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Impact of African Elephant (Loxodonta africana) on Flora and Fauna Community and Options for Reducing the Undesirable Ecological Impacts

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1. INTRODUCTION

1.1. Background and justification

African elephant (*Loxodonta africana*, Blumenbach, 1797), is the largest living terrestrial mammals (Feldhamer, 2007) and a long-lived species with a relatively long period of over 60 years (Dunham, 1988) but few do. Females generally become sexually mature at between 10 and 14 years of age (Moss, 1990) and may calve until death. Average calving interval is usually between 4 and 6 years in an increasing population (Eltringham, 1982). African elephants are intelligent animals that live in structured, family-oriented hierarchical societies in which individuals (particularly females) have strong permanent bonds with related animals (Moss, 1988). In general, males show little allegiance towards their natal group, which they leave at an average age of 14 years (Lee, and Moss, 1999). But females stay with their mothers as long as they are both alive (Foley, 2001). This results in matriarchal groups with complex multitier relationships and various degrees of cohesion, depending on a number of social and environmental factors, and the degree of human threat (Kangwana, 1993). Such groups can comprise large numbers of animals that may span several generations of related individuals.

The African elephant (*Loxodonta africana* Blumenbach, 1797) belongs to the order Proboscidea and family Elephantidae. Elephants are both graceful and beautiful land mammals of aesthetic attraction to local and international tourists. They have major ecological effects on savanna dynamics, playing significant roles in nutrient cycling, seed dispersal, the provision of space, and as a result they are considered as keystone or flagship species (Owen-Smith, 1988; Shoshani *et al.*, 2004). Despite their overall endangered status, extensive protected areas and effective control of poaching have led to the success of elephant conservation in Africa (Douglas-Hamilton, 1987). Continued increase of elephant populations may lead to a decrease in other species.

The African elephant (*Loxodonta Africana)* Blumenbach) is the largest extant land mammal, with recorded body mass of up to 6,000 kg for males, and 2,800 kg for females. Accordingly, its dietary intake is considerable (typically 1% (dry weight) of body mass daily) and the resulting effects on vegetation can be dramatic (Owen-Smith 1988). Pronounced reductions in trees and other woody plants have been experienced across the continent, including Cameroon, Tanzania, and South Africa (Pamo and Tchamba 2001). Conservationists and reserve managers have expressed concern about loss of rare or vulnerable trees and a possible concomitant loss of biodiversity. This has led to the paradoxical situation whereby managers of reserves with high elephant densities develop plans to limit or reduce population numbers of an endangered species (Caughley *et al.* 1990).

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 behaviors 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).

There are two sub-species of African elephant: The savannah elephant *(L. a. africana)*, also known as the bush elephant, is the largest elephant in the world, with a maximum shoulder height of 4m and weighing up to 7,500kg. It is recognizable by its large outward-curving tusks, and it lives throughout the grassy plains and woodlands of the continent. The forest elephant *(L. a. cyclotis*) is smaller and darker than the savannah elephant, has straighter, downward-pointing tusks, and lives in central and western Africa's equatorial forests. Recent studies provide strong genetic evidence to support the theory that the two subspecies of African elephant, the savanna elephant *(Loxodonta africana africana)* and the forest elephant *(Loxodonta africana cyclotis)* are actually two distinct species (Comstock, Georgiadis, , Pecon-Slattery, , Ostrander and Wasser, 2002). However, the IUCN/SSC African Elephant Specialist Group (AfESG) believes that premature allocation into more than one species may leave hybrids in an uncertain conservation status and continues to consider the forest and savanna elephants as two separate subspecies (AfESG,2002).

Elephants may have once inhabited most of the African continent (Cumming,, du Toit, and Stuart, 1990). They have been recorded from parts of northern Africa until 1000 AD (Scullard, 1974) and are presumed to have been widespread south of the Sahara (Sikes, 1971). Elephant numbers vary greatly over the 37 range states; some populations remain endangered, while others are now secure. For example, most countries in West Africa count their elephants in tens or hundreds, with animals scattered in small blocks of isolated forest; probably only three countries in this region have more than 1,000 animals. In contrast, elephant populations in southern Africa are large and expanding, with some 300,000 elephants now roaming across the sub-region. Elephants are generalist herbivores relying on widely distributed resources (Osborn, 2005; Archie *et al*., 2006; Wittemyer *et al*., 2007). They are extraordinarily manipulative mammalian mega herbivores, 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 present conservation status of the African elephant varies significantly across its range. Currently elephants are found in 37 sub-Saharan African countries, with the largest populations concentrated in southern and eastern Africa (Blanc, Thouless, Hart,, Dublin,, Douglas-Hamilton, Craig and Barnes, 2003).. It is estimated that there are at least 470,000 elephants on the African continent and possibly as many as 550,000; approximately 58% of the continental total is found in southern Africa (Blanc, Barnes, Craig, Dublin, Thouless, Douglas-Hamilton, and Hart, 2007).

Historically, the savanna elephant occurred south of the Mediterranean Sea until the Capen 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).

The African elephant is listed as *vulnerable* in the IUCN Red List of Threatened Species (IUCN. 2007). At present all populations of African elephants are listed in Appendix I of the Convention on the International Trade in Endangered Species of Wild Flora and Fauna (CITES), except those of Botswana, Namibia, South Africa and Zimbabwe, which are in Appendix II. CITES generally prohibits commercial international trade in specimens of Appendix I species, although trade may be allowed under exceptional circumstances, e.g. for scientific research (CITES. 2006). International trade in specimens of Appendix II species may be authorized by grant of an export permit or re-export certificate, but these are granted only if the relevant authorities are satisfied that certain conditions are met, above all that trade will not be *IUCN/SSC AfESG Review of Options for Managing the Impacts of Locally Overabundant African Elephants* detrimental to the survival of the species in the wild (Kangwana, 1993).

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 Ethiopia and in other protected areas like Omo National Park, Kaffita shiraro National Park , Mago National Park and Gambella National Park (Hillman, 1993; Yirmed Demeke, 2008) are home ranges of African elephant.

One of the diverse wildlife species conserved in Ethiopia's protected areas is the African elephant, *Loxodonta africana* (Blumenbach, 1797). Until the turn of the 19th century, the African elephant was widely distributed in the country (Largen and Yalden, 1987; Yirmed Demeke and Afework Bekele, 2000). Since then, however, the poaching of elephants for ivory and problems associated with human population growth and expansion has reduced the species range and number drastically. As a result, it is restricted to remote protected areas (EWCO, 1991; Yirmed Demeke, 1997). A recent assessment suggests that the country has lost about 90 percent of its elephant population since the 1980's alone. At present, the country's total number of elephants may not exceed 1000 and these inhabit nine separate localities, one being in Babile region of eastern Hararge.

Following Yirmed Demeke *et al.* (2006), the Babile Elephant Sanctuary (BES) is home to the only surviving elephant population in the farthest. Horn of Africa and is estimated to have a minimum of 300 elephants. BES is one of the protected areas, which is being highly declining in size and quality. As a result of mass influx of large farmers and their livestock, the home range of elephants of Babile has shrunk by 65 %. BES was established to protect the population of the
isolated elephants, *L. africana*.

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. 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 behavior and seasonal movement patterns is important for effective conservation and management of elephants in protected areas. Having poor conservation status, Ethiopia 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 (Anteneh Belayneh, 2006; Zelalem Wodu, 2007).

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 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. LITERATURE REVIEW

Despite many years of research by many scientists, the dynamic impact of elephant on the environment is poorly understood. Defining management policies to deal with the problem of elephant overabundance in conservation areas has been made difficult due to lack of scientific facts (Laws, 1970; Parker, 1983). Past attempts to manage elephant populations and their adverse impacts on vegetation have been targeted at keeping elephant populations at predetermined local densities in some conservation areas (Laws and Parker, 1968; Hanks, 1971; Hall- Martin, 1984; Cumming, 1981, 1983). Culling was in many ways used as a low risk strategy whereby elephant populations were held at artificially low levels while attempts were being made to understand the system dynamics of conservation areas.

Owen-Smith (1988) outlined the possible dimensions of the elephant problem as follows (a) radical modification of certain habitat types leading to perhaps the loss of species which depend upon them (b) elimination of certain sensitive plant species (c) reduced vegetation cover leading to accelerated erosion and decline in the overall productivity of the ecosystem (d) depression of the resource base for mega herbivores themselves and (e) loss of aesthetic features of landscape, such as mature trees.

The African elephant (*Loxodonta africana,* Blumenbach 1797) exerts a major impact on woody vegetation by selectively felling, debarking, snapping stems, breaking leader shoots, or otherwise damaging trees and shrubs (Owen-Smith, 1988). '*Selective utilization*' as used here refers to the relative acceptance of different woody species and size classes by elephant in order to consume specific plant parts such as leaves, bark, roots, stems and twigs to satisfy dietary requirements. The term '*acceptance*' reflects the likelihood of an animal commencing feeding on a species when that species is available nearby (Owen-Smith and Cooper, 1987, 1989).

Selective herbivores influences competitive interactions among plant species and growth forms, leading to changes in community composition and physiognomy (Owen-Smith and Danckwerts, 1997). As a result, herbivore may shape plant morphology, growth patterns and resource allocation in interacting with other environmental factors. Hence, a full knowledge of factors influencing selective utilization of woody plant species by elephant is fundamental to the management of both elephant and their habitats.

Elephants were reported to utilize woody species in proportion to their relative abundance (Anderson and Walker, 1974; Jachmann and Bell, 1985). Elephants were observed to prefer small size classes of woody plants (Wing and Buss, 1970; Laws et al., 1975; Caughley, 1976;), and large trees were selected only when preferred small size classes were not available (Laws et al., 1975).

The preferred feeding level of elephant appeared to be between 1 and 2 m (Caughley, 1976; Jachmann and Bell, 1985). Individual plants < 1 m of favored woody species were reported to be infrequently utilized by elephant (Leuthold, 1977; Pellew, 1983). However, Dublin et. al. (1990) reported that elephant alone appeared to prevent woodland regeneration in the Serengeti-Mara by feeding on small seedlings because there were fewer trees in larger height classes. Impact of elephant on saplings was also observed for *Acacia tortilis* in Lake Manyara National Park, Tanzania (Mwalyosi, 1987) but sufficient saplings survived and reached maturity.

Bull elephants were reported to have a higher impact on vegetation than females with respect to debarking and tree felling (Croze, 1974b; Guy, 1976; Barnes, 1980, 1982). Guy (1976) found that bulls were responsible for 80% of all the trees observed pushed over and uprooted as compared to 20% by females. Recent studies by Stokke (1999) and Stokke and du Toit (2000) within Chobe National Park found no evidence of feeding height stratification between family units and male groups. However, the authors confirmed that the preferred feeding level was about 2 m. Adult males were found to have the least diverse diet in terms of woody plant species included in the diet 9 but consumed more plant parts than family units. This was reflected in feeding site selection whereby family units selected patches with a higher diversity of plant species than males. In Ruaha National Park, Tanzania, Barnes (1982) reported that bulls and cows generally utilized a similar diet in terms of plant parts except during the dry season when cows tended to eat a diet containing significantly woodier browse than leafy browse.

African savannas have proven to be highly dynamic ecosystems, alternating between woodland and grassland states (e.g., Sinclair & Arcese 1995). In order to explain the apparent instability within savanna ecosystems, much emphasis has traditionally been placed on the role of elephant *(Loxodonta a. Africana* (Blumenbach)) (Laws 1970, Myers 1973, Pellew 1983). Destructive behavior by elephants increases tree mortality and may result in conversion of woodland to grassland. Caughley (1976) hypothesized a cyclic interaction between elephants and trees. Elephant populations increase under woodland conditions, leading to overexploitation of woodland and conversion of the vegetation to grassland. Elephants decrease in density under grassland conditions, allegedly due to lack of suitable food resources (Caughley 1976, Laws 1970). Low elephant browsing pressure in turn allows resurgence of woodland, completing the cycle. Dublin *et al.* (1990) hypothesized that fire rather than an elephant acts as the prime agent of woodland turnover. They argued that two stable states occur in savannas, one characterized by woodland and one characterized by grassland. Intense fires may shift the vegetation from the woodland to the grassland state. Once grassland is formed, however, elephants are able to maintain the situation. According to this hypothesis, both elephant and fire are necessary for a permanent shift from one state to another.

2.1. Elephant feeding patterns effect on vegetation

The level of impact of high elephant densities is governed by elephant feeding behavior acting in concert with other ecological and environmental factors. Elephants are mixed feeders, ingesting both grass and browse in varying proportions. Woody plants contain higher levels of crude protein than grasses in the dry season (Field 1971), so that browsing allows elephants to maintain body condition year-round (Williamson 1975). Elephants thus tend to increase the percentage of browse (when available) in their diet, causing most damage to woody plants, in the dry season (Barnes 1982, Glover 1963, Field and Ross 1976, Kalemera 1989, Bowland and Yeaton 1997). Browsing may also be increased as elephants take refuge in woodlands as a response to human disturbance (Lewis 1986, de Boer *et al.* 2000). The overall proportion of browse in the diet has been recorded at levels up to 98.8%, in Hwange National Park, Zimbabwe (Williamson 1975). Napier Bax and Sheldrick (1963) report that elephant diet is more diverse in the dry season than the wet season but de Boer *et al.* (2000) found that the diet became narrower at the late dry season. Intake of wood and bark tends to increase as the dry season progresses (Barnes 1982, Lewis 1986).

Preferred feeding height tends to be below 2m, the height of the browsed plants being somewhat greater (Jachmann and Bell 1985, Ruess and Halter 1990, Smallie and O'Connor 2000). Plants shorter than 1m tend to be ignored, and other height classes utilized in proportion to their availability (Croze 1974b, Kalemera 1989). Other workers have found a preference for adult trees (Barnes 1982, Okula and Sise 1986, Swanepoel and Swanepoel 1986), which may entail switching from stem and leaf browsing to bark stripping as height increases beyond 4m (Smallie and O'Connor 2000). Depending on the root system of the tree species, it may be uprooted frequently (*Combretum apiculatum, C. zeyheri, Acacia nigrescens, Terminalia sericea*) or merely browsed (*Sclerocarya birrea, A. tortilis, C. imberbe*) (van Wyk and Fairall 1969). Uprooting of adult trees by elephants may serve a social purpose (Lamprey *et al.* 1967, Guy 1976) but is chiefly associated with gaining access to fruit and leaves on the upper branches (Croze 1974a, Jachmann and Bell 1985, Mwalyosi 1987). Trees can survive toppling and regenerate if even half of their root system remains intact (Croze 1974b). Other elephant damage to trees includes felling, bark damage and stem breakage resulting from scratching-post behavior to shed ticks (Buss 1961).

Patterns of damage may be distributed differently by sex. Barnes (1982) notes that elephant cows moved more between plants than bulls, and breeding herds tend to be more selective than bulls in feeding patch and plant choice, apparently to minimize fiber intake (Stokke 1999). Duffy *et al.* (2002) advocate that managers should focus on numbers of male elephant, as mature bulls are responsible for the most of the tree toppling; Stokke and du Toit (2000) found that bulls topple five times as many trees as family units.

Damage rates to vegetation can vary greatly by elephant density. Elephant densities of approximately 1 per km2 have been reported as causing both little damage to trees (4.7% damaged, Anderson and Walker 1974; 18%, Birkett 2002) and extensive damage (77.6%, Mapaure and Mhlanga 2000; 87.2%, Thomson 1975). In general, elephant populations, or localized concentrations thereof, which exceed 2 km–2, cause damage to almost every individual tree (Buechner and Dawkins 1961, Ben-Shahar 1998, Jacobs and Biggs 2002b).

2.2. Dietary preferences effect on vegetation

While being bulk feeders, elephants still demonstrate distinct preference or avoidance for different plant species, which in turn affects (along with the individual species responses to utilization, see below) the extent and pattern of any vegetation change that may occur with elephant utilization of a habitat.

Preferentially utilized trees include those that provide shade or fruit (e.g. *Acacia albida* (Barnes 1983a) and marula, *Sclerocarya birrea* (Coetzee *et al.* 1979, Duffy *et al.* 2002)), nutrients – such as calcium and nitrogen (*Sterculia* spp and baobab, *Adansonia digitata* (Napier Bax and Sheldrick 1963)) and others (Williamson 1975, Hiscocks 1999) – or simply those individuals that are more exposed or accessible (Pamo and Tchamba 2001). Bowland and Yeaton (1997) found that elephants had a four- fold preference for trees from later succession stages (*Acacia caffra* and broadleaves) to earlier succession trees such as *A. nilotica*. Latex-bearing species such as *Euphorbia candelabrum* are generally avoided (Field 1971).

As a result, elephant damage tends not to be distributed among species in proportion to their relative abundance. For example, elephant damage around Lake Kariba, Zimbabwe, revealed that in *Colophospermum mopane* (mopane)-dominated woodland, elephants used mopane, *Combretum* spp and *Croton gratissimus* roughly in proportion to their occurrence, but that in *Combretum* woodland elephants selected mopane in preference to the other two species; *Meiostemon tetrandrus* was avoided, even in *Meiostemon*-dominated woodland (Jarman 1971). Similarly, Ben-Shahar (1998) found that although *Brachystegia* woodlands in northern Botswana had higher elephant densities, mopane woodlands experienced more elephant damage. Mopane is generally considered a preferred species (Williamson 1975, Ben-Shahar 1998), with coppiced trees often being continually pruned (Lewis 1991, Ben-Shahar 1993, Smallie and O'Connor 2000). Other workers, however, have argued that elephant dependence on mopane is over-emphasized (Lewis 1986, Styles and Skinner 2000; see also Anderson and Walker 1974). *Acacia tortilis*, the iconic savanna "umbrella thorn" tree is also generally considered a preferred species (Guy 1976, Ruess and Halter 1990, Ben-Shahar 1993; but see Smallie and O'Connor 2000). The baobab *Adansonia digitata* is frequently utilized for its soft pulpy wood in the dry season (Weyerhaeuser 1995).

3. Impact of African elephant on Flora community

Elephants are classified as mega herbivores; they graze and browse on a wide range of plant 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 (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).

Elephant, through their consumption of plant tissues, affect the relative growth, survival and reproductive output of these plants, with consequences for vegetation structure, community composition and ecosystem processes (Huntly, 1991). They affect the growth and survival of many herb, shrub and tree species, modifying patterns of relative abundance and vegetation dynamics. Cascading effects on other species extend to insects, birds, and other mammals. Sustained over-browsing reduces plant cover and diversity, alters nutrient and carbon cycling, and redirects succession simplified alternative states appear to be stable and difficult to reverse.

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). And this for longed consumption on plant species has impact based on plant existence.

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 mithers, 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, water requirement and shelter preference (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).

Elephants have been recorded felling or uprooting trees up to 60 cm in basal diameter (Chafota, 2007). Sometimes they feed on the branch tips or roots of these trees, but on other occasions they abandon the fallen tree without feeding on it. It has been suggested that some tree felling may be a social display unrelated to feeding (Hendrichs, 1971; Midgley *et al*., 2005), but this has not been confirmed. Trees pushed over in Kasungu National Park, Malawi, were taller (4–5 m) for favored species than for species generally rejected as food (2–3 m) (Jachmann & Bell, 1985).

Unlike most other herbivores, elephants' feeding actions may lead directly to the death of mature trees (through felling or uprooting), or otherwise expose these trees to other processes leading to tree mortality (through bark removal). Most other herbivores simply remove plant tissues, suppressing plant growth and reproductive potential, except in the case of small seedlings. In this sense, the consequences of elephant feeding for tree dynamics are more akin to those of a predator than is the case for other herbivores.

The African elephant is capable of extensive habitat modification and it has been shown that even at low elephant densities there can be significant effects on trees in some habitats (Mtui and Owen-Smith, 2006).This modification, commonly termed *elephant impact*, mostly takes place through elephants toppling (including pollarding) whole trees, by breaking and removing branches from their canopies (i.e. the elephants mechanically change the structure and composition of the canopy of trees, and by extension they change woodlands) and by preventing or reducing recruitment and regeneration (Guldemond and van Aarde, 2007). In such processes, browsing elephants commonly remove more material (biomass) than they finally consume (Owen-Smith, 1988) Moreover, elephants commonly strip bark off tree trunks, which is likely to result in the eventual death of the tree once fire or wood borers enter the exposed heartwood. These factors (i.e. browsing that affects the structure of a plant, 'wasteful' feeding and bark stripping) mean that an elephant population may have an effect on woody vegetation and biomass loss beyond what would be predicted by the physiological needs of the animals. This disproportionate effect is what leads to the recognition that elephants are a keystone species (Trevor, 1992).

3.1. Patterns of vegetation change

In concert with environmental factors, elephants can nonetheless precipitate declines in tree populations or marked changes in community composition. For example, Swanepoel and Swanepoel (1986) report baobab *Adansonia digitata* mortality of 15.5% over 6 months at an elephant density of 2 km–2 in the Zambezi Valley, Zimbabwe and Field (1971) reports a yearly decline in large trees of 14.6% in the Queen Elizabeth National Park, Uganda, as the elephant density approached 1.7 km–2. Marked declines can occur even at lower elephant densities. A sudden increase of elephant density to 0.135 per km2 in Serengeti National Park, Tanzania, led to a decline of large trees at an annual rate of 6% (Lamprey *et al.* 1967). Figures for overall woodland reduction can\mask more serious rates of individual species decline; for example, Field and Ross (1976) record a 1.6-1.8% overall loss of trees from Kidepo Valley National Park, Uganda, in 20 years, while *Acacia gerrardii* declined by 23% in 3 years.

Palatable species such *Acacia tortilis*, *A. xanthophloea* (Ruess and Halter 1990), *A. dudgeoni* (Jachmann and Croes 1991), *Brachystegia boehmii* (Guy 1989) *Colophospermum mopane* (Tafangenyasha 1997), *Commiphora* spp and the baobab, *Adansonia digitata* (Leuthold 1996) have declined while less preferred species (e.g. *Julbernardia globiflora* (Guy 1989); see also Jachmann and Croes 1991) or disturbance tolerant species such as *Lonchocarpus laxiflorus* (Buechner and Dawkins 1961) and *Combretum mossambicense* (Anderson and Walker 1974, see also Simpson 1978) increase. The nature and extent of species change also depends on habitat type (Anderson and Walker 1974, Guy 1981).

Elephant utilization can alter the vertical structure of the woody plant community, commonly manifested as reduced tree density and increased shrub density (Leuthold 1977, Guy 1989). For example, Pellew (1983) records a reduction in the proportion of mature *Acacia tortilis* (>6m in height) in the Serengeti National Park, Tanzania, from 48% to 3% of the population between 1971 and 1978, by which time individuals below 3m in height comprised 94% of the population. As mentioned above continued browsing may trap plants in more accessible size-classes (Jachmann and Bell 1985, Mapaure and Mhlanga 2000), although Lewis (1991) argues that such shrub lands are unstable, prone to crashes when nutrients are eventually depleted under persistent elephant utilization. Others have noted little structural change even with pronounced impacts (Jachmann and Croes 1991, Weyerhaeuser 1995), and Mwalyosi (1990) reports selective browsing for *Acacia tortilis* shrubs in Lake Manyara National Park, Tanzania, affecting a shift towards an older population structure.

Intensity of elephant habitat use and the emergent spatial patterns of change in vegetation, reflect the distribution of elephants across the heterogeneous savanna landscape (van Wyk and Fairall 1969, Thomson 1975, Swanepoel and Swanepoel 1986, Steyn and Stalmans 2001). Absolute elephant density can thus be a "relatively meaningless" guide to expected outcomes (Steyn and Stalmans 2001; see also Anderson and Walker 1974), while even seemingly identical areas can experience very different impacts (Duffy *et al.* 2002). Elephants have been reported to move up to 80km in response to localized rainfall (Leuthold and Sale 1973) and, as mentioned above, available water can concentrate elephant impacts (van Wyk and Fairall 1969, Laws 1970, Swanepoel and Swanepoel 1986, Pamo and Tchamba 2001), as can localized nutrient rich soil in rugged terrain (Nellemann *et al.* 2002).

Spatial distribution of tree use can be contagious, with preferred and/or fruiting trees forming focal points for elephant damage (Lamprey *et al.* 1967, Croze 1974b, Mwalyosi 1987, Calenge *et al.* 2002). In the Kruger National Park, South Africa, an enclosure to protect the roan *Hippotragus equines* population has also served as an incidental elephant- free refuge for the marula, *Sclerocarya birrea* (Jacobs and Biggs 2002a).

3.2. Techniques of Elephant impact on individual plants

3.2.1. Toppling effects

The ecological effects of pollarding (total breaking of the stem) differ from toppling, where the roots may be removed from the soil, which usually kills the plant. However, if the roots remain in the soil, many species can resprout quite effectively (e.g. *Combretum apiculatum* – Eckhardt *et al*., 2000). Factors that influence vulnerability to being toppled include strength of the wood, the depth and extensiveness of the root system and substrate stability (O'Connor *et al*., 2007). Shallow-rooted shrubs (e.g. *Commiphora* spp.) that are uprooted completely by elephants are greatly reduced in their prevalence by elephants, as has happened in sections of Tsavo East National Park, Kenya (Leuthold, 1977), and in Ruaha National Park, Tanzania (Barnes, 1985).

3.2.2. Bark stripping

The impact of stripping on a plant species is dependent on the degree to which the bark is stripped. Ring barking will kill the plant, but if some phloem remains intact, the bark may re-grow (Buechner & Dawkins, 1961; Laws *et al*., 1975). This may vary between species – mopane can lose up to 95 per cent of the bark without visible signs of stress (Styles, 1993). Features of the tree influence its vulnerability to being stripped, for example, elephants can cause more damage to trees with stringy bark (e.g. *Acacia* spp.) than those with bark that breaks off in chunks (e.g. *Sclerocarya birrea*) (O'Connor *et al*., 2007). Furthermore, toxins in the bark or stem spinescence reduce preference for bark stripping (Sheil & Salim, 2004; Morgan, 2007). Fluted or multistemmedtrunks are better protected against stripping (Sheil & Salim, 2004): in *Balanites maughamii* two-thirds of the bark is protected on account of fluting; while multistemmed trees that avoid total stripping (O'Connor *et al*., 2007) include various *Combretum* and *Gymnosporia* spp. Further, Sheil & Salim (2004) found that elephants selectively stripped larger trees.

3.2.3. Vulnerability of seedlings

Few studies explore elephant impact on seedlings (but see Jachmann & Bell, 1985; Kabigumila, 1993; Barnes, 2001), though there is evidence for species specific impacts. Examples are baobabs (Edkins *et al*., 2007), and about 35 percent mortality in *Acacia erioloba* in Chobe National Park, Botswana (Barnes, 2001). Elephants cause mortality by ripping seedlings from the soil, or prevent recruitment into adult size classes through top kill, maintaining the plants in a size class where they are caught in the 'fire trap' (Barnes, 2001).

4. Impact of African elephant on Fauna community

The direct effects of elephants on other animals include direct mortalities and interference competition (as opposed to resource competition). Thus, elephants temporally exclude other species from resources such as waterholes or other resources by actively chasing them away (Owen-Smith, 1996). Alternatively, elephants may also facilitate access to resources through, for example, excavating waterholes (Owen-Smith, 1988) and increasing the availability and quantity of forage (e.g. Skarpe *et al.,* 2004). The understanding of these interactions is again limited due to confounding factors, and the fact that these are normally cascading effects.

4.1. Invertebrates

There are few studies on the effects of elephants on invertebrates. Cumming *et al*. (1997) found significantly lower richness of ant species in woodlands that had been impacted by elephants than in intact woodlands. Cicadas were only recorded in the intact woodlands, not in the impacted woodlands. Mantid communities did not respond to changes in woodland structure (Cumming *et al*., 1997). Dung beetles are sensitive to habitat change (Klein, 1989). Disturbance in the form of elephants can have a significant effect on dung beetle species' diversity and biomass (Botes *et al*., 2006). In Tembe Elephant Park, Maputaland, dung beetle assemblages (Botes *et al*., 2006) differ between elephant impacted sand forest (a key endemic habitat type) and undisturbed sand forest sites (including the loss of some forest specialist species). Elephants may provide refuge for other species, particularly ground-living invertebrates, under dung and trunks of toppled trees (Govender, 2005). Musgrave & Compton (1997) demonstrated a significant increase in phytophagous insect feeding damage in the presence of elephants in Addo, and attributed this to an increase in the quality of browsed plants through a decline in secondary chemical compounds (e.g. tannins). This hypothesis does not have yet to be tested, nor has it been shown which insect species were involved, and what their population or overall insect biodiversity responses were. This apparent increase in nutritional quality of plants needs to be weighed up against the significant decline in overall plant phytomass (Kerley & Landman, 2006).

4.2. Reptiles and amphibians

In an attempt to explain high tortoise abundance in Addo, Kerley *et al*. (1999) hypothesis that elephant alteration of subtropical thicket habitat (through their creation of open habitat patches and paths) may favour increased access for tortoises (i.e. leopard tortoises *Stigmochelis pardalis* and angulate tortoises *Chersina angulata*).

4.3. Birds

Cummings *et al.* (1997) found a drop in species richness of birds and changes in bird communities (from woodland species to non-woodland species) in response to changes caused by elephants in Miombo woodlands, Zimbabwe. Reduced vertical and horizontal heterogeneity in the elephant-impacted woodlands probably accounts for their observed loss of species richness (c.f. MacArthur, 1964). In contrast, Herremans (1995), assessing bird community species shifts in riverine forest and Mopane woodland in northern Botswana, found that dramatic woodland change associated with the high abundance of elephants did not result in a reduction in bird diversity. This was possibly due to the fact that woodland conversion was spatially restricted. However, gallinaceous birds were more abundant in areas heavily impacted by elephants than elsewhere in the Chobe River region (Motsumi, 2002). Elephant removal of large standing trees in savanna (e.g. Eckhardt *et al*., 2000), may decrease the availability of nesting sites for raptors, especially vultures and other rare, open-savanna species (Monajem & Garcelon, 2005). Little is available in the scientific literature on the nesting requirements of savanna raptors. More research is needed to determine the outcomes of elephant-raptor interactions. Chabie (1999) showed that in transformed thicket in Addo, there were significant changes in the bird communities. At the guild level, there was a shift from frugivores in intact thicket to a community dominated by insectivores and granivores in opened-up thicket. In addition, there was a shift to larger bodied species in transformed thicket. The hypothesis that elephants drive these changes needs to be further tested.

Bats

The expected loss of large trees and snags due to elephants may decrease both roosting sites of bats and available habitat for species that specialize on feeding within dense vegetation (Fenton *et al*., 1998). However, Fenton *et al.* (1998) found no decrease in Vespertilionid and Molossid (airborne insectivores) bat species richness, or a loss in specialists, with a reduction in woodland canopy cover. Similar results were observed by Cumming *et al*. (1997)

in Miombo woodlands.

4.4. Small terrestrial mammals

There are few studies on the impacts of elephants on small mammals. Keesing (2000) showed that the presence of elephants in East African savannas results in an increase in species richness of small mammals, through habitat alteration.

4.5. Large terrestrial mammals

Browsers

There is a general negative correlation between elephant biomass and the biomass of browsers and medium-sized mixed feeders across ecosystems (Fritz *et al*., 2002). A number of mechanisms for this have been proposed, including (1) the reduction in resources through direct competition, (2) the alteration of habitats for browsers and other ungulates, (3) increase in visibility resulting in higher predation levels, and (4) competition for water (Owen-Smith, 1988; Skarpe *et al*., 2004; Valeix *et al*., 2007). While the patterns are significant, and sometimes obvious, the mechanisms are not yet clear: a possible explanation is that elephants reach highest abundances in areas of mopane and other vegetation types which they exploit more effectively than other browsers. The structural transformation from more wooded to more open habitat conditions benefits some browser species, but leads to a decline in others. The persistent abundance of elephants along the Chobe River and in Hwange National Park has been associated with an increase in kudu *Tragelaphus strepsiceros* and impala *Aepyceros melampus* (Skarpe *et al*., 2004). The mechanism for this is not clear, however; on the Chobe River, it may reflect the increase in *Capparis tomentosa* vines and *C. mossambicensis* shrubs, which are readily consumed by kudu and impala, but not elephants. In contrast, along the Chobe River, the abundance of bushbuck *Tragelaphus scriptus* has declined substantially following the opening of the riparian woodland by elephants (Addy, 1993).

In Addo, the opening of the succulent thicket vegetation by elephants brought about a decline in bushpig *Potamochoerus larvatus*, Cape grysbok *Raphicerus melanotis* and bushbuck abundance (Novellie *et al*., 1996). However, it is not known whether populations of these species outside the elephant enclosure have remained unchanged over this period, or whether putative changes in habitat structure are the consequences of elephant impacts (reasonably likely given the trends reviewed here) or some other process such as global climate change (Kerley & Landman, 2006). The reduction of vegetation cover and density by elephants in Addo results in a change in potential browse availability for black rhinoceros (Kerley & Landman, 2006). The increase in elephant paths, associated with increases in elephant densities, initially facilitates access to browse by black rhinoceros, but the subsequent dominance of the landscape by these paths results in a loss of foraging opportunities. Sigwela (1999) compared the diet of kudu in the elephant enclosure and botanical reserves of Addo, and showed that elephants had no apparent effect on kudu diet selection. This is surprising given that (1) extensive vegetation changes have occurred in the elephant enclosure, (2) kudu diet (28 species) includes many of the plant species recorded as being impacted by elephants, and (3) elephants consume all the plant species recorded in the diet of kudu here. This suggests that food availability is not limiting to either kudu or elephant at the present densities of vegetation and browsers at these sites (Kerley & Landman, 2006).

Grazers

Given that grass forms substantial parts of the diet of elephants for much of the year (Owen-Smith, 1988), elephants are expected to compete with grazing ungulates if forage is limited. On the other hand, elephants are able to open up the woodland and increase the grass cover (Caughley, 1976b). However, in their broad-scale analysis, Fritz *et al*. (2002) could not detect any effect of elephants on grazers. Western (1989) highlighted the role of elephants in East Africa in facilitating pasture for medium and small ungulates, including domestic livestock. In several cases, the decline of grazing species has been linked to the encroachment of woody vegetation in the absence of elephants (Owen-Smith, 1988), for example wildebeest *Connochaetus taurinus*, plains zebra *Equus burchelli*, waterbuck *Kobus ellipsiprymnus*, and reedbuck *Redunca arundinum* in Hluhluwe-Umfolozi Park (Owen-Smith, 1989). In Tsavo East National Park, Parker (1982) reported an increase in abundance of several grazing species, including oryx *Oryx gazella*, warthog *Phacochoerus africanus*, and zebra, following the opening of shrubland by the increasing elephant population. Young *et al.* (2004) found that by decreasing cattle grazing in a grassland area, elephants reduced the effects of competition between livestock and zebra. Not all grazers benefit; for example, the conversion of tall woodlands into shrub coppice is likely to be adverse for sable antelope *Hippotragus niger*, although possibly not for roan antelope *Hippotragus equinus* (Bell, 1981). Buffalo *Syncerus caffer* show a variety of responses to elephants. In the Chobe region, buffalo herds favoured areas recently grazed by elephants, suggesting facilitation rather than competition (Halley *et al*., 2003). Skarpe *et al*. (2004) suggested that there is no evidence for competition between buffalo and elephants in Chobe; however there is some evidence for competition between buffalo and elephants in Tanzania (De Boer & Prins, 1990).

5. Importance of African elephant in ecosystem

5.1. Nutrient cycling

Elephants typically constitute 30–60 percent of the large herbivore biomass in savanna ecosystems, and are thus responsible for 25–50 per cent (allowing for metabolic scaling) of the plant biomass consumption by herbivores (Owen- Smith, 1988; Fritz *et al*., 2002). About 50 per cent of the material eaten passes through the gut undigested. Furthermore, elephants process fibrous plant parts such as bark and roots (which are generally not eaten by other herbivores) and thereby accelerate biomass recycling. Their importance for biomass cycling is further enhanced through wasteful feeding (Paley, 1997; Lessing, 2007) and the toppling of trees (Owen-Smith, 1988).

This contribution by elephants to biomass recycling tends to be greater in nutrient-poor than in nutrient-rich ecosystems because of their capacity to exploit vegetation components of low nutritional value. The removal of branch ends as well as leaves, plus felling of mature trees, promotes compensatory regeneration by these plants (Pellew, 1983; Makhabu *et al*., 2006) and, hence, greater primary production and rates of nutrient recycling than would occur in the absence of elephants. Termites contribute to the release of the nutrients in the fibrous tissues in elephant dung, and fire to releasing the minerals held in the stems of trees toppled by elephants. It has been hypothesized that, in the nutrient-deficient savanna woodlands prevalent on Kalahari sands (with little capacity to retain nutrients), much of the biologically available nitrogen and sodium pool is held within elephant biomass (Botkin *et al*., 1981).

Elephants play a variety of roles in nutrient cycling, especially in nutrient deficient ecosystems. They may release the nutrients locked up in tree trunks and roots (Botkin *et al*., 1981). By removing large trees, they reduce the role that these trees play in extracting mineral nutrients from deep soil layers (Treydte *et al*., 2007), and also the contribution of these trees to small-scale heterogeneity in soil nutrients through the nitrogen-enrichment promoted by fallen leaves. This generally decreases the availability of high-quality forage resources beneath tree canopies, and could indirectly affect the persistence of grazers (Ludwig, 2001). By reducing the prevalence of nitrogen-fixing legumes such as many *Acacia* spp., elephants suppress the role that these species play in nitrogen enrichmen (Treydte *et al.*, 2007), although the absolute and relative extent of this effect has not been quantified.

5.2. Soil resources

Because of their large biomass, the trampling effects of elephants on soil compaction can also be substantial, with unclear consequences for vegetation (Plumptre, 1993). The large increase in woody cover associated with the exclusion of elephants in the experimental plots in Uganda dramatically increased soil organic matter and thereby pH, as well as extractable calcium, potassium, and magnesium levels. Organic carbon and nitrogen also increased, but total phosphorus declined slightly (Hatton & Smart, 1984).

Kerley *et al*. (1999) showed that in the Addo elephant enclosure the proportion of the landscape that represented run-on zones (i.e. where resources such as water, litter, soil, and nutrients are trapped during overland flow) declined, while the proportion of run-off zones (i.e. where these resources are lost) increased. The consequence of this was a decline in soil nutrients. Kerley *et al.* (1999) suggested that elephant impacts were less deleterious than goat impacts, but that these studies must be replicated.

5.3. Seed dispersal

Elephants play an important role in facilitating the dispersal and germination, and hence regeneration, of a large variety of plant species through endozoochory. Elephants are considered to be the only foragers (and hence dispersers) of the large-fruited *Balanites wilsoniana*, a canopy tree dominant in Kibale Forest, Uganda, as well as other large-fruited forest species (Chapman *et al*., 1992). Elephants enhance seedling germination (Cochrane, 2003) and increase seedling survival and growth by dispersing propagules far from adult trees (Babweteera *et al*., 2007). In savanna, seed germination and seedling survival of *Sclerocarya birrea* are also enhanced following fruit ingestion by elephants (Lewis, 1987).

Despite their dietary breadth in subtropical thicket (146 plant species – Kerley & Landman, 2006), elephants are relatively poor seed dispersers in Addo, dispersing only 21 plant species through endozoochory (Mendelson, 1999), comparable to black rhinoceros and eland (both 20 species – Mendelson, 1999). Why so few species are dispersed is not clear, but may reflect the rarity of most plant species in the diet (25 out of 146 species comprise 71 per cent of the diet – Kerley & Landman, 2005), selective foraging behavior in terms of plant phenology, complete loss of propagules during digestion, or inadequate sampling. The large volume of forage intake (and faecal output) by elephants (Owen-Smith, 1988), however, allows them to disperse large numbersof seeds (Sigwela, 2004), but their role in plant regeneration through this process needs to be quantified. Levels of zoochory vary between locations: for example, Robertson (1995) recorded 32 dicotyledonous species that were dispersed by elephants in nearby Shamwari Private Game Reserve.

Mortality of seeds during passage through the digestive tract was significantly lower in elephant compared to the goat *Capra hircus*, which served as a model ruminant (Davis, 2007). The effects of passage through the elephant digestive tract on germination differed between plant species (e.g. *Acacia karroo* germination declined, while *Azima tetracantha* germination improved). In addition, patterns of germination after ingestion differed between elephants, goats and pigs (Davis, 2007). This suggests that elephant effects on endozoochory will not be replaced by other herbivores.

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 (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).

6. Options for reducing the undesirable ecological impacts of African Elephants

The ecological impact of elephant populations can be managed either directly or indirectly (Cumming and Jones, 2005). Indirect options do not target individual elephant or groups of elephant and include range expansion, exclusion and manipulation of water supplies. Direct management specifically identifies individuals or groups and includes translocation, contraception, driving or disturbance, culling and killing individual problem animals (Hoare, 2001).

6.1. Indirect options

a) Non -intervention: A policy of not undertaking active management or failure to actively manage a population (such as translocation, contraception, culling and so on). In elephant management it usually refers to the process of allowing a population to increase or decrease with the only human contribution possibly being barriers to movement through human presence and activity or in some cases, through fencing.

The most common management option has been non-intervention or the laissez faire approach. This is not strictly a management action and the intention is not to reduce elephant densities but it may allow a natural decline to take place, such as when there is a resource-induced crash or a disease outbreak. An overview is therefore provided here with the following justification: Natural regulatory mechanisms, both density dependent and environmental forces, should be left to maintain the integrity of ecosystems by allowing elephant numbers to vary in time and space (Gillson, Lindsay, Bulte and Damiana, 2005), Managing an ecosystem to keep its components constant may weaken processes that enable it to resist change on its own account, decreasing its stability and resilience, Present vegetation composition and structure have developed in the absence of some herbivores (such as elephants) and is now being returned to its 'natural' state by the increase in number of herbivores (Skarpe et al., 2004). A population crash may result when animals are overstocked, but after the crash a healthy population will emerge from those individuals that are better adapted for and that have survived harsh environmental conditions (Sheldrick, 1965) and Use of some management options, especially lethal ones, may result in negative publicity and reduce the tourism potential of an area (Lindeque, 1988).

b) Range expansion: Is enabling an increased area of land to become available for animals to expand their movements and activities beyond some previously limited range. Apart from the obvious effect of making more land available for elephants and the consequential reduction in overall elephant density, range expansion has the added advantage of removing some of the restrictions on movement resulting from the initial range restriction. With increased movement come increased options for landscape use by the elephant population. Restricted movement has been identified as one of the factors resulting in excessive habitat impact in confined (fenced or otherwise) areas and thus the release of this restriction along with the reduction in overall density have the possibility of reducing the severity of elephant impact (van Aarde, and Jackson, 2007).

Increasing the area available for elephants can be done by: (1) increasing the size of protected areas (2) creating new protected areas (3) opening corridors to allow elephant movement between patches of suitable habitat (4) increasing the area available for elephants (5) allowing elephants to colonize lands already inhabited by humans (6) increasing elephant range by removing humans from the area in question.

6.2. Direct options

Direct management interventions have been justified on the following grounds: Undesirable changes in the ecosystem can result from an overabundance of elephants and management is necessary to maintain biodiversity and to prevent loss of other species of plants or animals (Kerley, and Landman, 2006). Knowledge of ecosystems is indeed inadequate but intervention may prevent undesirable outcomes of non-intervention such as erosion (Lugoloobi, 1993) and loss of biodiversity in plants and animals. Management may or may not affect stability or resilience but the current situation may be unacceptable (exceeding the limits to acceptable change).

a) Translocation: The deliberate movement (usually by means of mechanized transport) of wild African elephants from one natural habitat to another for the purpose of their conservation and/or management at the source site, release site or both (Dublin, and Niskanen, 2003). Translocation avoids some of the ethical and moral dilemmas associated with killing animals and is therefore emotionally appealing to the general public and finds international approval. Translocation can also be used to enhance populations that have declined or to reintroduce elephants to areas where they have become extirpated.

b) Fertility control – The permanent or temporary inhibition of reproduction in animals by any means. This includes contraception and sterilization. **Contraception** – Reversible pharmacological inhibition of fertility. **Sterilization** – The rendering of an animal permanently incapable of reproduction through surgical or chemical means. In general, however, fertility control methods are not practical for reducing an elephant population because the effect would be extremely slow; the rate of decline would be determined by the natural mortality rate, which is small. This is a problem common to all long-lived species like the elephant (Whyte, van Aarde, and Pimm, 1998)

c) Safari hunting: Safari or sport hunting is included here because there is an incorrect perception in some circles that this is an option for reducing the size of elephant populations. male elephants are often responsible for more tree damage than females, hunting may reduce adverse effects in localized key habitat areas (Guy, 1976).

d) Culling – Controlled killing of animals to reduce a population to a perceived optimum level consistent with the wider objectives of conservation (Pinchin, 1994).

7. Summary

The feeding actions of elephant may include digging and uprooting plants, tree felling, leaf stripping, bark stripping, branch breaking, plucking, chewing or any other manipulation of food items that may or may not be followed by consumption of plant parts. The severity of impact of elephant on woody vegetation depends largely on the type of impact suffered by a plant species and its response to the impact. Elephant impacts which are considered severe and likely to kill a woody species include uprooting, tree felling and bark stripping. Susceptible genera have been found to be *Acacia*, *Adansonia* and *Commiphora* (Bell, 1985). The probability of tree death following elephant impact has been found to be related to aridity, soil type, tree size, nutrient status and the woody species response to the damage. *Brachystegia, Julbernadia, Isoberlinia, Colophospermum*, some *Combretums, Terminalias*, and a range of other shrub species have a higher probability of coppicing (Bell, 1985). Despite the potential for coppicing following elephant impacts, elephant browsing may prevent recruitment of woody plants into larger size classes since the preferred feeding level was generally found to be in the range 1-2.5 m (Dublin et al., 1990). Impacts on larger trees were observed to occur only when regenerating woody plants were not available (Laws et al., 1975).

Bulls tended to have a greater impact in inflicting severe impacts during the hot-dry season particularly in the snapping of trunks and uprooting of plants. Comparative impacts between bull and cow elephants for other studies also suggested that bull elephant had greater impacts than cows with respect to severe impacts such as debarking and tree felling (Barnes, 1982).

Elephant impact types tended to be species and size class specific and varied seasonally. Snapping of stems appeared to be the most dominant type of impact all year round while leaf stripping was important during the wet and cool-dry seasons with severe impacts such as snapping of trunks, digging and uprooting of woody plants occurring mostly during the hot-dry season .In general, woody species commonly utilized by elephant and which suffered both severe and less severe impacts were the most commonly available woody species in the habitat. The height specific impacts for common, uncommon and rare species may negatively affect the physiognomy and recruitment dynamics of the targeted woody species.

The African elephant is capable of extensive habitat modification and it has been shown that even at low elephant densities there can be significant effects on trees in some habitats. This modification, commonly termed *elephant impact*, mostly takes place through elephants toppling (including pollarding) whole trees, by breaking and removing branches from their canopies (i.e. the elephants mechanically change the structure and composition of the canopy of trees, and by extension they change woodlands) and by preventing or reducing recruitment and regeneration. In such processes, browsing elephants commonly remove more material (biomass) than they finally consume. Moreover, elephants commonly strip bark off tree trunks, which is likely to result in the eventual death of the tree once fire or wood borers enter the exposed heartwood.

8. Recommendation

The impact of elephant on woody vegetation and ecosystem is common in elephant life. There are two possible options to reduce the impact of elephant on ecosystem. The direct and indirect option. For me the both options are best to manage the impact in different conditions.

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