POPULATION STATUS, DISTRIBUTION AND TRENDS OF AFRICAN ELEPHANT (*Loxodonta africana,* Blumenbach 1797) IN NIMULE NATIONAL PARK, SOUTH SUDAN

BY

BAYA PHILIP BROWN NGERE

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DECLARATION

DECLARATION BY THE CANDIDATE

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BAYA PHILIP BROWN NGERE DATE

NRM/PGW/02/08

DECLARATION BY SUPERVISORS

This thesis has been submitted for examination with our approval as University supervisors.

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MR. JIM K. KAIRU DATE
Department of Wildlife Management
University of Eldoret
Eldoret, Kenya.

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PROF. HELLEN IPARA DATE
Department of Wildlife Management
University of Eldoret
Eldoret, Kenya.

DEDICATION

I dedicate this piece of work to my beloved mother, the late Margaret Amona, and to my entire family in South Sudan, to all whom I owe my success.

ABSTRACT

The elephant population in Nimule National Park (NNP) underwent a serious decline in the mid 1990s as a result of poaching for ivory. The study was therefore carried out in NNP and its surrounding buffer zone, in Magwi County of Eastern Equatoria State in South Sudan between January and April 2010. The objectives of the study were: to determine the population size and distribution of elephants in NNP; to determine the trend in elephant population in NNP between 2000 and 2010; and to determine the age structure and sex ratio of elephants in NNP. A systematic random sampling design using line transect method was used to gather data on the status and distribution of the African elephant (*Loxodonta africana*) in NNP and buffer zone. A comparative population time trend analysis was used to determine elephant population trend. Data on age and sex structure of elephant population were obtained using visual assessment method through direct observation. Results showed that the study area had a total elephant population of 295. The distribution of elephant was not dependent on the types of vegetation within NNP ($\chi 2$ = 4.96, df =2, p=0.161). The elephant population showed a significant increasing trend ($\chi 2$ = 85.39, df =2; p=0.000) between 2000 and 2010. The age structure of the elephant population was unstable with a significantly lower numbers of young as compared to adults ($\chi 2$ = 42.48; df =3, p=0.000). The sex ratio of male to female elephants showed no significant difference ($\chi 2$ = 0.0898; df =1, p=0.764) among different age categories in the population. It is concluded that the population changed from 125 to 295 elephants between 2004 and 2010, indicating that mortality factors are becoming less severe. However, the low recruitment rate of young elephants in the population is a cause for worry. It is recommended that further studies be carried out to determine the overall ranging pattern of elephants in the whole Nimule ecosystem covering both dry and wet seasons.

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LIST OF ACRONYMS

AfERSG	African Elephant and Rhino Specialist Group
AWF	African Wildlife Foundation
AfESG	African Elephant Specialist Group
CPA	Comprehensive Peace Agreement
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
DRC	Democratic Republic of Congo
GOSS	Government of Southern Sudan
GPS	Global Positioning System
IUCN	International Union for Conservation of Nature (The Word Conservation Union)
KWS	Kenyan Wildlife Service
MAF	Ministry of Agriculture and Forestry
MWC&T	Ministry of Wildlife Conservation and Tourism
NNP	Nimule National Park
NPAs	Non Protected areas
NSWS	New Sudan Wildlife Society
NGOs	Non Governmental Organizations
PAs	Protected Areas
SPLM	Sudan People's Liberation Movement
SPLA	Sudan People's Liberation Army
SAF	Sudan Armed Forces
USA	United States of America
UNEP	United Nations Environment Programme
WCS	Wildlife Conservation Society
WWF	World Wide Fund for Nature

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CHAPTER ONE

INTRODUCTION

1.1 Background to the study

The ever-increasing demand for ivory on a global scale has led to over-exploitation of elephants in all its distribution ranges in Africa. Consequently, poaching of elephants for ivory was one of the major causes of severe decline in the global elephant populations during the 1970s and 1980s (Douglas - Hamilton *et al.*, 1992). However, loss of habitats and fragmentation, as a result of human population growth is yet another serious threat to the survival of elephants in central Africa (Omondi *et al.*, 2007; Steel *et al.*, 2007). Thus, the elephants, which once occurred in vast areas across Africa (Poole, 1996), now exist in smaller pockets of protected areas (PAs) and non-protected areas (NPAs) surrounded by human settlements and other development activities.

Sukumar *et al.*, (1998) and Menon *et al.*, (1997) pointed out that poaching of elephants for ivory is a serious impediment to the survival of the Asian elephants. Said *et al.*, (1995) argued that large-scale poaching of elephants for ivory in all its ranges across East, Central and West Africa have overwhelmingly affected the African elephants, thus making their current population status in many areas uncertain. Uncontrolled demands for ivory in India, China, United States of America and Europe have been the major contributing factors to the huge losses of both Asian and the African elephants over the past two hundred years (AfESG, 2004; Sukumar, 2003). These global demands for ivory have been on the rise since the ancient days of the Greek and the Roman civilizations. As a result, hundreds of thousands of elephants were reportedly killed between 1860s and 1930s (Burnie and Wilson 2001).

In the late 1970s and early 1980s, most populations of the African elephant had declined due to ivory poaching, and continental estimates showed that the population of elephants declined from an estimated 1,341,000 in 1970s to merely 700,000 in the late 1980s (Douglas-Hamilton, 1989). This significant decline in elephant numbers indicated that poaching was a serious threat to the survival of elephants, and required serious conservation attention both at the local and international levels. Despite international calls to combat illegal trade on elephants' ivory products (CITES 1989), the killing of elephants for ivory still remains a grave threat to the survival of elephants (Douglas-Hamilton, 2009).

South Sudan is not an exception and was submerged in one of the longest civil wars in Africa, which spanned over 2 decades. Since then, the country has faced serious challenges from poaching of elephants. According to Morjan *et al.*, (2000) most of the elephants in NNP were hunted between 1994 and 1995 during the peak of the civil war. This wanton killing of elephants was carried out by the former Sudan Armed Forces (SAF) mainly to satisfy ivory demand in the global markets (Morjan *et al.*, 2000).

To be able to get the true picture of elephant population in NNP, continuous studies on the population status of elephants are not only critical but also awfully necessary. As Lindeque (1991) and Stearns (1992) noted, results of such studies would assist in developing a comprehensive database necessary in the formulation of a management strategy of the populations. Despite this identified need, there has been no attempt to determine age structure and sex ratio of the elephant population in NNP during the past studies. Knowledge of the age structure of a population is essential for investigating trend in recruitment, mortality and reproductive status of the population (Lindeque, 1991; Stearns, 1992). Therefore, the need to establish a clear picture of the present population status, trends and social structure of the African elephant (*Loxondonta africana*) and their distribution is critical not only to develop a conservation strategy for elephant populations, but also to assist in the development of management objectives for Nimule National Park as well.

1.2 Statement of the Problem

The population of elephants in Nimule National Park underwent a serious decline in the middle of the 1990s as a result of poaching for ivory (Morjan *et al*., 2000). Selective removal of adult elephants including the young males and female matriarch from the population is believed to have negatively affected the social structure of elephant populations. Recent studies have also claimed that elephants in NNP are in grave danger of a population crash and change in their social structure (Morjan *et al.*, 2000; 2004). Data on current status of elephant populations, age and sex structures and their distribution are needed to assist in formulating an effective conservation strategy for the species in Nimule National Park. There are also conflicting results on previous estimates of elephant population, ranging from 151 in 1983 (Kenyi, 1983), 814 in 1987 (Abdullah, 1987), 156 in 2000 (Morjan *et al.*, 2000), 125 in 2004 (Morjan *et al.*, 2004) and 69 in 2008 (Grossmann *et al*., 2008).

It was therefore essential to establish a true picture of the elephant population in Nimule National Park for future management purposes. This study also aimed at generating data on elephant status and the effect of two decades of civil war in Sudan on this keystone species.

1.3 Objective of the study

Following severe killings of elephants during the conflict era in the 1990s, the overall objective of the study was to establish the status and a decadal trend in elephant population in NNP. The Specific objectives of the study were:

(i) To determine the population size and distribution of elephants.

(ii) To determine the trend in elephant population between 2000 and 2010.

(iii) To determine the age structure and sex ratio of elephants.

1.4 Hypotheses of the study

H_{O1}: The population size of elephant in NNP has not changed over the 10 year period between 2000 and 2010.

H_{O2}: Vegetation type has no effect on the distribution of elephants in NNP.

H_{O3}: The sex ratio of elephant population in Nimule National Park is even.

H_{O4}: The age structure of elephant in Nimule National Park is stable.

1.5 Research questions

(i) What is the current population size of elephants in Nimule National Park?

(ii) How does the distribution of elephant vary with vegetation types found in the park and in the buffer zone?

(iii) Does the population of elephants in NNP have an increasing or decreasing trend?

(iv) What is the age structure and sex ratio of elephants in Nimule National Park?

1.6 Justification of the study

It is important that the population of elephants in NNP is legally conserved as a core national heritage and also as an international tourism attraction. This study is significant in the sense that NNP is among one of the protected areas in South Sudan that is still holding a sizable population of elephants, which if well managed, will assist in boosting the tourism sector in the area. Although the elephant has been seriously threatened in South Sudan as a result of commercial poaching for ivory, no appropriate measures have been taken since the time of the civil war to specifically address elephant conservation and management.

However, after the peace agreement and subsequent independence, efforts are being made to stop the elephant population decline. Thus, deliberate effort to protect this vital population of elephants is critical not only to enrich the country's biodiversity, but also to ensure the survival of the species for the benefit of the future generations in South Sudan.

This research was therefore critical not only to achieve the ultimate objectives of the study, but also filled in the gap in knowledge on elephant conservation and management in NNP that became void over the last two decades of civil war. This information will also be used as source of reference for scholars and conservationists who are involved in similar or related studies.

1.7 Scope of the Study

The study focused on determining the current population status, distribution, age and sex structure and trend of elephants in Nimule National Park, with a view of generating information that can be used to spearhead development of comprehensive and strategic management plans for elephant populations in the park.

1.8 Definition of operational terms

African elephant - refers to one of the largest living terrestrial animals on earth. It is classified in the super order Paenungulata, Order Proboscidea, Family *Elephantidae*, Genera *Loxodonta* and species *africana*.

Buffer zone - is an area surrounding a National Park managed for the economic benefit of the local community by means of sustainable development. The Minister may by regulation declare the uses and area of a buffer zone in relation to the National Park (Goss, 2009).

Nimule National Park - refers to a protected area in South Sudan set aside for the conservation and management of fauna and flora (Government of Sudan, 1935).

Ivory - refers to either the whole or products of upper incisor teeth, normally referred to as tusks in elephants. Tusks are used as offensive and defensive weapons as well as for feeding.

Poaching – refers to activities involving illegal killing of wild animals for meat, skin or horns in contravention of local, state, regional or international law.

Population trend- means development in the size and make-up of a population.

Population structure- Categorization of the population of an animal by age and sex groups.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview of the African elephant (*Loxodonta africana*)

The African elephant is the largest terrestrial mammal on earth. This animal species and its closest cousin the Asian elephant *Elephas maximus* are the only two remaining species of elephants in the order Proboscidea today (Sukumar, 2003). The former remains in Africa, whereas the latter moved to Asia in the late Pleistocene periods (Maglio, 1973). However, preliminary genetic evidence (Blanc *et al*., 2007) have suggested that there are two races of African elephants, the savannah race, also known as the bush elephant (*Loxodonta africana africana*) and the forest elephant (*Loxodonta africana cyclotis*). These subspecies (races) differ substantially from one another in terms of their morphological appearance and ecological distribution.

The savannah subspecies differ significantly from the forest elephant by having larger body size, thin hair coverings, strong flexible trunks and triangular-shaped ears rather than smaller round ears, grey skins rather than dark-brown skins as in the case of forest elephants (Nowak, 1999). On the other hand, the forest elephants are comparatively smaller than savannah or bush elephants, with relatively long, thin and straight tusks.

In the African elephant, adult males are fairly superior to females of similar age and may reach a height of up to 2.5-2.8 meters tall at shoulder, and weigh about five tons (Stuart and Stuart 1996). However, both sexes of elephants have elongated tusks (incisors) which are used for various purposes including defense, handling food, communications, marking and digging soil for mineral salt licks among others (Stuart and Stuart 1996). The tusks are known to grow throughout the lifetime of an elephant, and it may reach 2.5 to 3 meters in length. Plates 1(a) and (b) show distinct physical characteristics between a savannah and a forest elephant in terms of body shape, tusks and ear curvature.

(Source: Author, 2010)

Plate 1: (a) Savannah elephant (Save the elephant, 2011) (b) Forest elephant (WWF, 2012)

2.2 Ecology and Distribution of African Elephant

The habitat of African elephant ranges from open and dense closed forest, savanna grasslands to extremely arid and semi desert areas of Africa. The forest elephant inhabits the thickest rainforest of West Africa, usually in a smaller assembly, whereas the savannah subspecies is found in open and thorny savannah, forest fringes, swamps and mountainous areas of Africa. The latter subspecies (savannah) usually occurs in big herds of over one hundred animals. The African elephant also inhabits a wide range of altitudes from ocean beaches (at sea level) to mountainous slopes of up to about 5000 meters above sea level (Nowak, 1999).

Diets of African elephant range from grass, tree foliage, roots, bark, twigs, shrubs, and tree branches to fruits and seed pods. Availability of fresh water and abundance in food supply has a significant effect on elephant distribution. In order to meet their food and water demands, they may be found active throughout the day and night but rest during the hottest hours of the day. Elephants therefore require a supply of fresh water and food in form of grass or browse to meet their nutritional requirements. It has, however, been noted that the elephant may consume about 150 - 300 kg of food and drinks up to 100 - 220 liters of water daily (Moss 1992; Stuart & Stuart 1996). Studies have shown that elephants are highly social animals, and sometimes they may be found in large herds of a hundred individuals or even more in some situations. Kangwana (1996) stated that family members of elephants always stay together in tight relationships with their young ones, while males live in a solitary lifestyle with few social bonds.

Douglas-Hamilton (1972) pointed out that both sexes of elephants are non territorial, although they share specific home areas in particular times of the year (Moss and Poole 1983). The savannah elephants are organized in stable matriarchal units of about ten individuals, with an experienced matriarch as a leader, together with the calves and her adult daughters. The new-born is suckled by its mother or sometimes by several lactating females within family units. Adult females and calves spend most of their times together, but parental care and security provision to young ones is a common responsibility of all adults in the elephant herd. In some situations two or more family herds can aggregate in one particular environment forming a "kinship group" or "clans" which may consists of up to 70 individuals. In female elephants, for instance, puberty begins at 11 years, and at this period females leave the family unit and form their own families, and remain fertile until the age of 55- 60 years.

On the other hand, puberty in males takes place between the age of 8 - 20 years, after which they are usually driven away from the family group, and form a small temporary bachelor herd consisting of only males (Nowak, 1999). Adult males start to reproduce at 25 and 30 years of age, and may reach prime breeding status at the age of 40- 50 years (Moss, 1992 and Poole, 1989). Elephants are slow breeders, with birth interval of 2.5 to 9 (on average 5) years. Birth occurs at any period of the year, but high calving peak occurs before the rain season and in the case of savannah elephants ovulation ceases during the dry season, mainly due to scarcity of food resources. The average lifespan of the African elephant is about 60 - 70 years (Macdonald, 2001).

Communication in elephants occurs in various forms which include visual and chemical signals, touch, display and vocalization (Moss, 1988). Vocalization varies from soft rumbles to ear-splitting trumpets depending on the prevailing conditions. In addition, sense of smell is well developed in elephants, and relies on it to locate water and food resources.

The home range of the savannah elephant varies from one population to another as well as from one habitat to the other; depending on the abundance of food and the availability of water and shade (Stuart and Stuart 1996). The largest home range size of the African elephant ever recorded was in Namib Desert (Namibia) at an average size range of about 5800 - 8700 sq. Km (Berger, 1997). An elephant study in Amboseli National Park (Kenya) showed an average home range size of male and female elephants at 2800 sq km (Osborn, 2004) based on minimum convex polygons and annual rainfall for each location.

2.3 Population estimates and trends of African elephant

As in much of Africa, elephants in South Sudan and in particular NNP have suffered a serious decline in number and a considerable alteration in the age and sex structure of its population during the 1970s and 1980s. AfESG (2004) reported that selective removal of elephants has profound effect on the social (age and sex) structure of the populations, with adult males and female matriarchs being targeted by hunters for their large tusks which would provide a high economic return. Poaching of elephants for ivory or meat has been on the increase since the late 1970s. It continues to spread southwards from the north of Africa (Ecosystem *Ltd*, 1980; Douglas-Hamilton *et al.*, 1980) and is eventually affecting most of the elephant range countries in Africa. Poaching for ivory is one of the major causes of huge decline in elephant numbers over the last two hundred years, and still continues to threaten most of the populations throughout their ranges both in Africa and Asia (Said *et al.*, 1995; Sukumar *et al.*, 1998; Sukumar and Santiapillai, 1996).

Corfield (1973) and Sheldrick (1976) contended that between 1970 and 1973, a considerable number of elephants died in Kenya’s Tsavo National Park, largely due to severe drought that overwhelmingly affected the country during these periods. It was, however, further argued that the wave of poaching for ivory during the same period had also claimed many elephant lives in Tsavo ecosystems. Estimates showed a declining trend in elephant population in Tsavo ecosystem from an estimated 12,000 in 1980 to about 5,363 in 1988.

Heavy poaching of elephants for ivory has been occurring since the late 1970s and 1980s (Ottichilo 1987) and Douglas-Hamilton (1979). This devastatingly affected the lives of many elephant populations, especially in the eastern parts of Kenya, with serious decline occurring in major populations such as Tsavo, Tana, Galana and Lamu. This prompted a ban on elephant hunting in 1974, a ban on all sport hunting in 1977 and a national ban on dealership in trophies in 1978 in Kenya (Ottichilo, 1987).

The aerial census conducted by KWS described the elephant population of Tsavo ecosystem as recovering from intensive poaching for commercial ivory trade (KWS, 2011). Records showed a remarkable increase in elephant numbers from an estimated 6,763 in 1991; 7,371 in 1994; 8,068 in 1999 to about 9,284 in 2002 respectively. These increasing trends in the numbers of elephants in Tsavo ecosystem over these years reflects the strength and competence of anti-poaching operations and law enforcement taken by the Kenyan Wildlife Service (KWS) against organized armed poachers, as well as the efforts and conservation measures enforced by CITES on the ban on international ivory trade in 1990. Similarly, during the late 1980s, significant declines in elephant population were also witnessed in some major protected areas in

Tanzania, such as Ruaha National Park (Barnes and Douglas-Hamilton, 1982), Selous Game Reserve and the Serengeti ecosystems (Dublin and Douglas-Hamilton, 1987).

However, it was argued that the ever-increasing demand for ivory in the global markets, together with habitat destruction by human activities, are among key factors that had contributed to decline in elephant numbers over the century (Douglas-Hamilton *et al*., 1992).

Douglas–Hamilton *et al.*, (1992) argued that loss of elephants to poachers for ivory trade continued to threaten most elephant populations in all its ranges throughout Africa during the 1970s and 1980s. Population estimates continued to show declining trends in elephant numbers from an estimated 1.3 millions in these periods to merely 600,000 in 1991. It was as a result of the tremendous decrease in elephant numbers that led to the global initiatives and concern towards conserving elephant populations, despite having been listed in Appendix I of the CITES, among other threatened animals in 1989 (CITES, 1989).

Blanc, J.J., *et al*., (2002) pointed out that the number of elephants had declined much faster both in Africa and Asia over the past 30 years while number of humans had increased substantially. In these periods a sizeable number of elephants were killed as a result of high market demand for ivory trade in Asia, Europe and later in the USA.

AfERSG (1989) reported the population of elephants in Cameroon as increasing, despite severe decline among the east and central African populations (Said *et al.*, 1995). It was also reported that in less than ten years, a tremendous increase in elephant population size had occurred, from an estimated 5,000 in 1981 to about 21,000 in 1987. This conspicuous raise in elephant numbers which occurred in this part of West Africa was primarily due to lower hunting pressure resulting from excellent conservation measures against illegal armed poachers (AfERSG, 1989).

2.4 Factors affecting the distribution and trends in elephant population

Sukumar (1990) argued that the most important causes of severe decline in the number of Asian elephants was killing of elephants as a reprisal against crop damage and hunting, while other authors (Sukumar 2003; Leimgruber *et al*., 2003 and Hedges, 2006) alluded to habitat loss resulting from expanding human population and the loss of forests in Asia. According to Olivier (1978), loss of potential elephant ranges to irrigation and development projects led to the conversion of forests to irrigated agriculture and settlements in the 1970s. As the elephant habitat continued to undergo fragmentation in most parts of Asia, little was done to improve elephant protection. However, it is worth mentioning that technological advances, together with other factors associated with colonial regimes, led to a drastic crash in elephant numbers in most countries during the 19th century.

In this regard, South Sudan is not an exception, and its elephant population in NNP suffered severe decline during the two decades of civil war between 1983 and 2005. This was largely due to lack of attention given to the protection of wildlife species including the elephants and since the available financial resources were mostly used to finance the war. There were no significant efforts made to document the status of elephant in NNP during the war. Despite these outstanding challenges, a few studies were successfully conducted in NNP and their results showed pitifully low numbers of elephant.

A study by Abdullah (1987) reported that the population of elephants in Nimule ecosystem was increasing although the areas covered by the survey and methods used in data analysis were not clearly explained (Morjan *et al.*, 2000). The aforesaid increasing trend in elephant population was deduced from an estimate of 151 in 1983 by Kenyi, (1983) to about 814 in 1987 (Abdullah, 1987). The increase may have largely been due to excellent protection offered by the game scout and wildlife forces through patrolling exercises against the poachers. However, both reports concluded that areas north of River Lorenz experienced re-occurrence of poaching incidents during the time of war and as a result no signs of elephants were seen in these areas during these surveys.

In the year 2000, a ground survey reported that no elephants were directly seen in the study area, except by indirect signs of dung observed, a situation attributed to the impact of war on the population (Morjan *et al.*, 2000). A later survey in the same year put the elephant numbers at 156. According to Morjan *et al.*, (2000) the lower counts of elephants was due to migration of larger herds of elephants outside the park from their wet season ranges in search of drier environments in areas such as Loa, Pageri and Acholi areas. It was further suggested that disturbance caused by war together with random shooting of elephants inside the park between 1994 and 1995 scared most populations, thus forcing resident herds to also become highly migratory (Morjan *et al.*, 2000). The survey results concluded that the main challenges to elephants during their migration in and outside the park are landmines and poaching. The elephant population census in 2004 estimated the population to be 125 animals (Morjan *et al.*, 2004). Morjan *et al.*, (2004) argued that seasonal movement of elephants in and outside the park together with the impact of war affected the results of the survey. They further stated that the profound decline in elephant numbers was largely due to unlawful killing of elephants for ivory and meat by the local people and Sudan Armed Forces (SAF).

The 2008 aerial survey (Grossmann *et al*., 2008) showed that Nimule ecosystem only held a small population of 69 elephants. It was, however, noted that the routine movement of elephants in and outside the park as well as their crossing the border to Uganda for their wet season ranges had affected the results of the aerial total count, and thus the results of population estimates for elephants in this survey was considered an underestimate. The report by Grossmann *et al*., (2008) also noted that the mushrooming growth in human populations in the surrounding areas (buffer zone) will make the future protection of these elephants a more difficult and contentious issue for the NNP managers.

In a study on food security situations in and around Nimule National Park by Kwaje *et al*., (2002) reported that the sprawling of settlements and agricultural activities reduced the habitats which were previously used by elephants, thus increasing the human-elephant interaction and illegal poaching. This situation was worsened by burgeoning human population resulting in huge demand for land and wood fuel (Grossmann *et al*., 2008). This study therefore sought to gather information on the status and population trends of elephants as well as factors affecting their distribution and structure to generate information that can assist in developing strategic development and management plan for Nimule National Park. The status and trends in elephant population were not satisfactorily determined in the previous studies, and as such there was need for further data collection and analysis to provide definitive conclusions.

This study also aimed at providing information on how armed conflict in Sudan affected the population of elephants in this region.

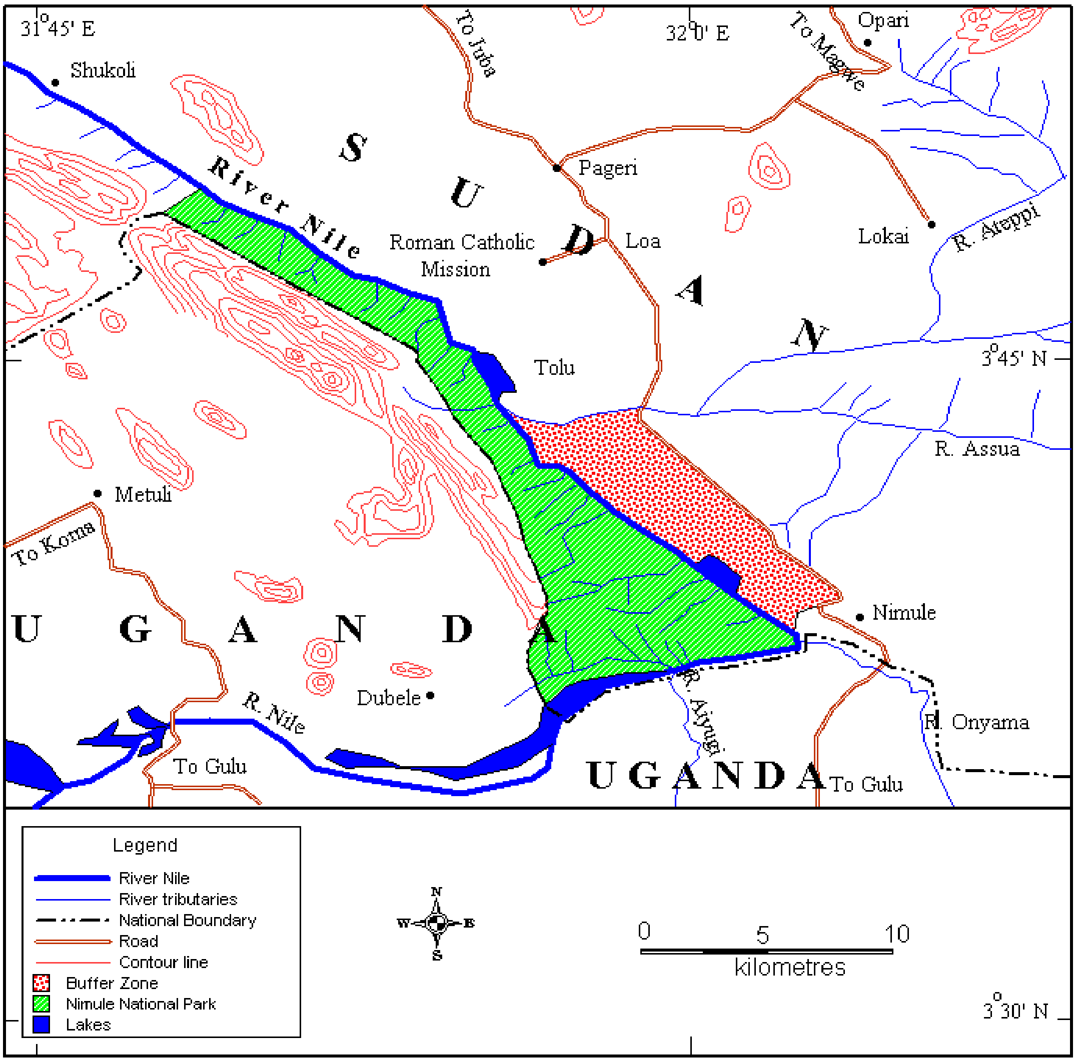
CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Area: Location and Size

The study was conducted in Nimule National Park and its surrounding buffer zone. The park is an important ecological area in South Sudan, with an abundance of flora and fauna. It is located in Magwi County of Eastern Equatoria State, on the border with the Republic of Uganda. Several studies conducted in NNP have shown varying estimates on the exact area of the park. A study by Abdullah (1987) estimated the area of the park to be 251 Km^2, Blower (1977) estimated the area at 256 Km^2 while Hillman (1985) gave the area of the park to be 410 Km^2. The larger area described by (Hillman, 1985) was believed to include both the park and buffer zone (Morjan *et al.*, 2000).

Initially, the park was established as a game reserve in 1935 and was upgraded to the status of a national park in 1954 (Sudan Government 1955), mainly to protect the now locally extinct Northern White Rhino population and later on the elephants. It lies between the latitudes 3^{o} $45''$ and 3^{o} $30''$ N and longitudes 31^{o} $45''$ and 32^{o} $0''$ E (Figure. 1). The eastern boundary of the park is bordered by a buffer zone which extends from River Onyama to the south up to River Assua to the north along Juba-Nimule road (Morjan *et al.*, 2000).



Source: Morjan *et al.* (2000)

Figure 1: Map of the study area

3.1.1 Climate

The climate of the study area is unique as compared to the general dry climate of South Sudan which is mostly dominated by continental climate. The climate in the park is largely influenced by topographical features such as elevated hills, undulating terrains and plateaus (Morjan *et al.*, 2000). The general topography and drainage system of the area forms the relief and convectional rainfall which is well distributed throughout the year. Most of the rains occur between March and November, and eventually followed by a dry period starting from December up to February. The average amount of rainfall ranges between 1000 mm and 1500 mm per annum. Daily mean temperature is 27^0C, with the highest temperatures of 29^0C recorded during the month of March and the lowest, 24^0C, recorded in the month of July (Lebon, 1965).

3.1.2 Topography and Geology

The geology of the area typically conforms to that of the late Precambrian period (Morjan *et al.*, 2000). The topographical features of Nimule protected area have interplay of rock type and climatic conditions that date back to the Pleistocene era through into the Holocene era. The hilly terrains are generally rounded with rough hill tops. This is evidence of the resistant rocks that largely underlie the area. Elevation of the area ranges between 500m and 800m above sea level. The main physical features found in the park are the Fula rapids on the River Nile and Illengwa hill on the western side of the park.

3.1.3 The Soil

The soil types in the study area are directly influenced by the prevailing climatic conditions, nature of the parent rock, relief, landscape, drainage and vegetation. The soils of Nimule National Park and its surrounding areas are characteristic of iron stone plateau (Mefit, 1983; Noordwijk, 1985). These soil types are an expansion of latosols found in the woodland savannah. Latosol soil is characterised by presence of red mottles and discrete modules lying on top of the clay horizon that is rich in iron and aluminium oxides. The soils of Nimule have lower pH values and high organic matter, and the component of clay soil is largely kaolinite in nature.

3.1.4. Fauna

Nimule National Park is an impressive ecosystem that harbours not only elephants but is also home to diverse species of wild animals. Some of the mammalian species found in the area include the hippopotamus (*Hippopotamus amphibious*), Uganda kob (*Kobus kob*), warthog (*Phacochoerus aethiopicus*), baboon (*Papio anubis*), Vervet monkey (*Cercopithecus aethiops*) and bush buck (*Tragaleptus scriptus*), to mention but a few (Appendix 3).

Birds are highly diverse and plentiful and the common species include Goliath heron (*Ardea goliath*), Purple herons (*Ardea purpurea*), long tailed cormorants (*Phalarcrocorax africana*), Egyptian goose (*Alopochen aegyptiaca*), crowned crane (*Balearica regulorum*), Secretary bird (*Sagittarius serpentarius*), Glossy ibis (*Plegadis facinellus*), Lesser jacana (*Microparra capensis*), to mention but a few. Some birds species found in Nimule ecosystem are Palearctic migrants from Europe and Asia (Appendix 4). Common reptiles found in Nimule ecosystem include the Nile crocodile (*Crocodylus niloticus*), monitor lizard (*Varanus exanthematicus*), Python (*Python sibae*) among others (Appendix 5).

3.1.5 Flora

The vegetation of NNP falls under deciduous woodland savannah categorized by broad-leaved trees (Morjan *et al*., 2000). Grasses are perennial types that grow up to heights of 4-8 feet (Kenyi, 1983; Abdullah, 1987). The vegetation of NNP can be categorized into three major types and these include:-

3.1.5.1 Wooded grasslands

This vegetation covers most parts of the western half of the park (Morjan *et al*., 2000) and is largely dominated by *Hyparrhenia filipendula* and *Hyparrhenia ruffa* grass species. The most common tree species found here include Combretum and Acacia species interspersed by *Tamarindus indica* and *Ziziphus abyssinica,* among others.

3.1.5.2 Bushed grasslands

This vegetation occupies larger parts of the highest and well-drained grounds of the park (Morjan *et al*., 2000). The common tree species found in this area is *Combretum collinum*, and largely interspersed by grass species such as *Hyperrhenia filipendula* and *Hyperrhenia ruffa*. Grasses grow tall up to about 2-4 meters.

3.1.5.3 Riverine woodlands

This vegetation category includes most of the sections or areas along the River Nile and several intermittent streams. *Acacia sieberiana* and *Borassus aethiopica* are among dominant tree species found in this area (Abdullah, 1987; Noordwijk, 1985). However, papyrus species and other grass species are also commonly found along the river Nile which provides suitable habitats for hippos and bushbuck.

3.1.6 Human population and their activities

The human population of Nimule and its surrounding areas has been increasing in recent years especially after the signing of the Comprehensive Peace Agreement (CPA) in 2005. Morjan *et al.*, (2000) noted that three quarters of local communities are returnees from Uganda, Ethiopia and Kenya after fleeing the country during the civil war of 1995 to 2005. Traditionally, fishing is among the most common activity practiced by the local people (Plate 2).

However, in the recent past, wholesale and retail businesses, and provision of accommodation facilities have increased this and together with livestock keeping are among economic activities that play a significant role in strengthening the local economy. Besides this, local community members are involved in destructive activities like killing of wild animals and harvesting of grass for construction of local houses (Plate 3).

The study was conducted in the dry season between January and April 2010. Before embarking on the elephant census using line transect sampling method, the map of the study area was thoroughly reviewed and studied with a view to identifying the most appropriate sites for laying transects. However, to minimize the occurrence of large sample variations (error) that may appear in the final estimates of elephant's population size and/or density, the study sites were carefully selected based on differences in vegetation of the park and at the buffer zone as described by Kenyi (1983) and Abdullah (1987). The buffer zone is an area lying adjacent to the park on the eastern bank of the River Nile, and was included in the study since it is frequently visited by elephants.

(Source: Author, 2010)

Plate 2: Fishing camp along the bank of River Nile inside the park

(Source: Author, 2010)

Plate 3: Human settlements and encroachment at the buffer zone

3.2 Data Collection

3.2.1 Research design

A systematic random sampling design was used as a basis for establishing transects (Figure 3). Distance sampling method was adopted for use to enable estimation of animal density from transects survey data. The study area was surveyed along transects oriented in an east-west and also north–south directions, depending on the terrain and vegetation conditions. This was significant as it helped in reducing the efforts exerted by census teams in each transect. Each member of the census teams, including two wildlife guards in each team, were trained on how to collect data using line transect sampling technique.

The training was aimed at ensuring that all the team members familiarized themselves with theory and application of line transect method, appreciating the expected field circumstances as well as obtaining some ideas about the targeted populations. An estimate of elephant population density was obtained for each vegetation type, and also at the buffer zone, and these were later combined together to provide an overall estimate of elephant population size in the whole study area.

3.2.2 Line transect sampling method

Due to the small size of NNP, and its inaccessibility by means of vehicles (Morjan *et al.*, 2000), the Kings Census method of counting animals on foot using line transect sampling technique was used (Giles, 1974). This method involves direct counts of wildlife species in a given sampling area. The Kings method is relatively simple compared to other indirect censusing methods and is much more practical in censusing large areas with appreciable animal populations. Because censuses employing the Kings method may be conducted relatively fast, it is possible to conduct seasonal or yearly censuses in the same area or compare population densities between different regions with minimum of time and effort. In addition, Kings Census Method (Giles, 1974) has an advantage in applications in areas whose boundaries are not clearly delineated, as in the case of NNP whose boundaries remain unclear due to encroachment.

According to Anderson *et al.* (1979) and Buckland *et al.* (1993; 2001), the line transect sampling technique is one of the most common and appropriate method for estimating abundance and/or density of biological populations. This involves observers walking along series of straight lines and counting the numbers of all animals encountered on both sides of the line transect and recording them. In addition, line transect technique has more benefit than other methods used in estimating the abundance of wildlife populations simply because it is easy to apply in the field compared to other methods and requires only minimal manpower and other resources (Norton-Griffiths, 1978). As a result, line transect sampling technique was selected for use in this study to count elephants in NNP.

A total of 23 line transects of varying lengths were laid, 19 of which were established inside the park in different vegetation types, and four (4) were placed in the buffer zone. Using Global position system (GPS), 7 transects were laid in the wooded grassland (each 2.9 Km in length), 7 in the bushed grassland (each 2.8 Km in length), and 5 in the Riverine woodlands (each 2.6 Km in length) in the park. Four transects (each 2.5 Km in length) were laid in the buffer zone. Each transect was placed at a distance of 0.5 - 1 Km from each other to avoid double counting of elephants.

The variations among transects lengths was due to the rough terrain of the study area coupled with thick vegetation cover in some areas. The width for each transect was obtained from average perpendicular distances on both side of the lines. Transect orientation and coordinate points were established using GPS.

During the survey, the following data were recorded for each visual sighting of elephant(s): (i) estimated distances from the elephant to the observer using direct observation, (ii) GPS location of observer, (iii) time of day (iv) angles or bearings relative to the transect line (obtained from magnetic compass) and (v) sex and age composition of the group using binoculars (7x35 zoom size). For the purpose of statistical analysis, all sighting angles together with sighting distances were concurrently transformed to sets of perpendicular distances of each observed individual or group of elephants. The perpendicular distances were then used in program DISTANCE version 6.0 (Thomas *et al*., 2009) to compute the size and/or density of elephants in each vegetation types in the park and buffer zone. The assumptions of line transect sampling technique (Anderson *et al*., 1979) considered in this study include:-

(i) An elephant directly located on the transect line is always detected (i.e. probability of detecting an elephant on center of the transect line must be 1.0).

(ii) Randomly placed transect lines were surveyed and elephants detected were recorded.

(iii) Elephants were detected at their initial location, prior to any movement before the observer(s) counted.

(iv) Distances from centre of the transect line to each observed elephant or groups were accurately measured and estimated.

(v) Transect lines were straight, well designed and properly conducted.

(vi) Elephants encountered were independent and did not affect the probability of detection of others.

3.2.3 Materials

For the purpose of enhancing collection of a comprehensive and precise data, materials and equipments used include, firstly, a Canon digital camera (10x50 mega-pixels), which was largely used for taking the photographs of elephants. Secondly, an Olympus field binocular (7x35 DPS I) was used throughout the survey to estimate the sighting distances and assess the age and sex structure of elephants seen along each line transect. Thirdly, a GPS unit was used to establish the waypoints and/or coordinates of transects and marking areas where elephants and carcasses were sighted. Fourthly, a magnetic compass was used to orient direction of line transects and measure bearing angles for each observation made along transect lines. Fifthly, vehicles (Toyota land cruisers (4x4) pick up) and motor boats were extensively used to assist in movements. Sixthly, writing materials such as pens and data forms were used.

The perpendicular distances for observed elephants/group were obtained from planar geometry (Figure 2) using trigonometric equation (Hayes and Buckland, 1983). This simply involved solving for one side of a right-angled triangle. However, this method requires that angles relative to the transect line be recorded at the time of initial detection.

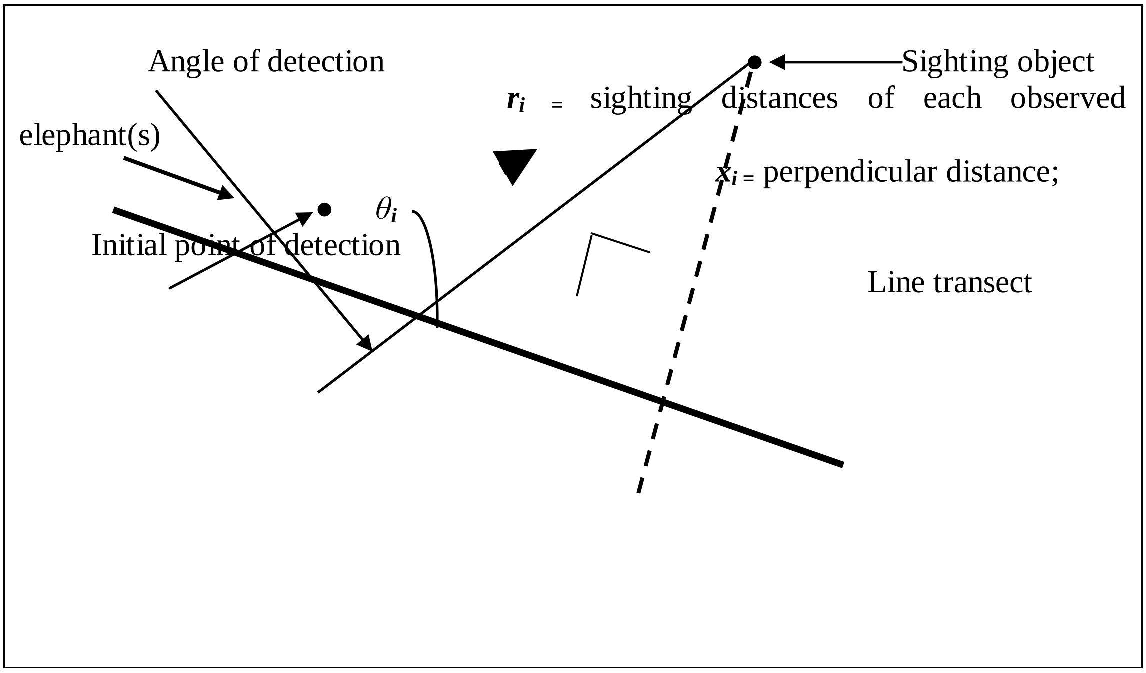
The equation is given by formula; ($\mathbf{x}_i = \mathbf{r}_i \,.\, \mathbf{Sin}\ \boldsymbol{\theta}_i$)....................................... (1)

Where:

x_i = perpendicular distance;

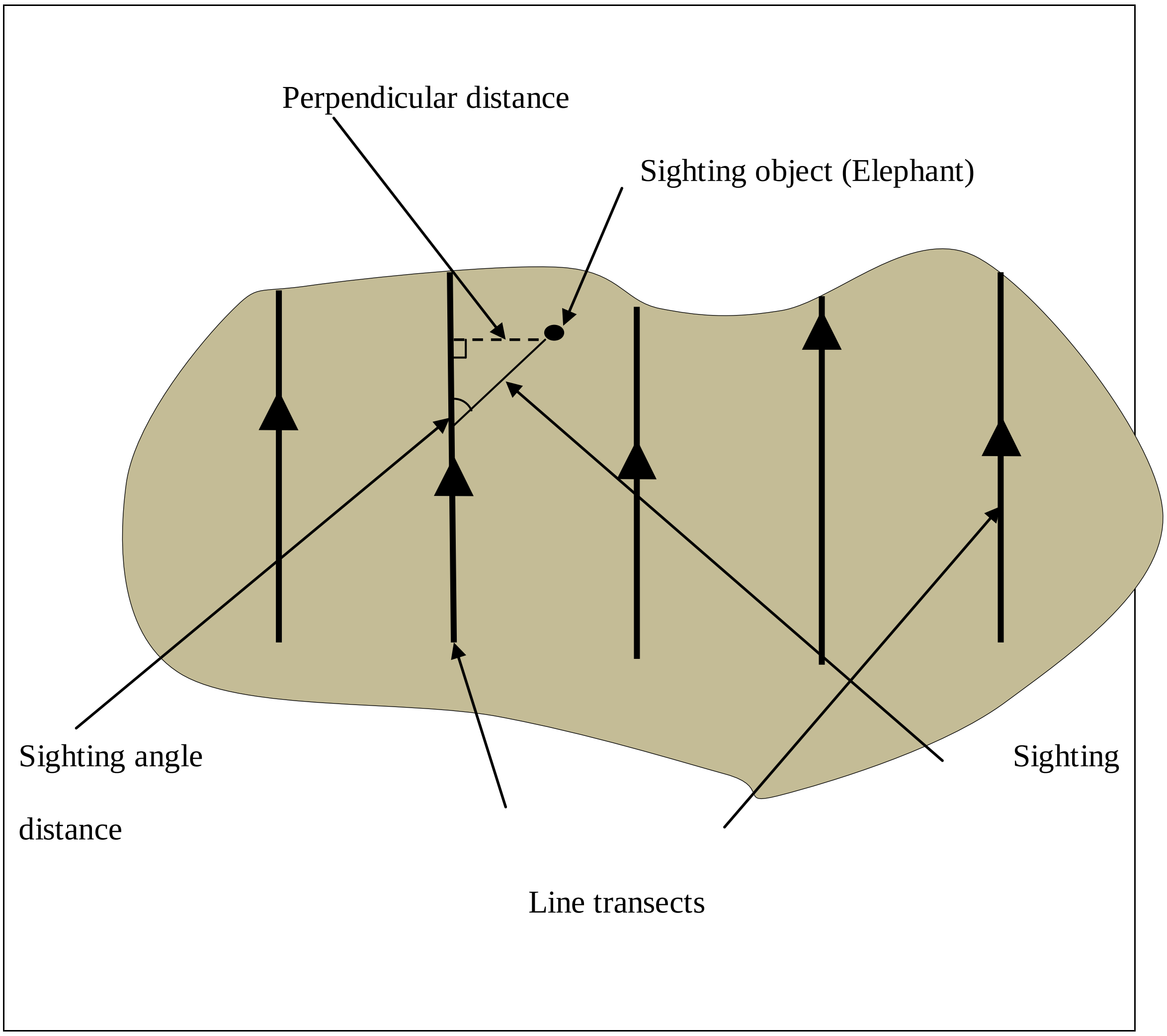
r_i = sighting distances of each observed elephant/group, and

θ_i (theta) = sighting angle, (bearing angle of an observed elephant from edge of the line).



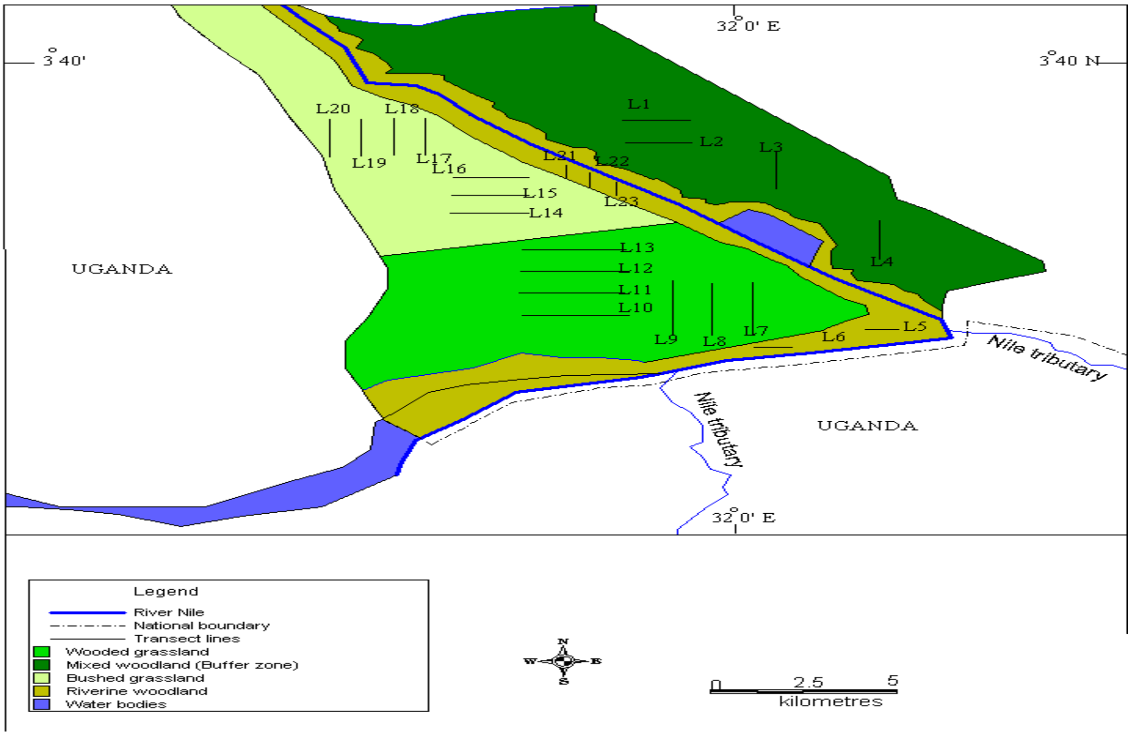
(Source: Author, 2010)

Figure 2: The perpendicular distance of an observed object (elephant) along a line transect



(Source: Author, 2010)

Figure 3: Systematic random sampling transects layout in the study sites



(Source: Author, 2010)

Figure 4: The layout and distribution of 23 line transects in the study area

3.2.4 Field Observations

3.2.4.1 Direct counts

Direct counts were carried out in the southern half and central part of NNP during the dry season between January and April, 2010 (Plates 6 and 7). The study was not extended to other parts of the park because of insecurity coupled with the rough terrain (particularly in the western and northern section of the park. During the study period, areas bordering the north and western boundaries of the park experienced insecurity problems arising from poachers who illegally entered the park. As a result the study was limited to areas in the southern half of the park. However, with the assistance from wildlife guards and rangers a fairly large area of NNP and buffer zone was surveyed.

In each counting day, the census teams walked on foot along transects in the morning (8:30 am), afternoon (12:30 pm) and evening (3:00 pm), and made direct observations of elephants. The rough terrain of the study area (Plate 8) greatly affected the study design and transect layout, as a result most transects were laid parallel to the gradients of the slopes both inside the park and at the buffer zone thus resulting in transects being laid in a north–south as well as east–west directions. Data gathered from transects surveys included the numbers of elephants sighted, sex (males and females) and age structures (adult, sub-adult, juvenile and calf).

Due to logistics and financial limitations coupled with the poor terrain of the study area, the census was conducted once for each transect within the park, except for those transects laid in the buffer zone for which 3 counts were made along each transect. During the study, means of transport to facilitate movement within and around the park was not easily available (Plates 4 and 5). However the NNP management offered a vehicle to assist the researcher and his team members throughout the research period.

(Source: Author, 2010)

Plate 4: Motor boat at a landing port ready for survey trip to NNP

(Source: Reuben)

Plate 5: Research team survey trip to the park via motor boat on River Nile

(**Source: Author, 2010)**

Plate 6: Census team during a transect survey inside the park

(Source: Author, 2010)

Plate 7: Census team during transect survey at the buffer zone

Source: Author, 2010

Plate 8: Land terrain of the study area at the buffer zone

3.2.4.2 Ageing of elephants

A visual assessment method documented by Kangwana (1996) and Ogola (2003) was used to determine the relative age of elephants. This method involves combinations of physical characteristic such as size; emergence, length and circumference of the tusks and body shape and size proportion of young relative to adults (Ogola, 2003). Because elephants almost grow throughout in most of their lifetime, the larger an elephant is, the older it is (Plate 11). Deviation of the mothers’ shoulder-heights from the calves (Kangwana 1996; Laws and Parker, 1975; Lee and Moss 1995) was also used to estimate the age of young calves (Plate 15). Additionally, a combination of various features including the nature of tusks (length and circumference), ear curvature, body shape and size were also used to establish the age of elephants. However, following what other authors have recommended, age-classes were used in estimating the ages of elephants.

3.2.4.3 Determinations of sexes

In order to determine the sex of elephants in this study, various methods were concurrently adopted (Kangwana 1996; Laws and Parker, 1968). Sexual dimorphism in terms of body size and shape was used to establish the sex and age structure of elephant. For example, males are larger than females of the same age class. The shape of the head was also used to distinguish the sexes of elephants. Males have slightly rounded heads and wider space between the eyes (Plates 11 and 13), as compared to heads of females which are less pointed with a narrowing space between the eyes (Plates 10 and 14). This characteristic was more distinct in elephant calves.

The size of tusks was also used to determine the sex of elephants in that males have considerably larger and thicker tusks and curved in shape (Plate 11) as compared to female tusks which are smaller and uniform in circumference up to the tip (Plate 14). Behavioral characteristics such as close associations of young calves and females were also used to differentiate between sexes of elephants (Plates 15 and 16).

(Source: Author, 2010)

Plate 9: A herd of elephants foraging at the buffer zone near River Onyama

(Source: Author, 2010)

Plate 10: Side view of the head and tusk shape of an adult female elephant

(Source: Author, 2010)

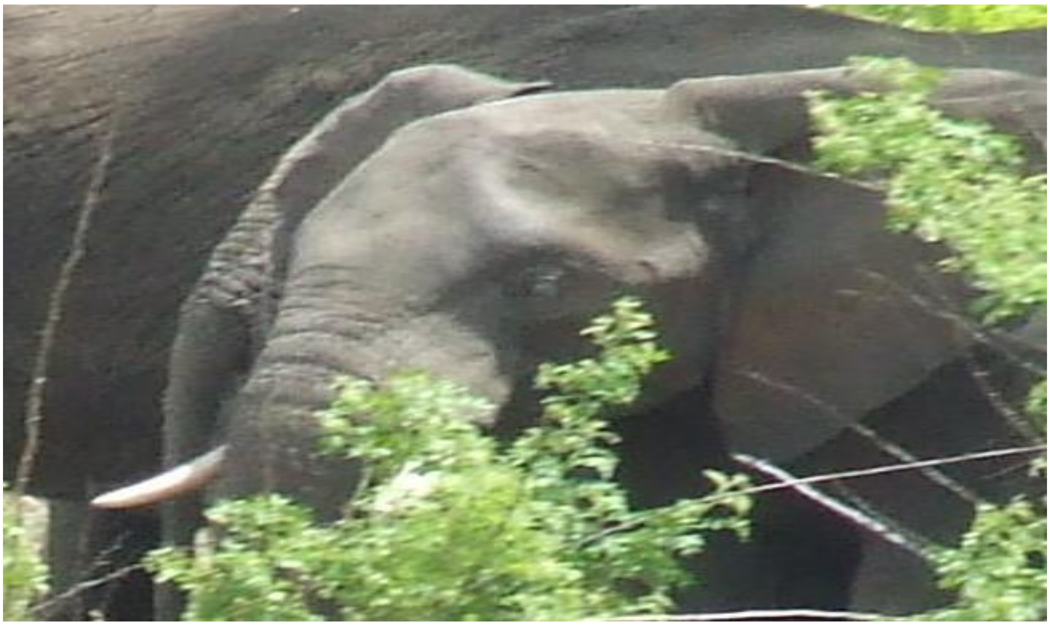
Plate 11: Side view of the body, size and ear shape of an adult bull elephant

(Source: Author, 2010)

Plate 12: Side view of the head shape and tusk size of an adult female elephant

(Source: Author, 2010)

Plate 13: Front view and ear shape of young male elephant at the buffer zone



(Source: Author, 2010)

Plate 14: Front side view of the head and tusk shape of a female elephant

(Source: Author, 2010)

Plate 15: Young calf in close association with an adult female elephant

(Source: Author, 2010)

Plate 16: Side view of a young male in close association with an adult female Elephant

Unlike male elephants, females are closely associated with their young calves most of the times, thus an elephant occurring in such a close relationship with a calf is likely to be a female (Plates 15 and 16). Sub-adult males are commonly found alone at varying distances from the family groups upon reaching 12 years of age (Poole, 1996). Photographs of the heads, ears and tusks of elephants were also taken using a digital camera and used as an additional aid for sexing and ageing elephants (Croze, 1972). These photographs were later loaded on to a computer for further analysis. These general behavioural and morphological features of elephants were used to differentiate between sexes of elephants.

3.2.4.4 Elephant mortality

Data on elephant mortality were obtained by counting carcasses encountered in the field (Plates 17 and 18). Although it was difficult to establish the specific age classes that had been affected, rough estimations of their sexes and age were made based on bone size and other distinguishable features. Additional information on elephant mortality was obtained from secondary sources such as past NNP reports and information gathered from the deputy park wardens.

(Source: Author, 2010)

Plate 17: Fresh carcass of a dead elephant found inside the park

(Source: Author, 2010)

Plate 18: Old carcass of an adult elephant found inside the park

3.3. Data analysis

Raw data gathered from transect surveys were loaded into MS excel spreadsheets for further management and analysis. For statistical analysis, transect survey data were prepared as data-files (including data on perpendicular distances and numbers of transects surveyed) and fed into program DISTANCE version 6.0 (Thomas *et al*., 2009). The analysis aimed at obtaining the population size and/or density of elephants in NNP and buffer zone. The program "DISTANCE 6.0" was preferred because of its wider application and flexible engine estimator for analyzing various forms of transects survey data. Descriptive and inferential statistics using chi-square test at $\alpha = 0.05$ level of significance was used to analyze and detect any differences.

The chi-square (χ^2) test for association between variables is given by the formula;

$$\chi^2 = \sum (O - E)^2 / E.$$

Where;

O = Observed value in each category,

E = Expected value in the corresponding category;

$\sum$ = Sum of the squared differences for each category $(O - E)^2$.

CHAPTER FOUR

RESULTS

4.1 Elephant population size estimate

A total of 178 elephants were cited during the survey. Of these 81 elephants were observed in NNP and 97 were in the buffer zone. Data was analyzed separately for each zone (i.e. NNP and buffer zone) and in combination using the program Distance. The elephant population estimates for NNP and the buffer zone were 134 (95% CI: 88-205) and 161 (95% CI: 90-291) respectively (see Tables 1 and 2). Results showed that there was no significant difference between the number of elephants in NNP and the buffer zone ($\chi2$= 1.438, df=1, p=0.23). The overall estimate of elephant population size in the study area was 295 (95% CI: 178-496) (see Table 3). Results further showed that there was a significant difference between the density of elephants in NNP and the buffer zone ($\chi2$= 40.6, df=1, p=0.000), and between the cluster density of elephants in NNP and the buffer zone ($\chi2$= 6.758, df=1, p=0.0032).

Table 1: Population size estimate of elephants in NNP in 2010

Parameters	Estimate	%CV	DF	95% Confidence Interval	
				Lower limits	Upper limits
DS	4.85	20.6	49.1	3.22	7.299
D	11.58	21.4	56.8	7.58	17.69
N	134	21.4	56.8	88	205

DS= density of cluster; D= density of individuals, N= population size estimate; %CV= percent coefficient of variation; DF = degrees of freedom.

Table 2: Population size estimates of elephants in the buffer zone in 2010

Parameters	Estimate	%CV	DF	95% Confidence Interval	
				Lower limits	Upper limits
DS	16.997	26.8	12.45	9.593	30.12
D	68.697	28.2	14.95	38.13	123.8
N	161	28.2	14.95	90	291

Table 3: Overall population size estimates of elephants in NNP and the buffer zone in 2010

Parameters	Estimate	%CV	DF	95% Confidence Interval	
				Lower limits	Upper limits
DS	21.84	47.4	61.42	12.81	37.465
D	80.28	49.6	71.73	45.71	141.468
N	295	49.6	71.73	178	496

4.2 Distribution of elephants

Of the 295 elephants, 54.5% were observed in the buffer zone while 45.5% were observed within Nimule National Park (Table 4). Elephants were observed in various vegetation types in NNP and the buffer zone. Within the park, more elephants were observed in the riverine woodland (45.5%) as compared to wooded grassland (35.1%) and bushed grassland (19.4%) as shown in Table 4. It appeared that elephants utilized the riverine habitats more than the other habitats within the park, but the difference was not significant ($\chi 2= 4.96$, df =2, p=0.161). These results indicated that the null hypothesis that the vegetation type has no effect in the distribution of elephants in NNP was accepted. The spatial distribution of elephants in the study area is shown in Figure 5.

Out of the four (4) transects laid in mixed woodland vegetation at the buffer zone, only 2 elephant observations were made along L1 and L3 transects. In contrast, no observation of elephants were made along transects L4 and L2. Within NNP, small groups of elephants were recorded in the riverine woodlands in 3 transects L5, L6 and L22. However, no elephants were observed in transects L21 and L23. In the wooded grasslands elephants were recorded in 4 transects L10, L11, L12 and L13, while none was observed in transects L7, L8 and L9. In the bushed grassland elephants were recorded in 2 transects L14 and L18, while no observations were made in transects L15, L16, L19 and L20. Hence, out of the 19 transects laid within NNP, elephants were observed and recorded in only 9 while no observations were made in the remaining 10 thus indicating that elephants did not utilize this area evenly.

Table 4: Distribution of elephants in various vegetation types in NNP and buffer zone in 2010

Study sites	Vegetation types	No. of elephants Estimated	Percentage (%)
NNP	Wooded grassland	47	15.9%
	Bushed grassland	26	8.8%
	Riverine woodland	61	20.7%
Buffer zone	Mixed woodland	161	54.6 %
Total		**295**	**100%**

4.3 Elephant population trend

As shown in Figure 6, the population estimates of elephant in NNP and buffer zone in 2000, 2004 and 2010 were 156, 125 and 295, respectively. The population nearly doubled between 2000 and 2010, indicating an overall increasing trend. However, the population more than doubled in the period between 2004 and 2010. The overall population estimates for the three census years were significantly different ($\chi2$ = 85.39, df =2; p=0.000). The decrease in elephants numbers between 2000 and 2004 was significant ($\chi2$ = 78.64, df =1; p=0.000). Therefore, the null hypothesis that the population size of elephants has remained the same over the last 10 years was rejected. The results showed

that the population size of elephants in NNP and buffer zone has increased significantly ($\chi2$ = 48.84, df =1; p=0.000) over the period between 2000 and 2010.

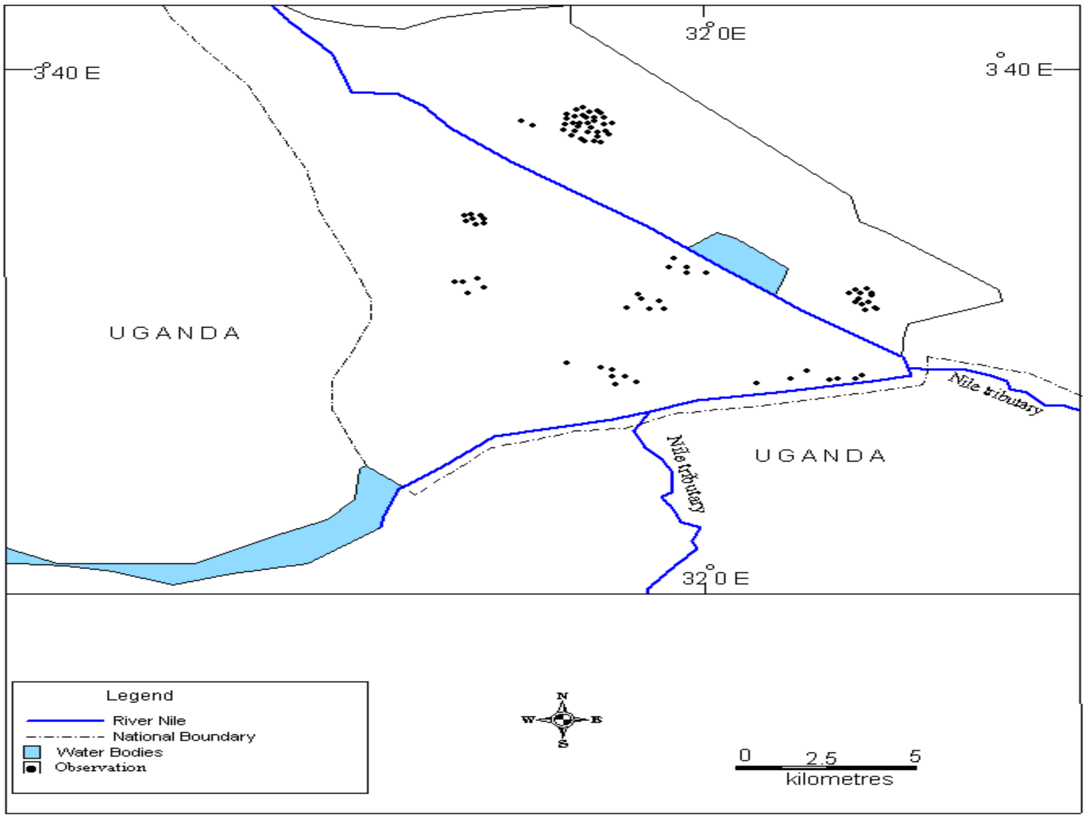


Figure 5: Distribution of elephants in NNP and buffer zone in dry season between January and April, 2010.

Data on elephant population estimates by Kenyi (1983), Abdullah (1987) and Grossmann *et al*., (2008) were not included in examining the trend of elephants in the study area. The results by Kenyi (1983) and Grossmann *et al*., (2008) were believed to be underestimates of elephant population as most elephant stayed out of the park occasioned by the effects of civil war and migration to their wet season range outside the park. The result by Abdullah (1987) was considered an overestimate of the population probably as result of overconcentration of elephants in NNP because of war in Uganda and surrounding areas (Morjan *et al*., 2000).

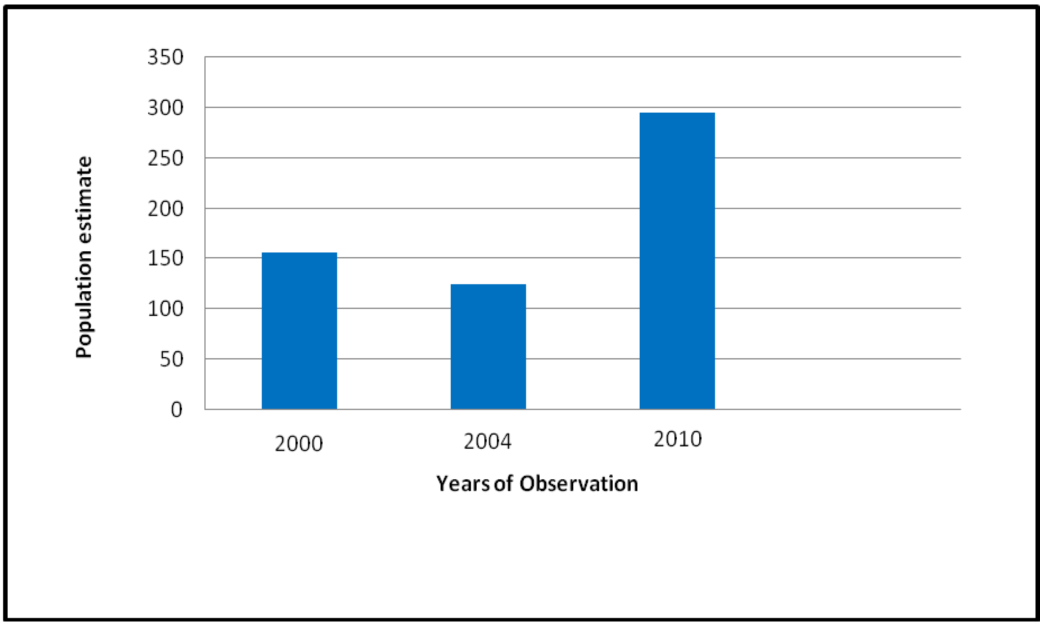


Figure 6: Elephant population trend in NNP and Buffer zone (2000 -2010)

4.4 Age and Sex structure of elephants in NNP and buffer zone in 2010

4.4.1 Age structure

As shown in Figure 7, the age structure of elephants in the study area was unstable. The overall distribution of the four age classes was significantly different ($\chi2$ = 42.48, df=3, p=0.000). The sub-adult elephants (age class 20-35 years) constituted the bulk of the population (36.5%) and the calves constituted the least (5.1%). The number of elephant calves and juveniles was significantly different ($\chi2$ = 24, df=1, p=0.000), as well as that between juveniles and sub-adult ($\chi2$ = 3.64, df=1, p=0.01). However, there was no significant difference between the number of sub-adult and adult elephants ($\chi2$ = 0.29, df =1, p=0.435).

The elephant calves were relatively closer to 6-9 years than 0-5 years. It is possible that smaller sized individuals (i.e. 0-5 years) could have been missed because of screening by tall grass and the large elephant groups, which moved in a compact manner (Plate 9). Therefore, the null hypothesis that the population age structure of elephants was not variable was rejected. These results showed that there was slow recruitment rate of young into the adult population. It was, therefore, concluded that the population of elephants in NNP was in the verge of a crush, since the recruitment rate of young individuals into the population was low.

4.4.2 Sex structure

The sex ratio of elephant population in NNP and buffer zone was expected to be unity or even and does not differ markedly from this as shown in Figure 7. The sex ratio of male (51.1%) to female (48.9%) elephants was not significantly different ($\chi2$ = 0.0898, df =1, p=0.764). Hence, it was concluded that the hypothesis that the sex ratio of elephants in NNP is unity or even was not rejected. There was no significant difference in the sex ratio of male and female in the calf age group ($\chi2$ = 0.12, df =1, p=0.655), indicating that the mortality rate was likely similar for this age group. The sex structure of juvenile age category showed no significant difference ($\chi2$ = 4.5, df =1, p=0. 0.51). The result further showed that the sex ratios between sub-adult and adult age group was not significantly different ($\chi2$ = 0.384, df =1, p=0.361) and ($\chi2$ = 0.153, df =1, p=0. 590) respectively.

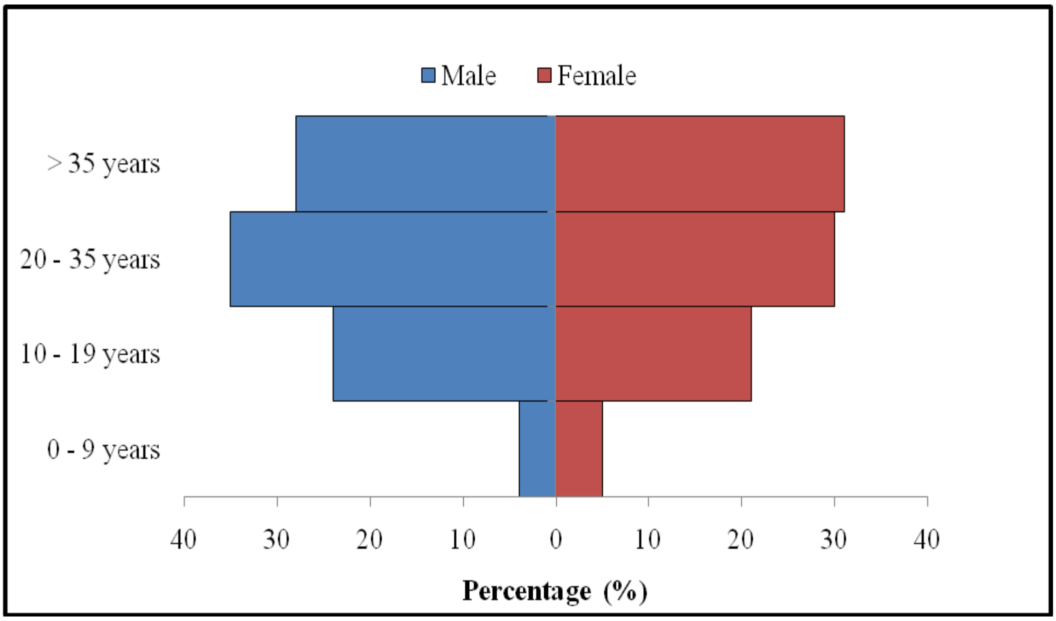


Figure 7: Age and sex structure of elephant population in NNP and the buffer zone in 2010

CHAPTER FIVE

DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

5.1 DISCUSSION

5.1.1 Elephant population size estimate

A total population of 295 elephants was estimated during the study. A comparison of the results of this study with data from previous studies conducted in NNP and buffer zone by Morjan *et al*., (2000; 2004) revealed that the overall population of elephants had significantly increased between 2000 and 2010. This increase could be attributed to varying effects of seasonality, poaching rates, effectiveness of law enforcement and availability of food plants. The season in which the survey was conducted may have coincided with the time when elephants migrate back to the park and as such a reasonably high count was obtained during the 2010 census. The 2010 estimate was however, lower than that of 817 elephants documented by Abdullah (1987).

There was a fairly lower rate of elephants poaching in the area between 2004 and 2010, resulting from effective anti-poaching operations that had reduced the death rate of elephants, and this may have also been coupled with recruitment of more adult individuals into the population. The effectiveness of law enforcement in the recent decades through foot patrols by wildlife forces based at Pajaala and Semu game posts which were established in the early 1950s and 60s inside the park may have increased thus reducing and crippling the illegal killing of elephants by poachers in the park, and as such more elephants have survived in the recent years.

Availability of food plants such as palm and acacia fruits in NNP in the dry season (Morjan *et al.*, 2004) may have attracted the elephants to the park during the study period. The palm and Acacia fruits provide essential and nutritious food sources to elephants in the dry season especially at a time when conditions and quantity of other food plants deteriorates outside the park (Morjan *et al.*, 2000). It could also be related to the political stability that has been experienced in the area after the signing of the CPA in 2005.

5.1.2 Distribution of elephants

Elephants were observed in all the vegetation types in the study area. This may be explained by the fact that elephants are known to be mixed feeders and utilize both graze and browse materials depending on their availability and conditions (Nowak, 1999). However, the distribution of elephants in the buffer zone may be more related to the increased security given to the elephants because it is closer to the Park Headquarters. The nearby River Onyama could also be another factor attracting the elephants to the buffer zones. Elephants are known to drink up to 100-220 liters of water daily and can travel over 12 Km to and from a water source (Moss, 1992; Stuart and Stuart 1996; Macdonald, 2001).

Although results indicated that vegetation types within NNP had no significant effects on the distribution of elephants ($\chi 2$ = 4.96, df =2, p=0.161), the relatively high number of elephants in the riverine woodland could be explained by the presence of Acacia trees and palm fruits which are found in this area. However, the lower number of elephants in the bushed grasslands could be due to lack of water. These bushed grasslands which cover half of the central part of the park have no water sources, and consequently have inadequate food to attract large elephant numbers.

The lower number of elephants in the bushy grasslands which are distributed in the north and western sides of the park may be explained by two major factors. First is that the northern portion of the park has difficult terrain, and secondly the northern and the western sides of the park experience high level of insecurity from poachers.

5.1.3 Elephant population trend

Results indicated that the number of elephants had slightly declined from an estimated 156 in 2000 to 125 in 2004, but significantly increased to about 295 in 2010, thus nearly doubling in size. The most plausible reasons for the decline or lower estimates of elephants in 2004 could be attributed to seasons, civil war and analytical methods used. These factors may have affected the 2004 elephant population estimates in NNP in various ways (Morjan *et al.*, 2004).

There may be seasonal differences in the exact time the census were conducted in the 3 time periods. State anarchy that prevailed during the war times increased poaching of elephants within the country thereby affecting their population. It is also possible that the statistical analysis programs used in 2004 had different model estimators, applications and capacities as compared to "DISTANCE" programme used in 2010, thus resulting to variations in population estimation.

5.1.4. Age structure

The overall picture of the age structure of elephant populations in the study area was generally unstable. The age structure of elephants (Figure 7) showed an inverted pyramid in which the older age classes (i.e. adults and sub-adults were much larger than the younger age classes (young and juveniles). The low number of young calves (0-9 years) could imply that the reproductive rate of the population was slow which could possibly be attributed to declining habitat condition and suitability for reproduction.

Alternatively, if indeed the adult females produce young, the young born die early. Such early deaths of young could be attributed to predation, e.g. by crocodile at drinking points (Morjan *et al.*, 2004), and death of mother elephants killed by poachers (Lt. Col. Charles A. deputy warden, Pers. Com., 2010). Elephants are slow breeders, with an inter-birth interval of 2.5-9 years or may average 5 years (Nowak, 1999). The long calving interval could have contributed to the low number of young individuals represented in the population of elephants in NNP ecosystem.

According to Ogola (2003), late maturity of females coupled with low reproductive rate could possibly be one of the factors that limit the population growth of elephants. Studies of elephant populations have shown that elephants appear to have a built-in birth control system and flexibility in reproduction (Nowak, 1999). Such intrinsic birth control mechanisms operate in several animals, such as wild horses, during periods of stress as a result of low food availability and harassment (Berger, 1983).

It is a fact that the elephants in NNP have faced serious challenges of drought and disturbance by human activities, especially during the protracted civil war. There are significant differences in reproductive parameters between elephant populations, and these differences can lead to profound differences in numbers of calves born in the population. For example, the age of sexual maturity for females may be delayed and the average interval between the births of calves can be lengthened under an adverse habitat conditions and at high elephant population density, simply due to low quality of food supply coupled with high grazing competition (Moss, 1988; Moss, 1992) to the extent that the population will decrease over time (Stuart and Stuart 1996; Nowak 1999).

The highly significant difference between the different age classes of elephants was not unexpected. Generally, in a normal population, the young and juvenile categories are usually larger than older categories, particularly in short-lived species (Pauly, 1985). However, in long-lived species such as the elephants, older individuals may be more than the young individuals since adults have a very low mortality after reaching sexual maturity. Unless killed by poachers, once elephants attain sexual maturity at about 12 years (Moss and Laws, 1988), they have lower mortality rates. This may explain the relatively larger number of elephants in the sub-adult and adult categories. However, in a normal age structure of elephant population (Ogola 2003), the number of young calves is expected to be more than the adult individuals in the population.

5.1.5 Sex structure

The sex ratio for all age categories was generally unity, which was in perfect agreement

with results of studies by Moss (1988). The results also showed that the overall sex ratio of elephants in the population were nearly similar among different age categories. Several factors are attributed to such similarity in the sex ratio in elephants as reported in different studies. These pertain to similar mortality rates for calves in their first year as indicated by case studies in South Africa (Whitehouse and Kerley, 2002), but thereafter male mortality rates are higher than those of females in all age classes.

It has been reported that half of all elephants of both sexes die before they reach the age of 15 (Stuart and Stuart, 1996). This could also explain the nearly similar proportion of females and males calves in the overall population in NNP. Several studies have also reported that the sex ratios of calves are unity. Studies in Amboseli (Kenya) from 1978 - 1980 have showed that there were no significant difference in the sex ratio of newborn calves, with a total of 50 males and 49 females being born (Moss, 1988). Also studies in conducted in Addo Elephant National Park in South Africa from 1954 - 1998 showed that the overall sex ratio of newborn calves did not differ significantly from 1:1 (157 males, 163 females) (Whitehouse and Kerley, 2002).

Further, a study by Nowak (1999) showed that majority of adult cows died of natural causes, while another study by Whyte *et al* (1998) suggested that between 2.5 - 5% of the females of all age categories in an elephant population die each year. These deaths among different age groups of females could explain the relatively few females in the overall elephant population in NNP. Except through poaching, the primary cause of death among adult bulls is intraspecific fighting, and several cases of deaths due to fighting have been witnessed in several occasions in NNP (Lt. Col. Charles Alexander, deputy park warden, Per. Comm., 2010). Thus, death among different sex and age groups could explain the relative similarities or balance in the sex ratio of males to females in the population of elephants in NNP.

5.2 CONCLUSIONS

The population size of elephants in the southern parts of NNP and buffer zone was estimated at 295 animals. Further, elephants were found in all the vegetation types in the study area.

In the buffer zone the distribution of elephants are largely affected by presence of people who inhabit this area and also security that is provided by presence of the Park Headquarters in the area. In addition, riverine woodlands and mixed woodlands vegetation attracted more elephants as compared to bushed grassland and wooded grassland.

The overall sex ratio of the elephant population in the study area was unity (i.e. one male to one female). Despite this, the age structure of elephant population in NNP is unstable, and there was lower recruitment of young individuals into the population.

5.3 RECOMMENDATIONS

5.3.1 Management and policy recommendations

The conservation and management of elephant population could be improved by:

1. Increasing the number of wildlife managers and game outposts along western and northern boundaries of the park to provide security for elephants and other wildlife species.

2. The Governments of South Sudan and Uganda need to initiate and strengthen the existing trans-boundary conservation program to provide protection for the migratory elephants.

3. The Government of South Sudan through the Ministry of Wildlife Conservation and Tourism need to establish and develop an effective law enforcement mechanism to control the illegal trafficking of elephant products, and also regulate the illegal entrance of humans into the park.
4. Increase funding and support from government, private sectors and other stakeholders (Conservation NGOs) to improve the management system of NNP that would ensure the survival of the remaining elephant populations.
5. Improving the road networks within NNP and buffer zone to facilitate mobility of security personnel (wildlife forces) and thus enhance security.
6. Re-demarcating the park boundaries, including the buffer zones, to define critical zones for elephant habitats and migratory corridors.

5.3.2 Recommendations for further research

1. There is need for further studies in the following areas (i) factors that influence the movement of elephants in and outside the park and to Otze forest reserve in Uganda (ii) factors affecting the distribution of elephants in NNP and buffer zone and (iii) factors that cause change in elephant population structure in NNP so as to provide baseline information for management purposes.

2. When the whole ecosystem will enjoy peace and stability, there is a need for studies to be conducted both in wet and dry seasons so as to have a complete picture of the annual distribution patterns of elephants in the Nimule elephant migratory range.

REFERENCES

Anderson, D.R., J. L. Laake, B. R. Crain., and K. P. Burnham. (1979): Guidelines for line transect sampling of biological populations. *Journal of Wildlife Management. Vol. 43: pp 70-78.*

Abdullah, R.Y. (1987). Wildlife Research Report in Nimule National Park, Directorate of Wildlife Conservation and National Parks forces. *Equatoria Region, Juba, File No.31.E.1/16. Unpublished Report*.

AfERSG (1989). African Elephant Status Report 1989. *In Pachyderm*, No-11. Report of the African Elephant Specialist Group, IUCN Species Survival Commission. Nairobi, Kenya.

AfESG (2004). IUCN/SCC African Elephant Specialist Group. Notes from the African Elephant Specialist Group on wild sourcing of African Elephant for Captivity. *In Pachyderm, No. 36.*

Blower, J. (1977). Wildlife Conservation and Management in the Southern Sudan; Project findings and Recommendations. Food and Agricultural Organization of the United Nations, Rome.

Barnes, R. F. W., and I. Douglas-Hamilton. (1982). The numbers and distribution patterns of large mammals in the Ruaha-Rungwa area of southern Tanzania. *Journal of Applied Ecology*. *19:41 1- 425.*

Berger, J. (1983). Induced abortion and social factors in wild horses. *Nature* 303, 59 – 61.

Buckland, S.T., Anderson D.R., Burnham, K.P., and Laake, J.L. (1993). Distance sampling: estimating abundance of biological populations. London: Chapman and Hall.

Berger, J. (1997). Population Constraints Associated with the use of black rhinos as an umbrella Species for Desert herbivorous. *Conservation Biology,* 11:73

Burnie, D., and Wilson (2001). Animal. Smithsonian Institution, DK publishing, Inc, NY, USA.

Buckland, S.T., D. R. Anderson, K. P. Burnham, J. L. Laake, D. L. Borchers, and L. Thomas. (2001). Introduction to Distance Sampling, Oxford University Press, Oxford, UK.

Blanc, J.J., C.R. Thouless., J.A. Hart., H.T. Dublin., I. Douglas-Hamilton., G.C. Craig and R.F.W. Barnes, (2002). African elephant status report 2002: An update from the African Elephant Database. Occasional Paper of the IUCN Species Survival Commission *No. 29.* IUCN, Gland.

Blanc, J.J., R.F.W. Barnes, G.C. Craig, H.T. Dublin, C.R. Thouless, I. Douglas-Hamilton and J.A. Hart (2007). African elephant status report: An update from the African Elephant Database. IUCN, Gland.

Croze, H. (1972). A modified photogrammetric technique for assessing age-structures of elephant populations and its use in Kidepo National Park. *East Africa Wildlife Journal. 10, 91–115.*

Corfield, T.F. (1973). Elephant mortality in Tsavo National Park, Kenya. *East Africa Wildlife Journal. 1, 339-368.*

CITES (1989). Terms of Reference for the Panel of Experts on the African Elephants and Criteria for the Transfer of Certain African Elephant populations from Appendix I to Appendix II. COP 7, Lausanne, 1989.

Douglas-Hamilton, I. (1972). On the ecology and Behavior of the African elephant. Ph.D. Thesis University of Oxford, UK.

Douglas-Hamilton, I. (1979). African Elephant Ivory Trade. Final Report to US Fish and Wildlife Service. Department of interior, Washington, DC.

Douglas-Hamilton, I., R. Malpas, E. Edroma., P. Holt, G. Laker-Ajok., and R. Weyerhaeuser. (1980). Elephant and wildlife survey, Uganda. Uganda Institute of Ecology. Report to WWF.

Dublin, H.Z., and Douglas-Hamilton, I. (1987). Status and trends of elephants in the Serengeti- Mara ecosystem. *African Journal of Ecology. 25, 19-33.*

Douglas-Hamilton, I. (1989). Overview of status and trends of the African elephant. In The ivory trade and the future of the African elephant (Cobb, S. ed.). Ivory Trade Review Group, International Development Center, Oxford, U.K.

Douglas-Hamilton, I. (1992). The Status of Kenya's elephants, 1992. A report by the Kenya Wildlife Service and the Department of Resource Surveys and Remote Sensing. *Typescript*, Nairobi-Kenya.

Douglas-Hamilton, I., Michelmore. F., and Inamdar, A. (1992). African Elephant Database. UNEP: Nairobi, Kenya.

Douglas-Hamilton, I. (2009). The current elephant poaching trend. *Pachyderm* 45: *pp* 154-157.

Eco-Systems Ltd. (1980). The status and utilization of wildlife in Arusha Region, Tanzania. Final Report. *88 pp.*

Giles, R. (1974). Wildlife management techniques. The Wildlife Society,Washington, D.C.

Grossmann, F., Elkan, P.Awol, P.P. and Penche, M.C. (2008). Aerial Surveys of Wildlife, Livestock, and Human Activity in and around Existing and

Proposed Protected Areas of Southern Sudan, Dry Season 2008. Technical Report 2. WCS in partnership with the Ministry of Wildlife Conservation and Tourism of the Government of Southern Sudan.

GOSS (2009). Laws of Southern Sudan, Wildlife Conservation and Management Bill, 2009. Draft No. 3, WCS in Partnership with the Ministry of Wildlife Conservation and Tourism, Juba, *S*outh Sudan.

Hayes, R.J., and Buckland, S.T. (1983). Radial - distance models for the line-transect method. *Biostatistics* 39, 29-49.

Hillman, J. C. (1985). Wildlife Research in the Sudan in Relation to Conservation and Management. Khartoum, Sudan.

Hedges, S. (2006). Conservation. In Biology, Medicine, and Surgery of Elephants. Fowler, M.E. and Mikota, S.K. (eds.), Blackwell Publishing, Ames, Iowa, USA.

Kenyi, J. M. (1983), Wildlife Research Report on Nimule National Park. Directorate of Wildlife Conservation and National Parks Forces. Equatoria Region, Juba, File No. 31.E 1/16, Unpublished Report.

Kangwana, K. (1996). Studying Elephants. Technical Handbook Series 7. African Wildlife Foundation, Nairobi, Kenya. A published Report.

Kwaje, J. William, P., Daniel, A., and Mark, J. O. (2002). The Impact of Conflict on Nimule National Park: A Survey on the Food Security Situation, University of Missouri and Maryland Eastern shore. *A published Report*.

Kingdon, J. (2003). The Kingdon Field Guide to African Mammals. New Edition, A & C Black Publishers Ltd, UK.

KWS (2011). Elephant Population in Upward Trend in Tsavo/Mkomazi Ecosystem. KWS, Nairobi, Kenya.

Lebon, J. H. G. (1965). Land use in Sudan: Geographical Publications Ltd. Bude, Cornwall, England.

Laws, R.M. (1966): Age criteria for the African elephant, Loxodonta africana. *East African Wildlife Journal 4: 1-37.*

Laws, R. M., and Parker, I. S.C. (1968). Recent studies on elephant population in east Africa. In Comparative Nutrition of Wild Animal (Ed. M.A Crawford*), Academic Press*, New York.

Laws, R.M., and Parker, I. S.C. (1975). Elephants and their Habitats: The Ecology of Elephants in North Bunyoro, Uganda. Clarendon Press, Oxford.

Lindeque, M. (1991). Age structure of the elephant population in Etosha National Park, Namibia, Madoqua. *18, 27-32.*

Lee, P.C., and Moss, C. J. (1995); Statural growth in Known age African elephants (*Loxodonta africana*). *Journal of Zoology. 236, 29-41.*

Leimgruber, P., Gagnon, J.B., Wemmer, C., Kelly, D.S., Songer, M.A., and Selig, E.R. (2003). Fragmentation of Asia’s remaining Wildlands: Implications for Asian elephant conservation. *Animal Conservation 6: 347-359.*

Maglio, J.M. (1973). *Origin and evolution of the Elephantidae*. Transaction of the American Philosophical society *63, 1-149.*

Mefit-Babtie, M. R. (1983).Technical assistance Contract for Range Ecology, Livestock Investigation and Water Supply, Final report. Glasgow, UK. Rome. Italy, Khartoum – Sudan.

Moss, C.J., and Poole, J.H. (1983). Relationships and social structure In African elephants. In Primate Social Relationship. An Integrated Approach. (Ed. R.A. Hinde). Blackwell Scientific Publications, Oxford, UK.

Moss, C.J. and Laws, R. M (1988). Elephant Memories. Thirteen years along the life of an elephant family. William Morrow and Company, New York.

Moss, C.J. (1992). Some Reproductive Parameters in a population of African Elephants Loxodonta africana. Pro. Second Int. Conf. on Human and Animal Reproduction. Nairobi, Kenya, May 1992, Amboseli Accords.

Menon, V., Sukumar, R., and Kumar, A. (1997). A God in distress: threats of poaching and the ivory trade to the Asian elephant in India. Bangalore: Asian Elephant Conservation Centre. New Delhi: Wildlife Protection Society of India.

Morjan, M. D., Ojok, I. L., Maker, J. Ackwoch, A., Kamdalla, J., and Nicholas, B.(2000) A pilot survey of Nimule National Park. A published report by New Sudan Wildlife Authority (NSWA), New Sudan.

Macdonald, D. (2001). The New Encyclopedia of Mammals. Oxford University Press, Oxford.

Morjan, M. D., Benneth, B. Nicholas., Seme, I., and Lam, J. (2004). The Impact of War on Nimule National Park – Survey No. 2. The New Sudan Wildlife Conservation Organization, New Sudan, Unpublished Report, Sudan.

Norton-Griffiths, M. (1978). Counting Animals, Handbooks on techniques currently used in African wildlife ecology. No.1.(Ed.J.J.R. Grimsdell), African Wildlife Leadership Foundation. Nairobi, Kenya.

Olivier, R. (1978). On the ecology of the Asian elephant. Ph.D. Thesis, University of Cambridge, Cambridge. UK.

Noordwijk, V. M. (1985). Ecology Textbook for the Sudan. Grafische Kring Groningen, Netherlands.

Nowak, R.M. (1999). Walker's Mammals of the World. The John Hopkins University Press, Baltimore and London.

Ottichilo, W.K. (1987). The census of the recent heavy elephant mortality in Tsavo Ecosystem, Kenya. 1975-80. *Biological Conservation. 41, 279-289.*

Ogola, P.O. (2003). Demographic Status of the Meru Elephants; A final Report to the Elephant Research Fund/ KWS and Save the Elephants, Nairobi - Kenya.

Osborn, F.V., (2004). The concept of home range in relation to elephants in Africa. *Pachyderm No.* 37, 37–44.

Omondi, P., Mayienda, R. and Tchamba, M. (2007). Total Aerial Count of Elephants, Giraffes, Roan Antelopes and other Wildlife Species and Ostrich in Waza National Park, Cameroon. Unpublished report. WWF Central Africa Regional Office.

Pauly, D. (1985). The Population Dynamic of Short-lived Species, with Emphasis on Squids. NAFO Sci. Counc. Studies (9) pp 143-154.

Poole, J.H. (1989). The effects of poaching on the age structures, social and reproductive patterns of selected East African elephant populations. In The Ivory Trade and the Future of the African Elephant. Vol. II Technical Reports. Prepared for the 7th CITES Conference of the Parties. Nairobi, Kenya, pp. 1-73.

Poole, J.H. (1996). The African Elephant. In Studying Elephants, Kadzo Kangwana (Ed.). African Wildlife Foundation, Technical Handbook Series 7: pp.1-8.

Sudan Government (1935): The Preservation of Wild Animals Ordinance 1935 and the Game Regulations 1935. Amended up to 31st December 1953. Issued as a Supplement for Sudan Government Gazette No. 622 dated 15th December, 1935: 29 pp.

Sheldrick, D.L.W. (1976). Report on Poaching in the Tsavo National Park. Manuscript Report, Nairobi, Kenya.

Somme latté, M., & Somme latté, H. (1990). A field guide to the trees and shrubs of the Imatong Mountains southern Sudan. Nairobi: Deutsche Gesellschaft fuer Technische Zusammenarbeit (GTZ).

Sukumar, R. (1990). Ecology of the Asian elephant in southern India. II. Feeding habits and crop raiding patterns. *Journal of Tropical Ecology*, Vol. 6: pp 33-53.

Said, M.Y., Chunge, R.N., Craig, G.C., Thouless, C.R., Barnes, R.F.W., and Dublin, H.T., (1995). African elephant database 1995. Occasional Paper of the IUCN Species Survival Commission 11. IUCN, Gland, Switzerland.

Sukumar, R., and Santiapillai, C. (1996). *Elephas maximus*: status and distribution. In Shoshani, J., and Tassy, P. (eds.) The Proboscidea: Evolution and Palaeoecology of Elephants and Their Relative. Oxford University Press, Oxford. Stearns, S.C. (1992). The Evolution of Life Histories. Oxford University Press, Oxford,UK.

Stuart, C., and Stuart, T. (1996). Field Guide to the Larger Mammals of Africa. Struik Publishers, Cape Town, South Africa.

Sukumar, R., Ramakrishnan, U., and Santosh, J.A. (1998). Impact of poaching on an Asian elephant population in Periyar, southern India: a model of demography and tusk harvest. *Animal Conservation*, Vol. 1, pp 281-291.

Sinclair, Ian., and Ryan, P. (2008). Birds of Africa South of the Sahara: A comprehensive illustrated field guide (Paperback). Random House Struik publishers, Chamberlain, Amazon.

Spawls, S., Howell, K., Drewes, R., and Ashe, J.(2004). A Field Guide to the Reptiles of East Africa: Kenya, Tanzania, Uganda, Rwanda and Burundi, Christopher Helm Publishers Ltd, UK. 544 pages.

Steel, L. (2007). Salonga-Lukenie-Sankuru Landscape Summary Results of WWF Biological Surveys: 2006 – 2007. Unpublished Report. WWF-DRC.

Sukumar, R. (2003). The living Elephants; Evolutionary Ecology, Behavior, and Conservation. Oxford University. Press, Oxford, UK.

Thomas, L., Laake, J.L., Strindberg, S., Marques, F.F.C., Buckland, S.T., Borchers, D.L., Anderson, D.R., Burnham, K.P., Hedley, S.L., Pollard, J.H., Bishop, J.R.B., and Marques, T.A. (2009). Distance 6.0. Release 2. Research Unit for Wildlife Population Assessment, University of St. Andrews, UK.

Whitehouse, A.M. and G.I.H. Kerley (2002). Retrospective assessment of long-term conservation management of elephants in Addo Elephant National Park, South Africa. *Oryx* 36(3), 243–248.

Whyte, I.J., Van Aarde, R., and Pimm, S.L. (1998). Managing the elephants of Kruger National Park. *Animal Conservation* 1: 77-83.

LIST OF APPENDICES

Appendix I: Data collection form (sheet)

Place/Name:	
# Transect Walked:	Date:
Start Time:	End Time:
Observer name(s):	

Time	WPT	Species Name:	Age & sex structures of elephants								# of animals counted	Group Size	Sighting distance (m)	Sighting angles (°)	Vegetation Types	Activity	Photos ID	Remarks
			Adult		Sub-adult		Juvenile		Calf									
			M	F	M	F	M	F	M	F								

Appendix II: Guideline for ageing elephants (Kangwana 1996, Laws 1966)

10 AND ABOVE - SUGGESTED AGE CLASSES FOR FEMALES	
10-15 years	Thin tusks, probably still splayed rather than convergent; more square in body shape than older females who are rectangular.
15-20 years	Tusks begin to take on their adult configuration, that is convergent, straight, or asymmetrical with one higher than the other.
20-35 years	Circumference of tusks at base distinctly bigger than teenaged females.
35-50 years	Tusks marginally thicker; back has lengthened so that animal appears long in body.
Over 50 years	Hollow above the eyes, ears held lower, longer back length, sometimes long tusks.

10 AND ABOVE - SUGGESTED AGE CLASSES FOR MALES	
10-15 years	Male head shape (sloping rather than angular) more noticeable; tusk circumference and shoulder height greater than females of same age.
15-20 years	At about 17 years old males reach same height as largest adult females over 40.
20-25 years	Taller than all adult females; but most still slender and narrow in the head compared to older males.
25-40 years	At about 25 years old male head shape has changed to an hour glass shape, that is wide at eyes and wide at base of tusks; the head gets broader as it moves through this age class; shoulder height increases steadily.
Over 40 years	Very big, tower over largest females by three feet or more at shoulder; neck thick; overall body heavy set; tusk circumference at lip strikingly greater than younger males and all females.

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Over 40 years	Very big, tower over largest females by three feet or more at shoulder; neck thick; overall body heavy set; tusk circumference at lip strikingly greater than younger males and all females.

Appendix III: Species of mammals found in Nimule National Park

English Names	**Scientific Names**
Aardvark	*Orycteropus ocycteropus afer*
African rabbit	*Poelagus marjorita*
African Crested Procupine	*Hystrix cristata*
Baboon	*Papio anubis*
Common Duiker	*Sylvicapra grimmia*
Civet cat	*Viverra civetta*
Elephant	*Loxodonta africana*
Hippopotamus	*Hippopotamus amphibius*
Oribi	*Ourebia ourebi*
Patas monkey	*Cercopithecus patas*
Rock hyrax	*Procavia capensis*
Serval-cat	*Felix serval*
Ugandan Kob	*Kobus kob (Thomasi)*
Vervet monkey	*Cercopithecus aethiops*
Warthog	*Phacochoerus* aethiopicus

Source: Kingdom, 2003

Appendix IV: Species of some birds found in NNP

English Names	Scientific Name
Abyssinian Roller	*Coracias abyssinicus*
African Jacana	*Actophilornis africanus*
African Mourning Dove	*Streptopelia decipiens*
African Grey Horn-bill	*Tockus nasutus*
African Fish Eagle	*Haliaeetus vocifer*
African Mourning Dove	*Streptopelia decipiens*
African Green pigeon	*Treron calvus*
Common Bulbul	*Pycnonotus barbatus*
Egyptian Goose	*Alopochen aegyptiaca*
Grey-headed Kingfisher	*Halcyon leucocephala*
Goliath heron	*Ardea goliath*
Glossy Ibis	*Plegadis facinellus*
Hadada Ibis	*Bostrychia hagedash*
Long tail Cormorant	*Phalacrocorax africanus*
Malachite Kingfisher	*Alcedo cristata*
Purple heron	*Ardea urpea*
Red-billed Quelea	*Quelea quelea*
Ring-necked Dove	*Streptopelia capicola*
Sacred Ibis	*Threskiornis aethiopicus*
White breasted cormorant	*Phalacrocorax lucidus*

Source: Sinclair and Ryan (2008)

Appendix V: Species of Reptiles and Snakes found in NNP

English Names	Scientific Names
Battersby's Green Snake	*Philothamnus battersbyi*
Monitor lizard	*Varanus exanthematicus*
Nile crocodile	*Crocodylus niloticus*
Python	*Python sibae*
Red-headed Rock Agama	*Agama agama*
Rainbow Skink	*Mabuya margaritifer*
Western forest Egg-eater	*Dasypeltis fasciata*

Source: Spawls, S, *et al*, 2004

Appendix VI: Tree species found in NNP

English Names	**Scientific Names**
African fan palm	*Borassus aethiopum*
Black-galled acacia	*Acacia malacocephala*
Bush-willow	*Combretum collinum*
Christ thorn	*Ziziphus abyssinica*
Camel foot	*Piliostigma thonningii*
Desert date	*Balanites aegyptica*
Marula	*Sclerocarya birrea*
Paper bark thorn	*Acacia sieberiana*
Scented-pod acacia	*Acacia nilotica*
Silver cluster-leaf	*Terminalia species*
Sickle bush	*Dichrostachys cinerea*
Sausage tree	*Kigelia africana*
Tamarind tree	*Tamarindus indica*
Three-thorned acacia	*Acacia senegal*
Velvet bush willow	*Combretum molle*
White-thorn acacia	*Acacia hockii*
White raisin	*Grewia bicolor*

Source: Somme latté, M., and Somme latté H., 1990