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*≤*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)

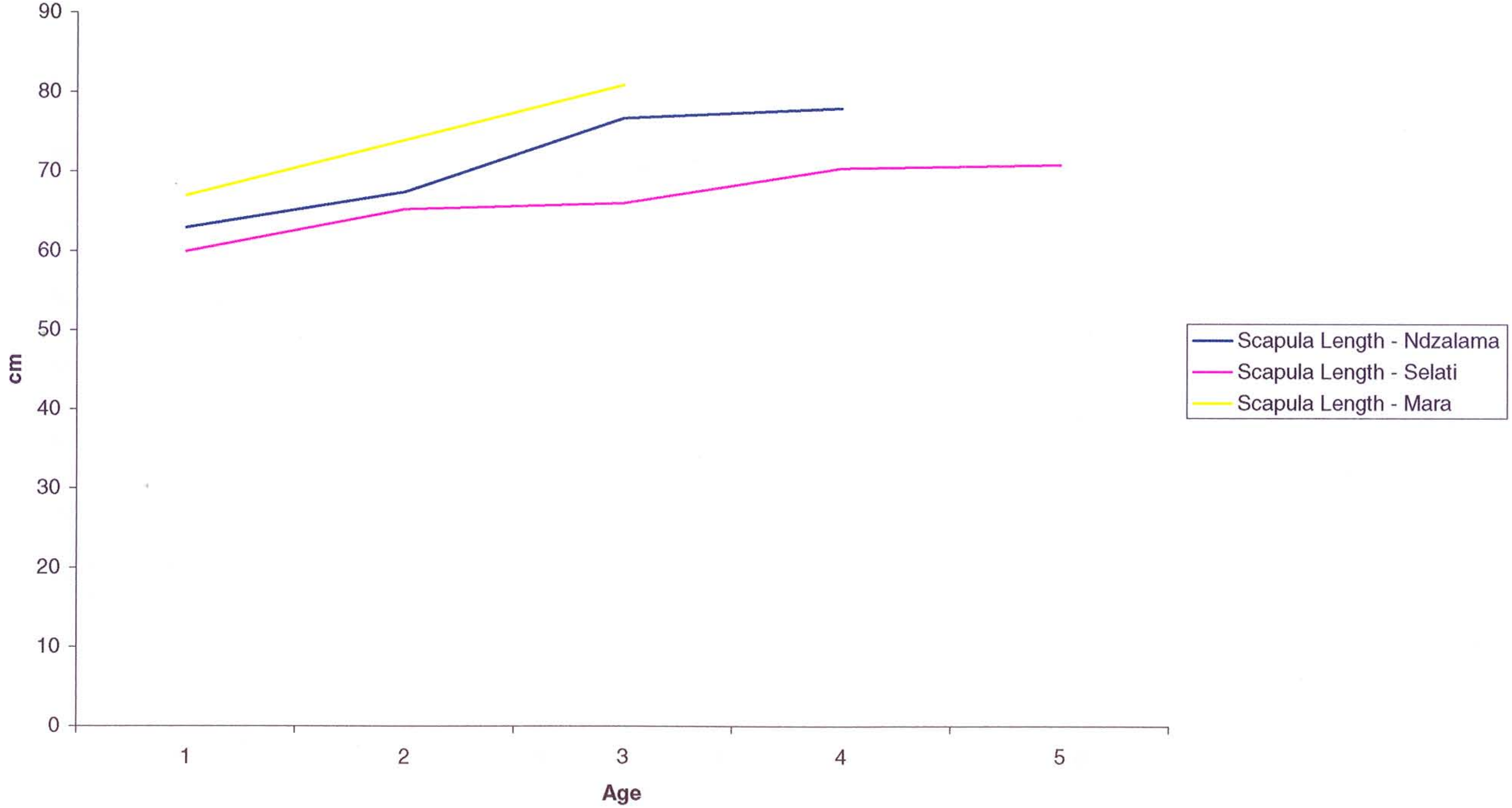


Figure 3.16: Linear measurements for male impala sampled at Mara, Selati and Ndzalama (n=76)

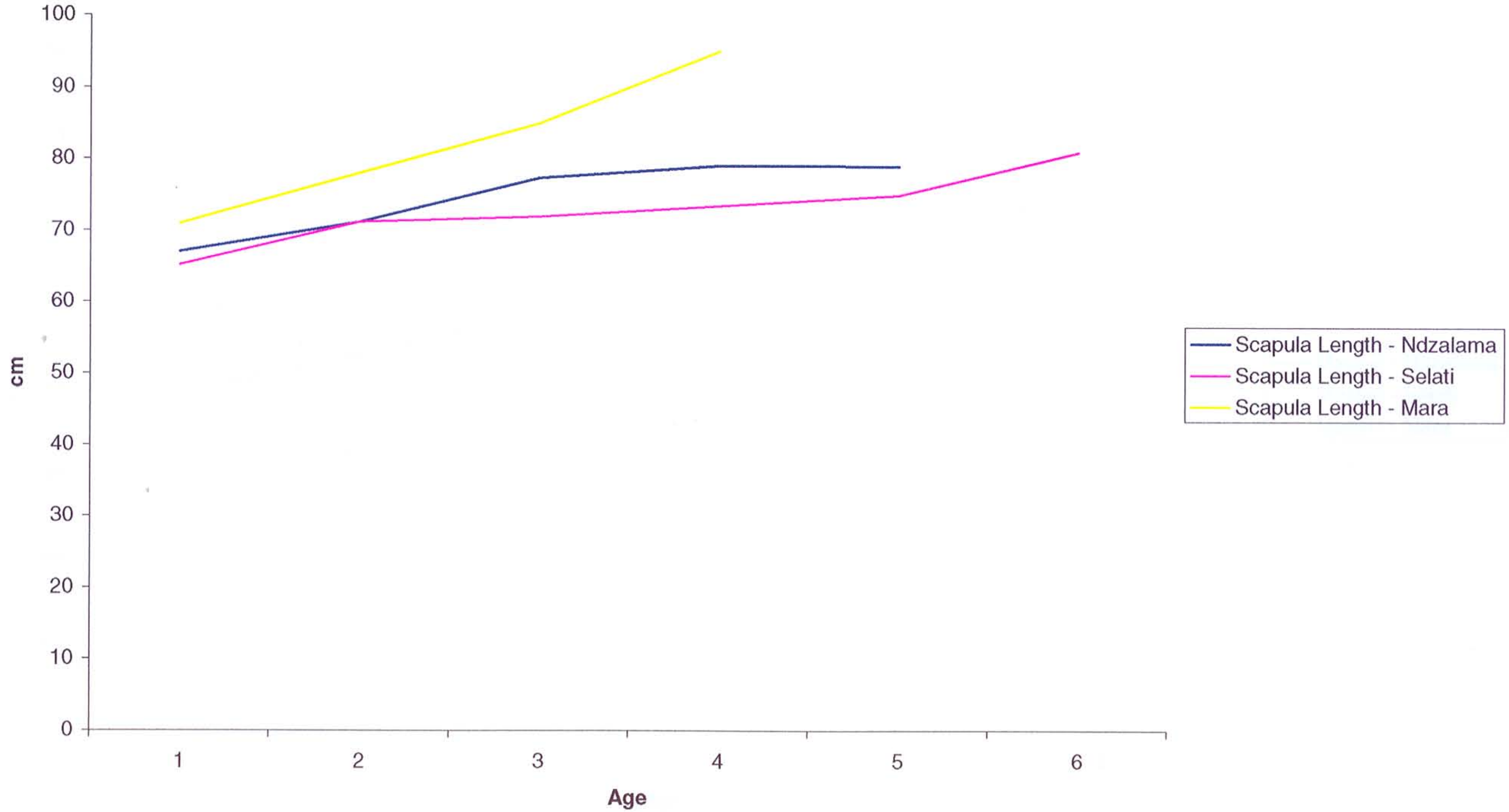


Figure 3.17: Mass (including intestines) for female impala sampled at Mara, Selati and Ndzalama(n=38)

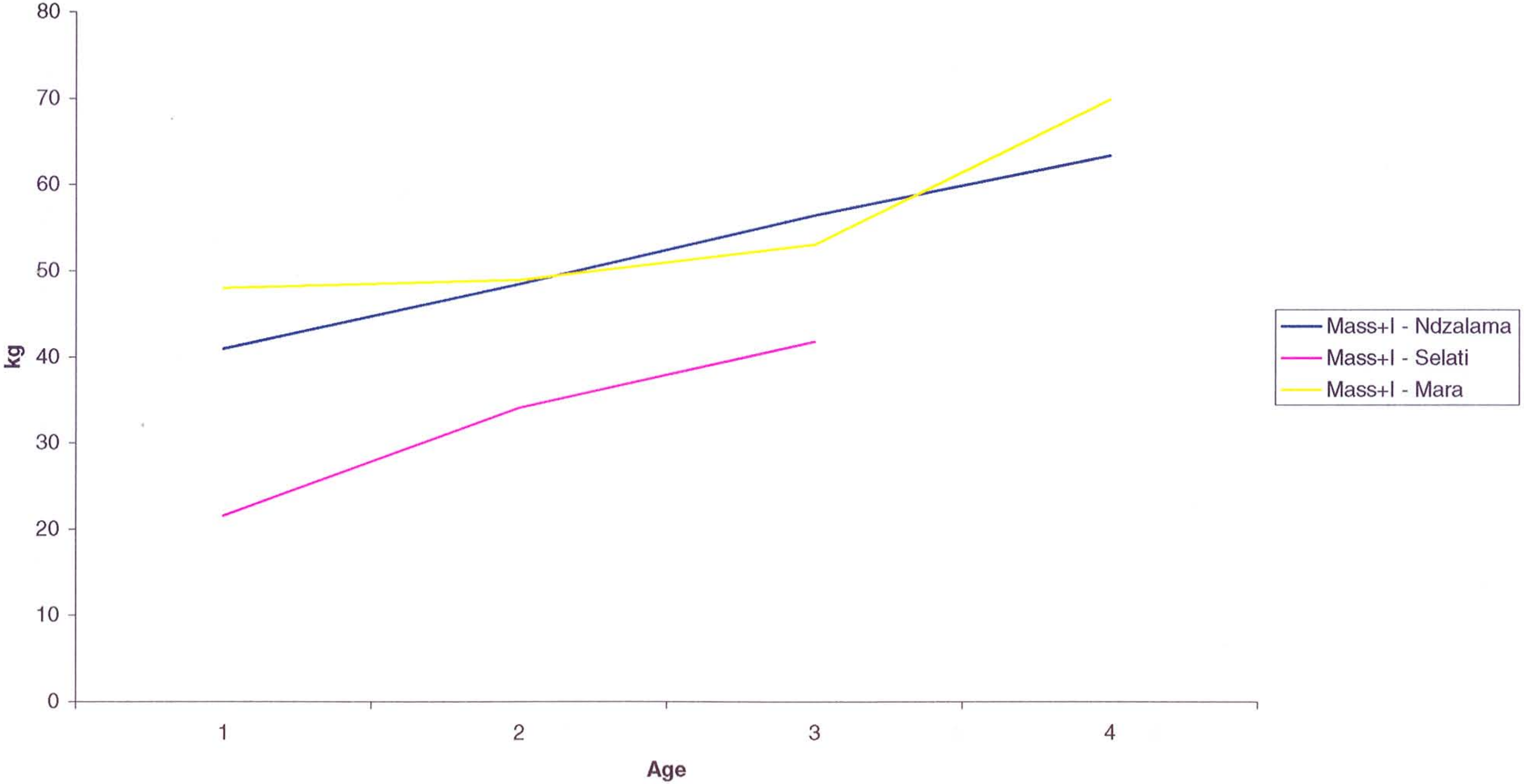
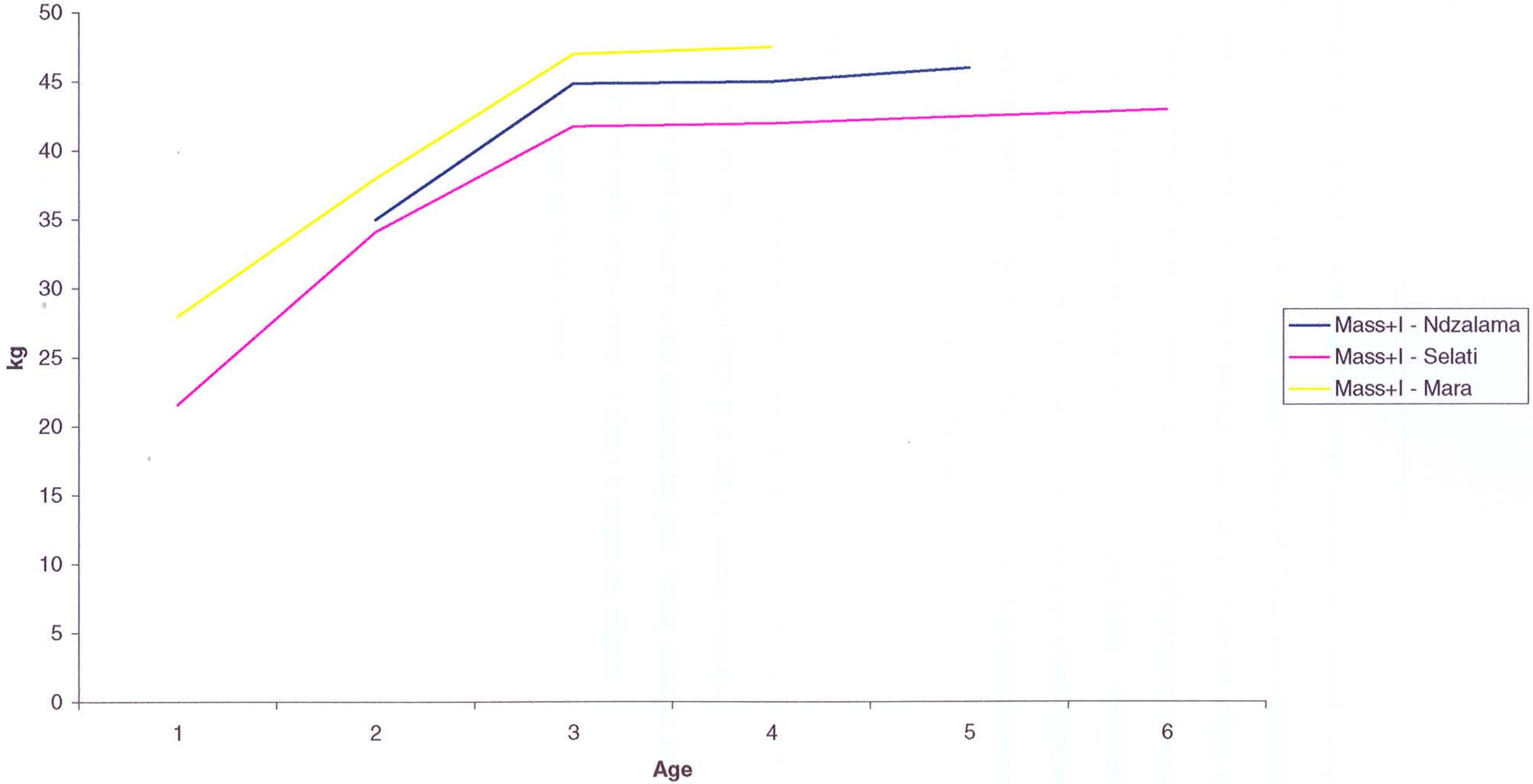


Figure 3.18: Mass (including intestines) for male impala sampled at Mara, Selat and Ndzalama (n=76)



CHAPTER 4

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≤0.05*)

CHAPTER 4

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.

CHAPTER 4

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 ($p > 0.05$)

CHAPTER 4

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.

CHAPTER 4

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.

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.

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.