Ranching with sable antelope (*Hippotragus niger niger*) in South Africa

by

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Declaration

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Abstract

This research focuses on aspects not currently known but essential to ranch with sable antelope (*Hippotragus niger niger*) successfully. This includes determining the metabolizable energy requirements, horn growth traits and how supplemental nutrition affects reproduction and horn growth on sable antelope ranched in South Africa.

An investigation into the methodologies presently employed determining carrying capacity of wildlife species illustrates that the large animal unit, grazing unit, and browsing unit methods only use metabolic weight as a factor to determine the energy requirements of game where the large stock unit method uses both metabolic weight and the energy requirements of the animal at a specific well defined physiological production state. The metabolizable energy requirement per day was regressed with weight (kg) using a log-log transformation of the herbivore species to model the suitability of the large animal unit method for defining/determining the metabolizable energy requirements of game. The resulting equations were used to model and compare the calculated metabolizable energy and large stock unit values to the published metabolizable energy and large stock unit values. The physiological production states analysed included calf/lamb, young dry cow/ewe, mature dry cow/ewe, young cow/ewe with calf/lamb, mature cow/ewe with calf/lamb, young bull/ram, and mature bull/ram. Six out of the seven categories have values higher than 0.75 with R^2 values of >0.99, the exception being calf/lamb data with the value of 0.742 with a R^2 = 0.97. These results indicate that metabolic weight is neither conceptually correct nor sufficiently accurate to calculate metabolizable energy requirements for game, confirming the acceptance of the alternative hypothesis. Therefore, the large animal unit (metabolic weight method) cannot replace the large stock unit (metabolizable energy method). The derived log-log transformation equation provides a more accurate method for determining the metabolizable energy requirements and dry matter intake values for sable antelope and other game species.

A study into horn growth characteristics (traits), horn length, basal circumference, and the number of horn rings of sable antelope in South Africa was conducted to investigate the environmental effects of sex, calving year and season on horn development for animals up to 50 months of age. Horn growth characteristics/traits within the age categories of 0-15 months, 15.1-36 months, 36.1-50 months were analysed. It was determined that the growth rate in cm per day of horn length between male and female sable antelope differed significantly (P < 0.05) for all age categories: male (0,089 ± 0.002cm; p-value = <0.0001) and female (0,068 ± 0.004cm; p-value = <0.0001) for 0-15 months, male (0.079 ± 0.002cm; p-value = <0.0001) and female (0.042± 0.001cm; p-value = <0.0001) for 15.1-36 months, male (0.044± 0.003cm; p-value = <0.0001) and female (0.015± 0.003cm; p-value = <0.0001) for 36.1-50 months respectively. When considering base circumference between male and female sable antelope, a significant difference

($P < 0.05$) in the age category 0-15 months was observed, where the base circumference growth rate for males was 0.026 cm and females 0.014 cm respectively. The number of horn rings did not differ. Horn length and base circumference results over the whole period, regardless of other environmental effects, illustrate a rapid initial growth for male and female animals. However, horn length and base circumference on males grew faster, while in the female animals, it slowed noticeably once they reached sexual maturity. Supplemental feeding regimes introduced on most farms in 2013 positively affected horn growth traits, resulting in longer horns at maturity.

When considering the results, if the metabolizable energy requirements for animals at different states is known, it is possible to estimate the carrying capacity and stocking rates of game reserves and ranches more accurately. Furthermore, knowing the metabolizable energy requirements of the species at different physiological states supplies animal nutritionists with the necessary information to improve supplemental and complete feeds. When considering horn growth, the data clearly shows that horn length increased year after year in both male and female sable antelope, and this was due to ranchers selecting better animals and supplying these animals with a more balanced diet.

Opsomming

Hierdie navorsing fokus op aspekte wat tans nie bekend is nie, maar noodsaaklik is om met swartwitpense (*Hippotragus niger niger*) suksesvol te kan boer. Dit sluit die bepaling van metaboliseerbare energievereistes, horinggroei-eienskappe en op welke mate aanvullende voeding reproduksie en horinggroei van swartwitpense in Suid-Afrika beïnvloed in.

'n Ondersoek na die metodologieë wat tans gebruik word om die drakrag van wildspesies te bepaal, het aangedui dat grootdier-eenheid-, wei-eenheid- en blaarvreter-eenheidmetodes slegs metaboliese massa as 'n faktor gebruik om die energiebehoeftes van wild te bepaal. Die grootvee-eenheid metode gebruik egter beide metaboliese massa en die energiebehoefte van die dier by 'n spesifieke goed gedefinieërde fisiologiese produksietoestand in. ’n Regressie van metaboliseerbare energie behoefte per dag met massa (kg) deur gebruik te maak van 'n log-log transformasie van die herkouer spesies om die geskiktheid van die grootdier eenheid metode vir die bepaling van die metaboliseerbare energie vereistes van wild te modelleer is oorweeg. Die gevolglike vergelykings is gebruik om die berekende metaboliseerbare energie en grootvee-eenheidwaardes te modelleer en te vergelyk met die gepubliseerde metaboliseerbare energie en grootvee-eenheidwaardes. Die fisiologiese produksie statusse wat ondersoek is, sluit kalf/lam, jong droë koei/ooi, volwasse droë koei/ooi, jong koei/ooi met kalf/lam, volwasse koei/ooi met kalf/lam, jong bul/ram en volwasse bul/ram in. Ses uit die sewe kategorieë het waardes hoër as 0.75 met R^2-waardes van >0.99 getoon. Die uitsondering was kalf-/lamdata met ‘n waarde van 0.742 met 'n R^2 = 0.97. Hierdie resultate dui aan dat metaboliese gewig nie konseptueel korrek of voldoende akkuraat is om metaboliseerbare energievereistes vir wild te kan bepaal nie, en dus die aanvaarding van die alternatiewe hipotese bevestig. Daarom kan die grootdier-eenheid (metaboliese massa-metode) nie die grootvee-eenheid (metaboliseerbare energie-metode) vervang nie. Die afgeleide log-log-transformasievergelyking verskaf 'n meer akkurate metode om die metaboliseerbare energiebehoeftes en droëmateriaal-innamewaardes van swartwitpense en ander wildspesies te bepaal.

'n Studie na horinggroei-eienskappe insluitende horinglengte, basale omtrek en die aantal horingringe van swartwitpense in Suid-Afrika is gedoen om die omgewingseffekte van geslag, kalfjaar en -seisoen op horingontwikkeling van diere tot 50 maande ouderdom te ondersoek. Horinggroei-eienskappe binne die ouderdomskategorieë van 0-15 maande, 15.1-36 maande, 36.1-50 maande is ontleed. Daar is vasgestel dat die horinglengte-groeitempo in cm per dag tussen manlike en vroulike swartwitpense beduidend verskil ($P < 0,05$) vir alle ouderdomskategorieë: manlik (0,089 ± 0.002cm; p-value = <0.0001) en vroulik (0,068 ± 0.004cm; p-value = <0.0001) vir 0-15 maande, manlik (0,079 ± 0.002cm; p-value = <0.0001) en vroulik (0,042 ± 0.001cm; p-value = <0.0001) vir 15,1-36 maande, manlik (0,044 ± 0.003cm; p-value = <0.0001 cm) en vroulik (0,015 ± 0.003cm; p-value = <0.0001 cm) vir 36,1-50 maande onderskeidelik. Horingbasisomtrek tussen manlike en vroulike swartwitpense het betekenisvolle

verskil (P < 0.05) in die ouderdomskategorie 0-15 maande, waar die basisomtrek se groeitempo vir manlik 0.026 cm en vroulik 0.014 cm onderskeidelik was. Die aantal horingringe het egter nie verskil nie. Horinglengte en basisomtrek resultate oor die hele tydperk, ongeag ander omgewingseffekte, dui op 'n aanvanklike vinnige groei vir manlike en vroulike diere. Horinglengte en basisomtrek by mannetjies het egter vinniger gegroei, terwyl dit by die vroulike diere merkbaar verlangsaam het sodra hulle geslagsryp geword het. Aanvullende voedingsstrategië wat in 2013 op die meeste plase ingestel is, het horinggroei-eienskappe positief beïnvloed, wat tot langer horings by volwassenheid gelei het.

As die resultate in ag geneem word, is die metaboliseerbare energiebehoeftes vir diere by verskillende fisiologiese status bekend is, is dit moontlik om die drakrag van wildreservate en plase meer akkuraat te voorspel. Verder, om die metaboliseerbare energiebehoeftes van die spesie by verskillende fisiologiese toestande te verstaan, verskaf dit die dierevoedingkundiges die nodige inligting om aanvullende en volledige voeding te verbeter. Wanneer horinggroei in ag geneem word, toon die data duidelik dat horinglengte jaar op jaar by beide manlike en vroulike swartwitpense toegeneem het. Hierdie was ‘n dierekte gevolg van beter seleksie deur telers sowel as die aanwending van 'n meer gebalanseerde dieet.

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List of Abbreviations

AI:	Artificial insemination
AU:	Animal unit
BC:	Base Circumference
BLUP:	Best linear unbiased prediction
BMR:	Basal metabolic rate
BU:	Browsing unit
CDNEC:	Chief Directorate of the then Nature and Environmental conservation
CP:	Crude Protein
CWC:	Cell wall component
DE:	Digestible energy
DM:	Dry matter
DMI:	Dry matter intake
FMR:	Field metabolic rate
GU:	Grazing unit
GWP:	Gravelotte Wildprodusente
HL:	Horn Length
HR:	Number of horn rings
IUCN:	International Union for Conservation of Nature
KNP:	Kruger National Park
LAU:	Large animal unit
LSM:	LSMeans
LSU:	Large Stock Unit
LU:	Livestock unit
ME:	Metabolizable energy
MJ ME:	Megajoule metabolizable energy
MJ:	Megajoule
N:	No
NPN:	Non-Protein Nitrogen
NRC:	National Research Council
PA:	Primary Annulations (rings)
SA:	Width of secondary growth
SCI:	Safari Club International
SE:	Standard error
SE$\dot{X}$:	Standard Error of the mean
TDN:	Total digestible nutrients

TMR:	Total mixed ration
VFA:	Volatile fatty acids
Y:	Yes

Chapter 1
Introduction

1.1. General introduction

The implementation of the game theft Act, Act 105 of 1991 (JUTA, 2011), gave rise to private ownership of game in South Africa. The game industry started small, with the primary aim being hunting and tourism and has since grown into a sector that covers hunting, tourism, breeding and meat production (Du Toit, 2007; Oberem & Oberem, 2016). Game ranching is an economical alternative for livestock farmers/ranchers, especially ranches situated on marginally profitable semi-arid savannas. Wildlife numbers have increased dramatically over the last few decades after a monetary value was attached to it with the very conflicting mantra of “If it pays, it stays” (Van Rooyen, 2002). It is not only wildlife numbers that have increased, but also the number of icon (expensive) species being bred. An icon species that numerous farmers favour is the sable antelope (*Hippotragus niger niger*).

Sable antelope numbered between 15000 and 20000 in the 1930s in the Gravelotte area (Rabie, 2011). In the general Lowveld region outside the Kruger National Park (KNP), sable antelope numbers were estimated to be over 36000 animals (Ebedes, 1992). The numbers declined rapidly, leading to the Gravelotte Wildprodusente (GWP) group starting in 1986. The GWP had a poor start, where the sable antelope population dwindled from about 800 to a total of about 400 animals between 1986 and 2000 (Table 2.3). In 2000, sable antelope breeders in co-operation with the Department of Nature Conservation managed to stop the declining trend. This success led to increased sable antelope numbers within the GWP (Warren & Meyer, 2005) and on other farms countrywide.

In 2010 the GWP vision changed from conservation, extension, and distribution of sable antelope herds in South Africa (Scholtz, 1992) to repairing the loss of good genetic material, improving the genetic pool and setting the target of obtaining 152.4cm (60inch) horns. The study group and other breeders countrywide have partly succeeded in reaching this goal, where bulls have been bred with approximately the same horn length as South African record (140.65cm (55.375inches)) bull hunted at Tshokwane in present-day Kruger National Park in 1898. Since 1898 and 2014, only four bulls with horns equal to or longer than 127cm (50inches) have been hunted in South Africa and entered into Rowland Ward’s Records of Big Game Africa book (Ward, 2014).

1.2. Objectives

This thesis aims to describe the sable antelope from a husbandry perspective, using published research, on-farm guidelines, horn length data and metabolizable energy calculations to not only applaud the ranchers involved but to investigate the science behind what was observed.

Published literature on the sable antelope in Africa, focussing on the Southern African subspecies, describing the species in terms of its distribution; conservation status; habitat; ecology; taxonomy; physical description, including horn growth characteristics and factors affecting it has been reviewed, focussing on the South African population of sable antelope being ranched outside the Kruger National Park. Animal husbandry factors like nutrition, feeding, breeding, genetic selection, and other selection criteria are discussed to successfully ranch with this species extensively (game reserves and large ranches), semi intensively and intensively on ranches throughout South Africa.

Considering the sable antelope in terms of ranching, similar to how livestock farmers farm with livestock, the available literature on the species, had little to no peer-reviewed published guidelines. This led to the following questions: what are the nutrient requirements for this species, particularly daily energy requirements, and will selection and feeding play a role in breeding animals more successfully, focusing on reproduction and horn growth?

A study was therefore conducted at the University of Stellenbosch to:

- Develop a more accurate mathematical model to calculate the metabolizable energy requirements of sable antelope (*H. niger niger*) at different physiological states.
- Calculate the dry matter intake (DMI) of sable antelope (*H. niger niger*) and other herbivores.
- Improve methods used to calculate carrying capacity and stocking rates on game reserves and ranches.
- Re-evaluate the grazing and browsing unit method (Van Rooyen & Du P Bothma, 2016) in terms of metabolizable energy (ME).

  Investigate differences between sex, calving year, season, vegetation on horn growth characteristics (horn length, base circumference and the number of rings)
- Determine if supplementary nutrition had any effect on horn growth.

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Chapter 2
Literature review

2.1. Introduction

Cornwallis Harris, an accomplished writer, naturalist, and artist; the author of “Portraits of the Game and Wild Animals of Southern Africa (1840 first edition)”, describes and illustrates each species of animals he hunted in detail. He visited the interior of South Africa in September 1836 and was the first European to describe and possibly hunt the sable antelope (*Hippotragus niger niger*). While following the tracks of a wounded elephant, Cornwallis Harris noticed a herd of black antelope with white bellies on the southern side of the Cashan Mountains (Magaliesberg west of Pretoria). After three days, he successfully shot a specimen. When standing next to the sable antelope carcass, he said, “I at length found myself actually standing over the prostrate carcass of so brilliant an addition to the catalogue of game quadrupeds – so bright a jewel amid the riches of zoology! Turning it over and over, I thought I could never have scanned the prize sufficiently; and my companion, after long feasting his eyes in silence, exclaimed that the sable antelope would doubtless become the admiration of the world” (Cornwallis-Harris, 1986; Du Toit, 1992). The sable antelope was initially called the Harris buck after being discovered in 1836 (Cornwallis-Harris, 1986). The sable antelope has genuinely become one of the most sought-after trophies for hunters worldwide.

2.2. Background

The implementation of the game theft Act, Act 105 of 1991 (JUTA, 2011), gave rise to private ownership of game in South Africa. The game industry started small, with the primary aim being hunting and tourism and has since grown into a sector that covers hunting, tourism, breeding and meat production (Du Toit, 2007; Oberem & Oberem, 2016). Game ranching is an economical alternative for livestock farmers/ranchers, especially ranches situated on marginally profitable semi-arid savannas. Wildlife numbers have increased dramatically over the last few decades after a monetary value was attached to it with the very conflicting mantra of “If it pays, it stays” (Van Rooyen, 2002).

Since the early 1800s, South Africa’s animal numbers, particularly the wild ungulates, declined rapidly. Some of the reasons being: settlers moving further into the interior of South Africa with their livestock, displacing the natural wildlife either by pushing them out or being hunted and eaten (Oberem & Oberem, 2016); in the 1880’s the rinderpest outbreak wiped out most of the cattle and wild ungulates in southern Africa; during the 2nd Anglo Boer war (the early 1900s) game was seen as a food source (Pienaar, 1969; Oberem & Oberem, 2016); in 1905 nagana, a trypanosome transmitted by the tsetse fly, was reported in Zululand, with game animals being the reservoir of the disease game animals were slaughtered in great numbers - particularly in Zululand (Du Toit, 2007; Oberem & Oberem, 2016) and Zimbabwe where at least 37657 sable and 5525 roan antelope were slaughtered over a 40 year period (Wilson & Hirst, 1977; Du Toit, 2007); during the different world wars policing in nature reserves were not very strict resulting in animals being poached for food. However, one of the largest yet overlooked contributors to the decline in animal numbers is drought (Pienaar, 1969). Historically, sable and roan antelope were eradicated from their natural range, including the Kruger National park (KNP) in South Africa, by indiscriminate hunting practices (Wilson & Hirst, 1977).

Fortunately, a small group of people with the vision of saving wildlife for future generations created safe havens, so-called “game reserves” such as the Kruger National park and the Umfolozi Game Reserve, where small populations of wild animals were left unhindered to multiply (Oberem & Oberem, 2016).

2.3. Sable antelope population dynamics – 1900s till present

In 1838 Harris described the sable antelope he encountered in the Magaliesberg area west of Pretoria (Cornwallis-Harris, 1986; Du Toit, 1992). Sable antelope were historically found widespread in the bushveld areas of the Transvaal (the provinces of the North West, Gauteng and Limpopo within South Africa) (Nel, 1992).

Historically, the total South African population of sable antelope, state-owned or private, was low. Kettlitz’s (1954) report estimated that the numbers were less than 1000 animals with isolated populations found on the Waterberg Plateau in the Pietersburg (Polokwane) district and the Sabi-Sand area. Due to the low numbers of sable antelope in the Transvaal (now Limpopo Province), the Chief Directorate of the then Nature and Environmental conservation (CDNEC) initiated a breeding project at Hans Merensky Nature reserve during the early 1950s, at this stage these animals still occurred along the Magalakwin River west of the Soutpansberg district (Nel, 1992).

The number of sable antelope found in other provincial game reserves outside the KNP (1963) was estimated to be 800 animals composed of two populations found at Hans Merensky and Loskop Dam (Lambrechts, 1974). The KNP Population at the time was estimated to be between 1080 and 1140 animals (Pienaar, 1963), making the total (800 + ((1080+1140)/2)) = 1910 animals. In 1974, Lambrechts’ mentioned that the present estimate of 800 animals had shown no increase since 1962. However, the general picture nationwide looked more positive, with small groups of sable antelope being relocated to eight different Game Reserves by the Division of Nature Conservation outside the KNP. These game reserves being Loskop Dam Nature Reserve (43 animals), Percy Fyfe Nature Reserve (16 animals), Rustenburg Nature Reserve (5 animals), Hans Merensky Nature Reserve (55 animals), Krugersdorp Game Reserve, Vesco Private Nature Reserve near Vanderbijlpark, Sabi Sand Wildtuin and the Umbabat Private Nature Reserve. The Letaba district had approximately 560 animals occurring naturally; about 70 animals occurred naturally in the Pilgrims Rest district, with a few found in the Waterberg (Lambrechts, 1974).

In 1985 the CDNEC initiated a survey of the total sable antelope population in the Transvaal, excluding the KNP. The survey indicated that sable antelope occurred at 90 localities, with the total accepted number of animals being 1413. Most of these animals lived on private land, whereas only 10.7% lived on provincial nature reserves; 841 of these animals were found in 37 different localities within the Letaba district, and 66.5% lived in fenced-off livestock camps, 33.5% of them living on unfenced ranches. The populations found in the Pilgrims Rest, Klaserie, Timbavati and Sabie Sand had decreased since 1963. The KNP population estimate was 1800, thus making the total for the Transvaal 3213 sable antelope, a 59% increase since 1963. The KNP population had a 61% increase, and the private populations had a 56.6% increase. Although the KNP population had the most significant growth, the privately-owned herds played a significant role in conserving natural sable antelope populations (Nel, 1992).

In 1990 the CDNEC initiated another survey where the sable antelope population outside Kruger national park numbered 1375, with 1287 in the North West, Limpopo, and Mpumalanga Provinces. The Cape Province, Free State and Natal had 67, 2 and 18, respectively. In 1991 the CDNEC surveyed the conservation areas of the old Transvaal (Gauteng, North West, Limpopo, and Mpumalanga Provinces): and counted 291 sable antelope on seven different provincial reserves, 1877 in Kruger National Park, 201 in the old homeland areas and nine animals in the old SANDF property, totalling 2378 animals.

The 2000 survey showed a population decrease from 2240 in 1993 to 1232 in 2000 in the Kruger National Park (Grant & Van der Walt, 2000). Besides KNP, sable antelope population numbers in other Game Reserves in South Africa have also declined. Populations found on game reserves are tiny, with the largest population of sable antelope found on private land with an estimated number greater than 5000 animals (Oberem & Oberem, 2016). The game reserves and national parks where sable antelope were recorded in 2016 are; Loskop Dam Nature Reserve, Borakalalo Nature Reserve, Kgaswane Nature Reserve (Rustenburg), Wonderkop Nature Reserve, Mokala National Park, Sandveld Nature Reserve, Willem Pretorius Nature Reserve, Koppies Dam Nature Reserve, Tswalu Kalahari Reserve and Rooiport Nature Reserve (Parrini *et al.*, 2016).

Unfortunately, some formally protected subpopulations have become locally extinct; for example, Songimvelo Nature Reserve in Mpumalanga had 12 individuals in 2003, and the Madikwe Game Reserve population went locally extinct in 2009 (Parrini *et al.*, 2016). From 1979 to 1983, Pilanesberg National Park introduced 67 sable antelope, which increased to 127 in 1991 (Magome *et al.*, 2008), which declined to 60 in 2000; there are no records of current sightings they are thought to be locally extinct.

Sable antelope populations found on Free State provincial nature reserves have increased from 139 to 294 individuals from 2004 to 2013. Mokala National Park's number of individuals has increased from 10 to 31 from 2008 to 2012 (Parrini *et al.*, 2016).

Other populations living on private game reserves and or game ranches isolated from predators and those receiving supplemental feed are growing. So overall, sable antelope numbers have increased dramatically due to the game industry boom over the last few decades, which has led to concerns regarding maintaining the genetic diversity of the southern African subspecies. The points of concern being: outbreeding with subspecies, artificial selection for horn growth, and being naive against naturally occurring diseases due to being captively bred (Parrini *et al.*, 2016).

"The Red List of Mammals of South Africa, Lesotho and Swaziland" states that there are 8067 sable antelope in South Africa (if you add the total numbers of each population together), of which 6995 live on privately owned game ranches (Parrini *et al.*, 2016). Only 2 - 10% of this population is considered wild. Unfortunately, the document states that this data is not complete, as the data only originates from 76 private properties, so it is not a true reflection of the total South African herd. It is a challenge to obtain accurate data as ranchers are reluctant to provide numbers of animals on their property; this is exasperated by the fact that a large number of ranchers do not belong to any formal organisation that would typically collect such data. A take-home message regarding the long-term survival of the sable antelope as a wild animal is that more privately-owned populations should switch from intensive management to light management to create herds of free-roaming sable antelope. This, in fact, is happening where stud breeders are removing "cull" animals that do not meet their breeding selection criteria and are instead releasing these animals onto large properties to roam without any intervention for hunting purposes.

2.3.1. Sable antelope population dynamics – decline in the Kruger National Park

Shortly after the 2nd Anglo Boer war (1903), Colonel Stevenson-Hamilton was appointed to be the first warden of the Sabi Game Reserve. He noticed that the numbers of wild animals were low in the old Sabi and Shingwidzi reserves. At their peak, the sable antelope population declined from approximately 3500 (1915) to a few hundred today. Since then, the sable antelope population increased to around 1000 animals in 1912, 3500 in 1915, 870 in 1954 (Pienaar, 1969), 1080-1140 in 1963 (Pienaar, 1963), 1065 in 1968 (Pienaar, 1969), 1877 in 1991 (Nel, 1992), 2240 in 1986, 1232 in 1993 (Grant & Van der Walt, 2000), 507 in 1999 (Grant *et al.*, 2002), whereafter this number had declined to 325 in 2006 (Owen-Smith *et al.*, 2012), and increased to 385 animals in 2012. Currently, the number is about 150 animals (Warren, 2021)(Figure 2.1).

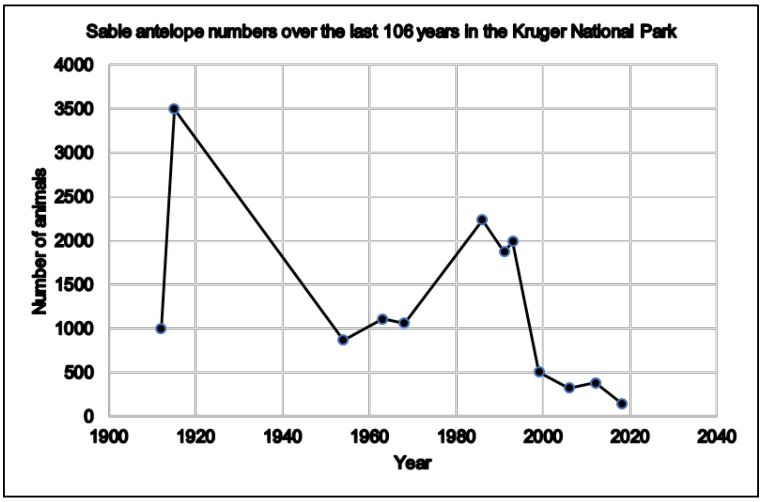

Figure 2.1 Graphical representation of the sable antelope population decline in the KNP (1912 – 2018).

Pienaar pointed out that the undulating population growth curve correlates well with the drought cycles found in the KNP. Before the severe drought of 1926-35, sighting sable antelope was common in the west of the Skukuza-Malalane main road, and large herds were found in the Lwakahle and Randspruit areas. By the end of 1935, the area was so severely trampled that the herds had disappeared. The droughts of 1926-35, 1944-48, 1950-54 (Pienaar, 1963), 1962-65 (Pienaar, 1969), 1982-83, 1986-87 (Grant & Van der Walt, 2000) and 1991-92 are possibly the most significant reason for the undulating population growth curve seen over the last 110 years (Figure 2.1).

Drought has led to severe losses of sable antelope in Kruger National Park (Pienaar, 1969) and other nature reserves situated in the northern parts of South Africa (Conservation Division official files) due to an overall reduction of edible forage. During times of drought, and if this coincides with a May/June calving period, the calves will have a limited chance of survival due to the poorer quality forage their mothers may have access to (Ebedes, 1992).

An increase in predator numbers in nature reserves would also contribute to high adult mortality rates. Recorded sightings of predators increased from 10 in 1980-1985 to 100 per year in 1986 in the Kruger National Park (Harrington, 1995). In smaller nature reserves with low numbers of sable antelope, predation of calves by leopard (Pienaar, 1969; Grobler J.H. & Wilson V.J., 1972; Grobler, 1974, 1981; Sekulic, 1981; Magome *et al.*, 2008) and cheetah (Magome *et al.*, 2008) could lead to a population decline in the long run.

Ebedes (1992) lists several reasons for the possible decline in sable antelope numbers: Tick and lice infestation; internal parasitism; diseases; drought; competition for grazing; increase in predator numbers; deaths of young males; poaching; hunting and poor mothering.

Sable antelope have specific habitat requirements, and the success of their conservation is dependent on the quality of the habitat. Animals are pushed out of their natural open grassland savannah to denser bush conditions; due to being physically pushed out or due to bush encroachment caused by overutilization of the veld by cattle and or the removal of elephants. These areas are also ideally suited for agriculture and mining (Ebedes, 1992). Conservation areas are mostly found on soils of marginal quality due to the higher quality soils used within the agricultural sector for growing crops and livestock ranching, resulting in poorer quality forage for sable antelope and other ungulates (Maskall & Thornton, 1996).

The introduction of high game proof fencing has also restricted the sable antelope's natural migration patterns and seasonal movement (Ebedes, 1992). Several African ungulates tend to inhabit and migrate through areas supportive of their nutritional needs (Ben-Shahar & Coe, 1992). With migration being limited, ungulates camped off into smaller national parks will have restricted opportunities to acquire adequate amounts of macro and micronutrients from the available forage. The increased restriction of free-roaming animals has led to more attention being focused on the geochemical nature of the soils present in the area and the availability of the elements to the wildlife species (Maskall & Thornton, 1991, 1992). The general health of these free-roaming/naturally occurring ungulates, particularly the rarer ones, is directly dependent on these conservation areas being able to supply these nutrients daily (Maskall & Thornton, 1996).

Grant and van der Walt (2000) hypothesised that the increase in high-density grazers in areas best suited to sable and other rare antelope species caused the decline in the population numbers of sable and other rare antelope in the KNP. The increase in high-density grazers like zebra is due to artificial water points (boreholes) being established. Mismanagement of veld by exceeding the carrying capacity for the area leads to increased competition from resident animals for the same limited food resource (Ebedes, 1992). Even though good rains have fallen since 1986, together with the boreholes being closed and the resulting lower numbers of predators, the sable antelope population has still not recovered in the KNP. Reasons for this point too enduring habitat degradation and or high predation pressure.

The population decline coupled with the subsequent lack of recovery raises the possibility that the Allee effect could be involved within the sable antelope population in the area (Owen-Smith *et al.*, 2012). “The Allee effect occurs when the population growth rate is reduced due to a low population size” the main reasons for this is surmised as; a lower number of animals finding mates, social dysfunction and inbreeding depression when populations are small (Dennis, 1989; McCarthy, 1997). Small herds/populations also have greater exposure to predation, thus decreasing the population size even further (Owen-Smith *et al.*, 2012).

2.3.2. Distribution of sable antelope in Africa

Naturally occurring sable antelope are restricted to the southern savanna, where most of the sable antelope occur within the well-watered Miombo Woodland Zone that girdles Africa from eastern Tanzania and Mozambique to central Angola and southern DRC (Estes, 1991). Figure 2.2 illustrates the historical range of the different sable antelope subspecies in Africa. There are four subspecies of *Hippotragus niger* listed: *Hippotragus niger roosevelti* found east of the Rift valley (Tanzania and Kenya); *Hippotragus niger kirkii* found west of the Rift valley (Tanzania and central Africa); *Hippotragus niger variani* (giant sable antelope) located in central Angola and *Hippotragus niger niger* found in Southern Africa (Estes, 1991; Matthee & Robinson, 1999b; Pitra *et al.*, 2002); (Figure 2.2). *Hippotragus niger niger*, in contrast to the other three subspecies, inhabit dry savannah and cover larger areas foraging for superior forage (Estes, 1991).

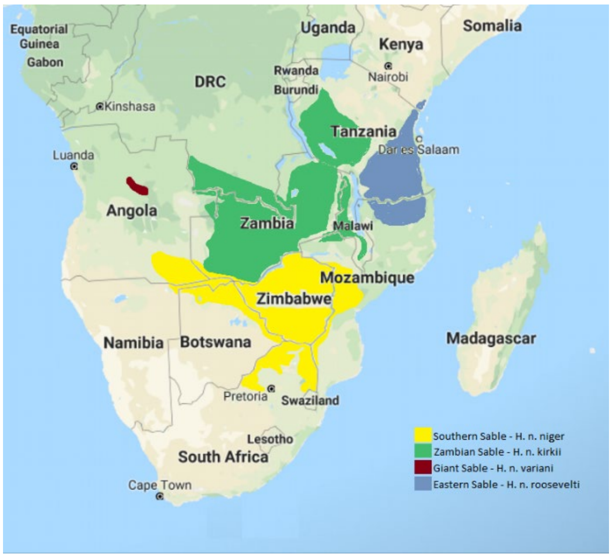

Figure 2.2 Historical distribution of the different sable antelope subspecies in Africa, adapted from Google Earth Maps (Shepstone, 2021).

When considering the sable antelope's distribution within South Africa from a historical perspective: sable antelope were found in the Letaba; Magaliesberg, west of Pretoria; Pilgrims Rest and the Waterberg district of the old Transvaal (current provinces of the North West, Gauteng, Limpopo and Mpumalanga) and the Kruger National Park within South Africa (Figure 2.3). Presently sable antelope occur throughout South Africa, being particularly popular in the Limpopo province, the northern and eastern Cape provinces (Basson, 1989; Du Toit, 1992), with some even being introduced into the winter rainfall regions of the Western Cape Province.

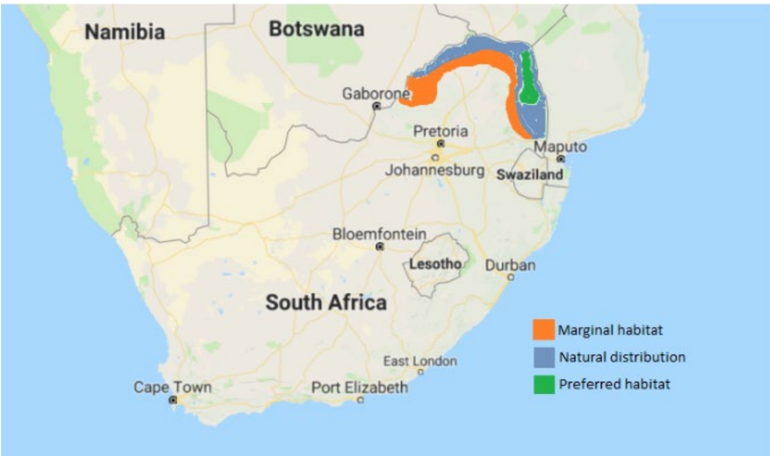

Figure 2.3 Sable antelope's natural, historical distribution range in South Africa adapted from Google Earth Maps (Shepstone, 2021).

2.3.3. Conservation status - Africa

Officially when considering the sable antelope in context to Africa as a whole, the International Union for Conservation of Nature Red List of Threatened Species categorizes the sable antelope under the category "of least concern" with an estimated total population of 75000 animals. However, the giant sable antelope (*Hippotragus* niger *variani*) subpopulation is characterized as vulnerable (IUCN SSC Antelope Specialist Group, 2008). The Regional Red list status for 2016 for the sable antelope is also vulnerable (Parrini *et al.*, 2016)

From a South African perspective, the sable antelope population numbers have increased from a few hundred to an estimated 25000. The game industry understood that unrelated male animals were needed to improve the genetic stability of the herds (Grobler & Van Der Bank, 1992). To do so, ranchers purchased animals from ranchers who had brought animals of the same subspecies from Zambia, Malawi, and Zimbabwe, supplying new genes to a tiny, inbred population. Many ranchers did not understand that outbreeding with these animals would dilute the original native South African population. Presently, few ranchers or game reserves in South Africa can prove that they still have 100% South African sable antelope. Concerning breeding in the last twenty years, the focus shifted from outbreeding to selection for horn length resulting in more western Zambian sable antelope being purchased and included in herds countrywide due to their longer horn length (Warren, 2021). Figure 2.4 is an example of an exceptional western Zambian sable antelope used as a breeding bull by Mr Piet Warren.

People in the game ranching industry believe that if ranchers had not started outbreeding with unrelated bulls, the sable antelope population would probably have died out due to inbreeding. The crossbred sable antelopes that are ranched on a large scale should be considered as the South African sable antelope population (Warren, 2021).

Figure 2.4 A good example of a Zambian sable bull: Piet, the breeding bull that helped Mr Piet Warren breed some of the biggest horned sable antelope bulls in South Africa, Piet measured 53.5 cm at his death in 2018.

2.3.4. Habitat, ecology, and food selection

In their natural habitats, sable antelope inhabit savanna woodland ecosystems within the savanna biome, providing sufficient perennial grass cover and water. Sable antelope prefer open woodland with the adjacent “vlei” or grassland with medium to high swards of grass; they tend to avoid areas with dense tree cover and short grass (Pienaar, 1963; Du Toit, 1992; Skinner & Chimimba, 2005). Sable antelope are selective grazers with a preference for green medium height grasses high in crude protein and low in crude fibre (Grobler, 1981), preferring young succulent grass (Sekulic, 1981). During the dry season, when the nutritional value of grass is generally low, sable will seek other green growth; they browse to a small extent during the dry season (Grobler, 1981). A study comparing grass selection between the sable antelope and the zebra (*Equus quagga*) in the Kruger National Park illustrated that the sable antelope willingly eat tall grass species rated as having a low to moderate forage value in the dry season (Owen-Smith *et al.*, 2013).

In Kenya (Shimba Hills National Park), sable antelope spend the green months in the woodland areas and the dry months ranging the grassland areas looking for green grass, forbs and foliage (Estes, 1991). The dry season movement of sable antelope is directly dependent on a steady water source and available food. Evidence exists that the grasslands in the Shimba Hills frequented by the sable antelope are due to the fresh regrowth of nutritious grass that grows out after burning the moribund. Game wardens burn and mow the moribund grass approximately two months after the last rains every year. The moisture-rich soils supply the grass with enough nutrients to grow again; the green regrowth attracts the animals, who receive more nutritious green grass than they would have if the grass were not burnt and mowed. The blackened woodland is empty of sable antelope until the woodland (Miombo) produces leaves, attracting the animals back into the woods; this takes place in spring, approximately a month before the seasonal rain starts falling. Sable antelope tend to frequent the base of copses and termite mounds for the highly nutritious green growth. These areas are typically composed of soils of superior nutrient quality compared to the infertile sandy soils found in the game reserve (Sekulic, 1981; Estes, 1991). Sable antelope have been observed licking natural salt licks found at the base of termite mounds and eating dry bones (osteophagia) in search of salt, calcium, phosphorous and other minerals (Sekulic & Estes, 1977; Sekulic, 1981; Estes, 1991).

In the Pilanesberg National Park, sable antelope used to move between the different ecotopes (Magome *et al.*, 2008), broadly classified as Sour Bushveld and Turf Thornveld (Acocks, 1988) in the valleys as the seasons change from green to dry in search of superior quality dry forage (Magome *et al.*, 2008). The use of burning programs in the dry season boosts the nutritional quality of the grazing, leading to the sable antelope herds moving to these areas.

In Kgaswane Mountain Reserve (Rustenburg), habitat choice was directly related to green grazing and water. Parrini (2006) focussed on how the changes in food availability during the dry season affected the sable antelope's foraging and social ecology. Contrary to expectation, the sable antelope did not limit their foraging to the woodland areas but fed in the open grassland and "vlei" areas. Sable antelope also frequented burnt areas caused by either veld fires or controlled burns, seeking higher quality forage.

2.4. The sable antelope

2.4.1. Taxonomy and origin

Sable antelope are members of the family Bovidae, subfamily; Hippotraginae, tribe; Hippotragini (Matthee & Robinson, 1999a) genus; Hippotragus (large antelope with backwardly curved horns) which was composed of three species: the sable antelope (*Hippotragus niger*), the roan antelope (*Hippotragus equines*) and the bloubok (*Hippotragus leucophaeus*) (Nel, 1992); the latter being extinct (Penzhorn, 1992). There are four subspecies of *Hippotragus niger niger* listed by Matthee (1999): *Hippotragus niger roosevelti* found east of the Rift valley (Tanzania and Kenya); *Hippotragus niger kirkii* found west of the Rift valley (Tanzania and central Africa); *Hippotragus niger variani* (giant sable antelope) located in central Angola and *Hippotragus niger niger* found in southern Africa, Zimbabwe, Zambia and southern Tanzania (Matthee & Robinson, 1999b; Pitra *et al.*, 2002). For interest, niger is Latin for black, so the southern sable antelope described as *H. n. niger* can be called *Hippotragus "black, black"*, which accurately describes this subspecies, where both male and female are black at adulthood (Estes, 1991). Figures 2.5 and 2.6 are photos of the giant sable antelope (Angolan) *Hippotragus niger variani* subspecies. Figures 2.7 and 2.8 are examples of the western Zambian variant of Southern sable antelope. Figure 2.9 is where the photos were taken (Figures 2.7 & 2.8), Nchila Wildlife Reserve (Zambia), run by Mr Peter Fisher.

Figure 2.5 Giant sable antelope bull (*Hippotragus niger variani*) on the left; note the black mask (Estes, 1980).

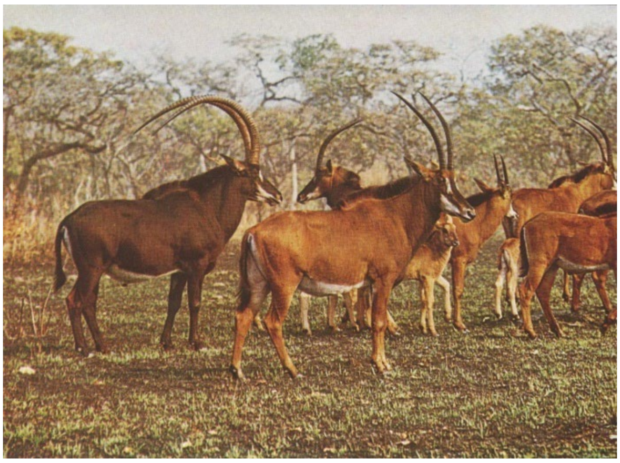

Figure 2.6 A herd of giant sable antelope on burnt veld in Angola (Silva, 1972).

Figure 2.7 Western Zambian sable antelope – bull with the cows in a herd (Shepstone, 2007).

Figure 2.8 Sub-adult western Zambian bulls; show the contrast relating to the facial markings found between individuals within the western Zambian sable antelope population. One animal shows the solid black facial marking similar to the Giant sable antelope, and the other shows the white patch that extends to the nose similar to the facial markings of the Southern sable antelope (Shepstone, 2007).

Figure 2.9 Location where the photos were taken (Fig. 2.7 & 2.8); in the far north-west of Zambia on the border of the DRC - Nchila Wildlife Reserve Zambia – 2012 (Google Maps) (Anonymous, 2021).

2.4.2. Physical description

Adult males have a shoulder height of between 1.17 and 1.40 m (Estes, 1991), whilst other sources state an average of 1.35 m (Skinner & Chimimba, 2005), with a weight that varies from 216 to 263 kg (235 kg) (Estes, 1991a); other souces use 200 to 250kg (225 kg) (Du P Bothma *et al.*, 2016). Adult cows weigh from 204 to 232 kg (220 kg) (Estes, 1991); other sources state 180 and 220kg, with a life expectancy of 13 to 17 years in the wild (Du P Bothma *et al.*, 2016).

Sable antelope have long faces with wide gapes (jaw opening), ears of average size without a terminal tuft as seen in the roan antelope; it has a small dewlap (bump) on the throat like that seen in the gemsbok. Horns are laterally compressed, strongly ridged and thicker and longer when comparing males with females. Horn lengths between 50 (19.69 inches) and 154 cm (60.62 inches) have been recorded, whilst horn lengths of 164.8 cm (64.88 inches) have been measured in the Angolan subspecies. They have preorbital and hoof scent glands (Estes, 1991).

Old adult males are black with a shiny polish to their coats. The belly region is pure white with a black penile button; the white extends over the inner parts of their hindquarters to the base of their tails (Skinner & Chimimba, 2005). The face pattern, illustrated in Figure 2.10 below, is a distinctive feature of the sable antelope, where black hair extends from behind the nose on the animal's face to the base of the horns, then across most of the body. A broad white stripe covers the length of the face, starting just below the base of the horns extending along the muzzle ending within the white of the lower parts of the face at the nostrils. The lower part of the face is a large white patch stretching from the chin and lower part of the nose along the edges of the mouth, broadening towards the posterior part of the lower jaw.

Figure 2.10 A 50 inch plus Southern sable antelope (*Hippotragus niger niger*) bull bred by Tembani Wildlife (Strydom, 2018).

The Giant sable antelope (*Hippotragus niger variani*) do not have the white stripe that extends to the nostrils; they have a much shorter white bar that ends a short distance in front of their eyes (Figure 2.5). The tip of the tail is tufted and fringed with long black hair that reaches the hocks. The upstanding mane of black or dark brown hair extends from the shoulders to the top of the neck. The narrow pointed ears are fringed with white hairs and reddish at the back (Skinner & Chimimba, 2005).

Figure 2.11 Zambian sable antelope bull (Piet), with some of his offspring (Warren, 2014).

Newborn calves are reddish-tan (Figures 2.11 & 2.14), except for the pale underside and facial markings. Sable antelope calves lose hair by moulting up to the age of 12 months (Grobler, 1980b) when the reddish-tan changes to a very dark brown to black in female animals from Southern Africa (Figure 2.12) (Grobler, 1980b; Cornwallis-Harris, 1986; Skinner & Chimimba, 2005). Female animals originally from the northern parts of their distributional range are dark red-brown in colour (Skinner & Chimimba, 2005).

Figure 2.12 Southern sable antelope (*Hippotragus niger niger*) (Matetsi) cow, note the dark body (Strydom, 2018).

The moult pattern explained by Grobler (1980b) illustrated by Figure 2.13 are: at 2 to 3 months (B), the underside of the neck closer to the torso darkens, between 4 – 5 months (C), the darker areas start spreading up towards the mane, at month 6 (D), the fringes of the white belly darken, month 7 (E) the neck, torso, main and tail have darkened, at 8 – 9 months (F), a saddle of light tan colouration encompasses the back and shoulder regions (Figure 2.15 lighter animal on the left).

Sub-adult bulls start to go dark auburn to jet black between the age of 40 and 48 months (3.3 and 3.8 years), Zambian bulls specifically (*H. n. niger*) darken at 45 months (3.5 years) of age (Warren, 2021). The darkening of the coat colour in males is testosterone-driven; as seen in the darkening of a male lion mane as the lion ages (West & Packer, 2002), with the testicles being the primary source of testosterone in the male animal, larger testicles is associated with more testosterone being produced (Preston *et al.*, 2012). In sable antelope, this was seen in reverse, where a 4.2-year-old jet black male sable antelope was castrated; within six months, this bull went from pitch black to the red calf-like colour (Warren, 2021).

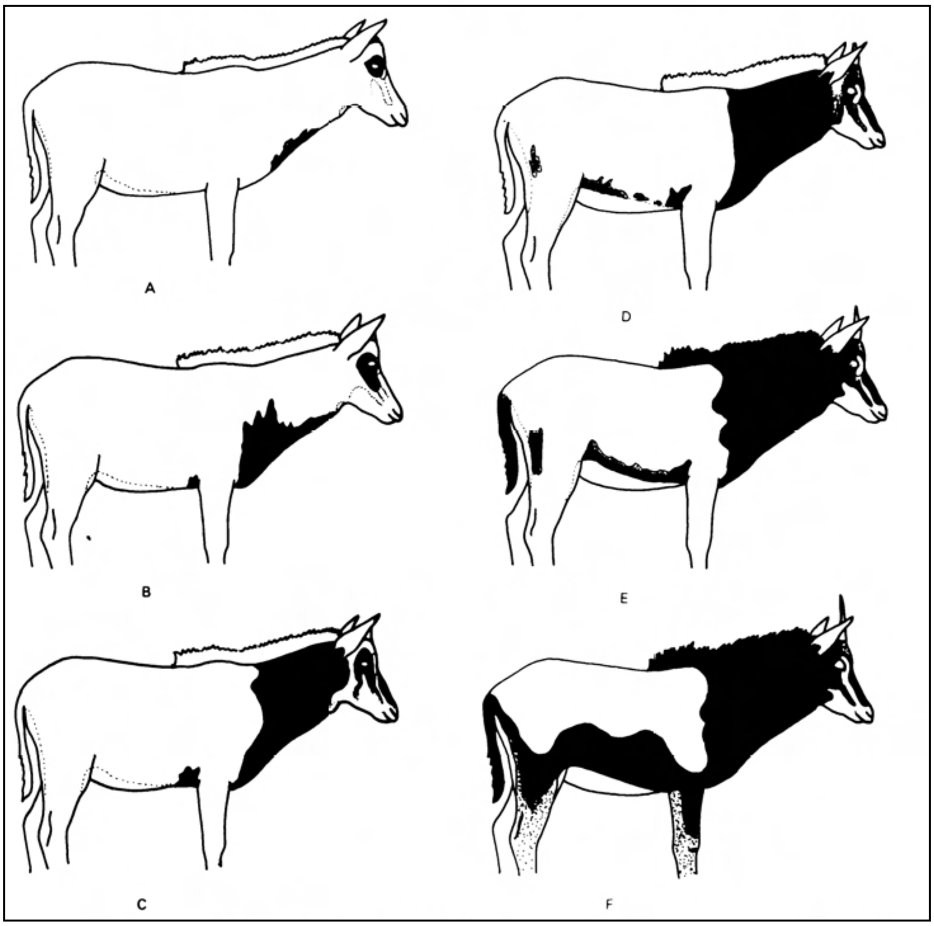

Figure 2.13 Moult pattern of young sable antelope, in the Matopos, Zimbabwe (Grobler, 1980b).

Figure 2.14 Young sable antelope show the red/fawn colouration (Strydom, 2018).

Figure 2.15 Sub-adult and adult sable antelope bulls illustrate the different colourations for sub-adult bulls as they mature (Strydom, 2018).

2.4.3. Growth

Growth can quantitatively be separated into two parts, isometric growth and allometric growth. Isometric growth is measured as the animal ages, measuring the animal's mass, height and length of the whole animal or parts thereof. Allometry is defined as measuring the changes of proportions, whether morphological or chemical, in relation to an increase in size (Hanks, 1972; Grobler, 1980b). Grobler (1980) used the equation that Beverton and Holt (1957) derived from von Bertalanffy's (1938) calculation on growth in weight, namely:

$$\mathbf{wt = W_\infty (1\text{-}e^{-k(t-t_0)})^3}$$

Where: wt = weight in kg at age t.

W_∞ = asymptotic weight

k = coefficient of catabolism of body materials per unit weight and time

t = age of the animal

t_0 = theoretical age at which the animal would have zero weight with the same growth pattern observed in later life.

For growth in height (ht) the formula used was:

$$\mathbf{ht = H_\infty (1 - e^{-k(t-t_0)})}$$

For the isometric growth: the mean body measurements of sable antelope in relation to age measured during 1971 to 1978 in the Rhodes Matopos National Park in Zimbabwe showed that most measured parameters reached their asymptote at 36 months of age. For the allometric growth, the body mass reached its asymptote at a later age than other measurements. As it typically reflects body condition, it was used as a correlation factor with other measurements. Good linear relationships were obtained for the hindfoot, tail, ear and hoof length as the body mass increased to approximately 19 months. Adult females in poor condition had an average mass of 130 to 140kg, those in an average to good condition had a mass of 160 to 180kg, while those in excellent condition had a mass of 180 to 200kg. Adult males in poor condition were 160kg, those in moderate condition 160-180kg, while those in an excellent condition had a mass of up to 230 kilograms (Grobler, 1980b).

From the data, it is evident that sable antelope reach sexual maturity before they reach physical maturity. Female animals can conceive at 27 months but reach physical maturity at 5 to 6 years of age. Males reach sexual maturity at 36 months and physical maturity at 7 to 8 years of age. Growth is not a uniform process but a continuous one, influenced by food quality and availability.

2.4.4. Horns

Both sexes have horns; females have shorter and more slender horns that are less sweepingly curved than males (Skinner & Chimimba, 2005). Three phases can characterise horn growth, (i) formation and subsequent exfoliation of the deciduous horn, (ii) the growth of the primary permanent horn, identified as the time when the bumps (rings) on the horn form, (iii) slow post mature or secondary permanent horn growth evident at the base of the horn (Grobler, 1980b).

2.4.5. Sable antelope horn appearance in both sexes relative to age

Grobler (1980b) explains how horn growth relative to age occurs in the free-ranging sable antelope of the Matopos. The growing points of sable antelope horns are small bumps of naked horny tissue hidden by coarse hair in neonates. The soft, deciduous horns start showing above the hairline on the frontal area of the skull at about two months of age. The rapidly growing young horn is smooth with an elastic texture. At approximately eight months of age, the horn is shorter than the animal's ear length and, on cross-section, has a clear transparent matrix. Primary permanent horn starts growing in the inner layers of the horn at approximately four months of age; this is recognized as the darkly pigmented layer within the transparent matrix.

At approximately 8 to 12 months, the horn length is equal to or greater than the ear length. In this study, the first annulus "ring" appears at approximately 12 to 13 months. Male horn length bypasses their female counterparts at around 12 to 16 months of age.

The primary annulations (rings) develop rapidly between 12 and 24 months (yearlings). The number of annulations in this group numbered between one to ten, with less than one-third of the horn bearing annulations. Exfoliation of the deciduous horn takes place at this time. At 16 months of age, the horns appear pale and dry. The horn starts to exfoliate on the smooth upper part and peels off to expose the dark primary horn. This process is usually completed by 20 to 24 months, although the left-over flakes of annulations (rings) may still be present after this.

In two-year old males (between 2 and 3 years of age), horns show the distinct curvature that adult males have, with approximately 10 to 20 primary annulations. Female animals have straighter horns with the same number of annulations as the males. Males stay in the breeding group as yearlings. Males will leave the herd at approximately three years old; these animals' horns will exhibit total adult curvature with 20 to 30 annulations. Female animals in the 3-year class are difficult to place into an annual age class. At four years of age, female animals start showing secondary growth (post) at the base of the horn, approximately 40mm in width. Compared to their western Zambian contemporaries, western Zambian and their respective crosses, secondary growth (posts) started at 5 to 5.5 years of age (Warren, 2021). A method to calculate a sable antelope cow's age is described below.

Secondary growth (posts) in males starts at four years of age, and they tend to look similar to five-year-old males. From this point, individual variation in horn length starts to become apparent. In the age classes, 4- and 5-year-olds, the secondary growth rarely exceeds 20mm in width, and the primary annulations generally exceed 30 in number. Secondary growth at the base of the horn increases with age until it reaches approximately 80mm in animals older than ten years of age. The general shape of the horns and the amount of secondary growth can assist in estimating the animal's age (Grobler, 1980b). Secondary growth (post) is a portion of the horn that grows without any annulations (rings).

In animals over the age of 13 years, horn tips become worn and eventually start fracturing.

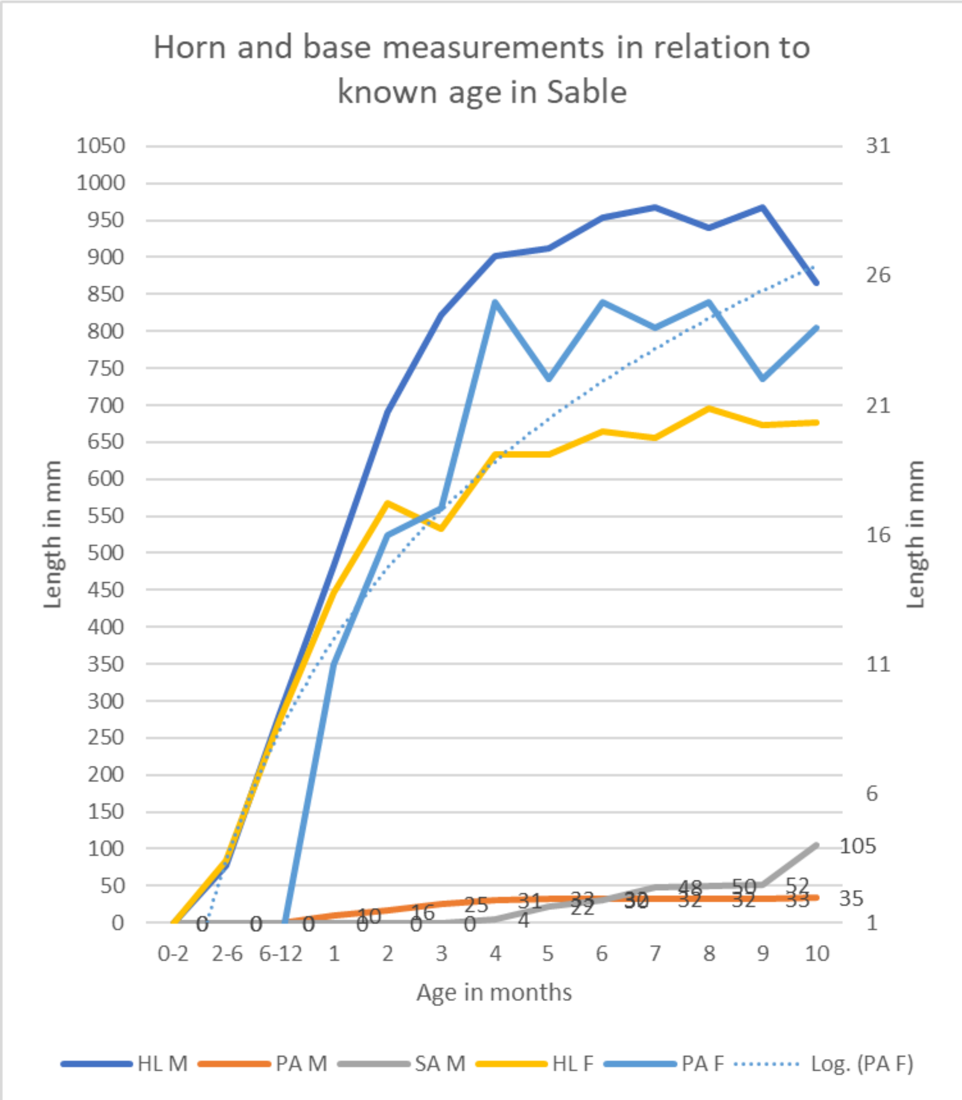

Figure 2.16 Graph showing growth in horn length of semi free-ranging known age sable antelope in Matopos, Zimbabwe, in relation to age (Grobler, 1980b).

The historical data used as a guideline for Chapter 3 (Horn growth) is shown in Table 2.1 and Figure 2.16 (Grobler, 1980b), where horn length and the number of rings (annulations) were used as a published comparison to the results obtained in Chapter 3.

Table 2.1 Mean horn measurements of sable antelope from the Matopos, Zimbabwe, in relation to age. Adapted from Grobler (1980b).

	Males							Females						
Age (Months)	**HL**	**$SE\dot{X}$**	**PA**	**$SE\dot{X}$**	**SA**	**$SE\dot{X}$**	**n**	**HL**	**$SE\dot{X}$**	**PA**	**$SE\dot{X}$**	**SA**	**$SE\dot{X}$**	**N**
0-2	0	0	0	0	0	0	26	0	0	0	0	0	0	23
2-6	78	10,7	0	0	0	0	8	85	11,1	0	0	0	0	7
6-12	284	29,8	0	0	0	0	7	275	20,2	0	0	0	0	6
Age (years)														
1	483	20,8	10	1,5	0	0	5	447	61,2	11	2,6	0	0	3
2	690	42,1	16	1,9	0	0	4	567	35,8	16	1,3	0	0	5
3	822	27,5	25	1,3	0	0	4	533	5	17	1	0	0	2
4	901	4,6	31	1	4	4,5	5	633	1,8	25	0,5	10	5,7	4
5	912	23,7	33	2	22	13,5	5	634	5,5	22	0,5	40	20	2
6	954	16,5	32	0,9	30	8,8	6	664	35,6	25	2,4	50	15	2
7	967	27,5	32	2,2	48	14,4	4	655	27,9	24	1,6	59	13,2	4
8	940	60,1	32	1,5	50	12,5	2	695	11,9	25	1,2	82	9,1	7
9	968	80,2	33	1,2	52	4,4	3	673	12	22	0,6	83	11,5	3
+10	865	-	35	-	105		1	677	80,2	24	3,5	138	24,5	3

HL = horn length mm, PA = primary annulations on horn, SA = width of secondary growth or annulations on horn mm, $SE\dot{X}$ = standard error of the mean, n = number in sample.

2.4.6. Using horns to age older female animals

Estimating age using horn growth as a guide is possible in both male and female animals. Horn length and measurements of certain horn growth traits can help estimate a cow's age, up to about 14 years (Warren, 2021).

It is essential to understand that these horn length estimations are observations made by a well-respected sable antelope farmer. He routinely kept detailed records of his animals, where birth dates are used to qualify the described method.

A female animal's (cow) horns grow as described above; by the age of 5.5 to 6 years, she may have up to 30 or more rings. The horn growth can be stunted depending on whether the cow calves early at approximately two years or three years of age. If the cow calves at two years of age, she will have used more nutrients to produce a calf, resulting in shorter horns. When estimating the age of these cows, an extra 2 inches should be added to the measured horn length.

At approximately 5.5 years of age, secondary growth starts (post). A post with an inch measurement (25.4mm) equals an additional 18 months of age. A two-inch (50.8mm) post is indicative of a cow of 8 to 9 years old (5.5 years plus three years (36-42 months)). A six-inch (152.4mm) post (6 x 18 months) equates to 9 years, adding the 5 to 5.5 years growth before the post develops, ageing the cow at approximately 14 to 15 years of age.

Using this method for southern sable antelope, concerning Grobler's (1980) data mentioned in the section above, keeping in mind secondary growth (posts) starts at approximately four years of age. A six-inch post (6 x 18 months) equates to 9 years plus the 4 to 4.5 years growth before the post develops, ageing the cow at approximately 13 to 14 years of age.

The older the cow, the more difficult it is to estimate her age due to wear and tear as she works the tips of her horns away.

Other on-farm observations (anecdotal data) show that; cows with the smoothest rings, are the animals that have bred offspring with longer horns, resulting in breeders selecting cows with horns that are gemsbok (*Oryx gazella*) -like (longer horns with smoother annulations). Animals with roan antelope (*Hippotragus equinus*) -like horns (shorter horns with many pronounced annulations) are not selected. When selecting cows, select cows with longer points with gentler (softer) rings where the horns basal circumference is oval and not round (Warren, 2021). Horns are present in male and female animals; currently, male animals are piped, or a small sleeve of plastic is placed on the tips to protect the horns from getting worn, damaged or broken (personal observation).

2.4.7. Horn measurements, Rowland ward measurements

Horn lengths of between 50 (19.69 inches) and 140.65 cm (55.375 inches) have been recorded for the subspecies *H. niger niger*, the longest horned sable antelope being hunted in Tshokwane (Kruger National Park) in 1898, whereas 61–102 cm (24-40 inches) for horn lengths of female animals have been recorded (Skinner & Chimimba, 2005).

For an animal to qualify, the animal must have a horn length of at least 106.36cm ($41^{3/4}$ inches) to be entered into Rowland Ward's Records of Big Game Africa. There are 1183 entries in the 28th Edition (Ward, 2014). Of the total 1183 animals, only 34 (2.87%) are above 127cm (50 inches). Of this group, 49 animals were hunted in South Africa, of which four animals measured 127cm (50 inches) or longer, shown in Figure 2.17.

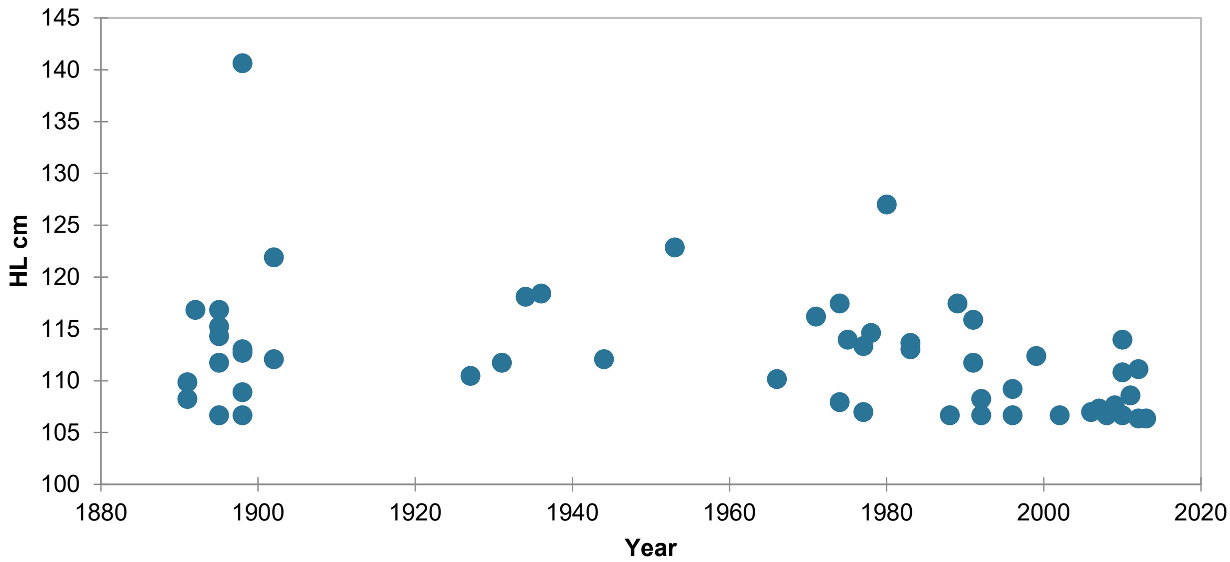

Figure 2.17 Graph showing horn length of sable antelope hunted in South Africa. Data was extracted from the book "Rowland Ward's Records of Big Game Africa" (Ward, 2014).

2.4.8. Behaviour and activity

Knowledge of the social behaviour in sable antelope is essential as it plays a crucial role in whether the ranching activity (commonly of an intensive nature) is successful or not.

2.4.8.1. Daily activity patterns

Sable antelope rest by lying down in a sternal position or standing semi motionless, often ruminating. Individual animals would generally rest close to each other, whereas different age groups would often rest together. The youngsters born that year always lie down close to each other (Grobler, 1974).

Individuals living in larger groups would often rest while others would be grazing and *vice versa*. Invariably if a resting group is disturbed, they would move off, individuals would defecate, and the group would start grazing before resting again (Grobler, 1974).

The peak grazing periods appear to be early morning from 07h00 to 09h00 and late afternoon between 16h00 to 18h00, which usually coincides with the cooler parts of the day in their natural surroundings (Grobler, 1974; Estes, 1991; Skinner & Chimimba, 2005). Sable antelope visit water holes frequently, if not daily, even in the green season, usually around midday, night-time visits have also been reported (Estes, 1991).

2.4.8.2. Postures and locomotion

Sable antelope walk with a diagonal stride known as the cross walk that changes to an amble at a quicker walk. The trot is not a regular gait but appears to be a transition between a walk and a gallop; when excited or alarmed, an elegant trot is performed, where the forelegs are lifted high. In sable antelope, the gallop is more pronounced when compared to other *Hippotragini,* where they flex their legs more than the rest. When running at full gallop, the chin is held towards the front with the horns lying in line with the head and neck (Estes, 1991).

2.4.8.3. Communication

Communication is divided into four parts: visual, vocal, olfactory, and tactile (Estes, 1991). Visual communication is the most important, discussed in more detail under agonistic behaviour in section 2.4.8.5 (Estes, 1991).

Vocal communication is auditory signalling between individuals (Estes, 1991). The most common sound in sable antelope herds is the warning snort, where a short gush of air is forced through the nose. This snort is made by all individuals whenever danger is suspected or threatening (Grobler, 1974; Estes, 1991). When a threat is suspected, another typical sound made by all age groups is a soft, high-pitched whine, most commonly heard amongst the calves (Grobler, 1974).

When sable antelope calves are caught, they utter extreme distress calls, unlike any other sound associated with other antelope being caught (Grobler, 1974).

The very young, almost newborn calves remain silent when hiding (Grobler, 1974). While the mother is looking for her calf, she makes short soft grunts that the calf responds to with bird-like calls (Grobler, 1974; Estes, 1991).

Apart from the warning snort and whine, the adult males bellow/roar when fighting and snort when retaining the breeding group in their territory (Grobler, 1974; Estes, 1991).

Olfactory communication is important in sable antelope. Hoof glands are well developed in sable antelope, whilst males use their dung to demarcate their territories. Urine testing is prominent in sable antelope, done by both male and female animals (Estes, 1991).

Tactile communication (physical touch) is not important in sable antelope; individuals tend to maintain a safe distance beyond the reach of each other's horns. Social grooming is rare, but rubbing the head or horns on another animal's torso is a common assertion of dominance among females and immature sable antelope (Estes, 1991).

2.4.8.4. Territorial behaviour

Territorial behaviour can broadly be divided into patrolling, ceremonial defecation, vegetation horning and herding (Estes, 1991).

Sable antelope bulls patrol their territories regularly, following roads and paths often frequented by other sable antelope, stopping to sniff the ground, mainly where dung of other sable antelope is found (Estes, 1991).

Ceremonial defecation occurs every hundred meters; the bull paws vigorously with alternate forefeet, before or while defecating. The tail is raised and waving at the time. Scrape marks made in the proximity of the dung are the only way to identify if the dung is a sable antelope's; roan antelope do not paw the ground when defecating (Estes, 1991).

Territorial male sable antelope normally walk at the back of a herd but manage/control the herd using dominance and or threat displays (Estes, 1991).

Horning or thrashing vegetation is common in sable antelope, where branches often get broken in the cleft of their horns whilst the outer curve of the horns are rubbed smooth against the stem of trees and shrubs (Estes, 1991).

2.4.8.5. Agonistic behaviour

Agnostic behaviour is characterised by dominance/threat and defensive/submissive displays (Estes, 1991).

Dominance/threat displays are composed of: the lateral presentation of the body in the erect posture; the approach of an individual in a low stretch posture; rubbing head/horns on the opponent; horn presentations (high, medium and low); head held at an angle (angle-horn); symbolic butting, head shaking; sweeping movement of the horns; chasing and roaring (Estes, 1991).

Defensive/submissive displays are composed of: the head held low posture, appeasement ceremony, fear gaping, lying out and producing a braying like distress call (Estes, 1991).

To illustrate many of the displays mentioned above, the section below interprets the sable antelope in context with the herd's social structure.

The social structure is characterised by aggressiveness and intolerance, where individuals exert dominance over one another. Dominance display can be defined as an act by one individual over another, between and within the different sexes, that results in signs of submission (Grobler, 1974).

Dominance displays in order of aggressiveness as described by Grobler (1974) are:

a. “Stiff-neck” display, where the head is held erect, the neck muscles contracted, and the chin tucked in.
b. “Lateral intimidation” display usually follows the “stiff-neck” display, where the head and neck are held in the same position, but in addition, the tail is held out stiffly. During this display, the two individuals stand laterally with heads at opposite ends. The tail twitches periodically.
c. “Low-intensity fighting” from the lateral position, the two animals may suddenly swing around, drop to their knees facing each other. The display may end after sparring or continue into high-intensity fighting.
d. “High-intensity fighting” is characterised as fighting between two contestants on their knees, accompanied by horn slashing and bellowing (males). It is not unknown for bulls to break off pieces of their horns during these fighting bouts.

Even though dominant adult females will lead stampedes and investigate danger, they are generally only concerned with the group's welfare (Grobler, 1974). Dominance among females is asserted by a series of actions of increasing severity, starting with displacing (ousting), followed by the dominant animal rubbing its head and horns on the other animal’s neck, shoulder, or rump. If the horns are aimed at any individual, it is considered a severe threat (medial horn presentation). The harshest dominance display is the charge, resulting in a jab to the rump or side with the horn tips, where the head is moved either in an upward or sideward movement. The lateral display is usually only seen when animals of nearly equal stature try to dominate each other. Females standing a couple of meters apart in what is known as the reverse parallel stance or circling, with heads and tails held up high, are a good indicator of confidence and intensity between individuals of similar stature (Estes, 1991).

Displacement activity is when an animal displays an alternative behaviour to what it was doing, typically seen when a bull wants to defend his mating territory but is afraid of being hurt (Fraser, 1959). “Play behaviour” between yearlings and the newcomers of the year of both sexes often result in some form of dominance display. Chasing and sparring amongst youngsters is often a form of displacement behaviour when they are disturbed by man. Bachelor herd males are on occasion stimulated into dominance displays by man's presence, which could be seen as a form of displacement activity. Territorial males have been observed to pretend that they are browsing on a shrub or bush while watching the approach of an observer (Grobler, 1974).

The flehmen response is observed throughout the year by males of all age groups but rarely observed in females (Grobler, 1974).

The territorial males exhibit the most prominent displays of dominance. The “stiff-neck” and “lateral intimidation” displays are shown by territorial males to both males and females irrespective of age groups, usually ending with a backward sweep of the horns at the rear end of the contestant, who would run away submissively. The territorial male uses the display to chase the young bulls out of the breeding herd to form or join a bachelor herd (Skinner & Chimimba, 2005). A characteristic submissive posture of a contester is to retreat with their tail between their legs and hindquarters pulled in (Grobler, 1974).

When sub-adult males and bachelor males accidentally mix with a breeding group that has a territorial male present, the territorial male may charge at a selected individual, sweeping his horns side to side with an occasional snort, rarely touching the fleeing victim of the assault. Out of rut, bachelor and young sub-adult males are often ignored by the dominant male (Grobler, 1974)

A territorial dispute during the breeding season may lead to vicious fighting, sometimes leading to death. Fierce fighting has been observed outside the rutting season. Territorial males seldom pursue a potential contestant over their territorial boundary (Grobler, 1974). Male animals show dominance when entering a breeding group of females by extending their heads and necks horizontally, often followed by urethral smelling and the flehmen response (Grobler, 1974).

The most active display by a territorial male is perhaps the individual’s attempts at retaining the breeding herd within his territory during the breeding season. Individual males vary concerning what extent this is done; some round up the females into a compact group - achieved by literally rounding up any stray individual, using loud snorts and vicious horn sweeps. However, this rounding up action eventually stops because the territorial male in the neighbouring territory will treat them in the same manner (Skinner & Chimimba, 2005). Another example is where the male animal will outrun a stampeding herd of females and keep them in his territory using loud snorts and fierce horn sweeps; this may continue until the male is exhausted and cannot turn the stampede (Grobler, 1974).

Grobler (1974) explains that the order of dominance within the herd is: highest-ranking territorial male, dominant females (usually about three adult cows), adult females, subadult males, yearling males, and yearling males/females, and the latest calves born that year.

Territorial males actively display dominance because they must ensure and maintain their dominance within a breeding group. They initiate displays that lead to mating, maintaining their territory, defending their territory against any other male challengers and maintaining or establishing a high social ranking as a territorial male (Grobler, 1974).

2.4.8.6. Breeding and parent/offspring behaviour

The first step in courtship behaviour is the urine test or flehmen response performed by males of all age groups (Grobler, 1974). The urine is tested for sex pheromones (Dulac & Axel, 1995); this is done by the male pushing his nose into the urine of a urinating female then lifting his nose into the air with the upper lip curled slightly and the mouth open. The head is lifted to varying degrees depending on the individual and held in this position for several seconds before either walking off or repeating the flehmen response (Grobler, 1974). The importance of the vomeronasal organ in mammalian reproduction, which is directly tied in with the Flehmen response, is discussed by Estes (1972).

If the male animal gets a positive response from flehmen, he will approach the female and raise one of his front legs between the female's hind legs; this action is known as “laufschlag". Territorial males persistently pursue receptive females who at times run off for short distances; this is presumed to be the females’ way of making sure the male mounts her when she is fully receptive (Grobler, 1974).

With calving season approaching, pregnant adult females tend to disband into smaller groups (Grobler, 1974). Pregnant females tend to leave the herd at partus (Grobler, 1974) and hide the calf for about two weeks (Wilson & Hirst, 1977). The calves remain hidden in the grass for the first seven days after birth, usually with their head and neck bent back along their bodies. The calves only leave the hiding place when it is time to suckle and be groomed by their mother (Grobler, 1974). After this, the cow with her newborn calf joins the small group or forms a loose association with a larger group. After two to three weeks, the cows join other females with calves, yearlings and sub-adults, forming the breeding herds (Grobler, 1974). After the mother leaves, the calves tend to hide and remain hidden when approached; when frightened, the flight distance of the older calves is about five metres. The newborns do not make any attempt to escape at all (Grobler, 1974).

Sable antelope cows synchronise their births within a social group resulting in more calves being born at approximately the same time. Calves of similar age form nurseries and stay together (Grobler, 1974; Thompson, 1998). Nurseries are hypothesised to be the mechanism for enhancing the survival of neonates by decreasing the total number of calves taken by predators, more effective maternal defence, communal care of the young and a reduction in male harassment, directed at the cows when the cows enter postpartum oestrus (Thompson, 1998). Sekulic (1981) found that in the Shimba Hills region of Kenya, births occur synchronously within large herds but at different times for different herds within the same locality.

There are two types of maternal care systems for ungulates: the follower and hider systems. “Follower” systems are categorised by species of animals that have synchronous births and breeding seasons (Rutberg, 1987); mothers are accompanied by their infants from birth, protecting them from predators (Estes & Goddard, 1967). In “Hider” ungulates, the infants are left lying in seclusion for most of their early lives and are reunited with their mothers for brief periods at infrequent intervals throughout the day. After several days to several months in hiding, the infants are integrated into the adult group. Ungulates in the hider system tend to have either fully or partial asynchronous births, decreasing deaths of infants by predators locating them (Ims, 1990).

Calves often form nursery groups within earshot of the breeding group. There usually is an adult female or a few yearlings present in this nursery group. If the very young calves are chased on foot, they tire soon and drop into the long grass and hide (Grobler, 1974).

2.4.9. Reproductive biology

In nature reserves, the rut is usually between April and July, with a pregnancy that generally lasts for approximately eight (240 days) (Wilson & Hirst, 1977) to 9 months (270 days) (Grobler, 1974, 1980a), using artificial insemination and/or embryo transplants, the duration of pregnancy is between 256 and 260 days (about 8.55 months) (De La Rey, 2020).

Calves are usually born in the green months in southern Africa. The peak calving season in the KNP is between February and March; in Zimbabwe, the peak calving period is March, and the peak calving season in Botswana is January into early February. These dates coincide with the peak plant growing season and availability of nutritious forage for milk production (Wilson & Hirst, 1977).

In the wild, females become receptive when they are approximately two years old, having their first calf when they are roughly three years old (Grobler, 1974; Estes, 1991). Sexual receptiveness continues through to old age as some old females (10 + years) have been seen with newborn calves (Grobler, 1974).

At oestrus, the cow’s vulva is slightly swollen, pink in colour, and has up to six small pimple-like swellings, and exudes a yellow discharge (Grobler, 1980a).

Cows have four nipples on their udders, of which two seem to be used for suckling (Grobler, 1974).

Pregnancy in sable antelope: at seven months into the pregnancy, pregnant sable antelope cows' udders start increasing in size; the four nipples become taut and pink in colour. The udders become progressively bigger and can be seen bulging between the legs at four weeks from birth. The stomach/belly region takes on a heavy sagging appearance, ultimately focussing to a point near the navel. The full-term foetus can be seen moving from the outside (Grobler, 1980a).

Cows move away from the herd to calve down in long grass (Grobler, 1980a). The cow licks the calf clean and eats the afterbirth (Grobler, 1974, 1980a). A wet/fresh umbilical cord that is still attached is a good indication of a newborn sable antelope, but once dry, it may remain attached for as long as eight weeks (Grobler, 1974). The birth mass for 26 males varied between 13.5 and 19.8kg (Mean of 18.95 with a SE of 0.76); for 22 females, it varied from 13.5 to 22.5kg (mean of 20.33 with a SE of 1.05) (Grobler, 1980a).

Captive sable antelope calves doubled their live mass gain in seven days showing rapid growth. Calves have been observed to suckle at any time of the day, which usually lasts for 5 to 10 minutes. As the calf gets older, the number of feeds decreases until weaning at about eight months (Grobler, 1980a). During suckling, the sable antelope cows groom their calves, licking the anal and inguinal region, stimulating the calf to defecate and urinate. Calves start grazing/nibbling grass at approximately 30 days old, where older calves have been seen to suckle until the age of eight months (Grobler, 1974)

2.4.10. Population ecology

Sable antelope's population structure is composed of three parts (Grobler, 1974):

1. Breeding groups: consisting of adult females, sub-adult males, yearlings, youngsters born that year and on occasion, a single adult territorial male.
2. Bachelor males: males varying from two to 12 in number, ranging from four years old to adult.
3. Territorial males: adult males who are either solitarily or found within breeding groups.

2.4.10.1. Breeding Groups

When considering wild sable antelope, the breeding group pass through three phases during the year (Grobler, 1974). Approximately three months before the calving season, the adult females disperse into smaller groups. The larger groups consist of last season's young, a few sub-adult males and a few sub-adult females (Grobler, 1974).

Once the small calves are old enough to join the herd, the herds merge into larger units within their home ranges, which continues into the rut (see section 2.4.8.6 for territorial males and their interaction with the cow herds during the rut) (Grobler, 1974). The rut coincides with the latter part of the green season, the dry season (May to July) for free-roaming sable antelope in South Africa (Kriek, 2005).

Post rut, the animals concentrate in larger groups on selected grazing areas regardless of home range boundaries (Grobler, 1974), coinciding with the latter half of the dry season for sable antelope living in South Africa.

2.4.10.2. Bachelor males

Male sable antelope either leave or are evicted from the breeding herds early in their fourth year. The ousted four-year-olds will group and live together for a short time; before joining the older males in bachelor herds (Grobler, 1974). A bachelor group supplies protection to the growing male until he is ready to stand alone as a territorial bull (Skinner & Chimimba, 2005). Males are tolerated in the herd they are born into while they are still calves approaching sub-adulthood. Young weaned bulls leave the herd at an older age when compared to other ungulates; the reason for this is that their resemblance to young females at the same age minimises the territorial male's aggression towards them (Estes, 1999).

Grobler (1974) noted that no male with pronounced secondary growth (post) was ever seen amongst the animals in a bachelor herd, making them sub-adult bulls between four to seven years old. Bachelor groups are tolerated within the territories of the territorial males. They may encounter the breeding herds during the year without showing any interest in the females. Bachelor herds tend to occupy particular areas, which they do not actively mark or defend in any way (Grobler, 1974).

2.4.10.3. Territorial Males

Once a bachelor sable antelope reaches full maturity, he establishes a territory at an estimated seven years of age and older, which is achieved by either taking up a vacant territory or evicting a territorial male from his (Grobler, 1974; Skinner & Chimimba, 2005). Territorial bulls reside in an area of between 25 to 40 ha (Grobler, 1974), which they guard and defend, keeping competing bulls away during the mating season (Grobler, 1974; Skinner & Chimimba, 2005).

Grobler (1974) described three classes of territorial bulls studied in the Matopos National park:

- Class one; Central territorial bull has the highest status, and he has continuous contact with the breeding herd.
- Class two: Peripheral territorial bull has a lower status, and he occasionally makes contact with the breeding herd.
- Class three: Outside territorial bull, with the lowest status in the breeding hierarchy, with little or no contact with the breeding herd.

2.5. Nutrition overview

When considering nutrition in terms of animal husbandry, it is crucial to understand its intricacies and how it affects the animals at different physiological production stages. Since the inception of sable antelope ranching, ranchers realized that traits like superior horn growth were achieved by combining outstanding quality animals in terms of horn length with an optimized feed supplement (Warren, 2021). Thus, arguing the genetic bias of genotype = phenotype + environment, where the supplement and the high-quality grazing in the area supplied optimal nutrients for optimal horn growth.

No species-specific data exists regarding nutrient requirements for the sable antelope; therefore, this section focuses on literature explaining essential factors that need to be considered when formulating a feed for a selective grazing species.

2.5.1. Forage quality or feed value

Forage quality or feed value can be defined as the link between the characteristics of the particular forage and how it influences animal performance, which can be broken down into its nutritive value and how much of it the animal physically eats (Meissner *et al.*, 1999).

The nutritive value of the selected forage is the chemical composition (nutrients) and the digestibility thereof; in other words, how much of what particular nutrient will the animal absorb per kilogram of ingested feed (Van Soest, 1994; Meissner *et al.*, 1999).

Generally speaking, the energy content in feedstuffs comprises an association of soluble carbohydrates, starch, organic acids, cellulose, hemicellulose and lipids (fats). Proteins, vitamins, minerals and trace minerals provide essential components for the animal's diet required in the correct amounts and ratio's for animals to perform optimally (Meissner *et al.*, 1999).

Forage plants may contain tannins or even poisonous elements within their leaves that negatively affect animal performance (Meissner *et al.*, 1999).

2.5.2. Chemical composition

Plant matter consists of various chemical constituents that serve as nutrients for herbivore animals (Van Soest, 1967). Some of these nutrients can be considered energy sources, while others satisfy specific requirements of the animal's body. The chemical components can be divided into two larger categories, the cell wall contents (CWC) and cell contents (CC); these two categories are broken down into the digestible, indigestible and poorly digestible fractions (Van Soest, 1967). Cell wall contents are highly digestible and soluble in neutral detergent where cell wall constituents are either indigestible or poorly digestible; thus, they are partially soluble in acid detergent (Table 2.2) (Van Soest, 1994).

When analysing feedstuffs, the correct analysis depends on identifying the physical and biochemical factors that influence the biological availability of the feed fractions, called class 1-3 (Table 2.2). In class 1, the total available nutrients and the actual extent of digestion are determined by the competition between rates of digestion and passage; in class 2, the nutrients exhibit incomplete availability, where portions of the feedstuffs are enzymatically nonhydrolyzable; in class 3, the nutrients are unavailable, due to being within the lignified fraction (Van Soest, 1994).

Table 2.2 Chemical constituents/bioavailability of forage components, adapted from Van Soest (1994) and (Meissner *et al.*, 1999) based on (Van Soest, 1967).

Plant constituent	Analytical constituent	Chemical constituent	True digestibility %	Limiting factor (relative to animal utilization and response)
Class 1 Cell contents (CC)	Soluble in neutral detergent	Soluble carbohydrate	100	Intake
		Starch	90+	Retention time in the digestive tract
		Organic acids	100	Intake
		Pectin constituents	95+	Fermentation via microbes to VFA’s and Ammonia + other microbial products
		Real protein	90+	Fermentation and accumulation of indigestible material
Class 2 Cell wall component (CWC)	Insoluble in neutral detergent	Cellulose	0-100	Fermentation via microbes to VFA’s and Ammonia + other microbial products
		Hemicellulose	0-80+	Fermentability is limited by Lignification, cutinisation, silicification
Class 3 Cell wall component (CWC)		Lignin	0	These chemical constituents restrict the digestibility of cellulose and other potentially digestible fractions
		Cutin	0	
		Silica	0	
		Tannins, essential oils, and polyphenols	0	Inhibit proteases and cellulases from functioning Low molecular weight components may be absorbed but are excreted without it being used.

Note: Class 1 = Completely digestible & available; Class 2 = Partially unavailable due to lignification; Class 3: Completely undigestible & unavailable

2.5.3. Structural constituents (cell wall, fibre)

The structural constituents, generally known as the cell wall and fibre fraction of plant material, consisting of polysaccharides, lignin and some proteins, can be subdivided into the following fractions: matrix polysaccharides like hemicellulose and pectic substances and fibre polysaccharides (cellulose, lignin and Maillard products (protein damaged by heat)) (Van Soest, 1994), traditionally known as fibre, which may be partially digested by the herbivore animal (Meissner *et al.*, 1999).

The stems of most forages contain a larger percentage of polysaccharides and lignin than what the leaves do (Buxton & Redfearn, 1997). This proportion increases as the plant mature in both temperate and tropical grass species. The same is true for leguminous species (Buxton & Redfearn, 1997; Meissner *et al.*, 1999). The lignin component in plant fibre resists enzymatic (microbe) attack, reduces the digestibility due to the way it is linked to specific points on the polysaccharide chain and prevents physical attachment of rumen bacteria to the cell walls (Meissner *et al.*, 1999).

Variations within the concentrations of the different structural constituents and their components in plant material are less significant in herbivore nutrition than the interactions found between the constituents, i.e., the lignin concentration relative to the concentration of other polysaccharides has less of an effect than the effect lignin has on the polysaccharide within the cell constituents. Once lignin has been removed, polysaccharides found in the cell wall are more digestible. Lignin and its association with polysaccharides in plants is essentially an anomaly and is not entirely understood. It is a phenyl-type polymer that interconnects in various proportions and sequences that is difficult to describe, and it cannot be broken down by normal hydrolysis (Meissner *et al.*, 1999).

2.5.4. Protein

Protein is usually the first limiting nutrient in low-quality veld / natural rangelands (Köster *et al.*, 1996; Bonhert & DelCurto, 2003). Crude protein is comprised of natural protein as well as non-protein nitrogen (NPN) and is calculated by multiplying the nitrogen content of the forage (feed source) x 6.25 (McDonald *et al.*, 2002). Crude protein is a gross measurement of protein, and it does not distinguish between the rumen degradable protein that is available to the microbes and the rumen undegradable portion that gets absorbed in the small intestine, it also does not take into account the origin or the quality of the protein (Meissner *et al.*, 1999; McDonald *et al.*, 2002).

Where the crude protein concentrations in veld/rangeland forages are low and unable to meet the animals' minimum requirements, as is frequently found in the sour veld regions during the dry seasons, protein needs to be supplemented; typically in the form of a lick, pellet or low intake feed, composed of a combination of natural protein and NPN (urea) (Meissner *et al.*, 1999; Foster *et al.*, 2020).

Crude protein concentrations vary widely among different forage plants and the maturity of the respective plant - where the crude protein concentrations decline relative to increasing age (Lee, 2018). Application of nitrogen fertilizer to planted forage will increase the crude protein concentration in that forage, where a significant portion will be in the form of NPN while the plant is still green and growing (Sun *et al.*, 2008).

2.5.5. Nutrient supplementation of the foraging animal

South Africa has over 14 different vegetation types that ecologists classify as areas where game ranching occurs (Van Rooyen & Du P Bothma, 2016). The range of veld types with the associated range in species composition, forage production and nutritive value of the produced veld forage varies greatly between vegetation types and within species; what confounds this further is the unreliable rainfall. The ruminant animal is not only confronted with a wide range of vegetation to choose from but that the food source fluctuates in quality and quantity (Meissner, 1999) as seasons change and drought sets in. Food sources fluctuating in quality and quantity is the main reason why supplementation is necessary if the objective of the ranch is for the animals to perform optimally (Bonhert & DelCurto, 2003).

The two most important reasons for supplementing minerals, energy and protein (Meissner, 1999), particularly rumen degradable protein (Köster *et al.*, 1996), is to correct deficiencies in the diet and to stimulate grass or forage intake (Meissner, 1999; Bonhert & DelCurto, 2003). The most important aspects of supplementation are; supply the appropriate amount and ratio of nutrients as economically as possible to the different types of animals at the appropriate time of the year (Meissner, 1999).

2.5.6. Protein and energy

Protein and energy supplementation individually or in combination is required in both sweet veld and sour veld. Insufficient forage is often the main limitation to animal production in the sweet veld, whereas in sour veld regions, the poor quality of the available grass limits animal performance. The dry season (winter) is problematic for animals in both sweet and sour veld regions, the main reason being that the plant cell walls lignify as the plant matures, resulting in less protein and energy for the animal to consume. Lignification and the decrease in protein and energy in the plant matter reduce digestibility and intake. Deficiencies of either protein or energy can result in weight loss and reduced fertility (Meissner, 1999).

Protein, more specifically rumen degradable protein (RDP), is the first limiting nutrient in dry pastures (Köster *et al.*, 1996). Energy supplementation on protein-deficient pastures can impact animal performance negatively (Van Niekerk, 1978; Bonhert & DelCurto, 2003). In contrast, energy is often limiting during summer due to the low dry matter content of green succulent forage and is thus associated with a low dry matter intake. Supplying energy at these times has boosted growth and conception rates in cattle (Bonhert & DelCurto, 2003).

2.5.7. Important principles when supplementing energy to animals

- Supplementing animals with readily available carbohydrates may reduce roughage intake by roughage substitution and reducing the fibre's digestibility (Doyle, 1987). Any form of energy supplementation will likely reduce the total intake of low-quality roughage if a protein source is not added (Coombe & Tribe, 1962; Hennessy *et al.*, 1983; Bonhert & DelCurto, 2003) because nitrogen is likely to be more deficient than energy. Increasing energy levels will increase the substitution rate (Crabtree & Williams, 1971; Mulholland *et al.*, 1976). However, these relationships are not linear due to a portion of the energy (starch) that can bypass rumen fermentation (Orskov, 1986). These bypass energy sources are digested and absorbed in the small intestine (Orskov, 1986). Thus they have no or little effect on substitution due to it not affecting the rumen microbe (Meissner, 1999).
- In order to gain the maximum benefit from energy supplements, other nutrients such as protein (N) and minerals should be added in the correct proportions for the specific level of desired animal performance (Meissner, 1999).

When considering the energy requirements of sable antelope, it is important to realize that no research has been done on this topic, so researchers, ranchers and veterinarians typically use data from the nearest well-studied livestock species as a guide. In an attempt to estimate energy requirements of the sable antelope in Megajoules per day, a derived log-log transformation equation was used on the data published in Meissner (1982), aiding researchers with a more accurate method in determining the metabolizable energy requirements of different game species at their respective physiological production stages. The results derived from this study will permit game reserves and game ranches a method to calculate carrying capacity estimates more accurately. This will be discussed in detail in chapter 4.

2.5.8. Supplementation practices

Most of the literature on supplementation practices is from work done on cattle and sheep. Salt licks containing macro and trace minerals are the most widely used form in which minerals are supplemented to livestock in South Africa. The use of salt is based on the assumption that salt can be used to regulate intake and has proved effective in supplementing protein (NPN), macro and trace minerals (Paulson *et al.*, 1968; Espinoza *et al.*, 1991; McDowell, 1996; Meissner, 1999; Greene, 2000; Stanton *et al.*, 2000; Orsmond, 2007; Handeland *et al.*, 2008).

Protein licks containing salt are also widely used to supplement livestock with protein, where natural protein and NPN are combined. These licks usually have macro and trace minerals combined into the final mix (Meissner *et al.*, 1999).

Prior to the game farm industry boom, feeding of game animals took place on an *ad-hoc* basis, where lucerne supplied roughage, protein and energy, salt blocks supplied salt and calf starter rations were the first form of feeds used as supplementation.

2.6. Animal Husbandry

2.6.1. Long term improvement strategies

2.6.1.1. The history behind the initiation of the Gravelotte Wildprodusente (GWP)

The following section describes the history of sable antelope living on private property in the Letaba region before the prolonged drought of 1960 to 1964. The Letaba area can broadly be classified as east of the Drakensberg mountains, west of the Kruger National Park, as far south as Hazyview and as far north as the southern slopes of the Soutpansberg mountains. In the 1920s, this mineral-rich area was sparsely inhabited by people due to malaria. Malaria did not prevent the people from entering the area to mine or hunt; it simply forced people to only visit the area during the dry winter season when the malaria mosquito was absent. Whilst searching the area for minerals such as mica, veldspar, emerald, silica, and corundum, the veld was regularly set alight (veld fires). This allowed the miners to find the sought after minerals and forced the animals out of the burnt areas (Osmers, 2018). The area was regarded as “wild Africa” due to very few people living in the area. Sable and roan antelope living in the area were hunted as a food source during the dry winter months (Osmers, 2018; Warren, 2021).

Sable antelope numbered between 15000 and 20000 in the 1930s in the Gravelotte area (Rabie, 2011a). In the general Lowveld region outside the KNP, sable antelope numbers were estimated to be over 36000 animals (Ebedes, 1992).

During the latter part of the 1940s and 1950s, Mr Osmers, a young man at the time, would join his father on hunting trips throughout the region, and *en route* to their destination, which was usually Klaserie, they would encounter many herds of sable antelope numbering between 40 and 60 at a time. Mr Osmers and his family also often encountered sable antelope when walking about in the veld in that region (Osmers, 2018).

Also, in the 1950s, Piet Warren's father purchased a property in the Gravelotte area (Figure 2.18) where the family ranched with cattle (Warren, 2021); at the time, sable antelope were considered a nuisance due to their habit of moving from ranch to ranch (draadkruipers), resulting in no-one owning the animal (Osmers, 2018; Warren, 2021). Nevertheless, today this ranch is considered one of the top breeders of quality sable antelope. Before the 1950s, the Letaba area east of the Drakensburg Mountains was predominantly grassland with scattered trees. A photographic survey in 1954, a few kilometres away from Mr Piet Warren's ranch Josephine, indicated a tree coverage of 250 to 400 trees per hectare; currently, this area has more than 3000 trees per hectare. The area has never returned to its original grassland ecosystem since the great drought of 1960-64; trees have taken over the landscape (Warren, 2021).

During the 1960's the magistrate stationed in Tzaneen, Honourable John Nel, encouraged ranchers in the Letaba district to start a committee that would keep an eye on the sable antelope population in that area. Mr Piet Warren's father and Mr Ben Vorster were part of this committee. The committee met at least once a year, where they discussed ranching matters, including the sable antelope. The classification of sable antelope and steenbok as royal game due to their low numbers were two of these meetings' outcomes. No sable antelope or steenbok was allowed to be hunted without the hunter purchasing a permit. Only male animals were allowed to be hunted (Warren, 2021).

Mr Warren mentioned that there were a few thousand sable antelope in the area at the time.

In 1985 the Chief Directorate of Nature and Environmental Conservation (CDNEC) initiated a survey of the total sable antelope population in the Transvaal, excluding the KNP, where 841 sable antelope were found to live in the Letaba district (Nel, 1992). With a historical estimation of over 15000 animals in the 1930s that declined to the 841 animals living in the Letaba district in 1985, Dr S. S. du Plessis, the director of Nature Conservation, requested Mr Pieter Vorster to start the Letaba Sable Antelope study group (Rabie, 2011a).

2.6.1.2. Gravelotte Wildprodusente (GWP)

The Gravelotte Wildprodusente (also known as the Letaba Sable Antelope Study Group, Gravelotte Sable Study Group, and the Mopani Wildtelers Vereeniging), will be referred to as GWP in this review, was started on the 5th of August 1986; the members at the time owned more than 80% of the sable antelope in the area. The study group's mission included the conservation, extension, and distribution of sable antelope herds in South Africa. The study group's approach to training started with the basics due to the different agricultural and business backgrounds individuals had, some being livestock, fruit farmers and others, game ranchers (Scholtz, 1992).

The GWP's first phase in reaching its goal was to train the relevant people by specialists on how to conserve the sable antelope and its habitat. Topics covered included: a bibliography on suitable habitat, research and behaviour of sable antelope; wildlife and pasture management; the role of climate and its influence on the environment; wildlife census, planning and evaluation; combating poaching and coordination; field excursions on wildlife management and habitat suitability; grass identification course; population dynamics; pasture management; the influence of fences on genetic diversity; the importance of population dynamics; ecology of the sable antelope, use of fire in veld management, habitat of sale antelope and veld burning trials (Scholtz, 1992).

Phase two was the data-gathering phase. Miss S.R. Basson, a Technicon student at the time, liaised between nature conservation and the study group members (landowners) in collecting ranch specific information to compare this with the other information collected from the other reserves and game ranches; the results were used to create the GWPs guidelines of how to ranch with sable antelope. The study was done in the Gravelotte – Letsitele- Phalaborwa district. This area housed approximately 700 of the 841 animals known to be alive outside the Kruger National Park. Figures 2.18 and 2.19 illustrate where the study was done, including the locations of the respective ranches situated relative to one another.

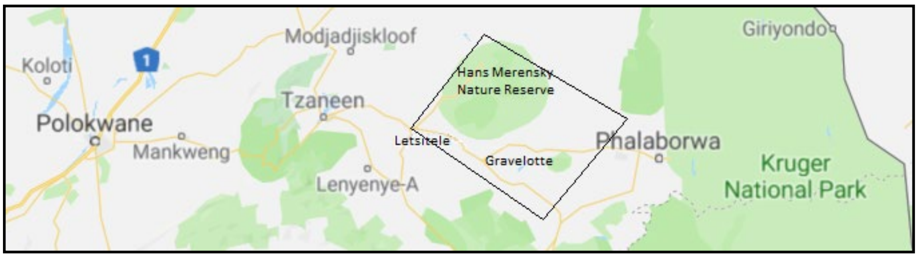

Figure 2.18 Study area relative to the nearest main towns and cities adapted from Google Earth Map (Shepstone, 2021).

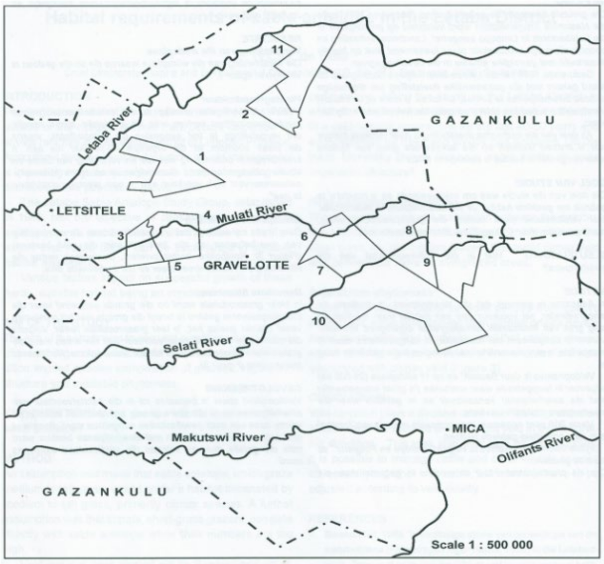

Figure 2.19 The ranches assessed during the study adapted from Basson (1989) and De Beer (1992). Ranches are 1 – Thiergarten; 2 – Blackhills; 3 – Cottondale; 4 – Rubbervale; 5 – Maranda; 6 – Josephine; 7 – Danie; 8 – BVB Ranch; 9 – Lekkersmaak; 10 – Ermelo Ranch; 11 – Hans Merensky Nature Reserve.

The data collected included: the history of the wildlife; climatological data; mapping of the individual ranches; aerial photograph interpretation and identification of plant communities; evaluation of the geology; regular monthly compilation of wildlife and livestock numbers; monitoring of the grass layer; monitoring the tree layer; determining the home range of the sable antelope; determining habitat preference and diet.

The GWP, established in 1986, had a bad start, where the sable population dwindled to a total of 400 between 1986 and 2000 (Table 2.3). In 2000, sable antelope breeders in co-operation with the Department of Nature Conservation managed to stop the declining trend. This success led to an increase in sable antelope numbers, leading to the Letaba Sable Study Group formalizing their findings as guidelines in an official document written by the late Dr Paul Meyer (wildlife Veterinarian) and Mr Piet Warren in 2005 (Warren & Meyer, 2005).

The main reason for the decline in sable antelope numbers was the degradation of their natural habitat, be it natural or man-made. The following are the main reasons documented for the decline in numbers (Du Toit, 1992; Warren & Meyer, 2005; Rabie, 2011a):

- Previously unoccupied ranches/areas now had people living on them all year round due to Dr Siegfried Annecke's success in controlling Malaria.
- Sable antelope prices increased from R1315 per animal in 1977 to R2983 in 1980, resulting in many animals being caught and sold in the Leydsdorp district.

- Increased cattle numbers since the 1950s and the fencing used to control them resulted in a reduction of natural habitat, natural movement, genetic restriction, and a decline in numbers.
- The Increased cattle numbers increased external and internal parasites, which spread across to the sable antelope, inducing loss of condition and mortalities.
- The use of organophosphates in tick control on cattle (dip) caused a near extinction of the red and yellow-billed oxpeckers in the region. These birds are essential in controlling ticks and thus tick-borne diseases. The decline in birds led to an increase in tick-borne problems in sable antelope.
- The establishment of artificial water points in areas where there was limited open water in the past led to an increase in game numbers, animal species, and predators. The increase in game numbers resulted in increased competition for the available high-quality forage.
- The drought, overgrazing by livestock, and the prevention of natural veld fires resulted in habitat changing (negative succession) from open tall grass savanna with <400 trees per hectare to invading bushveld with > 3000 trees per hectare.
- Sable antelope meat is delicious, so the animals were hunted for biltong and rations.
- Small meta-populations of sable antelope lived in livestock camps on different ranches full of predators. These isolated herds had little chance to mate with new unrelated animals, leading to severe inbreeding. The lack of home range and the ever-present predators resulted in few neonates making it to maturity, resulting in zero growth or a decline in animal numbers over time.

The above section summarised what the causes for the decline were; the section below summarises the implementation of a population recovery plan within the GWP's area (Du Toit, 1992; Rabie, 2011a). The GWP realised they would need to address the lack of suitable habitat for sable antelope since there was none available anymore. On ranch changes implementing habitat recovery and rehabilitation were as follows:

- Invasive tree and bush species were removed either physically or chemically.
- All cattle were removed in sable antelope suitable habitats; the grass was burnt to imitate the natural cycle and control the excessively high tick numbers (parasite control).
- Grass species composition was improved. Sable antelope prefer savanna bushveld with medium to tall grass.
- The camps' tree and bush compilation on study group ranches improved where it could be classified as suitable habitat for sable antelope.
- Sable antelope are water dependant; efforts were made to ensure available water in all camps.

- Species competing for the available grazing, such as impala, blue wildebeest, zebra, and cattle, were removed from sable antelope camps.
- Sable antelope are seasonal breeders; the majority of the cows calve down between February and March in the Letaba Gravelotte area, making the calves easy targets for predation, which lead to rancher's predator-proofing their camps using suitable fencing.

The GWP successfully took their original herd of animals (members only) from about 800 animals in 1986 to over 1800 in 2010/2011 (Table 2.3). It is important to consider what happened with the animals at farm level between 1986 and 2010: from 1986 to 1995, the animals roamed freely on the different farms (Figure 2.19); in 1995, a joint operation between the ranchers and the Department of Nature Conservation caught the surviving breeding herds and introduced them to suitably prepared camp systems; in 1996 unrelated bulls were introduced to these herds (Warren & Meyer, 2005); in 2002 the gathering of herd production data was initiated, where the number of bulls, cows, calves were collected, and different production parameters were calculated (Warren, 2021).

Production parameters, such as weaning percentages, were calculated, the weaning percentage was as low as 22% in the years 1999/2000 (1 June 1999-31 May 2000) and 2000/2001 (Warren, 2006)(Mopanie Studiegroep, 2006), which increased to 62% in 2003/2004, and increased to an approximate average of > 80% in following years (Table 2.3).

The downward trend stopped in 2000 (Warren & Meyer, 2005), indicating that it took about three to 4 years (one generation time it takes a female from birth to calving down) for the herd dynamics to stabilize and allow the population to grow in number again. In other words, the cows unable to calf or wean a calf, be it due to age or inbreeding coefficient, would have to die or be removed from the herd before the animal numbers, calving, and weaning percentages would improve.

Feed played an essential role concerning the improved calving percentage seen in 2003/2004 where the calving percentage increased to 76% when animals received extra supplemental feed (Gravelotte Wildprodusente, 2014). Nutrient supply in the form of balanced feed fortified with vitamins A, D and E, led to a dramatic increase in fertility, improving the inter-calving period to as short as ten months (Warren & Scholtz, 2010).

The fact that prime sable antelope breeding stock had increased in value during this period also made the transformation and implementation of the above strategies more financially attractive than traditional beef farming.

One of the most significant decisions the GWP made was to turn the tide on inbreeding. Twenty-two cases of sable antelope calves with unrelated parents were studied. Mortalities before six months of age were 18%; thus, 82% of them survived. On the other hand, seven out of 10 calves born from parents related to each other died, resulting in only 30% of them surviving (Ralls *et al.*, 1979). The paper on Genetic diversity in isolated populations of sable antelope (Grobler & Van Der Bank, 1994) convinced ranchers in the GWP to get unrelated bulls into their breeding programs (Warren, 2021). The demand for unrelated animals increased, resulting in suitable animals being imported from neighbouring countries like Zambia, Malawi, and Zimbabwe, supplying new bulls and cows to the growing South African herd (Kriek, 2016a; Warren, 2021). Outbreeding with unrelated animals positively affected the sable antelope population by increasing the numbers of sable antelope, reducing mortalities due to inbreeding and, improving the quality of the animals bred (Kriek, 2016b).

Table 2.3 Sable antelope population data and performance calculations recorded by residents in the Gravelotte area from 1930 to 2016/2017.

Year	Period 1 June - 31 May	Ranchers	Total animals 31-May	Bulls	Total cows	Total calves born	calves - dead	Calves weaned	Animals sold	Bulls hunted	Calving %	Weaning %	Reference
1930			15000-20000										Warren & Meyer, (2005)
1960			2000										Warren & Meyer, (2005)
1972			1400										(Warren & Meyer, 2005)
1986			800										(Warren & Meyer, 2005)
1993			417										(Warren & Scholtz, 2010)
2000	1999/2000		400[a]		100			22				22.0%	(Warren & Meyer, 2005[a]; Warren, 2006)
2001	2000/2001		470[b]		100			22				22.0%	(Warren, 2006, 2021[b])
2002	2001/2002		497-510[b]	104	134	103	32	71			76.9%	53.0%	(Warren 2021[b]; Gravelotte Wildprodusente, 2017)
2003	2002/2003		635		150			116				77.3%	(Warren, 2006)
2004	2003/2004		645		172	130	23	107			75.6%	62.2%	(Mopanie Wildtelers, 2006)
2005	2004/2005		772		223	208	8	200			93.3%	89.7%	(Mopanie Wildtelers, 2006)
2006	2005/2006		861	250	270	231	8	223	130		85.6%	82.6%	(Mopanie Studiegroep, 2006)
2007	2006/2007	21	1072	298	331	311	20	291	168		94.0%	87.9%	(Mopanie Wildtelers Vereeniging, 2009)
2008	2007/2008	20	1234	330	414	365	25	340	204		88.2%	82.1%	(Mopanie Wildtelers Vereeniging, 2009)
2009	2008/2009	22	1435	364	480	424	22	402	252		88.3%	83.8%	(Mopanie Wildtelers Vereeniging, 2011)
2010	2009/2010	25	1585	361	517	519	24	495	300		100.4%	95.7%	(Mopanie Wildtelers Vereeniging, 2011)
2011	2010/2011	23	1935	500	609	583	35	548	157	20	95.7%	90.0%	(Gravelotte Wildprodusente, 2013)
2012	2011/2012	24	2040	583	648	553	27	526	308	25	85.3%	81.2%	(Gravelotte Wildprodusente, 2013)
2013	2012/2013	24	2340	650	734	630	35	595	421	49	85.8%	81.1%	(Gravelotte Wildprodusente, 2015)
2014	2013/2014	21	2140	563	679	608	31	577	342	34	89.5%	85.0%	(Gravelotte Wildprodusente, 2015)
2015	2014/2015	24	2421	602	802	726	55	671	272	54	91.0%	84.0%	(Gravelotte Wildprodusente, 2016)
2016	2015/2016	25	2805	800	915	791	54	737	353	57	86.0%	81.0%	(Gravelotte Wildprodusente, 2016)
2017	2016/2017	28	3367	986	1087	862	81	781	285	51	79.0%	72.0%	(Gravelotte Wildprodusente, 2017)

Note, the subscripts in column "Total animals 31-May and in the Reference column refer to the origin of the data.

2.6.2. Guidelines for keeping sable antelope in captivity

Guidelines about keeping sable antelope in captivity are discussed below, using on-ranch investigations and the experience of the members of the GWP (Warren & Meyer, 2005). The guidelines are for animals living in medium camp systems, small camp systems and pens. When keeping animals in captivity without careful judgement, numerous problems may arise.

During the 1980s, the average game farm was approximately 2000 ha in size, which usually kept a breeding herd of sable antelope. Most of these farms were fenced, preventing animals from moving around, resulting in inbreeding. The GWP members witnessed a steady decline of the species. The weaning percentage at the time was about 20%. Further decline in numbers post-weaning can be attributed to inbreeding, predation, internal and external parasites and poaching (Warren & Meyer, 2005).

2.6.2.1. Medium camp systems (Warren & Meyer, 2005)

- This system consists of game fenced camps of between 400 and 1000 ha in size. Animals are routinely monitored and fed when local conditions warrant it. Feed is supplied near water points during the dry months, about four to 5 months of the year.
- Habitat management: strict burning programmes are followed, with little to no cattle kept in the same camps. Camps are fenced with jackal proof fencing to limit predation.
- Management practices employed in these systems are regular parasite (worms and ticks) counts, ascertaining why animals died, keeping a herd register, noting mortalities, births and other translocation and sale information.
- Herd size of between 20-30 animals, composed of 1 bull, 8-10 sexually mature cows and heifers, and the balance being calves between 0-15 months.
- Heifers are removed from the herd before they reach the age of 15 months unless the bulls are changed. Genetic improvement can only occur by physically moving the animals out of the camp.
- Bulls should be replaced every two years, preventing father-daughter mating. New bulls must be at the most 50% related to the animals in the camp.

2.6.2.2. Small camp systems (Warren & Meyer, 2005)

- This system consists of game fenced camps of between four and 400 ha in size where active management is routine. The minimum size for camps was increased to between 30 and 50 ha in 2006 (Warren, 2006). These camps are otherwise known as breeding camps.
- Genetic management and herd composition follow the same guidelines as in the medium camp systems; bar weaning the young bulls at 7-8 months of age to limit overgrazing. The weaning age was changed to 12 months, making the weaners large enough to resist predators such as

cheetah (Warren, 2006). This age has now increased to approximately 15 months, typically relocating the young bulls after their first ring shows (Warren, 2021).

- Animals must be monitored routinely (daily). Animals become used to the presence of humans, making the animals more docile and easier to monitor; it is important to remember that animals in intensive programs may carry a higher internal and external parasite load. An increase in ticks and worms can be controlled successfully under close observation.
- Practically camp management is more intense than the guidelines mentioned in the medium camp system, with the focus shifting to aspects that can have a deleterious effect in both the short and long term, the most important being: regular parasite counts, quantitatively determining the number of worm eggs per gram (EPG) of faeces; causes of all mortalities, post-mortems should be supported by laboratory results. A herd register noting mortalities, de-worming schedules, tick treatments and feeding must be kept up to date.
- Sable antelope are very selective feeders. High-quality grass roughage should always be available; if it is not available naturally in the camp, it is supplied as hay in a separate bowl. A balanced supplemental feed in meal or pelleted form is also supplied daily during the dry months. The supplementary feed should be available on-demand; dry spells have lasted as long as ten months. In dry times lucerne and high-quality grass hay can be used as a roughage source, supplied *ad libitum*.
- Water points must be easily accessed and controlled. Water points can play an essential role in parasite control (ticks), passive capture, and passive movement between rotation camps. Good quality water must always be available.
- The incidence of internal parasites decreases after animals are rotated between camps. Sable antelope should be moved from one camp to another before the average length of the available grass becomes shorter than 15.5cm.
- Breeding bulls are very aggressive; a 10m wide corridor should be built to keep bulls apart. If bulls are in sight of one another, the further apart the camps are, the better. Standard game fencing can be 1.8m high, but perimeter fences should be at least 2.4m high, preventing animals like kudu from jumping in. It is strongly recommended that a ranch has at least one rotation camp per herd.
- A carefully planned boma or holding pen adjacent to or within the camp will aid in easier management, like passive capture, parasite control, feeding and loading.

2.6.2.3. Holding pens (Warren & Meyer, 2005)

Sable antelope kept in small holding pens on a permanent and semi-permanent basis.

- These structures should be at least 2.4m high, with limited visibility preventing animals from getting a fright by the sudden appearance of humans. Wooden poles are ideal.
- Recommended pen sizes are 20m x 30m per group. Two interconnecting pens per group is ideal, allowing animals to seek sanctuary at feeding and when pens are cleaned.
- Enough good quality water must be provided daily in suitably made water troughs.
- Sufficient feed bowls must be available to prevent competition (at least 1 per animal, but an extra feed bowl or two is recommended).
- Place water and feed far apart as possible, preventing contamination (food falling into the water).
- Hygiene is of utmost importance, faeces and old feed must be removed daily and water troughs must be cleaned regularly. Wet areas should be dried out or drained where necessary.
- Protection against inclement weather is essential; this can be done by placing a shelter or allowing large trees to grow, protecting the animals from wind, sun and cold. Supply grass bedding during the calving season.
- Feed: suitable high-quality roughage *ad libitum* should always be supplied, additionally, follow supplemental feed guidelines mentioned under small camp systems.
- For more extended semi-permanent time frames, the management guidelines discussed under small camp systems should be followed.

2.6.3. GWP's shift from conservation to breeding animals with longer horns

With the ongoing success in breeding sable antelope, the study group's aim shifted from the conservation, extension, and distribution of sable antelope herds in South Africa (Scholtz, 1992) to repairing the loss of good genetic material, improving the genetic pool and by setting the target of obtaining 152.4cm (60inch) horns. Furthermore, the development and expansion of an exceptional sable antelope genetics pool, research base and the production of hunting bulls with a 101.6cm (40 inches) and longer horn length became a breeding target for the group. The GWP's vision was rephrased and is to establish South Africa as the international sable antelope Mecca (Warren & Scholtz, 2010).

The study groups success is accredited to improved management, nutrition, and selection. Both management and nutrition have improved considerably, the final step in making a good top-class breeder, was to perfect animal selection following predetermined selection criteria. The most significant factors that were considered by the group are discussed below under the headings of management, nutrition and breeding (Warren & Scholtz, 2010; Rabie, 2011b).

2.6.3.1. Management

- Removing other competitive grazing species and carnivores from the smaller, electrified, well-designed camps improved control and management.
- The continual introduction and removal of unrelated bulls together with routine herd observations have led to herd harmony.
- When establishing new herds with animals who do not know each other, the animals should be combined from the weakest to the most dominant individuals, combining animals with a similar hierarchy status.
- Regular camp visits, observations, problem identification and corrective action are quickly addressed in smaller breeding units.

2.6.3.2. Nutrition

- The selective reduction of trees improved the quality of the grazing.
- The nutrient shortages of the grazing and the soil should be determined by chemical analysis. The shortcomings are supplied *via* supplemental feed.
- Trace mineral levels are assessed by analysing the livers (compared to cattle data) from animals hunted on the properties, balancing the supplemental feed with the necessary trace minerals.
- Additional vitamins A, D, and E are included, improving herd fertility.

Adult animals in the more intensive systems received approximately 600kg of feed per animal per year, where intakes are typically the highest during the dry winter months (July to October), with little or no feed being eaten in the green summer months.

2.6.3.3. Selection

- With the successful implementation of management and nutrition, the focus shifted to selecting higher quality (longer horn) animals.
- The shortage of high-quality sable antelope (*H. niger niger*) genetics within South Africa led to animals being imported from Zimbabwe, Zambia, and Malawi.
- This practice has led to the realization of the ideal of making bulls with horns longer than 101.6 cm (40 inches) freely available.

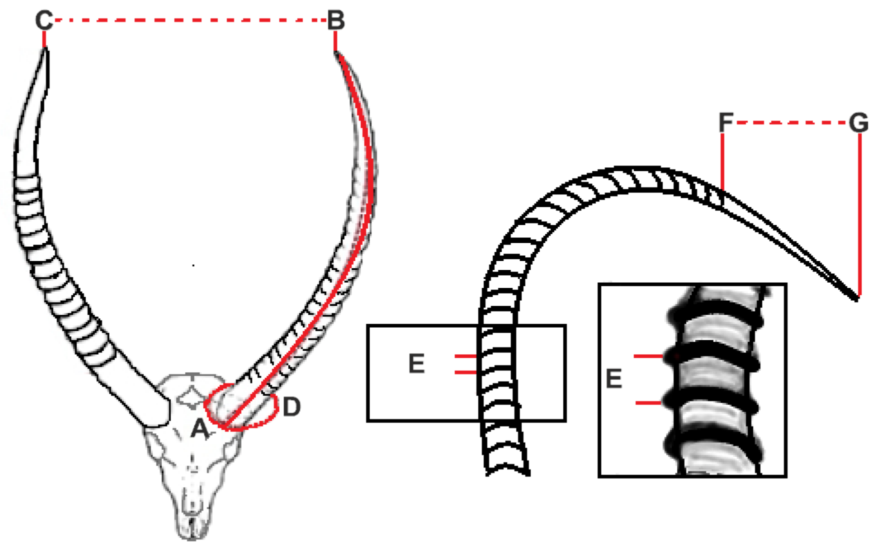

Figure 2.20 Horn measuring procedures; used to measure sable antelope horns, using the Safari Club International (SCI, 2021) guidelines and other ranch measurements. Horn length (HL) (A-B) is measured from the base along the front length of the horn to the horn tip; the measuring tape or cord must not be pressed down into each respective groove. Base circumference (BC) (-D) is measured at the base of the horn nearest to the skull. Tip length is the length from the last ring to the tip of the horn (F-G). Number of horn rings (HR); is the number of rings (-E) that circle the whole horn (Josling *et al.*, 2019). Space between the rings is the measurement between 2 consecutive rings.

2.6.3.4. Guidelines for breeding bulls

- The bull must have a masculine appearance and the typical male behavioural attitude; coats must be glossy, dark (auburn), to jet black.
- Testicles must be symmetrical, with a circumference of between 22 and 26cm; smaller than 20 cm is not advised.
- The angle between the dorsal part of the bull's nose and the horn base should be as small as possible.

Horn characteristics/traits (Figure 2.20)

- Horn length: longer horns are superior, minimum suggested size for a breeding bull is 109.2cm (43 inches) or longer
- Tip length: there is a direct correlation between tip lengths and long horns; 20 cm tip lengths should be seen as a minimum, 25cm and longer should be the norm.
- Curve: the horn should go straight up before curving backwards.
- Cross-section: exceptionally long horns are generally oval, measuring about 80mm by 45mm at the 20th ring.

- Space between the rings: rings must be spaced as far as possible from each other. The first ten rings must be at least 25mm from each other (the selection criteria as set in 2010); the greater the space between the rings, the longer the horns. Currently, the minimum measurement of the space between the rings is 32mm (Warren, 2021).
- Ring depth: The shallower the rings are, the longer the horns are. Coarse protruding rings are not good indicators of long horns.
- Most sable antelope bulls have 44 rings before the post-growth starts (Warren, 2021).
- Horn base circumference: Horn base circumference of about 25cm is ideal, horn bases thicker than 27cm is not ideal, thinner horns tend to be longer than thicker horns.
- Tip to tip measurements: animals with horns longer than 114.3 cm (45 inches) typically have horns with a tip-to-tip measurement exceeding the animals' back width, making it not only aesthetically pleasing but functionally efficient due to the horn tips passing the sides of the animal when mating.
- Young bull selection: Young bull's horns must grow 0.9mm in length per day until they reach an age of approximately 28 months. Refer to Table 2.4 below for the guideline used for estimating the performance potential of young bulls in terms of horn growth rate.

Table 2.4 Performance potential of sable antelope bulls, using the growth rate of the bulls' horns from birth to 48 months (Rabie, 2011b).

Below average						
Age		Growth per day	Total minimum	Total minimum	Total maximum	Total maximum
Days	Months	mm	cm	inch	cm	inch
0-360	0-12	0.80	0.00	0.00	28.80	11.34
361-540	12-18	0.90	32.49	12.79	48.60	19.13
541-900	18-30	0.80	43.28	17.04	72.00	28.35
901-1260	30-42	0.70	63.07	24.83	88.20	34.72
1261-1440	42-48	0.65	81.97	32.27	93.60	36.85
0-1440	0-48	0.72	0.00	0.00	103.68	40.82
Adult						42.00
Average						
Age		Growth per day	Total minimum	Total minimum	Total maximum	Total maximum
Days	Months	mm	cm	inch	cm	inch
0-360	0-12	0.90	0.00	0.00	32.40	12.76
361-540	12-18	1.00	36.10	14.21	54.00	21.26
541-900	18-30	0.90	48.69	19.17	81.00	31.89
901-1260	30-42	0.80	72.08	28.38	100.80	39.69
1261-1440	42-48	0.75	94.58	37.23	108.00	42.52
0-1440	0-48	0.82	0.00	0.00	118.08	46.49
Adult						47.00
Above average						
Age		Growth per day	Total minimum	Total minimum	Total maximum	Total maximum
Days	Months	mm	cm	inch	cm	inch
0-360	0-12	0.95	0.00	0.00	34.20	13.46
361-540	12-18	1.05	37.91	14.92	56.70	22.32
541-900	18-30	0.95	51.40	20.23	85.50	33.66
901-1260	30-42	0.85	76.59	30.15	107.10	42.17
1261-1440	42-48	0.80	100.88	39.72	115.20	45.35
0-1440	0-48	0.85	0.00	0.00	122.40	48.19
Adult						50.00

2.6.3.5. Guidelines for selecting mature cows

- External attributes considered when selecting cows is coat colour and horn length. Coat colour may vary from glossy light brown, red-brown and even dark brown to black, preferring the cows with light brown to red-brown glossy coats.
- As pregnancy progresses, cows become progressively darker from the neck area to the thigh and withers. Cows that are lighter in colour are generally less fertile
  Horn characteristics/traits (Figure 2.20)
- Horn length: An index was developed by the GWP to determine the relative genetic value of adult cows concerning their horn length; this index (Table 2.5) works well for cows from natural areas, who normally calve down at three years or older, tend to have longer horns. Cows in breeding projects where animals are supplemented with balanced feed often have shorter horn lengths, most probably due to first-time calvers calving down at a younger age; these cows also tend to calve down more often, using nutrients for maintaining pregnancy and lactation, thus suppressing the cow's horn growth.
- Tip Length: long tip lengths are essential; as seen in bulls, the longer, the better.
- Curve: horns with a moderate backward arch are preferred.
- Cross-section: a thin round horn is preferred in animals younger than five years of age. In older cows, the preference lies with a horn length exceeding 81.3cm (32 inches) with an oval-shaped cross-section.
- Space between the rings: rings should be as far away as possible from each other.
- Ring depth: the shallower the rings, the better, the shallower, the thinner the horn will be, making it longer.
- Circumference: Thin horns with a base circumference of 15 to 17 cm are ideal; thicker than 18cm is not desired.
- Colour: dark coloured horns are preferred; these horns may lighten with age.

Table 2.5 Gravelotte Sable Study groups proposed sable antelope cow index, where genetic value is based on horn length in cm and inches (Rabie, 2011b).

Horn length cm	Horn length Inch	Index	Horn length cm	Horn length Inch	Index
60.96	24	0	78.74	31	70
63.5	25	5	81.28	32	85
66.04	26	10	83.82	33	100
68.58	27	25	86.36	34	120
71.12	28	40	88.9	35	150
73.66	29	50	91.44	36	200
76.2	30	60	93.98	37	220

2.6.4. Problems noticed

With longer horns being an essential trait that many ranchers select for, some ranchers in this group chose to line-breed related animals, particularly father-daughter mating's. This resulted in one out of every four animals dying shortly after birth (term used for these animals that died is "gaper"); of the remaining three, one or two of the young animals would have the desired long horn trait, and the third or fourth animal would typically be a poor example of the species (Warren, 2021).

2.6.5. Sustainable utilization of the sable antelope (hunting and breeding)

The GWP and other private ranchers, initially focused on breeding the species so as to prevent the species from dying out in South Africa; the point has now been reached where it can be accepted that they have succeeded.

Breeding animals for live sale and/or hunting has been the primary revenue stream for this industry. Trophy hunting is a very selective form of utilization. When hunting is done correctly, individual animals are selectively removed from the herd without it negatively affecting the social behaviour of the herd, particularly trophy hunting. Hunting should occur outside the breeding season (April to June), focusing on bulls living on the periphery and or bulls out of bachelor herds (Du Toit, 1992). Sable antelope prices for live animals sold in the area ranged from R1315 in 1977, R2983 in 1980, R25 286 in 1991 (Du Toit, 1992), to R27 million in 2015 for a sable antelope bull with a horn length of 120 cm (Fin24, 2015).

The Game Theft Act, No. 105 of 1991, allowed private ownership of game (JUTA, 2011), resulting in more game ranches becoming desirous of obtaining a herd of sable antelope. With few unrelated animals available in South Africa, sable antelope (*H. niger niger*) were imported from

Malawi, Zimbabwe and Zambia (Kriek, 2017). Due to their scarcity, these animals were only available at a high cost (Cloete *et al.*, 2015).

The game industry boom changed the rules. Total income from game sales in 2011 was R433 337 065; in 2012, this nearly doubled (R856 712 460), which nearly doubled again by 2014 (R1 489 783 755) (Wildlife Campus, 2020). The sudden increase in value led to increased breeding of sable antelope and other rare species, resulting in more and more farmers entering the scarce game breeding market (Cloete *et al.*, 2015). These high-value animals were very well cared for to ensure calf survival and longer horns as superior quality breeding animals are associated with animals having longer horns. Therefore, animal husbandry practices were adapted to include strategic feeding practices, the measurement of horns, pedigree recording, and reproduction information, becoming an integral part of sable antelope management (Josling *et al.*, 2019).

2.7. Animal husbandry guidelines

This section will focus on aspects of animal husbandry that influence the productivity of sable antelope (*H. niger niger*) kept on game ranches. This will be viewed from the perspective of comparative management, reviewing the literature on domestic livestock and other ranched game species that may or has been shown to directly affect the health and well-being of sable antelope, in context with the more prominent topics covered in this study; namely, horn growth, and nutrition.

2.7.1. Genetic management

Appropriate breeding management strategies need to be developed and applied to optimise the money earned in any ranching operation (Haigh & Hudson, 1993).

2.7.1.1. Genetic selection and progeny testing

Ranchers have spent copious amounts of money over the last few decades on determining the specific subspecies or genetic clade of sable antelope they have on their properties. The sable antelope's natural range stretches from Mozambique in the east to Namibia in the west and into Zambia (Matthee & Robinson, 1999b; Pitra *et al.*, 2002; Jansen Van Vuuren *et al.*, 2010). Nuclear methods of determining origin have also been developed, making it possible for a rancher to find out if the particular animal in question is part of a particular genetic group or a combination of the five genetic clades mentioned, Eastern sable antelope from Kenya to Northern Mozambique, West Tanzanian sable antelope, Angolan sable antelope, Zambian sable and southern sable antelope (Jansen Van Vuuren *et al.*, 2010). Nuclear DNA analysis methods used to assess parentage and relatedness accurately have also been developed (Marx, 2015, 2016).

Performance of the progeny is the best gauge of breeding excellence, where artificial insemination (AI) is possibly the best way to practically get more offspring from the same bull over a shorter period. Genetic potential is evaluated using the performance data of its siblings (brothers and sisters) and its offspring (Haigh & Hudson, 1993).

Haigh (1993) mentioned in his book on farming with Wapiti and red deer, to establish actual genetic differences between groups of wapiti (elk) and red deer, substantially more research needs to be conducted within the different races and bloodlines available; similarly, this is necessary within the sable antelope ranching industry in South Africa. Until there is more detail on the genetic histories and pedigree information of the sable antelope ranched in South Africa, genetic conclusions are premature. Unfortunately, most of the sable antelope ranches or ranches that farm with sable antelope do not record any pedigree information. Ranchers who record pedigree information will aid the industry in determining reliable breeding statistics; it is suggested that pedigree information collected/retained should include BLUP (Best linear unbiased prediction) programs similar to that used for selection in the cattle and sheep industry, but with a focus on the characteristics that are important for sable. The pedigree information should include individual animals birth dates, their dam and sire, weaning age, age at first calving, inter calving period, the number of calves, weights at different ages (Muasya *et al.*, 2007) as well as the various horn measurements. Currently, animal selection is based solely on phenotypical characteristics.

2.7.1.2. Heritability

Heritability defines the percentage of variance in a trait that can be ascribed to its genotype. Heritability can be used to determine the effectiveness of genetic selection programmes, where it describes the closeness of the association between the phenotype and genotype. Heritability's are percentages, ranging from 1 to 100. When considering the heritability values obtained for traits, values lower than 20 are considered traits with low heritability and traits with values higher than 40 have high heritability. Values higher than 60 occur seldomly. Published sable antelope horn traits, heritability's vary from 0.085 (SD 0.045) for horn length, 0.103 (SD 0.023) for basal circumference and 0.224 (SD 0.041) for the number of rings (annulations) (Josling *et al.*, 2019) to 0.30 (SD 0.04) for horn length, 0.36 (SD 0.04) for basal circumference and 0.24 (SD 0.05)for the number of rings (annulations) (Cloete *et al.*, 2019).

Most species, including livestock prolificacy (fertility) and traits associated with health and soundness, have low heritability. Traits considered moderately heritable are birth weight, weaning weight, mature weight, growth rates, and feed conversion efficiency (Haigh & Hudson, 1993; Ryu & Lee, 2014). Coat colour and carcass quality are considered the traits with the most heritability (Haigh & Hudson, 1993).

2.7.1.3. Selection differential and rate of genetic improvement

The selection differential is simply the difference between animals to be the parents of the next generation and the current herd average:

Selection differential = ((males, average) + (females, average)) / 2

The selection differential depends on both the inherent variation in the herd and how strongly selection is applied. Progress in any individual trait can be estimated by multiplying the selection differential by the appropriate heritability. It is however, important that ranchers are aware of confounding factors that may alter the genetic performance of any individual animal or group. This includes environmental factors such as feeding, disease status, climate and the stockman, making good record keeping of utmost importance (Haigh & Hudson, 1993; Matthews *et al.*, 2019). For example, a cow considered fertile, producing a calf year after year, is then moved to a new ranch, where the cow does not calve down year after year, resulting in the rancher changing his opinion, where the highly fertile cow is perceived to be a poor doer. The cow gets the blame, but in reality, the cow is moved from a ranch/environment where she had received ample nutrients to produce a calf and supply enough milk for the calf to grow out properly, to a ranch where the cow only received a maintenance diet, resulting in a cow in poor condition, and fewer calves born.

2.7.1.4. Selection indices

Breeding programs should have a particular goal in mind when in search of certain traits. These traits are usually dictated by the market, representing a collective perception of quality. However, when considering traits, ranchers should be cautious, e.g., when focussing on traits such as body size, it is essential to consider how this could affect efficiency and manageability. For example, selection for heavier weaning weights may lead to increased dam size and/or greater incidence of dystocia (calving difficulties) (Haigh & Hudson, 1993).

When ranchers wish to select several traits simultaneously, this can be accomplished by using indices of net merit. These selection indices consider several traits relative to one another and their heritability's. In practice, ranchers use less scientific methods. For example, the rancher may decide to keep 10 out of 40 yearling heifers as replacement heifers for the breeding herd, the top 20 will be selected based on temperament, and from within this group, the ten heifers that are selected will be selected using their weaning weight. Considerable progress can be made in a herd if selection can be made by selecting relative to the herd average. It is just as important to compare animals from other ranching operations that have been raised under a variety of conditions. In the cattle industry, breeding males from different environments are assembled at testing stations, where they are compared to other bulls within their contemporary groups (Haigh & Hudson, 1993). Presently, this is not done for any of the wildlife species farmed in Africa.

When considering ranching with sable antelope and other wild game, horn traits are currently the most important trait considered. The GWP led the way and have created indices and other helpful tables where the performance of individual animals can be measured. Refer to Table 2.4 for horn growth selection guidelines used by the GWP when classifying bulls in terms of horn growth rate. Refer to Table 2.5 for selection indices used by the GWP for both captive-bred and wild-caught sable antelope cows.

2.7.1.5. Inbreeding, outbreeding and crossbreeding

Inbreeding involves mating relatives with each other. Despite its dangers, this has been used in the advancement of most livestock breeds. Inbreeding concentrates the desired genes known to be present in a particular line so that the line breeds true to the selected traits (Haigh & Hudson, 1993; Henryon *et al.*, 2019). The biggest problem with inbreeding is that negative genes can also be concentrated and expressed more frequently in more homozygous (closely related) animals, so constant, harsh to the point of ruthless, selection is required (Haigh & Hudson, 1993)

Outbreeding can broadly be defined as the mating of animals less related to each other than the average of the breed or race. Outbreeding introduces a desirable trait into the herd, generally done as a temporary line-breeding strategy. It may introduce a certain degree of hybrid vigour, but it results in heterozygosity which masks recessive genes (Haigh & Hudson, 1993; Pitra *et al.*, 2002).

Crossbreeding involves mating animals of different breeds and races (Haigh & Hudson, 1993), e.g., breeding southern sable antelope with western Zambian sable antelope.

The GWP has successfully taken the sable antelope from near local extinction by outbreeding the original inbred herd, as discussed in Section 2.6.

2.7.2. Breeding management

Calves should be born as close together as possible, preferably when adequate amounts of high-quality green forage are available, so their mothers can produce enough milk. The calves should also receive supplemental feed so they can reach maximum weight before weaning. Following the natural cycle will ensure good productivity for the dam and the growing calf (Haigh & Hudson, 1993). In sable antelope, the natural cycle can be referred to as managing the cows to calve down in the green season, optimising nutrient supply for milk production, and for improved body condition and growth.

2.7.2.1. Breeding group selection

Currently, breeding group selection is focused on the horn growth of the progeny; cows who produce young bulls of a particular horn length at four years of age get classed. The female offspring are then noted as possible replacement heifers (Strydom, 2020).

2.7.2.2. Soundness evaluation - bulls

A critical yet often overlooked step in selecting bulls, particularly in single sire mating systems, is examining the bull for breeding soundness. Breeding soundness is an industry standard for livestock such as beef and sheep (Chacon *et al.*, 1991); a single infertile male can damage the herd's reproductive success (Haigh & Hudson, 1993). Breeding soundness should include the analysis of semen quality, the physical examination of the internal and external genitalia, scrotal circumference and, if possible, the bulls serving ability. Structural conformation with emphasis on limb conformation is of utmost importance, especially the condition of feet and hind legs (Haigh & Hudson, 1993; De La Rey, 2020). Symmetrical testicles with a scrotal circumference between 22 and 26cm are advised (Warren & Scholtz, 2010; Rabie, 2011b). Larger testicles are associated with more sperm (Preston *et al.*, 2012). An aspect that has not yet enjoyed much attention, is the testing for venereal diseases when these reproductive organs are evaluated.

2.7.2.3. Mating systems

Single sire mating is the most preferred breeding management system, although a backup male is often used in the last 2 or 3 weeks of breeding in cattle, deer, and sheep (Haigh & Hudson, 1993). In intensive sable antelope breeding operations, the single sire mating system is the only one followed. If bulls are in adjacent camps, fighting becomes so intense that the bulls will break the fence to try and fight with each other; it is better to make sure male animals do not see each other if there are cows in the proximity.

Artificial insemination (AI) is possible in sable antelope. Synchronized fixed time AI under ideal conditions achieved a 60% pregnancy success rate. Sperm and embryos have also been successfully harvested and frozen. Frozen-thawed embryos have had a 40% success rate in achieving pregnancy, while freshly collected embryos have a 50% success rate (De La Rey, 2020).

2.7.2.4. Male to female ratio

In livestock species and deer, one of the most important considerations in deciding the male to female ratio concerns the duration of the calving season; this is between 6 to 8 weeks for wapiti (elk) and red deer ranched in Canada (Haigh & Hudson, 1993), up to three months for cattle and sheep on livestock ranches.

Bull to cow ratios in sable antelope herds range between 15 to 30 cows for each dominant bull; younger inexperienced bulls and old bulls get the fewer cows (Strydom, 2020); the average that the GWP works on is 20 to 30 cows per bull (Warren & Meyer, 2005). This number correlates to the number of animals found in nature reserves in southern Africa. South African herds number between 20 – 25 individuals, with herds as large as 40 (Wilson & Hirst, 1977). In Zimbabwe, maximum herd sizes vary between 32 and 44 animals during the rut (April to June).

A herd of one bull with 15 to 30 cows has a total herd size of one bull to 30 cows with calves (31 animals) and one bull with 60 cows with calves (61 animals), the average being 46. These herd sizes are roughly equal to the number of cows and calves encountered in game reserves in South Africa and Zimbabwe (between 32 and 44 animals).

2.7.2.5. Segregation of unused adult bulls

Subadult and old bulls are kept separate from the breeding herds. Subadult bulls are grouped in age categories, where two successive years are kept together (Strydom, 2018; Greeff, 2020). Young bulls tend to group, but as they reach sexual maturity, feeding troughs need to be moved further and further away due to territorial behaviour setting in. On some game ranches, small camps have been made where older bulls can be kept individually; the success of this system varies (Strydom, 2020).

2.7.2.6. The breeding season

Sable antelope are seasonal breeders (Kriek, 2005), the rut is usually between April and July, with a pregnancy that usually lasts for approximately 8 (240 days) (Wilson & Hirst, 1977) to 9 months (270 days) (Grobler, 1974, 1980a), calves are usually born in the green months in Southern Africa. The peak calving season in the KNP is between February and March; in Zimbabwe, the peak calving period is March, and the peak calving season in Botswana is January into early February. These dates coincide with the peak growing season and availability of nutritious forage for milk production (Wilson & Hirst, 1977). Using artificial insemination and or embryo transplants, the duration of pregnancy is between 256 and 260 days (about 8.55 months) (De La Rey, 2020).

On ranches where supplemental feeding occurs all year round, the inter-calving period has shortened from approximately a year to about ten months (Warren & Scholtz, 2010); many ranchers have reported an average of 9 months 15 days. Although the reduced inter calving period has advantages, it also has its own set of problems when it comes to cost-effectively feeding these animals. It is important to note that a portion of the herd is always pregnant, dry, or lactating, making it necessary to oversupply nutrients, ensuring the lactating animals consume the required nutrients at the desired quantities. The oversupply of nutrients makes feeding these animals more expensive than when only supplying what the animal needs, for its particular physiological production phase, where all the animals are either dry, or pregnant, or lactating. For more information regarding this, refer to chapter 6 (refer to the section on LSU).

In natural systems like game reserves, age at first mating usually occurs at about 27 months of age (first oestrus), where the bull is usually allowed about 3 to 4 days in which he can mount these heifers. After conception, these first-time heifers will then calve down at approximately 36 months (3 years of age). At oestrus, the cow's vulva is slightly swollen, pink in colour, has up to six small pimple-like swellings and exudes a yellow discharge (Grobler, 1980a).

Well-fed heifers on breeding ranches reach physiological maturity at a younger age than their contemporaries in nature reserves (De La Rey, 2020; Greeff, 2020; Strydom, 2020; Warren, 2021), similarly seen in wapiti and red deer (Haigh & Hudson, 1993). Early pregnancy often results in dystocia, where many of these calves need to be "pulled", or in some cases, the heifer has to undergo a caesarean section to remove the calf out, often resulting in the deaths of both the cow and the calf. This situation worsens with sable antelope in breeding camps, where bulls are usually kept in the camp with the females all year round, leading to the bull mounting the heifer who has come on heat before she is physically mature enough. Those that calve down and survive often skip a year before they calve again, creating the perception that it is a poor quality animal when compared to heifers which calve down for the first time at approximately three years of age and calve within a year, year after year (De La Rey, 2020).

Some veterinarians have reported that they have treated/handled heifers that have calved at ages younger than 2.2 years (26 months), making the age at first mating approximately 17.5 months. This situation is not ideal; if the heifer survives this calving, she is usually stunted in both body and horn growth for the rest of her life. It is strongly advised to wean the female animals into herds of their own or to remove the sire from the herd and replace him with another when the heifers are of age (De La Rey, 2020).

Some ranchers remove the bulls to ensure the cows calve down at a particular time of the year. In livestock farming, we call this breeding seasons, where the bulls are kept with the cows for approximately three months at a time, giving the bull enough time to adapt to the new circumstances in the camp, mount and mate all of the cows before he is removed. Ranchers with more than one herd of cows can use the same bull on more than one herd.

2.7.2.7. Pregnancy and pregnancy determination

Pregnancy of sable antelope can be confirmed in the same way as in livestock and other farmed deer, namely digital rectal palpation (people with small hands), ultrasound examination, progesterone concentration determination in serum and faeces and maternal serum evaluation for detection of pregnancy-specific proteins (Haigh & Hudson, 1993). What makes things complicated with these wild species is that the cows need to be immobilised to confirm pregnancy, making it risky and expensive.

A non-invasive method to confirm pregnancy would be a serious advantage for ranchers ranching with animals such as sable antelope. A non-invasive way used successfully or partially successful in confirming pregnancy in livestock and free-ranging wapiti (elk) is measuring faecal progesterone levels found in faeces of female animals (Haigh & Hudson, 1993; Peter *et al.*, 2018). It has its limitations, where the progesterone measured could be confused with progesterone from the normal oestrus cycle, but if this can be repeated 21 days later, the concentration difference could be a good indicator. For this to succeed, the faeces must be collected fresh and stored on ice because the time-lapse and exposure to sunlight and high temperatures between the faeces dropping to the ground and being collected can also lead to progesterone denaturation (De La Rey, 2020).

A possible practical application in a camp where a young bull is used is to collect the first sample at about 3 to 4 weeks after mating and then 21 days later. The direct costs, which include the veterinarian, staff, vehicle, helicopter (for darting) and the time, the risk of losing the cow with immobilisation need to be considered and weighed against sending someone out early morning / at feeding where they need to wait until a cow defecates, walk up to the animal, and collect and store the faeces. Most sable antelope ranches routinely collect faeces for determining internal parasite load (De La Rey, 2020).

Pregnancy in sable antelope; at seven months into the pregnancy, pregnant sable antelope cows' udders start increasing in size; the four nipples become taut and pink in colour. The udders became progressively bigger and can be seen bulging between the legs at four weeks from birth. The stomach/belly region takes on a heavy sagging appearance, ultimately focussing to a point near the navel. The full-term foetus can be seen moving under the skin (Grobler, 1980a).

2.7.2.8. Weaning

Calves wean naturally between the ages of six (Wilson & Hirst, 1977) and eight months (Grobler, 1980a) of age, usually at the end of the dry season (Wilson & Hirst, 1977; Grobler, 1980a). On many breeding ranches, young males and females are weaned (removed from the herd) between the ages of 13 and 16 months, normally after the first set of rings appear on the horns (Strydom, 2020; Warren, 2021). Young bulls that do not measure approximately 48.26cm (19 inches) are classed out and not used for future breeding (Warren, 2021). In more natural managed herds, young bulls are ousted from the breeding herds at approximately 17 to 19 months of age by the territorial bull (Wilson & Hirst, 1977), weaning them from the herd. Another reason for moving the bulls between the ages of 13 and 16 months is that at about 15 months of age, the young bulls can mate and produce viable offspring. Ranchers have been embarrassed thinking the breeding bull is the sire, just to be proven wrong with DNA (Warren, 2021). Weaning heifers and moving them to other camps prior to them reaching 17 months of age, will allow them to mature fully before first mating (De La Rey, 2020).

2.7.3. Nutrition

2.7.3.1. Management guidelines (reproduction)

The following points on nutrition management will be discussed: maximising conception rates, ensuring good foetal growth, the nutrition of the last trimester of pregnancy and other nutritionally related information.

The observations and consensus by GWP members indicate that an increase in weaning percentage can be attributed to creating a habitat as close as possible to the natural choice habitat of the sable antelope, whereas constant monitoring, intensive and aggressive management aided in reducing mortality rates in these holding pens and small camp systems (Warren & Meyer, 2005).

2.7.3.2. Maximise conception rates

Cows must be in a good body condition at the onset of the breeding season, albeit livestock, deer (Haigh & Hudson, 1993), and other ranched wild animals. If the available forage quality from pasture is less than optimal, nutrients need to be supplemented to get the female animals to cycle (Haigh & Hudson, 1993). Similar to cattle, sheep, deer and other ruminants, it has been noted that skinny animals may have delayed puberty, irregular cycling (oestrus) and poor fertility rates, while obese animals have reduced fertility and are sometimes sterile (Schingoethe *et al.*, 1993).

A body condition score chart is a practical and effective way to assess an individual’s condition compared to the herd. The body condition scoring methods used on dairy and beef cattle, European buffalo (Zielke *et al*., 2018) and other species consist of a five or a 10 point scoring chart. A skinny cow has a body condition score of 1, and an over fat animal has a body condition score of 5 or 10. Keeping sable antelope cows between 3.5 (7) and 4 (8) is easy on green grazing; feeding is necessary to achieve this on dry grazing. Keeping sable antelope cows between 3 (6) and 3.5 (7) will ensure optimal foetal growth and good milk production. The 5-point scoring chart is more than adequate for this purpose.

2.7.3.3. Optimal foetal growth

To optimise foetal growth, cows will have to receive adequate nutrition throughout the year, particularly in the dry season/winter (Haigh & Hudson, 1993). It is unnecessary to keep the cows in the same body condition as they were in the green season. A 10% loss in body condition is considered normal (Haigh & Hudson, 1993); this 10% loss equates to 1/2 a condition score on the 5 point scale.

2.7.3.4. Last trimester of pregnancy

It is essential to ensure that cows in the last trimester of their pregnancy are not overfed. Big calves, lazy unfit and overweight cows are the usual reasons for calving problems (dystocia). Maternal dystocia is often seen in animals who do not move around much and stay in or near the feeding sites (Haigh & Hudson, 1993). In intensive sable antelope camp systems, this can be prevented by keeping the animals exercised; an easy way to do this is to supply water and feed at different points in the camp, forcing the animals to exercise.

2.7.3.5. Other nutrition-related findings and general information

As sable antelope cows age, their teeth wear down, limiting their ability to bite off and ruminate the ingested forage, causing the animal to lose condition due to starvation and possible death; this starts to occur between 10 and 12 years of age. If the rancher expects calves from these older cows, they should be placed in camps with others of the same age (granny camp) and be supplied with a balanced diet; made up of high-quality grass hay, lucerne or a combination thereof, together with a feed fortified with minerals and vitamins (Kriek, 2005).

Trace mineral deficiency's such as copper can cause sable antelope coat colours to discolour, moving from the typical black to reddish-grey (Kriek, 2005; Shepstone, 2020). Copper deficiency is usually due to animals living in areas with little to no natural copper in the edible plant matter or animals in camps eating feed deficient in copper. The grey sable antelope cow in Figure 2.21 and other animals on other ranches with greyish coats returned to their typical colour after being supplemented with copper (Greeff, 2020; Shepstone, 2020).

Figure 2.21 Hair discolouration in sable antelope (Foggin, 2008).

Sable antelope require approximately 9 litres of water per day (Kriek, 2005) and prefer to drink water between 13h00 and 14h00; herds are usually found within 2.5km of the nearest water source (Du Toit, 1992).

2.7.4. Feed management at ranch level

2.7.4.1. Purchasing and storage

When purchasing and storing feed products, the rancher needs to keep the following in mind (Shepstone, 2015, 2016):

- Ensure feed supplements are made by feed companies that ensure raw material quality by laboratory analysis and mix the feed according to specification.
- Purchasing lucerne or other hay sources - source these products from reputable suppliers and obtain a certificate of analysis where possible.
- Ensure feed purchased is designed for the specific species type and production goal.
- Feeds designed as supplements should not exceed one-third of the animal's total daily intake.
- Follow suggested intakes, and make sure feed is stored and used up before it expires.
- Keep insects and rodents away from the stored feed.
- Keeping moisture and excessive heat away is essential; hot and humid environments can cause the feed to spoil, pellets tend to crumble (bliss) in humid areas, feed with no ventilation can sweat and create an ideal environment for mould growth.
- Feed transported long distances on the back of a truck often stand in the sun for extended periods. Although this feed is usually covered by a tarpaulin, keeping rain and dust out, this feed can sweat. The top layer of bags can reach temperatures high enough for the pellets to start sweating, creating a suitable environment for fungal growth. Use these bags immediately or open and air dry them before use.
- Feed that may have rained wet *en route* to the ranch must be air-dried if it cannot be used immediately.
- Moisture, be it from high humidity, water (rain) or the feed sweating, will cause fungal growth. Fungal growth typically takes a few weeks before making the feed look lumpy and mouldy. The fungus will grow and release toxins, leading to possible mycotoxicosis if animals eat the feed. This feed should be destroyed.
- When using the purchased/mixed feed, follow the 1st in 1st out approach, the first batch of feed gets finished before new feed gets used, where necessary mix the new with the old 50:50 in the case where the time between batches is longer than two months or so, raw materials may have changed leading to the feed smelling slightly different, which may cause the animals to abstain from eating it for a few days.

2.7.4.2. Ensuring each animal gets its share of feed daily

2.7.4.2.1. Feed or supplements with no intake inhibitor

When feeding pelletised or self-mixed feed products (supplements) that do not contain an intake inhibitor, only feed the animals if and when the animals are near the feeding site. When considering how many bowls, supply species where male and female animals have horns, with at least a feed bowl for every individual, although 20% more bowls than animals is better. Extra bowls limit competition, making it possible for all the animals to get their share of feed daily. If larger feeding troughs (long rectangular versions) are used, make sure that there is enough feeding space (crib space) for the animals to eat comfortably without competition from others. Large bowls work well with cows and young calves, which generally feed together at their respective bowls/troughs, but older cows and bulls often fight over the supplied feed, so following the bowl per animal suggestion will be better. It is vital that the rancher supplies the animals with the suggested amount of feed (as per manufacturer or consultants' guidelines) and that overconsumption is prevented (Shepstone, 2015).

Feeding time is also a perfect time for monitoring animals; furthermore, this prevents some animals from eating first and a group coming later and eating. If this happens, the animals that come first will eat most of the supplemental feed supplied, and the animals that come later get little or nothing (Shepstone, 2015).

When the seasons' change and green grass becomes available, the intake of pellets or self-mixed supplements suddenly drop, resulting in leftover feed in the bowls. This leftover feed should be removed; if this is not done, individual animals, such as bulls, the shy eaters, or the latecomers, have access to the leftovers, leading to possible over-eating. Over-eating can result in animals becoming ill and dying from gut disturbances, such as acidosis and red gut. The leftover feed should be weighed back, and the following day's amount should have that amount subtracted from it and fed. Feed bowls should be cleaned out regularly; no caking of old food may be allowed in any bowl, also do not add the fresh feed on top of the old feed (Shepstone, 2015).

When feeding semi-*ad libitum* feeds or full feeds(otherwise known as a total mixed ration (TMR)), the larger the bowl, the better; similarly, hay should preferably be placed in large bowls if hay racks are not used (Shepstone, 2015).

2.7.4.2.2. Feeding supplements or licks with an intake inhibitor

When feeding low intake supplements (salt included as an intake inhibitor), it is essential to keep the following points in mind; ensure each animal eats its recommended daily supplement; ensure that there are enough feed bowls to prevent dominance by larger or older animals. In other words, do not supply a herd of 20 to 30 sable antelope with only two or three feed bowls. The low number of feed bowls may lead to the situation where the larger, more dominant animal hurts younger ones that come alongside them while they are eating the lick, resulting in the dominant animals eating more than their share and the younger/smaller ones getting little or nothing at all (Shepstone, 2015).

Sable antelope cows are aggressive towards each other and have a well-defined hierarchy amongst themselves; for this reason alone, it is advisable to supply surplus feed bowls.

When starting animals on any winter lick that may contain urea and salt, start with a small amount daily, about ¼ of the recommended amount; this is done to prevent overconsumption of the product due to a condition known as salt hunger and thereby ingesting too much urea and other concentrated nutrients. If mineral licks containing salt are not used in the green season, supply coarse salt for a short time before placing the winter licks out *ad libitum* (Shepstone, 2015).

2.7.4.3. Changing feeds

When changing feed, adapt the animals onto the new feed for at least 4 to 5 weeks, where the new feed replaces the old feed incrementally over the period. When doing it over four weeks, add ¼ of the new feed to ¾ the old feed for about a week, week two ½ of the feed amount as new feed mixed with ½ of the feed amount as old feed, week three ¾ new feed mixed with ¼ old feed, week four on the new feed (Shepstone, 2016).

2.7.4.4. Feed bowl management

In general, when supplements are being fed, it is advisable to follow the ‘more bowls than animals’ approach. When semi-*ad libitum* and full feeds are fed, it is possible to use fewer feed bowls because there is usually feed always available, reducing competition for the feed; similarly, fewer bowls can be used for licks or meals that have an intake inhibitor like salt, in them (Shepstone, 2016, 2020).

Place the bowls 2.5 animal lengths from one another in a rectangular chess board-like fashion, which ensures limited contact with other animals while feeding. In camps where there is a lot of space, move the feed bowls daily or every second day – not all the bowls but the last bowls of each row. Move them to the front of the line. It not only saves time but it ensures that three or four bowls are cleaned daily/twice a week (Figure 2.22)(Shepstone, 2020).

Moving all the feed bowls in one day is very time-consuming, whereas that job is done if three or four bowls are moved daily. This method ensures all the feed bowls are cleaned monthly; bowls can be moved back and forth in a fixed feeding area; it is, however, essential to ensure that the area is large enough to allow each bowl to be moved in the same manner as mentioned above, where each bowl is cleaned, with the difference being the line moves from left to right and back again. It is advisable to have more than one feeding point in a camp, where all the bowls are moved to a different place within the camp or rotational camp system. Where bowls cannot be moved; clean the feed bowls regularly. Feed bowls that are cleaned regularly prevent old feed from caking onto the bowl and going mouldy, thus preventing mycotoxin build-up, resulting in possible illness or deaths (Shepstone, 2020).

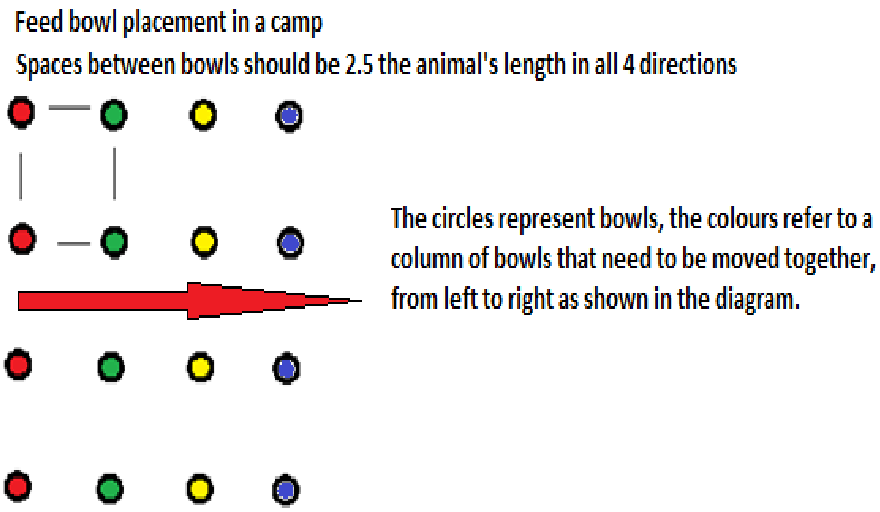

Figure 2.22 Feed bowl placement and movement suggestions when using tyre-like bowls.

2.7.4.5. Hay/roughage management

Hay should preferably be placed in hay racks or large bowls; bails placed on conveyor belt strips also work well; the reason for this is to prevent contact with soil. Hay racks should have a strip of conveyor belt under the rack at about 300 to 400cm from the ground, allowing the smaller pieces of hay to fall into this conveyor strip, preventing them from falling on the ground, for the animals to eat without it touching the ground.

If poor quality grass is the only source of grass hay available to the animals, it would be advisable to mix 10 to 20% legume hay (lucerne/alfalfa) into the roughage diet to correct the amount of protein. Macronutrient analysis of all hay sources should be done routinely; and be used as a guide to estimate how much legume hay (lucerne) needs to be mixed into a ration if the grass hay is of poor nutrient quality (Metrione & Eyres, 2014).

Exclusive use of small grain hay and lucerne/alfalfa hay for sable antelope is discouraged, as it may lead to mineral imbalances, laminitis, colic and diarrhoea (Cheeke & Dierenfeld, 2010). If peanut hay is used, shake the bails so all of the sand falls out; this accumulated sand can cause abomasal sand impaction (colic) in ruminants (Dierenfeld, 2021).

Sable antelope housed in holding pens, bomas, or zero-grazing situations should receive good-quality grass hay (6 to 9% Crude protein) as the biggest portion of their diet. Mouldy or dusty hay can cause pneumonia, colic and heaves (Metrione & Eyres, 2014; Shepstone, 2015).

2.7.4.6. Feeding suggestions for different systems

2.7.4.6.1. Game reserves, game ranches

Game reserves or ranches that focus on hunting or tourism as an income do not generally feed or supply their sable antelope or any other game species any form of feed or supplement, except possibly during severe droughts. Some game reserves/ranches have a herd of sable antelope on their property, which gets preferential treatment, where these animals get additional supplementation during the green and dry season, while the rest of the animals on the property only have natural vegetation as a food source. The general rule regarding feeding applies to these sable antelope as well, namely the feed is physically taken to the animals, albeit where they may be found, or at fixed feeding sites. The feed should be placed in feed bowls or troughs and not put directly on the ground (Shepstone & Slippers, 2016).

Supplementation

Green season; supply a palatable phosphorous lick that contains the necessary macro and trace minerals to balance the green grazing to ensure optimal milk production, horn growth, and health.

Dry season; supply lucerne as a roughage source to game reserves; lucerne is reasonably high in protein and energy. Game reserves/ranches that have a herd of animals that get fed a supplement; a lick (a low intake lick – meal), lick block, pellet or self-made feed is made/purchased and supplied where the animals are found. In times of drought, it is advisable to reduce the total number of animals that will need extra feed and supply suitable roughage adlib.

2.7.4.6.2. Medium and small camps

Most ranches in South Africa that ranch with sable antelope within the context of either intensive or semi-intensive systems usually keep their animals in a large camp where some farms may have more than one camp per herd. Intensive systems expect a calf from each mature cow within the standard 9.5-month to 10-month inter-calving period. Keep in mind that this system anticipates more calves than would have been produced naturally in a game reserve. Therefore cows must receive the necessary nutrients to achieve this goal (Shepstone & Slippers, 2016).

Supplementation

Green season; supply a palatable phosphorous lick that contains the necessary macro and trace minerals to balance the green grazing to ensure optimal milk production, horn growth and health.

Dry season; supply a lick (a low intake lick – meal), lick block, pellet or self-made feed can be made/purchased and supplied. In times of drought, it is advised to reduce the total number of animals that will need extra feed and supply suitable roughage adlib.

2.7.4.6.3. Holding pens (bomas) camps that do not have any available grazing

It is essential to know the difference between animals kept in a boma short term and those housed in a smaller camp or zoo type enclosure. Sable antelope kept in a zoo long term need to have their complete nutrient requirements supplied daily. These are usually supplied as hay with added pellets or lick that supplies the necessary protein and other nutrients (Shepstone & Slippers, 2016).

Wild-caught sable antelope kept in a boma short term have often never had access to feed other than natural vegetation before, so it may be difficult for them to eat pellets, lick, and hay. It is advisable to supply these animals with palatable lucerne (alfalfa) hay, where the protein, energy and fibrous component are highly digestible, supplying the animal with the necessary nutrients for the stressful period during which they are kept in the boma. For those staying in a boma for an extended period, slowly move them over to a diet comprised of a mixture of grass hay and a suitable pellet or lick (Shepstone & Slippers, 2015, 2016). Lucerne hay is not advised to be supplied as the sole diet for extended periods, as laminitis-like conditions have been diagnosed internationally (Cheeke & Dierenfeld, 2010).

Supplying electrolytes and probiotics to these animals when translocated to the boma will help with adaptation to the new feed and the boma environment quickly. The sooner the animals start eating the new feed, the better, and the probiotics added will provide the animals with the necessary microbes to optimise the degradation and digestion of the supplied food (Shepstone & Slippers, 2016).

When animals are used to a specific feed, supply the same feed the animals are used to, which will result in fewer adaptation issues and fewer problems in the long run (Shepstone & Slippers, 2016).

2.7.5. Practical ways to save costs on feed in different systems

The feeding of game can be expensive, but depending on the project's long-term goal, cheaper options exist, supplying the animals with nutrients they need and not simply giving them feed. Supplying animals with the nutrients that nature cannot, does not only focus on nutrients like protein, energy, fat, minerals and vitamins; it also considers the digestibility of the fibre component (Van Soest, 1994; Meissner *et al.*, 1999). Sable antelope, being classified as selective grazers, tend to select the best quality grass available to them (most digestible) (Skinner & Chimimba, 2005) so that they can stay in good body condition, reproduce and produce young. If it is crucial to maintain the animals in good condition, the feed (including the roughage) must mimic this. Do not supply poorly digestible roughage like veld hay and straw if animals are expected to stay in condition and produce milk.

2.7.5.1. Camp/ranch grass supply and quality

Before deciding what feed to purchase/make, it is strongly advised that an on-ranch assessment be done, where the physical carrying capacity is determined. It is important to know how much palatable forage the ranch/camp has, expressed as its carrying capacity in hectares per Large Stock Unit (LSU – 450 kg animal) (Meissner, 1982) or Grazing Unit (GU – 180 kg animal) (Van Rooyen & Du P Bothma, 2016). Carrying capacity indicates the amount of edible plant material a hectare of veld on the property has over a year (Grossman *et al.*, 1999). Secondly, the carrying capacity is used to calculate the stocking rate (how many animals of the particular species can be stocked) and should never be exceeded (Mentis, 1977; Van Rooyen & Du P Bothma, 2016). The grazing unit/browsing unit value ascribed to the sable antelope is 1.16 (Van Rooyen & Du P Bothma, 2016); this in terms of the large stock unit will be discussed in detail in chapter 4. When the carrying capacity is calculated and stocked accordingly, it is unnecessary to purchase any extra roughage. Biomass and carrying capacity estimations for a ranch/camp can be assessed by a rangeland scientist or ecologist locally.

2.7.5.2. Rotational grazing

In short, rotational grazing can be defined as moving livestock to different units of grazing in a regular sequence to permit the recovery and growth of the pasture plants after being grazed (Merriam-Webster.com Dictionary). With transportation of bulk products like grass and lucerne hay being expensive, the ranch needs to consider how it can save money by purchasing less of it. Making it essential that the ranch produces as much palatable forage as possible, the easiest way is to implement rotational grazing.

Practical application - a herd of animals will stay in a specific camp for a few days to a few weeks at a time. Time spent in a camp depends on the rainfall, the growth rate of the grass, and the amount of edible grass in the camp. As a partial explanation, the more palatable grass will be eaten first; to prevent the animals from over-utilizing the higher-quality grass, the animals are moved out into the other camps, giving the plant enough time to rest and regrow before the animals are brought back into the camp. Animals get moved in and out of camps more regularly in the green months than in the dry months. Rotational grazing has a few benefits, such as improving grass sward quality and volume (Tainton *et al.*, 1999; Shepstone, 2018).

It not only allows the ranch to run more animals than the calculated stocking rate long term, but it also aids the ranch in saving a lot of money by not purchasing truckloads of unnecessary roughage. Roughage will then only be necessary for animals in holding pens and bomas.

2.7.5.3. Feed supply and calculations (supplementation)

This section helps decide what feed is necessary to reach any specific goal for a specific group of animals in a camp/ranch, keeping the costs in mind.

It is important to understand that all feeds on the market intended for game or ruminants are not equal; some are designed as supplements (intake is ≤1/3rd total intake), semi-*ad libitum* feeds (2/3rds total intake) and full feeds (TMR). The feed chosen will directly affect the growth, body condition, health, and milk supply of the animals (Shepstone, 2017).

Supplements can be seen as a feed concentrate containing the necessary nutrients an animal needs at a particular intake to digest the available dry forage in the camp/ranch to reach the desired result (Meissner *et al.*, 1999; Bonhert & DelCurto, 2003). When feeding a mixture focussed on supplying concentrated nutrients at a low intake, if eaten at high amounts this can lead to toxicity's; whereas feeds designed as a full feed (TMR) supplied at low amounts can cause deficiencies. Guidelines set by the feed manufacturer or consultant must be followed.

Every kilogram of roughage in the form of grass and lucerne hay that is transported to the ranch will increase the living costs of the animals to a point where the project may seem financially unfeasible.

When considering what feed product is necessary to feed the animals, it is vital to know as much as possible about the camp, particularly the edible forage. If the ranch is in a sweet veld area, the grass will be of higher quality, extra lucerne or high-quality grass hay is only necessary when the camp is depleted of it, but if the camp's veld type is sour veld, it may be necessary to supply a more suitable supplement or a higher quality roughage in the camp near the end of the dry season.

Table 2.6 illustrates what a typical sable antelope bull and cow weighs and what it eats on a dry matter and on an as-fed basis (10% moisture). It illustrates a few options of what types of feed a rancher can use to supplement his animals during the green or dry season. Table 2.6 shows six different feed options, with 2021 prices for ease of use. More specifically, Table 2.6 shows four supplements (1-4) and two feed mixes (5-6), where the first four options are designed to be supplied at ≤1/3rd of total daily intake (10% moisture), and feed 5 and 6 are either supplied semi-*ad libitum* or as a full feed (TMR)(10% Moisture). Suggested daily intakes in grams or kilograms are written under each of the feed products for each animal category; these intakes are calculated on a semi worst-case basis, namely, the available veld grass has a crude protein value of ≈3-4% with a total digestible nutrient value of approximately 50-60%.

The most important nutrients: namely, protein, energy, fat, roughage, minerals, and vitamins, are mentioned on the left-hand side of Table 2.6; to the right, they have a Y (yes), or N (no) typed. If a Y is placed under a feed, next to the nutrient, it describes that the particular product aims at supplying the nutrient at optimal levels to reach a specific result. The lower half of Table 2.6 works out the different feed products costs (daily) at the specific intake per animal category, ending with total costs for the different categories over a year. Assumptions made under feed products; feed products 1-4, the camp has suitable grazing all year round; feed 5, the camp has poor quality grazing for the last five months of the year; feed 6, the animals have run out of grazing the last five months of the year.

For example, calculating the feed requirement and costs to keep a mature bull at maintenance living in a camp with ample grazing for a year. A bull weighing 250kg that eats approximately 5.5kg of feed per day at a 2% DMI basis will need approximately 55g per day of the salt mineral lick for the seven months of summer, and 0.69kg winter/protein lick (33% CP) per day for the five dry winter months, equating to a total cost of about R731.4 per year. Similarly, a cow living in a camp with ample grazing will need approximately 60g of salt mineral lick per day and 0.67kg winter/protein lick per day, equating to R720.32 per year. So, when considering keeping the animals at maintenance, this option is suitable, do not expect the cow's condition to stay optimal if she is lactating (raising a calf). A product designed for maintenance does not supply enough nutrients to keep the animal's condition optimal or supply it with enough nutrients to produce milk. Calculations for different combinations of animals within their categories and feed can be made to estimate costs over a year or fixed period using Table 2.6 as a guide.

When considering animals that must stay in tip-top condition, where cows must produce enough milk for their calves and stay in condition, the production lick or energy lick will supply them the necessary nutrients to digest the dry roughage, keep the cow in good condition and produce milk. Similarly, better-quality bulls can be supplied with higher quality feed, aiding optimal body and horn growth.

In areas where grazing becomes brittle in late winter, often associated with camps in sour veld regions, energy licks will work better than production licks in the latter part of the season, so it may be necessary to move the animals from the production lick onto the energy lick to ensure the animals receive more of the essential nutrients per day.

In camps where the grazing is sparse or depleted, any supplement can be supplied together with a high-quality hay source, or the animals can be supplied a semi-*ad libitum* feed (supplying the nutrients with enough roughage). Any one of the supplements can be supplied in holding pens and bomas, but the hay supply must be *ad libitum*, where strict feed bowl management must be followed. Supplying semi-*ad libitum* or full feeds with high-quality hay makes the holding pen or boma argument less risky if small groups of animals are housed together.

Table 2.6 Animal weights, approximate intakes, suggested intakes of different products, and their relative prices (2021 prices) for the different animal categories, where the animals get five months of winter feed and seven months of the mineral lick. Adapted from (Meissner, 1982; Köster *et al.*, 1996).

Category	**Weights**	**DMI**	**DMI**	**As fed intake (10% Moisture)**		
Unit	kg	%	kg	kg		
Bull	250	2%	5.00	5.50		
Mature cow	220	2.20%	4.84	5.32		
Cow with calf	220	3%	6.60	7.26		
Feed product and suggested minimum intakes to reach nutrient requirements						
Feed product	**Supplements**				**Feeds**	
Intake as % total feed intake	**1-2%**	**<=12.50%**	**<=25%**	**<=30%**	**66%**	**100%**
Common name for the feed product	**Summer mineral lick**	**Winter or licks**	**Production licks**	**Energy lick pellets or meal**	**Game semi adlib feed**	**Holding pens boma feed**
	1	**2**	**3**	**4**	**5**	**6**
Nutrient percentage	**6-8% Phosphorous**	**33% CP**	**22% CP**	**14% CP**	**12% CP**	**10% CP**
	g	**kg**	**kg**	**kg**	**kg**	**kg**
Bull	55.00	0.69	1.38	1.83	3.67	5.50
Mature cow	60.00	0.67	1.33	1.77	3.55	5.32
Cow with calf	100.00	0.91	1.82	2.42	4.84	7.26
Nutrients the different feed products supply						
Protein	N	Y	Y	Y	Y	Y
Energy	N	Y (10-20%)	Y (25-35%)	Y (40-50%)	Y (70-85%)	Y (100%)
Fat	N	N	N	N	Y	Y
Roughage	N	N	N	N	Y	Y
Minerals	Y	Y	Y	Y	Y	Y
Trace minerals	Y	Y	Y	Y	Y	Y
Vitamins	Y	Y	Y	Y	Y	Y

Product costs per ton and per kg (2021)						
Common name for the feed product		Winter or protein licks	Production licks	Energy pellets or meal#	Game Feed#	Holding pens Boma Feed#
	Phosphorous lick	33% CP lick	22% CP lick	14% CP pellet/meal	12% CP feed	10% CP feed
Cost of feed	R 8 600.00	R 6 000.00	R 5 000.00	R 4 900.00	R 4 000.00	R 3 500.00
Cost per kg	R 8.60	R 6.00	R 5.00	R 4.90	R 4.00	R 3.50
Cost per day						
Bull	R 0.47	R 4.13	R 6.88	R 8.98	R 14.67	R 19.25
Mature cow	R 0.52	R 3.99	R 6.66	R 8.70	R 14.20	R 18.63
Cow with calf	R 0.86	R 5.45	R 9.08	R 11.86	R 19.36	R 25.41
Costs for respective green and dry season						
	December to May	Dry months - June to October				
Days	212	153				
Bull	R 100.28	R 631.13	R 1 051.88	R 1 374.45	R 2 244.00	R 2 945.25
Mature cow	R 109.39	R 610.93	R 1 018.22	R 1 330.47	R 2 172.19	R 2 851.00
Cow with calf	R 182.32	R 833.09	R 1 388.48	R 1 814.27	R 2 962.08	R 3 887.73
Total cost per year, summer plus winter lick/feed						
Bull		R 731.40	R 1 152.15	R 1 474.73	R 2 344.28	R 3 045.53
Mature cow		R 720.32	R 1 127.61	R 1 439.86	R 2 281.58	R 2 960.39
Cow with calf		R 1 015.41	R 1 570.80	R 1 996.59	R 3 144.40	R 4 070.05

- Animals diagnosed with worms, please note that the low intake lick arguments do not work; with the animals requiring more energy, please do not simply add energy in the form of maize or other grains; add a balanced diet where more highly digestible roughage is supplied (Diets 3, 4 or 5).

2.7.6. Ailments common to sable antelope – near the feed bowl

This section will only cover ailments common to sable antelope. Sable antelope seem to be fairly resistant to diseases such as anthrax and cytauxzoonosis, but it is advised to vaccinate animals every two to three years in intensive systems. Animals living in holding pens or bomas for longer than three weeks should be treated against coccidiosis prophylactically every two to three weeks (Kriek, 2005, 2017).

When sable antelope are ranched in small camps, Haemonchus (wireworm) infestation may be considered one of the most common ailments sable antelope encounter (Kriek, 2005; Greeff, 2020; Shepstone, 2020). These worms attach themselves to the mucosal layer of the abomasum (melkpens), where they consume blood, resulting in anaemia and, in extreme cases, death. Treatment typically includes one of the following or a combination of the following; collecting faeces to assess worm egg numbers (Vatta *et al.*, 2001); the use of worm remedies (supplied orally, or by injection using a drop-out dart); rotational grazing as well as keeping the animals away from areas where the worms were present in the previous season.

When considering wireworm and other blood-sucking worms from a nutritional perspective, it is important to understand what this does to the animal's nutrient status. With blood being the worm's food source, the animal is losing white and red blood cells causing anaemia; they also lose other nutrients like glucose, amino acids, fatty acids, vitamins and minerals (Shepstone, 2020). Note that when feeding animals suffering from symptoms associated with worms, low intake licks (feeds 1 & 2 in Table 2.6) is not advised. Supply feeds 3, 4 or 5 depending on the camp and roughage supply.

Treatment – If blood can be produced quicker after treating the worms with a worm remedy, the animal will get back to optimal health faster; supplying the animals with a trace mineral top-up can aid in this. Some oral worm remedies harm the resident microbe population in the animal's rumen, making it essential to consider using a probiotic when dosing animals anthelmintics; probiotics supply the animals with the beneficial microbes needed to optimally degrade and digest the available feed (Greeff, 2020; Shepstone, 2020).

Traumatic pericarditis (hardware disease), when a piece of wire pushes through the rumen into the heart or the heart sack, has been seen in sable antelope and other ruminants. The pieces of wire are often found in the feed, be it mixed feed or bales; bales of lucerne bailed with wire instead of string is usually the source (Kriek, 2017). Placing a strong magnet where the feed exits a feed mixer helps catch small pieces of wire, preventing the animals from swallowing it.

Enterotoxaemia, otherwise known as red gut, is commonly seen in sable antelope and other similar wildlife when sudden changes in diet occur (Kriek, 2017).

Feeding sites in all camp systems may cause issues resulting in sick animals and death if not investigated and counter measures put in place. When a particular spot in a camp is used continuously as a feeding site, problems could arise in the long term; namely, parasite build-up such as wire- and other roundworms and coccidia. These feeding sites can become a breeding place for disease due to the high number of flies and mould growing in old food, leading to possible mycotoxicosis. Feeding sites used continuously are often also associated with accumulated faeces and urine.

To prevent the build-up of possible nutritional and disease-causing problems feeding sites should be moved regularly. Animal enclosures at zoos and those used in holding pens and bomas are exceptions due to their small size, making dedicated feeding sites necessary. These feeding areas need to be designed so they can be cleaned and disinfected routinely.

The feed should not be placed near water troughs – placing feed bowls a short distance away will limit the amount of collected feed falling out of the animals' mouths into the water. Water troughs and feed bowls must be cleaned routinely. Old feed and faeces must be removed (Shepstone, 2016).

2.7.7. Handling (immobilisation and translocation)

Handling in terms of sable antelope is limited to veterinary diagnosis and movement of animals from one camp to another using feed and opening and closing water troughs. These animals can be darted by a veterinarian or be passively captured in a boma or holding pen. Unfortunately, this species does not domesticate to the point where humans can handle them like livestock and other game species. Sorting and weaning is usually done with veterinary assistance, where the identified animals are darted (immobilised) and moved (Greeff, 2020). Wapiti (elk) and red deer are successfully handled like livestock, making sorting and selection a lot easier (Haigh & Hudson, 1993).

Sable antelope are well known to be aggressive towards each other, particularly newcomers. Indiscriminate mixing of individuals can lead to mortalities (Greeff, 2020). To minimize territorial behaviour, one should synchronize the mixing of animals unknown to each other in a small fenced area (pen or small camp), then move the animals to a new camp; this can be made easier by using tranquillizers (Warren & Meyer, 2005; Greeff, 2020). If mass capture is an option or animals are placed in groups on a truck, placing pipes on the horns is advisable (Kriek, 2017).

When creating a new breeding herd from animals out of other existing herds, the herd demographics must be similar to the natural herd: where there is one breeding bull, two cows, two older heifers and the balance young heifers (8 to 10 female animals) (Warren & Meyer, 2005).

Sable antelope are readily translocated; captive-bred animals accustomed to humans adapt easier than animals brought in from the wild. These animals are also used to getting supplemental feed, making it easier for the rancher to adapt the animals to a new camp, limiting breeding cycle disruptions (Warren & Meyer, 2005).

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Chapter 3

Carrying capacity methodology comparison, using the sable antelope (*Hippotragus niger niger*) as reference ungulate

3.1. Abstract

An investigation into the methodologies presently employed determining carrying capacity of wildlife species illustrates that the large animal unit, grazing unit, and browsing unit methods only use metabolic weight as a factor to determine the energy requirements of game where the large stock unit method uses both metabolic weight and the energy requirements of the animal at a specific well defined physiological production state. The metabolizable energy requirement per day was regressed with weight (kg) using a log-log transformation of the herbivore species to ascertain if the large animal unit method is suitable for defining/determining the metabolizable energy requirements of game. The resulting equations were used to compare the calculated metabolizable energy and large stock unit values to the published metabolizable energy and large stock unit values. The physiological production states analysed; calf/lamb, young dry cow/ewe, mature dry cow/ewe, young cow/ewe with calf/lamb, mature cow/ewe with calf/lamb, young bull/ram, and mature bull/ram. Six out of the seven categories have values higher than 0.75 with R^2 values of >0.99, except the calf/lamb data with the value of 0.742 with an R^2 = 0.97. These results indicate that metabolic weight is neither conceptually correct nor sufficiently accurate to calculate metabolizable energy requirements for game, confirming the acceptance of the alternative hypothesis. Therefore, the large animal unit (metabolic weight method) cannot replace the large stock unit (metabolizable energy method). The derived log-log transformation equation provides a more accurate method for determining the metabolizable energy requirements and dry matter intake values for sable antelope and other game species.

3.2. Introduction

The South African Animal Improvement Act, no 62 of 1998 (Government Gazette, 2019) amendment' classifies certain game animals kept on private property as livestock. It has enabled ranchers to ranch with game animals, similar to how farmers farm with livestock. Furthermore, it highlights the importance of understanding carrying capacity and its use as a management tool in animal and veld management, ensuring sustainable use of natural resources.

When estimating short and long-term carrying capacity for certain vegetation types on a game reserve or ranch, ecologists (rangeland scientists) and animal scientists follow different methods in determining this. The methods being: the large stock unit (LSU) (Meissner, 1982), the American animal unit (AU) (Scarnecchia, 1985), the large animal unit (LAU) and the grazing and browsing unit

(GU & BU) (Van Rooyen & Du P Bothma, 2016). The most significant difference between these methods is how the animal unit is calculated, which will be discussed in this paper.

Carrying capacity is defined as the number of animals of a particular species the veld can carry (Grossman *et al.*, 1999). Carrying capacity can broadly be described as a function of veld or pasture management which includes the effects of trampling, water point distribution, amount and availability of palatable and nutritious plant species, interspecies competition, animal behaviour (Meissner, 1982), rainfall and fire regime (Grossman *et al.*, 1999). These variables relate in various degrees to feed intake, where the feed intake by a herbivore is directly related to the animal's energy requirements and its ability to fulfil its nutrient requirements from the available feed (Meissner, 1982). Carrying capacity estimates is only reliable if feed intake under different circumstances is known. Intake is not easily measured in wild herbivores but can be determined if the energy requirements of the animals in question and the digestibility of the feed to meet these demands, are known (Meissner, 1982).

When ranching with sable antelope (*H. niger niger*) or any other herbivore , it is necessary to know how many animals a reserve or ranch can carry within different camp systems; intensive, semi-intensive (i.e., camps of known hectares) and extensive systems. The carrying capacity of the systems is essential so that it is possible to determine the stocking rate of the camp system, enabling the rancher to calculate how many animals must be removed or when supplementary feeding in the form of digestible roughage is necessary. Thorough knowledge of the veld/range carrying capacity is necessary for developing a comprehensive management strategy for the ranch or reserve that can evaluate these systems over time. Essential in determining the carrying capacity of a particular system is the knowledge of the vegetation type and the daily nutritional requirements (energy) of the animals to be kept there.

When considering the nutritional wellbeing of game and livestock species, guidelines in determining their energy and other nutrient requirements are vital. Research on cattle and other domestic livestock has shown that if the weight of the animal, their dry matter intake (DMI), as well as the digestibility of the selected feed is known, it is possible to assess whether the available feed will be able to supply sufficient nutrients required for the specific animal's physiological production state. i.e., to keep a 550kg domestic beef cow in her first month of lactation in a positive energy balance, the cow would need to consume 12.1kg feed (DM) that has a total digestible nutrient value (TDN) of 60%, supplying 112.28 MJ metabolizable energy (ME) (9.28 MJ ME per kg x 12.1kg feed) per day. A 550kg dry cow eating the same diet will consume 11.1kg (DM) feed supplying the animal with 103.00 MJ ME. This example shows that when comparing a dry cow to a cow in her first month of lactation, the cow in lactation requires 9.28 MJ ME more per day (NRC, 2016). In the same way, game ranchers can use similar data to improve animal production and veld management on their properties if the energy requirements for game are known.

The LSU method is the official method used to determine the carrying capacity of properties in livestock production systems in South Africa. Some ecologists working with game reserves and ranches disagree with this approach and created the grazing and browsing unit method (GU & BU) (discussed below).

To fully understand LSU methodology, it is necessary to understand how it was derived (Meissner, 1982). Historically data on vegetation studies were limited and difficult to obtain, resulting in carrying capacity calculations being expressed as biomass (Meissner, 1982), where biomass is represented by the biological weight of all the living organisms in a given area (Ilson, 1984). Energy consumption or requirement is only partially related to weight. It is more accurately a function of metabolic weight, expressed as $kg^{0.75}$ (Mentis, 1977). Biomass represented by biological weight has been investigated in detail by others (Brody, 1945; Kleiber, 1961; Schmidt-Nielsen, 1972; Heusner, 1982; Hayssen & Lacy, 1985), who provide evidence that biomass is not an accurate basis for comparison. A more accurate and scientifically correct method to calculate energy requirements would be to express animal size in terms of energy requirements, where a poorly studied animal (wild herbivore) is compared to a well-studied one (domestic livestock), using the common denominator of metabolic weight (Mentis & Duke, 1976; Mentis, 1977). When using metabolic weight, differences are assumed to be proportional to a particular exponent, i.e., the animal's body weight to the power of 0.75. Implying that feed consumption per unit metabolic weight would be the same for all animals at the same physiological production state.

Taking metabolic weight into consideration and the fact that the carrying capacity of a particular game reserve, ranch or camp is influenced by various environmental (vegetation) and physiological (animal) factors, Meissner (1982) suggested an alternative approach to the more conventional carrying capacity calculation methods, i.e., using ME requirements as the basis for the calculation of carrying capacity. To do so, Meissner (1982) followed the approach that the energy requirement of a particular species could be compared to a standardised norm for evaluating carrying capacity, namely the large stock unit (LSU). An LSU is defined as "the equivalent of a steer (cattle) with a weight of 450 kg which has a growth rate of 500g per day on grass pasture with a mean digestible energy (DE) concentration of 55% (to achieve this growth 75 MJ ME per day is required).

The energy requirements in MJ/Day and LSU equivalents in the appendix were calculated using research data from 14 different wild southern African herbivore species. The composition of growth, basal heat production, the efficiency of feed utilization for maintenance and growth within their actual nutritional niche of the animal was considered (Meissner, 1982). Similarly, field metabolic rate (FMR) is used in other published data in estimating animals energy requirements (Costa & Maresh, 2018). The FMR value for an animal at a particular weight is similar to the mature animal LSU's (maintenance) energy requirement value in Meissner (1982); refer to Table 3.11. Please note that the South African Department of Agriculture changed the abbreviation of an LU to an LSU. Meissner's (1982) paper uses a livestock unit (LU), not a large stock unit (LSU).

Ecologists and other scientists use the large animal unit (LAU) or the animal unit (AU) method to calculate carrying capacity. The LAU method uses the metabolic weight of the desired species divided by the metabolic weight of a 450kg animal (Van Rooyen, 2014). When calculating the values presented in Table 3.1 (Du P Bothma & Du Toit, 2014), ignoring the energy component, i.e. the sable antelope (*H. niger niger*) weighing 220kg has an LAU value of 0.58 (Van Rooyen, 2014); the calculation being: $220^{0.75} / 450^{0.75} = 0.58$.

Table 3.1 The approximate large animal unit (LAU) equivalents of three wild herbivores in South Africa (Van Rooyen, 2014).

Species	Average weight (kg)	LAU per animal	Animals per LAU
Blue wildebeest (*Connochaetes taurinus*)	180	0.50	2
Greater kudu (*Tragelaphus strepsiceros*)	140	0.42	2.38
Sable antelope (*Hippotragus niger niger*)	220	0.58	1.72

The AU approach used by the Americans since the early 1900s incorporates both body weight and intake, where the intake is calculated as the amount of feed the animals would eat relative to the AU. An AU is defined as a mature cow weighing 450kg ingesting 12 kg forage per day on a dry matter (DM) basis (bodyweight x 2.66%). The AU equivalent of a species of a particular weight equals its relative metabolic weight divided by the metabolic weight of an AU ($450^{0.75}$) (Scarnecchia, 1985; Perrier, 1996; Rangeland Management Society, 2016). Perrier (1996) suggests that an AU should be used as an ecological concept, and care should be taken when using it as an exact measurement. In essence, the LAU and the AU are mathematically similar.

Some ecologists in South Africa find the LSU and the LAU method limiting and have proposed and currently use another method, where the carrying capacity of a game ranch or reserve is expressed as a grazing (GU) and browser unit (BU) instead of a livestock unit (LSU) or large animal unit (LAU) (Van Rooyen, 2002, 2014; Van Rooyen & Du P Bothma, 2016).

Their reasons for stating that the LSU/LAU method is limiting is:

- Different wild herbivores' feeding and habitat preferences, particularly animals that combine grazing and browsing in different proportions, i.e., mixed feeders.
- The diversity in vegetation on ranches is influenced by habitat type, ecological condition, production, and thus the availability and quality of the grazing and browse. Accessibility of the terrain and recent occurrence of fire and or rainfall are also not taken into consideration.

Furthermore, when using the LSU method to calculate stocking densities of wild animals on a game ranch or reserve, it only supplies the rancher/researcher a broad guideline of how many individuals of a particular species can be substituted for every LSU or LAU (Van Rooyen & Du P Bothma, 2016).

A grazer unit (GU) is defined as the metabolic weight equivalent of a blue wildebeest (*Connochaetes taurinus*) with a live weight of 180kg. The GU method used to calculate the grazing capacity of a game ranch or reserve is expressed as the number of GU per 100 hectares (Van Rooyen & Du P Bothma, 2016).

When using the GU method for determining stocking densities on a ranch or reserve, it is necessary to conduct a survey of the grass and forb layer and calculate the veld condition index for the property. Furthermore, to improve accuracy, it is necessary to take note of the surface area covered by each plant community or habitat type and the veld condition index of each different plant community or habitat present. The percentage canopy cover of the grass layer, long term average rainfall or the mean average rainfall over the preceding two years, a fire factor or influence of fire and a topographical index indicating accessibility of the terrain for larger wild herbivores is also required (Van Rooyen & Du P Bothma, 2016).

A BU is defined as the metabolic weight equivalent of a greater kudu (*Tragelaphus strepsiceros*) cow weighing 180kg. Browsing capacity is expressed as the number of BU carried per 100 hectares. Browse can be seen as the edible portion of woody plant material below the height of 2m for most browsers but below 5.5m for the elephant (*Loxodonta africana*) and giraffe (*Giraffa camelopardalis)* (Van Rooyen & Du P Bothma, 2016).

When calculating stocking densities for browsers on a particular ranch or reserve, it is essential to remember that the browse supply in the late dry season generally limits the stocking density for browsers in camps on smaller game ranches (Van Rooyen & Du P Bothma, 2016).

With both the GU and the BU utilising the weight of 180kg, it is not necessary to calculate this value for both units. When calculating the sable antelope GU/BU value relative to a 180kg BU/GU, the following calculation is used (Table 3.2):

Bodyweight of average sable (*H. niger niger*) antelope to the power 0.75/$180^{0.75}$

$$220^{0.75}/180^{0.75} = 1.16 \text{ GU/BU}$$

In the GU/BU method for estimating carrying capacity, the sable antelope is compared to the blue wildebeest (*Connochaetes taurinus*) (GU) and the kudu (*Tragelaphus strepsiceros*) (BU).

When interpreting this value in terms of carrying capacity estimates, the GU/BU value gets multiplied by the respective % of grass and browse in their diet, obtaining the GU or BU value for the species. i.e., a herd of 100 sable antelope on a game ranch or reserve (in terms of a grazer/browser unit) will be equivalent to a herd of 99 blue wildebeest and 17 kudus:

1.16 (GU - sable antelope (*H. niger niger*)) X 85% (% grass in diet) = 0.99

0.99 GU X 100 = 99 GU or blue wildebeest (*Connochaetes taurinus*).

1.16 (BU - sable antelope (*H. niger niger*)) X 15% (% browse in diet) = 0.17

0.17 BU X 100 = 17 BU or kudus (*Tragelaphus strepsiceros*)

In essence, all LAU, AU, BU/GU methods regarding the relative animal values are essentially mathematically similar with metabolic weight as the common denominator.

In an attempt to simplify estimating/calculating the energy requirements of grazing and browsing game species, Meissner's paper was scrutinized for common denominators that can be used to develop a mathematical model for improving carrying capacity estimations for other herbivore species not included in the paper (Meissner, 1982). One such herbivore species is the sable antelope.

This paper aims to develop a more accurate mathematical model to calculate the metabolizable energy requirements, DMI of sable antelope and other herbivores at different physiological states, using their respective feeding habits to improve carrying capacity and stocking rate estimates on game reserves and ranches. Furthermore, the derived calculations can be used to re-evaluate the GU & BU method (Van Rooyen & Du P Bothma, 2016) in terms of ME. The following four questions were asked to reach these aims mentioned above:

1. Can metabolic weight alone be used to determine the ME requirements for game?
2. Can the calculated regression coefficient values be used to estimate the ME requirements for sable antelope (*H. niger niger*) and other animals not found in the appendix (Meissner, 1982)?
3. Can DMI be calculated using naturally selected forage?
4. Can the calculated ME values describe the GU/BU unit in terms of ME requirements?

Table 3.2 The approximate grazer and browser unit equivalents (substitution ratios) for three species of herbivore, their grazer/browser unit equivalent values based on metabolic weight and the percentage of grazing and browsing done by different herbivores in southern Africa (Van Rooyen & Du P Bothma, 2016).

Species	**Gut types**	**Mean weight in kg**	**Percentage grass in the diet**	**Percentage browse in the diet**	**Grazer units per animal based on % grass in the diet**	**Browser units per animal based on % browse in the diet**	**Grazer/browser units per animal based on metabolic weight**
Blue wildebeest (*Connochaetes taurinus*)	Selective grazer	180	87%	13%	0.87	0.13	1.00
Sable antelope (*Hippotragus niger niger*)	Selective grazer	220	85%	15%	0.99	0.17	1.16
Greater kudu (*Tragelaphus strepsiceros*)	Browser	140	15%	85%	0.12	0.70	0.83

3.3. Material and methods

The main objective of this study is to ascertain if metabolic weight can be used to determine the ME requirements of game. The ME requirement in megajoules per day (MJME/day) was regressed to weight (kg) using a log-log transformation for the herbivore species in the appendix (Meissner, 1982) to establish if the LAU method described by Van Rooyen & Du P Bothma (2016) is suitable for defining/determining the ME requirements of game (Table 3.5). The different physiological production states incorporated in the analyses included calf/lamb, young dry cow/ewe, mature dry cow/ewe, young cow/ewe with calf/lamb, mature cow/ewe with calf/lamb, young bull/ram, and mature bull/ram (Table 3.3).

The equations derived from the above (Table 3.3) were used to compare the calculated ME, and LSU values to the published ME and LSU values of Meissner (1982) (Table 3.5). Sable antelope weights for the different categories were entered into the models, where the calculated ME values were obtained in megajoules per day ME (MJ ME/day). The derived ME (calculated) values made it possible to calculate the DMI for sable antelope and other species. Lastly, the GU/BU method (Van Rooyen & Du P Bothma, 2016) was re-evaluated using the derived ME calculations.

3.4. Results

3.4.1. Question 1, can metabolic weight alone be used to determine the ME requirements for game?

Metabolizable energy requirement in megajoules ME per day (MJME/day) was regressed to weight in kg using log-log transformation for the herbivores listed in Meissner's appendix (Meissner, 1982). This data (Table 3.3) represented wildlife species ranging from the springbok (*Antidorcas marsupialis*) to the elephant (*Loxodonta africana*), excluding the warthog (*Phacochoerus africanus*). This wide diversity was used to determine whether the regression coefficient (gradient) would differ significantly from 0.75. To explain the rationale: ME requirements and weight are allometrically ($y = ax^b$) (Brody, 1945; Kleiber, 1961) and not linearly ($y = a + bx$) related, with the expected exponent value being 0.75 (metabolic weight), and the resultant graph curvilinear in shape. However, when the same data set of ME and weight are both log-transformed, the allometric equation expresses linear characteristics, i.e., $\log y = \log a + b (\log x)$, and the exponent 'b' (allometric equation) represents the regression coefficient (gradient) 'b'. The transformation of the data resulted in a better fit of the model.

The assumption is then that if the regression coefficient value 'b' is close to or equal to 0.75, the probability exists that the LAU method is correct and can be interpreted as an LSU (derived from ME) value, therefore suggesting that the LAU (derived from the metabolic weight) method is scientifically sound and thus equal to the LSU value (Meissner, 2020). Therefore all of the LAU values mentioned (Du P Bothma & Du Toit, 2014) should be correct.

Thus, the null hypothesis will be true if the regression coefficient in the log-transformed equation is 0.75 or close to it, which then suggests that the LAU values should correspond satisfactorily with the LSU values. The alternative hypothesis states that the regression coefficient will not be equal to 0.75. If the alternative hypothesis proves true, the LAU values based on metabolic weight will not match the LSU values and cannot simulate or replace the LSU method.

The LAU value of a specific species under question would be the live weight raised to the power of 0.75 divided by 450kg raised to the power of 0.75 (Van Rooyen, 2014).

In line with the LSU method, the following categories were analysed, calf/lamb, young dry cow/ewe, mature dry cow/ewe, young cow/ewe with calf/lamb, mature cow/ewe with calf/lamb, young bull/ram and mature bull/ram (Table 3.3). The results indicate that the regression coefficients of both mature male and female animals at maintenance were higher than 0.75; the mature dry cow/ewe and mature bull/ram had means with standard error values of 0.791 ± 0.021, and 0.799 ± 0.028, respectively (Table 3.4).

Table 3.3 Log of weight (kg) and Log of ME (MJ/day) transformed data derived from Meissner (1982) for the different physiological production states of different wildlife species.

Categories	Calf/lamb		Young dry cow/ewe		Mature dry cow/ewe		Young cow/ewe with calf/lamb		Mature cow/ewe with calf/lamb		Young bull/ram		Mature bull/ram	
Species	**Log weight (kg)**	**Log ME (MJ / day)**	**Log weight (kg)**	**Log ME (MJ / day)**	**Log weight (kg)**	**Log ME (MJ / day)**	**Log weight (kg)**	**Log ME (MJ / day)**	**Log weight (kg)**	**Log ME (MJ / day)**	**Log weight (kg)**	**Log ME (MJ / day)**	**Log weight (kg)**	**Log ME (MJ / day)**
Springbok (*Antidorcas marsupialis*)	1.10	0.50	1.43	0.80	1.49	0.85	1.43	0.89	1.49	0.96	1.48	0.85	1.56	0.87
Impala (*Aepyceros melampus*)	1.28	0.77	1.57	1.03	1.65	1.01	1.57	1.15	1.65	1.14	1.71	1.08	1.78	1.09
Blesbok (*Damaliscus pygargus phillipsi*)	1.37	0.88	1.78	1.09	1.83	1.17	1.78	1.19	1.83	1.28	1.86	1.16	1.91	1.17
Tsessebe (*Damaliscus lunatus lunatus*)	1.59	1.09	2.02	1.29	2.05	1.32	2.02	1.39	2.05	1.43	2.10	1.40	2.13	1.40
Black wildebeest / Gnu (*Connochaetes gnou*)	1.60	1.10	2.02	1.31	2.06	1.33	2.02	1.40	2.06	1.45	2.10	1.38	2.14	1.39
Greater Kudu (*Tragelaphus strepsiceros*)	1.67	1.18	2.10	1.45	2.20	1.47	2.10	1.54	2.20	1.59	2.29	1.57	2.33	1.56
Waterbuck (*Kobus ellipsiprymnus*)	1.71	1.19	2.11	1.44	2.20	1.45	2.11	1.54	2.20	1.56	2.29	1.57	2.35	1.55
Blue Wildebeest (*Connochaetes taurinus*)	1.74	1.20	2.16	1.47	2.20	1.47	2.16	1.57	2.20	1.58	2.34	1.62	2.38	1.60
Zebra (*Equus quagga*)	1.98	1.39	2.43	1.69	2.46	1.65	2.43	1.79	2.46	1.77	2.49	1.73	2.53	1.72
Eland (*Taurotragus oryx*)	2.16	1.50	2.66	1.88	2.70	1.86	2.66	1.98	2.70	1.94	2.70	1.95	2.81	1.94
African savanna buffalo (*Syncerus caffer*)	2.30	1.59	2.66	1.90	2.72	1.88	2.66	2.00	2.72	2.00	2.88	2.00	2.91	1.98
Giraffe (*Giraffa camelopardalis)*	2.59	1.76	2.89	2.05	2.93	2.00	2.89	2.14	2.93	2.11	2.98	2.10	3.08	2.10
Elephant (*Loxodonta africana*)	2.93	1.93	3.27	2.45	3.52	2.46	3.27	2.56	3.52	2.57	3.34	2.48	3.57	2.49

When considering the growth and lactation equations within these categories, the regression coefficients increase from 0.75 to an average of 0.841; being 0.864 for the young dry cow/ewe, 0.866 for the young cow/ewe with calf/lamb, 0.782 for the mature cow/ewe with calf/lamb and 0.853 for the young bull/ram (Table 3.4 and Figure 3.1). When considering the seven different categories, all but the young calf (Table 3.4 and Figure 3.1) have values larger than 0.75, with all the categories having highly significant P values ($P<0.001$). The only category that falls below 0.75 is the calf/lamb category, with values of 0.742 with a standard error of 0.077.

These results indicate that metabolic weight is neither conceptually correct nor sufficiently accurate to calculate ME requirements for game, confirming the acceptance of the alternative hypothesis. Therefore, the LAU (metabolic weight method) cannot replace the LSU (ME method). As illustrated in Table 3.3, the gradients were applied to the log weights to obtain the ME requirements for the respective physiological production states of the different species in MJ ME/day.

Table 3.4 Regression coefficients (gradient) for the different physiological production states of wildlife species calculated from the Log ME (MJ per day) to the Log weight (kg) and standard error values (SE).

Category	Gradient (a)	R^2	SE	SE -1	SE +1
Metabolic weight value	0.750				
Calf/lamb	0.742	0.966	0.077	0.665	0.818
Young dry cow/ewe	0.864	0.993	0.041	0.823	0.906
Mature dry cow/ewe	0.791	0.998	0.021	0.770	0.812
Young cow/ewe with calf/lamb	0.866	0.991	0.045	0.821	0.910
Mature cow/ewe with calf/lamb	0.782	0.998	0.021	0.761	0.803
Young bull/ram	0.853	0.995	0.033	0.820	0.886
Mature bull/ram	0.799	0.996	0.028	0.771	0.827

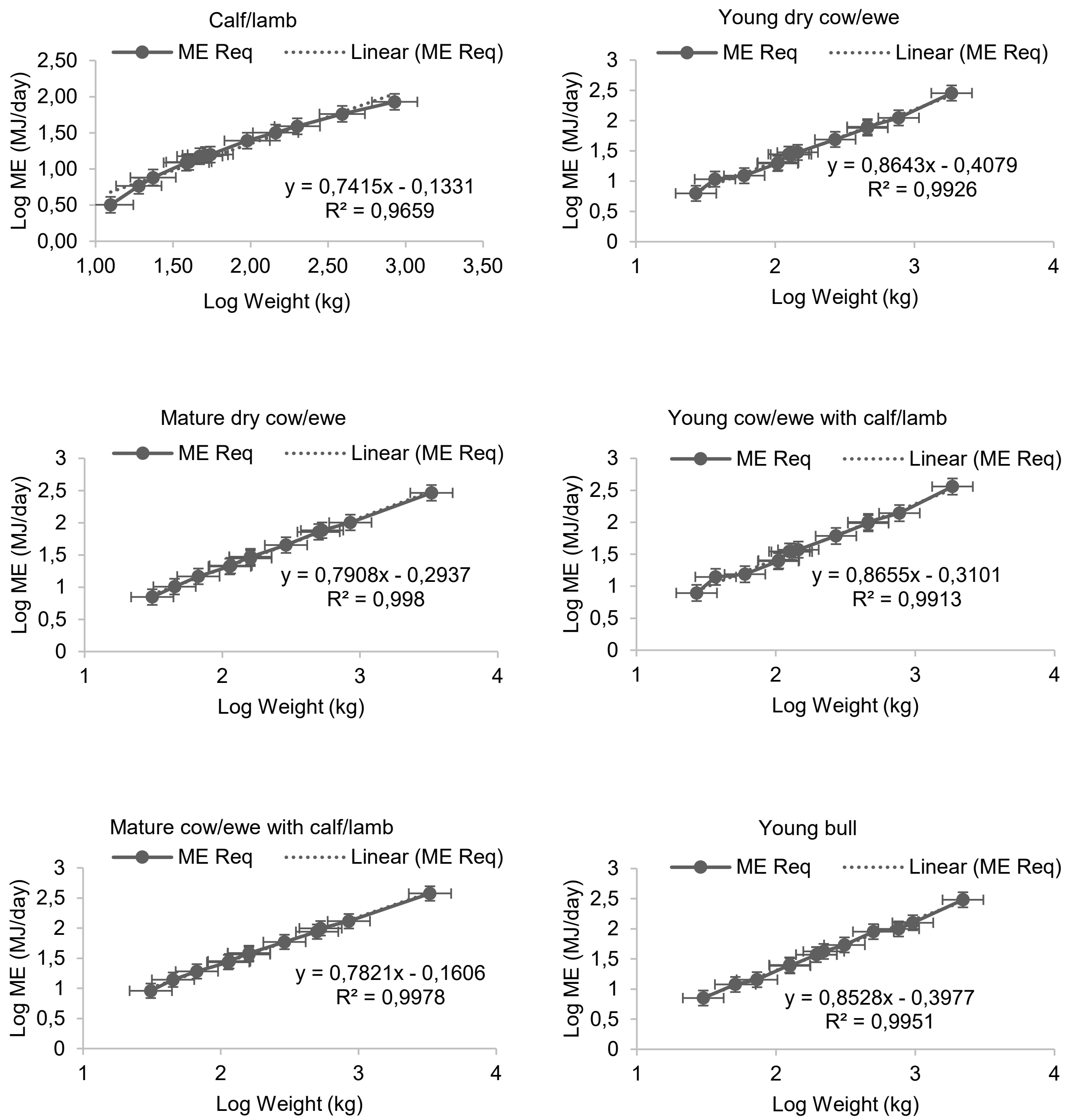
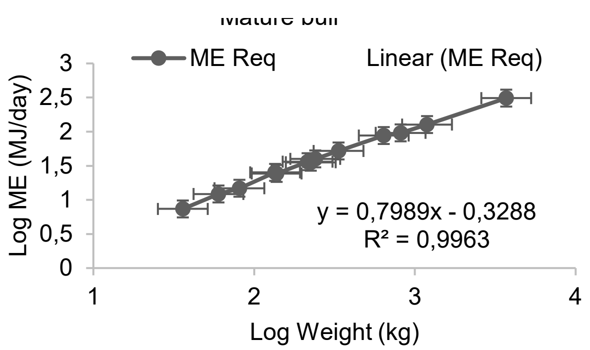


Figure 3.1 Log ME (MJ per day) / Log weight (kg) equation of the calf/lamb, young dry cow/ewe, mature dry cow/ewe, young cow/ewe with calf/lamb, mature cow/ewe with calf/lamb, young bull, mature bull data, showing their respective regression coefficients and R^2 values.



The calculated ME (MJ/day) values compared to published data from Meissner (1982) are shown in Table 3.5 Where the 13 herbivores species mentioned in Table 3.5 are categorised into calf/lamb, young dry cow/ewe, mature dry cow/ewe, young cow/ewe with calf/lamb, mature cow/ewe with calf/lamb, young bull/ram, mature bull/ram.

Table 3.5 Calculated metabolizable energy (ME) and large stock unit (LSU) values compared to published metabolizable energy (ME) and large stock unit values (LSU) for 13 herbivores of the 14 herbivore species from the appendix of Meissner (1982)[#], for the categories; calf/lamb, young dry cow/ewe, mature dry cow/ewe, young cow/ewe with calf/lamb, mature cow/ewe with calf/lamb, young bull/ram, mature bull/ram.

Species	Weight (kg)	ME (MJ/day) Appendix values[#]	Large stock unit LSU[#]	New calculated ME (MJ/day)	New calculated LSU
Elephant (*Loxodonta africana*)					
Calf/lamb	850.00	84.80	1.13	109.81	1.46
Young dry cow/ewe	1850.00	285.00	3.80	259.92	3.47
Mature dry cow/ewe	3300.00	291.00	3.88	308.42	4.11
Young cow/ewe with calf/lamb	1850.00	362.00	4.83	330.65	4.41
Mature cow/ewe with calf/lamb	3300.00	375.00	5.00	389.47	5.19
Young bull/ram	2200.00	303.00	4.04	283.85	3.78
Mature bull/ram	3700.00	310.00	4.13	332.65	4.44
Giraffe (*Giraffa camelopardalis*)					
Calf/lamb	390.00	57.80	0.77	61.60	0.82
Young dry cow/ewe	770.00	111.00	1.48	121.88	1.63
Mature dry cow/ewe	850.00	101.00	1.35	105.48	1.41
Young cow/ewe with calf/lamb	770.00	139.00	1.85	154.78	2.06
Mature cow/ewe with calf/lamb	850.00	130.00	1.73	134.84	1.80
Young bull/ram	960.00	126.00	1.68	139.92	1.87
Mature bull/ram	1190.00	127.00	1.69	134.39	1.79
Eland (*Taurotragus oryx*)					
Calf/lamb	200.00	38.90	0.52	37.53	0.50
Young dry cow/ewe	460.00	75.50	1.01	78.09	1.04
Mature dry cow/ewe	500.00	72.10	0.96	69.32	0.92
Young cow/ewe with calf/lamb	460.00	96.60	1.29	99.07	1.32
Mature cow/ewe with calf/lamb	500.00	87.10	1.16	89.04	1.19
Young bull/ram	760.00	99.50	1.33	114.64	1.53
Mature bull/ram	815.00	96.00	1.28	99.32	1.32

Species	Weight (kg)	ME (MJ/day) Appendix values#	Large stock unit LSU#	Calculated ME (MJ/day)	Calculated LSU
African savanna buffalo (*Syncerus caffer*)					
Calf/lamb	145.00	31.80	0.42	29.56	0.39
Young dry cow/ewe	460.00	79.10	1.05	78.09	1.04
Mature dry cow/ewe	530.00	76.40	1.02	72.59	0.97
Young cow/ewe with calf/lamb	460.00	101.00	1.35	99.07	1.32
Mature cow/ewe with calf/lamb	530.00	99.30	1.32	93.19	1.24
Young bull/ram	500.00	89.60	1.19	80.21	1.07
Mature bull/ram	640.00	87.70	1.17	81.87	1.09
Zebra (*Equus quagga*)					
Calf/lamb/foal	95.00	24.60	0.33	21.60	0.29
Young dry cow/ewe/mare	270.00	48.90	0.65	49.28	0.66
Mature dry cow/ewe/mare	290.00	45.00	0.60	45.06	0.60
Young cow/ewe/mare with calf/lamb/foal	270.00	61.00	0.81	62.45	0.83
Mature cow/ewe/mare with calf/lamb/foal	290.00	58.90	0.79	58.16	0.78
Young bull/ram/stallion	310.00	54.00	0.72	53.35	0.71
Mature bull/ram/stallion	335.00	52.10	0.69	48.81	0.65
Greater kudu (*Tragelaphus strepsiceros*)					
Calf/lamb	55.00	15.80	0.21	14.40	0.19
Young dry cow/ewe	125.00	27.90	0.37	25.34	0.34
Mature dry cow/ewe	160.00	29.80	0.40	28.15	0.38
Young cow/ewe with calf/lamb	125.00	34.90	0.47	32.06	0.43
Mature cow/ewe with calf/lamb	160.00	38.70	0.52	36.53	0.49
Young bull/ram	220.00	42.10	0.56	39.82	0.53
Mature bull/ram	240.00	39.90	0.53	37.39	0.50
Waterbuck (*Kobus ellipsiprymnus*)					
Calf/lamb	47.00	15.00	0.20	12.81	0.17
Young dry cow/ewe	130.00	27.60	0.37	26.21	0.35
Mature dry cow/ewe	160.00	28.10	0.37	28.15	0.38
Young cow/ewe with calf/lamb	130.00	34.60	0.46	33.16	0.44
Mature cow/ewe with calf/lamb	160.00	36.60	0.49	36.53	0.49
Young bull/ram	195.00	37.30	0.50	35.93	0.48
Mature bull/ram	225.00	35.60	0.47	35.51	0.47

Species	Weight (kg)	ME (MJ/day) Appendix values#	Large stock unit LSU#	Calculated ME (MJ/day)	Calculated LSU
Blue wildebeest (*Connochaetes taurinus*)					
Calf/lamb	51.00	15.60	0.21	13.61	0.18
Young dry cow/ewe	145.00	29.80	0.40	28.80	0.38
Mature dry cow/ewe	160.00	29.40	0.39	28.15	0.38
Young cow/ewe with calf/lamb	145.00	37.30	0.50	36.45	0.49
Mature cow/ewe with calf/lamb	160.00	38.30	0.51	36.53	0.49
Young bull/ram	195.00	37.20	0.50	35.93	0.48
Mature bull/ram	215.00	36.30	0.48	34.25	0.46
Black wildebeest / Gnu (Connochaetes gnou)					
Calf/lamb	40.00	12.50	0.17	11.37	0.15
Young dry cow/ewe	105.00	20.30	0.27	21.79	0.29
Mature dry cow/ewe	115.00	21.60	0.29	21.68	0.29
Young cow/ewe with calf/lamb	105.00	25.40	0.34	27.56	0.37
Mature cow/ewe with calf/lamb	115.00	28.20	0.38	28.21	0.38
Young bull/ram	125.00	25.10	0.33	24.58	0.33
Mature bull/ram	135.00	25.30	0.34	23.61	0.31
Tsessebe (*Damaliscus lunatus lunatus*)					
Calf/lamb	38.50	12.20	0.16	11.05	0.15
Young dry cow/ewe	104.00	19.60	0.26	21.61	0.29
Mature dry cow/ewe	113.00	20.90	0.28	21.38	0.29
Young cow/ewe with calf/lamb	104.00	24.60	0.33	27.34	0.36
Mature cow/ewe with calf/lamb	113.00	27.20	0.36	27.83	0.37
Young bull/ram	126.00	24.20	0.32	24.75	0.33
Mature bull/ram	138.00	24.40	0.33	24.03	0.32
Blesbok (*Damaliscus pygargus phillipsi*)					
Calf/lamb	23.50	7.63	0.10	7.66	0.10
Young dry cow/ewe	60.00	12.30	0.16	13.44	0.18
Mature dry cow/ewe	67.00	14.70	0.20	14.14	0.19
Young cow/ewe with calf/lamb	60.00	15.40	0.21	16.98	0.23
Mature cow/ewe with calf/lamb	67.00	19.10	0.25	18.49	0.25
Young bull/ram	73.00	14.30	0.19	15.54	0.21
Mature bull/ram	81.00	14.80	0.20	15.70	0.21

Species	Weight (kg)	ME (MJ/day) Appendix values#	Large stock unit LSU#	Calculated ME (MJ/day)	Calculated LSU
Impala (*Aepyceros melampus*)					
Calf/lamb	19.00	5.84	0.08	6.54	0.09
Young dry cow/ewe	37.00	10.80	0.14	8.85	0.12
Mature dry cow/ewe	45.00	10.20	0.14	10.32	0.14
Young cow/ewe with calf/lamb	37.00	14.00	0.19	11.17	0.15
Mature cow/ewe with calf/lamb	45.00	13.90	0.19	13.55	0.18
Young bull/ram	51.00	11.90	0.16	11.44	0.15
Mature bull/ram	60.00	12.20	0.16	12.35	0.16
Springbok (*Antidorcas marsupialis*)					
Calf/lamb	12.50	3.19	0.04	4.80	0.06
Young dry cow/ewe	27.00	6.28	0.08	6.74	0.09
Mature dry cow/ewe	31.00	7.02	0.09	7.69	0.10
Young cow/ewe with calf/lamb	27.00	7.85	0.10	8.50	0.11
Mature cow/ewe with calf/lamb	31.00	9.10	0.12	10.12	0.13
Young bull/ram	30.00	7.08	0.09	7.28	0.10
Mature bull/ram	36.00	7.36	0.10	8.21	0.11

3.4.2. Question 2, can the calculated regression coefficient values obtained be used to estimate the ME requirements for sable antelope (*Hippotragus niger niger*) and other animals not found in the appendix (Meissner, 1982)?

Derived calculations from Table 3.4 and Figure 3.1 can be used to calculate the ME/day requirements for the different categories: X is the desired animal/species' Log weight (kg) and y = Log ME (MJ/day).

Table 3.5 compares the appendix values of Meissner (1982) to the formulae results for the different categories (Table 3.6); the calculated values are similar to the published values, echoing the high R^2 values in the first section. The results illustrated in the above section and values shown in Table 3.5 indicate that it is possible to calculate the ME requirements for sable antelope and other animals not found in the appendix (Meissner, 1982).

Table 3.6 Derived standard equations used to calculate an animal's metabolizable energy (ME) requirement per day at the respective physiological states, where X is the desired animal/species' Log weight and y = Log ME (MJ /day).

Physiological production state categories	Calculation where y - Log ME (MJ /day)
Calf/lamb	y = 0.742x - 0.133
Young dry cow/ewe	y = 0.864x - 0.408
Mature dry cow/ewe	y = 0.791x - 0.294
Young cow/ewe with calf/lamb	y = 0.866x - 0.310
Mature cow/ewe with calf/lamb	y = 0.782x - 0.161
Young bull/ram	y = 0.853x - 0.398
Mature bull/ram	y = 0.799x - 0.329

For example: estimating a waterbuck (*Kobus ellipsiprymnus*) (Lactating mature cow), ME/day with a weight of 160kg

Log ME = (0.782 x Log 160) – 0.161

Log ME = (1.724) – 0.161

Log ME = 1.563

ME/day = $10^{1.563}$

ME/day = 36.528 MJ ME/day

By entering known sable antelope weights weighed in South Africa and Zimbabwe (Du P Bothma *et al.*, 2016), respective ME in MJ/day per category can be calculated (Table 3.7).

Table 3.7 Estimated sable antelope (*Hippotragus niger niger*) metabolizable energy (ME) requirements at a specified weight (kg) and the calculated large stock unit (LSU) value for the respective physiological state relative to the 75 MJ ME energy a 450kg large stock unit (LSU) requires per day.

Sable antelope (*Hippotragus niger niger*)	Weight (kg)	Calculated ME (MJ/day)	LSU = MJ/Day / 75 MJ ME for an LSU
Calf/lamb	77.00	18.48	0.25
Young dry cow/ewe	180.00	34.72	0.46
Mature dry cow/ewe	220.00	36.21	0.48
Young cow/ewe with calf/lamb	180.00	43.96	0.59
Mature cow/ewe with calf/lamb	220.00	46.86	0.62
Young bull/ram	220.00	39.82	0.53
Mature bull/ram	250.00	38.63	0.52

3.4.3. Question 3, can dry matter intake be calculated using naturally selected forage?

The data was interpolated, making it possible to estimate the DMI from ME in MJ/day if the animal's weight, forage digestibility, digestible energy (MJ DE) of the forage and calculated ME value in MJ/day are known (Meissner, 1982).

To accurately calculate DMI, the forage digestibility should be known. An example of calculating forage digestibility is:

Sable antelope are selective grazers that select grass and browse in different proportions, usually 85% grass and 15% browse (Van Rooyen & Du P Bothma, 2016). Assuming grass has a digestibility of 50%, browse a digestibility of 55%. Multiply the percentage intake with the digestibility coefficient of grass and browse, add the respective values to each other to obtain the total forage digestibility (Table 3.8). The digestibility values used are based on an average to poor quality veld, preventing the possibility of overestimating intake (AFMA, 2020).

Table 3.8 Percentage grass and browse in the diet of the sable antelope (*Hippotragus niger niger*), the assumed digestibility of grass and browse, and the final forage digestibility value for the species.

	% Grass in diet	% Browse in diet	% Bark and twigs	% Fruit & flowers	Forage digestibility
Digestibility coefficient	0.50	0.55	0.40	0.60	
Sable antelope (*Hippotragus niger niger*)	0.85	0.15	-	-	0.51

Calculating DMI as a % of live body weight, when the forage digestibility of the selected feed is known, it is possible to determine how much the animal will eat daily (expressed as a percentage of live body weight). The calculated ME formulae (Table 3.7) below, was used to determine the DMI for the different sable antelope categories illustrated in Table 3.9. Similarly, this can be done for other herbivorous species:

DMI (% of BW) = ((((ME MJ/day/0.82) / Forage digestibility %) / 18.2 MJ) / animal weight kg) x100 (Meissner, 1982).

Metabolizable energy is taken as 82% of digestible energy (DE) (Smith, 1965). The average gross energy value of roughage is 18.2 MJ/kg (Smith, 1965).

Table 3.9 Calculated dry matter intake (DMI) of sable antelope (*Hippotragus niger niger*) (as % of body weight) for the different physiological type categories.

Sable antelope (*Hippotragus niger niger*)	**Weight**	**DMI %**
Calf/lamb	77.00	3.15
Young dry cow/ewe	180.00	2.53
Mature dry cow/ewe	220.00	2.16
Young cow/ewe with calf/lamb	180.00	3.21
Mature cow/ewe with calf/lamb	220.00	2.80
Young bull/ram	220.00	2.38
Mature bull/ram	250.00	2.03

3.4.4. Question 4, can the calculated ME values describe the GU/BU in ME requirements?

Having determined that the calculated ME values are accurate estimations of the daily energy requirements of the animal, it needs to be compared to the GU/BU equivalent value of an animal weighing 180kg. The GU/BU considers what the animals' naturally select and derives a value for other species relative to their metabolic weight. Metabolizable energy is used as the baseline argument, providing researchers and conservationists who use the GU/BU system a more accurate method to determine how many of these units can be kept on a game ranch or reserve. Furthermore, the GU/BU method only reflects the average animal close to its maintenance requirement, and it does not consider animals in different physiological production states.

The sable antelope that selects 85% grass and 15% browse (Van Rooyen & Du P Bothma, 2016) will be used to describe a possible manner where the GU/BU method can be interpreted in terms of ME requirements for both maintenance and lactation:

A baseline value of 180kg GU/BU weight class is similar to the 450kg beef steer used in the LSU method requiring 75MJ ME/ day. The 180kg GU/BU has a ME value of 29.71 MJ ME per day. This value is obtained by inputting 180kg weight into the mature bull/ram equation.

Log ME = (0.799 x Log 180) – 0.329

Log ME = (1.802) – 0.329

Log ME = 1.473

ME/day = $10^{1.473}$

ME/day = 29.714 MJ ME/day

Considering maintenance values for sable antelope, the calculated (Table 3.7) mature dry cow ME of 36.21 MJ ME/day, and the mature bull calculated ME value of 38.63 MJ ME/day provides an average ME maintenance value for a mature sable antelope, irrespective of sex, of 37.42 MJ ME/day.

Therefore, the calculated average ME value for the mature sable antelope is divided by the above-mentioned 180kg GU/BU ME value of 29.71 MJ ME per day. The GU/BU for the mature sable antelope at maintenance is, therefore:

37.42/29.71=1.26 GU/BU

By incorporating the average ME for the growing sable antelope and the lactating cow, the grazing/ browser units can be calculated for all physiological production states, as illustrated in Table 3.10.

Table 3.10 Relative body weights and calculated metabolizable energy (ME) values (MJ/day), the average calculated metabolizable energy (MJ/day) and the respective BU/GU values for maintenance, lactation, and body growth of the sable antelope (*Hippotragus niger niger*).

Physiological production state	**Weight kg**	**Calculated ME (MJ/day)**	**Calculated BU/GU**
Grazing/browsing unit	180	29.71	1
Sable antelope (*Hippotragus niger niger*) – maintenance values			
Mature dry cow/ewe	220	36.21	1.22
Mature bull/ram	250	38.63	1.30
Mature sable irrespective of sex	Average	37.42	1.26
Sable antelope (*Hippotragus niger niger*) – cow with calf			
Mature cow/ewe with calf/lamb	220	46.86	1.58
Young cow/ewe with calf/lamb	180	43.96	1.48
	Average	45.41	1.53
Sable antelope (*Hippotragus niger niger*) – growing			
Young dry cow/ewe	180	34.72	1.17
Young cow/ewe with calf/lamb	180	43.96	1.48
Young bull/ram	220	39.82	1.34
	Average	39.50	1.33

3.5. Discussion

Ecologists and animal scientists use different methods to calculate the carrying capacity on a livestock farm or game ranch and reserve. Animal scientists calculate carrying capacity focussing on livestock, where the different physiological production states are considered, whilst ecologists evaluate the carrying capacity of a game reserve in terms of an average game animal at maintenance.

When considering carrying capacity concerning the animal component, it is important to remember that the feed intake by a herbivore is related to the animal's energy requirements and its ability to fulfil its nutrient requirements from the available feed (Meissner, 1982). It is important to consider this aspect when ranching with game. On some ranches, the focus has moved from keeping animals on a sizeable fenced-off piece of land (game reserve) to ranching with game species similar to farmer's farm with livestock (Oberem & Oberem, 2016). For this to be successful, prominent management interventions are necessary, such as stocking the ranch or reserve using the carrying capacity estimations, strategic feeding of balanced rations and internal and external parasite control.

Emphasising that the focus needs to shift from the average animal approach (LAU and GU/BU methods) to a production animal approach (LSU, calculated LSU and GU/BU methods) where the different physiological production states of the animals are considered according to their nutritional requirements and feed selection habits. The LAU, AU and GU/BU methods are based on Kleiber's metabolic weight ($weight^{0.75}$) equations, and their respective animal unit values are calculated using the average weight of a species as a proportion of the metabolic weight of either a 450kg LAU or a 180kg GU/BU. The log-log equation discussed in the results concluded that the LAU method could not replace the LSU method.

On the other hand, the LSU method describes other species relative to the 75 MJ ME energy a 450kg steer requires to grow 500g in weight per day. Using the log-log regression calculations shown in Table 3.3, where ME and weight are regressed, it is clear that the LAU (metabolic weight) method cannot replace the LSU (ME) method 1:1, except for possibly the calf/lamb category. The high average R^2 (0.995) and very small P-values ($P<0.000001$) values of six of the seven categories (excluding the calf/lamb category) obtained from the regressions emphasize that an LSU's ME requirement cannot be measured using Kleiber's body $weight^{0.75}$ (metabolic weight) calculation. With the regression coefficient (gradient) values being greater than 0.75, the LAU values calculated by Bothma and Du Toit (2014) are not equal to the LSU values published in the Meissner appendix (Meissner, 1982) and the calculated LSU values in Table 3.5 indicate that metabolic weight alone cannot be used to calculate ME.

When considering the accuracy of the energy requirements published in Meissner (1982), other published data obtained similar results when using field metabolic rate (FMR) as a measurement. FMR measures the total energy expenditure of the animal when all basic energy costs are accounted for (Costa & Maresh, 2018) and is commonly called the animal's maintenance requirement. Basal metabolic rate (BMR) (Heusner, 1982; Hayssen & Lacy, 1985) multiplied by 1.35 (low activity) and 1.85 for medium activity (Karasov, 1992) equals the approximate FMR value for an animal in a particular classification, at a specific weight, activity level and physiological state. The average of the low and medium activity values compares well to both the respective estimations of Meissner's (1982) and NRC (2007) maintenance values for animals of similar weights. Similar guidelines are used in energy estimations for a broad group of species in feed formulation software (Zootrition© 2.7 Software, St. Louis, USA) (Dierenfeld, 2021). Table 3.11 shows comparative values obtained from literature and compiled in this study.

Table 3.11 Comparative field metabolic rate (FMR) or metabolizable energy (ME) values in MJ/day for different species at a specific weight, compared with other published data and the calculated values in the current study.

Species / animal category	weight (kg)	FMR or ME (MJ/day)	Reference
White-tailed deer (*Odocoileus virginianus*), summer	50	10.04	NRC Small Ruminants (2007)
White-tailed deer (*Odocoileus virginianus*), winter	50	13.81	NRC Small Ruminants (2007)
	Average	11.92	
Generic animal (low activity)	45	8.74	Hayssen & Lacy (1985)
Generic animal (medium activity)	45	11.32	Hayssen & Lacy (1985)
	Average	10.03	
Impala ewe (*Aepyceros melampus*)	45	10.20	Meissner (1982)
Impala ewe (*Aepyceros melampus*)	45	10.32	The calculated value for this study
Elk (*Cervus canadensis*) summer	220	32.22	NRC Small Ruminants (2007)
Elk (*Cervus canadensis*) winter	220	41.42	NRC Small Ruminants (2007)
	Average	36.82	
Generic animal (low activity)	220	31.19	Hayssen & Lacy (1985)
Generic animal (medium activity)	220	42.74	Hayssen & Lacy (1985)
	Average	36.97	
Sable antelope (*Hippotragus niger niger*)	220	36.21	The calculated value for this study

Considering the metabolic energy requirements of game species not mentioned in the Meissner appendix (Meissner, 1982), the log-log transformation regression coefficient calculation can be used to calculate a reliable estimate of the ME requirements as well as the respective calculated LSU values of sable antelope at different physiological production states. When considering the calculated ME and LSU values in Table 3.5, it must be highlighted that some animal species under or overestimate the published data in Meissner (1982). This over and underestimates can be considered normal due to various reasons:

- In most instances, the animals live in groups/herds, where most individuals differ in their physiological production state, e.g., pregnant, lactating, growing, dry or a combination of these states.

- Measurements are at any point in time and may differ at a different time; for example, a wild animal is weighed at darting will have a variable weight due to when it last drank water or how long it was herded before weighing. Especially important when compared to domesticated livestock that is usually fasted for a short period, then walked through a crush and weighed quickly.
- The difference between the weighing of the game and domestic livestock demonstrates that a significant variation can be present. Therefore, the average weight of animals in a particular physiological production state is used, not a global average of the species where physiological production state is considered irrelevant.

The calculated ME and LSU Methodology, supported by its high correlation (R^2>0.995) and significant P-value (P<0.000001), makes it a reliable method to calculate the ME requirements and LSU values for the sable antelope (Table 3.12) and other herbivores.

In practice, the DMI of the sable antelope is unknown. Feed intake is usually expressed as a percentage of body weight on a DM basis. If the ME value for a particular animal at a specific weight is known, it is possible to calculate the DMI as a percentage of body weight.

The metabolic weight-based LAU and GU/BU method using the average weight of the species, ignoring its physiological production state, is generally used on ranches breeding game intensively (Van Rooyen & Du P Bothma, 2016). Even though the animal unit values derived from the Kleiber methodology may be incorrect and misleading where game species are bred more intensively, it does, supply the rancher a broad guideline of how many individuals of a particular species can be kept on the reserve or ranch. Refinement is required on ranches where animals are bred more intensively. The GU/BU method should be converted to the calculated GU/BU (ME) method explained above, where the ME value for an animal at maintenance, growth and lactation should be considered.

The GU/BU values generally accepted and published by Van Rooyen and Du P Bothma (2016) for maintenance for the sable Antelope is 1.16 (Table 3.2), whereas the calculated GU/BU (ME) value for an average sable (dry mature cow and bull) is 1.26 (Table 3.10). These values are close when considering the average animal at maintenance. However, when this method is used in more intensive ranching systems, the GU/BU method misses the calculated GU/BU values for the individual within the herd at their respective physiological production states (Table 3.10).

When considering lactation, where specific data on game species do not exist for pregnancy and lactation, comparative difference factors were calculated between the ME requirements for a “dry” female animal and its lactating counterpart; values obtained vary between 1.25 and 1.36 in Meissner (1982). Comparing this to the Nutrient Research Council values for beef cattle and meat goats, the calculated factor values for mature beef cows is 1.36, replacement heifers (beef) 1.57

(NRC Beef Cattle, 2016), mature meat goat 1.34 (NRC Small Ruminants, 2007) with an overall average of 1.4.

Table 3.12 summarises the values for the sable antelope obtained from the LSU methodology, providing the ecologist and animal scientist with a method to convert them to a calculated LSU or a calculated BU/GU value.

To improve the carrying capacity estimation on a game reserve or ranch, the vegetation study should include the edible browse found on the ranch so that all the game species that utilise grass and browse in different proportions are incorporated.

Table 3.12 Sable antelope (*Hippotragus niger niger*) summary, for each category individually; incorporating weight, calculated metabolizable energy (ME) requirement in MJ/day, dry matter intake as a % of body weight, the calculated large stock unit (LSU), Calculated browser (BU) and grazer (GU) unit, percentage grass/browse in the diet, the respective grazer and browser unit values based on the % graze or browse in the diet and dry cow multiplied by the lactation factor of 1.4.

Sable antelope (*Hippotragus niger niger*)	**Weight kg**	**Calculated ME MJ/Day**	**DMI %**	**Calculated LSU (450kg/75MJ ME/day)**	**Calculated BU/GU (180kg/29.7MJ ME/day)**	**% Grass in the diet**	**% Browse in the diet**	**Grazer units per animal based on % grass in the diet**	**Browser units per animal based on % browse in the diet**
Calf/lamb	77.00	18.48	3.15	0.25	0.62	85%	15%	0.53	0.09
Young dry cow/ewe	180.00	34.72	2.53	0.46	1.17	85%	15%	0.99	0.18
Mature dry cow/ewe	220.00	36.21	2.16	0.48	1.22	85%	15%	1.04	0.18
Young cow/ewe with calf/lamb	180.00	43.96	3.21	0.59	1.48	85%	15%	1.26	0.22
Mature cow/ewe with calf/lamb	220.00	46.86	2.80	0.62	1.58	85%	15%	1.34	0.24
Young cow/ewe with calf/lamb*	180.00	48.61	3.55	0.65	1.64	85%	15%	1.39	0.25
Mature cow/ewe with calf/lamb*	220.00	50.70	3.03	0.68	1.71	85%	15%	1.45	0.26
Young bull/ram	220.00	39.82	2.38	0.53	1.34	85%	15%	1.14	0.20
Mature bull/ram	250.00	38.63	2.03	0.52	1.30	85%	15%	1.11	0.20

*Cow with calf, 3 and 5 years, respectively multiplied with the 1.4 factor for lactation.

3.6. Conclusion

The investigation into the methodologies presently employed for determining the carrying capacity of various wildlife species ranched in southern Africa illustrate that metabolic weight alone cannot be used as a factor to determine the energy requirements of game making the LAU, GU, BU methods used to calculate the animal unit values based on metabolic weight alone, inaccurate.

In summary, the LAU, AU and BU/GU methods regarding the relative animal values are mathematically similar with metabolic weight as the common denominator. In contrast, the LSU method uses the animal's metabolic weight and ME requirements at a particular physiological production state (Meissner,1982).

A derived log-log transformation equation provides a more accurate method for determining the ME requirements of game species at different physiological production states. The calculated ME and LSU values derived in this study will enable game reserves and game ranches a method to calculate carrying capacity estimates more accurately. Furthermore, using the same principle, it is possible to calculate the relative calculated GU and BU values for the different species.

Using this approach, if weights are known for other species not mentioned in this paper, it is possible to determine the calculated LSU, GU, and BU values, for animals at different physiological states. This methodology will thereby contribute to optimal animal production and improve carrying capacity estimates, optimising veld management.

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Chapter 4

Horn growth characteristics of sable antelope (*Hippotragus niger niger*) in South Africa

4.1. Abstract

A study into horn growth characteristics (traits), horn length, basal circumference, and the number of horn rings of sable antelope in South Africa was conducted to investigate the environmental effects of sex, calving year and season on horn development for animals up to 50 months of age. Horn growth characteristics/traits within the age categories of 0-15 months, 15.1-36 months, 36.1-50 months were analysed. It was found that the growth rate in cm per day of horn length between male and female sable antelope differed significantly for all age categories; were male (0,089 ± 0.002cm; p-value = <0.0001) *and female* (0,068 ± 0.004cm; p-value = <0.0001)*for 0-15 months, male* (0.079 ± 0.002cm; p-value = <0.0001) *and female* (0.042± 0.001cm; p-value = <0.0001) *for 15.1-36 months, male* (0.044± 0.003cm; p-value = <0.0001) *and female* (0.015± 0.003cm; p-value = <0.0001) *for 36.1-50 months. When considering base circumference between male and female sable antelope, there was only a significant difference* ($P < 0.05$) *in the age category 0-15 months, where the base circumference for males (0.026) and females (0.014). The number of horn rings did not differ. Horn length and base circumference results over the whole period, regardless of other environmental effects, illustrate a rapid initial growth for male and female animals. However, horn length and base circumference on males increased faster, while in the female animals it slowed noticeably once they reached sexual maturity. Supplemental feeding regimes introduced on most farms in 2013 positively affected horn growth traits, resulting in longer horns at maturity. These mean values are much longer than those measured by Grobler between 1971 and 1978 in Zimbabwe.*

4.2. Introduction

The sable antelope has four recognised subspecies in Africa (Matthee & Robinson, 1999). The South African population (*Hippotragus niger niger*) was historically distributed from the Magaliesberg west of Pretoria, Pilgrims Rest, Waterberg, Letaba and the Kruger National Park on the eastern side of South Africa (Basson, 1989; Du Toit, 1992).

The Gravelotte/Letaba population, excluding the Kruger National park's population, declined from 15 000 – 20 000 in the 1930s to 400 animals in 2000. Attempts to stop this decline led to collaboration between the Gravelotte Wildprodusente (Letaba Sable Antelope Study Group) and the Department of Nature Conservation to end the declining trend in 2000 (Warren & Meyer, 2005; Rabie, 2011).

Initially occurring throughout northern South Africa, the sable antelope population declined because of human encroachment, mining, crop and livestock farming, habitat destruction, and uncontrolled hunting.

The Letaba/Gravelotte area's population stayed healthy during the early 1900s due to little or no people living in the area due to malaria (Du Toit, 1992; Warren, 2021).

The successful extermination of malaria in the area led to livestock and crop farmers moving into the region. The increased human presence resulted in a rapid decline in sable numbers. The main reasons being increased livestock and crop farming, less natural habitat, limited movement of resident sable antelope resulting in genetic constraint, more water points being established leading to increased competition with other species, large numbers of livestock and the prevention of natural veld fires that resulted in an increased tick burden and tick-borne diseases, amongst other diseases (Du Toit, 1992; Warren & Meyer, 2005; Rabie, 2011). The genetic constraints were mainly due to low genetic variation and increased levels of inbreeding in the area as animal numbers decreased. The increased levels of inbreeding also lead to higher levels of calf mortality (±20%), thus causing a further reduction in population size (Warren, 2021)

The Game Theft Act, No. 105 of 1991, allowed private ownership of game (JUTA, 2011), resulting in more game ranches desirous of obtaining a herd of sable antelope. With few unrelated animals available in South Africa, sable antelope (H. niger niger) were imported from Malawi, Zimbabwe and Zambia (Kriek, 2017). Due to their scarcity, these animals were only available at a high cost (Cloete *et al.,* 2015). The breeding of sable antelope in a controlled environment saved the species from local extinction, resulting in increased genetic variation, lower levels of inbreeding and the game farm industry breeding them for trophy hunting and high-value animal (genetics) sales.

The game industry boom changed the rules. Total income from game sales in 2011 was R433 337 065; in 2012, this nearly doubled (R856 712 460), which nearly doubled again by 2014 (R1489 783 755) (Wildlife Campus, 2020). The sudden increase in value led to increased breeding of sable antelope and other rare species, resulting in more and more farmers entering the scarce game breeding market (Cloete *et al.,* 2015). These high-value animals were very well cared for to ensure calf survival and longer horns. Superior quality breeding animals are associated with animals having longer horns. Therefore, animal husbandry practices were adapted to include strategic feeding practices, the measurement of horns, pedigree recording, and reproduction information, becoming an integral part of sable antelope management (Josling *et al.,* 2019). On most ranches, supplying these animals with a balanced feed fortified with minerals and vitamins started from 2012-2013.

The three main factors that determine the size of antlers or horns are genetics, nutrition and age. Even with the best genetics, trophy-sized antlers and horns are not guaranteed; good range/veld is also required. Unless there has been a severe winter or drought, good quality range/veld with a diversity of palatable forage species will supply the necessary nutrients to the animals to allow for maximum horn and antler growth (Knight, 2008). A constant supply of nutrients directly produces more naturally produced testosterone (Ruiz *et al.,* 2010). Testosterone plays a critical role in developing male characteristics, as shown in adult roe deer, where increased plasma concentrations of testosterone were positively correlated with the mineralization (hardening) of the antlers (Sempéré & Boissin, 1981). Larger testis circumference is correlated with more testosterone production (Preston *et al.,* 2012). The darkening of the coat colour in males is testosterone-driven, as seen in the darkening of a male lion's mane as the lion ages (West & Packer, 2002). Similarly, in sable antelope, this was seen in reverse, where a 4.2-year-old jet black male sable antelope was castrated, and within six months, this bull went from pitch black to a red calf-like colour (Warren, 2021). Considering published research on sable antelope horn growth, Grobler studied a herd of tagged sable antelope from 1971 to 1978 in a game reserve known at the time as the Rhodes Matopos National Park in Zimbabwe (now Matobo National Park) (Grobler, 1980b). Horn and body growth traits were observed, measured, and noted during this time. Horns were collected from animals at different ages, horn sections dissected and studied under a microscope to see how the horn tissue differs as the horns grow over time. This aided in describing the different horn growth phases, being the initial deciduous horn (from birth to first ring/annulation), the faster growth of permanent primary horn and the slow post mature phase, otherwise known as secondary permanent horn growth (Grobler, 1979, 1980b), commonly known by ranchers as "posts" – the section of horn with no rings at the base of the horns of older animals.

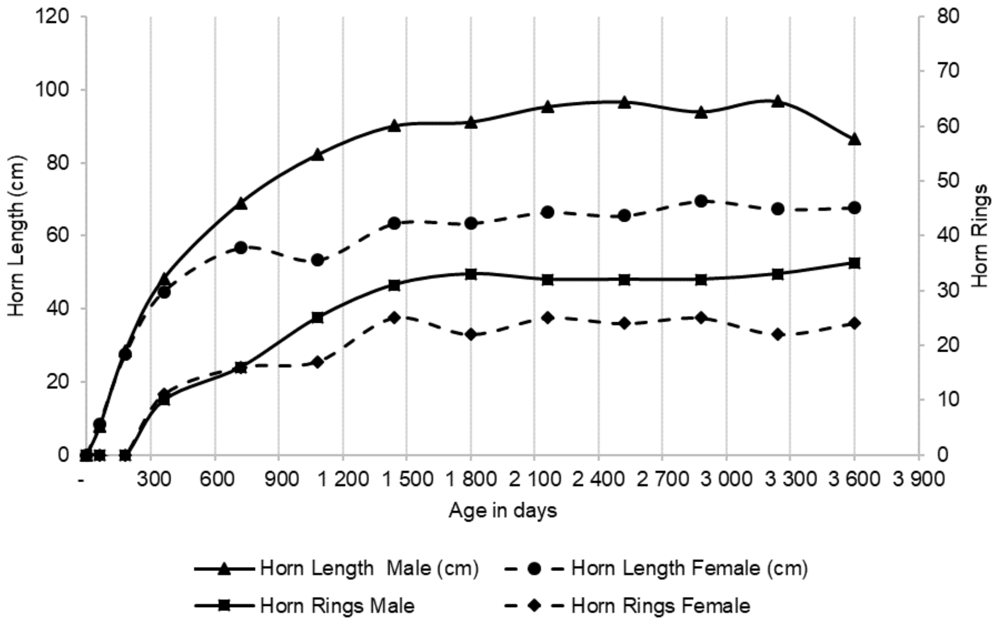

Figure 4.1 Horn length and horn rings by sex over age in days of sable antelope in Zimbabwe as presented by Grobler (1980a).

Figure 4.1 illustrates how two horn traits, namely horn length (HL) and the number of horn rings (HR), increased in length and number over time. The slope of Figure 4.1 for both male and female horn growth illustrates a reduction of exponential horn growth at approximately 365 days (12 months) after birth. Primary permanent horn growth grows up to an approximate 1460 days (4 years) after birth, indicated with a dip on the graph showing a slowing of horn growth in the male and female animals respectively, secondary growth normally starts showing at this time. This discussion was used as the basis for describing the age group categories in this study, namely, 0-15 months (0-1.25years / 0-450 days) designated as age category where rapid growth of deciduous and initial primary horn growth occur - exponential growth phase, 15.1-36 months (1.25-3years / 451-1080 days) known as the primary horn growth phase – logarithmic growth, and 36.1-50 months (3-4.17 years / 1081-1500 days), where growth of primary horn is at its slowest, the onset of secondary horn growth, otherwise known as “post growth”.

Horns are measured using the Rowland Ward (Ward, 2017) and Safari Club International (SCI, 2021) trophy measuring systems, including the horn length and circumference and the tip to tip distance between horns. Horn tip length, ring counts and measurement of the gap between the rings are other performance measurements (Josling *et al.*, 2019). Both the male and female sable have horn’s that curve backwards; the horns have characteristic rings. Male animals generally have longer and thicker horns when compared to their female counterparts (Estes, 1999). Both male and female animals have slower horn growth after secondary post-growth initiates. Males, however, work the tips off their horns by sparring with each other, rubbing their horns on trees and branches, and the tips breaking off in flakes due to the horns becoming brittle with old age (Grobler, 1980b). In both male and female animals, the posts start developing at about 1460 days (4 years), clearly shown in Figure 4.1, where the growth curve visibly starts to flatten. Coincidentally post-growth starts at roughly the same time the cows calve down for the second time in nature (Grobler, 1980a,b).

With the advent of the ‘ranching’ of sable with a focus on horn quality (which includes all the horn traits mentioned), questions arise on how these management interventions (selection of sires and dams on perceived horn quality and nutrition) have influenced the different growth parameters of the horns. In this investigation, horn trait data of sable antelope was recorded in four ecologically different regions in South Africa. All the herds were managed according to domestic livestock methods/principles, received nutritionally balanced feed, and where performance and production data was accurately collected and evaluated throughout the sable antelope’s life (repeated individual measurements).

The vegetation types from where the sable data were sourced are savannah-sour, savannah–sweet, rooigras-sweet and bushveld–sweet. This data set represents most of the performance recorded sable antelope being ranched within the chosen four regions in South Africa, from 2010 to 2018.

Please note that many of the ranchers who supplied information only measured the male animals resulting in the data set having more male than female values. It is also worth noting that most ranched sable are no longer from the original population of South African sable antelope but are part of the same sub-species, otherwise referred to as populations.

The aim of this research was to investigate the growth of horn characteristics of the sable antelope with particular reference to sex and environmental effects.

4.3. Material and methods

Data was provided by ranchers who collected data during routine management practices. The latter consisted of the individual sable antelope being darted under the supervision of a wildlife veterinarian. Sable antelope horns were measured using a measuring tape (mm or inch) by either the game rancher or the wildlife veterinarian assisting the darting procedure. Horn measurements were recorded using system standards set by Safari Club International for horn length (left and right) and basal circumference (left and right), and the number of rings. Due to sable antelope being scarce and expensive, darting was kept to a minimum to ensure minimal stress to the animals.

The horn traits analysed in this study are HL, HR and basal circumference (BC) of the horns, as described in Figure 4.2. Due to horns sometimes becoming damaged over time, only the longer horn or larger measurement was used in the analysis. The longer or greater left or right measurement of HL, HR and BC per animal is referred to as an observation included in the data set. Other horn growth measurements such as tip to tip, tip length, the distance between rings and post measurements were omitted in this study due to a lack of sufficient data representation as very few farmers measured these traits. The dataset compiled from the ranches was edited only to include those animals born after 2010 and younger than 1500 days (4 years). This data set was edited to 3343 observations (original data 3697) recorded from 2011 to 2018. The original dataset was also filtered to eliminate outliers and animals with incomplete data, reducing the number of observations in the data set from 3343 to 2265 for HL, BC, and HR recorded on 1599 individuals. As discussed in the introduction, the region/vegetation, month of birth, calving year, sex, and calving season were categorised as independent variables.

With the initial rapid horn growth of young animals in the first four years (48 months), they were grouped into three age categories, the first being the exponential horn growth phase; when considering the second and the third age category parameters, we considered that most females calve down at around three years of age. Several animals were measured in the first two months after four years (48 months). The older age category of 30.1 to 50 months was inclusive of these animals. These categories were: 0 to 15 months, 15.1 to 36 months, 36.1 to 50 months. The gender of all animals was known, thereby making it possible to compare growth in both male and female animals in all age groups. The mature animals older than 50 months were not included in this analysis.

The age categories will be analysed in terms of sex, male and female, respectively, calving-year, the actual year the animal was born, and calving season divided into summer (green - September to April) and winter (dry - May to August). Vegetation type was analysed to ascertain if it affected the growth of HL, BC and HR. The vegetation types are categorised as; savannah-sour, savannah–sweet, rooigras-sweet and bushveld–sweet. Vegetation was only included for the growth over the period of 0-1500 days.

In 2011/2012, many ranchers started breeding with sable, and only selected animals were recorded. Furthermore, due to the high costs and physical risks associated with darting, the ranchers were cautious in darting animals just for measurements; thus, only those moved or purchased were measured.

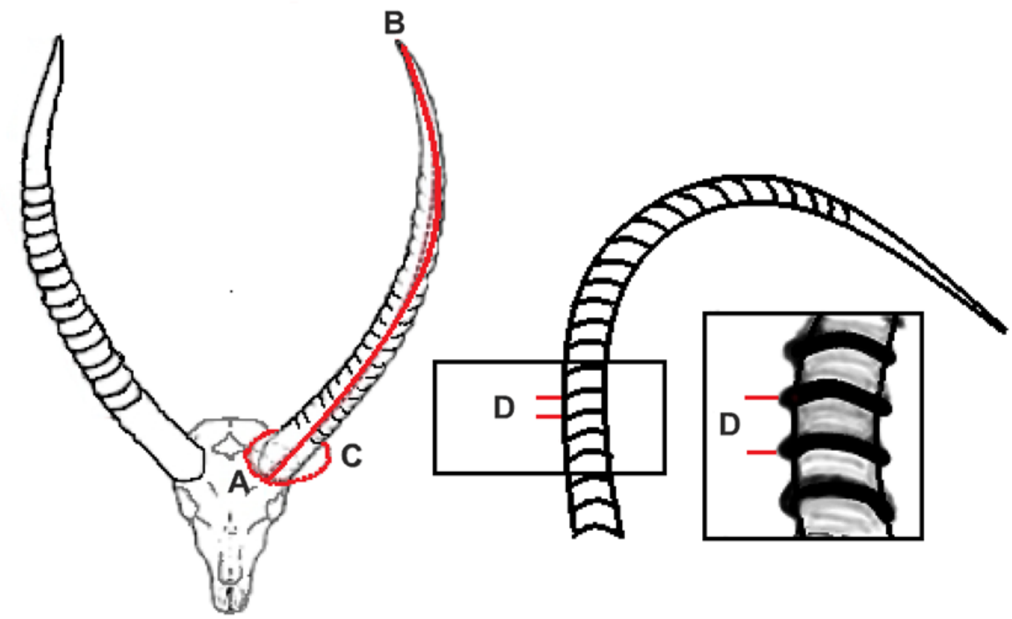

Figure 4.2 Horn measuring procedures; used to measure sable antelope horns, using the Safari Club International (SCI, 2021) guidelines and other ranch measurements. Horn length (HL) (A-B) is measured from the base along the front length of the horn to the horn tip; the measuring tape or cord must not be pressed down into each respective groove. Basal circumference (BC) (C) is measured at the base of the horn nearest to the skull. Number of rings (HR), only rings that circle (D) the whole horn is counted (Josling *et al.*, 2019), picture adapted from (Van Rooyen *et al.*, 2016).

4.4. Statistical analysis

The data was analysed by means of ANOVA for each age category with independent variables as fixed effects in different models. The data was analysed using SAS for Windows version 9.4 and XLSTAT 2021.2. The fixed effects for ANOVA analyses for all the categories included sex, calving-year, and calving season. Where applicable, the interactions between fixed effects were also investigated. In all cases, the final model only included the fixed effects. Per age category, as well as a combination of age category regressions, were applied. After that, separate regressions analyses for the vegetation, season and calving year were performed to determine their effect on the growth of HL, BC and HR over the whole 50-month period with specific reference to the individual environmental factors. There were considerable differences in the number of observations for the various measurements between male and female animals. This varied from 135 to 538. This was mainly due to differences in selection intensity between males and females, most males being sold to outfitters for hunting, while most females are sold to fellow breeders. This was also the case for the other independent variables of calving year and season. Where multiple readings were available per individual, care was taken to ensure that only one data point was used per category. Due to the unbalanced nature of the data in this study, the estimates calculated from the Type III sum of squares were interpreted in all cases. The LSMeans obtained from Bonferroni *post hoc* tests were interpreted for significance.

4.5. Results and discussion

The results of the per age category of the independent variables of HR, BC and HR will be presented and discussed separately. After that, the results of the association between age and growth will be discussed, per age category over the whole period of 50 months. The 0-12-months age category was raised to 0-15 months to include- and maximise the number of animals that show their first rings closer to 15 months of age. As the first ring is associated with the onset of primary horn growth, the longer the horn before the first ring, the greater the ring-to-ring distance, the greater the likelihood for a longer horned male animal.

4.5.1. Horn development between 0-15 months

The R^2 of the HL full effects model is small (11.6%) indicating large within-group variations (Table 4.1). When considering HL in the 0-15 months age category in terms of sex ($P<0.0001$) (Table 4.1), Table 4.2 shows that the LSMeans of HL for this age group is 32.75 ± 0.39cm and 27.77 ± 0.57cm for the male (n=521) and female (n=197) animals respectively. The mean difference in HL between male and female animals was 4.98cm, a difference of 15.21%. Considering HL in terms of calving year with a $P=0.007$ (Table 4.1), as the years progressed, 2013 was the lowest LSMeans value of 28.46 ± 0.63cm, and the highest being 33.12 ± 1.18cm in 2018, alludes to an improvement in HL growth over time.

As the HL was longer with the male animals, it would be expected that the basal circumference would also be larger in the males. The R^2 for basal circumference is the longest of the three variables but still low at 27.1%. Considering BC, in the 0–15-month age category in terms of sex, the LSMeans value for BC is also initially similar for both male and female animals, with the P-value of <0.0001 (Table 4.1). The LSMeans BC of 16.21 ± 0.12cm and 13.37 ± 0.19cm for male (n=465) and female (n=161) animals, respectively, show that the BC differed by 2.84cm (17.52% difference) (Table 4.2). There was no significant difference in calving year. Basil Circumference has a P-value ($P=0.110$) (Table 4.1), the shortest and longest LSMeans values being 14.38 ± 0.20cm and 15.33 ± 0.35cm, respectively, indicating no similar improvement in growth over time.

In contrast, concerning HR, there was no significant difference between the sexes ($P=0.9$). HR in terms of calving year was significant ($P=0.00$). The drop in HR from 3 in 2021/2013 to 2.1 in 2018 alludes to improved conditions. Calving years of 2012 and 2013 did not differ, while the least HR were observed in animals born in 2017, namely 2.1. Animals born in the latter portion of the study period have fewer rings than those born in the 2012 and 2013 groups (Table 4.2).

On the other hand, as indicated in the fixed effects ANOVA (Table 4.1), season had no effect on horn development in the age group 0-15 months for any of the measurements. With the season not showing an effect on HL (P=0.252), BC (P=0.947) and HR (P=0.65) indicating optimal conditions in both summer and winter.

Interactions were not significant except for calving year by season (P=0.023). However, this interaction only contributed 0.3% to the R^2 and was therefore not considered for further discussion.

Table 4.1 Summary of the ANOVA Model for HL, HR, and BC results for the age category 0-15 months for sex, calving year and calving season.

		HL (cm)	HR	BC (cm)
R^2		0.116	0.048	0.271
F		11.631	3.173	28.628
Pr > F (Model)		<0.0001	0.002	<0.0001
Sex	Pr > F	<0.0001	0.897	<0.0001
Calving year	Pr > F	0.007	0.000	0.110
Season	Pr > F	0.252	0.650	0.947

Growth in the first approximate three years of a sable antelope's life is centred on physical and physiological trait development, during which the deciduous and primary horn growth ensues**.** The LSMeans values for HL compared well with the measurements Grobler (1980a) published for sable antelope studied in the Matopos in Zimbabwe, in the age category of 6-12 months (n=13), HLs of 28.4 ± 2.98cm and 27.5 ± 2.02cm for female and male animals, respectively. Considering HR Grobler (1980a) mentioned that the first annulus (ring) appears at approximately 12-months of age, with the current data only having a few rings up to 15 months, supports this observation. Eighty-four of the observations in this study have zero rings in this age category.

With the focus shifting to horn growth, ranchers started focussing on supplying balanced feed from 2012/2013, seen clearly in the improved HL LSMeans values increasing from 28.92 ± 0.70cm in 2014 to 33.12 ±1.18cm in 2018 for HL. Considering horn rings, animals with the lowest HR in this category are classed as the best; the number decreased from 3.5 ± 0.21 in 2014 – 2.1 ± 0.29 in 2018, clearly indicating that additional feeding of balanced feed had a positive effect on HL and HR.

When considering the improved HL and BC growth for this age category, and the supply of nutritionally balanced feed from 2012/2013 alludes to nutrition having a positive effect on horn growth, be it the supply of nutrients for growth or its positive effect on testosterone production, resulting in superior horn growth, not only for the males but for both sexes respectively. When considering HL and BC differences between the male and female, where both the male HL and BC are longer than the females, the optimal plasma testosterone due to improved nutrition (Ruiz *et al.*, 2010) would have benefited the male animals more than the female animals, as seen in livestock, when comparing weaning weights between male and female animals, with males having heavier weaning weights than their female contemporaries (Raphaka & Dzama, 2009; Daza *et al.*, 2014).

Considering HR, the supply of balanced feed had a direct effect on the decrease of the HR, suggesting that the nutrients supplied and the production of extra male hormones (testosterone) allowed the horns to grow faster, making the ring-to-ring distance longer (Figure 4.2 D), resulting in fewer rings in this age category.

Table 4.2 LSMeans and standard error for all sable antelope horn traits (HL, HR, and BC), considering sex, calving year and season of birth as variables in the age category 0-15 months.

		HL (cm)		HR		BC (cm)	
	Factor	**LSM**	**SE**	**LSM**	**SE**	**LSM**	**SE**
Sex	M	32.75 [a]	0.39	2.8 [a]	0.12	16.21 [a]	0.12
	F	27.77 [b]	0.57	2.8 [a]	0.18	13.37 [b]	0.19
Calving year	2012	30.11 [ab]	0.91	3.0 [ab]	0.28	15.01 [a]	0.31
	2013	28.46 [b]	0.63	3.0 [a]	0.28	14.38 [a]	0.20
	2014	28.92 [b]	0.70	3.5 [ab]	0.21	14.76 [a]	0.23
	2015	30.78 [ab]	0.64	2.9 [b]	0.27	14.98 [a]	0.19
	2016	30.11 [ab]	0.70	2.6 [b]	0.20	14.56 [a]	0.22
	2017	30.34 [ab]	1.01	2.5 [b]	0.20	14.49 [a]	0.30
	2018	33.12 [a]	1.18	2.1 [ab]	0.29	15.33 [a]	0.35
Season	winter	29.88 [a]	0.57	2.8 [a]	0.17	14.78 [a]	0.18
	summer	30.64 [a]	0.40	2.8 [a]	0.12	14.79 [a]	0.13

[a-b] Values with different superscripts in the same column differ ($p < 0.05$)

HL – Horn length in cm, BC – basal circumference in cm, HR – number of horn rings

The sex of the animal had the most prominent influence on horn development in young sable, particularly for HL and BC. This can further be illustrated by fitting a linear regression for each sex (Figure 4.3 A & B) for all the animals in this age category, as well as the linear regression irrespective of sex (Figure 4.3 C). The correlation coefficient of 0.89 for HL in males is considerably larger than the 0.78 (square root of R^2) for the female animals indicating a diverging relationship between age and horn growth from an early age (Table 4.1, Figure 4.3).

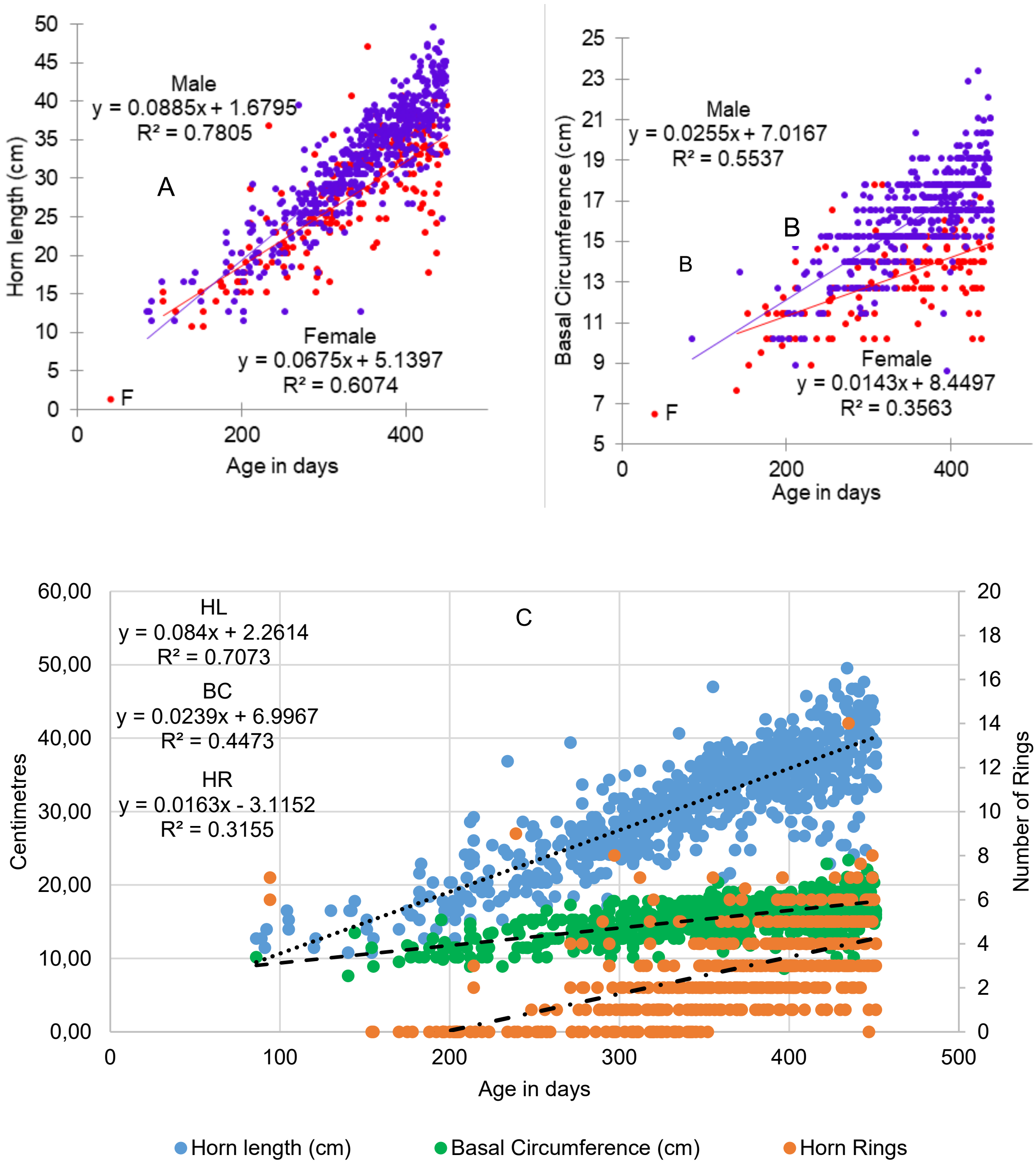

Figure 4.3 Scatter plot with a regression, illustrating male and female sable antelope separately for HL (A) and BC (B) growth, and (C) the combined HL, HR and BC growth over the number of days (age category 0-15 months).

4.5.2. Horn Development between 15.1-36 months

A marked increase in the variation for HL and BC explained by the ANOVA fixed effects model is seen when considering the age category 0 – 15 months and 15.1-36 months. The R^2 difference in the growth observed in the younger age group increased from 11.6% (Table 4.1) to 24.9% (Table 4.3) for HL. The mean value for HL in males (n=437) is 63.19 ± 0.73cm, while in females (n=538) it is 49.04 ± 0.7cm, a difference of 22.39 (Table 4.4), which is considerably more than the 15.21% difference calculated for the 0-15 months category (Table 4.2).

BC (P<0001) in terms of sex also differed, the BC R^2 increased from 27.1% (Table 4.1) to 65.2% (table 4.3) between age categories 0-15 and 15.1 to 36 months. The LSMeans values of the males 21.8 ± 0.12cm (n=414) and females 16.25 ± 0.11cm (n=521), a difference of 5.55cm (25.46% difference).

The number of HR (P=0.010) did not differ, and both male (n=416) and female (n=528) animals had approximately 12 rings (Table 4.4). Comparing this to the 0-15 months category, the LSMeans difference increased from approximately 3 to 12 rings.

Interactions between calving year and sex, was significant (P=0.04), but as it only contributed 1% to the R^2, it was not included in the final model; the main effects of sex and calving year contributed 21% and 2.7% respectively of an R^2 of 24%.

Calving year was significant for all the traits measured, HL (P<0.0001), BC (P<0.0001) and HR (P<0.0001).

Season had no effect on any of the horn growth traits, HL (P =0.821), BC (P=0.555) and HR (p=0.722) (Table 4.3).

Table 4.3 Summary of the ANOVA Model for HL, HR, and BC results for the age category 15.1-36 months for sex, calving year and calving season.

		HL (cm)	HR	BC (cm)
R^2		0.249	0.069	0.652
F		21.220	4.579	114.847
Pr > F (Model)		<0.0001	<0.0001	<0.0001
Sex	Pr > F	<0.0001	0.010	<0.0001
Calving year	Pr > F	<0.0001	<0.0001	<0.0001
Season	Pr > F	0.821	0.722	0.555

Calving year was similar for horn growth traits for both sexes in this age category (Table 4.4). The shorter HL for males in the 2017 calving year was expected as these represented only 46 animals whose average age was 22 months, resulting in a less accurate estimation for the older half of this age category where longer horns were measured (in the different years).

The HL stabilised between 53.2cm and 57cm for most animals born after 2011 (Table 4.4). Nutritionally balanced feed, supplying optimal amounts of energy, protein, minerals and vitamins to digest the available range/veld or supplied roughage, was started in 2012/2013. Animals receiving these balanced diets would have benefited from the additional formulated feed as typically seen in livestock (Daza *et al.*, 2014).

The female's HL was considerably shorter than their male contemporaries in this age category (15.1-36 months), which was expected as nutrients are used for reproductive functions during this time in a productive female animals' life. The nutrients necessary for HL and BC growth are redirected to initiating and maintaining pregnancy, where some would have already calved. Those that have calved undergo further nutritional stress due to extra nutrients required for lactation and uterine involution, leaving limited nutrients for body and horn growth. Furthermore, the starting value at 15 months for HL and BC was considerably longer for males than the females.

With an optimal supply of nutritionally balanced feed, male animals will naturally produce more testosterone (Ruiz *et al.*, 2010). With testosterone initiating and supporting male characteristics like larger body size, larger and stronger neck, horn growth (Sempéré & Boissin, 1981), darkening of the coat (West & Packer, 2002; Warren, 2021); the longer HL and BC seen in males is to be expected.

Considering the whole period from 15 months to 36 months (three years), the relationship between sex and age in days for each gender was assessed by means of linear regression (Figure 4.5 A & B).

Table 4.4 LSMeans and standard error for all sable antelope horn traits (HL, HR, and BC), considering sex, calving year and season of birth as variables in the age category 15.1-36 months.

		HL (cm)		HR		BC (cm)	
	Factor	**LSM**	**SE**	**LSM**	**SE**	**LSM**	**SE**
Sex	**M**	63.19^{a}	0.73	12.3^{a}	0.32	21.80^{a}	0.12
	F	49.04^{b}	0.69	12.8^{a}	0.30	16.25^{b}	0.11
Calving year	**2011**	62.07^{a}	1.27	15.5^{a}	0.55	20.25^{a}	0.22
	2012	53.21^{b}	1.13	11.3^{c}	0.49	18.73^{b}	0.18
	2013	56.78^{b}	1.01	12.9^{bc}	0.44	18.98^{b}	0.16
	2014	57.09^{b}	0.99	13.5^{ab}	0.44	19.09^{b}	0.16
	2015	55.04^{b}	1.17	11.1^{c}	0.51	18.62^{b}	0.19
	2016	55.59^{b}	1.42	12.4^{bc}	0.62	18.78^{b}	0.23
	2017	53.01^{b}	2.04	11.4^{bc}	0.89	18.74^{b}	0.33
Season	**winter**	56.25^{a}	0.91	12.7^{a}	0.40	19.00^{a}	0.09
	summer	55.98^{a}	0.57	12.5^{a}	0.25	19.05^{a}	0.15

$^{a-b\ \&\ c}$ Values with different superscripts in the same column differ ($p < 0.05$)

HL - Horn length in cm, BC - basal circumference in cm, HR - number of horn rings

The horn development over time for this category in comparison with the 0–15-month category, the HL of the females show a marked decline (gradient 0.068 compared to 0.042) (Figure 4.3 & 4.4, A and B respectively), while the male's horn growth traits (HL) still show a steady yet slower increase (gradient 0.089 compared to 0.079) (Figure 4.3 & 4.4, A and B respectively). BC in female animals plateaued when comparing the two categories (gradient 0.014 compared to 0.002) (Figure 4.3 & 4.4, B respectively). These results clearly show the differences between sexes for horn growth traits, emphasising the discussion above when comparing Tables and Figures 4.3 and 4.4.

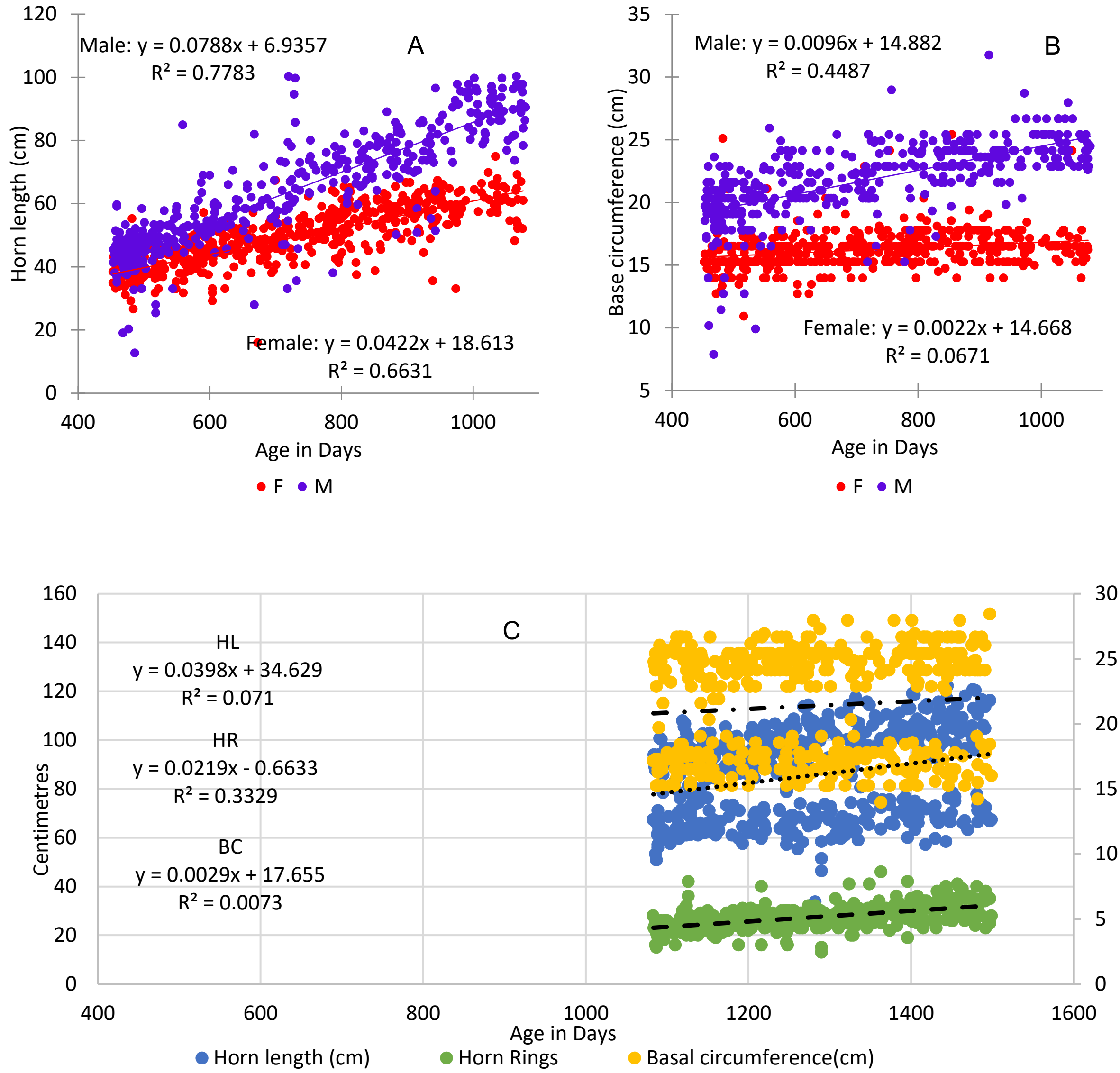

Figure 4.4 Scatter plot with a regression, illustrating male and female sable antelope separately for HL (A) and BC (B) growth, and (C) the combined HL, HR, and BC growth over the number of days (age category 15.1-36 months).

4.5.3. Horn Development between 36.1-50 months

An even more significant increase in R^2 for HL and BC for the ANOVA fixed effects model is seen when comparing the age category 15.1-36 months to 36.1-50 months. Considering HL (P<0.0001) and BC (P<0.0001) in terms of sex, the difference in the growth observed in the younger age group went from an R^2 of 24.9% (Table 4.3) to 82.4% (Table 4.5) for HL and an R^2 increase from 65.2% (Table 4.3) to 85.9% (Table 4.5) for BC.

The HL analyses for sex further illustrates the widening difference in horn development between male and female sable antelope (Table 4.5), with the male's (n=284) HL LSMeans measuring 100.98 ± 0.58cm and the females (n=214) 67.94 ± 0.61cm with a difference of 33.04cm (32.72% difference) (Table 4.6); a phenomenon that could be indicative of the female animals having reached reproductive maturity. As expected, the difference between the sexes for BC was also significant (P<0.0001) (Table 4.5), with the males (n=262) having an LSMeans of 24.87 ±0.13cm and the females (n=209) of 16.95 ± 0.13cm with a difference of 7.92cm (31.84% difference). This corresponds to the longer horns for the males. HR followed the same trend for males (n=256) and females (n=210) as seen in the age category 15.1-36 months. It should be noted that the decrease in female observations is due to female animals not being measured as regularly; some were never again measured because of their reproductive status (danger to themselves and/or their foetus during the darting process), limiting most older female measurements to animals being sold. Although all the interactions between calving year, sex and season in total were significant (P<=0.05), their combined contribution to the R^2 was 1.4%; therefore, the interactions were not included in the final model.

There was no difference in calving year for both HL and horn rings, while the statistically significant difference in BC (P=0.002) of 0.81cm between the largest and smallest LSMeans value is not practically significant (Table 4.5 and 4.6).

Table 4.5 Summary of the ANOVA Model for HL, HR, and BC results for the age category 36.1-50 months for sex, calving year and calving season.

		HL (cm)	HR	BC (cm)
R^2		0.824	0.088	0.859
F		327.069	6.308	403.094
Pr > F (Model)		<0.0001	<0.0001	<0.0001
sex	Pr > F	<0.0001	0.000	<0.0001
Calving year	Pr > F	0.064	0.046	0.002
Season	Pr > F	<0.0001	0.001	0.243

Contrary to the results obtained in both younger age categories, the results for HR differed (P=0.001) for the season between winter and summer in these older animals (Table 4.6). However, a difference of 1.6 rings between the seasons (Winter: 28.1; summer: 26.5) is not considered significant. HL differed significantly (P<0.0001) between seasons, irrespective of sex, while BC (P=0.243) did not (Table 4.5). As shown in Table 4.5, the much higher R-squared values for HL and BC, being 82% and 86%, respectively, indicates that a large proportion of the variation in the data can be explained by the fixed effects included in the ANOVA analyses.

When considering the female animals in this age category, their HL is considerably shorter than the horns of their male contemporaries; it is surmised that the nutrients that would have been used for horn trait development are used for pregnancy, maintaining pregnancy, lactation and uterine involution. Horn growth traits would be slower because most of the nutrient intake is allocated to reproduction once her maintenance requirements are met. When considering the growth of HL, BC, and HR in the males within this category, primary horn growth has slowed, BC stagnates, and posts start developing. With more of the available nutrients being used to express adult sexual dimorphism, including male characteristics such as a thicker neck, adult male behaviour (pacing his territory), sexual activities, mating and the production of sperm, horn growth traits take the back seat.

Table 4.6 LSMeans and standard error for all sable antelope horn traits (HL, HR, and BC), considering sex, calving year and season of birth as variables in the age category 36.1 to 50 months.

	Factor	HL (cm)	SE	HR	SE	BC (cm)	SE
Sex	M	100.98 [a]	0.58	28.1 [a]	0.35	24.9 [a]	0.13
	F	67.94 [b]	0.61	26.6 [b]	0.36	17.0 [b]	0.13
Calving year	2011	83.51 [a]	0.79	28.1 [a]	0.45	21.2 [a]	0.17
	2012	85.01 [a]	0.75	28.3 [a]	0.47	21.1 [a]	0.16
	2013	83.57 [a]	0.73	27.7 [a]	0.84	20.4 [b]	0.16
	2014	83.64 [a]	0.87	26.5 [a]	0.52	21.1 [a]	0.19
	2015	87.77 [a]	1.40	26.5 [a]	0.43	20.9 [ab]	0.31
	2016	83.25 [a]	1.58	26.8 [a]	0.93	20.7 [ab]	0.34
Season	winter	86.42 [a]	0.76	28.1 [a]	0.45	21.0 [a]	0.17
	summer	82.50 [b]	0.47	26.5 [b]	0.28	20.8 [a]	0.10

a-b Values with different superscripts in the same column differ significantly ($p < 0.05$)

HL - Horn length in cm, BC - basal circumference in cm, HR - number of horn rings

When one considers the horn development over time for this category in comparison with the 15.1-36 months category, the HL, BC and HR of both males and females show a marked decline (male gradient reduced from 0.079 to 0.044 where the female gradient reduced from 0.042 to 0.015) (Figure 4.4 & 4.5, A and B respectively). In both male and female animals, BC male gradient reduced from 0.01 to 0.002 and female gradient reduced from 0.002 to 0.0002 (Figure 4.4 & 4.5, A and B respectively).

The linear regressions fitted to the data for this age category further emphasise this slowing HL, particularly for the female horn development as they reach reproductive maturity (Figure 4.5).

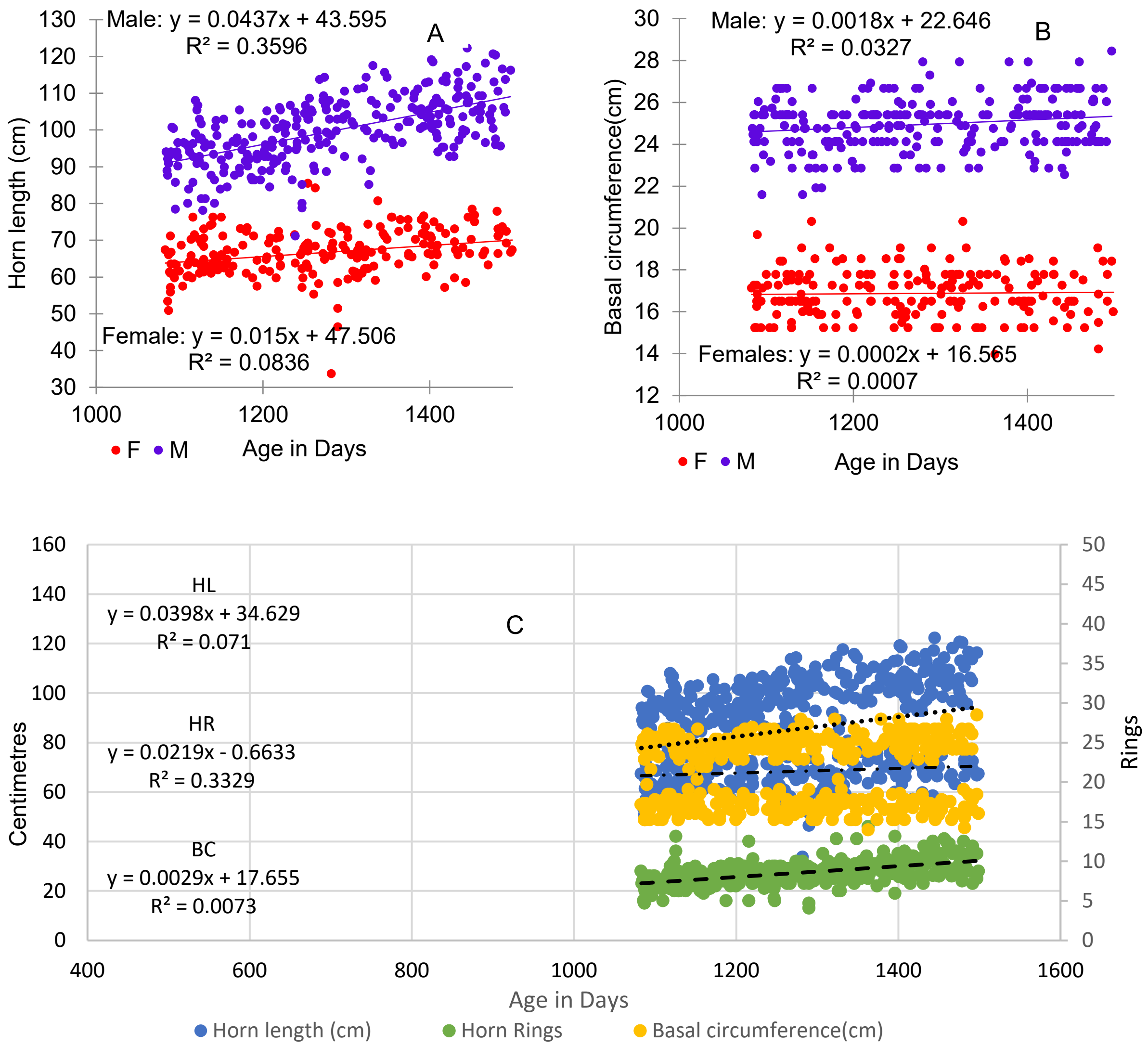

Figure 4.5 Scatter plot with a regression, illustrating male and female sable antelope separately for HL (A) and BC (B) growth, and (C) the combined HL, HR, and BC growth over the number of days (age category 36.1-40 months).

4.6. Overall horn development from birth to 4 years

Growth in the first approximate three years of a sable antelope's life is centred on physical and physiological trait development, during which the deciduous and primary horn growth ensues. Horn growth traits discussed below show a significant difference in the male and female horn growth manifested from an early age. Figure 4.6 clearly illustrates horn development in sable antelope over the total period of 4 years, where HL was initially similar in the first year up to 14 months of age, whereafter the males had a constant gradient of 0.044 shown in the graph with the trend line for the age category of 36-50 months. Male HL increased faster than the females in the same age category of 36-50 months, where the trend line illustrates the gradient of 0.015. This continued over the age period of 15 months to three years, with the female's HL slowing further between three and four years of age.

When comparing (Figure 4.6) the HL results to Grobler's historical data (1980b), the males have a similar trend up to approximately 900 days, while the female's trend is similar to approximately 800 days. From 900 days onward, the males in this study grew faster, and their gradient only starts slowing down, at approximately 1400 days compared to the 900 days from Grobler's data. Interestingly this plateau at about 1400days coincides with the blackening of the coat colour in bulls (Warren, 2021), the improved nutrition, which had a positive effect on testosterone production and growth, shifting the "flattening of the curve" to about 500 days later (improved quality of feed at the right applicable resulted in better growth). Female animals show a noticeable change from 800 days onward, where the study animals maintain their gradient throughout the study period, compared to Grobler's historical data (1980b), where a marked reduction in HL is also seen, coinciding with female animals initiating pregnancy or being pregnant. Furthermore, this demonstrates that both male and female animals receiving additional balanced feed have longer horns than the animals studied in the game reserve.

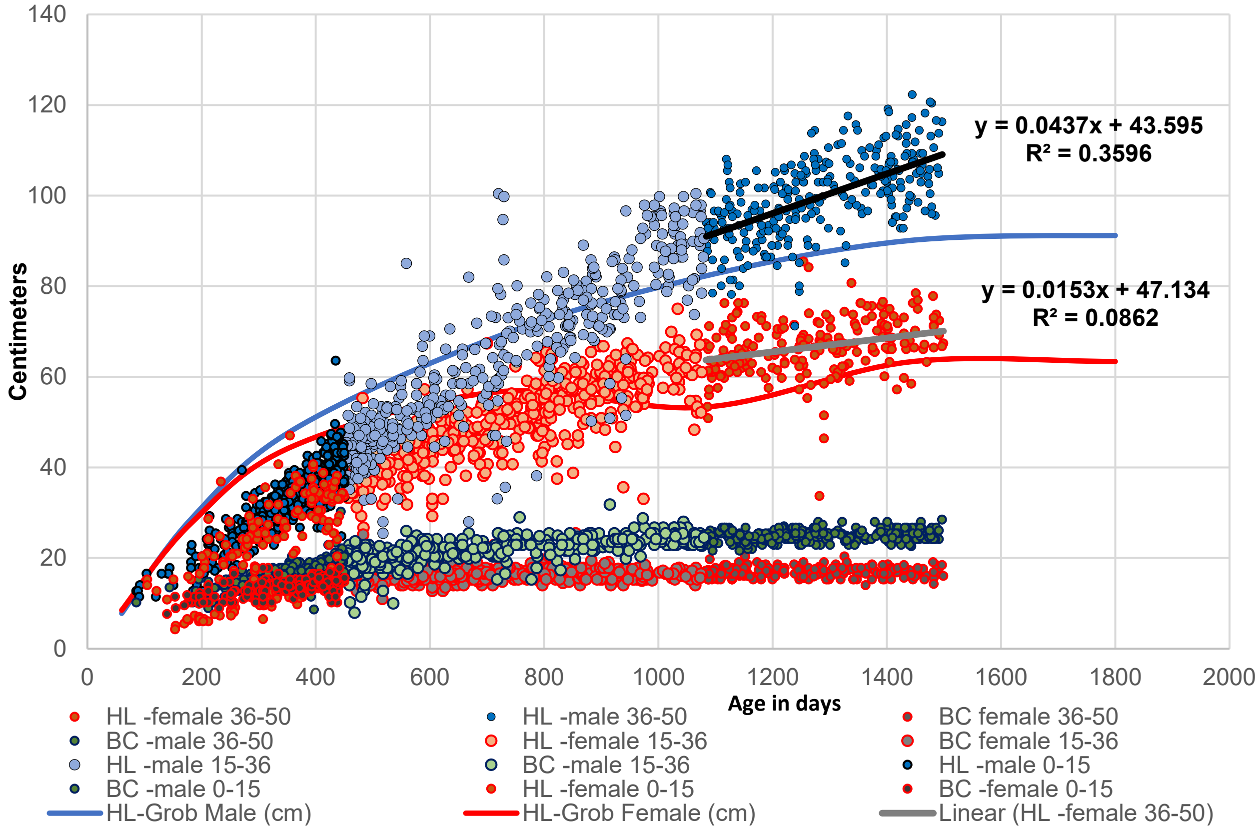

Figure 4.6 Scatter plot of male and female sable antelope HL and BC growth for the three age categories between birth and 1500 days (50 months), including historical data (Grobler, 1980b).

4.7. Conclusion

The investigation into horn growth characteristics (traits), HL, BC, and the HR's of measured sable antelope in South Africa shows that a significant difference exists between horn growth trait measurements between male and female sable antelope. Horn growth traits were statistically analysed within the age categories of 0-15 months, 15.1-36 months, 36.1-50 months. It was found that the rate of growth of horn length between male and female sable antelope differed significantly for all age categories. BC between male and female sable antelope showed a significant difference in the age category 0-15 months, although the number of horn rings did not differ. Overall horn growth traits between males and females in sable antelope indicate that although initially similar in the first year, these traits increased significantly over time for the male animals (0.044) while the female horn growth slowed noticeably over the same period (0.015). Indicating that the supply of supplemental feed had a positive effect on horn growth traits resulting in longer horns at maturity

The growth of HL for males is consistent over the first four years. These results confirm that female horn growth traits plateau as they reach sexual maturity and reproductive functions develop.

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Chapter 5
Conclusion and recommendations

5.1. General conclusion

The literature review clearly showed that the animal husbandry practices used when ranching with sable antelope (*Hippotragus niger niger*) have taken the species from close to local extinction to being a common species ranched nationwide. The quality of the animals also improved using animal husbandry practices and veterinary intervention; however, shortcomings were identified regarding the scientific knowledge around some management practices, which led to the following two studies where the species metabolizable energy requirements were modelled, and horn growth characteristics were measured. These two studies found that animal quality can be improved by selection and supplying nutritionally balanced feed, giving the game rancher or researcher the necessary tools to ranch with this species and others sustainably.

In Chapter 3, an investigation was made into the methodologies presently used for determining the carrying capacity of various wildlife species ranched in Southern Africa, illustrating that metabolic weight alone cannot be used as a factor to determine the energy requirements of game, making the large animal unit (LAU), grazing unit (GU), and browsing unit (BU) methods used to calculate the animal unit values based on metabolic weight alone, inaccurate. In summary, the LAU, AU and BU/GU methods regarding the relative animal values are mathematically similar with metabolic weight as the common denominator. In contrast, the large stock unit (LSU) method uses the animal's metabolic weight and ME requirements at a particular physiological production state. It was shown that a derived log-log transformation equation provides a more accurate method for predicting the ME requirements of game species at different physiological production states. This study's modelled calculated ME, and LSU values will aid game reserves and ranches with a method to determine carrying capacity and stocking rate estimates for sable more accurately. Furthermore, using the same principle, it is possible to determine the calculated LSU, GU, and BU values, for animals at different physiological states for other wildlife species if body weights are known. This methodology will contribute to optimal animal production and improve carrying capacity estimates, stocking rate and optimise veld management.

Chapter 4 investigated horn growth characteristics (traits), horn length (HL), basal circumference (BC), and the number of horn rings (HR) of measured sable antelope in South Africa and showed a significant difference between horn growth trait measurements between males and female sable antelope. Horn growth traits were statistically analysed within the age categories of 0-15 months, 15.1-36 months, 36.1-50 months. It was found that the rate of growth of horn length between male and female sable antelope differed significantly for all age categories. Basal circumference between male and female sable antelope showed a significant difference in the age category 0-15 months, although the number of horn rings did not differ. Overall horn growth traits between males and females in sable antelope indicate that although initially similar in the first year, these traits increased significantly over time for the male animals (0.044 cm) while the female horn growth slowed noticeably over the same period (0.015 cm). This observation confirms that the supply of supplemental feed positively affected horn growth traits resulting in longer horns at maturity. The growth of HL for males was consistent over the first four years. These results confirm that female horn growth traits plateau as they reach sexual maturity and reproductive functions develop.

Results obtained from Chapters 2, 3 and 4 indicate that the GWP and other sable antelope ranchers have successfully taken the sable antelope species from near local extinction to the point where animals have been bred, with horns that are as long as the longest horned animal hunted in the Kruger National Park in 1898. Furthermore, this thesis describes a method that can estimate the energy requirements of the sable antelope (*H. niger niger*) using a mathematical model based on domesticated livestock. It further quantifies how the selection of superior quality animals receiving balanced feed has led to ranchers breeding male and female animals with longer horns.

5.2. Recommendations

Future nutrition research should focus on protein, bypass protein, amino acids, minerals and trace minerals and the energy requirements for horn growth and development, where different levels of specific nutrients are compared. The effect of dietary sulphur-containing amino acids must be determined and the concentrations necessary to optimise horn growth in the 1st 15 months of life. Macro and trace mineral requirements must be determined for sable antelope and the concentrations necessary to optimise horn growth in the 1st 15 months of life. The effect of supplemental bypass protein on milk quantity and quality consumed by the calf and if this will affect its horn growth in the first 15 months of age should be studied. It is currently unclear how trace mineral status affects coat colour in sable antelope and what effect hormones have on the darkening of the hides in males.