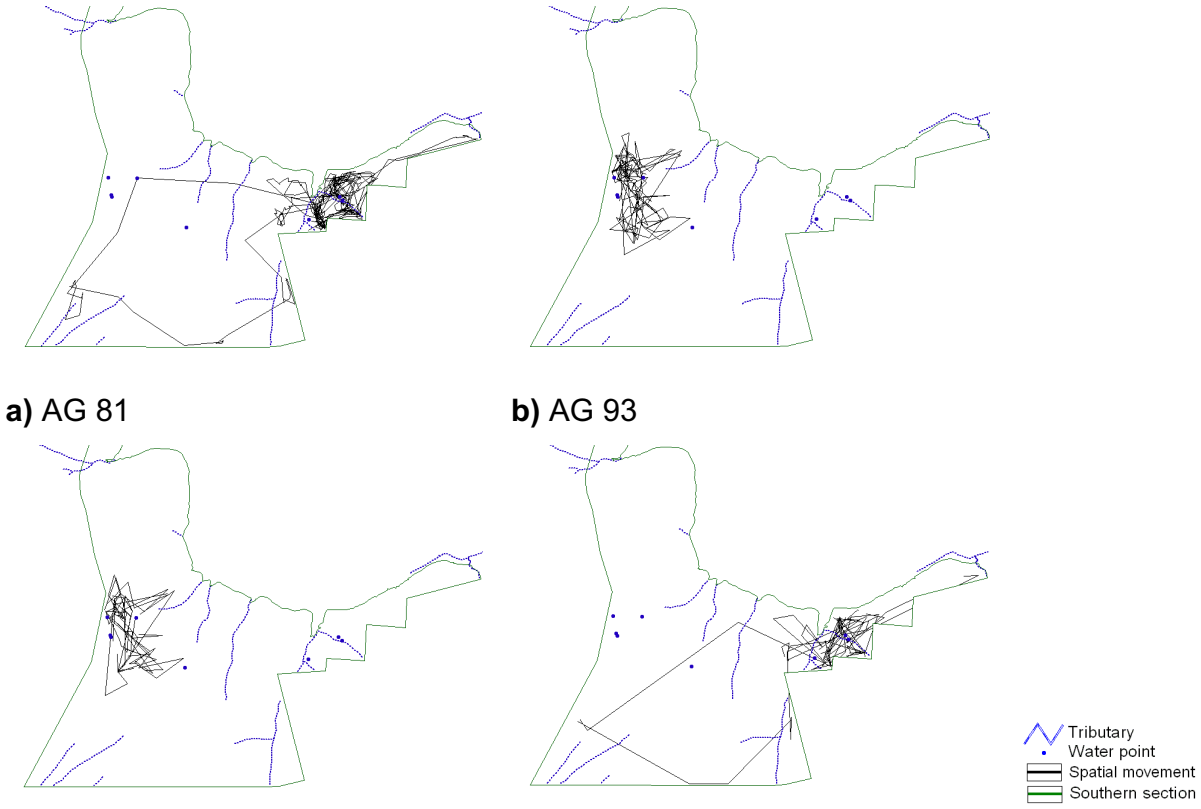


a) AG 81 **b)** AG 93

c) AG 242 **d)** AG 243 **Key**

Figure 4.11: Spatial movement patterns for December 2009.

During January 2010 a single expedition to the landing strip by AG 81 and AG 243 was observed from the movement patterns (Figures 4.12 a & d). It may be of interest to note that from Figure 4.12 a, AG 81 moved along or close to the boundary of the southern section of the reserve to go to the landing strip, thus avoiding the central part of this area. This may be due to unfavourable terrain within the central part of this section of the reserve. AG 93 and AG 242 remain on the western part of the study area (Figures 4.12 b & c), closely associated with the temporary water bodies that occurred in the area.



a) AG 81 **b)** AG 93

c) AG 242 **d)** AG 243 **Key**

Figure 4.12: Spatial movement patterns for January 2010.

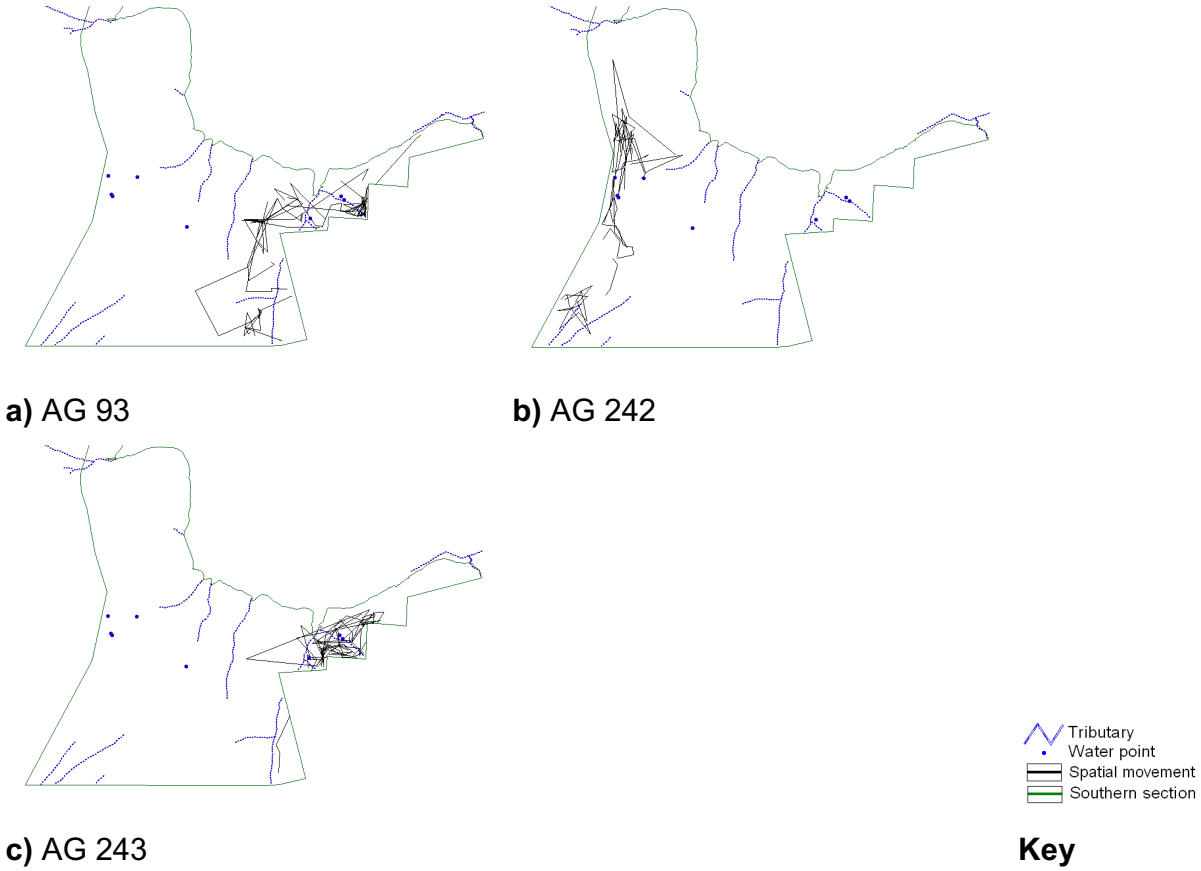
During February 2010 AG 93 (Figure 4.13 b) moved from the western side of the study area back to the previously used area on the eastern side, while AG 242 (Figure 4.13 c) remained on the western side. AG 81's collar battery went flat during this month, and thus no more data could be obtained as can be seen in Figure 4.13 a, by the lack of movement data compared to previous months. AG 243 remains confined to the eastern part of the study area (Figure 3.13 d).

a) AG 81 **b)** AG 93

c) AG 242 **d)** AG 243 **Key**

Figure 4.13: Spatial movement patterns for February 2010.

During March 2010 AG 242 (Figure 4.14 b) moves around and remains closely associated with the temporary water bodies that occur in that area. AG 93 (Figure 4.14 b) and AG 243 (Figure 4.14 c) split up within this month as seen from the movement where AG 93 makes far greater use of the eastern side than AG 243 does.



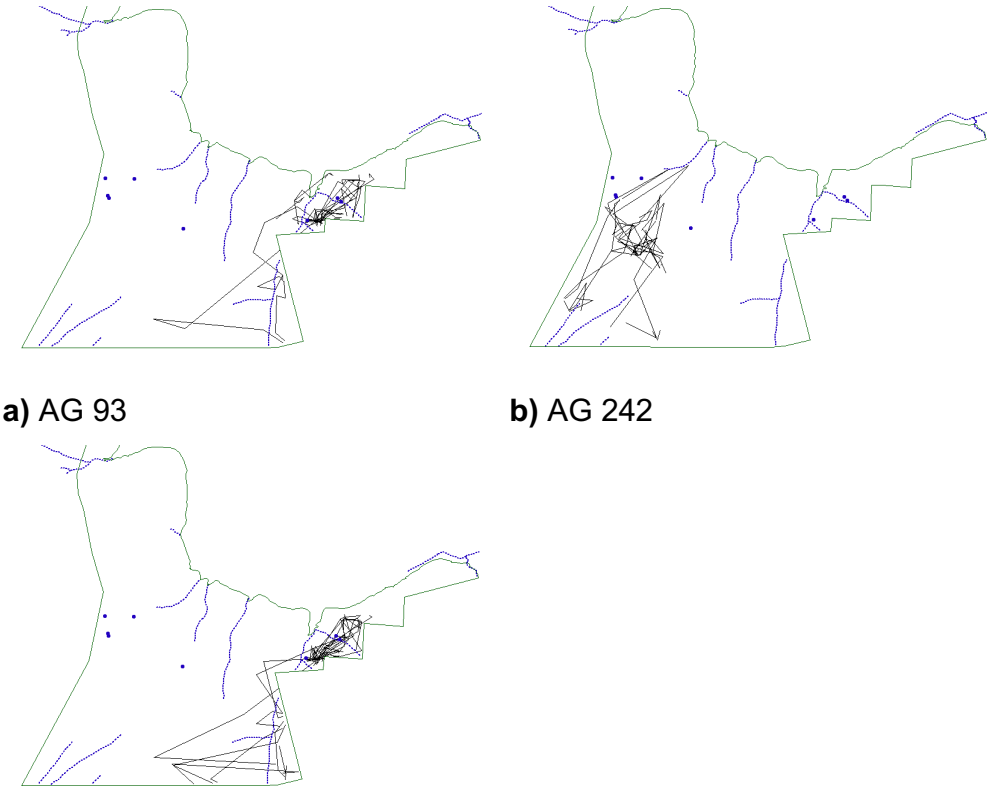
a) AG 93 **b)** AG 242

c) AG 243 **Key**

Figure 4.14: Spatial movement patterns for March 2010.

For the tsessebe AG 93 and AG 243 the months of April 2010 (Figures 4.15 a & c), May 2010 (Figures 4.16 a & c), June 2010 (Figures 4.17 a & c), July 2010 (Figures 4.18 a & c) and August 2010 (Figures 4.19 a & c) movements were more in line with each other which indicated that they had rejoined herds. During these months both these tsessebe made use of areas along the reserve fence. With regards to AG 242 who occupied the areas along the western part of the study area, remained strongly associated with the temporary water bodies in the home range (Figures 4.15 c - 4.19. c).

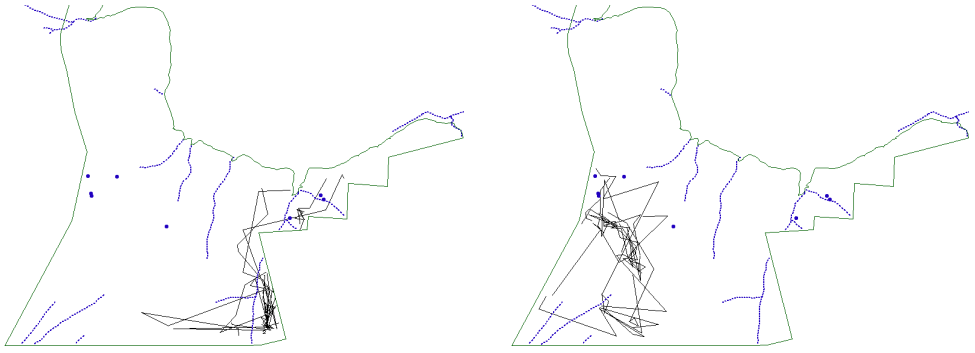
April 2010 had an unusually high rainfall that stimulated a green flush and allowed temporary water bodies to be replenished. Following that, it may explain the frequent excursions out of the normal home range that the herds underwent in May 2010 (Figures 4.16 a - c).



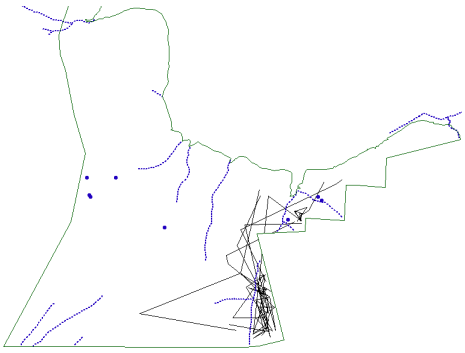
a) AG 93 **b)** AG 242

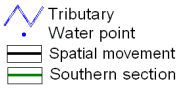
c) AG 243

Figure 4.15: Spatial movement patterns for April 2010.



a) AG 93 **b)** AG 242

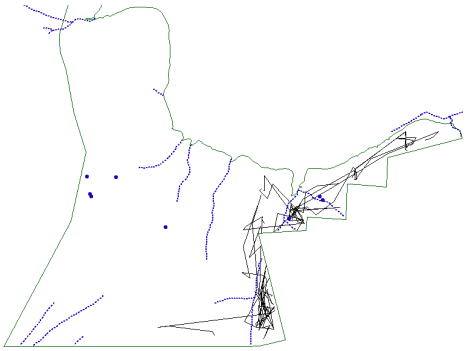


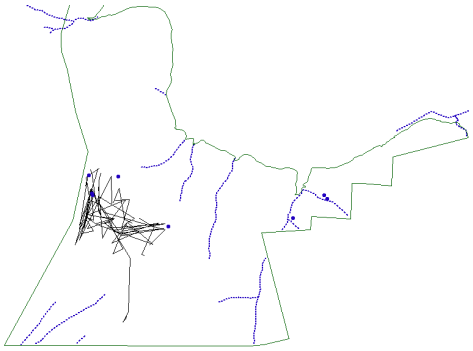


c) AG 243 **Key**

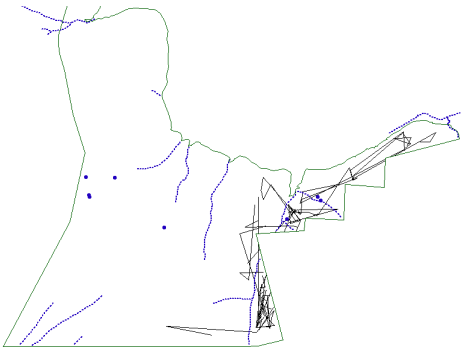
Figure 4.16: Spatial movement patterns for May 2010.

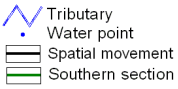
June 2010 (Figures 4.17 a-c), July (Figures 4.18 a-c) and August 2010 (Figures 4.19 a-c) saw a concentrated movement around the temporary water bodies, possibly due to tsessebe being dependent upon surface water. During August 2010 the battery for collar AG 243 died, thus limited data for this month was obtained as can be seen in Figure 4.19 c.





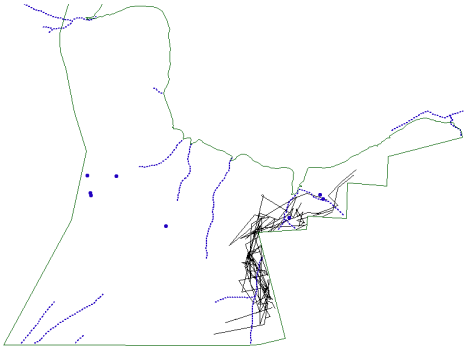
a) AG 93 **b)** AG 242

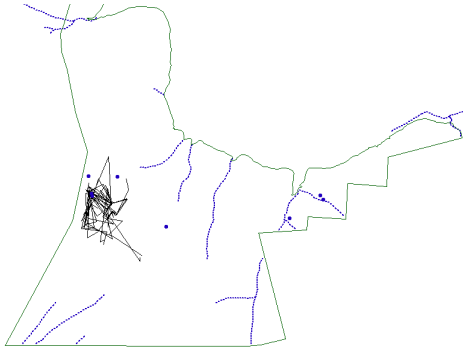




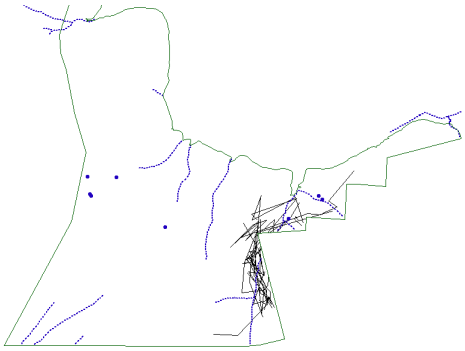
c) AG 243 **Key**

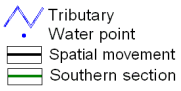
Figure 4.17: Spatial movement patterns for June 2010.





a) AG 93 **b)** AG 242





c) AG 243 **Key**

Figure 4.18: Spatial movement patterns for July 2010.

a) AG 93 **b)** AG 242

c) AG 243 **Key**

Figure 4.19: Spatial movement patterns for August 2010.

A noticeable change in the movement patterns of the tsessebe AG 242 (Figure 4.20 b) took place during September 2010. For the first time during the study period GPS fixes were recorded at the dam, indicating movement towards the dam and utilisation of the shore line. This may have been due to the sluice gates being opened to allow water out of the dam. The parks management was expecting a high volume of rain at that stage and allowed the water to recede (Figure 4.21 b). By doing so, the shore line, that was previously submerged, was exposed, allowing the regeneration of vegetation. The tsessebe made use of the young shoots that began to grow on the fertile foreshore. AG 93 (Figure 4.20 a) also made considerable use of the shore line on the eastern side of the study area during this month.

AG 93 made use of the much the same area in September 2010 as it did in September 2009, however AG 242 had different movements in September 2009 compared to September 2010. During September 2009 movements were on the eastern side of the study area as apposed to September 2010 their movements were on the western side.

a) AG 93 **b)** AG 242 **Key**

Figure 4.20: Spatial movement patterns for September 2010.

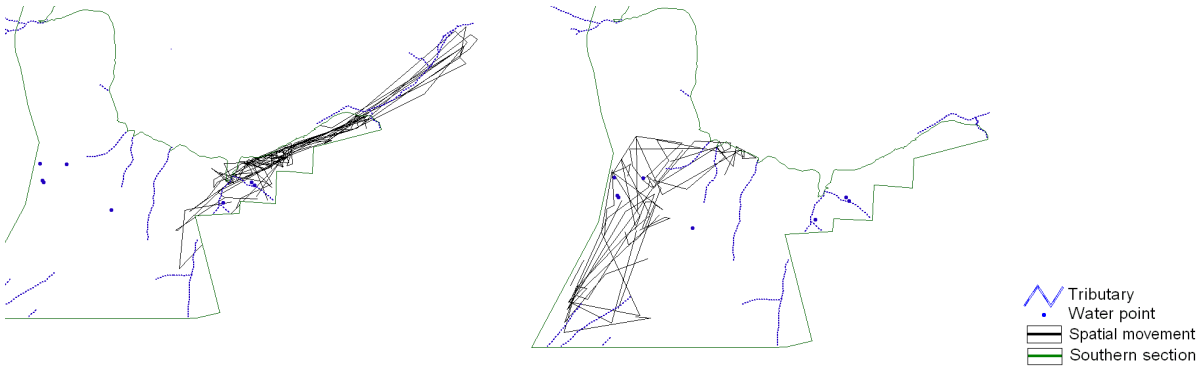
a) **b)**

Figure 4.21: The shore line: a) during wet months and b) after the sluice gate was opened for some time.

During October 2010, the tsessebe AG 242 (Figure 4.22 b) had a scattered use of their home range. They made use of the shore line, the area around the

temporary water bodies and along the landing strip. The tsessebe AG 93 (Figure 4.22 a) made movements well beyond their normal movement patterns, crossing over the Kutswane River, this would be the first time during the study period that they were recorded moving into this area.

AG 93 used much the same area in October 2010 as in October 2009, there was some difference in that in October 2009 movements included the south eastern corner where in October 2010 they make no considerable use of that area. During October 2009 AG 242 movements were on the eastern side of the study area as opposed to October 2010 where their movements were on the western side.



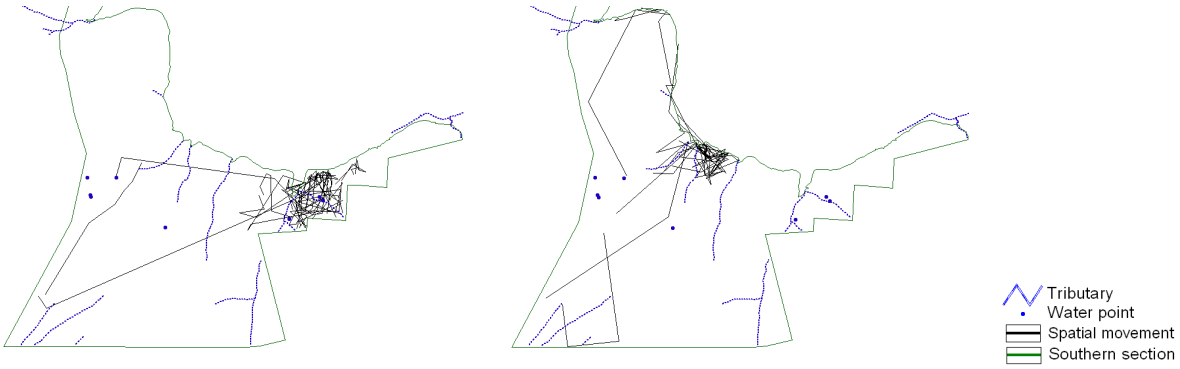
a) AG 93 **b)** AG 242 **Key**

Figure 4.22: Spatial movement patterns for October 2010.

During November 2010 AG 242 made particularly high use of the drainage channels and shore line of the dam where these channels entered the dam, also moving higher up the shoreline (Figure 4.23 b). AG 93 had a more concentrated use of the areas between the drainage channels on the eastern side and had a few expeditions to the temporary water bodies on the west side of the study area, as well as to the landing strip (Figure 4.23 a).

AG 93 used the same general area on the eastern side during November 2010 as in November 2009, there was some difference in that in November 2009

movements included the south eastern corner, in November 2010 no use of that area was recorded. AG 242 movements during November 2009 were on the eastern side of the study area and during November 2010 they were on the western side.

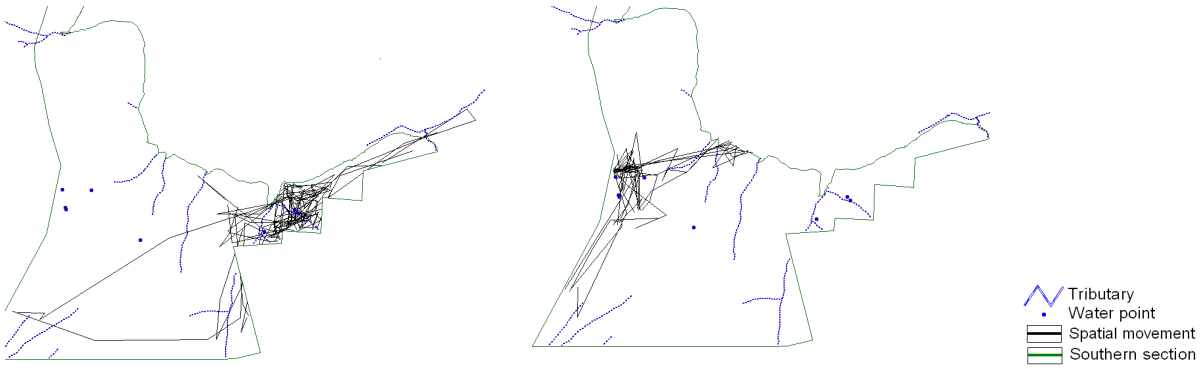


a) AG 93 **b)** AG 242 **Key**

Figure 4.23: Spatial movement patterns for November 2010.

During December 2010 AG 242 (Figure 4.24 b) made some use of the landing strip and shore line, but their main use was in and around the areas of the temporary water bodies. AG 93 (Figure 4.24 a) had much the same usage of the home range as in the previous month, but with excursions to the landing strip and up towards the Kutswane River on occasions.

AG 93 had different movements in December 2009 compared to December 2010, during December 2009 movements were on the western side of the study area and in December 2010 movements were on the eastern side. AG 242 made use of much the same general area in December 2010 as it did in December 2009.



a) AG 93 **b)** AG 242 **Key**

Figure 4.24: Spatial movement patterns for December 2010.

During January 2011 AG 93 (Figure 4.25 a) made use of similar areas as that of the previous two months, with an occasional excursion to the temporary water bodies on the western side, and back. AG 242 remained on the western side of the study area (Figure 4.25 b), as the battery went flat during this month little data was obtained.

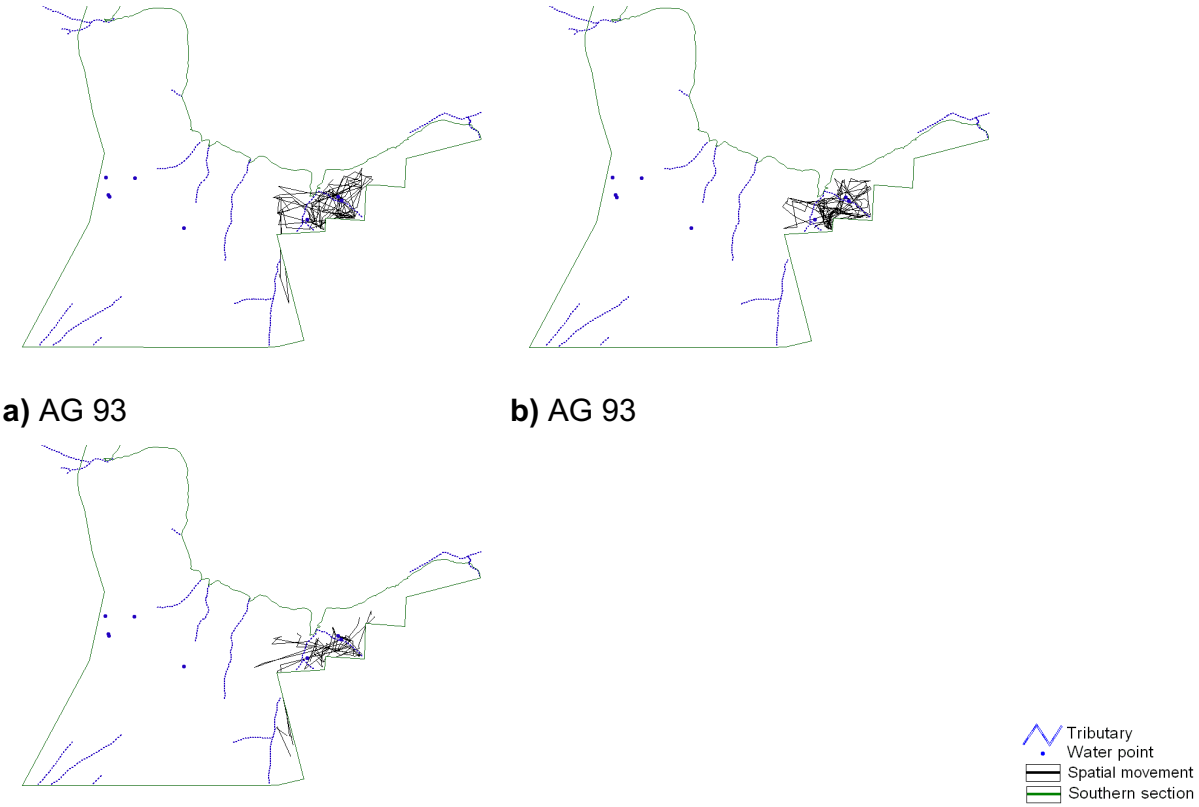
During January 2011 movements for AG 93 was on the eastern side of the study area compared to January 2010 movements were on the western side of the study area. AG 242 made use of much the same general area in January 2010 as it did in January 2011.

a) AG 93 **b)** AG 242 **Key**

Figure 4.25: Spatial movement patterns for January 2011.

For February (Figure 4.26 a), March (Figure 4.26 b) and April 2011 (Figure 4.26 c) AG 93 made much the same usage of the areas on the eastern side of the study area, with no extensive excursions to any other parts of the study area recorded.

Compared to the same months in 2010 a difference in movements for February 2010 is evident, as the movements for this month was in the western side of the study area. During March 2010 the south eastern corner of the study was used, however no movements in this corner were recorded during March 2011. In April 2010 and April 2011, much the same areas were used. AG 93 was poached in April 2011.



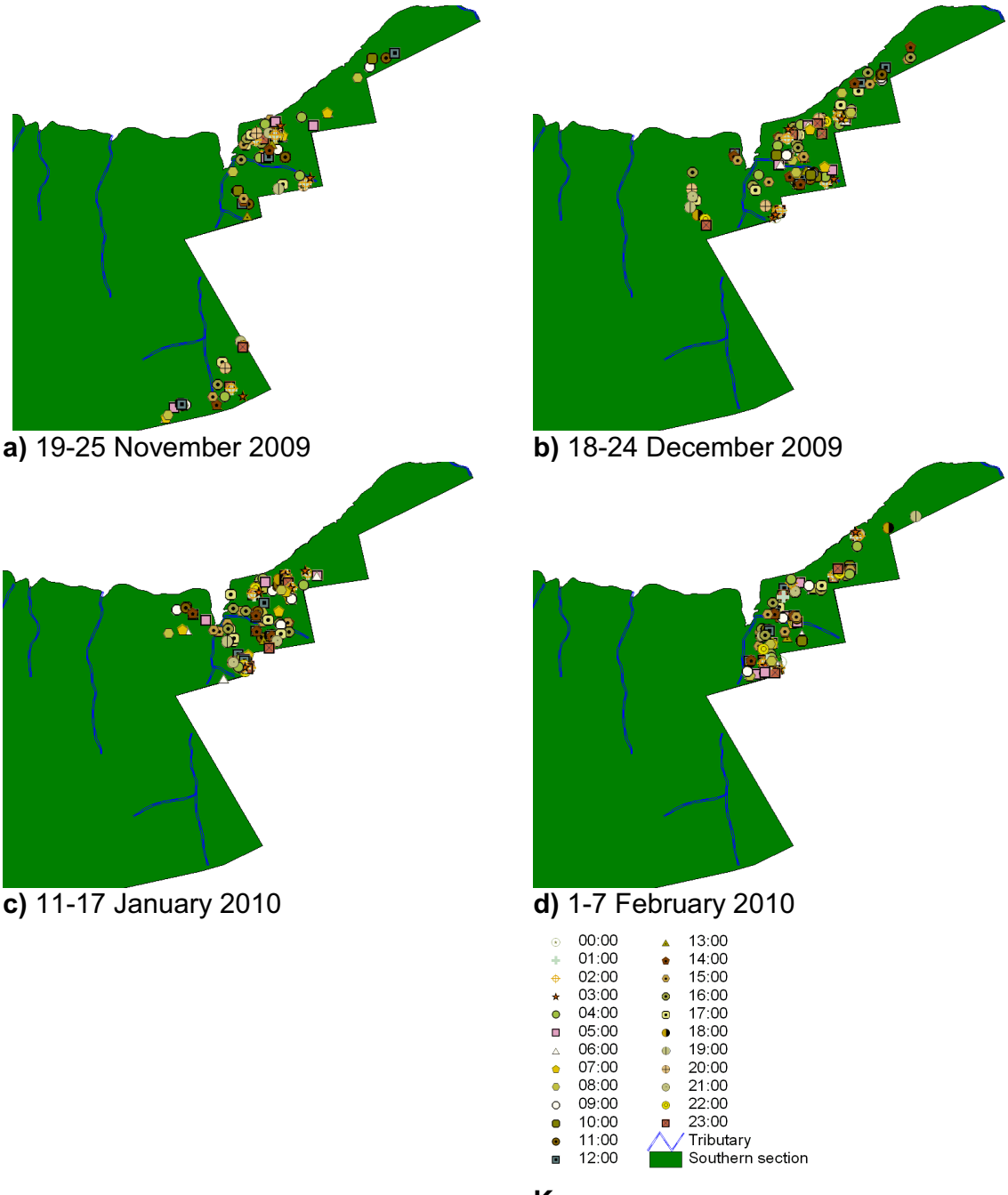
a) AG 93 **b)** AG 93

c) AG 93 **Key**

Figure 4.26: Spatial movement patterns for a) February, b) March and c) April 2011.

4.3.3 Patterns of movement

To assess whether tsessebe had particular preferences to an area at specific times, hourly data obtained from AG 81 was used (Figures 4.27 a-d).



a) 19-25 November 2009

b) 18-24 December 2009

c) 11-17 January 2010

d) 1-7 February 2010

Key

Figure 4.27: Hourly fixes for four randomly selected weeks to assess patterns of daily movement.

No significant patterns emerged from any of the random location samples that were used.

4.3.4 Home ranges

To better understand the home ranges, the study area was split into four quadrants. Quadrants were labelled 1, 2, 3 and 4 respectively. An illustration of the quadrants and their position is shown in Figure 4.28 below.

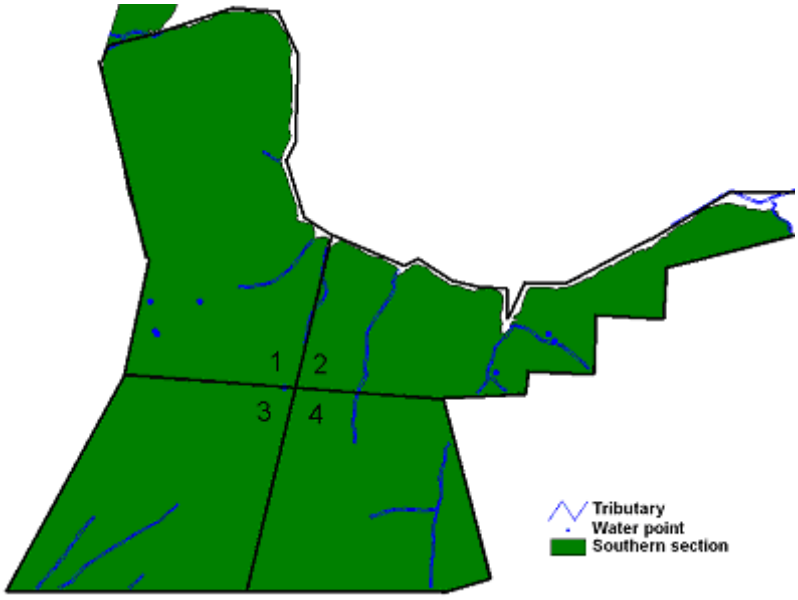


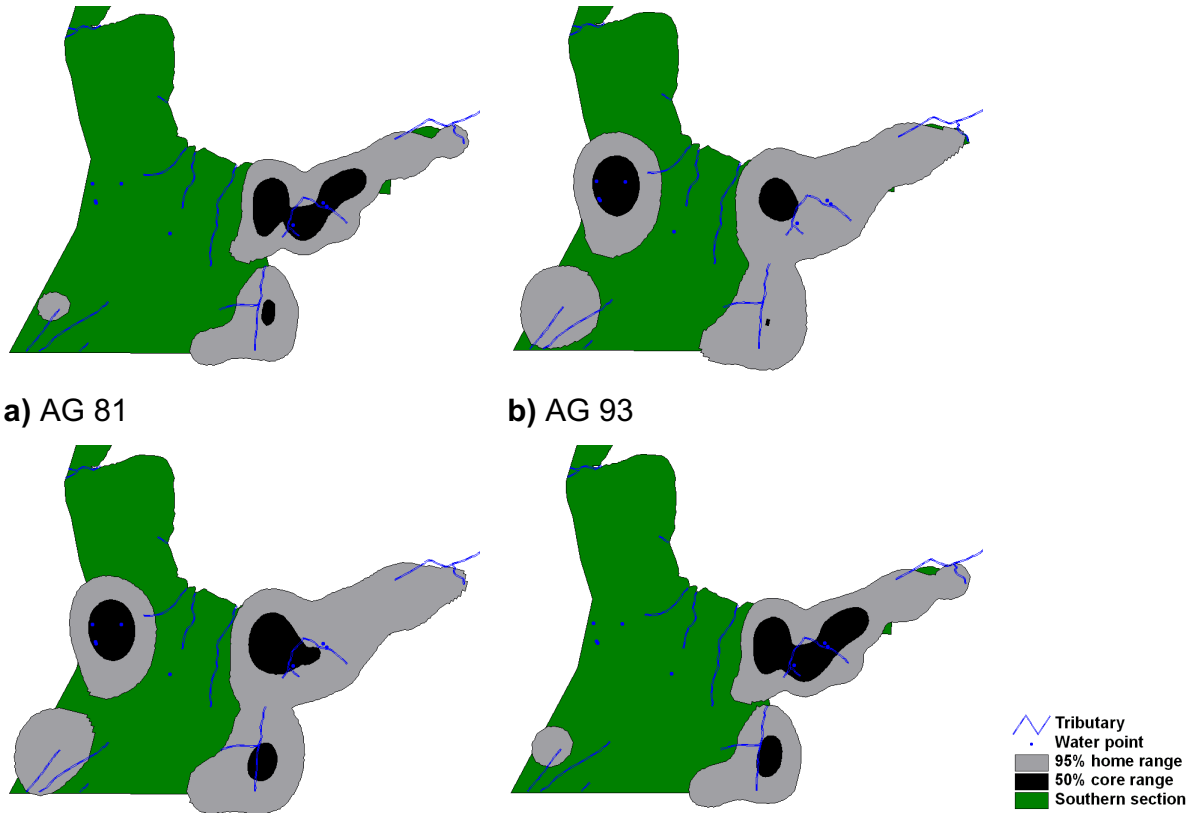
Figure 4.28: Southern section split into four quadrants.

Local convex hulls home ranges are comparable to the kernel density home ranges, with the major difference being that the kernels clearly overlap at the fence lines, as well as into the water of Klipvoor dam. Thus LoCoH was preferred as they are much better suited for the sharp edges that occur within this reserve (Getz & Wilmers 2004).

Looking at each period comparison across the four collared tsessebe can be made. An association can be seen for each of the tsessebe to each other. Initially

all four of the collared tsessebe share a common home range. However, towards the end of November 2009 AG 93 and AG 242 split off from the other two and move over to the western side. AG 242 and AG 93 occupied the same home ranges and AG 81 and AG 243 occupied another home range. From the kernel estimates it can be seen that AG 93 and AG 242 had two core home ranges on opposite sides of the study area, this is because of the split after November 2009.

For October - December 2009 core home ranges for AG 81 were mainly in quadrant 2 (Figure 4.29 a) along with that of AG 243 (Figure 4.29 d). Core ranges of AG 93 (Figure 4.29 b) and AG 242 (Figure 4.29 c) were split within Quadrants 1 and 2; AG 242 also had some core range in quadrant 4.

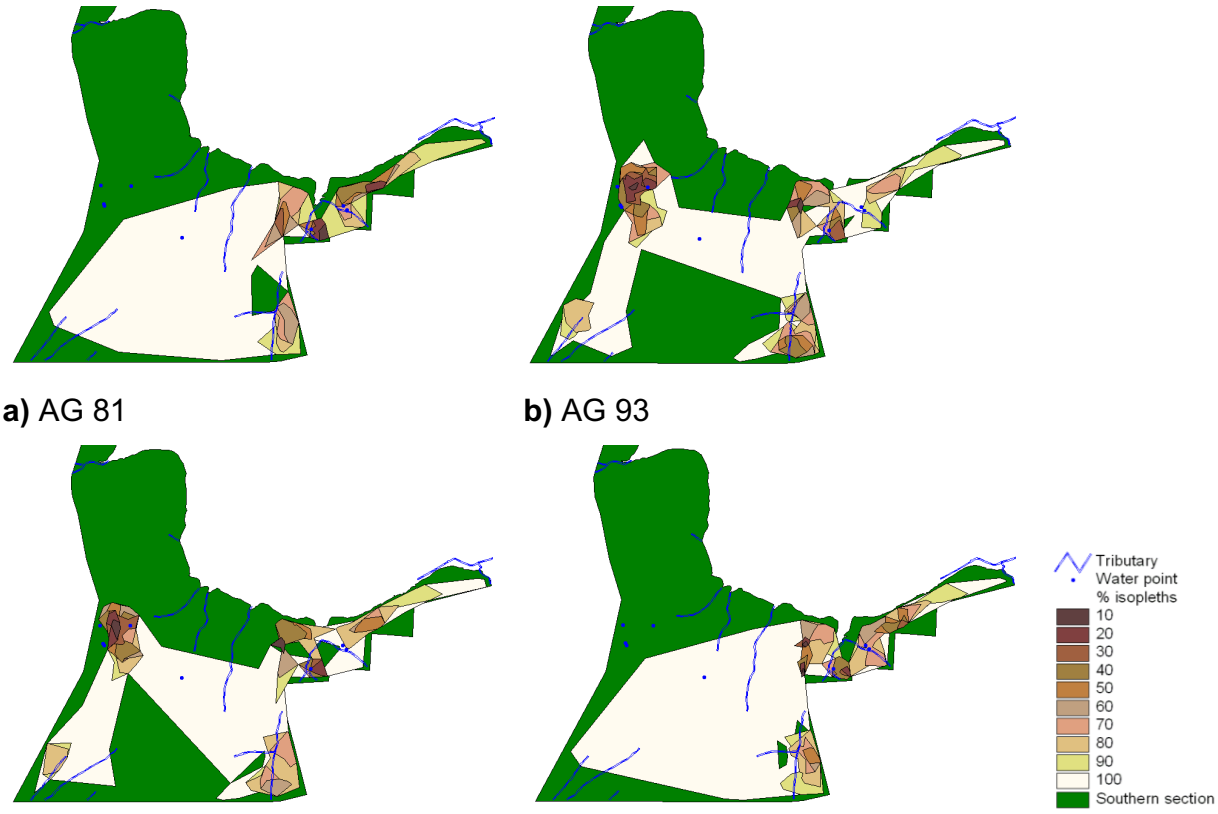


a) AG 81 **b)** AG 93

c) AG 242 **d)** AG 243 **Key**

Figure 4.29: KDE home ranges for the early wet period October - December 2009.

LoCoH home ranges (Figures 4.30 a-d) reflect similar results as those described for KDE home ranges.

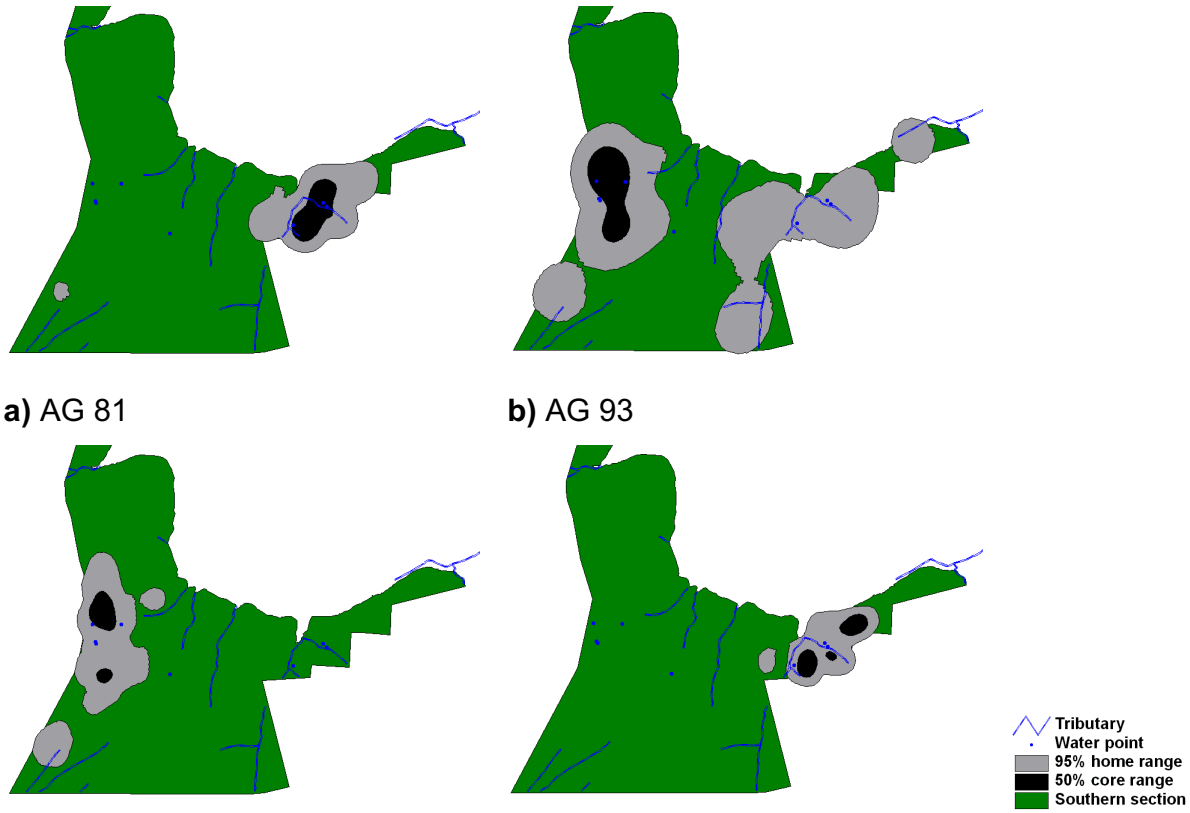


a) AG 81 **b)** AG 93

c) AG 242 **d)** AG 243 **Key**

Figure 4.30: LoCoH home ranges for the early wet period October - December 2009.

For January - March 2010, core ranges became more segregated, with AG 93 (Figure 4.31 b) and AG 242 (Figure 4.31 c) occurring solely in quadrant 1 and AG 81 (Figure 4.31 a) and AG 243 (Figure 4.31 d) solely in quadrant 2.

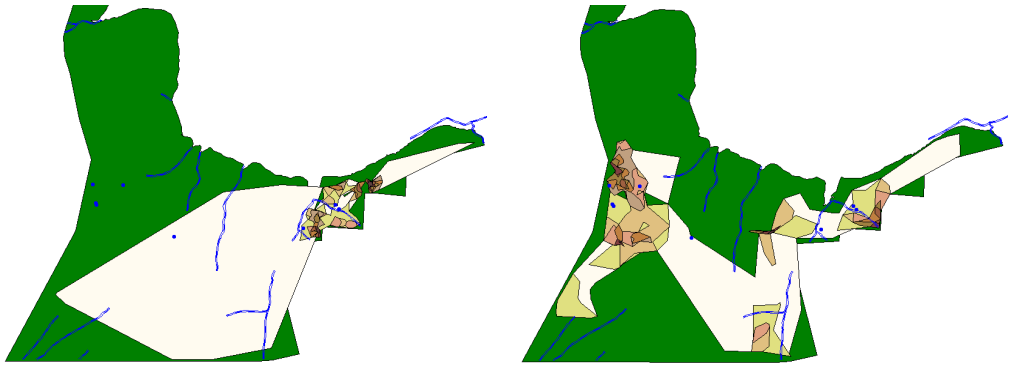


a) AG 81 **b)** AG 93

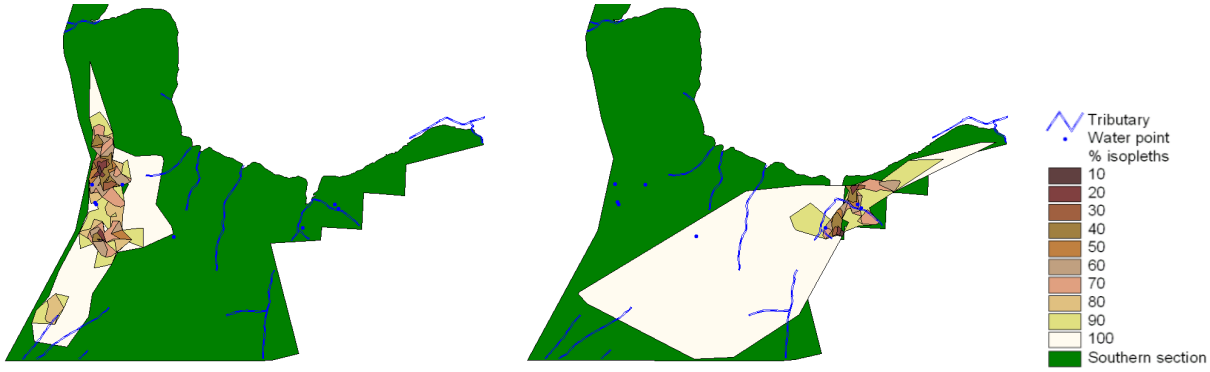
c) AG 242 **d)** AG 243

Figure 4.31: KDE home ranges for the late wet period January - March 2010.

LoCoH home ranges (Figures 4.32 a-d) reflect similar results as those described for KDE home ranges.



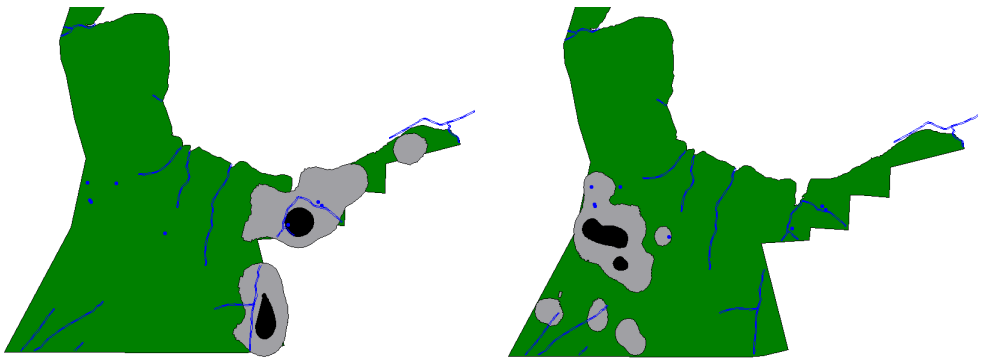
a) AG 81 **b)** AG 93



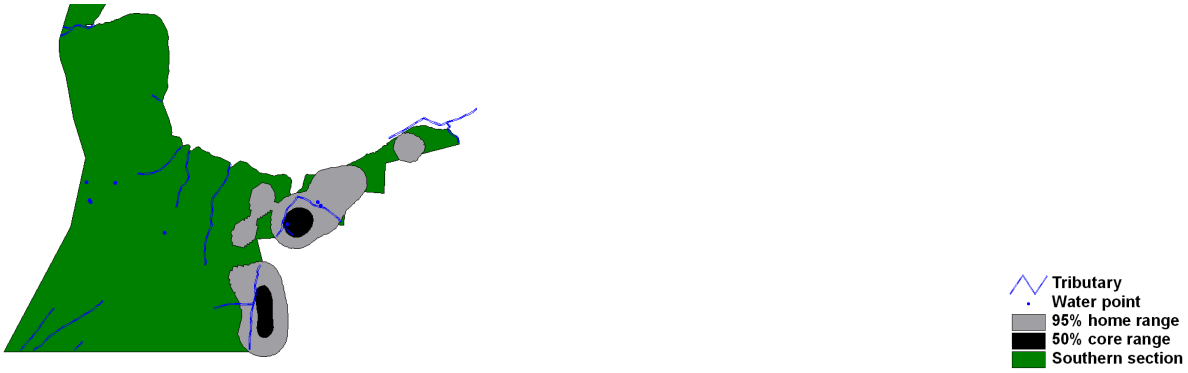
c) AG 242 **d)** AG 243 **Key**

Figure 4.32: LoCoH home ranges for the late wet period January - March 2010.

For April - June 2010, a different pattern emerged. With the ceasing of AG 81 no further data could be obtained thus no further reference to this collar can be made for comparison forthwith. Core home ranges for AG 243 now occurred within quadrants 2 and 4 (Figure 4.33 c), so did that of AG 93 (Figure 4.33 a), these ranges are very similar, indicating that these two females were moving around with one another and that AG 93 had moved over from its previous occupation on the west to join the herd with AG 243. AG 242 remained with its core range in quadrant 1 (Figure 4.33 b).



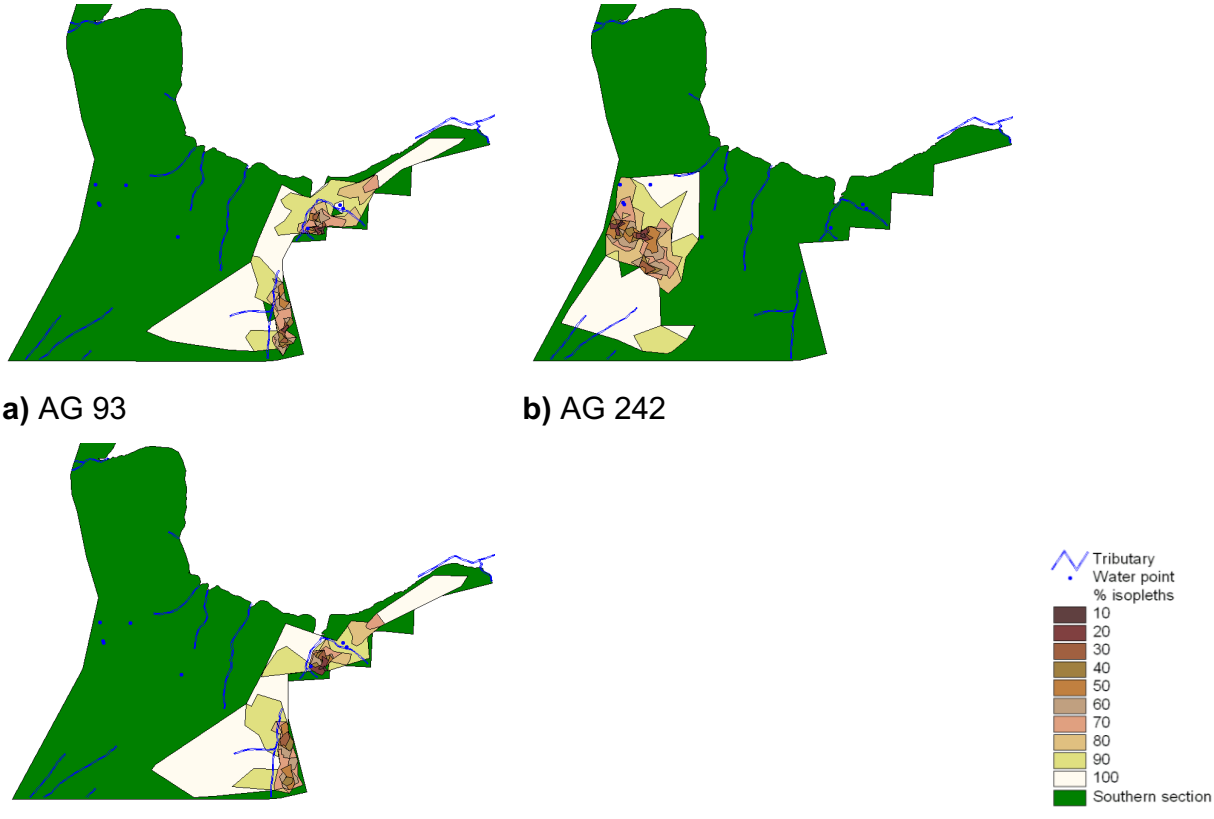
a) AG 93 **b)** AG 242



c) AG 243 **Key**

Figure 4.33: KDE home ranges for the early dry period April - June 2010.

LoCoH home ranges (Figures 4.34 a-c) reflect similar results as those described for KDE home ranges.

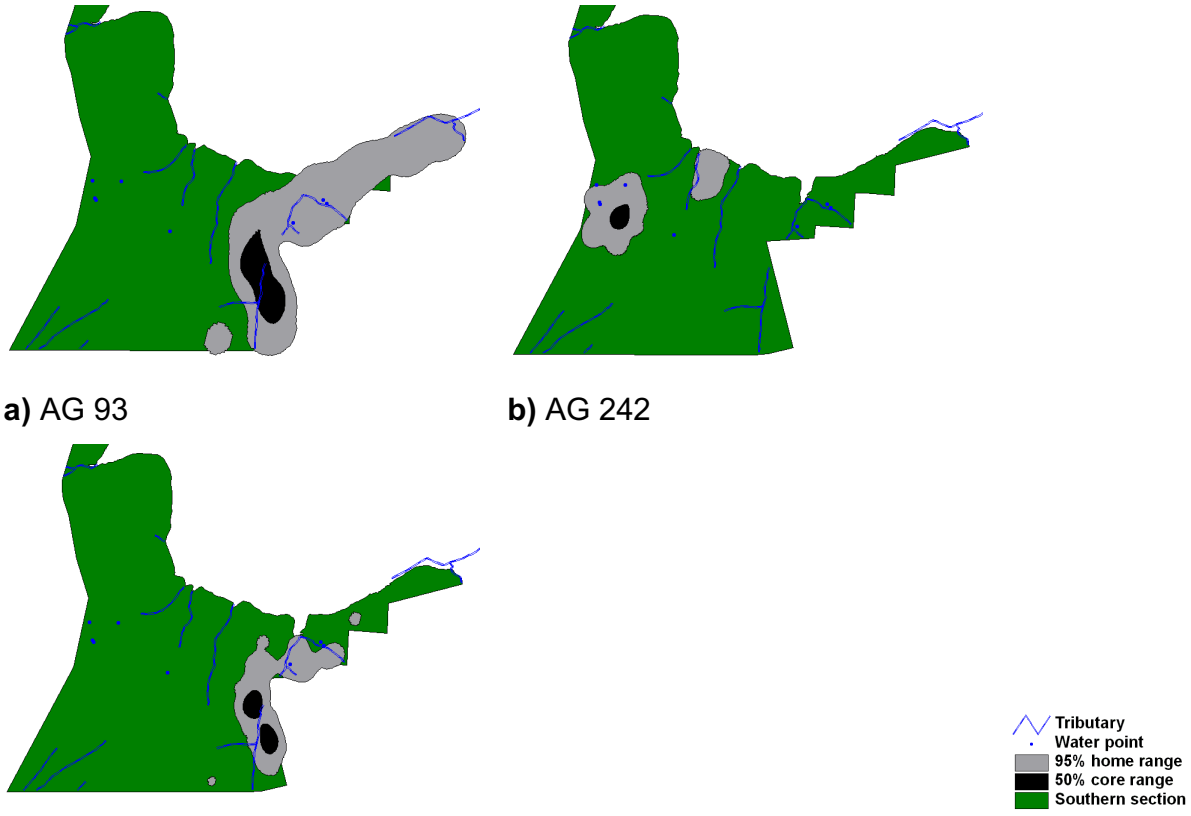


a) AG 93 **b)** AG 242

c) AG 243 **Key**

Figure 4.34: LoCoH home ranges for the early dry period April - June 2010.

For July - September 2010, core ranges for AG 93 (Figure 4.35 a) and AG 243 (Figure 4.35 c) move to quadrant 4. AG 243 ceased in August 2010 and explains why there is a difference in appearance between its home range compared to that of AG 93. AG 242 remained in quadrant 1 for this period (Figure 4.35 b).

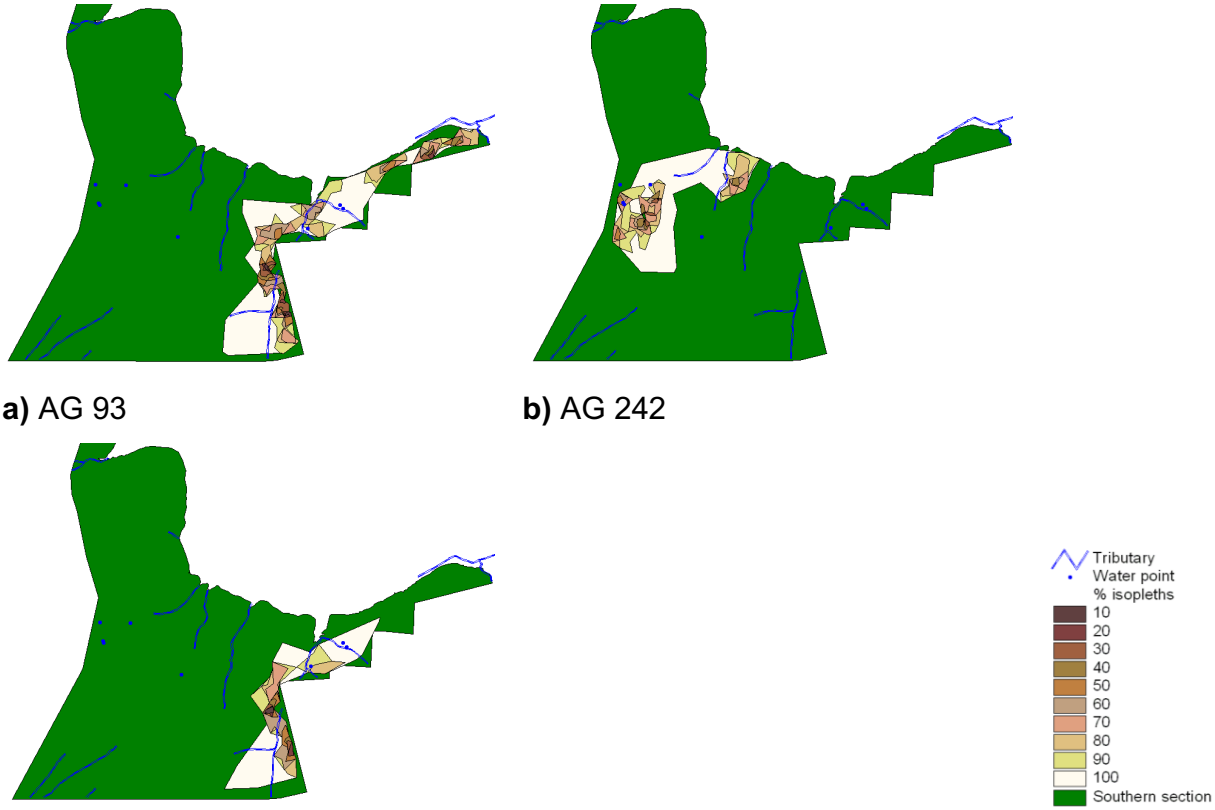


a) AG 93 **b)** AG 242

c) AG 243

Figure 4.35: KDE home ranges for the late dry period July - September 2010.

LoCoH home ranges (Figures 4.36 a-c) reflect similar results as those described for KDE home ranges.

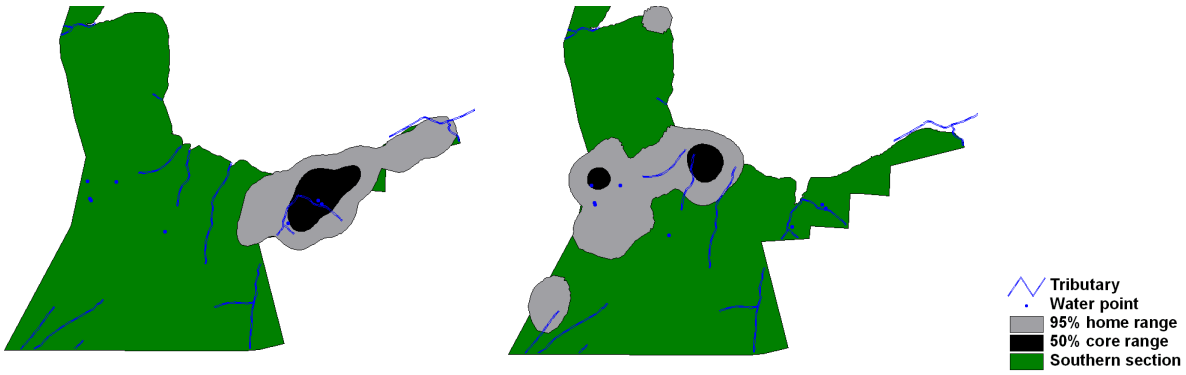


a) AG 93 **b)** AG 242

c) AG 243 **Key**

Figure 4.36: LoCoH home ranges for the late dry period July - September 2010.

For October - December 2010, the core range of AG 93 again moved to quadrant 2 (Figure 4.37 a). AG 242 core home range was split into two areas within quadrant 1 (Figure 4.37b). One of AG 242 core home ranged occurred close to the fence line near the temporary water bodies and the other core home range along the shore line.



a) AG 93 **b)** AG 242 **Key**

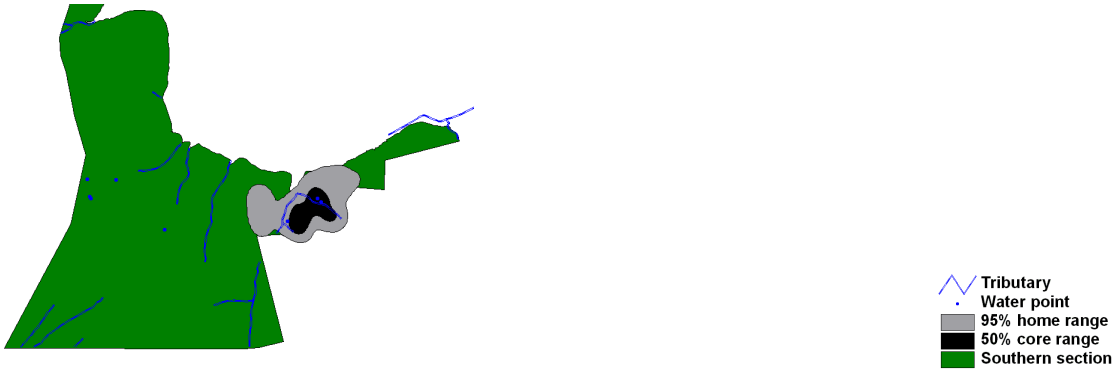
Figure 4.37: KDE home ranges for the early wet period October- December 2010.

LoCoH home ranges (Figures 4.38 a-b) reflect similar results as those described for KDE home ranges.

a) AG 93 **b)** AG 242 **Key**

Figure 4.38: LoCoH home ranges for the early wet period October- December 2010.

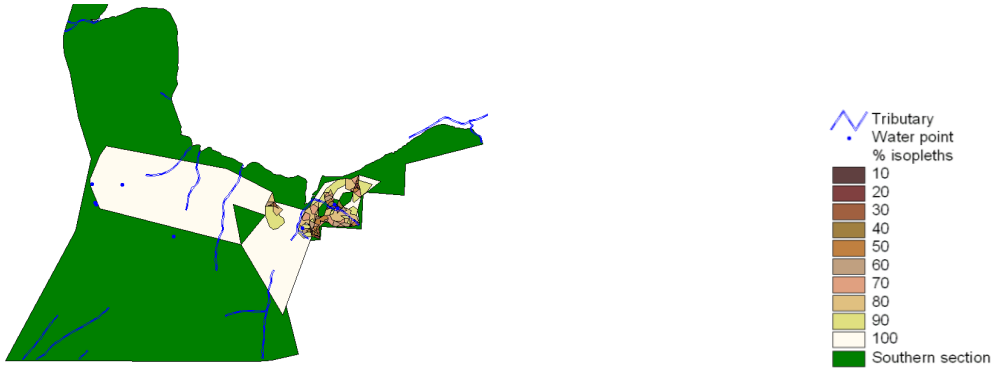
For January - March 2011, the core range of AG 93 remained in quadrant 2 (Figure 4.39 a).



a) AG 93 **Key**

Figure 4.39: KDE home ranges for the late wet period January - March 2011.

LoCoH home ranges (Figures 4.40 a) reflect similar results.



a) AG 93 **Key**

Figure 4.40: LoCoH home ranges for the late wet period January - March 2011.

4.3.5 Home range sizes

The mean home range of the tsessebe in Borakalalo is 248 ± 49 hectares (n=4) based on 90 % isopleths for LoCoH home ranges (Table 4.4). Mean home range for 95 % Kernel home range is 753 ± 157 hectares (n=4) from Table 4.5.

Based on the LoCoH home ranges, the largest home ranges were recorded in the period October - December 2009 with an mean of 349 ± 98 hectares (n=4).

The smallest home ranges were recorder in various periods for each of the collared animals.

A comparison of Table 4.4 and 4.5, shows that the kernel home range surface areas are a lot larger than that of the LoCoH home range areas, this may be due to the over estimation of the home ranges by the kernels.

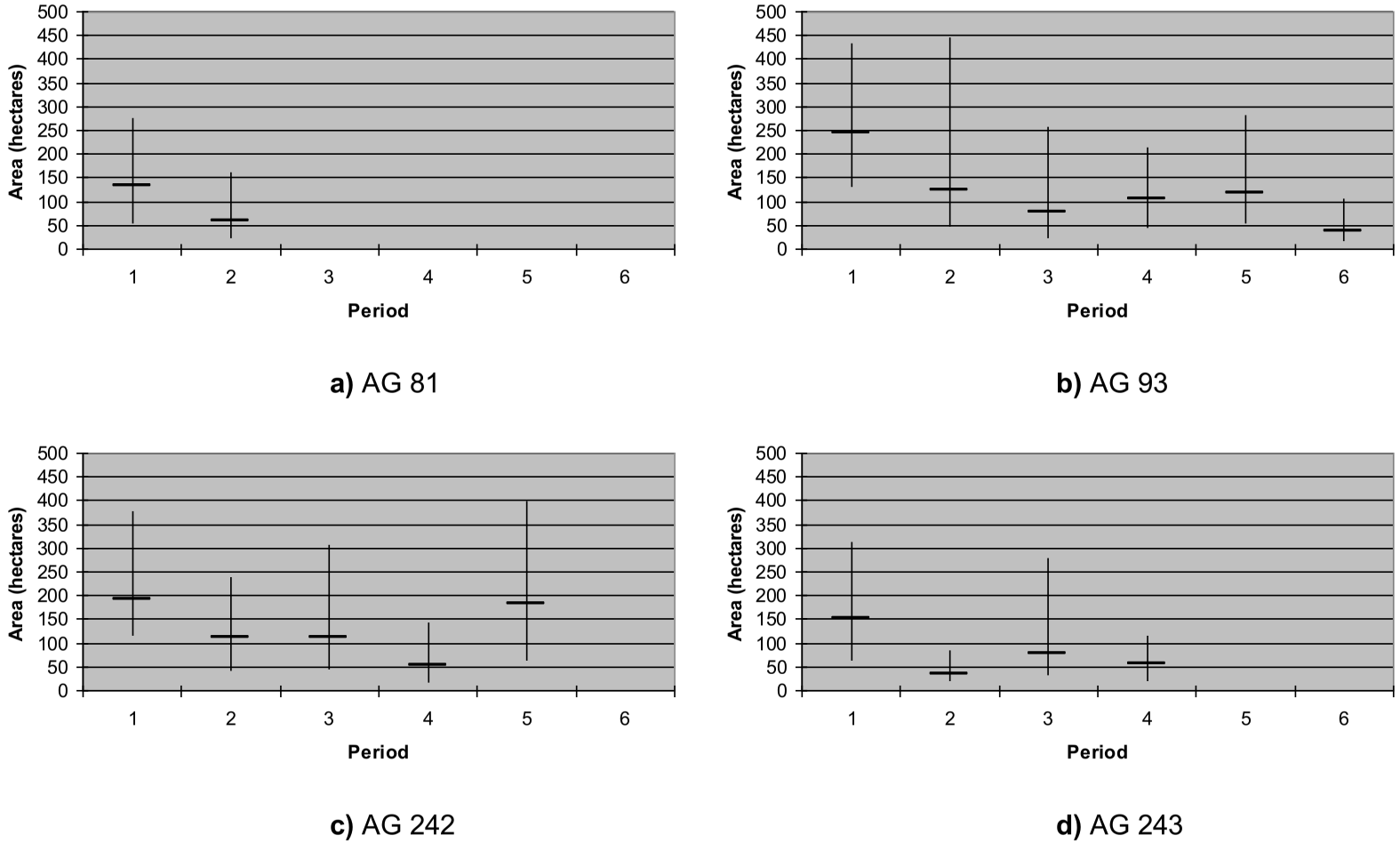


Figure 4.41: Graphical representation of the LoCoH home range areas used by each of the tsessebe.

Upper line represents the 90% isopleth, Centre line represents the 70% isopleth, and Lower line represents the 50% isopleth.

1 = October-December 2009 2 = January-March 2010 3 = April-June 2010

4 = July- September 2010 5 = October - December 2010 6 = January-March 2011

Table 4.4: Area covered by 95% home range and 50% core home range measured in hectares.

ID	% Isopleth	October-December 2009	January-March 2010	April-June 2010	July-September 2010	October - December 2010	January-March 2011
81	95	1064	371				
	50	212	78				
93	95	1951	1390	535	909	607	272
	50	167	131	60	105	135	58
242	95	2056	464	389	256	763	
	50	286	45	48	17	68	
243	95	1174	242	534	308		
	50	263	45	69	40		

Table 4.5: Area covered by 90%, 70% and 50% isopleths for the LoCoH home range measured in hectares.

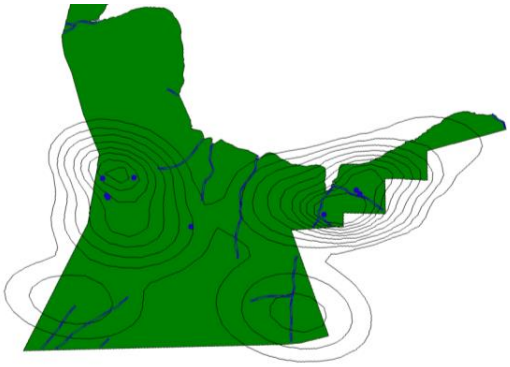
ID	% isopleth	October-December 2009	January-March 2010	April-June 2010	July-September 2010	October - December 2010	January-March 2011
81	90	274	159				
	70	133	58				
	50	54	21				
93	90	433	444	257	212	281	104
	70	243	124	78	106	117	38
	50	131	47	23	44	53	16
242	90	378	237	305	141	399	
	70	191	110	110	52	182	
	50	114	41	44	15	62	
243	90	312	83	279	113		
	70	150	34	78	56		
	50	63	18	32	19		

4.3.6 Total tsessebe range

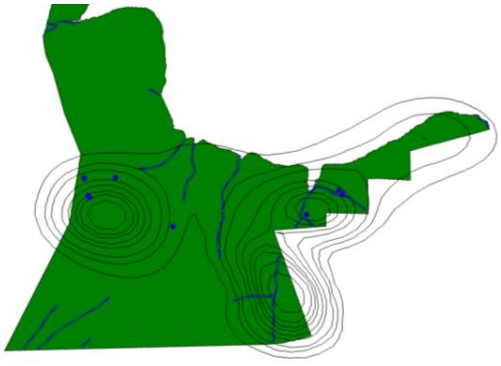
The combination of data from all four collared tsessebe data allowed for analysis of total utilization, by tsessebe, of BNP. Figure 4.42 d, represents the total usage by tsessebe. Patterns of ranges for the wet seasons (Figures 4.42 a & c) and the dry season (Figure 4.42 b) occur very much in the same area, namely along the drainage lines along the periphery of the study area. The differences projected in Figure 4.42 c, may be as a result of the noticeably less amount of data as the collar data diminished during this period.

Total range for the entire duration of study (September 2009 - April 2011) was recorded in Figure 4.42 d. This Figure indicates the overall usage of tsessebe during this study; the total range covers the areas that contain either drainage channels or temporary water points.

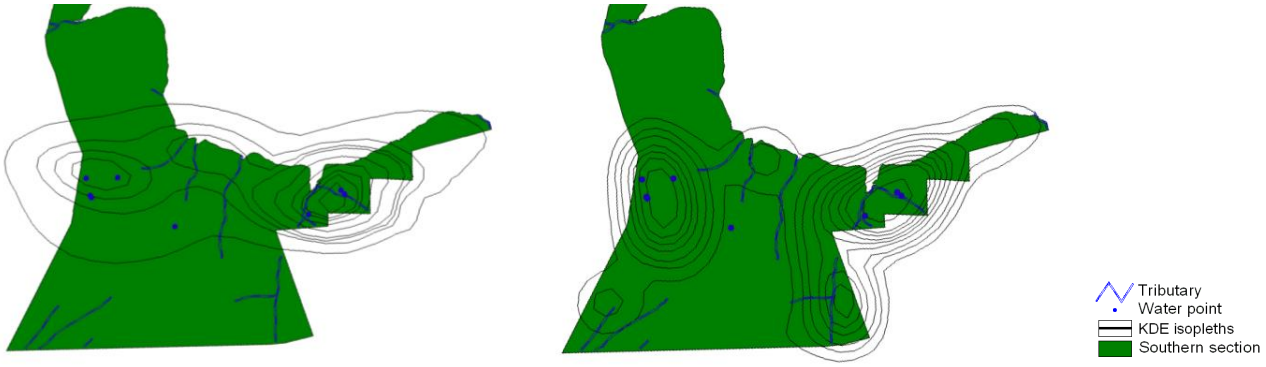
Figures 4.43 a - d are representative of the range as derived from LoCoH. Here again concentrations around temporary water holes and drainage channels can be seen.



a) Wet season Oct. ‘09 - Mar. ‘10

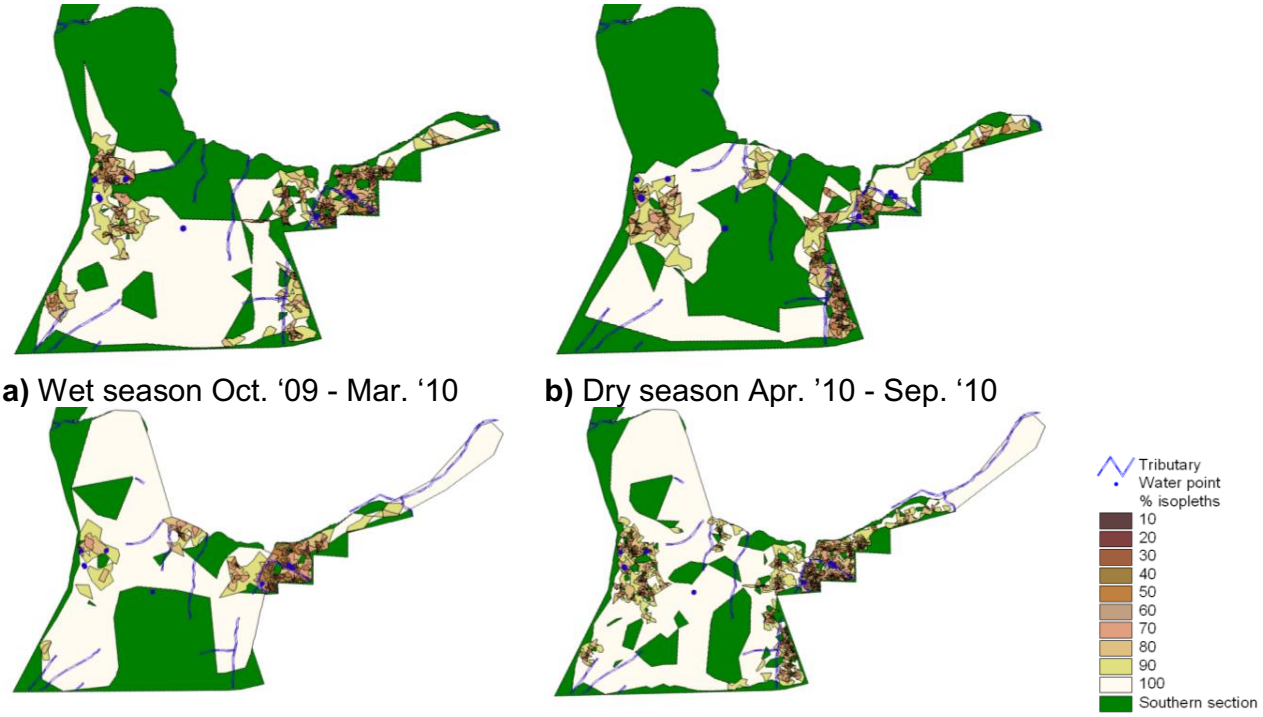


b) Dry season Apr. ’10 - Sep. ‘10



c) Wet season Oct. ’10 - Mar. ‘11 **d)** Total combined range **Key**

Figure 4.42: Combined KDE ranges of the four collared tsessebe in BNP.



a) Wet season Oct. ‘09 - Mar. ‘10 **b)** Dry season Apr. ’10 - Sep. ‘10

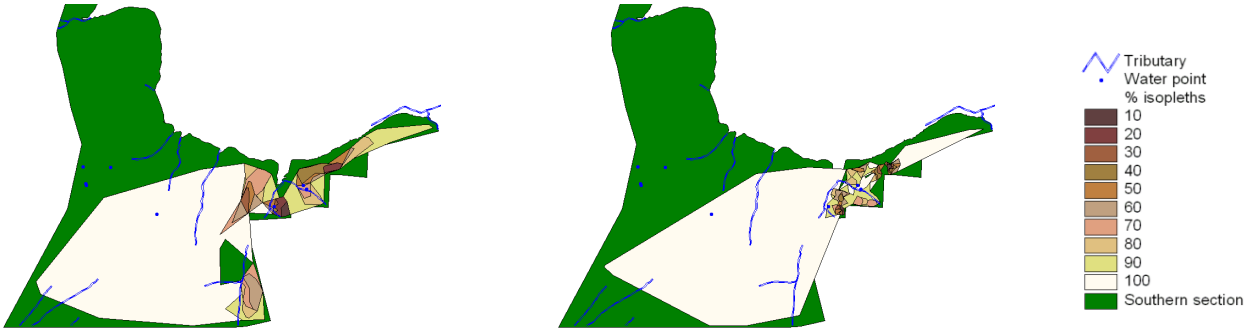
c) Wet season Oct. ’10 - Mar. ‘11 **d)** Total combined range **Key**

Figure 4.43: Combined LoCoH ranges of the four collared tsessebe in BNP.

4.3.7 Local Convex Hull home ranges within the described plant communities.

This description is based on Figures 4.44 a-b, of LoCoH ranges for AG 81 within the previously described vegetation communities (Chapter 3).

Grouping is predominantly on the eastern side of the study area, located within *Terminalia sericia - Digitaria eriantha* woodland (2) and *Acacia luederitzii* woodland (4). Predominant grasses found in this study for these areas include *Panicum maximum, Eragrostis rigidior, Digitaria eriantha, Perotis patens, Cynodon dactylon, Pogonarthria squarrosa, Heteropogon contortus, Tricholaena monachne, Branchiaria nigropedata, Schmidtia pappophoroides, Cymbopogon plurinodis, Eragrostis superba, Sporobolus nitens, Eragrostis lehmanniana* and *Melinis repens.*



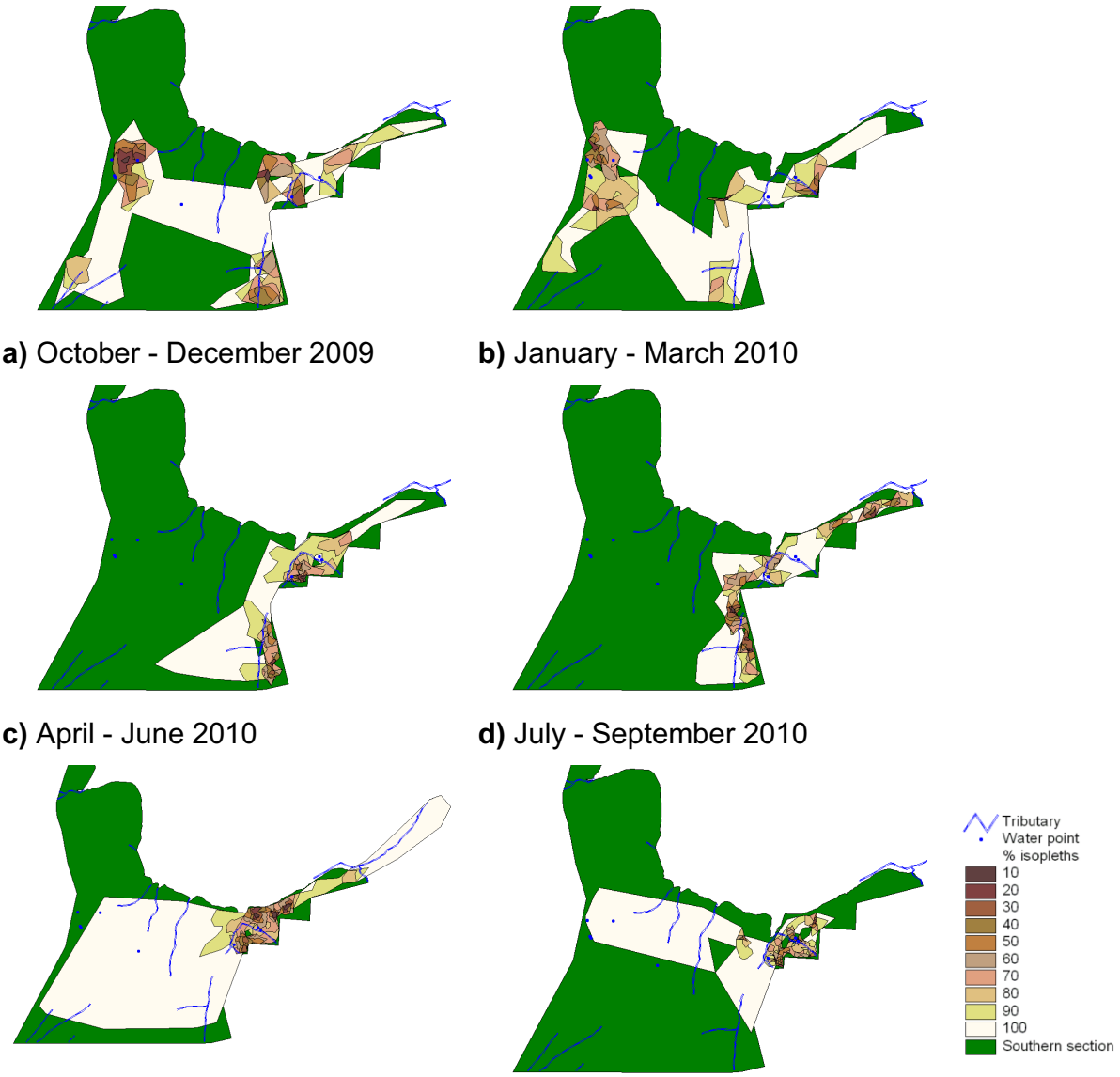
a) October - December 2009 **b)** January - March 2010 **Key**

Figure 4.44: LoCoH for AG 81.

The following description is based on Figures 4.45 a-f, of LoCoH ranges for AG 93 within the previously described vegetation communities (Chapter 3).

Grouping occurs both on the western and eastern sides of the study area, located within *Terminalia sericea - Digitaria eriantha* woodland (2) and *Combretum zeyheri - Eragrostis curvula* woodland (1) on the western side and *Terminalia sericea - Digitaria eriantha* woodland (2) and *Acacia luederitzii* woodland (4) on the eastern side. Grasses found in this study for these areas include *Panicum maximum, Eragrostis rigidior, Digitaria eriantha, Perotis patens, Cynodon dactylon, Aristida stipitata, Eragrostis curvula, Aristida congesta, Pogonarthria squarrosa, Heteropogon contortus, Tricholaena monachne, Branchiaria nigropedata, Schmidtia pappophoroides, Cymbopogon plurinodis,*

Eragrostis superba, Sporobolus nitens, Eragrostis lehmanniana, and *Melinis repens.*



a) October - December 2009 **b)** January - March 2010

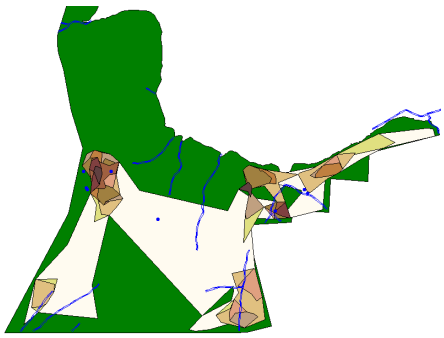
c) April - June 2010 **d)** July - September 2010

e) October - December 2010 **f)** January - March 2011 **Key**

Figure 4.45: LoCoH for AG 93.

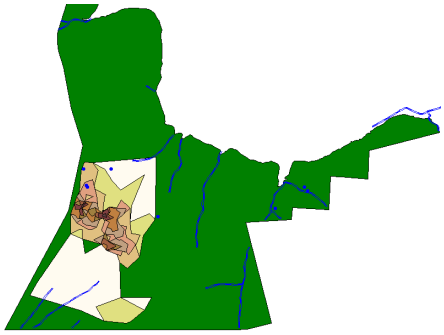
Description based on Figures 4.46 a-e, of LoCoH ranges for AG 242 within the previously described vegetation communities (Chapter 3).

Grouping is predominantly on the western side of the study area, located within *Terminalia sericea - Digitaria eriantha* woodland (2) and *Combretum zeyheri - Eragrostis curvula* woodland (1). Grasses found in this study for these areas include *Panicum maximum, Eragrostis rigidior, Digitaria eriantha, Perotis patens, Cynodon dactylon, Aristida stipitata, Eragrostis curvula, Aristida congesta, Pogonarthria squarrosa, Heteropogon contortus, Tricholaena monachne, Branchiaria nigropedata,* and *Melinis repens*.

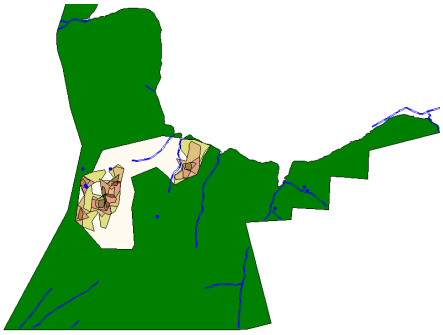


a) October - December 2009

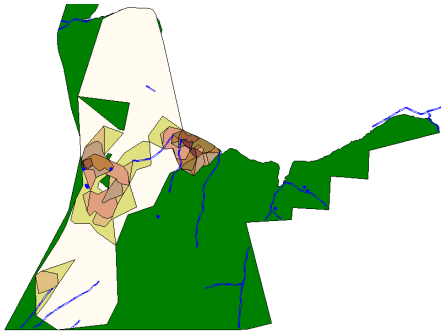
b) January - March 2010

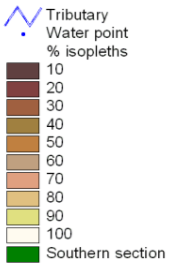


c) April - June 2010



d) July - September 2010



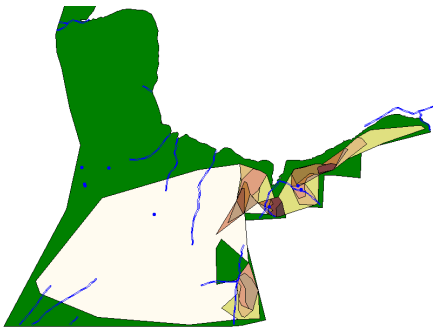


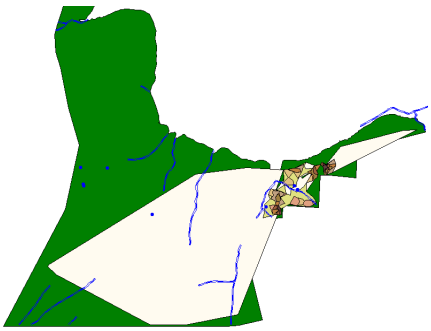
e) October - December 2010 **Key**

Figure 4.46: LoCoH for AG 242.

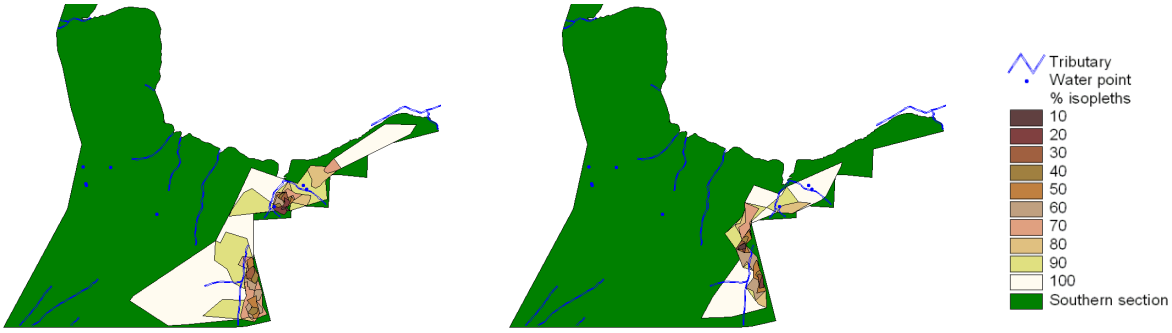
Description based on Figures 4.47 a-d, of LoCoH ranges for AG 243 within the previously described vegetation communities (Chapter 3).

Grouping is predominantly on the eastern side of the study area, located within *Terminalia sericea - Digitaria eriantha* woodland (2) and *Acacia luederitzii* woodland (4). Grasses found in this study for these areas include *Panicum maximum, Eragrostis rigidior, Digitaria eriantha, Perotis patens, Cynodon dactylon, Aristida stipitata, Eragrostis curvula, Aristida congesta, Pogonarthria squarrosa, Heteropogon contortus, Tricholaena monachne, Branchiaria nigropedata,* and *Melinis repens*.





a) October - December 2009 **b)** January - March 2010



c) April - June 2010 **d)** July - September 2010 **Key**

Figure 4.47: LoCoH for AG 243

4.3.8 Use of burnt areas

To make the explanation of burns easier to understand, Figure 4.28 (Southern section split into four quadrants) was used as the guide to the quadrants.

4.3.8.1 Burns for the year 2009

The following burns were undertaken for 2009. See also Figure 4.48. Security burn (SB1) was started on the 8th June 2009, located in quadrant 2 along the fence line. Prescribed burn (PB1) was started on the 29th June 2009, located in quadrants 3 and 4, between the lower end of the western fence, along the southern fence and Kgama loop. Prescribed burn (PB2) was started on the 30th June 2009 was located in quadrant 1 between the western fence and Korwe road. Prescribed burn (PB3) was started on the 16th July 2009, located in quadrant 2 between the fence and river. Prescribed burn (PB4) was started on the 20th July 2009, located in quadrant 4 in the lower south east corner from the management roads to the fence. Prescribed burn (PB5) was started on the 21st July 2009, located in quadrant 2, within the Mutumuga loop. Security burn (SB2) located along the fence line of quadrant 1 and 4 also was started on the 21st July 2009.

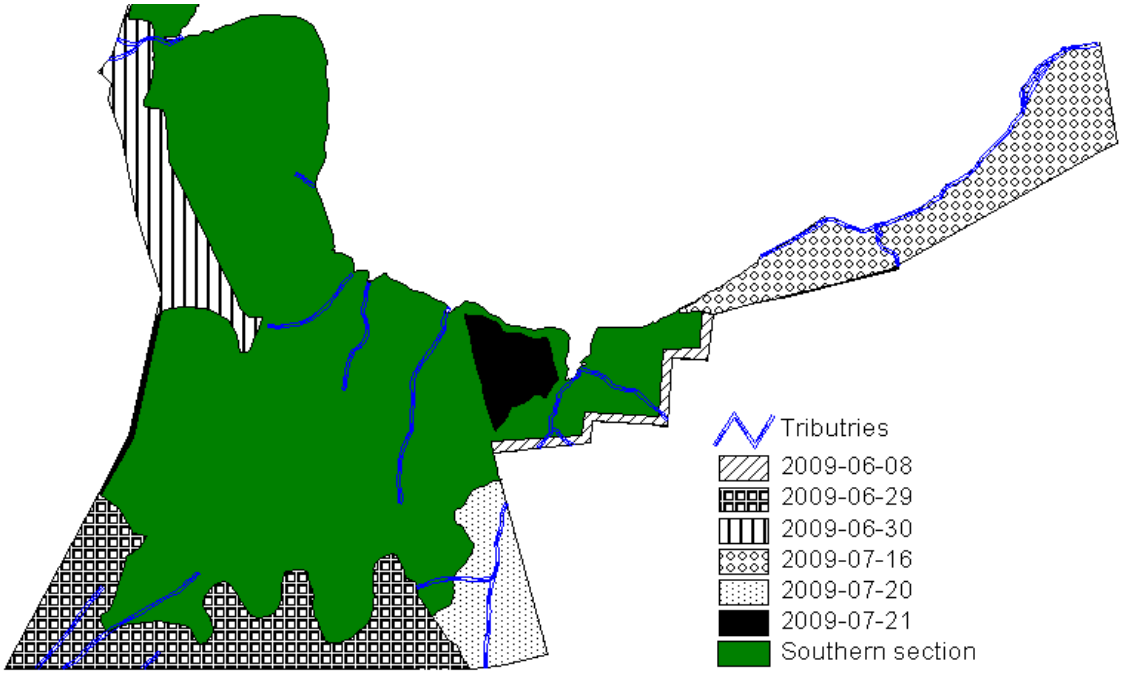


Figure 4.48: Position of burns that took place during 2009.

4.3.8.2 Burns for the year 2010

This paragraph describes the burns for 2010. See Figure 4.49 for more detail. Prescribed burn (PB6) was started on the 6th July 2010, located in quadrant 1 between the western fence and Korwe road. Security burn (SB3) was started on 7th July 2010, located on the western fence of quadrants 1 and 3. Prescribed burn (PB7) was started on the 12th July 2010, and burnt in quadrant 2, from the fence line to the dam shore line. Prescribed burn (PB8) was started on the 2nd August 2010, located in quadrant 4 up from the Kutswane River between the fence and Moretele River up to the eastern most fence. Security burn (SB4) was started on the 4th August 2010, located in quadrant 3 along the lower end of the western fence, along the southern fence and up along the eastern fence of quadrant 4.

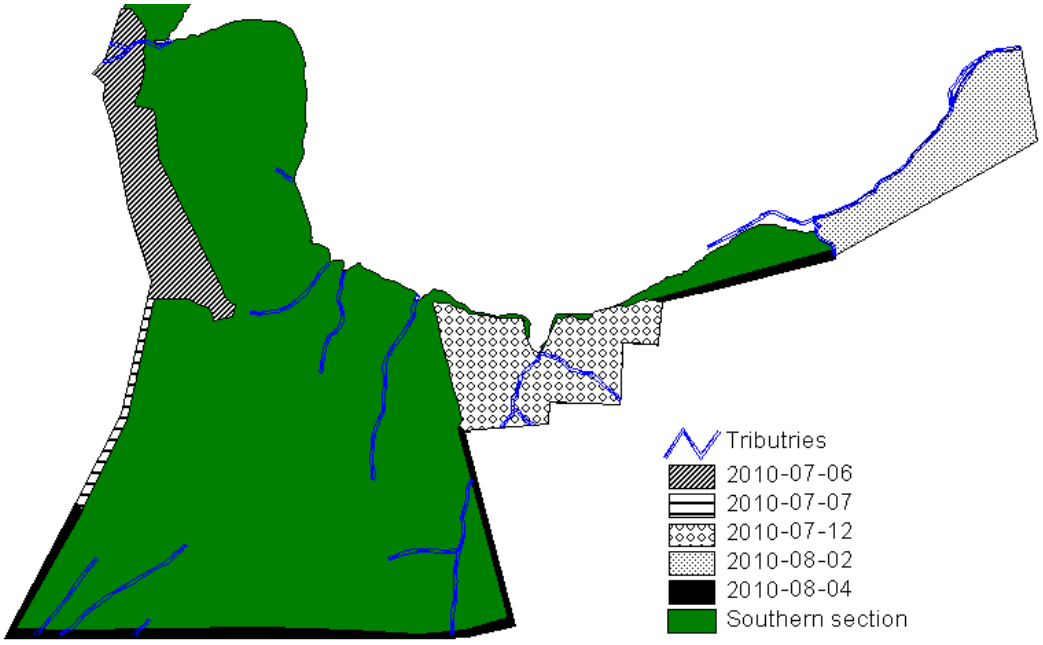


Figure 4.49: Position of burns that took place during 2010.

Table 4.6 and 4.7 indicates the burn number given to each of the burns, the date the burn was started, the type of burn (as classified by park management) and the total area that was burnt during each of the burns for 2009 and 2010 respectively.

Table 4.6: Details on burns conducted in 2009.

Burn number	**Date burn was started**	**Type of burn**	**Area burnt (Hectares)**
SB1	08/06/2009	Security burn	30
PB1	29/06/2009	Prescribed burn	331
PB2	30/06/2009	Prescribed burn	163
PB3	16/07/2009	Prescribed burn	442
PB4	20/07/2009	Prescribed burn	122
PB5	21/07/2009	Prescribed burn	58
SB2	21/07/2009	Security burn	8

Table 4.7: Details on burns conducted 2010.

Burn number	Date burn was started	Type of burn	Area burnt (Hectares)
PB6	06/07/2010	Prescribed burn	164
SB3	07/07/2010	Security burn	20
PB7	12/07/2010	Prescribed burn	211
PB8	02/08/2010	Prescribed burn	174
SB4	04/08/2010	Security burn	52

4.3.8.3 Post burn utilization

The Figures (4.50 – 4.65) represents one week in time from the 5th July until the 24th October 2010. The Figures depict the movements of the collared tsessebe in and around the burnt areas.

In all the Figures for this section the green dots are representative of AG 232, red dots are representative of AG 93 and blue dots are representative of AG 243.

Burn PB6 was set on the 6th July 2010 and burn SB3 was set on the 7th July 2010. No movement was recorded within the burnt areas post burn (Figure 4.50).

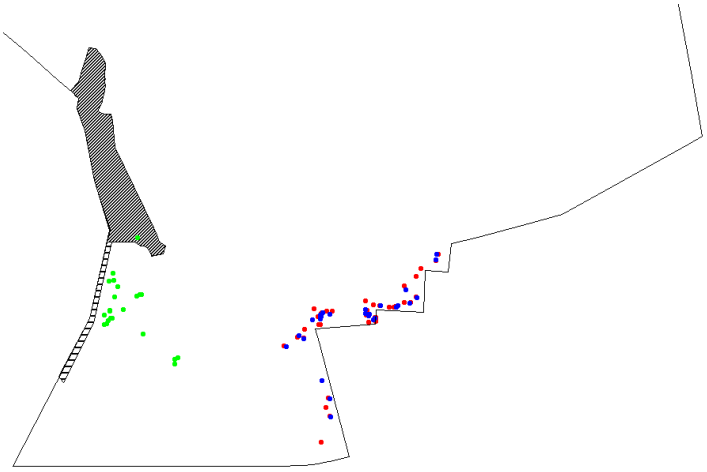


Figure 4.50: Distribution during the 5th July - 11th July 2010:

Burn PB7 was set on the 12th July 2010. AG 93 had 38% of its fixes recorded within the burnt area of PB7. AG 243 had 18% of its fixes recorded within the burnt area of PB7 (Figure 4.51).

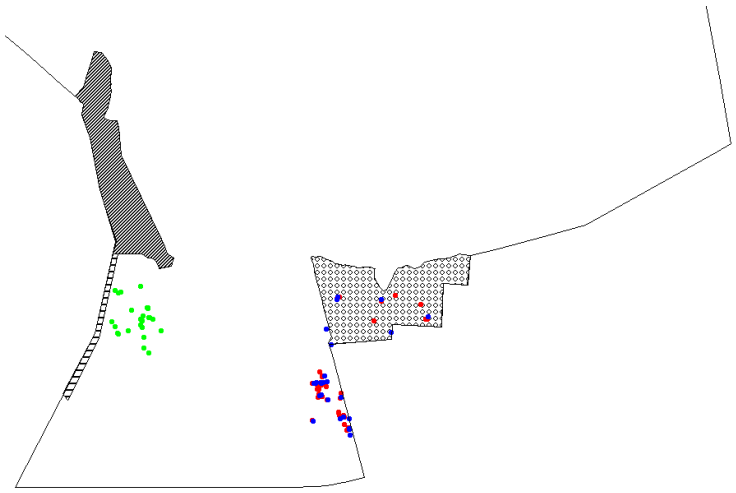


Figure 4.51: Distribution during the 12th July - 18th July 2010:

One week post PB7 burn, AG 93 had 7% of its fixes recorded within the burnt area of PB7 and AG 243 had 4% of its fixes recorded within the burnt area of PB7 (Figure 4.52).

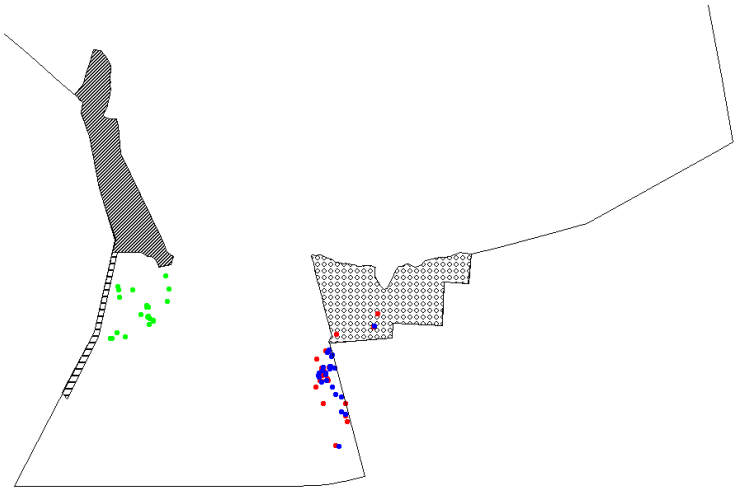


Figure 4.52: Distribution during the 19th July - 25th July 2010:

Two weeks post PB7 burn, AG 93 had 33% of its fixes recorded within the burnt area of PB7 and AG 243 had 30% of its fixes recorded within the burnt area of PB7 (Figure 4.53).

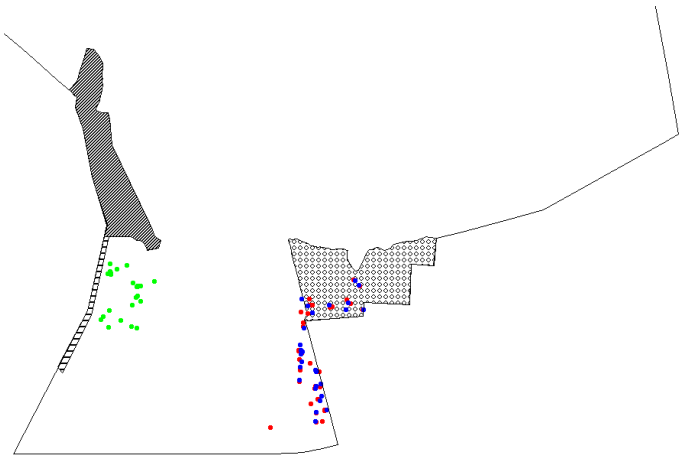


Figure 4.53: Distribution during the 26th July - 1st August 2010:

Burn PB8 was set on the 2nd August 2010 and Burn SB4 was set on the 4th August 2010. Three weeks post PB7 burn, AG 93 had 25% of its fixes recorded within the burnt area of PB7 and AG 243 had 25% of its fixes recorded within the burnt area of PB7 (Figure 4.54).

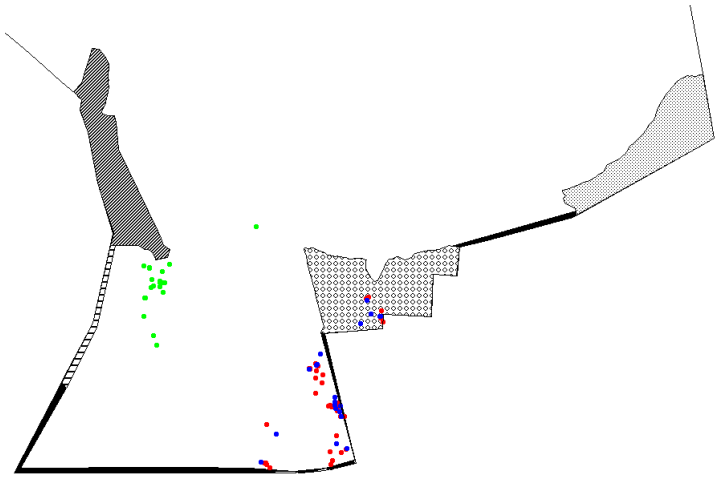


Figure 4.54: Distribution during the 2nd August - 8th August 2010:

Four weeks post PB7 burn, AG 93 had 43% of its fixes recorded within the burnt area of PB7 (Figure 4.55).

One week post SB4 burn, AG 93 had 36% of its fixes recorded within the burnt area of SB4 (Figure 4.55).

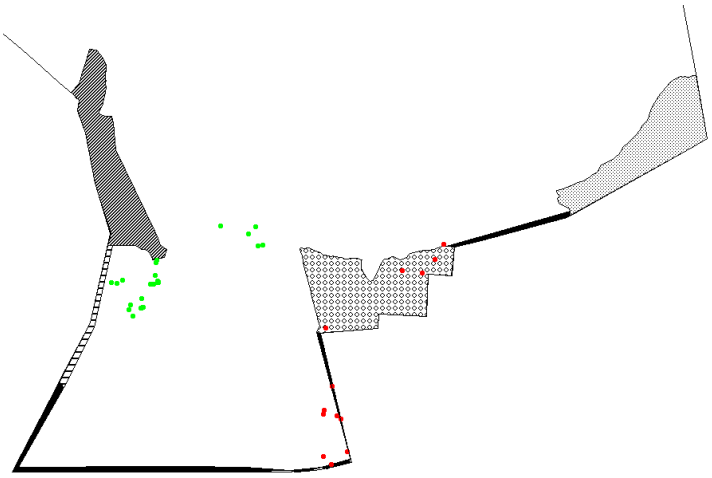


Figure 4.55: Distribution during the 9th August - 15th August 2010:

Five weeks post PB7 burn, AG 93 had 14% of its fixes recorded within the burnt area of PB7 (Figure 4.56).
Two weeks post SB4 burn, AG 93 had 12% of its fixes recorded within the burnt area of SB4 (Figure 4.56).
AG 242 had 4% of its fixes recorded within the burnt area of PB6 (Figure 4.56).

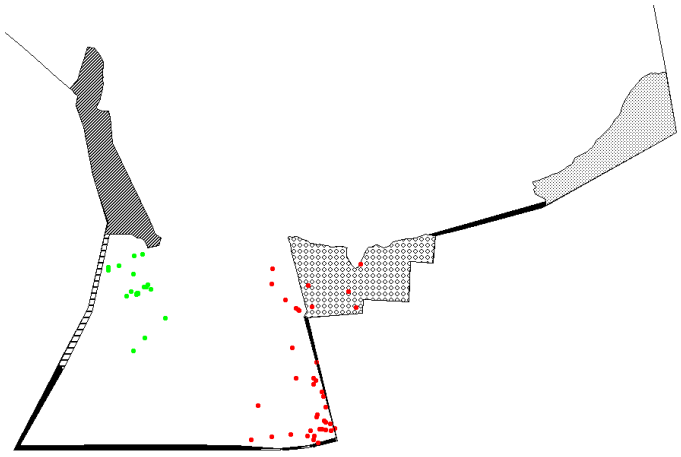


Figure 4.56: Distribution during the 16th August - 22nd August 2010:

Six weeks post PB7 burn, AG 93 had 29% of its fixes recorded within the burnt area of PB7 (Figure 4.57).

Three weeks post SB4 burn, AG 93 had 17% of its fixes recorded within the burnt area of SB4 (Figure 4.57).
AG 242 had 2% of its fixes recorded within the burnt area of PB6 (Figure 4.47).

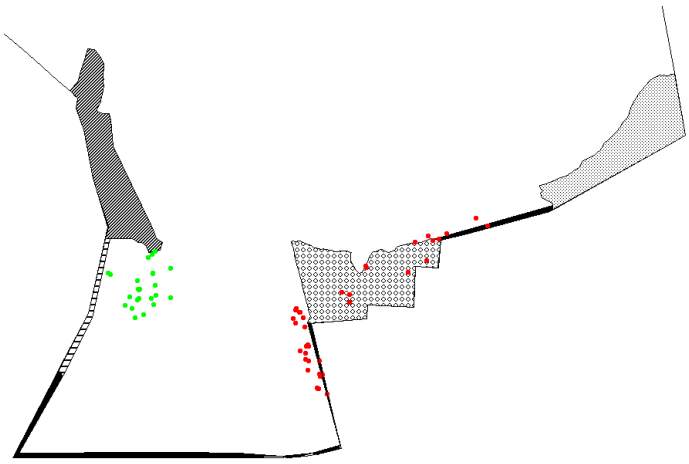


Figure 4.57: Distribution during the 23rd August - 29th August 2010:

Seven weeks post PB7 burn, AG 93 had 19% of its fixes recorded within the burnt area of PB7 (Figure 4.58).
Four weeks post SB4 burn, AG 93 had 29% of its fixes recorded within the burnt area of SB4 (Figure 4.58).

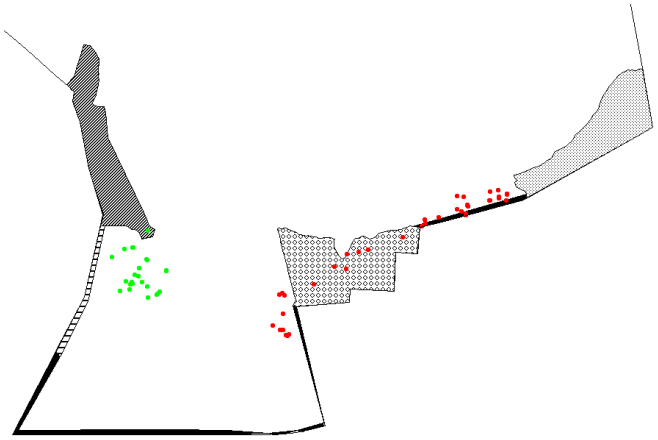


Figure 4.58: Distribution during the 30th August - 5th September 2010:

Eight weeks post PB7 burn, AG 93 had 38% of its fixes recorded within the burnt area of PB7 (Figure 4.59).

Five weeks post SB4 burn, AG 93 had 29% of its fixes recorded within the burnt area of SB4 (Figure 4.59).

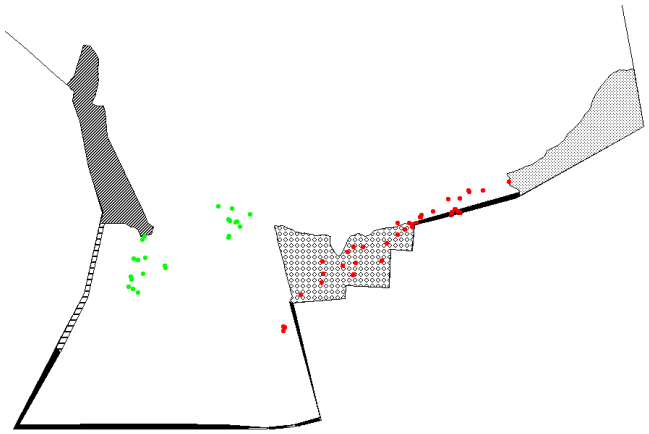


Figure 4.59: Distribution during the 6th September - 12th September 2010:

Nine weeks post PB7 burn, AG 93 had 26% of its fixes recorded within the burnt area of PB7 (Figure 4.60).
Six weeks post SB4 burn, AG 93 had 19% of its fixes recorded within the burnt area of SB4 (Figure 4.60).

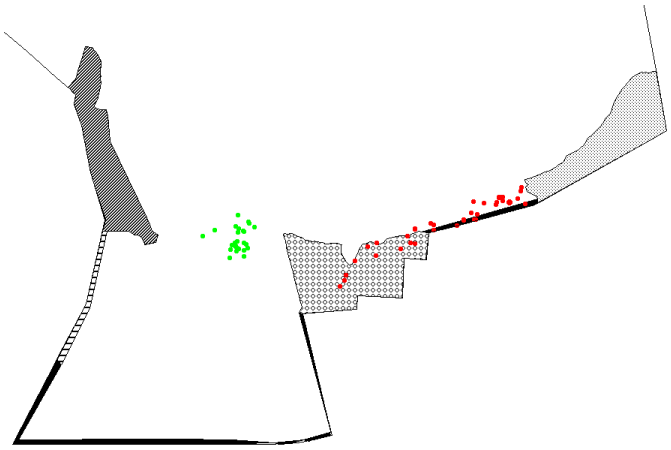


Figure 4.60: Distribution during the 13th September - 19th September 2010.

Ten weeks post PB7 burn, AG 93 had 43% of its fixes recorded within the burnt area of PB7 (Figure 4.61).
Seven weeks post SB4 burn, AG 93 had 17% of its fixes recorded within the burnt area of SB4 (Figure 4.61).

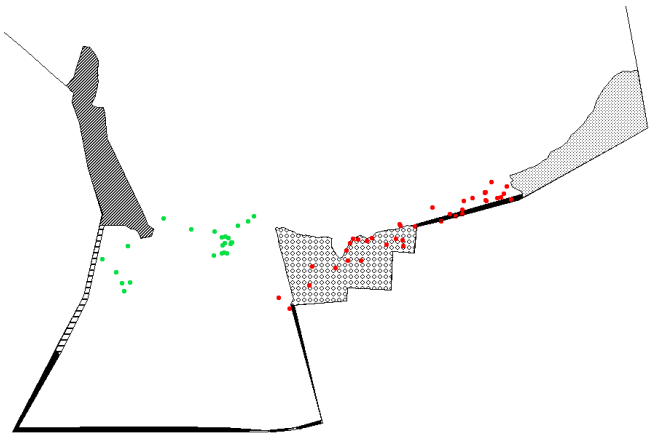


Figure 4.61: Distribution during the 20th September - 26th September 2010:

Eleven weeks post PB7 burn, AG 93 had 45% of its fixes recorded within the burnt area of PB7 (Figure 4.62).
Eight weeks post SB4 burn, AG 93 had 10% of its fixes recorded within the burnt area of SB4 (Figure 4.62).
Eight weeks post PB8 burn, AG 93 had 7% of its fixes recorded within the burnt area of PB (Figure 4.62).

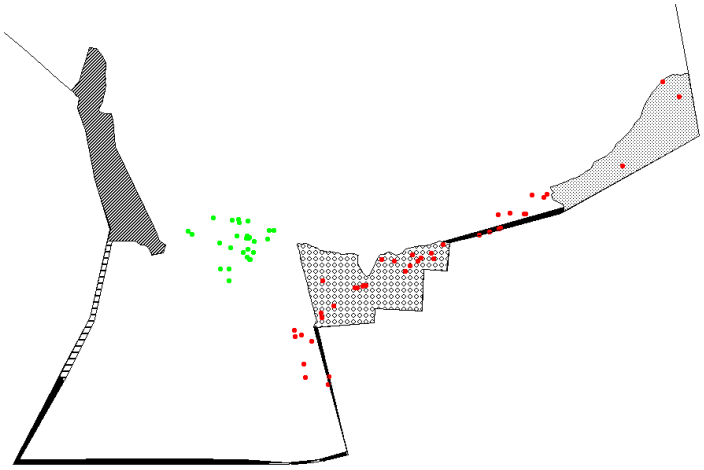


Figure 4.62: Distribution during the 27th September - 3rd October 2010:

Twelve weeks post PB7 burn, AG 93 had 62% of its fixes recorded within the burnt area of PB7 (Figure 4.63).

Nine weeks post SB4 burn, AG 93 had 10% of its fixes recorded within the burnt area of SB4 (Figure 4.63).

Nine weeks post PB8 burn, AG 93 had 7% of its fixes recorded within the burnt area of PB8 (Figure 4.63).

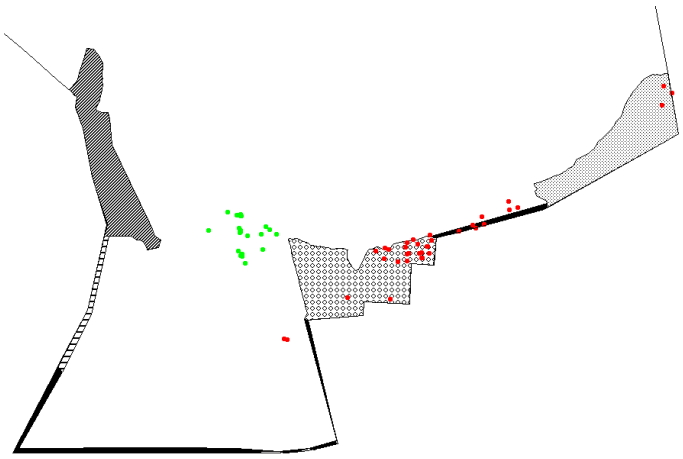


Figure 4.63: Distribution during the 4th October - 10th October 2010:

Thirteen weeks post PB7 burn, AG 93 had 69% of its fixes recorded within the burnt area of PB7 (Figure 4.64).

Ten weeks post SB4 burn, AG 93 had 5% of its fixes recorded within the burnt area of SB4 (Figure 4.64).

Ten weeks post PB8 burn, AG 93 had 17% of its fixes recorded within the burnt area of PB8 (Figure 4.64).

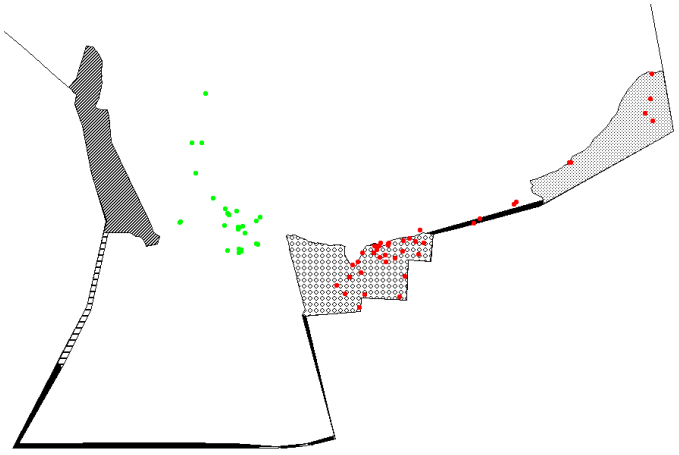


Figure 4.64: Distribution during the 11th October - 17th October 2010

Fourteen weeks post PB7 burn, AG 93 had 67% of its fixes recorded within the burnt area of PB7 (Figure 4.65).
Eleven weeks post SB4 burn, AG 93 had 7% of its fixes recorded within the burnt area of SB4 (Figure 4.65).
AG 242 had 4% of its fixes recorded within the burnt area of PB6 (Figure 4.65).

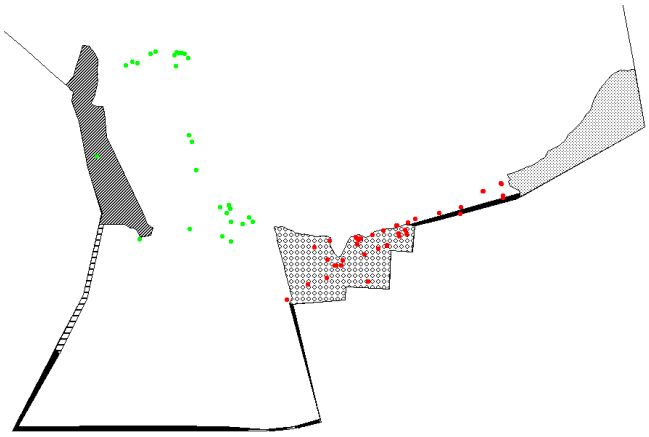


Figure 4.65: Distribution during the 18th October - 24th October 2010:

4.3.8.4 Periods of usage within burnt areas

Tsessebe made use of PB7 as early as one week post burn, but usage was relatively low compared to the following weeks. Weeks four, ten and eleven post burn had a usage of above 40% per week (Figure 4.66). Usage of the burnt area during week's 12 - 14 post burn increased to over 60% (Figure 4.66).

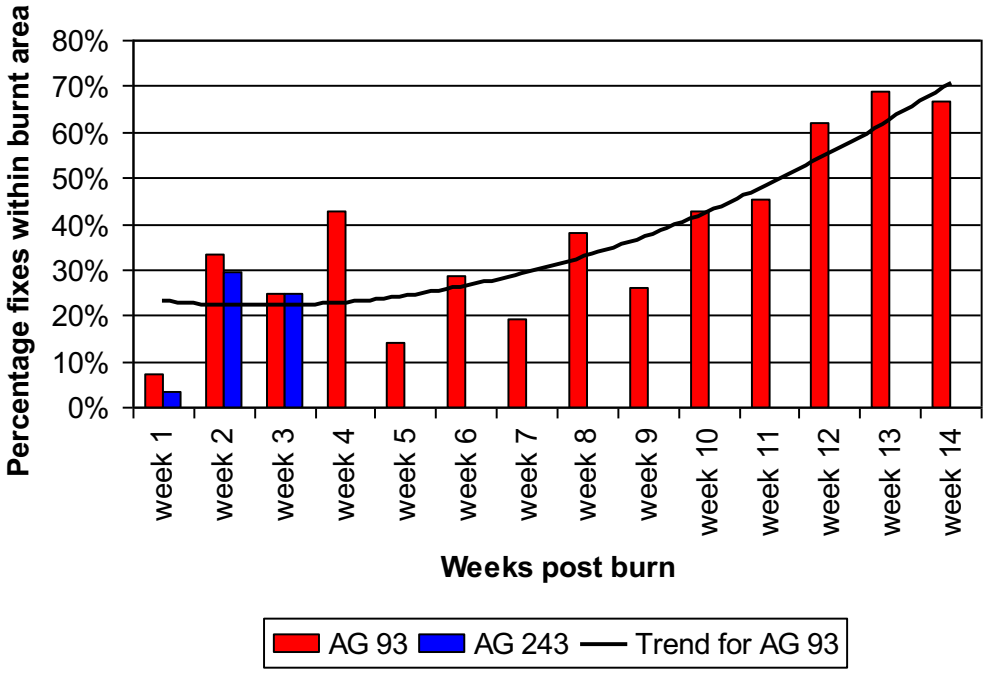


Figure 4.66: The percentage of fixes within the burnt area of PB7 (post burn) for the collars AG 93 and AG 243.

Tsessebe made 36% usage of SB4 one week post burn, which accounted for the highest usage of all 11 weeks post burn. Weeks two, three, four and five post burn saw a marginal increase in usage of this area, with the highest usage recorded for week five post burn. Week's six to eleven saw a gradual decrease in usage of the area, with the lowest usage recorded in week ten post burn (Figure 4.67).

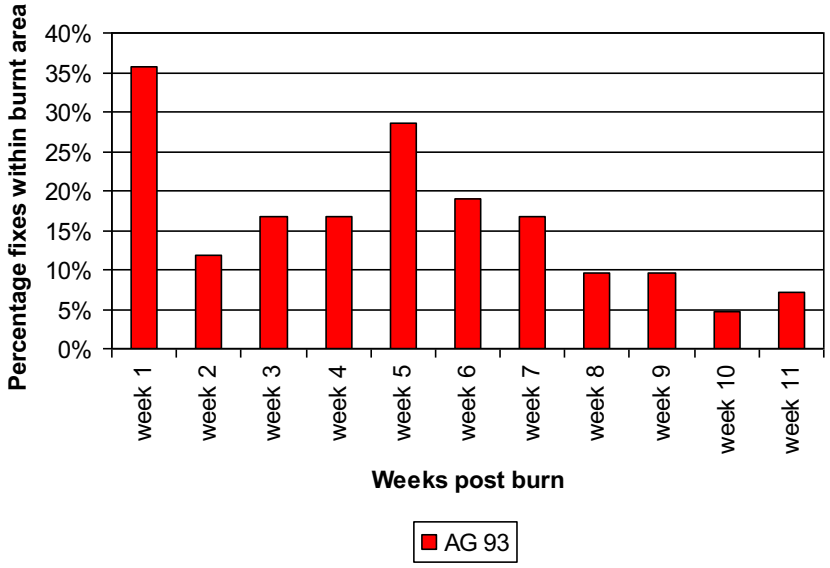


Figure 4.67: The percentage of fixes within the burnt area of SB4 (post burn) for the collar AG 93.

Tsessebe only made use of PB8 from week eight to week ten post burn, with the highest use recorded in week ten post burn (Figure 4.68).

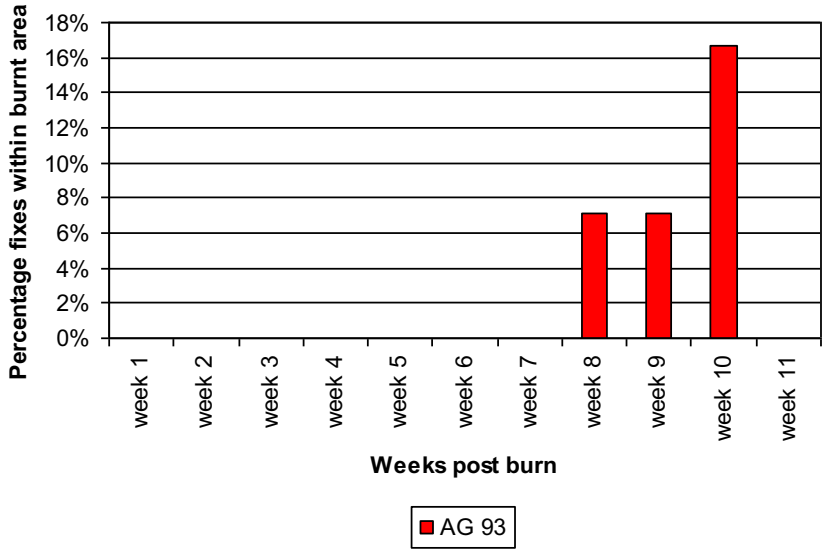


Figure 4.68: The percentage of fixes within the burnt area of PB8 (post burn) for the collar AG 93.

4.3.9 Remote cameras within core ranges

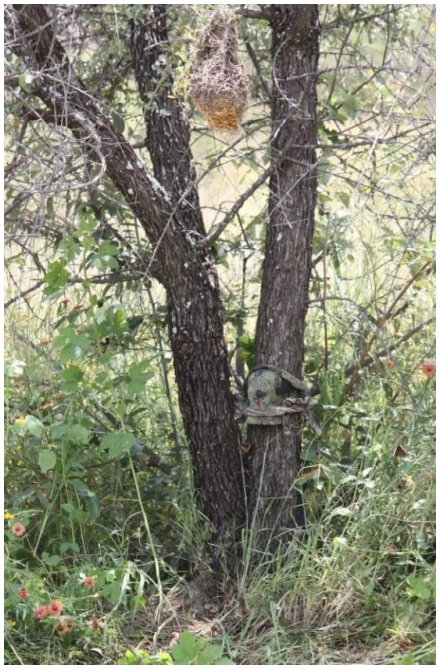


Figure 4.69: Remote camera positioned against a tree within the core home range.

In the Figures 4.70 a-d, the recorded behaviour between two collared females was caught by a remote camera. Bouts were recorded on different occasions thus seemingly indicating this may be of a regular occurrence amongst these animals.

a)

b)

c)

d)

Figure 4.70: Tsessebe horn clashing.

In Figures 4.71 a-d, tsessebe were captured by remote cameras while they were horning the soil of a temporary water body's dry bed. According to Skinner & Chimimba (2005), both sexes horn soil.

a)

b)

c)

d)

Figure 4.71: Tsessebe horning the soil.

The importance of surface water can be seen in Figures 4.72 a-n, where as the available surface water in the veld dries up, water in temporary water bodies become areas of concentration. In the Figures 4.72 a-l, it can be seen as time goes on the water body begins to dry up and tsessebe make use of the available water and graze on the vegetation that begins to grow on the dry bed. In Figure 4.72 j, the water body is replenished by rains and tsessebe make use of the partially full water body. The body of water became full (Figure 4.72 l) as a result of good rains. After the 25th March 2011, tsessebe were not captured in any

subsequent photographs. Rains kept the temporary water body full; this can be seen in Figures 4.72 m & n and thus resulted in water levels remained constant as can be deduced from the pond vegetation that grew during this time. From Figure 4.72 n, to Figure 4.72 m, a month had passed, with water levels still remaining relatively full. The depth of the temporary water body can be gauged from Figure 4.72 m, where a blue wildebeest was captured wading in the water.

a)

b)

c)

d)


HCO ScoutGuard
2.24.2011 7:04:48

e)


HCO ScoutGuard
2.26.2011 12:28:01

f)


HCO ScoutGuard
2.28.2011 8:29:25

g)


HCO ScoutGuard
3.01.2011 6:01:52

h)


HCO ScoutGuard
3.02.2011 7:16:55

i)


HCO ScoutGuard
3.25.2011 6:11:58

j)

k)

l)

m)

n)

Figure 4.72: Usage of temporary water points.

These two Figure were captured in the early evening at around 19:24 (Figure 4.73 a) and then again in the late evening at around 23:44 (Figure 4.73 b).

a) **b)**

Figure 4.73: Nocturnal activity.

4.4 Discussion

Of the total land available for use in Borakalalo National Park the four collared tsessebe prefer to confine their distribution to the southern section of the reserve. The southern section is naturally divided from the western section by the Mogosane mountain range and from the northern section by the Moretele River. It has a relatively flat terrain consisting of course grained granite, sandy soils, with scattered boulders in places. Ben-Shahar (1990) found that tsessebe were associated with flat areas and moderate slopes and areas with sandy and acidic soils with a low rock cover.

Core ranges border close to the fence lines on both sides of the study area. With little to no use of the interior of the southern section. A possible reason for this may be that unfavourable conditions exist within these areas. A great disadvantage to their preference to the edges of the reserve result in having a higher chance of being poached. Skinner & Chimimba (2005) report that tsessebe are vulnerable to snaring as they make use of regular paths to water.

From the LoCoH home ranges it can be seen that a pattern of usage in and surrounding the drainage channel emerges. It may be of value to note that the channels are located on or near the boundaries of the reserve. These channels either lead water into or out of the reserve. The centre of the southern section has no drainage channels. This may be a contributory factor to why the tsessebe avoid the central part of the southern section. Tsessebe only crossed the central area when they moved from one side of the study area to the other. They did not spend any significant time within this area.

It can therefore be hypothesised that their movements would then be according to the availability of water in these channels during the year. Moving from one channel to the next as the need arises. Studies into whether or not they do this could be done.

Gureja & Owen-Smith (2002) found tsessebe had utilized grasses such as *Pogonarthria squarrosa, Eragrostis gummiflua, Eragrostis rigidior* and *Tricholaena monachne* that are considered unpalatable to cattle. Tsessebe were also impartial to the selection of *Urochloa mosambicensis* and *Heteropogon contortus* (Gureja & Owen-Smith 2002). Grasses that occur within tsessebe home ranges during this study include *Panicum maximum, Eragrostis rigidior, Digitaria eriantha, Perotis patens, Cynodon dactylon, Aristida stipitata, Eragrostis curvula, Aristida congesta, Pogonarthria squarrosa, Heteropogon contortus, Tricholaena monachne, Brachiaria nigropedata, Schmidtia pappophoroides, Cymbopogon plurinodis, Eragrostis superba, Sporobolus nitens, Eragrostis lehmanniana* and *Melinis repens.*

This study found that tsessebe core home ranges were found near water bodies, and that their core range size changed as the seasons changed. They made use of a greater area during the wetter months and concentrated in specific areas in the drier months. Tsessebe are water dependant and required surface water, which influences their seasonal distribution patterns (Child *et al.*1972). Dörgeloh

(2006) found that tsessebe in the Nylsvley Nature Reserve were found not more than 2 km away from a water source. Cain *et al*. (2012) noted that grazers are commonly more water dependent than browsers are because by the late dry season the moisture content of grasses had decrease to below 10%.

Therefore the change in usage of area size from one season to another is due to the available temporary surface water that occurs in pools around the reserve, these pools would fill up during the wet months and as the area becomes drier and as the smaller pools began to dry up the tsessebe tended to congregate in areas where larger water bodies could be found, as these water bodies tended to retain water for much longer periods between rainfalls.

During 2009 and 2010 a total of four security burns totalling roughly 110 hectares was burnt and a total of eight prescribed burns with an estimated 1300 hectares of surface burnt within the southern section. Gureja & Owen-Smith (2002) found that tsessebe used burns grasslands within 2-3 weeks, but overall the most significant use of burnt areas was between 6-9 weeks after the burn. During this study a high usage of the burnt area of PB7 with 43 % of fixes recorded in the area. The general trend was an increase in use of the area. So much so that is became the core home range for AG 93 during the October - December 2010 period. Gureja & Owen-Smith (2002) concluded that the regrowth following management burns was a key part of food intake for tsessebe and other antelope. A study by Tomor & Owen-Smith (2002) on the comparative use by ungulates on regrowth post burns on Nylsvley Nature Reserve found that tsessebe limited their grazing to the floodplain margins where the grass species arrangement was more mixed than elsewhere on the reserve. According to the aforementioned authors, The Nylsvlei tsessebe did not make use of the burnt areas. They speculate this was due to territoriality or that the burns being in unsuitable terrain.

The area beyond the Kutswane River was only used from eight weeks post burn, for two weeks. However it was only periodically used. The total usage for the eighth week was 7 %, increasing to 10 % then to 17% the next two weeks respectively. They did not make use of this area again after that period. This area may have become accessible due to no rainfall for the months from June to December 2010, resulting in the Kutswane River drying up.

Remote cameras that were placed in the core home ranges caught some interesting observations. Of the three cameras that were placed in the various home ranges one gave a considerably large amount of pictures that could be utilized. One of the cameras was stolen and it may be of benefit for future researchers to make use of a securing device that it is thief proof.

A fight sequence described by Joubert (1972) resembled similar behaviour to that recorded on by one of the remote cameras (Figures 4.70 a-d). Joubert (1972) described the sequence as follows: two males stand face to face approximately two to three metres apart. From there they drop to their knees with their lower jaw pulled down towards their chest, horns slanted forward. They lunge forward, clashing their horns together, then retreat a metre or two and clash horns again; this may be repeated several times. Their actions could be seen in some of the photographs obtained from the camera.

Another typical behaviour by tsessebe was caught on camera (Figures 4.71 a-d) Joubert (1972) described horning by tsessebe as follows: they fall to their knees and with their horns they forcefully plough up the soil. According to Joubert (1972) soiling was preformed particularly after rain; clumps of damp soil could be seen stuck to their horns.

Estes (1995) reported that tsessebe had one or two activity period during the night. This action was captured on camera (Figures 4.73 a-b). These nocturnal activities could also explain the movements that occurred during the same

evening. This could be seen from the hourly locations of AG 81. There were on occasions movements during the evening.

During this study home ranges for each collared tsessebe was determined. This information was used to determine whether there were seasonal changes amongst these home ranges and if tsessebe made use of particular vegetation communities. Total distribution within BNP was determined from data obtained from the GPS/GSM collars and movement patterns were recorded. The information obtained from this study allows for a better understanding of where tsessebe are located within the park and where they move. This allows for better protection of these antelope by rangers as they are able to know where to locate and monitor the herds.

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Chapter 5

Genetic Status of Tsessebe in Borakalalo National Park

5.1 Introduction

5.1.1 Microsatellite markers

Microsatellites, also known as Simple Sequence Repeats (SSR) or Short Tandem Repeats (STR), are short, non-coding nucleotides that are repeated in tandem (Hale *et al.* 2005). The repeated unit can be a mono-, di-, tri- or tetranucleotide with di- repeats being most common. These markers are highly polymorphic in length when analysed between different individuals of the same species. These markers are found throughout prokaryotic (Field & Wills 1998; Gur-Arie *et al*. 2000) and eukaryotic (Weber 1990; Tóth *et al*. 2000; Katti *et al*. 2001) genomes in both non-coding and rarely coding regions (Sutherlands & Richards 1995; Hancock 1999) of the genome (Zane *et al*. 2002). Microsatellite loci are surrounded by Deoxyribonucleic Acid (DNA) known as flanking regions. Generally, flanking regions are conserved across those of the same species and occasionally across different species (Selkoe & Toonen 2006). The flanking region of an individual microsatellite locus can be used to identify it; this is done with oligonucleotides (primers), which are short sequences of nucleotides that are designed to bind to the flanking region of the microsatellite. Primers anneal to the flanking region and are used to initiate the Polymerase Chain Reaction (PCR). Microsatellites are the most popular marker for conservation genetic studies in animals (Barbara *et al*. 2007) because they conform to Mendelian inheritance. Applications of microsatellite markers includes; parentage, relatedness, genetic diversity (Zhang & Hewitt 2003) forensic investigation, diseases diagnosis, conservation biology and linkage analysis. Two types of

markers are currently available for conservation genetic research namely; cross-species microsatellite markers and species-specific microsatellite markers, as discussed in subsequent sections.

5.1.1.1 Species-specific microsatellite markers

Species-specific markers can be developed either via cloning or pyrosequencing. The advantage of species-specific markers is their high specificity. However, the procedures followed are costly and labour intensive (Zucoloto *et al.* 2006). Typically, microsatellite development entails constructing a genomic library, screening colonies through colony hybridisation screening probes, and sequencing the microsatellite-containing clones, primer design, and testing for polymorphisms (Zane *et al*. 2002). Species-specific markers have been described in several species including; meerkat (*Suricata suricatta*) by Griffin *et al*. 2001, elephant (*Loxodonta africana*) by Whitehouse & Harley (2001), bontebok (*Damaliscus pygargus pygargus*) and blesbok (*Damaliscus pygargus phillipsi*) by Dalton *et al*. (2011).

5.1.1.2 Cross-species microsatellite markers

Cross-species microsatellites are markers that have been developed for one species that can be used in closely related species (Schlötterer *et al*. 1991; FitzSimmons *et al*. 1995; Rico *et al*. 1996; Gemmel *et al*. 1997, Primmer & Ellegren 1998). For example; cross-species microsatellite markers that have been developed for domestic animals (goat, sheep and cattle) can be used to determine population structures of ungulate taxa (Galan *et al*. 2003; Vial *et al*. 2003; Maudet *et al*. 2004).

Cross-species microsatellite markers have been used to develop a panel of polymorphic miscrosatellite loci by; Galan *et al*. (2003) for Roe deer (*Capreolus capreolus*), Beja- Pereira *et al.* (2004) for Dorcas gazelle (*Gazella dorcas*) and

Barbary sheep (*Ammotragus lervia*), Cosse *et al*. (2007) for Pampas deer (*Ozotoceros bezoarticus*) and Eblate *et al.* (2011) for Grant's gazelle (*Nanger granti*), red hartebeest (*Alcelaphus buselaphus*), eland (*Taurotragus oryx*), roan antelope (*Hippotragus equines*), impala (*Aepyceros melampus*) and topi (*Damaliscus korrigum*).

5.1.2 Applications

Microsatellite markers have a wide scope and can be used in various applications. Some of these applications include gender determination, phylogeny, parentage studies, relatedness, genetic variation, population subdivisions, phylogoegraphy and conservation genetics. Appropriate examples for each of these applications can be found in Table 5.1.

Table 5.1 A list of microsatellite applications and examples for each

Application	Details of research	Reference
Gender determination	Downy woodpecker (*Picoides pubescens*), Mourning dove (*Zenaida macroura*), Brown-headed cowbird (*Molothrus ater*), Song sparrow (*Melospiza melodia*), Rufous-sided towhee (*Pipilo erythrophthalmus*), Common yellowthroat (*Geothlypis trichas*)	Ball & Avise (1992)
	Mountain quail (*Oreortyx pictus*)	Delehanty *et al.* (1995)
Phylogeny	Western Canary Island lizard (*Gallotia galloti*)	Richard & Thorpe (2001)
	Indian domestic goats (*Capra hircus*)	Rout *et al*. (2008)
Parentage	Lake Malawi cichlids (*Copadichromis* spp. *Pseudotropheus* spp. *Melanochromis* spp. *Protomelus* spp.)	Kellogg *et al.* (1995)
	Plateau pika (*Ochotona curzoniae*)	Li *et al.* (2010)
Relatedness	Wild mice (*Mus musculus*)	Blouin *et al.* (1996)
Genetic variation	Brown bears (*Ursus arctos*)	Paetkau & Strobeck (1994) and Paetkau *et al.* (1998)
	Grey wolves (*Canis lupus*)	Forbes & Boyd (1996)
	Alpine marmot (*Marmota marmota*)	Goossens *et al.* (2001)
Population subdivision	Harbour porpoise (*Phocoena phocoena*)	Andersen *et al.* (1995)
	Common frog (*Rana temporaria*)	Palo *et al.* (2004)
Phylogeography	Sheepshead minnow (*Cyprinodon variegatus ovinus*), Mummichog (*Fundulus heteroclitus macrolepidotus*)	Haney *et al.* (2009)
Conservation genetics	Northern hairy-nosed wombat (*Lasiorhinus krefftii*)	Taylor *et al.* (1994)
	Domestic cat (*Felis silvestris catus*), Southern African cheetah (*Acinonyx jubatus jabutus*), Eastern African cheetah (*Acinonyx jabutus rainey*), Puma (*Puma concolor*), Lion (*Panthera leo*)	Menotti-Raymond & O'Brien (1995)

In the study presented here, cross-species microsatellite markers were used to determine the level of genetic diversity in a small population of tsessebe found in BNP. Small populations become genetically threatened and are prone to extinction when random genetic drift, founder effects, bottlenecks, inbreeding and outbreeding depression affect the genetic variation in these populations (Sarrazin & Barbault 1997). Founder effects occur when a new smaller population is established from a larger population. The continual existence of a small population over several generations may cause genetic drift, with a distinct repercussion on gene frequencies (Hall & Hallgrimsson 2008). Bottlenecks occur when a thriving population is suddenly reduced to a fraction of its original size, which results in the instantaneous decrease in genetic diversity (Hall & Hallgrimsson 2008). Inbreeding depression is a reduction in the viability of the individuals in a population resulting from the increased homozygosity through inbreeding (Hale *et al.* 2005). Inbreeding results from mating between relatives. An individuals inbreeding coefficient (F) refers to how closely related its parents are to each other (Frankham *et al.* 2010). Offspring of unrelated parents have an F value of 0 and completely inbred individuals have an F value of 1 (Frankham *et al.* 2010). In closed population where no immigration exists inbreeding may accumulate and complete inbreeding can ultimately happen from repeated inbred mating (Frankham *et al.* 2010). Inbreeding values (F=0.986) can occur within 20 generations of brother-sister mating (Frankham *et al.* 2010).

Genetic diversity provides the basis for adaptability (through natural selection) as environmental conditions change. If a population lacks genetic diversity, it is in great danger of not having the resources to survive environmental change. Low levels of genetic diversity may also lead to the expression of deleterious recessive alleles. In practice, loss of genetic diversity (or “inbreeding”) may result in reduced survival, reproductive abnormalities, juvenile mortalities, physical deformities and reduced growth in populations (Simberloff 1988). It is therefore important to conserve representative levels of genetic diversity in artificially managed populations.

Genetic diversity may be lost through events such as (1) genetic bottlenecks, which occur when a population is reduced to a few reproducing individuals whose offspring then increase in numbers to re-establish the population; (2) founder events, when a population is started (or founded) using a small number of individuals which may not contain the full range of variation that occurs in the species; (3) isolation and lack of migration; and (4) small population size (Amos & Harwood 1998).

5.1.3 Non-invasive genetic sampling

DNA can be obtained from non-invasive samples such as hair, faeces, feathers, skin, and eggs shells, amongst others, without having to handle the animal or even observing it (Waits & Paetkau 2005). Thus, non-invasive sampling makes it unnecessary to capture and mark animals in order to sample them (Schwartz *et al*. 2006). Faecal samples are of particular importance as they require no contact with the animal. Faeces contains cells that have been shed from the intestinal tract, consequently DNA from these cells, once isolated, could be analysed (Kohn & Wayne 1997). Genetic information gained from such samples can be used to identify species and diets, be used to determine genetic diversity and determine population structure (Waits & Paetkau 2005).

However, there are negative aspects associated with non-invasive sampling, such as possible DNA contamination during the extraction and amplification of the DNA (Taberlet *et al.* 1999). Some of the limitations identified by Taberlet *et al*. (1999) with non-invasive sampling may include low DNA quantity or quality. Taberlet *et al.* (1999) indicated three possible results for microsatellite loci genotyping from nuclear DNA that may be obtained when using samples like hair, feather or faeces from wild animals, these results include: no PCR product or a PCR product with the incorrect genotype or PCR product with the correct genotype acquired. Taberlet *et al.* (1999) goes on further to say that without the comparison of the acquired products to that of samples of tissue or blood from

the same organism, it will not be possible to distinguish between the correct and incorrect genotype of the PCR product. In order to overcome problems such as allele drop-out that may occur with samples from non-invasive techniques during PCR, sample needs to be repeated at least seven times.

Thus far little or no molecular genetic studies using microsatellite markers have been conducted on tsessebe in South Africa. The specific objectives of this study include:

- Determine if a non-invasive sampling method is possible for collecting tsessebe DNA
- Determine the level of genetic diversity within the tsessebe population of Borakalalo National Park via cross-species microsatellite markers
- Determine the level of relatedness amongst individuals
- Use genetic data to contribute to the development of a management plan for the conservation of the specie in the park

5.2 Methods

5.2.1 Sample population

When this project commenced in 2009, 17 tsessebe were recorded to inhabit the study area. They were composed of two herds, with eight in the one herd and nine in the other herd. A total of five blood and tissue samples were obtained from tsessebe that were collared in the park. The other tissue samples were obtained from three tsessebe that had succumbed to poaching. Thus making a total of eight genetic samples, these samples represented 47% of the known population. The bushy terrain compounded by the fact that the tsessebe were extremely skittish made it nearly impossible to get close enough to the animals to obtain skin biopsies from any of the remaining un-sampled tsessebe. Thus, tissue and blood samples could only be obtained from animals that were

captured for collaring and via opportunistic sampling of the carcasses of poached animals.

5.2.2 Field sampling

5.2.2.1 Tissue samples

A qualified veterinarian cut off a small sample of ear of the anesthetised animal (Figure 5.1a). The sample was placed into a 50 mℓ bottle containing Ethylenediaminetetraacetic acid (EDTA) as the preservative (Figure 5.1b). The samples were stored in a sealed container with ample ice packs and taken back to the laboratory. Crystal violet was put on the wound of the animal's ear after the samples were taken to prevent any infection. Crystal violet is used as a topical antiseptic and has antibacterial, antifungal and anthelmintic properties.

a)

b)

Figure 5.1: a) Tissue sample taken from the ear. b) Tissue sample in EDTA in a 50 mℓ bottle.

5.2.2.2 Blood samples

Blood was collected from the anesthetised tsessebe. A clean 23G needle and 20 mℓ syringe was used to draw blood from a vein in the ear by a qualified veterinarian. Whole blood was then injected into an EDTA vacutainer and placed

on ice in a cooler box (Figure 5.2). These vacutainers were transported back to the laboratory and placed in the -40°C freezer until processed.

Figure 5.2: Blood sample stored in vacutainers.

5.2.2.3 Faecal samples

Using the last known GPS fixes to find the collared tsessebe, the herd was followed and faecal samples were collected in the vicinity where they were present. Using a pair of forceps, faecal pellets were placed into separate sealable plastic packets and marked (Figure 5.3). A GPS point was recorded for reference purposes. Samples were placed in a sealed packet and stored in a freezer until they were taken to the laboratory. In the laboratory the samples were stored in a -80°C freezer until they were used.

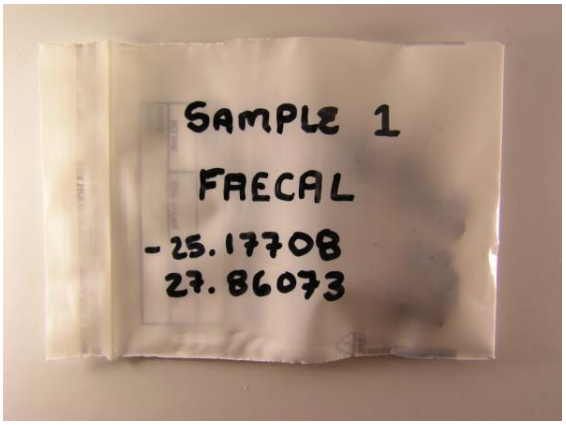

Figure 5.3: Faecal sample in sealable plastic packets.

5.2.2.4 Poached animal samples

For the two poached male tsessebe it was possible to obtain blood samples, and tissue samples as described in the methods above. This was possible because the samples were obtained within an hour of their deaths, as park rangers discovered the snared animals (Figure 5.4a). For the sample obtained from the unsexed tsessebe (Figure 5.4b), only a tissue sample was obtainable, which was taken.

a) **b)**

Figure 5.4: a) Poached male tsessebe. b) Unsexed tsessebe carcass.

5.2.3 DNA extraction

5.2.3.1 Tissue samples

Deoxyribonucleic acid (DNA) was isolated from tissue sample using the Qiagen® DNeasy® blood and tissue kit. DNA isolation was performed according to the manufacturer's instructions as outlined in the kit protocol.

A 25 mg piece of tissue was divided into small pieces by using a sterile scalpel blade and the pieces were transferred to a 1.5 mℓ eppendorf tube. A total of 180 µℓ tissue lysis buffer and 20 µℓ Proteinase K was added to the tube. The mixture was vortexed for 10 sec and incubated at 55°C for 1 to 3 hours or overnight if

complete lysis was not achieved. After incubation, the mixture was vortexed for 15 sec followed by the addition of 200 µℓ lysis buffer. Immediately after the addition of the lysis buffer, the mixture was vortexed for 15 sec and incubated for 10 min at 70°C.

For DNA precipitation, 200 µℓ of -20°C ethanol (EtOH) was added to the mixture and the mixture was vortexed and incubated at -20°C for 5 min. Following incubation, the mixture was transferred to a DNeasy® spin column and centrifuged at 6000 relative centrifugal force (rcf) for 1 min. After centrifugation, the column was transferred to a new collection tube and 500 µℓ of wash buffer 1 was added to the column. The column was centrifuged for 1 min at 6000 rcf after which the column was transferred to a new collection tube. A total of 500 µℓ of wash buffer 2 was added to the column followed by centrifugation at 16000 rcf for 3 min. In order to elute the DNA, the column was transferred to a labelled 1.5 mℓ eppendorf tube and 200 µℓ of elution buffer was added to the column. The column was incubated at room temperature for 5 min followed by centrifugation at 6000 rcf for 1 min. After centrifugation, the column was discarded and the DNA was stored at -20°C.

5.2.3.2 Blood samples

Using the 3R Genomic DNA™ - Tissue Mini Prep (Zymo Research Corp.) kit to isolate DNA from blood the following protocol was followed. Blood was allowed to thaw. The total volume was adjusted to 100 µℓ in volume by adding distilled water. 95 µℓ of 2X Digestion Buffer and 5 µℓ of Proteinase K were added to the blood. The solution was mixed by vortexing and incubated for 20 minutes at 55°C. 700 µℓ Genomic Lysis Buffer was added to the tube and vortexed. The mixture was transferred to a Zymo-Spin™IIC Column in a collection tube. This was then centrifuged at 7000 revolutions per minute (rpm) for one minute. 200 µℓ of DNA Pre-wash Buffer was added to the spin column and placed into a new collection tube and centrifuged for one minute at 7000 rpm. 400 µℓ of g-DNA

Wash Buffer was added to the spin column and centrifuged at 7000 rpm for one minute. The column was placed into a new microcentrifuge tube. 50 µℓ DNA Elution Buffer was added to the column and incubated for three minutes at room temperature. This was then centrifuged at full speed for 30 seconds to elute the DNA.

5.2.3.3 Faecal samples

Using the QIAGEN QIAamp® DNA Stool Mini Kit, the following procedure was followed in accordance with the accompanying manual: a single faecal pellet was crushed in 1.6 mℓ Buffer ASL in a 2 mℓ microcentrifuge tube and vortexed to ensure optimal homogenization had taken place. Samples were centrifuged at full speed for one minute. A total of 1.4 mℓ of the supernatant was pipetted into a new 2 mℓ microcentrifuge tube and the pellet was discarded. One InhabitEX tablet was added to the tube and vortexed until the tablet dissolved. The tube was incubated at room temperature for a period of one minute to allow the inhibitors to be absorbed. The sample was centrifuged at full speed for three minutes.

The supernatant was pipetted into a new 1.5 mℓ microcentrifuge tube and the pellet was discarded. A total of 25 µℓ Proteinase K was added to a 2 mℓ microcentrifuge tube and 600 µℓ of the supernatant was added to this, in addition 600 µℓ Buffer ASL was added and the sample was vortexed to ensure complete homogenation. The sample was incubated at 70°C for 10 minutes. A total of 600 µℓ of 96% Ethanol was added to lysate the sample and vortexed to mix. Into a QIAamp spin column with a 2 mℓ collection tube 600 µℓ lysate was placed. This was then centrifuged at full speed for one minute and the QIAamp spin column was placed into another 2 mℓ collection tube.

The filtrate was discarded. A second aliquot of 600 µℓ lysate was put into the spin column and centrifuged at full speed for one minute. The QIAamp was again

placed in a new 2 mℓ collection tube and the filtrate discarded. An amount of 500 µℓ Buffer AW1 was added to the QIAamp spin column and centrifuged for one minute at full speed. The column was placed into a new collection tube and the filtrate was discarded and 500 µℓ Buffer AW2 was added to the column and centrifuged for three minutes at full speed.

The filtrate was again discarded. The QIAamp spin column was placed into a 1.5 mℓ microcentrifuge tube, 200 µℓ Buffer AE was pipeted directly onto the QIAamp membrane, and left to incubate at room temperature for one minute. This was then centrifuged at full speed for one minute to elute the DNA.

5.2.4 DNA concentration

DNA concentration was determined with the use of a Thermo Fisher Scientific NanoDrop 1000 Spectrophotometer. Following the user manual the subsequent procedure was performed. 2 µℓ of distilled water was used to clean the measurement surfaces. The 'Nucleic Acid' spectral measurement was initiated using the operation system on the computer. With the sampling arm open, 1 µℓ of Buffer was pipetted onto the lower measurement pedestal. The sampling arm was closed and the 'Blank' button was clicked on. After opening the arm, the upper and lower pedestals were wiped off using a soft laboratory wipe. Once the NanoDrop 1000 Spectrophotometer was blanked samples of DNA could be read. With the sampling arm open, 1 µℓ of DNA sample was pipetted onto the lower measurement pedestal. The sampling arm was closed and the 'Measure' button was clicked on. The readings on the computer screen for the ratio 260/280 (absorbance ratio) and the ng/ µℓ was recorded. Following several consecutive sample readings the blanking process was followed to ensure accurate readings.

5.2.5 Cross-species microsatellite markers

A variety of cross-species microsatellite markers were tested to identify markers that would amplify in the tsessebe. The cross-species microsatellite markers tested in the study was selected based on the high level of heterozygosity they displayed in cattle, goat and sheep populations. In addition, markers that were originally developed for bontebok and blesbok were also tested for the cross applicability in tsessebe. Cross-species microsatellite markers used in the study presented here are listed in Table 5.2. Various parameters such as primer annealing temperature, elongation time and magnesium chloride ($MgCl_2$) concentration were considered during the optimization process.

Table 5.2: Microsatellite markers used in the study presented here with their relevant information including; size range, sequence and annealing temperature.

Microsatellite marker	Primer sequence	Size range (bp)	*Species*	Ta (°C)	Reference
ETH10	F: 5'- gtt cag gac tgg ccc tgc taa ca -3'	212-224	*Bos taurus*	60	Toldo *et al.* (1993)
ETH10	R: 5'- cct cca gcc cac ttt ctc ttc tc -3'				
ETH225	F: 5'- gat cac ctt gcc act att tcc t -3'	141-159	*Bos taurus*	50	Steffen *et al.* (1993)
ETH225	R: 5'- aca tga cag cca gct gct act -3'				
BM2113	F: 5'- gct gcc ttc tac caa ata ccc -3'	123-143	*Bos taurus*	50	Sunden *et al.* (1993)
BM2113	R: 5'- ctt cct gag aga agc aac acc -3'				
BM203	F: 5'- ggg tgt gac att ttg ttc cc -3'	201-233	*Bos taurus*	50	Bishop *et al.* (1994)
BM203	R: 5'- ctg ctc gcc act agt cct tc -3'				
BM804	F: 5'- cca gca tca act gtc aga gc -3'	136-158	*Bos taurus*	58	Bishop *et al.* (1994)
BM804	R: 5'- ggc aga ttc ttt gcc ttc tg -3'				
BM1824	F: 5'- gag caa ggt gtt ttt cca atc -3'	178-192	*Bos taurus*	50	Bishop *et al.* (1994)
BM1824	R: 5'- cat tct cca act gct tcc ttg -3'				
OARCP26	F: 5'- ggc cta aca gaa ttc aga tga tgt tgc -3'	120-170	*Ovis aries* (Sheep)	60	Ede *et al.* (1995)
OARCP26	R: 5'- gtc acc ata ctg acg gct ggt tcc -3'				

Table 5.2 continued:

Microsatellite marker	Primer sequence	Size range (bp)	*Species*	Ta (°C)	Reference
BB03	F: 5'- agc cat gtg cca atc ata tac t -3'	275	Blesbok	54	Dalton *et al.* (2011)
BB03	R: 5'- gga cac gga ctg aag cta ctt a -3'				
BB04	F: 5'- ata aag gca tgt acc cca cat c -3'	150	Blesbok	54	Dalton *et al.* (2011)
BB04	R: 5'- cag aca gga ctg aag cga att a -3'				
BB05	F: 5'- atg gac aga gga gcc tag tga g -3'	134	Blesbok	58	Dalton *et al.* (2011)
BB05	R: 5'- act gtg cct ttc aac act gga -3'				
BB08	F: 5'- acc tcc ctg tgg atg act tct -3'	173	Blesbok	58	Dalton *et al.* (2011)
BB08	R: 5'- gcc atg act gag caa cta aac a -3'				
BB10	F: 5'- aat ggg gac aat gac gta cct a -3'	202	Blesbok	50	Dalton *et al.* (2011)
BB10	R: 5'- aac agg aac cag ata gtg agt gg -3'				
BB20	F: 5'- gct ctc cac ctt atg ctc atc t -3'	189	Blesbok	50	Dalton *et al.* (2011)
BB20	R: 5'- aac aca tgg cct gac tct ctt t -3'				
BB22	F: 5'- atc gca tct ccc att gac tta t -3'	142	Blesbok	50	Dalton *et al.* (2011)
BB22	R: 5'- aag aaa cca ctg cat ttg gaa g -3'				

5.2.6 Polymerase Chain Reaction (PCR)

Polymerase Chain Reaction (PCR) is an *in vitro* enzymatic method used to amplify a specific DNA segment between two known sequences (Mullis *et al*., 1986). PCR takes place in three steps namely; denaturing of dsDNA to ssDNA, annealing of the primers to the ssDNA and elongation, where the complementary strand is synthesized by *Taq* DNA polymerase.

PCR reactions were optimised for each primer set to ensure high specificity during the amplification of the microsatellite markers. The annealing temperature, $MgCl_2$ and DNA concentrations were specific for the specific primer sets. Multiplex PCR were performed if reaction conditions for two different primer sets were similar and if the microsatellite markers were of different sizes and labelled with different fluorescent dies (FAM™, VIC®, PET® and NED™).
The PCR reaction was carried out in a total volume of 25 µℓ and Promega GoTaq® Flexi DNA polymerase were used to perform PCR. Promega GoTaq® Flexi DNA polymerase consisted of the following; 5 x buffer with proprietary formulation, 25 mM $MgCl_2$ and 5 units per microlitre (U/µℓ) *Taq* DNA polymerase. The final concentrations in the PCR reaction were as follows; 1x PCR buffer, 1.5 to 3.5 mM $MgCl_2$, 0.2 mM deoxynucleotide triphosphate (dNTP) mix, 10 mole of each primer (forward and reverse), 1 units (U) *Taq* DNA polymerase and 10-20 ng DNA. The PCR reaction was carried out in the BOECO TC-PRO Thermal Cycler. The standard PCR program listed in Table 5.3 was used.

Table 5.3: Standard PCR program

Step number	PCR step	Temperature	Elongation time	Number of cycles
Step 1	Denature	95°C	5 min	1
	Denature	95°C	30 sec	
	Anneal	50-55°C	1 min	
Step 2	Elongate	72°C	1 min	30
Step 3	Elongate	72°C	20 min	1
Step 4	Hold	4°C	Hold	Indefinite

5.2.7 Microsatellite genotyping

Once each primer set's optimal reaction conditions had been determined, capillary electrophoresis was used to determine if the microsatellite markers were monomorphic or polymorphic. Markers that displayed genetic diversity for the species were selected for further analysis. PCR products of different sizes and labelled with different fluorescent labels were plexed together. A plex consisted of 5 µℓ of each PCR product (per sample). After the PCR products have been plexed, 1 µℓ of the plex was mixed with 8.6 µℓ Hi-Di™ Formamide and 0.4 µℓ GeneScan™-500 Liz®.

The ABI PRISM® 3130 DNA sequencer was calibrated with Applied Biosystems™ five-dye chemistry, the DS-33 Dye set. A fluorescent internal standard GeneScan™-500 Liz® was added to the PCR product and the sample was denatured by using Hi-Di™ Formamide genetic analysis grade. The ABI PRISM® 3130 DNA sequencer was used for electrophoresis of the samples. The PCR product was detected by a laser that illuminates the incorporated fluorescent dyes. GeneScan™ Software (Applied Biosystems™) was used to analyse the wavelengths that are characteristic of the light emitted by particular dyes and

which was collected throughout the run. Genotyper® Software (Applied Biosystems™) was used for allele scoring.

5.2.8 Statistical analysis

Appropriate statistical computer programs were used to calculate the genetic variability and differentiation within the population. Allele frequencies and genetic diversity within populations were calculated using MSToolkit (Park 2001), an add-in for Excel software. To quantify genetic diversity within individual populations we used observed heterozygosity (H_o), average expected heterozygosity (H_e); (Nei 1987) and average number of alleles per locus.

Colony (Jones & Wang 2010) a computer program that uses likelihood methods to deduce parentage and sibship between individuals using multilocus genotype data (Jones & Wang 2010) was used to calculate relatedness amongst the sampled tsessebe.

5.3 Results

5.3.1 DNA extraction

A total of 33 faecal samples were collected for DNA analysis. The DNA concentration ranged from 5.4 ng/µℓ to 30.7 ng/µℓ and the purity was between 0.9 and 1.2. DNA concentration was sufficient for analysis; however the low purity of DNA resulted in the lack of success in obtaining any results.

The DNA from the tissue and blood samples collected was successful for analysis. The DNA concentration ranged from 52.3 ng/µℓ to 134.6 ng/µℓ and the purity was between 1.6 and 1.9. The DNA was of high quality and was used for further analysis.

5.3.2 Microsatellite analysis

A total of 14 microsatellite markers were successfully optimized. Of the 14 markers analysed, two of the markers were monomorphic and thus was excluded from further analysis. The monomorphic markers were ETH225 and BB20.

5.3.3 Allele frequencies

In total, 36 alleles were identified using 12 microsatellite markers in this study. The number of alleles varied widely between loci, with as few as 2 at locus BB03, BM804, Oarcp26, BB04, BB05, to as many as 5 at locus BM203 as indicated in Table 5.4. The average number of alleles was 2.71 ± 1.2.

Table 5.4: Allele frequencies obtained from each of the markers.

Marker	Alleles	No. of alleles	%
ETH10	215	3	18.75
	219	4	25
	223	4	25
	225	5	31.25
BM2113	135	12	75
	139	1	6.25
	141	3	18.75
BM203	213	2	12.5
	217	8	50
	237	4	25
	241	1	6.25
	243	1	6.25
BM804	135	11	68.75
	149	5	31.25
BM1824	180	1	6.25
	194	3	18.75
	196	2	12.5
	198	10	62.5
OARCP26	123	1	6.25
	125	15	93.75

Marker	Alleles	No. of alleles	%
BB03	252	11	68.75
	280	5	31.25
BB04	138	9	56.25
	144	7	43.75
BB05	153	6	37.5
	159	10	62.5
BB08	182	4	25
	186	11	68.75
	192	1	6.25
BB10	193	5	31.25
	195	1	6.25
	197	6	37.5
	199	4	25
BB22	144	12	75
	146	2	12.5
	168	2	12.5

5.3.4 Polymorphic Information Content (PIC)

PIC values (Bostein *et al.* 1980) were calculated and are depicted in Table 5.5. PIC values range from the lowest value of 0.110 for marker OARCP26 to the highest value of 0.694 for marker ETH10. Average PIC value was 0.425 ± 0.163.

Table 5.5: PIC values for each marker.

Marker	PIC values
ETH10	0.694
BM2113	0.354
BM203	0.618
BM804	0.337
BM1824	0.510
OARCP26	0.110
BB03	0.337
BB04	0.371
BB05	0.359
BB08	0.398
BB10	0.636
BB22	0.371

5.3.5 Heterozygosity

Heterozygosity was used as an additional method to assess genetic diversity. Takezaki & Nei (1996) determined that, for markers to be useful for measuring genetic variation, the average heterozygosity should be between 0.3 and 0.8 in a population. The range of heterozygosity of the markers in the local population in this study was 0.446 ± 0.067 for expected heterozygosity and 0.482 ± 0.047 for observed heterozygosity.

Heterozygosity values were also estimated per marker for the 12 markers included in the study presented in Table 5.6. Observed heterozygosity values ranged from the lowest value of 0.13 for marker OARCP26 to the highest value of 1 for markers ETH10 and BB10.

Table 5.6: Calculated expected and observed heterozygosity per marker.

Marker	Expected heterozygosities	Observed heterozygosities
ETH10	0.792	1.000
BM2113	0.425	0.375
BM203	0.708	0.625
BM804	0.458	0.625
BM1824	0.592	0.375
OARCP26	0.125	0.125
BB03	0.458	0.375
BB04	0.525	0.375
BB05	0.500	0.750
BB08	0.492	0.625
BB10	0.742	1.000
BB22	0.433	0.500

5.3.6 Relatedness

An analysis was run to determine which of the sampled tsessebe (Table 5.7) were related. Results of the analysis can be found in Tables 5.8 and 5.9. The samples were grouped into four groups by the programme Colony. AG 55 and AG 81 had a 99.6% chance of being related to each other and AG 93 and AG 242 had a 93.2% chance of being related to each other. The two male samples had a 54.8% chance of being related to each other. The unsexed tsessebe sample (Sample ID 8) had a low percentage (0.1%) relation to any of the other sampled tsessebe.

As shown in Table 5.9, cluster 1 indicates that three animals (samples 1, 4 & 7) had a 53.2% chance of being related. Cluster 2 indicates that the two samples (samples 2 & 3) had a 54.8% chance of being related. Cluster 3 indicates that the two animals (samples 5 & 6) had a 92.3% chance of being related.

Table 5.7: Identification labels given to each of the genetic samples for the Colony analysis.

Sample number	Tsessebe ID	Sex
1	AG 55	Female
2	Poached animal	Male
3	Poached animal	Male
4	AG 81	Female
5	AG 242	Female
6	AG 93	Female
7	AG 243	Female
8	Poached animal	Unsexed

Table 5.8: The relation of each of the samples to one another.

Sample ID	Sample ID	Probability %
1	4	99.6
1	7	53.3
2	3	54.8
2	5	0.5
2	7	1.3
2	8	0.1
3	7	0.1
3	8	5.9
4	7	53.4
5	6	93.2
5	7	0.9
6	7	1.4
7	8	0.1

Table 5.9: Relation groupings obtained for above data.

Cluster	Sample ID	Probability %
1	1	53.2
1	4	53.2
1	7	53.2
2	2	54.8
2	3	54.8
3	5	92.3
3	6	92.3
4	8	93.7

5.4 Discussion

5.4.1 DNA extraction

DNA obtained from the faecal samples could not be used in this study because the purity of DNA was low (0.9 - 1.2) and thus resulted in the lack of success in obtaining any results. Good quality DNA should have an A_{260}/A_{280} ratio of between 1.7 – 2.0. According to Taberlet *et al.* (1999) limitations do exist when DNA isolated from faecal samples is used, as the DNA is often degraded and isolated in small amounts. Bubb *et al.* (2011) reported that the storage of faecal samples in 95% Ethanol provided better DNA isolation results. Thus it is suggested that if further genetic studies be done on faecal samples that protocols be tested whereby ethanol could be used as a storage solution.

5.4.2 Microsatellite analysis

Statistics obtained for observed and expected heterozygosity was calculated for all loci and per locus. Polymorphism Information Content (PIC) was calculated for all loci. The mean number of alleles per locus was also calculated, as discussed in subsequent sections.

5.4.3 Allele frequencies and heterozygosity

The current study's results in terms of expected heterozygosity (H_e) 0.446±0.0667, observed heterozygosity (H_o) 0.482±0.0472 and the average number of alleles (A) 2.71±1.20 can be compared to the results obtained by Eblate *et al.* (2011) for the Grant's gazelle (*Nanger granti)* H_o: 0.668 A: 4.50, red hartebeest (*Alcelaphus buselaphus)* H_o: 0.666 A: 6.11, eland (*Taurotragus oryx)* H_o: 0.690 A: 8.10, roan antelope (*Hippotragus equines)* H_o: 0.610 A: 5.10, impala (*Aepyceros melampus)* H_o: 0.554 A: 4.56 and topi (*Damaliscus korrigum*) H_o: 0.671 A: 7.11.

According to Spencer *et al.* (2000) the average number of alleles (A) per locus is a more effective way of signifying bottlenecks and loss of diversity compared to that of heterozygosity. From the current results the heterozygosity and number of alleles was relatively lower compared to other antelope within the tsessebe's subfamily Alcelaphinae, in which red hartebeest and topi belong. Heterozygosity and the number of alleles from the current study's results were compared across members of the family Bovidae, (Grant's gazelle, eland, roan antelope and impala); the results were lower than for each of the species they were compared to. Compared to the results obtained from topi in Tanzania, the diversity was lower in the study group.

The reasons for the low H_e, H_o and A values may be as a result of a high degree of relatedness among the sampled tsessebe or that this group of tsessebe are inbred or that the sample size was too small. Further genetic studies could be done on these animals, by including all the tsessebe on the reserve. This would have to be done by herding all the tsessebe into a boma and taking a genetic sample for each individual. The costs of which would be very high and there is risk of capture myopathy, in which case a loss of genetic transfer is inevitable due to death of individuals. Due to cross-species markers being less sensitive which may result in incorrect results (Zucoloto *et al*. 2006) species specific markers could be used as an alternative. However species-specific markers are expensive and time consuming to obtain (Zucoloto *et al.* 2006).

The population as it currently stands exists in low numbers, with 13 individuals recorded in this study, therefore it is assumed that a high level of relatedness among these tsessebe do exist (as discussed in Section 5.3.4) and that new individuals be introduced into the current population thus allowing the genetic diversity to increase or that the few individuals that do exist be removed from the reserve and be placed into a tsessebe breeding programme for the benefit of the species as a whole.

5.3.4 Relatedness

AG 55 (sample 1), AG 81 (sample 4) and AG 243 (sample 7) have a 53.2% chance of being related and occur within the same home range of each other. The two males (samples 2 and 3) that were poached had a 54.8% chance of being related, they were caught within a few metres of one another indicating that they were together at the time, and most probably were together much of their lives forming a bachelor herd. Although AG 93 (sample 6) and AG 242 (sample 5) have a 92.3% chance of being related they only spent about three months sharing a home range, after which AG 93 reallocate and associated with the other herd in the western side of the reserve as discussed in Chapter 4. Sample 8's mutilated carcass was found in the eastern side of the reserve, it was postulated that it may have been associated with the herd on the eastern side of the study area, however could also have been a bachelor. As there were only pieces of tissue on the bones of the carcass, the sex could not be determined. The carcass was positively identified as tsessebe, by parts of the hide. According to Garstang (1982) harems abidingly linger with their territorial male. Considering this fact is plausible that the tsessebe that are related amongst each other are located within the same home ranges as described in Chapter 4.

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Chapter 6

Conclusion and Recommendations

This dissertation has investigated the ecology of tsessebe from the aspects of vegetation utilization, home ranges and genetic diversity. The purpose of the study was to determine whether tsessebe had habitat preference in BNP and if they made use of micro-habitats within the current plant communities. The study also aimed to report on seasonal habitat selection using GPS/GSM collars and to determine the population's genetic diversity and genetic status. This is the first report that describes factors that may be associated with tsessebe decline in BNP. Results from this study will assist the Park in establishing broad management guidelines for tsessebe.

In this study, the vegetation composition within the tsessebe's home range of BNP was ascertained. Tsessebe preferred less dense woody areas and areas that had medium height grass species. Home ranges for each collared tsessebe was determined and an average size of 248±49 hectares was found to be used per herd. Total distribution within BNP was determined from data obtained from the GPS/GSM collars and movement patterns were recorded. This information allows for a better understanding of where tsessebe are located within the park and where they move. In addition, it was observed that tsessebe in Borakalalo National Park are making use of areas close to the boundary fences. An implication of this is the possibility that tsessebe are a lot more susceptible to poaching that occurs within these areas. From the cross-species microsatellites that were used to assess genetic diversity and structure among the tsessebe in BNP it was found that the samples tested were highly related and that the average number of alleles was low. These findings suggest that in general some inbreeding amongst the population may have occurred.

Recommendations

Tsessebe are rare antelope and thus are an important species to conserve. Two possible management options exist. The first option would be to remove the tsessebe from BNP or the second option would be to keep the tsessebe in the Park, as discussed below.

Genetically, tsessebe in BNP have a low level of diversity. Therefore, in terms of genetic conservation within the species it may be of value to move the remaining tsessebe out of BNP and into a breeding program or relocate the remaining tsessebe to a reserve with a larger population of tsessebe to allow for a greater genetic diversity. By moving the tsessebe out of BNP the possibility of these antelope being poached in the Park will be eliminated.

Should tsessebe be kept within BNP the following steps would need to be taken in order to safeguard their future:

- Due to the large scale problem with poaching within BNP, it is recommended that an increased patrol regime be introduced in the southern section especially the areas that are utilized by tsessebe nearby the boundary fences. It is however acknowledged that this would take time and manpower to accomplish this.
- A suggestion to electrify the boundary fences would deter possible poachers from attempting to gain access to the Park.
- Early burns are recommended for tsessebe as they make use of burnt areas for long periods of up to 12 weeks post burn. However, burns should be conducted within tsessebe home ranges for maximum benefit to these antelope.
- Lastly, to increase genetic stock within BNP it is recommended that more tsessebe be introduced to the Park. The total number of recommended tsessebe for the southern section is 24. Currently there are 13 tsessebe in

BNP, therefore a new herd of eight and bachelor herd of three should be introduced into the southern section.

Overall an important part of conservation is community buy in. Therefore, it may be of benefit that the surrounding communities become part of this conservation initiative through education and training. A possible method for doing that may be to start conservation clubs in the communities and create a community based honorary ranger branch of BNP. This would serve as a vital conservation education tool as well as provide a pool of manpower resources that could be utilized within BNP.