ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATES STUDIES

Feeding Preference and Movement Patterns of the African Elephant (*Loxodonta africana*) and Vegetation Parameters in Babile Elephant Sanctuary, Ethiopia.

A Thesis Presented to the School of Graduate Studies, Addis Ababa University in Partial Fulfillment of the Requirement for the Degree of Master of Science in Biology (Ecological and Systematic Zoology)

By:

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DEDICATION

This work is dedicated to Prof. Jeheskel Shoshani (Hezy) and Dr. Zahoor Kashmiri who lost their lives while working to save elephants of Ethiopia. May the Almighty God rest their soul in his right including my departed grandmother.

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ABBREVIATIONS AND ACRONYMS

AAU	Addis Ababa University
asl	Above sea level
BES	Babile Elephant Sanctuary
DBH	Diameter at Breast Height
DMD	Daily movement distance
DMR	Daily movement range
EHZPEDO	East Hararge Administrative Zone, Planning and Economic Development Office
EWCO	Ethiopian Wildlife and Conservation Organization
EWNHS	Ethiopian Wildlife and Natural History Society
GIS	Geographic information systems
GPS	Geographic positioning systems
MCP	Minimum convex polygon
MMD	Monthly movement distance
SPSS	Statistical Package for Social Science

ABSTRACT

Seasonal dietary composition, feeding preference and movement patterns of elephants were studied in Babile Elephant Sanctuary (BES) from August 2008 to April 2009. Elephants eat fruits and other parts of 75 plant species (61 wild and 14 cultivated). Data on fresh feeding signs either browsed or barked showed 51 species, while an examination of elephant dung piles yielded seeds representing 21 species of which seven of them were not seen in diet observation in the field. Browse accounted larger proportion of forage in the diet of elephants during both seasons, *Acacia* species being the most important component of the diet. Using direct diet assessment observations over two seasons dietary preferences were calculated. The strongest preference was for *Acacia robusta* and *Opuntia ficus-indica*, while elephants exhibited a selective avoidance for the other important species in the diet including *Combretum molle* and *Grewia flavescens*. Three elephant bulls were fitted with GPS telemetry collar in order to study home range and movement patterns. Although it is not statistically significant elephants showed relatively larger home range during the wet season than the dry season (mean=611.8 ± 142.2 km^2). Two distinct movement patterns were observed by the collared elephants in Babile both starting in a north to south direction. Elephants moved an average of 10 km per day which is considerably a lower distance in comparison with elephants in other parts of Africa. The average daily movement range of the bulls was 20 km^2 which is about 3.3% of their total home range. They used about 20% of their home range outside the Sanctuary boundary in the north and south-west direction. The restricted movement patterns and home range of the elephants need immediate conservation measures.

Key words: Dung pile, GPS, home range, movement patterns, preference, telemetry.

I. INTRODUCTION

Ethiopia is gifted with diverse biological resources. The diversity in wildlife is mainly because of the diversity in habitats, climate and different topographic ranges. For this reason, the country is considered among the biodiversity rich nations in the world (Zemede Asfaw, 2001). Even though, the country is rich in biological resources, most of the wildlife has been threatened to varying degrees (Yalden *et al*., 1986; Yirmed Demeke *et al.*, 2006). Today, most of the wildlife is mainly restricted in conservation areas such as national parks, wildlife reserves, forest areas and sanctuaries. Babile Elephant Sanctuary (BES) is one of these conservation areas aimed at protecting ecologically distinct elephant species (*Loxodonta africana,* Blumenbach, 1797), in the eastern part of the country (Hillman, 1993; Barnes *et al*., 1999: Yirmed Demeke, 2008).

Both Asian and African elephants are the only surviving members of the Order Proposcidea. These two species remain important in terms of conservation efforts through out their range. However, their population has declined due to drought, loss of habitat associated with increased human population, desertification, and poaching for ivory (Hoare and Toit, 1999; Feldhamer, 2007). The habitat of African elephants has been shrinking ever since humans began cultivating wilderness areas, often encroaching into habitats designated to wildlife (Shoshani *et al*., 2000). As human population increased in Africa, large areas were cleared for agricultural purposes and the range of elephants became fragmented and more confined to restricted sites such as parks and reserves. African elephants are in competition with people and protected areas are inadequate to ensure the survival of elephants, especially in arid and semi-arid areas, where elephants depend on resources and large space that are also used by people (Roux, 2006). Unable to migrate or disperse to a wider range, a growing population of elephants in a restricted area causes damage to its habitat (Poole, 1998; Stephenson, 2007).

Elephants play an important ecological role in savannah and forest ecosystems, helping to maintain suitable habitats for numerous other species (Stephenson, 2007). They are known as *keystone* species (Chapman *et al*., 1992; White, 1994; Blake, 2002). Elephants can be used as a source of income for national economy as well as local communities through tourism (Douglas-Hamilton *et al*., 2005). The functional niche of elephants is unique in terms of the highly catholic nature of diet and the spatial extent of the effective foraging zone (Dudley, 2000). Elephants digest less than half of what they eat; the rest passes through to nourish others, from micro-organisms to primates and other large mammals (Mubalama and Sikubwabo, 2002). For example, guinea fowls, francolins, banded mongoose and baboons are observed foraging on elephant dung piles (Dudley, 2000).

Fryxell and Sinclair (1988) stated the characteristic of the African savanna ecosystem showing spatial and temporal variations in resource availability that forces the wildlife to move to where food and water can be obtained. Understanding ecological parameters that influence animal distribution can provide insight into which areas are important for that animal population (Foley, 2002). The aim of the present study is to investigate seasonal variation in feeding preference and movement patterns of elephants in BES.

1.1. Background and Problem Statement

African elephants (*Loxodonta africana*, Blumenbach, 1797), the largest living terrestrial mammals (Feldhamer, 2007), are generalist herbivores relying on widely distributed resources (Osborn, 2005; Archie *et al*., 2006; Wittemyer *et al*., 2007). They are extraordinarily manipulative mammalian megaherbivores, as they are mixed feeders, ingesting grass, leaves and branches (Owen-Smith, 1992; de Boer *et al*., 2000; Dudley, 2000; Codron *et al*., 2006; Stephenson, 2007). Elephant food items include bark, fruits, leaves and stems, with flowers and fruits consumed when available (Rode *et al*., 2006; Feldhamer, 2007). The forest elephant also feeds on a wide variety of tree fruits (Dudley, 2000; http://www.animalinfo.org). But they can be very specific about which parts of a plant they feed and when (Taylor, 1978; Osborn, 2004). In order to satisfy this need, African elephants are highly mobile with large home ranges (Jackson and Erasmus, 2005; Galanti *et al*., 2006).

Although the African elephants are known to be generalist herbivores (Wittemyer *et al.*, 2007), little is known about the diet composition and feeding preference of elephants in Ethiopia and particularly in BES. The movement patterns of elephants based on resource availability varies on a spatial scale. Human encroachment and shifting land use within and around the boundaries of the Sanctuary are the main causes that reduce the availability of potential forage and space required by the elephants (Anteneh Belayneh, 2006; Zelalem Wodu, 2007; Yirmed Demeke, 2008). Conversion of habitats for biofuels industry is an increasing problem in Africa (Stephenson, 2007), and the same investment activity is also underway in BES. Any aspect of elephant management should be based on the surroundings and the quality of the habitat available for elephants in the adjoining areas (Sukumar, 2008).

It is important to understand what resources drive the distribution of elephants as this may be of relevance to understanding and managing their impact (Rode *et al.*, 2006). An understanding of resource requirement, ranging behaviour and seasonal movement patterns is important for effective conservation and management of elephants in protected areas. Little is known about elephant movements and patterns of habitat utilization in BES or the factors influencing them. Therefore, long-term monitoring of individual species (both the food tree species and elephants) is also required in order to establish the precise relationship between elephants and their diets, and to make management decisions.

Having poor conservation status, BES is faced with many threats attributed to an increase in human activities including intensive agricultural activities, incursions of large number of livestock, deforestation for fuel wood and construction, uncontrolled bush fires for charcoal production, investment for biofuel production and poaching (Hillman, 1993; Anteneh Belayneh, 2006; Zelalem Wodu, 2007; Yirmed Demeke, 2008). For example, investment activity between the Upper Erer and Gobelle Valleys of the Sanctuary, by Flora Ecopower industry, aimed at producing biofuel since 2007, is currently considered as one of the factors influencing the forage species as well as the movement patterns of the elephants in addition to the above factors (Plate 1). Uncontrolled human activities will ultimately result in considerable loss of biodiversity, hamper movements of large herbivores such as elephants and consequently intensify human–wildlife conflicts (Mpanduji *et al.*, 2002). Therefore, the present study aims at defining the dietary composition, preference and movement patterns of elephants at BES which will have a valuable input for-long term conservation of the species and the biodiversity of the area at large.

Plate 1. Caster bean farm after harvest by Flora Eco-Power industry in Upper Erer Valley (Yihew Biru, Nov. 2008).

1.2. Objectives

1.2.1. General Objective

This study aims at learning about the food preference and movement patterns of elephants within and outside BES.

1.2.2. Specific Objectives

ð To make a list of plant species mostly preferred by elephants,

ð To observe and collect data on seasonal changes in feeding preference of elephants,

ð To show the status of the various food plants browsed by elephants

ð To show the regeneration status of the various food plants browsed by elephants and

ð To study the movement patterns as well as home range of the elephants in both dry and wet seasons.

2. LITERATURE REVIEW

2.1. Conservation status of African elephants

Historically, the savanna elephant occurred South of the Mediterranean Sea until the Cape region wherever sufficient water and trees are available, but its range and numbers have shrunk as human population and poaching have increased (Taylor, 1978). Reports in 2006 indicate continental elephant population estimates of 472,269, of which east Africa constitute 29.1% (Blanc *et al.*, 2007). In east Africa, Tanzania contributes 80% with about 137,485 elephants and Ethiopia is listed in fourth place in the Region with a population of only 1,200 elephants (Yirmed Demeke, 2008). Profitable trade in Africa with the Middle East, China, India and, subsequently Europe, caused the drastic decline of African elephant populations through illegal ivory trade (Lee and Graham, 2006). Although elephant populations may at present are declining in parts of their range, ongoing increases in major populations in Eastern and Southern Africa (Blanc *et al.*, 2005), which together account for the large majority of known elephants on the continent, overshadow the magnitude of any possible decline in other regions (Blanc, 2008). Due to a number of factors, many of the African nations are unaware of the size, distribution and trends of their national elephant populations (Sharp, 1997).

However, conservation of the African elephants has faced particular challenges. Many range states do not have adequate financial or human resources, remoteness and inaccessibility of much of the species range and even civil unrest in some cases made difficult to protect these elephants (Stephenson, 2007). The decline of the African elephant can be linked with desertification, which was a major cause for the disappearance of the species in North Africa and the Sahara (Bere, 1966), killing elephants to satisfy the demand for ivory, which has been the major factor in reducing elephant populations throughout most of known human history (Stiles and Martin, 2001) and recently human-elephant conflict for the use of land. Although, the last factor may have been of minor significance until recently, the rapid growth of human populations in Africa has resulted in major changes in the land-use patterns of former ranges of the African elephants (Thouless, 1994; Foley *et al.*, 2001).

There is a continuing decline in the extent and quality of elephant habitats all over its range (Stephenson, 2007). Habitat destruction is caused by alteration of natural habitats for different human uses such as cultivation, livestock grazing, construction of roads and space for human settlement (Balakrishnan, 1994; Mundy, 2006; Stephenson, 2007). Logging and mining industries also cause habitat destruction and improve accessibility of remote forests to poachers (Wilkie *et al.*, 2001 as cited in Stephenson, 2007). This aggravates desertification, which in turn affects the flora and fauna, especially species which are habitat-specific and those that require extensive home ranges such as the African elephant (Lee and Graham, 2006). Crops planted near protected areas are attractive to elephants as an alternative source of food, which creates conflict between humans and elephants.

Therefore, conservationists aim at improving the management programs, mitigating human-elephant conflicts, controlling illegal ivory trade, anti-poaching patrols, and provide financial incentives for conserving African elephants (IUCN/SSC AfESG, 1996). Conservation measures usually include habitat management and protection through law enforcement. Successful management at the site level can result in the build-up of high elephant densities. This is often perceived as a threat to local habitats of elephants as well as to other species. Management interventions to reduce elephant numbers and local densities have been limited and most recently been undertaken through contraception and/or translocation (Blanc, 2008).

2.2. Elephants in Ethiopia

Although the African savanna or bush elephant had a wider distribution until the end of the 19th Century in Ethiopia, currently they are confined in few areas of the country. These elephants also lived in a variety of habitats from semi-arid to highland areas. However, the population of elephants is declining from time to time due to various factors that are common for the majority of elephant range states in the continent. These include deterioration of habitat quality, investment activities near conservation areas like the case of BES, poaching for ivory, increased human activities near conservation areas and competition of wildlife with large density of livestock (Hillman, 1993; Yirmed Demeke and Afework Bekele, 2000; Anteneh Belayneh, 2006; Meseret Ademasu, 2006; Zelalem Wodu, 2007; Yirmed Demeke, 2008). Currently, most of the elephants in Ethiopia reside in protected areas (Hillman, 1993; Yirmed Demeke, 2008).

Out of the total of nine separate elephant populations in Ethiopia (three populations in the west, three in the south, two in the northwest and one in the east, the eastern population is found only in BES. Thus, BES holds ecologically distinct elephant population in the Horn of Africa (Yirmed Demeke, 2008). The accurate population and range of elephants in the study area was difficult to determine due to various factors. However, studies by Yirmed Demeke (2008), indicated the occurrence of 324 individual elephants in two big groups. Elephant conservation programs in Ethiopia have not become successful due to lack of resources, commitment, and law enforcement. As human settlements and agriculture have expanded into the protected areas, elephants were pushed further into marginal lands (Yirmed Demeke, 2003). Likewise, as the extent of their habitats continues to be reduced, elephants have to compete with other wildlife as well as humans and their livestock. Such activities have been severely affecting elephant populations in Ethiopia (EWCO, 1991). The prominent causes for the reduction in the number and home range of the African elephant in Ethiopia can be seen from two points, elephant killing, and habitat degradation and fragmentation (Blanc *et al.*, 2003 as cited in Griebenow, 2006).

2.3. Social organization

African elephants are highly social mammals. They are intelligent, emotional, and very sensitive (Poole, 1998). Next to humans, elephants have the largest social network amongst land mammals. They display advanced social behaviours such as celebrating birth and expressing sadness at death (Langbauer, 2000). The family herd is led by the female usually the largest cow or most experienced member of the group (McComb *et al*., 2001), who determines the group's activities and movement patterns (Dia *et al*., 2007). Males usually live in separate herds or alone, their rank being determined by seniority and the reproductive status. Young males are driven out from the maternal herd as they reach sexual maturity, usually around 14-16 years of age, and only join them again thereafter for short reproductive periods (Stephenson, 2007). Younger male elephants often form temporary herds, with older bulls (Smithers, 1983 as cited in Roux, 2006). The age of elephants stretches to about 60-65 years (Mundy, 2006).

2.4. Feeding preference and habitat association

Elephants are classified as megaherbivores; they graze and browse on a wide range of species (Owen-Smith, 1992; de Boer et al., 2000; Dudley, 2000; Hatt and Clauss, 2006; Stephenson, 2007). Although elephants were primarily grazers, browse generally accounts for the majority of the natural diet of both African and Asian species (Hatt and Clauss, 2006). Elephants feed on various plants by browsing leaves, fruits, twigs or stripping bark from woody trees and shrubs; by breaking-off branches and pushing over or frequently uprooting trees and shrubs (Prajapati, 2008), consuming herbs and creepers (Stoinski *et al.*, 2000), including roots as well as seedpods (Mundy, 2006). The milling action of the two/three pairs of huge, long, rasp-like molars and the incredible versatile trunk, are means that the elephant can feed from ground level up to 6m tall plant parts (Gillson, 1998). They spend between 12-18 hours feeding each day, with peaks in the morning, late afternoon and around midnight and adult males use more time foraging than females (Stoinski *et al.*, 2000; Prajapati, 2008). On the contrary, a study by Shannon *et al.*, (2008), showed that there was no overall difference between sexes in the proportion of time spent while feeding. Large adult elephants may consume from 150Kg up to 300Kg plant products a day (Wyatt and Eltringham, 1974; Guy, 1976). They also require about 225 liters of water daily (Jackson and Erasmus, 2005; Stephenson, 2007). These average requirements keep elephants within a circle of 25 km from the water source (Balakrishnan, 1994; Mundy, 2006).

Even though elephants are considered to be unspecialized herbivores, they are often extremely selective in their food choice depending on availability, palatability and nutritional quality of forage materials (Taylor 1978; Osborn, 2004). For example, protein, carbohydrate and mineral concentrations, the amount of fibre and presence of silica

(McNaugthon *et al.*, 1985), the presence of plant secondary compounds (Lindroth, 1989 as cited in Bergvall, 2007) are some of the factors involved in food selection. Dietary preferences of elephants change seasonally and this is seen particularly in the occurrence of grass in the diet which is generally high during the wet season and decreases during the dry season when browsing becomes increasingly important (Wyatt and Eltringham, 1974; Guy, 1976; Osborn, 2004).

Seasonal changes in distribution, home range size and habitat selection of elephants have been well documented in Africa and coincide with seasonal climatic changes in the food and water availability (Viljoen, 1989; Lindeque and Lindeque, 1991; Tufto *et al.*, 1996; De Villiers and Kok, 1997; Whitehouse and Schoeman, 2003). Due to fluctuations in these resources, elephants show preferences for some habitats and avoid others (Roux, 2006). The African elephant is widespread in its range, and is active both in day and night (Skinner and Smithers, 1990; as cited in Roux, 2006).

The African elephant could be found in various types of habitats because of its wide and diversified food habits (Afolayan, 1975). It occurs in dense forest, open and closed savanna woodlands and, in considerably lower densities, in arid environments (Blanc, 2008). Their range is restricted to areas below the Sahara desert, which is mainly confined to central, eastern, and southern Africa. In East Africa, elephant range has declined from 85% to 25% of total land during the period 1925-1975 (IUCN/SSC AfESG, 1996). Similarly the home ranges of elephants in Babile have been shrinking both inside and outside the Sanctuary boundary (Yirmed Demeke, 2008).

2.5. Seasonal movement and distribution

As stated by Blanc (2008), the African elephant is very diverse in its range, and tends to move between varieties of habitats. Previous accounts describe African elephants as making a wide range of daily travel distances and seasonal movements in home ranges that can vary greatly in size (Douglas-Hamilton *et al*., 2005). Migration routes in Mali of up to 450 km are known (Blake *et al*., 2002). However, current migrations and movement of elephants have tended to be shorter because of reduced range through increase in human settlement and disturbance (Viljoen, 1989; Osborn, 2004). The varied nature of the travel distances correlates highly with the availability and distribution of resources (Babaasa, 2000; Leggett, 2006b). For example, availability of surface water is one of the major constraints on elephant distribution (Stokke and Toit, 2002). Thus, elephant impacts are higher in the vicinity of water (de Beer *et al.,* 2006). While searching for food and water, the African elephant can walk up to 30 km a day to reach better habitat conditions (Feldhamer, 2007). However, models studying distribution of elephants in Africa revealed that distribution of elephants is inversely related to distribution of human population, as human population densities increases the population of elephants goes on decreasing (Hoare and Toit, 1999).

Understanding the patterns of habitat use by elephants is crucial to predict their impacts on ecosystems. They are not territorial and have large home ranges (Whitehouse and Schoeman, 2003; Jackson and Erasmus, 2005; Galanti *et al*., 2006). The home range of an animal can be defined as the "area traversed by the individual in its normal activities of food gathering, mating and caring for young" (Burt, 1943). The size of the home ranges is affected by various factors including the seasonal availability of abundance and nutritional value of food, habitat heterogeneity (Tufto *et al*., 1996; Theuerkauf and Ellenberg, 2000), the amount of space available (Whitehouse and Schoeman, 2003) and the sex of the elephants as well as reproductive status and presence of calves (De Villiers and Kok, 1997; Whitehouse and Schoeman, 2003; Jackson and Erasmus, 2005; Leighty *et al*., 2008). For example, males in musth have significantly larger home ranges as compared to the distribution of females (Whitehouse and Schoeman, 2003). Range expansion has also been attributed to availability of shade in the case of savanna dwelling animals (Leggett, 2006b).

Radio and satellite telemetry have been an essential part of many research and management projects in African elephants for several decades (Thouless, 1994). Data have proved invaluable in determining ranging patterns, home ranges, habitat preferences, seasonal distribution, long distance movements and migration (Blake *et al*., 2001). For example, Namibia, Kenya, Cameroon, Zaire, South Africa and Tanzania (Harris *et al*., 1990; Thouless *et al*., 1992; Douglas-Hamilton, 1998; Blake *et al*., 2001; Croze *et al*., 2005; Leggett, 2006b) have successful experiences using this technology. The method is particularly crucial in tracking small populations living in a very wide, inaccessible and difficult area like BES (Yirmed Demeke, 2008).

2.6. Impact of Elephants on Vegetation

African elephants and some other indigenous megaherbivores have a major impact on local vegetation structure (Samways and Paul, 2004). This can be due to the feeding habit of elephants, which plays an important role in altering their own environment (Waithaka, 2001). In savanna ecosystems, elephants can maintain species diversity by reducing bush cover and creating an environment favourable to both browsing and grazing animals (Western, 1989). At the same time, they demolish bushes, pull up trees along with roots and pack down the soil leading to erosion. Such activities of elephants also used to maintain the proportion between bush and grasslands that are needed by browsing and grazing animals (Balakrishnan, 1994; Mundy, 2006; Edkins *et al.*, 2007). In response to elephant browsing, local extinction of many tree species have been well documented in different parts of Africa (Gadd, 2002).

As elephants need large amount of food, sometimes their forage requirement can not match with the supply especially in conservation areas leading to harmful interaction with the habitat (Afolayan, 1975). Elephant utilization by branch breaking, main-stem breaking, bark peeling, uprooting and pushing over trees while feeding has resulted in a marked decline on the population of many woody species in most habitats while increasing the abundance of other species (Roux, 2006; Santra *et al.*, 2008). However, the impact of plant utilization by elephants varies based on the species selected, the levels of damage posed, season when damage occurs, period of continuing damage and elephant densities (Barnes, 1983; Owen-Smith, 1988) and interactive effects of other factors such as fire (Buechner and Dawkins, 1961), rainfall and soil properties (Owen-Smith, 1988).

2.7. Human-elephant conflict

Human–elephant conflict refers to the negative interactions between humans and elephants (Kioko *et al.*, 2008). This conflict is largely because of expanding human populations, demand for land, and increased agriculture and crop protection (Afolayan, 1975). Conflict between elephants and farmers because of crop raiding is an important issue in elephant conservation in Africa. With diminishing elephant habitats, crop raiding is anticipated to increase and to play a significant role in the decline of elephant populations (Thouless, 1994; Hoare, 1999). Human–elephant conflict is increasingly affecting elephant conservation as many elephants get killed by wildlife authorities and illegally by local people in attempts to reduce the conflict (Kioko *et al*., 2008). In areas where elephants and humans are in proximity, repeated raiding of crops by elephants can lead to local human displacement. Elephants and humans are often injured or killed in attempts to discourage crop raiding (Thouless, 1994; Barnes, 1996). In this case, subsistence farmers' livelihoods can be seriously affected by crop damage (Michael *et al*., 2008). For example, in some semi-arid rural farming areas of Zimbabwe and Kenya elephant damage to food crops accounts for 75 to 90% of all incidents by large mammal pest species (Waithaka, 1997). Elephant damage to crops and property creates negative attitudes towards conservation by those affected people (Osborn and Parker, 2002). This category of human–elephant interaction is exclusively negative and includes human death, injuries and illness, financial losses as a result of crop-raiding, livestock mortality and constraints on general day-to-day human activities (Lee and Graham, 2006). The same is true in BES, where every year, elephants are known to damage large amount of crops, fruits and vegetables, even creating problems on the survival of farmers around the Sanctuary. Although not detailed information on the extent and degree of interaction, human-elephant conflict dated back to the 1970s in which nine bulls were killed as a result of crop raiding at BES (Stephenson, 1976). The proximity of farms to the conservation areas has increased the possibility of clashes between farmers and elephants in Africa and the same is true in Ethiopia. For example Yirmed Demeke (2008) quantified the loss of different crops as a result of crop raiding by elephants around BES.

3. DESCRIPTION OF THE STUDY AREA

3.1. Location and Topography

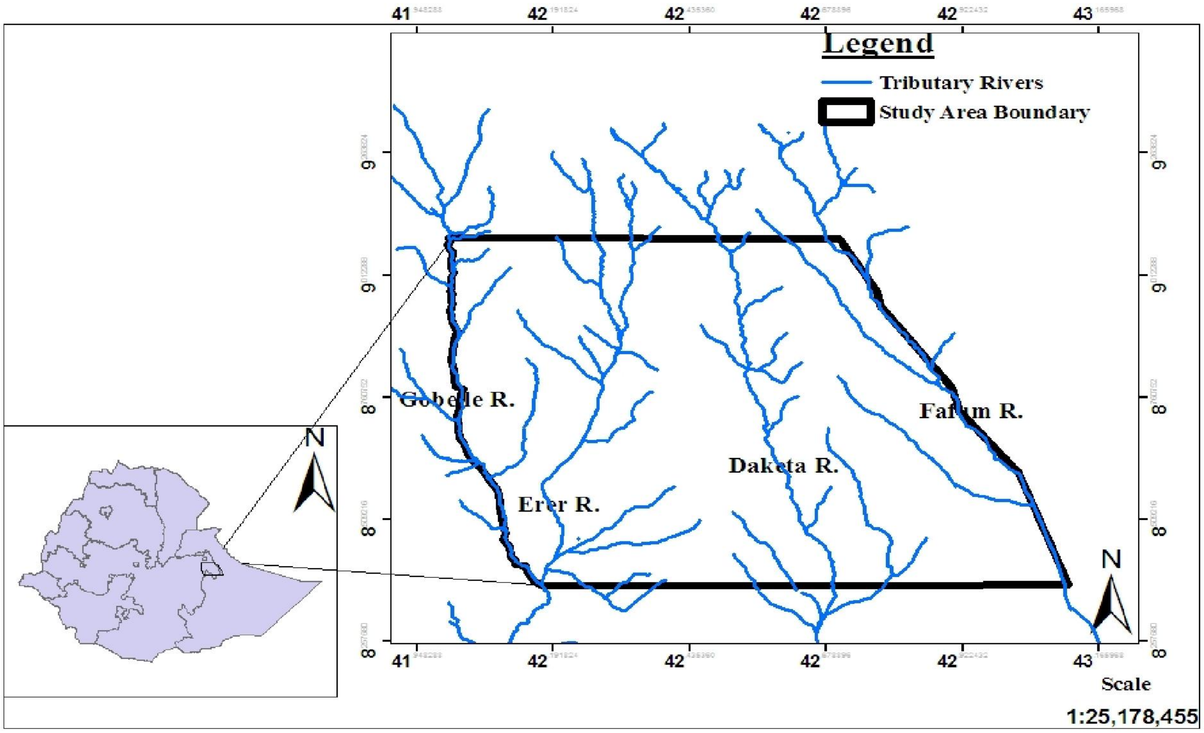

Figure 1. Location of BES in east Ethiopia (Yihew Biru).

BES is situated at the semi-arid transboundary of the Oromiya and Somali Regions, about 560 km from Addis Ababa. It is situated between latitudes 08°22'30''-09°00'30''N and longitudes 42°01'10''-43°05'50''E and elevations range between 850 m and 1,785 m asl. The major portion of the Sanctuary (77.7%) is located in the Somali Region, while the remaining 22.3% is in the Oromiya Region (Yirmed Demeke, 2008). The district is drained by perennial rivers such as Daketa River (137.5 km length in BES), Borale River (46 km in length) and Erer River (about 80 km in the Erer Valley) (OPEDB, 1997) (Fig. 1). This Sanctuary is one of the conservation areas in the country, established to protect the only known isolated, ecologically distinct population of elephants (Hillman, 1993; Barnest *et al.*, 1999; Yirmed Demeke, 2008). The Sanctuary covers an area of about 6,982 km^2 when it was established in 1970 (Stephenson, 1976). Through time, the Sanctuary boundary shrunk in size and deteriorated in quality. For example, the four valleys in BES (Fig. 1) (Daketa, Erer, Fafem and Gobelle) are currently highly impacted by human settlement and other activities, affecting the natural habitat of the elephants as well as other animals in the area.

3.2. Geology and soil

The geological structure of the current study area in particular and the adjacent areas in general consist of Precambrian complexes, Mesozoic-Tertiary sediments and upper Tertiary-Quaternary complexes (Mohr, 1964). The area is surrounded by characteristic rocky hills. The type and texture of soil in a given ecosystem is a key factor in influencing the distribution of palatable and unpalatable plant species, thereby indirectly affecting the distribution of animals in that particular area (Holdo and McDowell, 2004). Therefore, the composition of different soil types may have contributed for the presence of diverse flora in the study area. In general, the soil types in the Sanctuary include cambisols, luvisols, nitosols, orthic solonchakes, fluvisols, vertisols and xerosols (Mohr, 1964).

3.3. Climate

The ecological importance of climate is obvious both in relation to the diversity of vegetation and animals in an area which in turn controls elephant movements and food choice. The climate zone of the current study area encompasses two main categories, upper "Kolla" (characteristic arid climate) and "woinadega" (characteristic rainy climate), (Hillman, 1993; Yirmed Demeke, 2008). Mean monthly maximum and minimum temperatures recorded were 26.3^oC and 13.0^oC respectively (Fig. 2). The highest temperatures recorded were in the dry season in late January to March and April. December and January remained the coldest months during the night. Mean monthly rainfall ranges from 2 to 124 mm. Rainfall characterized by two peaks, occurring from March to May (short rain season) and July to October (long rain season) (Fig. 2).

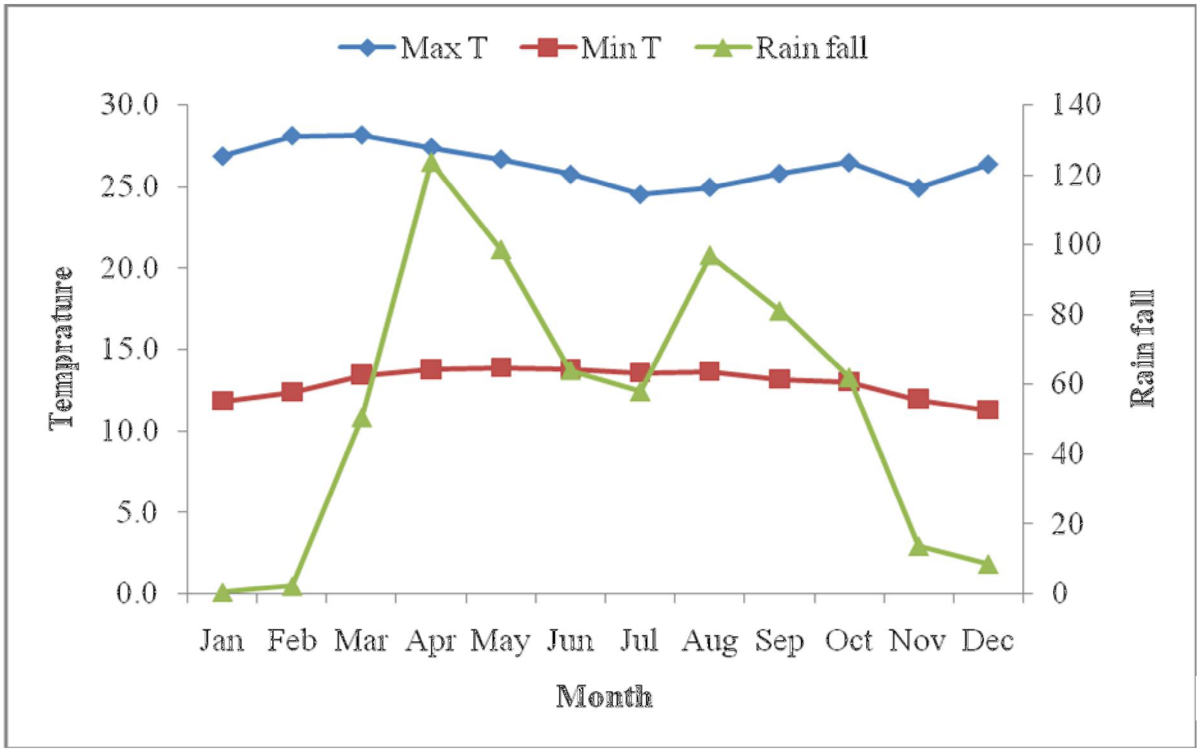

Figure 2. Mean monthly maximum and minimum temperature and rainfall data in Babile from 1995 to 2008 (Source; National Meteorological Service Agency).

3.4. Fauna and flora

The diversity of fauna and flora in eastern Ethiopia is considerably high. Some preliminary reports indicate that the area has many species of mammals, birds and reptiles, which are adapted to the semi-arid environment (Yirmed Demeke, 2008). According to Hillman (1993), there were about 22 species of mammals grouped under five Orders and 11 Families. A study by Yirmed Demeke (2008) documented an additional eight species, bringing the total number of mammalian species for the Sanctuary to 30, in seven Orders and 15 Families. The present study revealed the presence of more than 37 species of mammals in the Sanctuary. For example a one month preliminary survey between October and December 2008, by “The Joint Ethio-Russian Biological Expedition” (JERBE) Mammal Research Group reported the diversity of mammals in the Sanctuary. The survey reported four species of rodents (*Mus tenellus, Acomys cf. cahirinus, Mastomys sp.,* and *Tatera cf. robusta),* Naked mole-rat *(Hetrocelaphus glaber), Elephant* shrew *(Elephantulus rufescens)* and ground squirrels (*Xerus rutilus*). About seven species of bats were recorded and further seasonal studies can reveal more. Regarding large mammals, crested porcupines (*Hystrix cristata*), Abyssinian hare (*Lepus habessinicus*), Grivet monkey (*Cercopithecus aethiops*), Hamadryas baboon (P*apio hamadryas*) and Lesser galago (*Galago senegalensis*) the last one was not reported in earlier findings. Black-backed jackal (*Canis mesomelas*), White-tailed mongoose (*Ichneumia albicauda*), Dwarf mongoose (*Helogale parvula*), Spotted hyena (*Crocuta crocuta*), Large-spotted genet (*Genetta macullata*), Caracal (*Lynx caracal*), Lion (*Panthera leo*), Leopared (*Panthera pardus*) are among the common carnivores. Rock hyrax (*Procavia capensis*), Elephants, Warthogs (*Phacochoerus africanus and Ph. aethiopicus*), Bushbuck (*Tragelaphus scriptus*), Lesser and Grater kudus (*Tragelaphus imberbis and T. strepsiceros*), Bush duiker (*Sylvicapra grimmia*), Phillip’s dik-dik (*Madaqua saltiana*) and Guenther’s dik-dik (*Rhynchotragus guentheri*) were also recorded (Stephenson, 1976; Lavrenchenko *et al.*, 2008). The Sanctuary is also among the important bird areas in the country (EWNHS, 1996).

The Sanctuary consists of *Acacia-Commiphora* woodland, bushland, grassland, semi-desert scrubland and evergreen scrub ecosystems (Anteneh Belayneh, 2006; Yirmed Demeke, 2008) (Fig. 3). Because of the altitude-dependant differences in rainfall, a marked effect on the vegetation is observed (Yirmed Demeke, 2008). Tree cover proved important for mixed herds, probably because of the importance of shade and the higher nutritional requirements of the smaller-sized cows and calves (Smit *et al*., 2007).

Previous reports on floristic study revealed that the Sanctuary is rich in plant diversity. According to Anteneh Belayneh, (2006) there are 238 species of plants grouped under 155 Genera and 57 Families in the Upper Erer Valley. However, increased human activity and livestock encroachment in most parts of the Sanctuary resulted considerable reduction of vegetation which can affect the survival of elephants and other species in the area and still remains as one of the threats (Anteneh Belayneh, 2006: Yirmed Demeke, 2008).

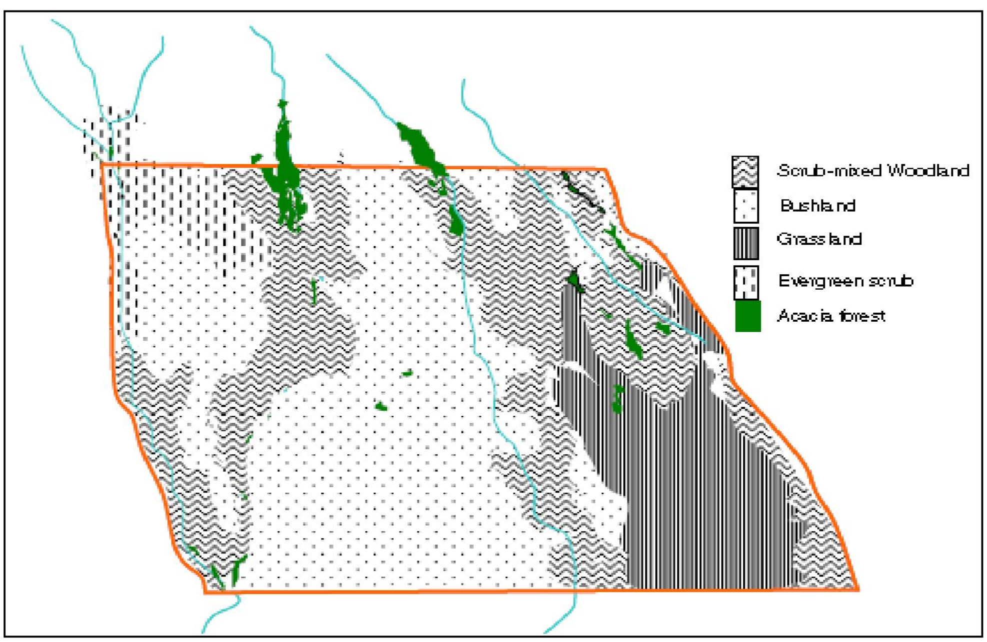

Figure 3. Vegetation coverage of Babile Elephant Sanctuary (Yirmed Demeke, 2008).

3.5. Methods

Elephant diet was studied by direct observations of elephants during feeding trials (Milewski and Madden, 2006), and indirectly by interviewing local residents, by identifying seeds in the dung (Morgan, 2007), microscopic analysis of fragments of leaf epidermis in faecal samples as elephant droppings contain a relatively large percentage of undigested material (Stewart, 1967; de Boer *et al*., 2000). Other valuable information left by elephants was also considered: chewed vegetation, browsed branches (Fig. 4), debarked trees and scratching posts (White, 1994; Yirmed Demeke and Afework Bekele, 2000; Shoshani *et al*. 2004; Chen *et al*., 2006).

Figure 4. Freshly chewed *Acacia* tree used as feeding sign, BES (Yihew Biru; Dec, 2008).

A reconnaissance survey was carried out on the first week of August 2008 in order to identify suitable sampling sites in the study area. Based on the distribution patterns of elephants in the study area, 12 blocks each having 20 m by 20 m a total of 74 quadrats were selected for vegetation study in Upper Erer Valley. The studied plots were immediately examined after the herd left for another location. In each quadrate, a record was kept on plant species and part(s) eaten and frequency of consumption. The total number of plants present in the plots was also recorded. A food plant was scored as having been eaten but the amount consumed was not assessed (Santra *et al.*, 2008). For woody species diameter at breast height (dbh) was measured and recorded. Plant samples were pressed for identification following standard procedures (Bridson and Forman, 1992) and identification was made in the National herbarium, Addis Ababa University (AAU). To study the regeneration status of species browsed by elephants, the total number of seedlings (woody plants with dbh < 2.5 cm and height ≤ 1 m) and saplings (woody plants with dbh < 2.5 cm and height > 1 m) were counted in all the study blocks. The saplings were counted in the main quadrats, where as the seedlings were counted using two sub quadrats developed at opposite sides in each of the 400 m^2 quadrats. To assess the seeds of plant species in elephant dung, fresh to nearly fresh boli at five meter interval were collected, this is to avoid collection of dung from same accumulation (Yumoto and Maruhashi, 1995). Dung collection follows Dudley, (2000) using plot samples and opportunistic site sampling techniques. A collected bolus was then dissected by hand, and the total number of intact, undamaged seeds of each species were identified and counted (Gonthier, 2007). In order to avoid bias, seeds which are difficult to identify during field work, were sowed in green house of AAU. During dung analysis contents such as (grass fragments, leaf fragments, fruit fiber, hard seeds, wood cellulose and other fibers), were observed and visual estimates of the proportion were made (Mubalama and Sikubwabo, 2002).

Data on feeding preference was collected both during the wet season, starting from August to November 2008 and dry season from December 2008 to March 2009. Preference is usually quantified by calculating preference indices for the species in the diet. The most widely used method of calculating preference index is dividing the percentage utilization by the percentage availability in the environment (Uresk, 1984; Fritz *et al*., 1996; de Boer *et al*., 2000; Parker *et al*., 2003; Roux, 2006; Kassa *et al*., 2007), and calculated using the following formula;

$$\text{Preference index (PI)} = \frac{\text{Percentage Utilization}}{\text{Percentage in the environment}}$$

Where, Percentage utilization is % of a given plant consumed as a food and is a ratio of species in the diet to all species consumed, while % in environment is a ratio of the total number of individuals of a single species to the total number of individuals of all species observed in all the observation blocks. Dietary composition and food preference can be used to identify plant species that may be threatened by elephants.

Data on movement patterns and range of elephants was collected from three GPS collared bulls (Figs. 5, 6 and 7) representing different family units (Wittemyer *et al*., 2007; Yirmed Demeke, 2008). During collaring, three wildlife veterinarians (from Ethiopia, Kenya and Sweden) and three elephant researchers (from Ethiopia, Namibia and South Africa) were participated. The bulls were darted from the ground using darting gun with Etorphine M99.

Therefore, in order to study the movement patterns of elephants in the present study, GPS telemetry data have been collected. This data was used to calculate the daily movement distance (DMD) which is the sum of straight line distances between consecutive locations obtained from satellite readings of a day, monthly movement distance (MMD), daily movement range (DMR) which is the area encompassing the daily movement rout (Ayalew Berhanu, 2007; Leighty *et al*., 2008) and the total home range (THR). Understanding these movement parameters can be used for both animal management and habitat conservation (Dickson *et al*., 2005).

Satellite tracking is a fundamental tool for modern wildlife research and management, providing information which could not have been collected by any other way (Fancy *et al*., 1986; Thouless *et al*., 1992). This methodology allows high spatio-temporal resolution in plotting animal movements. Consequently, it is important to measure and analyze how individuals and populations use their range (Douglas-Hamilton *et al*., 2005). These data were the continuation of the work conducted by Babile Elephant Conservation Project, aimed to determine full size of the home range and movement patterns, particularly in the south and southeast which was not fully determined in previous study, due to the large area size, difficult terrain and limited road networks, coupled with security problems in the southern section of the Sanctuary. Satellite data that were obtained from collared elephants are analyzed both for the wet and dry seasons. Data collection from GPS collared individuals was carried out from September 2008 to January 2009. The location of elephants was recorded daily at 4 hour intervals with an accuracy of approximately 3 m. The collaring operation was conducted in the Upper Erer Valley of the Sanctuary.

The collaring, tracking and data analyses follows the methods of Fancy *et al*., (1986), Thouless *et al*., (1992), Croze *et al*., (2005) and Leggett, (2006b). In general, this study examined the daily and seasonal movement as well as the home range of the collared bulls in BES. The data generated from the satellite telemetry will be used to develop methods to reduce competition for land use between people and elephants that have existed for decades. It is also used to promote elephant tourisem so as to enhance the income of the Sanctuary.

Figure 5. The late Dr. Zahoor Kashmiri giving the anti-dot for Goliath after successful collaring (Yirmed Demeke, Aug. 2008).

Figure 6. Right-Tusked with GPS satellite telemetry (Yirmed Demeke, 2008).

Figure 7. Big Daddy just after successful collaring (Yirmed Demeke, Sept. 2008).

3.6. Data analysis

Diet composition was analyzed by identifying the different species of vegetation consumed by elephants, computing their relative frequency in the diet, their relative abundance in the study area and thereby calculating preference indices as explained in 3.5 above. All plant species were recorded in each quadrat and used for vegetation characterization (calculation of food availability). The tree density, frequency, dbh and basal area were used to explain species availability in the study area. Basal area is the cross-sectional area of tree stems at breast height and is a measure of dominance, where the term "dominance" refers to the degree of coverage of species as an expression of the space it occupies at the ground level (Simon Shiberu and Girma Balcha, 2004).

And calculated using the following formula;

$$BA = \frac{\pi d^2}{4}$$

Where BA= Basal area in m^2 per hectare,

d= diameter at breast height and

π =3.14

Dominance= mean basal area per species X number of trees in species

Importance value index (IVI) of a species was calculated from the sum of relative dominance, relative density and relative frequency (Kent and Coker, 1992). Each component of IVI was calculated as follows;

$$\text{Relative density} = \frac{\text{Total no. of individual species of A}}{\text{Total no. of individuals of all species}} \times 100$$

$$\text{Relative frequency} = \frac{\text{Frequency of occurrence species A}}{\text{Total frequency of occurrence of all species}} \times 100$$

$$\text{Relative dominance} = \frac{\text{Dominance of species A}}{\text{Dominance of all species}} \times 100$$

Data collected on seasonal dietary composition and preference was coded and analyzed using Statistical Package for Social Sciences (SPSS) for windows, Version 16. Feeding preference was quantified using frequency of occurrence of each food item expressed as percentage and percentage availability of species in the field. χ^2 test of relative percentage frequency was performed to see significant food in the diet whereas the non-parametric Man Whitney U test was used to test significance of season on elephant diet. One way ANOVA test was used to see the effect of season on home range of the elephants. GPS location fixes were imported into MapInfo professional 8 and ArcGis 9.2 computer softwares for home range and movement analysis. Minimum convex polygon (MCP) with 95% of the fixes was applied to estimate seasonal home range sizes of elephants as it is the most used and enable us for comparison with previous studies.

3.7. Materials

Binocular, camera, compass, polythene bags, measuring tape, dissecting kit, rope, painting dye, topographic map, microscope slide, light microscope, and GPS collars were used during data collection in this study.

4. RESULTS

4.1. Dietary composition and feeding preference

Elephants were observed to feed on 61different species grouped in 30 families in the wild (Appendix 1) and 14 cultivated plant species consisting of 11 families (Table 1). Twenty eight of the consumed species constituted shrubs, 24 were trees and 5 species were herbs and 2 species were grasses. Visual estimation of dung analysis revealed the occurrence of more grass fragments during the wet season than the dry season. The proportion of fruits and seeds were significantly higher during the wet season than the dry season, while, the composition of fibre and woody materials was higher during the dry season than the wet season. Elephants were observed to feed relatively on diverse plant species during the wet season than the dry season. *Acacia nigrii, Acacia robusta, Acacia brevispica, Opuntia ficus-indica* and *Opuntia stricta* were the most abundant species in terms of elephant food resource available in BES while *Acacia albida* and *Acacia seyal* were the least encountered species. Among all the species consumed, *Opuntia ficus-indica* (23.81%), *Acacia robusta* (20.17%), *Acacia nigrii* (12.61%), *Opuntia stricta* (10.20%) and *Acacia brevispica* (8.81%) were the most utilized species by elephants (Table 2).

Elephants showed a selective preference for 22 of the 36 most important species in the diet as determined in field observation. The strongest preferences were for *Acacia robusta* and *Opuntia ficus-indica*. Elephants exhibited a selective avoidance for the other important species in the diet including *Combretum molle* and *Grewia flavescens* (See Appendix 2). On the other hand *Acacia robusta* was the most utilized species (20.2%), it was the most available plant next to *Acacia nigrii* (Table 2) in the Sanctuary and its use was considerably lower than its availability ($p<0.05$). *Combretum molle* had the lowest preference index value indicating that it was the most avoided species.

Results from direct observation and dung analysis showed that there was no significant difference among the species consumed across seasons (Man Whitney = 0.121, df = 1, $p>0.05$). However, there is significant difference among the species consumed within seasons, *Opuntia ficus-indica* was primarily browsed during the wet season (26.3%) (χ^2 = 19.1, df = 35, $p<0.001$) while *Acacia robusta* being the major component of the diet during the dry season (23.9%) (χ^2 = 14.7, df = 35, $p<0.001$). Except *Acacia nigrii,* and *Acacia mellifera,* the other *Acacia* species found to be browsed relatively during the dry season than the wet season (Fig. 8). *Balanites glabra* is exclusively browsed during the wet season while *Grewia flavences* is primarily browsed during the dry season.

Table 1. Cultivated plants consumed by elephants. All local names in Oromifa language.

Scientific name	Local name	Family	Part Consumed
Annona cherimola Mill.	Gishta	Annonaceae	Leaves and fruits
Arachis hypogea	Lewiz	-	Pod and leaves
Carica papaya L.	Papaye	Caricaceae	Leaves and fruits
Casimiroa edulis La Llave	Ambuka	Rutaceae	Leaves and fruits
Cucurbita pepo	Duba	Curcupitaceae	Leaves, stems and fresh fruits
Ipomea batatas Lam.	Mitatis	Convolvulaceae	Leaves, stems and tubers
Lagenaria siceraria	Buqqe	Curcupitaceae	Leaves and stems
Lycopersicon esculentum Mill.	Timatime	Solanaceae	Leaves and fruits
Mangnifera indica	Amba	Anacardiaceae	Leaves, bark and fruits
Musa paradisiaca L.	Muza	Musaceae	Leaves and fruits
Psiduim guajava L.	Zeyituna	Myrtaceae	Leaves, bark and fruits
Saccharum officinarum L.	Alla	Poaceae	Leaves and stems
Sorghum bicolor (L.) Moench	Bishinga	Poaceae	Leaves, stems and seeds
Zea mays L.	Boqollo	Poaceae	Leaves, stems and seeds

Table 2. Percentage occurrence of the most important species in the diet of elephants (% Consumption = percentage of a species in the diet, % Availability = percentage occurrence of a species in the field).

Species	% Consumption in Diet	% Availability in the Field
Acacia brevispica	8.81	10.88
Acacia bussei	1.51	1.25
Acacia mellifera	2.09	2.14
Acacia nigrii	12.61	17.68
Acacia nilotica	0.23	0.09
Acacia oerfota	0.48	0.42
Acacia robusta	20.17	15.43
Acacia tortilis	2.73	3.73
Acokanthera schimperi	0.29	0.16
Aloe pirottae	0.26	0.52
Asparagus leptocladodius	0.03	0.03
Balanites aegyptiaca	2.57	2.48
Balanites glabra	1.42	1.98
Berchemia discolor	0.29	0.23
Cadaba farinosa	0.42	0.47
Capparis tomentosa	0.19	0.19
Carissa spinarum	0.23	0.12
Combretum molle	0.10	0.69
Chionothrix latifolia	0.03	0.02
Dichrostachyus cinerea	2.03	1.58

Contd…

Dobera glabra	0.10	0.06
Euclea schimperi	0.23	0.17
Grewia bicolor	2.35	1.34
Grewia erythraea	1.74	1.23
Grewia flavescens	2.25	9.24
Grewia schweinfurthii	0.06	0.08
Grewia villosa	1.99	1.22
Kleinia squarrosa	0.58	0.71
Ochna inermis	3.60	2.53
Opuntia ficus-indica	23.81	11.61
Opuntia stricta	10.20	13.07
Trichilia emettca	0.26	0.10
Ziziphus spina-christi	0.29	0.39

Percentage availability based on individual observation and calculated only for the consumed species

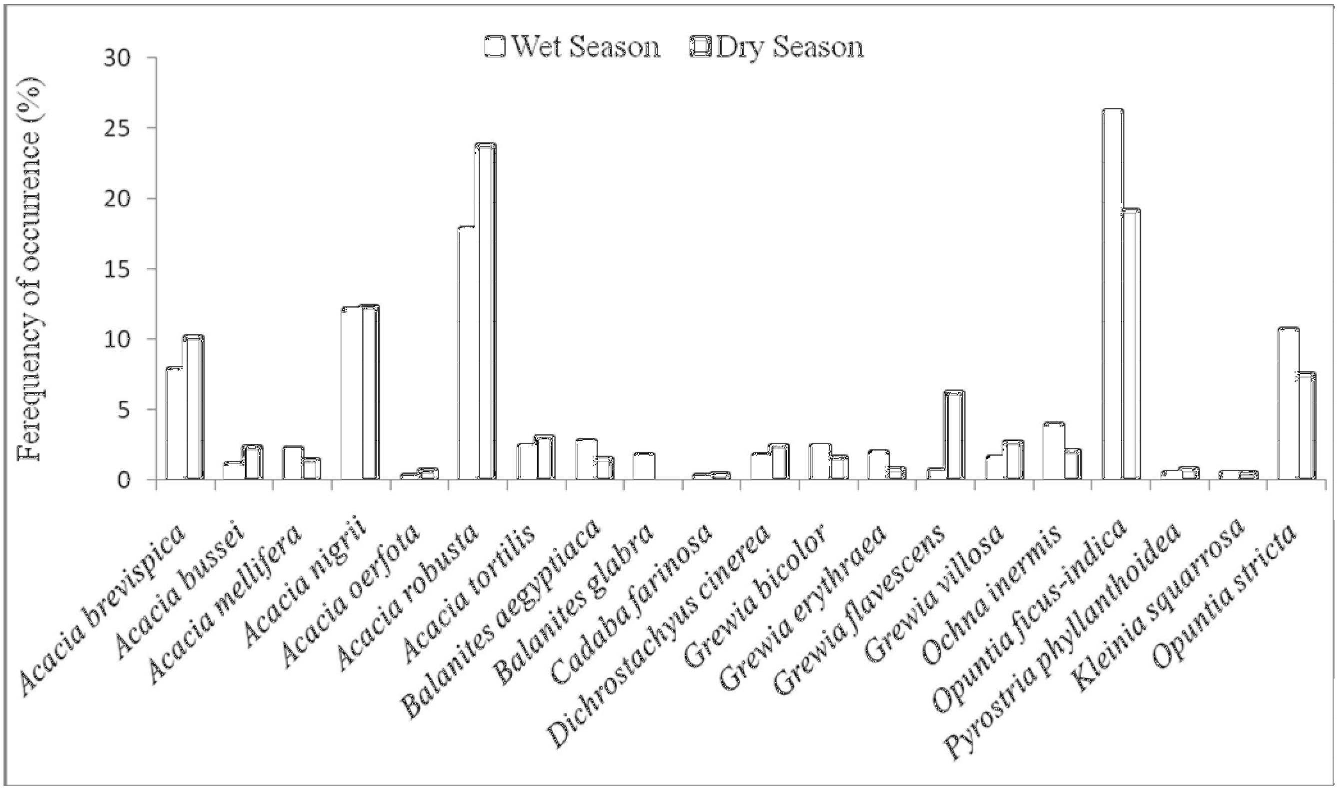

Figure 8. Seasonal comparison of the most important browse species in the diet of elephants.

Seventy-one dung boli were dissected, yielding 3442 seeds from 21 different plant species (Table 3). *Opuntia ficus-indica*, *Dichrostachyus cinerea*, *Acacia oerfota* and *Grewia erythraea* had the highest frequencies of seeds in the dung (>10%; Table 3). *Acacia robusta* and *Grewia bicolor* were also found to have greater than one seed per bolus. Twenty species were observed fruiting during the study period, of which 13 were present in the elephant dung survey (Table 3). Adult trees of all the seed species found in elephant dung were observed in the study area with the exception of the unidentified seeds. Seven species (*Lantana camara, Commiphora schimperi, Tamarindus indica, Terminalia brownie, Cryptostegia grandiflora*), were exclusively observed in the dung survey that were missed in diet observation during field work. The average number of woody plant seeds per bolus was 48.23.

Table 3. Seasonal seed composition of elephant dung and mean seed per dung bolus obtained from dung analysis (SFWS: Seeds found in wet season, SFDS: Seeds found in dry season, MSDB: Mean seed per dung bolus).

Species	SFWS	SFDS	Total	% in dung	MSDB
Acacia oerfota	317	121	438	12.72516	6.17
Acacia tortilis	21	12	33	0.958745	0.465
Acacia robusta	73	13	86	2.498547	1.211
Balanites aegyptiaca	-	3	3	0.087159	0.042
Berchemia discolor	51	11	63	1.830331	0.887
Dichrostachyus cinerea	597	249	846	24.57873	11.92
Grewia bicolor	53	28	81	2.353283	1.141
Grewia erythraea	296	131	427	12.40558	6.01
Grewia flavescens	-	27	27	0.784428	0.38
Grewia schweinfurthii	11	-	11	0.319582	0.155
Grewia villosa	46	16	62	1.801278	0.873
Lantara camara	201	153	354	10.28472	4.99
Commiphora schimperi	0	3	3	0.087159	0.042
Opuntia ficus-indica	622	289	911	26.46717	12.83
Tamarindus indica	1	3	4	0.116212	0.056
Terminalia brownii	4	-	4	0.116212	0.056
Trichilia emettca	1	6	7	0.20337	0.099
Ziziphus spina-christi	-	7	7	0.20337	0.099
Cryptostegia grandiflora	15	3	18	0.522952	0.254
Unkown 1	34	-	34	0.987798	0.479
Unkown 2	9	14	23	0.668216	0.0067
Total	2352	1090	3442	100	48.2

4.2. Vegetation characterization

4.2.1. Importance Value Indies (IVI) of woody species

Of the species browsed by the elephants, *Acacia robusta* (IVI=53.0), *Acacia nigrii* (25.6), *Opumtia stricta* (20.7), *Ziziphus spina-christi* (18.7), *Acacia brevispica* (18.3), *Grewia flavescens* (18.0), *Opuntia ficus-indica* (17.98), *Balanites aegyptiaca* (12.8), *Acacia tortilis* (11.6), *Acacia bussei* (11.3) and *Balanites glabra* (11.1) scored IVI greater than 10 (Table 4). The total density of the 36 frequently browsed woody species is 3395 individuals/ha. The maximum density recorded for *Acacia nigirii* is 590 individuals/ha followed by *Acacia robusta* 515 individuals/ha and the minimum density is 2 individuals/ha for *Dobra glabra* even less than 1 for *Acacia albida* and *Acacia seyal*. The total density of trees is 1316 individuals/ha and shrubs account 2079 individuals/ha. The highest relative dominance of species in the study area is 31.94 for *Acacia robusta* followed by *Ziziphus spina-christi* (17.5) and *Opumtia stricta* is the least (0.19).

Table 4. Importance Value Indies (IVI) of woody species browsed by elephants.

Scientific name	Habit	Density/ha	Rfrq	Rden	Rdom	IVI
Acacia robusta	T	515	5.882	15.157	1.938	53.0
Acacia nigrii	T	590	7.086	17.367	1.114	25.6
Opuntia stricta	Sh	436	7.620	12.838	0.197	20.7
Ziziphus spina-christi	Sh	13	0.802	0.378	17.491	18.7
Acacia brevispica	Sh/T	363	7.353	10.689	0.297	18.3
Grewia flavescens	Sh	308	6.283	9.076	2.644	18.0
Opuntia ficus-indica	Sh/T	398	6.016	11.734	0.228	17.98
Balanites aegyptiaca	Sh/T	83	6.684	2.438	3.685	12.8
Acacia tortilis	Sh	124	6.818	3.662	1.083	11.6
Acacia bussei	T	42	2.941	1.224	7.142	11.3
Balanites glabra	T	66	3.342	1.941	5.820	11.1
Pyrostria phyllanthoidea	T	23	1.471	0.667	7.371	9.5
Ochna inermis	Sh	84	3.476	2.488	2.311	8.3
Acacia mellifera	Sh/T	71	5.080	2.10	0.662	7.8
Grewia villosa	T	41	4.412	1.194	0.909	6.5
Dichrostachyus cinerea	Sh	53	4.545	1.553	0.297	6.4
Grewia bicolor	Sh	45	3.743	1.314	0.914	5.97
Grewia erythraea	Sh	41	4.278	1.204	0.266	5.7
Combretum molle	Sh	23	1.203	0.677	3.769	5.6
Acacia oerfota	T	14	0.936	0.408	3.520	4.9
Kleinia squarrosa	Sh	24	2.807	0.697	0.925	4.43

Contd…

Acacia nilotica	T	3	0.802	0.090	3.511	4.40
Berchemia discolor	Sh	8	2.005	0.229	1.785	4.02
Cadaba farinosa	T	16	2.540	0.458	0.235	3.2
Dobera glabra	Sh	2	0.535	0.060	0.888	1.482
Euclea schimperi	Sh	6	0.802	0.169	0.510	1.481
Capparis tomentosa	T	6	0.535	0.189	0.488	1.21

T=tree, Sh=shrub, ha=hectare, Rfeq=relative frequency, Rden=relative density, Rdom=relative dominance, IVI=Importance value index.

4.2.2. Regeneration status of woody plant species browsed by elephants

The total density of seedlings and saplings of the woody species was 3430 individuals/ha. *Acacia nigrii* (271 individuals/ha), *Acacia brevispica* (242 individuals/ha), *Acacia robusta* (107 individuals/ha) and *Acacia tortilis* (61 individuals/ha) showed relatively better regeneration among the tree species. Regarding the shrubs *Dichrostachyus cinerea* (20 individuals/ha), *Grewia flavescens* (18 individuals/ha), *Ochna inermis* (14 individuals/ha), *Kleinia squarrosa* (9 individuals/ha) and *Acacia oerfota* (8 individuals/ha) showed better regeneration than the other species (Figs. 9 and 10).

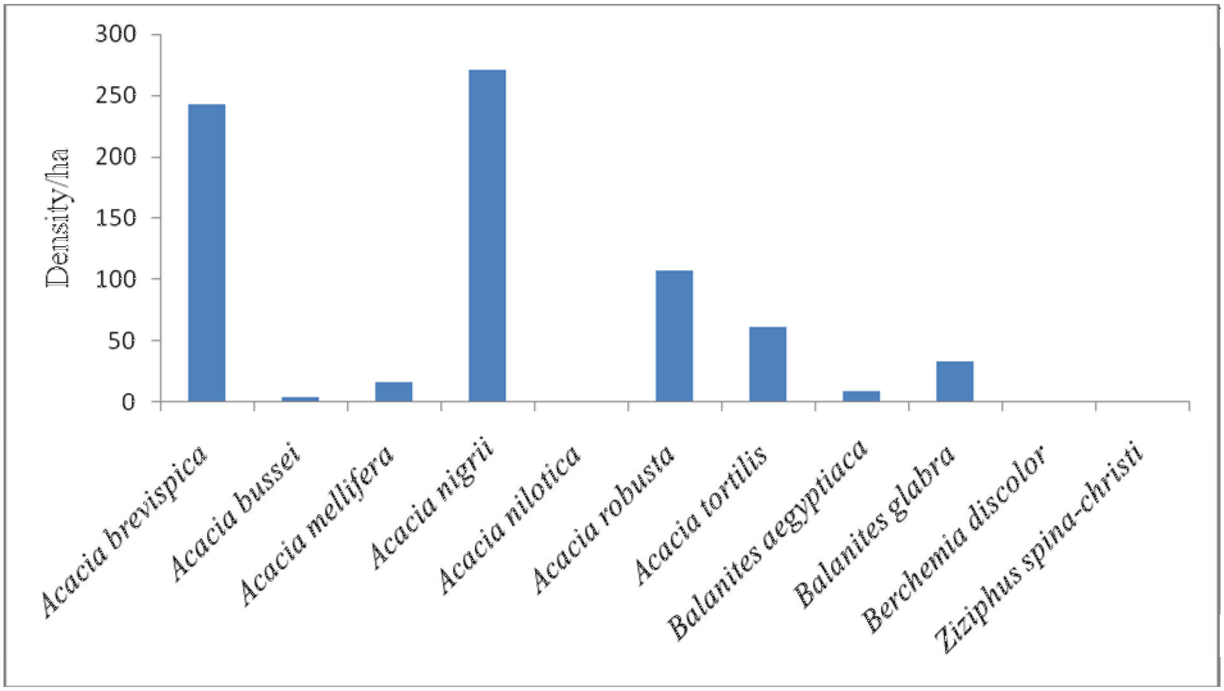

Figure 9. Regeneration density per hectare for the tree species browsed by elephants.

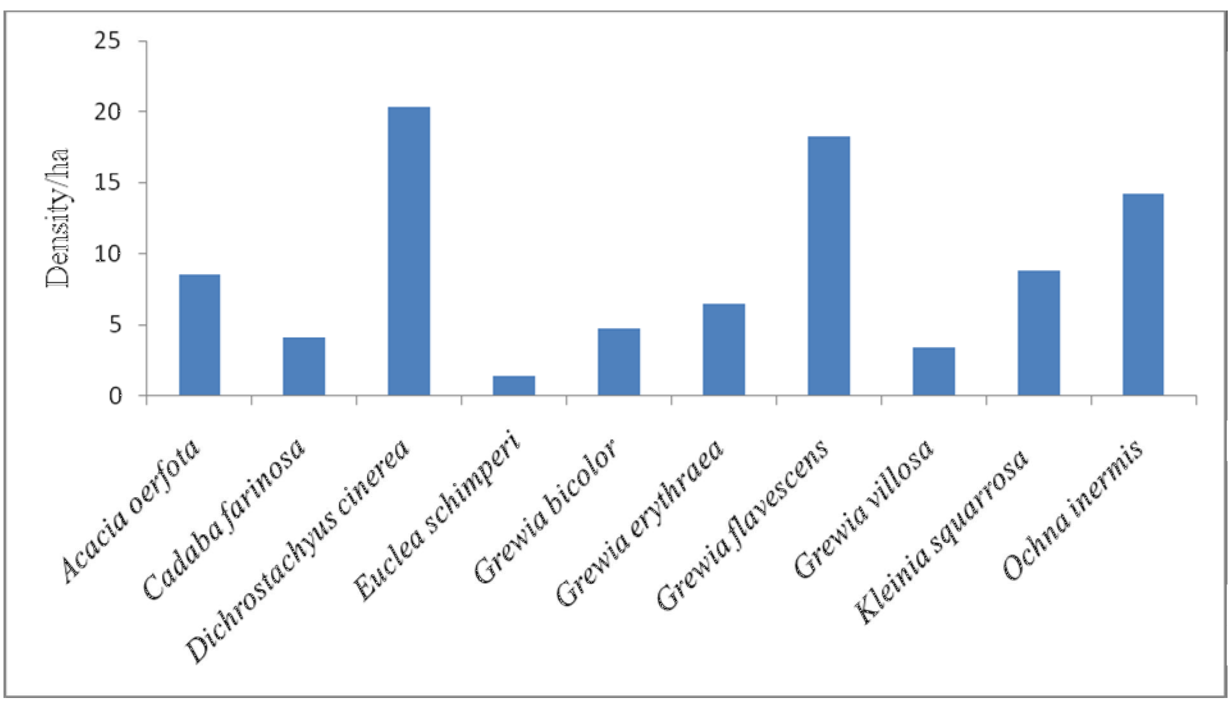

Figure 10. Regeneration density per hectare among shrub species browsed by elephants.

4.3. Home-range and movement patterns of elephants

4.3.1. Home range

Home range estimates were calculated for the three elephant bulls (Big Daddy, Goliath and Right-tusked) using the 95% MCP (Table 5). Although the home range sizes for the three bulls were larger during the wet season than the dry season (Figs. 11 and 12), it was not statistically significant (one-way ANOVA, df=1, F=0.015, p>0.005). Similarly, there was no significant difference between the home range sizes of the bulls within season (one way ANOVA, F=1.780, p>0.005). Among the three collared bulls, Right-tusked showed the largest home range 849.1 km^2 during the wet season while the smallest home range was recorded for Big Daddy during the dry season 415.5 km^2. Unlike the two bulls whose home ranges shrunk during the dry season, Goliath showed relatively a larger home range in the dry season (624) than the wet (514.1).

Table 5. Seasonal home range sizes for collared elephants.

Elephant	Home range size (km^2)	
	Wet	Dry
Big Daddy	796.4 ± 677.7	415.5 ± 238.1
Goliath	514.1 ± 338.5	624 ± 251.5
Right-tusked	849.1 ± 667.9	763.9 ± 441

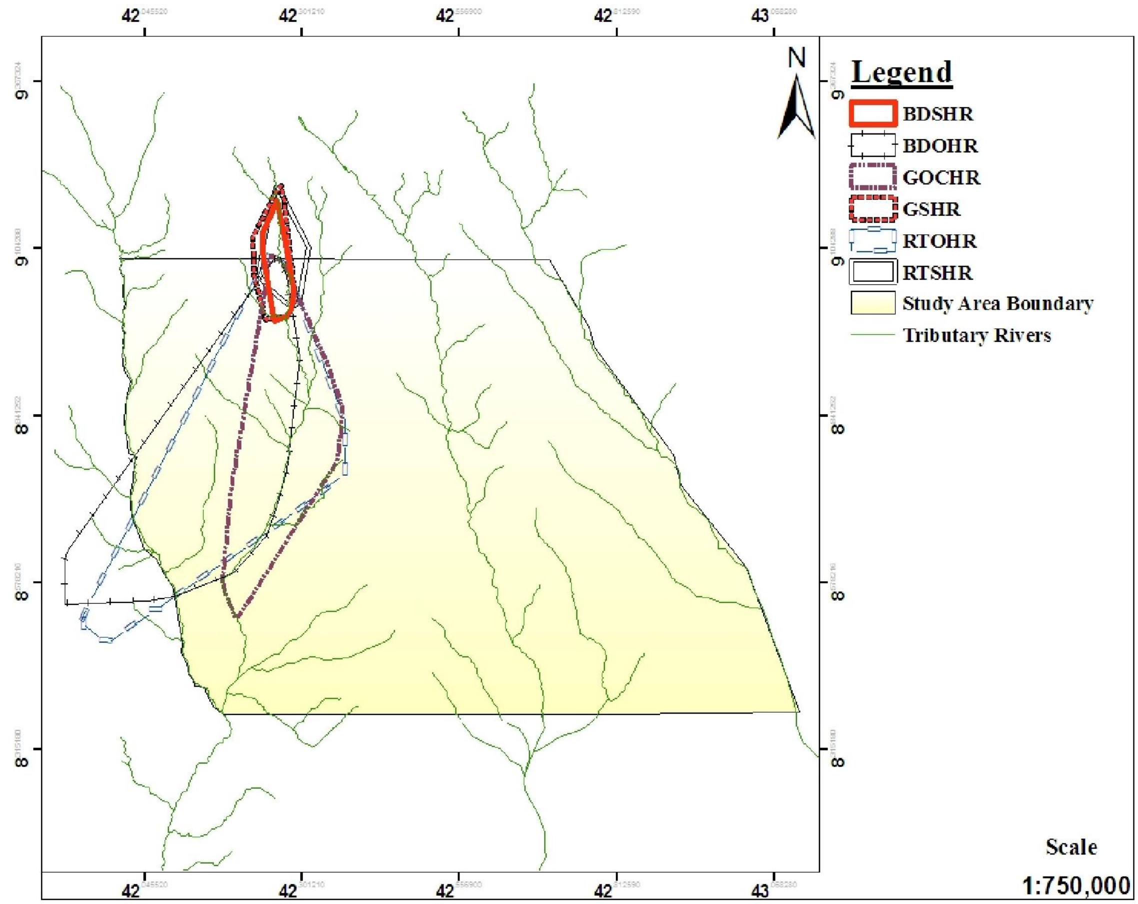

Figure 11. Wet season home range of collared bulls (BDSHR=Big Daddy, September home range, BDOHR= Big Daddy, October home range, GSHR=Goliath, September home range, GOCHR=Goliath, October home range, RTSHR=Right-tusked, September home range and RTOHR=Right-tusked, October home range).

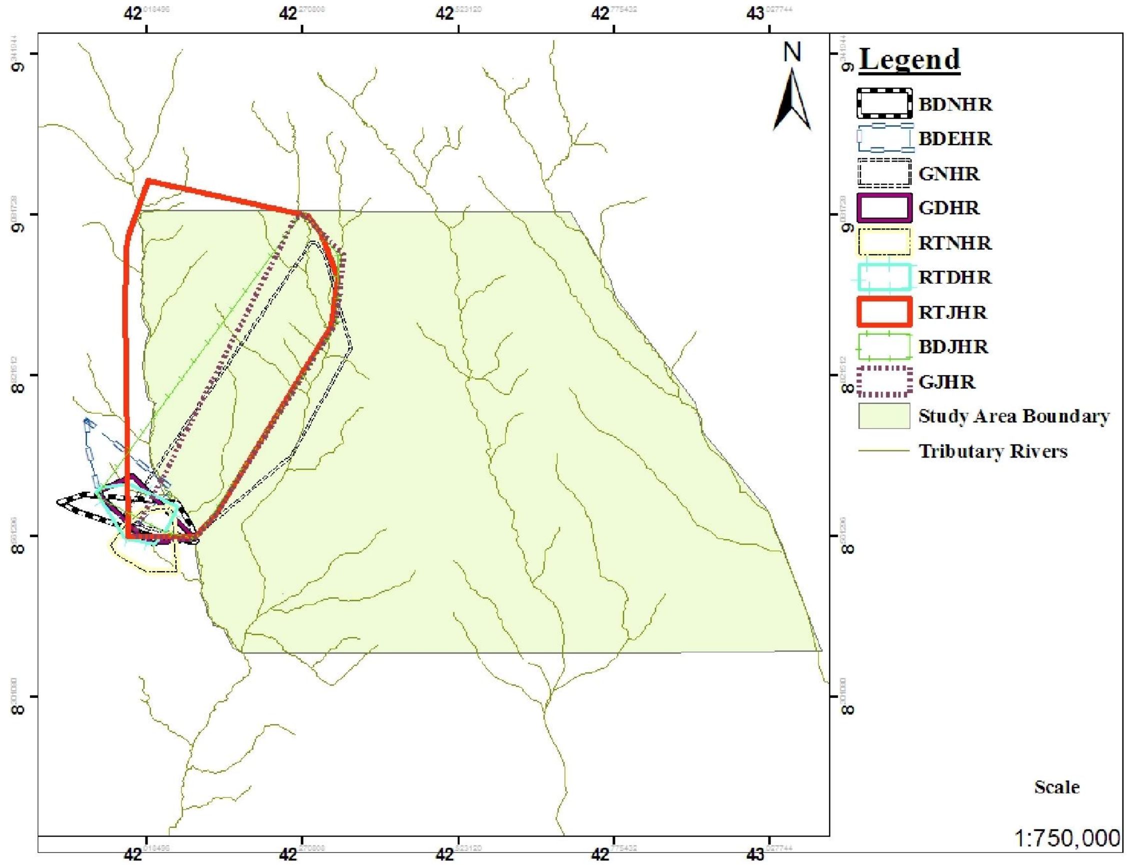

Figure 12. Dry season home range of collared bulls (BDNHR=Big Daddy, November home range, BDEHR=Big Daddy, December home range, BDJHR=Big Daddy, January home range, GNHR=Goliath, November home range, GDHR=Goliath, December home range, GJHR=Goliath, January home range, RTNHR=Right-tusked, November home range, RTDHR=Right-tusked, December home range and RTJHR=Right-tusked, January home range).

4.3.2. Movement patterns

In terms of movement patterns, elephants in the present study might be classified as residents mainly in the two valleys (in the Upper Erer and Lower Gobelle) (Figs. 13 and 14) and partially migratory in the case of individuals moving far in the southwest up to the highlands of Garamuleta town, in response to temporal availability of food and water. The results from five month satellite-based telemetry of the three bulls demonstrated two main movement patterns. Both movements start with Upper Erer Valley from the north to south direction. During the wet season (September-October), the bulls were observed together in upper Erer Valley. In September, the elephants moved to an area of 12 km (6.95% of their total range) crossing the boundary in the north. The first movement pattern is seen by Goliath commencing its journey from Upper Erer valley to south of the Sanctuary exploring along the tributaries of Erer River and return back to north along the same route (Fig. 13). In November, Goliath moved down crossing Gobelle River in the southwest (Fig. 14), joining the two bulls exploring habitats by dispersing outside the boundary along the vicinity of Gobelle Valley until the end of December. The second movement pattern is observed by Big Daddy and Right-tusked. They moved from Upper Erer to Gobelle Valley at the beginning of October (Fig. 13). The two bulls stayed longer (from second week of October to first week of January) exploring adjacent areas of Gobelle Valley and its escarpments up to the highlands of Garamuleta town. The bulls went back to Erer Valley at the beginning of January (Fig. 14). The maximum movement out of the boundary was seen in the southwest for about 22 km (13.85% of their total range) by the three bulls.

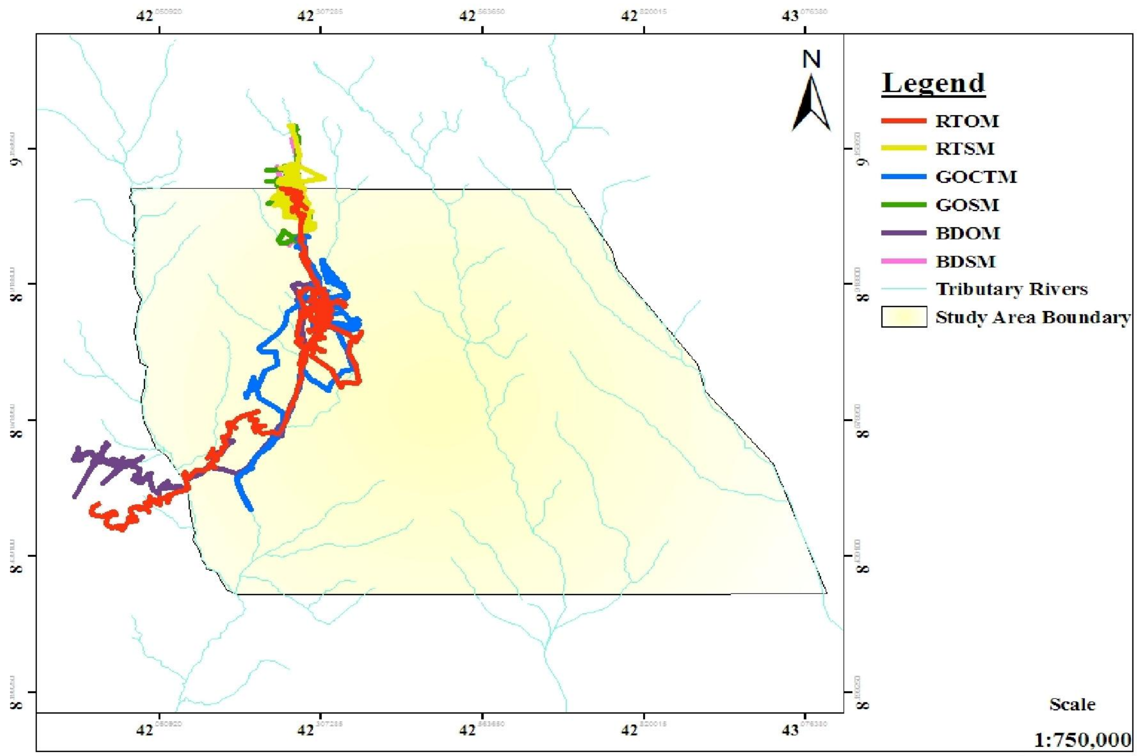

Figure 13. Wet season movement of collared bulls (RTOM=Right-tusked, October movement. RTSM=Right-tusked, September movement, GOCTM=Goliath, October movement, GOSM=Goliath, September movement, BDOM=Big Daddy, October movement and BDSM=Big Daddy, September movement).

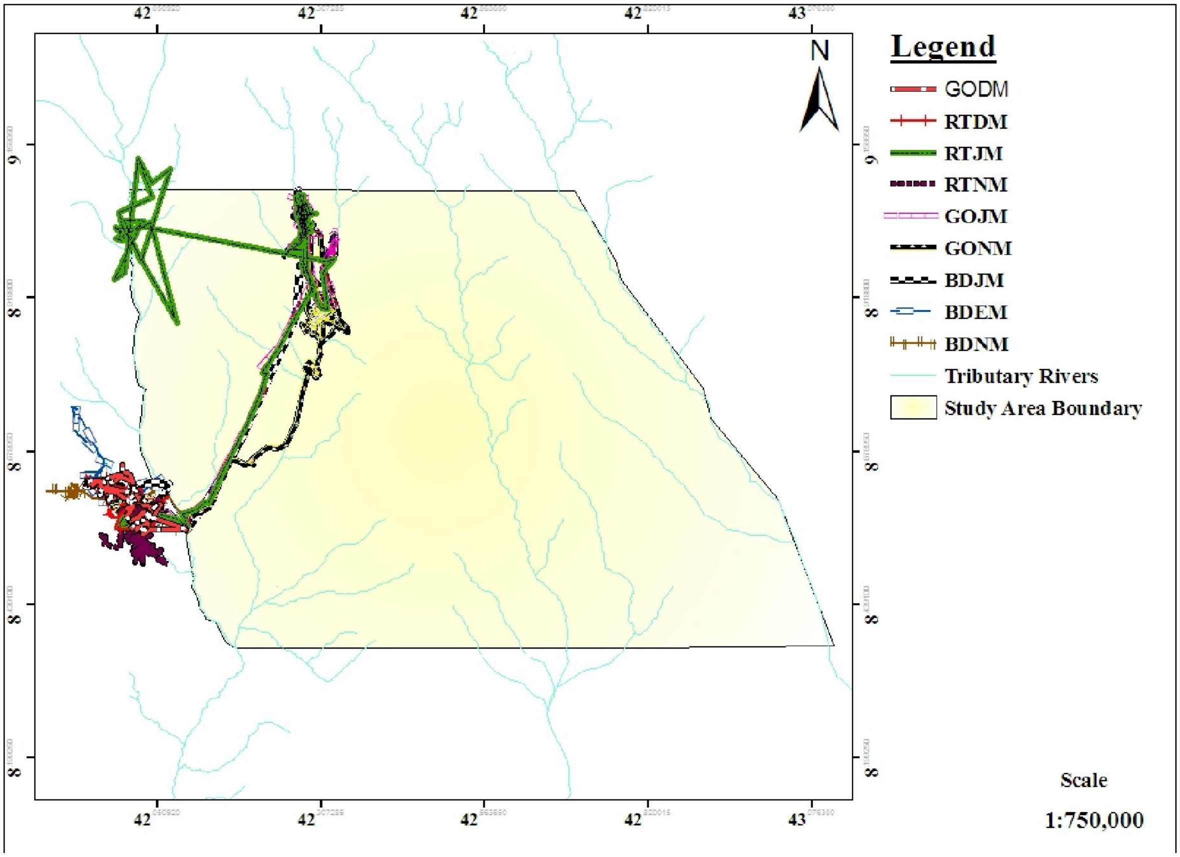

Figure 14. Dry season movement of collared bulls (GODM=Goliath, December movement, RTDM=Right-tusked, December movement, RTJM=Right-tusked, January movement, RTNM=Right-tusked, November movement, GOJM=Goliath, January movement, GONM=Goliath, November movement, BDJM=Big Daddy, January movement, BDEM=Big Daddy, December movement, BDNM=Big Daddy, November movement).

The bulls moved an average distance of 10 km/day. The daily movement distance (DMD) varied from 7 km for Big Daddy to 13 km for Right-tusked (Table 6). Regarding the monthly movement distance (MMD), the elephants moved an average of 301 km/month of which the maximum movement was observed in Right-tusked. The average DMR of the three bulls were 20 km^2 per day, which is about 3.3% of their mean total home range.

Table 6. Movement characteristics of collared elephants (DMD= Daily movement distance, MMD= monthly movement distance and DMR= daily movement range).

Movements	Big Daddy	Goliath	Right-tusked
DMD (km)	9.1 ± 2.1	10.1 ± 1.2	10.8 ± 2.2
	(11.2 - 7)	(11.3 – 8.9)	(13 – 8.6)
MMD (km)	266.9 ± 72.8	305.9 ± 37.5	329.4 ± 68.8
	(339.7 – 194.1)	(343.4 – 268.4)	(398.2 – 260.6)
DMR (km^2)	18.4 ± 8.6	19 ± 5.8	22.3 ± 10.7
	(27 – 9.8)	(24.8 – 13.2)	(33 – 11.6)

5. DISCUSSION

5.1. Dietary composition and feeding Preference

Elephant diet has been the focus of much research in Africa. Different dietary preferences have been reported for elephants throughout Africa and these preferences change seasonally (Wyatt and Eltringham, 1974; Guy, 1976; Cerling *et al*., 2004; Osborn, 2004). Seasonal changes in preference have been attributed to both changes in the availability of important food items and chemical changes in the leaves (Taylor 1978; Osborn, 2004). Previous studies have indicated that elephants feed from a diverse array of plant species, as many as 50-120 different species (Guy 1976; De Boer *et al*. 2000). The results for the present study confirm 75 species (61 wild and 14 cultivated plants) being consumed. The number of species consumed could be higher than the current result if the faecal analysis based on epidermis reference collection were successful. However identification of epidermal fragments at a species level was difficult and the results were excluded from analysis.

Many previous studies have highlighted a seasonal change in the importance of grass from the wet season to the dry season (Wyatt and Eltringham, 1974; Williamson, 1975; Osborn, 2004) but, the level of importance varied between the specific locality in which they occur and may vary with the plant species available to browsers (Westoby, 1978). However, during the dry season, when grasses dry, browse, which generally has higher levels and diversity of nutrients, becomes important (Osborn, 2004). For example, elephant diets in Hwange National Park, Zimbabwe, appeared to consist almost entirely of woody plants (Williamson, 1975). Again, in Maputo Elephant Reserve, browse is more important than grass during both wet and dry seasons (De Boer *et al*., 2000). Browse comprises the majority of the diet of elephants both during the wet and dry seasons in the present study. A similar result was reported for elephants in Chebera Churchura National Park (Meseret Ademasu, 2006). This change in feeding preference of elephants probably is linked with both human and habitat factors. Lack of extensive grassland habitat in BES can also be considered for looking higher proportion of browse in the diet of elephants during both seasons. Although food availability declines through the dry season, the presence of characterstic pioneer species in dry regions such as *Dichrostachys cinerea, Capparis* sp. and *Carissa spinarum* (Fernando *et al*., 2008) in addition to *Acacia* species, can provide food, leading to the absence of significant seasonal variation in dietary composition in the study.

Studies on food preference have shown that elephants have a definite preference for certain woody plant species and avoidance to others (Viljoen, 1989; Parker, 2004; Meseret Ademasu, 2006; Roux, 2006). Accordingly, elephants showed a strong preference for *Acacia robusta* and *Opuntia ficus-indica* while *Combretum molle* and *Grewia flavescens* were selectively avoided. Of the observed food plants, *Acacia* species were highly utilized during the study period. This may be due to the wide distribution of *Acacia* species in many parts of the Sanctuary (Anteneh Belayneh, 2006; Zelalem Wodu, 2007), as elephants used to utilize species based on their availability (Mwalyosi, 1990). It can also be associated with palatability of *Acacia* species either during wet or dry seasons (Caister *et al*., 2003) or may be due to the high crude protein content, low in fibre and high in water content of the species (Sauer *et al.,* 1977; Calenge *et al*., 2002; Parker *et al.,* 2003). The high preference index value of *Acacia albida* and *Acacia seyal* (Appendix 2) may be due to the rare occurrence in the environment or were undercounted during vegetation study in the diet, and they are avoided from analysis. However, de Garine-Wichatitsky *et al*., (2004) and

Milewski and Madden (2006), found that *Acacia seyal* was preferentially browsed by large browsers like giraffe, eland, impala and greater kudu which supports the present result. Again previous studies by Anteneh Belayneh, (2006) and Zelalem Wodu, (2007) in BES also indicated the impact of preferential utilization of elephants on *Acacia albida* and *Acacia seyal* that resulted in a high rate of decline of these species in the Sanctuary, which is an indication of selective preference for the two species. Studies on the feeding ecology of giraffe also revealed that the diet is composed of numerous species with various *Acacia* species being the most important and preferred food source during the wet season (Sauer *et al.,* 1977; Parker *et al.,* 2003). Report on the impact of elephants on woody species in South Africa by Steyn (2003) concluded that there was high impact on *Acacia* trees indicating selective utilization of elephants on this species.

Among *Acacia* species, elephants showed both preference and avoidance for individual species. However, it must be noted that a selective avoidance does not necessarily mean a species is avoided completely (Parker, 2004). A species could be an important component of the diet and still has a negative preference value. For example, *Acacia brevispica* and *Acacia nigrii* had relatively a closer frequency of occurrence in the diet (8.8 and 12.6% respectively) but *Acacia nigrii* was more abundant in magnitude than *Acacia nigrii* in all study blocks. Thus, while both are important in the diet, *Acacia brevispica* was relatively preferred while *Acacia nigrii* was used less than available (Roux, 2006), and it is likely that elephants will have a negative effect on *Acacia brevispica* than on *Acacia nigrii*.

The implication for high preference of *Opuntia ficus-indica* may be due to the succulence and low fibre content favouring digestibility and retention of fleshy green leaves during the dry season (Mukinya, 1973). In the present study, elephants were observed staying 3-4 days in cactus fields without visiting water sources, which may be due to the high water content of the cactus. The reason for relative preference of *Opuntia ficus-indica* during the wet season can be associated with fruiting of the species during this period that provided large amount of fruits for elephants. *Opuntia ficus-indica* is also used as food for humans and is a source of income in local markets. There is competition for this fruit between elephants and humans in addition to the high density of livestock looking for it.

Although elephants are generalist herbivores, they were observed selecting the food that offers the highest rate of nutrient intake at any given place or time (Osborn, 2004). Accordingly, selective utilization of elephants on *Acacia albida, Acacia seyal, Acacia nilotica, Acacia brevispica, Boscia minimifolia* and *Erythrina burana* makes the continued survival of these species questionable. For example, all the observed individuals of *Acacia brevispica* were small seedlings and saplings which are still exposed to small browsers, livestock and fire in the area. Fire has an effect in preventing regeneration or seedling growth (Laws, 1970; Mapaure and Campbell, 2002). According to information from the local people and wildlife scouts, the most preferred species *Erythrina burana* is difficult to find at any part of the Sanctuary. Therefore such food plants need nutrient analysis as it gives the best indications of nutrient content to understand the reason for the preference of the plants by the elephants.

Elephants were also observed feeding on cultivated crops and vegetables in BES, as crop raiding is a common phenomenon for both African and Asian elephants (Stephenson, 1976; Thouless, 1994; Hoare, 1999; Osborn, 2004). Fourteen different species were recorded to be consumed by elephants in this study (data obtained from farmers in the vicinity and direct field observations). Of which, sorghum, maize, mango, papaya, pumpkin, sweet potato and ground nut were the most preferred species in the farmer's fields. Selection of these species may be due to their high nutritional value, palatability, ease of handling during foraging, less fibre content and digestibility (Osborn, 2004; Hamilton *et al*., 2005; Lee and Graham, 2006).

5.2. Vegetation characterization

5.2.1. Importance Value Indies (IVI) of woody species

In the present study area, more than 85% is covered by only ten species, of which Shrubs accounted for 65.73% of the total density of the 53 woody species consumed by elephants, whereas trees comprised only 34.27%. This is because shrubs are the dominant components of the floristic composition of the study area (Zelalem Wodu, 2007). These ten species were also known for their high importance value (IVI), indicating the ecological importance of the species in an area (Lamprecht, 1989). Although, there are many dominant species, their utilization and preference by elephants differs considerably.

Out of the most preferred woody plant species, *Acacia albida, Acacia nilotica*, *Acacia seyal, Acokanthera schimperi*, *Carissa spinarum, Dobera glabra*, *Grewia bicolor, Grewia villosa* and *Trichilia emettca had* IVI of less than 10 and they account less than 4% of the total density. Lower IVI for these species shows these preferred species are highly threatened and there should be an immediate conservation measure. Preferentially utilized trees include those that provide shade or fruit such as *Acacia* species (Barnes, 1983; Milewski and Madden, 2006), nutrients such as protein, carbohydrate and mineral concentrations and those individuals that are more exposed or accessible and palatable (Taylor 1978; Osborn, 2004). According to Milewski and Madden, (2006), the density of *Acacia* species in the world is declining due to intensive browser utilization.

5.2.2. Regeneration status of woody plant species browsed by elephants

Among tree species browsed by elephants, *Acacia nigrii*, *Acacia brevispica*, *Acacia robusta* and *Acacia tortilis* showed relatively better regeneration. *Acacia nigrii* showed better regeneration which may be due to high density of matured trees producing viable seeds responsible for better seed dispersal and germination in the area. The result from dung analysis showed high number of seeds of *Acacia robusta* and *Acacia tortilis* (Table 2), which may be responsible for high regeneration status of the two species through their adaptation of dispersal and germination by elephants and other ungulates (Chapman *et al.*, 1992; White, 1994, Blake, 2002). However, *Acacia mellifera, Acacia nilotica* and *Balanites aegyptiaca* showed lower regeneration. This may be related to the high impact of elephants (Hemborg and Bond, 2007) and livestock especially camels on the small number of matured trees available in the area in addition to high anthropogenic need of the species (Zelalem Wodu, 2007). Huntly (1991) also suggested that elephant foraging can increase plant diversity by disproportionately damaging the more common species or decrease diversity by damaging rare species. Therefore, these species should be given priority in conservation for maintaining tree-shrub composition of the Sanctuary which is required for supporting high forage need of elephants and other herbivores.

Among the shrubs, *Dichrostachyus cinerea*, *Grewia flavescens*, *Ochna inermis*, *Kleinia squarrosa* and *Acacia oerfota* showed better regeneration. High regeneration of *Dichrostachyus cinerea, Ochna inermis* and *Acacia oerfota* may be due to high density of matured individuals and presence of substantial amount of viable seeds in the soil (White, 1994, Blake, 2002). Dung analysis also supported that these species had high number of seeds per dung bolus and elephants can be considered as the main agent of seed dispersal. On the contrary, *Cadaba farinose*, *Grewia villosa*, *Grewia bicolor* and *Euclea schimperi* had lower regeneration which can be associated with high impact of elephants due to their selective preferences. Previous studies by Anteneh Belayneh (2006) and Zelalem Wodu (2007) showed that the population structure of even the most dominant species like *Acacia robusta* is under question due to the combined effect of human and elephants.

5.3. Home-range and movement patterns of elephants

5.3.1. Home range

Home ranges of various sizes were recorded for elephants in different parts of Africa. The varied nature of the travel distances and home range recorded for African elephants are directly associated with the availability and distribution of resources. Mean total home range for the three bulls was 611.8 ± 142.2 km^2 in the present study, considerably larger during the wet season than the dry season and similar results were reported for elephants in Chebera Churchura National Park (Meseret Ademasu, 2006). Smaller home range during the dry season was concentration of elephant activities around permanent water sources (Owen-Smith, 1988; Lindeque and Lindeque, 1991; De Villiers and Kok, 1997; Osborn and Parker, 2003; Leggett, 2006a; Roux, 2006). The home range of elephants was also influenced by the size of the reserve in which the animals lived (Whitehouse and Schoeman, 2003). In addition to space and availability of water, many other factors will affect home range sizes. Roux, (2006) showed the importance of quality and quantity of food on elephant home range. During the dry season, the collared elephants concentrate their activities around

Gobelle Valley wherein they can get longer period of water sources as the river stays longer before drying. The valley provides them with evergreen vegetation which can support their daily forage requirements and the river bed also provides the elephants with sand bath at hottest time of the day. This can be considered for smaller home range of elephants during the dry season. The less occurrence of tree canopy that provided shade for the elephants can also be mentioned as a factor limiting the movement and ranging patterns of the bulls during the dry season (Dia *et al*., 2007; Shannon *et al*., 2008). In Erer, the riverine vegetation with many preferred *Acacia* and cactus species provide the required forage mostly during the dry season and Goliath was observed roaming freely throughout the Valley in order to minimize habitat deterioration. As a result he showed almost similar range in both seasons. Result of GPS data also showed the habitats mostly preferred by the elephants. Accordingly, the mixed woodland, *Acacia* forest and the bush land habitats were mainly seen in the preferred home range of elephants. Home range variation among the three bulls can be linked with age as matured bulls tend to wonder larger area in order to find potential mate (Villiers and Kok, 1997; Whitehouse and Schoeman, 2003; Jackson and Erasmus, 2005). Comparison of home range sizes in different parts of Africa is given in Table 7.

Table 7: Comparison of home range sizes (95 % MCPs; km^2) in different parts of Africa relative to reserve size.

Locality	Home range size (km^2)	Reserve size (km^2)	Reference
Addo Elephant National Park	54	103	Whitehouse and Schoeman, 2003
Shamwari PGR∗	111 ± 7.1	155	Roux, 2006
Kwandwe PGR	112 ± 9.3	160	Roux, 2006
Tembe National Elephant Park	72	300	Jackson and Erasmus, 2005
Nyika National Park	470	3000	Jackson and Erasmus, 2005
Tsavo National Park	1235	20000	Leuthold, 1977
BES**	611.8 ± 142.2	6000	The present study

PGR∗ = Private Game Reserve; BES**=Babile elephant Sanctuary the current study.

Until the mid of the 20th century, the home range of the eastern population of elephants was observed to extend to all river valleys (Gobelle, Erer, Daketa and Fafum), (Stephenson, 1976). Current data from Yirmed Demeke, (2008) and the present study confirmed that elephants were restricted only to Gobelle and Erer Valleys with little use in Daketa Valley. Poaching, increased human settlement, deforestation for different activities and lack of permanent water sources during the dry season can be considered as ths main factors responsible for considerable shrinkage of ranging patterns of the elephants especially in the Daketa and Fafum valleys in the eastern part of the Sanctuary (Barnes *et al*., 1991). Political unrest in this area can also be mentioned, for example Ethio-Somalia war (Stephenson, 1976) and local unstabilities may also have considerable effect on elephant movement.

5.3.2. Movement Patterns

Mammals exhibit widely diverse movement patterns that are influenced by available resources, social behaviour, presence or absence of predator and human disturbance (Osborn, 2004). Particularly the movement patterns of elephants can be highly influenced by such factors as they are highly mobile in nature. According to Yirmed Demeke, (2008), there are two clans (groups) of elephants in the study area based on their movement patterns and association to each other. The larger group known as the Gobelle group (about 290 individuals) spent most of the time in this valley whereas the smaller group known as the Erer group (about 90 individuals) stayed mostly in the Erer Valley. He also reported three movement patterns for elephants at Babile. Similar to other studies, the movement patterns of elephants at Babile coincides with seasonal variability of resources basically water and food. During the wet season, the three bulls were observed in Upper Erer Valley, to explore the northern part of the Sanctuary along the Erer Valley by moving outside of the boundary. This specific route in the north may be to look for the matured cactus fruit which is quite available in this area and the movement of the animals also coincides with fruiting time of the species (Yirmed Demeke, 2008). The separation of the bulls for most of the time during the dry season can be attributed to minimizing competition, most probably for food which is a limiting factor during this period (Matthysen, 2005; Chamaille-Jammes *et al.*, 2008). The third movement pattern was observed from east to south east inside the Sanctuary where elephants used to cross to Daketa Valley. The purpose of this journey may be to use salt licks according to information by the local people and Yirmed Demeke. Unfortunately, the GPS telemetry result did not show the third movement pattern and this variation may be due to the short period of tracking of elephants in the present study.

The average daily and monthly travel distances recorded was 10 and 301 km respectively, and it was relatively lower than distance covered by elephants in other parts of Africa. However, our result is comparable with the average daily movement distance of elephants under nonextreme conditions about 5 to 10 km (Leighty *et al*., 2008). The smaller daily movement and range of elephants in this study may be to avoid human disturbance (Viljoen, 1989; Cumming *et al*., 1990; Osborn, 2004) as most part of the Sanctuary and the surrounding is characterized by human settlement and related activities. It can also be associated with habitat heterogeneity that provides the essential resources for the present elephant density in the area (Tufto *et al*., 1996; Santra *et al*., 2008).

6. CONCLUSIONS AND RECOMMENDATIONS

6.1. CONCLUSIONS

During the present study period it was observed that elephants feed on diverse plant species. However, there was no significant variation on the quantity of species consumed during the two seasons. The diet of elephants in Babile is more of browse than grass as browse (particularly *Acacia* and cactus species) makes larger percentage both during the wet and the dry seasons. They are observed feeding on more fruits and freshly growing plant parts during the wet season and comparatively larger proportion of bark and stem during the dry season. Elephants were observed preferentially selecting some of the species in their diet while avoiding other species. The result also showed that selective preference of elephants to certain plant species affected the status of such important plants in their diet.

Elephant bulls at Babile had a home range which is comparable with other studies in Africa. However, the daily movement distance and range was relatively smaller than elephants in other parts. The elephants can also be considered as residents mainly in Upper Erer and Lower Gobelle Valleys and their movement route is based on the two river beds and long seasonal migration was not observed. The present study also revealed that the elephant's home range was restricted only to Gobelle and Erer Valleys and avoiding the Daketa and Fafum Valleys which were part of their home range in the last decades.

6.2. RECOMMENDATIONS

The result of this study is important for management and conservation because it provides information about the food requirements as well as ranging and movement patterns of elephants. In addition, this study on elephant diet is useful in that it provides the initial step towards understanding the resources and habitat required before any management efforts can be initiated. Accordingly the following recommendations are made.

- For better understanding the relationship between food plants and elephants, further study on nutrient analysis of the most important but threatened species such as *Acacia albida*, *Acacia seyal*, *Acacia nilotica*, *Acacia brevispica, Boscia minimifolia, Erythrina burana* and even on cactus species should be carried out.
- There should be an immediate plantation of the important food trees of elephants in and around the Sanctuary.

- Further studies are necessary on the most abundant seeds deposited in the elephant dung to understand fully the role of elephants in recruitment and distribution of plant species.

- Further conservation plan should give emphasis for reconsideration of the Sanctuary boundary especially in the northern part of Erer and southwest of Gobelle valley in which elephants spent considerable time outside the boundary.

- In order to have a clear picture on the DMD, DMR, total annual home ranges and all movement routes of elephants, further GPS telemetric data should be collected to minimize human-elephant conflict and conserve the animals by minimizing human impacts on the preferred habitats and ranges of elephants.

- Concerned parties: government, regional administrators, international and local organizations should participate in appropriate conservation planning, budget allocation and strict follow up of the implementation of the designed plan.

- Capacity building for the Sanctuary staff is mandatory in order to protect and save the declining vegetation through continuous patrol especially in areas of high illegal human activities within the Sanctuary.

- Tourist attraction initiatives such as development of infrastructure and promotion about the elephants through national and international media should be carried out.

- Preparation of a management plan to mitigate land use conflict in the area is paramount.

- There should be an immediate decision making activity in order to relocate the people with their huge livestock settled inside the Sanctuary. All the illegal activities carried out in and around the Sanctuary such as farming, charcoal production, logging for construction (plate 1) needs a strong attention from both the Federal Government as well as regional and local administrative bodies. In this case, the Ethiopian wildlife conservation authority in collaboration with the management of BES should follow and report the status of the illegal activities carried out in the area to the concerned decision making body in order to save the remaining fragmented habitats for the elephants.

- The effect of Flora Eco Power investment activity on elephant movement patterns and distribution needs immediate attention and there should be a means to relocate the biofuel project and rehabilitation of the area.

a

b

c

d

Plate 2. Some of the anthropogenic impacts at BES that needs immediate attention by all concerned bodies. (a). Cattle grazing in the Sanctuary (February, 2009), (b) herd of camel, primary competitors of elephants for food (February, 2009), (c) uncontrolled farming along Gobelle river, (Daketa valley, Nov, 2008) and (d) transporting charcoal to the market (Gobelle valley, Nov, 2008) (photo: Yihew Biru).

F implementation of community participation in all conservation planning and implementation activities, by creating opportunities in which the local people can get benefit from the Sanctuary so that they feel responsible for the species and the ecosystem in general.

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Appendix 1: Species browsed by elephants in the study area (H=Herb; Sh=Shrub; T=tree; Cl=climber; An-g=annual grass; Or=Oromifa language and S=Somali language).

Scientific name	Family	Habit	Local name	Parts consumed
Acacia albida# Del.	Fabaceae	T	Gerbi (Or)	Bark, Leaves, growing shoots
Acacia brevispica Harms	Fabaceae	Sh	Hamaressa (Or)	Bark, Leaves, growing shoots
Acacia bussei Harms ex. Sjostedt	Fabaceae	T	Hallo (Or)	Bark, Leaves, growing shoots
Acacia mellifera (Vahl) Benth.	Fabaceae	Sh/T	Bilela (Or)	Bark, Leaves, growing shoots
Acacia nigrii	Fabaceae	Sh	Sobensa (Or)	Bark, Leaves, growing shoots
Acacia nilotica (L.) Wild. ex Del.	Fabaceae	T	Serkema (Or)	Bark, Leaves, growing shoots
Acacia oerfota (Forssk.) Schweinf.	Fabaceae	Sh	Ajjo (Or)	Bark, Leaves, growing shoots
Acacia robusta Burch	Fabaceae	T	Wangeyo (Or)	Bark, Leaves, growing shoots
Acacia seyal# Del.	Fabaceae	T	Wachu (Or)	Bark, Leaves, growing shoots
Acacia tortilis (Forssk.) Hayne	Fabaceae	T	Dedecha (Or)	Bark, leaves, growing shoots, root
Acokanthera schimperi (A. DC.) Schweinf	Apocynaceae	Sh	Qeraru (Or)	Leaves, bark
Agava sisalina Perrine ex Engl.	Agavaceae	H	Algee (Or)	Bark, Leaves, growing shoots
Aloe pirottae Berger	Aloaceae	H	Hargessa (Or)	Leaves
Allophlus rubifolius (A. Rich.) Engl.	Sapindaceae	Sh		Leaves
Asparagus leptocladodius Chiov.	Asparagaceae	H		Bark, Leaves, growing shoots
Balanites aegyptiaca (L.) Del.	Balanitaceae	T	Bedeno (Or)	Leaves, fruits
Balanites glabra Mildbr. & Schlecht.	Balanitaceae	T	Kutika (S)	Leaves
*Berchemia discolor (*Klotzsch) Hemsl.	Rhamnacae	T	Gegeba (Or)	Leaves
Boscia minimifolia Chiov.	Capparidaceae	T	Meyigag (S)	Bark, Leaves, growing

				shoots
Cadaba farinosa Forssk.	Capparidaceae	Sh	Kelkelcha (Or)	Bark, Leaves, growing shoots
Capparis sepiaria L.	Capparidaceae	Sh		Leaves
Capparis tomentosa Lam.	Capparidaceae	Sh	Gemora (Or)	Bark, Leaves, growing shoots
Carissa spinarum L.	Apocynaceae	Sh	Agamsa (Or)	Bark, Leaves, growing shoots
Chionothrix latifolia Rendle	Amaranthaceae	Sh		Bark, Leaves, growing shoots
Combretum molle R. Br. ex. G. Don	Combretaceae	T	Abelbiyot (S)	Leaves, growing shoots
Commiphora schimperi (Berg) Engl.	Burserceae	T		Bark, Leaves, growing shoots
Cordia africana[#] Lam.	Boraginaceae	T	Wanza	Leaves
Cordia monoica[#] Roxb.	Boraginaceae	T	Oda (Or)	Leaves
*Cordia ovalis** R.Br.	Boraginaceae	T	Medero (Or)	Leaves
Cryptostegia grandiflora Roxb. Ex. R. Br.	Asclepiadaceae	Cl		Leaves
Cynodon dactylon* (L.) Pers.	Poaceae	An-g	Cheffe (Or)	Leaves
Dichrostachyus cinerea (L.)Wight& Arn.	Fabaceae	Sh	Girime (Or)	Bark, Leaves, growing shoots
*Dobera glabra (*Forssk.) Poir.	Salvadoraceae	Sh	Adde (Or)	Bark, Leaves, growing shoots
Dodonoea angustifolia L.f.	Sapindaceae	Sh	Ulaga (Or)	Leaves
Erythrina burana[#] Chiov.	Fabaceae	T	Walensu (Or)	Bark, leaves, growing shoots, root
Euclea racemosa Murr. Ssp.	Ebenaceae	Sh	Ameyisa (Or)	Leaves
Grewia bicolor Juss.	Tiliaceae	Sh	Aroressa (Or)	Bark, Leaves, growing shoots
Grewia erythraea Schweinf.	Tiliaceae	Sh	Deka (Or)	Bark, Leaves, growing shoots
*Grewia flavescen*s* Juss.	Tiliaceae	T	Tatyisa (Or)	Bark, Leaves, growing shoots
Grewia ferruginea Hochst. ex. A. Rich	Tiliaceae	Sh		Bark, Leaves, growing shoots
Grewia pennicillata Chiov.	Tiliaceae	Sh		Leaves
Grewia schweinfurthii Burret	Tiliaceae	Sh	Mida Gure (Or)	Leaves
Grewia tentax (Forssk.) Poir.	Tiliaceae	Sh	Midaska (Or)	Bark, Leaves, growing shoots

Grewia villosa Willd.	Tiliaceae	Sh	Ogemdi (Or)	Bark, Leaves, growing shoots
Kleinia squarrosa Cufod	Asteraceae	Sh	Luqqo (Or)	Leaves
Lantara camara L.	Verbenaceae	Sh	Beke Arkete(Or)	Leaves
Ochna inermis (Forssk.) Schweinf. ex Penzig	Ochnaceae	Sh	Alibal (Or)	Bark, Leaves, growing shoots
Oncoba spinosa# Forssk.	Flacourtiaceae	T	Gilbo (Or)	Bark, Leaves, growing shoots, fruits
Opuntia ficus-indica (L) Miller	Cactaceae	Sh/T	Tini (Or)	Fleshy leaves, fruits
Opuntia stricta (Haworth) Haworth	Cactaceae	Sh	Qenchere (Or)	Fleshy leaves, fruits
Pyrostria phyllanthoidea (Baill.) Bridson	Rubiaceae	Sh	Suta nekbu (Or)	Leaves and bark
*Tamarindus indica** L.	Fabaceae	T	Roqqa (Or)	Bark, Leaves, growing shoots & fruits
Terminalia brownii Fresen.	Combretaceae	T	Birdyisa (Or)	Leaves, growing shoots and fruits
Trichilia emettca Vahl.	Meliaceae	T	Ununu (Or)	Leaves, growing shoots and fruits
Typha elphantina Roxb*	Typhaceae	Sh	Filla (Or)	Leaves and stem
Ziziphus spina-christi (T.) Desf.	Rhamnaceae	T	Qurqura (Or)	Bark, Leaves, growing shoots & fruits
Elephant grass*	Poaceae	An-g		
Eucalyptus spp.		T		Leaves and growing shoots
Tree man tree*		T		Leaves and growing shoots

*=Species only observed in elephant dung piles missing in direct diet observation

#=Observation by wildlife scouts

Appendix 2: Preference indices (PI) for the most important species in the diet of elephants (%In Diet = percentage of a species in the diet, % In Field = percentage occurrence of a species in the field, P=Preference, +ve = preference of species, -ve = avoidance of species).

Species	% In Diet	% in Field	PI	P
Acacia albida	0.03	0.01	3.1747	+
Acacia brevispica	8.81	10.88	0.8099	-
Acacia bussei	1.51	1.25	1.2131	+
Acacia mellifera	2.09	2.14	0.9780	-
Acacia nigrii	12.61	17.68	0.7132	-
Acacia nilotica	0.23	0.09	2.4692	+
Acacia oerfota	0.48	0.42	1.1615	+
Acacia robusta	20.17	15.43	1.3070	+
Acacia seyal	0.03	0.01	3.1747	+
Acacia tortilis	2.73	3.73	0.7333	-
Acokanthera schimperi	0.29	0.16	1.7857	+
Aloe pirottae	0.26	0.52	0.4980	-
Asparagus leptocladodius	0.03	0.03	1.0582	+
Balanites aegyptiaca	2.57	2.48	1.0366	+
Balanites glabra	1.42	1.98	0.7163	-
Berchemia discolor	0.29	0.23	1.2423	+
Cadaba farinosa	0.42	0.47	0.8972	-
Capparis tomentosa	0.19	0.19	1.0025	+
Carissa spinarum	0.23	0.12	1.8519	+
Combretum molle	0.10	0.69	0.1401	-
Chionothrix latifolia	0.03	0.02	1.5873	+

Contd…

Dichrostachyus cinerea	2.03	1.58	1.2821	+
Dobera glabra	0.10	0.06	1.5873	+
Euclea schimperi	0.23	0.17	1.3072	+
Grewia bicolor	2.35	1.34	1.7557	+
Grewia erythraea	1.74	1.23	1.4168	+
Grewia flavescens	2.25	9.24	0.2437	-
Grewia schweinfurthii	0.06	0.08	0.7937	-
Grewia villosa	1.99	1.22	1.6402	+
Kleinia squarrosa	0.58	0.71	0.8163	-
Ochna inermis	3.60	2.53	1.4222	+
Opuntia ficus-indica	23.81	11.61	2.0502	+
Opuntia stricta	10.20	13.07	0.7801	-
Trichilia emettca	0.26	0.10	2.5397	+
Ziziphus spina-christi	0.29	0.39	0.7519	-

Percentage availability based on individual observation and calculated only for the consumed species.

Appendix 3. Distribution of sample sites (Blocks) for vegetation study in the study site.

No.	Site name (Block)	GPS reading	No. of quadrats	Vegetation type	Remark on the blocks
1	Fincho		6	Woodland	Agricultural expansion
2	Gera Bochiso	$09^{0}08^{'}97^{''}$ N $42^{0}16^{'}87^{''}$ E	5	Bushland/scrub	Tree cutting & charcoal production
3	Horo Roba	$09^{0}06^{'}46^{''}$ N $42^{0}15^{'}58^{''}$ E	6	Riverine forest	Agricultural expansion
4	Rare Adem	$09^{0}04^{'}30^{''}$ N $42^{0}29^{'}16^{''}$ E	6	Bushland	Agricultural expansion & high degree of browse
5	Suba Alah	$09^{0}06^{'}73^{''}$ N $42^{0}16^{'}67^{''}$ E	7	Woodland	Tree cutting & permanent agriculture
6	Walbi	$09^{0}00^{'}16^{''}$ N $42^{0}16^{'}44^{''}$ E	7	Bushland/scrub	Agricultural expansion & watering site
7	Qiltu Gudal	$09^{0}07^{'}25^{''}$ N $42^{0}15^{'}44^{''}$ E	7	Woodland	Tree cutting & charcoal production
8	Kurfa Guratii	-	5	Bushland	high livestock density
9	Shenjir	$09^{0}02^{'}30^{''}$ N $42^{0}16^{'}36^{''}$ E	5	Riverine forest	Agricultural expansion, settlement & high livestock density
10	Kurfa Dirri	$09^{0}03^{'}34^{''}$ N $42^{0}16^{'}11^{''}$ E	4	Woodland	Tree cutting
11	Kurfa Kara	$09^{0}03^{'}25^{''}$ N $42^{0}15$’$39^{''}$ E	10	Woodland	Tree cutting & initiation of agriculture
12	Sheka Dera	$09^{0}04^{'}58^{''}$ N $42^{0}17^{'}07^{''}$ E	6	Bushland	Overgrazing & initiation of agriculture

Appendix 4. Plant specimens collecting form.

Code	Local name	Block and Quadrat	Habitat	Season	Part of plant consumed			Source of Data			Frequency
					Bark	Fruit	Leaf/other	Direct observation	Feeding sign	Informants	

Appendix 5. Frequency of species in the diet of elephants and their occurrence in the field.

Species	Frequency in the diet	Frequency in all the study blocks
Acacia albida	1	1
Acacia brevispica	274	1074
Acacia bussei	47	123
Acacia mellifera	65	211
Acacia nigrii	392	1745
Acacia nilotica	7	9
Acacia oerfota	15	41
Acacia robusta	627	1523
Acacia seyal	1	1
Acacia tortilis	85	368
Acokanthera schimperi	9	16
Aloe pirottae	8	51
Asparagus leptocladodius	1	3
Balanites aegyptiaca	80	245
Balanites glabra	44	195
Berchemia discolor	9	23
Cadaba farinosa	13	46
Capparis tomentosa	6	19
Carissa spinarum	7	12
Combretum molle	3	68
Chionothrix latifolia	1	2
Dichrostachyus cinerea	63	156
Dobera glabra	3	6
Euclea schimperi	7	17
Grewia bicolor	73	132
Grewia erythraea	54	121

Grewia flavescens	70	912
Grewia schweinfurthii	2	8
Grewia villosa	62	120
Kleinia squarrosa	18	70
Ochna inermis	112	250
Opuntia ficus-indica	785	1179
Opuntia stricta	317	1290
Pyrostria phyllanthoidea	19	67
Trichilia emettca	8	10
Ziziphus spina-christi	9	38

Appendix 6. Monthly home range sizes for collared elephant bulls, BES.

Elephant	Month	Home range size (km^2)
Big Daddy	September*	118.7
	October*	1474
	November**	168
	December**	187
	January**	891.6
Goliath	September	175.6
	October	852.6
	November	1014
	December	153.9
	January	704.1
Right-tusked	September	181.2
	October	1517
	November	139.7
	December	138.2
	January	1462

*= Data used to calculate wet season home ranges

**= Data used to calculate dry season home ranges