

ASSESSMENT OF BODY CONDITION OF AFRICAN ELEPHANTS (*LOXODONTA AFRICANA*) IN NORTH EAST OF ETOSHA NATIONAL PARK, NAMIBIA: HOW IT RELATES TO STRONGYLE PARASITE EGG COUNTS AND NUTRITION VALUE OF FEED

A THESIS SUBMITTED IN FULFILMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE

OF

THE UNIVERSITY OF NAMIBIA

BY

Kaatri Ndapanda Brumfitt

200528921

FEBRUARY 2015

Main Supervisor: Dr. E. Julies

Co-supervisor: Dr. C. O'Connell-Rodwell (Stanford University, USA)

ABSTRACT

Elephants like most animals have different body condition, which in many cases is usually a reflection of their body fat content, food availability, presence or absence of diseases or disorders. Body condition in elephants and other factors that might affect it are not well studied. This study investigated the body condition of African elephants (*Loxodonta africana*) around the Mushara Waterhole in Etosha National Park, Namibia. The study focussed on possible correlations of body condition to strongyle parasite egg counts and nutrition value of the elephant diet within the park. Data were collected over a period of two years and about 63 elephant bulls were studied. Body condition was determined using a body condition index which allocated scores to six body parts of the elephant. The six parts of the elephants assessed for body condition were: thoracic region, temporal depression, scapula, flank area, lumbar vertebrae and pelvic bone. Strongyle parasite eggs were counted from fresh faeces of pre-identified elephant bulls. The nutrition value of elephant diet was determined through dung analyses for moisture, calcium, phosphate, ash, crude fibre, fat, acid detergent fibre and neutral detergent fibre. Results revealed that body condition of elephants was not correlated to strongyle parasite egg counts. The strongyle parasite eggs were not present in large numbers to negatively impact their body condition. In 2012, half of the elephant population had less than 1375 strongyle parasite eggs, while the other half of the population had more than 1375. In 2013, the median of the strongyle parasite egg counts in the elephant population was 2138. There was no correlation between elephant body condition and the nutrition parameters analysed. The nutrient levels found in the elephant diet met the minimum requirements set for elephants. On average the diet of elephants contained the following: moisture (4.58%), ash (6.51%), fat (1.90%), phosphorus (0.17%), calcium (1.07%), crude fibre (51.21%), acid detergent fibre (60.13%) and neutral detergent Fibre (66.08%). This study revealed that the body condition of elephants around the Mushara waterhole was good. The information

regarding the status of elephant body condition can be useful to the park management especially when allocating trophy hunting quotas.

Key Words: Body condition, *Loxodonta africana*, Etosha National Park, strongyle parasites, nutrition value, age class, elephants.

All maps, graphs and tables presented in this thesis were produced by the author, unless otherwise stated.

TABLE OF CONTENTS

ABSTRACT	ii
TABLE OF CONTENTS	vi
ABBREVIATIONS	ix
LIST OF TABLES	x
LIST OF FIGURES	x
LIST OF APPENDICES	xii
ACKNOWLEDGMENTS	xiii
DECLARATION	xvi
CHAPTER 1: INTRODUCTION	1
1.1 General Introduction	1
1.1.1 African elephants, numbers and conservation status	2
1.1.2 Social interactions among elephants	3
1.2 Factors that might affect body condition in elephants	4
1.2.1 Strongyle parasites	4
1.2.2 Nutrition quality of elephant diet	5
1.3 Statement of the problem	5
1.4 Objectives	6
1.5 Hypotheses	7
1.6 Significance of the Study	7
CHAPTER 2: LITERATURE REVIEW	9
2.1 Introduction.....	9
2.2 Body condition in elephants.....	9
2.3 Strongyle parasites and body condition in elephants and other wild animals	12
2.3.1 Strongyles in primates.....	12

2.3.2 Strongyles in hindgut fermenters	13
2.3.3 Strongyle parasites in elephants.....	13
2.4 Elephant body condition.....	17
2.5 Conclusion	20
CHAPTER3: MATERIALS AND METHODS	21
3.1 Study Area.....	21
3.2 Dung processing and parasite analysis	22
3.2.1 Dung mapping and collection	22
3.2.2 Preparation of saturated salt solution	23
3.2.3 Parasite analysis	23
3.3 Determination of age of elephants	24
3.4 Bull elephant identification.....	26
3.5 Determination of elephant body condition	28
3.6 Nutritional value of food ingested	32
3.7 Data Analysis	32
CHAPTER 4: RESULTS	34
4.1 Elephant body condition	34
4.2 Strongyle parasite loads	36
4.3 The relationship between strongyle parasite counts and elephant body condition	39
4.4 Nutrition value of elephant diet	43
4.5 The relationship between nutrition value of elephant diet and body condition.....	44
CHAPTER 5: DISCUSSION	46
5.1 Elephant body condition	46

5.2 Strongyle parasite counts within the elephant population.....	47
5.3 Nutrition value of elephant diet and how it correlates to elephant body condition....	50
CHAPTER 6: CONCLUSION AND RECOMMENDATIONS	54
6.1 Conclusion	54
6.2 Recommendations for future work	55
REFERENCES.....	56
APPENDICES.....	62

ABBREVIATIONS

ADF	-Acid Detergent Fibre
Ca	- Calcium
CP	- Crude Protein
CF	-Crude Fibre
DM	-Dry Matter
CITES	- Convention on International Trade in Endangered Species
K-S	-Kormogrov Smirnov
NZP	- Nehru Zoological Park
NDF	- Neutral Detergent Fibre
P	- Phosphorus
PCR	- Polymerase Chain Reaction

LIST OF TABLES

Table 1: Suggested elephant nutrition requirements (based on dry matter)	19
Table 2: Average shoulder height for bulls and family group members corresponding with age range estimates for African elephants in Etosha National Park.....	26
Table 3: Index of the overall body condition of elephants in Etosha National Park	29
Table 4: Asian elephant body condition index.....	31

LIST OF FIGURES

Figure 1: The life cycle of the strongyle parasites.....	14
Figure 2: Map showing the location of the Mushara water hole where the study was conducted, it is located in the north eastern part of Etosha National Park in Namibia.....	22
Figure 3: Strongyle parasite eggs from the elephants in the north eastern part of Etosha National Park	24
Figure 4: Features measured on the elephant bulls to determine their age.....	25
Figure 5: Ear identification features (Greg).....	27
Figure 6: Ear identification features (Smokey).....	28
Figure 7: Six different parts of elephants that were scored to assess body condition.....	29
Figure 8: Differences in body condition between two elephants in the same population.....	30
Figure 9: Average body condition scores of elephants for 2012 and 2013	35
Figure 10: Average body condition amongst age classes of elephants.....	36

Figure 11: Median number of strongyle parasite egg counts found in elephants during 2012 and 2013 37

Figure 12: Median number of strongyle parasite egg counts found in amongst age classes during 2012 and 2013 38

Figure 13: Median number of strongyle parasite egg counts found in amongst age classes during 2012 and 2013 39

Figure 14: Relationship between strongyle parasite egg counts and elephant body condition..... 40

Figure 15: Relationship between strongyle parasite egg counts and body condition within Full bulls age class 41

Figure 16: Relationship between strongyle parasite egg counts and body condition within Three quarter age class 42

Figure 17: Relationship between strongyle parasite egg counts and body condition within Quarter bull age class..... 43

Figure 18: Behaviour between nutrient parameters and elephant body condition; the graph shows no correlation amongst any of the nutrients to elephant body condition 45

LIST OF APPENDICES

Appendix 1: Elephant dung collection.....	61
Appendix 2: Microscopic analysis of strongyle parasite egg counts.....	61
Appendix 3: Research camp from which the elephant body condition was analysed.....	62
Appendix 4: Correlation test results between strongyle parasite egg counts within each age group	63
Appendix 5: Mann-Whitney test to test the difference in body condition scores over two years.....	63
Appendix 6: Nutrition data from elephant individuals	64
Appendix 7: The Spearman's correlation test between nutrient parameters and elephant body condition	65

ACKNOWLEDGMENTS

This research was conducted with the help of many people, without whom this research would not have been possible. I would like to start off by thanking one person that believed in me and made me feel like a true researcher. Dr. O'Connell-Rodwell through her non-profitable Organisation Utopia Scientific, provided me with a research team, funds, courage, strength and most of all knowledge. Dr. O'Connell-Rodwell was my mentor throughout the project and I am very grateful for this opportunity.

Secondly I would like to thank Dr. Elsabe Julies, my University of Namibia supervisor who also believed in me and gave me hope. Dr. Julies gave me invaluable feedback on my thesis; she gave me sound advice and guided me all the way to the end. Without her dedication I am not sure I could have completed this study. Any student would be lucky to have such as a supervisor, and I am eternally grateful.

I want to thank my loving husband for his support and understanding during this study.

I could not have completed this research without the help of a good friend Patrick Freeman, thank you for all your help during the data collection period.

During this research I had many questions that I could not ask my supervisors because I thought they were too busy. One person that proved to always be there was my friend Claudine Cloete who has completed her MSc already, thank you for always being there and willing to help me throughout this research.

Another friend I would like to thank is Marius Hedimbi, for his guidance and support at the beginning of this project. I would also like to thank Mr. Klemens Mutorwa for helping me with data analysis for this study. My gratitude is also extended to Katrina Shiningavemwe and Evaristo Lilungwe of the Ministry of Agriculture, Water and Forestry for assisting me with the nutrition analysis of this project.

My family gave me moral support throughout this project especially my mom, thank you very much. Last but not least, I would like to thank the Ministry of Environment and Tourism for granting me permission to conduct research in the magnificent Etosha National Park.

“Elephants are major sculptors of local land surfaces in Africa.”
GARY HAYNES (2011)

DECLARATION

I, Kaatri N. Brumfitt, declare hereby that this study is a true reflection of my own research, and that this work, or part thereof has not been submitted for a degree in any other institution of higher education.

No part of this thesis may be reproduced, stored in any retrieval system, or transmitted in any form, or by any means (e.g. electronic, mechanical, photocopying, recording or otherwise) without the prior permission of the author, or The University of Namibia in that behalf.

I, Kaatri N. Brumfitt, grant The University of Namibia the right to reproduce this thesis in whole or in part, in any manner or format, which The University of Namibia may deem fit, for any person or institution requiring it for study and research; providing that The University of Namibia shall waive this right if the whole thesis has been or is being published in a manner satisfactory to the University.

.....

Date

Kaatri N. Brumfitt

CHAPTER 1

INTRODUCTION

1.1 General Introduction

There are two species of elephants, namely the African elephant and the Asian elephant. African elephants live in the savannas and forests of Africa (Ceballos and Ehrlich, 2009). While the Asian elephants are distributed in the Southeast part of Asia (Sukumar, 2006). In Africa there is one elephant species divided into two subspecies namely, *Loxodonta africana africana* (Savanna elephant) and *Loxodonta africana cyclotis* (Forest elephant) (de Klerk, 2009). Elephants are social animals and learn about what to eat, where to find water and how to behave from their mothers and older bulls (Ceballos and Ehrlich, 2009). Elephants are considered to be a keystone species because the integrity of the ecosystems they live in depends on their existence due to the amount of vegetation they alter when feeding (Rode et.al, 2006). Despite the elephant being a keystone species and the many efforts to conserve it, the environmental factors that can affect their growth and survival are not entirely understood (Rode et.al, 2006).

There are insufficient studies on the growth and survival of elephants, as well as their body condition and how their body condition is affected by environmental factors (Wammer et al., 2006; Fernando et al., 2009). Elephants like most animals have different body conditions, which in many cases is usually a reflection of the body's fat content, food availability, presence or absence of diseases or disorders and may also determine an individual's reproductive potential (Ramesh et al., 2011). Elephant body condition is affected by various factors, such as resource availability and quality (de Klerk, 2009; Turner et al., 2012). Since the availability and nutrition quality of vegetation depends on rainfall, among other factors, rainfall is indirectly a contributing factor to the body condition of wild elephants (Turner et al., 2012). Body condition of male and female animals may differ because of energetic costs that are

different in species such as elephants (Wammer et al., 2006). Body condition in male elephants can also be affected by musth, a physiological and behavioural condition that happens only in elephants and is characterised by high levels of testosterone, aggression and heightened sexual activity (Hollister-Smith et al., 2007).

Many studies assessing body condition of elephants have been conducted on both Asian and African elephants. The studies assessed six different parts of the elephant body to determine their body condition, the body parts include: temporal depression, shoulder blade, ribs, flank area, lumbar vertebrae and pelvic bone (Wemmer et al., 2006; Fernando et al., 2009; Ramesh et al., 2011). Other studies investigated internal features to determine elephant body condition by weighing the fat and muscle content of individual elephants and comparing their ratios. The latter procedures were conducted on elephant carcasses (Albl and Giessen, 1971).

1.1.1 African elephants, numbers and conservation status

In the past, 5 - 10 million elephants were found across Africa (van Aarde and Jackson, 2007). In 1979 the population of elephants in Africa was 1.3 million, and in 1989 elephant numbers had dropped to 600 000. Therefore meaning that Africa lost more than 52% of its elephants between 1979 and 1989 (van Aarde and Jackson, 2007). For example, numbers in Kenya decreased from 130 000 to 17 000 elephants during that period. Haasbroek (2008) reported that the African elephant was moved from Appendix II of the Convention on International Trade in Endangered Species (CITES) to Appendix I in 1989 in Laussane, Switzerland. Appendix II requires permits to hunt or trade, while Appendix I is the highest level of protection and does not allow international trade. However in 1994 in Lauderdale, USA, the African elephant was placed back into Appendix II, since their numbers increased dramatically especially in southern Africa (Haasbroek, 2008). According to Blanc et al. (2005), the elephant population in southern

Africa is increasing and the countries are yet to come up with a method to manage the increasing population. Currently most of the elephant populations in Africa live in well protected areas and in 2009 Africa was estimated to have a population of about 690 000 elephants. According to Blanc et al., (2005), at the time of the study the elephant population in southern Africa was about 400 000 and over 150 000 were found in Botswana alone. According to Haasbroek (2008), approximately 10, 000 elephants were found in Namibia although they became almost extinct at the end of the last century due to trophy hunting and poaching. Many of these elephant populations are currently in the north-eastern and the northern parts of Namibia. The number of elephants in Etosha National Park is estimated at 2000 and is increasing (Ceballos and Ehrlich, 2009).

1.1.2 Social interactions among elephants

In elephants, very much like in humans, memory and communication are important factors in assisting them to reach maturity (Viljoen, 2008). Many of their actions are learned from their family units and their environments, including their reactions to humans. Mature elephants play an important role in transferring knowledge to the young ones (Viljoen, 2008). Although within a herd, older cows mostly transfer knowledge to the younger ones, the bulls are the ones that wander the furthest, and discover new resources. This knowledge is then brought back to the herds. Younger post-adolescent bulls, who cannot be controlled by the matriarchs, cause most problems to others (Haasbroek, 2008). These young bulls are disciplined by the older bulls, which also prevents them from breeding until they are responsible adults (Haasbroek, 2008). Removal of bulls could lead to a social breakdown within elephant populations and a decrease in knowledge. Lack of this knowledge would leave the elephants vulnerable to environmental change such as droughts (Viljoen, 2008).

1.2 Factors that might affect body condition in elephants

1.2.1 Strongyle parasites

Gastrointestinal parasite loads are among many factors that can potentially have negative impacts on the elephant body condition. Sukumar (2003) reported that high intestinal parasite loads have a potential to negatively influence body condition of elephants. This is because intestinal parasites feed on the food within the elephant gut, and therefore competing with the host for nutrients (Fowler and Mikota, 2006). Elephants carry a complex variety of gastrointestinal nematodes in the family Strongylidae which are currently divided into six genera: *Choniangium*, *Decrusia*, *Equinurba*, *Khalilia*, *Murshidia* and *Quilonia* (McLean et al., 2012; Thurber et al., 2011).

Elephants like many other host species if infected by strongyles may have crucial consequences for individuals and populations by influencing patterns of co-infection or shaping host population dynamics (McLean et al., 2012). Strongyle parasites have the potential to affect the reproduction potential of the elephant by reducing their health, this therefore might affect the population dynamics (Fowler and Mikota, 2006). The parasite infection rate is strongly influenced by seasonality and age related host immune response (Turner and Getz, 2010). According to McLean et al. (2012) understanding the patterns of strongyle parasite infections in elephants is difficult because the strongyle parasite species are difficult to distinguish using eggs from faecal samples. However, genetic identification is possible and there are many studies conducted on genetic identification of other parasite groups (Gasser et al., 1996; Shokoofeh et al., 2009).

1.2.2 Nutrition quality of elephant diet

Apart from parasites, another component that can influence elephant body condition is nutrition and the mineral composition of their feed (de Klerk, 2009). However, a comprehensive look at the nutritional content of their diets and the identification of potentially limiting nutrients is largely missing (Rode et al., 2006; Rees, 1982; Wemmer et al., 2006). Although there are various methods for determining the quality of the diet, faecal analysis has been shown to be the most practical for diet analysis of wild herbivores because it is non-invasive and samples are easy to collect (de Klerk, 2009; Rees (1982); Leslie and Starkey 1985). Rees (1982) reported that when taking into consideration the combination of hind-gut fermentation and rapid gut-transit times which cause poor digestive efficiency in elephants, faecal samples are also a representative of the diet consumed within the last day or two. Diet quality is generally related to the amount of protein, fibre and minerals (e.g. phosphorus, calcium) present in the food (de Klerk, 2009). Many studies have shown that values obtained in faecal samples are correlated with those found in the actual diet (Moir 1966; Leslie and Starkey 1987; Ulrey et al., 1997). Therefore faecal analysis is an easy and effective way to determine the diet quality of elephants.

1.3 Statement of the problem

Strongyle parasites are one of the gastrointestinal parasites that feed on the food material ingested by elephants, however their biology is not well understood. Thurber et al. (2011) confirmed that strongyle parasites exist within the elephant population in Etosha National Park. The effects of these parasites are unknown and since the parasites feed on the food within the elephant gut, it is suspected that strongyle parasites might influence body condition. A high load of strongyle parasites can potentially impact negatively on the body condition of elephants, which in turn may impact on vital processes such as reproduction. When the health of elephants becomes compromised by parasites it can potentially decrease the reproductive

rate and life expectancy of elephants. There is a lack of baseline data on the body condition of the African elephants across Africa as many published studies on elephant body condition focus on Asian elephants. Asian and African elephants face different environmental factors, hence the body condition of both species needs to be understood separately. With inconsistent rain patterns in Namibia over recent years, we need to understand the body condition of the elephants, because this might track changes in their body condition over time. Baseline data on body condition of elephants is essential, as it can serve as an indicator of environmental change in future.

Etosha National Park, like many parks is battling the problem of elephants constantly breaking out of the park to feed outside; this study will provide the park management with information regarding the nutrition quality of forage within the park, which can be compared to the nutrition quality of the forage outside the park in future studies. The latter will contribute to the existing knowledge on nutrition and can be viewed as a step closer in solving the problem of breakouts.

1.4 Objectives

- a) To determine the overall (average) body condition of the elephants around the Mushara waterhole in Etosha National Park;
- b) To determine whether there is a relationship between body condition and strongyle parasite egg counts amongst 4 age classes of African elephants;
- c) To determine the nutritional value of elephant diet;
- d) To determine if there is a relationship between body condition and nutrition value of elephant diet.

1.5 Hypotheses

- a) Thurber et al. (2011) found that the elephant population around the Mushara waterhole had strongyle parasites, which are gastrointestinal parasites that consume food within the elephant gut. therefore this study expects to find the body condition of elephants in poor condition;
- b) Since strongyle parasites consumes the food ingested by the elephants, the food within the gut is shared between the host (elephant) and the strongyle parasites. Therefore this study expects to find a significant negative correlation between body condition and strongyle parasite egg counts amongst 4 age classes of African elephants;
- c) Elephants constantly break out of the park in search for better diet, therefore this study expects to find that elephant diet within the study area does not meet the minumim diet requirements for elephants;
- d) Diet of high nutrition value is required for good body condition. Animals living within areas containing high nutritional forage tend to have good body condition. Therefore his study expects to find a significant positive correlation between body condition and nutrition value of forage ingested by the elephants.

1.6 Significance of the study

This study will provide information on whether strongyle parasites have a negative effect on the body condition of elephants. This will allow measures to be taken by the park management should the parasites have a negative effect. Little is known about strongyle parasites in elephants of northeast Etosha National Park and this study is important because it will add to the existing understanding on the biology of the strongyle parasites.

This study will provide the Ministry of Environment and Tourism with data on the diet quality of the elephant forage.

Furthermore, this study will demonstrate the application and usefulness of the body condition scoring index, which can also be adapted and used to determine body condition of other animals. This study will also provide the park management with baseline data on body condition of a keystone species which in future can assist to track environmental changes.

Finally, Etosha National Park is one of the protected areas set aside for conservation and categorised under the International Union for Conservation of Nature and Natural Resources (IUCN) II. The park is a huge tourist attraction area, attracting more than 100 500 tourists in 2011 (Ministry of Environment and Tourism, 2012). Thus, not only is the elephant a key species to the park's ecosystem, it also contributes greatly to attracting tourists to the park. Hence the results of this study will contribute to the management of elephant populations, which have both touristic and conservation value.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

According to Turner et al. (2012) estimates of animal body condition are used to determine the influence of factors such as environmental degradation and ecological interactions on animal health. In the same study they stated that in ruminants, the body condition varies with seasonal changes in energy and protein requirements and quality and availability of resources. Digestive capacity, diet composition, and foraging time are factors that can contribute to body condition change. Another important factor that influences body condition is parasite infections (Holmstad et al., 2005).

2.2 Body condition in elephants and other wild animals

According to Tennant et al., (2002) body condition, sometimes referred to as fat cover is an indication of energy reserves within the animal. Body condition in particular energy reserves can have crucial fitness consequences (Schulte-Hostedde et al., 2001). Measuring body condition of live animals is typically done by relating body mass to measures of body size and using excess fat reserves as an index of condition. Body condition measurements have been used to predict body mass in cattle, horses, sheep, pigs, goats and elephants; and also demonstrated that accurate estimates of body condition can be used in evaluation of feeding programmes, nutritional status and general health for anaesthesia (Hile et al., 1997).

Several studies have been conducted to study the body condition of wild animals including elephants. However, many of the latter studies were conducted on Asian elephants and not African elephants (Rode et al., 2006; de Klerk, 2009; Albl et al., 1971; Fernando et al., 2009; Ramesh et al., 2011; Wemmer et al., 2006).

A study conducted on springboks by Turner et al. (2012) in Etosha National Park investigated the influence of rainfall variation, demographic factors and parasite interactions on parasite prevalence or infection. The study also investigated whether parasitism or rainfall is a more important predictor of Springbok body condition. Authors reported that increased parasite intensity is associated with reduced body condition only in adult females. In addition, for all other demographic groups, the body condition was significantly related to rainfall and not parasitism. The main finding was, parasites and the environment can together affect host populations, but that these interactions might be influenced by other factors of demographic groups and the different time scales at which they operate (Turner et. al 2012). Turner et al. (2012) employed a body condition scoring system that was developed by Berry and Louw (1982) for wildebeests and adapted for springboks. The categories were based on the shape of the hind quarters and the visibility of the ribs and pelvis.

A study conducted in Zambia in 1971 compared a series of external measurements from 240 carcasses of African elephants during a dry season in order to measure fluctuating fat content and muscles (Albl et al., 1971). The study also investigated the ratio of the weight of kidneys to kidney fat as well as the fat content in the bone marrow. It produced a simple criteria for the assessment of physical body condition of African elephants. The main findings of the study were, extensive individual variations of external anatomical features complicate the measurements. Furthermore, the shape of the lumbar region and kidney fat index gives a fair and reliable indication of physical body condition (Albl et al., 1971).

In another study, a method of assessing body condition in Asian elephants was presented by Wemmer et al. (2006). The method used visual assessments to allocate numerical scores to six different regions of the body which are summed to give a numerical index ranging from 0-12. The study was conducted on 119 juveniles and young adult elephants from Southern India. No significant correlation between index of body condition and age over both sexes was revealed.

This method was meant to provide a practical tool for ecological studies (Wemmer et al., 2006). Unlike the later study conducted by Schulte-Hostedde et al. (2001), this study did not measure any fat content; it was conducted from a distance on live animals rather than on elephant carcasses.

Fernando et al. (2009) stated that body condition assessment is individual based but most meaningful when applied to a population. Measuring body condition can be used as an early indicator of the impact of management actions on the elephants considering age differences. Fernando et al. (2009) carried out a study on the body condition of Asian elephants in Sri Lanka by scoring elephants in pictures. The latter method allowed scientists to score elephants in their own comfort without having to go out in the field.

In another study by Ramesh et al. (2011) on body condition of Asian elephants, the same body scoring system used by Fernando et al. (2009) was used. They found that a higher percentage of adult females were either in poor or medium condition during the dry season compared to the wet season. The proportion of adult females with a poor body condition was higher compared to adult males. They based their findings on the availability of nutritional food during the dry season and since elephant calving occurs throughout the year, nutritional stress in lactating females could have caused the poor body condition. The study further suggested that the aging factor could also be one reason why medium to poor condition was noticed mainly in adult elephants. The study suggested that long-term monitoring of body condition evaluation should be carried out not only in elephants but also other wild animals. This is because individual based body condition assessment is the most meaningful method when applied as an early indicator of the impact of management actions and health status of elephants and other wild animals (Fernando et al., 2009).

2.3 Strongyle parasites and body condition in elephants and other wild animals

Endoparasites can exist in two forms, intercellular and intracellular. Intracellular parasites are those that are found inside cells of their hosts, while intercellular parasites are found outside the cells of the host (Fowler and Mikota, 2006). Examples of endoparasites are tapeworms, fluke worms, *Plasmodium* species and scabs. Gastrointestinal parasites are endoparasites that are found in the guts of organisms. Gastrointestinal parasites include tapeworms and strongyles. Parasites increase their own fitness at the expense of the host by consuming the host's food (Fowler and Mikota, 2006).

2.3.1 Strongyles in primates

A study was conducted on gorillas of Western Cowland at Bai Hokou, Central African Republic. The study focused on the examination of faeces to allow identification of parasite species present in gorilla populations and assessment of the relative abundance of these parasites (Freeman et al., 2004). The Cornell McMaster dilution egg counting technique was preferred to quantify parasite loads via egg counts, but this technique was not feasible. Instead, the parasite abundances were quantified using a scale of 0 to 5, corresponding to the number of each parasite found per microscope field. According to Freeman et al. (2004) ten parasite genera were identified as well as a number of unclassified Strongyle Trichostrongyles, Spirurids and Trematodes. The Strongyle abundance was +1 which means the abundance is low. This was due to the difficulty of differentiating Strongyles on the basis of egg sizes and morphology, the genera and species present could not be identified (Freeman et al., 2004).

2.3.2 Strongyles in hindgut fermenters

Boxell et al. (2004) studied gastrointestinal parasites in 29 horses in Perth, Australia using the polymerase chain reaction (PCR) method. They reported that the gastrointestinal tracts of 29 horses were submitted to a veterinary hospital and were examined for the presence of gastrointestinal parasites. The tracts were divided into six sections and were screened for the presence of parasites. Eighteen species of helminths were identified, 12 of these were Cyathostomes. They also found a large strongyle, *Triodontaphorus serratus* which was only found in 3 horses. According to Boxell et al. (2004) the apparent reduction in the number of large strongyles may be due to the widespread use of Ivermectin, which is very effective against strongyles. Another reason could be that some larvae may not have been detected.

2.3.3 Strongyle parasites in elephants

Even though little is known about the strongyles affecting elephants, Fowler and Mikota (2006) stated that the biology of these parasites is similar to that of strongyles described in horses and domestic livestock (Figure 1).

According to Fowler and Mikota (2006), adult strongyles are found in the stomach, small intestine, cecum and large intestines of animals. Females produce fertilized eggs containing embryos in the morula stage. The eggs are passed out through faeces and hatching occurs in 1 to 2 days. The larvae feed on microorganisms in the faeces and molt. The larvae then migrate out of the faeces in about 1 week and climb onto vegetation and the elephants ingest plant material infected with larvae which become adults in the stomach or the intestine where the females produce fertilized eggs, a process illustrated in Figure 1. In addition to strongyles, *Gasterophilus* species and *Anoplocephala* species are other examples of elephant gastrointestinal parasites.

Gastrointestinal parasites in mammals, especially nematodes can reduce voluntary food uptake and can decrease the efficiency of food use (Fowler and Mikota, 2006). These parasites can also affect the absorption and retention of the animal's minerals and nutrients. Hence one would expect high strongyle parasite egg loads to result in poor body condition in animals including elephants (Fowler and Mikota, 2006).

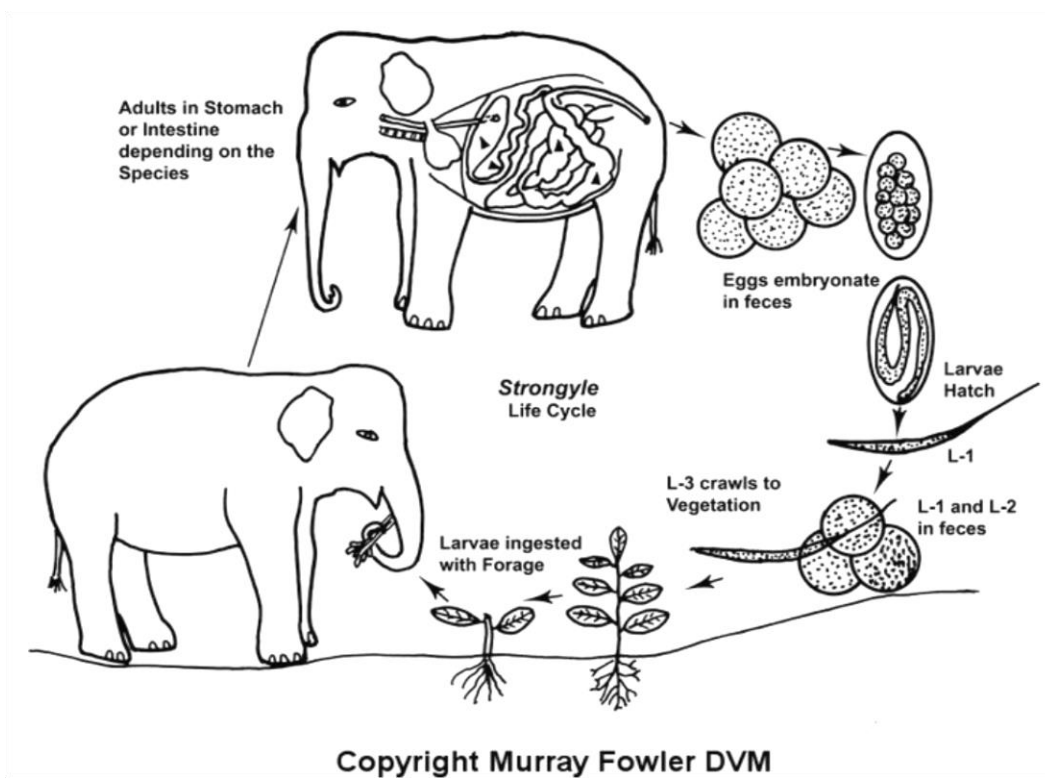


Figure 1: The life cycle of the strongyle parasites (Fowler and Mikota, 2006).

Potential factors determining the transmission of parasites include environmental conditions that affect the viability and behaviour of parasites. The internal conditions in the host e.g. gut physiology and the immune system response affects the success and reproduction of the parasites (Sukumar, 2003). It is therefore important to study the relations between parasite loads and the body condition.

In a study that was conducted in India on Asian elephants, morphological criteria and parasite loads were utilised to investigate factors that potentially influence intestinal parasite loads (Vidya and Sukumar 2002). This study found no correlation between body condition of the elephants and the parasite loads (Vidya and Sukumar, 2002). Gastrointestinal nematodes in elephants are very common and have been responsible for several illnesses and poor body condition (Vidya and Sukumar, 2002).

A study on gastrointestinal parasites of African forest elephants was done in the Republic of Congo Nouabale Ndoki National Park where faecal samples were collected from Six African forest elephants from two national parks, Nouabole-Ndoki and Dzangha-Sangha (Kinsella et al., 2004). In total twelve species of intestinal parasites were collected during a complete necropsy. They reported that the faecal samples revealed the presence of a *Schistosoma*, a tracheal nematode, intestinal strongyles and ciliates. The nematode genera *Decrusia* and *Equinurbia* were reported for the first time in African elephants and the ciliate genus *Latteuria* was reported for the first time from wild elephants.

In another study by Banerjee et al. (2006), faecal samples were collected from thirty three Asian elephants from the forest of South Uttarachal, India. Microscope examinations were used in this experiment and it revealed that 63.6% of elephants were positive for parasitic infections either for strongyles alone or mixed strongyles and coccidians. Amphistomes, strongyles and coccidian infections were common in elephants. The study however did not investigate the effects of the later parasites on body condition of elephants.

Sasseendran et al. (2004) carried out a study to assess the prevalence of parasitic infections in captive elephants in Kerala, India. Dung samples were collected from 44 elephants. The samples were examined by the concentration and centrifugation methods (Georgi 1985 cited in

Sasseendran et al., 2004). About 17.2% of the samples were positive for parasitic infections. Among the positive samples, 10.0% of the samples had strongyles and 7.7% had amphistomes. Fowler and Mikota (2006) reported that strongyles were observed in a group of elephants maintained in a private circus in India. Examination of faecal samples showed larvae which were identified as marshidiase, quilonia, and descrusia larvae. All elephants were treated with Fenbendazole at a dose of 5 mg/kg body mass. A decline of egg counts was observed after 1-2 days of treatment. They were identified at the earlier stages of infection. Good nutrition and hygiene and less exertion might have been the cause of absence of significant critical signs like anemia, dehydration and others. They concluded that the use of Fenbendazole at the rate of 5 mg/kg body mass in the elephants with repetition after 3 weeks, and regular de-worming every 3-6 months will yield satisfactory results.

In Nehru zoological park, clinical records of Asian elephants for a period of ten years (1987-1996) were examined to determine the percentage of strongylosis in relation to season, age and sex (Suresh, 2000). Faecal samples from elephants were screened for helminthosis. Eggs per gram of faeces were estimated by Stoll's dilution method. Analysis of old records revealed that strongylosis was predominant in summer (52.6%) and the incidence was lower in animals below the age of 15 years. Seven animals tested positive for ova of strongylosis in Nehru zoological park. On treatment with oral Kalbend the animals completely recovered on the seventh day. The study indicated the efficiency of Kalbend in the treatment of strongylosis in elephants (Suresh, 2000).

In another study by Halmiton and Desmond (2003) that was done in Zimbabwe, 44 fresh wild elephant faecal samples were collected. Baerman's technique resulted in 73% positive and 23% negative samples. Halmiton and Desmond (2003) reported that due to equipment difficulties the exact identification of the larvae was not possible. Sedimentation resulted in 36% of the

samples containing strongyles, 57% containing strongyloids and 36% of the samples containing negative samples. Floatation resulted in 93% of the samples containing strongyles 93% of the samples containing strongyloids and 51% negative samples (Halmiton and Desmond, 2003).

Strongyle parasites are therefore common in elephants. However the biology of strongyles in elephants is not quite well understood. One other highlight from the above studies is that strongyle parasites in elephants can be treated with different medicines for example Fenbendazole and Oral Kalbend (Fowler and Mikota, 2006: Suresh, 2000).

2.4 Elephant body condition and nutrition

Elephants in the wild have been described as general feeders consuming more than 400 different species of plants (Fowler and Mikota, 2006). Grass is preferred by elephants but they also consume trees, shrubs, leaves, twigs, roots, fruits, seeds and stones (Fowler and Mikota, 2006). It has been demonstrated through observational studies, faecal analysis and gastrointestinal studies that elephants are both grazers and browsers. The feeding choices of elephants have been linked to many factors with variation mainly influenced by habitat and season.

According to Fowler and Mikota (2006), elephants in Tsavo National Park in Kenya spend 48-63% of their time feeding. Fowler and Mikota (2006) indicated that even though there are quite a number of studies on elephant feeding behaviour, there are few studies focusing on nutrition analyses. The few nutrition analysis studies that have been conducted were through collection of plant materials, stomach content or other sections of the gastrointestinal tract. Another way to determine the quality of diet is through faecal sample analysis (Leslie and Starkey, 1985).

A study conducted by McCullagh (1967) investigated stomach content of 148 elephants at different times of the year for nutrition chemical composition. On average, the study found that samples contained 8.4g of protein, 1.5g of fat, 43.5g of carbohydrate, 35.7g of fibre and 11.0g of mineral material in 100g of their dry matter. This study concluded that those elephants may be deficient in protein in dry season than wet season, also the intake of calcium was high during the dry season than in the wet season. The analysis of the quality of the dietary fat showed it to contain relatively small amounts of essential poly unsaturated fatty acids. Ullrey et al., (1997) stated that while observations are not sufficient to set minimum nutrient requirements, analysis of plant parts eaten by elephants can help define nutrient intakes in wild diets.

For protein requirements, browse species in the Hwanke National Park in Zimbabwe in 1997 had 8-24% of crude protein (CP) (Ullrey et al., 1997). As for minerals, browse plant species eaten by wild African elephants during February 1997 in Hwanke National Park, Zimbabwe contained 0.35-2.4% calcium (Ca) and 0.11-0.33% phosphorus (P) (Ullrey et al., 1997). In another study, a 10yr old male African elephant was observed for 12 hours during daylight in Tsavo National Park, Kenya and 64 plant species were consumed (Bax et al., 1963). CP concentration ranged from 6-23% from the 59 plant species that were analysed. Crude fibre concentrations in the leaves of trees used by African elephants in the Kasungu National Park, Malawi, ranged from 13-62% (Ullrey et al., 1997).

Alternative analyses for neutral detergent fibre (NDF), acid detergent fibre (ADF), and lignin have been developed, which are more accurate in characterizing plant cell wall fractions that are mostly difficult to digest. NDF includes lignin, cellulose, and hemicellulose, whereas ADF includes lignin and cellulose (Robinson, 1999). This analytical system has been used to characterize fibre concentrations in plants consumed by African elephants in a private game reserve bordering the Kruger National Park in South Africa, and averages of 62% NDF, 48%

ADF, and 15% lignin were found (Ullrey et al., 1997). The nutrient requirements of elephants have not been defined; however the similarities in the digestive systems of the elephant and the horse suggested that the nutrient needs for the elephants might reasonably be compared to the nutrient requirements of the horse (Fowler and Mikota, 2006; Robbins, 1983).

A study that was conducted by Rode et al. (2006) investigating the nutritional ecology of elephants in Kibale National Park, Uganda, found that energy and protein concentrations were within the recommended levels, but the concentrations of several minerals such as sodium were low relative to the requirements (Table 1) based on captive elephants and values reported for other wild populations. The study suggested that mineral nutrition is most likely to be one of the important factors that drive elephant behaviour and patterns of habitat use.

Table 1: Suggested elephant nutrition requirements (on dry matter basis) (Rode et al., 2006).

Nutritional elements	Elephant Requirements	Horses Requirements
Copper (ppm)	-	10
Manganese (ppm)	-	40
Zinc (ppm)	-	40
Iron (ppm)	157.0	50
Sodium (ppm)	2000	1000
Magnesium (%)	0.1	0.3-0.4
Potassium (%)	0.6	0.3-0.6
Calcium (%)	1.5	-
Phosphorus (%)	-	-
Crude Protein	-	8.0
ADF (%)	10-12	-
Energy (KJg ⁻¹)	16.7	-

2.5 Conclusion

This chapter identified techniques used to determine elephant body condition of both African and Asian elephants. The studies revealed that measuring body condition of elephants using physical body scores has been used for a long time and is still used. Furthermore, literature revealed that there has been a relationship between strongyle parasites and body condition. Another highlight is that nutrition composition of elephant feed is not well studied, and hence the nutritional requirements for elephants are not clear. Studies investigating the relationship between individual nutrition and body condition are limited. What is also evident from literature is that the Asian elephants are far better studied than wild African elephants. Many African elephant studies have been done in Kenya and Uganda, and there is very little research conducted on elephants in Namibia.

CHAPTER 3

MATERIALS AND METHODS

This study was conducted with permission from the Ministry of Environment and Tourism under the supervision of the University of Namibia and a non-profitable organisation, Utopia Scientific. Data were collected during winter of 2012 and 2013 from June to August, this allowed for comparison of elephant body condition during winter over a period of two years.

3.1 Study Area

The study was conducted in Etosha National Park, one of southern Africa's most important game reserves, located at latitude 18° 94' 53''S and longitude 15° 89' 78''E and it covers an area of 22, 270 km² (du Plessis, 2001). In its centre is a salt pan which covers 40% of the park (du Plessis, 2001). The park has high biodiversity with grass and thorn savannah and Mopane bush land in the west and dry forests in the north-east (de Beer et al., 2005). The coolest and dry months are May to September, while the rainy season is from November to March. Average daily maximum temperature is 31°C and the average minimum temperature is 13.7°C. Rainfall is about 358 mm per year with January to March being the hottest and the wettest period of the year (Thurber et al., 2011).

The study was conducted at an artificial waterhole called Mushara which is located in the north eastern part of the park and situated about 35 km from the tourist camp Namutoni (Figure 2). The waterhole is located in a research area which is not accessible to the public. Observations were made from a 4m tower that is located 80 m from the waterhole.

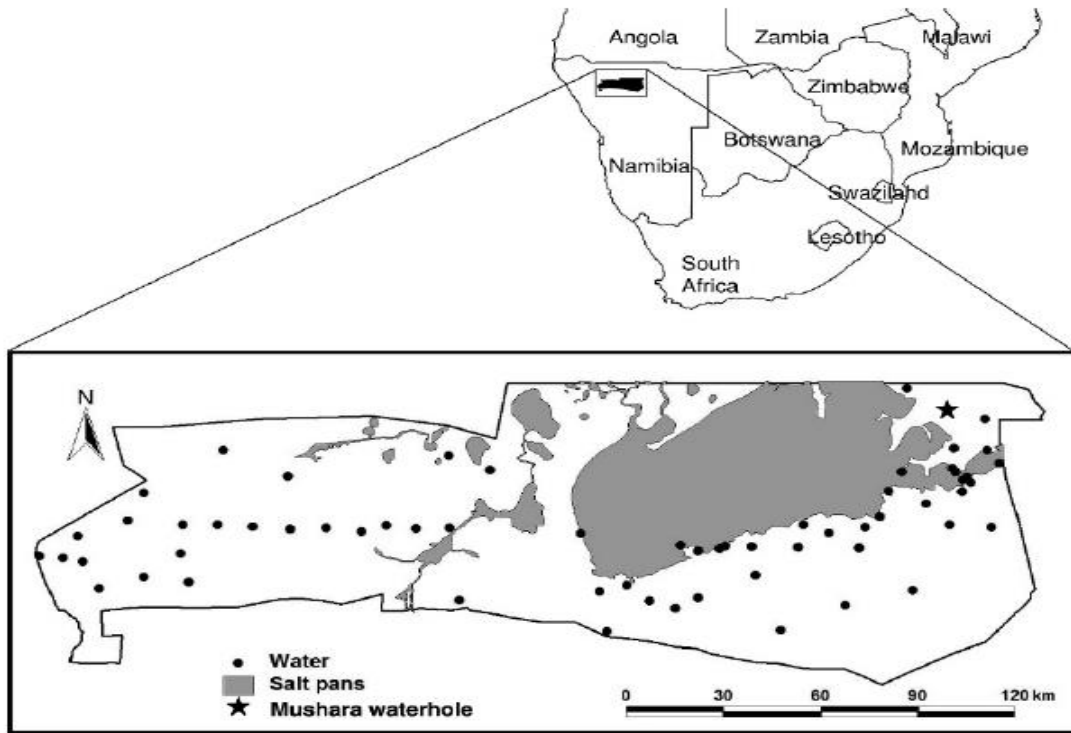


Figure 2: Map showing the location of Mushara water hole (star) where the study was conducted. It is located in the north eastern part of Etosha National Park in Namibia (Thurber et al., 2011).

3.2 Dung processing and parasite analysis

3.2.1 Dung mapping and collection

A map of Mushara waterhole that clearly indicates its surrounding was used to plot the elephant dung dropped in the area. Markers made of stones, bones, bushes and tracks in the clearing were used as reference in plotting the droppings.

While elephants defecated, the following information was collected: elephant identity, time of defecation, date of defecation, and number of dung piles dropped. The time of sample collection was also recorded. To get a representation of the whole dung pile, different parts of

the dung piles were collected and were placed in paper bags. Strongyle eggs develop quickly into larvae therefore it was important to collect and process the faeces within two hours.

3.2.2 Preparation of saturated salt solution

To prepare saturated salt solution, water was boiled and salt (NaCl) was added until it could no longer dissolve in the solution. The solution was super-saturated when a salt crust formed on the surface of the solution. The saturated solution had a specific gravity of around 1.2 m/s², which equals approximately 500 g NaCl per 1000 ml of water. The solution was then stored in a plastic container after cooling (Thurber et al., 2011).

3.2.3 Parasite analysis

Eight grams of faeces was weighed out and then placed in a plastic beaker. Small sub-samples were taken from different parts of the faecal sample to make up 8 g in total. Saturated salt solution of 112ml was added to the 8 g faecal sample. The faecal sample and saturated water was mixed using a spatula until the mixture became a brown slurry. The slurry was poured through a tea strainer into a plastic beaker to remove large plant debris. The filtrate was stirred with a plastic pipette and while stirring, a sample of the filtrate was pipetted out to the volume which the McMaster slide could hold. The sample was placed into the first chamber of a McMaster slide immediately. The process was repeated to fill the second chamber on the McMaster slide. The slide was allowed to stand for approximately 5 minutes before counting to allow the strongyle eggs to rise. Using a compound microscope, the number of strongyle eggs seen within each chamber of the McMaster slide was counted (Figure 3). The strongyle eggs counted were not counted per species of strongyles, but rather lumped together as strongyle parasite eggs. The eggs seen under the microscope that were not of strongyles were not considered in this study. To determine strongyles egg per gram (EPG) of faeces, the number of eggs from both chambers of the McMaster slides were multiplied by 50.

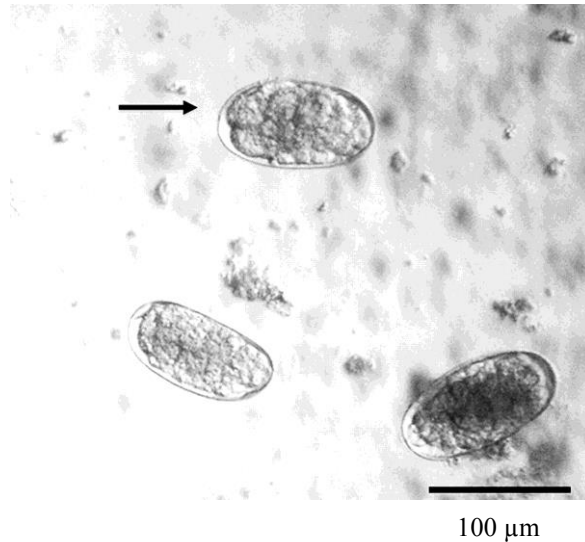


Figure 3: Strongyle parasite eggs from the elephants in Etosha National Park. Their average size varies from 70-90 μm . They are oblong and have a thin transparent shell (Bowman et al., 2003). The picture was captured at 40 times magnification (bar = 100 μm) (Thurber et al., 2011).

3.3 Elephant age determination

According to Laws (1966), elephants continue to grow throughout their lives and reliable methods to correlate their size with age were determined. The latter methods include shoulder height (Poole, 1999), hind foot length and tooth length measurements (Laws, 1966; Western et al., 1983). For this study, the elephant size was determined using hind foot, height and tusk base measurements (Figure 4). Elephant bulls were placed in 4 size categories based on their shoulder height which were used as an index of age, one quarter is the youngest and full elephant is the oldest (Table 2) (Thurber et al., 2011). The size index used for male elephants is different from the one used for elephants in a family group because of sexually dimorphic characteristics in elephant sizes and weight.

Shoulder height was measured using a Trupulse™ 200 Laser Technology laser altimeter on all the elephants from which faecal samples were obtained. Measurements were taken from a fixed

distance of 80 m from the source of fresh water (waterhole). These data were compared for accuracy against a fixed object positioned at the same spot with incremental measurements taped onto the object and visible from the measurement distance. Relative height was used to categorize elephants when exact height could not be measured.

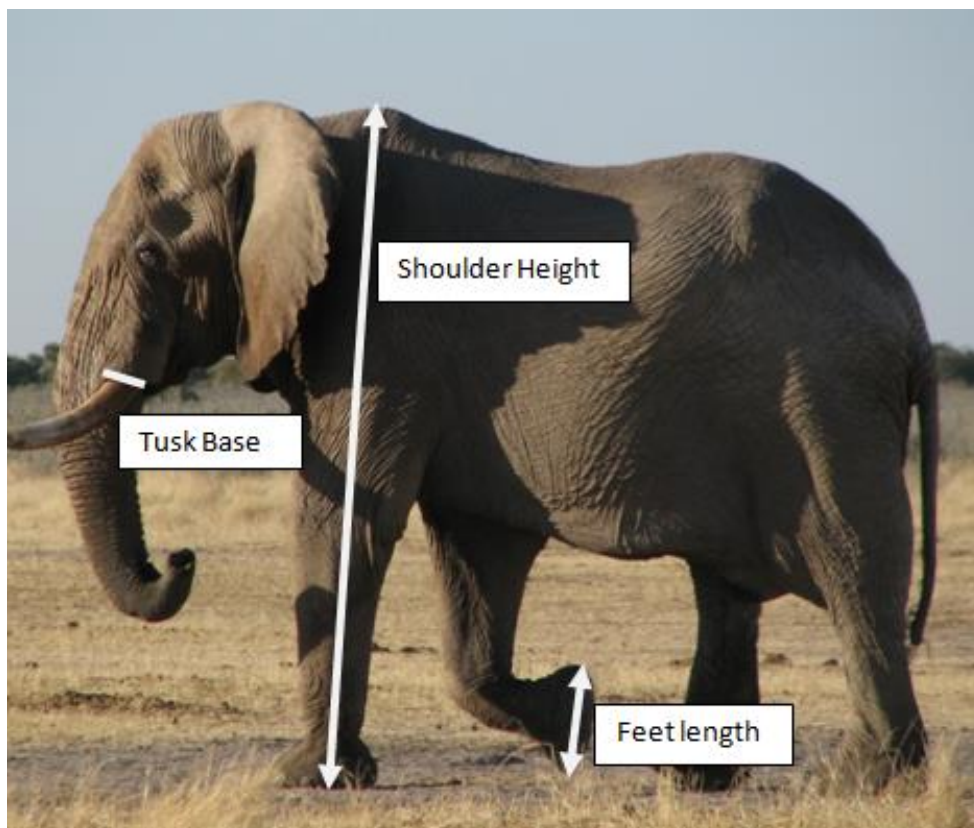


Figure 4: Features (tusk base, feet length and shoulder height) measured in metres (m) on elephant bulls to determine their age.

Table 2: Average shoulder height (m) for bulls and family group members corresponding with age range estimates for African elephants in Etosha National Park (Thurber et al., 2011)

Size	Average shoulder height of bulls (m)	Corresponding age of bulls (yr)	Average shoulder height of family group members (m)	Corresponding age of family group members (yr)
One-quarter	2.70	≤14	1.92	≤6
One-half	2.90	15-24	2.04	7-12
Three-quarter	3.07	25-34	2.35	13-19
Full	3.14	≥35	2.41	≥20

3.4 Bull elephant identification

Bull elephants were identified based on individual differences in their ears, tusks, tails, penises and their overall size (Figures 5 and 6). These differences were recorded in an on-going photo identification database that has been compiled since 2005 and about 175 bull elephants have been identified to date.

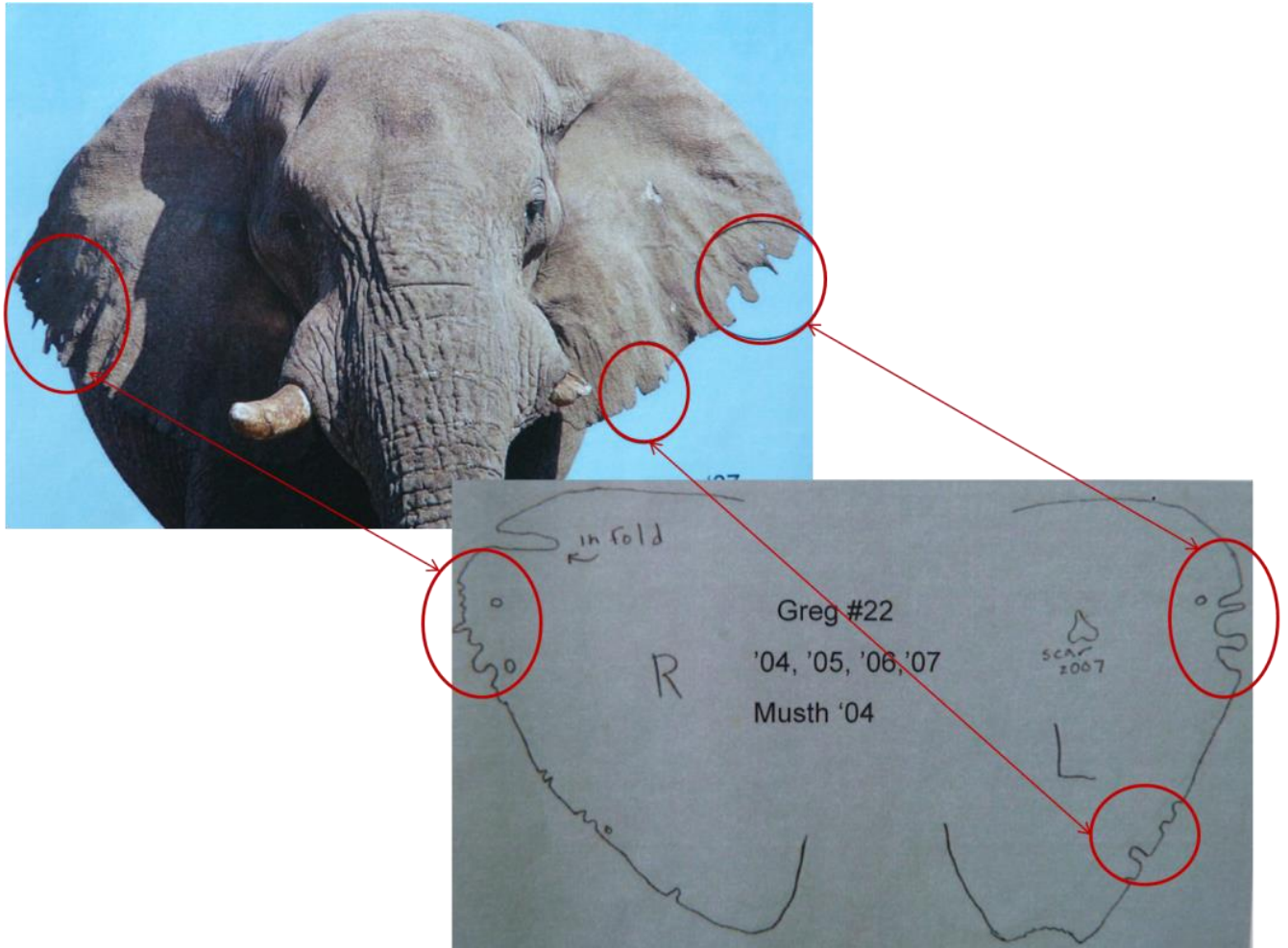


Figure 5: Greg (the elephant) ear identification features: the circle shows distinctive marks on the left and right ear drawn on paper and matched with the same areas on the actual elephant for identification (Utopia Scientific, 2012).

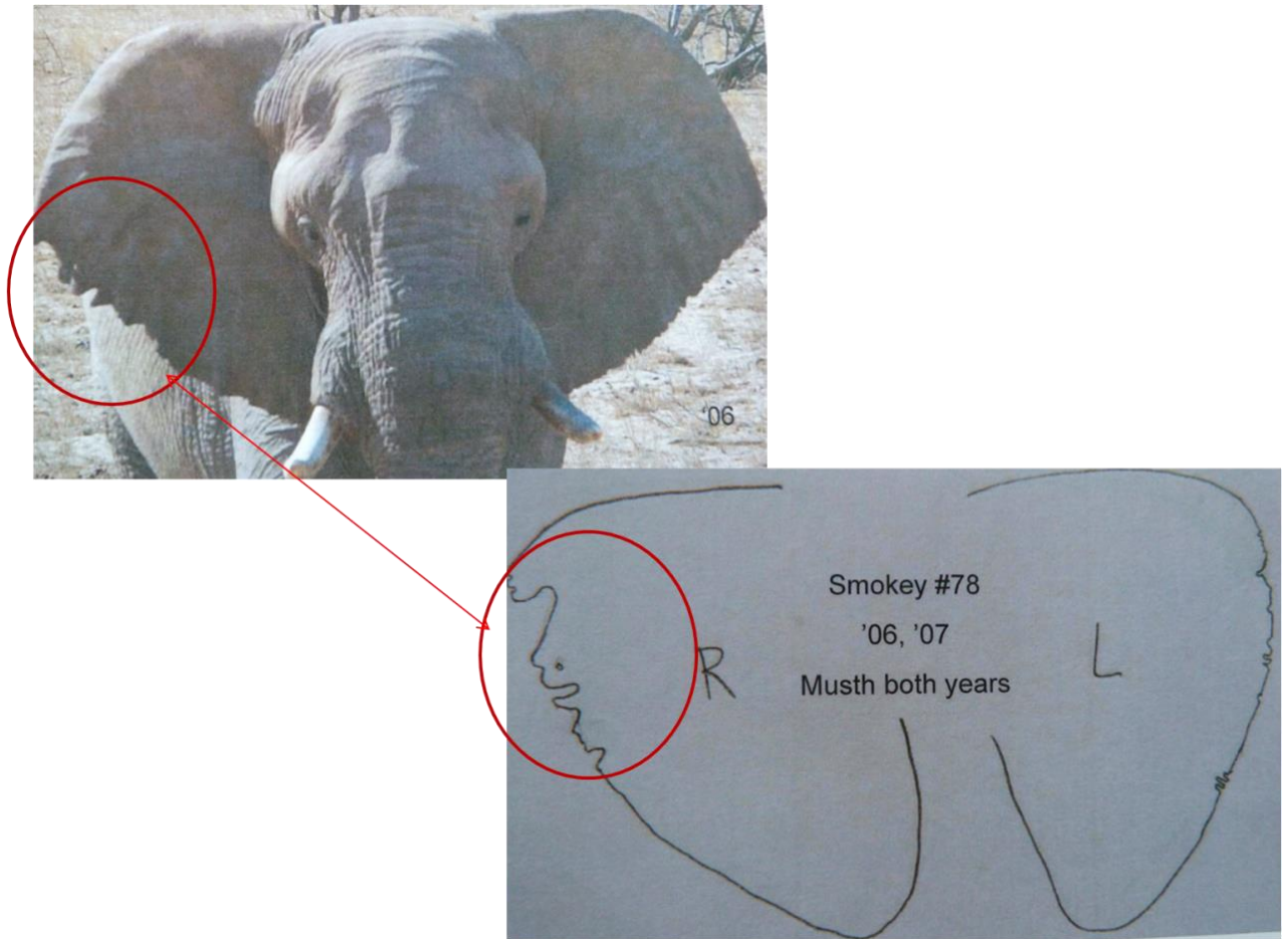


Figure 6: The elephant Smokey has clear distinctive features on his right ear (Utopia Scientific, 2012).

3.5 Determining elephant body condition

To determine the overall status of body condition of the elephant population, the index outlined in Table 3 was used. Elephant body condition was determined using a method as outlined in (Table 4). The elephants were scored when standing at the waterhole, about 80 m from the observation tower using binoculars of 8 x 56 magnifications. Six body parts of the elephant shown in Figure 7 were scored as per Table 4. Figure 8 reveals how different elephants within the same area can have very different body condition. The pictures were taken at the same waterhole.

Table 3: Index of the overall body condition of elephants in Etosha National Park (adapted from Wemmer et al., 2006).

Average body condition	Body condition status
10-12	Excellent
7-9	Good
4-6	Poor
0-3	Very poor (Critical)

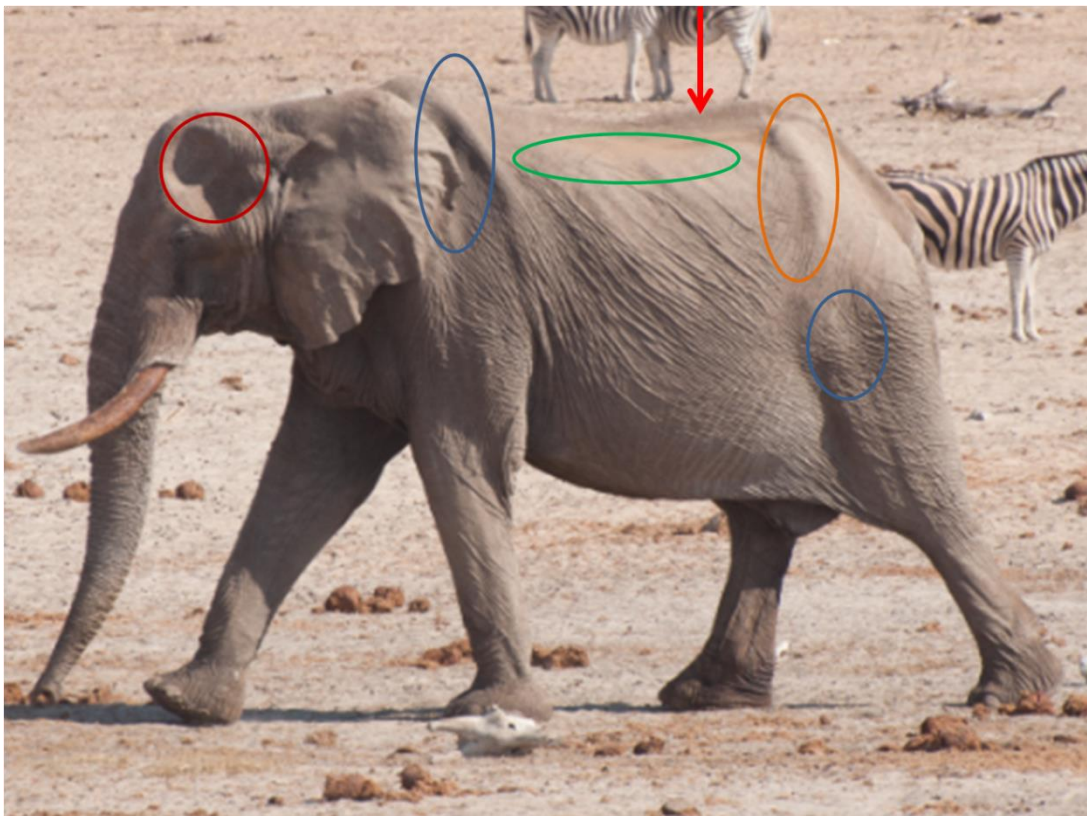


Figure 7: Six parts of the elephants that were scored to determine body condition (Thoracic region (green), head: temporal depression (red), scapula (shoulder blade) (dark blue), flank area (blue), Lumbar vertebrae (red arrow) and Pelvic bone (orange)).



Figure 8: Differences in body condition between two elephants in the same area: The elephant in the left picture is in excellent condition scoring 11/12, while the other elephant on the right has a poor body condition, scoring 4/12. Note the prominent bones on the elephant on the right which are not showing on the elephant on the left.

Table 4: Asian elephant body condition index (Wemmer et al., 2006).

Body Area	Observation Scores		
1. Head: Temporal depression (view from several angles)	Full and convex in outline when viewed from behind, frontal ridge vaguely outline = 2 points	Slightly to moderately concave, frontal ridge defined = 1 point	Deeply concave, frontal ridge forms a craterlike rim around the temporal depression = 0 points
2. Scapula (shoulder blade) view from side	Spinous process not visible or slightly visible = 2 points	Spinous process visible as a vertical ridge with a concavity between the ridge and the posterior edge of the scapula = 1 point	Spinous process pronounced and blade line with the acromial process appearing as a knot = 0 points
3. Thoracic region (view from side)	Ribs not visible, barrel smooth = 2 points	Some ribs visible, but the extent and demarcation not pronounced = 1 point	Many ribs strongly demarcated with pronounced intercostal depressions = 0 points
4. Flank area (immediately in front of pelvis) (view from side and behind)	Not visible, lower back smooth and rounded = 2 points	No depression visible, flank bulges outwards in front of pelvis = 1 point	Depression visible as a sunken area immediately in front of the pelvis = 0 points
5. Lumbar vertebrae (behind ribs and in front of pelvis) (view from behind; an elevated vantage point may be necessary)	Not visible or slightly visible; rump region between ilium and caudal vertebrae filled with tissue = 2 points	Visible but not pronounced; rump is slightly depressed between ilium and the caudal vertebrae = 1 points	Visible as a jutting bone; rump is a pronounced sunken zone between the ilium and caudal vertebrae = 0 points
6. Pelvic bone (external angle of the ilium) and rump (view from several angles)	Not visible (or slightly visible); rump region between the ilium and caudal vertebrae filled with tissue (and not forming a depressed zone) = 2 points	Visible but not pronounced; the rump is a slightly depressed zone between the ilium and the caudal vertebrae = 1 point	Visible as a jutting bone; rump is a pronounced sunken zone between ilium and the caudal vertebrae = 0 points

3.6 Nutritional value of food ingested

Faecal samples collected from each individual were placed in a dung drier for 24 hours to dry. The samples were placed in brown paper bags labelled with the elephant name (ID), elephant size and date. The dung samples were analysed in the laboratory at the Ministry of Agriculture, Water and Forestry to obtain the following: moisture, calcium, phosphate, ash, crude fibre, fat, acid detergent fibre (ADF) and neutral detergent fibre (NDF). The nutrition analysis was done according to the Feeds Analysis procedures by the Ministry of Agriculture, Water and Forestry.

3.7 Data Analysis

The body condition data that were collected over 2 years were analysed for normality using the Kolmogorov-Smirnov (K-S) test. Data were subjected to further statistical analysis using either parametric or non-parametric tests, based on the outcome of the K-S test. To test if there was a significant change in overall body condition of the population over two years, a Mann-Whitney U test was used as data were not normally distributed. To test whether there is a significant difference in body condition amongst three age classes, a Kruskal-Wallis test was used because the data were not normally distributed. Sets of Mann-Whitney U tests were conducted to determine where the difference was found.

Strongyle egg counts data collected over 2 years were tested for normality using the Kolmogorov-Smirnov test. Data were subjected to further statistical analysis using either parametric or non-parametric tests, based on the outcome of the K-S test. To test if there was a difference in strongyle parasite counts over the two years, a Mann-Whitney U test was used because the data were not normally distributed. To test if there was a significant difference between strongyle parasite counts amongst 3 age classes, the Kruskal-Wallis test was conducted. To test whether there was a significant correlation between strongyle egg counts

and elephant body condition, a Spearman's correlation test was used. The nutritional data were also tested for normality using the Kolmogorov-Smirnov test. To test whether there was a correlation between nutrition parameters and body condition, a multiple Spearman correlation was performed. The data were analysed using the SPSS statistical package version 17.0.

CHAPTER 4

RESULTS

This chapter presents the results of the elephant body condition in Etosha National Park. The findings include the analysis of strongyle parasite egg counts and nutrition quality of the elephant diet. The correlation analyses between body condition, nutritional value and strongyle parasite egg counts are presented.

4.1 Elephant body condition around Mushara waterhole

The data of elephant body condition collected over 2 years from 62 elephants bulls was not normally distributed ($df = 61$; $p = 0.003$; $D = 0.148$). The results show that half of the population sampled in 2012 had a body condition lower than 8.9 while the other half of the population had a body condition higher than 8.9, indicating that the overall body condition of elephants around Mushara is good (Table 3). In 2013 half of the population had a body condition score of less than 9.8 while the other half of the population had a body condition score of more than 9.8, also indicating that the overall body condition of elephants around Mushara is good (figure 9). In addition, the average body condition of elephants in Etosha National park in 2012 was 8.4, also indicating that the overall body condition of elephants around Mushara is good. In 2013 the overall body condition of the elephant population was 9.4, also indicating that in 2013 the overall body condition of elephants around Mushara was good, as per Table 3. There was a significant difference in the body condition of elephants during the years 2012 and 2013 ($U = 255.500$; $p = 0.002$).

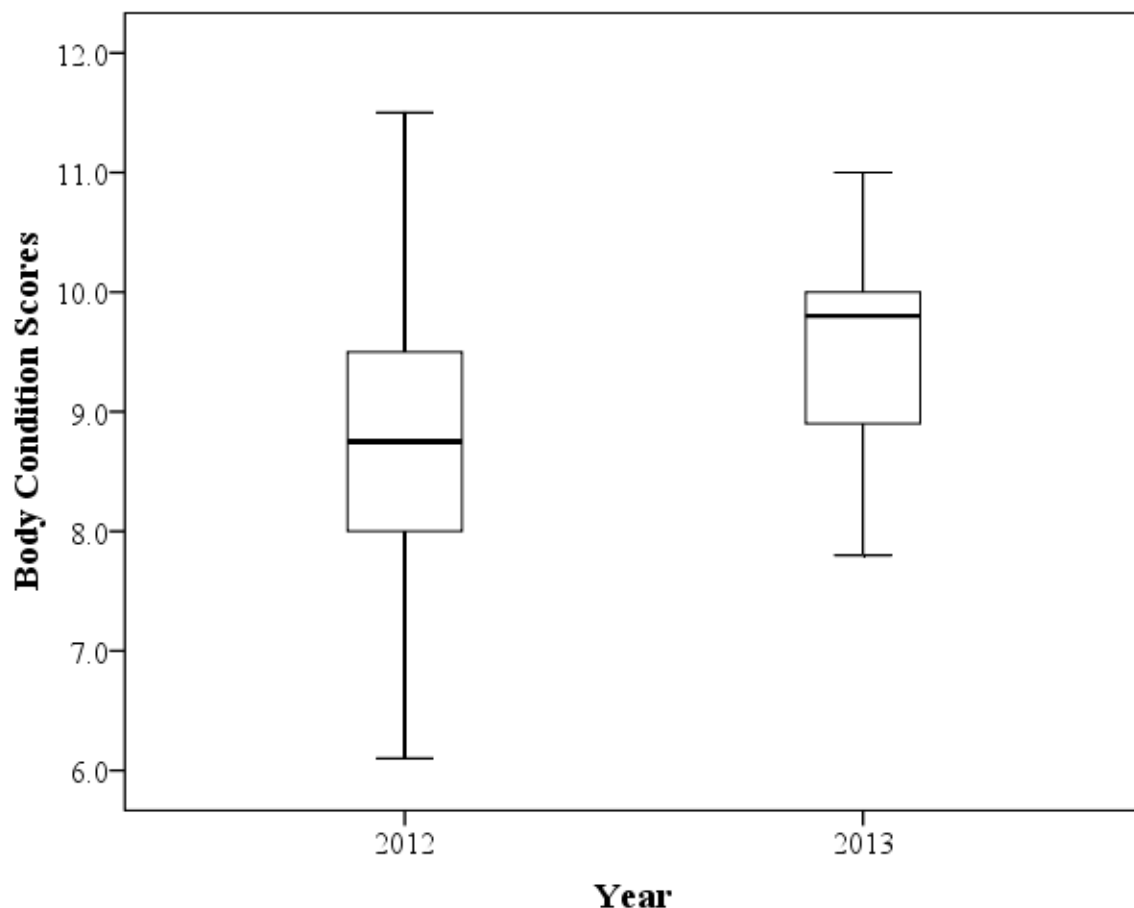


Figure 9: The median of elephant body condition scores during the years 2012 (N=32) and 2013 (N=30).

There was a significant difference in body condition found amongst different age classes from data collected over the 2 years (KW (Chi-Square)) = 13.88; df = 2; p = 0.001). The significant difference in body condition was found between full bulls and the quarter bulls (U = 87.50; p = 0.001). There was no significant difference in body condition between full bulls and three-quarter bulls (U = 144.00; p = 0.123). There was also a significant difference in body condition between three quarter and quarter bulls (U = 60.50; p = 0.010). Half of the Full bull class population had a body condition score less than 8.3 and the other half had a body condition score that was more than 8.3 (Figure 10). Figure 10 also shows that half of the population of Quarter bulls had a body score less than 10, while the other half had a body condition score of

more than 10. The average body condition of the half bull age class could not be determined because only two half size individuals were studied over 2 years. This is because only two half size bulls turned up at the waterhole during the study.

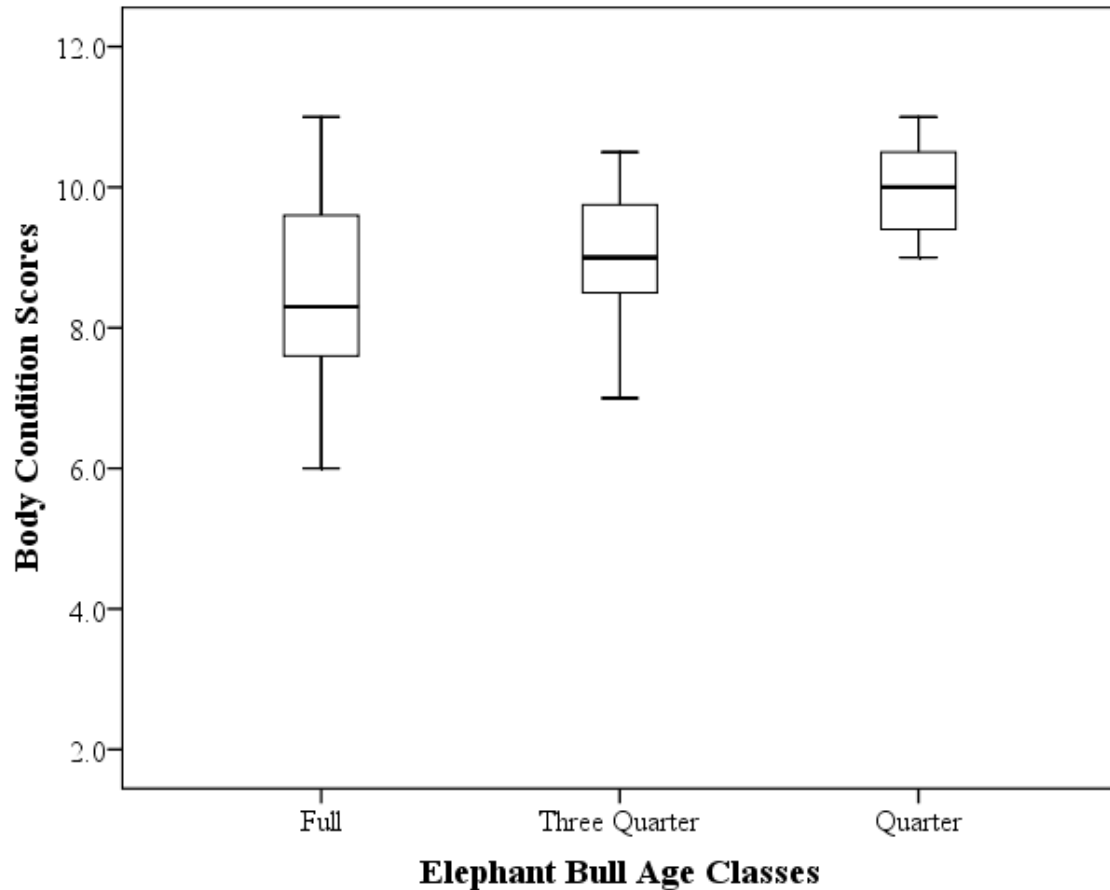


Figure 10: Median body condition of elephants found amongst age classes: full (N=27), three-quarter (N=15) and quarter (N=16) during 2012 and 2013.

4.2 Strongyle parasite egg counts in elephants around Mushara waterhole

The strongyle parasite egg counts data collected over 2 years were not normally distributed ($df=44$, $D = 0.177$, $p = 0.001$). In 2012 half of the elephant population had less than 1375 strongyle parasite eggs (EPG), while the other half had more than 1375 strongyle parasite eggs (EPG) (figure 11). Figure 11 also shows that in 2013, half of the population had less than 2138

strongyle parasite eggs (EPG), while the other half of the population had more than 2138 strongyle parasite eggs (EPG). The average strongyle parasite egg counts (EPG) found in elephants during 2012 was 1409 while on average 2204 EPG were found in the elephant population during 2013. There was a significant difference between the strongyle parasite egg counts in elephants during the years 2012 and 2013 ($U = 115.00$; $p = 0.001$). The strongyle egg counts found in elephants over two years varied from 0 - 5500 EPG.

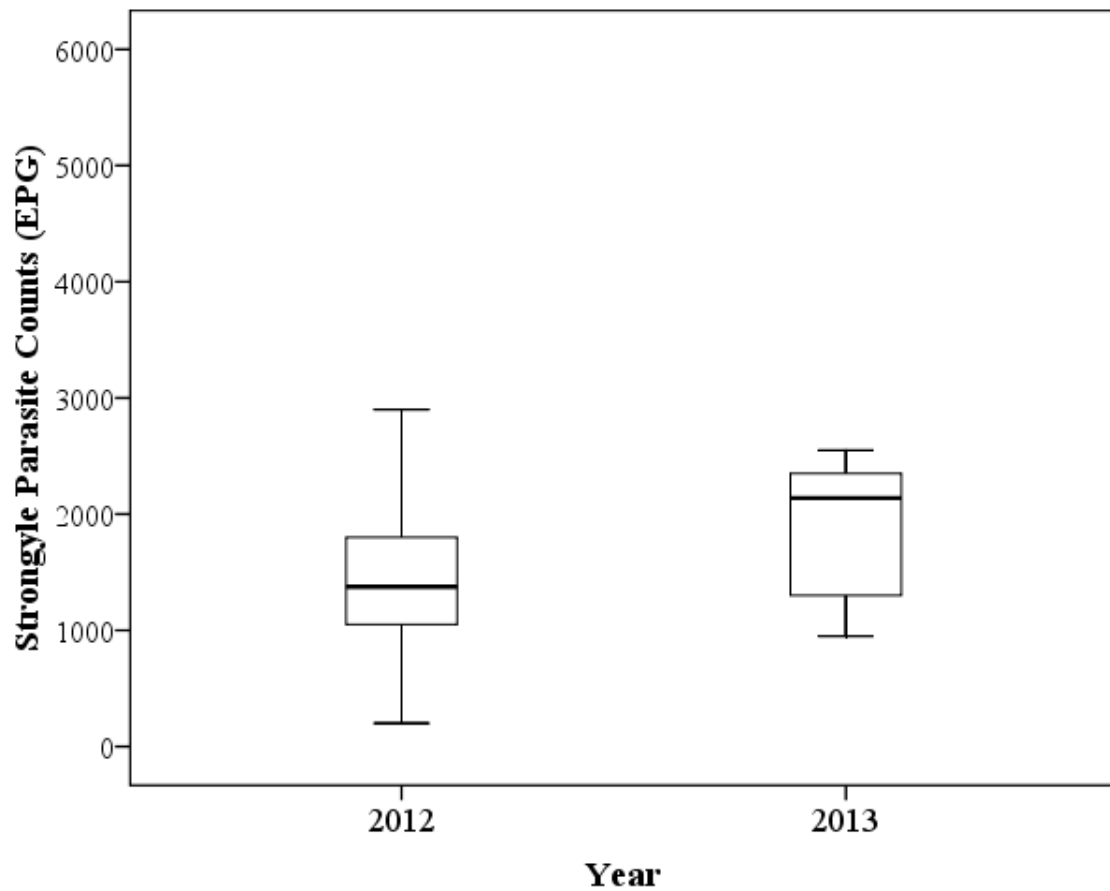


Figure 11: Strongyle parasite egg counts (EPG) found in elephants during 2012 (N=23, Median= 1375) and 2013 (N=21, Median= 2150).

The data for strongyle parasite egg counts amongst three age classes was not normally distributed ($df = 40$; $D = 0.191$; $p = 0.000$). There was no significant difference in strongyle parasite egg counts amongst different age classes from data collected over the 2 years (KW

(Chi-Square) = 3.870; $df = 2$; $p = 0.144$). Half of the full bull population that was studied over two years had strongyle parasite egg counts (EPG) that was less than 1512.5, while the other half of the population had strongyle parasite egg counts (EPG) above 1512.5 (figure 12).

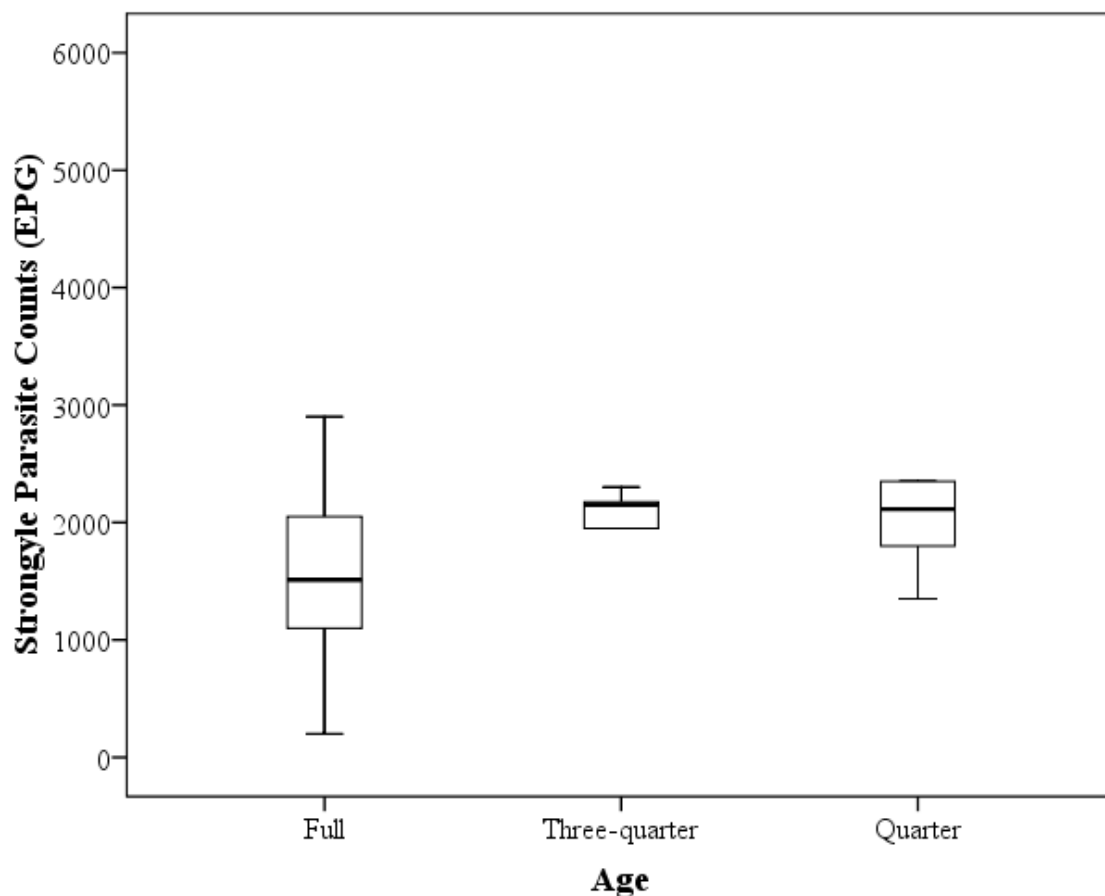


Figure 12: Strongyle parasite egg counts (EPG) found amongst age classes in 2012 and 2013. The data for the year 2012 and 2013 was combined.

Figure 13 shows the range and median of strongyle parasite counts found in each year within different age classes. For each age class the strongyle parasite counts were lower in 2012 than in 2013.

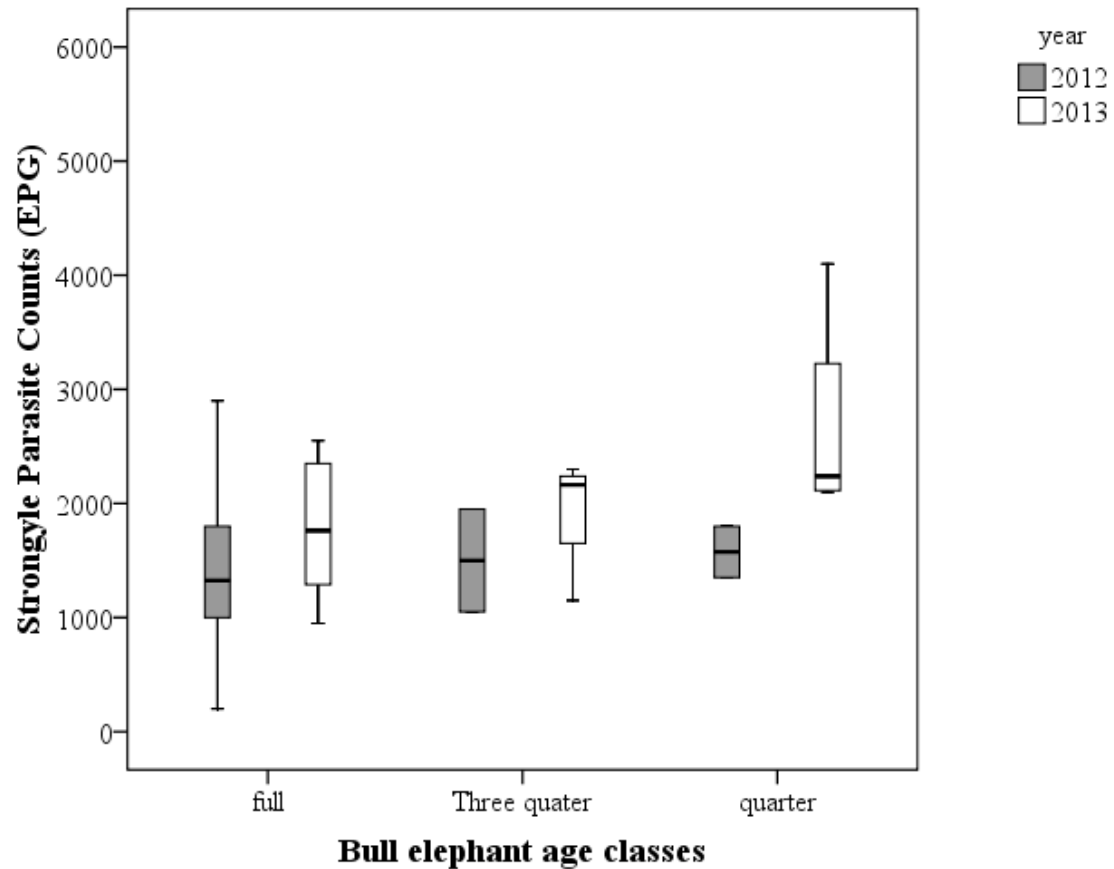


Figure 13: Range of strongyle parasite egg counts (EPG) found in amongst age classes during 2012 and 2013.

4.3 The relationship between strongyle parasite counts and elephant body condition

A Spearman's Correlation test revealed that there was no significant correlation between body condition and strongyle parasite egg counts ($r_s = 0.052$; $p = 0.748$) (figure 14).

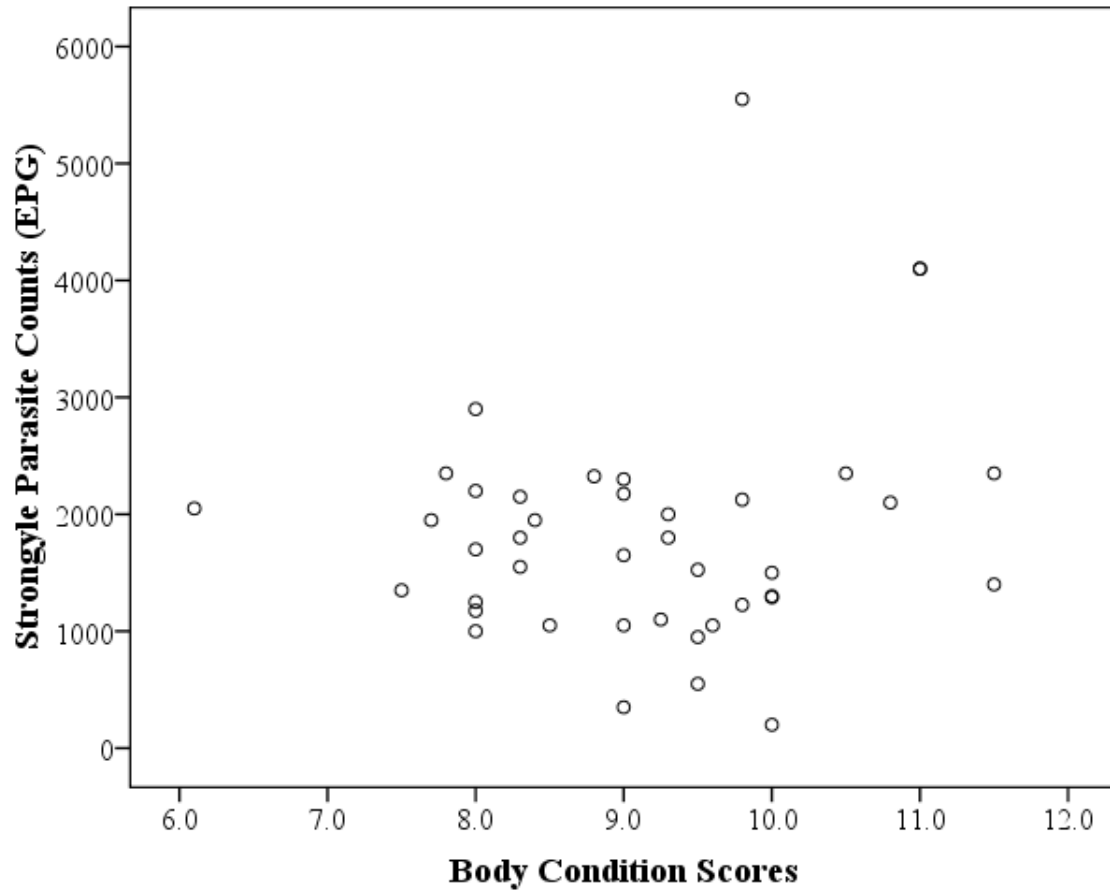


Figure 14: Illustrates the overall relationship between strongyle parasite egg counts and elephant body condition ($r_s = 0.052$, $N = 43$). The data collected over the two study years were lumped for this graph.

Since elephants in different age classes endure different social circumstance, correlation between strongyle parasite egg counts and elephant body condition has been tested within age class. There was a significant correlation found between the abundance of strongyle parasite eggs and elephant body condition in the quarter bull age class ($p = 0.042$; $r_s = 0.829$). However there was no significant correlation between strongyle parasite egg counts and body condition in the full and three-quarter age classes ($r_s = 1.00$; $p = 0.436$, $r_s = 1.00$; $p = 0.718$). Even though the latter r_s were equal to 1, the relationships were not stastically significant as all p-values were bigger than 0.05.

Figures 15, 16 and 17 indicate the relationships between strongyle parasite egg counts and body condition amongst different age groups.

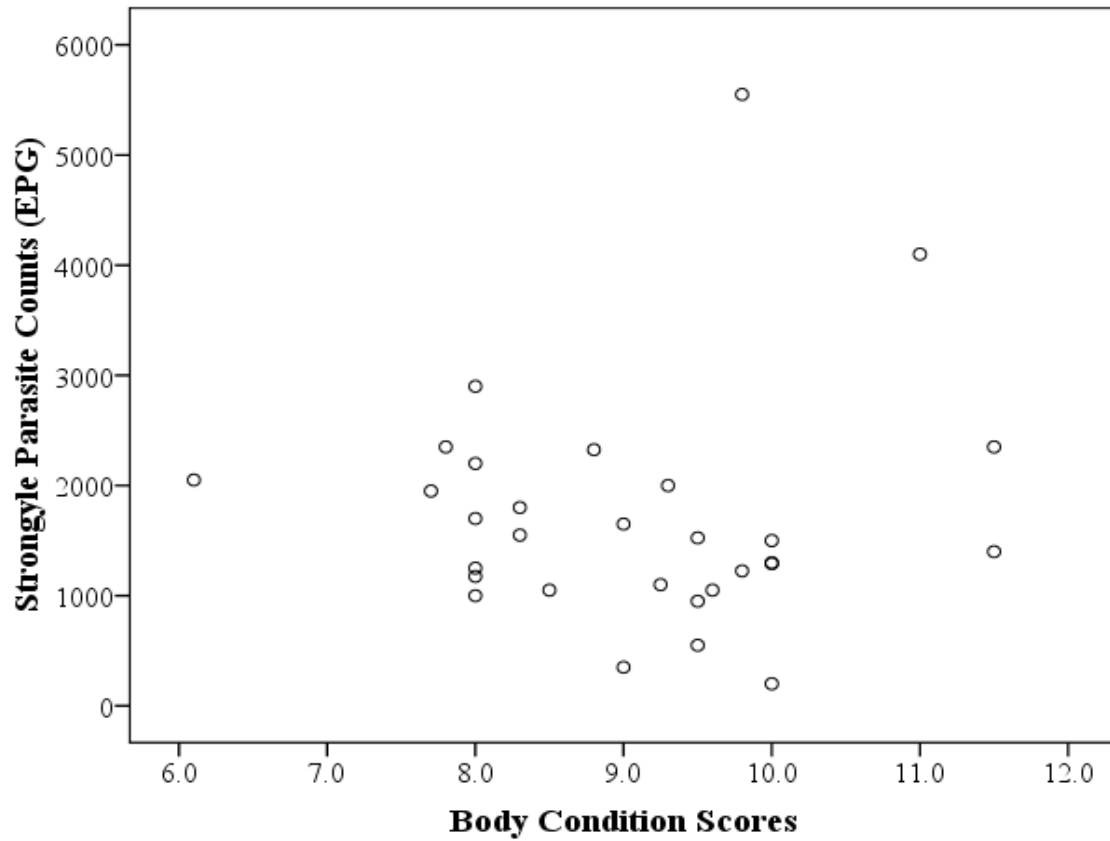


Figure 15: Relationship between strongyle parasite egg counts and body condition within Full bull age class.

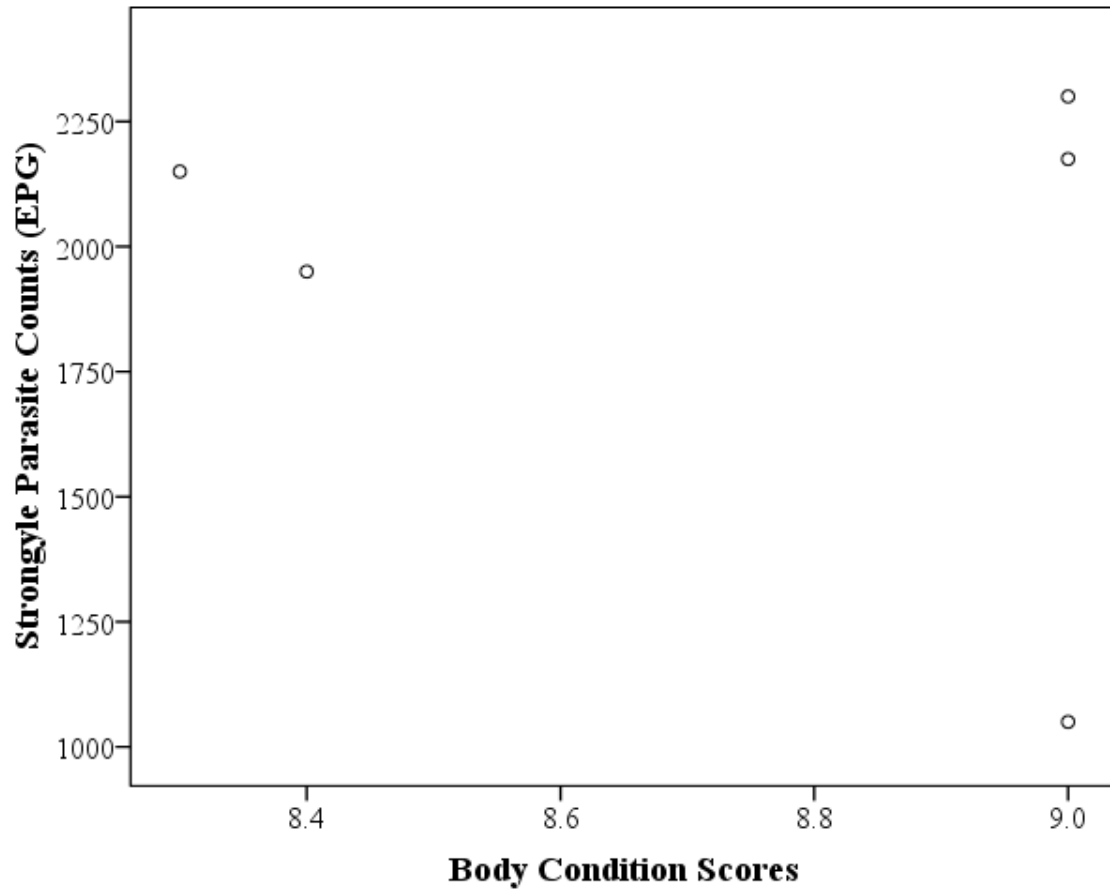


Figure 16: Relationship between strongyle parasite egg counts and body condition within Three-quarter bull age class.

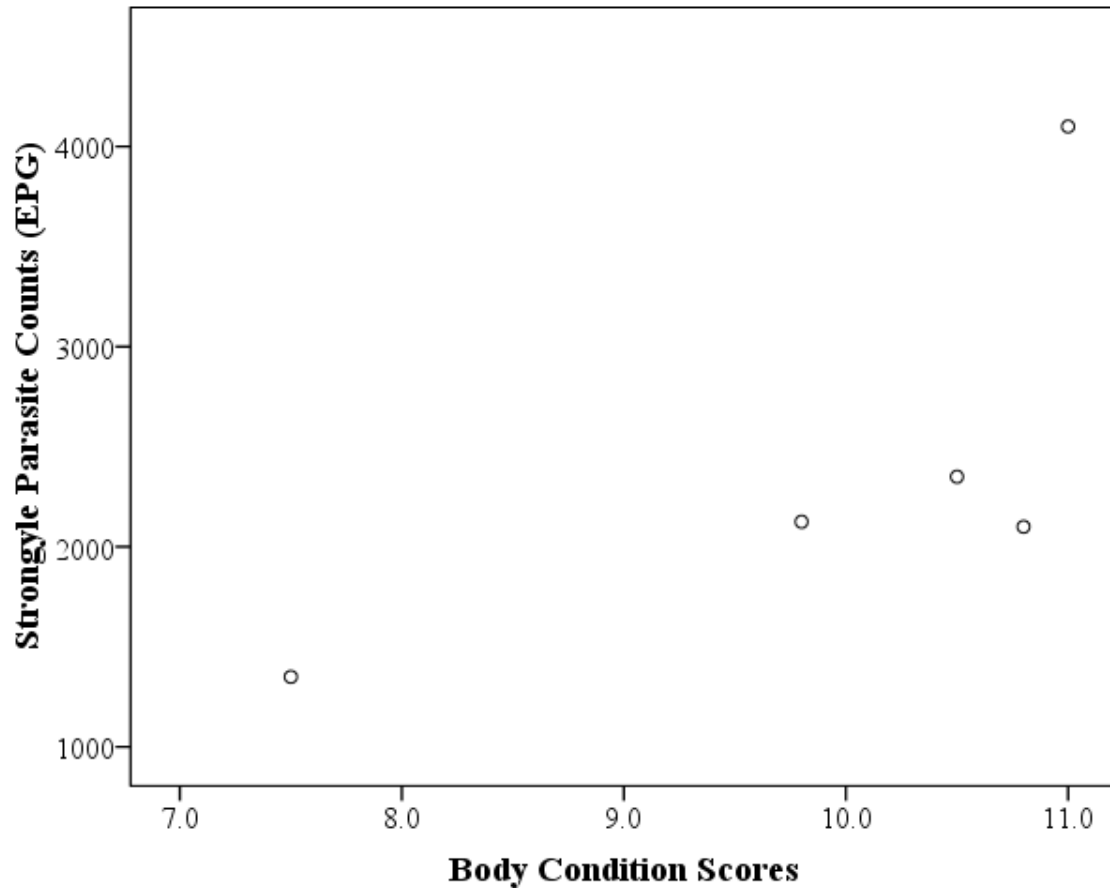


Figure 17: Relationship between strongyle parasite egg counts and body condition within Quater bull age class.

4.4 Nutrition value of elephant diet around Mushara waterhole

The nutrition data collected in 2012 were not normally distributed ($df= 624$; $D= 0.440$ $p = 0.001$). The elephant individuals that were analysed both for nutrition and body condition were 26. The study found that dung samples of 26 elephants consisted of 4.58% moisture, 6.5% ash, 1.9% fat, 0.171% phosphorus, 1.07% calcium, 51.21% crude fibre, 60.13% ADF and 66.08% NDF.

4.5 The relationship between nutrition value of elephant diet and body condition

After conducting a Spearman's Correlation test to determine if any of the nutrient parameters were correlated to body condition, there was no significant correlation found between any of the nutrient parameters to body condition (body condition and moist, $p = 0.328$, $r_s = -0.200$; body condition and ash, $p = 0.540$; $r_s = 0.126$; body condition and fat, $p = 0.77$, $r_s = -0.058$; body condition and phosphorus, $p = 0.710$, $r_s = -0.077$; body condition and calcium, $p = 0.840$, $r_s = 0.042$; body condition crude fibre, $p = 0.188$, $r_s = -0.266$; body condition and ADF, $p = 0.354$, $r_s = 0.016$). The relationship between the nutrient parameters and body condition are indicated in Figure 18.

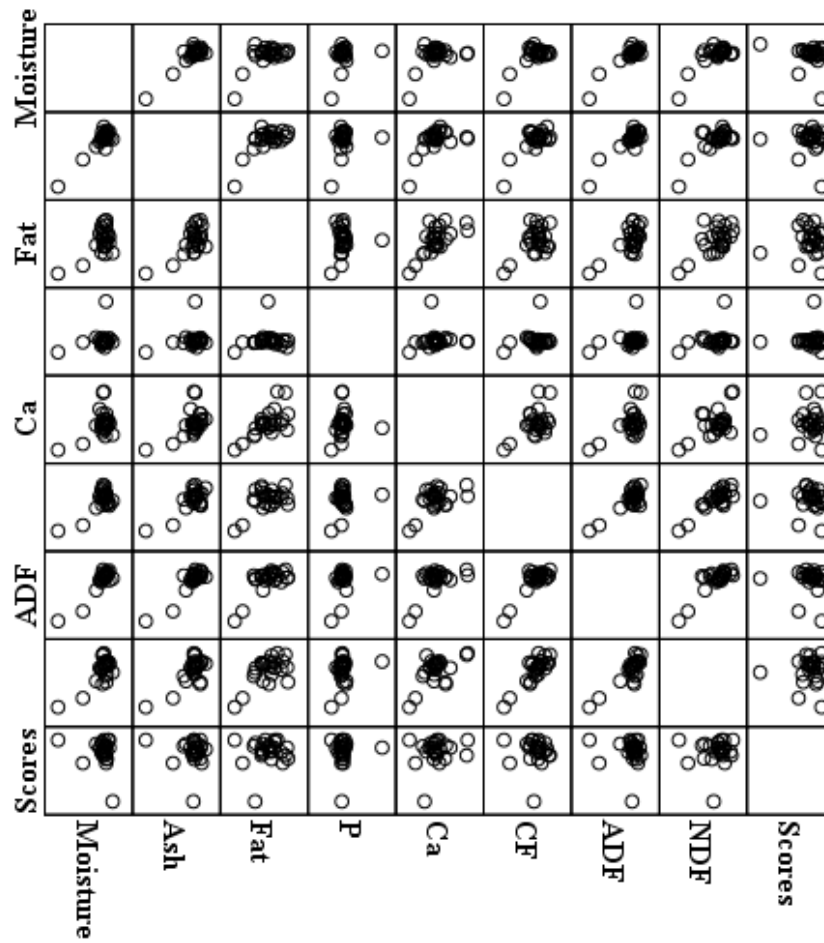


Figure 18: Matrix scatter plot indicating the correlation analyses between nutrient parameters and elephant body condition scores; the graph shows no correlation between any of the nutrients to elephant body condition.

CHAPTER 5

DISCUSSION

5.1 Elephant body condition at Mushara waterhole in Etosha National Park

It was hypothesized that the overall body condition of elephants in Etosha National Park is poor. This hypothesis was based on the finding of the study conducted by Thurber et al. (2011) who reported that the elephant population at Mushara waterhole has high loads of gastrointestinal parasites, in particular strongyles. The hypothesis was based on the assumption that the body condition of ruminants can change in response to seasonal change and parasite infections (Turner et al., 2012).

The present study found that the body condition of the elephants at Mushara waterhole was good (8.4/12 in 2012 and 9.4/12 in 2013). This study found that there was a significant change in body condition during the 2 year study period. The body condition was significantly lower in 2012 a year after a dry year (2011) in Namibia, despite the fact that rainfall was higher in 2012 than 2013. This might be because in an open system, elephant populations respond to factors such as increased density and food limitation more slowly (Chamaille-Jammes et al., 2008). Hence, the elephant body conditions might have been recovering from a dry year in 2012. de Klerk (2009) stated that decline in body condition is associated with a decline in the level of maintenance requirements in elephants. Hence there might have been a significant difference in the level of maintenance requirements during the two years to affect body condition.

According to Turner et al. (2012) the body condition may not only be affected by parasite loads, but also by changes within the energy requirements, foraging patterns and resources availability. Many of these factors are rainfall dependent and despite low rainfalls in Etosha National park over 2012 and 2013 that was 555 mm and 390 mm, respectively, the body

condition of the elephants was still good. This might be because it takes a significant decrease in rainfall to affect the availability of food resources (de Klerk, 2009).

The body condition of elephants can also be affected by other diseases such as “Anthrax” which according to Dragon and Rennie (1995) is a deadly disease of global importance that mainly affects herbivorous wildlife and livestock, especially grazing mammals. Anthrax is common within Etosha National Park and is seen as one of the population stabilizers within the park (Lindeque, 1991). Anthrax outbreaks are highest in elephants during the dry season and mostly occur to the west of Okaukuejo (Lindeque and Turnbull, 1994). This may explain the good body condition that was found within the elephants at Mushara, which is in the eastern part of the park. Despite the fact that this study was carried out during the dry season in which Anthrax is most prominent in elephants the body condition of the elephants is still good.

There was a significant difference in body condition found within the full bull and quarter bull age class. The quarter bulls had a significantly better body condition than the full bulls. Turner et al. (2012) stated that body condition in animals might also be affected by age. Thus, old age corresponds to poor body condition and this might be the reason why there was a significant difference between full bulls (oldest age class) and quarter bulls (youngest age class). Turner et al. (2012) found that body condition in springboks decreased with age. This explanation can be applied to why the three- quarter bulls had a significantly higher body condition than full bulls.

5.2 Strongyle parasite egg counts within the elephant population at Mushara in Etosha National Park

This study found a significant difference in strongyle parasite egg counts within the elephant population in 2012 and 2013. This might be because of the change in the amount of rainfall received in the park over the two years (2012, 555 mm; 2013, 390 mm). The change in rainfall

over the two years affect the amount of vegetation required by parasites to succeed (Turner, et al., 2012). There was however no significant difference in the strongyle parasite egg counts found amongst different age classes. The reason for the latter finding might be because the elephants share the same resources e.g. waterhole and are faced with the same environmental factors in the same area. Hence the chances of picking up parasites are equal despite age. Thurber et al. (2011) found a significant difference in strongyle parasite egg counts in different age classes, which is contrary to this study's findings. Thurber et al. (2011) found that the parasite eggs loads in elephant bulls decreased with increase in age in bulls. Poole (1999) stated that older bulls are more dominant and may have access to good quality resources (containing less parasites) and therefore causing the older bulls to have less strongyle parasite eggs compared to the younger bulls. The latter was the explanation given by Thurber et al. (2011).

The second aim of the present study was to determine if there was a significant correlation between strongyle parasite egg counts and body condition of the elephants. It was hypothesized that a significant negative correlation between strongyle parasite egg counts and elephant body condition will be found in this study. This hypothesis was based on the assumption that these gastrointestinal parasites compete with the elephant for the food within the elephant gut (Thurber et al., 2011; Fowler et al., 2006).

The present study found that there was no significant correlation between strongyle parasite egg counts and the body condition of elephants. Even though it is a fact that parasites are harmful to animals, the effects of the strongyle parasites on elephants are not specifically known. The fact that this study did not find any correlation between body condition and strongyle parasite egg counts might be because there is a symbiotic mutualism relationship between the strongyle parasites and elephants. A symbiotic relationship would mean that the strongyle parasites are not harmful to elephants, hence not affecting their body condition in a

negative way as hypothesized. This possibility needs to be investigated further in another study. An example of a symbiotic parasite-host relationship is that between the termites and their intestinal protozoa. Because termites have no enzymes to digest cellulose from wood, the protozoa digests the cellulose that benefit both the termites. The elephants have the symbiotic relationship with their intestinal protozoa as termites, the prozoa also assist the elephants to digest their food (Oslen, 1974).

According to Fowler and Mikota (2006), elephants have a low digesting efficiency hence this might prevent the parasites from affecting the elephant because there might be plenty of food for both the elephant and the parasites, explaining why there is no correlation between strongyle parasite egg counts and body condition. This possibility also needs to be investigated further. Another potential and most likely reason might be that parasite loads in the elephant gut might not be large enough to affect its body condition. The elephant's response to factors such as low food availability and parasites infection is slow and only bad cases of infection might reflect on body condition (Chamaillé-Jammes, 2008). Fowler and Mikota (2006) stated that the effects of parasite on the elephant would also depend on the immune system of the elephant. Strong immune systems can oppress the progress of the parasites and may explain why the strongyle parasite counts do not correlate to the body condition. Thus, elephants' immune systems are good and hence oppressing the parasite's progress (Fowler and Mikota, 2006).

When looking at individual age classes and not at the population, there was a significant correlation found between the abundance of strongyle parasites egg counts and elephant body condition in the quarter bull age class ($p = 0.042$; $r_s = 0.829$). This might explain that strongyle parasites might have a symbiotic relationship with elephants as the correlation is positive. Also because the quarter bulls are the youngest, they might not have developed an optimum system to digest their food, explaining why they might need strongyles within their gut to help with digestion as compared to the older age groups.

5.3 Nutrition Value of elephant diet around Mushara in Etosha National Park and how it correlates to elephant body condition

The third aim of the present study was to determine the nutritional value of elephant forage around Mushara waterhole. The nutritional parameters investigated in the present study were moisture, calcium, phosphate, ash, crude fibre, fat, ADF and NDF.

Fowler and Mikota (2006) reported that when taking into consideration the unique physiologies in elephants and until controlled experiments are conducted to determine actual requirements, minimum nutritional requirements for elephants are still based on extrapolation from dietary guidelines of domestic horses (Tables 1). Also nutritional requirements in elephants will differ during life stages e.g. during growth, during pregnancy (Fowler and Mikota, 2006). Calcium is a nutrient that plays a major role in bone and teeth formation coupled with vitamin D and Phosphorus (Rode et al., 2006). The recommended minimum requirements for elephants are 0.3-0.7% (Fowler and Mikota, 2006). In this study 1.07% of the Calcium was found in the diet of elephants, which is above the minimum requirements. In Zimbabwe's Wankie National Park, Calcium levels found were 0.35-2.47% which is higher than the recommended Calcium minimum requirements for elephants (Fowler and Mikota, 2006). The possible explanation for this can be that the levels of Calcium in Zimbabwe, Wankie National Park are higher in the soil in comparison to Etosha National Park. However in a study by Rode et al., (2006), it was stated that the minimum requirements of elephant Calcium as 1.5%.

Phosphorus a nutrient that plays a major role in formation of teeth and bones is also essential in the transfer and utilization of energy. The elephant diet analysed in this study contained 0.171 % of Phosphorus. The requirements for Phosphorus for elephants range from 0.20-0.40% (Fowler and Mikota, 2006). Hence the levels of Phosphorus found within the elephant diet in Etosha National Park fall within the minimum requirements compared to the required amount

stated by Fowler and Mikota (2006). According to Fowler and Mikota (2006) 0.11-0.33% of phosphorus was found in elephant diet in Zimbabwe's Wankie National Park, further backing that the phosphorus levels found in Etosha meet the minimum requirements.

Another essential component of the elephant nutrition is the fat content within the diet. The fatty acids are also important for the overall growth and function of animals. This study found the diet in Etosha National Park to contain 1.9% of fat on average. Research on fatty acid requirements for elephants is limited and hence minimum requirements seems to be missing. However in a study that was conducted on Asian elephants found 1.2-1.8% fat (Sukumar, 1989). According to Fowler and Mikota (2006), 1.2 - 1.8% of fatty acids was found in the elephant diet in Murchison Falls National Park in Uganda. Hence comparing these amounts to the fat levels found in the diet in Etosha National Park, the fat content is within the requirements. Crude fibre represents the organic fraction of plant cell walls that is not digested by mammalian enzymes. However the fibre is digested by the protozoa within the elephant gut and the elephant benefits from this (Ullrey et al., 1997). The amount of fibre reaching the lower gut of the elephant influences the way fermentation takes place, and may affect the rate at which fermentation products are produced and absorbed, and the rate at which undigested products are excreted (Ullrey et al., 1997). Lower fibre concentration in elephant diet can have significant effects on diet digestibility (Rode et al., 2006). According to Fowler et al. (2006), Crude fibre in African elephants was found to range between 13-62%, in the Kasungu National Park, Malawi. This study found 51.21% in the elephant diet within Etosha National Park, which falls within the range discovered in elephant diet elsewhere in Africa as indicated by Fowler et al. (2006).

According to Ullrey et al. (1997) this analytical system has been used to characterize fibre concentrations in plants consumed by African elephants in a private game reserve bordering the Kruger National Park in South Africa, and averages of 62% NDF, 48% ADF were found.

This study found 60.13% ADF and 66.08% NDF in the elephant diet within Etosha National Park. Rode et al., (2006) reported that the minimum requirements for the ADF within elephant diets are 10-12%, and the ADF contents found in the Kibale National Park, Uganda was 32.4% on average. The difference in fibre concentrations within the elephant diet might be caused by a difference in forage (de Klerk, 2009). Hence even though the nutrient parameters above fall within the minimum requirements, the ADF is high meaning, the digestive rate is low.

The moisture content indicates how much water is in the diet. Moisture in a diet is used as a solvent for other nutrients and used in the animal bodies during respiration and other vital biological process (Ullrey et al., 1997). The minimum levels of moisture required in elephant diet is not set and also not well investigated. However this study found an average moisture content in the elephant diet to be 4.58%.

The Ash content in the diet indicates the total amount of minerals present in the diet, even though minimum requirements not set for elephants, a study conducted by Borah and Deka (2008) on the diet of Asian elephants found 4.5 and 16.64% of total ash. This study found 6.51% of Ash which falls within the findings of Borah and Deka (2008).

One of the many factors that affect body condition is the quality of the food resources (Fowler et. al, 2006; Rode et al., 2006; Turner et al., 2012). Hence the present study hypothesized the nutrition value of the elephant feed to have a positive correlation to the body condition of the elephants.

The present study found that there was no significant correlation between body condition and all the nutrition parameters. Meaning that body condition of elephants is not affected by any of the nutritional factors analysed in this study. Van Soest (1994) indicated that good body condition in animals heavily depend on the good quality of food, meaning that there is a positive correlation which contradicts this study's findings. The nutrition parameters

investigated in this study might not be enough to see correlation between the two variables and body condition. There might be other factors such as stress and diseases that need to be investigated to indicate a correlation between nutrition parameters and body condition.

There is a need for more studies to investigate the nutrition needs of the African elephants in order to gain a better understanding on the nutrition and diet of African elephants.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The African elephant is a keystone species and contributes greatly to the integrity of our ecosystems. The African elephant's survival is threatened by many factors including habitat reduction and poaching. In order to fully understand factors that influence the elephant body condition, one first needs to have baseline data to allow for future monitoring in order to detect possible changes.

This study determined the status of body condition of the elephants in Etosha National Park and has also applied a body measuring index that can be adopted to determine body condition of elephants and other animals elsewhere. The study hence provided crucial information regarding the well-being of elephants in the eastern part of Etosha National Park. Many studies have found that parasites negatively affect the body condition of their hosts, this study therefore investigated the correlation between strongyle parasites egg counts and body condition in elephants.

One of the major findings of this study was that no correlation between strongyle parasites egg counts and body condition was found. This means elephant body condition is not significantly affected by the strongyle parasites egg counts in the elephant population in the eastern part of Etosha National Park.

The study also determined the nutrition value of the elephant feed within the park and found that the nutrient parameters analysed (moisture, ash, fat, P, CF, Ca, ADF, NDF) meet the minimum requirements for elephants. That means the elephant forage in the eastern part of Etosha National Park meet basic requirements of the nutrition parameters analysed. No correlation between nutrition value and body condition was found and this may be because many more factors such as stress need to be investigated. This means that body condition is not

associated with the nutritional parameters analysed in this study and hence more nutrition parameters e.g proteins and carbohydrates might need to be incorporated in order to see change in body condition.

6.2 Recommendations for future research

The strongyle parasites in Etosha National Park are known only to their genus levels, a future study can classify these strongyle parasites to their species level, which might aid to the understanding of their biology. The threshold of strongyle parasites that is detrimental to the elephant body condition is unknown and needs to be assessed. Future studies can also determine the relationship between strongyle parasites and egg counts. To have a better understanding on how and what diet elements affect the body condition of elephants, more studies involving more nutrient parameters (such as proteins, carbohydrates) need to be conducted. Cortisol is an important stress hormone that can give good indication of the stress levels of elephants; hence further studies can determine whether cortisol levels affect body condition in elephants. Nutrition value is affected by the different seasons, therefore future studies can determine nutrition value of elephant diet in different seasons.

REFERENCES

- Albl, P. and Giessen, V. (1971). Studies on assessment of physical condition in African elephants, *Biological Conservation*, 3, (2), pp 134-140.
- Banerjee, P.S., Rajat, G., Yadav, C.G., and Hira, R. (2006). Parasitic infections in some wild animals of Uttaranchal. *Indian Journal of Animal Sciences*, 4(5), 112-116.
- Berry, H. H. and Louw, G.N. (1982). Seasonal nutritive status of the wildbeast in Etosha National Park, *Madoqua*, 13, pp 127- 139.
- Blanc, J. J., Barnes, R. F. W., Craig, G. C., Douglas-Hamilton, I., Dublin, H., Hart, J. A., and Thouless, C. R. (2005). Changes in elephant numbers in major savanna populations in eastern and southern Africa, *Pachyderm*, 38, pp19-28.
- Borah, J. and Deka, K. (2008). Nutritional Evaluation of Forage Preferred by Wild Elephants in the Rani Range Forest, Assam, India, *Gajaha*, 28, pp41-43.
- Bowman, D., Lynn, R., Ederhard, M. and Alcaraz, A. (2003). *Georgi's parasitology for veterinarians*, Elsevier Health Science, St. Louis, Missouri, pp351.
- Boxell, A.C., Gibson, K.T., Hobbs, R.P. and Thompson, R.C.A. (2004). Occurrence of gastrointestinal parasites in horses in metropolitan Perth, Western Australia. *Australian Veterinary Journal*, 82 (1), 91-95.
- Ceballos, G. and Ehrlich, P.R. (2009). Discoveries of the new mammal species and their implications for conservation and ecosystem services. *Mammals 2nd Edition*, Longman, London. pp 226-237.
- Chamailé-Jammes, S., Fritz, H., Valeix, M., Murindagomo, F. and Clobert, J. (2008). Resource variability, aggregation and direct density dependence in an open context: the local regulation of an African elephant population. *Journal of Animal Ecology*, 77, 135-144.

- Cloete, C. (2013). *Influence of site and soil type on the distribution of anthrax infectious sites and the contribution of anthrax to elephant mortality in Etosha National Park, Namibia*. Unpublished Master's thesis, University of Namibia.
- de Klerk, C (2009). *Detecting changes in elephant body condition in relation to resource quality*. Unpublished Master's thesis, Faculty of Science, Nelson Mandela Metropolitan University, pp 7-11.
- Dragon, D.C. and Rennie, R.P. (1995). The ecology of anthrax spores: Tough but not invincible. *Canadian Veterinary Journal*, 36(5), pp 295-301.
- du Plessis, W.P. (2001). Effective rainfall defined using measurements of grass growth in the Etosha National Park, Namibia. *Journal of Arid Environments*,(48), pp 397–417.
- Fernando, P., Janaka, H.K., Ekanayaka, S.K., Nishantha, H.G. and Pastorini, J. (2009). A simple method for assessing elephant body condition, *Gajah*,31, pp 29-31.
- Freeman, A.S., Kinsella, J.M., Cipolletta, C., Deem S.L. and Karesh, W.B. (2004). Endoparasites of Western lowland gorillas (*Gorilla gorilla gorilla*) at Bai Hokou, Central African Republic, *Journal of Wildlife Diseases*, 40, (4), pp 775-781.
- Fowler, M.E and Mikota, S. K. (2006). *Biology, Medicine, and Surgery of Elephants*. Wiley-Blackwell, pp 159- 186.
- Gasser, R.B., Stewart, L.E., and Speare, R. (1996). Genetic markers in ribosomal DNA for hookworm identification, *Acta Tropica*, 62, (1), pp15-21.
- Haasbroek, J. (2008). Is Namibia killing the golden elephants? *Elephant Human Relations Aid*, 23 (5), pp 246-251.
- Halmiton, K. and Desmond, J. (2003). Survey of important parasitic and infectious diseases shared by elephants and livestock in Dimbangombe, Zimbabwe, Tufts University School of Veterinary Medicine (TUSVM).
- Hile, M.E., Hintz, H. F., and Erb, H. N. (1997). Predicting body weight from body

- measurements (*Elephas maximus*), *Journal of Zoo and Wildlife Medicine*, 28, (4), pp 424- 427.
- Hollister-Smith, J. A., Poole, J. H., Archie, E. A and Vance, E.A. (2007). Age, musth and paternity success in wild male African elephants, *Loxodonta african*, *Animal Behaviour*, 74, pp 287-296.
- Holmstad, P. R., Hudson, P.J, Skorpung, A., Benton, T. (2005). The influence of a parasite community on the dynamics of the host population: A longitudinal study on Willow Ptarmigan and their parasites, *Oikos*, 111, (2), pp 377-391.
- Kinsella, M.J., Deem, S. L., Blake, S., Freeman, A.S. (2004). Endoparasites of African forest elephants (*Loxodonta African cyclotis*) from the republic of Congo and Central African Republic, *Comparative Parasitology*, 71, (2), pp 104-110.
- Laws, R. M. (1966). Age criteria for the African elephant, *Loxodonta africana*. *East African Wildlife Journal*, 4, pp1–35.
- Leslie Jr., D.M. and Starkey, E.E. (1985). Fecal indices to dietary quality of cervids in old-growth forests. *Journal of Wildlife Management*, 49(1), pp 142-146.
- Lindeque P.M. (1991). *Factors affecting the incidence of anthrax in the Etosha National Park, Namibia*. Unpublished master's thesis, Centre for Applied Microbiology and Research, Porton Down, Salisbury, United Kingdom.
- Lindeque, P.M. and Turnbull, P.C. (1994). Ecology and epidemiology of anthrax in the Etosha National Park, Namibia. *Onderstepoort Journal of Veterinary Research*, 61(1), 71-83.
- McCullagh, K. (1967). The growth and Nutrition of the African Elephant II: The chemical nature of the diet. *African Journal of Ecology*, 7 (1), 91-97.
- Mclean, E.R., Kinsella, J.M., and Chiyo, P. (2012). Genetic identification of five strongyle nematode parasites in wild African elephants (*Loxodonta africana*), *Journal of Wildlife Diseases*, 48 (3), pp 707-716.

- Ministry of Environment and Tourism. (2012). *Directorate of Parks and Wildlife Management Annual Report*. Windhoek: Ministry of Environment and Tourism.
- Moir, K. (1966). Diagnosis of phosphorus deficiency in grazing cattle. *Queensland Journal of Agriculture and Animal Science*, 23, pp 97-100.
- Oslen, O.W. (1974). *Animals Parasites: Their life cycles and ecology*. University Park press, pp 1-5.
- Poole, J. H. (1989). Signals and assessment in African elephants: Evidence from playback experiments, *Animal Behavior*, 58, pp185–193.
- Ramesh, T., Sankar, K. Qureshi, Q. and Kalle, R. (2011). Assessment of wild Asiatic elephants (*Elephas maximus indicus*) body condition by simple scoring method in a Tropical Deciduous Forest of Western Ghats, Southern India, *Wildlife Biology*, 7 (2), pp47-54.
- Rees, P.A. (1982). Gross assimilation efficiency and food passage time in the African elephant. *African Journal of Ecology*, 20, pp193-198.
- Riney, T. 1982. *Study and Management of large mammals*. John Wiley and Sons, Chichester, New York, USA, pp 502- 552.
- Robbins, C.T. (1983). *Wildlife feeding and nutrition*. Academic Press Inc, New York, pp 6-10.
- Robinson, P.H. (1999). Neutral Detergent Fiber (NDF) and its role in Alfalfa analysis. Cooperative extension, University of California, Davis.
- Rode, K. D., Chiyo, P. I. Chapman, C. A. and McDowell, L. R. (2006). Nutritional ecology of elephants in Kibale National Park, Uganda, and its relationship with crop-raiding behavior, *Journal of Tropical Ecology*, 22, pp 441-449.
- Sassendran, P.C., Rajendran, S., Subramanian, H., Sasikumar, M., Vivek, G., and Anil, K.S.

- (2004). Incidence of helminthic infection among annually dewormed captive elephants. *Zoo's Print Journal*, 19(3), 1422.
- Schulte-Hostedde, A.I., Millar, J.S., Hickling, G.J. (2001). Evaluating body condition in small mammals. *Canadian Journal of Zoology*, 79, (6), pp 868-874.
- Shokoofeh, S., Norman, R., Gasser, R., and Beveridge, I. (2009). Genetic and morphological evidences for the existence of sibling species within *Cotracacaecum rudolphii* (Hartwich, 1964) (Nematoda: Anisakidea) in Australia, *Parasitology Research*, 105, (2), pp 529-538.
- Sukumar, R. (2003). *The Living Elephants: Evolutionary Ecology, Behavior and Conservation*. Oxford University Press, New York.
- Sukumar, R. (1989) *The Asian Elephant*. Cambridge University Press, Cambridge, UK.
- Suresh, K. (2000). Epidemiological and clinic- therapeutic studies of Strongylosis in elephants. *Zoo's Print Journal*, 16(7), 539-540.
- Tennant, C.J., Spitzer, J. C., Bridges, J. and Hampton, J. H. (2002). Weight necessary to change body condition scores in Angus cows, *Journal of Animal Science*, 80, pp 2031- 2035.
- Thurber, M.I., O'Connell-Rodwell, C.E., Turner, W.C., Nambandi, K., Kinzley, C., Rodwell, T.C., Faulkner, C.T., Felt, S.A and Bouley, D.M. (2011). Effects of rainfall, host demography, and musth on strongyle fecal egg counts in African elephants (*Loxodonta africana*) in Namibia, *Journal of Wildlife Diseases*, 48, (3), pp 707-716.
- Turner, W.C. and Getz, W.M. (2010). Seasonal and demographic factors influencing gastrointestinal parasitism in ungulates of Etosha National Park, *Journal of Wildlife Diseases*, 46 (4), pp 1108-1119.
- Turner, W. C., Versfeld, W. D., Kilian, J.W. and Getz, W. M. (2012). Synergistic effects of seasonal rainfall, parasites and demography on fluctuations in springbok body condition, *Journal of Animal Ecology*, 81, (1), pp58-69.

- Ullrey, D.E., Crissey, S.D. and Hintz, H.F. (1997). Elephants: nutrition and dietary husbandry. *Nutrition Advisory Group Handbook 4*, pp 1-15.
- Utopia Scientific. (2012). Mushara elephant bull identification book, Etosha National Park, Namibia.
- van Soest, P .J. (1994). Nutritional Ecology of the Ruminant. Cornell University Press, New York, pp.
- van Aarde, R. J.and Jackson,T. P. 2007. Megaparks for metapopulations: addressing the causes of locally high elephant numbers in southern Africa. *Biological Conservation*, 134, pp 289-297.
- Vidya, T.N.C. and Sukumar, R. (2002). The effect of some ecological factors on the intestinal parasite loads of the Asian elephant (*Elephas maximus*) in southern India. *Journal of Biosciences*, 27, (5) pp 521-528.
- Viljoen, P. (2008). Habitat selection and preferred food plants of a desert dwelling elephant population in the Northern Namib Desert, Namibia. *African Journal of Ecology*, 27 (3), 227-240.
- Wemmer, C., Krishnamurthy, V., Shrestha, S., Hayek, L.A., Thant, M., and Nanjappa, K. A. (2006). Assessment of body condition in Asian elephants (*Elephas maximus*), *Zoo Biology*, 25, pp187-200.
- Western, D., C. Moss, and Georgiadis, N. (1983). Age estimation and population age structure of elephants from footprint dimensions. *Journal of Wildlife Management*, 47, pp 1192–1197.

Appendices

Appendix 1: Elephant dung collection



Appendix 2: Microscopic analysis of strongyle parasite egg counts



Appendix 3: Research camp from which the elephant body condition was determined



Appendix 4: Correlation test results between strongyle parasite counts within each age group

Kruskal-Wallis Test

Ranks			
	Age	N	Mean Rank
Strongyle Parasite Count	Full	30	18.50
	Three-quarter	5	24.30
	Quarter	5	28.70
	Total	40	

Test Statistics^{a,b}

	Strongyle Parasite Count
Chi-Square	3.870
df	2
Asymp. Sig.	.144

a. Kruskal Wallis Test

b. Grouping Variable:
Age

Appendix 5: Mann-Whitney test to test the difference in body condition scores over two years.

Mann-Whitney Test

Ranks				
	Year	N	Mean Rank	Sum of Ranks
scores	2012	32	24.48	783.50
	2013	30	38.98	1169.50
	Total	62		

Test Statistics^a

	scores
Mann-Whitney U	255.500
Wilcoxon W	783.500
Z	-3.174
Asymp. Sig. (2-tailed)	.002

a. Grouping Variable: Year

Appendix 6: Nutrition data from elephant individuals

Elephant ID	Nutritional Parameters							
	Moisture	Ash	Fat	P	Ca	CF	ADF	NDF
Abe	4.86	7.095	2.09	0.0985	1.0855	45.08	63.565	70.25
Andreas 7/24/2012	4.81	5.99	1.01	0.075/2	0.788	44.32	51.63	63.08
Andreas 5/7/2012	4.3	6.07	1	0.103	1.001	19.83	54.71	59
Andreas	4.555	6.03	1.005	0.103	0.8945	32.075	53.17	61.04
Beckham 7/29/2012	4.81	7	1.66	0.109	1.031	58.03	54.58	64.24
Beckham 7/7/12	4.98	5.98	2.01	0.108	1.032	57.08	56.95	69.21
Beckham 7/27/2012	4.62	6.47	2.12	0.116	1.417	55.44	63.84	77.35
Beckham A 21/7/2012	4.61	6.83	1.76	0.103	0.945	57.31	55.93	70.39
	4.755	13.14	1.8875	0.109	1.10625	56.965	57.825	70.2975
Brendan 7/27/2012	4.7	7.28	2.35	0.108	1.089	53.62	63.41	71.1
Bump 7/20/2012	4.61	4.93	1.41	0.095	0.716	47.66	60.96	56.64
C. Conner 7/22/2012	4.58	6.12	1.66	0.109	1.032	60.63	60.6	69.6
C.powell 7/20/2012	4.47	7.78	1.66	0.096	1.108	58.89	59.91	68.99
Charlie Chaplan 7/29/2012	4.25	6.34	1.46	0.098	0.898	57.05	57.8	64.36
Gakulu 7/25/2012	5.01	7.17	1.98	0.117	0.985	41.72	64.84	69.8
Keith 4/7/12	4.84	6.39	2.01	1.009	0.982	57.46	59.98	71.96
Keith 7/27/2012	4.61	6.18	2.17	0.115	1.213	52.78	54.81	68.93
Keith 7/10/12	4.67	5.2	0.47	0.111	0.976	54.03	65.07	64.91
Keith 7/30/2012	4.08	6.02	2.89	0.103	1.891	53.76	64.64	72.64

Appendix 7 The Spearman's correlation test between nutrient parameters and elephant body condition

Correlations											
			Moist	Ash	Fat	P	Ca	CF	ADF	NDF	Body Condition
Spearman's rho	Moist	Correlation Coefficient	1.000	.474*	.149	.284	.100	.030	.554**	.345	-.200
		Sig. (2-tailed)		.014	.466	.159	.629	.883	.003	.084	.328
		N	26	26	26	26	26	26	26	26	26
	Ash	Correlation Coefficient	.474*	1.000	.411*	.191	.448*	.282	.585**	.414*	-.126
		Sig. (2-tailed)	.014		.037	.351	.022	.163	.002	.035	.540
		N	26	26	26	26	26	26	26	26	26
	Fat	Correlation Coefficient	.149	.411*	1.000	.061	.569**	.130	.347	.379	-.058
		Sig. (2-tailed)	.466	.037		.768	.002	.526	.083	.056	.779
		N	26	26	26	26	26	26	26	26	26
	P	Correlation Coefficient	.284	.191	.061	1.000	.326	-.011	.292	.234	-.077
		Sig. (2-tailed)	.159	.351	.768		.104	.959	.148	.250	.710
		N	26	26	26	26	26	26	26	26	26
	Ca	Correlation Coefficient	.100	.448*	.569**	.326	1.000	.286	.284	.411*	.042
		Sig. (2-tailed)	.629	.022	.002	.104		.156	.159	.037	.840
		N	26	26	26	26	26	26	26	26	26
	CF	Correlation Coefficient	.030	.282	.130	-.011	.286	1.000	.445*	.657**	-.266
		Sig. (2-tailed)	.883	.163	.526	.959	.156		.023	.000	.188
		N	26	26	26	26	26	26	26	26	26
	ADF	Correlation Coefficient	.554**	.585**	.347	.292	.284	.445*	1.000	.695**	-.190
		Sig. (2-tailed)	.003	.002	.083	.148	.159	.023		.000	.354
		N	26	26	26	26	26	26	26	26	26
	NDF	Correlation Coefficient	.345	.414*	.379	.234	.411*	.657**	.695**	1.000	.016
		Sig. (2-tailed)	.084	.035	.056	.250	.037	.000	.000		.938
		N	26	26	26	26	26	26	26	26	26
	BodyCondition	Correlation Coefficient	-.200	-.126	-.058	-.077	.042	-.266	-.190	.016	1.000
		Sig. (2-tailed)	.328	.540	.779	.710	.840	.188	.354	.938	
		N	26	26	26	26	26	26	26	26	26

*. Correlation is significant at the 0.05 level (2-tailed).
 **. Correlation is significant at the 0.01 level (2-tailed).