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Long-term monitoring of elephant impact on the woody vegetation in the Tembe Elephant Park, South Africa

by

Mary-Lee Potgieter

Submitted in partial fulfilment of the requirements for the degree of Magister Scientiae

In the Faculty of Natural & Agricultural Sciences
Department of Plant Science
University of Pretoria
Pretoria

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Supervisor: Prof. M.W. van Rooyen

DECLARATION

I declare that the thesis/dissertation, which I hereby submit for the degree, MSc Plant Science, at the University of Pretoria, is my own work and has not previously been submitted by me for a degree at this or any other tertiary institution.

Signature: ______________________

Date: _________________________

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SUMMARY

The African Elephant is a key component of the savanna ecosystem. They contribute to the generation of habitat for smaller vertebrates, as well as invertebrates, by the breaking of branches or uprooting of trees. Elephants also play a role in seed dispersal, germination and sapling recruitment. All these functions are advantageous to the ecosystem if the elephant population size is acceptable for the size of the reserve and the amount of available forage.

The Tembe Elephant Park covers an area of 30 013 ha and is situated in northern KwaZulu Natal. This reserve has a diversity of vegetation types and is part of the Maputaland Centre of Plant Endemism and the Maputaland-Pondoland-Albany Hotspot of Biodiversity. Elephant numbers in the park are currently high and the elephant population is still increasing. This is threatening, especially to the endemic Sand Forest communities within the park.

The extent of elephant impact in Tembe Elephant Park, South Africa, was investigated and compared to data collected six years prior to the current study. Elephant impact was determined in 44 transects within nine communities across the park. Percentage canopy removal was calculated for the woody individuals found in sites and with this data the targeted size classes and species could be identified. The preferences of elephants for specific woody species were determined by three electivity indices.

Elephant utilisation in Tembe Elephant Park, as reflected by percentage canopy removal, increased since 2004 as the elephant population increased. Communities that experienced

high values in 2010 of elephant utilisation were the Closed Woodland 1, Mature Sand Forest, Open Woodland 1 and the Closed Woodland 3. Not only did the actual canopy volume removed by elephant increase with approximately 57%, but the total canopy volume available for browsing decreased extensively since 2004.

The size classes targeted by the elephants remained approximately the same from 2004 to 2010 although the 2010 results showed that elephant canopy removal percentage increased in the large size classes. This was expected as elephants target individuals with large stem diameters.

A change in the selection for woody species by elephants was clear, but the change in species preference made future projections of canopy removal problematic. Elephants seem to utilise a species at extreme levels until the species is almost extirpated, then they move onto the next target species. This routine is evident in the results as highly preferred species in 2004, with high canopy volumes available and removed, had low canopy availability and electivity ratios in 2010, consequently the elephants moved on from these species as individuals became scarce.

It was clear that the structure of individuals, populations and communities were being altered, selected species were facing extirpation and composition of communities was changed through the browsing manners of elephants. Management actions should be implemented to prevent irreversible damage to the vegetation and to conserve the woody species currently under threat.

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CHAPTER 1

INTRODUCTION

Whether the impact of the African elephant, *Loxodonta africana* Blumenbach, on the vegetation is positive or negative is still a controversial matter. On the positive side, elephants are seen as ecosystem engineers (Goheen & Palmer, 2010) as they create habitat for smaller animal species (Pringle, 2008), enhance seed dispersal (Chapman *et al*., 1992; Dudley, 1999, Cochrane, 2003) and minimize bush encroachment (Goheen & Palmer, 2010). Nevertheless, they also have a negative impact on the vegetation and they may even lead to the extirpation of plant species (Barnes, 2001; Lombard *et al*., 2001; Steyn & Stalmans, 2001; O'Connor *et al*., 2007). The impact of elephants on their surrounding environment differs between regions and reserves as there are a number of factors that determine the effect. For instance, the plant species composition, water availability, ratio of elephant bulls to cows and the density of the elephant population play a role in the intensity and pattern of elephant utilisation (Midgley *et al*., 2005; Stokke & du Toit 2002).

The Tembe Elephant Park covers an area of 30 013 ha and is situated in northern KwaZulu-Natal (Kellerman, 2004; Gaugris, 2008). The park is part of the Maputuland Centre of Plant Endemism, which is an area containing high plant species richness and high levels of endemism and is reknown for the exceptional Sand Forest vegetation (Van Wyk, 1994; Smith *et al*., 2006). The vegetation of the Tembe Elephant Park contains a great number of endemic plant species which do not only occur within the Sand Forest (Matthews *et al*., 2001). As elephant numbers in the park are high and they are confined to the area, they hold a potential threat not only to the Sand Forest vegetation but to all woody-dominated habitat types in the park. Uncontrolled elephant utilisation may pose a threat to the survival of especially the endemic species.

It is known that elephants utilise vegetation in a destructive manner (De Beer *et al*., 2006) but at a low elephant density this could be seen as part of the ecosystem functioning where elephants could then open up a new niche for small mammals. However, if the population size of elephants in a small, enclosed reserve reaches a critical threshold, their destructive utilisation of the vegetation could threaten biodiversity (Moolman & Cowling, 1994; Wiseman *et al*., 2004).

Various studies have been undertaken to quantify elephant utilisation of the vegetation in the Tembe Elephant Park (Guldemond, 2006; Guldemond & Van Aarde, 2007; Gaugris, 2008; Gaugris & Van Rooyen, 2008, 2010a, 2011; Shannon *et al*., 2009; Matthews & Page, undated). However, these studies were all once-off surveys of elephant utilisation of woody species and trends in the utilisation patterns over time could not be analysed.

Two of these studies, i.e. the one undertaken in 1995 by Matthews and Page (undated) and the one undertaken in 2004 by Gaugris (2008) shared many sampling sites. The current study therefore surveyed these selected sites again in 2010 and intended to integrate previous datasets with the new dataset in order to establish a database that would allow for analysing long-term effects of elephant utilisation.

The main objectives of the current study were as follow:

(a) to quantify the impact of the elephant population on the woody vegetation by calculating percentage utilisation (per species, per community and per height stratum);

(b) to compare woody species' percentage utilisation of current vegetation to previous data from Gaugris (2008) and Matthews and Page (undated) to establish whether and how increasing elephant numbers are changing the utilisation patterns;

(c) to establish whether changes in species preferences by the elephants have occurred and lastly

(d) to determine whether species, such as *Albizia* species which appeared to be declining in the park, were in fact declining as elephant numbers increase.

The outcome of this study could be used for management purposes, as decisions have to be taken regarding the control of the elephant population. The Tembe Elephant Park is a medium-sized, fenced reserve containing large tracts of Sand Forest, which is a vegetation type that has been classified as critically endangered (Mucina & Geldenhuys, 2006). It is of paramount importance for the management of the park to know whether elephants are threatening this critically endangered vegetation type. The database which has been established and populated could be expanded in future and could allow questions of a theoretical nature to be investigated or hypotheses to be validated.

CHAPTER 2

BACKGROUND

2.1 HERBIVORES

In South Africa, the interest in and importance of wildlife and the management thereof have increased substantially, as is reflected in the establishment of numerous nature reserves, game ranches and lodges. All herbivores have an effect on plant communities as they trample plants and soil, alter the nutrient content and contribute to plant defoliation (Vallentine, 1990). The interaction between wildlife and vegetation is important to the conservation of the environment on a reserve. Understanding the herbivores' habitat preferences and distribution in a reserve is central to the development of a management programme (Dekker *et al*., 1996). The relationship between wildlife to vegetation should be maintained in such a way that the wildlife does not overutilise the vegetation as this might lead to a decrease in plant diversity (Laws, 1970; Moolman & Cowling, 1994; Wiseman *et al.,* 2004).

Herbivory shapes and maintains the savanna ecosystem (Du Toit, 1995; Oguto & Owen-Smith, 2003) as well as the associated patchiness of the tree-grass layer (Bergström & Skarpe, 1999; Klop *et al*., 2007). Heterogeneity within the habitat is also promoted by the activities of the herbivores that are present (Hobbs, 1996; Gordon *et al*., 2004). In addition, habitat use and distribution of large herbivores across a landscape is determined or influenced by surface water availability (Bergström & Skarpe, 1999; Chamaillé-Jammes *et al*., 2007), such as swamps, rivers and waterholes.

The spatial and temporal variability of the savanna ecosystem maintains the variation in quantity and quality of forage available for herbivores. Herbivores show different degrees of habitat preference and selectivity to their surrounding environment (Dekker *et al*., 1996). Therefore they will not be distributed evenly over a reserve as certain habitats will be favoured by specific herbivores. Habitat quality and vegetation structure can be expected to contribute to the ecological separation of herbivores (Dekker *et al*., 1996). A herbivore's foraging niche or habitat depends not only on the quality and quantity of the vegetation, but also on its accessibility (Hansen *et al*., 2009).

The diversity of habitat resource quality is also important in the partitioning of herbivores amongst vegetation units (Cromsigt *et al*., 2009). Plant communities are however, not the only determinants of herbivore distribution and other factors, such as proximity to water, fire and intraspecific and interspecific competition, also contribute to their distribution. Fire and the time elapsed since the vegetation was last burnt also plays a role in the preference of herbivores for vegetation units (Klop *et al*., 2007). The interaction between different animal species is also linked to their habitat preferences (Ritchie *et al*., 2009).

The body size of large herbivores determines how much forage they can ingest as gut volume and metabolic rates vary accordingly (Demment & Van Soest, 1985; Codron *et al*., 2007). To small herbivores the quality of forage is of prime importance, while for large herbivores, the quantity of forage available is more important (Owen-Smith & Novellie, 1982). Large herbivores may select a specific plant species in a particular patch within the landscape (Senft *et al*., 1987; Ganqa *et al*., 2005). This selective behaviour by large herbivores may be due to plant metabolite and nutrient concentrations (Bryant *et al*., 1991; Ganqa *et al*., 2005).

In their turn herbivores have the ability to influence ecosystems, for example mega-grazers may change the structure and biomass of vegetation (Speed *et al*., 2009). Knowing where herbivores select to forage is of great importance to manage ecosystems especially when there is an increase in herbivore numbers as managers would like to predict the impact of increasing population sizes on the ecosystem.

Wiseman *et al*. (2004) conducted a study in the Ithala Game Reserve, South Africa, to determine changes in species composition and tree dynamics as a result of herbivory. The results showed a variety of responses from the woody species as some species decreased in abundance, others stayed the same and there were even a few that increased in abundance. As would be expected, those that decreased in abundance had high mortality rates and were those highly selected for by a number of browsers, while those plant species that had an increase in abundance had low mortality rates as well as low levels of herbivory. Overall, species composition within the reserve changed to woody species less preferred by the herbivores (Wiseman *et al*., 2004).

A study done in the Sweetwaters Game Reserve, Central Kenya, highlighted the differences in the response of the woody species to the impact of herbivores (Birkett & Stevens-Wood, 2005). Even although elephant utilisation caused severe damage, this study identified some other browsers which also contributed to the damage of woody species in a landscape. During the 3-year period in which woody species were evaluated for utilisation damage it was observed that there was a 16.3% reduction in woody individuals. Elephants contributed to 40% of this reduction, while black rhinoceroses were responsible for 33% of the lost trees and 27% died due to drought (Birkett & Stevens-Wood, 2005).

2.2 ELEPHANTS AND THE ECOSYSTEM

The African Elephant, *Loxodonta africana* Blumenbach, is the largest terrestrial mammal in Africa. Their mass ranges from 2800 – 6300 kg, depending on whether it is a male or female. They have a wide habitat distribution with adequate food, water and shade being the only prerequisites. A forage amount of up to 300 kg per day may be consumed by a mature elephant and they may travel vast distances for preferred forage species (Stuart & Stuart, 2007).

Elephants are highly dependent on water and therefore their distribution is centred around water (Owen-Smith, 1996). As a consequence the most severe elephant damage is found along rivers, in the vicinity of waterholes and other locations of permanent water (Ben-Shahar, 1993; Redfern *et al*., 2003; De Beer *et al*., 2006; Shannon *et al*., 2009). In a natural, unenclosed environment elephants would show seasonal migration between habitats (Lombard *et al*., 2001; Wiseman *et al*., 2004; Van Aarde & Jackson, 2007), however in small, fenced off reserves they are forced to feed on the same habitat all year round. Elephants were initially fenced off in African reserves to conserve the species (Birkett, 2002; Wiseman *et al*., 2004). This resulted in high population numbers in small reserves. There is evidence that in these reserves and protected areas with high densities of specifically large herbivores plant diversity has been reduced (Laws, 1970; Moolman & Cowling, 1994; Wiseman *et al.,* 2004). Currently, in the majority of African reserves, the need to control the population size of elephants is recognised (Owen-Smith *et al*., 2006). Management strategies to control elephant numbers include translocation, habitat resource management (Walker *et al*., 1987) as well as contraception of elephants (Delsink *et al*., 2006). Culling is another option for elephant population control but this method is extremely controversial.

Elephants are generalist feeders because they graze on grass and browse on trees and shrubs (Buss, 1961; Codron *et al*., 2007). During the wet season, elephants prefer grasses which are widely distributed in the savanna and have a high biomass and are very nutritious (Osborn, 2004). As the season advances grasses become drier and have a lower nutritional value and biomass. Therefore, during the dry season elephants switch to the browsing of woody species as they have a higher nutritional value than the grasses (Hiscocks, 1999; Owen-Smith *et al*., 2006; O'Connor *et al*., 2007). However, trees in savanna ecosystems may shed their leaves during the dry season and elephant may target roots and bark (Osborn, 2004; Ihwagi *et al*., 2009). Ihwagi *et al*. (2009) reported high incidences of debarking during the dry season.

Elephant utilisation has major impacts on woody species (Ben-Shahar, 1993). The severity of elephant damage depends on elephant population density and the distribution of forage material, for instance, the proximity to water (Stokke & Du Toit, 2002; Redfern *et al*., 2003). It is known that elephants kill large mature trees through uprooting and debarking (Birkett, 2002), they also curb seedling and sapling growth and inhibit vertical growth of smaller individuals (Barnes, 2001). Their browsing behaviour not only alters vegetation structure, but also decreases the overall biomass of the vegetation and specifically that of targeted species leading to an increase of plant species not selected for (Mapaure & Campbell, 2002; Wiseman *et al*., 2004). Elephants apparently disperse into habitats depending on the amount of food available and consequently they will start utilising vegetation units they not necessarily prefer, thus impacting an extensive part of the landscape (Young *et al*., 2009). The destructive manner in which elephants browse is influenced by social and sexual factors such as segregation and ratio of male to female elephants (Midgley *et al*., 2005). Stokke and du Toit (2002) observed higher levels of damage by male elephants than by females. However, the consequences of a large breeding herd browsing in an area cannot be neglected.

Elephants have been found to prefer woody species with a specific stem diameter and therefore target certain size classes (Dublin *et al*., 1990; Ben-Shahar, 1993; Duffy *et al*., 2002; Bounja & Midgley, 2009). Several studies have showed an increase in abundance of woody individuals (specifically trees) in the smaller size classes, with a concomitant decrease in abundance of the larger size classes (Bounja & Midgley, 2009). The reduction in large woody individuals is attributed to the growing elephant populations in the study areas. The damage of specific size classes might be due to a loss of browser-preferred species (Kalwij *et al*., 2010). The trend of increasing canopy removal with increasing stem diameter is expected as large individuals are those that elephants will choose for browsing or rubbing against (Ben-Shahar, 1993). It is suggested that low intensity impacts by elephants should not be regarded as insignificant because elephant damage is cumulative and therefore the impact of elephant utilisation may increase over time (Roux & Bernard, 2007).

It is stressed that elephants may utilise certain woody species to such an extent that they may cause extirpation of those species (Barnes, 2001; Lombard *et al*., 2001; Steyn & Stalmans, 2001; O'Connor *et al*., 2007). A meta-analysis of the published literature was undertaken to establish whether elephants have such a notable impact on the vegetation. It was found that besides high elephant densities, the presence of fences and rainfall contributed towards the observed effect on the woody vegetation. In the more arid savannas vegetation reacted negatively to elephant browsing, whereas in mesic savannas the impact on woody species increased as the elephant population densities increased (Guldemond & Van Aarde, 2008).

Elephants reduce tree cover in an ecosystem and therefore they are seen as an advantage in those landscapes where bush encroachment is a problem (Bounja & Midgley, 2009). Boundja and Midgley (2009) however, challenge the statement that elephants are able to reduce bush encroachment, because they could not find any supporting evidence. A reduction in tree cover may become a problem in areas where tree cover is low. In these instances large numbers of the elephants could transform the landscape into open grasslands.

Elephants may enhance the dispersal and recruitment of seeds (Chapman *et al*., 1992; Dudley, 1999, Cochrane, 2003). Trees that produce large seeds or fruits, such as tropical forest trees, require large vertebrates for dispersal (Babweteera *et al*., 2007). Chapman *et al*. (1992) found that there is a relationship between elephants and *Balanites wilsoniana* (tropical forest tree species) in terms of the dispersal of this species' seeds. Barnes (2001) reported similar results for *Acacia erioloba* pods in Botswana. The digested pods (or seeds) in elephant dung germinated quicker than those pods that fell on the ground. The water and enzymes in the digestive system of the dispersal agent aids water uptake and in effect, germination (Barnes, 2001). Seeds of the marula tree (*Sclerocarya birrea*) were also found to germinate quicker after having passed through the digestive tract of elephants than those that had not (Dudley, 2000; Midgley *et al*., 2012).

Most of the elephant populations in large reserves in southern Africa number more than 5000 elephants in approximately 5000 km^2 (Cumming *et al*., 1997). Fifty percent of that carrying capacity (2500 elephants) in a reserve bigger than 5000 km^2 is considered to ensure the population survival (more than 99% probability), genetically and demographically, for more than 1000 years (Cumming *et al*., 1997). An elephant population at that carrying capacity will conserve a greater amount of plant and animal species (Cumming *et al*., 1997) than at a higher density. Since the prohibition of international ivory trade, elephant densities are increasing in conservation areas, and are reaching critical levels (Hoare & Du Toit, 1999).

The loss of plant diversity and extinction of targeted woody species have been documented in several African protected areas (Laws, 1970; Moolman & Cowling, 1994; Wiseman *et al.,* 2004). Several case studies in African conservation areas have demonstrated the impacts on elephants on the vegetation. A few of these case studies are briefly summarised below.

The Hluhluwe-Imfolozi Park in KwaZulu-Natal, South Africa, has an elephant population of 350–425 animals which is above the Park's carrying capacity (300-350) (Boundja & Midgley, 2009). The elephants were re-introduced to this park because it was thought that they would reverse bush encroachment and maintain ecosystem functioning (Boundja & Midgley, 2009). However, elephant impact on the vegetation became clearly visible and raised concern. Boundja and Midgley (2009) consequently assessed the patterns of elephant utilisation, whether it was toppling, debarking, uprooting or just general browsing and breaking of branches. The vegetation survey was done in a similar manner to the current study, especially in terms of the six size classes which were distinguished. They found that the Closed Woodlands were the most susceptible to debarking. It was hypothesised that elephants would select species based on their dominance or density but this was not the case in Hluhluwe-Imfolozi Park as the elephants selected woody species based on their size class. Even scarce species were targeted and could possibly be threatened with extirpation. Within a preferred species, the elephants would selectively utilise the individuals with larger stems over those with small stems. As a result little impact was observed on entities lower than 1 m in height. Consequently, there will be not only a decline in numbers of certain targeted species but overall there was a decrease in large stemmed individuals. Elephants in the Hluhluwe-Imfolozi Park showed notable selection for *Albizia versicolor* and *Schotia brachypetala,* while species associated with bush encroachment were avoided (Boundja & Midgley, 2009).

Elephant survival in relation to rainfall variation was evaluated in a study within ten study areas in South Africa, Botswana, Namibia and Zambia (Shrader *et al*., 2010). It was found that elephant survival was higher for individuals that were born in years with high rainfall than those born in low rainfall years. The effect of rainfall on elephants is probably indirect because the amount of precipitation determines the amount of forage during that particular year which in turn regulates the quantity and quality of browsing material available to them. Fencing of areas and the provision of artificial waterpoints leads to elephants browsing in a destructive manner year-round and should be prevented as far as possible (Shrader *et al*., 2010).

A study was conducted in Songimvelo Game Reserve, in the Barberton Mountainland, South Africa, to assess the utilisation and impact of elephants on a heterogeneous landscape (Steyn & Stalmans, 2001). Within the sampling plots 73 woody species were identified of which 31 were utilised in the forest, 39 species in the woodland and 18 in the shrubland. Some of the species were both high in dominance and utilisation, whereas others were not dominant but nevertheless utilised frequently and therefore selected for by elephants. It was concluded that if these levels of utilisation and selection by elephants continued, the selected woody species' persistence would be threatened (Steyn & Stalmans, 2001).

Overall, some general conclusions have been drawn regarding elephant utilisation in different ecosystems. Firstly, these megaherbivores sustain the heterogeneity of the landscape (Goheen & Palmer, 2010). Secondly, the use of vegetation increased with proximity to water. Thirdly, elephants prefer areas with high vegetation cover and lastly, areas with human activity (settlements) are avoided by elephants especially the bulls (Harris *et al*., 2008).

2.3 ELEPHANTS AND THE TEMBE ELEPHANT PARK

Tembe Elephant Park was proclaimed in 1983 and entirely fenced off in 1989 (Matthews *et al*., 2001). Before the park was declared a conservation area in 1983 it was estimated that the elephant population consisted of 30-60 animals. Elephant numbers as well as those of other herbivores increased gradually since 1989 when the park was fenced off (Gaugris & Van Rooyen, 2011). The park is situated within the Maputaland Centre of Plant Endemism which has a high biodiversity importance and it contains the rare Sand Forest, also referred to as the Licuati Forest. Gaugris (2008) identified three debates regarding the conservation of Maputaland's biodiversity. The debates are around:

1. The impacts on the vegetation of animal populations which increase within the protected areas due to successful conservation;

2. Whether the Sand Forest is resilient and self-maintained under the current climatic conditions;
3. The impacts of human natural resource use by residents from the surrounding communities and how this compares to herbivore utilisation levels.

2.3.1 Sand Forest

In South Africa, forests are tree-dominated vegetation units with a closed, overlapping canopy where the canopy height may be over 30 m for tall forests and 3 m for scrub forests. Indigenous forests in South Africa are mostly evergreen and occur in small patches (<10 ha to 100 ha). Forests occur in regions with high water availability which could be areas of high rainfall or riverine zones (Mucina & Geldenhuys, 2006). The mean annual rainfall in the Tembe Elephant Park is approximately 721.5 mm (Tarr, 2006), which is below the mean annual rainfall of 800 mm considered as the lower threshold for forests in southern Africa (Everard *et al.,* 1994). Conservation of the forest ecosystem in South Africa is a challenge as its distribution is patchy (Van Rensburg *et al*., 2000) and therefore a large area should be conserved as a whole to conserve the actual functionality of the forest network (Midgley *et al.,* 1990). The unique Sand Forest (Licuati) in southern Africa is restricted to the Maputaland region with the majority being part of the Maputaland-Pondoland-Albany hotspot (Smith *et al*., 2006). High levels of endemism, of both fauna and flora, are found within the Sand Forest patches (Matthews *et al*., 2001; Botes *et al*., 2006).

A study conducted in Tembe Elephant Park showed that elephants do not only have an impact on the vegetation in the Sand Forest. There were changes in dung beetle assemblages in the Sand Forest community which was attributed to alterations in the vegetation structure. Botes *et al*. (2006) concluded that elephant browsing not only damaged the vegetation but lead to changes in the invertebrate fauna.

2.3.2 Elephant population

The elephant population in the Tembe Elephant Park is currently still increasing (Gaugris & Van Rooyen, 2010a). One of the main objectives of establishing the Tembe Elephant Park was to conserve the unique Sand Forest with its associated fauna, yet ironically this vegetation unit is now threatened by the elephant utilisation and increasing population sizes (Matthews, 2007a; Gaugris & Van Rooyen, 2010a). The elephants within this particular park are known to browse/utilise vegetation in a destructive manner which is clearly noticeable (Guldemond & Van Aarde, 2007; Gaugris & Van Rooyen, 2010a). Gaugris and Van Rooyen

(2010a) assessed the utilisation of elephants in relation to the distance from permanent water. The method of evaluating the elephant damage is similar to what was used during the current study where the age, agent, type, regrowth and canopy volume removed were determined and recorded. From the 107 plots that were surveyed by the researchers, only three of these plots did not show any evidence of elephant utilisation (recent or old) (Gaugris & Van Rooyen, 2010a). They found that the Closed Woodlands had the highest values of recent elephant utilisation followed by the Sand Forest, Open Woodlands and the Sparse Woodland. 'Old' elephant damage, i.e. more than 12 months prior to the study, was the highest in the Closed woodland on Sand, followed by the Sand Forest and the Closed Woodland on Clay. A possible explanation for the high volume of canopy removal in the Closed woodlands may be ascribed to its close proximity to permanent water. The amount of recent elephant utilisation in the Sand Forest was high and raised concern.

Gaugris and Van Rooyen (2010a) hypothesized that the utilisation patterns of elephants had changed in the park in recent years. The intensity of utilisation by the elephants increased especially in areas close to permanent water as well as in the more open woodland regions. It is possible that there is a shift in distribution of elephant impact from the northern regions to the eastern sections of Tembe Elephant Park (Gaugris & Van Rooyen, 2010a). In the east of the park, a number of permanent water holes can be found. The Muzi swamp is also located in the east of the Park. The Closed Woodland on Clay community had high utilisation values and it could be due to the vegetation being more nutritious on these clay soils than the neighbouring sandy soils (Matthews *et al*., 2001; Gaugris & Van Rooyen, 2010a). Matthews and Page (undated) found that, compared to the other communities, the Sand Forest in the Tembe Elephant Park had very little canopy removed by elephants. Woody species which were recorded, in their study in 1995, with the most canopy removal and highest preference indices were *Albizia adianthifolia*, *Dialium schlechteri*, *Newtonia hildebrandtii*, *Manilkara discolor* and *Wrightia natalensis*.

Sand Forest in the Tembe Elephant Park contains a number of endemic plant species and the increase in elephant numbers may have a negative effect on this unique vegetation type and its endemic species. In 2000, according to Morley and Van Aarde (2007), the number of elephants in the park was estimated to be 167 elephants with the count and mark-recapture method. With the Bowden's estimator the estimated population size was 179 elephants (Morley & Van Aarde, 2007). In the park, 70% of the browser biomass is contributed by elephants and this species is estimated to be increasing annually at a rate of 4.6% (Guldemond & Van Aarde, 2007; Morley & Van Aarde, 2007). Another study (Guldemond & Van Aarde, 2007) evaluated the impact of elephants in the park by comparing the vegetation in the park to an area outside the park where elephants were absent. A number of browsers were identified as utilisation agents, but elephants were the only ones that caused high levels of damage such as uprooting and breaking of large branches (Guldemond & Van Aarde, 2007). The turnover of plant species occurred at higher rates in the park than in the control area. At the community level the elephants did not have an impact on the vegetation, however at a species level there was a strong influence. The results obtained showed that there is a decrease in the canopy volume of the preferred woody species. They contended that the functioning of the woody species was not affected by elephant browsing (Guldemond & Van Aarde, 2007). The study identified seven woody plant species which were selected by the elephants namely *Acacia burkei*, *Afzelia quanzensis*, *Albizia adianthifolia*, *Dialium schlechteri*, *Manilklara discolor*, *Sapium integerrimum* and *Spirostachys africana* (Guldemond & Van Aarde, 2007).

It is not only the feeding behaviour that may lead to destruction in the ecosystem. The movements of elephants between different feeding and watering points leads to the establishment of pathways. Shannon *et al*. (2009) identified and mapped elephant paths in the Tembe Elephant Park and accordingly it was possible to predict where elephant tended to feed and how their distribution related to water proximity. It was found that the most used and recognised pathways were those near water sources. Close to water and in some parts of the Sand Forest ‘resting’ points were observed along these elephant pathways. The density of these pathways differed between the different vegetation units. The Closed Woodlands had the highest density of pathways indicating elephant preference for this vegetation type (Shannon *et al*., 2009).

CHAPTER 3

STUDY AREA

3.1 LOCATION

The Tembe Elephant Park is situated in the KwaZulu-Natal province of South Africa (26° 51' 53.19" S to 27° 02' 45.04" S and 32° 24' 17.38" E to 32° 35' 24.01" E) (Figure 3.1). This park falls within the Maputaland Centre of Plant Endemism (Van Wyk, 1994) which is currently part of the Maputaland-Pondoland-Albany hotspot for biodiversity (Smith *et al*., 2006). The extent of the Tembe Elephant Park is 30 013 ha with its northern boundary representing the international border between South Africa and Mozambique and in the south it borders the main road which runs from KwaNgwanase to Jozini. The park was proclaimed in 1983 (under guidance of Chief Mazimba Tembe) in order to (a) protect the people of surrounding communities from elephants, (b) to conserve the elephant populations of KwaZulu-Natal and (c) lastly, to protect and conserve the unique Sand Forest vegetation as well as the suni (*Neotragus moschatus*) population (Kellerman, 2004). After the proclamation in 1983, the area was not fenced off completely, but was still open to the north. As elephant poaching increased from the north, the entire park was fenced off in 1989 (Van Eeden, 2006).

The Muzi swamp runs from just outside the Tembe Elephant Park in the south, through the park, all the way to the south of Maputo Bay (Mozambique) into the ocean. It is located in the eastern part of the park (Figure 3.1). Within the park, the Muzi swamp is 17 km in length and its width ranges from 200 m – 500 m (Tarr, 2006). This is the main permanent water source in Tembe Elephant Park and commonly used by buffalo and elephant for grazing (visual observation) (Figure 3.2).

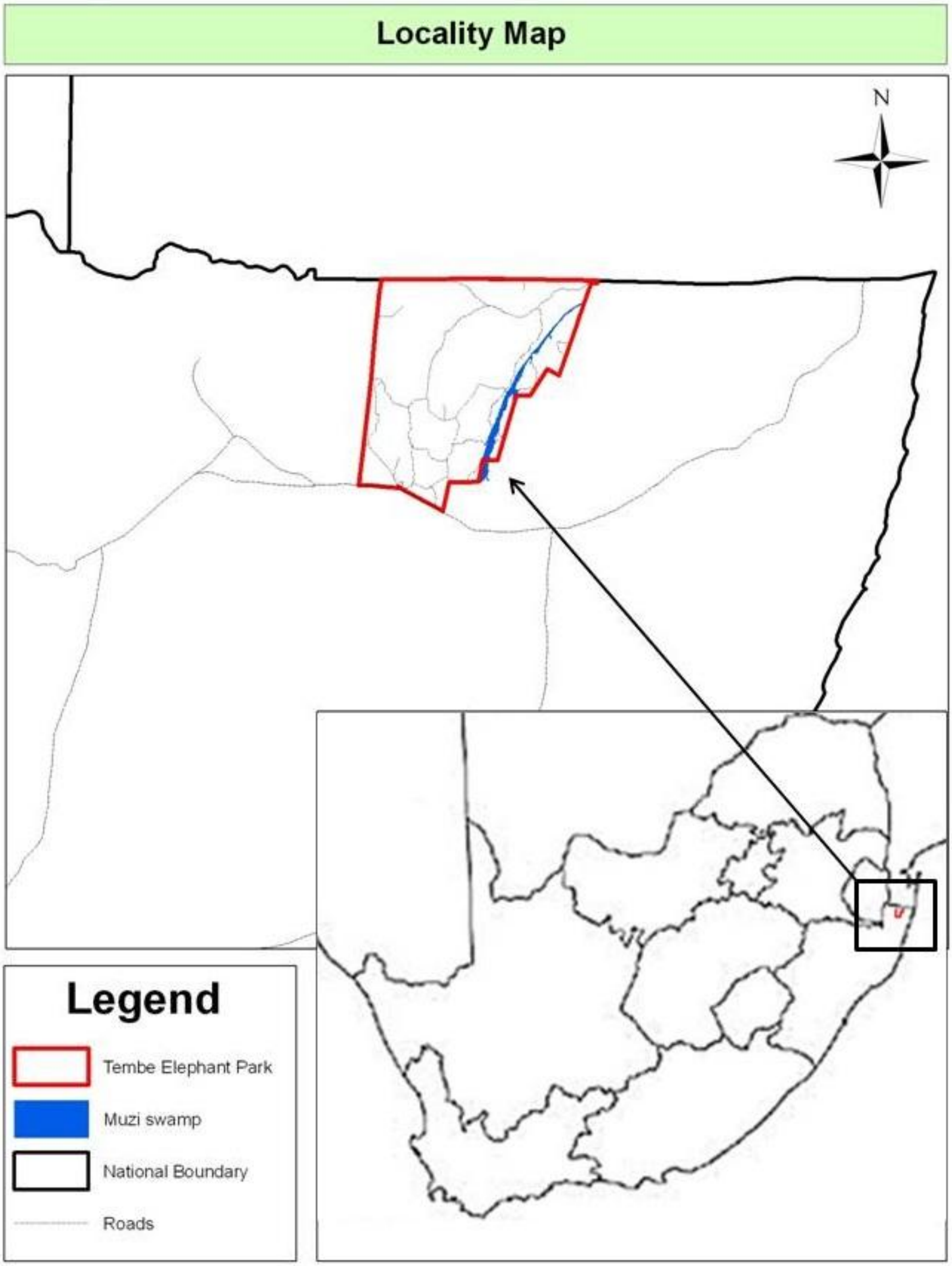

Figure 3.1 Locality map of the Tembe Elephant Park.

3.2 CLIMATE

The Tembe Elephant Park is situated south of the Tropic of Capricorn and is characterised by a tropical/subtropical climate with hot and humid summers, and warm and dry winters. Rainfall occurs predominantly in the summer months, but the odd shower may occur throughout the year (Schultze, 1982 in Matthews *et al*., 2001; Van Wyk & Smith, 2001). Around the swamp, mist is commonly observed in the mornings, especially in winter (Matthews *et al*., 2001; Gaugris *et al*., 2004).

Figure 3.2 The Muzi swamp of Tembe Elephant Park forms part of the Subtropical Freshwater Wetlands in southern Africa (Photograph by W.S. Matthews).

The mean annual rainfall (as recorded at Sihangwana weather station) for the park is 721.5 mm, with a range from 245 mm to 2105 mm (Tarr, 2006). The Sihangwana weather station is close to the entrance of the park in the south and consequently sites situated in the north of Tembe Elephant Park could experience different rainfall conditions. According to weather data obtained from the Sihangwana weather station, December has the highest mean rainfall and July the lowest (Figure 3.3). Annual rainfall data indicated fairly constant values since 2004, but a few exceptionally wet years prior to that (Figure 3.4). Temperatures in

Tembe Elephant Park range from an extreme minimum of 4°C to an extreme maximum of 45°C. The mean daily maximum temperature for the hottest month is 32.1°C and the mean daily minimum for the coldest month is 11.3°C (Matthews *et al*., 2001; Tarr, 2006; Gaugris, 2008). The temperature variation between summer and winter is modest (Figure 3.5).

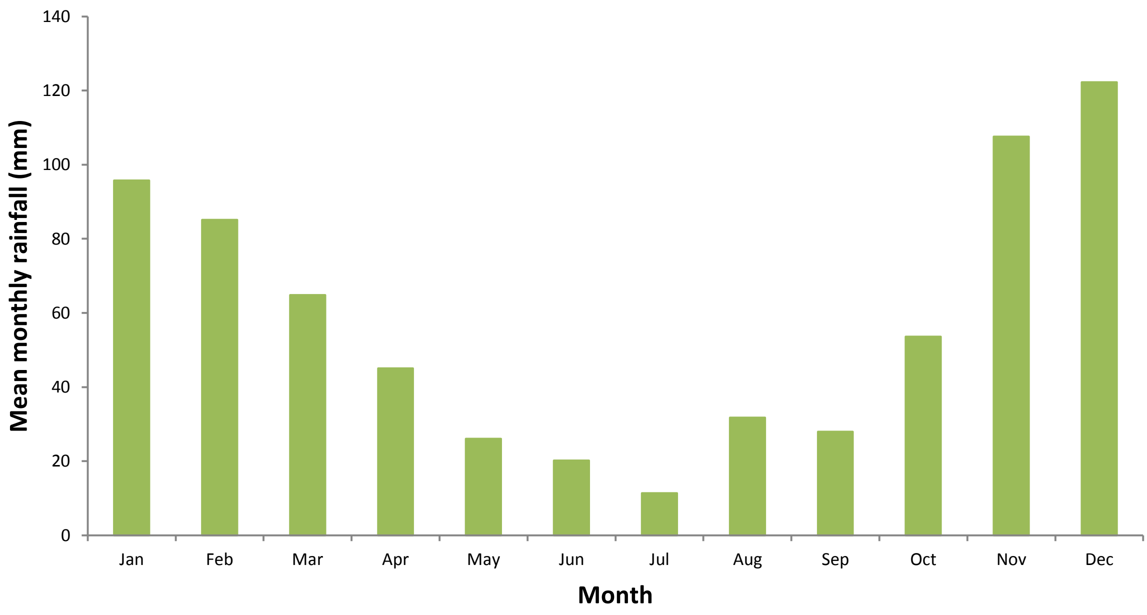

Figure 3.3 Monthly mean rainfall as recorded from 1994 to 2010 (data for the Sihangwana weather station).

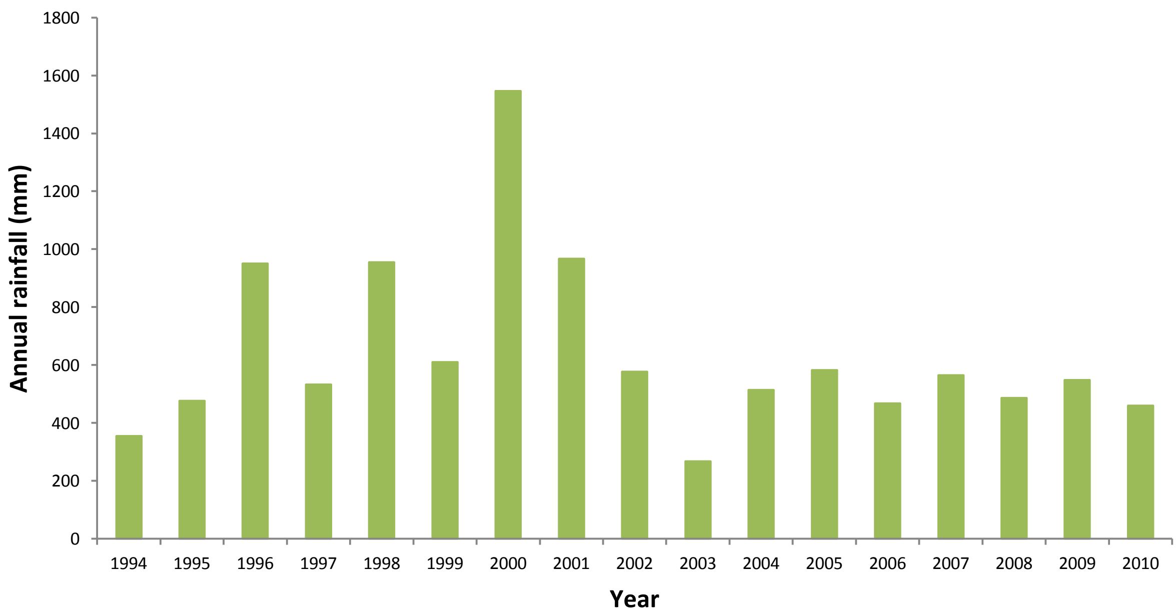

Figure 3.4 Annual rainfall from 1994 to 2010 (data for the Sihangwana weather station).

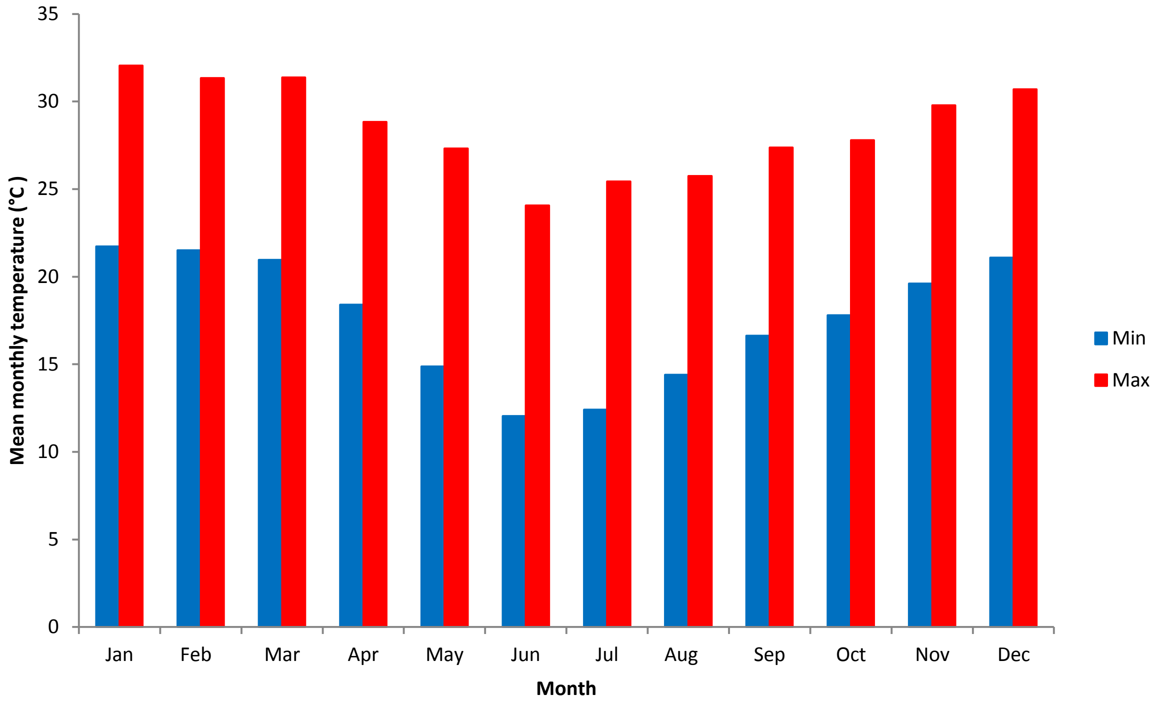

Figure 3.5 Mean minimum and maximum temperatures per month (data for the Sihangwana weather station).

3.3 GEOLOGY AND SOILS

The park forms part of the broader Mozambican Coastal Plain which stretches from the Indian Ocean in the east to the Lebombo Mountain range in the west (Potgieter, 2008). Topographically Tembe Elephant Park can be described as undulating dune ridges (trending north to south) combined with depressions and occasional perennial pans. The maximum elevation in the park is 129 m above sea level (Van Eeden, 2006; Potgieter, 2008) while the minimum is the Muzi swamp with an elevation of only 50 m above sea level (Van Eeden, 2006).

The geology of the coastal plain belongs to the Mesozoic and Cenozoic eras. The underlying geology consists of Cretaceous siltstone which forms the base of the Mozambican Coastal Plain (Van Wyk & Smith, 2001; Matthews, 2006). The siltstone is overlain by Miocene and Pleistocene sediments on top of which the Maputaland Group lies (Gaugris *et al.,* 2004). Most of the park is covered with arenite, with some sedimentary deposits occurring in the south and east of the Muzi swamp (Figure 3.6).

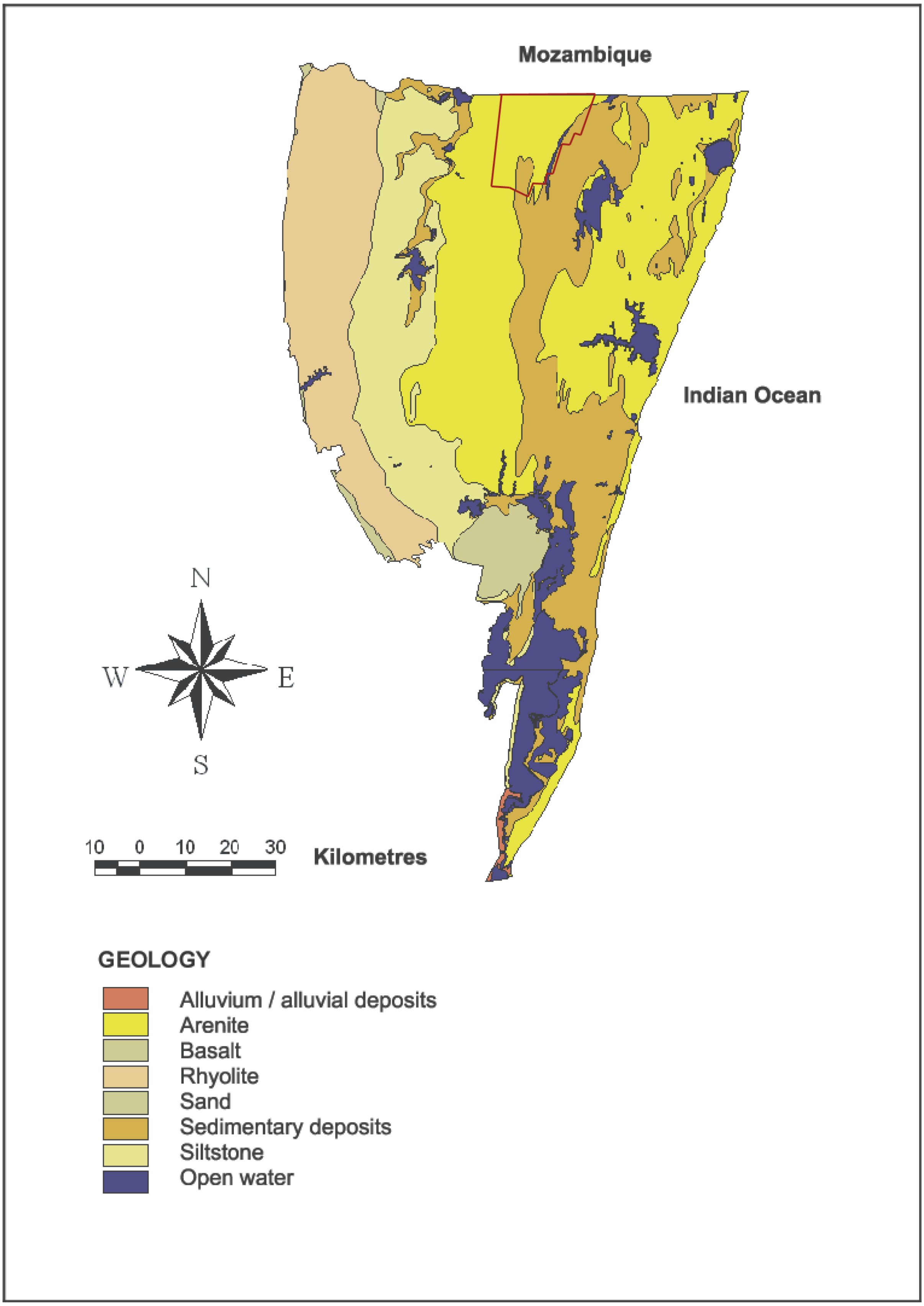

Figure 3.6 Geology of Maputaland, including Tembe Elephant Park (outlined in red) (after Van Eeden, 2006).

Most of the park is characterised by grey sands and in the higher topographical areas (such as Beacon ridge, 128 m above sea level) red or yellow soils are found (Matthews *et al*., 2001). The soils are well-drained with clay minerals being less than 5% of the matrix of the soil. Interdune depressions are also well-drained (Matthews *et al*., 2001). In localities with the occasional high clay content, perennial pans are likely to form (Kellerman, 2004). Dark brown to black sand is found in the Sand Forest and this changes to white sand on the forest edges where vegetation is more sparse (Matthews *et al*., 2001; Kellerman, 2004). In the Sand Forest the soil is extremely water-repellent (not very permeable), but as soil depth increases so does the permeability. Saturation point of the Sand Forest soil is 70 cm below the soil surface (Bigwood, 2011). Woodland soils differ from the soil in the Sand Forest.

3.4 VEGETATION

The vegetation within the Tembe Elephant Park is extremely diverse and ranges from grassland, through sparse to dense woodlands to dense forests. Wetlands are found mainly at the Muzi swamp in the east. The park is situated within the Maputaland Centre of Plant Endemism (Van Wyk, 1994, 1996; Matthews *et al*., 2001). Various animal and plant species are found to be endemic to this region. The Sand Forest especially has a number of endemic and rare plant species (Matthews *et al*., 2001).

According to Mucina and Rutherford’s (2006) classification four vegetation types occur in the park: namely Sand Forest, Tembe Sandy Bushveld, Subtropical Freshwater Wetlands and Maputaland Coastal Belt (Figure 3.7). The Sand Forest is characterised by its patchy occurrence, badly developed ground layer and well developed shrub layer. The height of the canopy may vary from 5–15 m. Dominant woody species are *Cleistanthus schlechteri*, *Dialium schlechteri*, *Psydrax locuples*, *Cola greenwayi*, *Croton pseudopulchellus* and *Pteleopsis myrtifolia* (Mucina & Geldenhuys, 2006). The Sand Forest is critically endangered and its conservation target is 100%. However, only 42% of the vegetation unit has been conserved in statutory reserves (Tembe Elephant Park, Sileza Nature Reserve, Ndumo Game Reserve, Mkhuze Game Reserve, Kruger National Park and the Greater St Lucia Wetland Park) of which Tembe Elephant Park contains the largest portion of Sand Forest (Mucina & Geldenhuys, 2006).

Terminalia sericea is the dominant woody species in the Tembe Sandy Bushveld which ranges from open woodland on flat plains to closed woodlands. Canopy height may range from 5-10 m and dominant woody species are *Terminalia sericea*, *Acacia burkei*, *Sclerocarya birrea* subsp. *caffra*, *Strychnos madagascariensis*, *Euclea natalensis*, *Grewia caffra*, *Afzelia quanzensis*, *Strychnos spinosa*, *Albizia adiantifolia and Albizia versicolor* (Rutherford *et al*., 2006). The vegetation unit is regarded as least threatened. Seventeen percent of the vegetation unit has been conserved in statutory reserves (most of it in Tembe Elephant Park). Due to cultivation, 8% of the Tembe Sandy Bushveld has been transformed (Rutherford *et al*., 2006). The Maputaland Coastal Belt is a grassland vegetation type with the occasional *Hyphaene coriacea*. Important woody species are *Strychnos spinosa*, *Bridelia cathartica*, *Canthium inerme* and *Euclea natalensis* (Mucina *et al*., 2006a). The vegetation unit is classified as vulnerable. Only a small portion (15%) of the vegetation unit has been conserved in reserves (Amathikulu, Enseleni and Sileza Nature Reserves as well as the Greater St Lucia Wetland Park). Thirty three percent of the vegetation unit has been transformed by cultivation, plantations, and urbanisation (Mucina *et al*., 2006a).

The wetlands in the study area fall within the Subtropical Freshwater Wetlands vegetation unit (Mucina and Rutherford, 2006). The landscape can be described as flat or shallow beds filled with (temporary) sedges and reeds (Figure 3.7). This vegetation unit can be found along the edges of depressions as well as artificial dams and backwater pans. Important plant species include *Hyphaene coriacea*, *Phragmites australis*, *Cyperus fastigiatus* and *Typha capensis*. The Muzi swamp in Tembe Elephant Park is an example of an interdune depression. Only 4% of the Subtropical Freshwater Wetlands have been transformed to cultivated land. The vegetation unit is highly conserved with 40 – 50% protected in reserves such as Kruger National Park, Tembe Elephant Park and Ndumo Game Reserve while a further 10% is conserved in private reserves (Mucina *et al*., 2006b).

Matthews *et al.* (2001) did a detailed phytosociological analysis of the vegetation of the Tembe Elephant Park (see Figure 5.1, Chapter 5), and Gaugris and Van Rooyen (2008) reclassified the Sand Forest vegetation. The main vegetation types in the park are Open Woodland, Sparse Woodland, Closed Woodland on Sand, Closed Woodland on Clay, Sand Forest, Hygrophilous Grassland and *Acacia borleae* Shrubland (Matthews *et al*., 2001; Gaugris *et al.,* 2004; Gaugris & Van Rooyen, 2008). The Sand Forest was further subdivided into the Short Sand Forest, Tall Sand Forest and Mature Sand Forest (Gaugris & Van Rooyen, 2008). Only those vegetation types which are relevant to this study will be discussed briefly.

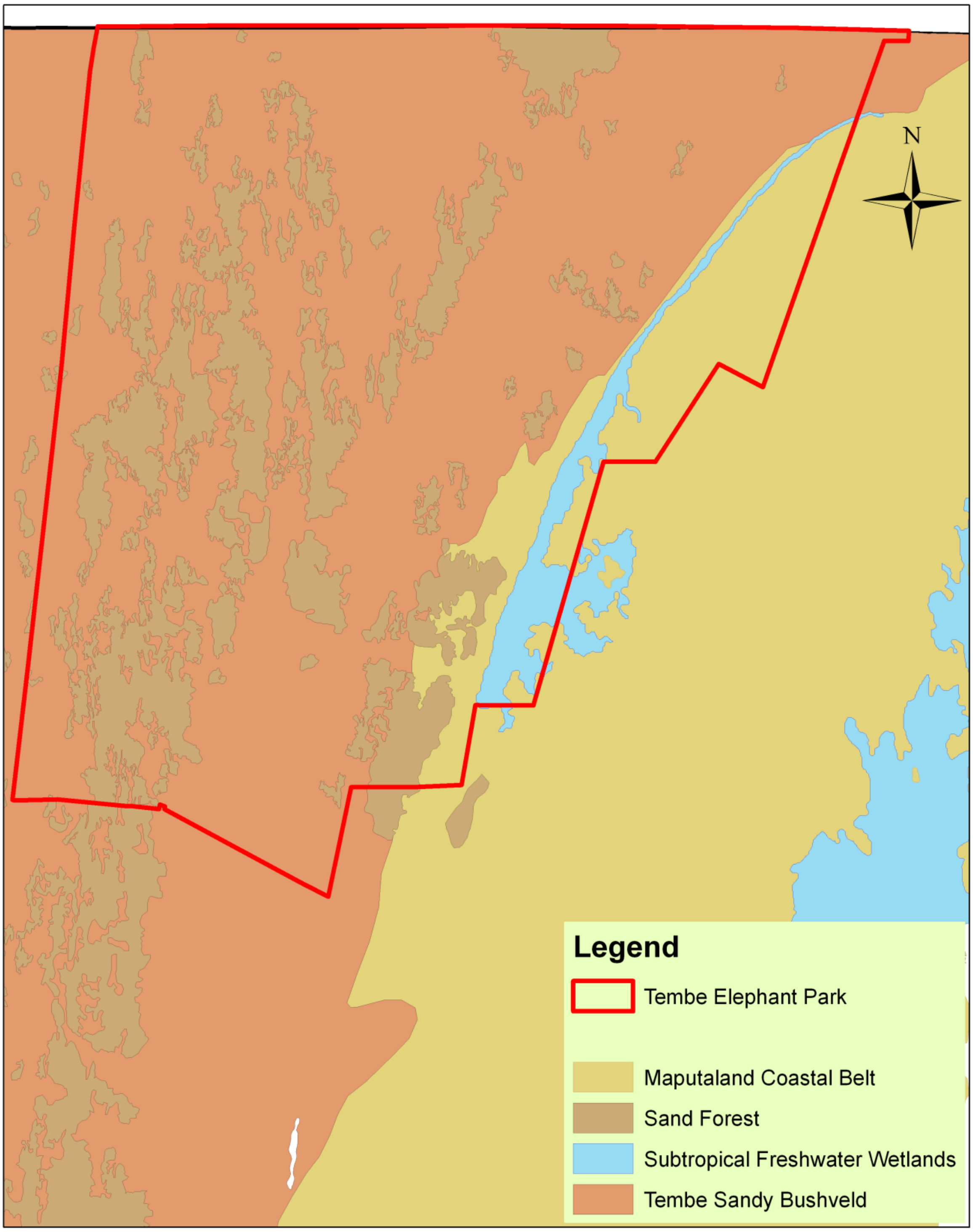

Figure 3.7 Vegetation map of the Tembe Elephant Park according to Mucina and Rutherford (2006).

3.4.1 Sparse Woodland on Sand

This plant community is situated on the plains in the park, primarily between the dunes and not so much on dune crests. Trees rarely occur and therefore this vegetation type is described as a sparse woodland. The soil is sandy with very little to no clay and a low pH of approximately 5.8 (Matthews *et al*., 2001). The profusion of plants with a geoxylic-suffrutex growth form is unique to this vegetation type and it is sometimes referred to as "woody grassland" (Matthews *et al*., 2001). Geoxylic suffrutices are dwarf woody plants with short-lived shoots but the enormous underground system is perennial. They have also been called "underground forests" (White, 1976 in Matthews *et al*., 2001).

Diagnostic species of the Sparse Woodland on Sand include the grasses *Themeda triandra*, *Perotis patens*, *Pogonarthria squarrosa* and *Diheteropogon amplectens*. *Terminalia sericea* and *Strychnos madagascariensis* are diagnostic woody species within this vegetation type. Geoxylic suffrutices in the Sparse Woodland on Sand are *Dichapetalum cymosum*, *Parinari capensis* subsp. *incohata* and *Salacia kraussii* (Matthews *et al*., 2001).

3.4.2 Open Woodland on Sand

This plant community is very similar to the Sparse Woodland on Sand and occurs on dune slopes and interdune depressions (Matthews *et al*., 2001). The soils are more acidic than that of the Sparse Woodland on Sand, but just as sandy. The difference between the open and sparse woodland lies in the abundance of trees. Within the Open Woodland on Sand trees of 8 – 10 m tall are found scattered across the area (Matthews *et al*., 2001).

Woody species that are characteristic of the Open Woodland on Sand are *Albizia versicolor* and *Albizia adianthifolia* as well as the grasses *Andropogon gayanus* and *Panicum maximum*. Other prominent woody species are *Terminalia sericea*, *Combretum molle*, *Sapium integerrimum* and *Strychnos madagascariensis*. This community also has an abundant geoxylic suffrutex species namely *Eugenia mossambicensis* (Matthews *et al*., 2001).

3.4.3 Closed Woodland on Sand

This community is widespread in the park and it is notably denser than the previous two woodland communities. Trees are common and occur within a range of height classes and represent a variety of different species. The soil is sandy with a low pH of 5.5 and clay may come about in narrow bands. Within these clay bands the species composition changes slightly. The Closed Woodland on Sand community shows a high species richness (Matthews *et al*., 2001).

Diagnostic species within this community include *Clausena anisata* and *Zanthoxylum capense* and the common woody species are *Vepris lanceolata*, *Phyllanthus reticulatus*, *Acacia burkei*, *Combretum molle*, *Grewia caffra* and *Terminalia sericea*. Grasses within this plant community are *Panicum maximum* and *Digitaria eriantha* (Matthews *et al*., 2001).

3.4.4 Closed Woodland on Clay

The Closed Woodland on Clay is different from all the other woodlands in that it occurs mainly on clay soils. These clay regions normally occur along the borders of the Muzi swamp as well as in the low-lying area between dunes. In some parts of this plant community the soil is still sandy and in those parts species that are associated with sandy soils, are found (Matthews *et al*., 2001).

The Closed Woodland on Clay is characterised by the woody species *Spirostachys africana*, *Ziziphus mucronata*, *Berchemia zeyheri*, *Dovyalis longispina*, *Sideroxylon inerme* and *Schotia brachypetala*. Prominent shrubs within this plant community include *Coddia rudis*, *Searsia gueinzii*, *Euclea divinorum* and *Carissa bispinosa*. The woody species, associated with sandy soils, occurring in the Closed Woodland on Clay consist of *Grewia caffra*, *Euclea natalensis* and *Catunaregam spinosa* subsp. *spinosa* (Matthews *et al*., 2001).

3.4.5 Sand Forest

The largest part of the Sand Forest in South Africa lies within the Tembe Elephant Park (Matthews *et al*., 2001; Gaugris & Van Rooyen, 2008). This vegetation type is situated on deep sandy, acidic soils with a pH of 5.6. The canopy of the Sand Forest ranges from 5 m up to about 15 m; the density of the lower woody stratum depends on the type of Sand Forest (Matthews *et al*., 2001).

The Short Sand Forest community is extremely dense with a crowded lower woody stratum. The height of the Short Sand Forest is ± 8 m, rarely more than that (Matthews *et al*., 2001; Mucina & Rutherford, 2006; Gaugris & Van Rooyen, 2008). Characteristic woody species within the Short Sand Forest include *Hyperacanthus microphyllus* and *Psydrax fragrantissima* (Matthews *et al*., 2001). Gaugris and Van Rooyen (2008) found the Short Sand Forest not to have a lot of diagnostic species. The Tall Sand Forest is less crowded, but still has a closed canopy. The height of the Tall Sand Forest ranges from 10 to 12 m, which is noticeably higher than that of the Short Sand Forest (Gaugris & Van Rooyen, 2008). Diagnostic species within this community consist of *Wrightia natalensis*, *Balanites maughamii*, *Cola greenwayi* and *Newtonia hildebrandtii* (Matthews *et al*., 2001; Gaugris & Van Rooyen, 2008). Matthews *et al*. (2001) described two Sand Forest communities, Short and Tall Sand Forest, whereas Gaugris and Van Rooyen (2008) added a third Sand Forest community namely the Mature Sand Forest. The Mature Sand Forest has a height of more than 12 m and it is the most distinct Sand Forest community (Gaugris & Van Rooyen, 2008). Woody species characteristic to this community include *Afzelia quanzensis*, *Strychnos decussata*, *Dalbergia obovata* and *Manilkara concolor* (Gaugris & Van Rooyen, 2008).

3.5 FAUNA

Apart from the rare plant species, Tembe Elephant Park also houses some rare animal species, such as the suni, *Neotragus moschatus*, and the red duiker, *Cephalophus natalensis* (Guldemond & Van Aarde, 2007). Other herbivores within the park include the African elephant (*Loxodonta africana*), giraffe (*Giraffa camelopardalis*), nyala, (*Tragelaphus angasii*), greater kudu (*Tragelaphus strepsiceros*), white rhinoceros (*Ceratotherium simum*), black rhinoceros (*Diceros bicornis*) and impala (*Aepyceros melampus*) (also see Table 3.1).

The largest part of the browsing guild in the park consists of elephants (Guldemond & Van Aarde, 2007). When the park was proclaimed a conservation area in 1983, the elephant population was between 30 and 60 animals (Gaugris & Van Rooyen, 2011). In 2001, Morley and Van Aarde (2007) estimated the elephant population to be 179 animals. Based on this value and the estimated growth rate, the population size in 2004 was estimated to be 200 elephants (Gaugris & Van Rooyen, 2010a). Population size for elephants derived from aerial counts (in 2005, 2006 and 2007) estimated the elephant population to be between 168 to 195 animals (Matthews, 2005, 2006, 2007b). In 2010 another aerial census was conducted and based on those counts the population estimate for elephants in 2010 was 250 animals (Muller & Matthews, 2010). Therefore the elephant population within Tembe Elephant Park has not yet reached ecological capacity and is still increasing. The breeding elephant herds in the park are concentrated more to the east of the reserve where they are distributed along the Muzi swamp (Figure 3.8, Muller & Matthews, 2010) mostly within the Closed Woodland communities. Elephant distribution is mainly associated with high water availability such as the Muzi swamp and water points (Figure 3.8 and 3.9).

Table 3.1 provides the large herbivore numbers as estimated during the 2007 census. The impact of smaller herbivores such as impala and nyala should not be neglected as their population sizes are very high. Another species that should be considered for damage on trees is giraffes as they feed at the same level as the elephants. Black rhinoceros, greater kudu and bushbuck also browse on trees and may cause damage.

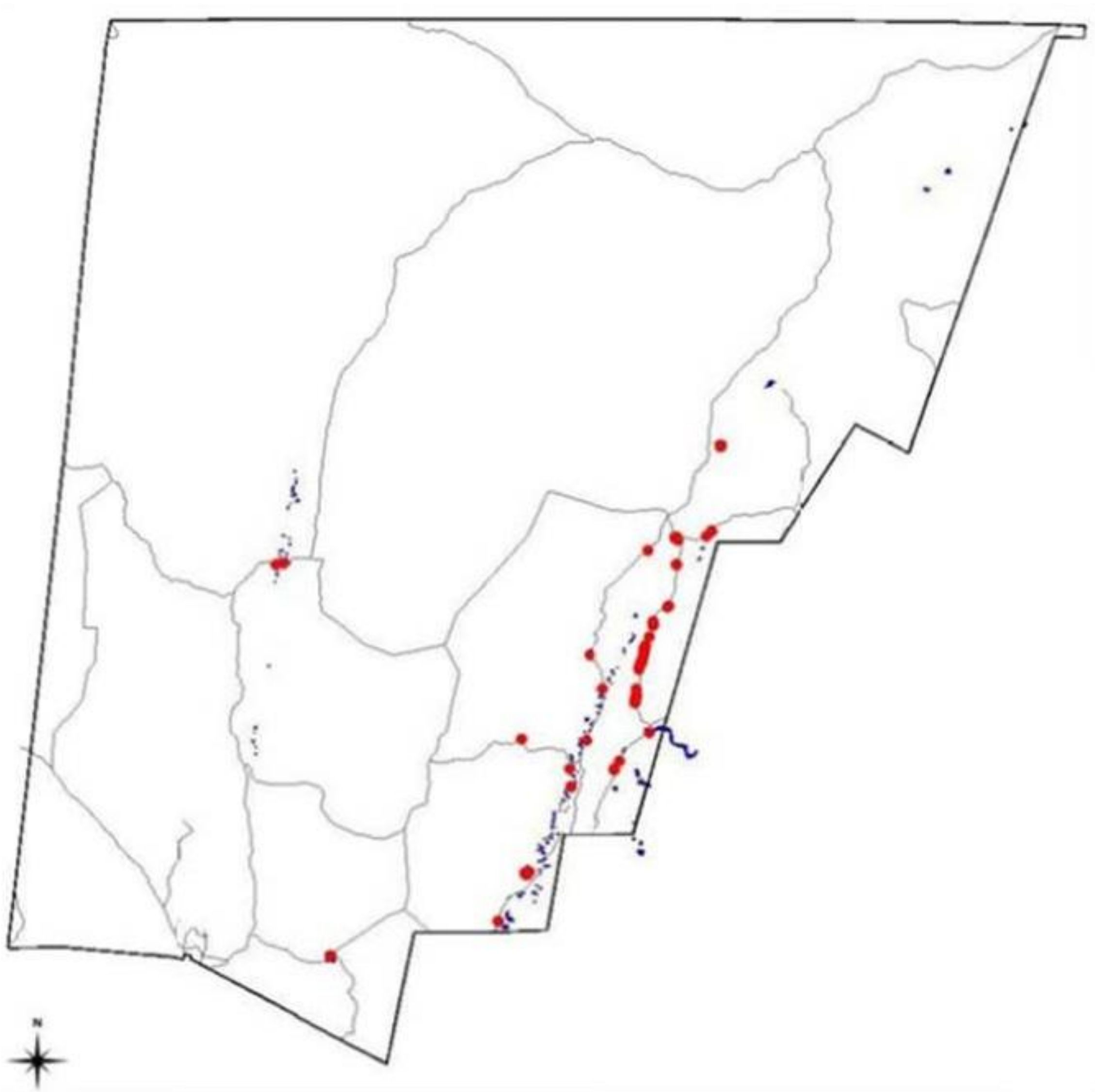

Figure 3.8 Distribution of all elephant breeding herds in Tembe Elephant Park, South Africa, marked with red dots (from Muller & Matthews, 2010). This data is based on GPS coordinates of elephant sightings from the elephant monitoring programme in Tembe Elephant Park.

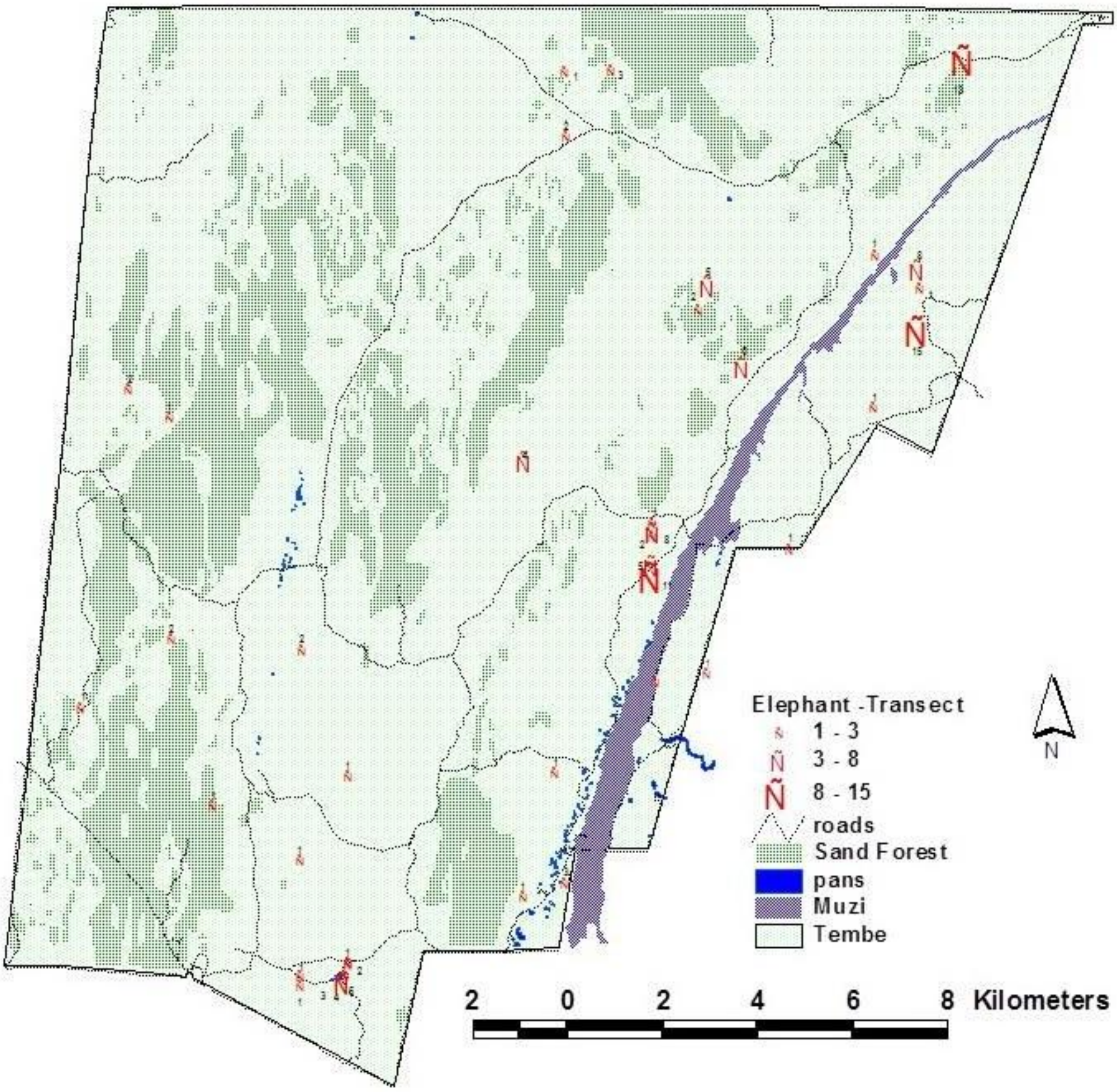

Figure 3.9 Distribution of different group sizes of elephant from transect counts of the November 2006 census (from Matthews, 2007b).

Table 3.1 Estimated population sizes of the animals present in Tembe Elephant Park as recorded during the census of 2006 (Matthews, 2007b)

Animal species	Total (Estimate)
Buffalo	101
Bushbuck	40
Bushpig	-
Eland	1
Elephant	168-195
Giraffe	138
Grey duiker	252
Hippopotamus	201
Impala	660
Greater kudu	613
Lion	21
Nyala	1707
Red duiker	393
Reedbuck	402
Black rhinoceros	17
White rhinoceros	40
Side-striped Jackal	-
Steenbok	-
Suni	-
Warthog	200
Waterbuck	580
Blue wildebeest	421
Burchell's zebra	170

CHAPTER 4

MATERIALS AND METHODS

4.1 INTRODUCTION

Several studies undertaken in the Tembe Elephant Park have investigated elephant utilisation of the vegetation (Guldemond, 2006; Guldemond & Van Aarde 2007; Gaugris 2008; Gaugris & Van Rooyen 2010a, 2011; Matthews & Page, undated). However, these studies were all once-off surveys of elephant utilisation of woody species and trends in the utilisation patterns over time were not analysed. The study undertaken in 1995 by Matthews and Page (undated) and the one undertaken in 2004 by Gaugris (Gaugris, 2008) shared many sampling sites. In the current study these sites were revisited in 2010 in order to establish a database that would allow for analysing long-term effects of elephant utilisation.

4.2 SELECTION OF STUDY SITES

Forty-four study sites, corresponding with those surveyed by Gaugris[1] in 2004, were selected to cover all plant communities across the park (Figure 4.1, Table 4.1). Twenty-five of these study sites also corresponded with those surveyed by Matthews[2] and Page[3] in 1995. Although a different method was applied by the latter researchers, certain data regarding species occurrence and utilisation could be used for comparative purposes. Table 4.1 compares the 44 study sites that had been surveyed in 2010 with the previous surveys. All the sites surveyed in 2010 were also surveyed in 2004 and these sites represented seven plant communities although the Mature Sand Forest was underrepresented.

Four of the 44 sites were situated within the enclosure (Figure 4.2) which was fenced in such a way that giraffes and elephants had no access. Within the enclosure the different Sand

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[2] Dr W.S. Matthews: wayne@icon.co.za
[3] Dr B. Page: Research and consulting Ecologist. Email: brupage@gmail.com

Forest vegetation types as well as Open Woodland on Sand occurred. Three of the sites were located in the Sand Forest and one in the Open Woodland on Sand (Figure 4.2). The three Sand Forest study sites located within the enclosure gave a good dataset to verify whether the removal of elephants from the Sand Forest had a positive effect or not on this vegetation type.

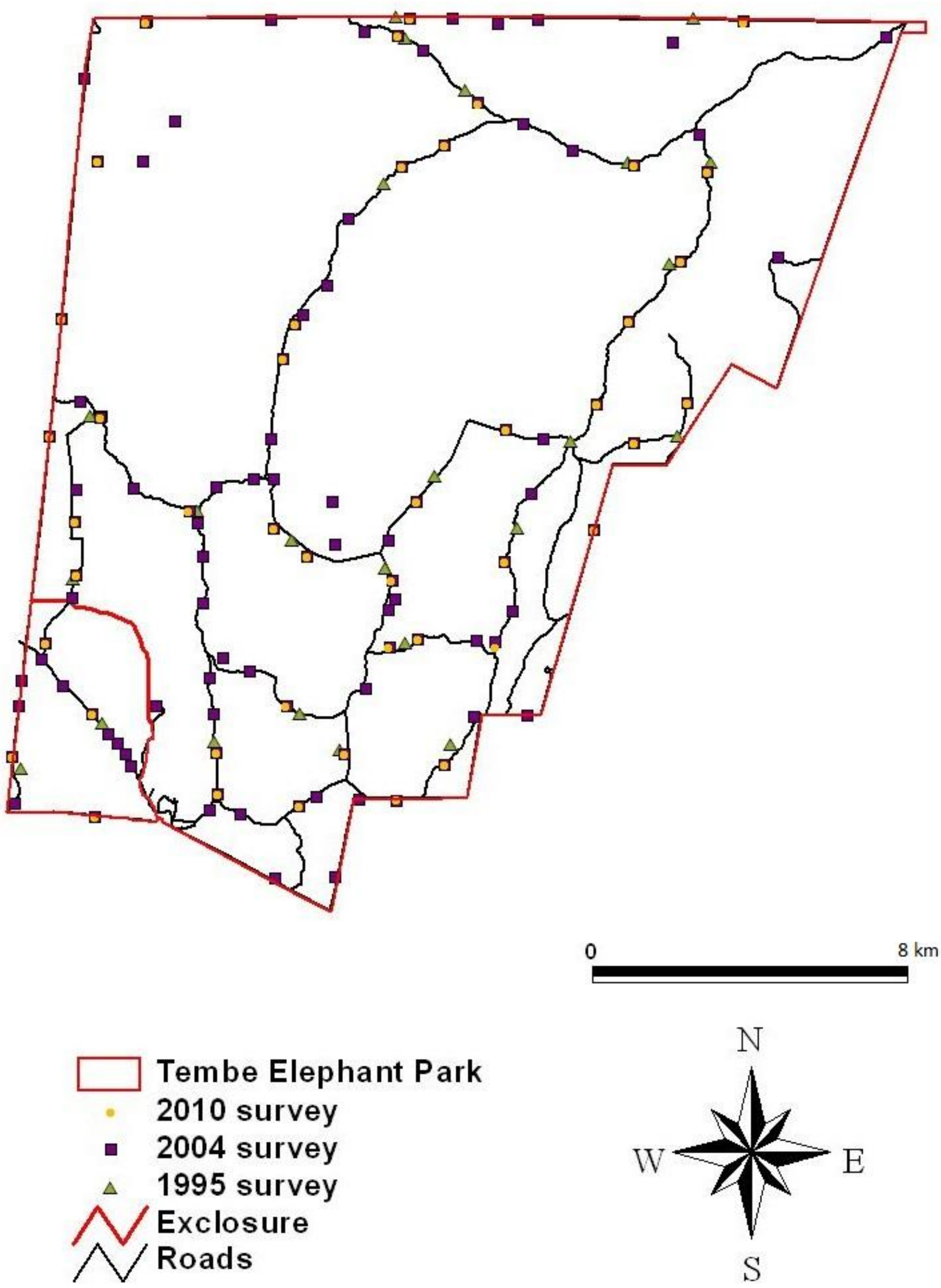

Figure 4.1 Map of Tembe Elephant Park with sites surveyed in 1995 (green), 2004 (purple) and the study sites of 2010 (yellow).

Table 4.1 Study sites that were sampled in 2010 and the corresponding data collections, as well as the 2010 study sites' transect sizes and vegetation type

Site nr	Data collections			Vegetation type (Gaugris 2008)	Transect size (m^2)
	2010	2004	1995		
1	•	•		Closed Woodland On Clay	150
2	•	•	•	Open Woodland On Sand	200
3	•	•	•	Sparse Woodland On Sand	200
4	•	•	•	Closed Woodland On Clay	300
5	•	•		Closed Woodland On Clay	200
6	•	•	•	Closed Woodland On Clay	200
7	•	•	•	Open Woodland On Sand	200
8	•	•	•	Closed Woodland On Sand	200
9	•	•	•	Closed Woodland On Sand	200
10	•	•	•	Closed Woodland On Sand	160
11	•	•	•	Open Woodland On Sand	300
12	•	•	•	Open Woodland On Sand	300
13	•	•		Open Woodland On Sand	200
14	•	•		Open Woodland On Sand	160
15	•	•		Closed Woodland On Sand	160
16	•	•		Open Woodland On Sand	300
17	•	•		Open Woodland On Sand	300
18	•	•		Open Woodland On Sand	300
19	•	•	•	Open Woodland On Sand	200
20	•	•	•	Sparse Woodland On Sand	200
21	•	•		Open Woodland On Sand	300
22	•	•		Closed Woodland On Sand	200
23	•	•	•	Open Woodland On Sand	200
24	•	•	•	Closed Woodland On Sand	200
25	•	•	•	Open Woodland On Sand	200
26	•	•		Closed Woodland On Sand	200
27	•	•	•	Open Woodland On Sand	200
28	•	•	•	Open Woodland On Sand	200
29	•	•	•	Open Woodland On Sand	200
30	•	•	•	Open Woodland On Sand	200
31	•	•		Open Woodland On Sand	300
32	•	•		Open Woodland On Sand	300
33	•	•		Short Sand Forest	100
34	•	•	•	Short Sand Forest	100
35	•	•		Short Sand Forest	100
36	•	•	•	Tall Sand Forest	160
37	•	•	•	Mature Sand Forest	160
38	•	•		Mature Sand Forest	160
39	•	•	•	Tall Sand Forest	100
40	•	•		Tall Sand Forest	160
41	•	•	•	Tall Sand Forest	200
42	•	•		Tall Sand Forest	100
43	•	•	•	Tall Sand Forest	100
44	•	•		Mature Sand Forest	160

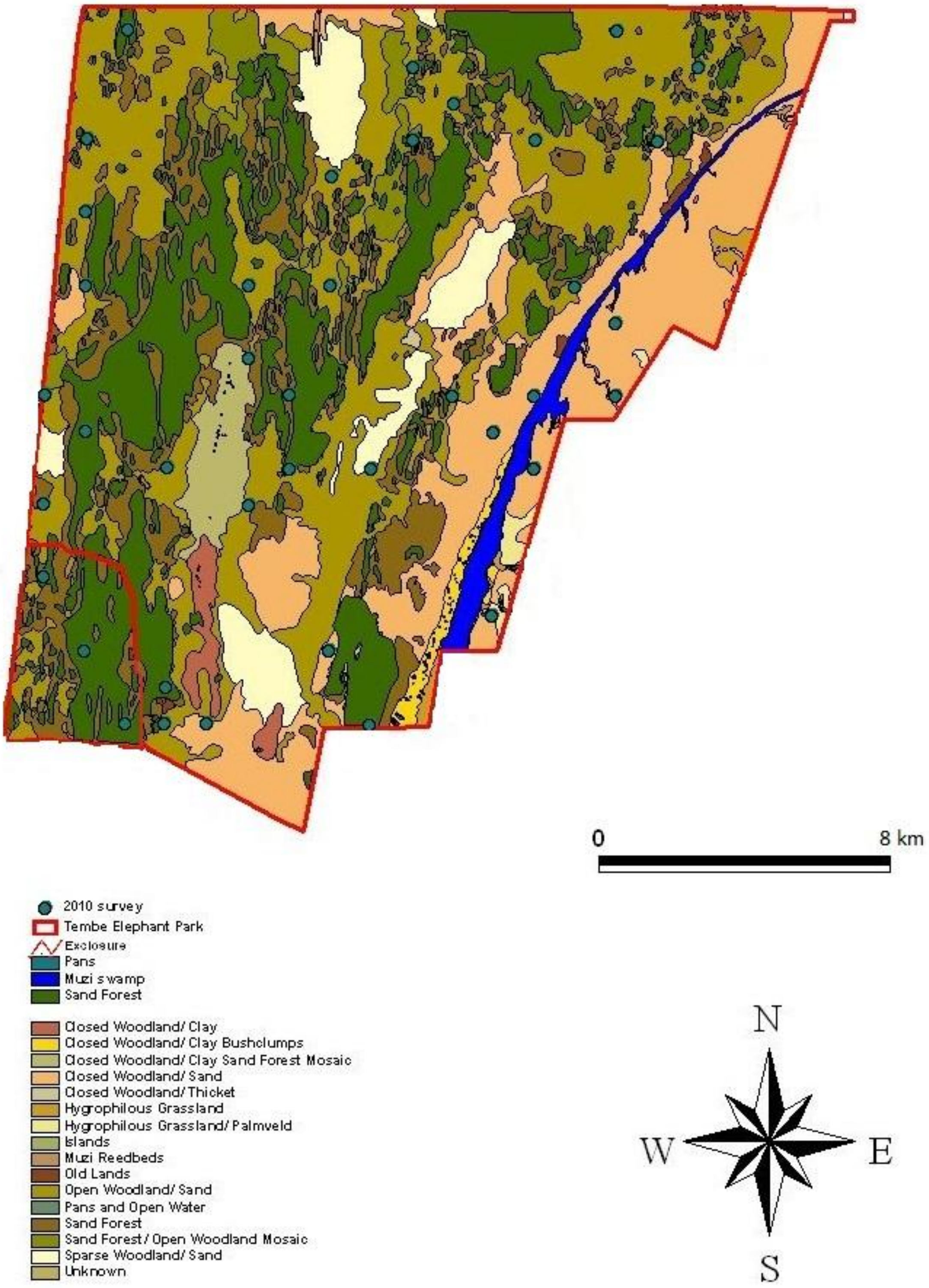

Figure 4.2 Map of the Tembe Elephant Park with the 44 sites surveyed in 2010 represented by the blue dots. The red rectangle in the left corner is the exclosure (derived from Gaugris, 2008).

4.3 FIELDWORK

Field techniques applied during the vegetation surveys in May and June 2010 in the Tembe Elephant Park were based on a previous study by Gaugris who conducted a survey in 2004 to measure elephant utilisation (Gaugris, 2008). In his study all vegetation data as well as Geographical Positioning System (GPS) coordinates were recorded in a database for the possible use by future studies.

4.3.1 Site layout

At each of the 44 identified sampling sites, which were positioned 10 to 100 m from the road networks, a single belt transect was laid out. The GPS point, as obtained from the Gaugris database served as the starting point. The transect was laid out perpendicular to the road and the length of thetransect varied from 25 to 75 m, depending on the density of the vegetation within the survey site. On the right hand side of the rope the first half of the transect was 2 m wide. The second half of the transect was on the left hand side of the rope and also 2 m wide. Within the first half, all woody plant species were identified, evaluated and recorded, but in the second half only woody plant species more than 0.4 m tall were identified, evaluated and recorded (Figure 4.3). The transects were divided into 5 m sections, which could in future be used for frequency data.

In addition to this belt transect, a 50 x 50 m plot was surveyed for woody species taller than 8 m. For database purposes this is called the third sector. This sector was included in order to accommodate the large trees in the woodland which are rarely encountered within the 4 m wide transect. These large individuals are often the ones targeted by elephants. This enlarged plot was situated next to the second half of the transect (where woody species taller than 0.40 m were recorded). These tall individuals were measured and evaluated in the same manner as the main belt. Each woody individual was identified and measured in terms of structure and utilisation.

The following attributes were measured and evaluated for each individual tree (see Table 4.2):

- Basal diameter (cm) of main stem of tree, or clump diameter for many stemmed shrubs;
- Height (m) of tree or shrub;
- Number of stems;

- Lowest canopy width and height (m);
- Widest canopy width and height (m);
- Estimated canopy removal (categories: 1 – 10% removed; > 10 – 25%; > 25 – 50%; > 50 – 75%; > 75 – 90%; > 90 – 99%; 100%);
- Age of utilisation (categories: <1 month; 1 - 6 months; > 6 months – 1 year; > 1 – 2 years; > 2 years);
- Type of impact (e.g. branch broken, bark removed, see Table 4.3 for other categories);
- Utilisation agent (e.g. elephant, unknown large browser, human, natural, see Table 4.3 for other categories);
- Bark removal (categories: 1 – 10% removed; > 10 – 25%; > 25 – 50%; > 50 – 75%; > 75 – 90%; > 90 – 99%; 100%); and
- Growth response to utilisation.

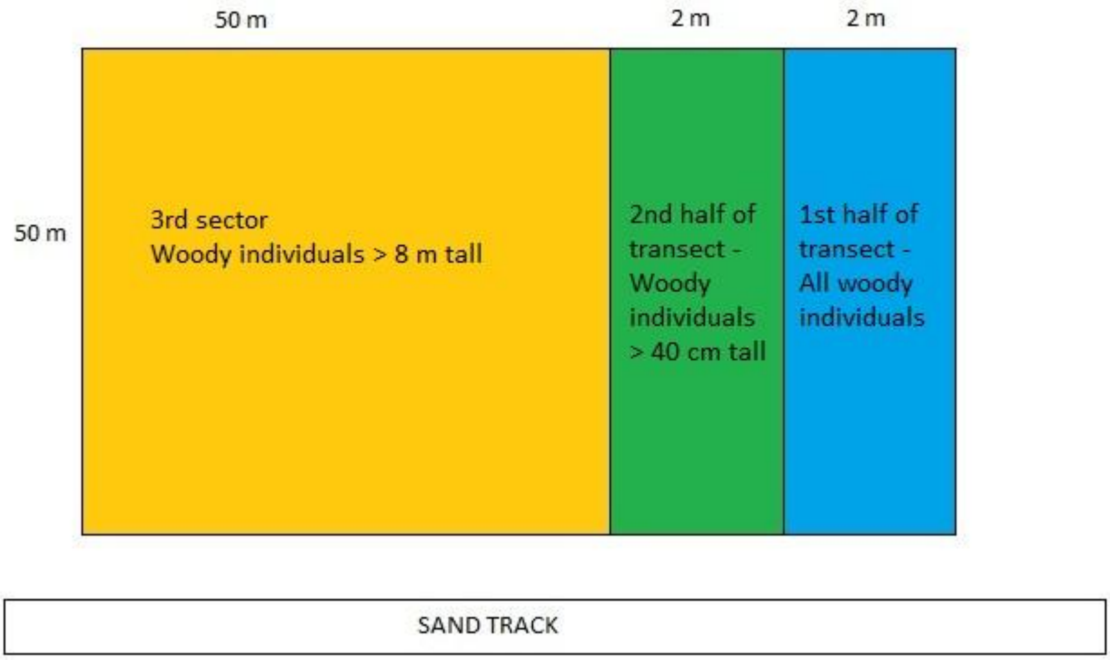

Figure 4.3 Layout of the sampling site (not to scale). First half of the transect in blue, second half in green and third sector in yellow.

4.3.2 Evaluation and measurements

The evaluation of utilisation by browsers/natural causes on an individual woody plant consisted of seven main categories (Table 4.3):

A. State: The state of the individual was the first measure of utilisation, this indicated whether the plant had been utilised or not. If it had been utilised, the appearance of the woody individual was recorded in this category. If an individual showed the presence of utilisation, the next category to evaluate was type of utilisation.

B. Type: This just stated whether an individual had been pushed over, leaves stripped, plucked off or branch ends bitten off.

C. Agent: This category identified the agent involved in the utilisation of the evaluated individual. The field assistant (Bongani Tembe, Figure 4.4) was of great help in this regard, he grew up in the vicinity of the Tembe Elephant Park and knew the animals, their habits and feeding manners very well.

D. Age: The age of utilisation indicated the time (months) since the identified utilisation. Age was another category where a second judgement was appreciated.

E. CVR: Canopy volume removal was the estimated percentage of the total canopy volume that had been utilised or lost due to utilisation.

F. GR: Growth response that indicated the manner in which the individual had responded to the utilisation, was recorded in the category. This indicated whether an individual was dying, resprouting or initiating a different growth form.

G. BR: Bark removal was estimated as a percentage of either stem height or circumference of the individual.

Recording the measurements of all the woody individuals within the transect was time consuming. Height (in m, in 10 cm increments) was firstly recorded and it was relatively simple for the smaller individuals but for the large individuals a 2 m metal rod, which could extend to 4 m, was used and height was estimated accordingly (Figure 4.5). Stem diameter (in cm, in 0.5 cm increments) was measured using the principle of callipers: two thin rods were put horizontally on both sides of the stem and the distance between the rods was measured with a measuring tape. Two different canopy measurements were taken, the lowest canopy and the widest canopy (both in m, 50 cm increments). Both height and diameter were measured for the lowest and widest canopies. For the large individuals the graduated metal rod was used and for the small individuals a measuring stick or measuring tape was used. The number of dead and live stems was counted. A ‘copies’ column was added to the field form for those cohorts of a species where measurements and utilisation were identical. All individuals were then counted and the sum was recorded in this copies column.

Table 4.2 Data capturing form used to quantify elephant utilisation of the vegetation in Tembe Elephant Park

Tembe Elephant Park – Survey M Potgieter	Date:___/___/2010	Vegetation Type (Gaugris):_________	Diam-cm Height-m
Transect No:___________ Dimensions:_______x___ _____	GPS Coordinates:S____________E_____________	Page:____	
	Community Description:_________________________		

5 m	Species name	Seedling	No Live Stems	No Dead Stems	Stem Diam (cm)	Old Diam (cm)	Max Height (m)	Height of lowest canopy (m)	Height of widest canopy (m)	Lowest canopy Diam (m)	Widest canopy Diam (m)	A - State	B - Type	C - Agent	D - Age	E - CVR	F - GR	G - BR	Chew	Comments	Copies

Figure 4.4 Field assistant, Bongani Tembe (Photograph by M. Potgieter, 2010).

Figure 4.5 Measuring large woody species with a metal rod (Photograph by M. Potgieter, 2010).

Table 4.3 Codes used for evaluating the utilisation of vegetation by browsers, man and natural damage in Tembe Elephant Park (after Gaugris, 2008)

A - State of the woody plant as encountered		**C - Agent of utilisation**	
1	Normal growth	1	Elephant
2	Normal with branch regrowth from breakage	2	Giraffe
3	Pollarded (main stem snapped off, height reduced) – tree living, resprouting	3	Kudu
4	Pollarded (main stem snapped off, height reduced) – tree living, coppicing	4	Eland
5	Pollarded (main stem snapped off, height reduced) – tree living, no growth response	5	Black rhinoceros
6	Pushed over, stem intact, still partially rooted - living	6	Nyala
7	Pushed over, stem partially broken - living	7	Impala
8	Mostly normal growth with some hedge growth	8	Bushbuck
9	Hedge growth from continuous, regular browsing	9	Grey duiker
10	Coppice growth from larger (older) dead stem	10	Red duiker
11	Coppice growth from accumulated browsing of young plant	11	Suni
12	Coppice growth from repeated fire	12	Unidentifiable megabrowsers (elephant, giraffe)
13	Coppice growth from repeated moisture stress	13	Unidentifiable large/medium size browsers (kudu, nyala, eland, etc)
20	Senescent	14	Unidentifiable medium/small size browsers (impala, bushbuck, duiker, etc)
30	Tree dead - main stem partially broken	15	Moisture stress
31	Tree dead - main stem completely broken (pollarded)	16	Flooding
32	Tree dead - main stem pushed over (partially uprooted)	17	Shading
33	Tree dead - main stem debarked	18	High light intensity
34	Tree dead - main stem intact, accumulated branch removal	19	Fire
35	Tree dead - debarking and branches / stems removed	21	Wind
50	Tree dead - intact - cause of death unknown	22	Accidental
51	Tree dead - intact - killed by moisture stress	23	Unknown
52	Tree dead - intact - dead from shading	24	Human
53	Tree dead - intact - dead from high light	25	Insects
54	Tree dead - killed by combination of moisture stress and branch removal	26	Cane rat
55	Tree dead - killed from combination of shading and branch removal	27	Lightning
56	Tree dead - killed by fire	28	Cattle
60	Tree dead - totally uprooted	29	Porcupine
70	Top kill - drought dieback	30	Goats
71	Top kill - frost dieback		
72	Top kill - dieback from debarking		
80	Windfall		
90	Live – deciduous leaf loss		
91	Dying some branches still alive		
92	Hedge growth from human utilisation		
93	Tree dead, pushed over and broken, not uprooted		

B - Type of utilisation observed

1	Whole plant (canopy and roots) utilised
2	Whole canopy utilised (roots still intact in ground)
3	Leaves and small twigs removed
4	Leaves, twigs, small branches, and large branches removed
5	Branch ends bitten off
6	Leaves plucked off
7	Leaves stripped
8	Parts of leaves removed
9	Only young leaves and leaf buds removed
10	Only mature leaves removed
11	Only senescent leaves removed
12	Bark removed
13	Roots removed
14	Flowers removed
15	Fruit / seeds removed
16	Dieback of main vertical branches/stems from top down
17	Dieback of horizontal branches/branch ends
18	Main stem/s cut
20	Accidental damage
21	No use / not damaged
22	Fire
23	Lightning
24	Pushed over and main stem broken
25	Pushed over and main stem intact

E - Canopy volume removal (CVR)

1	1 % - 10 %
2	11 % - 25 %
3	26 % - 50 %
4	51 % - 75 %
5	76 % - 90 %
6	91 % - 99 %
7	100%

F - Growth responses (GR.) to branch removal, stem breaking and debarking

1	Coppice growth
2	Wound regrowth
3	Main stem resprouting
4	No coppice or regrowth - vigour appears unaffected
5	No coppice or regrowth - vigour appears reduced (tree dying)
6	Hedge growth
7	Mostly hedge growth with some normal growth
8	Mostly normal growth with some hedge growth
9	Tree dead

D - Age of utilisation (Age)

1	< 1 month
2	> 1 – 2 months
3	> 2 – 4 months
4	> 4 – 6 months
5	> 6 – 12 months
6	> 12 – 24 months
7	> 24 months
8	Continuous Regular Use

G - Debarking – circumference (BR)

1	1 % - 10 %	of the circumference of the stem removed
2	11 % - 25 %	
3	26 % - 50 %	
4	51 % - 75 %	
5	76 % - 90 %	
6	91 % - 99 %	
7	100%	

G - Debarking - stem height (BR)

0.1	1 % - 10 %	of the height of stem removed
0.2	11 % - 25 %	
0.3	26 % - 50 %	
0.4	51 % - 75 %	
0.5	76 % - 90 %	
0.6	91 % - 100 %	
0.7	Whole stem plus branches	

4.4 DATA ANALYSIS

4.4.1 General data input

Data collected in the field on elephant utilisation were captured in Microsoft Excel in a specifically formatted datasheet and that datasheet was then converted to a database in Microsoft Access. Data from the 2004 survey conducted by Gaugris (44 sites that were revisited in 2010) were also converted to Microsoft Access, with the purpose of having two datasets that could be used for comparisons. A program designed by Page did the conversion of the data from the datasheet to Microsoft Access. The output in the database consisted not only of data collected in the field but also calculations such as densities, available canopy volumes and removed canopy volumes. Queries were designed to extract data of single sites from the database.

It is important to note that only the raw data was used from the study by Gaugris in 2004. The PhD-study by Gaugris (Gaugris 2008) focused on elephant impact at the population level and the analyses were done accordingly for that study. However, for the current study (by Potgieter), the focus was on the community level and therefore all data (obtained from the 1995, 2004 and 2010 surveys) were analysed for this purpose in 2010.

4.4.2 Plant community classification

It was deemed necessary to check whether the plant communities found in the current survey were still the same as distinguished by previous researchers (Matthews *et al.*, 2001; Gaugris & Van Rooyen, 2008). As a proper plant community classification was not the aim of the study, variables such as cover values were not recorded but instead available canopy volume (CVA) was used for this purpose. A matrix was drawn up for the whole 2010 dataset for species against the study sites in terms of CVA. The classification of the table followed Braun-Blanquet principles of the Zurich-Montpellier school of phytosociology (Werger, 1974, Kent & Coker, 1995). The data were also analysed by means of a Principal Co-ordinate Analysis (PCoA) in SynTax 2000 (Podani, 2001) to determine whether the ordination supported the classification. A Bray-Curtis distance measure was used for the ordination with no standardization of data. The same was done for the 2004 dataset in order to compare the classification of the study sites in the different plant communities. The ordinations as well as the classification table were used to define plant communities and group the study sites.

4.4.3 Percentage canopy volume

The program, which did the conversion to the database, used the height and diameter measurements to calculate canopy volumes. The canopy volume available (CVA) per transect was converted to canopy volume available per hectare (CVAPH) which was used further in most calculations. Additionally, the estimated percentage of canopy volume removed was used to calculate removed canopy volume (RCV) per transect, which was converted to removed canopy volume per hectare (RCVPH). Densities per hectare were also calculated per site for both the total number of individuals as well as those individuals utilised. All values were calculated per site and the database contained approximately 8 000 entries.

Queries were designed in Microsoft Access to extract the data to compile tables of which species were available and utilised in terms of density as well as canopy volume. To relate utilisation to different heights or sizes of species, six size classes were identified. The size classes were distinguished on the basis of the main stem diameter of the individual (Table 4.4).

Table 4.4 Six size classes were classified based on stem diameter

Size class	Stem diameter
SC1	0 - <1 cm
SC2	1 - <3 cm
SC3	3 - <10 cm
SC4	10 - <20 cm
SC5	20 - <50 cm
SC6	>50 cm

The first table that was compiled contained all the available species within a study site. Firstly, each species' density within that study site was put into the different size classes and added up for a total density for that species. Secondly, the canopy volume available per hectare (CVAPH) was also divided into the different size classes for each species and added up for a total available canopy volume per hectare per species. A second table was drawn up in the same way but only for the species that were utilised, indicating the canopy volume removal per hectare (RCVPH). For all 44 study sites both of these tables, one for availability and another for utilisation, were compiled. The same method was followed for the data in the 2004 database.

A third table was drawn up for the percentage utilisation that occurred. This was achieved by calculating the canopy volume that had been removed as a percentage of the canopy volume that was available. Again this was done per species in the study site that had been utilised and they were grouped within the different size classes. A total percentage utilisation for the whole study site was also calculated. The same procedure was followed for the 2004 dataset. The changes in percentage canopy volume removal within each site were tested for significance with a paired t-test (two-tailed) where the significant value is considered 0.05.

The availability and utilisation tables that were compiled for each study site were then allocated to the different communities to calculate mean values per species per community. The percentage utilisation tables were also grouped into the different plant communities. In the end there was a mean percentage utilisation per species, mean percentage utilisation per size class and a mean total percentage utilisation for each community for both the 2004 and 2010 dataset.

A summary table was also prepared for each community. In this table the total available canopy volume per species was calculated by obtaining the sum from all the individual sites where the species occurred. Similarly, the total canopy volume removed per species was calculated by adding the removed volumes of all the individual sites. Percentage utilisation per species and per community was calculated from these values by expressing the removed volume as a percentage of the total available volume. These utilisation values do not represent mean values, but is a cumulative value per species per community. These species values were used to calculate the electivity indices.

4.4.4 Electivity indices

Comparisons between the percentage utilisation in a community could be used to establish whether an increase or decrease had occurred from 2004 to 2010. However, if a change was detected it would be important to know whether the elephants had changed their species preferences, or whether they still targeted the same species. Electivity indices were used to determine the elephants' preferences towards the different species in each community. This analysis was done on the 2010, 2004 and 1995 datasets in order to have a decent timeline to study elephant preferences in the Tembe Elephant Park.

Three different values were used to compare species preference by elephants.

(i) The forage ratio was calculated as follows (Cock, 1978; Krebs, 1989):

$$FR_i = r_i / n_i \qquad (1)$$

where

FR_i = forage ratio for a species *i*

r_i = percentage/proportion of species *i* that has been utilised

n_i = percentage/proportion of species *i* available.

This equation or ratio links the amount of damage (CVR) for a specific species in a community to the available canopy volume for this species in the community. This ratio may vary between 0 and ∞. Whenever the forage ratio was above 1, it served as an indication that the elephants preferred the woody species.

(ii) The electivity index was calculated as follows (Ivlev, 1961; Krebs, 1989):

$$E_i = r_i – n_i / r_i + n_i \qquad (2)$$

where

E_i = Ivlev's electivity measure for species *i*

r_i = percentage/proportion of species *i* that has been utilised

n_i = percentage/proportion of species *i* available.

The electivity index is often preferred to the forage ratio, because it ranges from -1 to +1 and the positive values indicate preference while the negative values indicate avoidance. This index was used in the discussion of results and the values were subjectively interpreted as follows:

- Species with values <-0.1 were regarded as being avoided;
- Species with values ≥-0.1 – 0.1 were neither preferred or avoided; and
- Species with values >0.1 were regarded as preferred.

(iii) The Rank Procedure method (Johnson, 1980) was also applied to determine the preferences of elephants for different woody species. The method involves ranking the utilised woody species based on the available canopy volume (availability rank) within the particular community. Thus the species with the largest available canopy volume will be ranked first. The same was done with removed canopy volume (usage rank). Consequently the species with the highest volume canopy removed by elephants will be ranked first for this category. Each species therefore has a ranking for each of these two categories. The difference between the two rankings was calculated. The species were then arranged (ranked) from the lowest to highest value. Woody species with the highest rank were most selected for by elephants. This approach differs from the other two electivity indices because the ranking in this case is relative and not absolute.

4.4.5 Relative percentage utilisation

As previously stated, the sampling method in 1995 differed from those in 2004 and 2010 and not all values were available in the 1995 database to do the comparative calculations. In order to use the species data in this particular dataset another means of analysis was used, one with relative values. Canopy volume, both available and removed, was obtained from the 1995 dataset but these values could not be expressed per hectare because the Point Centre Quarter method had been used which is a point-based method as opposed to a plot-based method. Within each community every species had a total Canopy Volume Removed (CVR) value. These volumes were added to obtain a total CVR per community. Every species' CVR was then divided by the total CVR and expressed as a percentage utilisation. As CVR values were not compared directly but divided by the total, this is a relative percentage utilisation. Relative percentage utilisation was similarly calculated for each community within the 2010, 2004 and 1995 dataset. It should be noted that the relative utilisation of each community in 1995 includes only certain sites but for 2004 and 2010 all sites within the community were used. This is due to the fact that only 25 of the 44 sites were surveyed in 1995.

4.5 DATA PRESENTATION

The elephant utilisation data will be discussed from a community perspective. For each community the following tables and figures were compiled:

- A table reflecting the total available canopy and total removed canopy for all utilised species in the community. From this data the cumulative percentage utilisation as well as the relative utilisation percentage per utilised species was calculated.

Available canopy of unutilised species in the community was not separated per species.

- A table providing the utilisation per species per size class in the community. These values are represented as mean canopy removal (%).
- A table indicating elephant preferences for the utilised species in the community by means of Ivlev's Electivity Index (Ivlev, 1961), Forage Ratio (Cock, 1978) and Rank Procedure method (Johnson, 1980).
- A figure reflecting the cumulative percentage canopy volume removed per size class for all utilised species. Note the percentage canopy removal is expressed as a percentage of the available canopy of only the utilised species and not of all available canopy. This value will be referred to as mean percentage utilisation or mean canopy removal percentage per size class.
- A figure illustrating the percentage utilisation per species (expressed as canopy removal percentage) in the community. Note that the values in this figure are mean values for the species at the different plots in the community. The value therefore differs from that provided in the table where the sum of all available and all removed canopy volume was used to calculate a percentage utilisation. The following subjective scale was used to describe the canopy removal:
    - Very high canopy removal >50% canopy removed
    - High canopy removal >25 to 50% canopy removed
    - Moderate canopy removal >10 to 25% canopy removed
    - Low canopy removal >2 to 10% canopy removed
    - Very low canopy removal ≤2% canopy removed
- A figure indicating the percentage utilisation for each plot in the community. Note that the values represent the utilisation as percentage of only the utilised woody species.
- A figure of the overall canopy removal in the community calculated as the total canopy removed per community expressed as a percentage of the total available canopy volume of all species.
- A figure reflecting the relative utilisation percentage for all three surveys.

4.6 METHODOLOGICAL ISSUES

For this study, data were used from different researchers during different times. It is possible that errors might have slipped in. Potential errors may include:

- Fieldwork was completed late in the season. Even although the survey included only woody species, the identification without inflorescences was often difficult and differences in identification between surveyors could have occurred.
- Because of incorrect or inconsistent identification between the different researchers, the species allocated to have elephant damage might possibly differ between the 1995, 2004 and 2010 survey. In some instances identification problems had to be resolved by grouping a few species into a single genus for comparative studies.
- Differences in interpretation of the agent or age of a particular utilisation incident could have occurred among the different researchers. Certain features of a utilisation event are distinctive for specific herbivores but there is still a possibility of wrongfully identifying agents of utilisation/damage to a tree. A field guide who grew up in the area and knew the plant and animals species assisted with the utilisation assessment in 2010.
- The transects were not permanently marked. The accuracy of the GPS coordinates, as received from previous researchers, might be accurate to 4 m for the 2004 surveys but since the transect is 4 m wide the allocation of the site may not always be entirely correct.
- Calculating relative utilisation might contain a level of uncertainty as the methods for gathering data differed for the 2004 and 2010 survey and the 1995 survey. Even though canopy removal was used for all three surveys there is a possibility that the manner in which these values were derived, differed.
- In some cases the data may highlight a single utilisation event within a community. When drawing conclusions on elephant utilization of species these single events should not be over-emphasized. In the current study, confidence was therefore placed in data based on multiple utilization events. Such single utilization events will always occur, but may be partly ruled out when a larger dataset has been accumulated. This was however, beyond the scope of the current MSc study.

CHAPTER 5

VEGETATION CLASSIFICATION

5.1 INTRODUCTION

A phytosociological classification was conducted for the Tembe Elephant Park by Matthews *et al*. (2001) (Figure 5.1). The main vegetation types in the park were Open Woodland, Sparse Woodland, Closed Woodland on Sand, Closed Woodland on Clay, Sand Forest, Hygrophilous Grassland and *Acacia borleae* Shrubland. The Hygrophilous Grassland and *Acacia borleae* Shrubland were not evaluated for elephant impact during the current survey. Matthews *et al*. (2001) recognised two communities within the Sand Forest, whereas Gaugris and Van Rooyen (2008) subdivided the Sand Forest into three communities: Short Sand Forest, Tall Sand Forest and Mature Sand Forest. The latter classification was used in the current study. Based on these previous classifications, seven plant communities were identified to be assessed for elephant utilsation/damage in 2010. Due to excessive elephant utilisation it was possible, and also suspected, that the vegetation composition had been altered at a community level. Consequently the floristic data of the 44 plots surveyed in 2010 were classified to determine whether the previous classifications were still appropriate.

Plant communities were classified based on the presence or absence of species as well as their abundance (canopy cover). No environmental factors, other than soil type, were included for classification purposes because soil characteristics were found to be a key environmental factor that had an influence on the separation of plant communities (Matthews *et al.,* 2001).

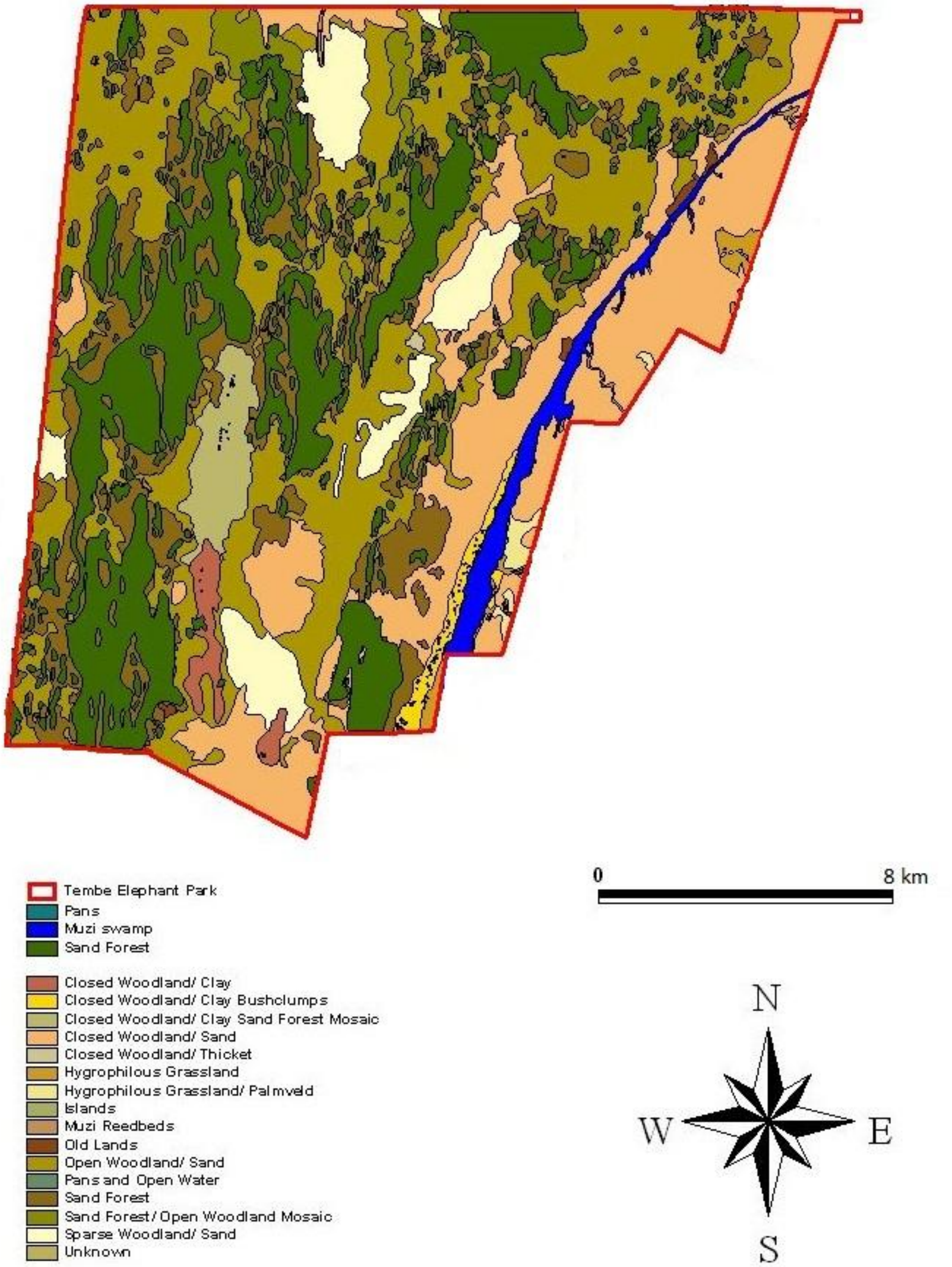

Figure 5.1 Vegetation of the Tembe Elephant Park as described by Matthews *et al.* (2001).

5.2 CLASSIFICATION

Seven plant communities were identified in the 2010 data, of which two were further subdivided into two subcommunities each.

The plant communities recognised in the Tembe Elephant Park were as follows (Table 5.1):

1. *Combretum mkuzense – Hyperacanthus microphyllus* Short Sand Forest
2. *Cola greenwayi – Croton pseudopulchellus* Tall Sand Forest
3. *Newtonia hildebrandtii – Todalliopsis bremekampii* Mature Sand Forest
4. *Dialium schlechteri – Psydrax locuples* Closed Woodland on Sand
    - 4.1 *Strychnos decussata – Dialium schlechteri* Closed Woodland on Sand
    - 4.2 *Acacia burkei – Psydrax locuples* Closed Woodland on Sand
5. *Spirostachys africana – Euclea natalensis* Closed Woodland on Clay
6. *Terminalia sericea – Strychnos madagascariensis* Open Woodland on Sand
    - 6.1 *Ozoroa engleri – Terminalia sericea* Open Woodland on Sand
    - 6.2 *Pavetta lanceolata – Brachylaena discolor* Open Woodland on Sand
7. *Carissa bispinosa – Terminalia sericea* Sparse Woodland on Sand

Table 5.1 Phytosociological table of the woody vegetation of the Tembe Elephant Park (grass layer not included)

Community	1					2			3			4									5				6																		7	
												4.1					4.2								6.1												6.2							
Site no.	33	34	39	42	43	35	36	40	37	38	44	9	10	14	15	22	8	25	24	26	1	4	5	6	2	7	11	41	12	13	21	23	27	28	29	30	16	17	18	19	31	32	3	20
Species group 1																																												
Combretum mkuzense	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.
Oxyanthus latifolius	1	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Tricalysia allenii	.	.	.	1	1	+	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Combretum celastroides	.	.	.	a	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Monodora junodii	.	.	.	1	1	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Croton steenkampianus	.	1	.	1	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Hippocratea delagoensis	1	.	.	1	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Species group 2																																												
Drypetes natalensis	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pavetta catophylla	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	+	.	.
Species group 3																																												
Hyperacanthus microphyllus	1	1	1	5	1	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Croton pseudopulchellus	1	1	1	1	1	1	a	1	1	.	.	.	.	1	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Brachylaena huillensis	1	.	1	.	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Canthium setiflorum	.	.	1	1	1	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Psydrax fragrantissima	a	.	1	1	1	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cassipourea mossambicensis	.	.	1	1	0	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Sclerochiton apiculatus	.	.	.	a	a	.	.	a	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Memecylon sousae	a	1	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Erythroxylum emarginatum	.	1	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Species group 4																																												
Newtonia hildebrandtii	.	.	.	.	.	3	.	.	.	1	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Azima tetracantha	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Species group 5																																												
Salacia leptoclada	1	1	a	1	1	1	1	1	.	1	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.
Drypetes arguta	1	1	a	a	a	a	1	1	1	+	1	1	.	.	.	.	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cola greenwayi	.	1	a	1	.	b	a	1	a	.	1	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cleistanthus schlechteri	.	1	4	4	.	1	1	.	.	.	b	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Todalliopsis bremekampii	1	1	1	1	1	.	a	1	1	1	1	.	.	.	.	1	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Manilkara discolor	1	.	.	.	1	.	.	1	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ochna natalitia	1	.	.	1	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Boscia filipes	.	.	.	1	.	.	a	.	.	1	.	a	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

Community	1					2			3			4									5				6																		7	
												4.1					4.2								6.1												6.2							
Site no.	33	34	39	42	43	35	36	40	37	38	44	9	10	14	15	22	8	25	24	26	1	4	5	6	2	7	11	41	12	13	21	23	27	28	29	30	16	17	18	19	31	32	3	20
Species group 6																																												
Strychnos decussata	.	.	.	.	.	.	.	.	1	.	.	1	.	3	1	1	.	.	+	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.
Albizia forbesii	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Trichilia emetica	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Sideroxylon inerme	.	.	.	.	.	.	.	.	.	.	.	.	.	1	a	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Species group 7																																												
Dovyalis longispina	.	.	.	.	.	+	1	.	1	.	.	.	1	1	+	1	1	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Diospyros inhacaensis	.	.	.	.	.	.	.	1	1	.	.	1	.	.	a	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ptaeroxylon obliquum	.	.	.	1	.	.	a	+	a	1	.	.	.	.	.	1	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Species group 8																																												
Pteleopsis myrtifolia	a	1	1	1	a	.	b	1	a	1	+	.	.	.	.	.	.	1	.	1	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.
Hymenocardia ulmoides	a	a	1	1	a	.	b	1	3	.	1	.	.	.	.	1	.	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	1
Haplocoelum gallense	.	+	.	1	.	b	b	.	a	.	1	.	.	.	.	.	.	1	.	+	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Species group 9																																												
Afzelia quanzensis	.	.	.	.	.	.	.	.	.	.	.	a	.	.	1	5	a	.	.	.	.	1	1	.	.	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Coddia rudis	.	.	.	.	.	.	.	.	+	+	.	.	+	.	.	.	1	+	+	.	+	1	1	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.
Acacia kraussiana	.	.	.	.	.	.	.	.	.	.	.	+	.	1	1	.	.	.	.	b	+	.	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Euphorbia ingens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Erythroxylum delagoense	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	+	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Plectroniella armata	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	.	.	1	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.
Schotia brachypetala	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Commiphora neglecta	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	+	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.
Rothmannia fischeri	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Acalypha glabrata	.	.	.	.	.	.	.	.	1	.	1	.	.	.	1	.	1	.	.	.	a	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Acacia robusta	.	.	.	.	.	.	.	.	1	.	.	.	.	a	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.
Species group 10																																												
Tricalysia junodii	1	1	1	.	.	.	.	+	1	1	+	1	.	1	1	1	+	1	+	+	.	+	.	.	.	.	.	1	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.
Tricalysia capensis	.	.	.	1	1	.	.	.	.	.	1	1	.	.	.	.	1	.	.	+	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Suregada zanzibariensis	.	1	.	1	.	.	.	.	1	.	.	a	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Phyllanthus reticulatus	1	.	.	1	.	.	.	.	.	.	.	.	.	1	.	1	.	.	.	.	.	1	+	+	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.
Tricalysia delagoensis	1	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Species group 11																																												
Bridelia cathartica	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	1	+	.	1	.	.	1	+	.	.	.	1	.	.	.	.	.	.	.	.	.
Ozoroa engleri	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	.	1	.	.	.	.	.	1	.	.	1
Xylotheca kraussiana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.

Community	1					2			3			4									5				6																		7	
												4.1					4.2								6.1												6.2							
Site no.	33	34	39	42	43	35	36	40	37	38	44	9	10	14	15	22	8	25	24	26	1	4	5	6	2	7	11	41	12	13	21	23	27	28	29	30	16	17	18	19	31	32	3	20
Species group 12																																												
Diospyros dichrophylla	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	1	.	.	.	.	.	+	1	1	.	+	1	1	.	1	.	+	1	1	1	.	.	.	.	.	.	.	1
Gymnosporia senegalensis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	+	.	.	1	.	1	.	.	.	.	.	1	1	.	.	.	.	.	.	+	.
Capparis tomentosa	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1	1	.	1	.	.	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Maytenus undata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	1	.	.	.	.	+	+	.	.	.	+	.	1	.	.	.	+	.
Hyphaene coriacea	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Elaeodendron transvaalense	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Species group 13																																												
Grewia caffra	.	.	.	.	.	.	.	.	.	+	.	1	1	+	1	+	1	.	1	1	1	1	1	1	1	.	1	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	1
Searsia gueinzii	.	.	.	+	.	.	.	.	.	.	1	1	1	1	.	+	1	.	1	+	1	1	+	.	1	.	.	1	1	.	+	.	.	.	1	.	.	.	.	.	.	.	.	.
Sclerocarya birrea	.	.	.	.	.	.	.	.	.	.	.	.	1	1	3	.	.	.	1	.	.	1	.	1	.	.	a	.	.	.	a	+	1	.	.	.	.	1	.	1	.	.	.	.
Garcinia livingstonei	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	a	.	.	.	.	.	.	1	+	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Zanthoxylum capense	.	.	.	.	.	.	.	1	.	.	.	.	1	a	.	.	.	.	.	+	.	.	.	.	.	.	1	+	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	1
Ancylanthos monteiroi	.	.	.	.	.	.	.	.	+	.	.	.	+	.	.	.	.	.	+	1	.	.	.	.	.	.	.	+	1	.	1	.	.	+	.	.	.	.	.	.	.	.	.	.
Ziziphus mucronata	.	.	.	.	.	.	.	.	.	.	1	.	.	.	1	.	.	.	.	.	.	.	a	.	.	.	a	.	1	.	.	+	.	.	+	.	.	.	.	.	.	.	.	.
Clausena anisata	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	+	.	.	.	.	.	.	.	.	.	+	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.
Species group 14																																												
Catunaregam spinosa	.	.	.	.	.	.	.	.	.	+	+	.	a	.	1	.	+	1	+	.	.	.	1	1	1	.	1	.	.	1	1	1	.	1	.	.	.	.	+	1	.	.	.	+
Spirostachys africana	.	.	.	.	.	.	.	.	a	.	.	5	.	.	.	a	b	.	1	1	3	1	b	.	.	.	.	1	.	.	1	a	.	.	1	.	.	.	.	.	.	.	.	.
Euclea natalensis	.	.	.	.	.	.	.	+	.	1	1	1	1	.	1	1	1	.	.	+	a	1	1	1	+	+	1	1	1	1	.	1	.	.	.	.	.	.	.	+	.	.	.	.
Species group 15																																												
Monanthotaxis caffra	1	1	1	1	1	1	.	+	1	1	+	1	1	+	1	1	1	1	1	.	1	1	.	1	.	.	1	1	.	1	1	.	.	.	.	1	.	.	.	.	.	.	.	.
Vepris lanceolata	.	.	+	.	.	+	.	+	+	1	.	a	1	1	a	a	1	.	.	.	a	.	1	.	.	.	1	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Psydrax locuples	1	+	.	+	1	.	.	+	.	+	+	+	1	+	1	.	+	1	1	1	+	.	.	1	1	.	.	1	.	1	1	.	.	+	1	.	.	.	.	.	.	.	.	.
Ochna barbosae	1	+	.	1	.	.	.	.	.	.	.	1	1	.	.	1	1	1	.	1	+	.	.	1	.	.	1	1	+	.	.	1	.	.	.	1	.	.	.	.	.	.	.	+
Sapium integerrimum	.	.	1	.	.	.	.	.	+	.	1	.	.	.	.	.	+	1	1	.	.	.	.	1	.	1	a	1	1	1	.	.	.	.	1	a	.	.	.	.	.	.	.	.
Balanites maughamii	.	.	.	.	.	+	+	1	1	.	5	+	.	.	.	.	+	.	1	.	.	1	.	.	1	.	.	1	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.
Albizia versicolor	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	+	.	.
Species group 16																																												
Parinari capense	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	.	+	+
Carissa bispinosa	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	1	1	.	.	1	1
Pavetta lanceolata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	1	.	.	.	1	.	.	.	.	1	.	1	+	1	.	.	1
Species group 17																																												
Dichrostachys cinerea	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	+	.	.	.	.	.	+	1	.	.	1	1	1	.	1	1	1	1	+	1	+	1	1	1	1	+	1	1
Terminalia sericea	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	a	+	.	.	.	a	1	1	1	1	a	1	b	1	a	a	3	1	1	1	1	1	1	1	1	1
Strychnos spinosa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	+	.	1	.	1	+	1	1	+	+	1	1	.	.	1	1	.	+	1	1	1	.	+	.	.

Community	1					2			3			4									5				6																		7	
												4.1					4.2								6.1												6.2							
Site no.	33	34	39	42	43	35	36	40	37	38	44	9	10	14	15	22	8	25	24	26	1	4	5	6	2	7	11	41	12	13	21	23	27	28	29	30	16	17	18	19	31	32	3	20
Brachylaena discolor	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1	.	1	.	.	.	.	.	1	.	.	1	.	.	.	.
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Species group 18																																												
Acacia burkei												a	a		a			a	b	a	a	a	a			a	+				a		a	a				+	a			a	.	.
Strychnos madagascariensis	.	.	.	.	.	.	.	.	.	.	1	.	a	.	.	.	.	+	1	1	.	.	.	1	+	1	1	1	+	1	1	+	1	a	1	1	1	1	1	1	1	1	1	.
Species group 19																																												
Combretum molle	.	a	.	.	.	.	1	.	.	.	.	.	1	.	.	.	.	1	a	a	.	.	1	.	1	1	.	1	1	1	1	.	.	1	.	.	+	.	.	1	.	1	.	+
Dialium schlechteri	.	4	a	.	a	.	a	a	1	.	.	5	3	3	b	3	a	1	1	1	1	.	.	1	.	1	.	1	.	1	1	.	.	+	.	1	.	.	.	1	1	.	.	.
Grewia microthyrsa	1	.	a	+	a	.	.	1	1	1	1	+	.	.	.	.	.	1	+	1	.	.	.	+	.	1	.	1	.	.	1	.	.	.	.	.	.	1	.	1	.	.	.	1
Acridocarpus natalitius	.	.	.	.	.	.	+	.	.	.	+	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	+	.	.	1	.	.	.
Albizia adianthifolia	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	+	.	.
Diospyros galpinii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.
Acacia borleae																+																										+	.	.
Deinbollia oblongifolia	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Strychnos henningsii	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	+	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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Erythrococca berberidea	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Vitex amboniensis	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.
Mundulea sericea	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	+	.	.	.	.
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Tabernaemontana elegans	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.

5.3 ORDINATIONS

Overall the Principal Coordinate Analysis on the 44 sites surveyed in 2010 in the Tembe Elephant Park confirmed the classification of the communities. The main features in the ordination were:

- The Open Woodland on Sand 2 contains the Sparse Woodland sites. This supports the result from the phytosociological table, that the Sparse Woodland and the Open Woodland on Sand 2 could not be distinguished floristically.
- The Closed Woodland on Sand community is divided into two subcommunities which are very distinct structurally. According to the ordination diagram the two subcommunities (Community 4.1 and 4.2) are not closely related. Subcommunity 4.1 lies close to the Mature Sand Forest community (Community 3) in ordination space and a number of the dominant woody species of Community 3 and 4.1 overlap. When the presence of woody species within subcommunity 4.1 is studied (Table 5.1), it is found that this subcommunity's characteristic and dominant woody species are very similar to the Mature Sand Forest identified in Gaugris and Van Rooyen (2008).
- The Closed Woodland on Sand 2 did not form a coherent group in the ordination. Some sites of the Closed Woodland on Sand 2 showed a close floristic relationship with the Closed Woodland on Clay. These two communities are distinguished by having two very different soil types. The two sites in the Closed Woodland on Sand 2 could possibly have an underlying clay layer as the overlapping woody species are characterised by clay soils, such as the woody species *Spirostachys africana*.
- The ordination of only the woody species did not support the separation between the Short Sand Forest and Tall Sand Forest and site 35 of the Tall Sand Forest showed an affiliation with the Mature Sand Forest (Table 5.2, Figure 5.2). Gaugris and Van Rooyen (2008) noted that the Mature Sand Forest (Community 3) is very distinct from the other two Sand Forest communities while these, Short and Tall Sand Forest (Community 1 and 2), are closely related and share a lot of dominant woody species. It is clear on the ordination diagram how similar the Short and Tall Sand Forest are to one another with the Mature Sand Forest grouped separately.

Based on the structure and species occurrence in a particular sampling site, the initial classification of some sites (Gaugris classification) had to be changed for the current analysis. Based primarily on the structure of the vegetation (not incorporated in the ordination) and the phytosociological table, sites 39, 42 and 43 were changed from Tall Sand

Forest (Gaugris) to Short Sand Forest (Potgieter). Site 35 was changed from Short Sand Forest (Gaugris) to Tall Sand Forest (Potgieter) but according to the ordination diagram it could even be moved up as far as Mature Sand Forest.

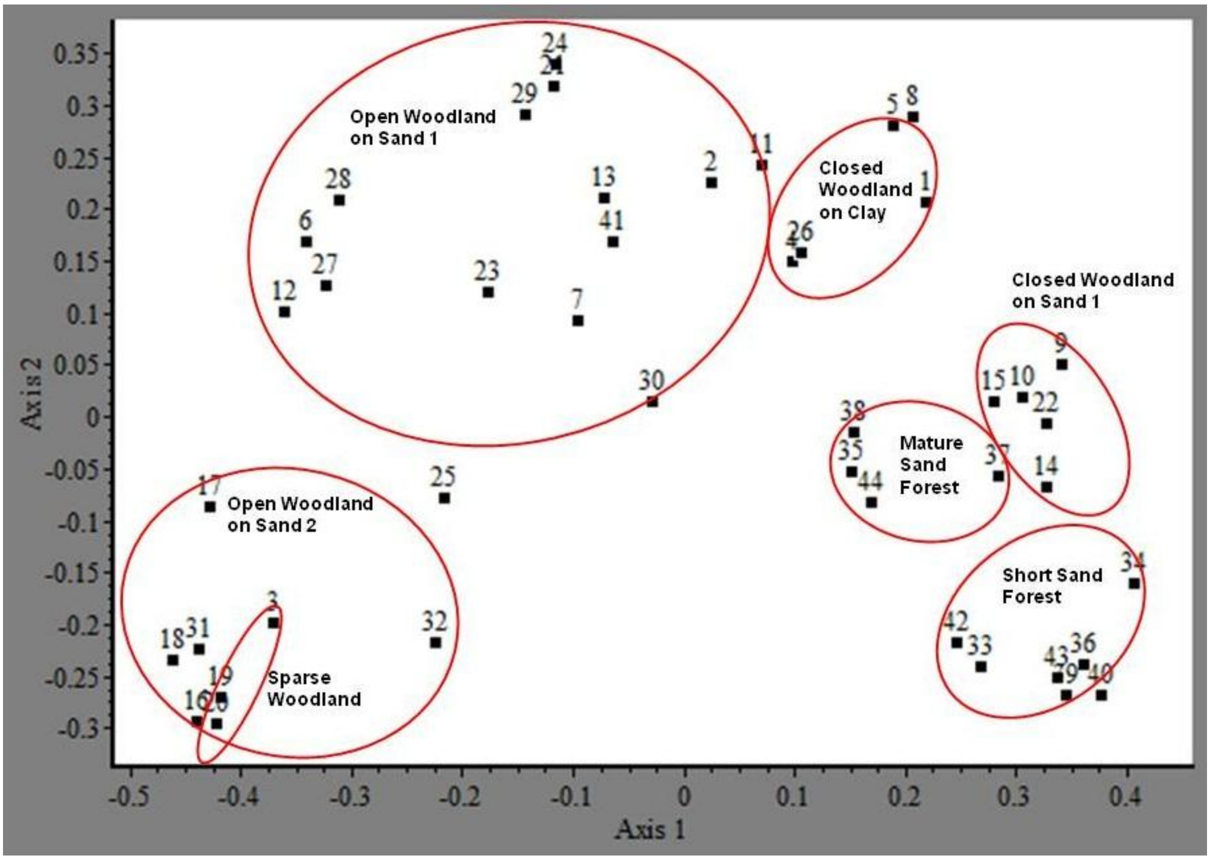

Figure 5.2 Ordination of the 44 sites surveyed in 2010.

Table 5.2 Changed vegetation communities of sampling sites

Site	Vegetation (Gaugris in 2004)	Vegetation (Potgieter in 2010)
14	Open Woodland on Sand	Closed Woodland on Sand 1
25	Open Woodland on Sand	Closed Woodland on Sand 2
35	Short Sand Forest	Tall Sand Forest
39	Tall Sand Forest	Short Sand Forest
41	Tall Sand Forest	Open Woodland on Sand 1
42	Tall Sand Forest	Short Sand Forest
43	Tall Sand Forest	Short Sand Forest

5.4 DESCRIPTION OF PLANT COMMUNITIES

The seven major plant communities that were recognised by Gaugris (2008) are still the same seven plant communities. However, two of these communities can now be divided into subcommunities. Consequently nine vegetation units were assessed for elephant utilisation in the current study.

5.4.1 Combretum mkuzense – Hyperacanthus microphyllus Short Sand Forest

This community is commonly located on the outer boundaries of large Sand Forest sections. The vegetation is extremely dense from the ground up to the closed canopy (Figure 5.3). The height of the Short Sand Forest community ranges from 3 – 5 m. The soil is sandy and not covered by an herbaceous layer. Woody species that are diagnostic for this community are the trees *Combretum mkuzense*, *Combretum celastroides*, *Monodora junodii* and *Oxyanthus latifolius* (species group 1). Diagnostic shrubs are *Croton steenkampianus, Hippocratea delagoensis* and *Tricalysia allenii* (species group 1).

Dominant woody species within the Short Sand Forest community include the shrubs *Croton pseudopulchellus* (species group 3) and *Monanthotaxis caffra* (species group 15) and the trees *Hyperacanthus microphyllus* (species group 3), *Salacia leptoclada*, *Drypetes arguta*, *Todalliopsis bremekampii* (species group 5), *Pteleopsis myrtifolia* and *Hymenocardia ulmoides* (species group 8).

The strong relationships between the Short Sand Forest and the Tall Sand Forest and the Mature Sand Forest are clearly indicated by the shared species in species groups 3 and 5.

5.4.2 Cola greenwayi – Croton pseudopulchellus Tall Sand Forest

The Tall Sand Forest community is not as dense as the Short Sand Forest community. Although the edge of the Tall Sand Forest is impenetrable and dense, the interior of the community is open with no ground layer (Figure 5.4) and a closed canopy, which is 8 – 10 m high. Sandy soil is found throughout the community. Diagnostic woody species in this community are the trees *Drypetes natalensis* and *Pavetta catophylla* (Species group 2).

Figure 5.3 Dense edge of the *Combretum mkuzense* – *Hyperacanthus microphyllus* Short Sand Forest (Phototgraph by M. Potgieter, 2010).

In this community, the dominant woody species include the trees *Salacia leptoclada*, *Drypetes arguta*, *Cola greenwayi* (species group 5), *Balanites maughamii* (species group 15), *Hyperacanthus microphyllus* and the shrub *Croton pseudopulchellus* (species group 3). Other dominant woody species in the Tall Sand Forest include *Haplocoelum gallense* (species group 8), *Dialium schlechteri* (species group 19), *Ptaeroxylon obliquum* (species group 7), *Todalliopsis bremekampii* and *Cleistanthus schlechteri* (species group 5). Other woody species that are also prominent in the Tall Sand Forest community include members of species group 3 such as *Cassipourea mossambicensis*, *Sclerochiton apiculatus* and *Erythroxylum emarginatum*.

Figure 5.4 Sparse ground and first layer of the *Cola greenwayi* – *Croton pseodopulchellus* Tall Sand Forest (Photograph by M. Potgieter, 2010).

5.4.3 *Newtonia hildebrandtii – Todalliopsis bremekampii* Mature Sand Forest

The Mature Sand Forest community is the most open Sand Forest community; it is also the tallest with a canopy exceeding 10 m (Figure 5.5). The ground and first layers are open and the upper canopy is closed, although occasional gaps do occur. The soil is sandy. All three the Sand Forest communities (community 1, 2 and 3, Table 5.1) are scattered throughout the east, centre and north of the park and none of the three Sand Forest communities dominate a specific location. The classification of the Sand Forest communities is based on the presence of woody species and generally the further away the site was from the forest edge, the higher the canopy and the species present related more to Mature Sand Forest.

Diagnostic woody species of this community include the shrub *Azima tetracantha* and the tree *Newtonia hildebrandtii* (species group 4). The Mature Sand Forest community is dominated by woody species such as the tree *Drypetes arguta*, *Todalliopsis bremekampii* (species group 5), *Pteleopsis myrtifolia* (species group 8) and *Grewia microthyrsa* (species group 19). Dominant shrubs include *Monanthotaxis caffra* (species group 15) and *Tricalysia junodii* (species group 10). Other prominent woody species within this community are

Hippocratea delagoensis (species group 1), *Cola greenwayi* (species group 5), *Ptaeroxylon obliquum* (species group 7), *Hymenocardia ulmoides, Haplocoelum gallense* (species group 8), *Balanites maughamii* (species group 15), and *Acalypha glabrata* (species group 9).

Figure 5.5 The *Newtonia hildebrandtii* – *Todalliopsis bremekampii* Mature Sand Forest with gaps in the canopy (Photograph by M. Potgieter, 2010).

5.4.4 Dialium schlechteri – Psydrax locuples Closed Woodland on Sand

The three Closed Woodland communities are loosely related to one another as species group 9 suggests with several shared woody species occurring. The Closed Woodland on Sand community differs from the Sand Forest communities in vegetation structure. This community is extremely dense and has a wide variety of woody species (Figure 5.6). Species that are characteristic to Sand Forest communities are found within the Closed Woodland on Sand community as well as woody species that are known to be found in Open Woodland communities. The canopy of the community is closed because of the presence of large trees in close proximity to one another. Height of the canopy varies between sites but across the community it would be considered rather tall with a number of individuals reaching 8 m or more. The herb layer of the Closed Woodland on Sand is sparse. Soil composition within the community is predominantly sandy but the occurrence of a clay layer is possible, especially when certain species such as *Spirostachys africana* are present. This community can be subdivided into two subcommunities based on species composition.

5.4.4.1 Strychnos decussata – Dialium schlechteri Closed Woodland on Sand

This subcommunity leans more towards a Sand Forest structure than to a Closed Woodland and it also shares many Sand Forest species. Diagnostic woody species in the *Strychnos decussata – Dialium schlechteri* Closed Woodland on Sand subcommunity include *Strychnos decussata*, *Albizia forbesii*, *Trichilia emetica* and *Sideroxylon inerme* (species group 6).

Woody species dominant in this subcommunity include the shrubs *Monanthotaxis caffra* (species group 15) and *Grewia caffra* (species group 13), while the trees include *Vepris lanceolata* (species group 15), *Dialium schlechteri* (species group 19), *Dovyalis longispina* (species group 7) and *Searsia gueinzii* (species group 13). Woody species that are also commonly found within this subcommunity are *Afzelia quanzensis* (species group 9), *Tricalysia junodii* (species group 10), *Sclerocarya birrea* (species group 13), *Euclea natalensis* (species group 14), *Psydrax locuples* (species group 15) and *Acacia burkei* (species group 18).

Hereafter the *Strychnos decussata – Dialium schlechteri* Closed Woodland on Sand subcommunity will be referred to as Closed Woodland 1.

5.4.4.2 *Acacia burkei – Psydrax locuples* Closed Woodland on Sand

This subcommunity is extremely dense and is found to be more closely related to the Closed Woodland on Clay community than with the Sand Forest communities. This confirms the need to separate the Closed Woodland on Sand community into these two subcommunities. No particular diagnostic species are present in this subcommunity and its identity is based on the absence of species that are diagnostic to the other Closed Woodland subcommunity (*Strychnos decussata – Dialium schlechteri* Closed Woodland on Sand).

Woody species that are dominant in the *Acacia burkei – Psydrax locuples* Closed Woodland on Sand subcommunity include the shrubs *Tricalysia junodii* (species group 10), *Psydrax locuples* (species group 15), and *Coddia rudis* (species group 9) and the trees *Dialium schlechteri* (species group 19), *Spirostachys africana* (species group 14), *Acacia burkei* (species group 18) and *Combretum molle* (species group 19). Other prominent woody species within this subcommunity include *Grewia caffra*, *Searsia gueinzii* (species group 13), *Grewia microthyrsa (species group 19*), *Catunaregam spinosa* (species group 14), *Monanthotaxis caffra Ochna barbosae*, *Sapium integerrimum* (species group 15) and *Strychnos madagascariensis* (species group 18).

Species groups 9, 10, 13 and 14 show the close relationship between the two Woodland on Sand subcommunities even although these species groups are also shared by other communities. Species that showed overlap in the subcommunities include *Dialium schlechteri* (species group 19), *Tricalysia junodii* (species group 10), *Grewia caffra* (species group 13) and *Psydrax locuples* (species group 15).

Hereafter the *Acacia burkei – Psydrax locuples Closed Woodland on Sand* subcommunity will be referred to as Closed Woodland 2.

Figure 5.6 The dense *Strychnos decussata – Dialium schlechteri* Closed Woodland on Sand subcommunity (top) and the *Acacia burkei – Psydrax locuples* Closed Woodland on Sand subcommunity (bottom) (Photograph by M. Potgieter, 2010).

5.4.5 *Spirostachys africana – Euclea natalensis* Closed Woodland on Clay

This community is different to all the other communities classified in this study as the main soil type is clay and not sand. Perennial pans are commonly found throughout the Closed Woodland on Clay community. Although this community is also referred to as a Closed Woodland it is not as dense as the Closed Woodland on Sand subcommunities. Large trees are scattered within this community (Figure 5.7). No distinct diagnostic species are found within the Closed Woodland on Clay community and it is characterised by the absence of woody species that are diagnostic to other closely related communities.

Figure 5.7 The *Spirostachys africana – Euclea natalensis* Closed Woodland on Clay community with perennial pans in the surrounding area (Photograph by M. Potgieter, 2010).

Dominant woody species present in this community include the shrubs *Grewia caffra* (species group 13), *Phyllanthus reticulatus* (species group 10) and *Capparis tomentosa* (species group 12) and the trees *Euclea natalensis* (species group 14), *Acacia burkei* (species group 18) and *Spirostachys africana* (species group 14). Other prominent woody species found within the Closed Woodland on Clay community are *Gymnosporia senegalensis* (species group 12), *Searsia gueinzii* (species group 13), *Monanthotaxis caffra* and *Vepris lanceolata* (species group 15).

Hereafter the *Spirostachys africana* – *Euclea natalensis* Closed Woodland on Clay subcommunity will be referred to as Closed Woodland 3.

5.4.6 Terminalia sericea – Strychnos madagascariensis Open Woodland on Sand

This community covers a large area in Tembe Elephant Park and is extremely diverse in species composition as well as vegetation structure. The density within this community varies as some areas have a great number of shrubs and trees closely spaced and other parts have the woody individuals scattered across the landscape (Figure 5.8). The Open Woodland on Sand community is subdivided into two subcommunities because of diversity in floristics and density.

5.4.6.1 Ozoroa engleri – Terminalia sericea Open Woodland on Sand

This subcommunity has more woody individuals and is denser than the second subcommunity. Woody species that are diagnostic for the *Ozoroa engleri* – *Terminalia sericea* Open Woodland on Sand subcommunity include *Bridelia cathartica*, *Ozoroa engleri* and *Xylotheca kraussiana* (species group 11).

Dominant woody species within this subcommunity are the shrubs *Diospyros dichrophylla* (species group 12), *Strychnos madagascariensis* (species group 18) and *Strychnos spinosa* (species group 17) and the trees include *Euclea natalensis* (species group 14), *Dichrostachys cinerea*, *Terminalia sericea* (species group 17), and *Combretum molle* (species group 19). Other prominent woody species contained in the *Ozoroa engleri* – *Diospyros dichrophylla* Open Woodland on Sand subcommunity are *Dialium schlechteri* (species group 19), *Acacia burkei* (species group 18), *Sapium integerrimum* (species group 15) and *Catunaregam spinosa* (species group 14).

Hereafter the *Ozoroa engleri* – *Terminalia sericea* Open Woodland on Sand subcommunity will be referred to as Open Woodland 1.

Figure 5.8 The *Ozoroa engleri* – *Terminalia sericea* Open Woodland on Sand subcommunity (top) with larger woody individuals than the *Pavetta lanceolata* – *Brachylaena discolor* Open Woodland on Sand subcommunity (bottom) (Photograph by M. Potgieter, 2010).

5.4.6.2 Pavetta lanceolata – Brachylaena discolor Open Woodland on Sand

This subcommunity of the Open Woodland on Sand community has fewer woody individuals and more open grassland areas than the previous subcommunity. The diagnostic woody species for this subcommunity is *Pavetta lanceolata* (species group 16). This subcommunity is dominated by the shrubs *Strychnos spinosa* (species group 17), *Strychnos madagascariensis* (species group 18) and *Pavetta lanceolata* (species group 16) as well as the trees *Terminalia sericea* (species group 17) and *Dichrostachys cinerea* (species group 17). Other conspicuous woody species found in this subcommunity include *Sclerocarya birrea* (species group 13), *Acacia burkei* (species group 18) and *Combretum molle* (species group 19).

Hereafter the *Pavetta lanceolata – Brachylaena discolor* Open Woodland on Sand subcommunity will be referred to as Open Woodland 2.

5.4.7 Carissa bispinosa – Terminalia sericea Sparse Woodland on Sand

This is the plant community with the lowest density of woody species and could be considered as grassland with only the occasional woody individual. Within this community trees higher than 8 m are not generally found (Figure 5.9). Floristically, this community cannot be distinguished from the *Pavetta lanceolata – Brachylaena discolor* Open Woodland on Sand subcommunity and the separation is based purely on the differences in structure. There is no species in the community that can be regarded as diagnostic. The Sparse Woodland on Sand community is recognized by the absence of woody species rather than by the presence of diagnostic species.

Dominant woody species within this community include the shrubs from species group 16, *Parinari capense* and *Carissa bispinosa* and the trees from species group 17, *Dichrostachys cinerea* and *Terminalia sericea*. Other dominant woody species within the Sparse Woodland on Sand community include *Strychnos madagascariensis* (species group 18) and *Ozoroa engleri* (species group 11).

Figure 5.9 The *Carissa bispinosa* – *Terminalia sericea* Sparse Woodland on Sand community. Note low density of tall woody individuals (Photograph by M. Potgieter, 2010).

CHAPTER 6

UTILISATION IN THE SHORT SAND FOREST

6.1 INTRODUCTION

The Short Sand Forest community in the Tembe Elephant Park is the densest of all seven plant communities surveyed. As a result of this community's density, an elephant can damage the vegetation by simply moving through a patch of Short Sand Forest in order to get from one point to another. Therefore, elephants may cause damage to this community without actually feeding. Elephant utilisation, which includes both consumptive and destructive use, was evaluated by means of the percentage of the canopy that had been removed. Results regarding elephant utilisation in the Short Sand Forest were retrieved from the data collected in 2004 by Gaugris (Gaugris, 2008) and these results were compared with the data collected in 2010 to determine whether elephant impact had increased or decreased.

In the south-western corner of the park a section had been fenced off (approximately 3.7 x 5.3 km) and no elephants or giraffes could enter, although smaller animals were able to enter this section. This exclosure contained several plant communities and three of the five Short Sand Forest sampling sites were located within this section. Apart from studying the changes of elephant utilisation over a period of time in the Short Sand Forest, the absence of elephants in the exclosure provided an opportunity to compare elephant utilisation within this plant community in the presence and absence (two years prior to 2010 survey) of elephants.

A summary of each site, in terms of total density and total available canopy volume as well as elephant-utilised density and canopy volume are provided (available on a DVD in the back cover of the dissertation). Additional tables and spreadsheets are also available on the DVD. The density data will not be discussed further.

6.2 RESULTS

6.2.1 Elephant utilisation - 2010 survey

Cumulative canopy removal by elephants, expressed as a percentage of the available canopy volume of only the utilised species, increased with increasing size class (Figure 6.1). Size class 1 had the least utilisation with only 0.01% canopy removed and size class 6 had 76.02% of the canopy removed. All of these overall canopy removal percentages include the damage of all ages. Therefore, it is important to note that the majority of utilisation in size class 6 was more than 2 years old.

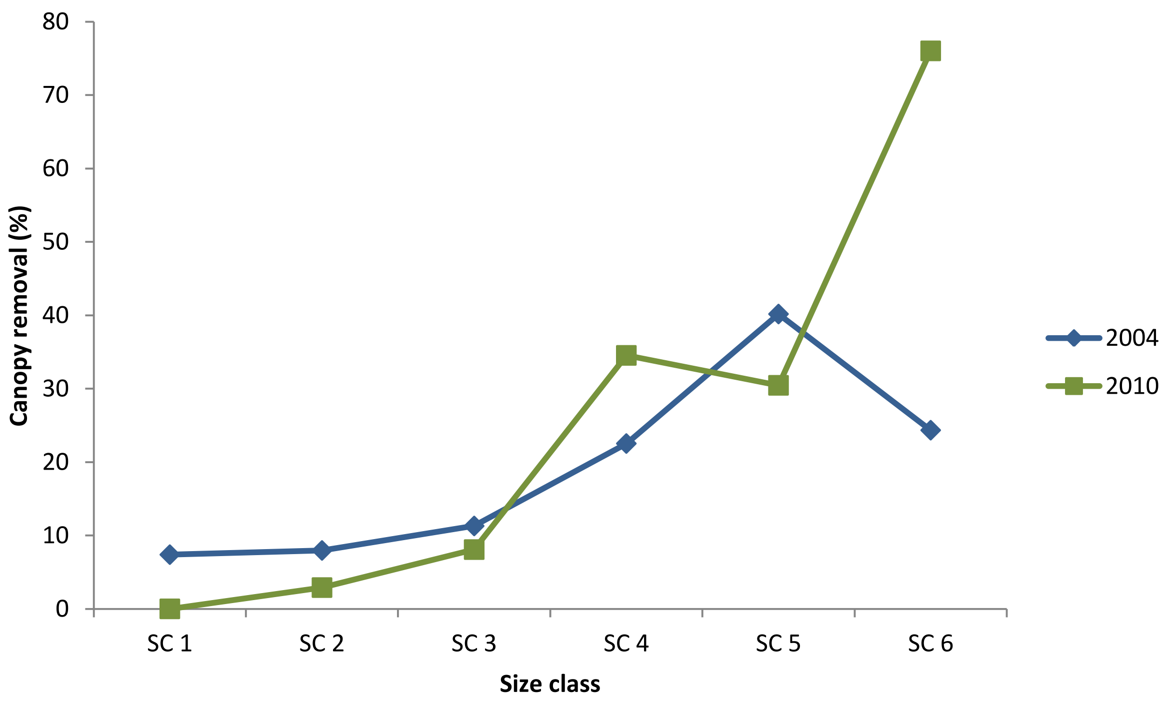

Figure 6.1 Cumulative percentage canopy volume (of utilised species) removed per size class (SC) in 2004 and 2010 in the Short Sand Forest community in the Tembe Elephant Park.

There were several species that were noteworthy for their high levels of mean canopy removal by elephants in the Short Sand Forest (Figure 6.2). *Dialium schlechteri* was the species within the Short Sand Forest with the highest mean canopy removal (47.13%) (Figure 6.2). *Ochna barbosae* was moderately utilised with a mean of 19.09% of total canopy removed across all sites. Moderate levels of canopy volume removal were also recorded for *Cleistanthus schlechteri* (16.91%), *Combretum molle* (14.12%) as well as *Hymenocardia ulmoides* (13.20%). The rest of the species that were utilised had low or very low levels of elephant utilisation.

Dialium schlechteri and *Cleistanthus schlechteri* contributed 80.16% of the total canopy volume removed (Table 6.1). These were also the two species with the largest available canopy. *Cleistanthus schlechteri* was utilised in size class 3 to 6 in 2010 (Table 6.2). The utilisation of *Combretum molle* was a single site event and the species was not utilised throughout the Short Sand Forest. Although *Drypetes arguta* had a low mean canopy removal (only 4.74%) it was utilised throughout most of the Short Sand Forest sites, as was the case for *Pteleopsis myrtifolia*.

The Short Sand Forest site surveyed in 2010 with the highest elephant impact was site 34. Cumulative canopy removal of the utilised species reached 57.00% at this site. Site 33 had the lowest elephant utilisation with only 13.40% of canopy volume of the utilised species removed (Figure 6.3). Both, site 34 and site 39 (57.00% and 48.58% canopy removal, respectively), were highly utilised by elephants and the impact was clearly visible. The mean cumulative canopy removal (of utilised species) among the five sites in the Short Sand Forest, as surveyed in 2010, was 32.71%. This made it the highest utilised Sand Forest community in the Tembe Elephant Park in the 2010 survey. If all canopy available is considered then the utilisation in the Short Sand Forest was 14.98% in 2010 (Figure 6.4, Table 6.1).

6.2.2 Elephant utilisation - 2004 survey

Similar to the 2010 survey, the cumulative percentage canopy removed, expressed as a percentage of the available canopy volume of utilised species only, showed a general increase with increasing size classes (Figure 6.1). *Ptaeroxylon obliquum* had the highest percentage elephant utilisation with a mean overall canopy removal of 24.00% (Figure 6.2). *Grewia microthyrsa* had the second highest elephant utilisation in the Short Sand Forest with 21.84%, followed by *Pteleopsis myrtifolia* (20.88%), *Suregada zanzibariensis* (18.90%) and *Cleistanthus schlechteri* (12.28%).

Two species that had high levels of utilisation in 2004 were *Pteleopsis myrtifolia* and *Cola greenwayi* (Figure 6.5, Tables 6.2 & 6.3). Both these woody species experienced a decrease in utilisation after 2004, but not across all the size classes. In some size classes the damage increased from 2004 to 2010 but in other size classes it decreased. *Pteleopsis myrtifolia* had the highest utilisation value in 2004 in size class 5 (22.19%) and *Cola greenwayi* had a mean percentage canopy removal of 15.75% in 2004 in size class 4. In contrast to the reduced levels of utilisation for the two previous species, *Dialium schlechteri* (Figure 6.6a) and *Hymenocardia ulmoides* (Figure 6.6b) showed an increase from 2004 to 2010 in mean percentage canopy removal in all six the size classes (Tables 6.2 & 6.3). *Hymenocardia ulmoides* had the highest utilisation in 2010 in size class 5 (18.41%), whereas *Dialium schlechteri* had a very high utilisation level in size class 6 (51.97%). *Cleistanthus schlechteri* showed similar utilisation values in both surveys up to size class 5, however utilisation in size class 6 was substantially higher in 2010 than in 2004 (Figure 6.6c).

Erythrophleum lasianthum and *Newtonia hildebrandtii* contributed 67.76% of the total canopy volume removed in 2001, but were not among the species utilised in 2010. These species were also those with the most canopy volume available in 2004.

The sampling site with the highest impact in 2004 was site 43 with an overall canopy removal among the utilised species of 35.76% and sampling site 39 experienced the lowest elephant utilisation with the cumulative[1] canopy removal being only 8.45% (Figure 6.3). In 2004, the mean cumulative canopy removal for the Short Sand Forest community was 18.45%. This was one of the communities with the highest elephant utilisation in 2004 and the Sand Forest community with the highest elephant impact in 2004. If all canopy available is considered then the utilisation in the Short Sand Forest was 14.08% in 2004 (Figure 6.4, Table 6.1). The elephant utilisation in the sites from 2004 and 2010 is not significantly different (p=0.209).

Overall, a large reduction in canopy volume was observed from 2004 to 2010 (from 39 873 to 16 678 $m^3.ha^{-1}$), however a similar reduction was also noted in the available canopy volume (from 283 199 to 111 363 $m^3.ha^{-1}$) in the intervening years (Table 6.1).

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[1] Cumulative canopy removal percentage refers to the total volume of the canopy removed of all species expressed as a percentage of the available volume of only the utilised species.

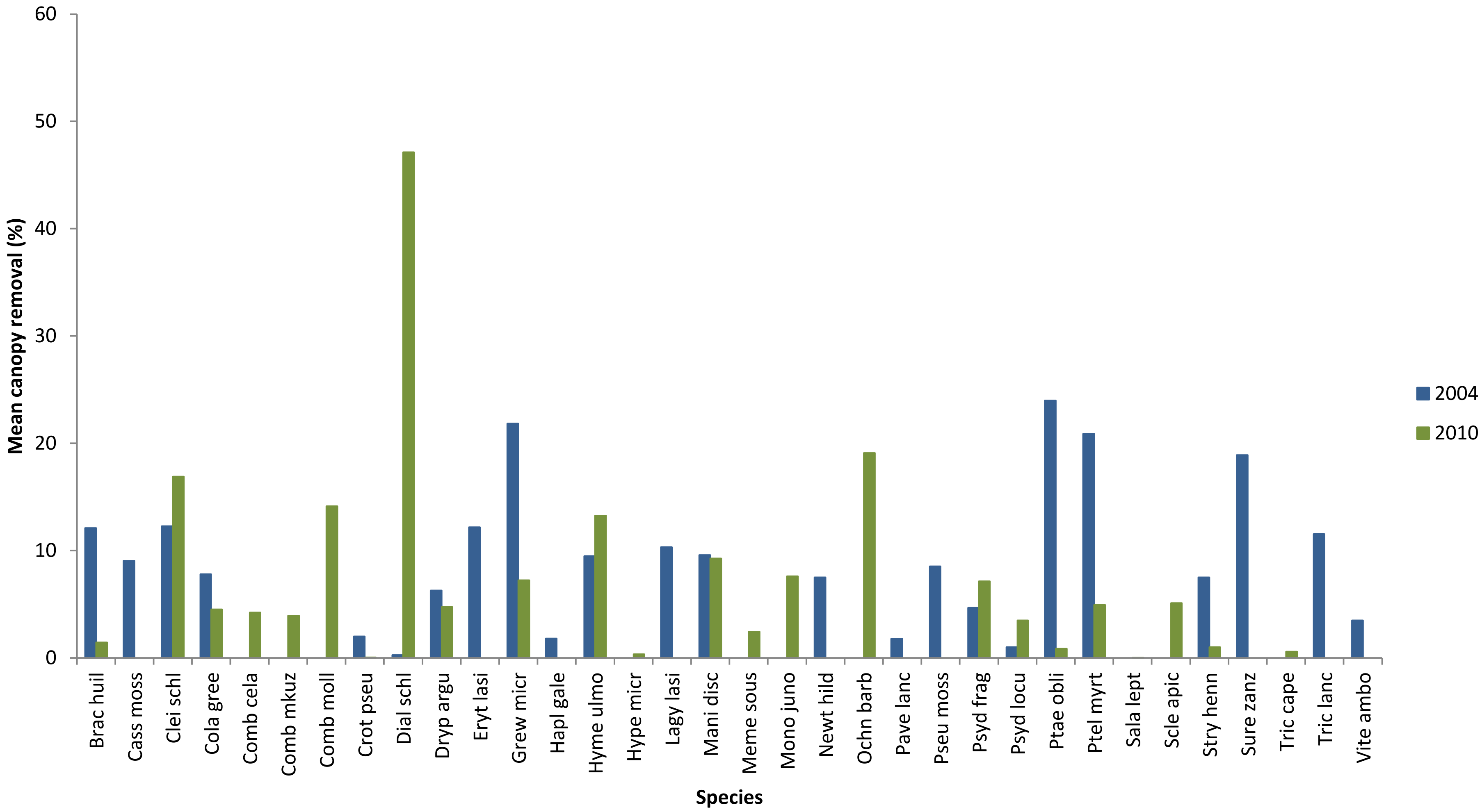

Figure 6.2 Woody species utilised by elephants in the Short Sand Forest as recorded in 2004 and 2010. Appendix A contains a list of abbreviations of all species names.

Table 6.1 Available canopy volume and removed canopy volume per utilised species within the Short Sand Forest community for 2010 and 2004. Elephant utilisation is expressed as cumulative percentage utilised as well as a relative utilisation percentage

Species	2010				2004			
	Available (m^3/ha)	Removed (m^3/ha)	% Utilised	Relative utilisation (%)	Available (m^3/ha)	Removed (m^3/ha)	% Utilised	Relative utilisation (%)
Brachylaena huillensis	696	23	3.32	0.14	2438	93	3.82	0.23
Cassipourea mossambicensis	-	-	-	-	1530	336	21.97	0.84
Cleistanthus schlechteri	12747	5869	46.04	35.19	1777	1091	61.38	2.74
Cola greenwayi	1919	433	22.56	2.59	5549	801	14.43	2.01
Combretum celastroides	692	72	10.45	0.43	-	-	-	-
Combretum mkuzense	393	77	19.65	0.46	-	-	-	-
Combretum molle	924	652	70.61	3.91	-	-	-	-
Croton pseudopulchellus	88	0	0.23	0.00	2944	129	4.38	0.32
Dialium schlechteri	11594	7501	64.69	44.97	14399	198	1.38	0.50
Drypetes arguta	2669	212	7.93	1.27	1670	228	13.64	0.57
Erythrophleum lasianthum	-	-	-	-	20944	12763	60.94	32.01
Grewia microthyrsa	1961	710	36.22	4.26	878	173	19.76	0.44
Haplocoelum gallaense	-	-	-	-	241	22	9.04	0.05
Hymenocardia ulmoides	2332	530	22.74	3.18	8382	1881	22.44	4.72
Hyperacanthus microphyllus	89	1	1.65	0.01	-	-	-	-
Lagynias lasiantha	-	-	-	-	138	71	51.64	0.18
Manilkara discolor	209	97	46.38	0.58	26025	2038	7.83	5.11
Memecylon sousae	476	58	12.17	0.35	-	-	-	-
Monodora junodii	170	27	16.06	0.16	-	-	-	-

Newtonia hildebrandtii	-	-	-	-	38013	14255	37.50	35.75
Ochna barbosae	2	2	95.46	0.01	-	-	-	-
Pavetta lanceolata	-	-	-	-	21	2	8.87	0.00
Pseudobersama mossambicensis	-	-	-	-	252	108	42.67	0.27
Psydrax fragrantissima	1021	184	18.06	1.11	2926	684	23.37	1.72
Psydrax locuples	101	18	17.50	0.11	95	5	5.00	0.01
Ptaeroxylon obliquum	1	0	4.32	0.00	2766	756	27.32	1.90
Pteleopsis myrtifolia	1715	110	6.39	0.66	9622	3057	31.77	7.67
Salacia leptoclada	5	0	0.17	0.00	-	-	-	-
Sclerochiton apiculatus	369	94	25.54	0.56	-	-	-	-
Strychnos henningsii	85	4	5	0.03	1117	419	37.50	1.05
Suregada zanzibariensis	-	-	-	-	50	47	94.50	0.12
Tricalysia capensis	104	3	2.88	0.02	-	-	-	-
Tricalysia lanceolata	-	-	-	-	201	58	28.58	0.14
Vitex amboniensis	-	-	-	-	3770	660	17.50	1.65
Total of utilised species	40362	16678	41.32		145748	39873	27.36	
Total of not utilised species	71001	0	0.00		137451	0	0.00	
Total available of all species	111363	16678	14.98		283199	39873	14.08	

Table 6.2 Mean utilisation per size class (SC) (expressed as % of canopy volume removed) for utilised Short Sand Forest species in the 2010 survey

Species	SC 1	SC 2	SC 3	SC 4	SC 5	SC 6
Brachylaena huillensis	0.00	1.85	0.37	1.79	0.00	0.00
Cleistanthus schlechteri	0.00	0.00	1.44	7.78	14.53	13.70
Cola greenwayi	0.00	0.77	1.00	8.72	4.67	0.00
Combretum celastroides	0.00	0.00	6.65	1.00	0.00	0.00
Combretum mkuzense	0.00	0.00	6.58	0.00	1.95	0.00
Combretum molle	0.00	0.00	0.00	0.00	14.12	0.00
Croton pseudopulchellus	0.00	0.06	0.00	0.00	0.00	0.00
Dialium schlechteri	0.00	0.00	1.00	12.88	0.00	51.97
Drypetes arguta	0.00	0.80	3.41	17.26	1.95	0.00
Grewia microthyrsa	0.00	0.00	2.23	18.29	0.00	3.50
Hymenocardia ulmoides	0.00	0.00	2.68	7.87	18.41	0.00
Hyperacanthus microphyllus	0.00	2.03	0.00	0.00	0.00	0.00
Manilkara discolor	0.00	0.00	7.50	0.00	13.81	0.00
Memecylon sousae	0.00	0.00	0.05	0.00	3.93	0.00
Monodora junodii	0.00	0.00	7.50	0.00	5.11	0.00
Ochna barbosae	0.00	0.00	19.09	0.00	0.00	0.00
Psydrax fragrantissima	0.00	0.00	2.12	7.28	4.32	0.00
Psydrax locuples	0.00	0.00	3.50	0.00	0.00	0.00
Ptaeroxylon obliquum	0.00	0.00	1.00	0.00	0.00	0.00
Pteleopsis myrtifolia	0.00	0.00	4.50	1.07	0.00	0.00
Salacia leptoclada	0.11	0.00	0.00	0.00	0.00	0.00
Sclerochiton apiculatus	0.00	0.00	0.00	5.11	0.00	0.00
Strychnos henningsii	0.00	0.00	1.00	0.00	0.00	0.00
Tricalysia capensis	0.00	0.00	0.58	0.00	0.00	0.00

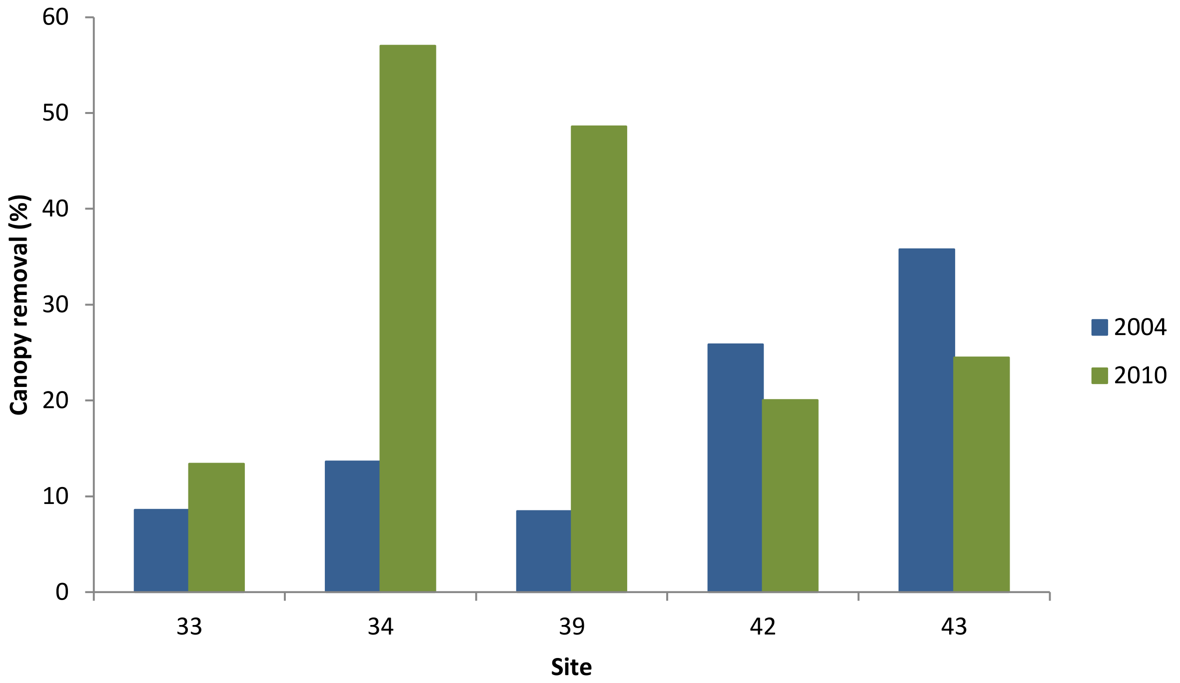

Figure 6.3 Cumulative percentage canopy removal (of utilised species only) by elephants at the five Short Sand forest sites as surveyed in 2004 (blue) and 2010 (green). Sites 33, 42 and 43 were situated within the exclosure and therefore not utilised by elephants in the last couple of years preceding the 2010 survey. On the other hand, elephants were present at site 34 and 39.

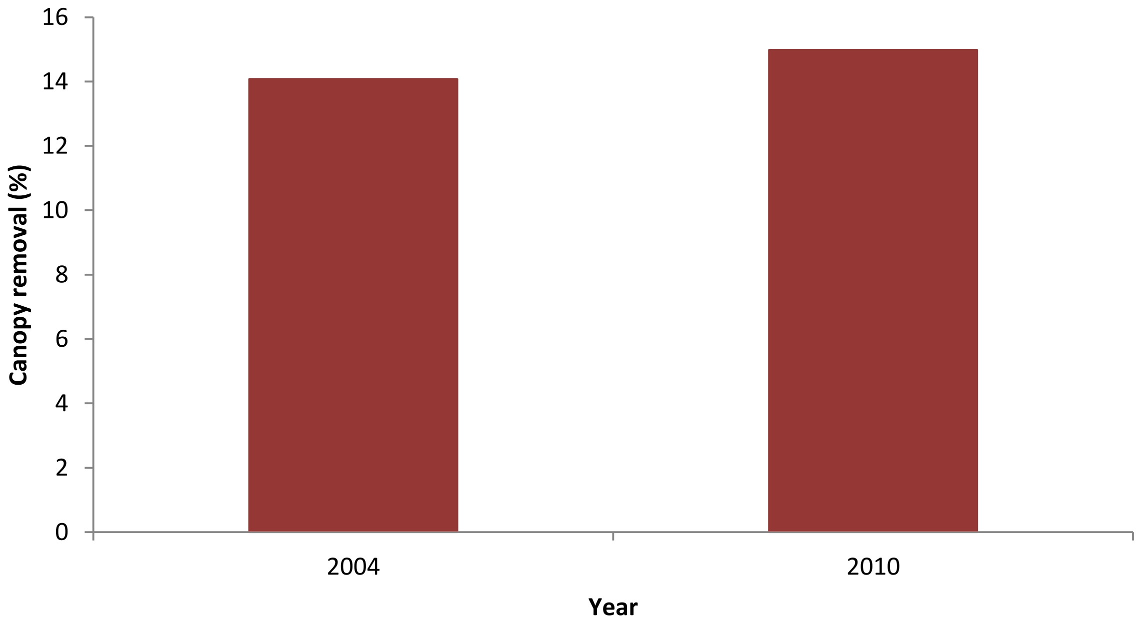

Figure 6.4 Cumulative percentage canopy removal (expressed as percentage of all species) in the Short Sand Forest community for 2004 and 2010.

Table 6.3 Mean utilisation per size class (SC) (expressed as % of canopy volume removed) for utilised Short Sand Forest species in the 2004 survey

Species	SC 1	SC 2	SC 3	SC 4	SC 5	SC 6
Brachylaena huillensis	0.00	0.00	12.11	0.00	0.00	0.00
Cassipourea mossambicensis	0.00	0.00	9.04	0.00	0.00	0.00
Cleistanthus schlechteri	0.00	0.00	0.00	8.36	18.90	0.00
Cola greenwayi	0.00	0.06	1.47	15.75	0.00	0.00
Croton pseudopulchellus	0.32	0.53	4.09	0.00	0.00	0.00
Dialium schlechteri	0.00	0.00	0.00	0.00	0.00	0.52
Drypetes arguta	0.00	0.00	12.79	3.50	0.00	0.00
Erythrophleum lasianthum	0.00	0.00	0.00	0.00	12.19	0.00
Grewia microthyrsa	0.00	19.14	0.00	2.70	0.00	0.00
Haplocoelum gallaense	0.00	0.00	1.81	0.00	0.00	0.00
Hymenocardia ulmoides	0.00	0.00	1.98	7.62	0.00	0.00
Lagynias lasiantha	13.81	7.50	0.00	0.00	0.00	0.00
Manilkara discolor	0.00	0.00	0.00	0.00	8.91	0.95
Newtonia hildebrandtii	0.00	0.00	0.00	0.00	0.00	7.50
Pavetta lanceolata	0.00	1.80	0.00	0.00	0.00	0.00
Pseudobersama mossambicensis	0.00	0.00	8.53	0.00	0.00	0.00
Suregada zanzibariensis	0.00	0.00	1.00	0.00	0.00	0.00
Psydrax fragrantissima	0.00	0.00	0.00	0.00	7.50	0.00
Psydrax locuples	0.00	18.90	0.00	0.00	0.00	0.00
Ptaeroxylon obliquum	0.00	0.00	2.34	17.11	0.00	0.00
Pteleopsis myrtifolia	0.00	24.00	0.00	0.00	7.50	0.00
Strychnos henningsii	0.00	0.00	0.28	11.00	22.19	0.00
Tricalysia lanceolata	0.00	4.82	19.09	0.00	0.00	0.00
Vitex amboniensis	0.00	0.00	0.00	3.50	0.00	0.00

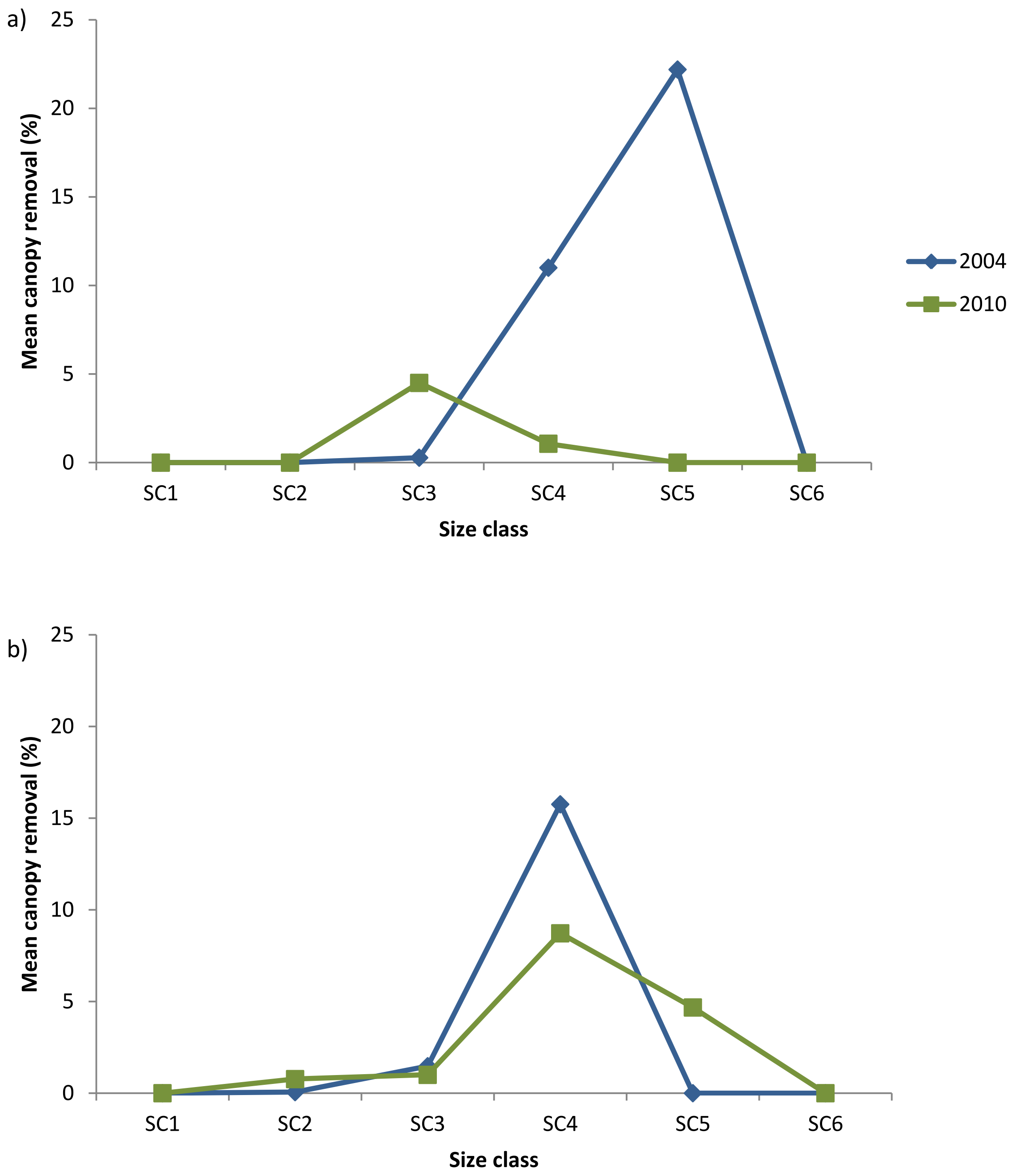

Figure 6.5 Mean percentage canopy removal by elephant per size class for (a) *Pteleopsis myrtifolia* and (b) *Cola greenwayi* in 2004 and 2010 within the Short Sand Forest community in the Tembe Elephant Park.

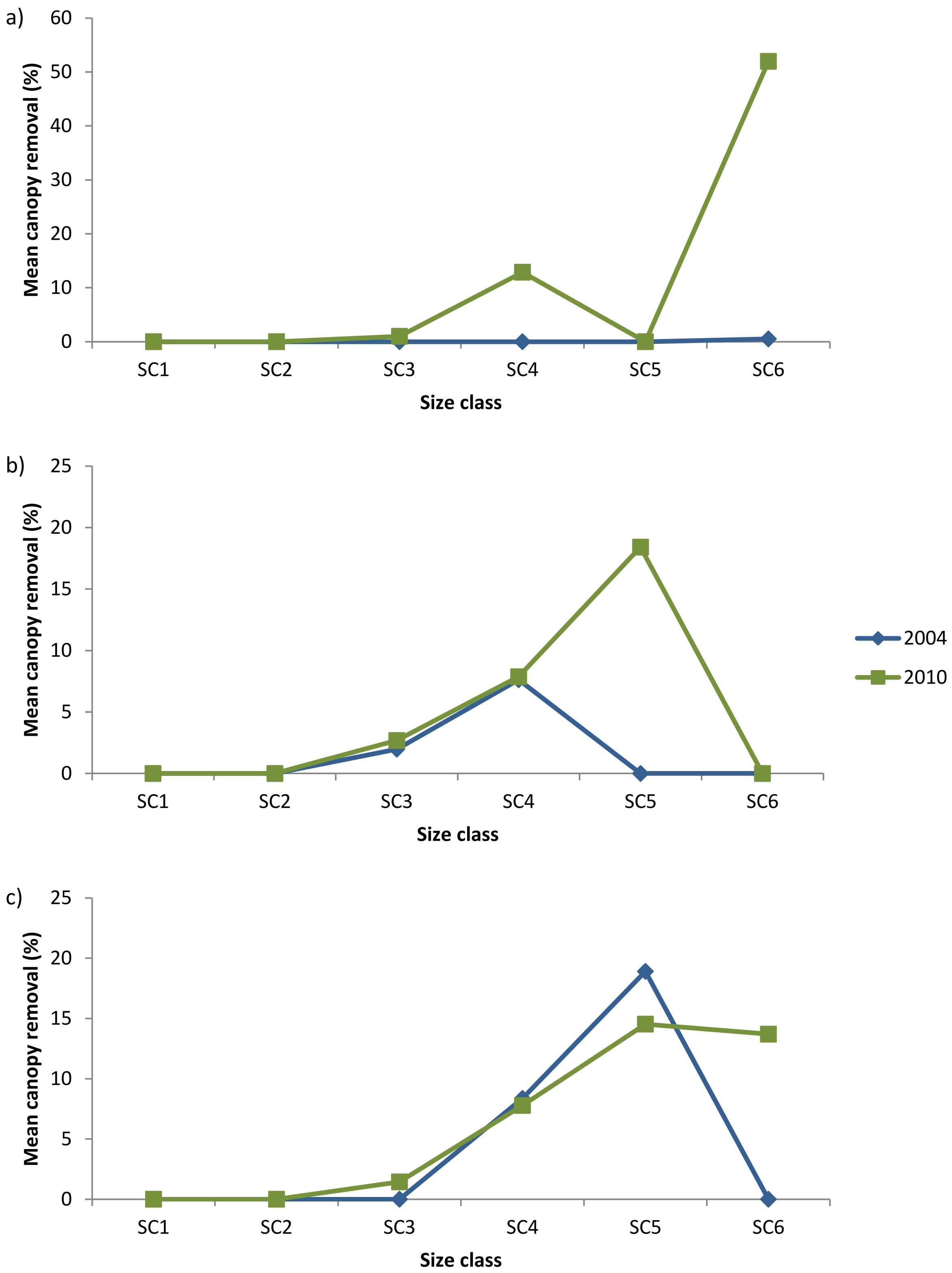

Figure 6.6 Mean percentage canopy removal by elephant per size class for (a) *Dialium schlechteri*, (b) *Hymenocardia ulmoides* and (c) *Cleistanthus schlechteri* in 2004 and 2010 within the Short Sand Forest community in the Tembe Elephant Park.

6.2.3 Elephant utilisation - 1995 survey

The survey that was completed in 1995 used a different method for recording elephant utilisation (Matthews & Page, undated). While the 2004 and 2010 survey made use of transects where all woody species inside the transects were evaluated (see Chapter 4), the 1995 survey conducted Point Centre Quarter (PCQ) surveys. The output derived by means of the PCQ method did not include canopy volumes per hectare. As a result only relative utilisation by elephants could be compared directly between all three datasets.

Figure 6.7 illustrates the relative utilisation by elephant for all three surveys since 1995. In each of the surveys, a different complement of species came out to be most utilised by elephants in the Short Sand Forest. According to the 1995 survey, elephants removed an appreciable proportion of the canopy of *Terminalia sericea* (21.09%), *Albizia adianthifolia* (16.62% of all canopy removed), *Hymenocardia ulmoides* (11.70%), *Newtonia hildebrandtii* (11.15%) and *Pteleopsis myrtifolia* (7.19%). Almost ten years later, in 2004, the elephants were still utilising *Pteleopsis myrtifolia* (7.67%), but had increase their use of *Newtonia hildebrandtii* (35.75%) and seemed to have developed a preference for *Erythrophleum lasianthum* (32.01%). The 2010 survey had two species that were highly utilised: these were *Cleistanthus schlechteri* (35.19%) and *Dialium schlechteri* (44.97%). Both these species were also utilised in 1995 and 2004, but they contributed to a small proportion of the total utilisation.

6.2.4 Elephant preferences

During the classification of the vegetation (Chapter 5) the possibility was mentioned that a change in species composition had occurred since 2004 and that this change necessitated a revised classification. Therefore it was important to determine whether the preferences of the elephants in Tembe Elephant Park had also changed. Three different indices were used for determining the preferences or selection of the elephants towards woody species. The three indices were the Forage Ratio (Cock, 1978), Ivlev's Electivity Index (Ivlev, 1961) and the Rank Procedure method (Johnson, 1980). These indices were used to calculate elephant preference for the 2004 and 2010 datasets. All three indices used to express species preference by elephants were based on canopy removal as measure of utilisation.

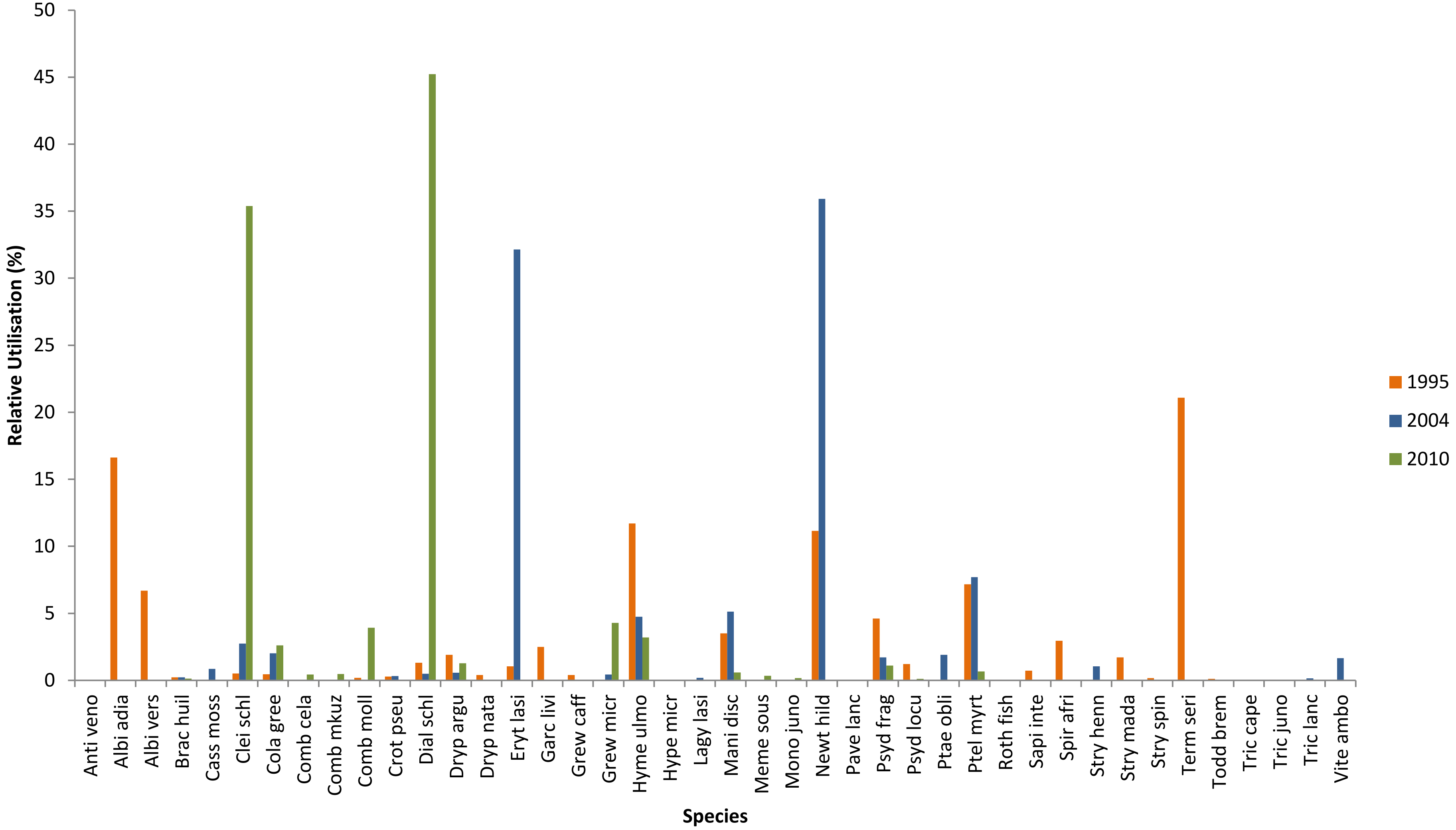

Figure 6.7 Relative utilisation of various species by elephants in 1995, 2004 and 2010 in the Tembe Elephant Park. Appendix A contains a list of abbreviations of all species names.

The ranking of species in the table is from the most preferred to least preferred based on Ivlev's Electivity Index. Species present in this community but not utilised by elephants were not included in the table. There was a clear lack of agreement in the most preferred species between 2004 and 2010. The most preferred species according to both Ivlev's Electivity Index and the Forage Ratio in 2010 were *Combretum molle*, *Dialium schlechteri* and *Cleistanthus schlechteri* (Table 6.4), whereas the most preferred species in 2004 were *Suregada zanzibariensis*, *Lagynias lasiantha*, *Pseudobersama mossambicensis, Erythrophleum lasianthum, Pteleopsis myrtifolia*, *Tricalysia lanceolata*, *Strychnos henningsii* and *Ptaeroxylon obliquum* (Table 6.5). In 2010, *Erythrophleum lasianthum* was not recorded in the Short Sand Forest and *Suregada zanzibariensis* was not browsed by elephants. *Pteleopsis myrtifolia*, *Strychnos henningsii* and *Ptaeroxylon obliquum* were utilised by elephants in the Short Sand Forest but the Ivlev's Electivity Index of all three species was negative, therefore they were not considered selected for by the elephants. The available canopy volume of all these species was severely reduced in 2010 compared to 2004 levels.

Hymenocardia ulmoides moved from the eleventh position in 2004 up to the seventh position in 2010, although Ivlev's Electivity values went down and showed negative values in 2010. *Grewia microthyrsa* and *Psydrax fragrantissima* showed a similar pattern.

The Rank Procedure method also showed that *Combretum molle* was most preferred in 2010 (Table 6.4), but it was followed by *Manilkara discolor* and *Strychnos henningsii* occupied the third position shared by several other species. In 2004, the most preferred species were *Strychnos henningsii*, *Ptaeroxylon obliquum* and *Cassipourea mossambicensis* (Table 6.5).

Table 6.4 Elephant preferences for woody species in 2010 in terms of Ivlev's Electivity Index (Ivlev, 1961), the Forage Ratio (Cock, 1978) and the Rank Procedure method (Johnson, 1980). The woody species recorded within the Short Sand Forest in 2010 are ranked from most preferred to least preferred based on Ivlev's Electivity Index

Woody Species	Ivlev's Electivity Index	Forage Ratio	Rank Procedure method
Combretum molle	0.37	2.18	1
Dialium schlechteri	0.34	2.02	6
Cleistanthus schlechteri	0.13	1.30	8
Manilkara discolor	0.04	1.08	2
Ochna barbosae	0.01	1.02	4
Grewia microthyrsa	-0.07	0.87	3
Hymenocardia ulmoides	-0.25	0.60	7
Psydrax locuples	-0.30	0.54	3
Cola greenwayi	-0.33	0.50	7
Monodora junodii	-0.34	0.50	3
Psydrax fragrantissima	-0.36	0.47	6
Sclerochiton apiculatus	-0.45	0.38	7
Memecylon sousae	-0.46	0.38	5
Combretum celastroides	-0.51	0.32	7
Combretum mkuzense	-0.65	0.21	9
Drypetes arguta	-0.66	0.21	10
Strychnos henningsii	-0.73	0.15	3
Ptaeroxylon obliquum	-0.77	0.13	6
Pteleopsis myrtifolia	-0.77	0.13	11
Brachylaena huillensis	-0.81	0.11	9
Tricalysia capensis	-0.92	0.04	8
Hyperacanthus microphyllus	-0.96	0.02	8
Croton pseudopulchellus	-1.00	0.00	13
Salacia leptoclada	-1.00	0.00	12

Table 6.5 Elephant preferences for woody species in 2004 in terms of Ivlev's Electivity Index (Ivlev, 1961), the Forage Ratio (Cock, 1978) and the Rank Procedure method (Johnson, 1980). The woody species recorded within the Short Sand Forest in 2004 are ranked from most preferred to least preferred based on Ivlev's Electivity Index

Woody Species	Ivlev's Electivity Index	Forage Ratio	Rank procedure method
Suregada zanzibariensis	0.74	6.66	4
Lagynias lasiantha	0.57	3.64	4
Pseudobersama mossambicensis	0.50	3.01	3
Erythrophleum lasianthum	0.49	2.95	5
Pteleopsis myrtifolia	0.38	2.24	3
Tricalysia lanceolata	0.34	2.01	6
Strychnos henningsii	0.33	1.97	1
Ptaeroxylon obliquum	0.32	1.92	1
Cassipourea mossambicensis	0.22	1.55	2
Hymenocardia ulmoides	0.21	1.52	4
Grewia microthyrsa	0.16	1.39	3
Newtonia hildebrandtii	0.11	1.25	7
Vitex amboniensis	0.10	1.23	5
Psydrax fragrantissima	0.03	1.06	5
Manilkara discolor	-0.31	0.53	6
Cola greenwayi	-0.38	0.45	8
Drypetes arguta	-0.39	0.44	8
Croton pseudopulchellus	-0.54	0.30	9
Psydrax locuples	-0.57	0.28	7
Brachylaena huillensis	-0.58	0.27	9
Cleistanthus schlechteri	-0.68	0.19	10
Dialium schlechteri	-0.91	0.05	12
Pavetta lanceolata	-0.95	0.03	11
Haplocoelum gallaense	-0.95	0.03	13

6.2.5 Exclosure

In 2008 the management of the Tembe Elephant Park decided to restrict the access of elephants into the Sand Forest in the south-western corner of the park in order to conserve and protect this indigenous forest type. Three of the five Short Sand Forest sites were situated within the exclosure which provided a valuable opportunity for comparing the impact of elephants on woody species. It was hoped that this two year time period would be sufficient to distinguish between the effects of continuous elephant browsing versus the release from browsing on the canopy structure of the Short Sand Forest.

The species that were utilised intensively outside the exclosure included *Combretum molle* (70.61%), *Dialium schlechteri* (62.87%) and *Cleistanthus schlechteri* (62.17%) (Table 6.6). Within the exclosure, the utilised species (due to damage that had been accumulated prior to the erection of the exclosure) were *Ochna barbosae* (95.46%), *Dialium schlechteri* (95.17%), *Manilkara discolor* (46.38%) and *Cleistanthus schlechteri* (22.36%). The difference between the utilisation of woody species inside and outside the exclosure was not significant (p=0.247).

A comparison of elephant utilisation per size class for the two plots currently outside the exclosure and for the three plots currently within the exclosure showed that utilisation had noticeably increased outside the exclosure, whereas within the exclosure utilisation levels were relatively unchanged in size classes 1 to 5, but a reduction was evident in size class 6 (Figure 6.8).

Table 6.6 Differences in canopy volume available and removed canopy volume within the exclosure and outside the exclosure. Elephant utilisation is expressed as percentage utilised

Woody species	Non-Exclosure			Exclosure		
	Available	Removed	% Utilised	Available	Removed	% Utilised
Brachylaena huillensis	935	2	0.19	536	37	6.97
Cleistanthus schlechteri	18954	11784	62.17	8609	1925	22.36
Cola greenwayi	4797	1082	22.56			
Combretum celastroides				1153	120	10.45
Combretum mkuzense	982	193	19.65			
Combretum molle	2309	1631	70.61			
Croton pseudopulchellus				147	0	0.23
Dialium schlechteri	27347	17193	62.87	1092	1039	95.17
Drypetes arguta	3143	363	11.56	2354	111	4.71
Grewia microthyrsa	4903	1776	36.22			
Hymenocardia ulmoides	1413	614	43.42	2946	475	16.13
Hyperacanthus microphyllus	222	4	1.65			
Manilkara discolor				349	162	46.38
Memecylon sousae				794	97	12.17
Monodora junodii				284	46	16.06
Ochna barbosae				3	3	95.46
Psydrax fragrantissima				1701	307	18.06
Psydrax locuples				168	29	17.50
Ptaeroxylon obliquum				2	0	4.32
Pteleopsis myrtifolia	1866	168	9.00	1615	71	4.38
Salacia leptoclada				9	0	0.17
Sclerochiton apiculatus				614	157	25.54
Strychnos henningsii				142	7	5.00
Tricalysia capensis				174	5	2.88
Total of utilised species	66868	34808	52.05	22691	4592	20.24
Total of not utilised species	82585	0	0.00	63278	0	0.00
Total available of all species	149453	34808	23.29	85969	4592	5.34

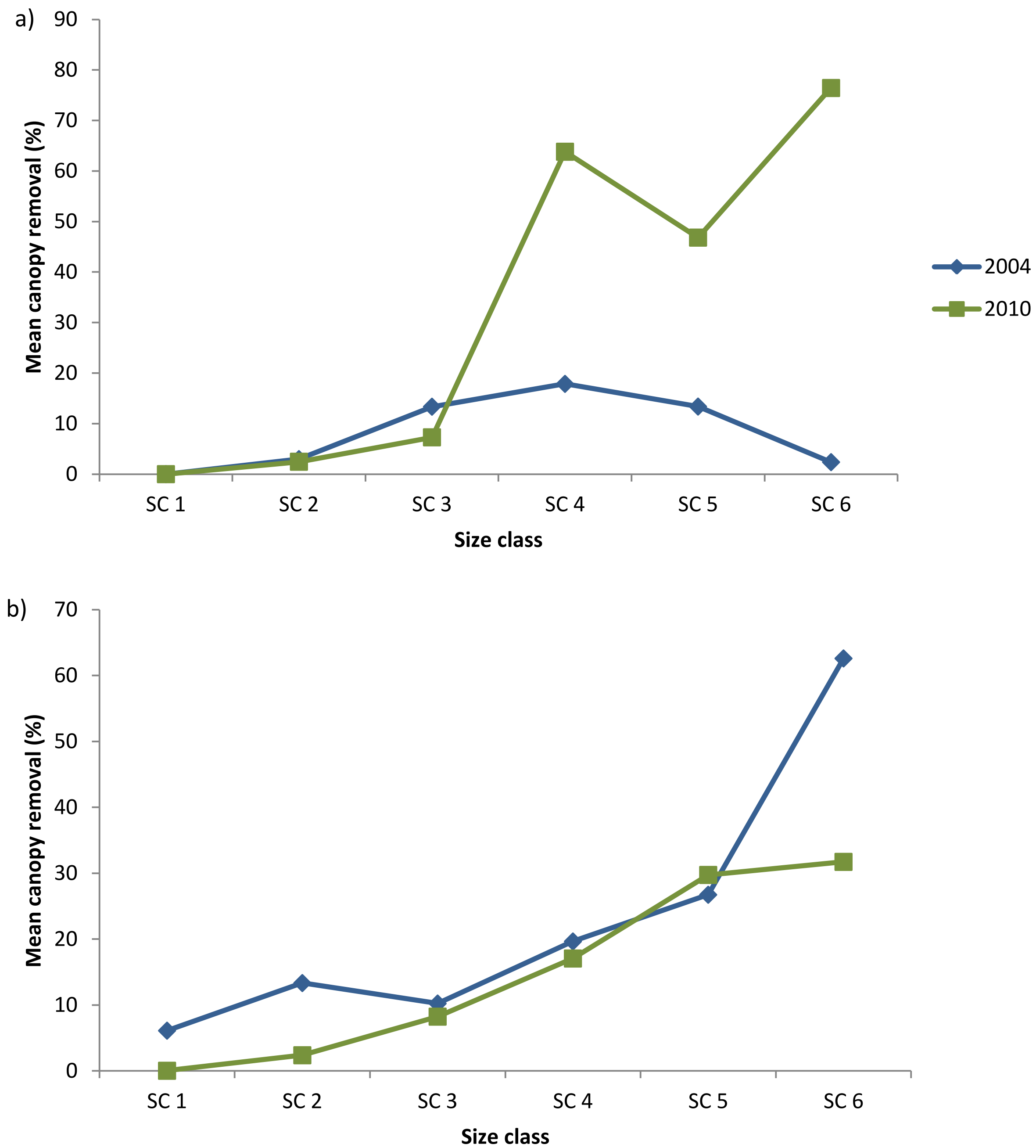

Figure 6.8 Comparison of elephant utilisation per size class in 2004 and 2010 a) for the two plots currently outside the exclosure and b) for the three plots currently within the exclosure.

6.3 DISCUSSION

6.3.1 Percentage canopy removal

In certain areas of the Tembe Elephant Park the impact of elephants was obvious and the damage that occurred was easily noticeable to any individual passing by. However, in communities such as the Short Sand Forest elephant utilisation was more difficult to detect as the community was closed and only the edge was visible to those observing from the road. As one entered the Short Sand Forest it remained a problem to visualise the extent of the overall canopy removed because of the density, but as soon as an individual tree was assessed the degree of utilisation became apparent.

Using the data obtained by J.Y. Gaugris[2] in 2004 (Gaugris, 2008), a comparison with 2010 could be made in terms of canopy volume removed by elephants. The number of woody species utilised in the Short Sand Forest by elephants was similar in 2004 and 2010. In 2004, 24 species were recorded with elephant utilisation and in 2010, 24 species were identified with elephant utilisation (Figure 6.2). Fourteen woody species were common to both datasets. In 2010, ten woody species were recorded with elephant utilisation in the Short Sand Forest that were not identified in 2004 as having been utilised by elephants. The same for ten other species with elephant utilisation in 2004. Species were also identified in the 2010 surveys with high elephant utilisation values, which differed from the 2004 dataset.

Elephant utilisation declined from 2004 to 2010 in the lower size classes (Figure 6.1). This is encouraging as these are young individuals that may still develop into large trees. On the other hand, the increase in elephant utilisation within the larger size classes remains a big problem. The trend of increasing canopy removal with increasing stem diameter is expected as large individuals are those that elephants will choose for browsing or rubbing against (Ben-Shahar, 1993). Boundja and Midgley (2009) conducted a similar study on elephant utilisation in the Hluhluwe-Imfolozi Park, South Africa. The size class definitions of the woody species were the same as that of the present study. Their results also showed an increase in elephant damage as stem diameter increased. Elephants targeted the larger individuals with the bigger stems.

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The increase in elephant utilisation within size class 4, 5 and 6 is probably not only because of a larger elephant population and therefore more utilisation, but it could also be due to accumulated damage (O'Connor, 2010). The calculated percentage canopy removed represented several years' accumulated damage. Within the large size classes a large proportion of the damage by elephants was old damage, i.e. more than 2 years prior to the surveys. Consequently, the percentage canopy removal in 2010 (as seen in Figure 6.1) could even include some of the damage that was already recorded in 2004. That could be the reason why size class 6 generally had the largest amount of elephant utilisation.

Ptaeroxylon obliquum was a moderately utilised species in 2004 but showed hardly any utilisation in 2010. The mean percentage canopy removal of this species was reduced from 24.00% to 0.86% and the available canopy volume for this woody species also declined from 2004 to 2010 (Table 6.1). The changes in utilisation of *Ptaeroxylon obliquum* was also reflected in changed preferences. *Pteleopsis myrtifolia* was also moderately utilised in 2004 within the Short Sand Forest and the mean percentage canopy removal decreased from 20.88% (2004) to 4.95% in 2010. The available canopy volume of *Pteleopsis myrtifolia* also experienced a decline from 2004 to 2010. In 2004 elephants utilised primarily size class 5 and to a lesser degree size class 4, whereas elephants primarily utilised size class 3 in 2010 and almost no utilisation of the larger size classes was recorded. *Suregada zanzibariensis*, *Grewia microthyrsa*, *Brachylaena huillense*, *Strychnos henningsii* and *Cola greenwayi* were also species with high percentages canopy removal in 2004, but low percentages elephant utilisation in 2010. In all cases, except for *Grewia microthyrsa*, the canopy volume available showed a sharp decline from 2004 to 2010 of these species. The distribution of utilisation in *Cola greenwayi* across the different size classes remained rather constant from 2004 to 2010, the elephants were still mainly utilising individuals within size class 4.

Dialium schlechteri was one of the woody species in the Tembe Elephant Park that underwent large changes in utilisation percentage (Figure 6.2). This species went from having almost zero utilisation by elephants in 2004 to the species with the most elephant utilisation in the Short Sand Forest in 2010 (44.97% of all utilisation, Table 6.1) and by far the largest percentage canopy removal. The percentage canopy removal of *Dialium schlechteri* increased from 0.28% in 2004 to 47.13% in 2010, while the available canopy volume of this species in the Short Sand Forest showed a slight decrease since 2004. Utilisation of *Dialium schlechteri* mainly occurred within the large size classes. *Combretum molle* and *Ochna barbosae* were moderately utilised by elephants in 2010 but because these species were not common in the Short Sand Forest they were not encountered in the 2004 survey. *Hymenocardia ulmoides* and *Cleistanthus schlechteri* experienced a slight increase in elephant utilisation from 2004 to 2010. For both these species more or less the same size classes were utilised and to about the same degree. Size class 5 was targeted amongst the *Hymenocardia ulmoides* individuals according to the 2004 surveys, whereas elephant damage in this size class was not recorded in 2004. *Cleistanthus schlechteri* had an extra size class that was utilised by the elephants with damage recorded in size class 6 in 2010 but not in 2004. It should be noted that the available canopy volume of *Cleistanthus schlechteri* was far higher in 2010 than in 2004.

If only the utilised species are considered the cumulative canopy removal of 27.36% in 2004 increased to 41.32% in 2010 (Table 6.1). Similar increases in elephant utilisation over time with increased elephant population sizes have been reported by Ihwagi *et al*. (2009) in Samburu and Buffalo Springs National Reserves, Kenya and Young *et al*. (2009) in Kruger National Park, South Africa. Compared to the other vegetation communities in the Tembe Elephant Park the Short Sand Forest was one of the highest utilised communities in terms of elephant browsing (Gaugris & Van Rooyen, 2010a). The Sand Forest has a number of indigenous and rare species and the impact of elephants on these species can be immense.

However, if canopy removal is expressed as a percentage of the available canopy of all species the increase in canopy removal from 14.08% in 2004 to 14.98% in 2010 was slight (Figure 6.4). This could possibly be attributed to the fact that elephants were excluded from three of the five plots since 2008.

6.3.2 Electivity

The Electivity Index, Forage Ratio and Rank Procedure expressed the species that were preferred by elephants based on utilisation. Elephants seem to utilise their preferred species to such an extent that the species' available canopy decreases to such low levels that the species is no longer preferred. Subsequently, they move on to a new species and form a new selection (Ben-Shahar, 1993; O'Connor *et al*., 2007).

Combretum molle was not utilised in 2004, but was the most selected species in the Short Sand Forest in 2010 with a Forage Ratio of 2.18. A possible reason for this was that the only big individual in the community was so badly damaged by elephants that almost the whole canopy was removed. As the ratio uses available canopy volume together with canopy volume removed, it made *Combretum molle* a highly preferred species because the one available individual was severely damaged. Another species that was high on the electivity list was *Dialium schlechteri*. This species moved up to be one of the most preferred species in 2010 after being one of the least selected for species in 2004. It currently has an Ivlev's Electivity measure of 0.34 and a Forage Ratio of 2.02 and in 2004 these values were 0.05 and -0.91, respectively. It was also seen as a preferred species in 2010 based on the Rank Procedure method (ranked 6^{th}) but it was avoided in 2004.

Although the Forage Ratios of various species declined from 2004 to 2010, these species moved up in ranking in 2010. *Suregada zanzibariensis*, *Erythrophleum lasianthum*, *Pteleopsis myrtifolia*, *Strychnos henningsii* and *Ptaeroxylon obliquum* were five of the eight most preferred species in 2004. In 2010, neither *Erythrophleum lasianthum* nor *Suregada zanzibariensis* were recorded in the Short Sand Forest. *Pteleopsis myrtifolia*, *Strychnos henningsii* and *Ptaeroxylon obliquum* were utilised by elephants in the Short Sand Forest in 2010, but the Ivlev's electivity measure of all three was negative, therefore they were not considered selected for by the elephants in 2010. The latter three species all showed a sharp decline in the available canopy from 2004 to 2010.

The Forage Ratio and Ivlev's Electivity Index produced exactly the same ranking of species, however the electivity index has the advantage that the sign of the value can indicate whether the species is selected for by elephants or not. Results derived by means of the Rank Procedure method often ranked the species slightly differently, especially in the case of the 2010 data.

6.3.3 Relative utilisation

Studying the utilisation of woody species by elephant over a period of six years brought about interesting results. Increasing that time period to 15 years delivered another fascinating perspective on elephant utilisation in the Tembe Elephant Park. Each of the three surveys showed a different group of woody species that was utilised by elephants at that time. It appears that the elephants select a specific plant species and then utilise it to such a degree that it is almost extirpated. In 1995, the elephants showed a clear selection for *Albizia adianthifolia* and currently, in the Short Sand Forest, there is very little to no *Albizia adianthifolia* individuals left. At present *Dialium schlechteri* is the most utilised species with a relative utilisation of 44.97% and *Cleistanthus schlechteri* second most utilised with a relative utilisation of 35.19%.

The utilisation pattern of woody species by elephants seems to have been different in 1995 than in 2004 and 2010, and not just in terms of species but the overall manner in which they fed. The selection of woody species by elephants in 1995 was a lot broader. There were six or seven species that were clearly favoured and the relative utilisation of those species ranged from 4.61% to 21.09%. Apart from these species there were a number of others that were visibly utilised. Comparing these results to those in 2004 and 2010, it appeared as if the species selection of the elephants narrowed down. In 1995 they moderately utilised several species, whereas they now heavily utilise only one or two species.

6.4 WHAT HAPPENS WHEN ELEPHANTS ARE PROHIBITED FROM THE SHORT SAND FOREST?

The exclosure results demonstrated that the canopy volume removed within the exclosure was substantially less than outside the exclosure. Most of the canopy removal within the exclosure was attributed to damage of more than 2 years ago. The fact that differences could be detected after only two years without elephants points to the very high levels of elephant utilisation in the Short Sand Forest of the Tembe Elephant Park. Increasing this time period would increase the confidence in the results of the effects of continuous elephant browsing versus no browsing on the canopy structure of the Short Sand Forest.

Site 34 and 39 were situated north of the exclosure on the western side of Tembe Elephant Park and were accessible to elephants. This region generally experienced low elephant numbers as elephant groups were distributed primarily along the eastern fence, mainly because of the presence of permanent water (Muller & Matthews, 2010). In spite of these low elephant numbers, elephant damage was still obvious. These two sites had overall canopy removal percentages (utilised species) in 2010 that had increased more than three times since 2004 (Figure 6.3). The size classes, which showed a drastic increase in elephant damage within these Short Sand Forest sites, were size class 4, 5 and 6. The smaller size classes basically had the same percentage canopy removal in 2004 and 2010 (Figure 6.8a).

Sites 33, 42 and 43 were surveyed within the exclosure. At site 33 canopy removal increased slightly in 2010, but it remained a site with very low elephant utilisation. Sites 42 and 43 had higher utilisation than site 33 in 2010, however, canopy removal decreased since

2004, or since the exclosure was put up (Figure 6.8b). Compared to the other Short Sand Forest sites surveyed in 2004, these two sites were heavily utilised by elephants at that time.

Figure 6.8 shows the high utilisation levels (especially in size class 6) in the Short Sand Forest in the south-western corner of the park during the 2004 surveys compared to those situated more north, outside the current exclosure, with very little elephant utilisation. During the 2010 surveys in the exclosure sites, the elephant utilisation recorded was old damage (more than two years; before the exclosure was established) and no recent utilisation was picked up. Outside the exclosure, elephant utilisation increased drastically in the larger size classes. The utilisation levels on the outside were very high with 52.04% of the canopy removed of the utilised species. This illustrates the effectiveness of the exclosure in Tembe Elephant Park to protect the Short Sand Forest from elephant overutilisation. Several other studies have also reported increasing levels of utilisation when elephant pressure is continuous (Ben-Shahar, 1993; Cumming & Fenton, 1997; O'Connor *et al*. 2007; Boundja & Midgley, 2009).

Dialium schlechteri and *Cleistanthus schlechteri* were species with particularly high utilisation values in 2010. Within the exclosure the utilisation of *Dialium schlechteri* was high but it was the result of a single individual that was badly utilised. Outside the exclosure the damage by elephants to *Dialium schlechteri* was high and the available and removed canopy volume was immense. Inside the exclosure, far more woody species had old damage (more than two years) than the number of species outside the exclosure but these species were heavily utilised with very high utilisation percentages.

Based on these preliminary data, the erection of the exclosure seems to be having the desired effect of protecting the Short Sand Forest from negative elephant impact. It also proved ideal to track the changes in woody species structure in the presence and absence of elephants.

6.5 CONCLUSION

The Short Sand Forest is highly utilised by elephants due to the density of woody species (feeding material) as well as the suitable height (Guldemond, 2006; Gaugris & Van Rooyen, 2008).

In the Short Sand Forest community there was a distinct change in elephant utilisation from 2004 to 2010. The amount of elephant damage decreased in the exclosure, which was inaccessible to elephants whereas outside the exclosure, elephant utilisation increased considerably. These differences between areas where elephants were absent and those where elephants were free to utilise on any woody species, illustrated the major effect of elephant utilisation on woody vegetation and that their presence in a community may lead to the damage of the vegetation.

CHAPTER 7

UTILISATION IN THE TALL SAND FOREST

7.1 INTRODUCTION

The Tall Sand Forest community in the Tembe Elephant Park is a fairly open Sand Forest community and one is able to walk around without restraint. Species richness of woody species is less than that of the Short Sand Forest, which has a high species diversity.

From an observer's point of view, the Tall Sand Forest did not seem to be intensively utilised by elephants, but whether the amount of elephant utilisation had increased since 2004 will be examined in this chapter. Data collected by J.Y. Gaugris in 2004 (Gaugris, 2008) was analysed and compared with the 2010 results to determine whether any change in elephant utilisation was taking place in the Tembe Elephant Park.

7.2 RESULTS

7.2.1 Elephant utilisation – 2010 survey

The cumulative percentage canopy removal of the utilised species increased as the size classes increased (Figure 7.1). Size class 1 had no utilisation, followed by size class 2 and 3 with 2.57% and 4.92% canopy removal, respectively. From size class 4 and upwards the utilisation by elephants was in excess of 5% of the available canopy volume. Size class 6 had the highest canopy removal at 48.84%. Lower levels of utilisation were found in size class 5 (19.87%) and size class 4 (15.41%).

Haplocoelum gallaense showed the highest mean percentage utilisation of all species in the Tall Sand Forest in 2010 with a canopy removal of 32.58% followed by *Cleistanthus schlechteri* with 20.86% mean canopy removal (Figure 7.2). *Haploecoelum gallaense* contributed 51.90% of the total canopy volume removed, but was also the species with the most available canopy volume (Table 7.1). Although *Haplocoelum gallaense* was the species with the highest utilisation value, it was only utilised in the largest size class. Other woody species in the Tall Sand Forest, which showed moderate levels of utilisation in 2010 included *Memecylon sousae* (16.25%), *Dialium schlechteri* (15.03%) and *Zanthoxylum capense* (12.50%). *Cleistanthus schechteri* had high elephant utilisation levels in size class 6, the only size class in which it experienced utilisation in the Tall Sand Forest in 2010 (Table 7.2). *Cola greenwayi* (mean canopy removal of 4.54%) and *Drypetes arguta* (6.82%) were utilised throughout all the Tall Sand Forest sites even though their utilisation levels were low. *Cola greenwayi*, *Drypetes arguta*, *Toddaliopsis bremekampii* and *Croton pseudopulchellus* were utilised within a variety of size classes.

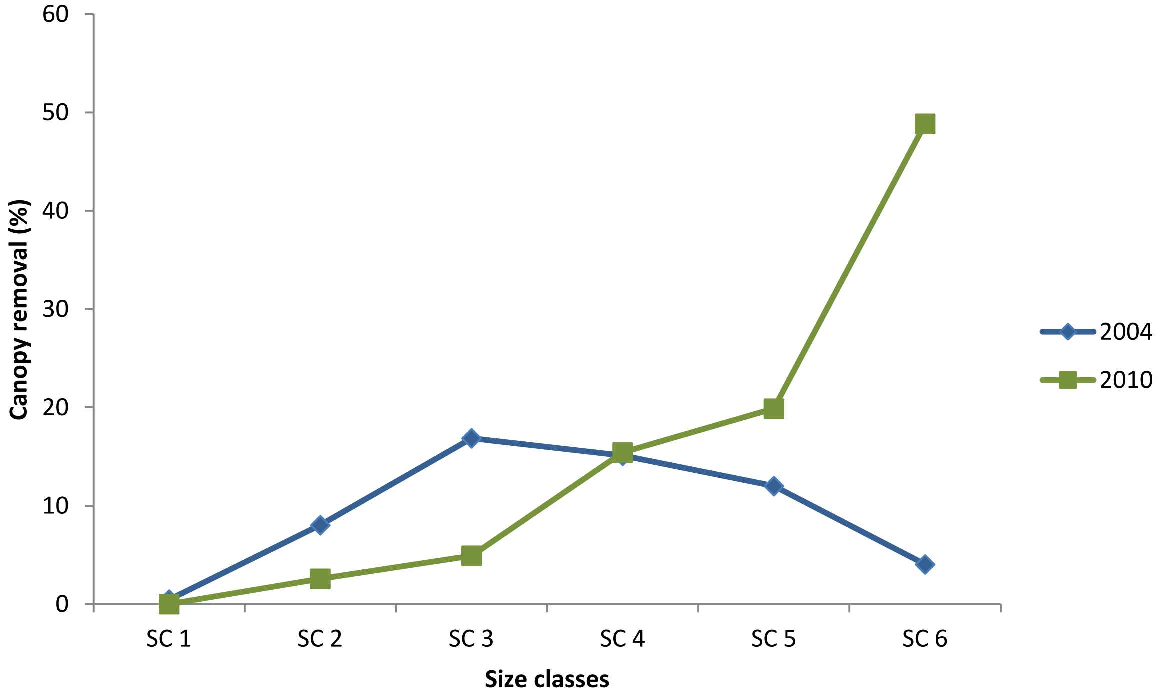

Figure 7.1 Cumulative percentage canopy volume (of utilised species) removed per size class (SC) in 2004 and 2010 in the Tall Sand Forest community in the Tembe Elephant Park.

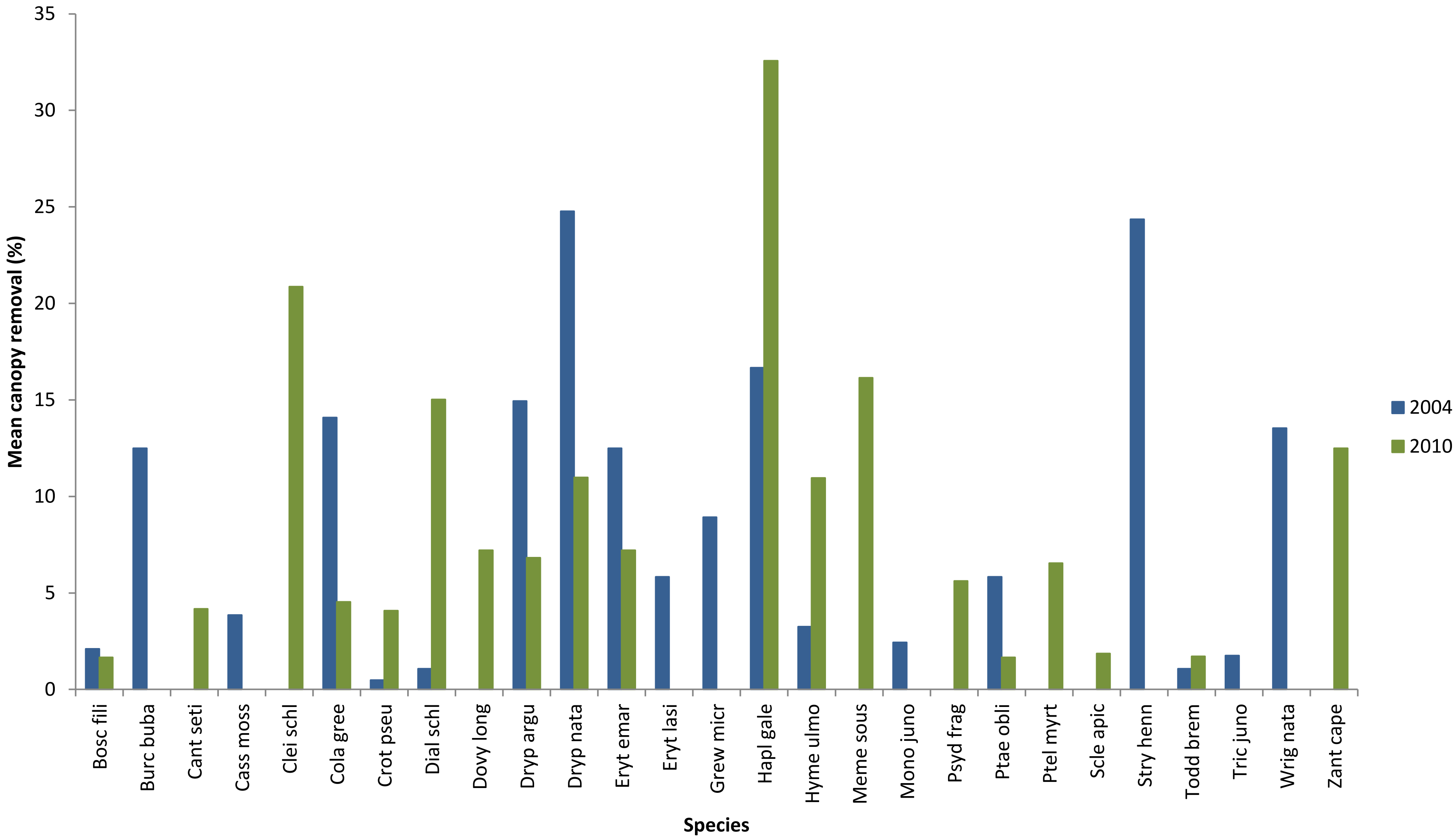

Figure 7.2 Woody species utilised by elephants in the Tall Sand Forest as recorded in 2004 and 2010. Appendix A contains a list of abbreviations of all species names.

Table 7.2 Mean utilisation per size class (SC) (expressed as % of canopy volume removed) for utilised Tall Sand Forest species in the 2010 survey

Species	SC 1	SC 2	SC 3	SC 4	SC 5	SC 6
Boscia filipes	0.00	0.00	1.67	1.67	0.00	0.00
Canthium setiflorum	0.00	0.00	5.83	0.00	0.00	0.00
Cleistanthus schlechteri	0.00	0.00	0.00	0.00	21.46	0.00
Cola greenwayi	0.00	0.00	2.28	4.39	0.87	0.00
Croton pseudopulchellus	0.00	0.23	1.04	5.82	5.83	0.00
Dialium schlechteri	0.00	0.00	0.00	0.00	15.03	0.00
Dovyalis longispina	0.00	0.00	0.00	7.21	0.00	0.00
Drypetes arguta	0.02	8.65	1.86	13.04	0.00	0.00
Drypetes natalensis	0.00	0.00	13.40	0.00	6.63	0.00
Erythroxylum emarginatum	0.00	0.00	0.00	7.21	0.00	0.00
Haplocoelum gallaense	0.00	0.00	0.00	0.00	0.00	32.58
Hymenocardia ulmoides	0.00	0.00	0.00	7.21	11.65	0.00
Memecylon sousae	0.00	0.00	0.00	16.15	0.00	0.00
Psydrax fragrantissima	0.00	0.00	0.00	5.83	0.00	0.00
Ptaeroxylon obliquum	0.00	0.00	0.00	1.67	0.00	0.00
Pteleopsis myrtifolia	0.00	0.00	0.00	6.54	0.00	0.00
Sclerochiton apiculatus	0.00	0.00	0.00	7.21	0.00	0.00
Toddaliopsis bremekampii	0.00	0.07	1.20	4.92	0.00	0.00
Zanthoxylum capense	0.00	12.50	0.00	0.00	0.00	0.00

Table 7.1 Available canopy volume and removed canopy volume per utilised species within the Tall Sand Forest community for 2010 and 2004. Elephant utilisation is expressed as cumulative percentage utilised as well as a relative utilisation percentage

Species	2010				2004			
	Available (m^3/ha)	Removed (m^3/ha)	% Utilised	Relative utilisation (%)	Available (m^3/ha)	Removed (m^3/ha)	% Utilised	Relative utilisation (%)
Boscia filipes	2043	102	5.00	0.57	481	30	6.31	0.35
Burchellia bubalina	-	-	-	-	245	92	37.50	1.06
Cassipourea mossambicensis	-	-	-	-	417	48	11.57	0.56
Canthium setiflorum	329	41	12.54	0.23	-	-	-	-
Cleistanthus schlechteri	1350	645	47.75	3.60	-	-	-	-
Cola greenwayi	10054	360	3.58	2.01	21043	3298	15.67	38.15
Croton pseudopulchellus	6420	656	10.21	3.66	289	4	1.47	0.05
Dialium schlechteri	12548	2793	22.26	15.61	15917	513	3.22	5.94
Dovyalis longispina	128	28	21.62	0.16	-	-	-	-
Drypetes arguta	3971	238	5.99	1.33	6527	1022	15.66	11.82
Drypetes natalensis	2011	450	22.39	2.52	1191	258	21.65	2.98
Erythrophleum lasianthum	-	-	-	-	24	4	17.50	0.05
Erythroxylum emarginatum	188	41	21.63	0.23	707	265	37.50	3.07
Grewia microthyrsa	-	-	-	-	1956	524	26.77	6.06
Haplocoelum gallaense	19013	9287	48.84	51.90	6965	576	8.27	6.67
Hymenocardia ulmoides	4274	977	22.86	5.46	3133	307	9.78	3.55
Memecylon sousae	11	5	48.44	0.03	-	-	-	-
Monodora junodii	-	-	-	-	1510	111	7.33	1.28
Psydrax fragrantissima	408	69	16.86	0.38	-	-	-	-

Ptaeroxylon obliquum	2074	104	5.00	0.58	641	112	17.50	1.30
Pteleopsis myrtifolia	10419	1823	17.50	10.19	-	-	-	-
Sclerochiton apiculatus	2420	135	5.59	0.76	-	-	-	-
Strychnos henningsii	-	-	-	-	1796	628	34.97	7.27
Toddaliopsis bremekampii	4259	137	3.22	0.77	4609	86	1.86	0.99
Zanthoxylum capense	8	3	37.50	0.02	-	-	-	-
Tricalysia junodii	-	-	-	-	18	1	5.27	0.01
Wrightia natalensis	-	-	-	-	1885	766	40.62	8.86
Total of utilised species	81928	17894	21.84		69356	8645	12.46	
Total of not utilised species	206918	0	0.00		264474	0	0.00	
Total available of all species	288846	17894	6.19		333830	8645	2.59	

Sites 35 and 36 had the most elephant utilisation with 25.53% and 25.40% cumulative[1] canopy removal respectively (Figure 7.3). Site 40 had the lowest elephant impact of all the Tall Sand Forest sites in 2010, with a cumulative canopy removal of only 10.26%. The mean cumulative canopy removal for the three Tall Sand Forest sites in 2010 was 20.40%. However, this value considers only the utilised species and not all available canopy. If all available woody species are considered, elephants removed 6.19% of the available canopy (Figure 7.4). Table 7.1 illustrates the difference when percentage utilisation was calculated by using the total available canopy volume of all species (6.19%), both utilised and not utilised, versus only utilised species (21.84%).

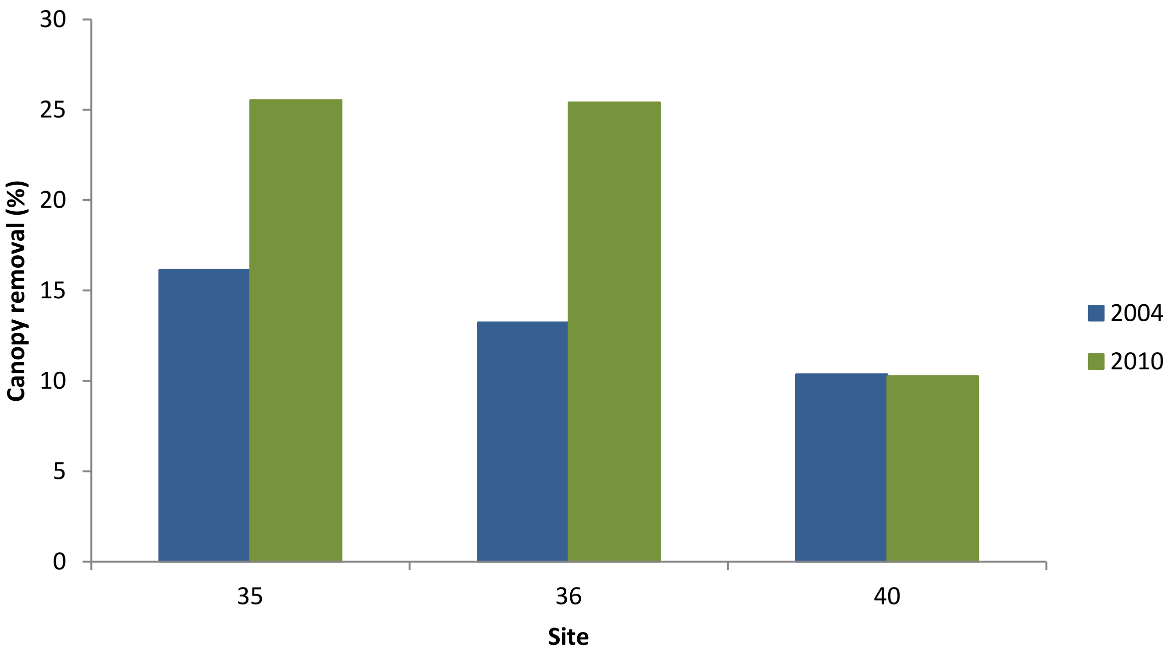

Figure 7.3 Cumulative percentage canopy removal by elephants (expressed as percentage of utilised species only) at the three Tall Sand Forest sites as surveyed in 2004 (blue) and 2010 (green).

[1] Cumulative canopy removal percentage refers to the total volume of the canopy removed of all species expressed as a percentage of the available volume of only the utilised species.

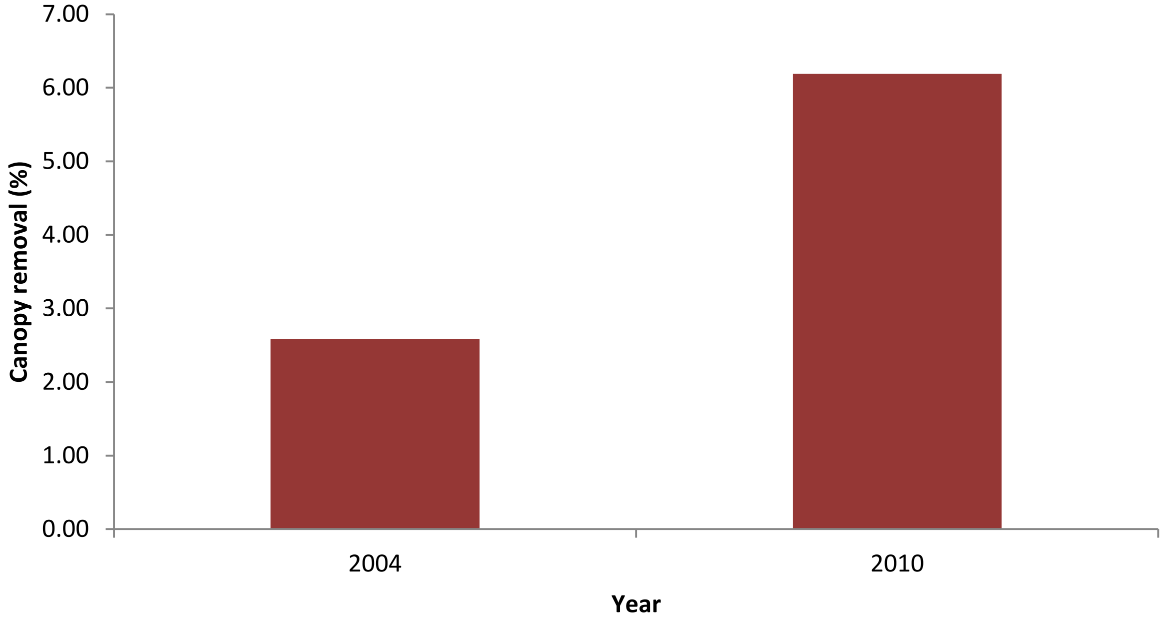

Figure 7.4 Cumulative percentage canopy removal (expressed as percentage of all species) amongst all available species in the Tall Sand Forest community for 2004 and 2010.

7.2.2 Elephant utilisation – 2004 survey

Cumulative canopy removal in the smaller size classes decreased since 2004 (Figure 7.1) as seen by the decrease from 8.02% in 2004 to 2.57% in 2010 in size class 2 and from 16.86% to 4.92% in size class 3. Size class 5 and 6, which are the large individuals, had a notable increase in elephant utilisation in 2010 compared to the 12.00% (size class 5) and 4.03% (size class 6) in 2004.

Strychnos henningsii and *Drypetes natalensis* had moderate utilisation levels in 2004 with 24.36% and 24.78% canopy removed, respectively (Figure 7.2). *Haplocoelum gallaense,* which had the highest percentage canopy removal in the Tall Sand Forest during the 2010 survey, had a moderately level of canopy removal in 2004 (16.68%). Other woody species with moderate canopy removal values in 2004, included *Drypetes arguta* (14.95%), *Cola greenwayi* (14.09%), *Wrightia natalensis* (13.54%) and *Burchellia bubalina* (12.50%). All four these woody species experienced a decline in canopy availability and a concomitant decline in elephant utilisation from 2004 to 2010. *Cola greenwayi* decreased in elephant utilisation from 2004 to 2010 in all the size classes within which utilisation took place whereas the trend was not that clear for *Drypetes natalensis* by or *Drypetes arguta*.

Elephant utilisation, considering utilised species only, increased in site 35 (16.14%) and 36 (13.23%) since 2004 (Figure 7.3). There was no change in the cumulative percentage canopy removed at site 40 (10.37%) between 2004 and 2010, yet the species being utilised were different. The change in percentage canopy removal did not show a significant difference from 2004 to 2010 in the different sites (p=0.541). Cumulative elephant utilisation in the Tall Sand Forest increased from 12.46% cumulative canopy removal in 2004 to 21.84% in 2010. However, this is the Sand Forest community with the lowest elephant impact in 2010. Canopy removal in terms of all available woody species was a low 2.59% in 2004 (Figure 7.4, Table 7.1).

7.2.3 Elephant utilisation – 1995 survey

Figure 7.5 illustrates the contribution of species towards utilisation by elephants in the long-term. Each one of the datasets showed a different set of species being highly utilised. The 1995 survey showed that *Hymenocardia ulmoides* contributed most to elephant utilisation (71.42%), followed by *Dialium schlechteri* (21.62%) and *Strychnos decussata* (5.11%). In 2004, the survey indicated that *Cola greenwayi* was the most utilised species with 38.15% of all canopy being removed belonging to this species. *Drypetes arguta* (11.82%), *Haplocoelum gallaense* (6.67%) and *Drypetes natalensis* (2.98%) were the other species notably utilised by elephants. *Haplocoelum gallaense* was the species with the highest relative utilisation in 2010 (51.90%) and *Dialium schlechteri* (15.61%), *Pteleopsis myrtifolia* (10.19%) and *Hymenocardia ulmoides* (5.46%) all made substantial contributions to elephant utilisation.

Table 7.3 Mean utilisation per size class (SC) (expressed as % of canopy volume removed) for utilised Tall Sand Forest species in the 2004 survey

Species	SC1	SC2	SC3	SC4	SC5	SC6
Boscia filipes	0.00	25.52	0.00	0.00	0.00	0.00
Burchellia bubalina	0.00	0.00	12.50	0.00	0.00	0.00
Cassipourea mossambicensis	0.00	0.00	4.28	0.00	0.00	0.00
Cola greenwayi	0.00	0.00	14.95	8.17	6.95	0.00
Croton pseudopulchellus	0.00	0.81	0.00	0.00	0.00	0.00
Dialium schlechteri	0.00	0.00	0.00	0.00	0.00	1.34
Drypetes arguta	0.00	0.00	9.00	23.53	0.00	0.00
Drypetes natalensis	0.00	0.00	23.67	1.44	0.00	0.00
Erythroxylum emarginatum	0.00	0.00	0.00	12.50	0.00	0.00
Erythrophleum lasianthum	0.00	5.83	0.00	0.00	0.00	0.00
Grewia microthyrsa	0.00	0.00	3.47	12.50	0.00	0.00
Haplocoelum gallaense	0.00	0.00	41.56	0.00	0.86	0.00
Hymenocardia ulmoides	0.00	31.50	28.13	0.00	14.39	0.00
Monodora junodii	0.00	0.00	2.44	0.00	0.00	0.00
Ptaeroxylon obliquum	0.00	0.00	0.00	5.83	0.00	0.00
Strychnos henningsii	0.00	0.00	10.65	25.35	0.00	0.00
Toddaliopsis bremekampii	0.00	3.29	0.45	0.00	0.00	0.00
Tricalysia junodii	1.76	0.00	0.00	0.00	0.00	0.00
Wrightia natalensis	0.00	0.00	0.00	0.00	13.54	0.00

7.2.4 Elephant preferences

According to Ivlev's Electivity Index the most preferred woody species in 2010 included *Haplocoelum gallaense*, *Memecylon sousae*, *Cleistanthus schlechteri*, *Zanthoxylum capense*, *Hymenocardia ulmoides*, *Drypetes natalensis* and *Dialium schlechteri*. The Rank Procedure method also indicated that these seven species had the highest preference within this community. However, this method allocated *Cleistanthus schlechteri* to be the woody species which was selected for most, followed by *Drypetes natalensis* and *Hymenocardia ulmoides* (Table 7.4). The elephants' preferences differed from 2004 to 2010 because in 2004 the woody species that showed the highest Ivlev's Electivity Index were *Erythroxylum emarginatum*, *Burchellia bubalina*, *Strychnos henningsii*, *Grewia microthyrsa*, *Wrightia natalensis, Drypetes natalensis* and *Cola greenwayi*. *Erythroxylum emarginatum* and *Strychnos henningsii* had the highest ranking with the Rank Procedure method (Table 7.5).

Haplocoelum gallaense and *Hymenocardia ulmoides* were selected for in both surveys but they increased in electivity values and rank from 2004 to 2010. *Dialium schlechteri* and *Croton pseudopulchellus* were not preferred in 2004, as both had negative Ivlev's Electivity Index values (-0.45 and -0.90, respectively), but became species with prominent elephant preference in 2010 as *Dialium schlechteri* had an electivity value of 0.56 and *Croton pseudopulchellus* of 0.24. *Cleistanthus schlechteri* was highly preferred in 2010 with an Ivlev Electivity of 0.77 and ranked first according to the Rank Procedure method. *Drypetes natalensis* and *Erythroxylum emarginatum* were woody species highly preferred by elephants in 2004 with Ivlev's Electivity Index values of 0.79 and 0.87 respectively. Although they were still highly selected for in 2010, their rank and preference indices decreased to 0.57 and 0.55 respectively (Ivlev's Electivity Index).

Cola greenwayi, *Ptaeroxylon obliquum*, *Drypetes arguta* and *Boscia filipes* had rather high index values in 2004 and even though they were utilised in 2010 they did not show any selection by the elephants as they all have negative Ivlev's Electivity Index values. In 2004, *Burchellia bubalina*, *Grewia microthyrsa, Erythrophleum lasianthum, Strychnos henningsii* and *Wrightia natalensis* experienced high selection by the elephants and were some of the highest ranked woody species but these five species were not even utilised in 2010.

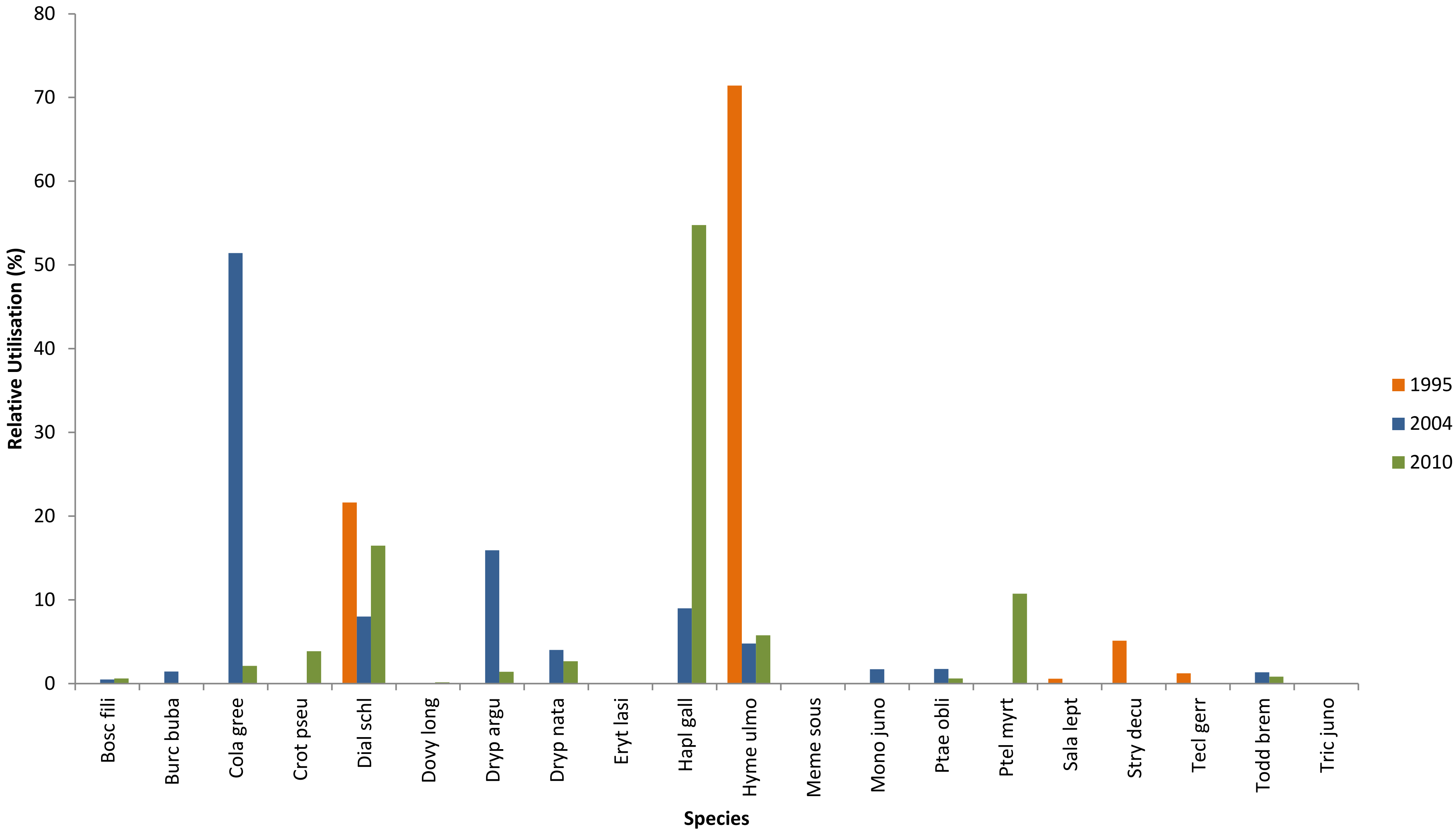

Figure 7.5 Relative utilisation of various woody species by elephants in 1995, 2004 and 2010 in the Tall Sand Forest of Tembe Elephant Park. Appendix A contains a list of abbreviations of all species names.

Table 7.4 Elephant preferences for woody species in 2010 in terms of Ivlev's Electivity Index (Ivlev, 1961), the Forage Ratio (Cock, 1978) and the Rank Procedure method (Johnson, 1980). The woody species recorded within the Tall Sand Forest in 2010 are ranked from most preferred to least preferred based on the Ivlev's Electivity Index

Woody Species	Ivlev's Electivity Index	Forage Ratio	Rank Procedure method
Haplocoelum gallaense	0.77	7.88	4
Memecylon sousae	0.77	7.82	4
Cleistanthus schlechteri	0.77	7.71	1
Zanthoxylum capense	0.72	6.05	4
Hymenocardia ulmoides	0.58	3.77	3
Drypetes natalensis	0.57	3.61	2
Dialium schlechteri	0.56	3.59	4
Erythroxylum emarginatum	0.55	3.49	4
Dovyalis longispina	0.55	3.49	4
Pteleopsis myrtifolia	0.48	2.82	4
Psydrax fragrantissima	0.46	2.72	4
Canthium setiflorum	0.34	2.02	4
Croton pseudopulchellus	0.24	1.65	4
Drypetes arguta	-0.02	0.97	5
Sclerochiton apiculatus	-0.05	0.90	6
Boscia filipes	-0.11	0.81	6
Ptaeroxylon obliquum	-0.11	0.81	6
Cola greenwayi	-0.27	0.58	7
Toddaliopsis bremekampii	-0.32	0.52	7

Table 7.5 Elephant preferences for woody species in 2004 in terms of Ivlev's Electivity Index (Ivlev, 1961), the Forage Ratio (Cock, 1978) and the Rank Procedure method (Johnson, 1980). The woody species recorded within the Tall Sand Forest in 2004 are ranked from most preferred to least preferred based on Ivlev's Electivity Index

Woody species	Ivlev's Electivity Index	Forage Ratio	Rank Procedure method
Erythroxylum emarginatum	0.87	14.48	1
Burchellia bubalina	0.87	14.48	2
Strychnos henningsii	0.85	11.94	1
Grewia microthyrsa	0.82	10.34	2
Wrightia natalensis	0.80	9.06	2
Drypetes natalensis	0.79	8.36	3
Cola greenwayi	0.72	6.05	5
Drypetes arguta	0.72	6.05	4
Erythrophleum lasianthum	0.71	5.79	6
Cassipourea mossambicensis	0.63	4.47	5
Ptaeroxylon obliquum	0.55	3.44	5
Haplocoelum gallaense	0.52	3.20	8
Monodora junodii	0.48	2.83	7
Hymenocardia ulmoides	0.44	2.58	8
Boscia filipes	0.42	2.44	7
Tricalysia junodii	0.34	2.03	6
Toddaliopsis bremekampii	-0.17	0.71	10
Dialium schlechteri	-0.45	0.38	9
Croton pseudopulchellus	-0.90	0.06	10

7.3 DISCUSSION

7.3.1 Percentage canopy removal

Even though the complement of species utilised in 2004 differed from that in 2010, the number of utilised woody species remained constant at 19 species (Table 7.2 and 7.3). Eleven of the species recorded with elephant damage in 2010 were in fact also utilised by elephants in 2004. The species utilised in 2004 but not in 2010 can be divided into two groups, those still recorded in the community but not utilised by elephants and those not recorded in the surveys anymore. The first group of species (such as *Erythroxylum emarginatum*, *Cola greenwayi* and *Drypetes arguta*) provided a measure of reassurance as the elephants no longer utilised them but they still occurred within the community. Consequently, elephant utilisation did not seem to have a negative effect on the survival of these woody species. Nevertheless, the available canopy volume of all three species was severely reduced by 2010. On the other hand, species such as *Burchellia bubalina*, *Strychnos henningsii* and *Wrightia natalensis*, all highly preferred species in 2004, raised concern. It is possible that the utilisation by elephants caused the depletion of these woody species as they were not recorded in the Tall Sand Forest in 2010. Some margin for error should however be allowed, as the boundaries of the sampling sites (same sites as J.Y. Gaugris in 2004) could have been slightly different in 2010 than in 2004.

In Figure 7.2 the species with a moderate level of canopy removal in 2004 can be identified as *Drypetes arguta*, *Drypetes natalensis*, *Strychnos henningsii* and *Wrightia natalensis*. They all experienced a decrease in utilisation since 2004 or no utilisation at all. Utilisation by elephants of *Toddaliopsis bremekampii* and *Boscia filipes* remained constant and the percentage canopy removal was very low (less than 3%). A decrease in elephant utilisation was observed for *Cola greenwayi and Ptaeroxylon obliquum* from 2004 to 2010. Both species showed utilisation in the same size classes in both surveys. There was an increase in canopy utilisation since 2004 for *Haplocoelum gallaense*, *Memecylon sousae*, *Cleistanthus schlechteri* and *Dialium schlechteri*. *Cleistanthus schlechteri* was recorded in 2004 but not utilised by elephants at all and in 2010 canopy removal amounted to 20.86%, although actual volume removed remained low. At the same time available canopy volume for this species showed a marked decline since 2004. *Memecylon sousae* was not even recorded in 2004 as an available species in the Tall Sand Forest but in 2010 it experienced an utilisation value of 16.15%. *Haplocoelum gallaense* almost doubled its percentage canopy removal since 2004, a couple of large individuals (size class 6) were highly utilised by elephants compared to the utilisation levels in the intermediate size classes in 2004.

Dialium schlechteri also showed a marked increase in percentage canopy removal, from a mean utilisation of 1.07% in 2004 to 15.03% in 2010. Utilisation of *Dialium schechteri* was only in the large size classes, both in 2004 and 2010. The available canopy volume for *Dialium schlechteri* decreased substantially since 2004. It was interesting to note that during the time that the available canopy volume was so high, elephants barely utilised this woody species (513 m^3/ha in 2004 as opposed to 2 793 m^3/ha in 2010). However according to Gaugris and Van Rooyen (2011), *Dialium schlechteri*, *Ptaeroxylon obliquum* and *Psydrax locuples* were the woody species mostly utilised by elephants in the Tall Sand Forest community of the Tembe Elephant Park.

The trend of increasing canopy removal as the size classes increased was again evident in the Tall Sand Forest (Figure 7.1) as was the case for the Short Sand Forest and the Mature Sand Forest. This is considered normal for elephant utilisation as tall trees are the individuals they tend to target (Ben-Shahar, 1993). Utilisation by elephants in the smaller size classes was uncommon in 2010 as that was not their foraging height. The woody plants that elephants generally feed on start from size class 4 and an occasional individual in size class 3. Whenever there was utilisation in the lower size classes it could be regarded as accidental damage or trampling. The high utilisation levels in the large size classes and low levels of elephant utilisation in the smaller size classes could be considered as more favourable than high utilisation levels in the small size classes and little utilisation in the larger size classes. This means that the small individuals are able to recruit and grow, but when elephant utilisation in the small size classes is high, it prevents species recruitment. Utilisation by other animal species was recorded on small woody plants, but their effect was not as devastating as the effect of large elephants on small woody individuals. Gaugris (2008) concluded that the small browsers might have a detrimental effect on the vegetation even although they do not leave the scars as the elephants do. Their impact on the small size classes may cause changes in species recruitment and regeneration of woody species which could lead to changes in species composition and possibly homogenisation of the habitat (Gaugris, 2008).

In 2010, size class 6 had the highest percentage canopy removal of all the size classes and in 2004 it was one of the size classes with the lowest canopy removal. The Tall Sand Forest has many large woody species more than 8 m tall with some species growing up to 12-15 m tall (Matthews *et al*., 2001; Gaugris & Van Rooyen, 2011). Therefore it makes sense that the highest percentage canopy removal was in the larger size classes. However, a high percentage canopy removal in the large size classes could be ascribed to accumulative damage (O'Connor, 2010). Utilisation on the large trees is visible for a long period of time.

When a large branch is broken off, it does not show regrowth on that exact place but leaves a scar which is evident for years to come. Therefore the percentage canopy removal calculated for the 2010 survey may even include elephant damage that was already incurred in 2004. A study, similar to the current one, was conducted by Boundja and Midgley (2009) on elephant utilisation in the Hluhluwe-Imfolozi Park, South Africa. They had the same size class definitions of the woody species as the present study. Their results also showed an increase in elephant damage as stem diameter increased implying that elephants favoured the large individuals with the big stems.

Overall, the actual canopy volume removed almost doubled from 2004 to 2010 (8 645 — 17 894 m^3/ha), and there was a decrease in total available canopy volume (333 830 — 288 846 m^3/ha). The mean cumulative percentage canopy removal increased from 12.46% in 2004 to 21.48% in 2010 (Table 7.1). The cumulative values were in terms of the utilised species thus, this is the percentage removed from the utilised species in relation to what is available of those species. This higher canopy utilisation value represents a 75% increase above 2004 levels. When the total canopy volume removed was taken as a percentage of the available canopy volume (utilised and non-utilised), the total utilisation was 6.19% in 2010 as against 2.59% in 2004 (Table 7.1). An increase in vegetation utilisation within a reserve where elephant population is increasing has been found in a number of other studies (Ihwagi *et al*., 2009; Young *et al*., 2009; Gaugris & Van Rooyen, 2010a).

The Tall Sand Forest had the lowest elephant utilisation of all the Sand Forest communities. It appears that Sand Forest succession is taking place from Short Sand Forest to Tall Sand Forest until it reaches Mature Sand Forest (Gaugris & Van Rooyen, 2011) and the Tall Sand Forest includes a number of primary species which are essential for succession to continue to the next stage. Pioneer species are also maintained in this community such as *Cleistanthus schlechteri* and *Dialium schlechteri* (Gaugris & Van Rooyen, 2011).

7.3.2 Electivity

In 2004, the two most preferred woody species in the Tall Sand Forest according to Ivlev's Electivity Index, *Erythroxylum emarginatum* and *Burchellia bubalina*, were utilised only in one of the sites, in a single size class. Therefore these species with single utilisation incidents could be small individuals trampled by elephants or large individuals highly utilised or pushed over by the elephants. *Strychnos henningsii*, *Drypetes natalensis*, *Cola greenwayi* and *Drypetes arguta* were four species also highly selected for in 2004, with electivity values ranging from 0.72 to 0.85. These species were utilised within most of the

Tall Sand Forest sites and consequently their high electivity values can be viewed with confidence.

In 2010 *Haplocoelum gallaense* was the woody species most preferred by elephants. It had the highest Electivity Index (0.77) and it was ranked fourth according to the Rank Procedure method. In addition, *Haplocoelum gallaense* was utilised throughout the Tall Sand Forest community and therefore these results were reliable. In contrast, the electivity values of *Memecylon sousae*, *Cleistanthus schlechteri*, *Zanthoxylum capense* and *Hymenocardia ulmoides* were based on individual events and these species were not utilised throughout the whole community. *Drypetes natalensis* and *Dialium schlechteri* were two woody species also highly preferred by elephants, according to the survey in 2010. They were ranked second and fourth with the Rank Procedure method and the Electivity Index showed their high preferences with *Drypetes natalensis* having a value of 0.57 and *Dialium schlechteri* a value of 0.56. Both these woody species were targeted throughout the Tall Sand Forest community and not just in a single site.

The preferences of elephants seemed to have changed from 2004 to 2010. Some of the species that were selected by elephants were still present in the community in 2010 but not as highly preferred, for instance *Erythroxylum emarginatum*, *Cola greenwayi* and *Drypetes arguta*. Preferences changes such as these could be viewed as positive, because the species were still present in the community although with a lower available canopy. Species such as *Wrightia natalensis* and *Strychnos henningsii* which were extremely high on the elephant preference list in 2004, according to all three indices, and not at all recorded in the Tall Sand Forest in 2010, could be experiencing problems.

The results obtained by the Rank Procedure method differed slightly with those from the other two indices, both in 2004 and 2010, but nevertheless the most preferred species were grouped together and agreed well with that found by the Forage Ratio and Electivity Index. Furthermore, it is important to note that the Rank Procedure does not provide absolute values but merely a ranking of species against each other.

7.3.3 Relative utilisation

In the 1995 survey two woody species emerged as contributing more than 5% to the utilisation by elephants, four species in 2004 and four species in 2010 as well. However, *Dialium schlechteri* was the only species shared between all three surveys. *Haplocoelum gallaense* showed an initial preference in 2004 and in 2010 it was the species with the highest relative utilisation. The high levels of relative utilisation by *Hymenocardia ulmoides* in 1995 and *Cola greenwayi* in 2004 were not continued unto 2010.

7.4 CONCLUSION

The Tall Sand Forest community had the lowest elephant utilisation of all the Sand Forest communities. Nevertheless, an increase in elephant utilisation was observed within the Tall Sand Forest community since 2004. In each of the surveys the relative utilisation values singled out one species contributing to more than 50% of the utilisation, but the species was different in each survey. Even although there were a number of newly utilised woody species in 2010, there were still several species that were recorded as being utilised by elephants in 2004 and 2010. The Tall Sand Forest seem to have a great proportion of woody species that are not being utilised by elephants and this vegetation types does not have the vast utilisation pressure compared to other plant communities in Tembe Elephant Park.

CHAPTER 8

UTILISATION IN THE MATURE SAND FOREST

8.1 INTRODUCTION

The Mature Sand Forest in the Tembe Elephant Park is the tallest of all the communities with a canopy height exceeding 10 m. This community represents the classical example of a forest with the large trees, closed canopy with low sunlight penetration and almost no ground cover (Gurevitch *et al*., 2006). Therefore the Mature Sand Forest is not a very dense plant community. There are patches of this vegetation type throughout the park and there is an ongoing process of succession in the Sand Forest with the Mature Sand Forest regarded as the climax or final stage of succession (Gaugris & Van Rooyen, 2011). Consequently, this is a community that needs protection and its vulnerability to elephant utilisation should be carefully studied.

The sites which were surveyed in this community were located in the east of the park, towards the Muzi swamp. This is an area with high elephant activity, especially sites 37 and 44. All results obtained from the 2010 survey were compared to the survey done in 2004 (Gaugris, 2008) to establish whether the impact of the growing elephant population was increasing and whether it was threatening the Mature Sand Forest.

8.2 RESULTS

8.2.1 Elephant utilisation – 2010 survey

With increasing size classes woody individuals were larger and had larger canopy volumes. As the size classes increased (Figure 8.1) there was a concomitant increase in elephant utilisation values, whether the woody species were pushed over or just a branch broken off. Considering only the utilised species size class 1 and 2 had barely any canopy removed by elephants. Cumulative[1] utilisation was moderate in size class 3 and 4 with 12.27% and 12.26% canopy removed in 2010, respectively. Size class 5 followed with 25.57% utilisation and size class 6 had the highest elephant utilisation value in 2010 in this community with a total of 44.99% of the canopy of utilised species removed.

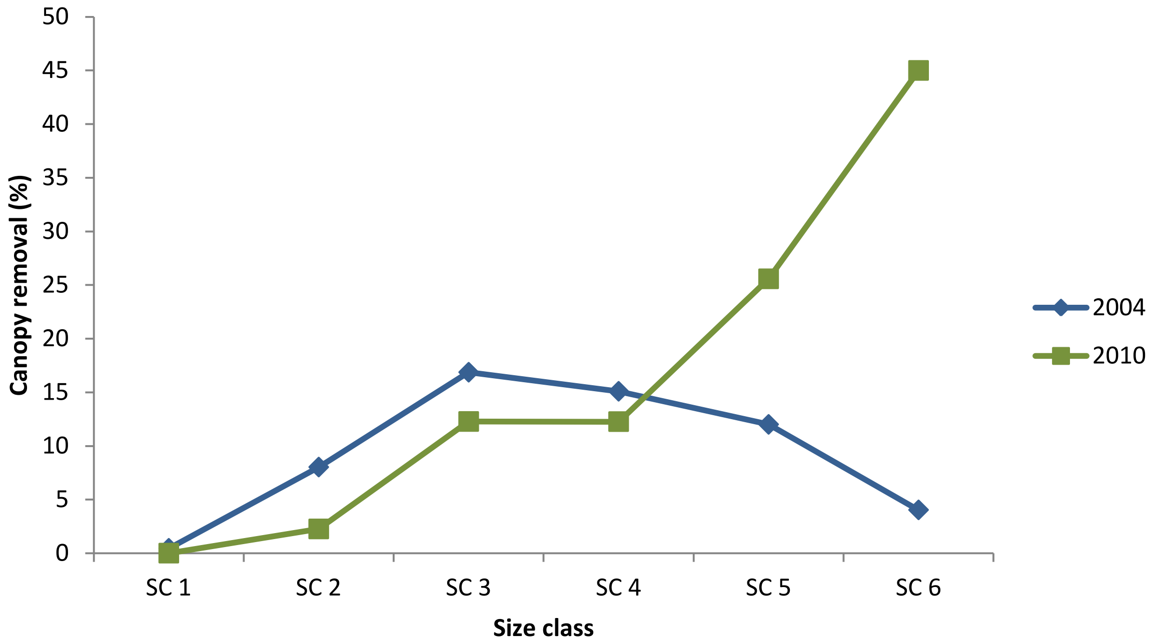

Figure 8.1 Cumulative percentage canopy volume (of utilised species) removed per size class (SC) of utilised species in 2004 and 2010 in the Mature Sand Forest community in the Tembe Elephant Park.

In 2010, a volume of 50 905 m^3/ha was removed from the 136 967 m^3/ha volume available, representing a canopy removal of 37.40% (Table 8.1). *Haplocoelum gallaense* had the highest mean utilisation value with 48.88% canopy removed (Figure 8.2). This highly damaged species was utilised in the large size classes with 17.82% in size class 5 and 31.05% in size class 6 (Table 8.2). *Cleistanthus schlechteri*, *Pteleopsis myrtifolia* and *Balanites maughamii* were moderately utilised with mean canopy removal values of 28.36%, 24.21% and 18.75% respectively. Other moderately utilised species included *Boscia filipes* (17.82%), *Grewia microthyrsa* (17.74%) and *Newtonia hildebrandtii* (16.71%). Most of these species were utilised throughout the community. *Boscia filipes* and *Cleistanthus schlechteri* were only utilised in a single site. *Cleistanthus schlechteri*, *Newtonia hildebrandtii*, *Grewia microthyrsa* and *Pteleopsis myrtifolia* were utilised in a variety of size classes.

[1] Cumulative canopy removal percentage here refers to the total volume of the canopy removed of all species expressed as a percentage of the available volume of only the utilised species.

Table 8.1 Available canopy volume and removed canopy volume per utilised species within the Mature Sand Forest community for 2010 and 2004. Elephant utilisation is expressed as cumulative percentage utilised as well as a relative utilisation percentage

Species	2010				2004			
	Available (m^3/ha)	Removed (m^3/ha)	% Utilised	Relative utilisation	Available (m^3/ha)	Removed (m^3/ha)	% Utilised	Relative utilisation
Acalypha glabrata	625	4	0.65	0.01	1383	53	3.80	1.14
Balanites maughamii	63756	26667	41.83	52.39	-	-	-	-
Boscia filipes	509	272	53.46	0.53	118	74	62.50	1.60
Capparis tomentosa	15	1	3.55	0	-	-	-	-
Cleistanthus schlechteri	8703	7405	85.09	14.55	11792	187	1.59	4.07
Cola greenwayi	5097	842	16.52	1.65	6655	183	2.74	3.97
Croton pseudopulchellus	-	-	-	-	1030	5	0.45	0.10
Drypetes arguta	538	84	15.66	0.17	2104	193	9.16	4.20
Euclea natalensis	92	2	1.86	0	-	-	-	-
Gardenia volkensii	768	109	14.26	0.22	-	-	-	-
Grewia microthyrsa	877	184	20.99	0.36	314	152	48.44	3.31
Gymnanthemum coloratum	1	0	40.63	0	-	-	-	-
Haplocoelum gallaense	6763	5976	88.36	11.74	5585	411	7.36	8.94
Hymenocardia ulmoides	14135	1733	12.26	3.40	3488	321	9.22	6.99
Manilkara discolor	118	48	40.63	0.09	-	-	-	-
Newtonia hildebrandtii	15415	4372	28.36	8.59	-	-	-	-
Ptaeroxylon obliquum	5531	1409	25.47	2.77	7430	279	3.75	6.07
Pteleopsis myrtifolia	3066	695	22.68	1.37	198	74	37.50	1.62
Salacia leptoclada	282	32	11.41	0.06	-	-	-	-
Schotia brachypetala	-	-	-	-	495	379	76.56	8.25

Spirostachys africana	5964	582	9.75	1.14	-	-	-	-
Strychnos decussata	491	52	10.57	0.10	4580	1459	31.85	31.74
Strychnos henningsii	-	-	-	-	2791	145	5.19	3.15
Strychnos madagascariensis	42	7	17.50	0.01	-	-	-	-
Toddaliopsis bremekampii	1641	126	7.69	0.25	2764	329	11.89	7.15
Tricalysia species	18	4	21.62	0.01	1614	277	17.14	6.02
Vepris lanceolata	535	52	9.66	0.10	-	-	-	-
Vitex amboniensis	1143	247	21.63	0.49	-	-	-	-
Wrightia natalensis	-	-	-	-	6944	77	1.10	1.67
Total of utilised species	136123	50905	37.40		59285	4596	7.75	
Total of not utilised species	844	0	0.00		161603	0	0.00	
Total available of all species	136967	50905	37.17		220888	4596	2.08	

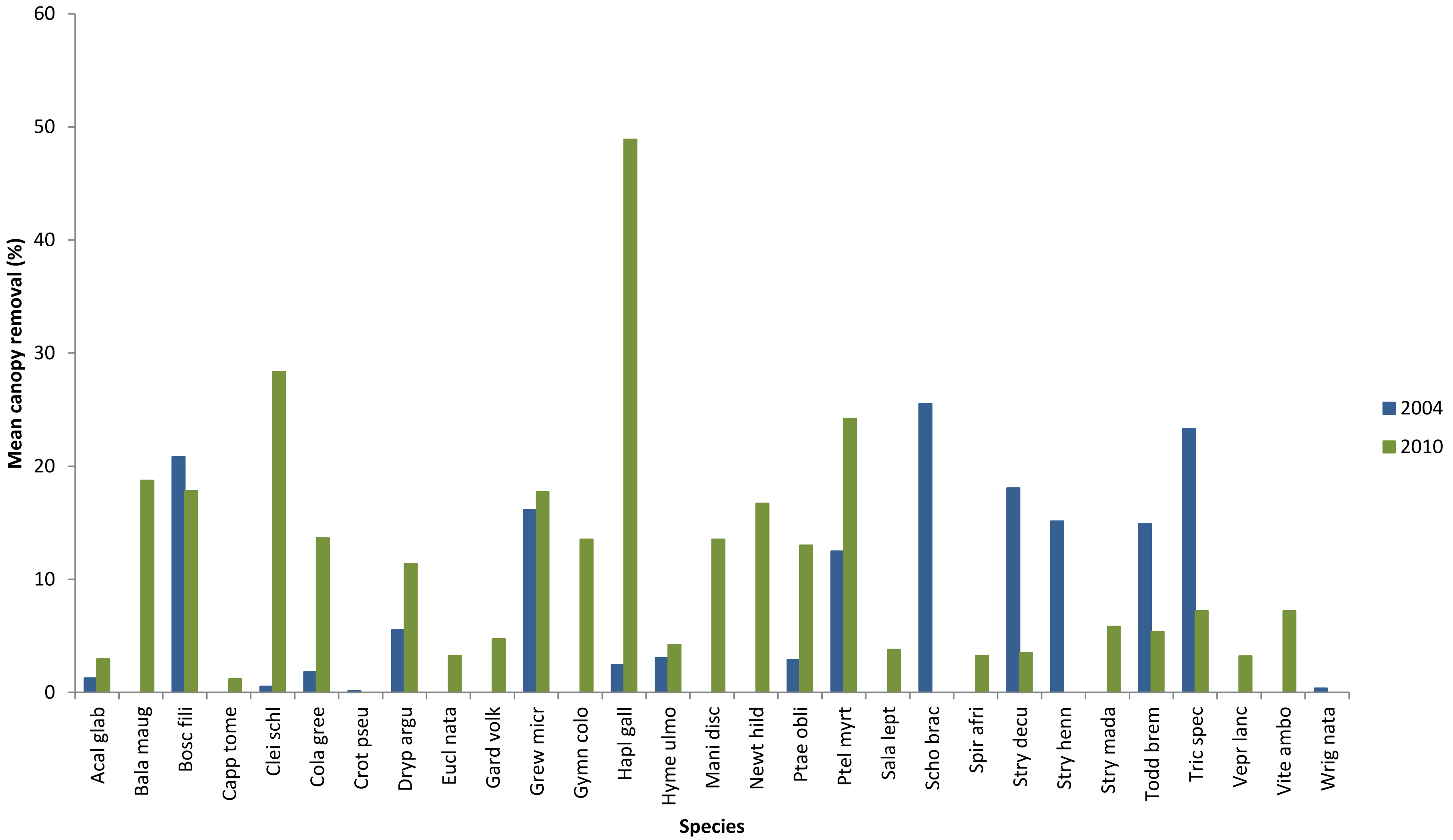

Figure 8.2 Woody species utilised by elephants in the Mature Sand Forest as recorded in 2004 (blue) and 2010 (green). Appendix A contains a list of abbreviations of all species names.

Table 8.2 Mean utilisation per size class (SC) (expressed as % of canopy volume removed) for utilised Mature Sand Forest species in 2010

Woody species	SC 1	SC 2	SC 3	SC 4	SC 5	SC 6
Acalypha glabrata	0.00	0.03	3.25	3.09	0.00	0.00
Balanites maughamii	0.06	0.00	0.00	0.00	4.75	14.00
Boscia filipes	0.00	0.00	0.00	17.82	0.00	0.00
Capparis tomentosa	0.00	0.00	7.21	0.00	0.00	0.00
Cleistanthus schlechteri	0.00	0.00	1.40	7.97	0.00	44.64
Cola greenwayi	0.00	0.97	8.22	12.50	14.94	0.00
Drypetes arguta	0.00	0.00	12.70	0.00	0.00	0.00
Euclea natalensis	0.00	3.25	0.00	0.00	0.00	0.00
Gardenia volkensii	0.00	0.00	0.00	0.00	4.75	0.00
Grewia microthyrsa	0.00	0.00	25.12	25.22	0.00	0.00
Gymnanthemum coloratum	0.00	13.54	0.00	0.00	0.00	0.00
Haplocoelum gallaense	0.00	0.00	0.00	0.00	17.82	31.05
Hymenocardia ulmoides	0.00	0.00	5.83	1.67	14.76	0.00
Manilkara discolor	0.00	0.00	0.00	0.00	0.00	13.54
Newtonia hildebrandtii	0.00	0.00	0.00	4.75	7.21	9.76
Ptaeroxylon obliquum	0.00	0.00	0.00	4.75	0.00	8.51
Pteleopsis myrtifolia	0.00	0.00	0.00	17.01	7.21	0.00
Salacia leptoclada	0.00	5.83	0.00	3.25	0.00	0.00
Spirostachys africana	0.00	0.00	0.00	0.00	0.00	3.25
Strychnos decussata	0.00	0.00	0.00	3.52	0.00	0.00
Strychnos madagascariensis	0.00	0.00	5.83	0.00	0.00	0.00
Toddaliopsis bremekampii	0.00	0.54	8.73	2.61	0.00	0.00
Tricalysia species	0.00	0.00	0.00	7.21	0.00	0.00
Vepris lanceolata	0.00	0.00	0.00	3.25	0.00	0.00
Vitex amboniensis	0.00	0.00	0.00	0.00	7.21	0.00

Cumulative canopy removal by elephants (total of utilised species) in the Mature Sand Forest in 2010 was exceptionally high (Figure 8.3). Site 38 had the lowest degree of elephant utilisation with 19.96%. The site with the highest utilisation value was site 44 with more than double that of site 38 (43.42%). Site 37 had 26.70% canopy removed in 2010. The mean cumulative canopy removal for the Mature Sand Forest was 37.40% for 2010. This was one of the communities with the highest canopy removal in the Tembe Elephant Park during the 2010 survey. Total canopy removal in the Mature Sand Forest, in terms of all available woody species was 37.17% (Table 8.1; Figure 8.4), the highest of all Sand Forest communities.

8.2.2 Elephant utilisation – 2004 survey

Cumulative percentage canopy removal, for the 2004 survey, also increased as the size classes increased, peaking at size class 3 (Figure 8.1). In size class 6 the canopy removal declined to a low value of 4.03%. Size class 3 was moderately utilised with 16.86% cumulative canopy removal, even higher than the utilisation in 2010. Size class 4 had elephant utilisation values very similar to the 2010 survey with canopy removal of 15.09%.

Elephant utilisation in 2004 was fairly evenly distributed among the species. *Schotia brachypetala* was the woody species with the highest mean utilisation value in terms of elephant browsing in 2004 with 25.52% mean canopy removed (Figure 8.2). This species was present only in a single site and utilised heavily within that site. *Boscia filipes*, *Grewia microthyrsa*, *Strychnos decussata*, *Strychnos henningsii*, *Toddaliopsis bremekampii* and *Tricalysia* species were other moderately utilised species in the Mature Sand Forest in 2004. *Boscia filipes* (20.83%) and *Grewia microthyrsa* (16.15%) were only utilised in a single site within this community, although they also occurred in the other sites. Species utilised in many sites within the Mature Sand Forest included *Tricalysia* species (23.37%), *Strychnos decussata* (18.08%), *Strychnos henningsii* (15.15%) and *Toddaliopsis bremekampii* (14.92%). *Drypetes arguta* and *Hymenocardia ulmoides* did not have exceptionally high mean utilisation values in 2004 but these two woody species were utilised by elephants in a range of size classes (Table 8.3). Species such as *Boscia filipes, Cleistanthus schlechteri*, *Grewia microthyrsa*, *Ptaeroxylon obliquum*, *Pteleopsis myrtifolia* and *Schotia brachypetala* were utilised in a single size class with canopy removal of 20.83% (size class 4), 14.06% (size class 4), 16.15% (size class 3), 12.58% (size class 3), 12.50% (size class 3) and 25.52% (size class 5) respectively.

Acalypha glabrata, *Cola greenwayi, Hymenocardia ulmoides* and *Grewia microthyrsa* showed fairly low levels of utilisation up to size class 4 or 5 in 2004. Utilisation values in these size classes generally increased during the 2010 survey with an additional utilised size class being added. *Toddaliopsis bremekampii* experienced a slight decrease in elephant utilisation from 2004 to 2010.

In general, utilisation by elephants in the Mature Sand Forest was low in 2004. Site 38 had the highest cumulative canopy removal (12.28%) and site 44 the lowest (4.87%) (Figure 8.3). All the sites experienced an increase in elephant utilisation from 2004 to 2010. The difference in utilisation values of the Mature Sand Forest sites between 2004 and 2010 was not significant (p=0.059). Total canopy removal in the Mature Sand Forest, in terms of all available woody species was 2.08% in 2004 (Figure 8.4). This value showed more than a ten-fold increase from 2004 to 2010, when elephant damage reached 37.17%.

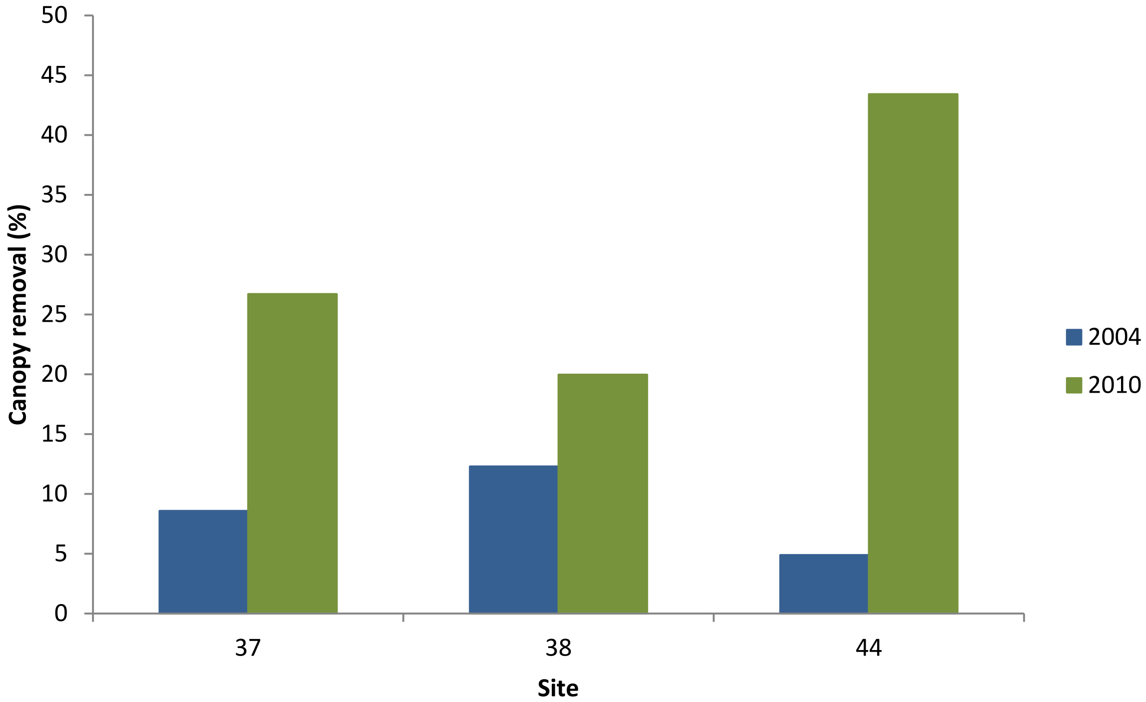

Figure 8.3 Cumulative percentage canopy removal (of utilised species only) by elephants at the three Mature Sand forest sites as surveyed in 2004 (blue) and 2010 (green).

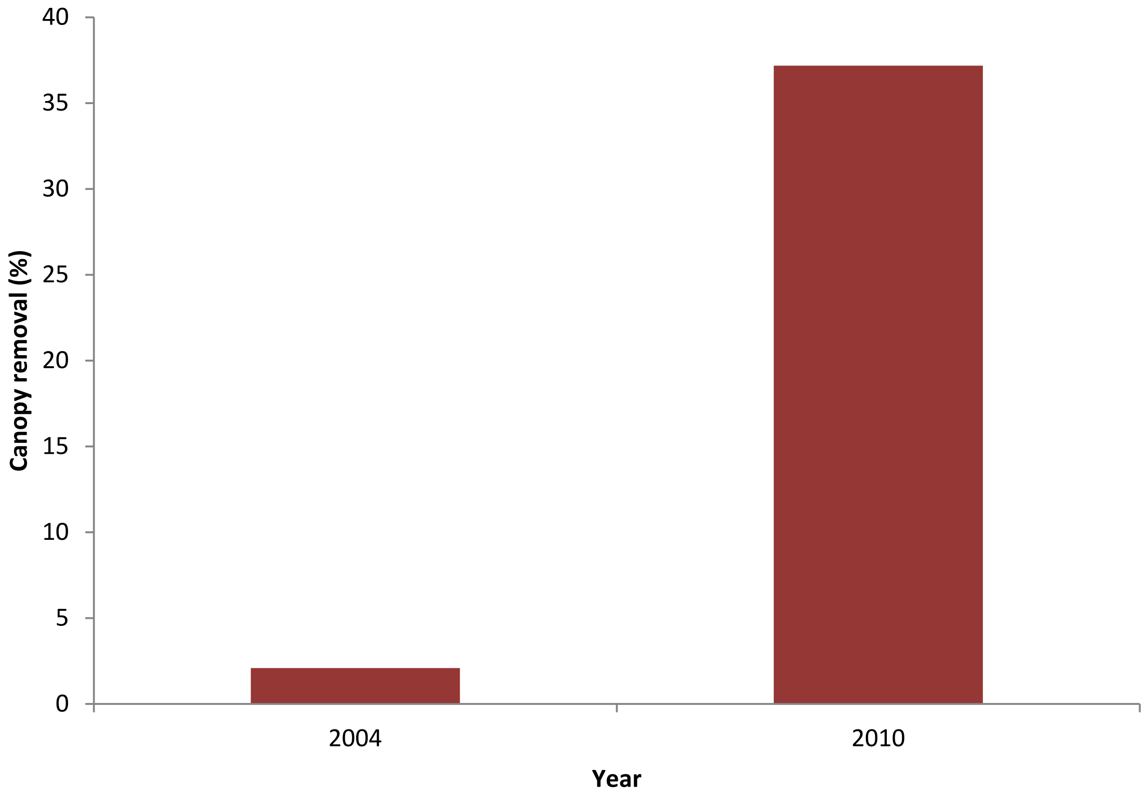

Figure 8.4 Cumulative percentage canopy removal (expressed as percentage of all species) in the Mature Sand Forest community for 2004 and 2010.

Table 8.3 Mean utilisation per size class (SC) (expressed as % of canopy volume removed) for utilised Mature Sand Forest species in 2004

Woody species	SC 1	SC 2	SC 3	SC 4	SC 5	SC 6
Acalypha glabrata	0.00	0.00	1.74	0.00	0.00	0.00
Boscia filipes	0.00	0.00	0.00	20.83	0.00	0.00
Cleistanthus schlechteri	0.00	0.00	0.00	14.06	0.00	0.00
Cola greenwayi	0.00	0.00	1.81	3.25	0.00	0.00
Croton pseudopulchellus	0.00	0.00	0.22	0.00	0.00	0.00
Drypetes arguta	0.00	0.35	2.02	12.50	0.00	0.00
Grewia microthyrsa	0.00	0.00	16.15	0.00	0.00	0.00
Haplocoelum gallaense	0.00	0.00	0.00	0.00	0.00	2.45
Hymenocardia ulmoides	0.00	2.28	7.84	2.32	0.00	0.00
Ptaeroxylon obliquum	0.00	0.00	12.58	0.00	0.00	0.00
Pteleopsis myrtifolia	0.00	0.00	12.50	0.00	0.00	0.00
Schotia brachypetala	0.00	0.00	0.00	0.00	25.52	0.00
Strychnos decussata	0.00	0.00	0.00	2.23	34.35	0.00
Strychnos henningsii	0.00	0.00	4.31	21.98	0.00	0.00
Toddaliopsis bremekampii	0.00	0.91	27.36	0.00	0.00	0.00
Tricalysia species	0.00	0.97	25.61	0.00	0.00	0.00
Wrightia natalensis	0.00	0.00	0.00	1.15	0.00	0.00

8.2.3 Elephant utilisation – 1995 survey

Relative utilisation in 1995, 2004 and 2010 is illustrated in Figure 8.5. Compared to the other surveys, the 1995 survey showed a different suite of species utilised. *Wrightia natalensis* had the highest relative utilisation at 63.21% in 1995, followed by *Afzelia quanzensis* (7.28%), *Albizia adianthifolia* (7.28%), *Tabernaemontana elegans* (6.09%) and *Sapium integerrimum* (5.47%). The 2004 relative utilisation values were more evenly spread amongst species. Approximately ten years after the 1995 survey, *Strychnos decussata* was the species with the highest relative utilisation (31.74%) followed by *Haplocoelum gallaense* (8.94%), *Hymenocardia ulmoides* (6.99%), *Ptaeroxylon obliquum* (6.07%) and *Tricalysia* species (6.02%). In 2010, *Balanites maughamii* had the highest relative utilisation at 52.39% while *Haplocoelum gallaense* had a relative utilisation value of 11.74%, *Hymenocardia ulmoides* of 3.40% and *Ptaeroxylon obliquum* of 2.77%. However, because the total utilisation has increased from 2004 to 2010, the absolute volume of canopy removed from *Strychnos decussata* in 2004 (1 459 m^3/ha) representing 31.74% relative utilisation, is less than that of *Hymenocardia ulmoides* in 2010 (1 733 m^3/ha) representing only 3.4% relative utilisation.

8.2.4 Elephant preferences

Elephant foraging patterns could lead to changes in species abundances and in turn this could possibly affect their selection of particular species. Therefore it was important to determine whether the preferences of the elephants in Tembe Elephant Park have changed with the possible modification in floristic composition. The ranking of elephant species selection in 2010 depended on the index used. The Forage Ratio and Ivlev's Electivity (EI) Index corresponded with each other, but the results of the Rank Procedure method ranked species differently. The three most preferred woody species in 2010 (based on Ivlev's Electivity) were *Haplocoelum gallaense* (0.41), *Cleistanthus schlechteri* (0.39) and *Boscia filipes* (0.18) (Table 8.4). According to the Rank Procedure method these species were among the two most preferred species for 2010, but *Manilkara discolor*, *Strychnos madagascarienses* and *Strychnos decussata* showed the same ranking as *Haplocoelum gallaense* and *Cleistanthus schlechteri*, even although the Ivlev's Electivity Index did not indicate these species as being preferred. Keeping in mind that only Electivity Index value >0.1 were regarded as preferred in this study (see Chapter 4), only three of the utilised species were actually preferred by elephants.

In 2004 the elephants showed a high preference for *Schotia brachypetala* (EI: 0.95), a species generally regarded as a Closed Woodland species (Matthews *et al*., 2001). This species was also ranked first with the Rank Procedure method. *Boscia filipes* (0.93), *Strychnos decussata* (0.88), *Grewia microthyrsa* (0.85), *Strychnos henningsii* (0.76), *Hymenocardia ulmoides* (0.63), *Drypetes arguta* (0.61) and *Haplocoelum gallaense* (0.56) were also highly selected by elephants, in the Mature Sand Forest, based on their Electivity Index values. According to the Rank Procedure *Tricalysia* species had the second highest ranking followed by *Strychnos decussata* and *Grewia microthyrsa*, all with high Electivity Index values.

Table 8.4 Elephant preferences for woody species in 2010 in terms of Ivlev's Electivity Index (Ivlev, 1961), Forage Ratio (Cock, 1978) and the Rank Procedure method (Johnson, 1980). The woody species recorded within the Mature Sand Forest in 2010 are ranked from most preferred to least preferred based on Ivlev's Electivity Index

Woody species	Ivlev's Electivity Index	Forage Ratio	Rank Procedure method
Haplocoelum gallaense	0.41	2.38	2
Cleistanthus schlechteri	0.39	2.29	2
Boscia filipes	0.18	1.44	1
Balanites maughamii	0.06	1.13	4
Gymnanthemum coloratum	0.04	1.09	4
Manilkara discolor	0.04	1.09	2
Newtonia hildebrandtii	-0.13	0.76	6
Ptaeroxylon obliquum	-0.19	0.69	3
Pteleopsis myrtifolia	-0.24	0.61	3
Vitex amboniensis	-0.26	0.58	4
Tricalysia species	-0.26	0.58	3
Grewia microthyrsa	-0.28	0.56	4
Strychnos madagascariensis	-0.36	0.47	2
Cola greenwayi	-0.38	0.44	3
Drypetes arguta	-0.41	0.42	4
Gardenia volkensii	-0.45	0.38	5
Hymenocardia ulmoides	-0.50	0.33	6
Salacia leptoclada	-0.53	0.31	4
Strychnos decussata	-0.56	0.28	2
Spirostachys africana	-0.58	0.26	7
Vepris lanceolata	-0.59	0.26	5
Toddaliopsis bremekampii	-0.66	0.21	7
Capparis tomentosa	-0.83	0.10	4
Euclea natalensis	-0.90	0.05	6
Acalypha glabrata	-0.97	0.02	8

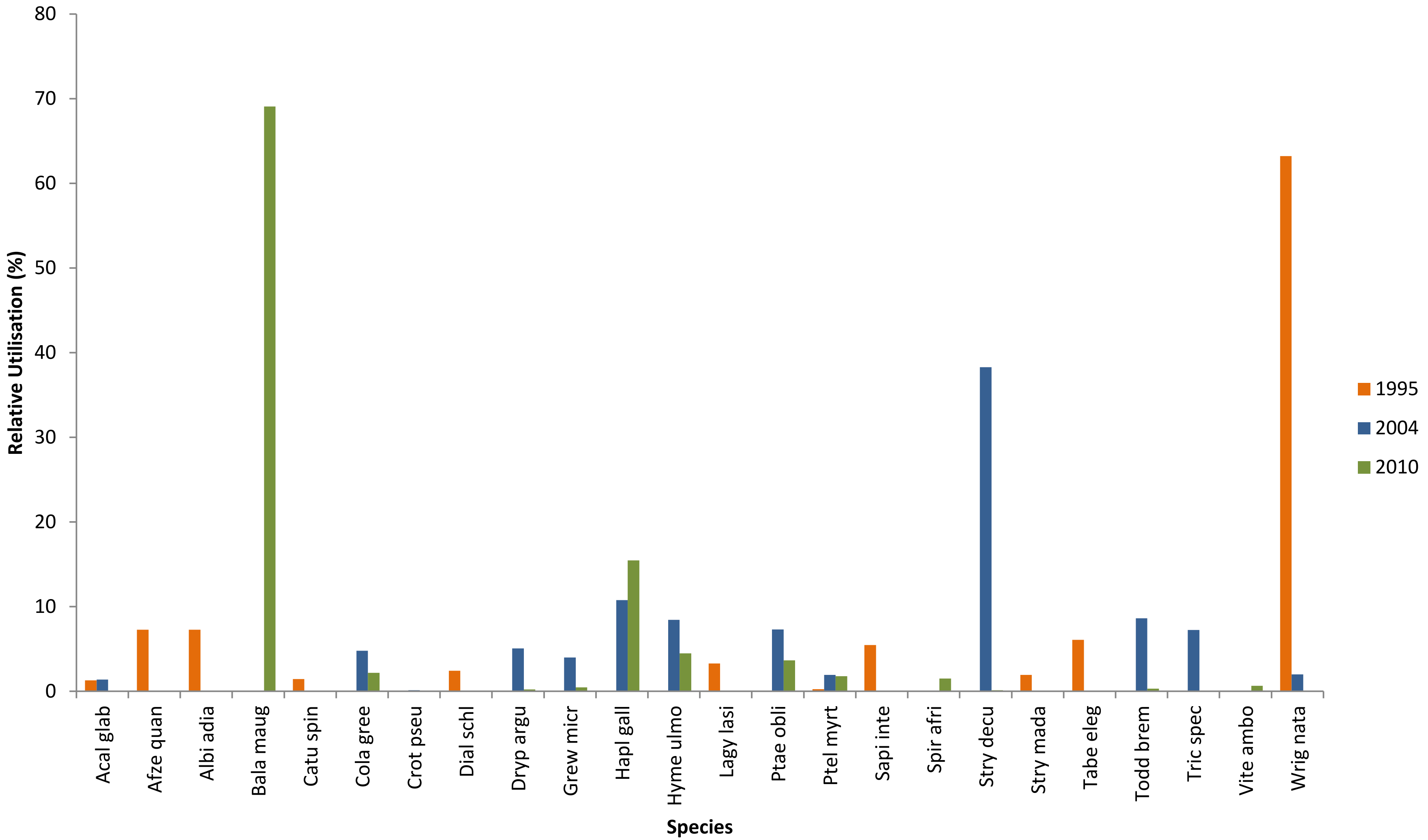

Figure 8.5 Relative utilisation of various species by elephants in 1995, 2004 and 2010 in the Mature Sand Forest of Tembe Elephant Park. Appendix A contains a list of abbreviations of all species names.

Table 8.5 Elephant preferences for woody species in 2004 in terms of Ivlev's Electivity Index (Ivlev, 1961), the Forage Ratio (Cock, 1978), and the Rank Procedure method (Johnson, 1980). The woody species recorded within the Mature Sand Forest in 2004 are ranked from most preferred to least preferred based on Ivlev's Electivity Index

Woody species	Ivlev's electivity index	Forage ratio	Rank Procedure method
Schotia brachypetala	0.95	36.80	1
Boscia filipes	0.93	29.72	5
Strychnos decussata	0.88	15.07	3
Grewia microthyrsa	0.85	11.98	4
Strychnos henningsii	0.76	7.40	5
Tricalysia species	0.74	6.71	2
Hymenocardia ulmoides	0.63	4.43	4
Drypetes arguta	0.61	4.17	4
Haplocoelum gallaense	0.56	3.53	4
Toddaliopsis bremekampii	0.32	1.93	6
Acalypha glabrata	0.29	1.83	8
Ptaeroxylon obliquum	0.29	1.80	7
Cola greenwayi	0.14	1.32	8
Cleistanthus schlechteri	-0.13	0.76	9
Wrightia natalensis	-0.31	0.52	10
Croton pseudopulchellus	-0.65	0.21	8
Pteleopsis myrtifolia	-0.70	0.18	11

8.3 DISCUSSION

8.3.1 Percentage canopy removal

The result of elephant utilisation and the extent thereof, in the Mature Sand Forest is of importance to the conservation of the endemic Sand Forest vegetation type. The number of species utilised increased from 17 in 2004 to 25 species in 2010. Elephant utilisation was recorded for thirteen woody species in the Mature Sand Forest for the first time in 2010, even though the canopy removal percentages were low in most instances. Of the 17 species utilised in 2004, 12 were also utilised by elephants in 2010 (Figure 8.2). Although almost half the species were still utilised by elephants in 2010 only two species (*Boscia filipes* and *Haplocoelum gallaense*) were among the 10 most preferred species in both surveys. The proportion of species utilised, in relation to the number of woody species available in the community, increased from 2004 to 2010.

In the Mature Sand Forest there were many tall individuals with fairly small stem diameters even although one would not expect so many individuals in these size classes in a late successional community like the Mature Sand Forest. The high density of these individuals could be a possible explanation for the high canopy removal in size class 3 and 4. It was noteworthy that the 2004 survey did not deliver high elephant utilisation values in size class 6, compared to the high value of 44.99% in 2010 (Figure 8.1). A large proportion of the damage by elephants to this size class in 2010 was old damage (utilisation that took place more than 2 years ago). The species that showed evidence of old damage in size class 6 included *Balanites maughamii*, *Cleistanthus schlechteri*, *Haplocoelum gallaense* and *Manilkara discolor*. These were extremely large, old individuals that were previously utilised by elephants. Ben-Shahar (1993) also reported that elephant utilisation increased as the size classes increased. In 1995, Matthews and Page (undated) did not find any utilisation in the small (<0.5 m) size classes.

Boscia filipes is a typical Sand Forest species (Table 5.1 in Chapter 5; Gaugris & Van Rooyen, 2011). In 2004 and 2010 elephants utilised almost all the individuals of this species which occurred in the Mature Sand Forest. This trend is likely to continue as the elephant population increases further. The woody species that showed high elephant utilisation in 2004 and 2010 differed noticeably. Species such as *Toddaliopsis bremekampii*, *Schotia brachypetala*, *Strychnos decussata*, *Strychnos henningsii* and *Tricalysia* species decreased in elephant utilisation from 2004 to 2010 or were not at all utilised by elephants in 2010 (Figure 8.2). *Schotia brachypetala* was the most preferred species within this community in

2004. In Hluhluwe-Imfolozi Park (KwaZulu-Natal, South Africa), Boundja and Midgley (2009) found that *Schotia brachypetala* was one of the most preferred woody species, by elephants, and utilised in several different ways.

There were a number of woody species that showed an increase in elephant utilisation values or were newly utilised species in 2010. These species included *Haplocoelum gallaense, Cleistanthus schlechteri, Cola greenwayi, Gymnanthemum coloratum, Ptaeroxylon obliquum, Newtonia hildebrandtii* and *Manilkara discolor. Gymnanthemum coloratum* and *Manilkara discolor* were the only two of these seven woody species that were not available in the Mature Sand Forest during the 2004 surveys. The other five species were moderately available throughout the whole community in 2004 even although they were not recorded as utilised during that survey. According to Table 8.1 the elephants utilised almost all the available woody species at some stage, even if they did not utilise them everywhere they occurred. Matthews and Page (undated) found that, compared to the other communities, the Sand Forest in Tembe Elephant Park had very little canopy removed by elephants. This seems to have changed since, with 37.71% of all available canopy removed in the Mature Sand Forest in 2010. Woody species which were recorded in 1995 with the most canopy removed and highest preference indices were *Albizia adianthifolia*, *Dialium schlechteri*, *Newtonia hildebrandtii*, *Manilkara discolor* and *Wrightia natalensis*. *Albizia adianthifolia*, *Dialium schlechteri* and *Wrightia natalensis* were not recorded as available during the 2010 survey.

From an observer's point of view, the Mature Sand Forest sites (surveyed in 2010) did not resemble the typical Sand Forest sites in the west of the park. The canopy of the Mature Sand Forest sites was more open and the sites in general had a low density of woody plants. Site 44 and 37 were located in an area of high elephant density and were closer to water sources than site 38 which had the lowest elephant utilisation of these three sites (but still higher than 2004 utilisation values) in 2010. A possible explanation for the increased elephant utilisation in the Mature Sand Forest could be that their preferred species were no longer present in other communities. As preferred species become less abundant elephants could start to forage in new places and select new species. Apart from these Mature Sand Forest sites being more open than the ones in areas of lower elephant density, a number of woodland species were recorded in the Mature Sand Forest in 2010. It is possible that by the intense utilisation of this community the elephants are opening up space for recruitment of new species from neighbouring communities (Shannon *et al*., 2009; Lagendijk *et al*., 2011).

The Mature Sand Forest was one of the communities with the biggest increase in elephant utilisation from 2004 to 2010. The percentage canopy removed increase 10-fold in the course of six years (Figure 8.4). The Sand Forest was regarded as the community with the second highest elephant utilisation values in Tembe Elephant Park by Gaugris and Van Rooyen (2010a) and exhibited a lot of recent elephant damage according to that study. In the Maputo Elephant Reserve in Mozambique De Boer *et al*. (2000) found that elephants also preferred Sand Forest communities.

Considering all Sand Forest communities (Chapter 6, 7 and 8) it could be concluded that the range of woody species targeted and utilised, by elephants in Tembe Elephant Park, have increased. In the 2004 survey, 34 woody species were identified with elephant utilisation in the Sand Forest and this increased to 44 species in 2010. Twenty-five of the 34 utilised species recorded in 2004 were also utilised by elephants in 2010. This means that there were 19 newly utilised species in the Sand Forest in 2010. The original incentive for proclaiming the park as a conservation area was to conserve the Sand Forest also known as Licuati Forest, which forms part of the Maputaland Centre of Endemism (Matthews *et al*., 2001). This vegetation type includes many Maputaland Centre endemic (and near-endemic) plant species such as *Acacia kraussiana*, *Croton steenkampianus*, *Oxyanthus latifolius*, *Tricalysia junodii* var. *junodii*, *Sclerochiton apiculatus* and *Memecylon sousae* (Van Wyk, 1996; Matthews *et al*., 2001). According to the IUCN Red List of Threatened Species (Raimondo *et al*., 2009) there are also three red data plant species which include *Brachylaena huillensis* (lower risk/near threatened) *Combretum mkuzense* (lower risk/near threatened) and *Encephalartos ferox* (near threatened). The increase in the number of species utilised by elephants and an increase in the volume of canopy removed (in absolute terms as well as in relation to what was available) is threatening this unique vegetation type.

8.3.2 Electivity

The percentage of canopy removed from a tree or species, by elephants, gave a clear indication whether it was severely damaged or not. When a species was only utilised in small amounts in the low size classes it could be described as accidental damage such as trampling. Based on Ivlev's Electivity Index *Haplocoelum gallaense* was the most preferred species in the Mature Sand Forest in the 2010 survey although the species had the ninth highest value in 2004. *Cleistanthus schlechteri* was the second most preferred species in 2010 with substantial old utilisation but it had a negative EI in 2004, indicating that it was avoided by elephants at that time. According to the Ranking Procedure of 2010 *Boscia filipes* was ranked the most preferred species. In 2004 the results were contradicting, since it also had a high EI of 0.93 but on Ranking Procedure it was only ranked 5th. *Balanites maughamii*, *Gymnanthemum coloratum* and *Manilkara discolor* were highly selected for by elephants in the Mature Sand Forest as recorded in 2010 but six years previously they were not documented as utilised by elephants. Guldemond and Van Aarde (2007) also found that *Manilkara discolor* was one of the most preferred woody species, by elephants, in the Sand Forest of Tembe Elephant Park. *Strychnos decussata*, *Tricalysia* species and *Grewia microthyrsa* were highly selected for by elephants in 2004 and even although these species were still being utilised by elephants in 2010, they have negative electivity indices.

Even though the number of woody species utilised by elephants in the Mature Sand Forest has increased, the Electivity Index values indicated that the number of species actually selected for, decreased. During the 2004 survey, 13 woody species were preferred by elephants (based on EI >0.1) but in 2010 only three species showed elephant preference. These three preferred species showed exceptionally high canopy removal values, i.e. *Haplocoelum gallense,* 88.36%; *Cleistanthus schlechteri,* 85.09% and *Boscia filipes* 53.46% (Table 8.1). Although elephants were also utilising a variety of woody plant species they were showing little preference for most of these species in 2010.

8.3.3 Relative utilisation

Extending the study period of elephant utilisation to 15 years improved insight into elephant feeding patterns and preferences but it should be remembered that the 1995 data were not on the exact locations as the 2004 and 2010 data, and a different method and site layout was used by the researchers. This might be the reason for woodland species such as *Tabernaemontana elegans*, *Sapium integerrimum*, *Catunaregam spinosa* and *Strychnos madagascariensis* being recorded 1995. *Wrightia natalensis*, an endemic Sand Forest species, had the highest relative utilisation in 1995 and was regarded as one of the most preferred species by elephants in the Sand Forest of Tembe Elephant Park (Matthews and Page, undated). In 2004, this species was still available and utilised in the Mature Sand Forest but in 2010, *Wrightia natalensis* was only recorded at one site and it was not utilised by elephants. *Strychnos decussata* had the highest relative utilisation in 2004 but its availability had been reduced by 2010 to 11% of the 2004 level. *Balanites maughamii* had the highest relative utilisation in 2010 and contributed to more than 50% of all canopy removal. Utilisation of *Cola greenwayi*, *Grewia microthyrsa*, *Haplocoelum gallaense*, *Hymenocardia ulmoides* and *Ptaeroxylon obliquum* was fairly similar in the 2004 and 2010 surveys but did not correspond well with the 1995 survey.

8.4 CONCLUSION

Elephant utilisation in the Mature Sand Forest of Tembe Elephant Park increased substantially from 2004 to 2010. As elephant numbers rise in the park they tend to concentrate in the eastern section where the Muzi swamp and several other water points are located. The sites surveyed for this community were in the east of the park, two of them being very close to the Muzi swamp, and therefore high utilisation values could be expected, nevertheless the increase in utilisation since 2004 is concerning. The selection of elephants for woody species seemed to have changed and this could constitute a problem. Further research would be required to determine whether this change in preference is due to the depletion of favourite species and they are therefore forced to move onto a new species or whether it is a behavioural matter.

CHAPTER 9

UTILISATION IN THE *STRYCHNOS DECUSSATA – DIALIUM SCHLECHTERI* CLOSED WOODLAND ON SAND

9.1 INTRODUCTION

The *Strychnos decussata – Dialium schlechteri* Closed Woodland on Sand (hereafter referred to as Closed Woodland 1) is a subcommunity of the bigger *Dialium schlechteri - Psydrax locuples* Closed Woodland on Sand community in the Tembe Elephant Park. This is the subcommunity with the largest amount of *Dialium schlechteri* available and the woodland subcommunity closest related to the Sand Forest. Apart from the utilisation recorded by elephants, which will be discussed in this chapter, there was an abundance of utilisation by small and medium browsers, specifically by nyala. All five the sampling sites in this community were situated along the Muzi swamp in the eastern side of the park. Because the Closed Woodland 1 is close to permanent water, it is consequently utilised by a large number of elephants.

9.2 RESULTS

9.2.1 Elephant utilisation - 2010 survey

Utilisation by elephants in this subcommunity was extremely high during the survey done in 2010. Almost a third of all individuals recorded as utilised by elephants in the 2010 survey Tembe Elephant Park was in the Closed Woodland 1 subcommunity. Figure 9.1 illustrates the cumulative[1] canopy removal within the six size classes and once again the largest volume of canopy removed was found in the largest size classes with 44.29% and 48.39% canopy removal (in terms of utilised species) in size class 5 and 6, respectively. The canopy

[1] Cumulative canopy removal percentage refers to the total volume of the canopy removed of all species expressed as a percentage of the available volume of only the utilised species.

removal by elephants in size class 2 of 20.38% was worrying as these were the emerging individuals. These woody species utilised in size class 2 included *Strychnos decussata*, *Catunaregam spinosa*, *Plectroniella armata*, *Searsia gueinzii*, *Tricalysia* species and *Strychnos madagascariensis*. Size class 1 had the least elephant damage with 0.40% canopy removed followed by size class 4 with 12.95%.

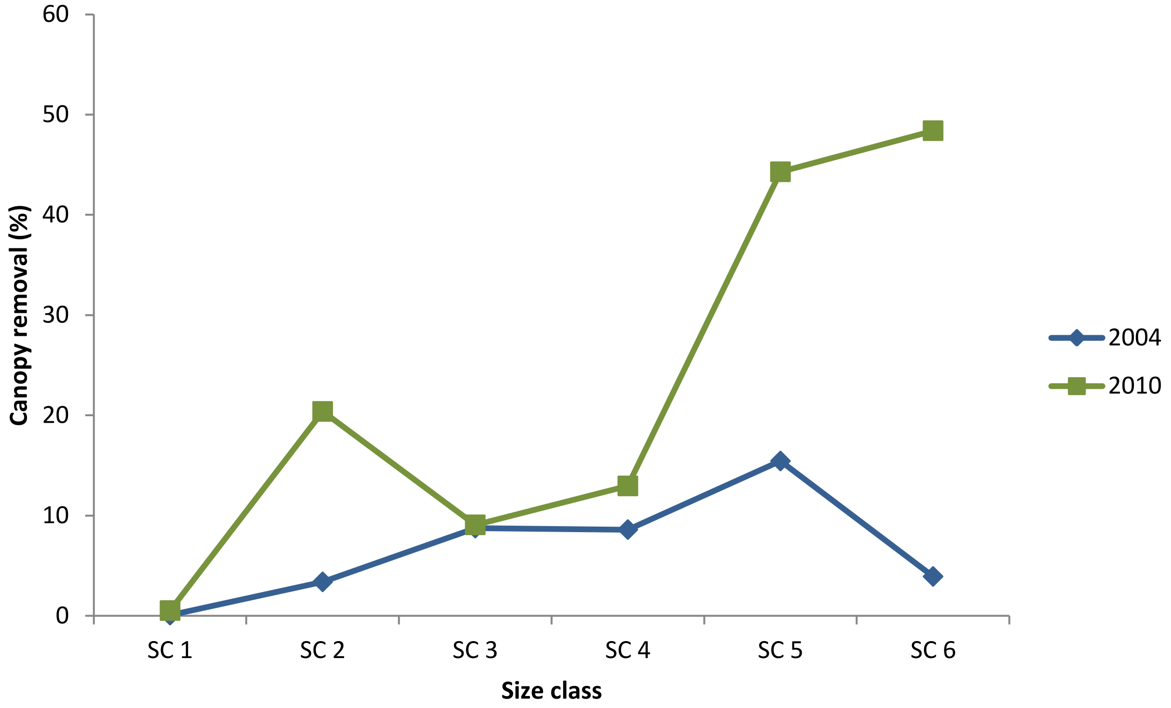

Figure 9.1 Cumulative percentage canopy volume (of utilised species) removed per size class (SC) in 2004 and 2010 in the Closed Woodland 1 in the Tembe Elephant Park.

The number of woody species utilised by elephants in this subcommunity was high as 44 species were utilised. *Dialium schlechteri* had the highest mean percentage canopy removed in the Closed Woodland 1 (57.49%) (Figure 9.2). *Dialium schlechteri* was abundant and a large canopy volume was available (Table 9.1). This species was utilised in all the size classes except in size class 1, but especially in size class 5 and 6 (Table 9.2). Other abundantly available woody species, utilised throughout this subcommunity included *Afzelia quanzensis* with a mean of 28.92% canopy removal, *Sclerocarya birrea* (20.44%), *Spirostachys africana* (15.35%) and *Vepris lanceolata* (11.87%).

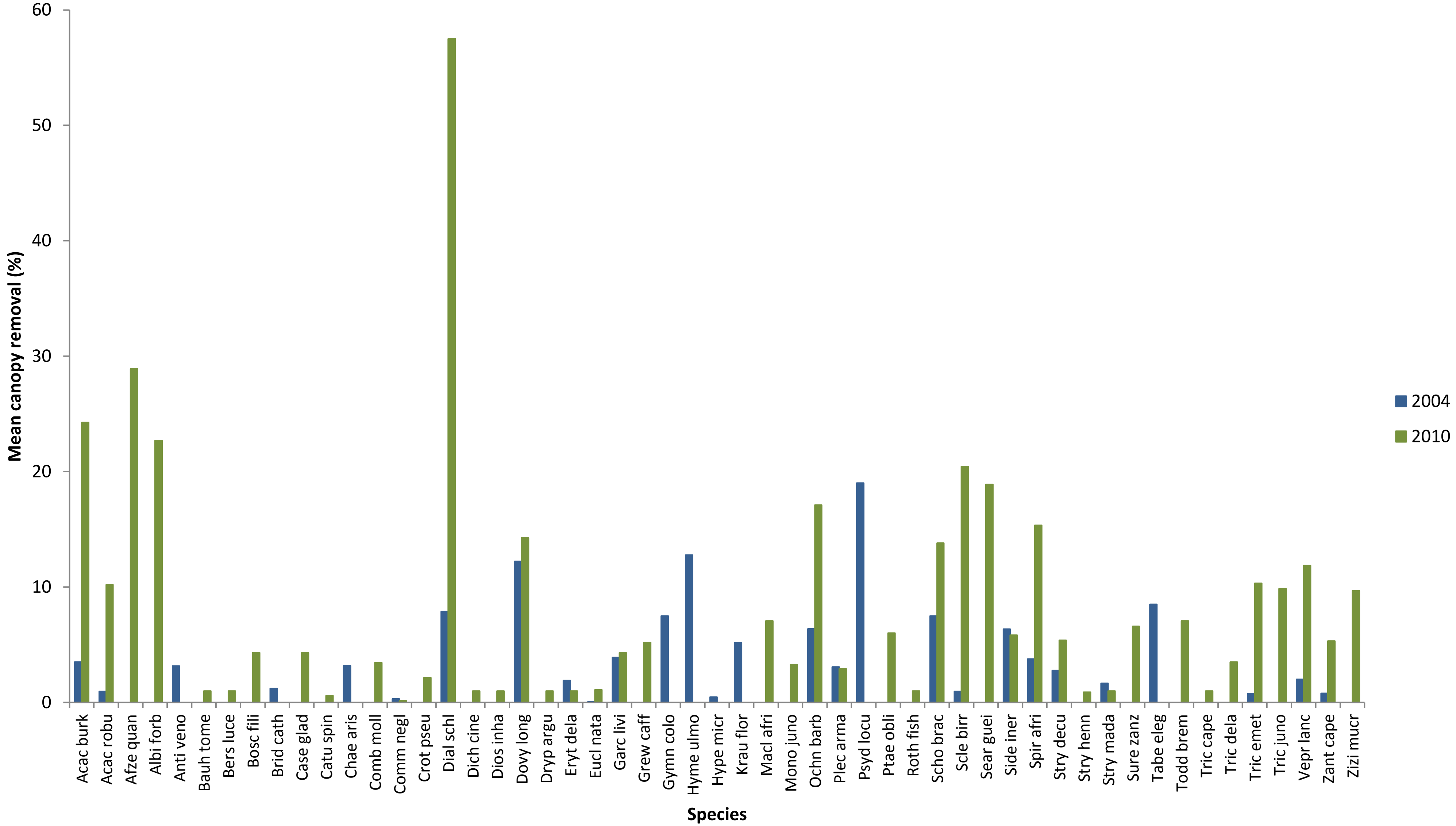

Figure 9.2 Woody species utilised by elephants in the Closed Woodland 1 community as recorded in 2004 and 2010. Appendix A contains a list of abbreviations of all species names.

Table 9.1 Available canopy volume and removed canopy volume per utilised species within the Closed Woodland 1 for 2010 and 2004. Elephant utilisation is expressed as cumulative percentage utilised as well as a relative utilisation percentage

Species	2010				2004			
	Available (m^3/ha)	Removed (m^3/ha)	% Utilised	Relative utilisation (%)	Available (m^3/ha)	Removed (m^3/ha)	% Utilised	Relative utilisation (%)
Acacia burkei	824	521	63.22	0.76	6635	327	4.92	3.69
Acacia robusta	1221	623	51.02	0.91	-	-	-	-
Afzelia quanzensis	26771	9254	34.57	13.49	76	12	15.77	0.14
Albizia forbesii	696	393	56.42	0.57	-	-	-	-
Bauhinia tomentosa	586	29	4.98	0.04	-	-	-	-
Bersama lucens	53	3	5.00	0.00	-	-	-	-
Boscia filipes	1244	269	21.62	0.39	-	-	-	-
Bridelia cathartica	-	-	-	-	1907	117	6.14	1.32
Casearia gladiiformis	378	82	21.56	0.12	-	-	-	-
Catunaregam spinosa	4446	131	2.96	0.19	-	-	-	-
Chaetachme aristata	-	-	-	-	1882	299	15.90	3.38
Combretum molle	126	22	17.19	0.03	-	-	-	-
Commiphora neglecta	14	0	0.77	0.00	155	2	1.50	0.03
Croton pseudopulchellus	89	10	10.75	0.01	-	-	-	-
Dialium schlechteri	62613	37390	59.72	54.52	23850	2266	9.50	25.57
Dichrostachys cinerea	0	0	5.00	0.00	-	-	-	-
Diospyros inhacaensis	60	3	5.00	0.00	-	-	-	-
Dovyalis longispina	1059	136	12.83	0.20	271	166	61.13	1.87

Drypetes arguta	81	4	5.00	0.01	-	-	-	-
Erythroxylum delagoense	190	9	5.00	0.01	2210	210	9.50	2.37
Euclea natalensis	820	17	2.11	0.03	1486	5	0.32	0.05
Garcinia livingstonei	44	10	21.63	0.01	351	68	19.51	0.77
Grewia caffra	925	122	13.21	0.18	-	-	-	-
Gymnanthemum coloratum	-	-	-	-	119	45	37.50	0.50
Hymenocardia ulmoides	-	-	-	-	1120	715	63.90	8.07
Hyperacanthus microphyllus	-	-	-	-	176	4	2.37	0.05
Krausia floribunda	-	-	-	-	407	105	25.90	1.19
Maclura africana	327	115	35.34	0.17	-	-	-	-
Monodora junodii	952	157	16.46	0.23	-	-	-	-
Ochna barbosae	34	29	85.56	0.04	57	18	31.94	0.20
Plectroniella armata	1332	100	7.50	0.15	1747	25	1.44	0.28
Psydrax locuples	-	-	-	-	319	304	95.11	3.43
Ptaeroxylon obliquum	270	81	30.04	0.12	-	-	-	-
Rothmannia fischeri	53	3	5.00	0.00	-	-	-	-
Schotia brachypetala	221	153	69.06	0.22	591	222	37.50	2.50
Sclerocarya birrea	13400	2471	18.44	3.60	3318	158	4.75	1.78
Searsia gueinzii	239	226	94.50	0.33	-	-	-	-
Sideroxylon inerme	4857	1020	21.00	1.49	15455	2290	14.82	25.84
Spirostachys africana	25845	12006	46.45	17.50	1081	204	18.87	2.30
Strychnos decussata	9326	817	8.76	1.19	7441	78	1.04	0.88
Strychnos henningsii	34	2	4.45	0.00	-	-	-	-
Strychnos madagascariensis	1265	63	5.00	0.09	73	6	8.30	0.07

Suregada zanzibariensis	3306	514	15.56	0.75	-	-	-	-
Tabernaemontana elegans	-	-	-	-	2044	869	42.52	9.80
Toddaliopsis bremekampii	31	11	35.34	0.02	-	-	-	-
Tricalysia capensis	6	0	5.00	0.00	-	-	-	-
Tricalysia delagoensis	101	18	17.50	0.03	-	-	-	-
Tricalysia junodii	511	65	12.74	0.09	-	-	-	-
Trichilia emetica	402	208	51.60	0.30	2681	105	3.92	1.19
Vepris lanceolata	10527	1059	10.06	1.54	4257	162	3.81	1.83
Zanthoxylum capense	1460	285	19.49	0.41	2059	81	3.95	0.92
Ziziphus mucronata	322	156	48.44	0.23	-	-	-	-
Total of utilised species	177063	68585	38.73		81766	8863	10.84	
Total of not utilised species	4619	0	0.00		25385	0	0.00	
Total available of all species	181682	68585	37.75		107151	8863	8.27	

Table 9.2 Mean utilisation per size class (SC) (expressed as % of canopy volume removed) for Closed Woodland 1 species in 2010

Species	SC 1	SC 2	SC 3	SC 4	SC 5	SC 6
Acacia burkei	0.00	0.00	0.00	16.50	12.72	11.49
Acacia robusta	0.00	0.00	0.00	0.00	0.00	10.20
Afzelia quanzensis	0.00	0.00	0.00	0.00	3.87	29.90
Albizia forbesii	0.00	0.00	0.00	0.00	3.50	25.05
Bauhinia tomentosa	0.00	0.00	1.00	0.00	0.00	0.00
Bersama lucens	0.00	0.00	1.00	0.00	0.00	0.00
Boscia filipes	0.00	0.00	0.00	0.00	4.32	0.00
Casearia gladiiformis	0.00	0.00	0.00	0.00	4.32	0.00
Catunaregam spinosa	0.32	0.22	0.56	1.00	0.00	0.00
Combretum molle	0.00	0.00	3.44	0.00	0.00	0.00
Commiphora neglecta	0.00	0.00	0.16	0.00	0.00	0.00
Croton pseudopulchellus	0.00	0.00	3.26	0.00	0.00	0.00
Dialium schlechteri	0.00	1.93	10.73	7.82	34.34	51.61
Dichrostachys cinerea	0.00	1.00	0.00	0.00	0.00	0.00
Diospyros inhacaensis	0.00	0.00	0.00	1.00	0.00	0.00
Dovyalis longispina	0.00	0.00	15.36	1.00	0.00	0.00
Drypetes arguta	0.00	0.00	1.00	0.00	0.00	0.00
Erythroxylum delagoense	0.00	0.00	1.00	0.00	0.00	0.00
Euclea natalensis	0.00	0.00	1.39	0.00	0.00	0.00
Garcinia livingstonei	0.00	0.00	0.00	0.00	4.33	0.00
Grewia caffra	0.00	0.00	4.50	0.00	5.50	0.00
Maclura africana	0.00	0.00	0.00	0.00	0.00	7.07
Monodora junodii	0.00	0.00	0.00	0.00	3.50	0.00
Ochna barbosae	0.00	0.00	17.11	0.00	0.00	0.00
Plectroniella armata	0.00	7.39	4.64	2.67	0.00	0.00
Ptaeroxylon obliquum	0.00	0.00	0.00	0.00	6.01	0.00
Rothmannia fischeri	0.00	0.00	0.00	1.00	0.00	0.00
Schotia brachypetala	0.00	0.00	0.00	0.00	0.00	13.81
Sclerocarya birrea	0.00	0.00	0.00	0.00	1.00	20.66
Searsia gueinzii	0.00	18.90	0.00	0.00	0.00	0.00
Sideroxylon inerme	0.00	0.00	7.67	3.50	0.00	0.00
Spirostachys africana	0.00	0.00	0.00	0.00	14.43	14.26
Strychnos decussata	0.00	0.42	1.39	6.58	0.00	0.00
Strychnos henningsii	0.00	0.00	0.89	0.00	0.00	0.00
Strychnos madagascariensis	1.00	1.00	1.00	0.00	0.00	0.00
Suregada zanzibariensis	0.00	0.00	3.98	0.00	4.32	0.00
Toddaliopsis bremekampii	0.00	0.00	0.00	7.07	0.00	0.00
Tricalysia capensis	0.00	1.00	0.00	0.00	0.00	0.00
Tricalysia delagoensis	0.00	0.00	3.50	0.00	0.00	0.00
Tricalysia junodii	0.17	2.00	11.84	0.92	2.00	0.00
Trichilia emetica	0.00	0.00	0.00	0.00	0.00	10.32
Vepris lanceolata	0.27	0.33	14.98	6.64	13.97	0.00
Zanthoxylum capense	0.00	0.00	1.00	4.33	0.00	0.00
Ziziphus mucronata	0.00	0.00	0.00	0.00	0.00	9.69

The less abundant woody species, which were moderately utilised, included *Acacia burkei* (24.26%), *Albizia forbesii* (22.70%), *Ochna barbosae* (17.11%) and *Searsia gueinzii* (18.90%). Woody species utilised across a number of size classes included *Plectroniella armata, Strychnos decussata, Tricalysia* species*, Vepris lanceolata* and *Catunaregam spinosa.*

Site 9 and 10 had high cumulative canopy removal values of 50.86% and 45.26%, respectively (Figure 9.3). Site 14 had the least elephant utilisation with 23.26% canopy of the utilised species removed. The overall canopy removal (calculated as an average) by elephants in the Closed Woodland 1 community was 36.51% (Figure 9.4). If total canopy volume removal was calculated as a percentage of what was available in the community, an utilisation value of 37.75% was retrieved (Table 9.2).

9.2.2 Elephant utilisation – 2004 survey

Utilisation values for this subcommunity differed substantially between the 2004 and 2010 survey with a large increase recorded during the 2010 survey. In 2004, the utilisation by elephants increased as the size classes increased, but only up to size class 5 as size class 6 had less than 4.00% cumulative canopy removal (Figure 9.1). Size class 5 had the highest elephant utilisation with a canopy removal of 15.44% and size class 1 the lowest with 0.06%.

The most utilised species in the Closed Woodland 1, in 2004, was *Psydrax locuples* with a mean canopy removal of 19.02% (Figure 9.2). *Dovyalis longispina*, *Hymenocardia ulmoides*, *Tabernaemontana elegans* and *Gymnanthemum coloratum* had moderate to low utilisation values in this subcommunity with canopy removal values of 12.23%, 12.78%, 8.50% and 7.50% respectively. All five of these woody species were only utilised by elephants in a single size class, size class 3 and up (Table 9.3). Species which were utilised in a variety of size classes in 2004 included *Dialium schlechteri* (7.89% canopy removal), *Garcinia livingstonei* (3.90%), *Sideroxylon inerme* (6.37%) *and Vepris lanceolata* (2.01%). All these species, except *Garcinia livingstonei*, were also utilised in a range of sites within this subcommunity. Comparing the utilisation of species by elephants in the 2004 and 2010 data, it was clear that before 2004 the elephants utilised single species in particular size classes and sites. Whereas the 2010 survey, showed that species were being utilised across the whole subcommunity. A large increase in elephant canopy removal percentage, from 2004 to 2010, was recorded for *Acacia burkei*, *Afzelia quanzensis*, *Dialium schlechteri*, *Sclerocarya birrea*, *Spirostachys africana*, *Vepris lanceolata* and *Ochna barbosae* although there were also species which showed reduced levels of utilisation, such as *Sideroxylon inerme*.

In 2004, site 22 had the least cumulative canopy removal percentage in the Closed Woodland 1 with 3.04% canopy removal (Figure 9.3). A significant difference was noted for the change in percentage canopy removal on the different sites from 2004 to 2010 (p=0.008). The site with the highest value for elephant utilisation was site 9 with 23.51% of the utilised species' canopy removed, which is almost the same value as the site that had the lowest amount of elephant utilisation in 2010 within this subcommunity. A mean cumulative canopy removal of 12.59% was calculated for this community in 2004 (Figure 9.4). If total canopy volume removal was calculated as a percentage of what was available in the community, an utilisation value of 8.27% was derived (Table 9.2). This means that elephant canopy removal percentage increased more than four times since 2004.

9.2.3 Elephant utilisation – 1995 survey

In each of the surveys in the Closed Woodland 1 particular species with high relative utilisation could be identified (Figure 9.5). *Acacia burkei* had the highest relative utilisation in 1995 (21.19%) followed by *Terminalia sericea* and *Albizia adianthifolia* with relative utilisation of 13.21% and 10.46% respectively. *Afzelia quanzensis* (7.65%), *Dialium schlechteri* (6.35%) and *Sclerocarya birrea* (7.56%) had moderate relative utilisation values in 1995 as well. In 2004, *Dialium schlechteri* was the woody species with the highest relative utilisation of 25.57%. *Tabernaemontana elegans* had the second highest relative utilisation, 9.80%, followed by *Hymenocardia ulmoides* with 8.07%, *Psydrax locuples* (3.43%) *Erythroxylum delagoense* (2.37%), *Spirostachys africana* (2.30%) and *Sclerocarya birrea* (1.78%). In 2010, *Dialium schlechteri* was still the woody species with the highest relative utilisation, at a high of 54.52%. Second highest relative utilisation value was 18.03% for *Spirostachys africana*, followed by *Afzelia quanzensis* and *Sclerocarya birrea* with relative utilisation values of 13.49% and 3.60% respectively. All three datasets indicated the utilisation of *Dialium schlechteri*, *Sclerocarya birrea*, *Vepris lanceolata* and *Spirostachys africana*.

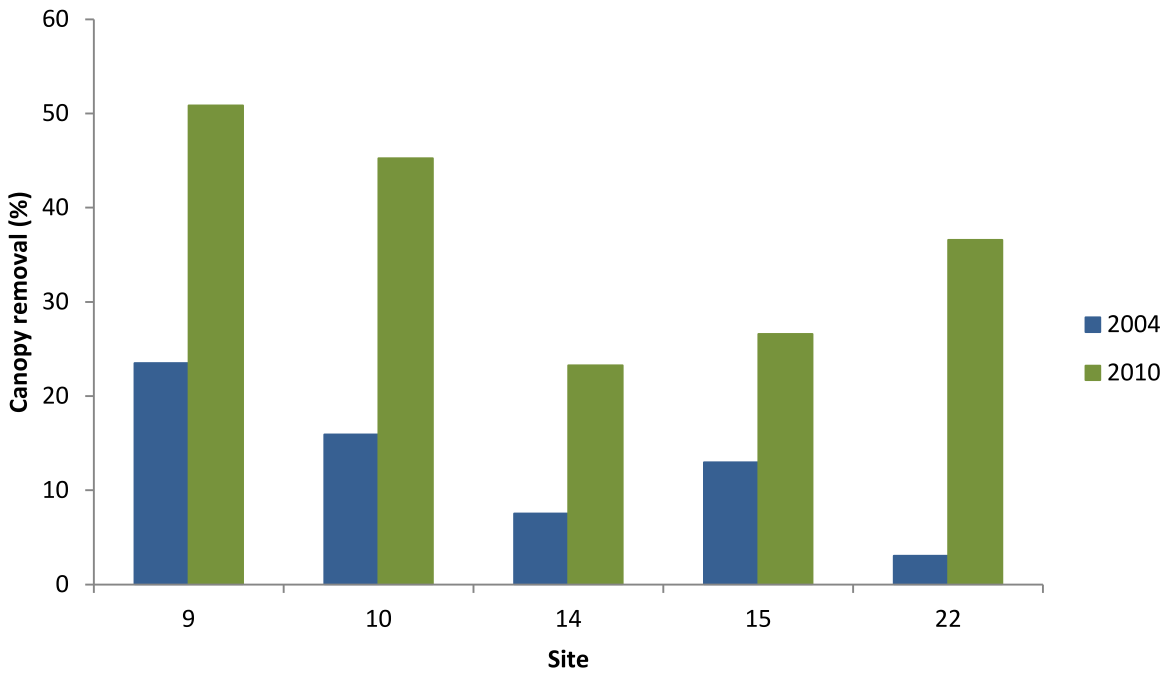

Figure 9.3 Cumulative percentage canopy removal (of utilised species only) by elephants at the five Closed Woodland 1 sites as surveyed in 2004 (blue) and 2010 (green).

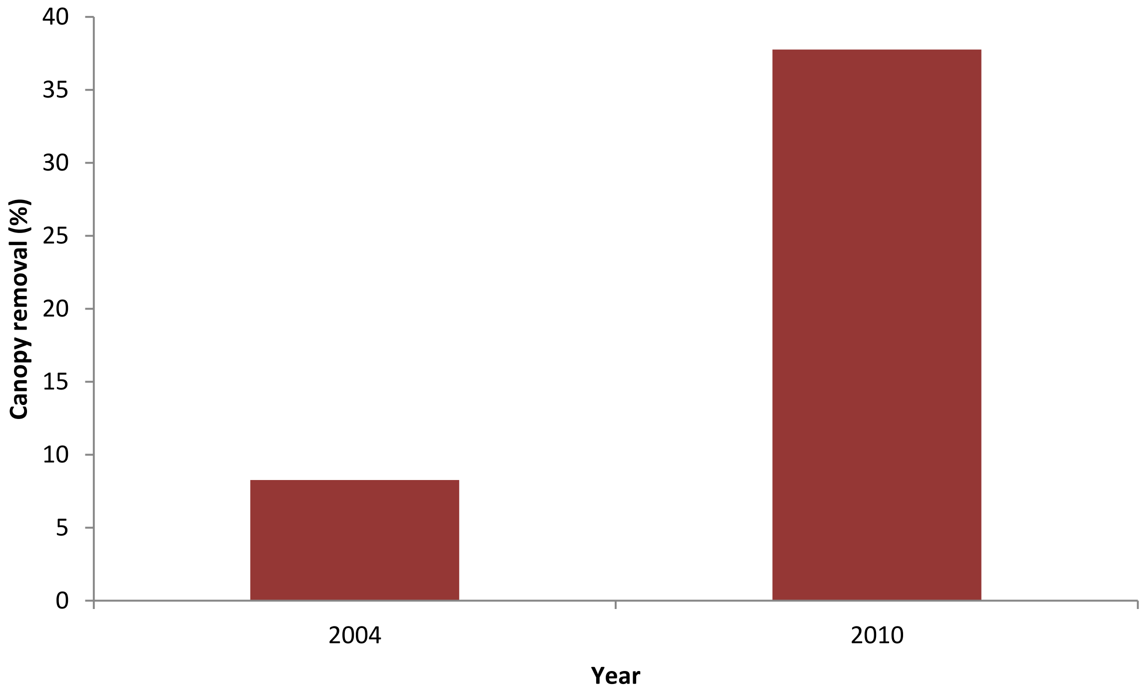

Figure 9.4 Cumulative percentage canopy removal (expressed as percentage of all species) in the Closed Woodland 1 for 2004 and 2010.

Table 9.3 Mean utilisation per size class (SC) (expressed as % of canopy volume removed) for Closed Woodland 1 species in 2004

Species	SC 1	SC 2	SC 3	SC 4	SC 5	SC 6
Acacia burkei	0.00	0.00	3.50	0.00	0.00	0.00
Acacia robusta	0.00	0.00	0.00	0.00	0.95	0.00
Antidesma venosum	0.00	0.00	3.50	0.00	0.00	0.00
Bridelia cathartica	3.62	0.00	2.15	0.00	0.00	0.00
Chaetachme aristata	0.00	0.00	0.00	3.18	0.00	0.00
Commiphora neglecta	0.00	3.36	0.00	0.00	0.00	0.00
Dialium schlechteri	0.00	0.00	0.00	1.45	3.54	0.78
Dovyalis longispina	0.00	0.00	12.24	0.00	0.00	0.00
Erythroxylum delagoense	0.00	0.00	1.72	2.01	0.00	0.00
Euclea natalensis	0.00	12.50	0.00	0.00	0.00	0.00
Garcinia livingstonei	0.00	0.00	0.00	12.50	3.50	0.00
Gymnanthemum coloratum	0.00	0.00	7.50	0.00	0.00	0.00
Hymenocardia ulmoides	0.00	0.00	0.00	0.00	14.51	0.00
Hyperacanthus microphyllus	0.00	0.00	0.53	0.00	0.00	0.00
Krausia floribunda	0.00	0.00	5.28	0.00	0.00	0.00
Ochna barbosae	0.00	0.00	6.39	0.00	0.00	0.00
Plectroniella armata	0.00	0.94	2.93	0.00	0.00	0.00
Psydrax locuples	0.00	0.00	19.09	0.00	0.00	0.00
Schotia brachypetala	0.00	0.00	0.00	0.00	7.50	0.00
Sclerocarya birrea	0.00	0.00	0.00	0.00	0.95	0.00
Sideroxylon inerme	0.00	17.49	6.31	5.12	3.20	0.00
Spirostachys africana	0.00	0.00	0.00	0.00	3.93	0.00
Strychnos decussata	0.00	0.00	6.62	0.00	0.00	0.00
Strychnos madagascariensis	0.00	0.00	1.66	0.00	0.00	0.00
Tabernaemontana elegans	0.00	0.00	0.00	0.00	8.51	0.00
Trichilia emetica	0.00	0.00	0.00	0.00	0.78	0.00
Vepris lanceolata	0.00	0.21	0.32	4.10	0.00	0.00
Zanthoxylum capense	0.00	0.00	1.03	0.00	0.00	0.00

9.2.4 Elephant preferences

Schotia brachypetala was the most preferred species in this subcommunity in 2010 according to all three indices (Table 9.4). It was followed by *Acacia burkei*, which was ranked second by the Rank Procedure method. The third preferred woody species, based on EI, was *Dialium schlechteri* but according to the Rank Procedure method it was ranked 10^{th}. *Ochna barbosae, Albizia forbesii, Searsia gueinzii, Trichilia emetica, Acacia robusta* and *Ziziphus mucronata* were also selected by elephants in the Closed Woodland 1, with EI values of 0.21, 0.20, 0.19, 0.16, 0.15 and 0.12 respectively. These species were also high on the ranking list.

In 2004, *Psydrax locuples* was the woody species selected for most with an EI of 0.84 followed by *Hymenocardia ulmoides* (0.77) and *Dovyalis longispina* (0.76) (Table 9.5). *Psydrax locuples*, *Hymenocardia ulmoides, Dovyalis longispina* and *Schotia brachypetala*, were ranked highly preferred according to the Rank Procedure method and they had high EI greater than 0.64. Electivity index values showed that *Gymnanthemum coloratum*, *Krausia floribunda*, *Garcinia livingstonei*, *Acacia burkei*, *Antidesma venosum, Sideroxylon inerme* and *Bridelia cathartica* were all preferred by elephants in this subcommunity. It is noteworthy that the available canopy volume of all the most preferred species in 2004 was greatly reduced. *Acacia burkei*, *Ochna barbosae* and *Schotia brachypetala* moved up on the preference list from 2004 to 2010 although the electivity values declined. *Dialium schlechteri* was not preferred by elephants in 2004 but according to the electivity index it became one of the most selected woody species in 2010. The Rank Procedure method arranged the species in more or less the same order as the other indices during both surveys.

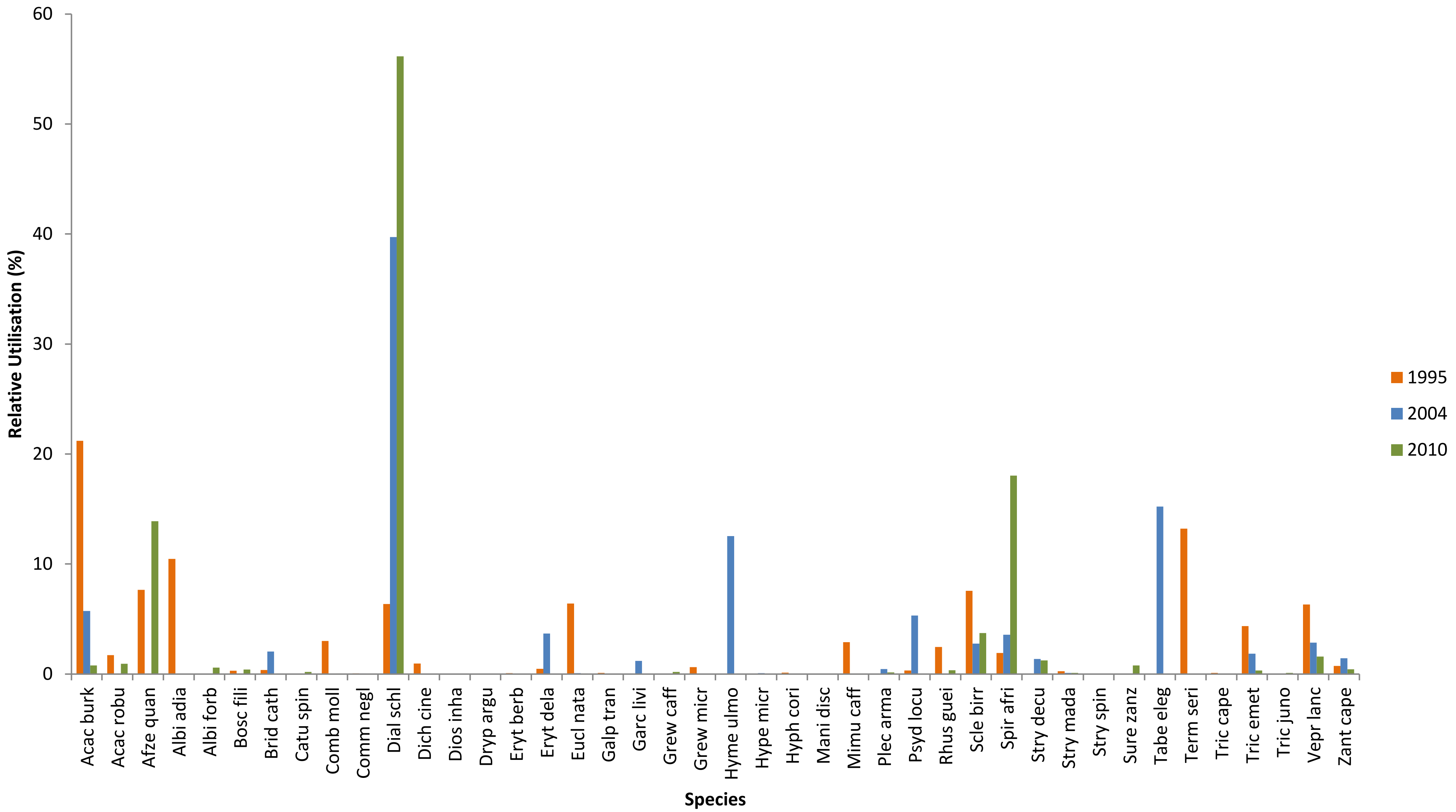

Figure 9.5 Relative utilisation of various species by elephants in 1995, 2004 and 2010 in the Closed Woodland 1 community of Tembe Elephant Park. Appendix A contains a list of abbreviations of all species names.

Table 9.4 Elephant preferences for woody species in 2010 in terms of Ivlev's Electivity Index (Ivlev, 1961), Forage Ratio (Cock, 1978) and the Rank Procedure method (Johnson, 1980). The woody species recorded within the Closed Woodland 1 in 2010 are ranked from most preferred to least preferred based on the Ivlev's Electivity Index

Woody species	Ivlev's Electivity Index	Forage Ratio	Rank Procedure method
Schotia brachypetala	0.29	1.83	1
Acacia burkei	0.25	1.67	2
Dialium schlechteri	0.23	1.58	10
Ochna barbosae	0.21	1.55	3
Albizia forbesii	0.20	1.49	2
Searsia gueinzii	0.19	1.47	3
Trichilia emetica	0.16	1.37	3
Acacia robusta	0.15	1.35	5
Ziziphus mucronata	0.12	1.28	2
Spirostachys africana	0.10	1.23	9
Toddaliopsis bremekampii	-0.03	0.94	4
Maclura africana	-0.03	0.94	6
Afzelia quanzensis	-0.04	0.92	11
Ptaeroxylon obliquum	-0.11	0.80	7
Garcinia livingstonei	-0.27	0.57	6
Boscia filipes	-0.27	0.57	9
Casearia gladiiformis	-0.27	0.57	8
Sideroxylon inerme	-0.29	0.56	9
Zanthoxylum capense	-0.32	0.52	12
Sclerocarya birrea	-0.34	0.49	10
Tricalysia delagoensis	-0.37	0.46	8
Combretum molle	-0.37	0.46	8
Monodora junodii	-0.39	0.44	9
Suregada zanzibariensis	-0.42	0.41	11
Grewia caffra	-0.48	0.35	13
Dichrostachys cinerea	-0.49	0.34	13
Croton pseudopulchellus	-0.56	0.28	11
Vepris lanceolata	-0.58	0.27	10
Strychnos decussata	-0.62	0.23	11
Tricalysia junodii	-0.64	0.22	14
Plectroniella armata	-0.67	0.20	16
Diospyros inhacaensis	-0.77	0.13	10
Dovyalis longispina	-0.77	0.13	12
Rothmannia fischeri	-0.77	0.13	13
Erythroxylum delagoense	-0.77	0.13	14
Bersama lucens	-0.77	0.13	13
Tricalysia capensis	-0.77	0.13	9
Strychnos madagascariensis	-0.77	0.13	19
Bauhinia tomentosa	-0.77	0.13	15
Strychnos henningsii	-0.79	0.12	11
Catunaregam spinosa	-0.85	0.08	17
Euclea natalensis	-0.90	0.05	18
Commiphora neglecta	-0.96	0.02	11
Drypetes arguta	-0.99	0.01	20

Table 9.5 Elephant preferences for woody species in 2004 in term of Ivlev’s Electivity Index (Ivlev, 1961), Forage Ratio (Cock, 1978) and the Forage Ratio (Cock, 1978), Ivlev’s Electivity Index (Ivlev, 1961) and the Rank Procedure method (Johnson, 1980). The woody species recorded within the Closed Woodland 1 community in 2004 are ranked from most preferred to least preferred based on the Ivlev’s Electivity Index

Woody species	Ivlev's Electivity Index	Forage Ratio	Rank Procedure method
Psydrax locuples	0.84	11.50	1
Hymenocardia ulmoides	0.77	7.73	2
Dovyalis longispina	0.76	7.34	2
Tabernaemontana elegans	0.67	5.14	4
Gymnanthemum coloratum	0.64	4.53	7
Schotia brachypetala	0.64	4.53	3
Ochna barbosae	0.59	3.86	5
Krausia floribunda	0.52	3.13	7
Garcinia livingstonei	0.40	2.36	9
Acacia burkei	0.36	2.12	8
Chaetachme aristata	0.32	1.92	6
Antidesma venosum	0.31	1.91	8
Sideroxylon inerme	0.28	1.79	9
Bridelia cathartica	0.13	1.30	8
Erythroxylum delagoense	0.07	1.15	10
Spirostachys africana	0.04	1.08	12
Strychnos madagascariensis	0.00	1.00	8
Dialium schlechteri	-0.05	0.90	11
Acacia robusta	-0.27	0.57	10
Zanthoxylum capense	-0.35	0.48	15
Trichilia emetica	-0.36	0.47	16
Vepris lanceolata	-0.51	0.33	14
Sclerocarya birrea	-0.56	0.28	16
Hyperacanthus microphyllus	-0.67	0.20	13
Plectroniella armata	-0.71	0.17	15
Strychnos decussata	-0.79	0.12	19
Commiphora neglecta	-0.88	0.06	17
Euclea natalensis	-0.94	0.03	18

9.3 DISCUSSION

9.3.1 Percentage canopy removal

An important difference between the Closed Woodland 1 and the Sand Forest communities was the age of utilisation incidents. Although the Sand Forest had recent damage by small/medium browsers and the occasional incident where elephants recently utilised a woody individual, most of the elephant utilisation incidents in the Sand Forest communities occurred more than 6 or 12 months before the field evaluation. In contrast, the Closed Woodland 1 had a large amount of recent utilisation events by elephants (less than a year before field evaluation) as well as older damage.

This subcommunity was a highly utilised vegetation unit, not only by elephants, but also by small and medium herbivores. Site 9 had the highest elephant utilisation within the subcommunity and it had a large amount of recent utilisation (less than a year before the survey). In addition, it also showed a high level of nyala utilisation. The second highest elephant utilised site was site 10, which contained some recent elephant damage. The other three sites had elephant utilisation ranging from recent to old and included many instances of utilisation by unknown small/medium browsers such as kudu, nyala, impala and duiker.

In Hluhluwe-Imfolozi Park, Boundja and Midgley (2009) found that most of the damage caused by elephants within a closed woodland community was through the breaking of branches and the uprooting of trees. This was also the case for the Closed Woodland 1 in the Tembe Elephant Park. Debarking of trees by elephants would be expected in woodland communities and is reported in most elephant utilisation studies as one of the main problems linked to damage by elephants (Ihwagi *et al*., 2009; O'Connor, 2010) but debarking was not present in the Tembe Elephant Park.

In Figure 9.2 it was clear that few were utilised in both 2004 and 2010. In 2004, 28 species were recorded with elephant utilisation and 44 species in 2010. A total of 25 species were recorded with elephant utilisation in 2010 but not in 2004 and 9 species were recorded in 2004 but not in 2010. This means that only 19 of the 44 utilised species in 2010 (43% of species) were browsed on by elephants in both 2004 and 2010. Utilisation of the majority of the species observed in 2004 has declined, probably due to decreased abundance. The majority of these species had lower available canopy volume during 2010 while some had increased canopy removal. From the 2010 dataset it was clear that there was either a new preference by the elephants or as some species disappear, other species become abundant and therefore increasingly utilised. White and Goodman (2009) suggested that species composition may be changed through elephant utilisation as they prefer communities with high canopy diversity such as was the case in the current study in Tembe Elephant Park's Closed Woodland 1. The observed change in species preference may possibly lead to changes in the species composition of the Closed Woodland on Sand subcommunities or it is the consequence of changes in species composition that have already occurred. In the current study the Closed Woodland on Sand community evaluated in 2004 by Gaugris (2008) was divided into two clearly defined subcommunities in 2010.

Cumulative canopy removal in the smaller size class (up to size class 4) was slightly higher in 2010 than in 2004, but utilisation in size classes 5 and 6 showed a marked increase in 2010. Size class 6 was utilised at very low levels in 2004 (3.92%) but in 2010 it contained the highest canopy removal (48.39%). A clear trend of increasing percentage utilisation with increasing tree diameter was evident, a trend confirmed by Matthews and Page (undated). This trend is visible throughout most of the surveyed communities. The utilisation values included damage of all ages. Therefore it was important to note that the majority of damage in size class 6 was more than 2 years old, thus the high utilisation value in the large size classes could possibly be ascribed to accumulated damage (O'Connor, 2010). Because elephant impact is cumulative, changes within a vegetation community, such as decline in species richness and biomass, are likely to increase over time (Roux & Bernard, 2007). One would expect to find the highest amount of damage by elephants in the higher size classes which consist of the larger trees as these were the individuals that the elephants would rub and lean against and possibly damage. For utilisation purposes, the foliage of tall trees is at a suitable level for browsing and if the foliage is too high, these would be the individuals they would push over in order to reach the fruits or leaflets. The relatively high level of damage or utilisation in the small size classes, especially size class 2 (20.38% canopy removal), was a point of concern in this subcommunity.

A change in species utilisation patterns under increased utilisation by elephants seems to be evident since the 1995 survey. A number of species observed in 2004 were highly targeted and damaged by elephants, such as *Psydrax locuples*, which was not utilised by elephants during the 2010 field survey. It is possible that *Psydrax locuples* was depleted by elephants and was now primarily available in the lower size classes and therefore not utilised by elephants. This species was browsed frequently by small herbivores but not by elephants. In 2004, it was the species with the highest canopy removal, but it only contributed towards 3.43% of the total utilisation and was a single event. *Dialium schlechteri* experienced a large increase in elephant utilisation, especially in the higher size classes and contributed to

54.52% of the total utilisation in 2010. This species was also mentioned as preferred by Matthews and Page (undated). Most of the damage observed in this species was the breaking of large branches and individuals being pushed over. Not only did the utilisation of *Dialium schlechteri* increase from 2004 to 2010 but the canopy volume available also almost doubled from 2004 levels. In 2004, *Sideroxylon inerme* had high elephant utilisation values in a variety of size classes but particularly in size class 2. The utilisation of this woody species declined since 2004 and during the 2010 survey it had moderate utilisation levels and only utilised in two size classes. Other heavily utilised woody species recorded in 2010, which have been reported in the literature as preferred elephant species, included: *Afzelia quanzensis*, *Albizia forbesii*, *Spirostachys africana* (Matthews & Page, undated), *Searsia gueinzii*, *Sclerocarya birrea* (De Boer *et al*., 2000; White & Goodman, 2009; Boundja & Midgley, 2009; Matthews & Page, undated) and *Dovyalis longispina.*

Cumulative utilisation by elephants within the Closed Woodland 1 increased from 8.27% (of all available canopy) in 2004 to 37.75% in 2010 (Table 9.1). That is more than a fourfold increase in elephant utilisation. Closed woodlands in the Tembe Elephant Park have been reported to contain higher elephant path densities than other communities (Shannon *et al*., 2009). Gaugris and Van Rooyen (2010a) found that the Closed Woodlands, in general, had the most elephant utilisation, primarily recent canopy removal, and the second oldest elephant damage. The high utilisation values in this subcommunity could be ascribed to the proximity to permanent water as the subcommunity is located next to the Muzi swamp (Shannon *et al*., 2009; Gaugris & Van Rooyen, 2010a). Nevertheless, the extent of the increase in elephant utilisation since 2004 is cause for concern.

9.3.2 Electivity

The four most preferred woody species in the Closed Woodland 1 in 2004 experienced notable decreases in available canopy volume and were no longer selected in 2010. There were however, some species in this subcommunity that were utilised and preferred in both surveys. Such species included *Schotia brachypetala*, *Ochna barbosae*, *Acacia burkei* and *Spirostachys africana.* These species have also been reported in other studies as being preferred by elephants (White & Goodman, 2009; Matthews & Page, undated). In terms of these species' position on the ranking list they increased in preference from 2004 to 2010. *Schotia brachypetala* is also one of the most preferred species, in terms of elephant utilisation and damage, in Hluhluwe-Imfolozi Park in KwaZulu-Natal, South Africa (Boundja & Midgley, 2009).

9.3.3 Relative utilisation

Each of the three surveys showed different woody species that were utilised by elephants at that time. In 1995, the elephants showed a great selection for *Acacia burkei.* In 2004 the species was still utilised and was ranked 10th in preference by the Electivity Index and currently (2010), this species is still utilised by elephant in the Closed Woodland 1 but it is ranked as second most preferred. At present *Dialium schlechteri* is the most utilised species with a relative utilisation of 54.52%. This species also had the highest relative utilisation value in 2004 but was not a preferred species at that time.

9.4 CONCLUSION

In the Closed Woodland 1 subcommunity there was a marked increase in elephant utilisation from 2004 to 2010. The subcommunity is located along the Muzi swamp, which is a source of permanent water, and elephants often concentrate in this region (Chapter 3). Any increase in the elephant population will therefore lead to a concomitant increase in the utilisation of this subcommunity.

CHAPTER 10

UTILISATION IN THE *ACACIA BURKEI* - *PSYDRAX LOCUPLES* CLOSED WOODLAND ON SAND

10.1 INTRODUCTION

The *Dialium schlechteri* - *Psydrax locuples* Closed Woodland on Sand community was subdivided into the two subcommunities with the *Strychnos decussata – Dialium schlechteri* Closed Woodland on Sand subcommunity (Closed Woodland 1, Chapter 9) more related to the Sand Forest communities and the *Acacia burkei* - *Psydrax locuples* Closed Woodland on Sand subcommunity (Closed Woodland 2), which is discussed in this chapter, more related to the Closed Woodland on Clay (Closed Woodland 3). Dominant species in the Closed Woodland on Clay such as *Spirostachys africana, Psydrax locuples, Acacia burkei* and *Grewia caffra* were also prevalent in the Closed Woodland 2 subcommunity.

This subcommunity was situated along the Muzi swamp with the majority of the sites located in the north-eastern section of the park. According to Muller and Matthews (2010) the large elephant breeding herds, which have a high utilisation intensity, occur mainly in the east of the park, although generally not as far north as where this plant subcommunity is located. Site 8 was however in a section along the Muzi swamp where elephant breeding herds often forage.

10.2 RESULTS

10.2.1 Elephant utilisation – 2010 survey

The cumulative[1] percentage canopy removal in 2010 increased linearly with an increase in the size classes (Figure 10.1). Size class 1 had very little utilisation, followed by size class 2

[1] Cumulative canopy removal percentage refers to the total volume of the canopy removed of all species expressed as a percentage of the available volume of only the utilised species.

and 3 with 3.07% and 13.28% canopy removal, respectively. Size class 6 had the highest canopy removal with 29.81%. A lower level of utilisation was found in size class 5 (19.00%) and high canopy removal was identifies in size class 4 (29.49%).

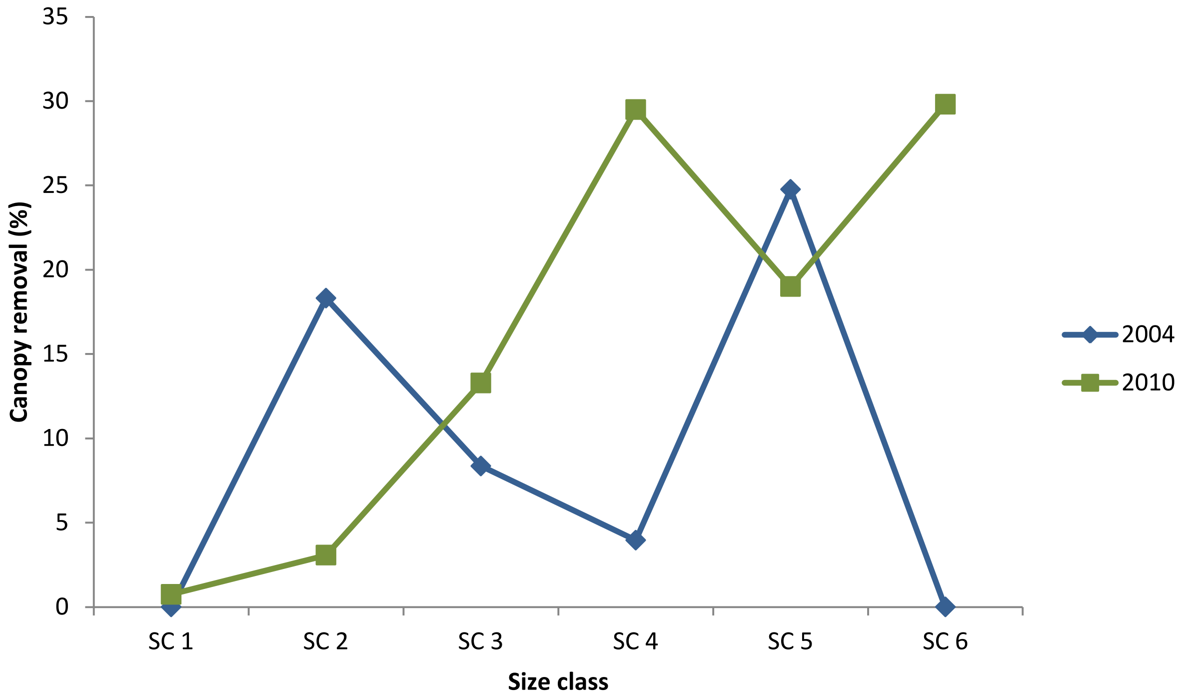

Figure 10.1 Cumulative percentage canopy volume (of utilised species) removed per size class (SC) in 2004 and 2010 in the Closed Woodland 2 subcommunity in the Tembe Elephant Park.

Sclerocarya birrea had the highest mean canopy removal in the Closed Woodland 2 in 2010 with a canopy removal of 20.84% followed by *Acalypha glabrata* with 20.63%. Both these species were utilised in a single site. Other woody species in this community which showed moderate levels of utilisation during the 2010 survey included *Spirostachys africana* (18.37%), *Strychnos madagascariensis* (18.67%), *Tabernaemontana elegans* (16.34%), *Afzelia quanzensis* (13.18%) and *Combretum molle* (13.42%) (Figure 10.2). *Spirostachys africana* was utilised throughout most of this woodland subcommunity as were *Dialium schlechteri* (with canopy removal of 10.60%) and *Grewia caffra* (7.27%) even though the utilisation levels of the latter species was low.

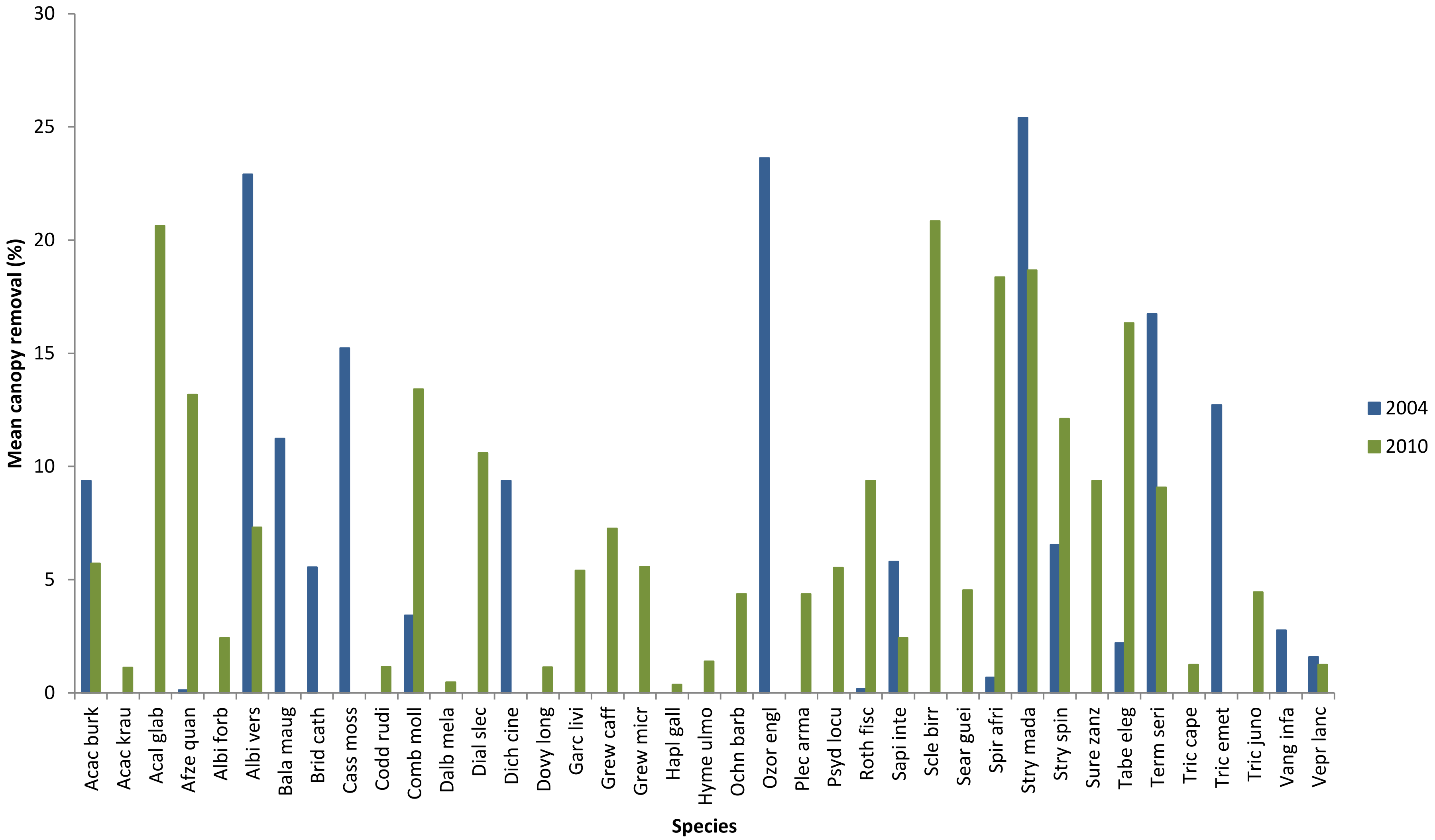

Figure 10.2 Woody species utilised by elephants in the Closed Woodland on Sand 2 community as recorded in 2004 (blue) and 2010 (green). Appendix A contains a list of abbreviations of all species names.

Table 10.1 Available canopy volume and removed canopy volume per utilised species within the Closed Woodland 2 for 2010 and 2004. Elephant utilisation is expressed as cumulative percentage utilised as well as a relative utilisation percentage

Species	2010				2004			
	Available (m^3/ha)	Removed (m^3/ha)	% Utilised	Relative utilisation (%)	Available (m^3/ha)	Removed (m^3/ha)	% Utilised	Relative utilisation (%)
Acacia burkei	7503	183	2.43	1.88	155	58	37.50	0.62
Acacia kraussiana	276	13	4.50	0.13	-	-	-	-
Acalypha glabrata	10	8	82.50	0.08	-	-	-	-
Afzelia quanzensis	2651	1398	52.73	14.35	5360	26	0.49	0.28
Albizia forbesii	289	28	9.75	0.29	-	-	-	-
Albizia versicolor	797	233	29.27	2.39	2542	2329	91.63	24.76
Balanites maughamii	-	-	-	-	818	368	44.94	3.91
Bridelia cathartica	-	-	-	-	184	41	22.20	0.43
Cassipourea mossambicensis	-	-	-	-	111	67	60.94	0.72
Coddia rudis	3	0	4.59	0.00	-	-	-	-
Combretum molle	9339	2492	26.69	25.59	6552	484	7.38	5.14
Dalbergia melanoxylon	63	1	1.89	0.01	-	-	-	-
Dialium schlechteri	2397	456	19.00	4.68	-	-	-	-
Dichrostachys cinerea	-	-	-	-	460	173	37.50	1.83
Dovyalis longispina	11	1	4.53	0.01	-	-	-	-
Garcinia livingstonei	1629	352	21.62	3.62	-	-	-	-
Grewia caffra	1089	88	8.10	0.91	-	-	-	-
Grewia microthyrsa	698	77	10.98	0.79	-	-	-	-
Haplocoelum gallaense	12	0	1.50	0.00	-	-	-	-

Hymenocardia ulmoides	196	11	5.56	0.11	-	-	-	-
Ochna barbosae	138	24	17.50	0.25	-	-	-	-
Ozoroa engleri	-	-	-	-	10	9	94.50	0.10
Plectroniella armata	251	44	17.50	0.45	-	-	-	-
Psydrax locuples	56	9	15.84	0.09	-	-	-	-
Rothmannia fischeri	354	133	37.50	1.36	6815	49	0.72	0.52
Sapium integerrimum	244	24	9.72	0.24	132	31	23.20	0.33
Sclerocarya birrea	594	495	83.37	5.08	-	-	-	-
Searsia gueinzii	382	62	16.23	0.64	-	-	-	-
Spirostachys africana	6282	1721	27.39	17.66	4831	133	2.75	1.41
Strychnos madagascariensis	964	297	30.83	3.05	2071	568	27.41	6.03
Strychnos spinosa	209	101	48.44	1.04	829	72	8.67	0.76
Suregada zanzibariensis	236	89	37.50	0.91	-	-	-	-
Tabernaemontana elegans	825	539	65.34	5.53	3153	278	8.83	2.96
Terminalia sericea	4086	837	20.48	8.59	20954	4197	20.03	44.62
Tricalysia capensis	111	6	5.00	0.06	-	-	-	-
Tricalysia junodii	13	2	17.79	0.02	-	-	-	-
Trichilia emetica	-	-	-	-	743	378	50.89	4.02
Vangueria infausta	-	-	-	-	113	13	11.07	0.13
Vepris lanceolata	370	19	5.00	0.19	2127	135	6.35	1.43
Total of utilised species	42074	9740	23.15		57959	9408	16.23	
Total of not utilised species	11877	0	0.00		23166	0	0.00	
Total available of all species	53951	9740	18.05		81125	9408	11.60	

Table 10.2 Mean utilisation per size class (SC) (expressed as % of canopy volume removed) for utilised Closed Woodland 2 species in 2010

Woody species	SC 1	SC 2	SC 3	SC 4	SC 5	SC 6
Acacia burkei	0.00	1.25	1.25	23.63	0.00	5.41
Acacia kraussiana	0.00	0.00	0.00	0.00	1.25	0.00
Acalypha glabrata	0.00	20.63	0.00	0.00	0.00	0.00
Afzelia quanzensis	0.00	0.00	15.63	19.36	4.38	12.78
Albizia forbesii	0.00	0.00	0.00	0.00	0.00	2.44
Albizia versicolor	0.00	0.00	0.00	0.00	0.00	7.32
Coddia rudis	0.47	1.25	0.00	0.00	0.00	0.00
Combretum molle	0.00	0.00	0.00	7.64	14.85	0.00
Dalbergia melanoxylon	0.00	0.00	0.48	0.00	0.00	0.00
Dialium schlechteri	0.00	0.13	3.16	0.35	9.23	7.98
Dovyalis longispina	0.00	1.25	0.00	0.00	0.00	0.00
Garcinia livingstonei	0.00	0.00	0.00	0.00	0.00	5.41
Grewia caffra	5.59	0.00	7.28	5.56	0.00	1.25
Grewia microthyrsa	0.00	1.25	0.00	4.38	4.37	1.25
Haplocoelum gallaense	0.37	0.00	0.00	0.00	0.00	0.00
Hymenocardia ulmoides	0.00	0.00	0.00	0.00	1.39	0.00
Ochna barbosae	0.00	0.00	0.00	0.00	0.00	4.37
Plectroniella armata	0.00	0.00	4.37	0.00	0.00	0.00
Psydrax locuples	0.00	0.00	1.19	6.39	0.00	0.00
Rothmannia fischeri	0.00	0.00	0.00	9.37	0.00	0.00
Sapium integerrimum	0.16	0.86	4.51	0.00	0.00	0.00
Sclerocarya birrea	0.00	0.00	0.00	0.00	20.84	0.00
Searsia gueinzii	0.00	1.25	4.09	0.00	0.00	0.00
Spirostachys africana	0.00	0.68	2.15	7.47	4.38	22.90
Strychnos madagascariensis	0.00	5.13	0.00	0.00	19.65	0.00
Strychnos spinosa	0.00	0.00	0.00	0.00	12.11	0.00
Suregada zanzibariensis	0.00	0.00	9.37	0.00	0.00	0.00
Tabernaemontana elegans	0.00	0.00	20.63	15.89	0.00	0.00
Terminalia sericea	0.00	0.00	0.49	2.44	3.48	7.64
Tricalysia capensis	0.00	0.00	0.00	0.00	1.25	0.00
Tricalysia junodii	0.00	0.00	0.00	0.00	6.19	0.00
Vepris lanceolata	0.00	0.00	1.25	0.00	0.00	0.00

Acacia burkei, Combretum molle, Spirostachys africana and *Terminalia sericea* were the woody species with the highest availability in terms of canopy volume (Table 10.1) and, except for *Acacia burkei*, were also the species contributing most to canopy utilisation. A diversity of species, not just individuals, was utilised in the large size classes especially size class 6 (Table 10.2).

Figure 10.3 illustrates the cumulative percentage canopy volume removed amongst the different survey sites. Site 24 had the highest percentage removal of utilised species (27.07%) followed by site 8 (23.09%). Site 25 had the lowest cumulative canopy removal percentage with 15.48% of the canopy of the utilised species removed. The mean cumulative canopy removal of the Closed Woodland 2 was 23.15% for 2010. The total canopy removal in the Closed Woodland on Sand 2, in terms of all available woody volume was 18.05% (Table 10.2, Figure 10.4).

10.2.2 Elephant utilisation – 2004 survey

Cumulative canopy removal in the small size classes, especially size class 2, decreased since 2004 (Figure 10.1). Size class 4 and 6 had a notable increase in elephant utilisation in 2010 compared to the 8.35% (size class 4) and no utilisation in size class 6 in 2004.

Strychnos madagascariensis, *Ozoroa engleri* and *Albizia versicolor* had high to moderate utilisation levels in 2004 with 25.41%, 23.63% and 22.91% canopy removed, respectively (Figure 10.2). Other woody species with moderate utilisation, as recorded in 2004, include *Terminalia sericea* (16.74%), *Cassipourea mossambicensis* (15.23%) and *Trichilia emetica* (12.72%). All six these woody species, experienced a decline in elephant utilisation from 2004 to 2010 or were only utilised in 2004. *Strychnos madagascariensis, Terminalia sericea* and *Combretum molle* were utilised by elephants in a number of size classes and also in most of the Closed Woodland 2 sites (Table 10.3). *Rothmannia fischeri* had a major increase of elephant utilisation since 2004 as the percentage canopy removal increased from 0.72% to 37.5% in 2010. A sturdy decrease in available canopy volume since 2004 should be noted.

The sampling site with the highest impact in 2004 was site 24 with a cumulative canopy removal of 29.71% and sampling site 8 experienced the lowest elephant utilisation with the cumulative canopy removal of the utilised species being only 3.53% (Figure 10.3). In 2004, the mean cumulative canopy removal for the Closed Woodland 2 subcommunity was 16.23%. This was the community with the second highest elephant utilisation in 2004 and in

2010 it was one of the communities with the lowest elephant utilisation. The total canopy removal in the Closed Woodland on Sand 2, in terms of all available woody volume was 11.60% in 2004 (Table 10.2,Figure 10.4). The percentage canopy removal in the Closed Woodland 2 sites from 2004 and 2010 is not significantly different (p=0.447).

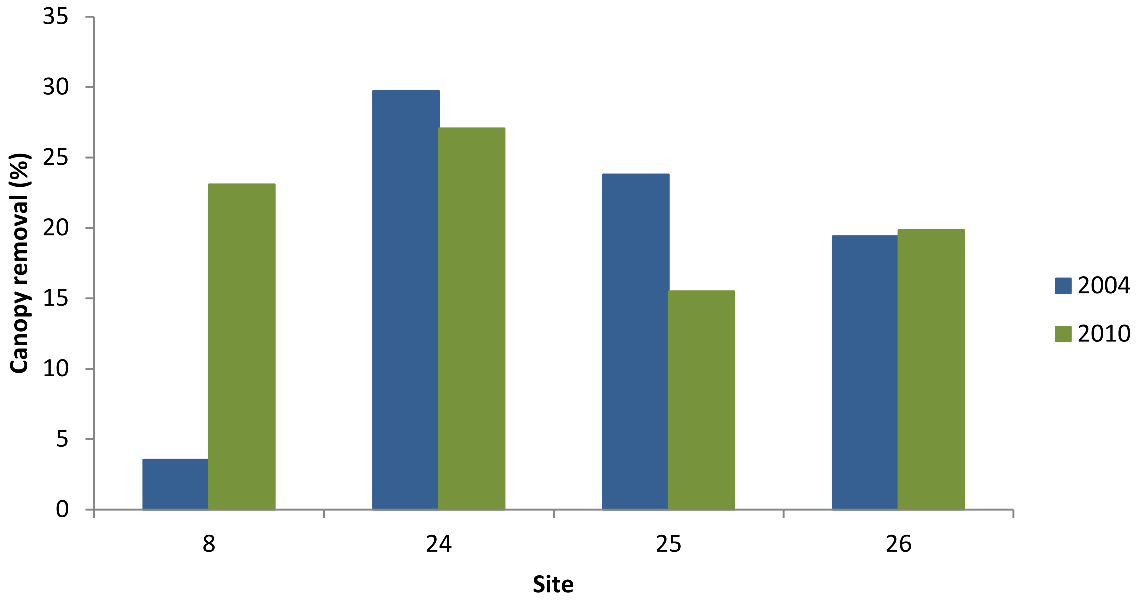

Figure 10.3 Cumulative percentage canopy removal (of utilised species only) by elephants at the four Closed Woodland 2 subcommunity sites as surveyed in 2004 (blue) and 2010 (green).

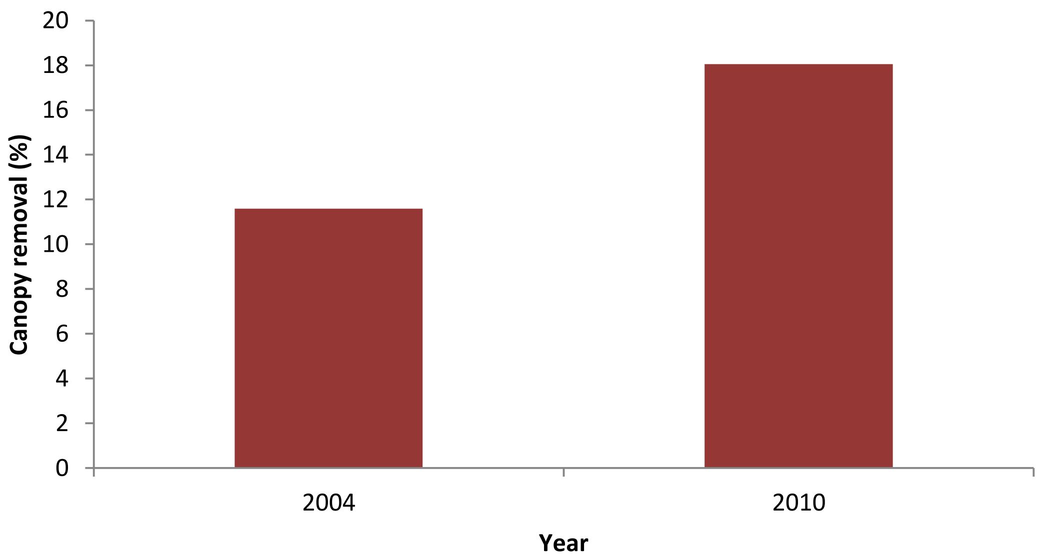

Figure 10.4 Cumulative percentage canopy removal (expressed as percentage of all species) in the Closed Woodland 2 subcommunity for 2004 and 2010.

10.2.3 Elephant utilisation – 1995 survey

Figure 10.5 illustrates the relative utilisation per species (canopy volume removed expressed as a percentage of all canopy removed) by elephant for all three surveys. In each of the surveys, a different complement of species emerged as most utilised by elephants in the Closed Woodland 2 subcommunity. In 1995 *Albizia adianthifolia* (22.87%), *Albizia versicolor* (19.27%), *Terminalia sericea* (15.40%), *Acacia burkei* (11.81%) and *Sclerocarya birrea* (11.31%) contributed most to canopy removal by elephants. Almost ten years later, in 2004, *Terminalia sericea* (44.62%) and *Albizia versicolor* (24.76%) were the most utilised species, but *Albizia adianthifolia* was no longer utilised. *Combretum molle* (5.14%), *Strychnos madagascariensis* (6.03%) and *Trichilia emetica* (4.02%) had moderate relative utilisation values in the 2004 survey. *Combretum molle* had the highest relative utilisation in 2010 with 25.59%. Other species which also contributed substantially to canopy removal by elephants in 2010 and were also utilised in one or both of the other surveys included *Spirostachys africana* (17.66%), *Afzelia quanzensis* (14.35%), *Terminalia sericea* (8.59%), *Tabernaemontana elegans* (5.53%) and *Dialium schlechteri* (4.68%).

10.2.4 Elephant preferences

There was a clear lack of agreement in the most preferred species between 2004 and 2010. The most preferred species according to Ivlev's Electivity Index in 2010 were *Sclerocarya birrea, Acalypha glabrata, Tabernaemontana elegans and Afzelia quanzensis* (Table 10.4), whereas the most preferred species in 2004 were *Cassipourea mossambicensis, Albizia versicolor, Trichilia emetica* and *Balanites maughamii* (Table 10.5). In 2010, *Cassipourea mossambicensis* and *Trichilia emetica* were not recorded in the Closed Woodland 2 while *Balanites maughamii* was not utilised by elephants. In contrast, the preferred species in 2010, *Afzelia quanzensis* and *Tabernaemontana elegans*, were utilised by elephants in the Closed Woodland 2 but the Ivlev's Electivity Index was negative, therefore they were not considered selected for by the elephants in 2004. There were two species which were selected by elephants in both the surveys, based on Ivlev's Electivity Index, and these were *Strychnos madagascariensis* and *Albizia versicolor*.

Albizia versicolor moved from the second position in 2004 down to the 8th position in 2010, based on the electivity index. *Spirostachys africana* moved up in the table in 2010 and is currently ranked 9th (16th in 2004) on the ranking list in the Closed Woodland 2 and changed from being avoided to marginally preferred. *Rothmannia fischeri* increased in preference by the elephants as it was ranked 10th in 2004 and 2nd in 2010. It also had a much higher electivity index in 2010.

Table 10.3 Mean utilisation per size class (SC) (expressed as % of canopy volume removed) for utilised Closed Woodland 2 species in 2004

Woody species	SC 1	SC 2	SC 3	SC 4	SC 5	SC 6
Acacia burkei	0.00	0.00	0.00	9.37	0.00	0.00
Afzelia quanzensis	0.00	20.62	0.00	0.00	0.00	0.00
Albizia versicolor	0.00	0.00	0.00	0.00	22.91	0.00
Balanites maughamii	0.00	0.00	0.00	0.00	11.24	0.00
Bridelia cathartica	0.00	0.00	5.56	0.00	0.00	0.00
Cassipourea mossambicensis	0.00	0.00	0.00	15.23	0.00	0.00
Combretum molle	0.00	0.00	2.37	4.25	2.88	0.00
Dichrostachys cinerea	0.00	0.00	9.38	0.00	0.00	0.00
Ozoroa engleri	0.00	23.62	0.00	0.00	0.00	0.00
Rothmannia fischeri	0.00	0.00	0.00	0.23	0.00	0.00
Sapium integerrimum	0.00	0.00	6.17	0.00	0.00	0.00
Spirostachys africana	0.00	0.00	1.59	0.00	0.00	0.00
Strychnos madagascariensis	0.00	0.00	12.86	20.50	12.36	0.00
Strychnos spinosa	0.00	0.00	1.25	5.41	0.00	0.00
Tabernaemontana elegans	0.00	0.00	0.00	0.00	3.61	0.00
Terminalia sericea	0.00	0.00	0.00	1.84	17.85	0.00
Trichilia emetica	0.00	0.00	0.00	0.00	12.72	0.00
Vangueria infausta	0.00	0.00	2.77	0.00	0.00	0.00
Vepris lanceolata	0.00	0.00	20.63	0.00	0.00	0.00

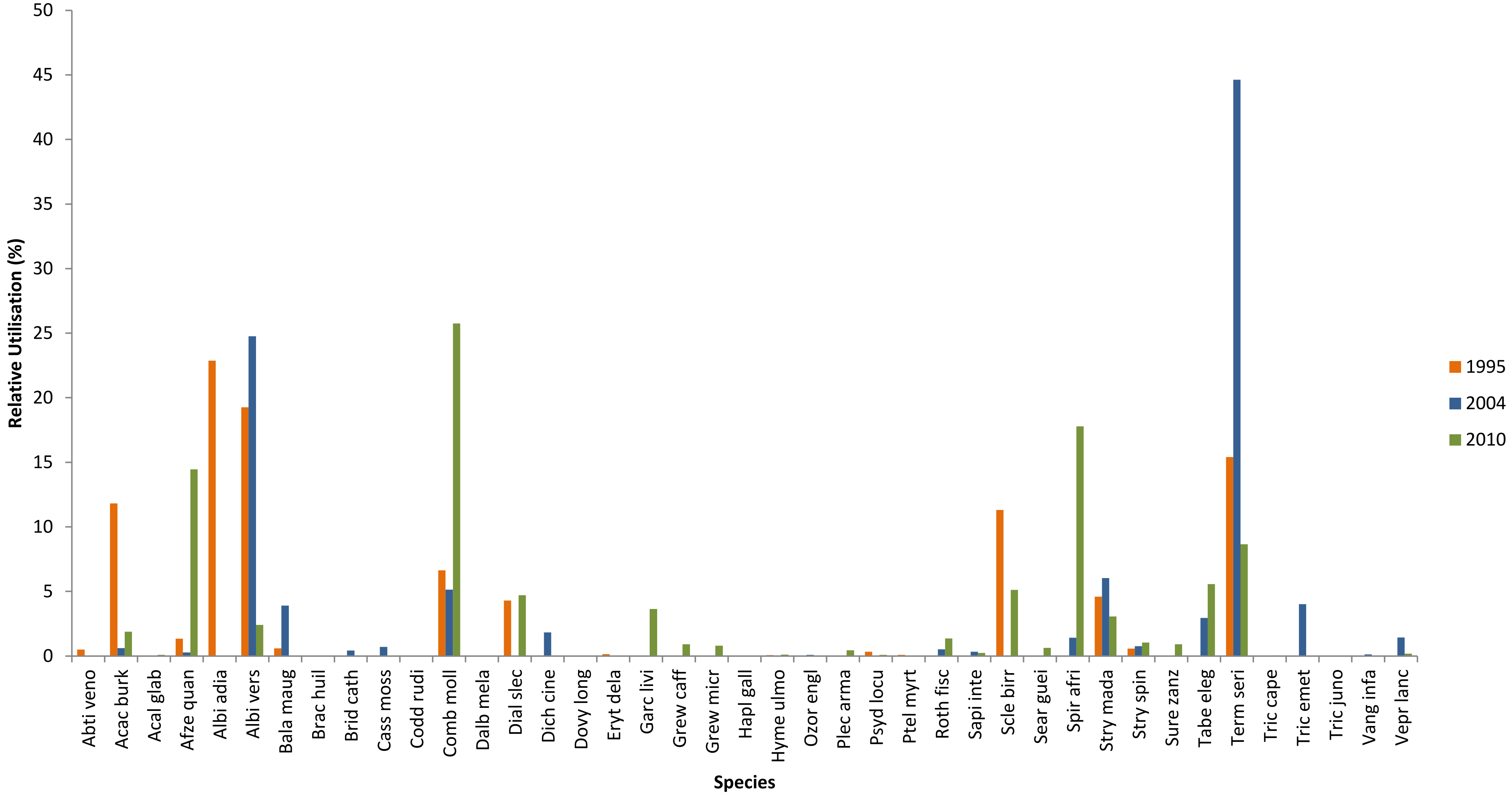

Figure 10.5 Relative utilisation of various species by elephants in 1995, 2004 and 2010 in the Closed Woodland on Sand 2 community of Tembe Elephant Park.

Table 10.4 Elephant preferences for woody species in 2010 in terms of Ivlev's Electivity Index (Ivlev, 1961), the Forage Ratio (Cock, 1978) and the Rank Procedure method (Johnson, 1980). The woody species recorded within the Closed Woodland 2 subcommunity in 2010 are ranked from most preferred to least preferred based on Ivlev's Electivity Index

Woody species	Ivlev's electivity index	Forage ratio	Rank Procedure method
Sclerocarya birrea	0.58	3.77	1
Acalypha glabrata	0.58	3.73	3
Tabernaemontana elegans	0.49	2.96	2
Afzelia quanzensis	0.41	2.39	5
Suregada zanzibariensis	0.26	1.70	1
Rothmannia fischeri	0.26	1.70	2
Strychnos madagascariensis	0.17	1.40	7
Albizia versicolor	0.14	1.32	5
Spirostachys africana	0.11	1.24	6
Combretum molle	0.09	1.21	6
Acacia kraussiana	0.01	1.01	8
Garcinia livingstonei	-0.01	0.98	8
Terminalia sericea	-0.04	0.93	7
Dialium schlechteri	-0.08	0.86	8
Plectroniella armata	-0.12	0.79	5
Ochna barbosae	-0.15	0.74	4
Tricalysia junodii	-0.15	0.74	7
Searsia gueinzii	-0.15	0.73	8
Psydrax locuples	-0.24	0.61	6
Strychnos spinosa	-0.32	0.52	10
Grewia microthyrsa	-0.34	0.50	10
Albizia forbesii	-0.39	0.44	7
Sapium integerrimum	-0.40	0.43	7
Grewia caffra	-0.46	0.37	12
Vepris lanceolata	-0.63	0.23	11
Tricalysia capensis	-0.63	0.23	9
Dovyalis longispina	-0.66	0.21	7
Coddia rudis	-0.71	0.17	7
Acacia burkei	-0.80	0.11	14
Hymenocardia ulmoides	-0.84	0.09	13
Dalbergia melanoxylon	-0.84	0.09	9
Haplocoelum gallaense	-0.89	0.06	9

Table 10.5 Elephant preferences for woody species in 2004 in terms of Ivlev's Electivity Index (Ivlev, 1961), the Forage Ratio (Cock, 1978) and the Rank Procedure method (Johnson, 1980). The woody species recorded within the Closed Woodland 2 subcommunity in 2004 are ranked from most preferred to least preferred based on Ivlev's Electivity Index

Woody species	Ivlev's electivity index	Forage ratio	Rank Procedure method
Cassipourea mossambicensis	0.68	5.25	3
Albizia versicolor	0.68	5.19	4
Trichilia emetica	0.63	4.39	1
Balanites maughamii	0.59	3.88	3
Ozoroa engleri	0.43	2.48	6
Strychnos madagascariensis	0.41	2.36	2
Dichrostachys cinerea	0.37	2.19	3
Terminalia sericea	0.27	1.73	6
Bridelia cathartica	0.17	1.40	5
Vangueria infausta	-0.02	0.95	7
Strychnos spinosa	-0.15	0.74	6
Tabernaemontana elegans	-0.17	0.71	5
Combretum molle	-0.22	0.64	7
Vepris lanceolata	-0.29	0.55	6
Sapium integerrimum	-0.41	0.42	7
Spirostachys africana	-0.64	0.22	8
Acacia burkei	-0.77	0.13	9
Rothmannia fischeri	-0.88	0.06	10
Afzelia quanzensis	-0.93	0.04	11

10.3 DISCUSSION

10.3.1 Percentage Canopy Removal

The damage caused by elephants within the Closed Woodland 2 was predominantly through the breaking of branches and the uprooting of trees. Similar results were obtained by Boundja and Midgley (2009) and Valeix *et al*. (2011) in other reserves with a high density of elephants. Debarking of trees by elephants was expected in the woodland communities (Ihwagi *et al*., 2009; Boundja & Midgley, 2009) because elephants are known to strip the bark of some of the species which were highly utilised and available in this community in 2010. These species include Acacia burkei (Hiscocks, 1999; White & Goodman, 2009) and Sclerocarya birrea (O'Connor, 2010). However bark stripping was not observed in the Tembe Elephant Park at all, as mentioned in previous chapters.

Using the data obtained by Gaugris[2] in 2004 (Gaugris, 2008), a comparison with 2010 could be made in terms of the removal of canopy volume by elephants. The number of woody species utilised in the Closed Woodland 2 by elephants increased from 19 species in 2004 to 32 species in 2010 (Figure 10.2). Only 12 woody species were common to both periods. In 2010, 20 woody species were recorded with elephant damage in the Closed Woodland on Sand 2 that were not identified in 2004 as being utilised by elephants. Conversely *Balanites maughamii, Bridelia cathartica, Cassipourea mossambicensis, Dichrostachys cinerea, Trichilia emetica* and *Vangueria infausta*, amongst others, were utilised in 2004 but not in 2010. Some woody species were also identified in the 2010 surveys with severe elephant utilisation, which differed from the 2004 dataset.

Figure 10.1 illustrates the distribution of cumulative canopy removal in the Closed Woodland 2 across the different size classes. Elephant utilisation declined from 2004 to 2010 in the lower size classes. It was encouraging to observe a decrease in elephant utilisation in size class 2 and 3, especially size class 2, as these are the saplings that need to grow into woody adults. On the other hand, the increase in elephant utilisation within the larger size classes is a cause for concern. The trend of increasing canopy removal with increasing stem diameter is expected as large individuals are those that elephants will choose for browsing or rubbing against (Ben-Shahar, 1993). An increase in elephant utilisation with an increase in size class was also reported by Dublin *et al*. (1990) in the Serengeti-Mara Woodlands and Boundja and Midgley (2009) in Hluhluwe-Imfolozi Park, South Africa. The increase in

[2] Dr J.Y. Gaugris: Centre for Wildlife Management, University of Pretoria, Pretoria 0002, South Africa. Email: jeromegaugris@florafaunaman.com

elephant utilisation within size class 4 and 6 is probably not only because of a larger elephant population and therefore more utilisation, but it could also be ascribed to accumulated damage (Shannon *et al*., 2008; O'Connor, 2010). Within these large size classes a large proportion of the damage by elephants was old damage, i.e. more than 2 years prior to the surveys. Consequently, the percentage canopy removal in 2010 (as seen in Figure 10.1) could include some of the damage that was already recorded in 2004. In addition, the large trees had excessive, regular browsing damage (Calenge *et al*., 2002), which could be the reason why size class 6, most of the time, had the largest cumulative canopy removal.

Sclerocarya birrea was the woody species in 2010 with the highest percentage canopy removal (83.37%, Table 10.2) although it constituted only 5.08% of the utilised canopy volume. It was not available in the Closed Woodland 2 during the 2004 surveys and in 2010 it was not available throughout the community. However, the high levels of utilisation on *Sclerocarya birrea* were supported by a number of studies. Duffy *et al*. (2002) found that *Sclerocarya birrea* was threatened in the Pongola Game Reserve, South Africa, and the proportion of individuals in the large size classes was found to be much higher than those in the small size classes. In the Tembe Elephant Park, the majority of *Sclerocarya birrea* individuals were large individuals as very few seedlings and saplings were recorded. The *Sclerocarya birrea* population has also declined in the Kruger National Park, South Africa from 2001 to 2008 (Helm *et al*., 2009) as it is one of the species selected by elephants (Shannon *et al*., 2008).

Dialium schlechteri was moderately utilised throughout the Closed Woodland 2 according to the 2010 survey but not at all in 2004 although it was available in most of the community. This raises the question whether a new preference has been developed for *Dialium schlechteri* by elephants? Overall, an increase in *Dialium schlechteri* utilisation was observed in several communities and this could be related to an increase in the available canopy volume of this species.

Observations over a couple of years by management in the park noticed a decline in *Albizia* species (*Albizia versicolor*, *Albizia adianthifolia* and *Albizia forbesii*). One of the aims of the study was to determine whether this was the actual case. Matthews and Page (undated) considered *Albizia* species to be abundant in the Tembe Elephant Park and found *Albizia adianthifolia* to have the highest percentage of canopy removed, in terms of utilised species, and *Albizia versicolor* the third highest percentage in 1995. In 2004, *Albizia versicolor* was available in the majority of Closed Woodland 2 sites and it had an utilisation value of 22.91%

(Figure 10.2), which made it the third most utilised species during that survey. However, in 2010 the availability of this species declined and so did the utilisation value. From an observer's point of view, one would not say that the *Albizia* species were abundant in the Tembe Elephant Park in 2010. In the Maputo Elephant Reserve, Mozambique, *Albizia versicolor* was utilised by elephants but not in a way that it raised concern, it was not preferred by elephants at all (De Boer *et al*., 2000). Other species that showed an increase in elephant utilisation since 2004 or were newly utilised in 2010 included *Dalbergia melanoxylon, Grewia caffra*, *Grewia microthyrsa* and *Spirostachys africana*. The utilisation of these species by elephants has been reported by Hiscocks (1999, first three species mentioned) and Shannon *et al*. (2008, latter species mentioned).

The total percentage canopy removed increased from 11.60% in 2004 to 18.05% in 2010 (Table 10.2), which represents an increase of 56% on the 2004 level. Compared to the other vegetation communities in the Tembe Elephant Park the Closed Woodland 2 was one communities/subcommunties with the highest elephant utilisation in 2004. The high level of utilisation of the closed woodlands in the Tembe Elephant Park is substantiated by higher elephant path densities than in other communities (Shannon *et al*., 2009). Furthermore, Gaugris and Van Rooyen (2010a) found that the Closed Woodlands, in general, had the highest amount of elephant utilisation and the Closed Woodland on Sand in particular had the second highest amount of recent canopy removal and the highest amount of old elephant damage. The current study showed that the absolute canopy volume that had been removed was approximately the same in 2004 and 2010 (9 408 m^3/ha in 2004 versus 9 740 m^3/ha in 2010). However, the total available canopy volume in 2010 was about a third less than in 2004 (81 125 m^3/ha in 2004 versus 53 951 m^3/ha in 2010).

10.3.2 Electivity

Sclerocarya birrea was not utilised in 2004, but was the most selected species in the Closed Woodland 2 subcommunity in 2010 with an Ivlev Electivity Index (EI) of 0.58. A possible reason for this was that the only big individual in the community was so badly damaged by elephants that almost the whole canopy was removed. As the ratio uses available canopy volume together with canopy volume removed, it made *Sclerocarya birrea* a highly preferred species because the one available individual was severely damaged. However, a number of other studies also found *Sclerocarya birrea* to be highly preferred by elephants (De Boer *et al*., 2000; Duffy *et al*., 2002; Shannon *et al*., 2008; Helm *et al*., 2009; White & Goodman, 2009; Boundja & Midgley, 2009; Matthews & Page, undated).

In 2004, *Albizia versicolor* was ranked the sixth most preferred species and it had an Electivity Index of 0.63. In 2010 *Albizia versicolor* was the eighth most preferred woody species by elephants with an EI of only 0.14. This could possibly be ascribed to the small canopy volume that remained as well as the absence of canopy in the elephant preferred size classes. The fact that *Albizia versicolor* was highly preferred by elephants in the Closed Woodland 2 of Tembe Elephant Park, prior to the 2010 survey, is supported by Matthews and Page (undated) in the park and Boundja and Midgley (2009) in Hluhluwe-Imfolozi Park. The latter study *Albizia versicolor* was the most preferred species for branch breaking and toppling (Boundja & Midgley, 2009).

Dublin *et al*. (1990) contend that the change in woody species selection of elephants may be a matter of availability rather than actual preference. In all probability changes in selection is a combination of availability and preference. Ben-Shahar (1993) and O'Connor *et al*. (2007) argue that elephants utilise their preferred species to such an extent that the species' available canopy decreases to such low levels that the species is no longer preferred and subsequently, they move on to a new species and form a new selection. This appears to be evident in the Closed Woodland 2 community, especially for *Albizia versicolor* and *Albizia adianthifolia.*

10.3.3 Relative Utilisation

The distribution of woody species utilisation across the 15 year time period clearly illustrated some changes in elephant utilisation pattern in the Closed Woodland 2 (Figure 10.6). In the 1995 survey five woody species contributed more than 10% to the relative utilisation, two species in 2004 and four species in 2010. There was some agreement in species between years although each survey had its own main species that stood out. Woody species that were utilised in all three surveys included *Albizia versicolor*, *Terminalia sericea*, *Combretum molle, Strychnos madagascariensis*, *Acacia burkei* and *Strychnos spinosa. Albizia versicolor* showed a decrease in availability and this was accompanied by a change in elephant utilisation. In 1995 and 2004 it was heavily utilised and in 2010 there were few individuals available to actually have elephant utilisation.

10.4 CONCLUSION

Elephant utilisation in the Closed Woodland 2 increased from 2004 to 2010, by approximately 56%. In comparison with other communities' utilisation values as recorded in 2010, this community was not too badly damaged by the large herbivore. Woody species that are considered threatened by elephants within this particular community comprised *Albizia versicolor*, *Rothmannia fischeri*, *Sclerocarya birrea* and *Tabernaemontana elegans*.

CHAPTER 11

UTILISATION IN THE *SPIROSTACHYS AFRICANA* - *EUCLEA NATALENSIS* CLOSED WOODLAND ON CLAY

11.1 INTRODUCTION

The *Spirostachys africana* - *Euclea natalensis* Closed Woodland on Clay community (also referred to as Closed Woodland 3) is situated in the south of the Tembe Elephant Park and mainly in the east, towards the Muzi swamp. This particular vegetation unit is generally located close to permanent water, such as the Muzi swamp and pans. The Closed Woodland 3 is also the only vegetation unit not occurring on sand. This community is closely related to Closed Woodland 2 by the many woody species that are common to both vegetation units.

Nyala, impala and rhinoceros (black and white) were commonly observed within this vegetation unit. The sites sampled within the community were generally not very dense but badly damaged.

11.2 RESULTS

11.2.1 Elephant utilisation – 2010 survey

The cumulative[1] percentage canopy removal in 2010 increased fairly linearly with an increase in the size classes (Figure 11.1). A similar trend was also reported for the other closed woodlands. The highest cumulative percentage canopy removal was found in the largest size classes with 34.48% and 64.59% canopy removal (of utilised species) in size class 5 and 6, respectively. The canopy removal by elephants in size class 3 (27.63%) was

[1] Cumulative canopy removal percentage refers to the total volume of the canopy removed of all species expressed as a percentage of the available volume of only the utilised species.

amongst the highest of all (sub)communities for the particular size class. Size class 1 had the least elephant utilisation with 4.08% canopy of utilised species removed followed by size class 2 with 4.78%.

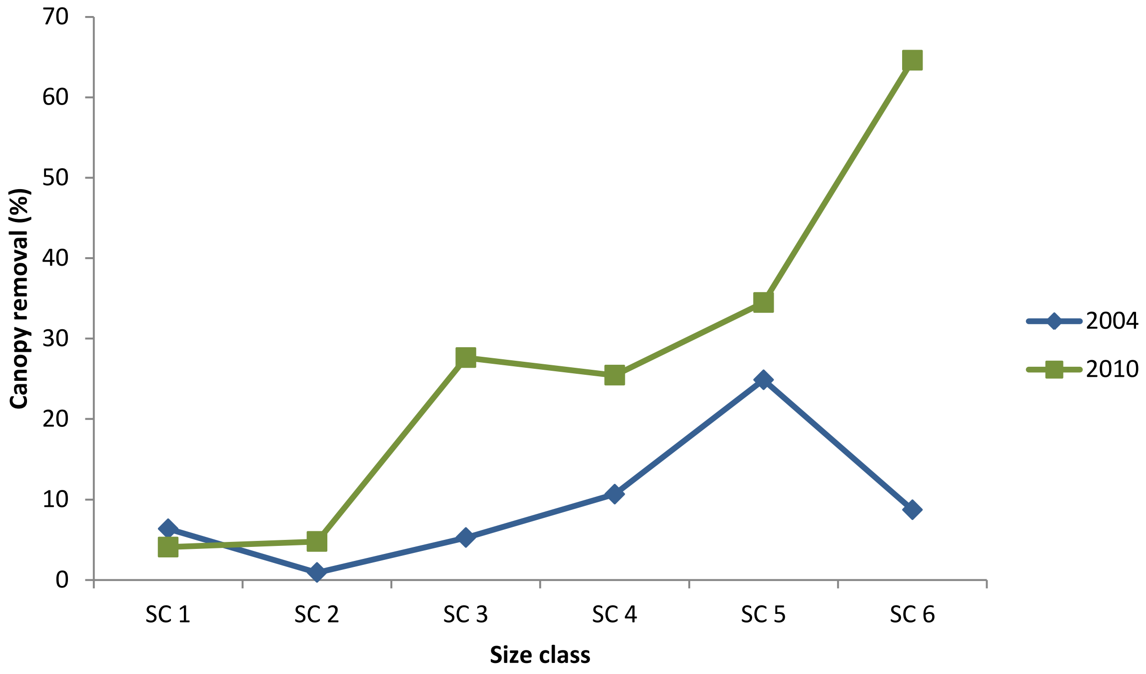

Figure 11.1 Cumulative percentage canopy volume (of utilised species) removed per size class (SC) in 2004 and 2010 in Closed Woodland 3 in the Tembe Elephant Park.

Figure 11.2 illustrates the mean canopy removal of all elephant utilised woody species across the Closed Woodland 3 sample sites. The high canopy removal values in 2010 are notable (Table 11.1). *Afzelia quanzensis* had the highest utilisation value with 34.59% canopy removed. This woody species was only utilised in the large size classes with 23.62% in size class 5 and 10.96% in size class 6 (Table 11.2). *Acacia burkei*, *Spirostachys africana* and *Schotia brachypetala* were also highly utilised with canopy removal values of 34.27%, 29.53% and 28.00% respectively. Other moderately utilised species within Closed Woodland 3 include *Strychnos spinosa* (24.98%), *Capparis tomentosa* (15.63%) and *Combretum molle* (15.62%). Most of these species were utilised throughout the community. However, *Capparis tomentosa* and *Combretum molle* were only utilised in a single site. *Dialium schlechteri*, *Grewia caffra*, *Spirostachys africana*, *Strychnos madagascariensis* and *Terminalia sericea* were utilised by elephants in a range of size classes.

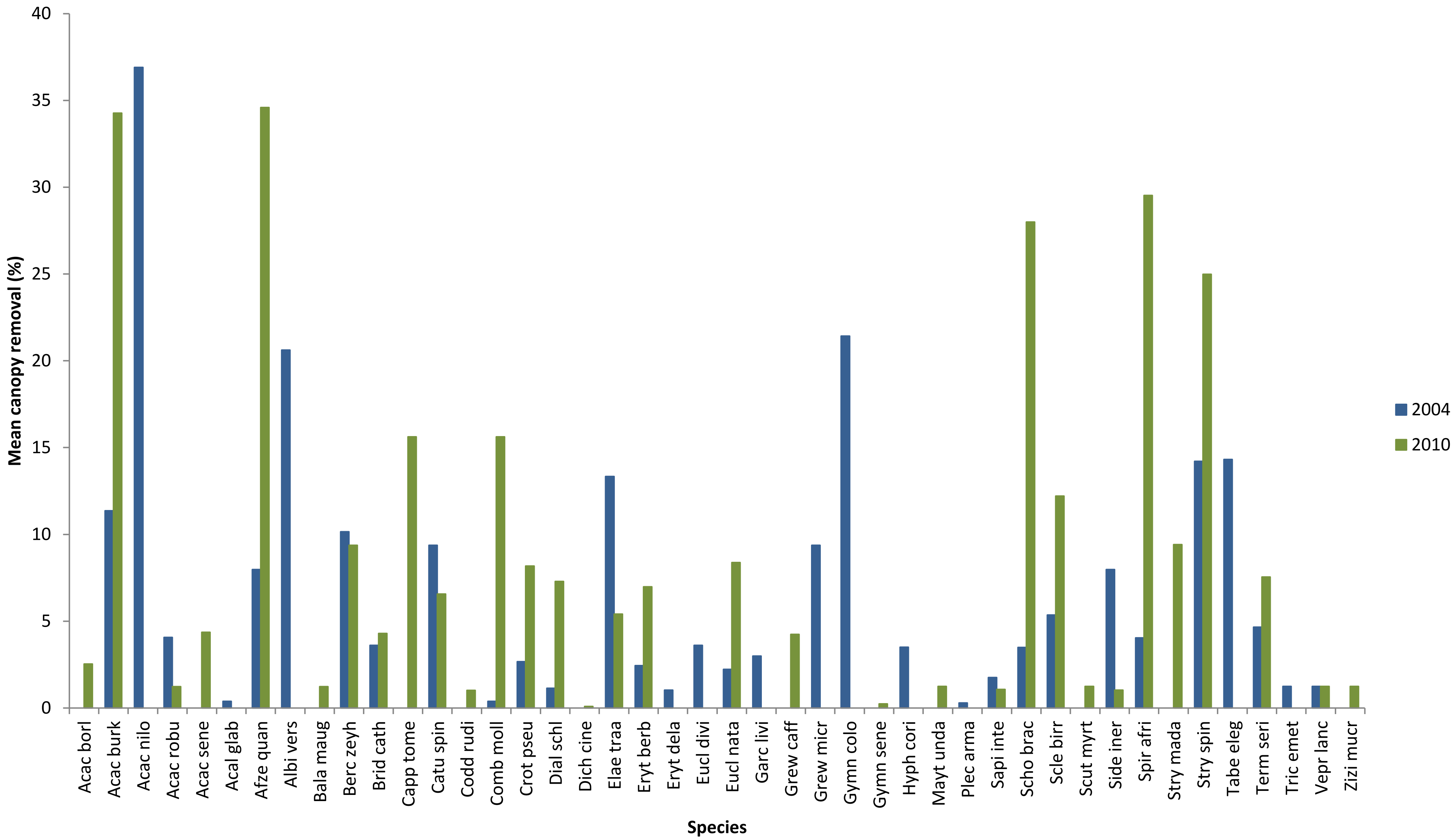

Figure 11.2 Woody species utilised by elephants in the Closed Woodland 3 subcommunity as recorded in 2004 (blue) and 2010 (green). Appendix A contains a list of abbreviations of all species names.

Table 11.1 Available canopy volume and removed canopy volume per utilised species within the Closed Woodland on Clay community for 2010 and 2004. Elephant utilisation is expressed as cumulative percentage utilised as well as a relative utilisation percentage

Species	2010				2004			
	Available (m^3/ha)	Removed (m^3/ha)	% Utilised	Relative utilisation (%)	Available (m^3/ha)	Removed (m^3/ha)	% Utilised	Relative utilisation (%)
Acacia borleae	37	4	10.15	0.03	-	-	-	-
Acacia burkei	537	176	32.85	1.37	16813	1727	10.27	14.62
Acacia nilotica	-	-	-	-	190	159	83.71	1.34
Acacia robusta	289	14	4.95	0.11	42	7	16.28	0.06
Acacia senegal	113	20	17.47	0.15	-	-	-	-
Afzelia quanzensis	630	538	85.41	4.18	2356	753	31.94	6.37
Albizia versicolor	-	-	-	-	1	1	82.50	0.01
Balanites maughamii	82	4	4.91	0.03	-	-	-	-
Berchemia zeyheri	55	21	37.50	0.16	291	118	40.63	1.00
Bridelia cathartica	81	14	17.19	0.11	166	24	14.44	0.20
Capparis tomentosa	40	25	62.50	0.19	-	-	-	-
Catunaregam spinosa	2	1	26.25	0.00	53	20	37.50	0.17
Coddia rudis	46	2	4.07	0.01	-	-	-	-
Combretum molle	3	2	62.50	0.01	80	1	1.55	0.01
Croton pseudopulchellus	339	111	32.71	0.86	555	59	10.67	0.50
Dialium schlechteri	676	177	26.10	1.37	83	4	4.56	0.03
Dichrostachys cinerea	20	0	0.38	0.00	-	-	-	-
Elaeodendron traansvaalensis	435	94	21.62	0.73	8027	1727	21.52	14.62
Erythrococca berberidea	377	105	27.92	0.82	1026	101	9.80	0.85
Erythroxylum delagoense	-	-	-	-	305	13	4.12	0.11
Euclea divinorum	-	-	-	-	1309	189	14.44	1.60

Euclea natalensis	2183	732	33.55	5.69	666	31	4.69	0.26
Garcinia livingstonei	-	-	-	-	295	35	11.98	0.30
Grewia microthyrsa	-	-	-	-	421	158	37.50	1.34
Grewia caffra	54	8	13.84	0.06	-	-	-	-
Gymnosporia senegalensis	8	0	0.95	0.00	-	-	-	-
Gymnanthemum coloratum	-	-	-	-	140	31	22.29	0.26
Hyphaene coriacea	-	-	-	-	163	23	14.02	0.19
Maytenus undata	12	1	5.00	0.00	-	-	-	-
Plectroniella armata	-	-	-	-	620	7	1.15	0.06
Sapium integerrimum	47	2	4.29	0.02	785	55	7.02	0.47
Schotia brachypetala	230	65	28.26	0.51	13826	1933	13.98	16.36
Sclerocarya birrea	248	35	14.05	0.27	193	41	21.42	0.35
Scutia myrtina	287	14	5.00	0.11	-	-	-	-
Sideroxylon inerme	147	6	4.15	0.05	32	10	31.94	0.09
Spirostachys africana	20792	9687	46.59	75.29	34150	2871	8.41	24.31
Strychnos madagascariensis	107	40	37.67	0.31	-	-	-	-
Strychnos spinosa	808	143	17.73	1.11	454	54	11.80	0.45
Tabernaemontana elegans	-	-	-	-	2384	1079	45.25	9.13
Terminalia sericea	2227	673	30.19	5.23	3039	567	18.64	4.80
Trichilia emetica	-	-	-	-	141	7	5.00	0.06
Vepris lanceolata	1396	70	5.00	0.54	193	10	5.00	0.08
Ziziphus mucronata	1710	86	5.00	0.66	-	-	-	-
Total of utilised species	34013	12867	37.83		88795	11812	13.30	
Total of not utilised species	3188	0	0.00		11069	0	0.00	
Total available of all species	37201	12867	34.59		99864	11812	11.83	

Table 11.2 Mean utilisation per size class (SC) (expressed as % of canopy volume removed) for the Closed Woodland 3 species in 2010

Woody Species	SC 1	SC 2	SC 3	SC 4	SC 5	SC 6
Acacia borleae	0.00	0.02	4.37	0.00	0.00	0.00
Acacia burkei	0.00	20.62	0.00	0.00	13.88	0.00
Acacia robusta	0.00	1.25	0.00	1.25	0.00	0.00
Acacia senegal	0.00	0.00	0.00	4.37	0.00	0.00
Afzelia quanzensis	0.00	0.00	0.00	0.00	23.62	10.96
Balanites maughamii	0.00	0.00	0.00	0.00	1.25	0.00
Berchemia zeyheri	0.00	0.00	0.00	9.37	0.00	0.00
Bridelia cathartica	0.00	0.00	4.38	0.00	4.37	0.00
Capparis tomentosa	0.00	0.00	15.63	0.00	0.00	0.00
Catunaregam spinosa	23.63	1.25	0.00	0.00	0.00	0.00
Coddia rudis	0.00	0.41	1.25	0.00	1.25	0.00
Combretum molle	0.00	0.00	15.62	0.00	0.00	0.00
Croton pseudopulchellus	0.00	0.06	9.38	0.00	0.00	0.00
Dialium schlechteri	1.25	1.04	4.81	12.11	0.00	0.00
Dichrostachys cinerea	0.00	0.10	0.00	0.00	0.00	0.00
Elaeodendron transvaalense	0.00	0.00	0.00	0.00	0.00	5.41
Erythrococca berberidea	0.00	0.00	0.00	8.84	0.00	0.00
Euclea natalensis	0.00	0.00	8.04	15.63	0.00	0.00
Grewia caffra	0.00	0.00	0.14	0.00	0.60	4.38
Gymnosporia senegalensis	0.89	0.00	0.00	0.00	0.00	0.00
Maytenus undata	0.00	1.25	0.00	0.00	0.00	0.00
Sapium integerrimum	0.00	0.00	0.00	1.25	0.00	0.00
Schotia brachypetala	0.00	0.00	0.00	0.00	23.62	4.37
Sclerocarya birrea	0.00	0.00	0.00	0.00	1.25	10.96
Scutia myrtina	0.00	0.00	0.00	0.00	1.25	0.00
Sideroxylon inerme	0.00	0.00	1.06	0.00	0.00	0.00
Spirostachys africana	0.00	0.00	0.00	3.73	32.92	26.34
Strychnos madagascariensis	0.00	8.39	4.52	0.00	23.63	0.00
Strychnos spinosa	0.00	0.00	23.25	0.00	4.38	0.00
Terminalia sericea	0.00	0.00	0.00	1.25	7.72	13.42
Vepris lanceolata	0.00	0.00	0.00	69.82	0.02	0.00
Ziziphus mucronata	0.00	0.00	0.00	0.00	1.25	0.00

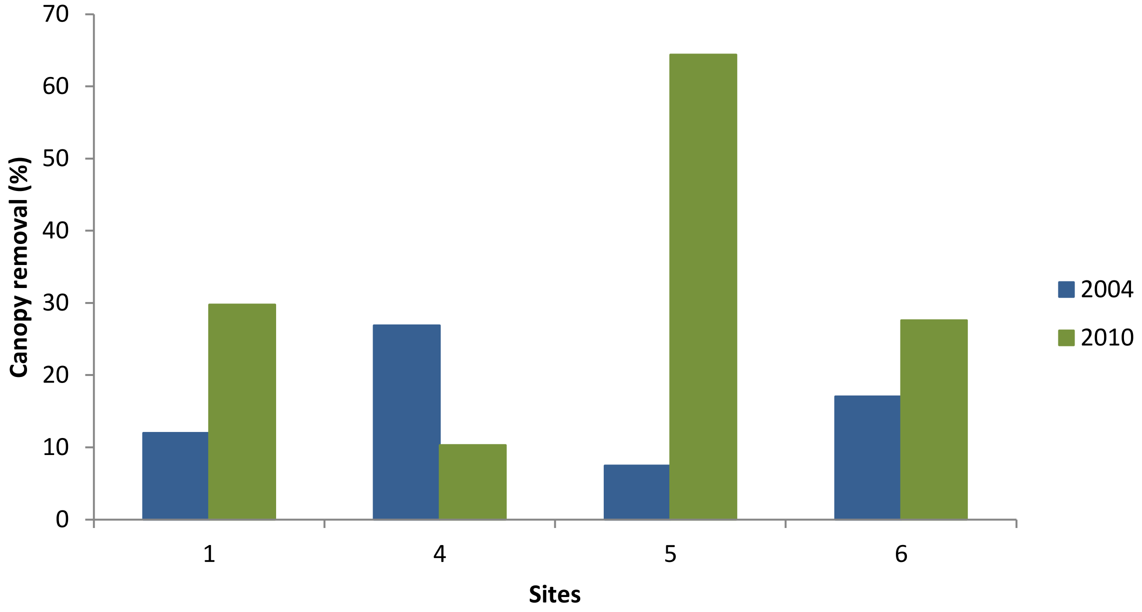

Figure 11.3 Cumulative percentage canopy removal (of utilised species only) by elephants at the four Closed Woodland on Clay sites as surveyed in 2004 (blue) and 2010 (green).

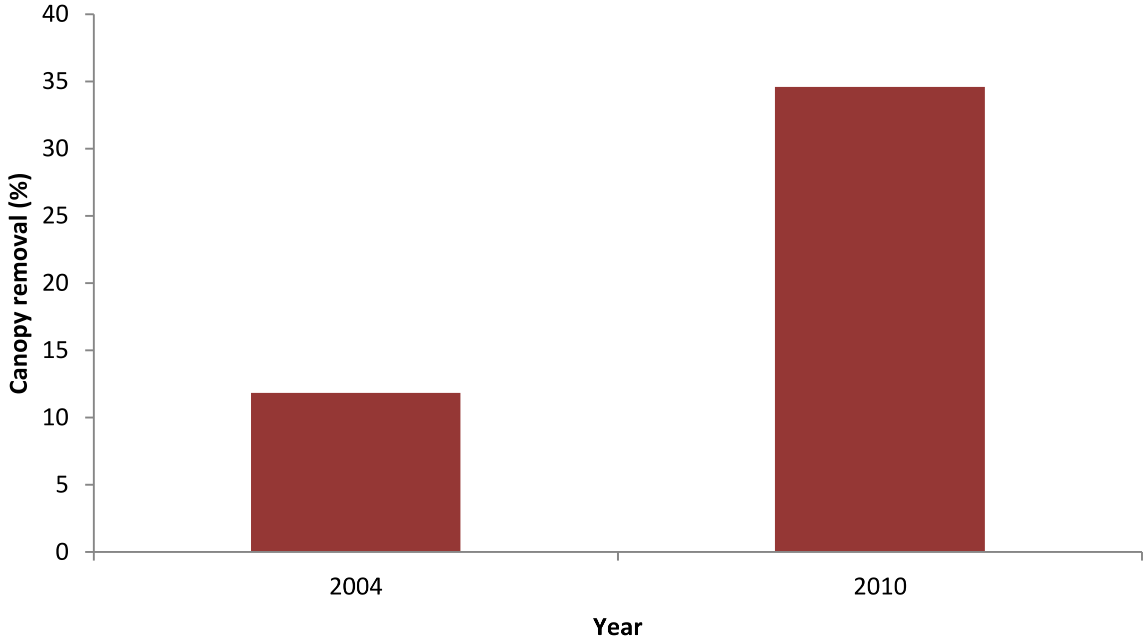

Figure 11.4 Cumulative percentage canopy removal (expressed as percentage of all species) in the Closed Woodland on Clay for 2004 and 2010.

Cumulative canopy removal percentage (total of utilised species) in Closed Woodland 3 in 2010 was high (Figure 11.3 & 11.4). Site 4 had the lowest degree of elephant utilisation among the utilised sites with 10.30% of the canopy being removed. The site with the highest utilisation value was site 5 with about six times the percentage utilisation of site 4 (64.39%). Site 1 and 6 had intermediate canopy removal values in 2010. The mean canopy removal in Closed Woodland 3 for the utilised species was 37.83% in 2010. This was one of the communities with the highest canopy removal in the Tembe Elephant Park during the 2010 survey. Total canopy removal in Closed Woodland 3, in terms of all available woody species, was 34.59% (Table 11.2, Figure 11.4).

11.2.2 Elephant utilisation – 2004 survey

Compared to the 2010 values cumulative canopy removal in all the size classes was lower in 2004, except for size class 1 (6.36%). The difference in percentage removal was fairly consistent across the size classes except for size class 6 (Figure 11.1), which had a notable increase in elephant utilisation in 2010 compared to the 8.72% in 2004.

Elephant utilisation during the 2004 survey was fairly evenly distributed among the species. *Acacia nilotica* was the woody species with the highest mean elephant utilisation value in 2004 with 36.90% canopy removed (Figure 11.2). *Gymnanthemum coloratum* and *Albizia versicolor* had moderate utilisation levels in 2004 with 21.43% and 20.63% canopy removed, respectively (Figure 11.2). Other woody species with moderate utilisation in 2004 included *Strychnos spinosa* (14.21%), *Elaeodendron transvaalense* (13.34%) and *Acacia burkei* (11.37%). *Albizia versicolor* and *Elaeodendron transvaalense* were the only two of the mentioned species which were only utilised within a single site during the 2004 survey. Other species which were utilised by elephants in more than one site within Closed Woodland 3 included *Euclea natalensis* (2.23%) and *Spirostachys africana* (4.05%). *Croton pseudopulchellus, Spirostachys africana* and Strychnos *spinosa* were utilised by elephants in a range of size classes (Table 11.3).

The sampling site with the highest elephant impact in 2004 was site 4 with a cumulative canopy removal of 26.90% and sampling site 5 experienced the lowest elephant utilisation with the cumulative canopy removal being 7.48% (Figure 11.3). The difference of percentage canopy removal of this community's sites from 2004 to 2010 was not significant (p=0.256). In 2004, the mean canopy removal for the Closed Woodland 3 community was 15.87%, which was approximately half of the value in 2010. Total canopy removal in Closed Woodland 3, in terms of all available woody species, was 11.83% (Table 11.2).

Table 11.1 Mean utilisation per size class (SC) (expressed as % of canopy volume removed) for the Closed Woodland 3 species in 2004

Woody Species	SC 1	SC 2	SC 3	SC 4	SC 5	SC 6
Acacia burkei	0.00	0.00	0.00	1.03	17.50	0.00
Acacia nilotica	0.00	0.00	15.62	0.00	21.39	0.00
Acacia robusta	0.00	0.00	4.38	0.00	0.00	0.00
Acalypha glabrata	0.00	0.13	0.41	0.00	0.00	0.00
Afzelia quanzensis	0.00	0.00	0.00	0.00	7.98	0.00
Albizia versicolor	0.00	0.00	20.63	0.00	0.00	0.00
Berchemia zeyheri	0.00	0.00	0.00	10.16	0.00	0.00
Bridelia cathartica	0.00	0.00	3.61	0.00	0.00	0.00
Catunaregam spinosa	0.00	0.00	9.38	0.00	0.00	0.00
Combretum molle	0.00	0.00	0.39	0.00	0.00	0.00
Croton pseudopulchellus	2.74	18.91	2.54	0.00	0.00	0.00
Dialium schlechteri	0.00	0.00	1.25	0.00	0.00	0.00
Elaeodendron transvaalense	0.00	0.00	7.98	0.00	0.00	5.35
Erythrococca berberidea	0.00	17.27	2.40	0.00	0.00	0.00
Erythroxylum delagoense	0.00	0.00	0.00	1.25	0.00	0.00
Euclea divinorum	0.00	0.00	0.00	0.00	3.61	0.00
Euclea natalensis	13.40	0.00	0.00	0.00	1.25	0.00
Garcinia livingstonei	0.00	0.00	0.00	2.99	0.00	0.00
Grewia microthyrsa	0.00	0.00	9.38	0.00	0.00	0.00
Gymnanthemum coloratum	0.00	0.00	20.63	1.25	0.00	0.00
Hyphaene coriacea	0.00	0.00	0.00	0.00	4.37	0.00
Plectroniella armata	0.00	0.00	0.34	0.00	0.00	0.00
Sapium integerrimum	0.00	0.00	0.00	0.00	2.44	0.00
Schotia brachypetala	0.00	0.00	0.00	0.00	23.62	0.00
Sclerocarya birrea	0.00	0.00	0.00	0.00	5.35	0.00
Sideroxylon inerme	0.00	0.00	0.00	7.98	0.00	0.00
Spirostachys africana	0.00	0.00	2.08	2.73	5.76	1.35
Strychnos spinosa	0.00	2.25	27.78	1.25	0.00	0.00
Tabernaemontana elegans	0.00	0.00	0.00	1.25	4.37	0.00
Terminalia sericea	0.00	0.00	0.00	10.16	4.37	0.00
Trichilia emetica	0.00	0.00	0.00	1.25	0.00	0.00
Vepris lanceolata	0.00	0.00	0.00	1.25	0.00	0.00

11.2.3 Elephant utilisation – 1995 survey

Figure 11.5 illustrates the contribution of species towards utilisation by elephants in the long-term. Each one of the datasets showed different species being highly utilised. The 1995 survey showed that *Acacia robusta* (17.42%) and *Acacia burkei* (17.07%) were the most utilised species even although their individual contributions were not particularly large. The *Acacia* species were followed by *Dialium schlechteri* (13.24%). In 2004, *Spirostachys africana* was the woody species with the highest relative utilisation (24.31%). *Schotia brachypetala* had the second highest relative utilisation (16.36%), followed by *Acacia burkei* (14.62%), *Tabernaemontana elegans* (9.13%) and *Afzelia quanzensis* (6.37%). Yet again, *Spirostachys africana* was the species with the highest relative utilisation in 2010 (75.29%) and *Euclea natalensis* (5.69%), *Terminalia sericea* (5.23%) and *Afzelia quanzensis* (4.18%) made far smaller contributions to the utilisation.

11.2.4 Elephant preferences

When classifying the floristic data of 2010 it appeared that some of the community delineations of 2004 (Gaugris, 2008) were no longer valid (Chapter 5). It could be argued that the high levels of elephant utilisation in the park were changing the abundances of some of the species and consequently community composition. Therefore it was important to establish whether the food preferences of the elephants in the park have changed with the modification in vegetation.

There was a clear lack of agreement in the most preferred species between 2004 and 2010. Similar results were found for other woodland communities The most preferred species according to Ivlev's Electivity Index in 2010 were *Afzelia quanzensis*, *Combretum molle*, *Capparis tomentosa* and *Spirostachys africana* (Table 11.4), whereas the most preferred species in 2004 were *Acacia nilotica*, *Albizia versicolor*, *Tabernaemontana elegans* and *Berchemia zeyheri* (Table 11.5). The Rank Procedure supported the lack of agreement between the five most preferred species of both surveys, except for *Berchemia zeyheri* which was ranked second most preferred species in both the surveys. In 2010 there were fewer woody species selected for than in 2004 and the Electivity Index was already negative from the seventh species onwards. The Rank Procedure method rated *Capparis tomentosa* to be the most preferred species in 2010, followed by *Berchemia zeyheri* and *Strychnos madagascariensis*. In 2004 *Acacia nilotica* was the most preferred woody species according to all the analyses. *Berchemia zeyheri* and *Grewia microthyrsa* followed according to the Rank Procedure Method.

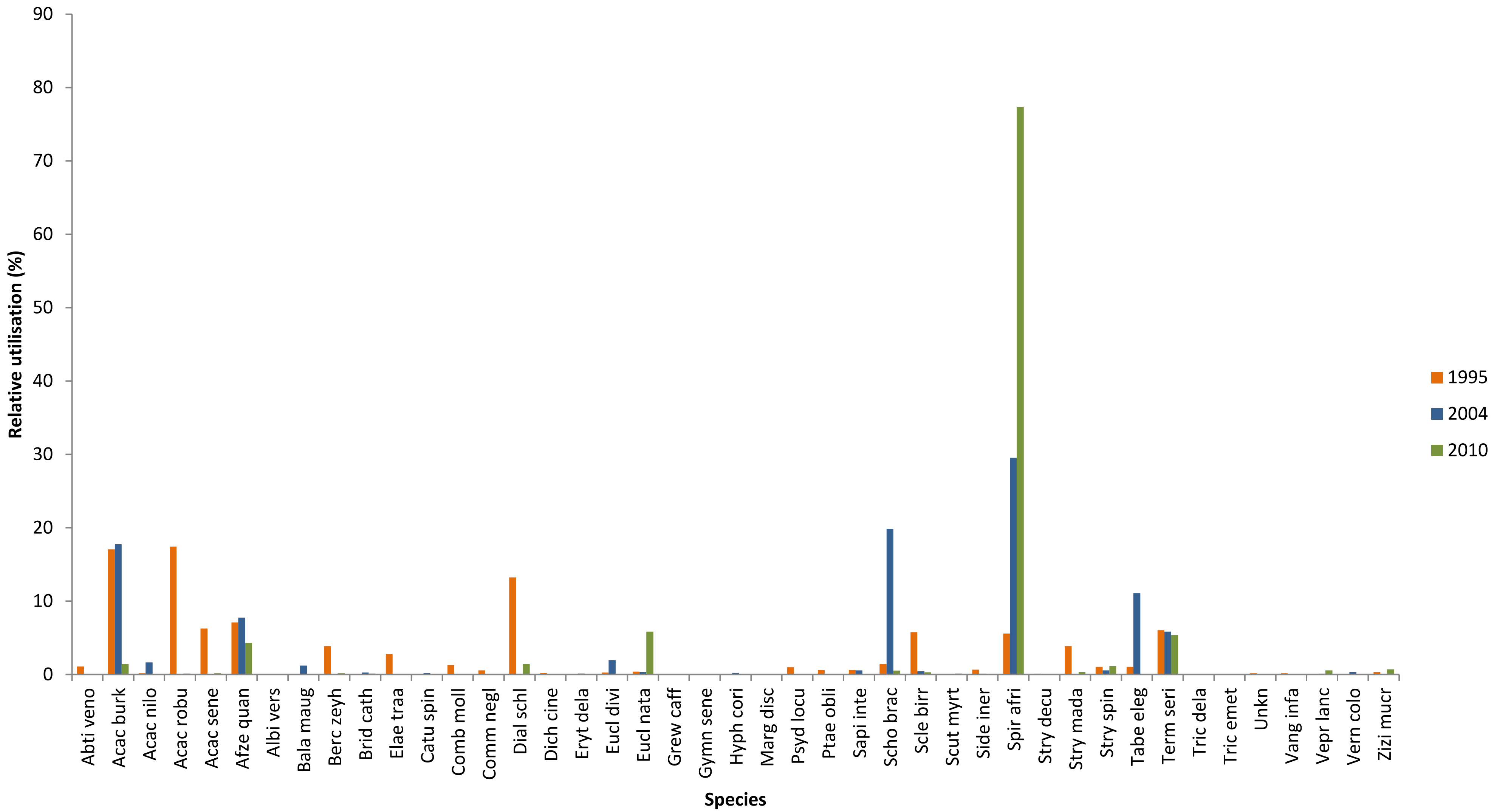

Figure 11.5 Relative utilisation of various species by elephants in 1995, 2004 and 2010 in the Closed Woodland 3 community of the Tembe Elephant Park. Appendix A contains a list of abbreviations of all species names.

Table 11.4 Elephant preferences for woody species in 2010 in terms of Ivlev's Electivity Index (Ivlev, 1961), the Forage Ratio (Cock, 1978) and the Rank Procedure method (Johnson, 1980). The woody species recorded within the Closed Woodland 3 community in 2010 are ranked from most preferred to least preferred based on Ivlev's Electivity Index

Woody species	Ivlev's Electivity Index	Forage Ratio	Rank Procedure
Afzelia quanzensis	0.42	2.47	4
Combretum molle	0.29	1.81	4
Capparis tomentosa	0.23	1.59	1
Spirostachys africana	0.15	1.35	8
Strychnos madagascariensis	0.04	1.09	3
Berchemia zeyheri	0.04	1.08	2
Acacia burkei	-0.03	0.95	5
Croton pseudopulchellus	-0.03	0.95	4
Terminalia sericea	-0.07	0.87	8
Euclea natalensis	-0.10	0.83	8
Schotia brachypetala	-0.10	0.82	5
Erythrococca berberidea	-0.11	0.81	6
Dialium schlechteri	-0.14	0.75	6
Elaeodendron transvaalense	-0.23	0.63	8
Strychnos spinosa	-0.32	0.51	9
Acacia senegal	-0.33	0.51	8
Bridelia cathartica	-0.34	0.50	8
Sclerocarya birrea	-0.42	0.41	8
Catunaregam spinosa	-0.45	0.38	7
Grewia caffra	-0.49	0.34	8
Acacia borleae	-0.55	0.29	6
Ziziphus mucronata	-0.75	0.14	13
Scutia myrtina	-0.75	0.14	12
Maytenus undata	-0.75	0.14	8
Acacia robusta	-0.75	0.14	14
Balanites maughamii	-0.75	0.14	11
Sapium integerrimum	-0.78	0.12	9
Sideroxylon inerme	-0.79	0.12	13
Vepris lanceolata	-0.79	0.11	15
Coddia rudis	-0.81	0.10	10
Gymnosporia senegalensis	-0.96	0.02	9
Dichrostachys cinerea	-0.98	0.01	11

Table 11.5 Elephant preferences for woody species in 2004 in terms of Ivlev's Electivity Index (Ivlev, 1961), the Forage Ratio (Cock, 1978) and the Rank Procedure method (Johnson, 1980). The woody species recorded within the Closed Woodland 3 community in 2004 are ranked from most preferred to least preferred based on Ivlev's Electivity Index

Woody species	Ivlev's electivity index	Forage ratio	Rank Procedure method
Acacia nilotica	0.75	7.08	1
Albizia versicolor	0.75	6.97	9
Tabernaemontana elegans	0.59	3.83	6
Berchemia zeyheri	0.55	3.40	2
Grewia microthyrsa	0.52	3.17	3
Catunaregam spinosa	0.52	3.17	4
Afzelia quanzensis	0.46	2.70	6
Sideroxylon inerme	0.46	2.70	4
Gymnanthemum coloratum	0.31	1.88	4
Sclerocarya birrea	0.29	1.81	5
Elaeodendron transvaalense	0.29	1.81	8
Acacia burkei	0.28	1.80	8
Terminalia sericea	0.22	1.58	9
Euclea divinorum	0.10	1.22	7
Acacia robusta	0.08	1.18	8
Schotia brachypetala	0.08	1.18	9
Bridelia cathartica	0.06	1.12	6
Garcinia livingstonei	0.01	1.01	8
Strychnos spinosa	0.00	1.00	9
Hyphaene coriacea	-0.02	0.96	10
Croton pseudopulchellus	-0.05	0.90	8
Erythrococca berberidea	-0.10	0.82	11
Spirostachys africana	-0.19	0.68	9
Sapium integerrimum	-0.26	0.59	11
Trichilia emetica	-0.41	0.42	12
Erythroxylum delagoense	-0.48	0.35	13
Dialium schlechteri	-0.58	0.27	12
Euclea natalensis	-0.58	0.26	14
Acalypha glabrata	-0.77	0.13	15
Combretum molle	-0.83	0.10	12
Plectroniella armata	-0.84	0.08	16
Vepris lanceolata	-0.97	0.01	17

11.3 DISCUSSION

11.3.1 Percentage canopy removal

The Closed Woodland on Clay community was a highly utilised vegetation unit, not only by elephants, but also by small and medium-sized herbivores. Site 5 had the highest cumulative canopy removal within the community in the 2010 survey and it had both signs of recent and old (> 2 years old) utilisation. In addition to elephant utilisation, it also showed a high level of utilisation by black rhinoceros. The second highest elephant utilised site was site 1, which was utilised mainly by elephants together with the occasional nyala and it contained some recent elephant damage but mostly old utilisation. In the Hluhluwe-Imfolozi Park, South Africa, Boundja and Midgley (2009) found that most of the damage caused by elephants within the closed woodland communities was through the breaking of branches and the uprooting of trees.

In 2004, 32 species were recorded with elephant utilisation and the same number for 2010. Twenty of the 32 utilised species (more than 50% of species) were common to both datasets. Canopy removal to the majority of the species utilised in 2004 has increased since then, probably due to decreased canopy availability. As the total available canopy volume in 2010 had decreased by two-thirds of the volume calculated in 2004 (Table 11.2) and the amount of plant material utilised increased by 9% due to an increase in the elephant population, a striking increase in canopy removal values was noted.

Cumulative canopy removal percentage in approximately all the size classes (up to size class 5) was slightly higher in 2010 than in 2004, but utilisation in size classes 6 showed a striking increase in 2010. Size class 6 was slightly utilised in 2004 (8.72%) but in 2010 it contained the highest cumulative canopy removal (64.59%). A clear trend of increasing percentage utilisation with increasing tree diameter was evident, a trend already noted by Matthews and Page (undated) in 1995 who found almost no utilisation in the lower size classes (<0.5 m). Large trees generally sustain more elephant damage as these are the individuals that the elephants would rub and lean against. The relatively high level of damage or utilisation in the small size classes, especially size class 3 (27.63% canopy removal) in this subcommunity was a point of concern.

Studying the change in species utilisation patterns under increased utilisation by elephants showed interesting results. Several species observed in 2004 were severely utilised by elephants, such as *Acacia nilotica*, which was not noted as utilised by elephants during the

2010 field survey as there are no individuals of this species recorded in the Closed Woodland 3 during the 2010 survey. However, in 2004 it was the species with the highest canopy removal percentage, even although this utilisation incident was only in two of the sites in the Closed Woodland 3 and only contributed 1.34% of the total utilisation in the community. Both, *Acacia burkei* and *Spirostachys africana* experienced increased canopy removal percentages since 2004, especially in the higher size classes (a trend already noted by Matthews & Page, undated). Most of the damage observed within these two species was the breaking of large branches and individuals being pushed over. The availability of *Acacia burkei* within the Closed Woodland 3 decreased substantially compared to results obtained in 2004 (Table 11.2) and the relative utilisation decreased from 14.62% to 1.37%. Other studies also found *Acacia burkei* to be a highly utilised plant species (Matthews & Page, undated; White & Goodman, 2009). In 2010 *Spirostachys africana*'s available canopy volume had also decreased since the 2004 survey, but the amount removed by elephants increased and the relative utilisation increased from 24.32% to 75.29%. Other heavily utilised woody species recorded in 2010, which have been reported as preferred by elephants, included: *Afzelia quanzensis* (Matthews & Page, undated) and *Schotia brachypetala* (White & Goodman, 2009; Boundja & Midgley, 2009; Matthews & Page, undated).

Total canopy removal by elephants within the Closed Woodland 3 increased from 11.83% in 2004 to 34.59% in 2010 representing a threefold increase in elephant utilisation. Closed woodlands in Tembe Elephant Park had higher elephant path densities than other communities (Shannon *et al*., 2009) and especially in the drier seasons these communities, had a higher presence of elephants (Gaugris & Van Rooyen, 2010a; Gaugris, 2008). The high utilisation values within the Closed Woodland on Clay could be due to browsing material being more nutritious on these soils than on sandy soils (Matthews *et al*., 2001; Gaugris & Van Rooyen, 2010a). In the current study the Closed Woodland on Clay had the highest amount of recent canopy removal and the third highest old elephant damage. The high utilisation values in this community could possibly be ascribed to the proximity to permanent water as the community is located close to the Muzi swamp (Shannon *et al*., 2009; Gaugris & Van Rooyen, 2010a). The major increase in canopy removal percentage and decrease in available canopy since 2004 are a cause for concern.

11.3.2 Electivity

Species which were utilised and preferred in both surveys included *Afzelia quanzensis* (supported by Matthews & Page, undated) and *Berchemia zeyheri* (supported by Wiseman *et al*., 2004; Boundja & Midgley, 2009). In terms of these species' position on the ranking list, *Afzelia quanzensis* increased in preference from 2004 to 2010 and *Berchemia zeyheri* remained at the same ranking. *Acacia nilotica, Albizia versicolor* and *Tabernaemontana elegans* were the most preferred woody species in 2004 or even encountered in the Closed Woodland 3 in 2010.

11.3.3 Relative utilisation

It appears that the elephants select a specific plant species and then utilise it to such a degree that it is almost extirpated. Subsequently, they move on to new species and form new selections or preferences (Ben-Shahar, 1993; O'Connor *et al*., 2007). In 1995, *Acacia burkei* contributed most towards the canopy removal by elephants. In 2004 the species made a similar contribution to canopy removal and currently (2010), this species has a low relative utilisation percentage in the Closed Woodland 3. At present *Spirostachys africana* is the most utilised species, with a value of 75.29%. This species also had a high relative utilisation value in 2004.

11.4 CONCLUSION

The Closed Woodland 3 community is located along the south of the Muzi swamp and close to permanent waterholes, and elephants often concentrate in this region, especially in drier seasons (Chapter 3). With the increase in elephant population size the large increase in elephant utilisation within this community could therefore be expected. Except for the water being an attraction for the elephants the nutritive value of woody species is also higher on the clay soils of the Closed Woodland on Clay.

CHAPTER 12

UTILISATION IN THE *OZOROA ENGLERI* – *TERMINALIA SERICEA* OPEN WOODLAND ON SAND

12.1 INTRODUCTION

The *Ozoroa engleri* – *Terminalia sericea* Open Woodland on Sand (referred to as Open Woodland 1) is a subcommunity of the *Terminalia sericea* - *Strychnos madagascariensis* Open Woodland on Sand community in the Tembe Elephant Park. This community is extremely diverse in species composition as well as vegetation structure with varying densities of woody plants. This subcommunity (Open Woodland 1) occurs throughout the park. It is a particularly large vegetation unit, and consequently many sampling sites were surveyed. The Open Woodland 1 is a very sandy subcommunity and has a higher density of woody individuals than the *Pavetta lanceolata* – *Brachylaena discolor* Open Woodland on Sand subcommunity (Open Woodland 2).

The Open Woodland 1 was not associated with the proximity of water, and was located in the drier northern and south-western sections of Tembe Elephant Park.

12.2 RESULTS

12.2.1 Elephant utilisation – 2010 survey

The cumulative[1] percentage canopy removal in 2010 increased with an increase in the size classes (Figure 12.1). Figure 12.1 illustrates the utilisation within the six size classes and once again the highest cumulative canopy removal was found in the largest size classes with 23.26% and 50.13% canopy removal (of utilised species) in size class 5 and 6, respectively.

[1] Cumulative canopy removal percentage refers to the total volume of the canopy removed of all species expressed as a percentage of the available volume of only the utilised species.

The canopy removal by elephants in size class 3 (5.88%) was low while size class 4 (13.56%) had moderate levels of canopy removal. Size class 1 had the least elephant damage with 0.60% canopy removed followed by size class 2 with 3.91%.

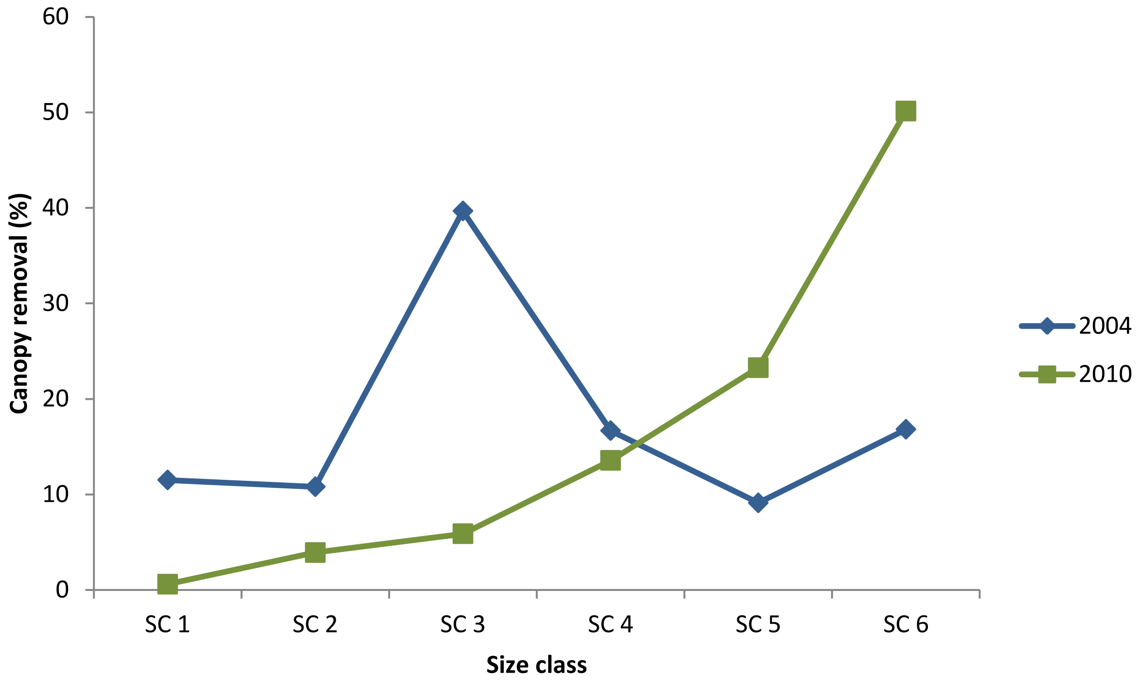

Figure 12.1 Cumulative percentage canopy volume (of utilised species) removed per size class (SC) in 2004 and 2010 in the Open Woodland 1 subcommunity in the Tembe Elephant Park.

Figure 12.2 illustrates the mean canopy removal of all elephant utilised woody species in the Open Woodland 1. *Strychnos madagascariensis* had the highest canopy removal values with 26.52% canopy removed (mean value). The decrease in canopy availability of this species since 2004 is evident in Table 12.1. This woody species was utilised by elephants in all the size classes with highest canopy removal values in size class 5 (18.36%) followed by size class 3 (10.28%) (Table 12.2). *Terminalia sericea*, *Acacia burkei*, and *Sclerocarya birrea* were moderately utilised with canopy removals of 22.84%, 21.41% and 16.14% respectively. Other utilised species within the Open Woodland 1 with low canopy removal values include *Combretum molle* (9.84%), *Spirostachys africana* (8.41%) and *Dialium schlechteri* (8.09%). *Acacia burkei, Combretum molle, Strychnos madagascariensis* and *Terminalia sericea* were utilised in the majority of the sites of this subcommunity and were utilised in a range of size classes.

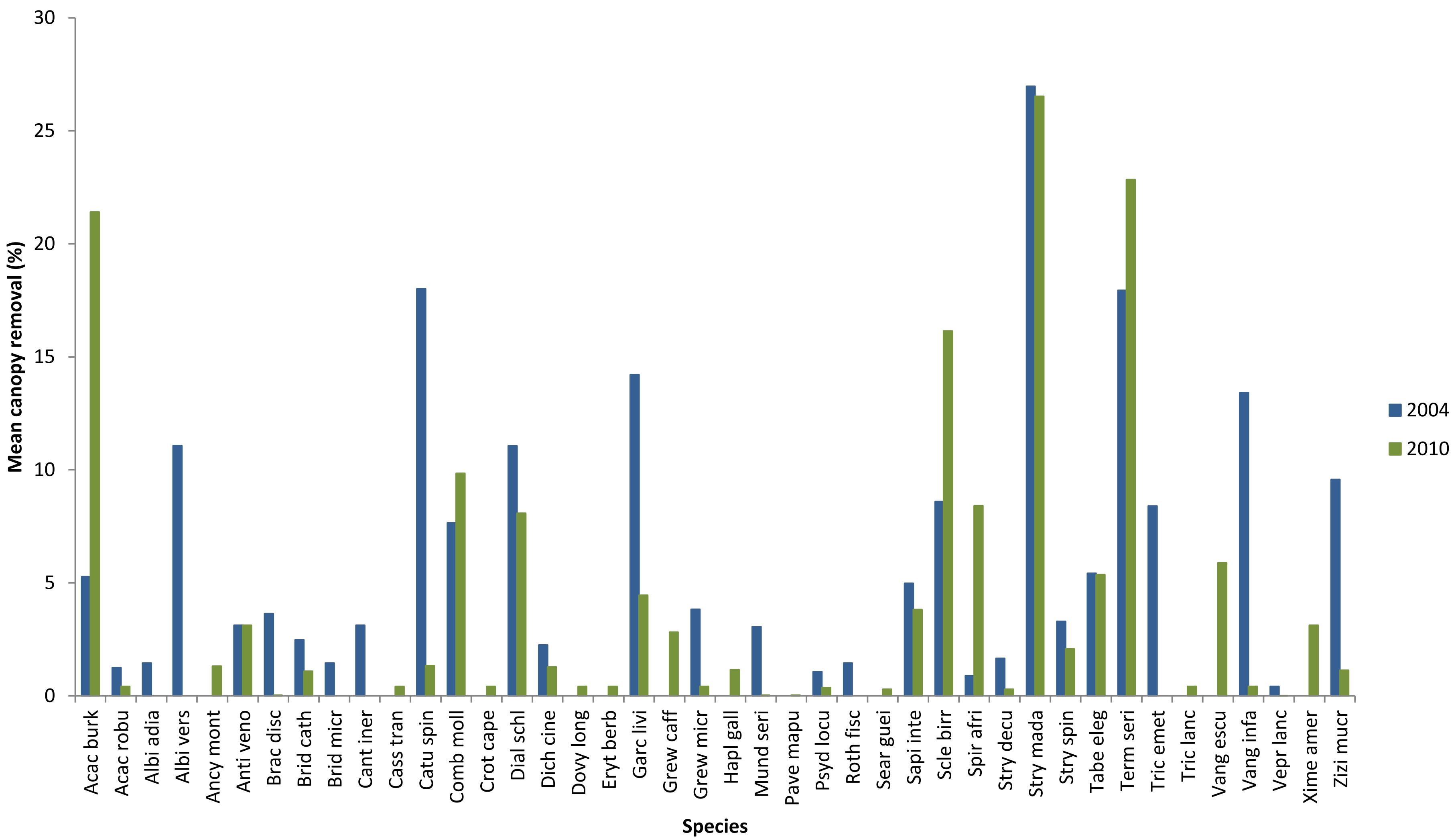

Figure 12.2 Woody species utilised by elephants in the Open Woodland 1 subcommunity as recorded in 2004 (blue) and 2010 (green). Appendix A contains a list of abbreviations of all species names.

Table 12.1 Available canopy volume and removed canopy volume per utilised species within the Open Woodland 1 for 2010 and 2004. Elephant utilisation is expressed as cumulative percentage utilised as well as a relative utilisation percentage

Species	2010				2004			
	Available (m^3/ha)	Removed (m^3/ha)	% Utilised	Relative utilisation (%)	Available (m^3/ha)	Removed (m^3/ha)	% Utilised	Relative utilisation (%)
Acacia burkei	3141	1172	37.32	14.07	12697	1302	10.25	22.13
Acacia robusta	258	13	5.00	0.15	284	43	15.04	0.73
Albizia adianthifolia	-	-	-	-	1636	286	17.50	4.87
Albizia versicolor	-	-	-	-	2645	1077	40.72	18.31
Ancylanthos monteiroi	0	0	9.61	0.00	-	-	-	-
Antidesma venosum	6	0	5.00	0.00	198	74	37.50	1.26
Brachylaena discolor	2	0	0.36	0.00	25	11	43.59	0.18
Bridelia cathartica	3	0	6.93	0.00	79	24	29.79	0.40
Bridelia micrantha	-	-	-	-	31	5	17.50	0.09
Canthium inerme	-	-	-	-	46	17	37.49	0.29
Catunaregam spinosa	14	1	4.74	0.01	56	26	46.27	0.44
Combretum molle	762	104	13.61	1.24	1267	224	17.65	3.80
Crotalaria capensis	0	0	5.00	0.00	-	-	-	-
Dialium schlechteri	486	212	43.64	2.55	200	58	29.12	0.99
Dichrostachys cinerea	239	9	3.60	0.10	109	13	11.82	0.22
Dovyalis longispina	1	0	5.00	0.00	-	-	-	-
Elaeodendron traansvaalensis	6	0	5.00	0.00	-	-	-	-
Erythrococca berberidea	1	0	5.00	0.00	-	-	-	-
Garcinia livingstonei	527	103	19.58	1.24	470	180	38.38	3.06

Grewia caffra	101	8	8.15	0.10	-	-	-	-
Grewia microthyrsa	112	6	5.00	0.07	3	1	46.02	0.02
Haplocoelum gallaense	0	0	13.94	0.00	-	-	-	-
Mundulea sericea	168	1	0.46	0.01	82	30	36.70	0.51
Pavetta lanceolata	7	0	0.33	0.00	-	-	-	-
Psydrax locuples	4	0	3.33	0.00	69	9	12.77	0.15
Rothmannia fischeri	-	-	-	-	111	20	17.50	0.33
Sapium integerrimum	1029	230	22.36	2.76	1269	149	11.75	2.54
Sclerocarya birrea	2181	1373	62.93	16.47	3796	157	4.14	2.67
Searsia gueinzii	45	2	3.55	0.02	-	-	-	-
Spirostachys africana	1406	573	40.72	6.87	1339	75	5.59	1.27
Strychnos decussata	13	1	3.59	0.01	2	0	19.95	0.01
Strychnos madagascariensis	1710	729	42.62	8.75	2125	463	21.79	7.87
Strychnos spinosa	82	9	10.62	0.11	139	32	23.19	0.55
Tabernaemontana elegans	106	68	64.37	0.82	406	101	24.81	1.71
Terminalia sericea	8892	3572	40.17	42.87	12569	1044	8.31	17.75
Tricalysia lanceolata	79	4	5.00	0.05	-	-	-	-
Trichilia emetica	-	-	-	-	568	263	46.19	4.46
Vangueria esculenta	14	10	70.61	0.12	-	-	-	-
Vangueria infausta	3	0	5.00	0.00	160	43	26.83	0.73
Vepris lanceolata	76	0	0.08	0.00	601	30	5.01	0.51
Ximenia americana	2	1	37.50	0.01	-	-	-	-
Ziziphus mucronata	1551	133	8.59	1.60	620	125	20.21	2.13
Total of utilised species	23027	8332	36.18		43601	5882	13.49	
Total of not utilised species	1260	0	0.00		3552	0	0.00	
Total available of all species	24287	8332	34.31		47153	5882	12.47	

Table 12.2 Mean utilisation per size class (SC) (expressed as % of canopy volume removed) for utilised Open Woodland 1 species in 2010

Woody species	SC 1	SC 2	SC 3	SC 4	SC 5	SC 6
Acacia burkei	1.45	1.24	0.83	0.83	7.37	18.14
Acacia robusta	0.00	0.00	0.00	0.42	0.00	0.00
Ancylanthos monteiroi	1.25	4.96	0.00	0.00	0.00	0.00
Antidesma venosum	0.00	0.00	0.42	0.00	0.00	0.00
Brachylaena discolor	1.57	0.00	0.00	0.00	0.00	0.00
Bridelia cathartica	0.00	0.83	0.70	0.00	0.00	0.00
Catunaregam spinosa	0.69	1.12	0.16	0.00	0.00	0.00
Combretum molle	0.00	0.01	7.83	2.91	0.00	0.81
Crotalaria capensis	0.42	0.00	0.00	0.00	0.00	0.00
Dialium schlechteri	0.00	0.00	1.88	0.00	2.62	5.90
Dichrostachys cinerea	0.01	1.41	0.71	0.00	0.00	0.00
Dovyalis longispina	0.00	0.42	0.00	0.00	0.00	0.00
Elaeodendron transvaalensis	0.00	0.00	0.00	0.00	0.42	0.00
Erythrococca berberidea	0.00	0.42	0.00	0.00	0.00	0.00
Garcinia livingstonei	0.00	0.00	0.00	0.00	4.45	0.00
Grewia caffra	0.00	0.00	1.46	0.42	1.36	1.46
Grewia microthyrsa	0.00	0.00	0.42	0.00	0.00	0.42
Haplocoelum gallaense	1.46	0.00	0.42	0.00	0.00	0.00
Mundulea sericea	0.00	0.19	0.42	0.00	0.00	0.00
Pavetta lanceolata	0.00	0.27	0.00	0.00	0.00	0.00
Psydrax locuples	0.45	0.42	0.00	0.00	0.00	0.00
Sapium integerrimum	0.42	0.00	0.40	0.00	1.46	2.44
Sclerocarya birrea	0.00	0.00	0.00	0.00	0.00	11.89
Searsia gueinzii	0.00	0.00	0.30	0.00	0.00	0.00
Spirostachys africana	0.00	0.23	0.00	0.00	2.13	13.06
Strychnos decussata	0.00	0.40	0.00	0.00	0.00	0.00
Strychnos madagascariensis	0.27	2.19	10.28	0.42	18.36	7.32
Strychnos spinosa	0.00	0.69	1.77	0.42	0.00	0.00
Tabernaemontana elegans	0.00	0.00	0.00	0.00	5.36	0.00
Terminalia sericea	0.00	1.64	0.33	4.57	12.67	24.09
Tricalysia lanceolata	0.00	0.00	0.42	0.00	0.00	0.00
Vangueria esculenta	0.00	0.00	0.00	5.88	0.00	0.00
Vangueria infausta	0.00	0.00	0.42	0.00	0.00	0.00
Vepris lanceolata	0.17	0.00	0.01	0.00	0.00	0.00
Ximenia americana	0.00	3.12	0.00	0.00	0.00	0.00
Ziziphus mucronata	0.00	0.42	0.42	1.27	0.42	0.00

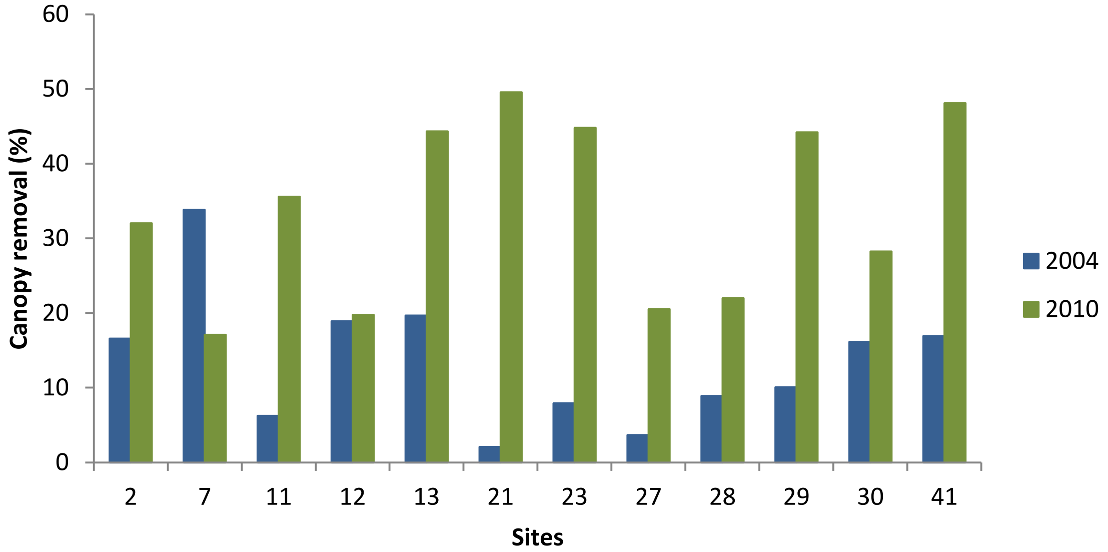

Figure 12.3 Cumulative percentage canopy removal (of utilised species only) by elephants at the 12 Open Woodland 1 subcommunity sites as surveyed in 2004 (blue) and 2010 (green). Only utilised species were considered.

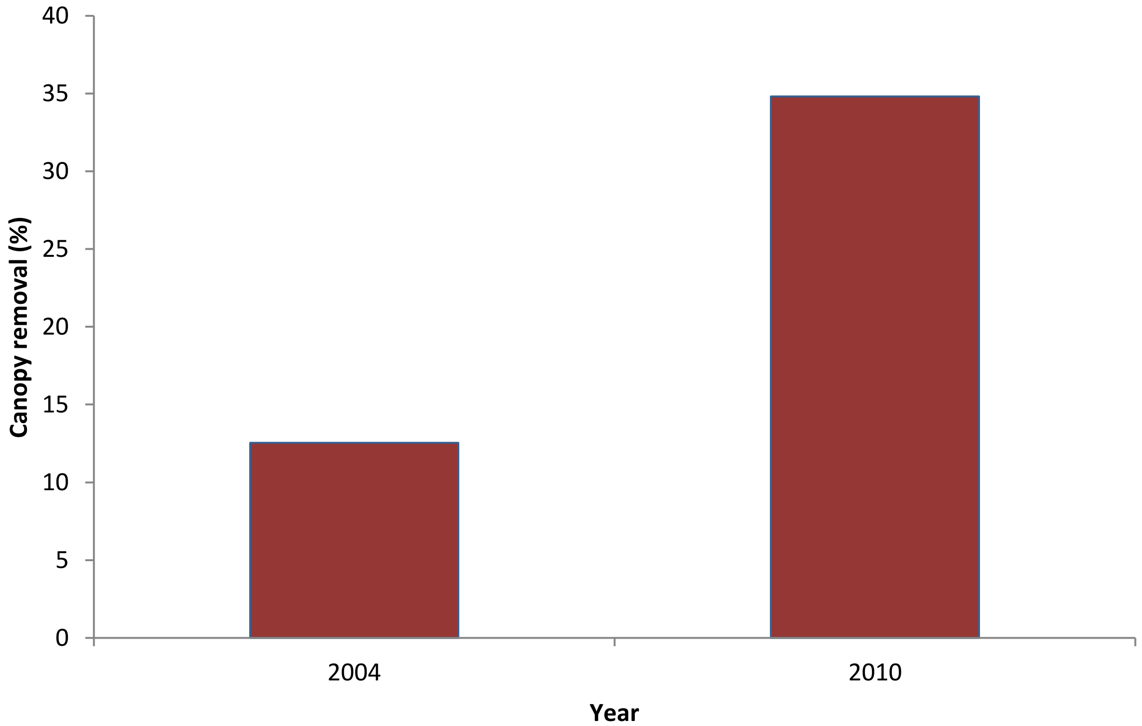

Figure 12.4 Cumulative percentage canopy removal (expressed as percentage of all species) in the Open Woodland 1 subcommunity for 2004 and 2010.

Cumulative canopy removal (total of utilised species) in the Open Woodland 1 in 2010 was exceptionally high (Figure 12.3). Site 7 had the lowest degree of elephant utilisation with 17.10% cumulative canopy removal, which is still a substantial volume of the canopies being removed, this site also had a decrease since 2004. The majority of sites within the Open Woodland 1 subcommunity had elephant cumulative canopy removal above 20% in 2010. The canopy removal for the Open Woodland 1 in terms of utilised species was 36.18% for 2010 (Table 12.1). This was the community with the third highest canopy removal in the Tembe Elephant Park during the 2010 survey. The total cumulative canopy removal in the Open Woodland 1, in terms of all the available woody species was 34.31% (Figure 12.4, Table 12.1).

12.2.2 Elephant utilisation – 2004 survey

Compared to 2010 data cumulative canopy removal in size classes 1 – 4 was higher in 2004 (Figure 12.1) but the large size classes experienced a dramatic increase since 2004. Especially size class 6 had a notable increase in elephant utilisation in 2010 compared to the moderate 16.81% in 2004. Size class 3 and 4 had prominently higher elephant utilisation values compared to the 2010 survey with canopy removal of 39.69% and 16.69%, respectively. Many woody species with high canopy removal values in 2010, already displayed relatively high utilisation values in 2004. *Strychnos madagascariensis* was the woody species with the highest elephant mean canopy removal value in 2004 with 26.97% canopy removed (Figure 12.2). *Catunaregam spinosa* and *Terminalia sericea* had moderate utilisation levels in 2004 with 18.01% and 17.94% canopy removed, respectively (Figure 12.2). Other woody species with moderate to low mean canopy removal values in 2004, included *Garcinia livingstonei* (14.22%), *Vangueria infausta* (13.41%), *Albizia versicolor* (11.07%) and *Dialium schlechteri* (11.07%). *Catunaregam spinosa* was the only one of the mentioned species which was only utilised in a single site during the 2004 survey. Species which were utilised in the majority of sites in 2004 within the Open Woodland 1 included *Acacia burkei* (5.27%), *Combretum molle* (7.66%), *Sapium integerrimum* (4.97%), *Strychnos madagascariensis* (26.97%) and *Terminalia sericea* (17.94%). *Combretum molle, Dialium schlechteri, Garcinia livingstonei*, *Sapium integerrimum, Strychnos madagascariensis*, *Terminalia sericea* and *Ziziphus mucronata* were utilised by elephants in three or more size classes (Table 12.3).

The sampling site with the lowest impact in 2004 was site 21 with a cumulative canopy removal of 2.08% and sampling site 7 experienced the highest elephant utilisation with the cumulative canopy removal being 33.81% (Figure 12.3). Mean canopy removal for the Open

Woodland 1 (utilised species only) was 13.49% in 2004. In 2004, the total canopy removal for the Open Woodland 1 community was 12.47%, calculated in terms of all available species, (Figure 12.4) which was far less than in 2010. The change in utilisation values in the sites from 2004 and 2010 is not significantly different (p=0.057).

12.2.3 Elephant utilisation – 1995 survey

Figure 12.5 illustrates the relative utilisation per species (canopy volume removed expressed as a percentage of all canopy removed) by elephant for all three surveys since 1995. In each of the surveys, a different complement of species emerged as most utilised by elephants in the Open Woodland 1. According to the 1995 survey, elephants utilised primarily *Albizia adianthifolia* (37.63%), *Albizia versicolor* (12.75%), *Terminalia sericea* (11.69%), *Dialium schlechteri* (7.20%) and *Trichilia emetica* (5.47%). About ten years later, in 2004, the elephants were still utilising *Albizia versicolor* (18.31%) and *Terminalia sericea* (17.75%) but *Albizia adianthifolia* was no longer utilised at such high levels. *Acacia burkei* (22.13%) and *Strychnos madagascariensis* (7.87%) also emerged as species with substantial relative utilisation values. *Terminalia sericea* was the species with the highest relative utilisation in 2010 (42.87%) together with *Acacia burkei* (14.07%), *Sclerocarya birrea* (16.47%), *Spirostachys africana* (6.87%) and *Strychnos madagascariensis* (8.75%).

12.2.4 Elephant preferences

There was a distinct difference in elephant preferences for woody plant species between the 2004 and 2010 surveys. The most preferred species in 2010 were *Vangueria infausta, Tabernaemontana elegans, Sclerocarya birrea* and *Strychnos madagascariensis* (Table 12.4), whereas the most preferred species in 2004 were *Catunaregam spinosa, Trichilia emetica, Albizia versicolor, Dialium schlechteri* and *Garcinia livingstonei* (Table 12.5). The Rank Procedure supported this lack of agreement between the most preferred species of both surveys. In 2010 there were fewer woody species selected by the elephants than in 2004 as the Electivity index is negative for more than half the utilised species. The Rank Procedure method ranked *Ximenia americana* as the most preferred species in 2010, but this was not supported by the Electivity Index. In 2004 *Catunaregam spinosa* was the most preferred woody species according to all three the analyses. There were three species which were selected for by elephants in both the surveys, based on the Electivity Index, and these were *Vangueria infausta, Tabernaemontana elegans* and *Strychnos madagascariensis*. *Dialium schlechteri* moved from the third position in 2004 down to the 9th position in 2010 (according to the Rank Procedure method) and was no longer preferred (EI value negative).

Sclerocarya birrea moved up in the table in 2010 and is currently ranked seventh (11th in 2004) on the ranking list in the Open Woodland 1. The Electivity Index of *Sclerocarya birrea* increased from -0.54 in 2004 to 0.30 in 2010. In 2004 *Albizia versicolor* and *Trichilia emetica* were highly preferred by the elephants but not in 2010.

Table 12.1 Mean utilisation per size class (SC) (expressed as % of canopy volume removed) for the Open Woodland 1 species in 2004

Woody Species	SC 1	SC 2	SC 3	SC 4	SC 5	SC 6
Acacia burkei	0.00	0.00	0.00	0.69	1.59	4.23
Acacia robusta	0.00	0.00	0.00	0.00	1.46	0.00
Albizia adianthifolia	0.00	0.00	0.00	0.00	0.00	1.46
Albizia versicolor	0.00	0.00	7.88	0.00	0.00	3.39
Antidesma venosum	0.00	0.00	0.00	0.00	3.12	0.00
Brachylaena discolor	0.00	0.00	0.00	3.63	0.00	0.00
Bridelia cathartica	0.00	0.00	2.13	0.00	0.00	0.00
Bridelia micrantha	0.00	0.00	1.46	0.00	0.00	0.00
Canthium inerme	0.00	0.00	3.12	0.00	0.00	0.00
Catunaregam spinosa	0.41	0.00	21.97	0.00	0.00	0.00
Combretum molle	0.00	7.87	3.99	2.29	2.44	2.95
Dialium schlechteri	0.00	0.00	3.12	3.13	1.80	0.00
Dichrostachys cinerea	0.00	0.00	1.46	1.46	0.00	0.00
Garcinia livingstonei	0.00	0.00	0.00	3.26	10.55	0.42
Grewia microthyrsa	0.00	3.84	0.00	0.00	0.00	0.00
Mundulea sericea	0.00	0.00	0.00	5.21	0.00	0.00
Psydrax locuples	0.00	0.00	1.07	0.00	0.00	0.00
Rothmannia fischeri	0.00	0.00	1.46	0.00	0.00	0.00
Sapium integerrimum	0.00	7.88	0.39	4.24	3.77	0.00
Sclerocarya birrea	0.00	0.00	0.00	4.14	5.15	0.00
Spirostachys africana	0.00	0.00	0.00	0.00	0.34	0.55
Strychnos decussata	0.00	7.88	0.00	0.00	0.00	0.00
Strychnos madagascariensis	0.00	0.00	14.37	22.86	11.67	3.19
Strychnos spinosa	0.00	0.00	0.00	5.42	0.00	0.00
Tabernaemontana elegans	0.00	0.00	3.97	0.00	1.46	0.00
Terminalia sericea	0.00	0.00	18.99	5.89	8.27	1.46
Trichilia emetica	0.00	0.00	0.00	0.00	8.41	0.00
Vangueria infausta	0.00	0.00	8.89	5.49	0.00	0.00
Vepris lanceolata	0.00	0.00	7.88	0.42	0.00	0.00
Ziziphus mucronata	0.00	0.00	7.87	2.39	1.01	0.00

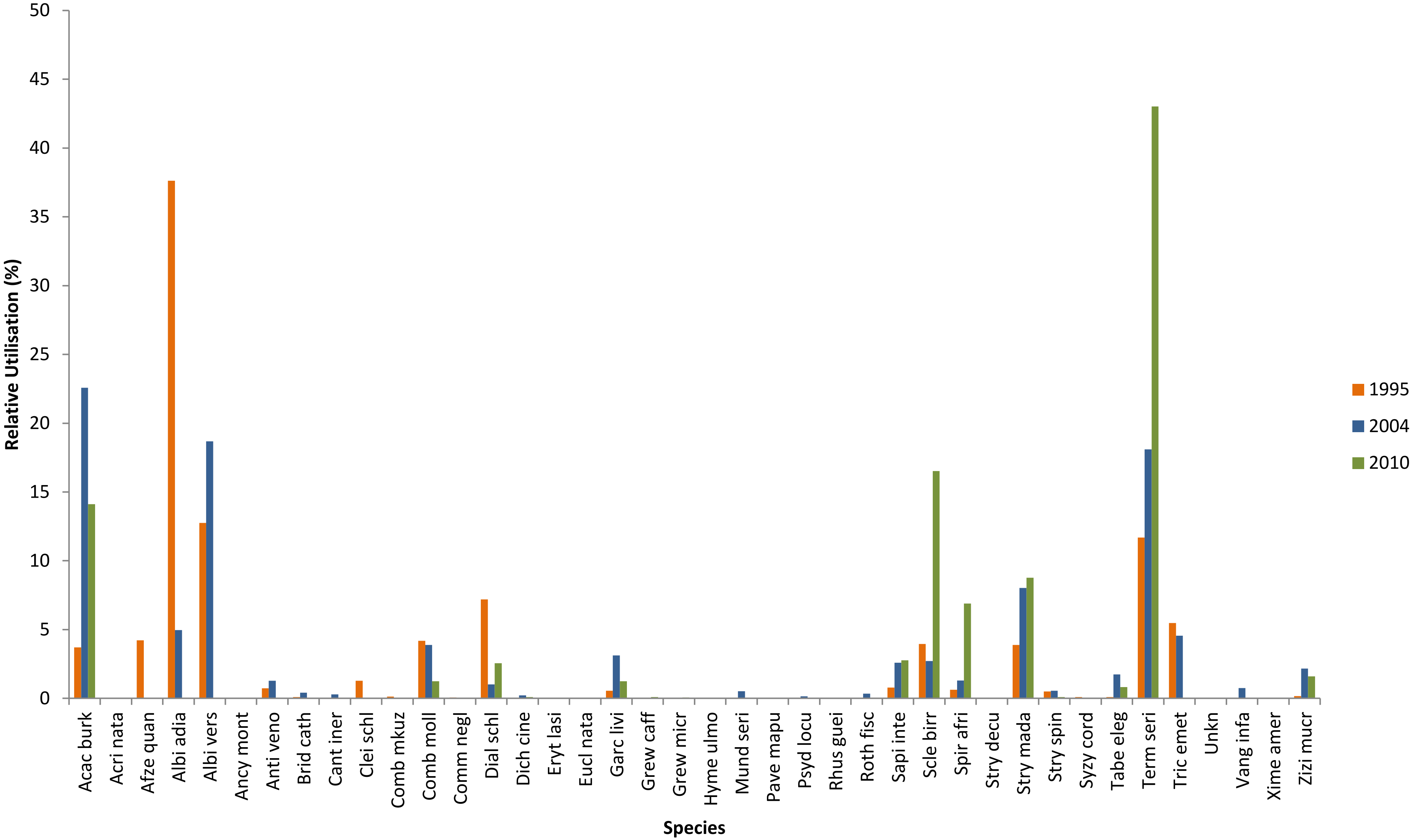

Figure 12.5 Relative utilisation of various species by elephants in 1995, 2004 and 2010 in the Open Woodland 1 community of Tembe Elephant Park. Appendix A contains a list of abbreviations of all species names.

Table 12.4 Elephant preferences for woody species in 2010 in terms of Ivlev's Electivity Index (Ivlev, 1961), the Forage Ratio (Cock, 1978) and the Rank Procedure method (Johnson, 1980). The woody species recorded within the Open Woodland 1 subcommunity in 2010 are ranked from most preferred to least preferred based on Ivlev's Electivity Index

Woody species	Ivlev's electivity index	Forage ratio	Rank Procedure method
Vangueria infausta	0.35	2.08	2
Tabernaemontana elegans	0.31	1.89	3
Sclerocarya birrea	0.30	1.85	7
Strychnos madagascariensis	0.11	1.25	8
Terminalia sericea	0.09	1.21	8
Spirostachys africana	0.09	1.20	7
Ximenia americana	0.05	1.10	1
Acacia burkei	0.05	1.10	9
Garcinia livingstonei	-0.27	0.58	8
Sapium integerrimum	-0.28	0.56	7
Haplocoelum gallaense	-0.42	0.41	6
Combretum molle	-0.43	0.40	8
Strychnos spinosa	-0.57	0.27	5
Ziziphus mucronata	-0.59	0.25	10
Grewia caffra	-0.61	0.24	8
Bridelia cathartica	-0.71	0.17	4
Vangueria esculenta	-0.74	0.15	5
Elaeodendron transvaalensis	-0.74	0.15	5
Tricalysia lanceolata	-0.74	0.15	8
Antidesma venosum	-0.74	0.15	5
Dovyalis longispina	-0.74	0.15	4
Acacia robusta	-0.74	0.15	8
Grewia microthyrsa	-0.76	0.14	11
Strychnos decussata	-0.81	0.11	8
Dialium schlechteri	-0.81	0.11	9
Dichrostachys cinerea	-0.82	0.10	12
Searsia gueinzii	-0.85	0.08	7
Crotalaria capensis	-0.86	0.08	9
Catunaregam spinosa	-0.86	0.08	9
Erythrococca berberidea	-0.87	0.07	5
Psydrax locuples	-0.93	0.04	11
Ancylanthos monteiroi	-0.97	0.01	13
Mundulea sericea	-0.97	0.01	14
Pavetta lanceolata	-0.99	0.01	15
Brachylaena discolor	-0.99	0.00	13
Vepris lanceolata	-1.00	0.00	16

Table 12.5 Elephant preferences for woody species in 2004 in terms of Ivlev's Electivity Index (Ivlev, 1961), the Forage Ratio (Cock, 1978) and the Rank Procedure method (Johnson, 1980). The woody species recorded within the Open Woodland 1 subcommunity in 2010 are ranked from most preferred to least preferred based on Ivlev's Electivity Index

Woody species	Ivlev's electivity index	Forage ratio	Rank Procedure method
Catunaregam spinosa	0.67	5.15	1
Trichilia emetica	0.57	3.65	2
Albizia versicolor	0.53	3.22	4
Dialium schlechteri	0.51	3.05	3
Garcinia livingstonei	0.50	3.04	3
Canthium inerme	0.50	2.97	5
Mundulea sericea	0.49	2.91	4
Brachylaena discolor	0.42	2.46	6
Vangueria infausta	0.30	1.86	6
Antidesma venosum	0.29	1.81	7
Strychnos madagascariensis	0.28	1.76	5
Strychnos decussata	0.22	1.57	7
Strychnos spinosa	0.20	1.49	6
Rothmannia fischeri	0.16	1.39	8
Bridelia micrantha	0.16	1.39	7
Ziziphus mucronata	0.14	1.33	8
Tabernaemontana elegans	0.12	1.29	8
Bridelia cathartica	0.12	1.28	8
Acacia robusta	0.09	1.19	9
Combretum molle	0.07	1.14	7
Psydrax locuples	-0.04	0.92	9
Sapium integerrimum	-0.05	0.90	8
Acacia burkei	-0.11	0.79	7
Albizia adianthifolia	-0.13	0.78	8
Terminalia sericea	-0.21	0.65	8
Dichrostachys cinerea	-0.26	0.58	11
Spirostachys africana	-0.39	0.44	10
Vepris lanceolata	-0.45	0.38	12
Grewia microthyrsa	-0.49	0.34	7
Sclerocarya birrea	-0.54	0.30	11

12.3 DISCUSSION

12.3.1 Percentage Canopy Removal

The damage caused by elephants within the Open Woodland 1 was predominantly through the breaking of branches and the uprooting of trees, similar to results in the Closed Woodlands and Sand Forest in the Tembe Elephant Park as well as studies done in other reserves (Boundja & Midgley, 2009; Valeix *et al*., 2011). Moreover, many woody species known for being targeting by elephants for bark stripping were highly utilised and available in this subcommunity in 2010. These species included *Acacia burkei* (Hiscocks, 1999; White & Goodman, 2009) and *Sclerocarya birrea* (O'Connor, 2010).

Using the data obtained by Gaugris in 2004 (Gaugris, 2008), a comparison with 2010 could be made in terms of the removal of canopy volume by elephants. The number of woody species utilised in the Open Woodland 1 by elephants increased from 30 species in 2004 to 36 species in 2010 (Figure 12.2). Twenty-four woody species were common to both periods. In 2010, 12 woody species were recorded with elephant damage in the Open Woodland 1 that were not identified in 2004 as having been utilised by elephants. On the other hand, six species were utilised in 2004 but not in 2010. Considering the large number of sample sites in the subcommunity these differences in species richness of utilised woody species were small compared to some of the other communities.

Elephant utilisation declined from 2004 to 2010 in the lower size classes (Figure 12.1). The high utilisation in the lower size classes during the 2004 survey could have affected population growth as these categories are meant to sustain the new emerging individuals. It was encouraging to observe a decrease in elephant utilisation in size class 1, 2, 3 and 4, especially size class 1 and 2, as these are the saplings that need to grow into woody adults. On the other hand, the increase in elephant utilisation within the larger size classes is a cause for concern. Utilisation in size classes 5 and 6 showed a marked increase in 2010. Size class 6 was moderately utilised in 2004 (16.81%) compared to 2010 where it had a very high canopy removal (50.12%).

The trend of increasing canopy removal with increasing stem diameter, found in almost all communities in the current study, was not unexpected as large individuals are those that elephants choose for browsing or rubbing against (Ben-Shahar, 1993). Dublin *et al*. (1990) also found elephant utilisation in the Serengeti-Mara Woodlands to be higher in the larger size classes. Matthews and Page (unpublished) as well as Boundja and Midgley (2009) reported the same pattern. However, this trend was not evident in the 2004 dataset.

The comparison of the 2004 dataset to the 2010 dataset revealed some changes in elephant utilisation patterns under increased utilisation pressure. For example, *Catunaregam spinosa*, which had a high canopy removal value in 2004 was not utilised as much by elephants during the 2010 field survey. *Strychnos madagascariensis* was the woody species in 2010 with the highest mean percentage canopy removal (Figure 12.2). This species was also the most utilised species in 2004 with approximately the same mean percentage utilisation. However, if the cumulative canopy removal percentages were calculated (Table 12.2) then it can be seen that the percentage canopy removal doubled from 2004 to 2010 (21.79% versus 42.62%). This increase is due to an increase in the canopy volume which was removed as well as a decrease in the available canopy volume. *Strychnos madagascariensis* had high utilisation values in the large size classes (Table 12.1 and 12.3) and this could be assigned to the fact that the stem of this species is multi-stemmed and very bulky. Therefore a big stem diameter was recorded and not necessarily a large tall tree. Both, *Acacia burkei* and *Sclerocarya birrea* experienced a tremendous increase in canopy removal percentage (Table 12.2), especially in the higher size classes. In the case of *Acacia burkei* the absolute canopy volume removed remained fairly constant from 2004 to 2010, however the available canopy volume showed a sharp decline after 2004. *Sclerocarya birrea* had 62.93% of its canopy removed in 2010 whereas only 4.14% of its canopy was removed in 2004. Elephant damage to this particular species has been reported in a number of studies (Duffy *et al*., 2002; Shannon *et al*., 2008; Helm *et al*., 2009). Canopy volume removed of *Dialium schlechteri* increased more than threefold from 2004 to 2010 (Table 12.1). This supports the ongoing concern in this study that the preference of elephants for *Dialium schlechteri* has increased over time as it was highly utilised in the 2010 survey in almost all the communities. The only community thus far where it did not have a high degree of elephant utilisation was in the Closed Woodland on Clay. Availability of *Dialium schlechteri* in that subcommunity was very low probably it prefers deep sandy soils and not clay (Van Wyk & Van Wyk, 1997). It is interesting to note that a decrease in canopy volume of *Dialium schlechteri* since 2004 did not occur, but there was an increase in the availability of this species.

Observations over a couple of years by management in the park noticed a decline in *Albizia* species (*Albizia versicolor*, *Albizia adianthifolia* and *Albizia forbesii*) (Matthews, pers.com.)[2].

[2] Dr W.S. Matthews. Regional Ecologist, Ezemvelo KZN Wildlife. Email: wayne@icon.co.za

Matthews and Page (undated) found *Albizia adianthifolia* to have the highest percentage of canopy removed, of all utilised species, and *Albizia versicolor* the third highest percentage in 1995 and they considered *Albizia* species to be abundant in Tembe Elephant Park. In 2004, *Albizia versicolor* and *Albizia adianthifolia* were still fairly available in the Open Woodland 1 (Table 12.2) and they had utilisation values of 40.72% and 17.50% respectively (Table 12.2). However, in 2010 the availability of these species had declined to a point that there were no more trees of *Albizia* species. In site 29 an *Albizia versicolor* as well as an *Albizia adianthifolia* seedling was recorded. Site 31 also had an *Albizia versicolor* seedling. From an observer's point of view, one would not say that the *Albizia* species were abundant in Tembe Elephant Park in 2010. In the Maputo Elephant Reserve, Mozambique, *Albizia versicolor* was utilised by elephants but it was not preferred by elephants (De Boer *et al*., 2000). Other plant species, known for elephant utilisation, that showed an increase in canopy removal percentages (Figure 12.2) since 2004 included *Combretum molle* (Hiscocks, 1999) and *Spirostachys africana* (Shannon *et al.,* 2008).

At a few localities within this subcommunity holes in the sand were observed where elephants had been digging (Figure 12.6). It was assumed that they searched for the roots of some woody species. In the Open Woodland 1 the holes were usually at the base of *Terminalia sericea* and *Dichrostachys cinerea* individuals.

The overall canopy removal of 12.47% in 2004 increased to a substantial 34.31% in 2010 (Table 12.2) an almost three-fold increase. This increase was due not only to an increase in the absolute canopy volume removed (42% increase above 2004 level), but also to a decrease in available canopy volume (52% decrease below 2004 level). Compared to the other vegetation communities in the Tembe Elephant Park the Open Woodland 1 was one of the communities/subcommunties most utilised by elephants in 2010. This contradicts the statement by Gaugris and Van Rooyen (2010a) who found that the Open Woodland on Sand community in Tembe Elephant Park had the lowest amount of elephant utilisation, together with the sparse Woodland on Sand. Gaugris and Van Rooyen (2010a) stated that elephant utilisation had moved from the northern parts of the park to the eastern parts. For the Open Woodland 1 this statement could not be confirmed as utilisation increased in all sites across the whole reserve. However, in the two most western Open Woodland 1 sites (7 and 12) elephant utilisation either decreased or remained unchanged compared to all other sites which increased. Thus a shift from the west to the east could possibly be demonstrated.

Figure 12.6 Illustration of a site where the elephants have been digging for roots.

12.3.2 Electivity

The changes in the elephants' selection towards woody species is a problem as they seem to utilise some woody species to such an extent that the species' available canopy decreases to extremely low levels (Ben-Shahar, 1993). This appears to be evident in the Open Woodland 1 community, especially for *Albizia versicolor* and *Albizia adianthifolia*.

Vangueria infausta was the most preferred species, by elephants, in 2010 according to its Ivlev's Electivity index (EI) of 0.35 and it was ranked second by the Rank Procedure Method. In 2004, *Vangueria infausta* was already a preferred woody species as it was ranked sixth and had an EI of 0.30. However, there is reason for concern regarding this woody species. In 2004 it was utilised by elephants throughout the majority of the community but in 2010 it was only utilised in a single site because of the large decline in available canopy (Table 12.2).

In 2004, *Albizia versicolor* was ranked the fourth most preferred species and it had a high EI of 0.53, however it made the second highest contribution (40.72%) to the total canopy removal. *Albizia adianthifolia* was ranked eighth but was avoided according to its negative EI. Neither of these species were utilised by elephants in this community during the 2010 survey, because only a few seedlings were present. The fact that *Albizia versicolor* was highly preferred by elephants in the Open Woodland 1 of Tembe Elephant Park, prior to the 2010 survey, is supported by Matthews and Page (undated) in the park and Boundja and Midgley (2009) in Hluhluwe-Imfolozi Park. The study in Hluhluwe-Imfolozi Park, South Africa, found *Albizia versicolor* to be the most preferred species for branch breaking and toppling (Boundja & Midgley, 2009). The change in woody species selection of elephants may be a matter of availability rather than actual preference (Dublin *et al*., 1990).

12.3.3 Relative Utilisation

In the 1995 survey three woody species could be identified as being heavily utilised by elephants with a relative utilisation above 10%, four species in 2004 and four species in 2010 as well. There was some agreement among survey periods, although each survey had its own main species that stood out. The relative utilisation of *Trichilia emetica*, *Albizia versicolor* and *Albizia adianthifolia* showed some similarity between 1995 and 2004. Woody species that were utilised in all three surveys included *Acacia burkei*, *Combretum molle*, *Sclerocarya birrea*, *Spirostachys africana*, *Strychnos madagascariensis* and *Terminalia sericea*. *Albizia adianthifolia* showed a decrease in availability and this was accompanied by a change in elephant utilisation. The 1995 survey revealed a high relative utilisation of this species, in 2004 it had a moderate relative utilisation value and in 2010 there were only single seedlings available, with no elephant utilisation.

12.4 CONCLUSION

Utilisation by elephants in the Open Woodland 1 subcommunity increased notably since 2004 and the availability of a number of woody species decreased. Increased damage by elephants is therefore unavoidable if the numbers of these megabrowsers increase further and the amount of available browsing material decreases. Woody species that should be considered threatened by elephants within this particular community comprised *Albizia adianthifolia*, *Albizia versicolor*, *Vangueria infausta* and *Tabernaemontana elegans*.

CHAPTER 13

UTILISATION IN THE *PAVETTA LANCEOLATA – BRACHYLAENA DISCOLOR* OPEN WOODLAND ON SAND

13.1 INTRODUCTION

The *Pavetta lanceolata – Brachylaena discolor* Open Woodland on Sand subcommunity (referred to as Open Woodland 2) is a subcommunity of the *Terminalia sericea - Strychnos madagascariensis* Open Woodland on Sand community in the Tembe Elephant Park. This subcommunity (Open Woodland 2) is situated in the west of the park and can be described as an open woodland or wooded grassland in contrast to the *Ozoroa engleri – Terminalia sericea* Open Woodland on Sand (Open Woodland 1) which has a higher density of tall woody individuals.

The Open Woodland 2 was not in close proximity to water. It is located primarily in the western section of Tembe Elephant Park where elephant activity is generally low, possibly because of the large distance to permanent water. This subcommunity was utilised by a range of herbivores in the medium to large class.

13.2 RESULTS

13.2.1 Elephant utilisation – 2010 survey

The cumulative[1] percentage canopy removal of the utilised species increased as the size classes increased (Figure 13.1) even although utilisation was at very low intensities within this subcommunity (Table 13.1). Size class 1 had no utilisation, followed by size class 2, 3

[1] Cumulative canopy removal percentage refers to the total volume of the canopy removed of all species expressed as a percentage of the available volume of only the utilised species.

and 4 with minimal canopy removal of 0.14%, 2.46% and 7.25% respectively. Size class 6 had the highest canopy removal at 39.65%.

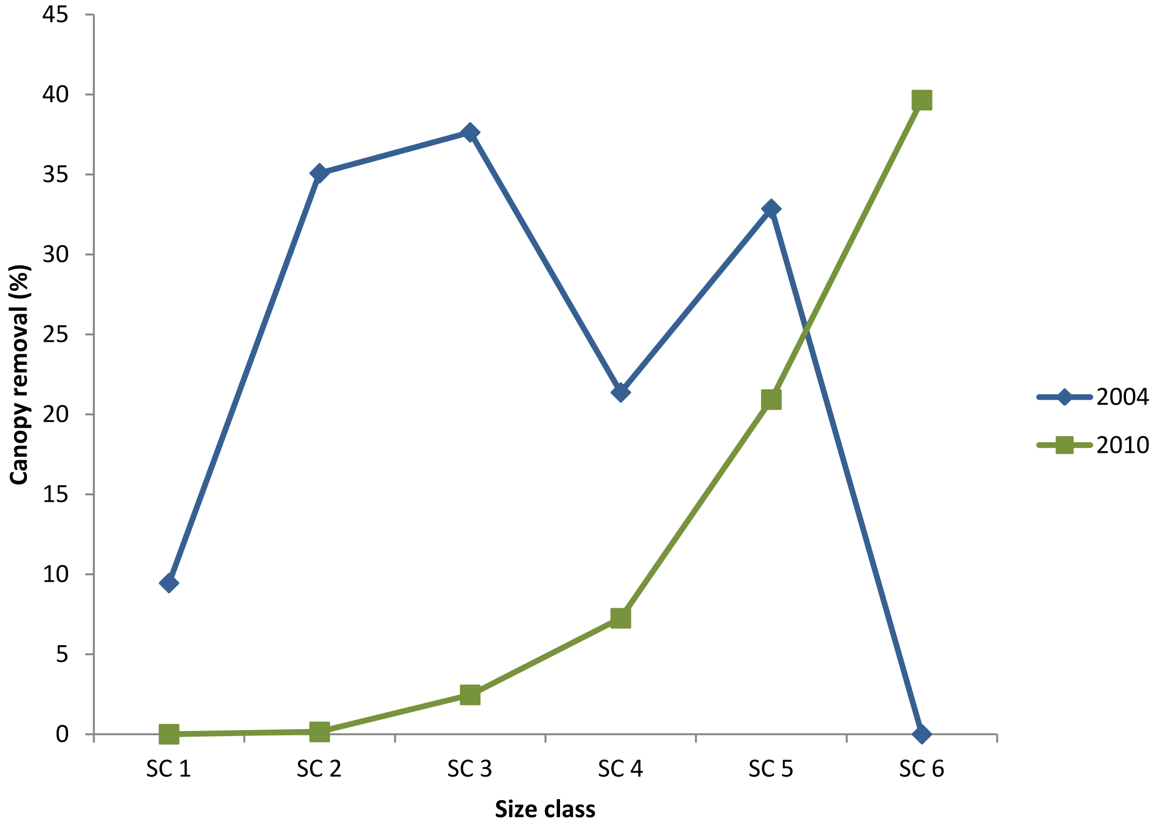

Figure 13.1 Cumulative percentage canopy volume (of utilised species) removed per size class (SC) in 2004 and 2010 in the Open Woodland 2 subcommunity in the Tembe Elephant Park.

Acacia burkei had the highest mean canopy removal in the Open Woodland 2 in 2010 with a canopy removal of 31.28% followed by *Terminalia sericea* with 22.36% canopy removal (Figure 13.2). *Terminalia sericea* and *Strychnos madagascariensis* (3.28%) were utilised in three or more of the Open Woodland 2 sites even although *Strychnos madagascariensis* had low levels of canopy removal. Other woody species in the Open Woodland 2 which had signs of utilisation by elephants in 2010 include *Dialium schlechteri* (12.70%), *Strychnos spinosa* (4.97%) and *Pteleopsis myrtifolia* (4.89%). *Terminalia sericea, Dialium schlechteri* and *Strychnos madagascariensis* were utilised within a variety of size classes (Table 13.2).

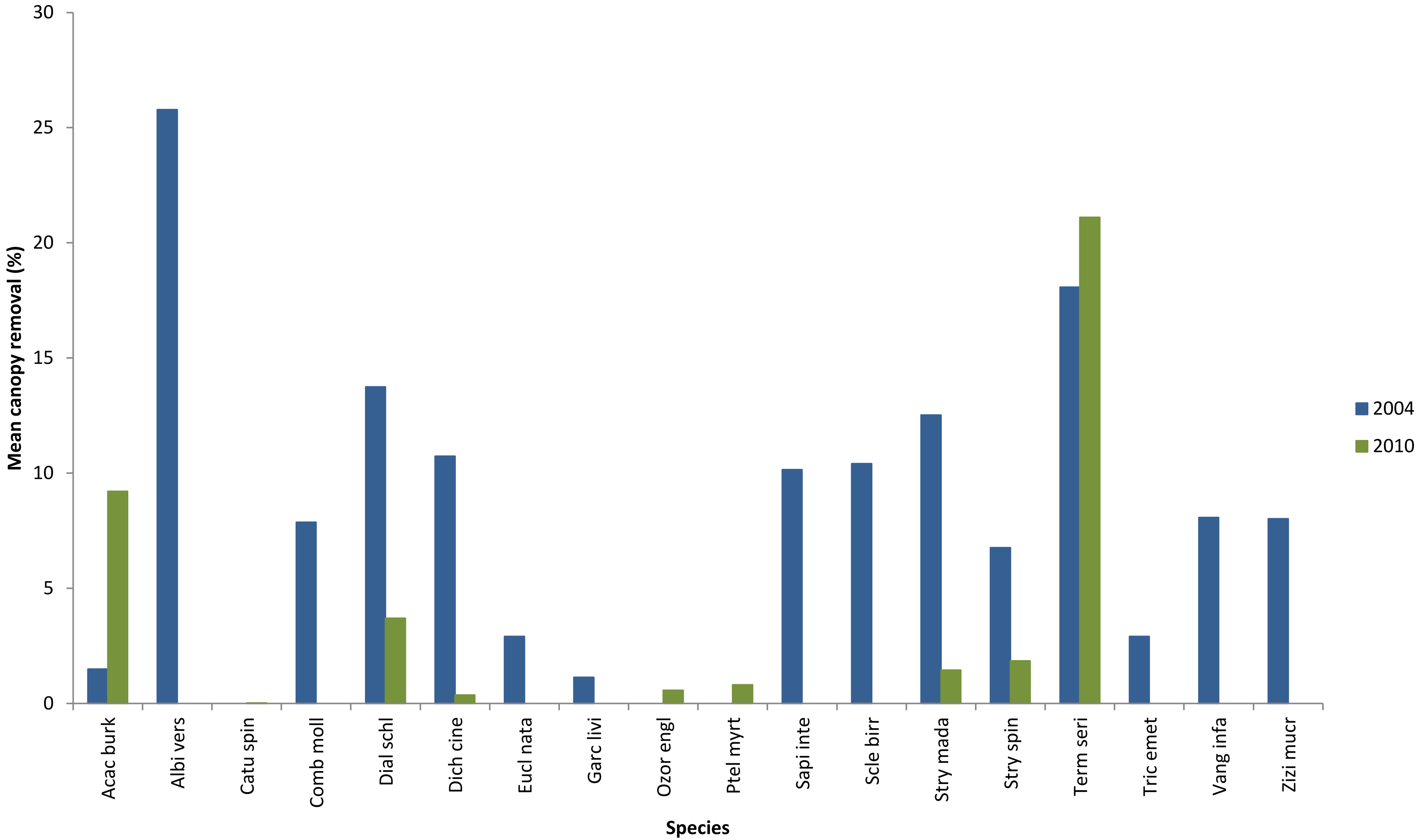

Figure 13.2 Woody species utilised by elephants in the Open Woodland 2 as recorded in 2004 and 2010. Appendix A contains a list of abbreviations of all species names.

Table 13.2 Available canopy volume and removed canopy volume per utilised species within the Open Woodland 2 subcommunity for 2010 and 2004. Elephant utilisation is expressed as cumulative percentage utilised as well as a relative utilisation percentage

Species	2010				2004			
	Available (m^3/ha)	Removed (m^3/ha)	% Utilised	Relative utilisation (%)	Available (m^3/ha)	Removed (m^3/ha)	% Utilised	Relative utilisation (%)
Acacia burkei	601	188	31.28	24.37	211	19	8.96	0.89
Albizia versicolor	-	-	-	-	460	354	76.90	16.57
Catunaregam spinosa	10	0	0.14	0.00	-	-	-	-
Combretum molle	-	-	-	-	188	34	17.79	1.57
Dialium schlechteri	128	16	12.70	2.10	169	140	82.50	6.54
Dichrostachys cinerea	98	1	0.60	0.08	52	15	28.84	0.70
Euclea natalensis	-	-	-	-	50	9	17.50	0.41
Garcinia livingstonei	-	-	-	-	41	3	6.82	0.13
Ozoroa engleri	37	1	3.47	0.17	-	-	-	-
Pteleopsis myrtifolia	8	0	4.89	0.05	-	-	-	-
Sapium integerrimum	-	-	-	-	36	22	60.94	1.03
Sclerocarya birrea	-	-	-	-	1	1	62.50	0.03
Strychnos madagascariensis	77	3	3.28	0.33	848	199	23.44	9.32
Strychnos spinosa	7	0	4.97	0.05	36	15	40.62	0.68
Terminalia sericea	2515	562	22.36	72.86	3959	951	24.03	44.57
Trichilia emetica	-	-	-	-	78	14	17.50	0.64
Vangueria infausta	-	-	-	-	218	106	48.44	4.95
Ziziphus mucronata	-	-	-	-	531	256	48.16	11.98
Total of utilised species	3481	772	22.17		6878	2134	31.03	
Total of not utilised species	316	0	0.00		2364	0	0.00	
Total available of all species	3797	772	20.33		9242	2134	23.09	

Cumulative canopy removal of utilised species in Open Woodland 2 ranged from 2.63% (site 19) to 61.45% (site 16) in 2010 (Figure 13.3). The mean cumulative canopy removal of only utilised species was 22.17%. If all canopy available is considered then the total canopy removal for the six Open Woodland 2 sites in 2010 was 20.33% (Figure 13.4, Table 13.1).

Table 13.2 Mean utilisation per size class (SC) (expressed as % of canopy volume removed) for utilised Open Woodland 2 species in 2010

Woody species	SC 1	SC 2	SC 3	SC 4	SC 5	SC 6
Acacia burkei	0.00	0.00	0.00	0.00	5.29	9.55
Catunaregam spinosa	0.00	0.47	0.00	0.00	0.00	0.00
Dialium schlechteri	0.00	0.00	0.83	0.83	3.10	3.77
Dichrostachys cinerea	0.00	0.81	0.53	0.00	0.00	0.00
Ozoroa engleri	0.00	0.00	0.00	0.00	2.92	0.00
Pteleopsis myrtifolia	0.00	0.00	0.00	0.00	2.92	0.00
Strychnos madagascariensis	0.00	0.00	0.26	1.31	0.83	0.00
Strychnos spinosa	0.00	0.00	0.83	2.05	0.00	0.00
Terminalia sericea	0.00	0.49	1.64	1.62	9.27	21.98

12.2.2 Elephant utilisation – 2004 survey

Cumulative canopy removal in all size classes, except for size class 6, was higher in 2004 than 2010 (Figure 13.1). Size class 6 had a noticeable increase in elephant utilisation in 2010 compared to the zero elephant utilisation in 2004. Size class 1, 2 and 3 had prominently higher elephant utilisation values in 2004 compared to the 2010 survey with canopy removal of 15.75%, 25.21% and 71.24%, respectively. The high levels of utilisation in the lower size classes during the 2004 survey could have negatively affected the ability of the subcommunity to maintain its canopy volume.

Albizia versicolor and *Terminalia sericea* had moderate mean utilisation levels in 2004 with 25.79% and 18.08% canopy removed, respectively (Figure 13.2). Figure 13.2 shows the extent of woody species utilised in 2004 and it is clear that the number of species and their respective levels of utilisation were higher in 2004 than 2010. Other woody species with moderate levels of canopy removal in 2004, included *Dialium schlechteri* (13.75%), *Dichrostachys cinerea* (10.73%), *Sclerocarya birrea* (10.42%) and *Strychnos madagascariensis* (12.53%). All four these woody species experienced a decline in elephant utilisation from 2004 to 2010 and it should be noted that *Sclerocarya birrea* was not recorded as utilised in the Open Woodland 2 during the 2010 survey. *Strychnos madagascariensis* decreased in elephant utilisation from 2004 to 2010 in all the size classes (Table 13.3) within which utilisation took place. A similar trend was reported for *Terminalia sericea* and *Dichrostachys cinerea* where only one size class had higher utilisation in 2010 than 2004.

The sampling site with the highest elephant impact in 2004 was site 31 with a cumulative canopy removal of 38.83% (of utilised species) and sampling site 18 experienced the lowest elephant utilisation with no elephant utilisation present in the site (Figure 13.3). Site 19, 31 and 32 showed a decrease in elephant damage from 2004 to 2010. The difference for percentage canopy removal for the sites is not significant for 2004 and 2010 (p=0.938). In 2004, the cumulative canopy removal for the Open Woodland 2 community was 23.09%, calculated in terms of available canopy volume of all species (Figure 13.4). Utilisation in this community decreased since the 2004 survey.

13.2.3 Elephant utilisation – 1995 survey

Figure 13.5 illustrates the contribution of species towards utilisation by elephants over a 15 year period. *Terminalia sericea* had the highest relative utilisation in all three surveys. In 1995 *Terminalia sericea* contributed most to elephant utilisation (81.95%), followed by *Afzelia quanzensis* (5.83). In 2004, the survey demonstrated that *Terminalia sericea* was the most utilised species with 44.57% followed by *Strychnos madagascariensis* (9.32%) and *Dialium schlechteri* (6.54%). *Terminalia sericea* was the species with the highest relative utilisation in 2010 (72.86%) and *Acacia burkei* (24.37%) was clearly a highly utilised species as well.

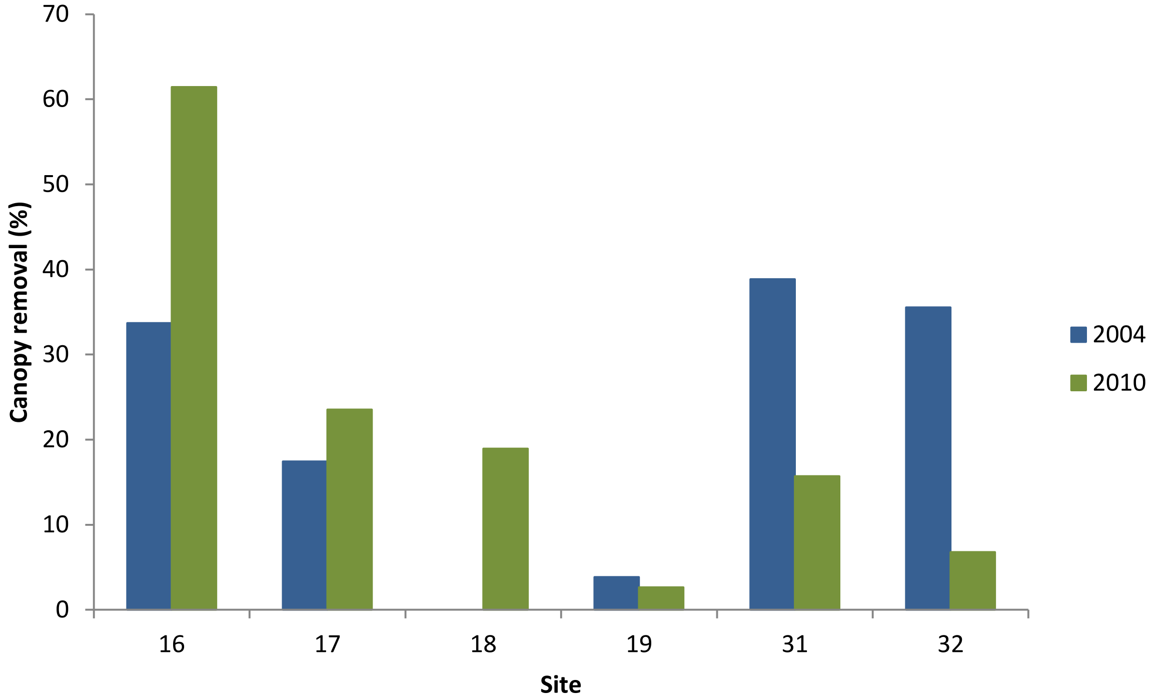

Figure 13.3 Cumulative percentage canopy removal (of utilised species only) by elephants at the six Open Woodland 2 subcommunity sites as surveyed in 2004 (blue) and 2010 (green).

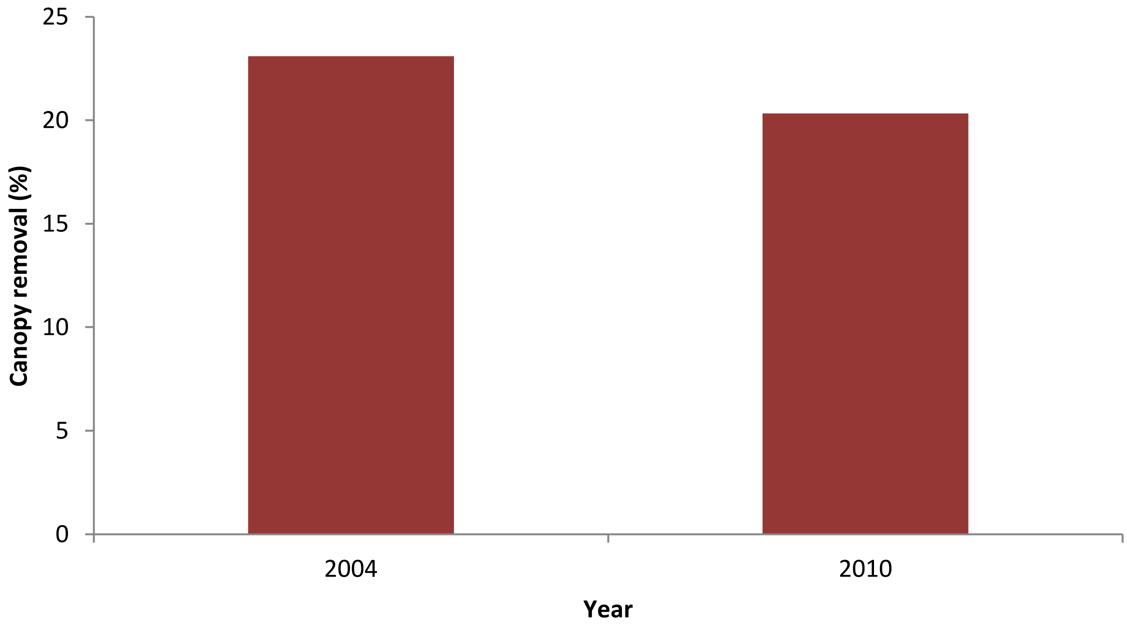

Figure 13.4 Cumulative percentage canopy removal (expressed as percentage of all species) in the Open Woodland 2 subcommunity for 2004 and 2010.

Table 13.3 Mean utilisation per size class (SC) (expressed as % of canopy volume removed) for Open Woodland 2 species in 2004

Woody species	SC 1	SC 2	SC 3	SC 4	SC 5	SC 6
Acacia burkei	0.00	0.00	0.00	0.47	2.92	0.00
Albizia versicolor	0.00	0.00	0.00	15.57	25.26	0.00
Combretum molle	0.00	0.00	0.00	7.88	0.00	0.00
Dialium schlechteri	0.00	0.00	13.75	0.00	0.00	0.00
Dichrostachys cinerea	15.75	0.00	6.15	10.42	0.00	0.00
Euclea natalensis	0.00	0.00	2.92	0.00	0.00	0.00
Garcinia livingstonei	0.00	0.00	0.00	1.09	1.14	0.00
Sapium integerrimum	0.00	0.00	0.00	10.16	0.00	0.00
Sclerocarya birrea	0.00	0.00	10.42	0.00	0.00	0.00
Strychnos madagascariensis	0.00	6.51	16.47	7.27	7.30	0.00
Strychnos spinosa	0.00	0.00	6.77	0.00	0.00	0.00
Terminalia sericea	0.00	27.07	9.14	16.30	17.59	0.00
Trichilia emetica	0.00	0.00	0.00	0.00	2.92	0.00
Vangueria infausta	0.00	0.00	0.00	0.00	8.07	0.00
Ziziphus mucronata	0.00	0.00	0.00	0.00	8.07	0.00

7.2.4 Elephant preferences

According to Ivlev's Electivity Index the most preferred woody species in 2010 was *Acacia burkei.* Although *Terminalia sericea* had a positive electivity value it was too low to determine true preference (Table 13.4). The elephants' preferences differ from 2004 to 2010 because in 2004 the woody species that showed the highest Ivlev's Electivity Index were *Albizia versicolor*, *Sclerocarya birrea*, *Dialium schlechteri*, *Vangueria infausta* and *Ziziphus mucronata*. *Albizia versicolor*, *Dialium schlechteri* and *Strychnos spinosa* had the highest ranking with the Rank Procedure method (Table 13.5). *Acacia burkei* was not selected during the 2004 survey although it was the most preferred species in 2010.

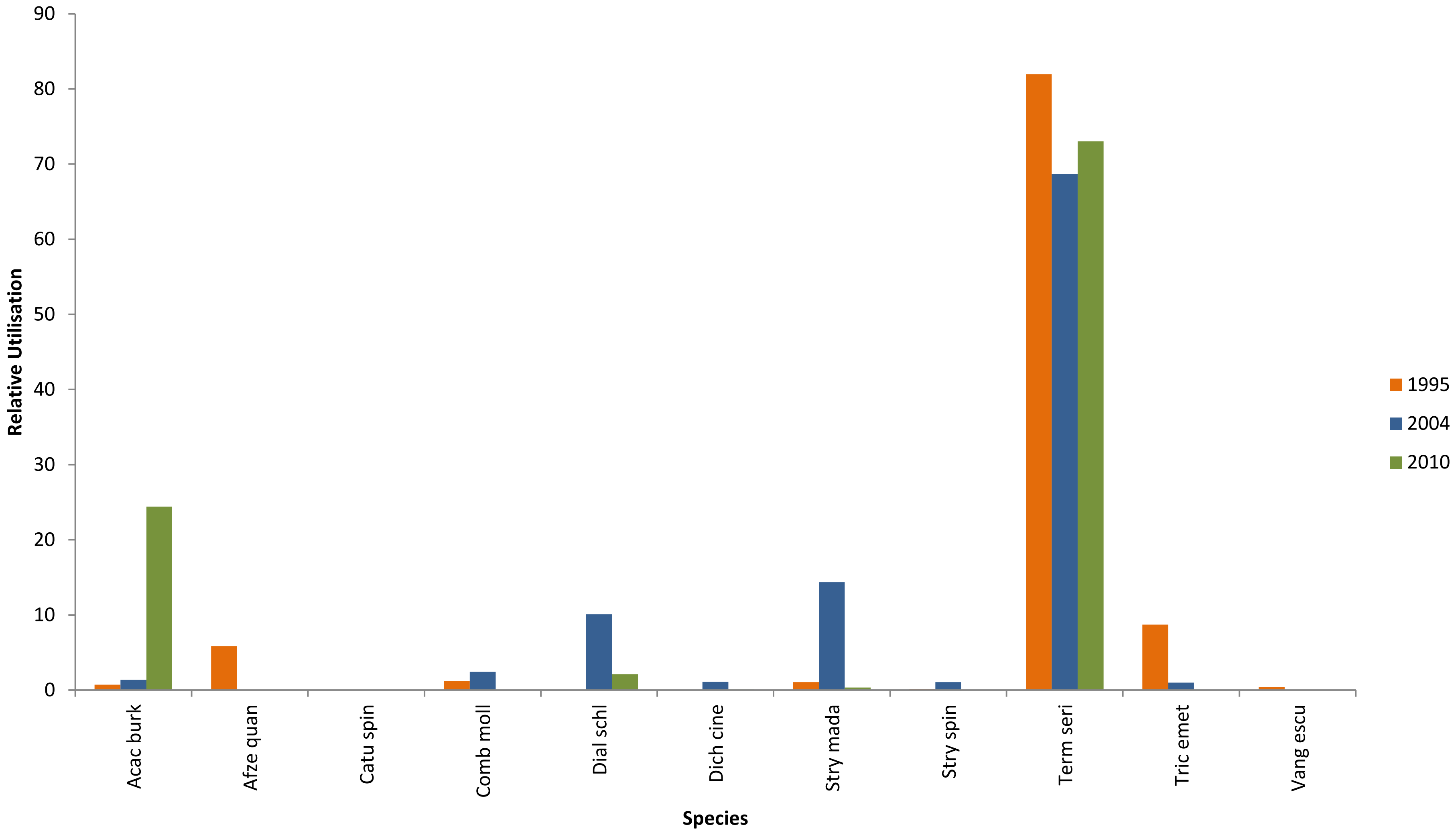

Figure 13.5 Relative utilisation of various species by elephants in 1995, 2004 and 2010 in the Open Woodland 2 community of Tembe Elephant Park. Appendix A contains a list of abbreviations of all species names.

Table 13.4 Elephant preferences for woody species in 2010 in terms of Ivlev's Electivity Index (Ivlev, 1961), the Forage Ratio (Cock, 1978) and the Rank Procedure method (Johnson, 1980). The woody species recorded within the Open Woodland 2 subcommunity in 2010 are ranked from most preferred to least preferred based on the Electivity Index

Woody species	Ivlev's Electivity Index	Forage Ratio	Rank Procedure
Acacia burkei	0.21	1.54	3
Terminalia sericea	0.05	1.10	3
Dialium schlechteri	-0.23	0.62	3
Pteleopsis myrtifolia	-0.61	0.24	1
Strychnos spinosa	-0.68	0.19	3
Ozoroa engleri	-0.71	0.17	2
Strychnos madagascariensis	-0.76	0.13	2
Dichrostachys cinerea	-0.95	0.03	4
Catunaregam spinosa	-0.99	0.01	4

Table 13.5 Elephant preferences for woody species in 2004 in terms of the Forage Ratio (Cock, 1978), Ivlev's Electivity Index (Ivlev, 1961) and the Rank Procedure method (Johnson, 1980). The woody species recorded within the Open Woodland 2 subcommunity in 2004 are ranked from most preferred to least preferred based on the Electivity Index

Woody species	Ivlev's Electivity Index	Forage Ratio	Rank Procedure
Albizia versicolor	0.54	3.33	1
Sclerocarya birrea	0.46	2.71	4
Dialium schlechteri	0.37	2.19	2
Vangueria infausta	0.35	2.10	1
Ziziphus mucronata	0.35	2.09	3
Strychnos spinosa	0.27	1.73	1
Terminalia sericea	-0.03	0.94	4
Strychnos madagascariensis	-0.07	0.86	5
Trichilia emetica	-0.14	0.76	5
Combretum molle	-0.21	0.65	3
Euclea natalensis	-0.24	0.61	5
Dichrostachys cinerea	-0.36	0.48	4
Garcinia livingstonei	-0.54	0.30	5
Sapium integerrimum	-0.64	0.22	6
Acacia burkei	-0.85	0.08	7

13.3 DISCUSSION

13.3.1 Percentage canopy removal

In woodland vegetation it is common for elephants to break branches, uproot trees (Boundja & Midgley, 2009; Valeix *et al*., 2011) and debark stems (Hiscocks, 1999; Ihwagi *et al*., 2009; Boundja & Midgley, 2009; White & Goodman, 2009; O'Connor, 2010). Signs of elephants breaking branches and the occasional uprooting of trees were observed in the Open Woodland 2, but no bark stripping was encountered.

Using the data obtained by J.Y. Gaugris[2] in 2004 (Gaugris, 2008), a comparison with 2010 was made in terms of canopy volume removed by elephants. The number of woody species utilised by elephants in the Open Woodland 2 decrease from 15 species in 2004 to nine species in 2010 (Figure 13.2). Six woody species were common to both datasets. Overall, this subcommunity was characterised by a low diversity of woody species and consequently also a low diversity of utilised species. Generally, elephants prefer habitat with a heterogeneous structure and composition (White & Goodman, 2009) and the Open Woodland 2 is a very homogeneous plant subcommunity (see Figure 5.7).

Elephant utilisation in this subcommunity, as indicated by the cumulative canopy removal, declined from 2004 to 2010 in size classes 1 to 5 (Figure 13.1), but there was an increase in elephant utilisation within the largest size class. The expected trend of increasing canopy removal with increasing stem diameter (Ben-Shahar, 1993; Dublin *et al*., 1990; Matthews & Page, undated; Boundja & Midgley, 2009) was evident within the community in 2010, but not in 2004.

Utilisation values in the current study included damage of all ages and the majority of damage in size class 6 was more than 2 years old. Thus the high utilisation value in the large size classes could possibly be ascribed to accumulated damage (O'Connor, 2010). Evidence for the cumulative nature of elephant impact on species richness and biomass, was reported by Roux and Bernard (2007). For utilisation purposes the foliage of tall trees is at a suitable level for browsing and if the foliage is too high, these would be the individuals they would push over in order to reach the fruits or nutritious leaflets. The relatively high

[2] Dr J.Y. Gaugris: Centre for Wildlife Management, University of Pretoria, Pretoria 0002, South Africa. Email: jeromegaugris@florafaunaman.com

level of damage or utilisation in the small size classes in 2004, especially size class 3 (37.63% canopy removal) was a point of concern.

Changes in species utilisation patterns over a 15-year period were apparent in the Open Woodland 2. A number of species with high canopy removal values in 2004, such as *Albizia versicolor, Sclerocarya birrea* and *Sapium integerrimum*, were no longer present in this subcommunity during the 2010 field survey (Table 13.2). *Terminalia sericea* was the woody species contributing most to canopy removal in both 2004 and 2010 (Table 13.2) and had high utilisation values in almost all the size classes (Table 13.1 and 13.3). *Acacia burkei* experienced a tremendous increase in elephant utilisation, especially in the larger size classes. Utilisation of *Dialium schlechteri,* on the other hand, was reduced from 82.50% to 12.70% of its canopy removed.

The decline in abundance of *Albizia* species was once again evident in Open Woodland 2. *Albizia versicolor* contributed fourth most to available canopy in 2004 and made the second largest contribution towards utilised canopy in that survey (Table 13.2). However, in 2010 the availability of this species declined to a point that there were no *Albizia* trees. In the Maputo Elephant Reserve, Mozambique, *Albizia versicolor* was utilised by elephants but it was not preferred by elephants (De Boer *et al*., 2000). In Tembe Elephant Park is the utilisation of *Albizia* species was clearly different (see paragraph 13.3.2).

The overall canopy removal of 23.09% in 2004 decreased slightly to 20.33% in 2010 (Table 13.2). However, it should also be noted that the available canopy volume decreased substantially (41% decrease below 2004 level) from 2004 to 2010. The absolute canopy volume removed also decreased van 2004 to 2010 (36% decrease below 2004 level). Compared to the other vegetation communities in the Tembe Elephant Park the Open Woodland 2 was the most heavily utilised community/subcommunty in 2004 by elephants. In 2010, however it was one of the least utilised subcommunities but the percentage canopy removal was still quite high. Gaugris and Van Rooyen (2010a) found that the Open Woodland on Sand community, which includes the Open Woodland 2 subcommunity, in the Tembe Elephant Park had the lowest amount of elephant utilisation.

In this subcommunity holes were found at the base of *Dichrostachys cinerea* where elephants had been digging (see Figure 12.6). It was assumed that they searched for the roots of this species.

13.3.2 Electivity

Based on Ivlev's Electivity Index *Acacia burkei* was the most preferred species in the Open Woodland 2 in the 2010 survey. However in 2004 it was on the bottom of the preference list. In 2004, *Albizia versicolor* was ranked the most preferred species and it had a high Electivity index of 0.54. This species was not utilised by elephants in this subcommunity during the 2010 survey, only a seedling was recorded. The fact that *Albizia versicolor* was highly preferred by elephants in the Open Woodland 2 of the Tembe Elephant Park, prior to the 2010 survey, is supported by Matthews and Page (undated). In a study in Hluhluwe-Imfolozi Park, South Africa, Boundja and Midgley (2009) found *Albizia versicolor* to be the most preferred species for branch breaking and toppling. The change in woody species selection however also depends on availability (Dublin *et al*., 1990). Even although the number of woody species utilised by elephants in the Open Woodland 2 has declined slightly, the Electivity Index values indicated that the number of species actually selected for, decreased. During the 2004 survey, six woody species had positive Electivity Index values, but in 2010 only two species had positive values.

13.3.3 Relative utilisation

Each of the three surveys showed a different group of woody species that were utilised by elephants. It appears that the elephants select a specific plant species and then utilise the preferred plant species until they reduce the availability of that species. In 1995, the elephants showed high levels of relative utilisation for *Terminalia sericea* and that was still the case in 2004 and aggravated in 2010 with a relative utilisation of 97.16%.

The utilisation of woody species by elephants seems to have been similar from 1995 to 2010, not just in terms of species but the overall manner in which they fed. The selection of woody species by elephants in 1995 was a bit broader. There were six or seven species that were clearly targeted but the relative utilisation of those species ranged from 0.41% to 81.95%. Comparing these results to those in 2004 and 2010, it is as if the preferences or the selection of the elephants narrowed down in 2004 and in 2010 it became a bit more diverse again.

13.4 CONCLUSION

Woody species that should be considered threatened by elephants within this particular community include *Albizia versicolor* and *Strychnos spinosa*. Elephant utilisation in the Open Woodland 2 subcommunity experienced a decrease from 2004 to 2010. Although this might seem encouraging, it could be because the woody species are no longer present and the available browsing material left for the elephants has been reduced to such an extent that elephants no longer visit this community.

Within the Sand Forest communities the role of fire is negligible (Gaugris & Van Rooyen, 2011) but within the woodlands it could be very important. Fire events in Tembe Elephant Park are uncommon (Matthews, 2007a; Gaugris & Van Rooyen, 2010b). The decrease of available canopy volume since 2004 in the communities, especially the open and sparse woodlands, could be due to fire events during the past two years prior to the field survey. Incidences of fire damage were recorded in the field. It is known that woody cover will decrease as the frequency of fire increase (Eckhardt *et al*., 2000). In woodlands, fire had a more severe impact on elephant utilised woody species (Shannon *et al*., 2011).

CHAPTER 14

UTILISATION IN THE *CARISSA BISPINOSA* – *TERMINALIA SERICEA* SPARSE WOODLAND ON SAND

14.1 INTRODUCTION

The *Carissa bispinosa* – *Terminalia sericea* Sparse Woodland on Sand community (referred to as Sparse Woodland) is situated in the centre of the southern region of the Tembe Elephant Park. The Sparse Woodland is a very sandy plant community with a number of woody individuals but most remain small shrubs and few individuals become large (see Figure 5.8).

Based on species composition, the Sparse Woodland did not differ from the Open Woodland 2, and the separation was primarily on vegetation structure. Elephant activity is low in this community (Muller & Matthews, 2010) but it is visited as they pass through from one woodland to the other.

14.2 RESULTS

14.2.1 Elephant utilisation – 2010 survey

With increasing size classes woody individuals were larger and had larger canopy volumes, even although in this particular community there were not many such individuals. Size class 3 had the most elephant cumulative canopy removal in 2010 at 20.68% utilisation (Figure 14.1). Considering only the utilised species size class 1, 5 and 6 had no canopy removed by elephants. Utilisation was relatively low in size class 2 and 4 with 7.15% and 0.60% respectively. Size class 6 did not have any observed elephant utilisation even although there was canopy available in this size class within transect 3. The low availability (canopy volume) of woody species is evident in Table 14.1.

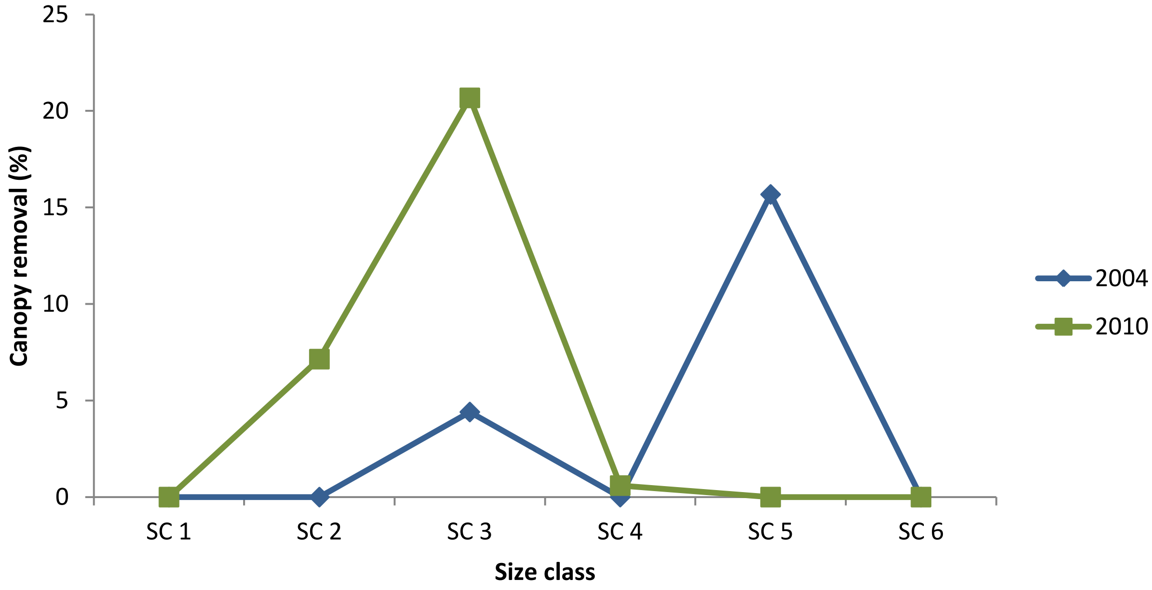

Figure 14.1 Cumulative percentage canopy volume (of utilised species) removed per size class (SC) in 2004 and 2010 in the Sparse Woodland community in the Tembe Elephant Park.

Figure 14.2 illustrates the mean canopy removal of all elephant utilised woody species in the Sparse Woodland. It is noticeable that utilisation levels were low as none of the species had a percentage canopy removal above 9.00%. *Strychnos madagascariensis* had the highest mean utilisation value with 8.70% canopy removed and was browsed in the second size class only (Table 14.2). *Dichrostachys cinerea, Grewia caffra* and *Terminalia sericea* were poorly utilised with canopy removals of 0.01%, 2.50% and 1.35% respectively. All these utilisation events were single incidents, thus only occurring in a single size class within a particular site.

Cumulative canopy removal (total of utilised species) in the Sparse Woodland in 2010 was exceptionally low and Figure 14.3 shows utilisation percentages for all available woody species. Both sites had similar canopy removal values (Figure 14.4). This was the community with the lowest canopy removal in Tembe Elephant Park during the 2010 survey. The total canopy removal in the Sparse Woodland, in terms of all available woody species was 3.39% (Table 14.1).

Table 14.1 Available canopy volume and removed canopy volume per utilised species within the Sparse Woodland on Sand community for 2010 and 2004. Elephant utilisation is expressed as cumulative percentage utilised as well as a relative utilisation percentage

Species	2010				2004			
	Available (m^3/ha)	Removed (m^3/ha)	% Utilised	Relative utilisation (%)	Available (m^3/ha)	Removed (m^3/ha)	% Utilised	Relative utilisation (%)
Dichrostachys cinerea	708	1	0.10	0.52	-	-	-	
Grewia caffra	23	1	5.00	0.80	-	-	-	
Strychnos madagascariensis	609	105	17.14	74.57	1929	287	14.84	89.39
Terminalia sericea	1251	34	2.70	24.12	813	34	4.18	10.61
Total of utilised species	2590	140	5.40		2743	321	11.68	
Total of not utilised species	1539	0	0.00		3250	0	0.00	
Total available of all species	4129	140	3.39		5992	321	5.35	

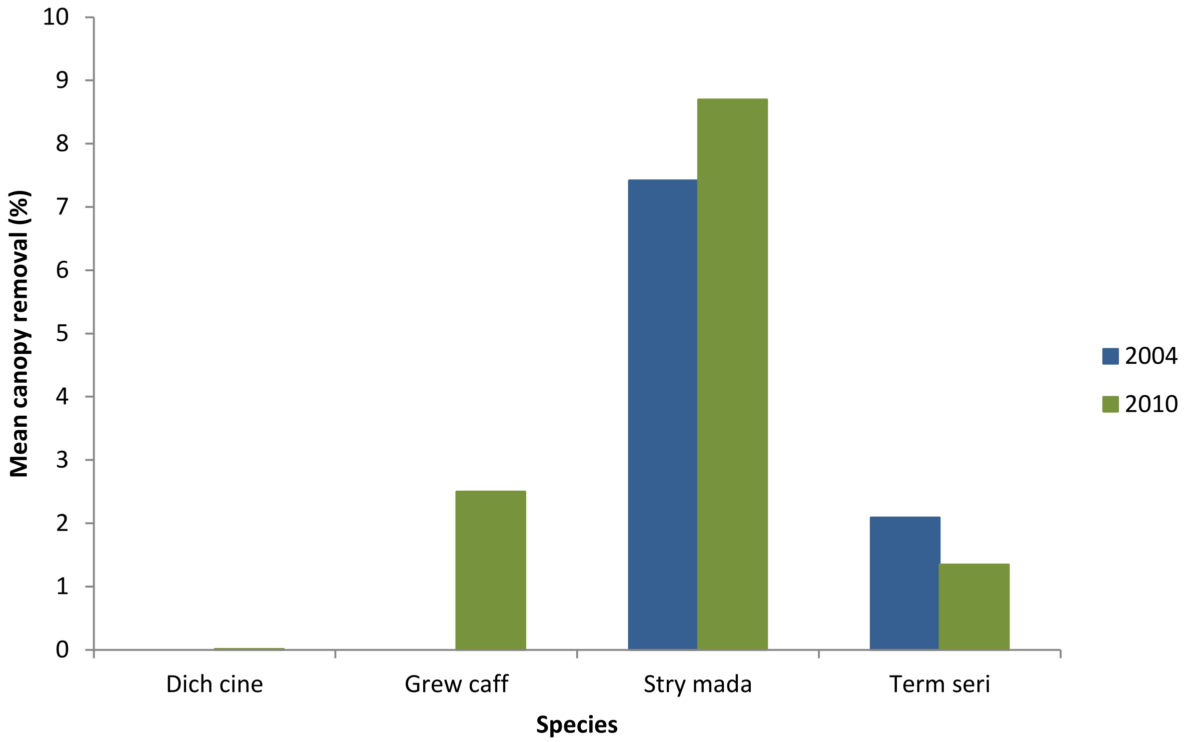

Figure 14.2 Woody species utilised by elephants in the Sparse Woodland as recorded in 2004 and 2010. Appendix A contains a list of abbreviations of all species names.

Table 14.2 Mean utilisation per size class (SC) (expressed as % of canopy volume removed) for Sparse Woodland species in 2010

Woody species	SC 1	SC 2	SC 3	SC 4	SC 5	SC 6
Dichrostachys cinerea	0.00	0.00	0.00	0.04	0.00	0.00
Grewia caffra	0.00	0.00	0.00	2.50	0.00	0.00
Strychnos madagascariensis	0.00	0.00	26.09	0.00	0.00	0.00
Terminalia sericea	0.00	3.79	0.00	0.00	0.00	0.00

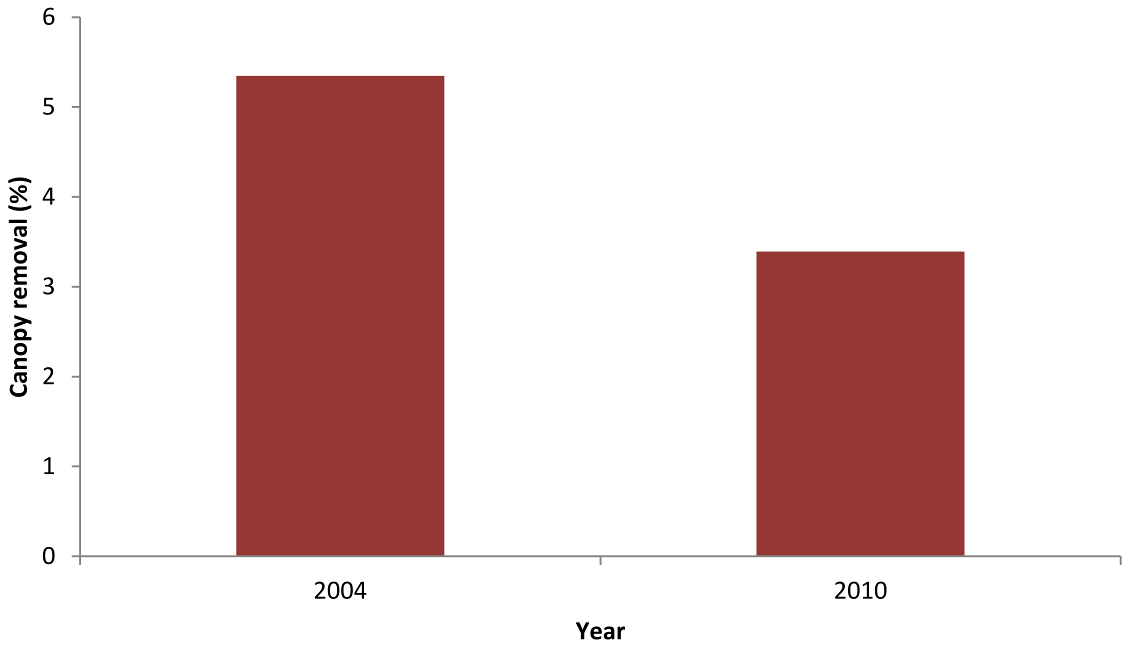

Figure 14.3 Cumulative percentage canopy removal (expressed as percentage of all species) in the Sparse Woodland community for 2004 and 2010.

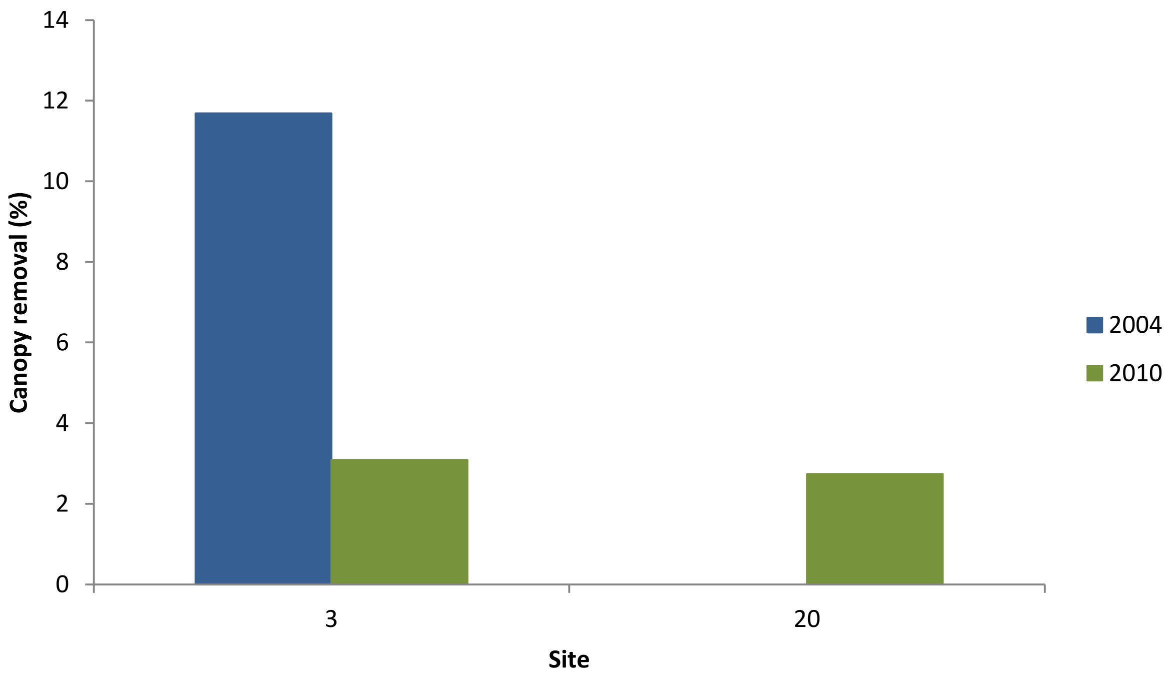

Figure 14.4 Cumulative percentage canopy removal (of utilised species only) by elephants at the two Sparse Woodland community sites as surveyed in 2004 (blue) and 2010 (green).

8.2.2 Elephant utilisation – 2004 survey

Cumulative percentage canopy removal, for the 2004 survey, was restricted to two size classes (Figure 14.1). In size class 3 the canopy removal was low with 4.41% in 2004. Size class 5 experienced a decrease in elephant utilisation since 2004, which had a cumulative canopy removal of 15.68% in 2004 compared to zero in 2010.

The elephant utilisation observed during the 2004 survey was only amongst two woody species. In addition to this, the utilisation recorded was only in a single site as the other site did not have any elephant utilisation. *Strychnos madagascariensis* was the woody species with the highest canopy removal in 2004 with 7.42% canopy removed (Figure 14.2). This species was present only in a single site. The other species utilised in the Sparse Woodland, in 2004, was *Terminalia sericea* with 2.08% canopy removed. Both these species were only utilised by the elephants in a single size class (Table 14.3).

In general, utilisation by elephants in the Sparse Woodland was very low in 2004. Site 3 had the highest elephant utilisation with 11.68% (Figure 14.4), which was almost four times higher than the utilisation in 2010. Site 20 did not have any elephant utilisation. The change in elephant utilisation in the Sparse Woodland sites from 2004 and 2010 is not significantly different (p=0.877). Overall elephant utilisation in the Sparse woodland was 5.35% in 2004 (Figure 14.3). This value is in terms of all available species (Table 14.2).

Table 14.3 Mean utilisation per size class (SC) (expressed as % of canopy volume removed) for Sparse Woodland species in 2004

Woody species	SC 1	SC 2	SC 3	SC 4	SC 5	SC 6
Strychnos madagascariensis	0.00	0.00	0.00	0.00	7.84	0.00
Terminalia sericea	0.00	0.00	2.49	0.00	0.00	0.00

8.2.3 Elephant utilisation – 1995 survey

Compared to the other surveys, the 1995 survey showed a different suite of species utilised even though some of them did overlap with the 2004 and 2010 dataset (Figure 14.5). *Acacia burkei* had the highest relative utilisation with 27.05% in 1995, followed by *Sclerocarya birrea* (23.25%), *Terminalia sericea* (19.97%), *Strychnos madagascariensis* (15.51%) and *Albizia adianthifolia* (10.28%). The 1995 relative utilisation values were evenly spread amongst a range of species. Approximately ten years after the 1995 survey, *Strychnos madagascariensis* was the species with the highest relative utilisation (89.39%) followed by *Terminalia sericea* with a relative utilisation of 10.61%. In 2010, *Strychnos madagascariensis* had a relative utilisation value of 74.57%, *Terminalia sericea* of 24.12%, *Grewia caffra* of 0.80% and *Dichrostachys cinerea* of 0.52%. There was a good agreement between the species utilised in 2004 and 2010.

14.2.4 Elephant preferences

In 2010, two woody species were selected for by elephants while two were not. The two preferred woody species in 2010 (based on all indices) were *Strychnos madagascariensis* and *Grewia caffra* (Table 14.4). In 2004 only one woody plant species, *Strychnos madagascariensis,* was preferred (Table 14.5).

Table 14.4 Elephant preferences for woody species in 2010 in terms of Ivlev's Electivity Index (Ivlev, 1961), the Forage Ratio (Cock, 1978) and the Rank Procedure method (Johnson, 1980). The woody species recorded within the Sparse Woodland community in 2010 are ranked from most preferred to least preferred based on the Electivity Index

Woody species	Ivlev's electivity index	Forage ratio	Rank Procedure method
Strychnos madagascariensis	0.67	5.06	1
Grewia caffra	0.19	1.47	2
Terminalia sericea	-0.37	0.46	3
Dichrostachys cinerea	-0.95	0.03	4

Table 14.5 Elephant preferences for woody species in 2004 in terms of Ivlev's Electivity Index (Ivlev, 1961), the Forage Ratio (Cock, 1978) and the Rank Procedure method (Johnson, 1980). The woody species recorded within the Sparse Woodland community in 2010 are ranked from most preferred to least preferred based on the Electivity Index

Woody species	Ivlev's electivity index	Forage ratio	Rank Procedure method
Strychnos madagascariensis	0.42	2.43	1
Terminalia sericea	-0.42	0.41	1

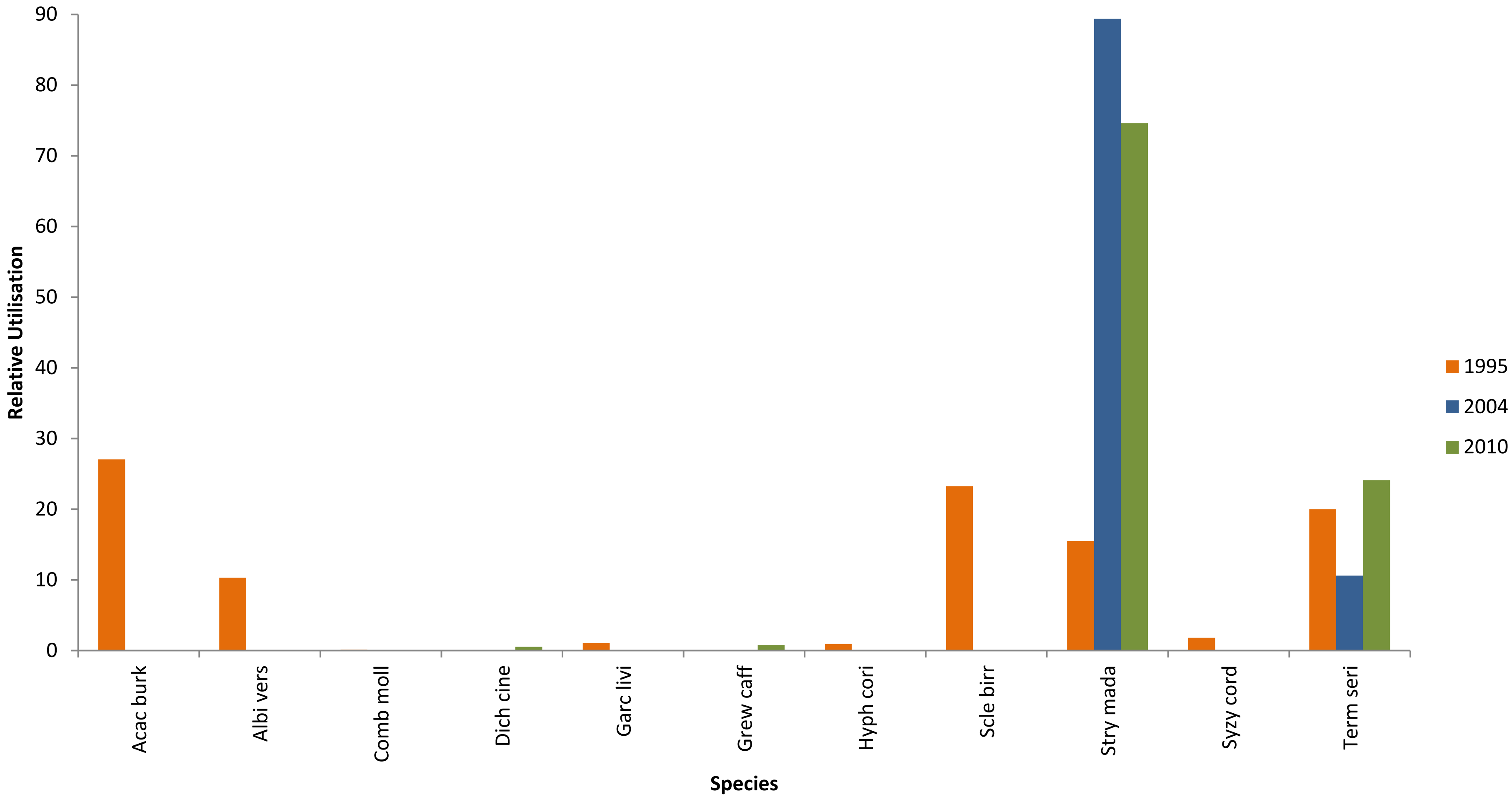

Figure 14.5 Relative utilisation of various species by elephants in 1995, 2004 and 2010 in the Sparse Woodland community of Tembe Elephant Park. Appendix A contains a list of abbreviations of all species names.

14.3 DISCUSSION

14.3.1 Percentage canopy removal

The damage caused by elephants within the Sparse Woodland was predominantly through the breaking of branches, resulting in the pollarding of trees, similar to reports in other reserves (Boundja & Midgley, 2009; Valeix *et al*., 2011). In 2004, two species were recorded with elephant utilisation and in 2010, four species were identified with elephant utilisation (Figure 14.2). Two woody species were common to both datasets. The level of utilisation as well as the number of species utilised in the Sparse Woodland was less than in the other plant communities. The reason could be that elephants prefer habitats with a heterogeneous structure and composition (White & Goodman, 2009) and the Sparse Woodland is a very homogeneous plant community (see Figure 5.8).

The trend of increasing canopy removal as the size classes increased was not as clearly evident in the Sparse Woodland as for the denser communities. Utilisation by elephants in the smaller size classes was common in 2010 (size class 2 and 3) and 2004 (size class 3) even though it is not their foraging height (size class 2 with 3.79% utilisation). Whenever there was utilisation in the lower size classes (1 and 2) it could be regarded as accidental damage or trampling. Utilisation by other animal species was recorded on small woody plants, but their effect was not as devastating as the effect of large elephants on small woody individuals. Dublin *et al*. (1990) found elephant utilisation in the Serengeti-Mara Woodlands to be higher in the larger size classes and the small woody individuals had the lowest utilisation values.

Strychnos madagascariensis was the woody species with the highest percentage canopy removal in 2010 and 2004 (Figure 14.2). The overall canopy removal of 5.35% in 2004 decreased to 3.39% in 2010 (Figure 14.3). Both the volume of the removed canopy and the available canopy showed decreases below the 2004 levels. Compared to the other vegetation communities in the Tembe Elephant Park the Sparse Woodland was the least utilised community/subcommunty in terms of elephant browsing in 2004 as well as in 2010. Gaugris and Van Rooyen (2010a) grouped the Open and Sparse Woodland of Tembe Elephant Park together in their results and also concluded that the Sparse Woodland on Sand community in Tembe Elephant Park had the lowest level of elephant utilisation. The

Sparse Woodland on Sand and the Open Woodland 2 were the only two communities/ subcommunities that showed a decrease in elephant utilisation.

14.3.2 Electivity

Due to the small number of woody species found in this community conclusions regarding changed preferences cannot be made in this community. *Strychnos madagascariensis* was the most preferred species in the Sparse Woodland in the 2004 and 2010 survey. In 2004 it was the only woody species selected for by elephants. *Grewia caffra* was the second most preferred species in 2010 and it had an Electivity Index of 0.19. This was one of the very few communities where the Rank Procedure method agreed with the other electivity indices.

14.3.3 Relative utilisation

Extending the study period of elephant utilisation to 15 years improved insight into elephant feeding patterns and preferences but it should be remembered that the 1995 data were not on the exact locations as the 2004 and 2010 data, as a different method and site layout was used by the researchers. This might be the reason for other woodland species such as *Acacia burkei*, *Albizia versicolor*, *Garcinia livingstonei* and *Sclerocarya birrea* being recorded in 1995. The species with the highest relative utilisation in 1995 was *Acacia burkei*. In 2004 and 2010, this species was not utilised in the Sparse Woodland. *Strychnos madagascariensis* had the highest relative utilisation in 2004 as well as in 2010. This species was also utilised during the 1995 survey and then had the fourth highest relative utilisation.

14.4 CONCLUSION

Elephant utilisation in the Sparse Woodland on Sand community experienced a decrease from 2004 to 2010. This community is not considered threatened by elephant utilisation but further studies are required to determine what the vegetation structure and perhaps composition was about 20 years ago when elephant densities were lower. From observation it seems like the abundance of shrubs has increased and the reason for this (whether herbivory, fire or global warming) should be established.

CHAPTER 15

SYNTHESIS

15.1 INTRODUCTION

The consequences of elephant impact on the African savanna are still hotly debated. Elephants are a necessary component of savanna habitats and the destructive manner in which they browse is part of ecosystem functioning (Boundja & Midgley, 2009). An uprooted tree or a broken branch opens up a new niche for invertebrates or even small vertebrates (Pringle, 2008). However, this is only true when the elephant population is of moderate size. The intermediate disturbance hypothesis (Connell, 1978) may explain this occurrence as it proposes that a small or big (rare or frequent) disturbance may alter the environment or limit biodiversity but intermediate levels of disturbance will promote biodiversity. At high elephant densities their destructive manner of browsing may have a negative impact on the vegetation (Van Rensburg *et al*., 2000; Guldemond & Van Aarde, 2007; Gaugris, 2008; Gaugris & Van Rooyen, 2010a; Gaugris & Van Rooyen, 2011).

The Tembe Elephant Park covers an area of 30 013 ha and is situated in northern KwaZulu Natal. This reserve has a diversity of vegetation types and is part of the Maputaland Centre of Plant Endemism (Van Wyk, 1994; Gaugris *et al*., 2008) and the Maputaland-Pondoland-Albany Hotspot of Biodiversity (www.cepf.net). In the Tembe Elephant Park elephant numbers are currently high and the elephant population is still increasing (Matthews, 2005, 2006, 2007b; Morley & Van Aarde, 2007; Muller & Matthews, 2010). The impact that the elephants have on the vegetation can clearly be seen in the field and was evident in the data obtained. If these high levels of utilisation are sustained or even increased it may have severe negative consequences for the vegetation.

The intensity of elephant utilisation was measured during surveys conducted in 2004 and 2010. Data from these surveys were analysed and compared to establish whether elephant utilisation had increased in the Tembe Elephant Park since 2004. Electivity indices were calculated for the utilised species (of both surveys) to determine whether there was a change in the preferences of elephants for specific woody species. These results were used to establish which species were under threat of extirpation due to elephant utilisation.

15.2 COMPARISON OF 2004 AND 2010 DATA

15.2.1 Utilisation by elephants within the plant communities

The Closed Woodland 1 had the highest percentage elephant utilisation (37.75% of all available canopy removed; Figure 15.1, Table 15.1) in the Tembe Elephant Park, in 2010. Three other communities had utilisation values within 3% of this community's utilisation percentages. These communities include the Mature Sand Forest (37.17%), Open Woodland 1 (34.31%) and the Closed Woodland 3 (34.59%). All these communities experienced a marked increase in the elephant utilisation percentage since the 2004 survey and had canopy removal percentages in 2010 that were more than double that during the 2004 survey.

The Mature Sand Forest in the west of the park as well as within the elephant exclosure was hardly utilised, but an extremely high utilisation pressure was observed at the sites to the east. These sites were close to the Mahlasela waterhole, which might explain the high utilisation percentages. Elephant densities are generally extremely high close to permanent water, which in turn leads to increased damage to vegetation (Parker & Witkowski, 1999; Redfern *et al*., 2003; De Beer *et al*., 2006; Shannon *et al*., 2009; Muller & Matthews, 2010; Gaugris & Van Rooyen, 2010a). However, because the same sites were surveyed in 2004 and 2010 the proximity to the waterhole does not explain the increase from 2.08% canopy removed in 2004 to 37.17% in 2010. Both recent and old damage was found in this community.

The two Closed Woodland communities with high utilisation values were situated in close proximity to the Muzi swamp thus high levels of elephant utilisation would be expected and were clearly visible during the 2010 surveys (Figure 15.2). The results of these two communities support the statement by Gaugris and Van Rooyen (2010a) who contended that these communities had the highest utilisation values. Furthermore, waterholes in Tembe Elephant Park, such as Mahlasela, are located within the Closed Woodland on Clay community. Gaugris and Van Rooyen (2010a) found that sites in close proximity to waterholes had higher utilisation values than sites further afield. The Closed Woodland on Clay therefore has experienced an increase in elephant utilisation since the 2004 survey.

Table 15.1 Summary of changes in numbers of species utilised and canopy volumes in the communities. Positive changes indicated in green and negative changes in red

	2004 survey	2010 survey	Evaluation
Short Sand Forest			
No of spp utilised	24	24	No change
No spp preferred	13	3	Decrease
Cumulative utilisation (%)	14.04	14.98	No change
Volume removed (m^3/ha)	39 873	16 678	Decrease
Volume available (m^3/ha)	283 199	111 363	Decrease
Tall Sand Forest			
No of spp utilised	19	19	No change
No spp preferred	16	13	Decrease
Cumulative utilisation (%)	2.59	6.19	Increase
Volume removed (m^3/ha)	8 645	17 894	Increase
Volume available (m^3/ha)	333 830	288 846	Decrease
Mature Sand Forest			
No of spp utilised	17	25	Increase
No spp preferred	13	3	Decrease
Cumulative utilisation (%)	2.08	37.17	Increase
Volume removed (m^3/ha)	4 596	50 905	Increase
Volume available (m^3/ha)	220 888	136 967	Decrease
Closed Woodland 1			
No of spp utilised	28	44	Increase
No spp preferred	14	10	Decrease
Cumulative utilisation (%)	8.27	37.75	Increase
Volume removed (m^3/ha)	8 863	68 585	Increase
Volume available (m^3/ha)	107 151	181 682	Increase
Closed Woodland 2			
No of spp utilised	19	32	Increase
No spp preferred	9	9	No change
Cumulative utilisation (%)	11.60	18.05	Increase
Volume removed (m^3/ha)	9 408	9 740	No change
Volume available (m^3/ha)	81 125	53 951	Decrease
Closed Woodland 3			
No of spp utilised	32	32	No change
No spp preferred	14	4	Decrease
Cumulative utilisation (%)	11.83	34.59	Increase
Volume removed (m^3/ha)	11 812	12 867	Increase
Volume available (m^3/ha)	99 864	37 201	Decrease
Open Woodland 1			
No of spp utilised	30	36	Increase
No spp preferred	18	4	Decrease
Cumulative utilisation (%)	12.47	34.31	Increase
Volume removed (m^3/ha)	5 882	8 332	Increase
Volume available (m^3/ha)	47 153	24 287	Decrease
Open Woodland 2			
No of spp utilised	15	9	Decrease
No spp preferred	6	1	Decrease
Cumulative utilisation (%)	23.09	20.33	No change
Volume removed (m^3/ha)	2 134	772	Decrease
Volume available (m^3/ha)	9 242	3 797	Decrease
Sparse Woodland			
No of spp utilised	2	4	Increase
No spp preferred	1	2	Increase
Cumulative utilisation (%)	5.35	3.39	Decrease
Volume removed (m^3/ha)	321	140	Decrease
Volume available (m^3/ha)	5 992	4 129	Decrease

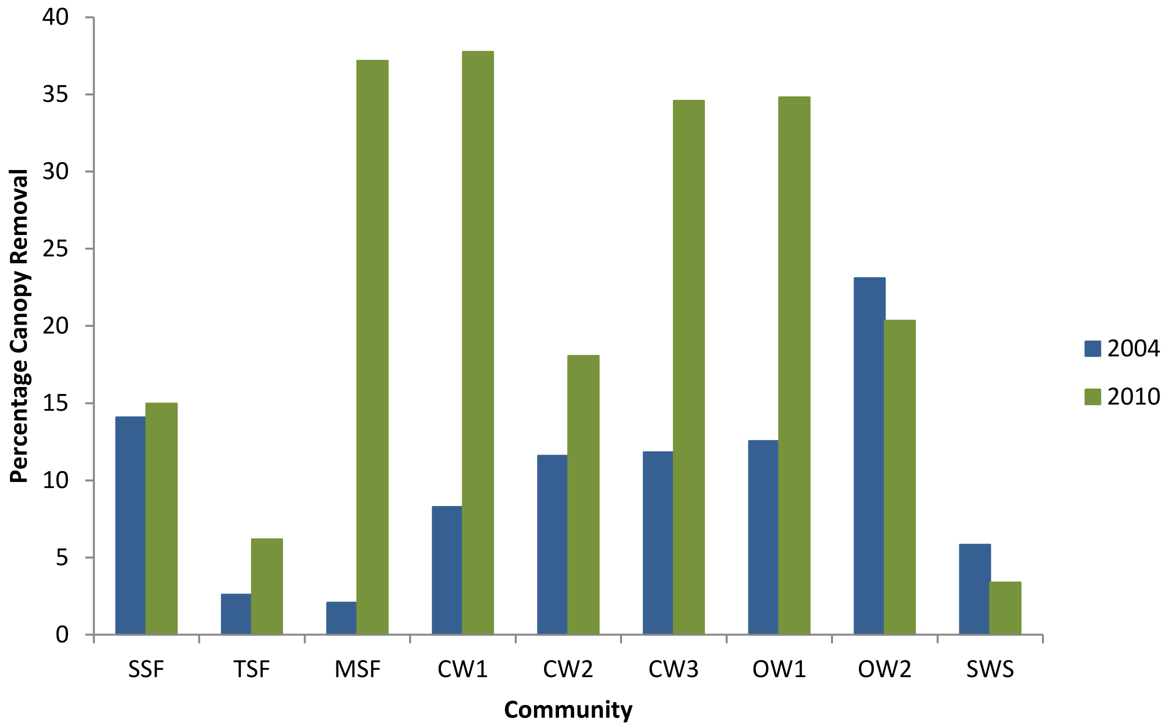

Figure 15.1 The percentage canopy removal in 2004 (blue) and 2010 (green) for all nine plant communities in Tembe Elephant Park.

The Open Woodland 1 community is widespread across the park and not associated with water and consequently it was assumed that elephant impact would be low in this community. Elephant utilisation was however very high in this open woodland community. The high percentage utilisation could possibly be ascribed to the low canopy volume which is available in the Open Woodland 1 community. Compared to the Sand Forests and Closed Woodlands the removal of the same volume in the Open Woodland would constitute a higher percentage removal. Many studies have shown that because open woodland sites are not generally close to permanent water, elephant impact is not high in these communities (Ben-Shahar, 1993; Owen-Smith, 1996; Redfern *et al*., 2003; De Beer *et al*., 2006; Shannon *et al*., 2009) or that elephants prefer a higher cover of woody species than is available in open woodlands (Harris *et al*., 2008). Figure 3.8 and 3.9 illustrates the distribution of elephants in the Tembe Elephant Park and they are clearly concentrated along the Muzi swamp (mainly Closed Woodland 1 and 3) and the southern part which contains some Sand Forest sites. The distribution of elephants correlates with the extent of canopy removal by elephant within the communities, high elephant utilisation values were primarily in the regions of elevated elephant density (Figure 15.3 and 15.4). The areas of high canopy removal along the northern and western border in 2010 were mainly old utilisation incidences by elephants. The decrease in of elephant utilisation within the exclosure is evident in these figures. However, the increase since 2004 is clear around the Muzi swamp.

Figure 15.2 Damage by elephants in areas close to the Muzi swamp (Photograph by M. Potgieter, 2010).

In order to conserve and protect the Sand Forest the management of the Tembe Elephant Park decided to restrict the access of elephants into this indigenous forest in the south-western corner of the park. An exclosure was therefore erected in 2008 to exclude elephants. Three of the five Short Sand Forest sites which were surveyed in 2010 were situated within the exclosure which made it the ideal experiment for comparing woody species structure with and without elephants present. During the 2010 surveys in the exclosure sites, all elephant utilisation recorded was old damage (more than two years; i.e. before the exclosure was established) and no recent utilisation was picked up. Outside the exclosure, elephant utilisation increased substantially in the higher size classes. Although only two years without elephants from a region does not seem sufficient to detect changes, the study demonstrated that even in this short period of time a change in utilisation and preferences could be observed. Increasing this time period would probably give even more satisfactory results of the effects of continuous elephant browsing versus no browsing on the canopy structure of the Short Sand Forest. The results of this study illustrate the effectiveness of the exclosure in Tembe Elephant Park to conserve the Short Sand Forest.

Overall, the Short Sand Forest showed a decrease of only 0.90% (no statistical difference) in utilisation since the 2004 survey (Table 15.1). The fact that the percentage utilisation basically stayed the same can be ascribed to the fact that three of the five sites were in the exclosure. The utilisation levels outside the exclosure were exceptionally high for the community.

The Open Woodland 2 community also experienced a decrease in elephant utilisation since 2004 as canopy removal by elephants dropped from 23.09% to 20.33% (not statistically different). Vegetation of the landscape can now be described as sparse with very little woody cover apart from the scattered shrubs (*Dialium schlechteri, Dichrostachys cinerea* and *Terminalia sericea*). Since 2004 the available canopy of woody species halved and the amount of utilisation by elephant reduced severely.

Overall there was an increase in the number of species utilised by elephants from 2004 to 2010 (Table 15.1). This increase was more pronounced in the Closed Woodland communities, than in the Sand Forest and Open Woodlands. In spite of the increased number of species utilised in 2010, the number of preferred species (based on an Electivity Index ≥ 0.1) showed a sharp decline.

The diversity of woody species utilised by elephants was weakly related to the percentage canopy removal (r^2 = 0.2959, Figure 15.5). In 2004 and 2010 the Sparse Woodland had the lowest levels of elephant utilisation and only two and four species were utilised, respectively (Table 15.1). The Closed Woodland 1 had the highest percentage of canopy volume removed in 2010 and 33 different species utilised. The great variety of species utilised in the Tall Sand Forest (17 woody species) is unexpected as the canopy volume removed is extremely low. In comparison, the Open Woodland 2 had a much higher percentage canopy removal and only nine woody species were utilised.

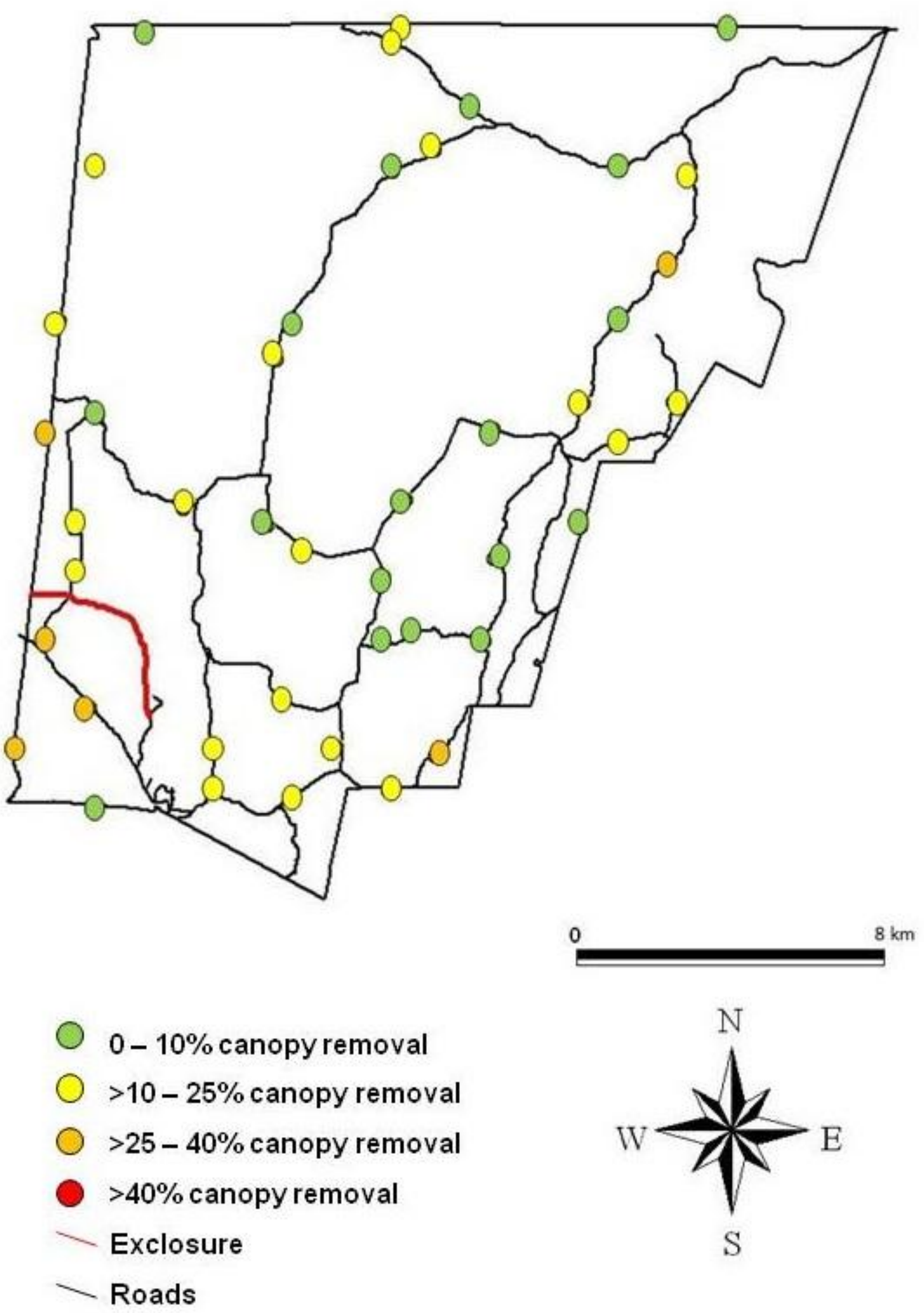

Figure 15.3 Percentage canopy removal recorded on sites in 2004 illustrated on a map of Tembe Elephant Park.

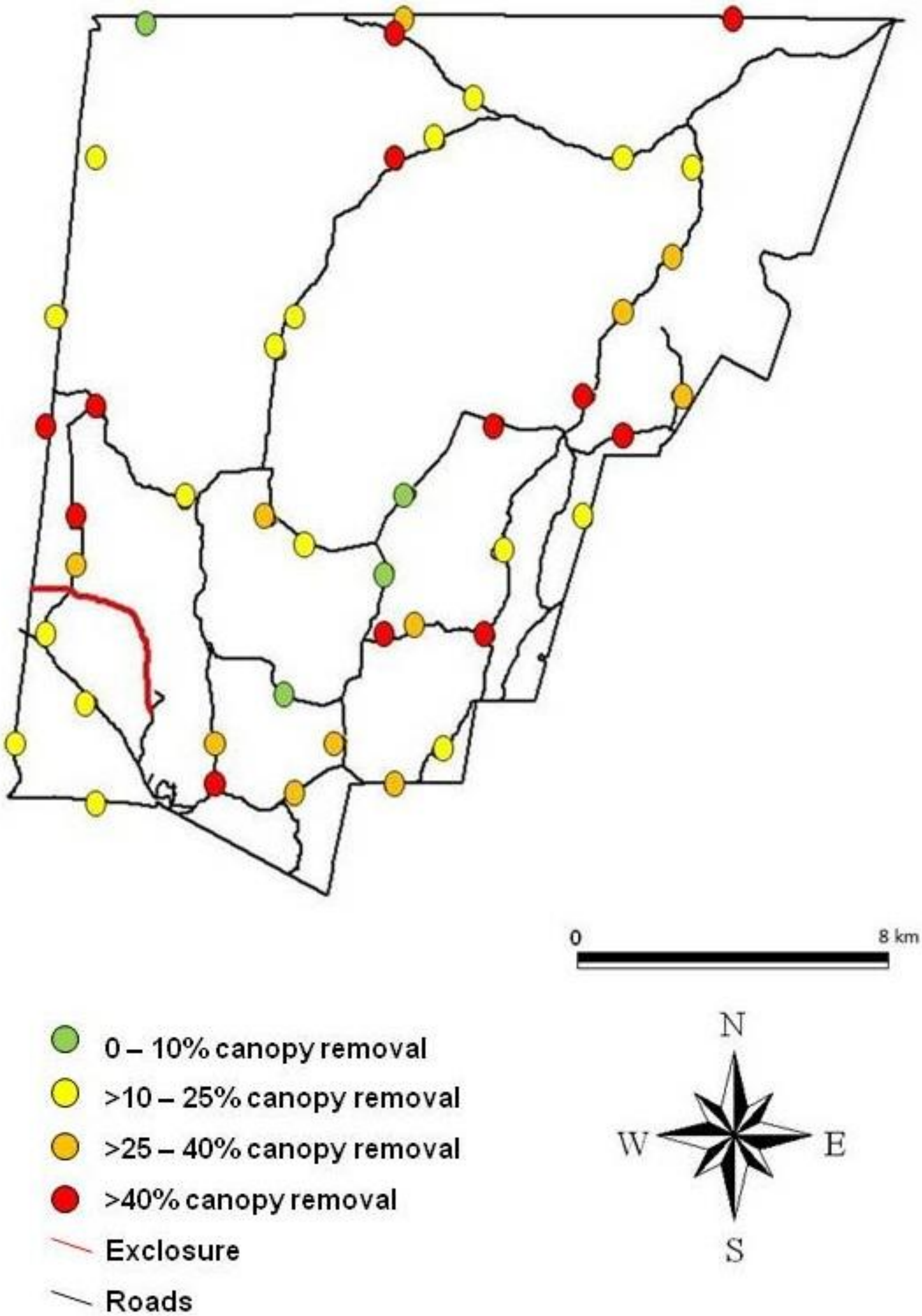

Figure 15.4 Percentage canopy removal recorded on sites in 2010 illustrated on a map of Tembe Elephant Park.

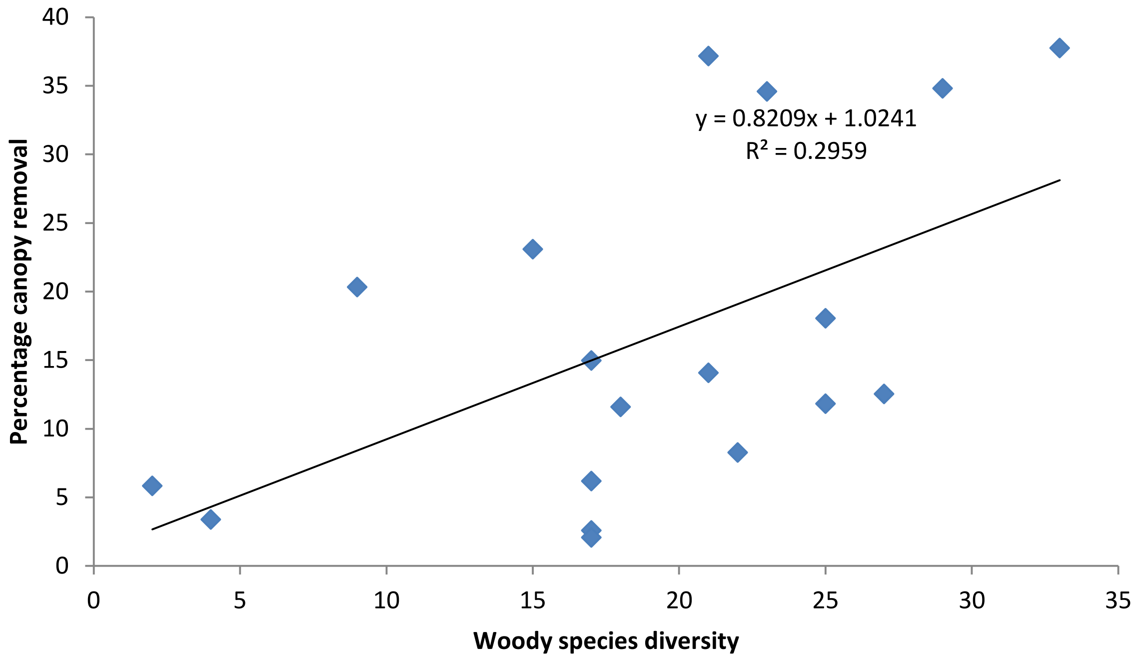

Figure 15.5 Relationship between the richness of woody species and the percentage elephant utilisation.

Table 15.2 Summary of utilised woody species in the different communities for the 2004 (blue) and 2010 (orange) survey. Occurrences where utilisation by elephant were recorded during the 2004 and 2010 survey was marked in bold

Woody species	SSF		TSF		MSF		CW1		CW2		CW3		OW1		OW2		SWS	
Acacia burkei							**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**		
Acacia nilotica											x							
Acacia robusta								x			**x**	**x**	**x**	**x**				
Acalypha glabrata					**x**	**x**				x								
Afzelia quanzensis								x	**x**	**x**	**x**	**x**						
Albizia forbesii								x		x								
Albizia versicolor									**x**	**x**	x		x		x			
Antidesma venosum							x						**x**	**x**				
Balanites maughamii						x			x			x						
Berchemia zeyheri											**x**	**x**						
Boscia filipes			**x**	**x**	**x**	**x**		x										
Brachylaena discolor		x											**x**	**x**				
Bridelia cathartica							x		x		**x**	**x**	**x**	**x**				
Burchelia bubalina			x															
Canthium inerme				x									x					
Capparis tomentosa						x						x						
Cassipourea mossambicensis	x		x						x									
Catunaregam spinosa								x			**x**	**x**	**x**	**x**		x		
Cleistanthus schlechteri	**x**	**x**		x	**x**	**x**												
Cola greenwayi	**x**	**x**	x	x	**x**	**x**												
Combretum molle		x						x	**x**	**x**	**x**	**x**	**x**	**x**	x			
Croton pseudopulchellus	**x**	**x**	**x**	**x**	x			x			**x**	**x**						
Dialium schlechteri	**x**	**x**	**x**	**x**			x	x		x	**x**	**x**	**x**	**x**	**x**	**x**		
Dichrostachys cinerea								x	x			x	**x**	**x**	**x**	**x**		x
Dovyalis longispina				x			**x**	**x**		x				x				

Woody species	SSF		TSF		MSF		CW1		CW2		CW3		OW1		OW2		SWS	
Drypetes arguta	x	x	x	x	x	x		x										
Drypetes natalensis				x		x												
Erythrophleum lasianthum	x		x															
Erythroxylum emarginatum			x	x			x				x							
Euclea natalensis							x	x			x	x			x			
Garcinia livingstonei							x	x		x	x		x	x	x			
Grewia caffra								x		x		x		x				x
Grewia microthyrsa	x	x	x		x	x				x	x		x	x				
Gymnanthemum coloratum						x	x				x							
Haplocoelum gallaense	x		x	x	x	x				x				x				
Hymenocardia ulmoides	x	x	x	x	x	x	x			x								
Krausia floribunda							x											
Lagynias lasiantha	x																	
Manilkara discolor	x	x				x												
Memecylon sousae		x		x														
Monodora junodii		x	x					x										
Mundulea sericea													x	x				
Newtonia hildebrandtii	x					x												
Ochna barbosae		x					x	x		x								
Ozoroa engleri									x							x		
Pseudobersama mossambicensis	x																	
Psydrax locuples	x	x					x			x			x	x				
Ptaeroxylon obliquum	x	x	x	x	x	x		x										
Pteleopsis myrtifolia	x	x		x	x	x										x		
Rothmannia fischeri								x	x	x			x					
Sapium integerrimum									x	x	x	x	x	x	x			
Schotia brachypetala					x		x	x			x	x						
Sclerocarya birrea							x	x		x	x	x	x	x	x			

Woody species	SSF		TSF		MSF		CW1		CW2		CW3		OW1		OW2		SWS	
Searsia gueinzii								x		x				x				
Sideroxylon inerme							**x**	**x**			**x**	**x**						
Spirostachys africana						x	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**				
Strychnos decussata					**x**	**x**	**x**	**x**					**x**	**x**				
Strychnos henningsii	**x**	**x**	x		x			x										
Strychnos madagascariensis						x	**x**	**x**	**x**	**x**		x	**x**	**x**	**x**	**x**	**x**	**x**
Strychnos spinosa									**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**		
Suregada zanzibariensis	x							x		x								
Tabernaemontana elegans							x		**x**	**x**	x		**x**	**x**				
Terminalia sericea									**x**	**x**	x	x	**x**	**x**	**x**	**x**	**x**	**x**
Toddaliopsis bremekampii			**x**	**x**	**x**	**x**		x										
Tricalysia delagoensis					x			x										
Tricalysia lanceolata	x													x				
Trichilia emetica							**x**	**x**	x		x		x		x			
Vangueria infausta									x				**x**	**x**	x			
Vitex amboniensis	x					x												
Wrightia natalensis			x		x													
Ximenia americana														x				
Zanthoxylum capense				x			**x**	**x**										
Ziziphus mucronata								x				x	**x**	**x**	x			
Number of species utilised	21	17	17	17	17	21	22	33	18	25	25	23	27	29	15	9	2	4

X - utilised during the 2004 survey

X - utilised during the 2010 survey

SSF – Short Sand Forest

TSF – Tall Sand Forest

MSF – Mature Sand Forest

CW1 – Closed Woodland 1

CW2 – Closed Woodland 2

CW3 – Closed Woodland 3

OW1 – Open Woodland 1

OW2 – Open Woodland 2

SWS – Sparse Woodland on Sand

15.2.2 Species utilised by the elephants

The elephants utilised a different complement of species in each community. Within the Sand Forest communities *Cola greenwayi*, *Drypetes arguta*, *Hymenocardia ulmoides* and *Ptaeroxylon obliquum* were consistently utilised (Table 15.2). In the Woodlands *Acacia burkei*, *Dialium schlechteri, Combretum molle, Spirostachys africana*, *Strychnos madagascariensis* and *Terminalia sericea* were commonly utilised. *Albizia versicolor*, *Bridelia cathartica* and *Trichilia emetica* were utilised by elephant more widespread in 2004 than in 2010. However, species such as *Dovyalis longispina*, *Grewia caffra* and *Searsia gueinzii* were newly utilised species in 2010 and in a greater variety of communities.

Table 15.3 summarises the percentage utilisation of the different species (in terms of available canopy volume in the specific community) within each community for both the 2004 and 2010 survey. Increases in elephant utilisation that were more than double the 2004 value were marked in red, whereas decreases which were half the 2004 value were marked in green. The differences between the two surveys in terms of utilisation percentages is clear in the table, some species show a great increase and other a decrease. In the majority of the communities *Acacia burkei* experienced an increase since 2004 as well as *Dialium schlechteri* and *Spirostachys africana*. As a matter of fact, most of the species experienced an increase since the 2004 survey was conducted. However, some of the woody species with extreme increases in canopy removal are endemic to the area, such as *Dialium schlechteri, Haplocoelum gallaense, Memecylon sousae* and *Ochna barbosae*. There were woody species that showed a decrease since 2004 in a range of communities, examples of such species include *Acacia robusta*, *Drypetes arguta* and *Pteleopsis myrtifolia.*

Elephant utilisation was also calculated for the most selected woody species across the entire Tembe Elephant Park. Percentage canopy removal was calculated as a percentage of the total available canopy volume throughout all the communities. Table 15.4 illustrates how these utilisation values compared between the 2004 and 2010 survey. *Trichilia emetica* is the only elephant utilised species which was highly utilised in both 2004 and 2010. *Albizia versicolor*, *Berchemia zeyheri*, *Strychnos henningsii* and *Tabernaemontana elegans* were moderately utilised in both the surveys. There were five woody species that experienced a drastic increase in elephant utilisation since 2004. These species included *Dialium schlechteri*, *Schotia brachypetala*, *Sideroxylon inerme* and *Wrightia natalensis.* In all of these instances, available canopy had also been greatly reduced.

Table 15.3 Percentage utilisation of the species mostly selected for by elephants for each community for both the 2004 and 2010. Species which had doubled the utilisation values in 2010 than 2004 were marked in red while species with half its utilisation values in 2010 than 2004 were marked in green. Endemic species are marked with an *

Woody species	Plant communities																	
	SSF		TSF		MSF		CW1		CW2		CW3		OW1		OW2		SWS	
	2004	2010	2004	2010	2004	2010	2004	2010	2004	2010	2004	2010	2004	2010	2004	2010	2004	2010
Acacia burkei							4.9	63.2	37.5	2.4	10.3	32.9	10.3	37.3	9.0	31.3		
Acacia nilotica											83.7							
Acacia robusta								51.0			16.3	5.0	15.0	5.0				
Acalypha glabrata					3.8	0.7				82.5								
Afzelia quanzensis								34.6	0.5	52.7	31.9	85.4						
Albizia forbesii								56.4		9.8								
Albizia versicolor									91.6	29.3	82.5		40.7		76.9			
Antidesma venosum							15.8						37.5	5.0				
Balanites maughamii						41.8			44.9			4.9						
Berchemia zeyheri											40.6	37.5						
Boscia filipes			6.3	5.0	62.5	53.5		21.6										
Brachylaena discolor		3.3											43.6	0.4				
Bridelia cathartica							6.1		22.2		14.4	17.2	29.8	6.9				
Burchelia bubalina			37.5															
Canthium inerme				12.5									37.5					
Capparis tomentosa						3.6						62.5						
Cassipourea mossambicensis *	22.0		11.6						60.9									
Catunaregam spinosa								3.0			37.5	26.3	21.1	4.7		0.1		
Cleistanthus schlechteri	61.4	46.0		47.8	1.6	85.1												
Cola greenwayi	14.4	22.6	15.7	3.6	2.7	16.5												
Combretum molle		70.6						17.2	7.4	26.7	1.6	62.5	17.7	13.6	17.8			
Croton pseudopulchellus	4.4	0.2	1.5	10.2	0.5			10.8			10.7	32.7						
Dialium schlechteri *	1.4	64.7	3.2	22.3			9.5	59.7		19.0	4.6	26.1	29.1	43.6	82.5	12.7		
Dichrostachys cinerea								5.0	37.5			0.4	11.8	3.6	28.8	0.6		0.1

Woody species	Plant communities																	
	SSF		TSF		MSF		CW1		CW2		CW3		OW1		OW2		SWS	
	2004	2010	2004	2010	2004	2010	2004	2010	2004	2010	2004	2010	2004	2010	2004	2010	2004	2010
Dovyalis longispina *				21.6			61.1	12.8		4.5				5.0				
Drypetes arguta	13.6	7.9	15.7	6.0	9.2	15.7		5.0										
Drypetes natalensis				22.4		1.9												
Erythrophleum lasianthum *	60.9		17.5															
Erythroxylum emarginatum			37.5	21.6			9.5				4.1							
Euclea natalensis							0.3	2.1			4.7	33.6			17.5			
Garcinia livingstonei							19.5	21.6		21.6	12.0		38.4	19.6	6.8			
Grewia caffra								13.2		8.1		13.8		8.2				5.0
Grewia microthyrsa *	19.8	36.2	26.8		48.4	21.0				11.0	37.5		46.0	5.0				
Gymnanthemum coloratum						40.6	37.5				22.3							
Haplocoelum gallaense *	9.0		8.3	48.8	7.4	88.4				1.5				13.9				
Hymenocardia ulmoides	22.4	22.7	9.8	22.9	9.2	12.3	63.9			5.6								
Krausia floribunda							25.9											
Lagynias lasiantha	51.6																	
Manilkara discolor	7.8	46.4				40.6												
Memecylon sousae *		12.2		48.4														
Monodora junodii		16.1	7.3					16.5										
Mundulea sericea													36.7	0.5				
Newtonia hildebrandtii	37.5					28.4												
Ochna barbosae *		95.5					31.9	85.6		17.5								
Ozoroa engleri									94.5							3.5		
Pseudobersama mossambicensis	42.7																	
Psydrax locuples	5.0	17.5					95.1			15.8			12.8	3.3				
Ptaeroxylon obliquum	27.3	4.3	17.5	5.0	3.8	25.5		30.0										
Pteleopsis myrtifolia	31.8	6.4		17.5	37.5	22.7										4.9		
Rothmannia fischeri								5.0	0.7	37.5			17.5					
Sapium integerrimum									23.2	9.7	7.0	4.3	11.8	22.4	60.9			
Schotia brachypetala					76.6		37.5	69.1			14.0	28.3						

Woody species	Plant communities																	
	SSF		TSF		MSF		CW1		CW2		CW3		OW1		OW2		SWS	
	2004	2010	2004	2010	2004	2010	2004	2010	2004	2010	2004	2010	2004	2010	2004	2010	2004	2010
Sclerocarya birrea							4.8	18.4		83.4	21.4	14.1	4.1	62.9	62.5			
Searsia gueinzii								94.5		16.2				3.6				
Sideroxylon inerme							14.8	21.0			31.9	4.2						
Spirostachys africana						9.8	18.9	46.5	2.8	27.4	8.4	46.6	5.6	40.7				
Strychnos decussata					31.9	10.6	1.0	8.8					20.0	3.6				
Strychnos henningsii	37.5	5.0	35.0		5.2			4.5										
Strychnos madagascariensis						17.5	8.3	5.0	27.4	30.8		37.7	21.8	42.6	23.4	3.3	14.8	17.1
Strychnos spinosa									8.7	48.4	11.8	17.7	23.2	10.6	40.6	5.0		
Suregada zanzibariensis	94.5							15.6		37.5								
Tabernaemontana elegans							42.5		8.8	65.3	45.3		24.8	64.4				
Terminalia sericea									20.0	20.5	18.6	30.2	8.3	40.2	24.0	22.4	4.2	2.7
Toddaliopsis bremekampii *			1.9	3.2	11.9	7.7		35.3										
Tricalysia delagoensis *					17.1			17.5										
Tricalysia lanceolata	28.6													5.0				
Trichilia emetica							3.9	51.6	50.9		5.0		46.2		17.5			
Vangueria infausta									11.1				26.8	5.0	48.4			
Vitex amboniensis	17.5					21.6												
Wrightia natalensis *			40.6		1.1													
Ximenia americana														37.5				
Zanthoxylum capense				37.5			4.0	19.5										
Ziziphus mucronata								48.4				5.0	20.2	8.6	48.2			

SSF – Short Sand Forest

TSF – Tall Sand Forest

MSF – Mature Sand Forest

CW1 – Closed Woodland 1

CW2 – Closed Woodland 2

CW3 – Closed Woodland 3

OW1 – Open Woodland 1

OW2 – Open Woodland 2

SWS – Sparse Woodland on Sand

Table 15.4 Differences in mean canopy volume available and mean removed canopy volume for the woody species highly selected for by elephants during the 2004 and 2010 survey. Damage or utilisation by elephants among species is best compared as percentage utilised

	2010			2004		
Woody Species	Available (m^3/ha)	Removed (m^3/ha)	% Utilisation	Available (m^3/ha)	Removed (m^3/ha)	% Utilisation
Acacia burkei	1948	437	22.44	5818	557	9.57
Acacia nilotica	0	0	0.00	18	14	79.97
Acacia robusta	236	76	32.10	903	12	1.36
Acalypha glabrata	242	4	1.78	984	4	0.36
Afzelia quanzensis	3482	1228	35.26	1456	71	4.86
Albizia forbesii	105	47	44.78	0	0	0.00
Albizia versicolor	73	21	28.91	1981	554	27.95
Antidesma venosum	2	0	5.00	97	22	22.27
Balanites maughamii	4360	0	0.01	1014	33	3.30
Berchemia zeyheri	5	2	37.50	35	11	30.70
Boscia filipes	316	43	13.48	50	7	14.06
Brachylaena discolor	15	0	0.01	42	7	15.97
Bridelia cathartica	8	1	15.7	341	22	6.42
Burchelia bubalina	0	0	0.00	49	6	12.94
Canthium inerme	22	3	12.54	13	5	37.49
Capparis tomentosa	13	2	17.67	0	0	0.00
Cassipourea mossambicensis	3	0	0.00	216	48	22.04
Catunaregam spinosa	521	15	2.91	29	9	30.54
Cleistanthus schlechteri	4199	724	17.23	8679	137	1.57
Cola greenwayi	1637	86	5.26	3320	328	9.89
Combretum molle	1326	332	25.00	1272	110	8.62
Croton pseudopulchellus	742	56	7.58	677	21	3.05
Dialium schlechteri	11144	5409	48.54	15156	350	2.31
Dichrostachys cinerea	125	2	1.98	196	21	10.83
Dovyalis longispina	131	2	1.49	33	19	56.47
Drypetes arguta	1144	54	4.71	1013	109	10.73
Drypetes natalensis	137	31	22.39	82	18	21.57
Erythrophleum lasianthum	120	15	12.83	3462	1451	41.90
Erythroxylum emarginatum	20	3	14.04	48	18	0.00
Euclea natalensis	396	69	17.31	587	5	0.78
Garcinia livingstonei	297	61	20.63	200	61	30.20
Grewia caffra	246	25	10.13	135	0	0.00
Grewia microthyrsa	1044	100	9.54	409	80	19.69
Gymnanthemum coloratum	96	0	0.00	26	8	30.13
Haplocoelum gallaense	1811	661	36.51	1781	70	3.92
Hymenocardia ulmoides	2193	150	6.83	1731	338	19.52
Krausia floribunda	1	0	0.00	52	12	23.20
Lagynias lasiantha	0	0	0.00	18	8	46.39

Woody Species	2010			2004		
	Available (m^3/ha)	Removed (m^3/ha)	% Utilisation	Available (m^3/ha)	Removed (m^3/ha)	% Utilisation
Manilkara discolor	37	11	29.73	3196	232	7.25
Memecylon sousae	163	7	4.26	0	0	0.00
Monodora junodii	166	21	12.57	254	8	2.97
Mundulea sericea	46	0	0.46	31	8	26.54
Newtonia hildebrandtii	14874	0	0.00	27304	1620	5.93
Ochna barbosae	24	6	24.31	14	2	14.29
Ozoroa engleri	23	0	0.78	15	1	5.50
Pseudobersama mossambicensis	0	0	0.00	31	12	39.42
Psydrax locuples	46	3	6.26	177	37	21.11
Ptaeroxylon obliquum	550	35	6.43	1244	113	9.05
Pteleopsis myrtifolia	1642	142	8.64	2636	352	13.37
Rothmannia fischeri	38	12	32.37	727	10	1.34
Sapium integerrimum	383	65	17.01	709	51	7.26
Schotia brachypetala	80	49	61.54	1439	239	16.60
Sclerocarya birrea	2195	703	32.03	1955	65	3.30
Searsia gueinzii	102	32	31.29	16	0	0.00
Sideroxylon inerme	565	273	48.28	1759	261	14.85
Spirostachys africana	6222	2401	38.59	4920	305	6.19
Strychnos decussata	1099	192	17.52	1403	108	7.73
Strychnos henningsii	33	11	31.76	375	100	26.72
Strychnos madagascariensis	803	242	30.12	1210	219	18.07
Strychnos spinosa	180	25	13.67	172	22	12.85
Suregada zanzibariensis	502	67	13.25	129	5	4.16
Tabernaemontana elegans	306	129	42.02	854	250	29.23
Terminalia sericea	3469	1128	32.53	6957	849	12.20
Toddaliopsis bremekampii	486	33	6.80	678	28	4.17
Tricalysia delahoensis	37	21	56.77	232	19	8.14
Tricalysia lanceolata	21	1	5.00	551	7	1.19
Trichilia emetica	46	24	51.6.	207	120	58.16
Vangueria infausta	59	7	12.64	122	27	22.42
Vitex amboniensis	92	0	0.00	436	75	17.19
Wrightia natalensis	8	5	62.44	703	57	8.17
Ximenia americana	1	0	37.50	2	0	0.00
Zanthoxylum capense	169	33	19.22	250	9	3.70
Ziziphus mucronata	611	62	10.11	380	69	18.19
Total utilised	73237	15398	21.02	113010	9823	8.69
Total not utilised	5799	0	0.00	8802	0	0.00
Total available	79035	15398	19.48	121812	9823	8.06

Ivlev's Electivity index was used for determining the preferences of elephants in Tembe Elephant Park. The index can only range from -1 to +1 where all negative values indicate avoidance by the elephants and positive values preference. In this study only values from 0.1 to 1.0 were treated as preferred species and <0.1 to -1.0 as avoided. A number of important conclusions emerged:

- In general, the 2004 survey showed higher electivity values than the 2010 survey. The lower values are as a result of increases in canopy removal volume and decreases in available canopy volume.
- There was limited agreement in species preference between the 2004 and 2010 surveys.
- The changed pattern of preference in different surveys and different communities made it difficult to detect clear overall species preferences.
- The elephants showed a preference for *Haplocoelum gallaense* within the Sand Forest communities during the 2004 and 2010 surveys.
- They showed a new preference for *Cleistanthus schlechteri* in the 2010 survey: electivity index of 0.34 (Short Sand Forest), 0.77 (Tall Sand Forest) and 0.39 (Mature Sand Forest).
- During the 2004 survey there was a clear preference for *Albizia versicolor* and *Trichilia emetica*.
- *Tabernaemontana elegans* was selected by the elephants according to both surveys in the woodland communities.
- Elephants showed preference for *Acacia burkei* in the 2010 survey.

The increase of elephant utilisation percentages in some of these selected woody species is of concern as elephant preferences for many of these species have already been published. Matthews and Page (undated) identified some woody species which already raised concern during their survey in 1995 (in Tembe Elephant Park) with the most canopy removal and highest preference indices. These species included *Afzelia quanzensis, Albizia versicolor, Dialium schlechteri, Garcinia livingstonei, Manilkara discolor, Sclerocarya birrea, Terminalia sericea* and *Wrightia natalensis* amongst others. Another study in Tembe Elephant Park (Guldemond & Van Aarde, 2007) also identified woody plant species which are selected by the elephants, these included *Acacia burkei*, *Combretum molle, Dialium schlechteri*, *Spirostachys africana*, *Strychnos madagascariensis* and *Trichilia emetica.* Other studies, not in Tembe Elephant Park, showed elephant preference for the following woody species: *Acacia burkei* (Hiscocks, 1999), *Albizia versicolor* (Gaugris, 2008; Boundja & Midgley, 2009), *Berchemia zeyheri* (Wiseman *et al.,* 2004; Boundja & Midgley, 2009), *Schotia brachypetala*

(Boundja & Midgley, 2009), *Searsia gueinzii* (Wiseman *et al.,* 2004), *Sideroxylon inerme* (Boundja & Midgley, 2009), *Strychnos madagascariensis* (Boundja & Midgley, 2009) and *Terminalia sericea* (De Boer *et al*., 2000). The conservation of these species is important as the extirpation of woody species in Tembe Elephant Park may potentially lead to a homogenisation of the vegetation in the different communities.

Observations over a couple of years by the management of the Tembe Elephant Park noticed a decline in *Albizia* species (*Albizia versicolor*, *Albizia adianthifolia* and *Albizia forbesii*) which they ascribed to elephant utilisation. One of the aims of the study was to determine whether this was indeed the case. Matthews and Page (unpublished) found *Albizia adianthifolia* to have the highest percentage of canopy removed, in terms of utilised species, and *Albizia versicolor* the third highest percentage in 1995 and they considered *Albizia* species to be abundant in Tembe Elephant Park. In 2004, *Albizia versicolor* and *Albizia adianthifolia* were still abundantly available throughout a number of communities in the park. However, in 2010 the availability of these species declined to a point where there were no trees of *Albizia* species. A couple of *Albizia versicolor* as well as *Albizia adianthifolia* seedlings were recorded in some woodland communities. Therefore *Albizia* species could be considered extirpated in the Tembe Elephant Park due to elephant utilisation. From an observer's point of view, *Albizia* species were practically non-existent in Tembe Elephant Park in 2010. In the Maputo Elephant Reserve, Mozambique, *Albizia versicolor* was utilised by elephants but not in a way that it raised concern. It was not considered to be preferred by elephants at all (De Boer *et al*., 2000).

Another group of species that needs to be carefully monitored for excessive elephant utilisation is the endemic species. *Cassipourea mossambicensis*, *Dialium schlechteri*, *Dovyalis longispina*, *Erythrophleum lasianthum*, *Grewia microthyrsa*, *Haplocoelum gallaense*, *Memecylon sousae*, *Ochna barbosae*, *Ozoroa engleri*, *Toddaliopsis bremekampii*, *Tricalysia delagoensis* and *Wrightia natalensis* are all endemic or near-endemic species of the Maputaland Centre (Matthews *et al*., 2001) and they are some of the most selected for species by elephants (Table 15.4). They are of great conservation priority based on their endemism.

As mentioned in previous chapters, the main purpose for proclaiming the park as a conservation area in 1983 was to conserve the Sand Forest also known as Licuati Forest, which forms part of the Maputaland Centre of Endemism (Matthews *et al*., 2001). This vegetation type includes many Maputaland Centre endemic (and near-endemic) plant species such as those mentioned in the previous paragraph. According to the IUCN Red

List of Threatened Species (Raimondo *et al.,* 2009) there are also three red data plant species which include *Brachylaena huillensis* (lower risk/near threatened) *Combretum mkuzense* (lower risk/near threatened) and *Encephalartos ferox* (near threatened). The increase in the number of species utilised by elephants and an increase in the volume of canopy removed (in absolute terms as well as in relation to what was available) is threatening this unique vegetation type.

Elephant utilisation was studied across six size classes in Tembe Elephant Park and in 2010 there was a trend of increasing percentage utilisation as the stem diameter of woody species increased. This trend of increasing percentage utilisation with an increase in size has been reported in several studies (Dublin *et al*., 1990; Ben-Shahar, 1993; Duffy *et al*., 2002; Boundja & Midgley, 2009). In contrast, in 2004 the results regularly showed higher utilisation percentages in size class 3, 4 and 5 than size class 6 in the woodland communities. The great difference between 2004 and 2010 surveys in the percentage canopy removal within the size class 6 could be due to the enlarged transect for Woodlands in 2010, which focused on the larger individuals. The enlarged transect was instituted to encounter more large individuals to improve the accuracy of the utilisation values for these large individuals. Because all available and removed canopy volumes are expressed per ha the increased transect size would have provided a better reflection of the utilisation in all size classes than was possible in 2004 where the largest size class was underrepresented. The sampling sites for the Sand Forest communities were not enlarged, as all other sampling sites, the size of the transect were based on the density of the vegetation.

It was reassuring to note that the percentage damage did not increase noticeably in the lower size classes, as these were the young individuals important for recruitment and regeneration.

The increased percentage utilisation did not always occur just because of an increase in actual canopy removal but in many communities there was a great decrease in canopy volume available for browsing since 2004. Similar results have been reported in other reserves with high elephant densities (Moolman & Cowling, 1994; Wiseman *et al.,* 2004; Birkett & Stevens-Wood, 2005; Guldemond & Van Aarde, 2007). The decreased availability of browse in many communities in the park supports the contention that the increasing elephant population is having a negative impact on vegetation.

15.3 OTHER FACTORS CONTRIBUTING TO DAMAGE ON WOODY PLANTS

It is important to keep in mind that the decrease in canopy volume of woody species or the damage to certain individuals can not necessarily be ascribed exclusively to elephant utilisation, other herbivores might play a big role. Not only may other herbivores damage the trees but small mammals may forage on the seeds of the woody species and lower the recruitment rate or utilise the small individuals to such an extent that they do not develop into proper trees with larger canopies (Gaugris, 2008).

Another factor playing a role is fire even though the impact of fire is not as great as that of herbivory (Levick *et al*., 2009). Within the Sand Forest communities the role of fire is negligible (Gaugris & Van Rooyen, 2011) but within the woodlands it could be very important. Fire events in Tembe Elephant Park are uncommon in the Sand Forest (Matthews, 2007a; Gaugris & Van Rooyen, 2010b). However, within the woodlands regular seasonal fires take place. These occur in the form of natural mosaic fires (Matthews, 2007a).

The interaction of elephants and fire is important for the dynamics of a savanna ecosystem (Eckhardt *et al*., 2000; Shannon *et al*., 2011; Vanak *et al*., 2012). In woodlands, fire generally has a more severe impact on elephant utilised woody species (Shannon *et al*., 2011). The decrease of available canopy volume since 2004 in the communities, especially the open and sparse woodlands, could be due to fire events since the previous survey. Incidences of fire damage were recorded in the field. It is known that woody cover will decrease as the frequency of fire increases (Eckhardt *et al*., 2000).

15.4 METHODOLOGICAL ISSUES

All data used for this study were obtained from different researchers during different times therefore it is possible that errors or inconsistencies may occur. Plant identification, site location and interpretation of elephant/animal utilisation is some of the areas where methodological issues may slip in. These issues are discussed in Chapter 4.

15.5 MANAGEMENT IMPLICATIONS AND RECOMMENDATIONS

Managing waterholes in the park, or altering the periods that artificial waterholes are opened or closed, may stop overutilisation of a certain area close to permanent water. This will have a great effect on elephant utilisation values in the immediate vicinity of the waterhole and it will reduce the damage by small herbivores which may inhibit regeneration and sapling growth. However, overall it would not lead to lower levels of elephant impacts, but will only redistribute them and reduce the excessive utilisation by them in certain areas. This may restore the ecosystem processes in some parts of the communities as elephant and other browser activity would be minimized. This recommendation is supported by Gaugris and Van Rooyen (2010a). Considering the results obtained from the Short Sand Forests where the elephant exclosure was present, it is greatly recommended that either elephant densities should be lowered through translocation (as culling is not permitted and contraceptive methods do not seem to deliver results) or more areas within the park should be enclosed (elephants absent). However, the latter action would result in an increase in elephant utilisation in the remainder of the park and these regions could become sacrifice zones. The exclosure within the Sand Forest community clearly illustrated the negative impact of elephant on the vegetation. The implementation of a fire management program which will encourage heterogeneity of the vegetation, protect the Sand Forest communities and maintain vegetation cover across Tembe Elephant Park is recommended.

15.6 CONCLUSION

Megaherbivores, such as elephants, are a key component of savanna ecosystems (Guldemond & Van Aarde, 2008; Shannon *et al*., 2011). These ecosystem engineers create a new niche for smaller fauna species during branch breaking and uprooting (Pringle, 2008; Goheen & Palmer, 2010). They also promote seed dispersion, seedling recruitment and they open up space to maintain the grass-tree relationship (Chapman *et al*., 1992; Cochrane, 2003). As soon as elephant densities become too high, these positive influences are outweighed by the negative impacts they have on the vegetation. Elephants may open up too much space, cause the extirpation of the woody species in the area (O'Connor *et al*., 2007) or bush encroachment may occur (Boundja & Midgley, 2009; Goheen & Palmer, 2010). Their preferences for certain species may result in the extirpation of such a species in the park or reserve and if it persists, extinction of a species in the country. *Albizia* species in Tembe Elephant Park are an example of such a sequence of events.

In the Tembe Elephant Park, the impact of elephant utilisation is clearly visible from the roadside by any observer, no matter their knowledge. These observations were supported by the data obtained in the field and analysed using different methods. Elephant utilisation in Tembe Elephant Park, as reflected by percentage canopy removal, has definitely increased since 2004 as the elephant population increased. Percentage canopy removal obtained from the 2010 survey was more than double what it was in 2004. Not only did the actual canopy volume removed by elephant increase with approximately 57% but the total canopy volume available for browsing decreased extensively since 2004. The percentage canopy volume lost due to the impact of elephants is alarmingly high. Management actions need to be established soon because at this rate of elephant utilisation irreversible damage to the vegetation and biodiversity might ensue.

The size classes targeted by the elephants remained approximately the same from 2004 to 2010 although the 2010 results showed that elephant canopy removal percentage increased in the large size classes. This was expected as elephants target individuals with large stem diameters.

A change in the selection for woody species by elephants was clear, but the change in species preference made future projections of canopy removal problematic. Elephants seem to utilise a species at extreme levels until the species is almost extirpated, then they just move onto the next target species. This routine is evident in the results as highly preferred species in 2004, with high canopy volumes available and removed, had low canopy availability and electivity ratios in 2010, consequently the elephants moved on from these species as individuals became scarce.

Elephants in the Tembe Elephant Park have a noticeable impact on the vegetation at a species, population as well as community level. The structure and composition of communities were altered, selected species were facing extirpation and structure of individuals and populations was changed through browsing manners of elephants. Management actions should be implemented to prevent irreversible damage to the vegetation and to conserve the woody species currently under threat.

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APPENDIX

A. Abbreviations for species names

Species name	Abbreviation	Comment
Acacia borleae Burtt Davy	Acac borl	
Acacia burkei Benth.	Acac burk	
Acacia kraussiana Meisn. ex Benth.	Acac krau	
Acacia nilotica (L.) Willd. ex Delile	Acac nilo	
Acacia robusta Burch.	Acac robu	
Acacia senegal (L.) Willd.	Acac sene	
Acalypha glabrata Thunb.	Acal glab	
Acridocarpus natalitius A.Juss.	Acri nata	
Afzelia quanzensis Welw.	Afze quan	
Albizia adianthifolia (Schumach.) W.Wight	Albi adia	
Albizia forbesii Benth.	Albi forb	
Albizia versicolor Welw. ex Oliv.	Albi vers	
Ancylanthos monteiroi Oliv.	Ancy mont	
Antidesma venosum E.Mey. ex Tul.	Anti veno	
Artabotrys monteiroae Oliv.	Arta mont	
Azima tetracantha Lam.	Azim tetr	
Balanites maughamii Sprague	Bala maug	
Bauhinia tomentosa L.	Bauh tome	
Berchemia zeyheri (Sond.) Grubov	Berc zeyh	
Bersama lucens (Hochst.) Szyszyl.	Bers luce	
Boscia foetida Schinz subsp. filipes (Gilg) Lotter	Bosc fili	
Brachylaena discolor DC.	Brac disc	
Brachylaena huillensis O.Hoffm.	Brac huil	
Bridelia cathartica G.Bertol.	Brid cath	
Bridelia micrantha (Hochst.) Baill.	Brid micr	
Burchellia bubalina (L.f.) Sims	Burc buba	
Canthium inerme (L.f.) Kuntze	Cant iner	

Species name	Abbreviation	Comment
Canthium setiflorum Hiern	Cant seti	
Capparis tomentosa Lam.	Capp tome	
Carissa bispinosa (L.) Desf. ex Brenan	Cari bisp	
Carissa macrocarpa (Eckl.) A.DC.	Cari macr	
Casearia gladiiformis Mast.	Case glad	
Cassipourea mossambicensis (Brehmer) Alston	Cass mosa	
Catunaregam spinosa (Thunb.) Tirveng.	Catu spin	
Chaetacme aristata Planch.	Chae aris	
Clausena anisata (Willd.) Hook.f. ex Benth.	Clau anis	
Cleistanthus schlechteri (Pax) Hutch.	Clei schl	
Coddia rudis (E.Mey. ex Harv.) Verdc.	Codd rudi	
Cola greenwayi Brenan	Cola gree	
Combretum celastroides Welw. ex M.A.Lawson	Comb cela	
Combretum mkuzense J.D.Carr & Retief	Comb mkuz	
Combretum molle R.Br. ex G.Don	Comb moll	
Commiphora neglecta I.Verd.	Comm negl	
Coptosperma littorale (Hiern) Degreef	Tare litt	
Crotalaria capensis Jacq.	Crot cape	
Croton pseudopulchellus Pax	Crot pseu	
Croton steenkampianus Gerstner	Crot stee	
Dalbergia melanoxylon Guill. & Perr.	Dalb mela	
Dalbergia obovata E.Mey.	Dalb obov	
Deinbollia oblongifolia (E.Mey. ex Arn.) Radlk.	Dein oblo	
Dialium schlechteri Harms	Dial schl	
Dichrostachys cinerea (L.) Wight	Dich cine	
Diospyros dichrophylla (Gand.) De Winter	Dios dicr	
Diospyros galpinii (Hiern) De Winter	Dios galp	
Diospyros inhacaensis F.White	Dios inha	
Dovyalis longispina (Harv.) Warb.	Dovy long	
Drypetes arguta (Müll.Arg.) Hutch.	Dryp argu	
Drypetes natalensis (Harv.) Hutch.	Dryp nata	

Species name	Abbreviation	Comment
Elaeodendron transvaalense (Burtt Davy) R.H.Archer	Elae tran	
Erythrococca berberidea Prain	Eryt berb	
Erythrophleum lasianthum Corbishley	Eryt lasi	
Erythroxylum delagoense Schinz	Eryt dela	
Erythroxylum emarginatum Thonn.	Eryt emar	
Euclea divinorum Hiern	Eucl divi	
Euclea natalensis A.DC.	Eucl nata	
Euphorbia ingens E.Mey. ex Boiss.	Euph inge	
Galpinia transvaalica N.E.Br.	Galp tran	
Garcinia livingstonei T.Anderson	Garc livi	
Gardenia volkensii K.Schum.	Gard volk	
Grewia caffra Meisn.	Grew caff	
Grewia microthyrsa K.Schum. ex Burret	Grew micr	
Gymnanthemum coloratum	Gymn colo	
Gymnosporia senegalensis (Lam.) Loes.	Gymn sene	
Haplocoelum foliolosum (Hiern) Bullock	Hapl gall	*Haplocoelum gallaense* is a misapplied name
Hippocratea delagoensis Loes.	Hipp dela	
Hymenocardia ulmoides Oliv.	Hyme ulmo	
Hyperacanthus microphyllus (K.Schum.) Bridson	Hype micr	
Hyphaene coriacea Gaertn.	Hyph cori	
Isoglossa woodii C.B.Clarke	Isog wood	
Kraussia floribunda Harv.	Krau flor	
Lagynias lasiantha (Sond.) Bullock	Lagy lasi	
Leptactina delagoensis K.Schum.	Lept dela	
Maclura africana (Bureau) Corner	Macl afri	
Manilkara discolor (Sond.) J.H.Hemsl.	Mani disc	
Maytenus undata (Thunb.) Blakelock	Mayt unda	
Memecylon sousae A.& R.Fern.	Meme sous	
Mimusops caffra E.Mey. ex A.DC.	Mimu caff	

Species name	Abbreviation	Comment
Monanthotaxis caffra (Sond.) Verdc.	Mona caff	
Monodora junodii Engl. & Diels	Mono juno	
Mundulea sericea (Willd.) A.Chev.	Mund seri	
Mystroxylon aethiopicum (Thunb.) Loes.	Cass aeth	Name changed from *Cassine aethiopica*
Newtonia hildebrandtii (Vatke) Torre	Newt hild	
Ochna arborea Burch. ex DC.	Ochn arbo	
Ochna barbosae N.Robson	Ochn barb	
Ochna natalitia (Meisn.) Walp.	Ochn nata	
Oxyanthus latifolius Sond.	Oxya lati	
Ozoroa engleri R.Fern. & A.Fern.	Ozor engl	
Pappea capensis Eckl. & Zeyh.	Papp cape	
Parinari capensis Harv.	Pari cape	
Pavetta catophylla K.Schum.	Pave cato	
Pavetta lanceolata Eckl.	Pave lanc	
Phyllanthus reticulatus Poir.	Phyl reti	
Plectroniella armata (K.Schum.) Robyns	Plec arma	
Pseudobersama mossambicensis (Sim) Verdc.	Pseu moss	
Psydrax fragrantissima (K.Schum.) Bridson	Psyd frag	
Psydrax locuples (K.Schum.) Bridson	Psyd locu	
Ptaeroxylon obliquum (Thunb.) Radlk.	Ptae obli	
Pteleopsis myrtifolia (M.A.Lawson) Engl. & Diels	Ptel myrt	
Rothmannia fischeri (K.Schum.) Bullock	Roth fish	
Salacia leptoclada Tul.	Sala lept	
Sapium integerrimum (Hochst.) J.Léonard	Sapi inte	
Schotia brachypetala Sond.	Scho brac	
Sclerocarya birrea (A.Rich.) Hochst. subsp. *caffra* (Sond.) Kokwaro	Scle birr	
Sclerochiton apiculatus Vollesen	Scle apic	
Scutia myrtina (Burm.f.) Kurz	Scut myrt	
Searsia gueinzii (Sond.) F.A.Barkley	Rhus guei	

Species name	Abbreviation	Comment
Sideroxylon inerme L.	Side iner	
Spirostachys africana Sond.	Spir afri	
Strychnos decussata (Pappe) Gilg	Stry decu	
Strychnos henningsii Gilg	Stry henn	
Strychnos madagascariensis Poir.	Stry mada	
Strychnos spinosa Lam.	Stry spin	
Suregada zanzibariensis Baill.	Sure zanz	
Syzygium cordatum Hochst.	Syzy cord	
Tabernaemontana elegans Stapf	Tabe eleg	
Teclea gerrardii I.Verd.	Tecl gerr	
Terminalia sericea Burch. ex DC.	Term seri	
Toddaliopsis bremekampii I.Verd.	Todd brem	
Tricalysia allenii (Stapf) Brenan	Tric alle	
Tricalysia capensis (Meisn. ex Hochst.) Sim	Tric cape	
Tricalysia delagoensis Schinz	Tric dela	
Tricalysia junodii (Schinz) Brenan	Tric juno	
Tricalysia lanceolata (Sond.) Burtt Davy	Tric lanc	
Trichilia emetica Vahl	Tric emet	
Vangueria esculenta S.Moore	Vang escu	
Vangueria infausta Burch.	Vang infa	
Vepris lanceolata (Lam.) G.Don	Vepr lanc	
Vitex amboniensis Gürke.	Vite ambo	
Wrightia natalensis Stapf	Wrig nata	
Ximenia americana L.	Xime amer	
Ximenia caffra Sond.	Xime caff	
Xylotheca kraussiana Hochst.	Xylo krau	
Zanthoxylum capense (Thunb.) Harv.	Zant cape	
Ziziphus mucronata Willd.	Zizi mucr	

B. GPS points of the 2010 survey

2010 Plots	Latitude	Longitude
M 1	-27.04391	32.45195
M 2	-27.03202	32.46225
M 3	-27.02107	32.44895
M 4	-27.03436	32.48491
M 5	-27.00774	32.49652
M 6	-27.03185	32.43292
M 7	-27.03255	32.38650
M 8	-26.98823	32.49874
M 9	-26.95218	32.51974
M 10	-26.96097	32.52828
M 11	-26.98058	32.44595
M 12	-26.97672	32.42657
M 13	-27.04129	32.43321
M 14	-26.98075	32.51915
M 15	-26.95184	32.54052
M 16	-26.95965	32.39479
M 17	-26.93277	32.39756
M 18	-26.93406	32.45104
M 19	-26.99248	32.47301
M 20	-26.97453	32.47850
M 21	-26.95802	32.49891
M 22	-26.93334	32.52712
M 23	-26.89792	32.47520
M 24	-26.91978	32.53880
M 25	-26.89928	32.54491
M 26	-26.89321	32.48503
M 27	-26.88356	32.49263

M 28	-26.89784	32.52823
M 29	-26.86502	32.55318
M 30	-26.86433	32.47702
M 31	-26.89675	32.40571
M 32	-26.86502	32.41695
M 33	-27.04626	32.40522
M 34	-26.97909	32.40075
M 35	-27.04249	32.47411
M 36	-26.99135	32.40090
M 37	-27.00593	32.47906
M 38	-26.98691	32.45369
M 39	-26.95523	32.40645
M 40	-26.94180	32.44815
M 41	-26.86828	32.47430
M 42	-27.00672	32.39394
M 43	-27.02293	32.40463
M 44	-27.00770	32.47240

C. Comparison of the survey sites for all three surveys

2010 Site number	2004 site number	1995 site number	Vegetation 2004	Vegetation 2010	Site Area 2004	Site Area 2010	2010 Tree Plots
1	52		CWC	CWC	120	150	50x50
2	54	20	OWS	OWS 1	200	200	50x50
3	57	5	SWS	SWS	150	200	no trees
4	72	19	CWC	CWC	270	300	50x50
5	76		CWC	CWC	160	200	50x50
6	35	28	CWC	CWC	250	200	50x50
7	11	38	OWS	OWS 1	180	200	50x50
8	78	4	CWS	CWS 2	150	200	50x50
9	84	32	CWS	CWS 1		200	50x50
10	99	24	CWS	CWS 1	80	160	50x50
11	70	11	OWS	OWS 1	400	300	50x50
12	32	29	OWS	OWS 1	300	300	50x50
13	36		OWS	OWS 1	320	200	50x50
14	75		OWS	CWS 1	120	160	50x50
15	100		CWS	CWS 1	150	160	50x50
16	20		OWS	OWS 2	300	300	no trees

2010 Site number	2004 site number	1995 site number	Vegetation 2004	Vegetation 2010	Site Area 2004	Site Area 2010	2010 Tree Plots
17	24		OWS	OWS 2	900	300	50x50
18	89		OWS	OWS 2	280	300	50x50
19	65	26	OWS	OWS 2	300	200	no trees
20	83	43	SWS	SWS	180	200	no trees
21	85		OWS	OWS 1	525	300	50x50
22	106		CWS	CWS 1	240	200	50x50
23	97	14	OWS	OWS 1	210	200	50x50
24	107	7	CWS	CWS 2	240	200	50x50
25	108	31	OWS	CWS 2	210	200	50x50
26	98		CWS	CWS 2	180	200	50x50
27	91	13	OWS	OWS 1	210	200	50x50
28	104	45	OWS	OWS 1	350	200	50x50
29	94	40	OWS	OWS 1	400	200	50x50
30	59	41	OWS	OWS 1	400	200	50x50
31	23		OWS	OWS 2	470	300	50x50
32	27		OWS	OWS 2	300	300	50x50
33	13		SSF	SSF		100	SF

2010 Site number	2004 site number	1995 site number	Vegetation 2004	Vegetation 2010	Site Area 2004	Site Area 2010	2010 Tree Plots
34	30	37	SSF	SSF		100	SF
35	71		SSF	TSF		100	SF
36	18	17	TSF	TSF		160	SF
37	81	6	MFS	MFS		160	SF
38	69		MFS	MFS		160	SF
39	16	30	TSF	SSF		100	SF
40	88		TSF	TSF		160	SF
41	93	44	TSF	OWS 1	160	200	50x50
42	17		TSF	SSF		100	SF
43	7	39	TSF	SSF		100	SF
44	82		MFS	MFS		160	SF