# Nutritional status and growth of Impala (*Aepyceros melampus)* in the Limpopo Province

by

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## DECLARATION

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# ABSTRACT


**Nutritional status and growth of Impala (*Aepyceros Melampus*) in the Limpopo Province**

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Man has used game meat obtained from the cropping of wild populations for many years. The impala (*Aepyseros melampus)* is numerically the most important single species (Fairall, 1983) available for game farming in the Lowveld and the bushveld areas of the Limpopo Province, Mpumalanga and KwaZulu - Natal. Wildlife nutrition has an important effect on the growth and successful production of offspring in animal populations. Knowledge of wildlife nutrition is, therefore, an important facet of game ranch management. A number of studies were conducted over the past two decades to determine the forage intake and nutritional status of herbivores.

The aim of this research project was to study the nutritional status and growth of impala in three areas in the Limpopo Province. The following areas were investigated namely Gravellotte, Bandolierskop and Louis Trichardt. The study was conducted between January 2000 and December 2002.

## ABSTRACT

Samples of the vegetation, soil, liver and blood from impalas as well as water samples were collected from each of the farms. The blood and liver samples were taken from culled impala every two months. Linear measurements were taken on all the culled animals. Mineral and pathological analyses were done on the liver samples. The vegetation and soil samples were collected from each farm during the wet season and mineral analyses were done on the samples. The blood samples were used for DNA analysis to determine genetic variation within impala populations at each of the farms.

The graze present at the respective game farms showed no difference in nutrient quality. The phosphorus (P) concentration of browse was significantly lower at Ndzalama and Selati (Lukhele & Van Ryssen, 2000.). Soil samples collected at Ndzalama showed lower P levels than Selati and Mara. This lower concentration of P in the soil as well as the browse could play a role in the reduced growth of the impala at the game farms in the Gravellotte area. Multivariate analysis on the liver samples showed significant differences between the animals at Mara and those on the two Lowveld farms. The copper (Cu) concentrations were significantly lower at Ndzalama than Mara (P=0.03), while the selenium (Se) concentrations at both Ndzalama and Selati were significantly lower than those concentrations at Mara (P=0.001). The liver concentration of Se suggests a Se deficiency at the Lowveld farms.

## ABSTRACT

The faecal P concentrations at Mara, Selati and Ndzalama were 2.22, 1.39 and 2.12 g P/kg organic matter (OM) respectively. The faecal nitrogen (N) for Mara, Selati and Ndzalama were 18.53, 18.19 and 17.97 g N/kg OM respectively.

Pathology results from the Onderstepoort pathology laboratory showed severe infection with *Paracooperioides peleae* (Nematoda: *Trichostrongylidae*), bankrupt worm, which is a fairly common parasite in antelope. Liver fluke, *Cooperia hepatica,* was also present in moderate to severe infestations in the liver samples from Ndzalama. Samples from Mara showed little or no parasitic infection. It was suggested that due to the severe parasitic infection, the live mass and empty body mass of the impala were lower at Ndzalama and Selati compared with those samples at Mara. Linear measurements did not differ between the areas.

Initial DNA analyses suggest very little genetic variation among impala on all three farms sampled and, therefore, it is advisable to introduce impala from Mara or another farm in the Louis Trichardt area to increase the genetic variation at Ndzalama and Selati.

Supplementation in the form of a mineral lick can be provided to the impala. An effort should be made to move the cattle at the BVB Ranch at Selati, which roam freely with the impala, to alleviate the severe parasitic infection present. This aspect requires further research.

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# CHAPTER 1

# INTRODUCTION

## Introduction

Impala probably evolved along the moist eastern seaboard of Africa (Skinner *et al.*, 1984) and now occur over a large area of east and southern Africa. Although smaller-bodied versions of present day impala existed in the past, their basic form has remained almost unchanged and there has never been more than one species of impala present in the fossil assemblage at any given time. Such evolutionary stability is astounding when considering that the closely related alcelaphine antelopes (blesbok *Damaliscus dorcas phillipsi*, hartebeest *Alcelaphus buselaphus* and blue wildebeest *Connochaetes taurinus*), which share a common ancestor with impala, have split into new species of diverse morphology at least 18 times during the same time period (Skinner *et al.*, 1984). Not only are impala intrepid evolutionary survivors, but they are a phenomenal ecological success story (Appendix 1). Natural selection has dressed impala for success with a number of important adaptations to solve problems they face in the natural environment (Skinner *et al.*, 1984).

These adaptations enabled impala to survive, reproduce and thrive under conditions in which other species did not fare well. They were able to disperse into disturbed habitat that more specialised antelope would avoid.

# CHAPTER 1

The impala prefers fairly open wooded savannas with short grasses. Impala are mixed feeders; the bulk of the diet is generally made up of grass with forbs and leaves of woody plants. During the past three decades impala have achieved distinction as a suitable ungulate species for improving meat production, although not as a sole source. However, when meat production and trophy hunting are combined, it becomes profitable to utilise game on a commercial basis (Bothma, 1989).

Over recent years the interest in wildlife management has taken a giant leap and led to the development of increased research on game. The purpose of this dissertation was to study the causes of the different sizes of impala in three regions of the Limpopo Province.

Bothma (1989) showed that there appears to be a size difference between impala from different regions of South Africa. Adult rams of the Kruger National Park were shown to be lighter than those in the north-western Limpopo Province (Bothma, 1989).

The differences between the sizes of the impala have never actually being studied in detail. In this study a comparison is made between the measurements of impala from different regions in South Africa. The aim was to determine if there is a difference and if so, to study their differences. Parameters that were addressed include: the nutritional status and growth physiology of impala in different regions of South Africa.

# CHAPTER 2

# LITERATURE OVERVIEW

## 2.1 Nutritional status

Wildlife nutrition has a determining effect on growth and successful production of offspring in animal populations. Knowledge of wildlife nutrition is an important facet of game ranch management.

Utilisation of the grazing is of great importance. To determine which food an animal selects, helps to determine preference of the animal for a type of forage. Selection is also influenced by palatability of the plant (Bothma, 1989).

The most important function of food is the production of energy for body processes. Determination of the intake and loss of energy thus provides an important measure to determine whether the animal is well nourished. Of importance for this study is the mineral status of the impala. According to Bothma (1989), the game in the Limpopo Province suffer from copper (Cu) and zinc (Zn) deficiencies, which may affect the nutritional status of animals in the area.

Over the past two decades there have been various studies to determine the forage intake and nutritional status of herbivores. Dunham (1982) assessed the foraging behaviour of the impala in the Senqwa Wildlife Research Area, Zimbabwe. Dunham used the method of Owen-Smith (Dunham, 1982).

Foraging impala were monitored from tree top observation platforms. The time spent feeding and moving per 50 steps taken while foraging was recorded. The diet quality was directly related to proportion of grass in the diet, being at a maximum in December and January, and at a minimum in July and August (Dunham, 1982). The mean feed intake was calculated by averaging the intake rates for grasses, forbs and woody browse. Dunham (1982) found the mean feed intake of the dry season to be 96 % of the wet season intake. Dunham (1982) noted that the impala fed on grasses in mopane woodland during the wet season. Forbs were an important component of their diet. During the dry season the impala fed mainly on woody plants, with an increasing percentage being at a maximum in August and September.

In another study done by Skinner *et al.* (1984) the feed intake of impala was determined on mixed tree savanna of the Nylsvley Nature Reserve. A single person collected data from daily observations on foot covering most of the study area on a monthly basis over a six-month summer period and a six-month winter period. October to March was considered as the summer months and April to September as the winter months.

The results from the study show that the *Acacia* savanna was significantly preferred to the *Burkea* and *Diplorhychus* savanna. Finger grass (*Digitaria eriantha*) was regarded as the most popular grass in summer with *Acacia* pods being the most important constituent of the winter diet.

Skinner *et al.* (1984) calculated the daily feed intake to vary between 2.1 and 2.6 % of the body weight per day for the impala. The crude protein (CP) concentration of the diet varied between 106 and 213 g/kg dry matter DM, with a digestibility of between 57 and 69 %. Daily faecal production was estimated at 7.0 – 11 g/kg DM of the body mass. The CP concentration of the faeces was 170 – 200 g/kg DM.

Berry & Louw (1982) investigated the seasonal nutritional status of blue wildebeest in the Etosha National Park. The nutritive status of wildebeest was assessed using visual condition ratings, kidney fat, bone marrow and blood plasma as indicators of nutritional stress.

The visual physical appearance is a good indicator of the nutritional status (Berry & Louw, 1982). Five mutually exclusive categories, whereby the nutritive level of the wildebeest could be subjectively measured, were used. The ratings were based on skeletal details of the animal's body. The points were awarded on the following basis:

- 5 (excellent) - hindquarters well rounded and no ribs showing; general appearance in relation to posture and coat sheen excellent.
- 4 (good) - hindquarters rounded, but ribs showing slightly
- 3 (fair) - hindquarters angular in appearance and ribs well defined.
- 2 (poor) - pelvic bones prominent and ribs protruding

1 (very poor) - skeletal details clearly visible and rump concave; general appearance, posture and coat condition deteriorated.

Using the above ratings Berry & Louw (1982) found 78 % of the wildebeest to be in good to excellent condition. Thirty one percent were in fair condition and less that 1 % were classified as being in poor condition. Tests for seasonal differences in the nutritive level of all age-sex classes showed that more wildebeest were in excellent condition during the dry, cold season than during the wet, hot season (Berry & Louw, 1982). This might have been due to the stresses imposed by sexual activity in the bulls and lactation in cows, which were maximal in the wet, hot season.

The analysis of the nine blood parameters confirmed that Etosha's wildebeest were at a normal level of nutrition. Inorganic phosphorus appeared to be marginally deficient. Liver analyses showed lower P, Cu and cobalt (Co) concentrations, but not at a degree that nutrition was a limiting factor to the population(Berry & Louw, 1982).

Fairall & Klein (1984) did a comparison between two equivalently sized African antelope, namely the blesbuck (*Damaliscus dorcas*) and the impala with respect to their protein intake and their water turnover. They found that the impala had a water turnover double that of the blesbuck. The difference was related to differences in the CP concentration in their diets. The nutritional value of the higher rainfall grasslands of South Africa where the blesbuck is adapted has a low fibre and an average CP concentration during the hot wet season and a high fibre, low protein content during the dry winters.

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The habitat of the impala provided a food source of much greater annual stability for a selective feeder that can adapt its feeding.

The necessity of drinking water for the impala would seem to be coupled to the physiological need to eliminate nitrogenous waste imposed by their high CP intake. This high protein content of its diet has led to the high levels of nitrogenous waste products that have to be excreted in the urine, thus higher water turnover and nitrogen excretion (Fairall & Klein, 1984).

Recently, Pietersen & Meissner (1993) determined the food selection and intake by male impalas in the Timbavati area, Mpumalanga. The aim was to obtain information on quality of diet selected during different seasons and to determine intake.

Pietersen & Meissner (1993) used four 18 to 30 month old hand-raised, partially tamed impala males. The animals were oesophageally fistulated to obtain samples of forage grazed. The impala were also regularly treated with helminthics. The test impala grazed in a 10 hectare fenced off paddock.

Pietersen & Meissner (1993) found that intake dropped significantly in May. The decrease in intake corresponded with a very low *in vivo* dry organic matter and a high lignin content of the forage. They suggested that a second reason for the decreased DM intake might have been because May is the peak of the rutting season.

During June and July the intake was not decreased. This was attributed to the fact that the area experienced late rainfall in May, which enabled consumption of higher digestible material and because the CP was partly supplemented through the intake of significant amounts of browse.

Pietersen & Meissner (1993) found that the intake generally increased in response to the increase in forage CP, digestibility of organic material (DOM) and cell wall constituents. The forage selected had a CP concentration of approximately 97 g/kg and a DOM of 572 g/kg. The influence of lignin content is noticeable by the variation in intake and digestibility. An increase in lignin led to a decrease in intake.

Grant *et al.* (1995), using the faecal P and N as indicators, determined the nutritive value of the veld. The research was conducted during the drought of 1992 – 1993 in the Kruger National Park. A drought is expected to result in a decline in both the quality and quantity of the fodder. This decline often leads to a loss in condition, mortalities and a failure to reproduce. It would therefore be of value to monitor the decline in forage quality to facilitate timely decisions. The sample collection was of fresh, clean faeces at monthly intervals from May 1992 to May 1993. Two grazer species buffalo (*Syncerus caffer*) and blue wildebeest, a mixed feeder, impala and two browser species, the kudu (*Tragelaphus strepsiceros*) and the giraffe (*Giraffa camelopardalis*) were included in the study.

The results obtained, showed significant differences between species, season and landscape (Grant *et al.,* 1995). For species, results corresponded with their feeding habits; the grazers differed from the mixed feeders and browsers. The season, July – September showed the lowest faecal concentrations of N and P. The highest concentrations for N were recorded in January – March and for P, October – December. For both nutrients, the lowest concentrations occurred in the dry season and the highest in the wet season.

With respect to landscapes, the P concentration was lower on granite soils than basalt soils and alluvial soil. The alluvial soils of the Limpopo / Luvuvhu floodplains recorded the highest P concentration. The highest faecal N concentrations were recorded in the *Combretum* veld. Faecal N concentrations were higher on granite than on basalt and higher during the wet season. The faecal P concentrations were also higher in the wet season than the dry season (Grant *et al.,* 1995).

Grazers showed the lowest faecal N concentration and browsers the highest. In contrast, P concentrations were highest for mixed feeders followed by grazers and browsers.

The faecal N concentrations are well correlated with the condition of the animals. From the results Grant *et al.* (1995), concluded that the buffalo as bulk grazers would suffer most in a long-term drought because of the rapid decline in food quality.

Short grass feeders such as blue wildebeest and a browser such as the kudu, which compete with other browsers, would only experience a decline in population numbers when the food becomes limiting.

Impala numbers are most probably not controlled by nutritional means because they are highly selective animals. This would allow them to obtain a diet adequate in quality and quantity (Grant *et al.*, 1995).

Dietary N concentrations may influence P excretion (Wrench *et al.*, 1997) when dietary N concentrations are low. It was found that including faecal N concentration did not improve the prediction of dietary P concentration. Tannins did not affect the predictability of P concentration.

Faecal N concentrations are needed to predict N concentrations of the browse. Tannins affect the digestibility of N, thus showing a high faecal N concentration. Browsers therefore, show a higher faecal N concentration as a result of the high level of tannins in the leaves of some of the browse that they consume (Wrench *et al.* 1997), than grazers. The faecal samples have proven to be valuable in determining nutritional status of wild herbivores.

Factors affecting the concentration of N and P in the faeces are:

a. Environmental factors

Rain reportedly has a leaching effect on faecal minerals due to the erosion of the pellets (Wrench *et al.,* 1996). Results showed that up to 20 mm of rain had no influence on N concentrations in the faeces, whereas more than 5 mm of rain decreased the P concentrations. Samples that were left open in the sun for two days or longer had significantly lower P and N concentrations. These results indicate that only fresh samples that have not been exposed for more than one day should be collected for assessment of nutrient status.

Dung beetles are very active in summer and it is often difficult to even obtain fresh samples without dung beetles. Samples that have been processed by dung beetles had a higher nitrogen concentration, while the P concentration was not affected. The increase in the N concentration could be due to the excretions from the dung beetles, flies or mites.

b. Laboratory factors

When samples are collected in the veld, it is not always possible to dry the wet samples. Fungal growth often occurs on dung samples even when fresh samples are oven dried. Samples that are air dried in a ventilated room did not differ significantly from samples dried in an oven. Samples that were dried in paper bags in the sun showed significantly lower N and P levels (Wrench *et al.,* 1996).

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Wrench *et al.* (1996) found that N concentration was lower and the P concentration higher due to the fungal growth. To prevent fungal growth the samples should be well ventilated and should be placed where they can dry quickly.

The chemical composition of body tissue, particularly the liver, is a good reflection of the dietary status of domestic and wild animals (Webb *et al.* 2001). Some minerals, including selenium, copper and manganese are stored in the liver. These minerals are essential for the growth and health of the animal.

## 2.2 Growth Physiology

Man has used game meat obtained from the cropping of wild populations for many centuries. Since pioneering work of the Americans, Dasmann & Mossman (1960) the concept of using the African ungulate fauna for game farming, has become established. The impala is numerically the most important single species (Fairall, 1983) available for game farming in the Lowveld, the bushveld areas in the Limpopo Province, Mpumalanga and Northern KwaZulu - Natal.

Fairall (1983) recorded the body weight as an indication of the growth of the impala and presented it in the form of the theoretical Von Bertanlanffy growth curve. It illustrates the concept of exponential growth and attainment of the asymptotic weight more clearly than the raw data.

The growth rate was seen to be high and the asymptotic weight is achieved at an age of five years, but 75 % of mature mass is achieved by two years of age. Mature weight in the population was 49.2 ± 1.02 kg in males and 38.3 ± 1.79 kg in females.

Fairall (1983) analysed carcass composition of 15 impala. Fat extraction from samples of the *longissimus dorsi* muscles was done on these carcasses.

The dressing percentage was calculated as 57 %, while the relative mass of hind leg and foreleg compared to the neck and rib cage, showed that the better cuts make up a large proportion of the carcass. While impala in good condition have free intestinal fat deposits, the carcass rarely has any visible fat. Fat extraction of the *longissimus* muscle gave a mean value of 2.8 % fat in nine-month-old impala, 4 % in the two year olds and 3 % in the mature animals.

According to Anderson (1982) the male impala on the

- Nyala game ranch, situated near Emangeni, is lighter and smaller than those from the Kruger National Park, and considerably lighter than those of the Serengeti Game Park. Anderson's final conclusion was that male impala from a smaller game ranch were lighter than those from larger reserves. This has, however, never been studied.

# CHAPTER 2

## 2.3 Parasitology

Diseases, parasites and preventative disease and parasite management are an integral part of wildlife management. The parasites and their game hosts have undergone evolution together and the association has developed to a near perfect balance.

In natural populations and in their feral state, mortality and predators eliminate overpopulation and all weak and parasite susceptible individuals until the equilibrium is re-established. Supplementary feeding and some form of parasite control are necessary. The parasites of game can be divided into the following groups: ectoparasites, which live on the surface of the host's skin, for example ticks, lice and fleas, and endoparasites that live within the host's for their continued existence, such as round worms, tape worms and liver flukes.

As a general rule it may be accepted that blue wildebeest and smaller game carry mainly the immature stage of ticks, while larger game such as kudu, giraffe and buffalo carry both the immature and adult stages of ticks in large numbers (Bothma, 1989).

Ticks have a simple life cycle which can be described briefly as follows: the adult, fully engorged female tick falls from the host and lays her eggs in a protected place. In time the eggs hatch and the small larvae, also sometimes known as *pepper ticks* (*Rhipicephalus spp.)* climb onto the grass stems to await the arrival of a suitable host. The larvae then attach onto the host and engorge themselves on blood. These larvae then dismount and turn into the adult (Bothma, 1989).

One of the most interesting adaptations that accounts for the success of the impala, and one which was unknown until recently, is the unique grooming system they employ to defend themselves against the threat of ectoparasties (Bothma, 1989).
The ecotone habitat in which impala occurs exposes them to a higher density of ticks than the grassland savanna inhabited by antelope like springbok or gazelle. Because of this, the impala is the only hoofed mammal that engages in reciprocal grooming, in addition to the self-grooming.

There are four large groups of endoparasites, which are of varying importance to game: Trematoda, tapeworms, round worms and Nematoda.

Wireworn (*Haemonchus contortus*) has been recorded in 19 species of antelope. Infestations of *Cooperia spp* in the liver on impala cause enlargement and inflammation in the bile ducts. Cases of bilharzias, conical fluke and liver fluke have been recorded too, but without apparent effect on their hosts (Maree & Casey, 1993).

## 2.4 Motivation

Many farms in the Limpopo Province utilise the game meat obtained from the cropping of wildlife populations as a source of income. The problem presently is attempting to determine the environmental factors affecting the size of the impala. The aim of this study is to determine these factors and assess the degree to which each environmental parameter affects the size of the impala in the Limpopo Province.

# CHAPTER 3

# MATERIALS AND METHODS

Due to the variation in size of impala in the Limpopo Province, four farms at different locations within the province were identified to obtain impala samples from. Two farms, Ndzalama and Selati, were identified in the lowveld area near Tzaneen. While the other two, Mara Research Station and Messina Nature Reserve, were in the northern parts of the Limpopo Province, near Louis Trichardt.

## 3.1 Description of the study areas

South Africa has one of the richest floras in the world. The vegetation can be divided into seven biomes and 68 vegetation types. Each biome is characterised by its own ecological capacity. The biomes are: Thicket, grassland, succulent karoo, forest, nama-karoo, savanna and fynbos. These biomes are again divided into 13 ecological regions (Bothma, 1989). The savanna biome is the largest biome in southern Africa. It is well developed over the lowveld and Kalahari region of South Africa. This biome is characterised by relatively high summer rainfall, and high mean temperatures. The savanna is characterised by a grassy ground layer and a distinct upper layer. Where the upper layer is near the ground the vegetation may be referred to as shrubveld; where it is dense it is known as woodland, and the intermediate stages are locally known as bushveld. Savanna provides the best regions for game ranch management, since the large diversity of vegetation can support a large variety of browsers and grazers (Bothma, 1989).

# CHAPTER 3

### 3.1.1 Savanna

This biome is sub divided into five veld types, namely valley bushveld, Kalahari bushveld, sour mixed bushveld, sweet bushveld and lowveld. The Selati Game Reserve and Ndzalama are situated in the mixed and lowveld veld type. The biome is characterised by species such as red bush willow (*Combretum apiculatum*) and knob thorn (*Acacia nigrescens*).

A dense grass stratum occurs and consists of rooigras (*Themeda triandra*), guinea grass (*Panicum maximum*), bushveld signal grass (*Urochloa mosambicensis*) and finger grass. The most abundant tree species are mopane (*Colophospermum mopane*), red bush willow and sickle bush (*Dichrostachys cinerea*)

The average rainfall is 235 - 1 000 mm per annum, and frost may occur for 120 days per year. Almost every major geological and soil type occurs within the biome.

### 3.1.2 Mixed lowveld Bushveld

The locality of this vegetation type is flat undulating landscapes between 350 - 500 m above sea level, in Limpopo and includes Mara Research Station. The annual rainfall varies from 450 - 600 mm and temperatures vary between -4 °C to 45°C, with an average of 22°C.

The soil is characterised by sandy soils in the uplands and clayey soils with high sodium content in the bottomlands. The geology is granite and gneiss with numerous dolerite intrusions (Low & Rebelo, 1998).

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The vegetation type can be described as dense bush on the uplands, open tree savanna in the bottomlands, and dense riverine woodland on riverbanks. The tree layer is characterised by red bush willow, sickle bush, silver cluster leaf (*Terminalia sericea*) and knob thorn. The grass layer consists of guinea grass, finger grass and bushveld signal grass. This vegetation type is ideal for game farming, ecotourism and cultivation of subtropical fruit.

### 3.1.3 Mopane Bushveld

This veld type is located on the undulating landscapes from the Kruger National Park to the Soutpansberg in Limpopo, and includes the Messina Experimental Farm and Nature Reserve.

There is an annual summer rainfall of between 250 to 500 mm, with temperatures varying between 1.5 °C and 42.5°C, with and average of 22 °C.

This mopane veld occurs on loamy sand and clayey soils in the undulating granitic landscape of the northern Kruger National Park and also on sandstone shale from north of the Soutpansberg in the Limpopo River Valley.

The vegetation is dominated with a fairly dense growth of mopane and mixtures of mopane and red bush willow, associated with knob thorn, and umbrella thorn. The shrub layer is moderately well developed and individuals of wild raisin bush.

The herbaceous layer includes grasses such as common nine-awn grass (*Enneapogon cenchriodes*), guinea grass and finger grass.

## 3.2 Study Areas

### 3.2.1 Ndzalama

Ndzalama Wildlife Reserve and Pieterskamp are part of Thiergarten, a 10 000 ha game ranch, situated in the Limpopo Province of South Africa, 80 km to the west of the Kruger National Park. The road divides Thiergarten from Letsitele to Eiland, with

Ndzalama encompassing 8000 ha and Pieterskamp approximately 2000 ha, on either side of the road. The Shangaan people, who first explored the northeastern Lowveld, gave this area its name, which means "sacred rock". Both sections are privately owned, and part of a much larger business.

#### 3.2.1.1 *Climate*

Ndzalama wildlife reserve and the Vorster farm have a distinctive wet and dry season. The wet season lasts from December till April with a peak in January and February. Figure 3.1 represents the rainfall on Ndzalama and Figure 3.2 represents the rainfall on the Vorster's Farm. The average rainfall is approximately 450 mm. The average minimum temperature is 15.3 °C (Tzaneen/ Grenshoek pol, weather station no. 0679106 3), (Figure 3.3) and the maximum temperature is 25.4°C (Figure 3.4).

**Figure 3.1: Ndzalama - Average monthly rainfall**

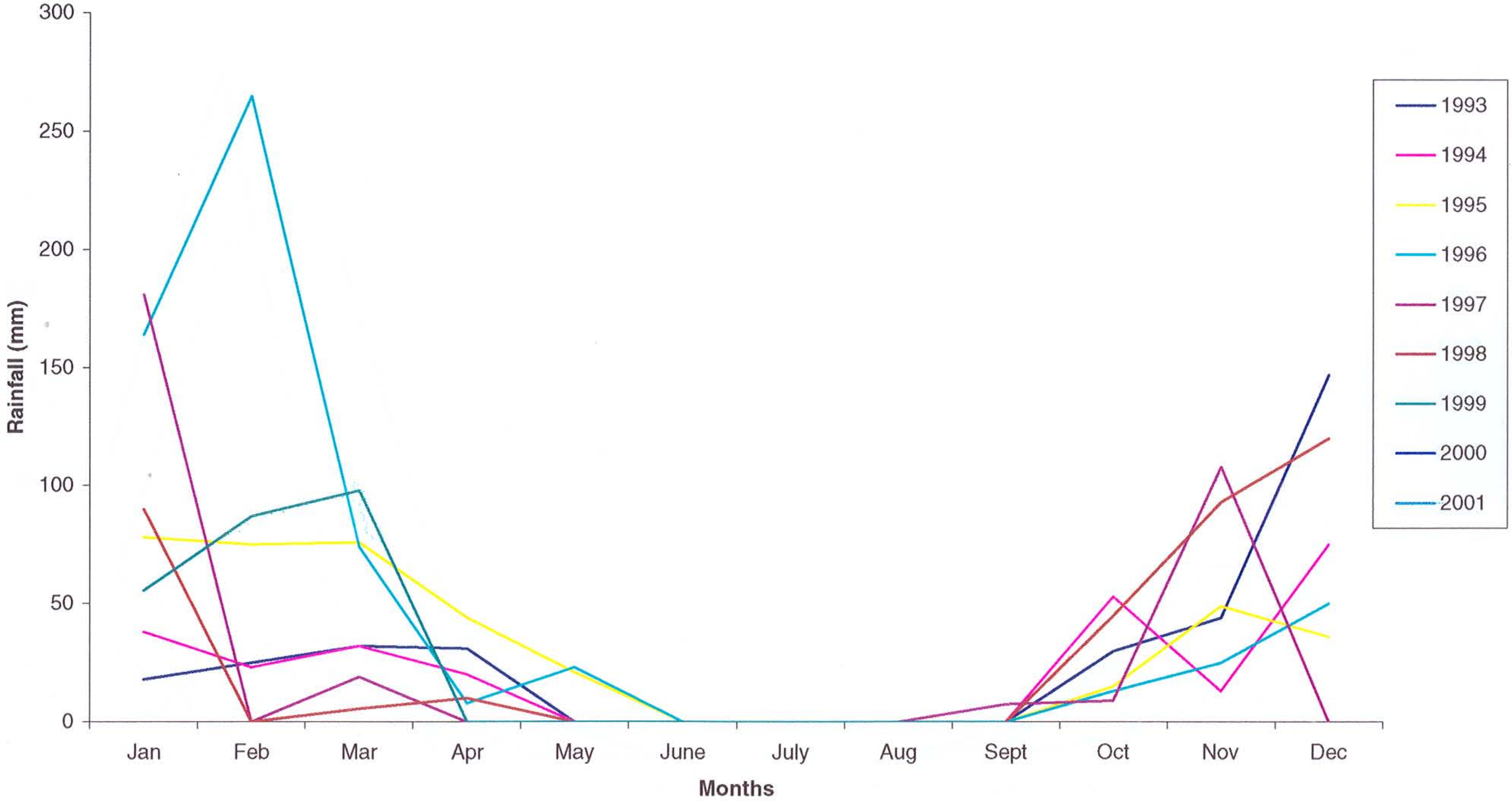


**Figure 3.2: Thiergarten - average monthly rainfall**

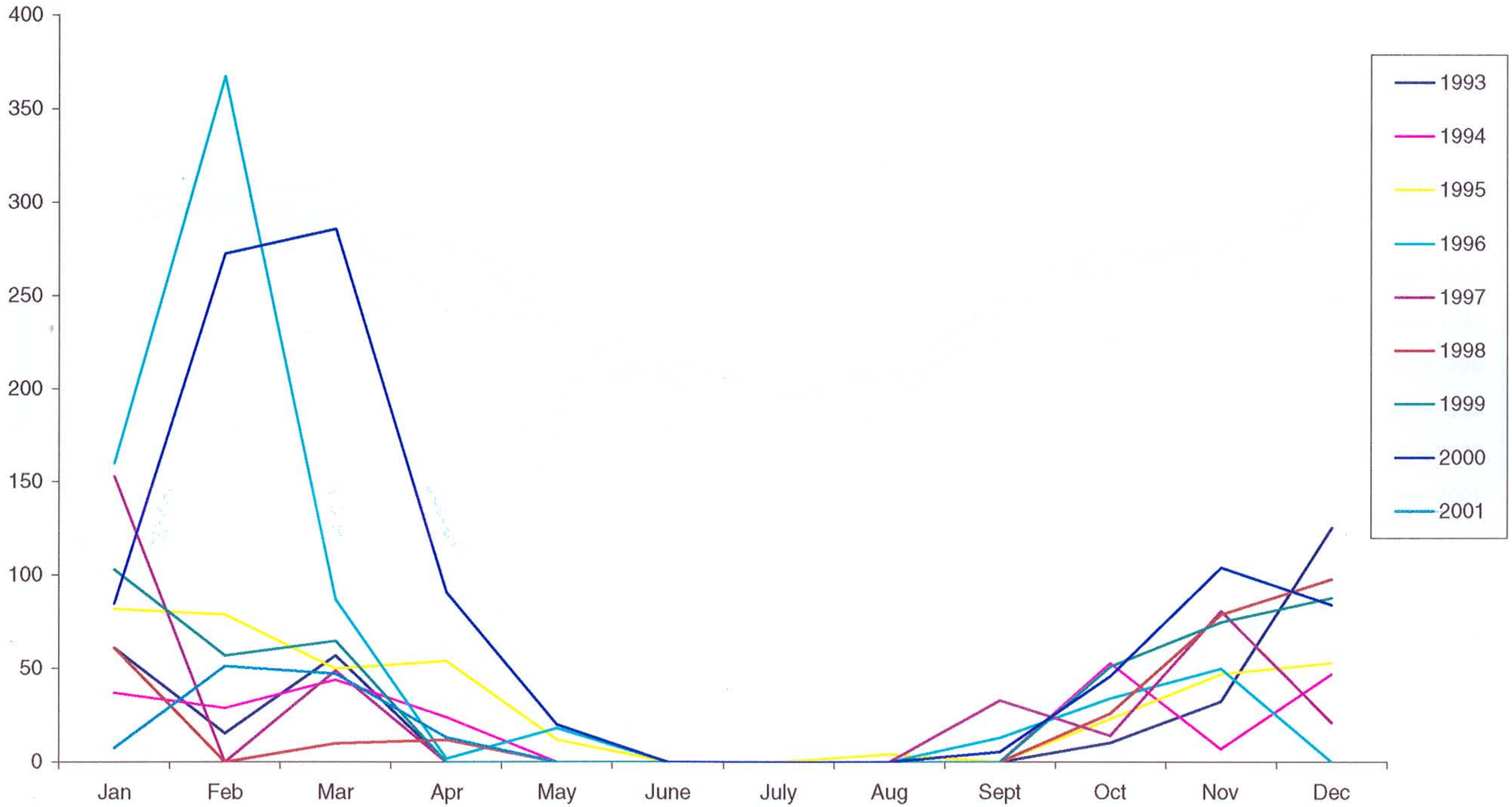


Figure 3.3: Ndzalama - Average monthly minimum temperatures

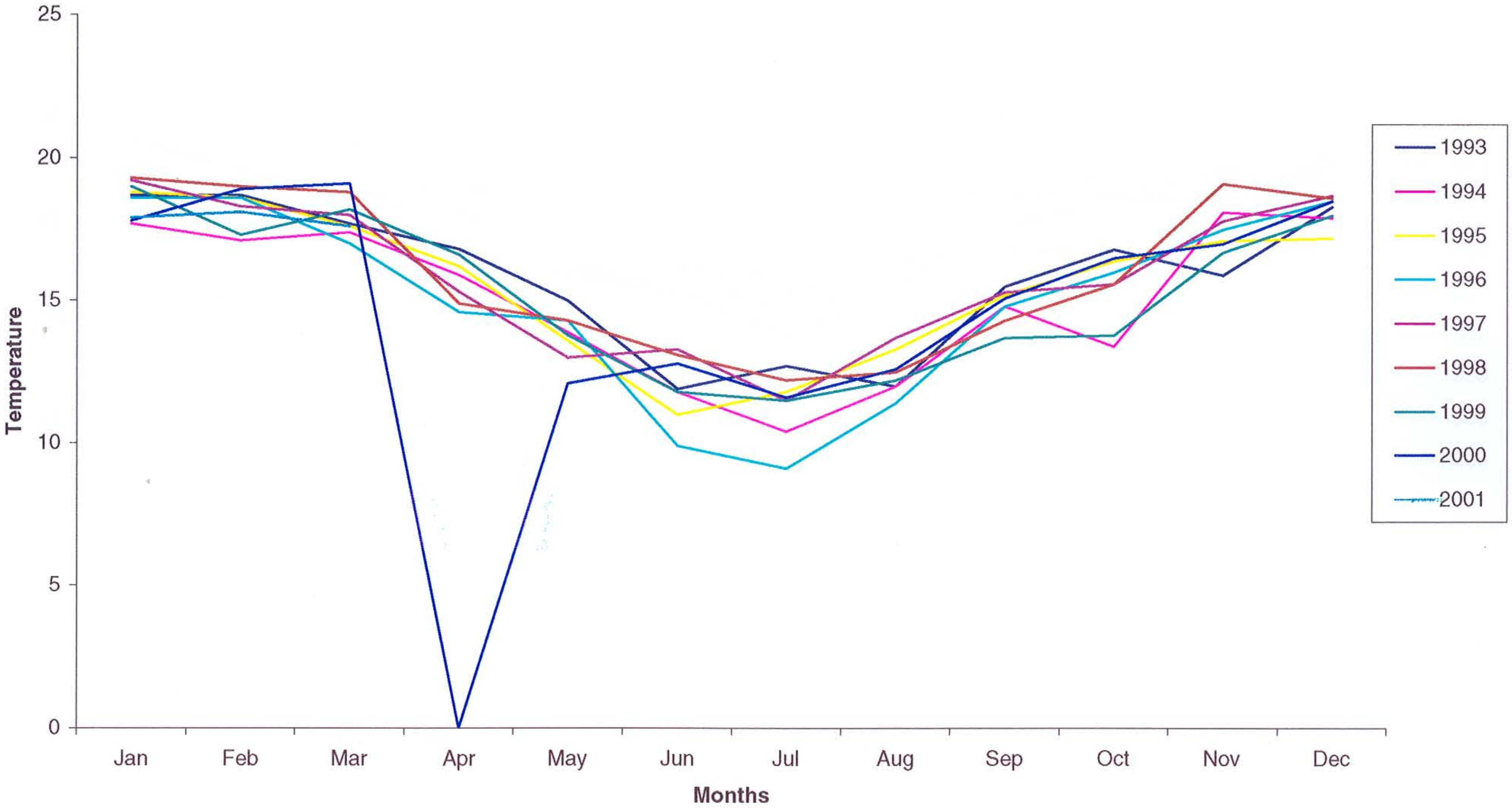
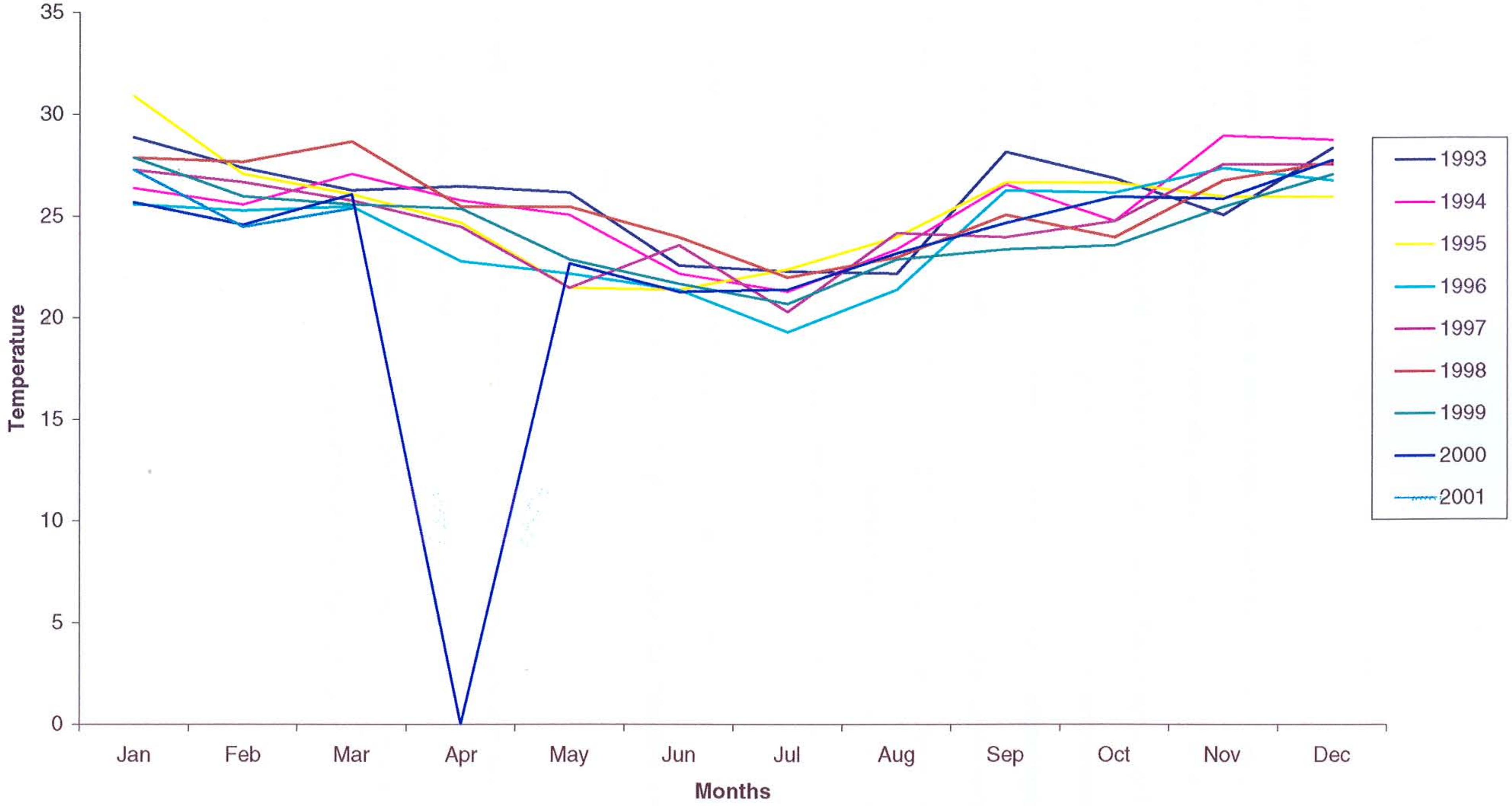


Figure 3.4: Ndzalama - average monthly maximum temperatures



#### 3.2.1.2 *Animal species present*

Today, the reserves are a sanctuary to a wide variety of wildlife, including impala, giraffe, blue wildebeest, kudu, lion (*Panthera leo*), elephant (*Loxodonta africana*), white rhino (*Cerathotherium simum*), leopard (*Panthera pardus*), eland (*Taurotragus oryx*), bushbuck (*Tragelaphus scriptus*), nyala (*Tragelaphus angasii*), warthog (*Phacochoerus aethiopicus*), cheetah (*acinonyx jubatus*), tsessebe (*Damaliscus lunatus*), klipspringer (*Oreotragus oreotragus*), mountain reedbuck (*Redunca fulvorufula*), duiker (*Sylvicapra grimmia*), reedbuck (*Rednca arundinum*), sable antelope (*Hippotragus niger*), steenbok (*Raphicerus campestris*), zebra (*Equus burchellii*), hartebeest, waterbuck (*Kobus ellipsiprymnus*), caracal (*Felis caracal*) and hippopotamus (*Hippopotamus amphibious*).

The reserve partakes in the Sable breeding project and has a number of lions in a fenced camp. Due to the size, intensive management is required to maintain the optimum ecological capacity.

Although Ndzalama is only 30 km from Selati, it has a larger water surface and has a number of artificial dams, which fill in the summer months. The infestation of external parasites is compounded by this increase in water and dense grass cover. The small pepper tick (*Rhipicephalus appendiculatus*) is of great concern on the reserve.

**3.2.1.3 *Vegetation***

The vegetation is typical of the mixed lowveld vegetation type, with an abundance of mopane, red bush willow and knob thorn. A dense grass stratum occurs and consists of *Themeda triandra* , guinea grass, bushveld signal grass and finger grass.

There are a number of lodges and other facilities present on the reserve.

**3.2.2 Selati Game Reserve**

The Selati game reserve is perhaps one of the largest private conservancy's. The reserve comprises of 27 372 hectares of unspoiled lowveld wilderness located in the north eastern Limpopo bushveld within the triangle formed by the tarred roads joining Phalaborwa, Mica and Gravelotte, known as the Selati Triangle. Originally the land was used for cattle farming with several low-key hunting and tourist orientated operations. The area within the reserve is best known for its Sable antelope herds. There are high deposits of ore in the area of Phalaborwa. This gives rise to the unique topography with varied and interesting geological formations manifesting themselves throughout the area. The reserve also boasts the cycad (*Encephlartos dyerianos*), which does not occur naturally anywhere else in the world.

The reserve is a joint ownership of seven landowners, with a goal "*to conserve and enhance the bio-diversity of the ecosystem and to realise its full economic potential on a sustainable basis*".

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From the initial meetings in 1992 till now the participants are working on a well managed reserve with no internal fencing and significant commercial activity.

### *3.2.2.1 Climate*

The Selati game reserve has an altitude of approximately 400 – 778 m. The average rainfall is approximately 500 mm per annum (Tzaneen/ Grenshoek pol, weather station no. 0679106 3) (Figure 3.5), with a ten- year cycle. The rainfall season is from December till April, with the peak being in February. The average minimum temperature is 15.6 °C (Figure 3.6), with the coldest month being June. The average maximum temperature is 25.4 °C (Figure 3.7) with the hottest month being January.

### *3.2.2.2 Animal species present*

There are 22 species of large animals to be found on the reserve: white rhinoceros, eland, kudu, bushbuck, elephant, blue wildebeest, nyala, leopard, warthog, cheetah, tsessebe, klipspringer, mountain reedbuck, duiker, reedbuck, sable antelope, steenbok, zebra,

**Figure 3.5: Selati average monthly rainfall**

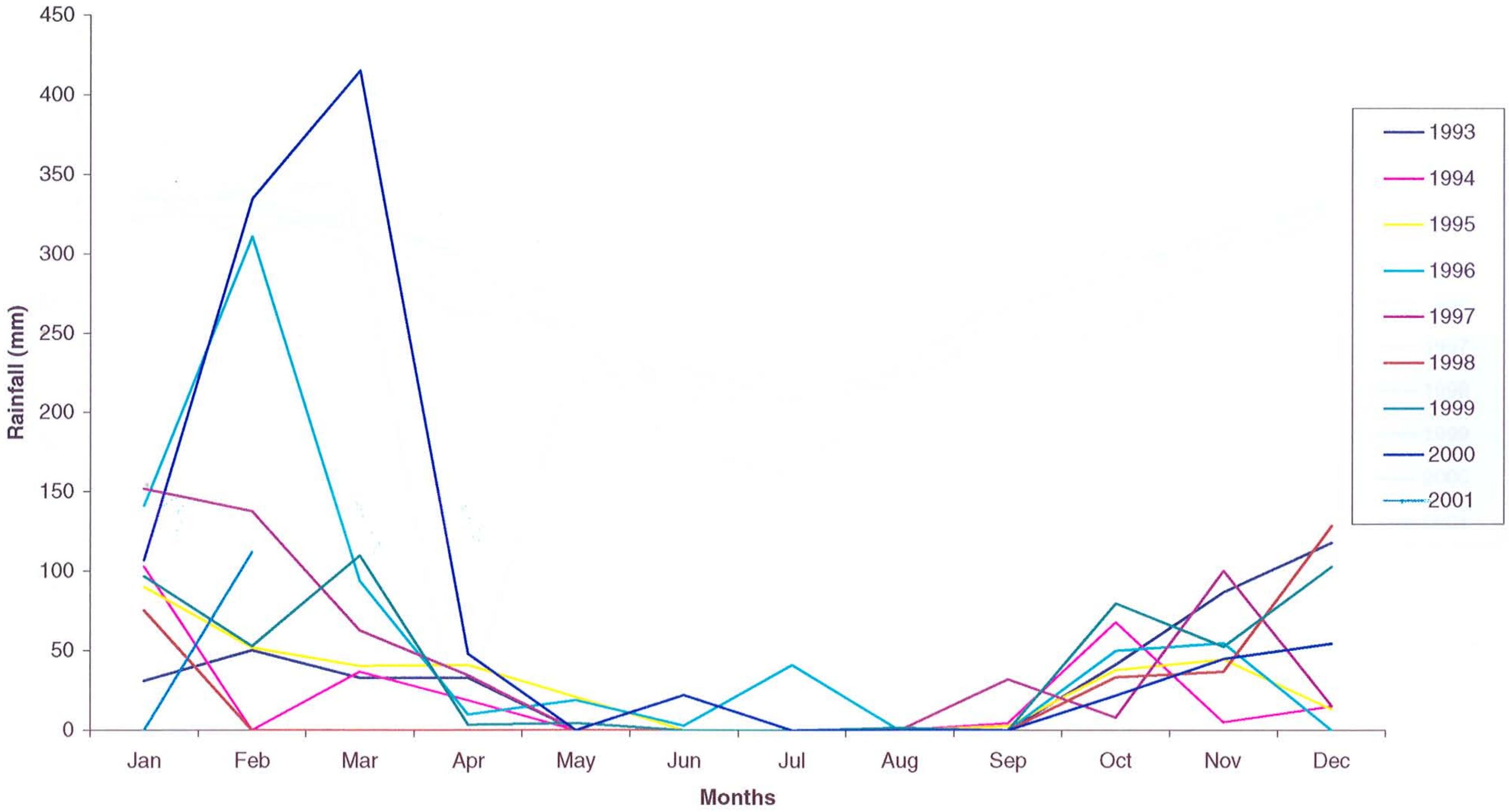
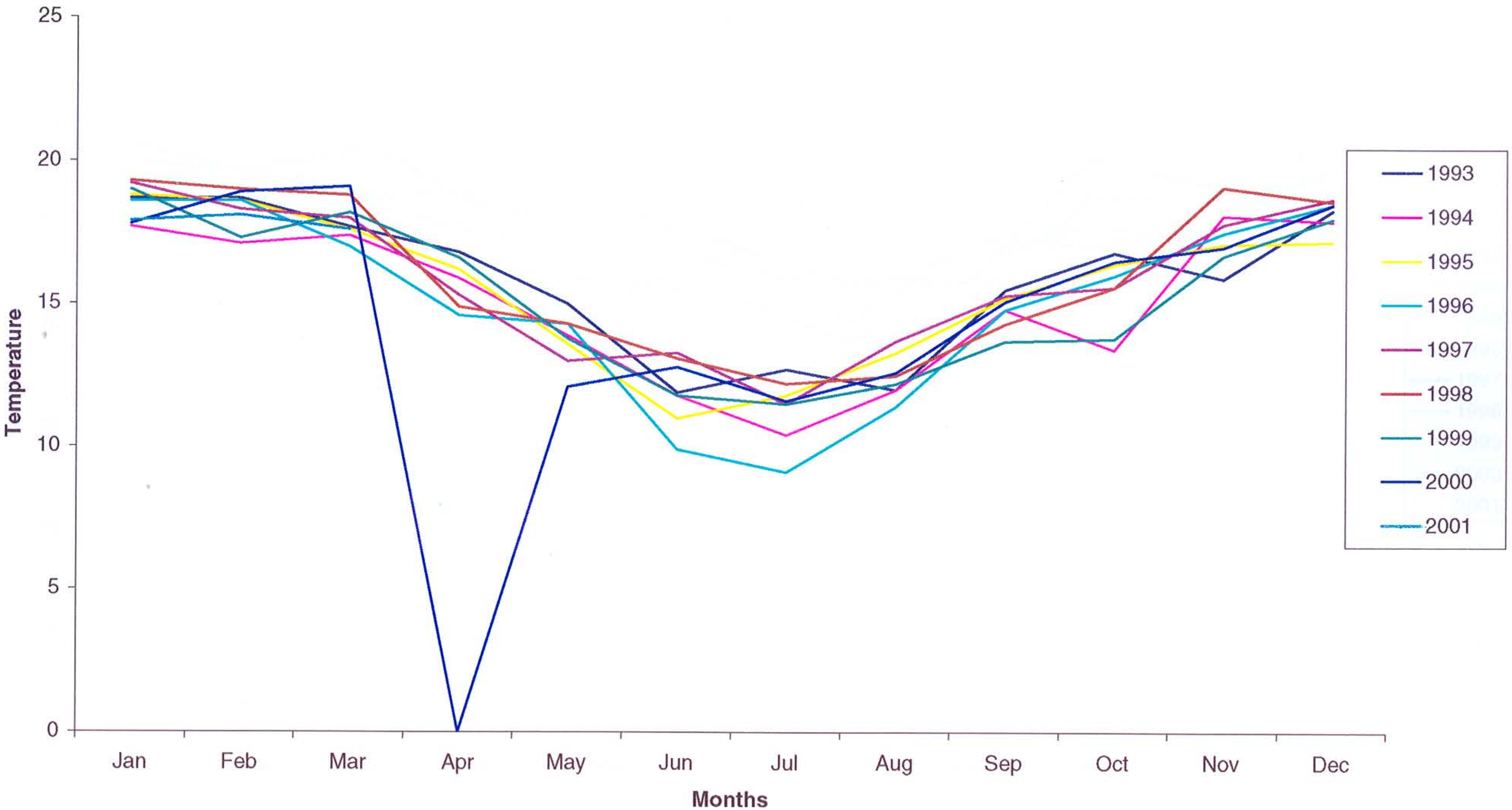


**Figure 3.6: Selati average monthly minimum temperature**



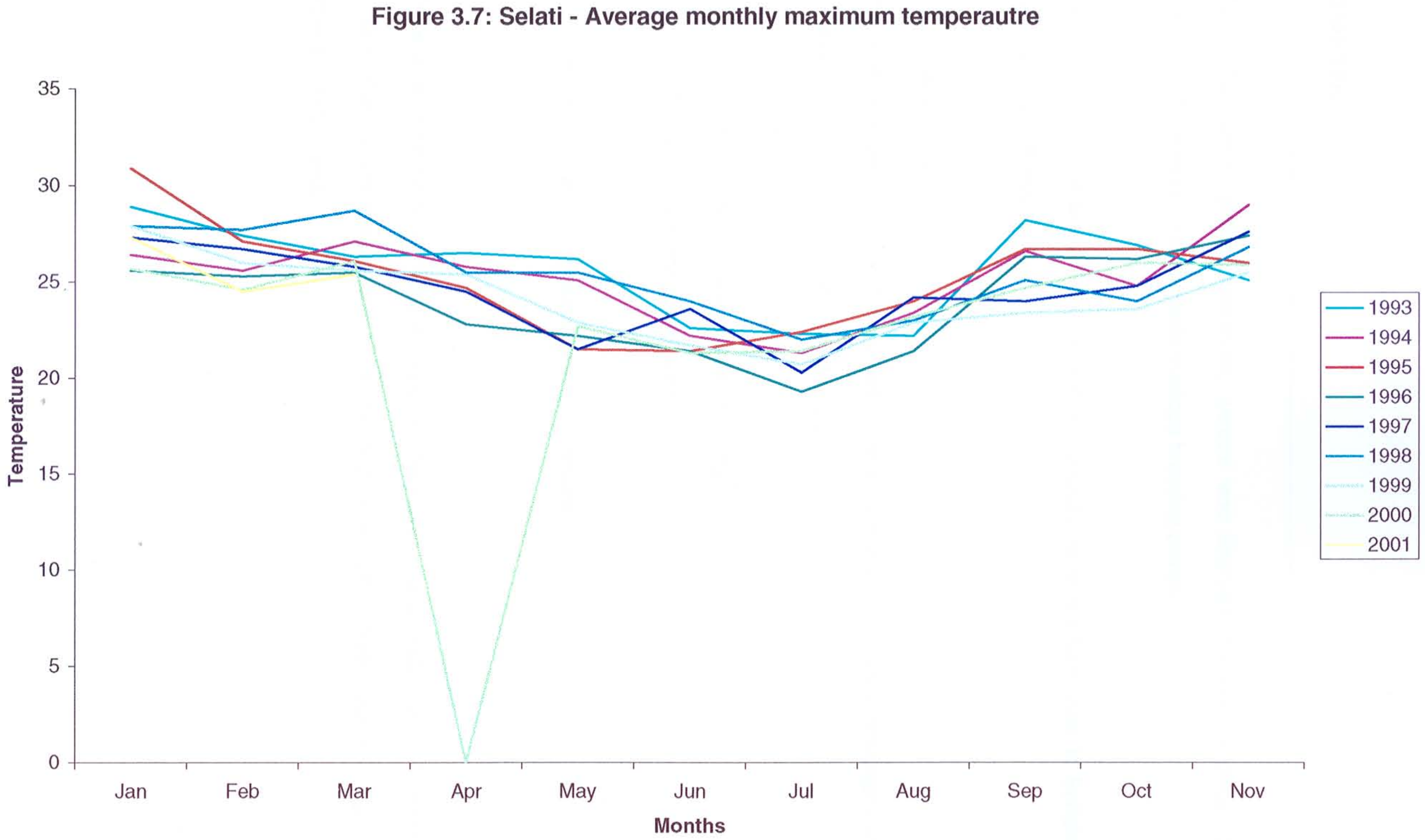


Figure 3.7: Selati - Average monthly maximum temperautre
35
30
25
20
15
10
5
0
Temperature
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Months
1993
1994
1995
1996
1997
1998
1999
2000
2001

impala, hartebeest, giraffe, waterbuck, caracal and Sharpe's grysbok (*Raphicerus sharpei*). The reserve also has sable antelope breeding camps.

Cattle farming is still present on the northern boundaries of the farm, next to Buffalo Ranch and BVB Ranch.

#### *3.2.2.3 Vegetation*

This reserve is characteristic of the mixed lowveld bushveld. The varied topography of the area encompasses six different veld types:

a. *Combretum* veld
b. Mixed *combretum* and marula on quartz
c. Mixed mopane and *combretum*
d. Mopane
e. Mixed mopane, *combretum* and cederwood
f. *Terminalia*

There is an abundance of mopane trees, red bush willow and knob thorn. A dense grass stratum occurs and consists of *Themeda triandra*, guinea grass, bushveld signal grass and finger grass.

### 3.2.3 Mara Research Station

Mara is a government run research station, belonging to the Department of Agriculture, Limpopo province situated approximately 30 km from Louis Trichardt. It covers 10 000 hectares of sweet bushveld. Mara is an experimental farm for cattle with a small compliment of wildlife present.

#### 3.2.3.1 *Climate*

Mara research station has an altitude of 961 m. The average rainfall is 452 mm (Mara pol, weather station no. 0722099 1) (Figure 3.8). The average minimum temperature is 12.8 °C (Figure 3.9) with the coldest month being June. The average maximum temperature is 27.5 °C (Figure 3.10), with the hottest months being December. On average the daily maximum temperature exceeds 20°C for 337 days of the year.

#### 3.2.3.2 *Animal species present*

Mara is an experimental farm with only naturally occurring wildlife present. Wildlife species present include: civet (*Civettictis civetta*), steenbuck, kudu, impala, warthog, duiker, waterbuck, caracal, black backed jackal, cheetah and leopard.

**Figure 3.8: Mara average monthly rainfall**

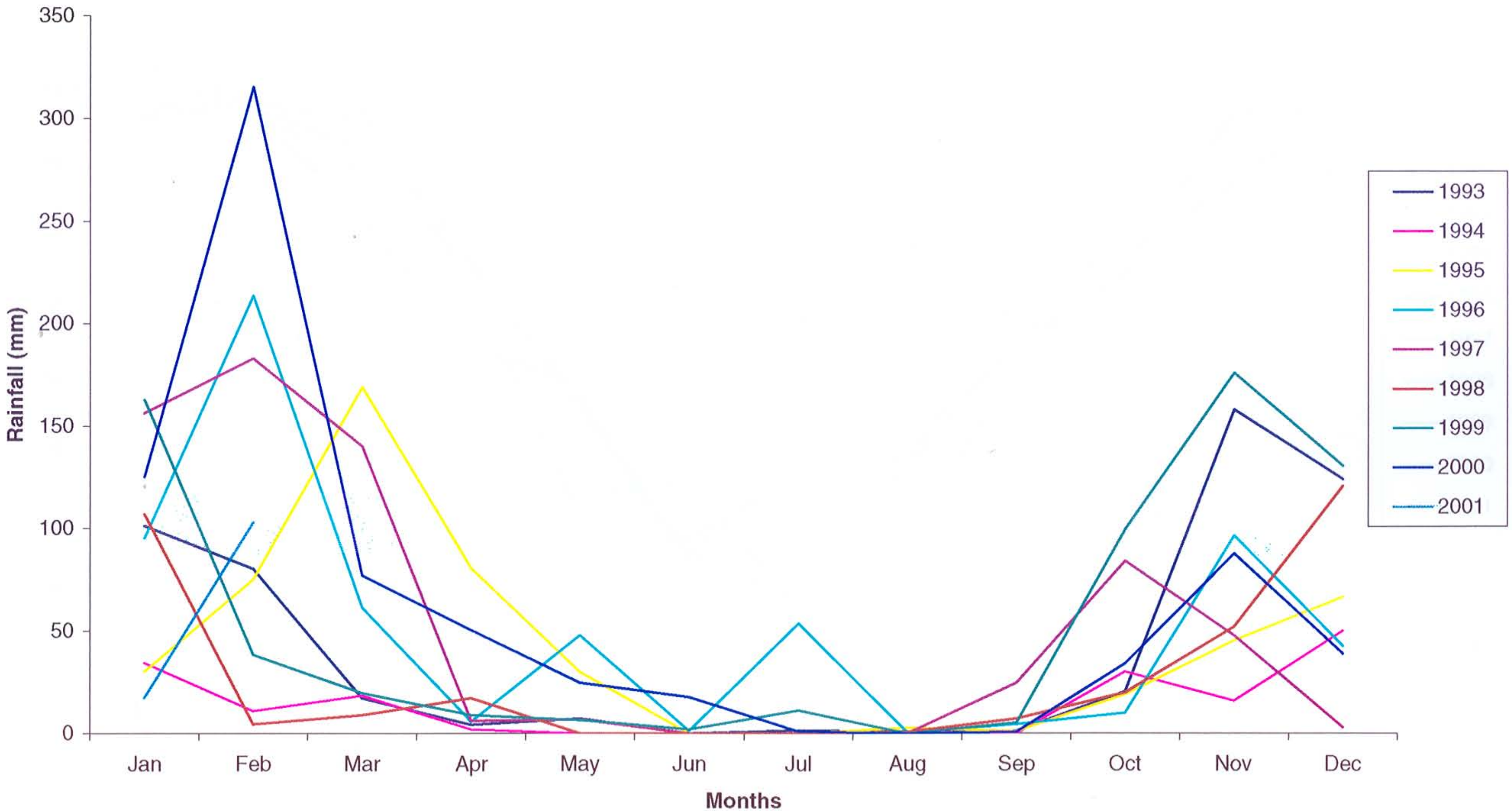


**Figure 3.9: Mara - average monthly minimum temperatures**

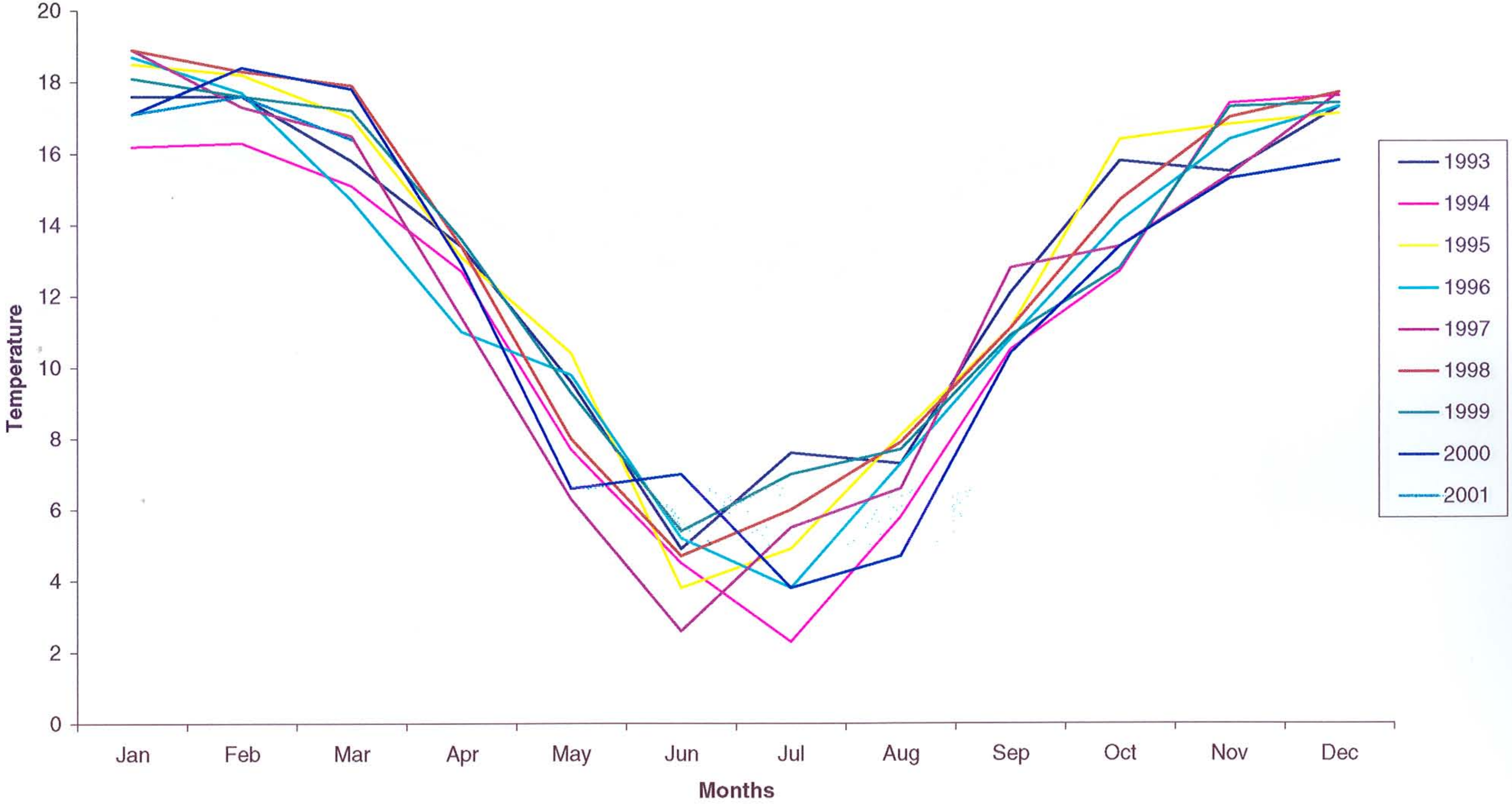
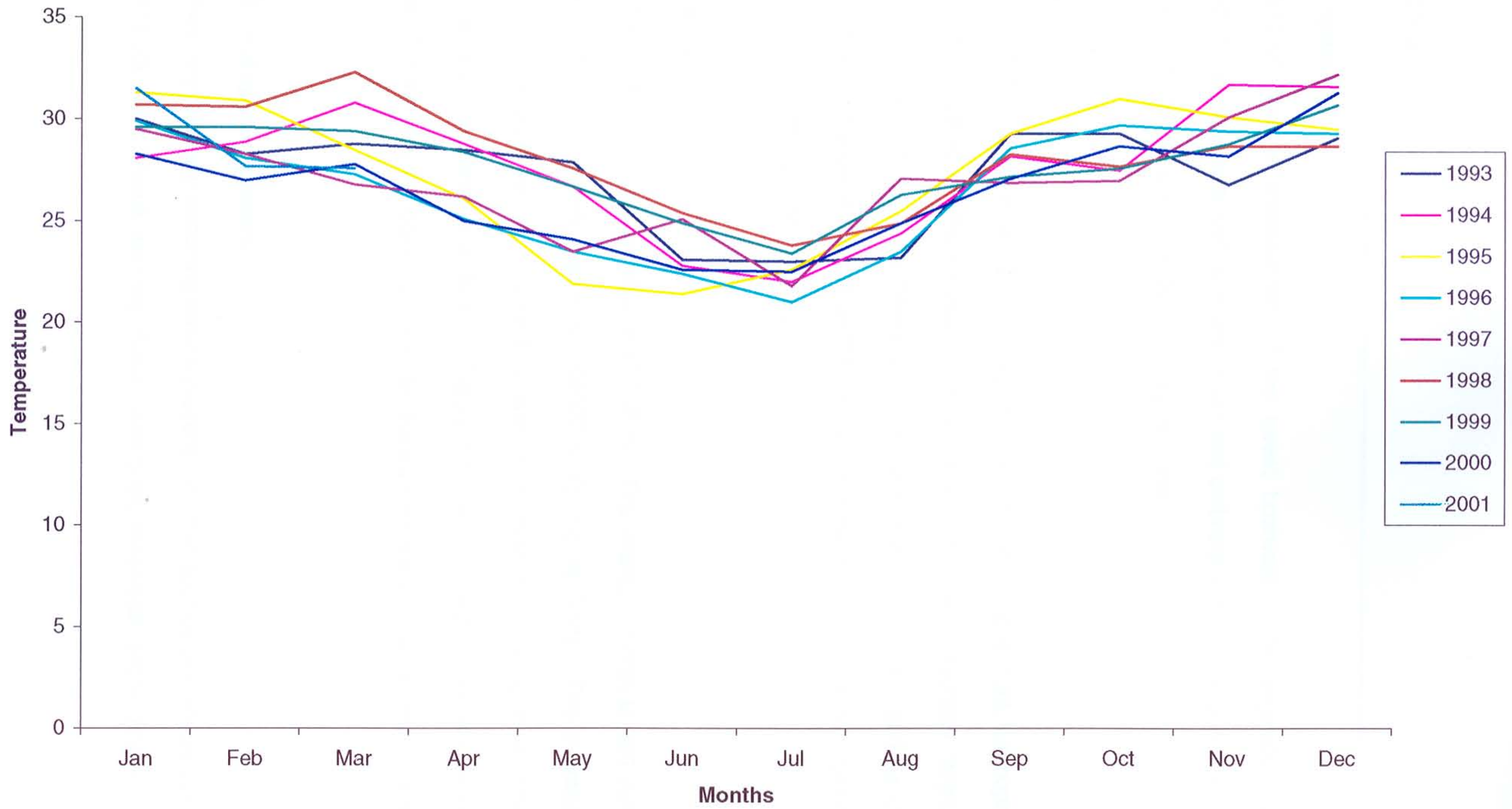


Figure 3.10: Mara - average monthly maximum temperature



#### 3.2.3.3 *Vegetation*

The vegetation here is characteristic of the sweet bushveld. The vegetation is dominated with silver cluster leaf, wild raisin bush and umbrella Thorn. The grass layer is dominated with guinea grass and bushveld signal grass.

### 3.2.4 Messina

Messina is a nature reserve, which is run by the Department of Agriculture, Limpopo Province. It is located on the northern side of the Soutpansberg mountain range, approximately 100 km from Louis Trichardt. The nature reserve spans 7 500 ha of mopane veld, with only game present on the reserve. During the hunting season, game is hunted either for biltong or for trophies.

#### 3.2.4.1 *Climate*

Messina Nature Reserve has an altitude of 780 m. The average rainfall is 350 mm (Messina / Macuville weather station no. 0809706 X) (Figure 3.11). The average minimum temperature is 16.0 °C (Figure 3.12) with the coldest month being June. The average maximum temperature is 30.1 °C (Figure 3.13), with the hottest months being December. On average the daily maximum temperature exceeds 22°C for most of the year.

#### 3.2.4.2 *Animal species present*

Messina has only naturally occurring wildlife present. Wildlife species present include: civet, steenbuck, kudu, impala, warthog, duiker, waterbuck, wildebeest, zebra, giraffe,

**Figure 3.11: Messina average monthly rainfall**

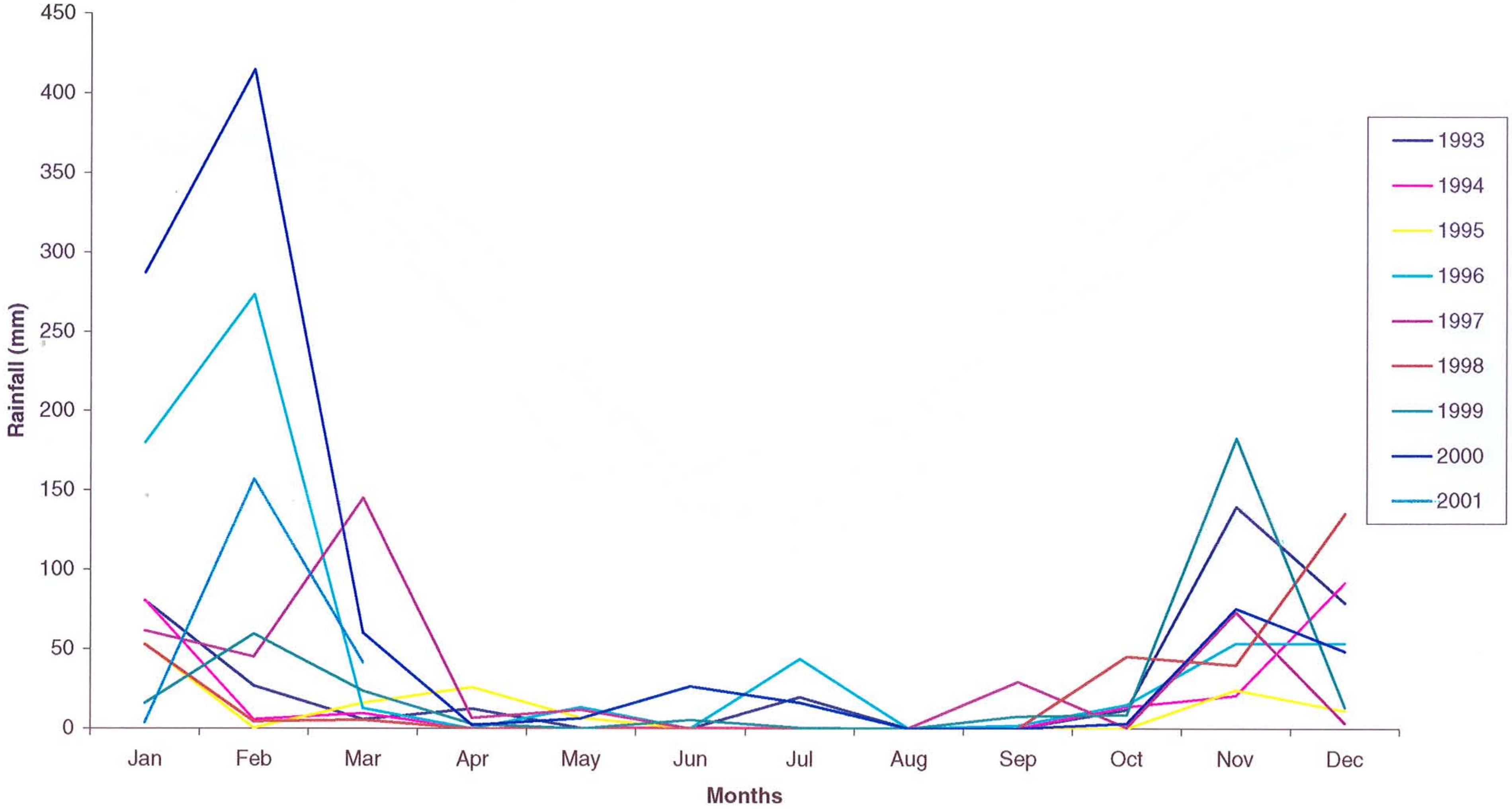


**Figure 3.12: Messina - average monthly minimum temperatures**

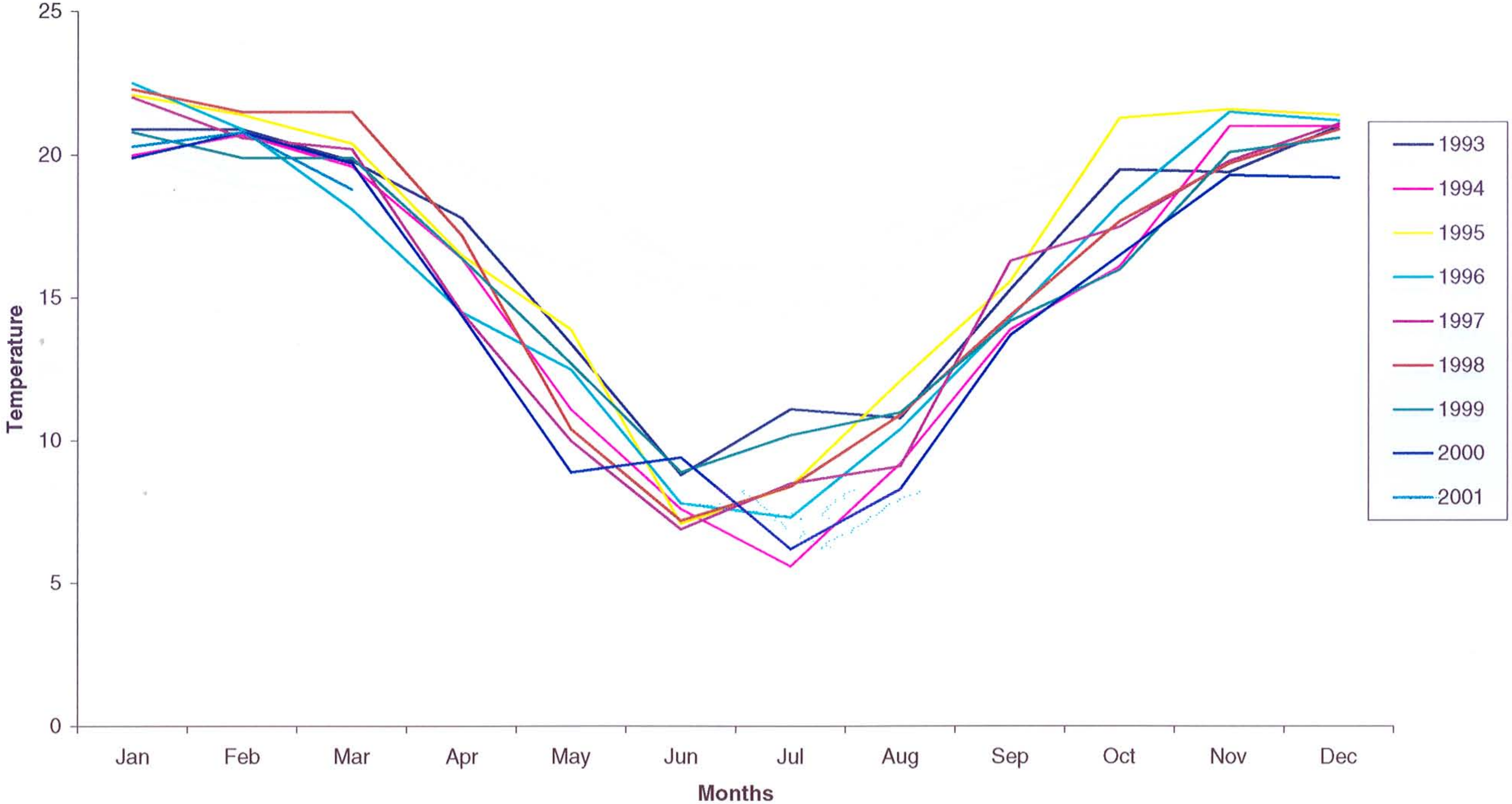
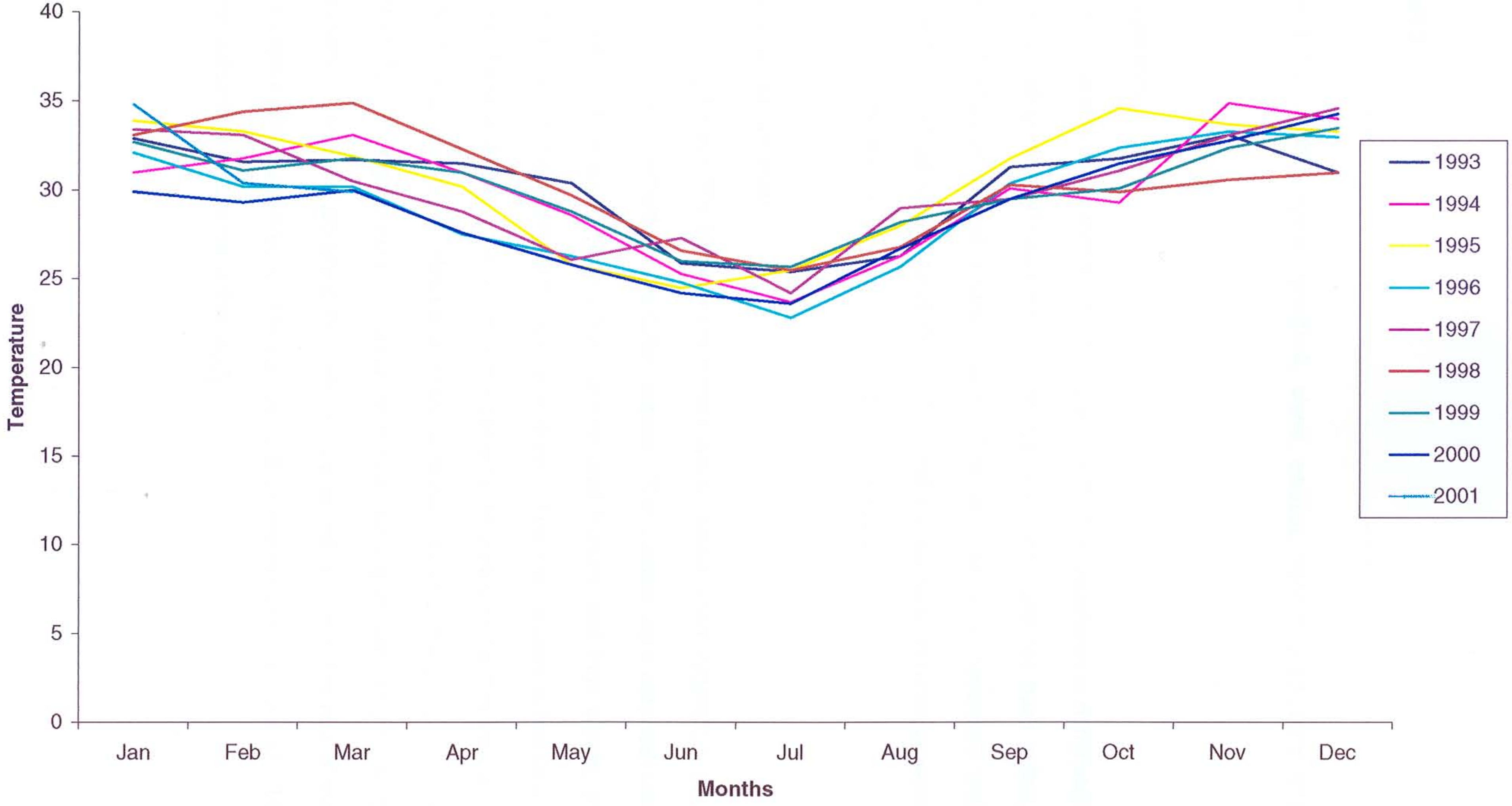


**Figure 3.13: Messina - average monthly maximum temperatures**



leopard, wild dog, spotted hyena, gemsbok, eland, caracal, black backed jackal and cheetah.

#### 3.2.4.3 *Vegetation*

The vegetation here is characteristic of the mopane veld. The vegetation is dominated with a fairly dense growth of mopane and mixtures of mopane and red bush willow, associated with knob thorn and umbrella thorn. The shrub layer is moderately well developed and individuals of wild raisin bush. The herbaceous layer includes grasses such as common nine-awn grass, guinea grass and finger grass

## 3.3 Experimental animals

This study required many different samples: impala livers, impala blood, vegetation, soil, water and linear measurements of the culled impala. The animals were obtained with the help of different persons, ranging from professional hunters and their clients, to assistant managers or managers of the game reserves. The impala were culled using either a .223 rifle or a .375 rifle. At each of the game farms visited in the Tzaneen and Louis Trichardt area, impala samples were taken randomly. Most of the samples were collected from April through to August, during the normal hunting season. Night culling was the preferred method of obtaining the samples, so as not to disturb the rest of the herd. The impala was numbered on the ear using a permanent pen. A total of 114 impala were culled for the purpose of this study.

## 3.4 Blood and Liver samples

The aim of the experiment was to identify the mineral status through the Cu, manganese (Mn) and Se concentrations in the livers of the impala. A genetic analysis was done on the blood to determine if there was any evidence of inbreeding.

The blood was taken immediately after the animal was culled. This was done by making an incision into the jugular vein. The blood was placed in a test tube with heparin or EDTA and tilted thoroughly, so to avoid clotting. The test tubes were labelled with the number of the impala and the area in which it was shot. The blood samples were placed on ice till returning to the lodge.

Back at the lodge, plasma was prepared by centrifugation of the heparinised blood. This, however, proved to be problematic, as it was often a couple of hours before returning to the lodge.

The liver samples were preserved in buffered formalin. The formalin was prepared at the University of Pretoria prior to departing to the game reserves. The buffered formalin was prepared using sodium orthophosphate, sodium hydroxide pellets and glucose dissolved in analytical grade formalin. The solution was then made up to five litres using distilled water. Liver samples were taken on return to the lodge, the impala were disembowelled and a 6 x 6 cm block (150 g) sample was taken from the centre of the liver. This sample was then placed in a sample bottle containing 200 ml buffered analytical grade formalin.

The bottle was labelled with the number and area where the impala was culled. This sample in formalin was then kept in the refrigerator. Whilst travelling back from the game farms the samples were kept on ice until they could be placed in the cool room at the University of Pretoria.

### 3.5 Faecal Samples

The aim of collecting these samples was to determine the mineral concentration of the faeces. Nitrogen and ash was also determined. The minerals analysed, include Cu, Mn, P, Zn, Ca and Mg.

Faecal samples were collected every second month from commencement of the project, from impala on each of the farms and analysed.

Wrench *et al.* (1996)'s suggestion for the collection of faeces of free ranging animals was followed for the collection of the impala faeces:

- Faecal samples were collected from free ranging animals
- Samples up to a day old, showing no signs of dung beetle activity were collected The samples were kept in brown paper bags in a ventilated room at room temperature, to prevent fungal growth.

Whilst travelling back from the game farms the samples were kept cool until they could be placed in an oven at the University of Pretoria to dry.

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## 3.6 Vegetation, soil and water samples

Soil samples were taken from each of the farms to determine the soil fertility, soil type and soil acidity on each of the farms. Samples were taken by digging a hole 500 mm deep and then taking hand sample of the soil.

A sample of the graze and the browse was taken from each of the farms. These samples were taken to determine the mineral concentration of the graze and browse. Nitrogen and ash were also determined. The minerals that were analysed included Cu, Mn, P, Zn, Ca and Mg.

The condition of the veld was determined for each of the seasons and records of the rainfall and distribution were collected. The following information was determined:

Veld management:

- Type of veld in which the impala move in
- Average rainfall and distribution
- The presence of licks
- Sources of drinking water

Samples were taken from the veld in areas where the impala were seen to be grazing. Grass samples included the roots, which were included in the analyses of the grass samples. Excess soil was shaken off the grass samples. The samples were placed in brown paper bags. The grass sample was then sun dried and kept in a cool place until leaving the game farms.

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Samples were taken from the trees and shrubs that were utilised by the impala. Leaves, pods and branches were taken. These were placed in a brown paper bag in the field. At the lodge the samples were sun dried and placed in a labelled brown paper bag and stored in a cool place until transferred to the University of Pretoria.

A water analysis was done by the Department of Soil and Climate during November 1998. Samples were collected in accordance with prescribed methods for water quality. Samples were collected from many subterranean sources, predominantly from the point of intake by the game. Natural earth dams were also included (Meyer, 1999).

## 3.7 Laboratory analysis

Liver, vegetation and faecal samples were oven dried at 60 °C, to a constant weight at the University of Pretoria. The livers were left in the oven for 48 hours while the vegetation and the faeces were left in the oven for 24 hours, until the samples were at a constant weight . All the samples were then ground to fine particles for subsequent laboratory analysis.

### 3.7.1 Dry matter analysis

This was done on all the samples. The DM concentration was determined using the AOAC (1984) method. One gram of the sample was weighed into porcelain crucibles and then placed in an oven at 100 °C overnight. Thereafter, the crucibles were put in a desiccator for 30 minutes to cool before being weighed.

To determine the dry mass of the sample the following equations are used:

| | | | |
|---|---|---|---|
| 1 | Mass of empty, dry and clean crucible | 14.5192 g | |
| 2 | Mass of crucible and air dried sample | 15.7286 g | |
| 3 | Mass of crucible and dry sample | 15.6042 g | |
| 4 | Mass of air-dried sample | 1.2094 g | (2 –1) |
| 5 | Mass of over dried sample | 1.0850 g | (3 –1) |

Percentage of dry material $\frac{1.0850 \text{ g}}{1.2094 \text{ g}} \times \frac{100}{1} = 89.71\ \%$

### 3.7.2 Ash Determination

A crucible with a dry sample for DM determination was placed in a cold incinerating oven. The sample was incinerated at 600 °C for four hours. The residue was then left to cool down for at least two hours before being placing it in a desiccator to cool for another half an hour. The crucible and ash were then weighed and the value recorded.

To determine the ash of the sample the following equations are used:

| | | |
|---|---|---|
| 1 | Mass of crucible | 14.5192 g |
| 2 | Mass of crucible of dried sample | 15.6042 g |
| 3 | Mass of air dried sample | 1.2094 g |
| 4 | Mass of crucible and ash | 14.6000 g |
| 5 | Mass of ash | 0.0808 g |

Percentage of ash in sample: $\frac{0.0808 \text{ g}}{1.2094 \text{ g}} \times \frac{100}{1} = 6.68\ \%$

### 3.7.3 Determination of crude protein

The Macro-kjeldahl method (AOAC, 1984) was used to determine the protein concentration of the faecal and vegetation samples. One gram of the sample was placed into a digestion flask (250 ml) and placed on the bloc digester and thereafter the sample was distilled with a Tecor kjeltec system model 1026 (Distillation Unit, manual part No: 1000 2790, T8806, Prabin & Co, Klippan.

The N and CP were calculated as follows:

% N = {sample titration – blank titration (factor) / sample mass (g)} x 100

% N was corrected for DM and reported as g N/kg DM

% CP = % N x 6.25

### 3.7.4 Determination of minerals

These analyses were done on the liver, faeces and vegetation. However, not all the minerals were analysed on the liver, as discussed earlier. Minerals analysed include, Cu, Mn, Mg, Zn, Ca and P. The wet ashing method for digestion was used for the samples.

A gram of each sample, in duplicate, was digested in a block digester at 230 °C. The concentrations of Ca, Mg ad Zn were determined using the Perkin Elmer 2380 Atomic Absorbtion Spectrophotometer pp Ay II. The minerals Mn and Cu were determined using the Varian Atomic Absorbtion Spectrophotometer 50 (1997). The concentration of P was determined from calibration curve using the Auto Analyser.

The concentration of the macrominerals, Ca, P and Mg were expressed as g/kg DM and those of the trace minerals, Zn, Cu and Mn, were expressed as mg/kg DM.

Selenium analyses were only done on the blood and liver samples. One gram of sample was used for the determination of Se. This sample was digested on a block digester with a temperature-timed programmer. The concentration of Se was determined on the same spectrophotometer that was used for Ca and Mg except that a continuous flow hydride vapour generator was attached. An internal laboratory standard liver sample with known concentration was included in the analysis. The readings of all the samples were done on the spectrophotometer and expressed as mg/kg. This value was converted to ng/g by using the following equation:

$$\text{Se ng/g} = \frac{\text{Reading (mg/kg)} \times \text{Dilution factor}}{\text{Mass}}$$

### 3.7.5 Determination of Neutral Detergent Fibre

This analysis was done on the vegetation samples using the Dosi Fiber and Fibertec system (Robertson & Van Soest, 1981). The samples were air dried and milled to pass through a sieve with circular openings 1 mm in diameter.

Exactly 1 gram samples were weighed into the sintered glass crucibles (porosity 2) and placed on the hot extraction unit of the system. A neutral detergent solution (NDS) was added into the crucible and allowed to boil for one hour. The solution was then washed out with hot distilled water. The residues in the crucibles were dried at 100 °C overnight, cooled the following day a desiccator for 30 minutes.

After cooling the samples were weighed and placed in a muffle furnace to be ashed at 600 °C for 3 hours. The furnace was allowed to cool to at least 250 °C. The crucibles were then removed and placed in a desiccator and cooled for 30 minutes and then weighed. The following equation was used to determine the NDF:

- RCD = residue in crucible after drying

  RCA = residue in crucible after ashing

$$\%NDF = \frac{RCD - RCA}{\text{original sample mass}} \times 100$$

Corrected for dry matter content of the sample

### 3.7.6 Determination of Acid Detergent Fibre

The ADF was determined according to the method of Goering & Van Soest (1970) using the Tecator fibretec system. The samples were air dried and milled to pass through a sieve with circular opening 1 mm in diameter (Goering & van Soerst, 1970). One gram of sample was weighed. The analysis is exactly the same as the NDF analysis except that the acid detergent solution (ADS) was used.

- RCD = residue in crucible after drying

  RCA = residue in crucible after ashing

$$\%NDF = \frac{RCD - RCA}{\text{original sample mass}} \times 100$$

Corrected for DM content of the sample.

## 3.8 Linear measurements

All measurements were taken using a flexible roller measuring tape, using the metric scale. Linear measurements were taken from the impala that were culled. The animals were hung upside down, from their hindlegs. The measurements were taken on the right side of the carcass. The following parameters were collected for comparison:

- Body length – the length was taken from the atlas- joint along the neck and the curve of the body on the back bone till the tip of the tail.
- Shoulder height – this was measured at the right foreleg of the animal. The measurement was taken from the tip of the hoof to the most protruding part of the scapula. These measurements were used as an indicator of growth and size.
- Horn length – the length of the impala horn is measured along the front curve, from the base to the tip of the horn (Bothma, 1989).
- Horn circumference – this measurement is taken at the base of both horns as close as possible to the head, at right angle to the axis.
- Testicular circumference – the testis were pulled down and the measurement was taken at the widest part of the testis.
- Further measurements were done on the bone structure of the animal. These included measuring the metatarsus and the metacarpus

The data obtained for the impala in the Kruger National Park (KNP) was kindly provided by Dr. V de Vos, Head of Research at the KNP, for comparative purposes.

See figure 3.14 for detailed measurements. Abbreviations used are:

Bp – Breadth of the proximal end of the metatarsus

Gl – Greatest length

Sd – Smallest breadth of diameter

Li – Lateral length of the outer side

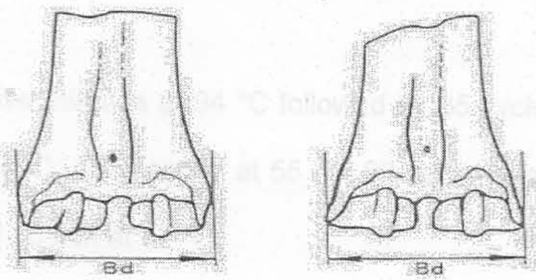
Gli – Greatest length of the lateral part

Bd – Greatest breadth

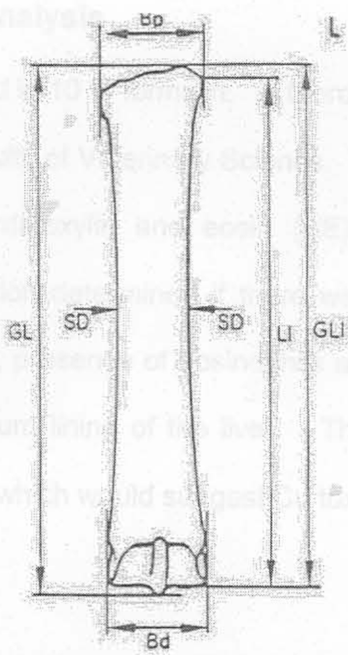
## 3.9 Genetic Analysis

To determine the genetic variation of the impala populations, either a hair or blood sample was taken from the culled impala. The blood samples were kept in EDTA tubes and stored at -70°C at the University of Pretoria. The DNA extraction was done using the puregene DNA – isolation kit (Gentra systems, Minneapolis). Primers were used as standards for comparison of the impala DNA. A primer is a synthetic oligonucleotide – also referred to as a marker. The markers used for the impala are mostly from the Bovine, as this genome map have a large number of microsatellite (microsats) markers useful for diversity studies. Microsats, are short tandem repeats found in the non-coding region of the DNA, highly polymorphic and, therefore, often used to distinguish between individuals, parentage verifications and biodiversity. Eight microsats were used for these samples

**Figure 3.14: Schematic representation of the metatarsus and metacarpus measurements**




Metatarsi – dorsal view




Metacarpus – dorsal view

PCR – Polymorphic :

- Add 1 x 10 mM buffer, $MgCl_2$, 200uM dNTP's 4 pmol of each primer, 02, units Taq Polymerase (Promega) and 50 ng of DNA. The final volume equals 15 ul.
- Samples are then placed into Thermal controller (Perkin Elmer) with the following program:
    - Five minutes at 94 °C followed by 35 cycles consisting of 30 seconds at 94 °C, 45 seconds at 55 °C, 90 seconds at 72 °C and an extension step of 10 min at 72 °C.
- PCR products are then analysed on an automated DNA sequencer (ABI 373 A).

## 3.10. Histopathology analysis

Liver samples were collected in 10 % formalin. A thorough histological examination was done on the liver at the Faculty of Veterinary Science. The samples were sectioned and stained routinely with haematoxylin and eosin (HE) for examination under a light microscope. The examination determined if there were any abnormalities in the bile ducts, epithelial hyperplasia, presence of eosinophils and lymphocytes in the ducts and any changes to the epithelium lining of the liver. The livers were examined also for signs of a haemolytic crisis, which would suggest Cu toxicity.

## 3.11 Statistical analysis

Data was analyses by the analysis of variance procedure of the General Linear Models (GLM) program (SAS, 1985), with measurements, concentration of minerals and age, area and gender as variables. To determine statistical differences in mineral concentrations classified according to soil, vegetation and faeces the Bonferroni (Dunn) *t* test was used in the case of empty cells. Means and standard errors were calculated for all parameters. A multi-factorial analysis of variation (ANOVA) was used to analyse the effect of area and environment on liver mineral concentrations for the impala.

# CHAPTER 4

# RESULTS AND DISCUSSION

## 4.1 Linear measurements

The Rowland Wards records of big game has been an international method for measuring game (Bothma, 1989). All trophies from all over the world are listed in this book, which is published every year. In the present study linear measurements were taken to establish if the mineral status of the animal affected the growth. The linear measurements and the horn measurements of impala, sampled at the different farms, showed no significant differences. However the carcass mass and empty body mass did differ significantly between Selati and Ndzalama, P= 0.05 (Table 4.1), Ndzalama being the heaviest. The empty body mass (EBM) of the impala at Mara averaged between 35 – 40 kg, while those at Selati were between 22 – 35 kg, and the EBM at Ndzalama was between 28 – 40 kg.

These mass differences may be explained by a nutritional difference in the diet of the impala. Mara is on a sweetveld which has better quality grazing. There was no significant difference in body length between Ndzalama of Selati. The animals of Selati showed a tendency to be shorter in body length compared to Mara (Figure 3.15 and Figure 3.16). Bothma (1989) stated that adult rams of the KNP were lighter than those in the north western Limpopo Province. Findings from this study also indicated that the impala from Mara and Messina Game Reserve were heavier than those at Ndzalama and Selati (Figure 3:17 and Figure 3:18)

**Table 4.1: Descriptive analyses of the linear measurements and mass (± standard deviation) of impala (*n* = 116)**

| rea | Gender | Age Group | Number Of animals | Mass+I (kg) | Mass-I (kg) | Intest Mass (kg) | Heartgirth (cm) | GL (mm) | Bp (mm) | Sd (mm) | Bd (mm) | Horn (cm) | Scapula length (cm) | Scrotum circumference (cm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| dzalama | Male | Juvenile | 15 | 58.3 (±6.6)[§] | 30.0 (±4.8) | 15.4 (±2.3) | 74.2 (±4.6) | 231 (±2.4) | 26.9 (±1.7) | 15.8 (±1.2) | 29.5 (±2.0) | 45.7 (±3.5) | 71.6 (±4.2) | 10.6 (±2.4) |
| | | Adult | 7 | 74.0 (±4.1)[§] | 42.0 | 16.0 (±3.4) | 77.8 (±2.3) | 235 (±2.1) | 29.5 (±2.3) | 17.4 (±2.3) | 30.2 (±2.3) | 47.8 (±4.5) | 79.0 (±2.3) | 17.4 (±2.3) |
| | Female | Juvenile | 8 | 54.8 (±1.2)[§] | 30.5 (±3.3) | 15.2 (±2.1) | 73.9 (±2.8) | 210 (±3.0) | 26.2 (±1.4) | 16.0 (±1.0) | 25.6 (±1.8) | | 68.0 (±4.1) | |
| | | Adult | 1 | 73.0 (±5.1)[§] | 44.5 | 15.5 (±1.9) | 76.0 (±4.2) | 216 (±4.1) | 28.2 (±2.4) | 16.8 (±3.1) | 26.2 (±1.3) | | 75.2 (±3.2) | |
| elati | Male | Juvenile | 15 | 54.0 (±3.7)[§] | 28.0 (±6.9) | 12.0 (±4.1) | 68.5 (±5.1) | 219 (±4.1) | 27.5 (±2.2) | 16.7 (±1.8) | 26.3 (±1.7) | 43.5 (±2.3) | 69.5 (±3.4) | 11.7 (±2.5) |
| | | Adult | 3 | 60.0 (±3.1)[§] | 41.4 | 13.3 (±2.3) | 82.0 (±5.1) | 230 (±3.5) | 28.75(±2.3) | 17.2 (±2.3) | 29.1 (±2.3) | 46.8 (±3.8) | 76.3 (±2.3) | 16.8 (±4.1) |
| | Female | Juvenile | 15 | 52.0 (±2.7)[§] | 23.8 (±7.2) | 11.5 (±3.7) | 73.3 (±5.4) | 216 (±4.3) | 24.4 (±1.9) | 15.5 (±1.4) | 24.6 (±1.1) | | 63.6 (±2.8) | |
| | | Adult | 8 | 58.0 (±3.2)[§] | 39.5 | 12.2 (±2.4) | 79.0 (±4.2) | 228 (±4.7) | 28.4 (±3.2) | 16.0 (±2.3) | 26.4 (±2.1) | | 69.0 (±2.1) | |
| ruger ational ark | Male # | | 19 | 43.6 (±6.3)[§] | 31.0 (±4.3) | 10.5 (±2.8) | 68.1 (±3.2) | 217 (±2.7) | 26.5 (±1.4) | 16.2 (±1.3) | 27.3 (±1.5) | 44.8 (±3.2) | 67.2 (±2.8) | 14.2 (±3.6) |
| | Female # | | 11 | 32.3 (±6.7)[§] | 22.8 (±4.7) | 11.2 (±3.0) | 65.3 (±3.5) | 213 (±3.4) | 24.9 (±1.6) | 12.5 (±1.1) | 24.3 (±1.2) | 46.5 (±2.5) | 65.2 (±3.3) | |
| ara | Male | Juvenile | 6 | 56.1 (±4.2)[‡] | 26.2(±6.4) | 15.6 (±4.2) | * | * | * | * | * | 50.0 (±5.6) | 78.7 (±4.9) | 11.5 (±2.8) |
| | | Adult | 5 | 77.2 (±3.7)[§] | 38.2 | 16.2 (±3.2) | | | | | | | 83.0 (±2.3) | 17.6 (±2.3) |
| | Female | Juvenile | 3 | 55.0 (±2.4)[§] | 24.0 | 15.1 (±3.5) | | | | | | | 74.0 (±2.3) | |

1 means within the same column with different superscripts (§‡) differ significantly (*$P \leq 0.05$*)
2 * no measurements obtained on the skeleton of the sampled impala
3 # no age records were kept for these animals sampled

Mass +I – Live mass of the impala

Mass-I – Mass of carcass with the intestines removed

Intest mass – Mass of intestines

GL – Greatest length of metacarpus

Bp – Breadth of the proximal end of the metacarpus

Sd – Smallest breadth of diameter

Bd – Greatest breadth of metacarpus

**Figure 3.15: Linear measurments for female impala sampled at Mara, Selati and Ndzalama (n= 38)**

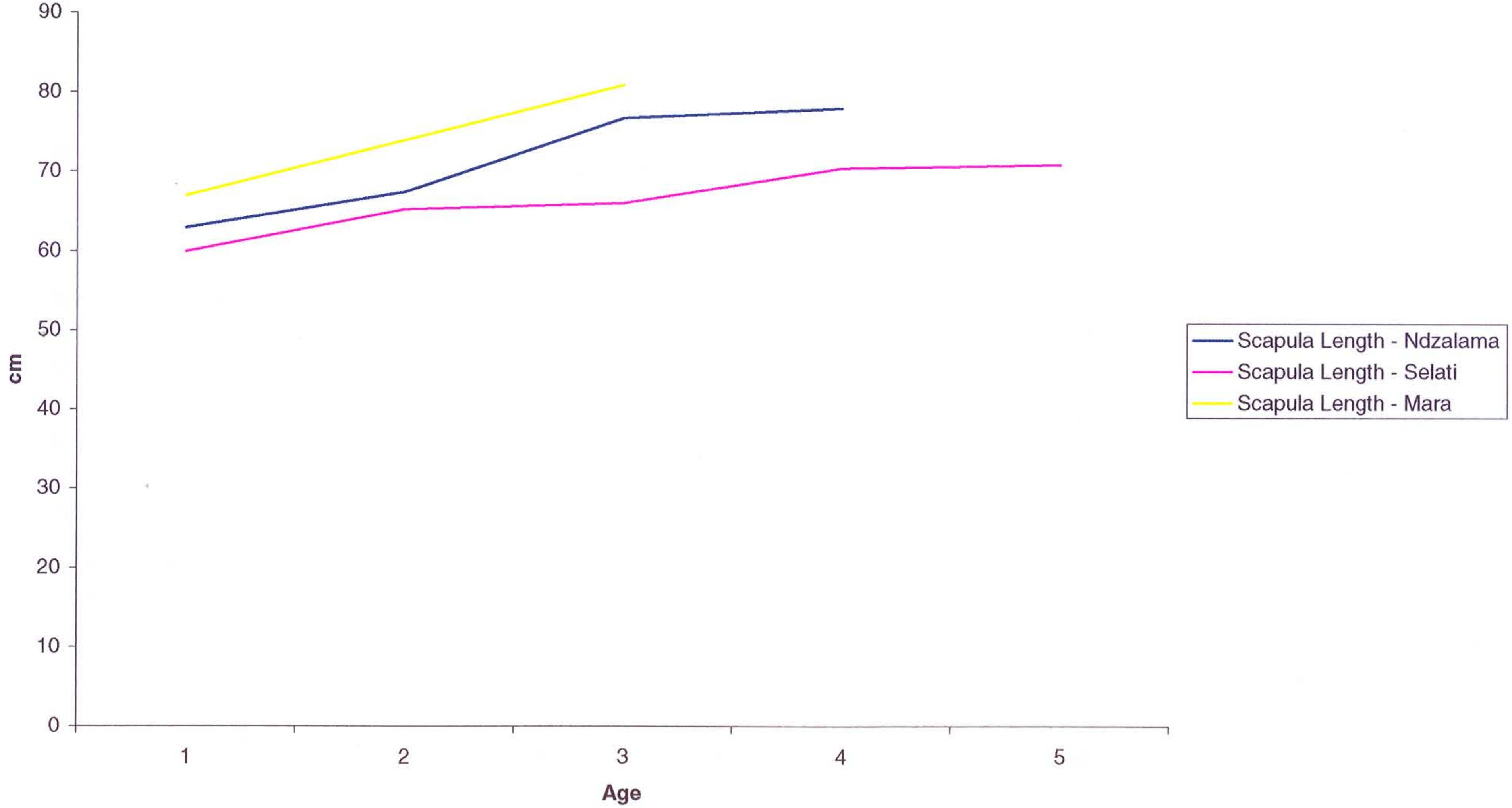


**Figure 3.16: Linear measurements for male impala sampled at Mara, Selati and Ndzalama (n=76)**

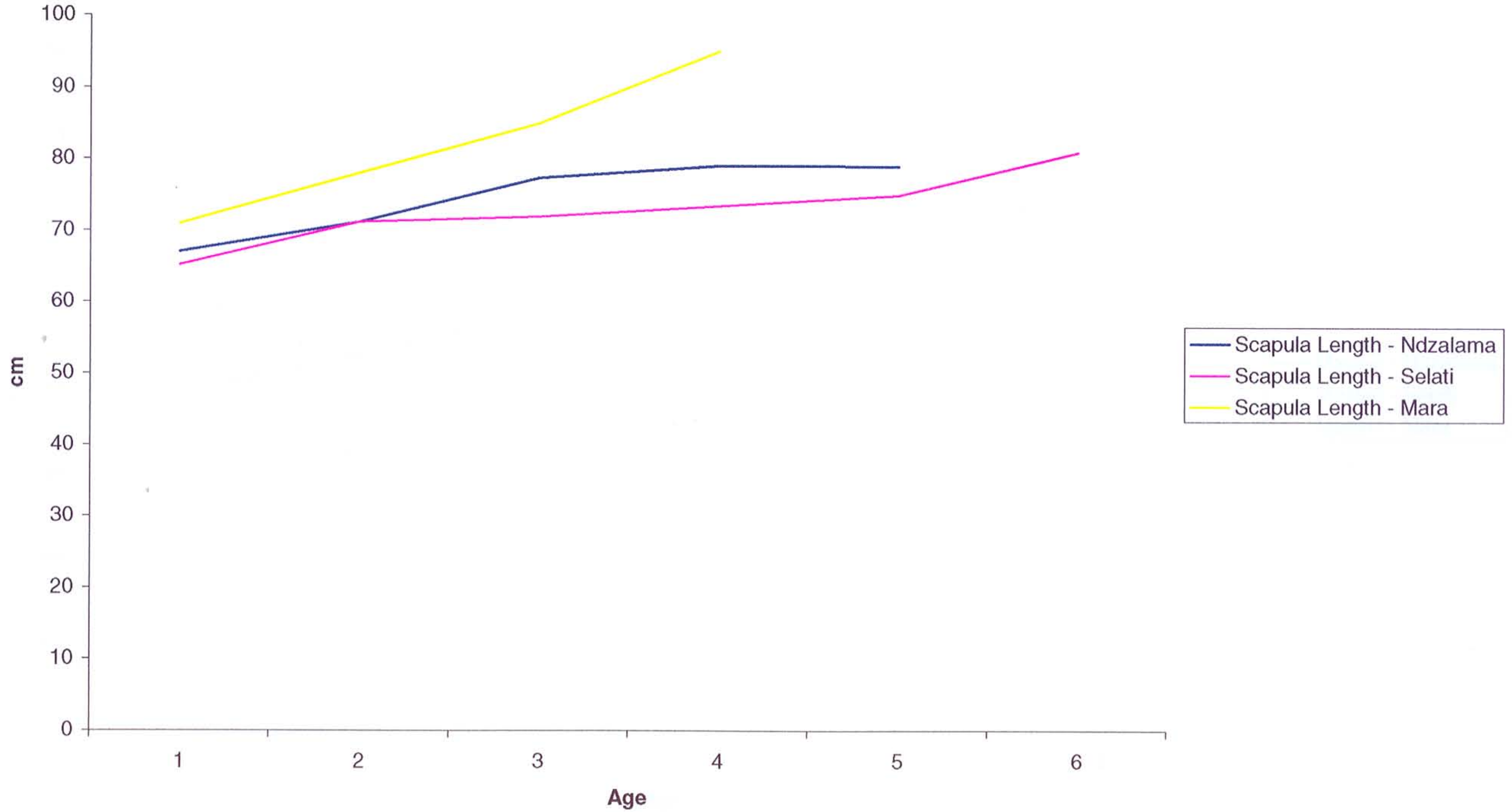


**Figure 3.17: Mass (including intestines) for female impala sampled at Mara, Selati and Ndzalama(n=38)**

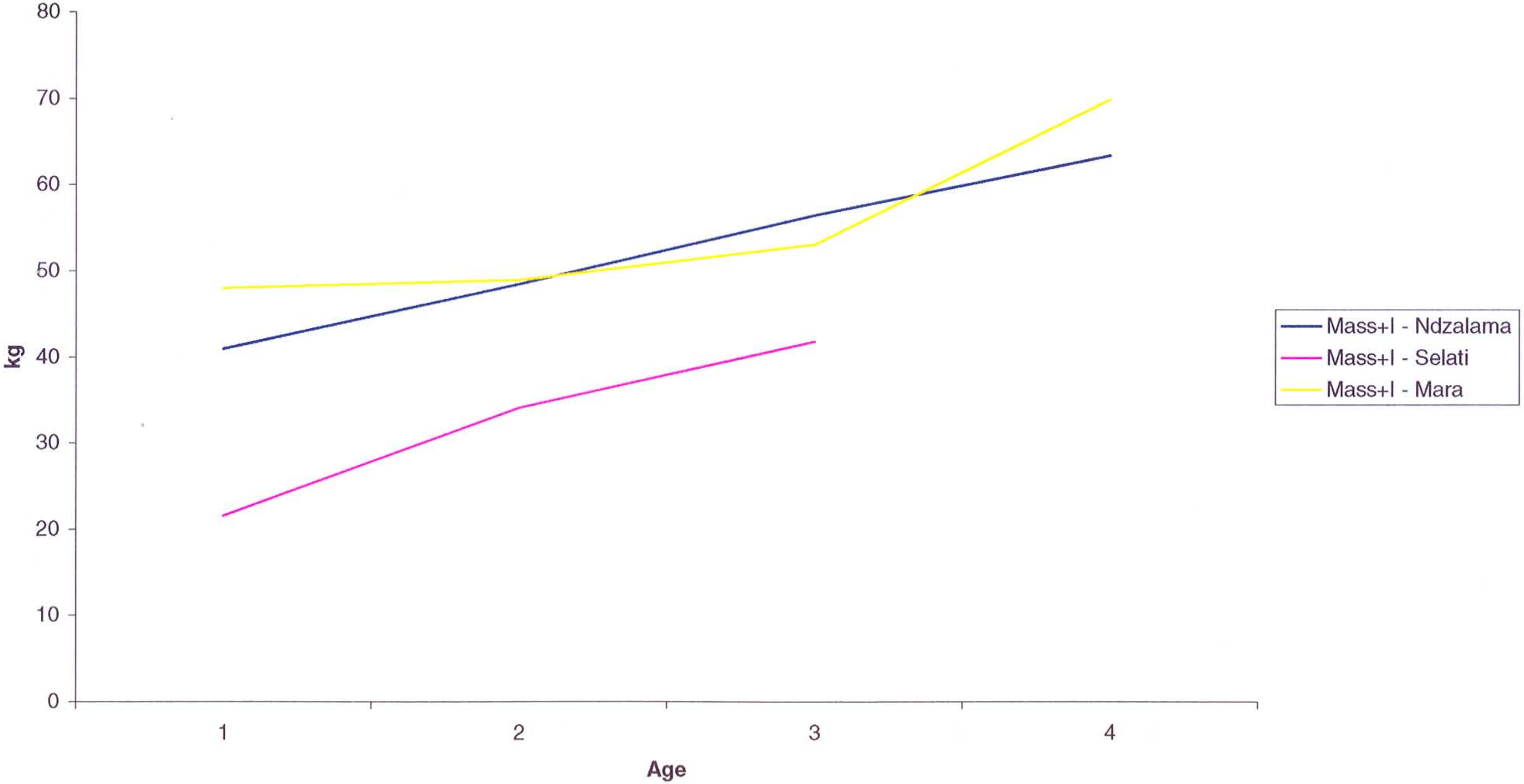
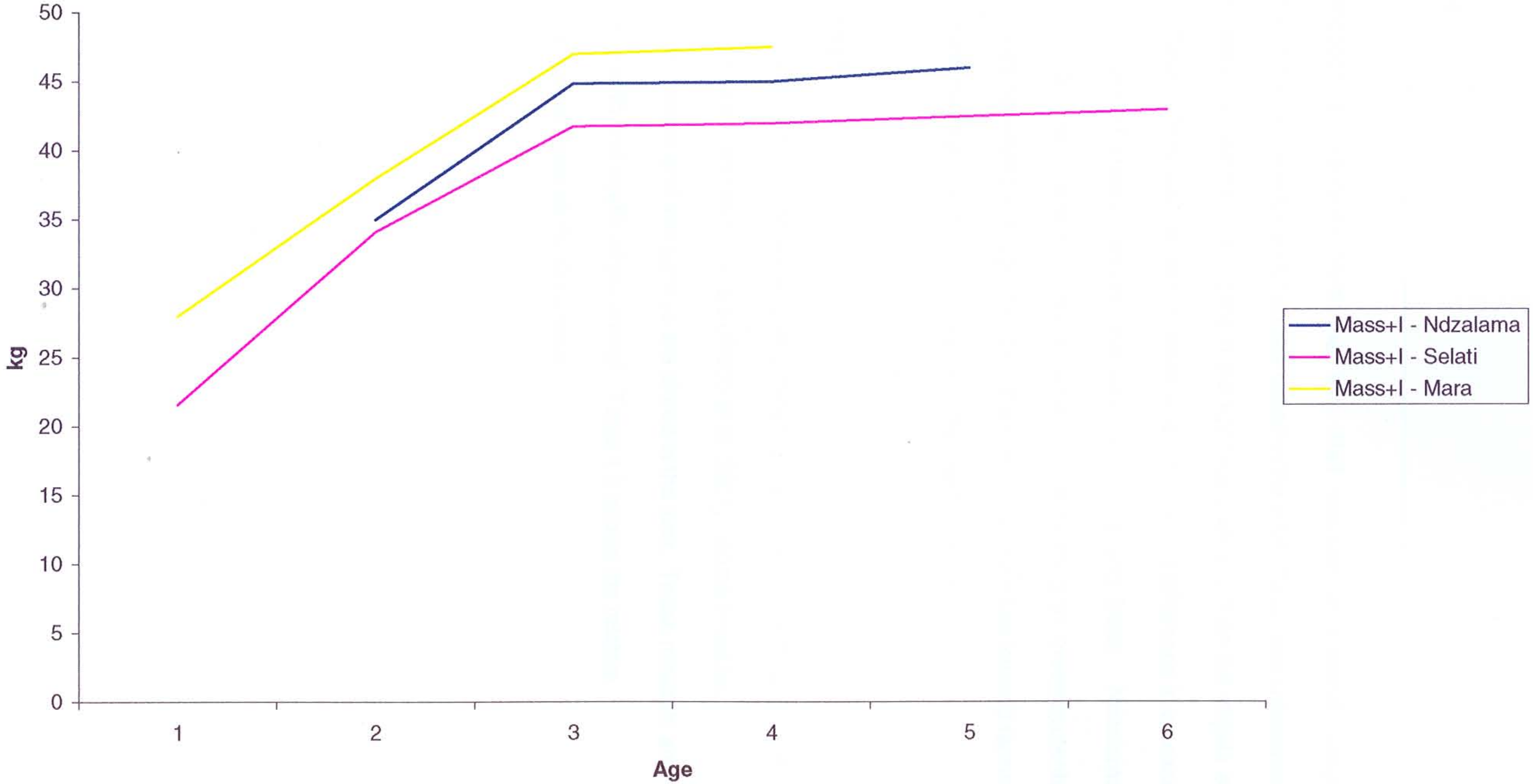


Figure 3.18: Mass (including intestines) for male impala sampled at Mara, Selat and Ndzalama (n=76)



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In an investigation by students from the Van Hall Institute in Holland, linear measurements and mass were taken for impala culled in the KNP, Selati and Ndzalama. The measurements showed that the impala in the KNP were smaller than the impala at Ndzalama and Selati. They also found that there was a significant difference in carcass mass and total mass of impala sampled between Ndzalama and Selati. Ndzalama impala were heavier than those sampled at Selati. The heart girth measurements differed significantly between the Kruger National Park (KNP) and the two lowveld farms. The KNP had lower heart girth measurements than the lowveld farms.

## 4.2 Liver Analysis

The chemical composition of body tissue, particularly the liver, is a good reflection of the dietary status of domestic and wild animals (Webb *et al.* 2001). Some minerals, including selenium, copper and manganese are stored in the liver. These minerals are essential for the growth and health of the animal. Table 4.2 shows the relative importance of the above minerals for the animal.

**Table 4.2: Important minerals for growth and health that were analysed from the liver samples**

| Element | Function | Deficiency | Excess |
|---|---|---|---|
| Copper | Haemoglobin synthsis, bone metabolism, central nervous system functioning. | Anaemia, poor growth, ataxia | Nausea, haemolytic crisis |
| Selenium | Growth, reproduction, immunity | Muscular dystrophy, uterine infections and decrease in immune response. | Lameness, blindness, |
| Manganese | Enzyme systems | Ataxia, retarded growth, skeletal abnormalities | |

Table 4.3 shows the multivariate analysis of liver samples and the growth measurements taken. There were significant differences between the animals at Mara and those at Selati and Ndzalama. The copper levels were significantly higher in impala at Mara and Selati compared with those at Ndzalama (P = 0.03). Grobler (1996) investigated copper toxicity in the central and northern regions of the KNP. Impala that were culled in the area of the KNP closest to the Phalaborwa industrial complex showed higher Cu concentrations in the liver than those sampled in the rest of the KNP. Buffalo within the same area also showed significantly higher tissue Cu concentration than the central parts of the KNP (Gummow *et al.*, 1991). Webb *et al.* (2000) also found high concentrations of Cu in the liver of the buffalo culled in the northern and central parts of the KNP, which is in agreement with the findings of Grobler & Swan (1999) and Gummow *et al. (1991).* Boyazoglu *et al.* (1972) reported impala liver concentration to be approximately 26.9 ± 11.9 mg/kg DM. Although liver Cu concentrations exceeding 116 mg/kg DM occurred in some of the impala at Mara, Ndzalama and Selati, there were no clinical signs or indications of chronic Cu poisoning.

**Table 4.3: Multivariate analyses of the mineral concentration in the liver samples collected at Mara, Ndzalama and Selati, on a DM basis**

| Area | Gender | Age Group | No of observations | Copper (mg/kg) | Selenium (mg /kg) | Manganese (mg/kg) |
|---|---|---|---|---|---|---|
| Mara | Female | Juvenile | 3 | 113 (±5.5) | 1.09§ (±0.37) | 14.2 (±1.5) |
| | Male | Juvenile | 6 | 99.6(± 5.4) | 1.09§ (±0.36) | 12.5 (± 1.1) |
| | Male | Adult | 5 | 166§ (± 6.1) | 1.03§ (± 0.22) | 11.2 (± 3.4) |
| Ndzalama | Female | Juvenile | 8 | 104 (±8.3) | 0.64‡ (±0.31) | 7.2 (±1.5) |
| | | Adult | 1 | 44.6‡ (± 2.5) | 0.52 (±0.23) | 10.9 (± 1.9) |
| | Male | Juvenile | 15 | 105 (± 6.5) | 0.45‡ (± 0.18) | 10.6 (± 2.8) |
| | | Adult | 7 | 68.6‡(± 5.3) | 0.45‡ (± 0.18) | 11.1 (± 1.9) |
| Selati | Female | Juvenile | 15 | 140 (±9.3) | 0.63‡ (±0.17) | 10.5 (±2.5) |
| | | Adult | 3 | 152 (± 14.2) | 0.50‡ (± 0.14) | 10.1 (± 0.9) |
| | Male | Juvenile | 15 | 161§ (± 11.5) | 0.69‡ (± 0.24) | 10.8 (± 2.0) |
| | | Adult | 8 | 131 (±14.5) | 0.53 (±0.18) | 12.01 (±2.9) |

1 means within the same column with different superscripts (§‡) differ significantly (*$P \leq 0.05$*)

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Faeces have previously been used to indicate Cu concentration in sheep (Grobler & Swan, 1999). The faecal Cu concentration was between 25 and 28 mg/kg DM at all the farms. This is similar to the Cu concentration of faeces of impala in the KNP (Grobler & Swan, 1999).

The levels of selenium were significantly lower in Ndzalama and Selati compared with the samples from Mara (P = 0.000). Webb *et al.* (2001) reported that the Se concentration of buffalo in the southern regions of the KNP suggested a marginal Se deficiency. The Se concentration of the impala at Ndzalama and Selati were 0.45 ± 0.25 mg/kg and 0.62± 0.24 mg/kg. According to Van Ryssen (2001) the Se concentrations could be considered to be marginal. The Se concentration at Mara was 1.09 ± 0.36 mg/kg, which was considered to be adequate (Van Ryssen, 2001).

The Mn concentration did not differ between the liver samples from either of the farms examined. The National Research Council recommendation for goats states that 9 mg/kg is adequate (NRC, 1981). So far data are inadequate to suggest optimum levels. However, it should be emphasised that the Mn concentration in the liver is a poor indicator of the Mn status of the animals, except in situations of abnormally high or low intakes. The Mn levels for the farms varied between 7,2 mg/kg and 14,2 mg/kg.

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Histopathological examinations were done on the livers of impala collected at Mara, Ndzalama and Selati. The liver samples were representative of both the dry and the wet seasons. Pathology results from the Onderstepoort Pathology Laboratory showed severe epithelial hyperplasia in the medium to large bile ducts. There were parasites present in the lumen. There were also concentric layer of fibrosis aroua severe infection of the liver with *Paracooperioides peleae* (Nematoda: Trichostrongylidae), which is a fairly common parasite in antelope (Bothma, 1999). This parasite could have been transmitted from the livestock on the BVB Ranch at Selati through the livestock faeces. At Ndzalama there was a moderate infestation of *Cooperia hepatica* (more common) or *Paracooperioides peleae* (Nematoda: Trichostrongylidae). The liver samples from Mara showed little or no parasitic infestation. The presence of parasites could lead to a severe decrease in the growth of the animals as well as the reduced absorption of minerals and nutrients from the gut. The bankrupt worm *(Paracooperioides peleae)*, manifests itself in the small intestine of the animals, while the liver fluke (*Cooperia hepatica*) manifest themselves in the bile ducts of the liver, reducing the secretion of bile (Bothma, 1999).

## 4.3. Faecal analysis

Table 4.4 shows the descriptive analysis for the faecal samples taken. The Se concentration could not be determined due the presence of silica in the faeces.

**Table 4.4: Mean chemical analyses of faecal samples (± standard deviation) collected during the wet season at Mara, Ndzalama and Selati on a DM Basis**

| Area | No of Observations | Ash (%) | Crude protein (%) | P (%) | Ca (%) | Mg (%) | Cu (mg/kg) | Mn (mg/kg) | Zn (mg/kg) |
|---|---|---|---|---|---|---|---|---|---|
| Mara | 14 | 14.7 (±0.6) | 11.0 (±1.5) | 0.67 (±0.2) | 2.17 (±0.6) | 0.51(±0.1) | 28.4 (±3.1) | 235 (±40.5) | 57.9 (±11.2) |
| Ndzalama | 31 | 17.8 (±5.3) | 10.8 (±1.5) | 0.31 (±0.1) | 2.39 (±0.7) | 0.41 (±0.1) | 26.6 (±6.2) | 276 (±57) | 52.3 (±10.4) |
| Selati | 41 | 14.6 (±1.7) | 10.6(±1.4) | 0.53 (±0.1) | 2.55 (±0.8) | 0.37 (±0.1) | 28.4 (±2.6) | 200 (±64) | 59.4 (±12.5) |

1. no significant differences between the different areas ($p > 0.05$)

According to Wrench *et al.* (1997) faecal P and N can be used as indicators of the nutritive content of the veld. An accurate estimate of dietary P can be made from the faecal P using the following equation Wrench *et al.* (1997) :

$$Y = 0.33X + 0.37$$

Where Y is the estimate of the dietary P (g/Kg OM)

X is the faecal P value (g/kg)

In southern Africa where P deficiency is one of the most common causes of poor fertility (Wrench *et al.*, 1997), estimation of dietary P could be important to establish when P supplementation may be necessary. It has been reported that faecal P levels lower than 2 g P/kg Organic Matter (OM) indicates a deficiency in most species (Grant *et al.*, 1995). Using the above equation the P values of faeces from Mara, Selati and Ndzalama were 2.22, 1.39 and 2.12 g P/kg OM respectively. It can be concluded that Selati has a P deficiency based on the faecal results. Mara and Ndzalama showed adequate faecal concentrations, above 2 g P/kg OM.

The prediction of dietary N is slightly more complicated than that for P, as the availability of N is influenced by the presence of phenolic compounds. The following equation can be used to predict the dietary N concentration of the vegetation (Wrench *et al.*, 1997):

$$Y = 0.83(X) + 00.37$$

Where Y = the estimate of the dietary N (g N /kg OM)

X = the faecal N value (g/kg)

A faecal N concentration of less than 14 g N/kg OM would indicate a N deficiency in grazers. For browsers this in not as simple, since many factors may affect the prediction. The N concentrations for the impala collected at Mara, Ndzalama and Selati were 18.53, 18.19 and 17.97g N/kg OM respectively. These values indicate that there is sufficient protein in the diet of the impala at the different areas.

## 4.4 Genetic analysis

The blood samples that were taken for genetic analysis were of a poor quality and only a few of the samples were used. Although no conclusions can be made yet, the initial DNA analysis suggest very little genetic variation among the impala on all three farms. The idea would be to scan as many samples as possible with these polymorphic markers. This would allow one to determine the allelic diversity, which will indicate the genetic variation in the population.

Low diversity could be the result of inbreeding. Natural selection can favour certain genotypes.

## 4.5 Vegetation

### 4.5.1 Grazing

The grazing habits of the impala were studied at Mara, Ndzalama and Selati. Impala are browsers and grazers, the intensity of either dependent on the locality in which they occur. The portion of either is dependent on the abundance of either in the area.

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The three locations where the research was conducted showed different vegetation types. Ndzalama Game Reserve and Selati Game Reserve showed the typical mixed lowveld vegetation type (Low & Rebelo, 1998). The dominant grass species present were, *Themeda triandra*, guinea grass, bushveld signal grass and finger grass.

Botanical composition of the reserves is essential in determining the specific ecological status (pioneer vs. climax), grazing gradient (increasers vs. decreasers) and grazing value (production, quality and availability) for each reserve, in order to determine the specific grazing and browsing capacity. The ecological status is the classification of grasses and forbs into groups on the basis of their reaction to grazing. According to this criterion, all the grasses and forbs can be classified into one of the following groups (Van Oudtshoorn, 1992):

- Decreaser A species that dominated in good veld, but decreases when veld is mismanaged.
- Increaser I A species that dominated in poor veld and increases with understocking or selective grazing.
- Increaser IIa A species that increases with light overgrazing
- Increaser IIb A species that increases with moderate overgrazing
- Increaser IIc A species that increases with severe overgrazing.

*Themeda triandra* is classified in the Decreaser group. *Themeda triandra* has a high to very high grazing value and is classified as one of the best grazing grasses with a high palatability. It does, however, lose its nutritional value in winter.

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Bushveld Signal grass is classified as an Increaser IIc. It is a very palatable grass with high grazing value. It is preferred by white rhinoceros, hippopotami and impala.

Guinea grass is classified as a Decreaser. It is very palatable and valuable pasture grass preferred by most game species with a very high grazing value. The CP value for the mature growth phase is 5.4 %, the Ca concentration is 0.4 %, Mg concentration is 0.23 % and the P concentration is 0.19 % (NRC, 1981.)

Finger grass is classifies as a Decreaser. It is a highly digestible and palatable grass, which is well utilised by grazers, preferred by impala and roan *Hippotragus equinus*. The CP value for the mature growth phase is 8,5 %, the Ca concentration is 0.39 % and the P concentration is 0,23 % (Dugmore, 1995)

The vegetation at Mara Research Station and Messina Game Reserve was dominated by guinea grass, finger grass and common nine-awn grass.

Common nine-awn grass in classified as an Increaser IIc. It is a hardy species, able to withstand long droughts and heavy grazing. The grazing value can be described as variable but usually low.

There were no significant differences between the grazing in the Lowveld and that in the Limpopo Province. It is generally accepted that 8 % CP is necessary in vegetation for young growing livestock (Bothma, 1996) and only 5 % CP is required for African ungulates. The graze available on all the farms sampled showed sufficient CP.

Guinea grass had the highest concentration of CP with levels between 6.1 % at Mara and 7.1 % at Selati. Bushveld signal grass had concentrations between 6.4 % at Mara and 6.9 % at Ndzalama. Finger grass had the lowest concentration of 4.5 for Selati and 5.1 % for Ndzalama, yet these concentrations still meet the requirements for African ungulates.

The P concentration of the graze at Mara, Ndzalama and Selati was lower than the recommended concentration for livestock. The recommended concentration for livestock is 0.28 % (McDonald *et al.,* 1994). The average concentration measured for the graze at Mara, Ndzalama and Selati were 0.04%, 0.03% and 0.03% respectively. These values show a P deficiency in the graze available to the impala at all the farms, although only the impala sampled at Selati showed P deficiency in the faecal analysis. The rest of the minerals analysed were within the requirements for ruminants (McDonald *et al.,*1994), ash 10.5 %, Ca 0.48 %, Mg 0.02 %, Cu 7 mg/kg, Mn 16 mg/kg, Zn 5.0 mg/kg and Se 0.04 mg/kg. Table 4.5 represents the mineral, ash, NDF and ADF analyses for the grass samples taken in their mature stage of growth.

### 4.5.2 Browsing

Leaves from indigenous trees are an important source of nutrients for herbivores in southern Africa. Various samples were taken of trees and shrubs that were being utilised by the impala. On Ndzalama Game Reserve and Selati Game Reserve there was an abundance of mopane, red bush willow and knob thorn. The mean composition of browse in the impala diet is 54 % and 11 % of herbaceous plants (Bothma 1996). Game and cattle browse mopane.

**Table 4.5 Mean chemical analyses of grass species (± standard deviation) collected in mature growth stage at Mara, Ndzalama and Selati on a DM Basis**

| | | No of Observations | Ash (%) | Crude protein (%) | P (%) | Ca (%) | Cu (mg/kg) | Mn (mg/kg) | Zn (mg/kg) | Mg (%) | Se (mg/kg) | NDF (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *. Eriantha* | | | | | | | | | | | | |
| | Ndzalama | 8 | 8.9(±4.4) | 5.1(±1.1) | 0.07(±0.02) | 0.27(±0.03) | 11.7(±2.5) | 107(±30.7) | 23.9(±7.9) | 0.06(±0.02) | 0.09 (±0.03) | 64.7(±4.9) |
| | Selati | 4 | 8.6(±2.7) | 4.5(±0.7) | 0.08(±0.03) | 0.23(±0.14) | 11.5(±1.8) | 104(±35.1) | 35.9(±2.8) | 0.06(±0.02) | 0.10 (±0.05) | 65.4(±5.6) |
| *. Maximum* | | | | | | | | | | | | |
| | Mara | 5 | 9.6(±2.7) | 6.1(±1.4) | 0.14(±0.05) | 0.45(±0.23) | 11.6(±2.5) | 54.3(±13.5) | 42.6(±13.1) | 0.20(±0.05) | 0.46(±0.15) | 56.5(±9.1) |
| | Ndzalama | 8 | 10.3(±1.2) | 7.0(±1.4) | 0.12(±0.07) | 0.39(±0.10) | 12.5(±3.2) | 95.2(±14.8) | 59.2(±12.7) | 0.11(±0.07) | 0.35(±0.05) | 62.2(±9.3) |
| | Selati | 4 | 10.2(±1.4) | 7.1(±2.2) | 0.14(±0.05) | 0.34(±0.08) | 10.8(±1.7) | 67.8(±12.8) | 36.3(±9.5) | 0.14(±0.04) | 0.89(±0.07) | 62.6(±7.8) |
| *.Mosamb.* | | | | | | | | | | | | |
| | Mara | 5 | 9.4(±12.5) | 6.4(±1.1) | 0.11(±0.03) | 0.45(±0.15) | 12.6(±1.7) | 66.1(±15.1) | 43.3(±10.5) | 0.09(±0.02) | 0.10(±0.08) | 54.5(±2.5) |
| | Ndzalama | 8 | 10.5(±12.5) | 6.9(±1.6) | 0.11(±0.01) | 0.44(±0.15) | 13.6(±2.2) | 74.6(±12.5) | 44.3(±11.8) | 0.10(±0.02) | 0.29(±0.03) | 63.2(±3.8) |
| | Selati | 4 | 10.8(±12.5) | 6.6(±0.7) | 0.13(±0.01) | 0.46(±0.10) | 12.2(±0.4) | 86.4(±12.8) | 30.5(±9.5) | 0.13(±0.02) | 0.32(±0.02) | 61.4(±3.9) |

1. means within the same column with different superscripts (§‡) differ significantly (*P≤0.05*)

**Table 4.6: Mean chemical analyses of foliage samples (± standard deviation) collected in mature grwoth stage at Mara, Ndzalama and Selati on a DM Basis**

| | No of Observations | | Ash (%) | Crude protein (%) | P (%) | Ca (%) | Cu (mg/kg) | Mn (mg/kg) | Zn (mg/kg) | Mg % | Se (mg/kg) | NDF (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *C. Mopane* | | | | | | | | | | | | |
| | 8 | Ndzalama | 4.9(±0.5) | 11.2(±1.4) | 0.09(±0.01) | 0.11(±0.01) | 19.2(±2.5) | 56.8(±2.8) | 33.6(±1.9) | 0.11(±0.01) | 0.67(±0.08) | 43.1(±6.4) |
| | 4 | Selati | 4.6(±0.4) | 11.2(±0.9) | 0.11(±0.05) | 0.11(±0.02) | 18.2(±5.7) | 56.7(±3.3) | 24.2(±1.3) | 0.11(±0.02) | 0.82(±0.09) | 42.5(±5.7) |
| *C. Apiculatu* | | | | | | | | | | | | |
| | 4 | Mara | 6.1(±1.1) | 10.8(±1.1) | 0.09(±0.01) | 0.81(±0.3) | 12.6(±0.8) | 98.9‡ (±7.3) | 15.4(±3.4) | 0.18(±0.01) | 0.39(±0.02) | 36.4(±3.4) |
| | 8 | Ndzalama | 5.5(±1.1) | 10.3(±1.7) | 0.09(±0.01) | 1.20(±0.3) | 12.8(±1.9) | 142‡ ±12.5) | 19.8(±4.8) | 0.18(±0.05) | 0.38(±0.03) | 42.8(±5.8) |
| | 4 | Selati | 4.9(±0.9) | 10.0(±1.0) | 0.09(±0.02) | 0.80(±0.03) | 12.1(±1.1) | 121‡ (±8.4) | 10.6(±0.4) | 0.14(±0.03) | 0.33(±0.01) | 33.9(±2.8) |
| *A. Nigrecens* | | | | | | | | | | | | |
| | 5 | Mara | 7.8(±0.9) | 16.1(±1.2) | 0.12(±0.02) | 1.80(±0.04) | 5.7(±2.0) | 35.8(±7.1) | 51.8(±0.3) | 0.17(±0.02) | 0.66(±0.04) | 62.1(±3.8) |
| *D. Cinerea* | | | | | | | | | | | | |
| | 5 | Mara | 5.6(±1.4) | 10.3(±1.5) | 0.08(±0.01) | 1.50(±0.14) | 13.7(±1.9) | 35.3‡ (±2.1) | 17.2(±1.6) | 0.22(±0.1) | 0.45(±0.01) | 51.6(±2.2) |
| | 8 | Ndzalama | 6.9(±0.2) | 14.3(±1.2) | 0.08(±0.02) | 1.6(±0.2) | 18.9(±3.3) | 33.1‡ (±3.1) | 19.7(±1.1) | 0.18(±0.02) | 0.64(±0.10) | 56.7(±1.4) |
| | 4 | Selati | 6.0(±0.6) | 13.4(±0.7) | 0.08(±0.04) | 1.4(±0.2) | 14.6(±0.2) | 36.3‡ (±1.8) | 13.9(±1.3) | 0.15(±0.01) | 0.45(±0.02) | 54.4(±2.8) |

1. means within the same column with different superscripts (§‡) differ significantly ($P \leq 0.05$)

The leaves of the red bush willow are browsed by game and the fallen ones by cattle (Van Wyk, 1997). Knob thorn is browsed by stock and game, especially giraffe and elephant.

At Mara Research Station and Messina Game Reserve the browse is predominantly silver cluser leaf, wild raisin bush and umbrella thorn. The leaves and pods of the umbrella thorn that are browsed by stock and game are very nutritious.

A multivariate analysis of the minerals in the vegetation, showed no significant difference between the trees in the Lowveld and those in Limpopo. Table 4.6 represents the mineral analysis for the trees species sampled at the different farms. The CP concentration of the foliage was within the requirements for livestock (Bothma, 1996). The knob thorn at Mara had the highest CP concentration, 16.1 %. Mopane had CP concentrations of 11.2 % for Ndzalama and Selati, red bush willow had CP concentration of 10.8 %, 10.3% and 10.0 % for Mara, Ndzalama and Selati and sickle bush had CP concentrations of 5.6 %, 6.9 % and 6.0 % for Mara, Selati and Ndzalama, all of which are adequate for African ungulates. The concentrations of the macronutrients for the foliage were similar to those for the foliage collected by Lukhele & Van Ryssen, (2000), which were considered to be within the requirements for livestock. The P concentration was lower than the required concentration needed for livestock, 0.28 %. The P concentration varied between 0.01 % and 0.04 % for the browse collected at the different farms. Lukhele & Van Ryssen (2001) noted that the P concentrations were 0.1 % in the browse sampled.

The Ca:P ratio was within the 2:1 ratio which is acceptable for ruminants (McDonald *et al,* 1994). However the ratio obtained by Lukhele & Van Ryssen, (2000) was very wide, namely a ratio of between 7:1 to 12:1. The high concentrations of Ca can suppress the availability of the P in the browse. There were significant differences between the Mn concentration of mopane, 98.9 mg/kg, 142 mg/kg, 121 mg/kg and sickle bush, 35.3 mg/kg, 33.1 mg/kg and 36.3 mg/kg. However, this did not lead to any deficiencies in the impala, as the liver samples taken showed no deficiencies for either of the areas.

## 4.6. Soil

Soil and the parent rock from which it was formed have a major influence on veld management. Soil affects the supply of water and nutrients to the plant. Different soil types and depths determine the production and palatability of vegetation in the long term. The deeper the soil the greater the production of plant material per unit area. Other important physical characteristics include colour (determined from the different forms of iron present), texture, and structure which affect the nutrient cycle through the soils.

### 4.6.1 Selati Game Reserve

On the hill tops on Willie, Farrel, Danie and Arundel (Appendix 3) show land types with exposed rock covering 60 – 80 % of the area. A sample taken from Josephine indicates land with high base status, dark coloured red soils usually clayey. From the sample taken from Koedoesrand, this also represents Lekkersmaak, BVB Ranch, Arundel, Hoed, Huja and Thankerton, shows pedologically young landscapes. Lime is rare or absent in the upland soils but widespread in the bottomland soils. These soil forms are present :-

- Glenrosa This soil is normally a shallow soil and stores nutrients and water.
- It is however prone to drought and erosion. This form has a low organic matter compound.
- Mispah This soil form encompasses hard rock, with little or no organic matter present.
- Clovelly normally found on well drained kopjies

### 4.6.2 Ndzalama Game reserve

The geology found on this reserve is similar to that found on Selati Game Reserve. The soils included Mispah, Glenrosa and Clovelly.

The soils showed a significant difference in the P levels. The Limpopo Province generally has a P shortage (Wrench *et al.,* 1997), Ndzalama showed a P concentration in soil of 2.6 mg/kg while Selati and Mara had P concentrations of 13.9 mg/kg and 32.5 mg/kg.

The lower concentration of P at Ndzalama could be as a result of the topography in the area.

# CHAPTER 4

### 4.6.3 Mara Research Station

Various samples were taken on the farm. A geology report showed the following soil types present on the farm. In areas 1,2,3 and four (Appendix 4) the Hutton form was noted.

This form is ideal for agricultural purposes, yet has a high degree of weathering, where the parent material is dolerite or basalt.

The soil can become water logged, which often leads to a decrease in leaching. Samples 5, 6, 7, on the eastern side of the farm have the Glenrosa form present. The soils found on the western side of the farm, sample 9, were of the Mispah form. The clay content varies from 12 – 25 % between the different forms.

Generally it can be seen that the soils have good properties with the ability to store nutrients and water for the plants. The only form which is of little use for the plants as a nutrient source is the Mispah form which encompasses mainly hard rock and little or no organic matter. Table 4.7 shows the mineral analysis of the soil samples taken on the different farms.

From the statistical analysis of the data, no evidence was found to show a significant difference between the soil samples taken from the various farms.

**Table 4.7 : Mean chemical analyses of soil samples (± standard deviation) collected at Mara, Ndzalama and Selati on a DM Basis**

| Area | No of Observations | | pH | Phosphorus mg/kg | Calcium mg/kg | Potassium mg/kg | Magnesium mg/kg | Sodium mg/kg |
|---|---|---|---|---|---|---|---|---|
| Mara | | | | | | | | |
| | 2 | Hutton | 6.9(±0.5) | 49(±12.1) | 848(±253) | 231(±64) | 328(±120) | 7.0(±4.4) |
| | 3 | Glenrosa | 6.5(±0.4) | 11.2(±2.5) | 751(±237) | 285(±55) | 256(±88) | 7.0(±4.2) |
| Ndzalama | | | | | | | | |
| | 7 | Glenrosa | 6.1(±0.1) | 2.6(±1.6) | 440(±135) | 130(±46) | 142(±31) | 4.4(±1.2) |
| Selati | | | | | | | | |
| | 4 | Glenrosa | 6.5(±0.5) | 13(±2.1) | 824(±325) | 543(±160) | 316(±54) | 2.5(±0.8) |

1. no significant differences between the different areas ($p > 0.05$)

The pH, however, did vary. Mara had a higher pH than the other farms. On the sourveld, where there is an increase in the rainfall the pH tends to decrease as a result of leaching of minerals (Bonsma, 1980). The solubility of P and Ca increases with the high rainfall leading to loss of these minerals due to leaching. On the sweetveld where the rainfall is generally lower the pH is higher, with less leaching of minerals from the soil. Results showed a higher P level in the samples collected at Mara.

Where granite is present as the parent material there is a tendency for an increase in potassium (K) levels and a decrease in the values of Ca and Mg (Bothma, 1996).

## 4.7 Water analysis

Water chemistry serves as a good indication of the regional geochemistry (Casey *et al.*, 1998). Water quality can impact on, via palatability, the presence of animals, absence and movement in and around the watering points.

Results obtained from a colleague in the department, Dr Meyer (1999) indicated that many water quality constituents (WQC's) are present in potentially hazardous levels. Many of the constituents involved have significant adverse single-dose effects and therefore may present a health hazard, even to game that would normally have a beneficial effect by the dilution. The greatest hazard is presented by the constituents mercury (Hg), selenium and arsenic (As). These concentrations are noted in many of the boreholes at Lillie, Transport, Willie and Koedoesrand (Appendix 3).

High nitrate ($NO_3$) concentrations were recorded at Lekkersmaak and Ermelo Ranch, which was attributed to the poor water provision design, leading to faecal contamination of the water supply.

Further samples indicate the adverse effect of a watering point not being utilised by game for long periods. This is due to evaporative losses and pollution by avian faecal matter and dust.

Samples at Lillie indicated a relationship between pH and Total Dissolved Solutes (TDS). The lower TDS value leads to a higher pH, which leads to an increased palatability for many game species, resulting in higher ingestion at a single watering point.

The adverse effects that may occur are difficult to predict (Casey *et al.*, 1998) due to the occurrence of so many potentially hazardous constituents (PHC). PHC's indicate the WQC in question is likely to result in adverse effects. Although the Se concentration in the water was present as a potentially hazardous constituent, there is still a deficiency of Se in the area, as seen with the liver Se concentration. This Se deficiency may be present due to the As-Se interaction in the water, thus rendering the Se unavailable for the animal.

# CHAPTER 5

# CONCLUSIONS

African savannas are dynamic and food resources change continuously due to changes in the environment. The impala is one of the single most important species available for game farming in the Lowveld (Fairall, 1982), and therefore the environmental parameters in which the impala occur need to be quantified in order to manage an ecological balance.

A number of important parameters that could affect the size and growth of the animals were studied in this project. All linear measurements were taken from impala sampled at each of the farms. These measurements showed no significant differences between the areas, which is an indication that there are no genetic differences between the populations on the three game farms sampled. According to Skinner (1990) the measurements are average compared to other impala sampled. Initial genetic analyses also suggests that genetic variation among impala is small.

The live mass of the impala differed significantly p=0.03 indicating a nutritional deficiency at Selati. The vegetation however only differed significantly in relation the P concentrations (Lukhele & Van Ryssen, 2000), but the CP concentrations were sufficient to sustain the growth of impala. Liver samples taken from Selati showed a severe infestation with Bankrupt worm, which may impair the growth of the animals. This internal parasite manifests itself in the intestine and the liver of the impala, rendering available nutrients unavailable

This would decrease the live mass of the impala. The quality of the grazing at Mara may be of a better quality due to the fact that the grazing is sweetveld. The grazing quality and the severe infestation of internal parasites may be the vectors resulting in a deficiency in the nutritional status of the animals at Selati.

The low P concentrations may affect the growth of the impala. The concentrations in the browse sampled in the Northern Province were below the accepted level of 0.1 %. In certain browse the ratio exceeds the highest acceptable ratio of 7:1, with *Combretum molle* showing a ratio of 12:1. The provision of phosphates in the form of a wildlife lick, would provide P to the impala and possibly alleviate the P deficiency

In order to alleviate the severe infestation of bankrupt worm, one would have to remove the livestock interaction at BVB Ranch on the Selati Game Reserve, as this is the method of transfer between the livestock and the impala.

## REFERENCES

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**AOAC. 1984.** *Official methods of analysis.* 14th Ed. Association of Official Analytical Chemists. Arlington, Virginia, USA.

**BERRY, H.H. and LOUW, G.N. 1982.** Seasonal nutritive status of wildebeest in the Etosha National Park. *Madoqua* 13, 127 - 139

**BERRY, H.H. and LOUW, G.N. 1982.** Nutritional balance between grassland productivity and large herbivore demand in the Etosha National Park. *Madoqua* 13, 141 – 150.

**BONSMA, J. 1980.** *Animal trends and a Global Approach.* Tafelberg.

**BOTHMA, J, DU P. 1989.** *Game ranch management.* Pretoria, Van Schaik.

**BOYAZOUGLA, P.A. 1976.** A review of mineral imbalances of grazing animals in southern Africa. *Journal S.Afr. Vet. Ass.* 47 : 129-132.

**CASEY, N.H., MEYER, J.A. and COETZEE, 1998.** An investigation into the quality of water for livestock production with emphasis on Subterranean water and the development of a water quality guideline Index system, *WRC Report No K5/644/2/98,* Water Research commission, Pretoria, South Africa

**DUGMORE. T. J. (Ed). 1995.** *Dairying in Kwa-Zulu Natal.* Kwa-Zulu Natal Department of Agriculture.

**DUNHAM, K. M. 1982.** The foraging behaviour of the impala *Aepyceros melampus.* *S. Afr. J. Res.* 12:36 – 40.

**FAIRALL, N. 1983.** Production parameters of the impala, *Aepyceros melampus.* *S. Afr. J. Anim. Sci.* 13, 176 – 179.

## REFERENCES

**FAIRALL, N. and KLEIN, D. R. 1984.** Protein intake and water turnover: A comparison of two equivalently sized African antelope the blesbok *Damaliscus dorcas* and impala *Aepyceros melampus. Can. J. Anim. Sci.* 64 (Suppl.): 212 - 213

**GOERING, H.K. and VAN SOEST, P.J. 1970.** Forage Fibre Analyses (Apparatus, reagents, procedures and some applications). Agricutural Handbook No 379. A.R.S., U.S. Dept of Agric.

**GRANT, C. C., MEISSNER, H. H. and SCHULTHEISS, W. A. 1995.** The nutritive value of veld as indicated by faecal phosphorus and nitrogen and its relation to the condition and movement of prominent ruminants during the 1992 – 1993 drought in the Kruger National Park. *Koedoe* 38, 17 – 31.

**GROBLER, D.G. 1996**. An investigation of copper poisoning in ungulates in the Kruger National Park. MSc, University of Pretoria.

**GROBLER, D.G. and SWAN, G.E. 1999**. Copper poisoning in the Kruger National Park: Field investigation in wild ruminants. *Onderstepoort J. Vet Res.*, 66.

**GUMMOW, B,. BOTHA, C.J., BASSON, A.T., and BASTIANELLO, S.S., 1991.** Copper toxicity in ruminants: air pollution as a possible cause. *Ondestepoort J. Vet. Res.* 58:38-39

**KLEIN, D.R. and FAIRALL, N. 1984.** Comparative thermoregulatory behaviour of Impala *Aepyceros melampus* and blesbok *Damaliscus dorcas. Can. J. Anim. Sci.* 64 (Suppl.): 210 – 211

**LOW, A.B. and REBELO, A.G. 1998.** *Vegetation of South Africa, Lesotho and Swaziland.* Dept of Environmental Affairs and Tourism. Pretoria.

## REFERENCES


**LUKHELE, M.S. and VAN RYSSEN, J.B.J. 2000.** The Chemical composition of leaves from indigenous fodder trees in South Africa. *S. Afr. J. Anim. Sci.* 30 (Supplement 1).

**MAREE, C. and CASEY, N.H. 1993.** *Livestock Production Systems. Principles and Practice.* Agri-Development Foundation. Pretoria

**McDONALD, P., EDWARDS, R.A. and GREENHALGH, J.F.D. 1994.** *Animal Nutirition. 4th Edition.* Longman Scientific and Technical. United Kingdom.

**NATIONAL RESEARCH COUNCIL, 1981.** *Nutrient requirements of goats.* National Academy Press, Washington, D.C.

**PIETERSEN, L. M. and MEISSNER, H.H. 1993.** Food selection and intake by male impalas in the Timbavati area. *S. Afr. J. Res.* 23, 6 – 11.

**ROBERTSON, J.B. and VAN SOEST, P.J., 1981.** The analysis of Dietary Fibre in food. W.P.T. James and O. Theander (Editors). Dekker, New York

**S.A.S. 1985.** *S.A.S. Users guide.* S.A.S. Institute Inc. Raleigh, N. Carolina.

**SKINNER, J. D., MONRO, R. H. and ZIMMERMAN, I. 1984.** Comparative food intake and growth of cattle and impala on mixed tree savanna. *S. Afr. J. Res.* 14, 1-7.

**SKINNER, J.D. and SMITHERS, R.H.N. 1990.** *The mammals of the Southern African sub region.* University of Pretoria.

**VAN OUDTSHOORN, F.P. 1992.** *Grasses of South Africa.* Briza Publications Cc, Pretoria.

**VAN RYSSEN, J.B.J. 2001.** Geographical distribution of the selenium status of herbivores in South Africa. *S. Afr. J. Anim. Sci.* 31, 1-8.

## REFERENCES

**VAN WYK, B. and VAN WYK, P. 1997.** *Field guide to trees of Southern Africa.* Struik Publishers. Cape Town

**WEBB, E.C., VAN RYSSEN, J.B.J., ERASMUS, M.E.A. and McCRINDLE, C.M.E. 2001.** Copper, manganese, cobalt and selenium concentrations in liver samples from African buffalo (*Syncerus caffer)* in the Kruger National Park. *J. Environ Monit., 2001, 3, 583-585.*

**WRENCH, J., MEISSNER, H. H., GRANT, C.C. and CASEY, N. H. 1996.** Environmental factors that affect the concentration of P and N in faecal samples Collected for the determination of nutritional status. *Koedoe* 39, 1-5.

**WRENCH, J.M., MEISSNER, H.H. and GRANT, C.C. 1997.** Assessing diet quality of African ungulates from faecal analyses: the effect of forage quality, intake and herbivore species. *Koedoe* 40, 125-135.

# APPENDICES

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## Appendix 1

### The Impala *Aepyceros melampus* (Lichtenstein, 1812)

The impala belongs to the Genus *Aepyceros,* and was originally described from a specimen from "southern Bechuanaland" which is the former British Bechuanaland and what is today part of the northern Cape Province. The name was most probably from the Tswana name "Phala", although it has been claimed to be derived from the Zulu name for the species. Ansell (1972; in Skinner & Smithers 1990) listed six sub species for the impala from the continent, only two of which occur in the southern African subregion: the impala *Aepyceros melampus melampus* (Lichtenstein, 1812), which has an eastern distribution and the isolated population of the black-faced impala *Aepyceros melampus petersi* (Bocage, 1879), which is found in northern Namibia and South Western Angola.

### Description

Impala are one of the most graceful and beautiful of the antelopes with their shiny reddish coats and long slender legs. The adult males of the *A. melampus* stand approximately 0.9 m at the shoulder and have a mean mass of about 50 kg; the females are slightly smaller, with a mean mass of about 40 kg.

The upper parts of the body are rich reddish brown. The flanks, from behind the shoulders are a pale fawn. The underpants such as the belly and throat are pure white. They have white patches above the eyes, which run down the face in narrow white bands in front of the eyes. They have a dark brown nearly black patch on top of the forehead. The insides of the ears are white and they have contrasting black tips. Impala have black patches above the ankle joint these are oval in shape. The upper parts of the limbs are pale fawn like the flanks. There is a distinct black band on either side of the base of the tail. These bands are wider at the top than at the bottom and extend to the back of the thighs. The tail is white on the underside with a black band running over the top (Skinner & Smithers 1990).

Only male's carry the lyrate horns, which swing back from their heads, then bow outwards, then inwards and slightly forward to their sharp inwardly directed points. They are strongly ridged for about two thirds of their length, but smooth towards the points.

**Distribution**

Impala are widely distributed in the eastern woodland parts of Africa, from Northern Kenya south to northern Natal, extending westwards in more southerly parts of their range to the extreme southern parts of Angola. In the Subregion they have been introduced widely, and reintroduced to privately owned lands and game reserves in Zimbabwe, Northern Province, Mpumalanga and Natal where they are now distributed widely throughout.

## APPENDICES

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**Habitat**

The impala are associated with woodland, preferring semi open areas. In the Northern Province they are associated with mopane and *Acacia,* but are also associated with other veld types such as *Combretum* and *Terminalia*. Generally the impala avoid open Grasslands. However, they do occur on an ecotone which is a combination of woodland and open grassland. Cover and availability of surface water are essential habitat requirements.

**Habits**

Impala are gregarious animals, occurring in small herds of six to 15 or 20 in the dry season and they will congregate to herds of up to 50 to 100 animals in the wet and early dry season. Herds can be divided into three social organisations: bachelor herd, breeding herd and nursery herd.

***Breeding herds***

Breeding herds consist of adult females and juvenile females, juvenile males and at times, other than during the rut, include a number of adult males. Breeding herds are cohesive and stay together most of the time, though there are instances of females switching herds. The juvenile females will stay with the herd after they have reached adulthood. The dominant male, however, evicts juvenile males, from the herd when they reach sexual maturity at the age of 13 months.

## APPENDICES

### *Bachelor herds*

Bachelor herds consist of adult males and juvenile males, the adults being potential territorial males. The bachelor herds tend to occupy areas away from those of the breeding herds, where they are less subject to disturbance. This is most apparent during the rut when members of the herd are subject to aggression from the territorial males. They are less organized than the breeding herds and adults leave them during the rut to establish their territories, returning to the herd when the rut is over. Just prior to the rut adult members destined to become territorial become aggressive, and this leads to spacing within the herd, and therefore a loss of structure.

From January onwards, members of the bachelor herd become increasingly restless, alert and aggressive towards the other males. Adult males eventually break away from the bachelor herds and establish territories for themselves, which vary in size from 50 – 80 km$^2$. These territories are established by males between the ages of 4.5 and 8,5 years only during the rut and are relinquished thereafter.

### *Nursery herds*

These herds are temporary and only consist of juveniles of both sexes, members of these herds will return to the breeding herds after a short period of time.

Impala are diurnal, with some nocturnal activity. They stand or lie down to rest during the hotter hours of the day. When active they keep moving with tails wagging, ears twitching and feet stamping.

## APPENDICES

**Reproduction**

Impala are short-day breeders, with a restricted mating season in autumn. Though many researchers have found different breeding peaks, they all coincide with a peak of births at the beginning of the wet season. Males reach sexual maturity at the age of 13 months. Rams are able to mate with females in their second year of life but can only breed when they are three to four years old, due to the fact that they are physiologically unprepared for assuming territories. The male sexual cycle peaks in autumn and reaches a low point in the spring. This parallels a decline in body condition, fat reserves of male impala declining rapidly during the rut. Fat reserves of the female declines to a minimum in January when milk production is at its maximum.

The breeding herds are mobile and move through several male territories. Males will herd females from the herd and will determine oestrus by genital smelling and licking. The females will be courted and copulation will follow if the female is receptive.

The male will then mount the female repeatedly in brief contacts of up to ten seconds and after successful copulation the male usually snorts and roars.

The females conceive at just over the age of two years for the first time. The gestation period is approximately 197 days. The females break away from the herds to give birth in isolation, parturition taking place in thick underbush. The young are hidden for a period of a day or two. The young are seldom in close association with their mothers, except when suckling (Skinner & Smithers 1990).

## APPENDICES

Predation by spotted hyenas and other large predators including cheetahs is high during the early stages of their life, when jackals and pythons also take their toll.

**Diet**

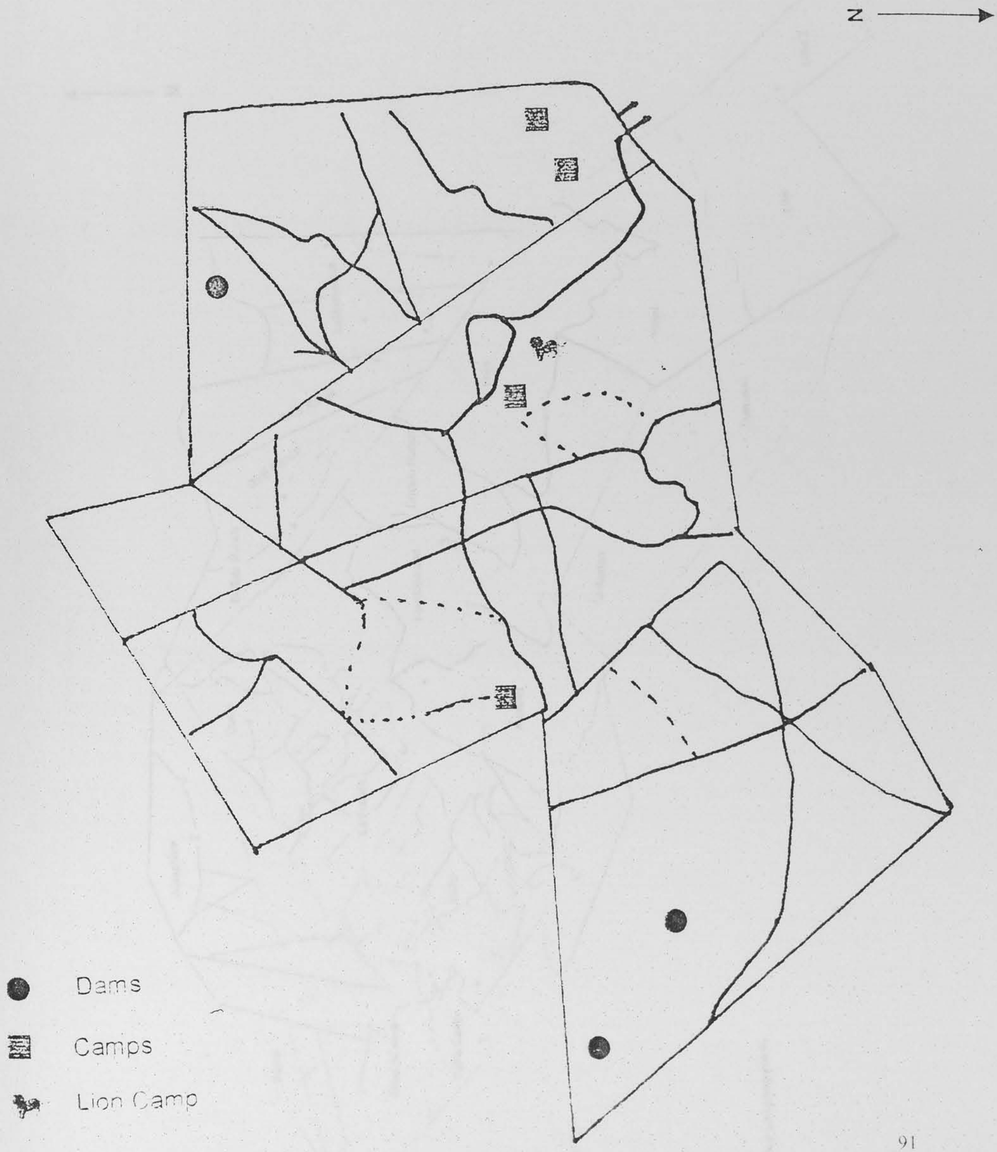
Impala are browsers and grazers (intermediate mixed feeders), the intensity of either depending on the locality in which they occur. The proportion of grass in the diet is reflected by the availability of abundant green grass in the area. The intake of grass can reach a proportion of 75 % of the diet, but can also be as low as 9 % during the dry season. Some grass species occur regularly in the diet of the impala, Finger grass, *Themeda triandra, Cynodon dactylon,* Guinea grass and many more.

The browse consists of the leaves and fine twigs of shrubs and trees, either eaten while green or picked up dry from the ground. A wide range of browse plants is eaten. The impala are partial to wild fruits. The *Acacia* is common in most areas where the impala are found and the fine leaves and twigs are common in their diet. Other common species include: *Combretum* spp, *Grewia* spp, *Dichrostachys* spp, *Terminalia* spp, mopane.

Impala are dependent on availability of drinking water and remain within eight kilometres of it. Under certain circumstances they can obtain their moisture requirements from succulent foods.

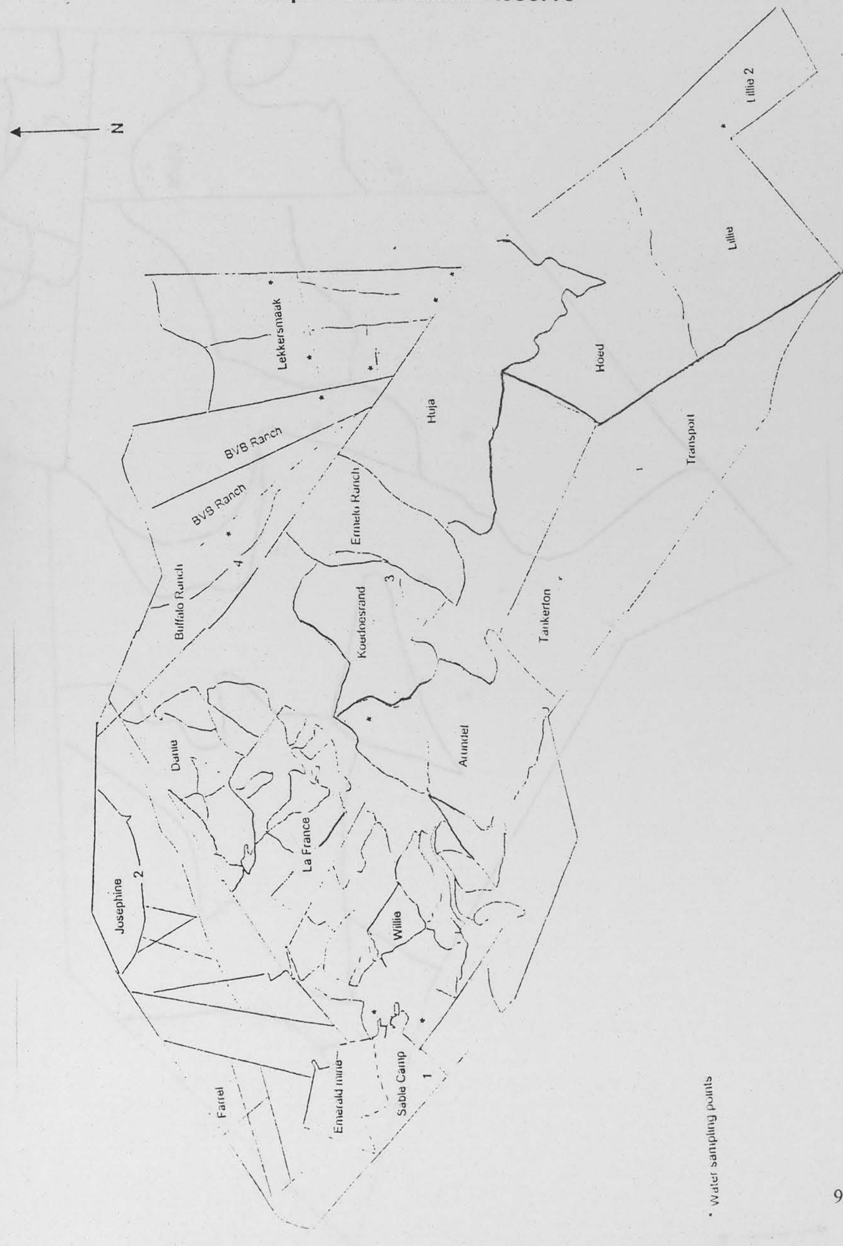
# Appendix 2

## Map of Ndzalama Game Reserve



## Appendix 3

### Map of Selati Game Reserve



## Appendix 4

### Map of Mara Research Station