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The impacts of herbivores and humans on the utilisation of woody resources in conserved versus non-conserved land in Maputaland, northern KwaZulu-Natal, South Africa

by

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Submitted in partial fulfilment of the requirements for the degree

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In

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Centre for Wildlife Management
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University of Pretoria

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This thesis represents a conclusion to the past seven years of my life. I have been involved in the northern Maputaland society in one way or another since June 2000, and it feels strange to turn a page by handing in a document. This document has changed many times through the course of these past two years, and it has been a thorough work of breaking preconceived ideas and thoughts until the very end. This thesis is also the result of many contributions from other people at some stage. To name everyone would be impossible but I would like to extend special thanks to some who have been at the heart of my work.

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Disclaimer

I hereby declare all the work to be my own and that I have acknowledged all those that helped me and contributed in producing this thesis. This work has not been submitted previously at any other institution.

Jerome Yves Gaugris

CURRICULUM VITAE

Jerome Yves Gaugris was born in 1977 and grew up in Burundi in central Africa. He received his school education at the French School of Bujumbura, and then completed his undergraduate studies in Biology and Geology at the Université Blaise Pascal in Clermont Ferrand in France. He completed a MSc. in Cellular Biology and Physiology at this University before coming to South Africa in 1999 where he enrolled for a BSc. Honours in Wildlife Management at the Centre for Wildlife Management of the University of Pretoria, followed by an MSc., which he received with distinction in 2004. His dissertation investigated the sustainable utilisation of hardwood species in a rural community of Maputaland in South Africa.

Jerome has done a lot of research on vegetation and sustainable utilisation of plant resources in the Maputaland area, and published seven papers from his MSc., and another two are in review.

Jerome has travelled widely and is familiar with Wildlife Management in Europe, Northern America and Australia.

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Abstract

This study presents an exploration of the structure, dynamics and utilisation of woody plants in vegetation units of northern Maputaland. Animal (in Tembe Elephant Park) and human (in the rural community of Manqakulane) utilisation of woody plants were compared against a control area (Tshanini Community Conservation Area) where animals were extirpated and people were precluded through tribal rules.

The tree assemblages of the unique Sand Forest were explored, and compared with previous studies. A new classification was proposed and a new subcommunity was established. Contrary to previous studies, a gradient from Short to Intermediate to Tall Sand Forest was defined, and it was suggested that structurally different Sand Forest subcommunities represent a mosaic of different evolutionary states, rather than stationary states as perceived currently. Animal utilisation appeared to have transformed Sand Forest in conserved land to such an extent that it no longer resembled Sand Forest outside conserved areas.

The structure of Sand Forest and woodlands of the region was evaluated at the vegetation unit level (21 vegetation units), through a size and height class distribution analysis of woody plants. Humans and animals had clearly modified the woodlands and appeared to force succession from closed woodland to open woodland. The Sand Forest appeared to benefit from low intensity animal utilisation, with increased diversity, and possibly enhanced dynamics. However, signs that current animal utilisation have negative effects were perceived.

The size class distribution of Sand Forest and woodland woody species was presented and an analysis of species grain was performed. The grain concept was successfully applied to woodland species for the first time. It appeared that nearly all vegetation units were fine-grained, and therefore governed by small-scale dynamics. Frequent small disturbances are necessary to maintain diversity. There was cause for concern that current animal and human utilisation threaten such fine-scale dynamics.

The utilisation level by the browsing mammals guild in Tembe Elephant Park and by small browsers and people in Manqakulane Rural Community were evaluated over two periods. Small to medium browsers utilised more woody species and height classes than any other agent, but with short-term effects. However, utilisation marks linked to elephants and people were accumulating significantly, and the long-term effects of these agents were threatening the dynamics of Maputaland vegetation.

The case of woody species utilisation by elephants was evaluated further and compared with a previous study. Overall utilisation by elephants reached 100% of individuals for several woody species, while other species’ regeneration potential was severely threatened. Woody species preferred in 1994 were nearly extirpated. Utilisation of woody species by elephants throughout Tembe Elephant Park appeared correlated with distance to permanent water points during a dry spell.

In conclusion, it appeared clear that policies in favour of high animal numbers in formally conserved areas were not suited for northern Maputaland and this result should be considered when the expansion of the South African protected areas of Maputaland into Mozambique becomes effective. Community-based conservation appeared promising, but novel ways of generating income should be investigated.

CHAPTER 1

INTRODUCTION

The biodiversity and conservation debate in Maputaland

The Maputaland region represents *ca*. 17 000 km^2 shared by South Africa (*ca*. 9 500 km^2), Swaziland and Mozambique and has been described as a Centre of Plant Endemism (Van Wyk 1996; Van Wyk and Smith 2001), and is currently included in the Maputaland – Pondoland – Albany hotspot of biodiversity (Matthews 2006; Smith *et al.* 2006). Maputaland harbours a wide range of endemic or near endemic plant, mammal, insect, reptile, and bird species (Matthews 2006). The diversity of Maputaland is thought to stem from a great variety of habitats, but also from its geographical position at the extreme of the tropical zone and with a considerable influence from the temperate zone (Matthews 2006). It is hypothesized that biological evolution, including speciation, is particularly active among the plant and animals of the Maputaland Centre, especially due to its recent geological formation, which favour the appearance of neo-endemic (recently formed) species (Van Wyk and Smith 2001; Matthews 2006). Approximately 28% of the South African part of Maputaland is under formal conservation and the remainder of the land is under tribal landownership (Smith *et al.* 2006).

The region is dominated by a finely interwoven mesh of forest-like woodlands (Van Rensburg *et al.* 1999) of varying densities and the intriguing Sand Forest, interspersed with swamps and grasslands including wooded grasslands (Matthews 2006). The Sand Forest and wooded grasslands are considered the two most unique vegetation types of this region and in the case of the Sand Forest it also hosts a great portion of Maputaland's biodiversity (Matthews 2006). Wooded grasslands are characterised by an extreme abundance of dwarf shrubs growing from perennial underground stems of exceptional proportions. This vegetation type has also been called an underground forest because of its underground biomass (Matthews 2006). The Sand Forest is considered an anomalous vegetation type for such a nutrient poor, acidic soil and a mean rainfall well below that observed for forests of similar richness and growth form (Kirkwood and Midgley 1999; Lewis and Mander 2000; Matthews 2006; Mucina and Rutherford 2006). A wealth of herbivore mammals, with important tourism appeal, roams these landscapes within the parks and reserves but they have been nearly completely extirpated from non-conserved areas (Matthews *et al.* 2001; Gaugris *et al.* 2004; Morley 2005; van Eeden 2005; Guldemond and Van Aarde In Press).

Three debates currently dominate biodiversity conservation in Maputaland. The first debate is within conserved areas, where the size of animal populations have increased as a consequence of successful conservation efforts (Guldemond and Van Aarde In Press). These populations are believed to have reached densities that are incompatible with biodiversity conservation, especially in the case of African elephant *Loxodonta africana* (Blumenbach 1797) impact on the Sand Forest vegetation (Matthews 2006; Botes *et al.* 2006; Guldemond and Van Aarde In Press). Ideally, the management of reserves should ensure that their natural resources and dynamics are retained (Margules and Pressey 2000) and there is now a concern that natural dynamics could be perturbed within formally conserved areas. Only two studies (Guldemond 2006; Matthews and Page In Prep) have quantified the potential impact of mammals on vegetation in conserved areas of the region. Both concentrated on the African elephant and did not evaluate the contribution of other mammals that have also increased in density (Matthews 2000; Matthews 2006). Moreover, the results are either already outdated (Matthews and Page In Prep) or are too superficial to describe plant species responses to increased animal densities and only provide trends at community level (Guldemond 2006).

The second debate is that Sand Forest represents a forest in stasis, which maintains itself under current climatic conditions that are not optimal. The proponents of this hypothesis argue that Sand Forest is not resilient and is most likely to disappear and become dense woodland if it is cleared (Van Rensburg *et al.* 1999; Matthews 2006). This argument is challenged by the fact that surveys of the Sand Forest at present are preliminary (see Everard *et al.* 1995; Matthews *et al.* 1999; Matthews *et al.* 2001) and that studies conducted outside conserved area where human utilisation was low showed a dynamic system with potential transitions between the two described Sand Forest units (Gaugris *et al.* 2004; Gaugris and van Rooyen In Press).

The third debate developed further in the next section is about the use of vegetation by people outside protected areas. The level of utilisation is variable. On the one hand, cases have been documented where utilisation is so low that these areas were possibly in a better state than formally protected ones (Brookes 2004; Botes *et al.* 2006; Gaugris *et al.* 2007). However, this is in stark contrast to other studies that document intensive use and loss of natural landscapes to an ever increasing human population and a modernising society (Lewis and Mander 2000; Peteers 2005). The problem to solve for Maputaland is therefore defining what is happening in terms of vegetation utilisation in order to understand why such contradictory results are documented.

The rural people of Maputaland and the biodiversity conservation question

African rural people rely heavily on “free” resources found in woodlands and forests to live (Shackleton *et al.* 2007). Two particularly important aspects are the gathering of firewood to cook food and heat the house during cold seasons (Shackleton 1993), and the harvesting of poles and laths for the construction of houses (Gaugris *et al.* 2007). In terms of energy, this reliance on natural resources continues even when a modern source of energy has been provided. Interestingly, the energy provided through an electrification of rural households programme in South Africa did not lead to a reduction of firewood utilisation, but the energy was used for new purposes (Madubansi and Shackleton 2006; Madubansi and Shackleton 2007). In the Lowveld region of South Africa it was established that unless the South African government were to change their policy and provide more free electricity, firewood utilisation was likely to remain as widely utilised as before (Madubansi and Shackleton 2007). The likelihood of a similar situation occurring in Maputaland where the electrification programme has yet to reach the most remote parts of the subregion appears high, and it must be expected that firewood utilisation in rural households will remain at current level.

In terms of household construction in rural Maputaland, two building types seem to have become popular choices. When money is limited, rectangular buildings with locally sourced (from the surrounding vegetation) wooden frames and reed walls are favoured, but when money is available, people build houses with brick walls and purchase wood for the roof frame (Peteers 2005; Gaugris *et al.* 2007). This construction pattern is encouraging as it reduces the wood volume used considerably (Gaugris and Van Rooyen 2006; Gaugris *et al.* 2007). However, two factors are undermining these potential savings in Maputaland. These factors are population growth and society modernisation (Peteers 2005). Population growth is self explanatory, but the more delicate case of society modernisation needs explaining.

Modernisation is observed in two ways. The first way represents the increased access to, and use of modern technology such as cell phones, televisions, radios, fridges, cars, tractors and implements, powered tools and many more items that make life easier and more comfortable (Kloppers 2001; Muchagata and Brown 2003; Peteers 2005; Madubansi and Shackleton 2006). While desirable and beneficial, this aspect of modernisation, especially cars and tools, improves access to resources, both natural and from a market economy. By using vehicles, the distance from a resource no longer limits people to harvest preferred materials (Brookes 2004). On the other hand, it may equally favour the use of bought materials, which is considered superior to using materials sourced from the surrounding environment, as ownership of a vehicle often correlates with sufficient wealth to purchase construction material (Peteers 2005). Of even more concern could be the improved access to modern agricultural machines and powered tools. The Maputaland region is considered of low agricultural potential for subsistence farming (Matthews 2006). However, if mechanised means of production combined with irrigation are utilised, the agricultural potential of the region becomes viable (Eeley *et al.* 2001; Reyers *et al.* 2001). The prospect of forest clearing for agricultural development is raised and might indeed be worth considering, because it may be that local people will benefit more from agriculture than conservation (Perrings and Lovett 1999).

The second way represents a change in household social structure and is probably more significant. More households are built but fewer people live in them than before (Peteers 2005). This trend is the result of new immigrants that have arrived recently, or mostly local young people that have left the family homestead to settle themselves either someplace of their own or in a different community where work is more likely (Peteers 2005). The net result is the clearing of more land for new households, an increased number of buildings being constructed and more firewood used for a greater number of cooking and heating fires. These changes alone are sufficient to offset the potential gains from a modernised building method that utilises less wood sourced from the surrounding vegetation (Gaugris *et al.* 2007).

The resulting question is therefore how much has the utilisation of natural resources from the surrounding vegetation changed the vegetation patterns and structure and potentially its dynamics, and how much has it affected the local biodiversity? It is crucial that these details be known as it appears most unlikely that wood utilisation will decrease, and highly possible that further forest and woodlands will be cleared for agriculture by mechanised means.

Key questions

As presented above, several pertinent questions are raised about the ecology of Maputaland and its conservation value, and have made clear the need to have abundant baseline information on the natural resources of the region. Resolving all of them would be well beyond the scope of a single study, and it will therefore not be attempted here. However, it has become obvious that the baseline information on vegetation is needed in several ways and needs to be interpreted within the context of several debates that currently separate other studies. The goals of the present study were to present and / or debate the following aspects:

- A refinement of current perceptions and debating the hypotheses presented by several authors regarding the nature of the Sand Forest based on a representative study of this vegetation type in the Maputaland region.
- An analysis of the vegetation structure at the community and species levels, within protected areas, outside protected areas under the influence of people, and within a control zone where neither animals nor people have influenced vegetation in order to gain an understanding of the underlying dynamics.
- A quantitative assessment of the influence of animals and people on the vegetation structure and discussing their possible future effects on vegetation dynamics
- After obtaining, analysing and defining the above an informed discussion on the intrinsic value of flora and fauna in Maputaland and their possible management along well known or less explored conservation strategies is presented, within the current Maputaland demographic context.

To evaluate the above aspects botanical surveys were conducted in Tembe Elephant Park and the Manqakulane community. These sites offer the advantage of studying two well-separated treatments (animals / people) on similar and comparable vegetation (Matthews *et al.* 2001; Gaugris *et al.* 2004), and the comparisons of effects with a control zone (Tshanini Community Conservation Area on the land of the Community of Manqakulane, previously studied by Gaugris in 2004) where neither treatment was applied. Coincidentally, the treatments and control areas have been subjected to their various regimes over a similar period of time, since 1989 for Tembe Elephant Park, and 1992 for the other 2 sites. The added advantage of such a design is to provide a time scale over which changes become evident.

The present study will also serve as a baseline to evaluate the ecological integrity of northern Maputaland and can form part of the baseline building blocks needed for discussing the future of conservation in this valuable region.

Note on the layout of the thesis

The thesis is presented as a collection of manuscripts, of which some have been submitted for publication or will soon be submitted for publication in scientific journals. In that respect, study area, methodology and reference lists are presented in each chapter / manuscript, and a certain amount of duplication of information for these sections was unavoidable.

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CHAPTER 2

STUDY AREA

General location and baseline information

Maputaland is a region shared by Mozambique and South Africa, along the eastern coast of the southern African subcontinent (Figure 1). The region, previously identified as the Maputaland Centre of Plant Endemism (Van Wyk 1996), is now part of the Maputaland – Pondoland – Albany hotspot of biodiversity (Smith *et al.* 2006). The region is characterized by a high coastal dune cordon that reaches nearly 200 m above sea level (a.s.l.), followed inland by a low-lying coastal plain of undulating dunes that reach 129 m a.s.l., as measured on top of the Sihangwane dune cordon in Tembe Elephant Park. The coastal plain varies in width from 30 to 80 km from south to north and the dune cordons run along a north to south axis. These inner dune cordons represent littoral lines from the marine transgressions and regressions since the Miocene – Pliocene eras (for a condensed geological history see Matthews 2006). The Lebombo Mountains to the west of the coastal plain form the continental limit of the Maputaland region and reach an altitude of 600 m. The area evaluated in the present study is situated within a narrow strip of land approximately 20 km wide that runs along a north-south axis between the Pongola River to the west and the hygrophilous grasslands of the coastal plains to the east (Matthews *et al.* 2001).

People of the study area

The people of Maputaland are either called the Tembe or the Tembe-Thonga. Historically they settled the region that spans from Maputo Bay in Mozambique in the north to the Mkhuze River in the south, and the Pongola River in the west in the middle of the 16th century (Kloppers 2001). The Tembe people are named after Chief Mthembu, who arrived from Zimbabwe around 1554 and settled in the region around Maputo Bay. The word Thonga means dawn in Zulu and the Zulus referred to all people living north and east of the Zulu Kingdom as Thonga. The Zulus traded with the Portuguese colonial authority in Mozambique using Thonga people as intermediaries and slaves, and therefore the word Thonga also relates to slaves. As a result of this connotation the word is not popular in Maputaland and people prefer to be called Tembe (Kloppers 2001; Peteers 2005; Matthews 2006).

The ways of life of the Tembe people have always been based on an intense utilisation of natural resources inland and along the sea-shore (Matthews 2006). This

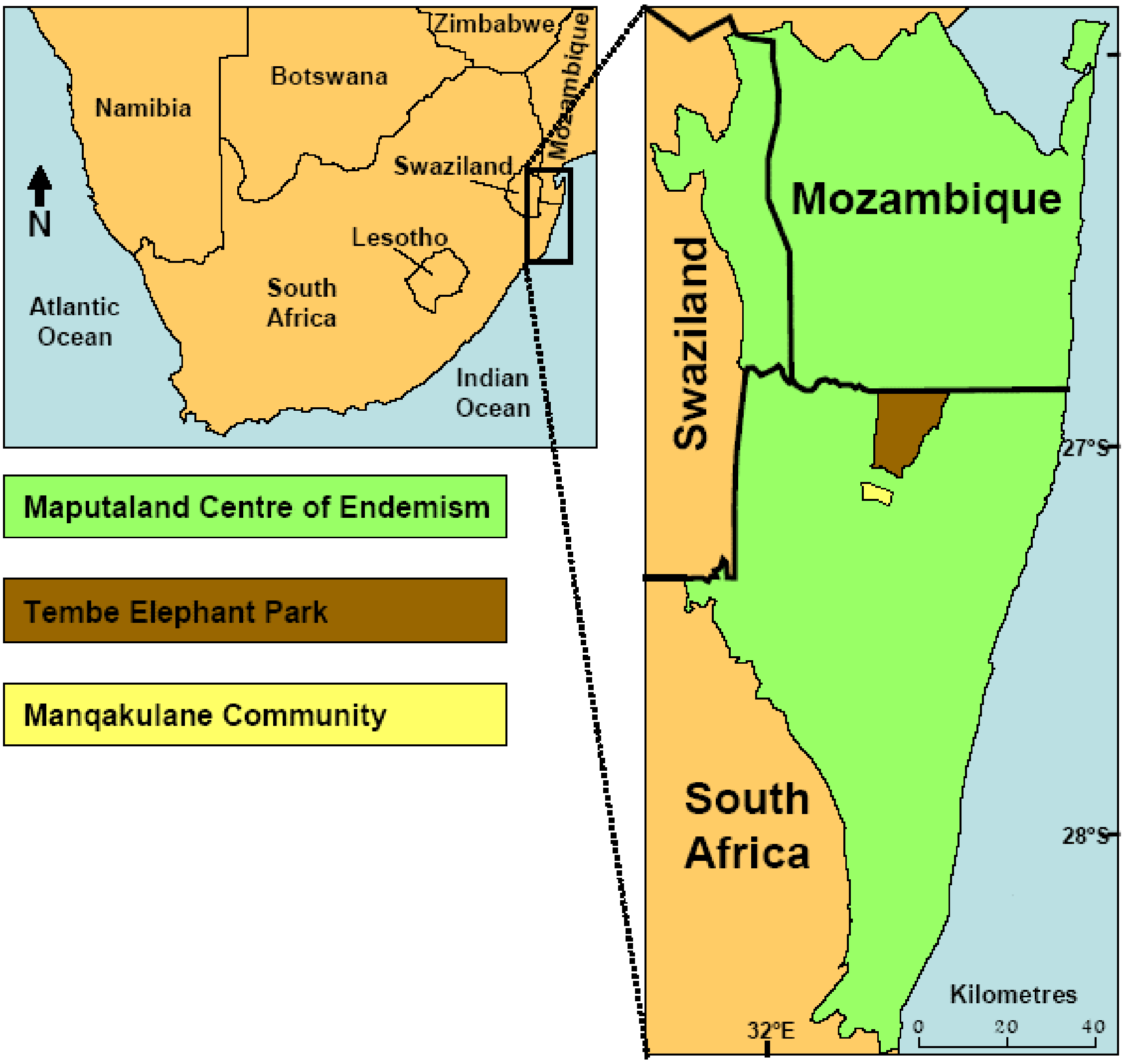

Figure 1: The Maputaland region and the study area location in the southern African subcontinent, the green area represents the Maputaland Centre of Plant Endemism (adapted from Gaugris *et al.* 2007).

pattern was enforced because of the reduced agricultural possibilities of soils in the region and also because the region is not ideally suited for keeping cattle. The latter explains why the cattle herding Zulus did not stay in Maputaland (Matthews 2006). The traditional lifestyle of the Tembe people is now in jeopardy because of an increasing rural population, which threatens the resilience of the vegetation and forces the clearing of ever more land for households and their fields (Peteers 2005; Matthews 2006). The population increase (15.22% between 1996 and 2001) is considered inflated and is in all likelihood fuelled by immigration from Mozambique, as well as from within KwaZulu-Natal and further afield in South Africa. This immigration is linked to the current development of the region through the Lubombo Spatial Development Initiative, and a boom in tourism to the coastal resorts of Kosi Bay in South Africa, and Ponta Malongane and Ponta de Ouro in Mozambique (Peteers 2005; Matthews 2006).

The rural communities in this part of Maputaland are headed by a local iNduna, representing the king (iNkosi) of the Tembe Tribal Area. The iNduna is responsible for keeping the law and order in the community and has considerable power vested in him. He rules the community through advice and communication with a steering committee that is usually composed exclusively of men from his community. Gatherings of steering committees and the whole community at the iNduna’s household are regular, often held on a weekly schedule. These gatherings are used to discuss and resolve important community matters but also day to day affairs (Gaugris 2004). The iNduna is a central figure regulating the access to the natural resources within the community, and he has the power to grant or restrict access to these resources to community members. The Tembe Tribal Authority is constituted of 46 communities, each with their own iNduna, and is headed by the iNkosi. This self-governing institution allows the local tribes to retain their traditional political structure, and maintains the hierarchy of local authorities in their respective areas of jurisdiction (Cowden 1996; Gaugris 2004).

Climate

Maputaland falls within the transition zone between the tropical and subtropical climate regimes. The region experiences a warm to hot, humid, subtropical climate (Matthews *et al.* 2001). Rainfall is concentrated during the hot summers, while winters are cool and generally drier. Rainfall varies considerably from east to west, with 1 000 – 1 300 mm per annum received on the coast, 500 – 600 mm in the drier interior, and 800 – 1 000 mm along the Lebombo Mountains that act as natural barrier where clouds collect. The predominantly northeasterly and southwesterly winds in the region are generally light although gale force winds and hurricanes with destructive effects have been observed (Guldemond 2006). Rain-bearing winds usually come from the southeast (Matthews 2006).

The weather station referred to in the present study is that of Sihangwane (50 m above mean sea level, S -27° 02.12'; E 032° 25.00'), located within Tembe Elephant Park at the park's administrative headquarters (Matthews 2006). The weather station is within 7 km of the central point of all three study sites evaluated in the present study and is therefore considered representative of the climate in all three sites

Rainfall and temperatures for Sihangwane have been recorded since 1959 and 1988 respectively. The mean annual temperature is 23.10°C, the mean summer months (October to March) temperature is 25.45 °C with a maximum recorded temperature of 45.00°C and the mean winter months (April to September) temperature is 20.81 °C with a minimum recorded temperature of 4.00°C (1988 – 2001 data) (Matthews *et al.* 2001). The mean annual rainfall for Sihangwane is 700.27 mm per year (1959 – 2006 data). The years 1999 – 2001 received above average rainfall (> 900 mm / year) but the years 2002 to 2006 received below average rainfall, with 2002 and 2003 being declared drought years with only 246.90 mm rainfall received in 2002 and 373.30 mm in 2003 (Figure 2). Humidity is relatively high, even during the drier months and is conducive to mist in the interdune plains in winter.

Geology and soils

The Maputaland coastal plain is covered by deep sands that lie over a cretaceous siltstone bedrock. The Miocene and Pleistocene formations are derived from marine sedimentation and are covered by a sandy topsoil of present and aeolian origin. The plain is the result of a succession of marine regressions and transgressions since the late Pleistocene that saw the sea level vary by amplitude of +5 to -130 m compared to current mean sea level (Matthews 2006).

Three main soil types are found on the coastal plain where the present study was conducted. The dystrophic regosols (Namib soil form) are the most common soil type and cover most of the region. They are moderate to well-drained acidic sands from Quaternary deposits. Of low fertility and found mostly on dune crests and slopes, they are considered unsuitable for agriculture (Matthews 2006). Histosols (Champagne soil form) underlie marshy areas and pans, and are acidic soils with an organic rich A horizon > 400 mm deep (Matthews 2006). Humic gleysols are observed in depressions in associations with a high water table. They are wet acidic sands where organic matter has accumulated (Matthews 2006). Also observed in depressions are duplex soils, which consist of a sandy horizon, underlain by a clay layer that becomes saturated

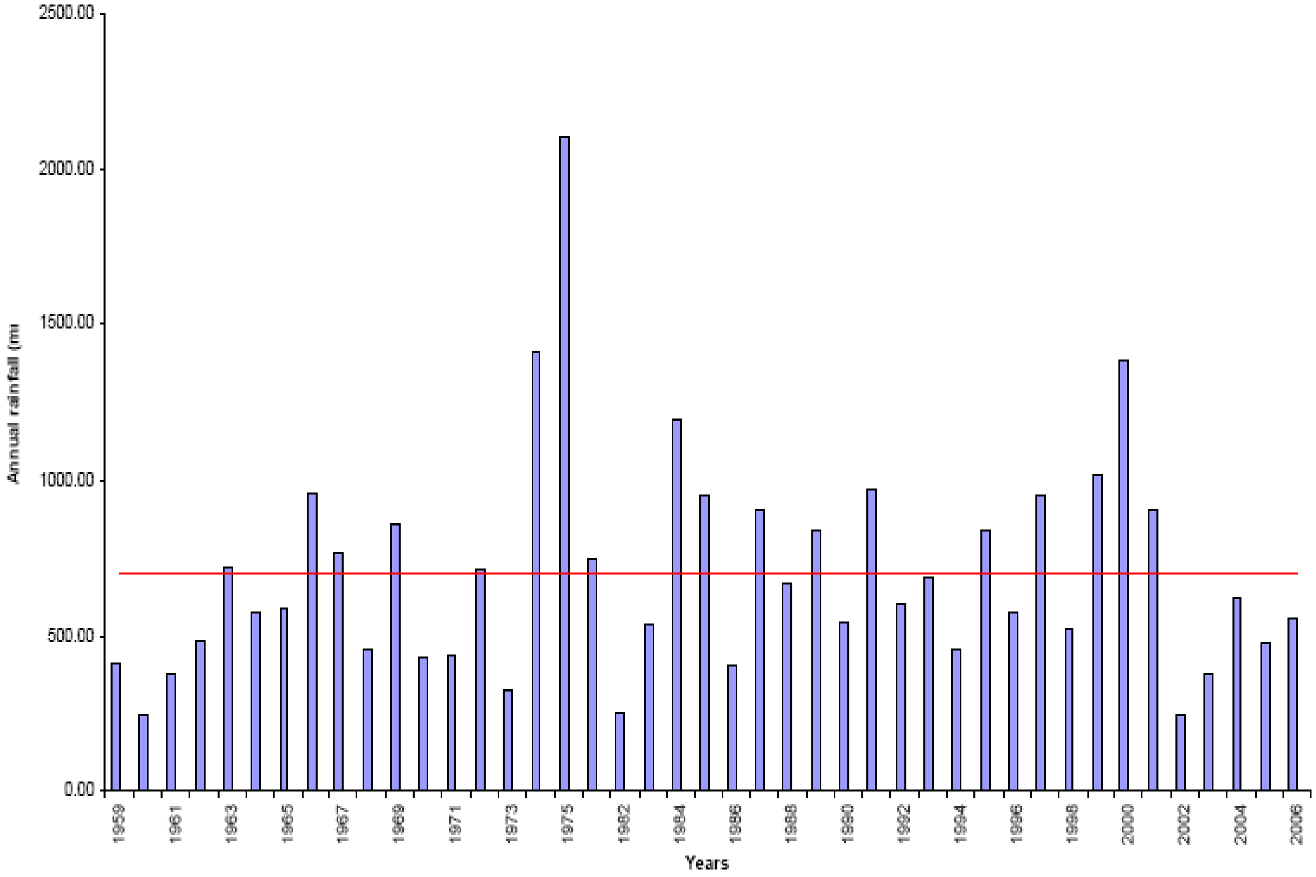

Figure 2: The annual rainfall in mm (blue line) observed at the Sihangwane Weather Station (50 m above mean sea level, 27° 02.12'S; 32° 25.00'E) in Tembe Elephant Park from 1959 to 2006, northern Maputaland, KwaZulu-Natal, South Africa. The red line represents the mean annual rainfall calculated over the same period.

during intense summer rainfall periods and sometimes form pans (Matthews 2006). For more details, a condensed description and interpretation of the geological history of northern Maputaland, based on a review of available geological literature is presented in Matthews (2006).

A note on biodiversity

The Maputaland region is considered a centre of plant endemism with approximately 9% of its 2 500 identified vascular plants endemic to the region (Van Wyk 1996; Matthews *et al.* 2001; Morley 2005; Matthews 2006). It is thought that most of these are neo-endemics, or of recent appearance, as speciation is considered an active process in this geologically young region at the interface between the subtropical and tropical climates (Van Wyk 1996; Matthews *et al.* 2001; Van Wyk and Smith 2001) The region's herpetofauna is composed of 112 species and subspecies, of which 23 species are endemic. In terms of batrachians, three frogs are endemic. The avifauna diversity for Tembe Elephant Park stands at 472 species, with five endemics and 43 near-endemics. The ichtyofauna of the region is represented by 67 species, eight of which are unique to Maputaland. A total of 102 mammal species occur in the region, of which one species and 14 subspecies are considered endemic. The number of insect species for Maputaland is unknown, although 257 butterfly species have been recorded (Matthews *et al.* 2001; Morley 2005; Matthews 2006). This exceptional biodiversity in Maputaland is also a result of the large diversity of habitats found in the region. Current research programmes conducted in the region are expected to bring forward new species (Matthews *et al.* 2001; Morley 2005).

The study sites

Three study sites were selected for the present study (Figure 3). Site one, Tembe Elephant Park, is the leading conservation area of northern Maputaland in South Africa. Site two, the Manqakulane commons under community village rule, is the eastern portion of the tribal land of this rural community. Site three is the Tshanini Community Conservation Area, located in the western portion of the land of the Manqakulane rural community.

Tembe Elephant Park

This relatively small park (30 013 ha / 300 km^2) on an African scale was created in 1983 following negotiations between the Tembe Tribal Authority with Chief Mazimba

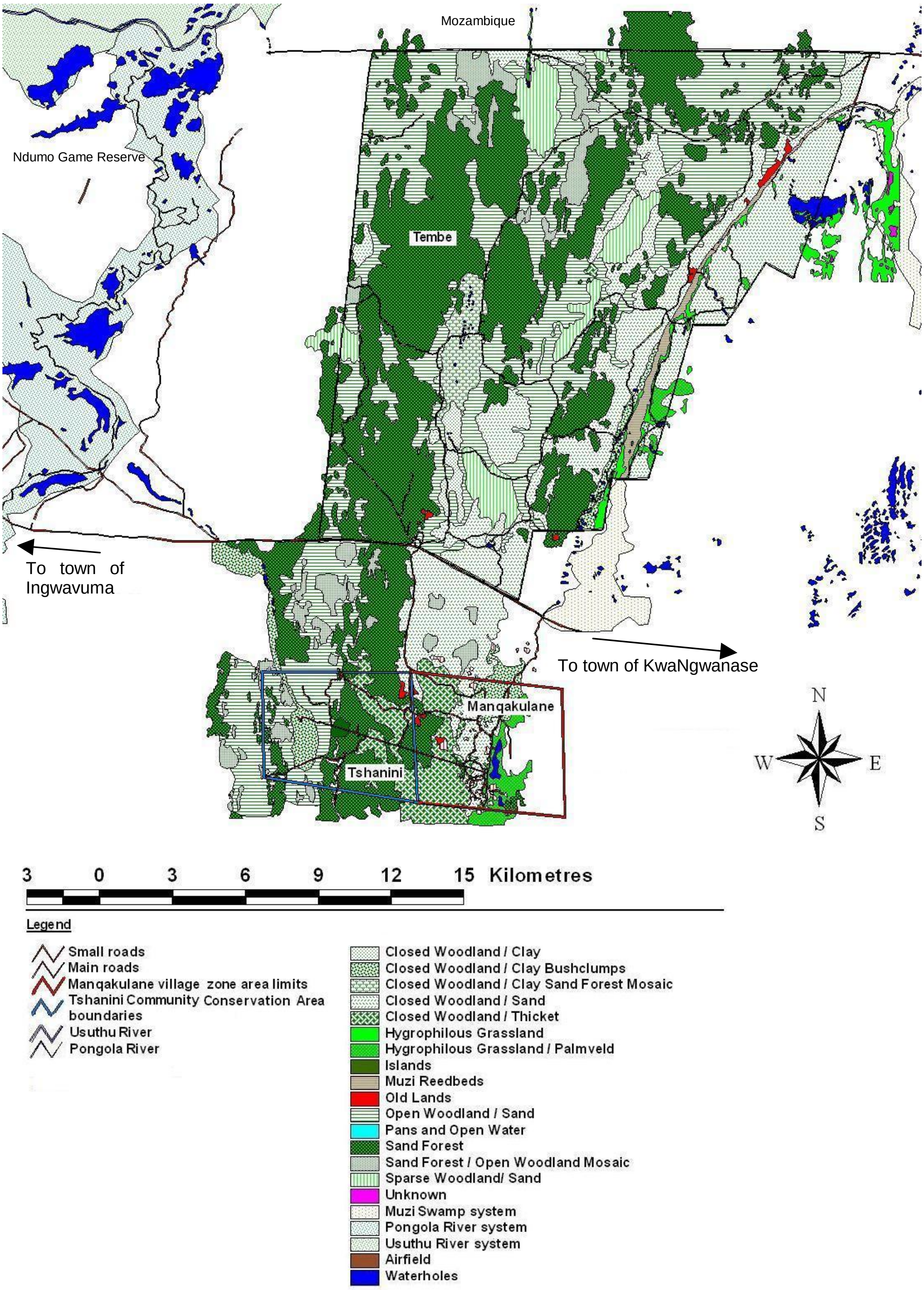

Figure 3: A map of the three study sites in northern Maputaland, showing the main vegetation units and main roads, northern Maputaland, KwaZulu-Natal, South Africa (map adapted from Matthews *et al*. 2001 and Gaugris *et al*. 2004).

Tembe and the then KwaZulu Bureau of Natural Resources (Matthews 2006). The park was created to fulfil the following conservation mandates:

- Protect the local people and their crops from wild animals, especially African elephant *Loxodonta africana* (Blumenbach 1797).
- Protect the few remaining elephants of the Maputaland coastal plain in South Africa, as well as the suni *Neotragus moschatus* (Von Dueben) population.
- Protect the rare Sand Forest vegetation.

Following its proclamation the park was fenced on the South African sides and became a closed system in 1989 when the northern boundary fence with Mozambique was closed to prevent poaching and illegal immigration (Kellerman 2004; Guldemond 2006; Matthews 2006).

Tembe Elephant Park is not a mass tourism destination. Tourism access is limited to the southern third of the reserve and is only accessible to 4x4 vehicles (Figure 4). The northern section or two third of the park is considered a wilderness area and only three tracks allow management vehicles through. All visitors and management access roads in Tembe Elephant Park are sandy tracks that follow old elephant paths in the interior or the fence line along the boundaries (Matthews 2006).

The mammal populations in Tembe Elephant Park are composed of species originally present at proclamation as well as re-established species. The larger mammals (re-established species are marked with an asterisk) encountered in the park are the following (scientific names follow Skinner and Chimimba (2006), numbers in brackets represent: 2000 census (Matthews 2000) - 2005 census (Matthews 2005)):

- African elephant *Loxodonta africana* (130[1] – 179[2] (195[3]))
- White rhinoceros* *Ceratotherium simum* (35 - 43)
- Black rhinoceros* *Diceros bicornis* (22 - 20)
- Giraffe* *Giraffa camelopardalis* (100 - 131)
- Hippopotamus *Hippopotamus amphibius* (14 - 20)
- Plain’s zebra* *Equus quagga* (200 - 176)
- Eland* *Tragelaphus oryx* (40 - 0)
- Buffalo *Syncerus caffer* (60 -100)
- Kudu* *Tragelaphus strepsiceros* (290 - 532)
- Blue wildebeest* *Connochaetes taurinus* (130 - 434)

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[1] Educated guess from a 2000 survey, not a true count

[2] Estimate of 2002 population from a mark recapture method by Morley (2005), for the known and identified number of animals was 167 individuals at that date

[3] Combination of known group count, total area count and informed guess (Matthews 2005)

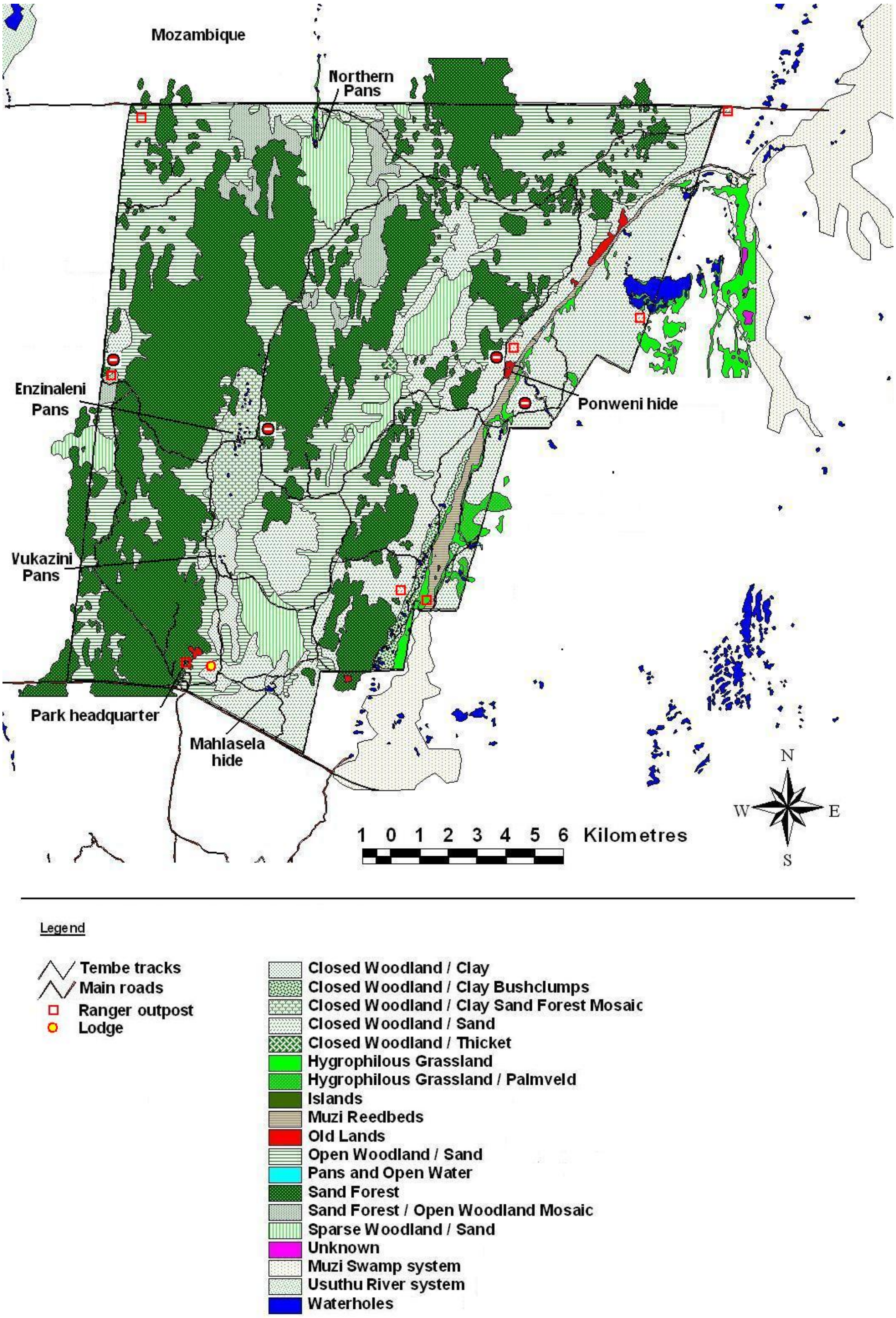

Figure 4: A map of Tembe Elephant Park in northern Maputaland, showing the vegetation units, roads and infrastructure, KwaZulu-Natal, South Africa (map adapted from Matthews *et al.* 2001 and Gaugris *et al.* 2004).

- Waterbuck* *Kobus ellipsiprymnus* (360 - 419)
- Impala* *Aepyceros melampus* (600 - 694)
- Nyala *Tragelaphus angasii* (300 - 1800)
- Bushbuck *Tragelaphus scriptus* (unknown - 40)
- Reedbuck *Redunca arundinum* (880 - 268)
- Grey duiker *Sylvicapra grimmia* (unknown - 200)
- Red duiker *Cephalophus natalensis* (unknown - 400)
- Suni *Neotragus moschatus* (unknown but estimated at > 500)
- Warthog *Phacochoerus africanus* (260 - 300)
- Bush pig *Potamochoerus porcus* (unknown)
- Lion* *Panthera leo* (4[4] – 18)
- Leopard *Panthera pardus* (unknown)
- Spotted hyena *Crocutta crocutta* (unknown)
- Side stripped jackal *Canis adustus* (unknown)

The Tembe Elephant Park landscape is typical of the central Maputaland plain, which is formed by interdune plains and high, forested dune cordons. It is crossed along its entire north – south axis by the Muzi Swamp along the eastern boundary. The swamp represents the water table level and is fed during the rainy season when it flows irregularly towards the north. Sections of the swamp are permanently wet, while other sections, especially in the south, become dry during drought years (Tarr *et al.* 2004).

The park is covered by dense woodland vegetation, with large tracts of Sand Forest, wooded grassland and swamps, which form a diverse and aesthetically pleasing mosaic of vegetation. The vegetation management of Tembe Elephant Park allows irregular burning of woodland areas and reed beds. The Sand Forest is considered as fire intolerant and is not included in the burning programme, although, because of mechanical opening of the forest edge by elephants, some sections and isolated small patches have burned within the past 10 years. These sections are not regenerating as Sand Forest, and mostly woodland species are observed growing back (Matthews 2006). The vegetation of Tembe Elephant Park is described in great detail by Matthews *et al.* (2001).

Tembe Elephant Park will form part of the Lubombo Transfrontier Conservation Area, a Peace Parks Foundation initiative (Kloppers 2001; Guldemond 2006). To that

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[4] Lions were re-introduced in 2002, 2 males and 2 females formed the seed population

purpose several areas are being evaluated as links between conservation areas in South Africa, Mozambique and Swaziland. The first link, and oldest in the debate, will join Ndumo Game Reserve, approximately 5 km to the west of Tembe Elephant Park's western boundary. This link was given the go-ahead by the end of 2006. However, due to the presence of many people in the link section nearest to Ndumo Game Reserve (Jones 2006), and the lack of a satisfying solution with regards to the Tembe Elephant Park lion population, the two reserves will remain separate a while longer, although the fencing of most of the corridor between these two reserves is scheduled for late 2007. The next link of most significance is the planned Futi corridor. This corridor will join Tembe Elephant Park to the Maputo Elephant Reserve, approximately 60 km further north in Mozambique. The corridor agreement has been signed and its implementation in the field should follow before 2010. Issues that have not yet been resolved are whether elephant-proof fencing is needed and how to deal with the threat of the Tembe Elephant Park lion population. Another link, of less direct influence for Tembe Elephant Park is the link between Ndumo Game Reserve via its direct neighbour the Usuthu Gorge Community Conservation Area in South Africa, to the Hlane National Park and Mlawula and Ndzinda Game Reserves in Swaziland (W. Matthews, pers. comm. 2006)[5].

Manqakulane rural community

The Manqakulane rural community rules a portion of land in northern Maputaland that covers approximately 5 000 ha (Peteers 2005). However, based on some studies this could also be up to 7 000 ha (Gaugris *et al.* 2004; Gaugris *et al.* 2007). This flexibility is a peculiar feature linked to committee members from the various rural communities setting and adjusting the boundaries of their communities depending on the various agreements in place at the time between neighbouring communities. While in theory the boundaries should be fixed and not subject to changes, the actual location of the boundary markers for Manqakulane have changed on at least four occasions since 2000 by up to 1 km. The core area is unlikely to change and can therefore be considered as representing the smaller size presented above, but the possibility that the larger area could be correct cannot be discounted. For the present study, the smaller area is used to define the community's tribal land. This area is divided into two near equal sections (Figure 5). The eastern section represents the zone under village rule, while the western section is occupied by the

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[5] Wayne Matthews, Regional Ecologist for Maputaland, Ezemvelo KwaZulu-Natal Wildlife, Tembe Elephant Park, Private Bag 356, KwaNgwanase 3973.

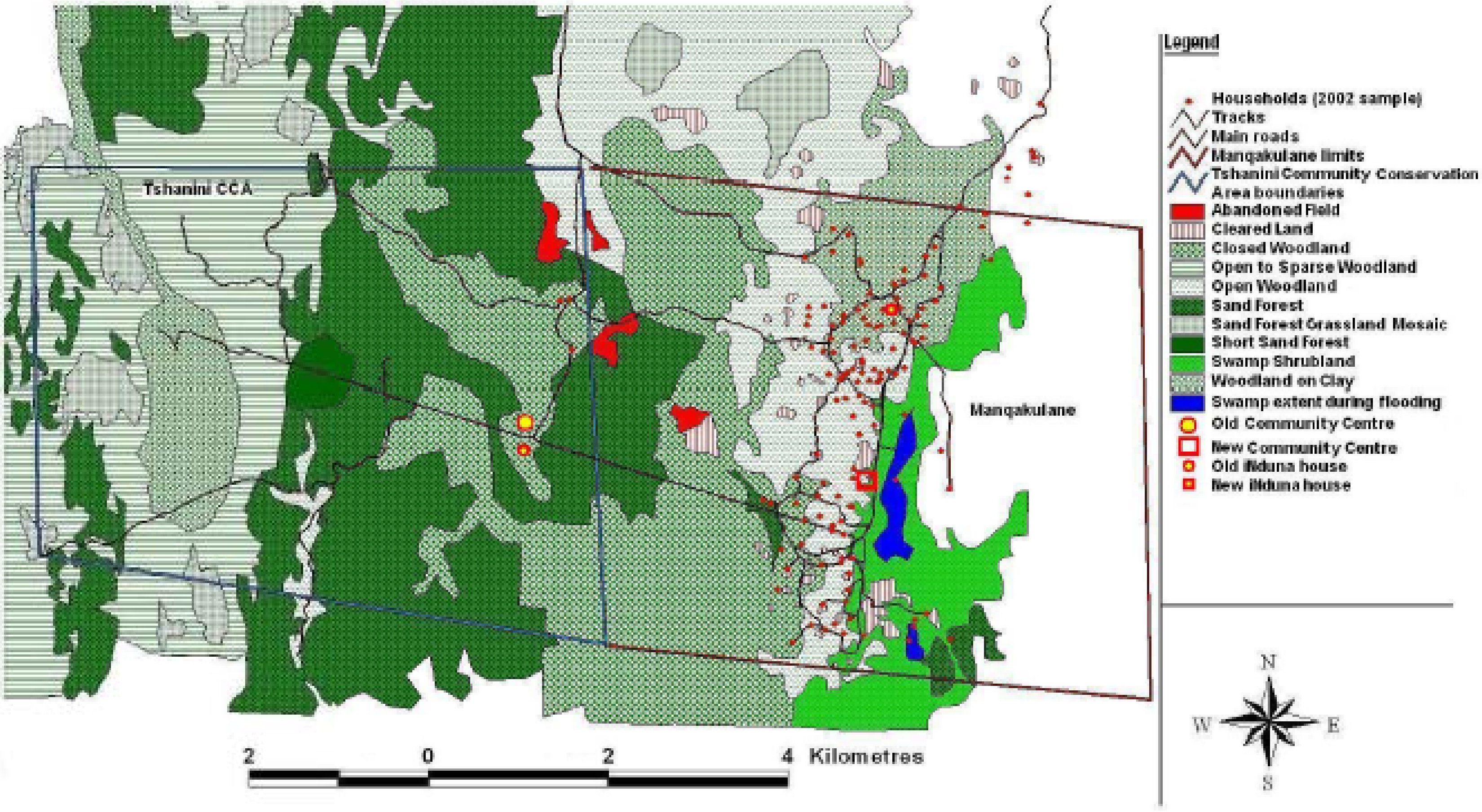

Figure 5: A map of the Manqakulane community in Maputaland, northern KwaZulu-Natal, South Africa, showing the village zone and the Tshanini Community Conservation Area locations, as well as vegetation units, roads and infrastructures (map adapted from Gaugris *et al.* 2004).

Tshanini Community Conservation Area described below. The northern boundary of the community's land is approximately 6 km due south of the Ingwavuma – KwaNgwanase main road that forms the southern boundary of Tembe Elephant Park. Only one main access road bisects the eastern portion of the community along a north – south axis and leads to the Ingwavuma – KwaNgwanase main road 6 km north. Households are connected by simple sandy tracks, rarely wide enough to accommodate a vehicle.

A total of 898 people were considered as Manqakulane community members in 2004. Of these people, 778 lived in the village permanently while the remainder were living elsewhere usually for work purposes. A total of 124 active households were counted during a 2004 household census. This represented an increase of five active households (+0.95%) compared to a 2002 household census study (Peteers 2005).

The village zone consists of the following three types of land-use:

- Land cleared for dwellings and access roads
- Land cleared for subsistence farming
- Uncleared land used for resource harvesting and cattle grazing.

Households in the Manqakulane community consist of one to 13 structures (Gaugris *et al.* 2007) erected within a cleared area on the community land. The structures in the households are either full houses (Figure 6), or what could best be considered as rooms (Figure 7), that belong to the various household members and communal facilities such as a kitchen (see Figure 7), maize store (see Figure 7), and storage rooms (Figure 8). Most structures are built with wooden main frames that support the walls and the roof. The walls can either be made fully with wood (7.3% of structures in 2002), or with wooden lattice panels that may be covered in mud or cement (65.7% of structures in 2002). A relatively newer building method is to fill the wooden frame with stones (Figure 9) and plaster the outer and inner walls (6.1% of structures in 2002). Alternatively, the wall panels can be made of reeds later covered with mud or cement (13.1% of buildings in 2002). The wealthier people of the community use brick walls (7.8% of structures in 2002, see Figure 10) and imported gum poles for the roof beams (Gaugris 2004; Gaugris *et al.* 2007). The study of 2004 concluded that the majority of recently built houses had walls made of reeds and corrugated iron sheets on the roof (Peteers 2005) thus confirming a trend predicted by the study of 2002 (Gaugris 2004; Gaugris *et al.* 2007).

The households are not connected to water or electricity directly. A water supply line runs along the main road between Ingwavuma and KwaNgwanase and brings water pumped from the Pongola River. A fork in the water line runs south along

Figure 6: A complete house with several rooms. This house consists of two bedrooms (one of them visible to the left with a glass window) separated by a common room to which is attached an unclosed veranda style room to the right that also serves as a kitchen. The walls are made entirely of small wooden poles stacked between larger supporting poles. The roof consists of corrugated iron sheets supported by wooden beams. Note the single room house in the background to the left, built in the same style. Photo by J. Gaugris: Manqakulane community, northern Maputaland, KwaZulu-Natal, South Africa, 2002.

Figure 7: A single room round house (middle), flanked by a maize store raised on a platform (left) and a kitchen (right). The walls of the house and maize store are made of a wooden lattice stacked between larger supporting poles. The kitchen walls are made of planks. The roofs of the house and maize store are thatched while the roof of the kitchen consists of corrugated iron sheets supported by wooden beams. Note the chicken pen under the maize store. Photo by J. Gaugris: Manqakulane community, northern Maputaland, KwaZulu-Natal, South Africa, 2002.

Figure 8: A round storage house. The walls of the house are made of a wooden lattice stacked between larger supporting poles and partly covered in mud. The roof is thatched. The storage house is no different from other constructions except that it usually has no windows. At 12 years since construction, this particular house was among the oldest wooden structures sampled by Gaugris (2004). Photo by J. Gaugris: Manqakulane community, northern Maputaland, KwaZulu-Natal, South Africa, 2002.

Figure 9: A rectangular single room house in construction. This picture illustrates the packed stones within a wooden frame wall structure, a new building method observed in the Manqakulane community. The roof structure is also clearly seen and shows the corrugated iron plates resting on a minimalist plank frame. Photo by J. Gaugris: Manqakulane community, northern Maputaland, KwaZulu-Natal, South Africa, 2002.

Figure 10: A rectangular multiple room house of a wealthier household. The roof beams are gum poles bought in the trading store of the nearby town of KwaNgwanase. Photo by J. Gaugris: Manqakulane community, northern Maputaland, KwaZulu-Natal, South Africa, 2002.

the western side of the Muzi Swamp. The provision of this water supply in 1998 led to the full resettlement of all households along the north – south axis represented by the water line in the community's land (Gaugris *et al.* 2007). People have to walk or drive to three distribution points where they can buy clean water for one cent per litre (Peteers 2005). Most households do not have toilets or ablution facilities and people use the surrounding environment for their natural needs, which represents a serious health hazard that requires urgent attention (Gaugris *et al.* 2007). This is currently being addressed by the Lubombo Spatial Development Initiative, charged with developing northern Maputaland. Waterless toilets are being installed throughout the region in an effort to improve health and sanitary conditions (Peteers 2005).

No power line serves the community, although one is planned for the near future (2010) (Peteers 2005). The wealthier people use generators or gas to power household appliances, and some households have solar panels. Most households, even those with electricity-generating devices, use wood for cooking and heating (Peteers 2005), a trend also reported in other locations of South Africa (Madubansi and Shackleton 2007). A detailed description of the Manqakulane community village zone appears in Gaugris (2004) and Peteers (2005).

Tshanini Community Conservation Area

In 1983, when Tembe Elephant Park was created, the steering committee and iNduna of the Manqakulane community were enthused by the concept. From these early beginnings, the idea of using a section of their tribal land with little value, as a game reserve grew steadily. In 1992, the majority of people decided to relocate from the central section of the tribal land to the eastern section along the Muzi Swamp. The former village area was therefore returned to nature and the land left fallow, with only a few fields that remained cultivated until early 2001. The migration of the village created the opportunity for the steering committee to declare the land west of the Sihangwane dune where the old village was located as a "game reserve" for the benefit of the community (Gaugris 2004).

The land was declared out of bounds for wood harvesting but remained available for hunting, fruit and honey gathering, as well as cattle grazing. While some wood harvesting did take place despite the ban, it was kept under control by the steering committee members. In 2000 the steering committee sought assistance from the University of Pretoria for establishing the reserve officially and evaluating the best utilisation possibilities. The Centre for Wildlife Management and former Centre for Indigenous Knowledge of the university led a conservation-based community development programme in the community, which was later expanded to the neighbouring communities as well. By the end of 2000 the name Tshanini Game Reserve was coined and the reserve under ecological study, while its boundaries were recognised for the first time. Funding for the first phase of development of the reserve was obtained in 2004 from the Poverty Relief Fund, a government programme that assists community-based initiatives. The reserve was gazetted by the end of 2005 as the Tshanini Community Conservation Area and was fenced subsequently. Some herbivores (nyala and impala) donated by Ezemvelo KwaZulu-Natal Wildlife (EKZNW) were re-established when the fence was completed (Gaugris 2004; Matthews 2006).

The future of the reserve is uncertain at present as no further development plan has been proposed. Tshanini Community Conservation Area is in the unfortunate position of having to compete with Tembe Elephant Park, but is much smaller, has no animals of mass tourism interest and offers similar landscape as Tembe Elephant Park. The fencing of the reserve and money obtained has motivated neighbouring communities to join their unused land to Tshanini Community Conservation Area to create a larger community-run conservancy of approximately 15 000 ha that would be able to compete with Tembe Elephant Park or offer real alternative options. In 2006, negotiations between communities, EKZNW, the Peace Parks Foundation and the Poverty Relief Fund for such a conservancy were ongoing.

At present the reserve is 2 420 ha in extent and offers a landscape of dune plains between relatively high old sand dunes. The vegetation is similar to that of Tembe Elephant Park except for the absence of the wetland component. The best asset of the reserve at present is probably the fact that it preserves a further 1 045 ha of the rare Sand Forest, in a location where animal utilisation is nil and where human utilisation was remarkably low from 1992 to 2000. This tract of “intact” Sand Forest could be of interest to several organisations searching for conservation concessions in hotspots of biodiversity. The latter could represent a novel and undemanding way of obtaining funds for these cash-limited rural communities (Ellison 2003). The reserve is described in detail by Gaugris *et al.* (2004).

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CHAPTER 3

GENERAL METHODS

Fieldwork details

This section only describes the fieldwork methodology of the study. The analytical phase is presented in each relevant chapter. The research was conducted in northern Maputaland in the Tembe Elephant Park (Tembe) and the community of Manqakulane.

Timeline

In the present study, fieldwork was conducted over two periods. The first period was during 2001 from January to June, when 48 plots were sampled in the Tshanini Community Conservation Area (Tshanini) and 25 plots in Tembe to describe the distribution and abundance of hardwood species as part of a Masters research project by the author of the present thesis. While many other aspects were evaluated during the remainder of the 2001 research phase (July – December) only the data on abundance and distribution of woody species of Tshanini and Tembe were re-analysed within the present study, along with new data collected during the 2004 fieldwork period.

In 2004 the Manqakulane village zone (Manqakulane) was sampled. From March to April, 42 plots measuring abundance and distribution of woody species as well as parameters of vegetation utilisation by herbivores or people were surveyed and from May to October 141 plots were sampled in Tembe, 107 of which measured vegetation utilisation by herbivores in addition to standard woody species abundance and distribution information.

Plot placement in the field

While it was relatively easy to travel wherever required by vehicle or by foot outside Tembe, vehicle movements inside the park were restricted to management roads and movement on foot was prohibited unless accompanied by an armed ranger. Unfortunately, due to financial constraints and particularly dire conditions faced by the Tembe management, it proved difficult to impossible to obtain armed rangers when required and plot locations in Tembe were therefore restricted to the areas accessible by the road network. Therefore and for safety reasons due to the dangers associated with working in a “Big Five” environment inside Tembe, the park manager suggested restricting plot placement to areas alongside the road network of the park. The plots in Tembe were placed at least 50 m away from little-used management tracks and at least 100 m away from more established tourist tracks to avoid road-induced bias as much as possible. The southern section of Tembe is relatively well covered by the road network and therefore fairly well represented in terms of surveys (Figure 1). However, the northern section is less extensively accessible and could not be sampled in the same detail as the rest of the park (Figure 1).

In the Manqakulane community village zone (Manqakulane) and in Tshanini, driving and walking were allowed anywhere as long as prior permission was obtained from either the steering committee or the head of the household using the land. Due to the exceptionally dense vegetation, plot placement was restricted to sites along the sandy track network, except in the western section of Tshanini where it was possible to travel through the open and sparse woodlands (Figure 2).

In Manqakulane and Tshanini, all sandy tracks were narrow (Figure 3) and were seldom used by vehicles. Mostly pedestrians and sometimes cattle-drawn carts use these tracks. Some vehicles were using the tracks getting from Manqakulane to Tshanini in 2004 as the fence lines for the reserve were being cleared to install the game-proof fence around Tshanini. In Tembe tracks were better-defined and designed for vehicles use (Figure 4).

Plot layout

Once on site, the exact geographical coordinates (map datum: WGS 84, Lat-Long coordinates) of the midpoint of the rectangular plot was recorded by using a Global Positioning System (GPS) device. Plot numbering followed a standard increasing count preceded by a coded suffix indicating the general location, season of the year, and purpose of the plot. For example, TWALL stands for Tembe, Winter, All purposes, where all purposes refers to surveys which included the evaluation of the vegetation utilisation by herbivores. The accuracy of the GPS unit was set to maximum, and averaged 4.5 m for the plot’s midpoint coordinates. Plots were laid out by using a knotted rope with knots tied every metre (Figure 5). The fieldwork sampling was designed to gather a similar amount of information in all plots. Therefore, plot length and width were determined for each vegetation unit and varied between units. Some adjustments were made in the field based on a visual assessment of the general density of woody species while laying out the rope and the number of data sheets filled while walking the plot. The plot length and width varied from a minimum of 15 m by 2 m in length and width respectively in an extremely dense Short Sand Forest patch to a maximum of 100 m by 19 m in sparse woodland. The general direction, exact length

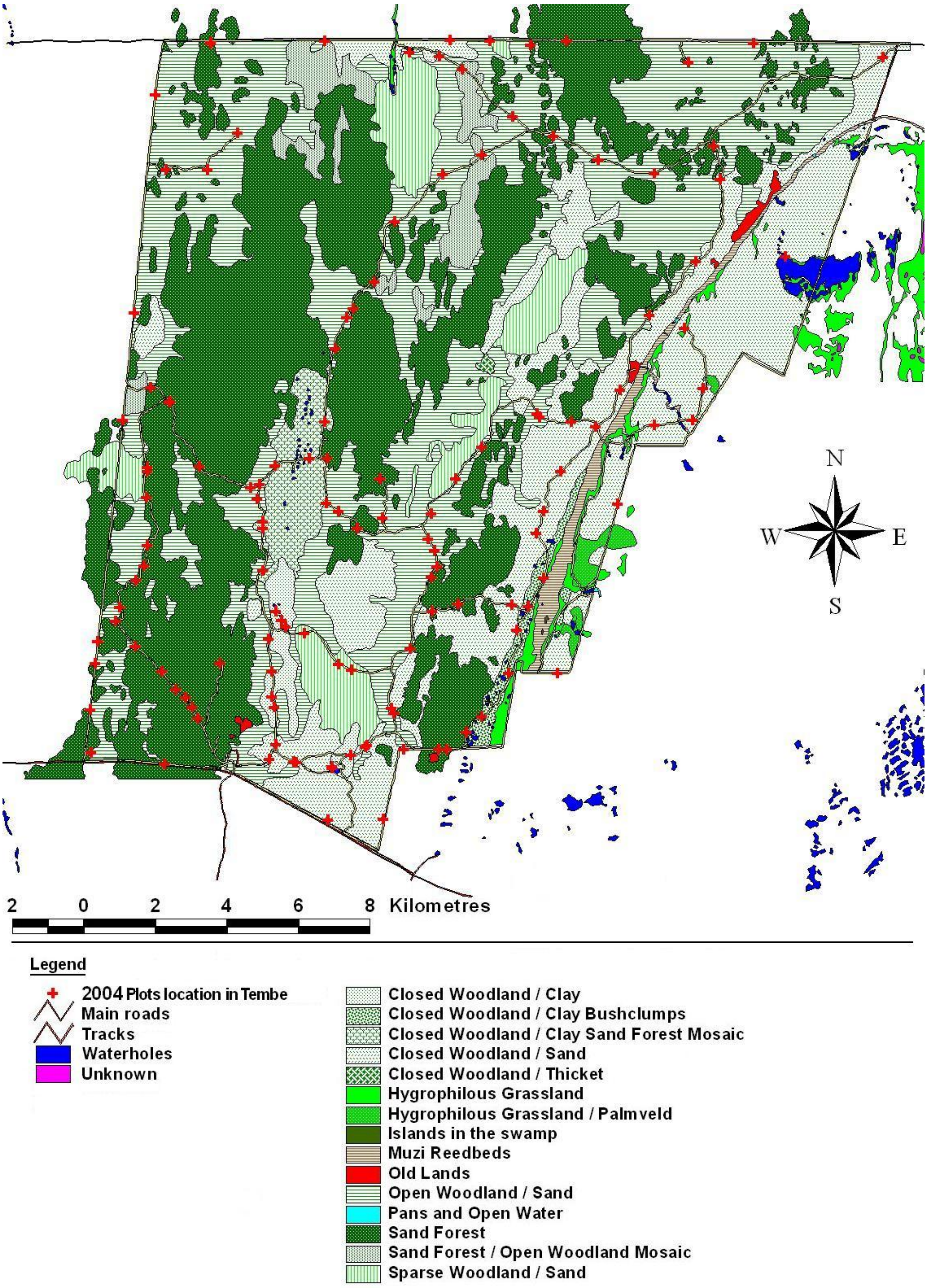

Figure 1: The location of 2004 survey plots in Tembe Elephant Park, Maputaland, northern KwaZulu-Natal, South Africa (map adapted from Matthews *et al.* 2001).

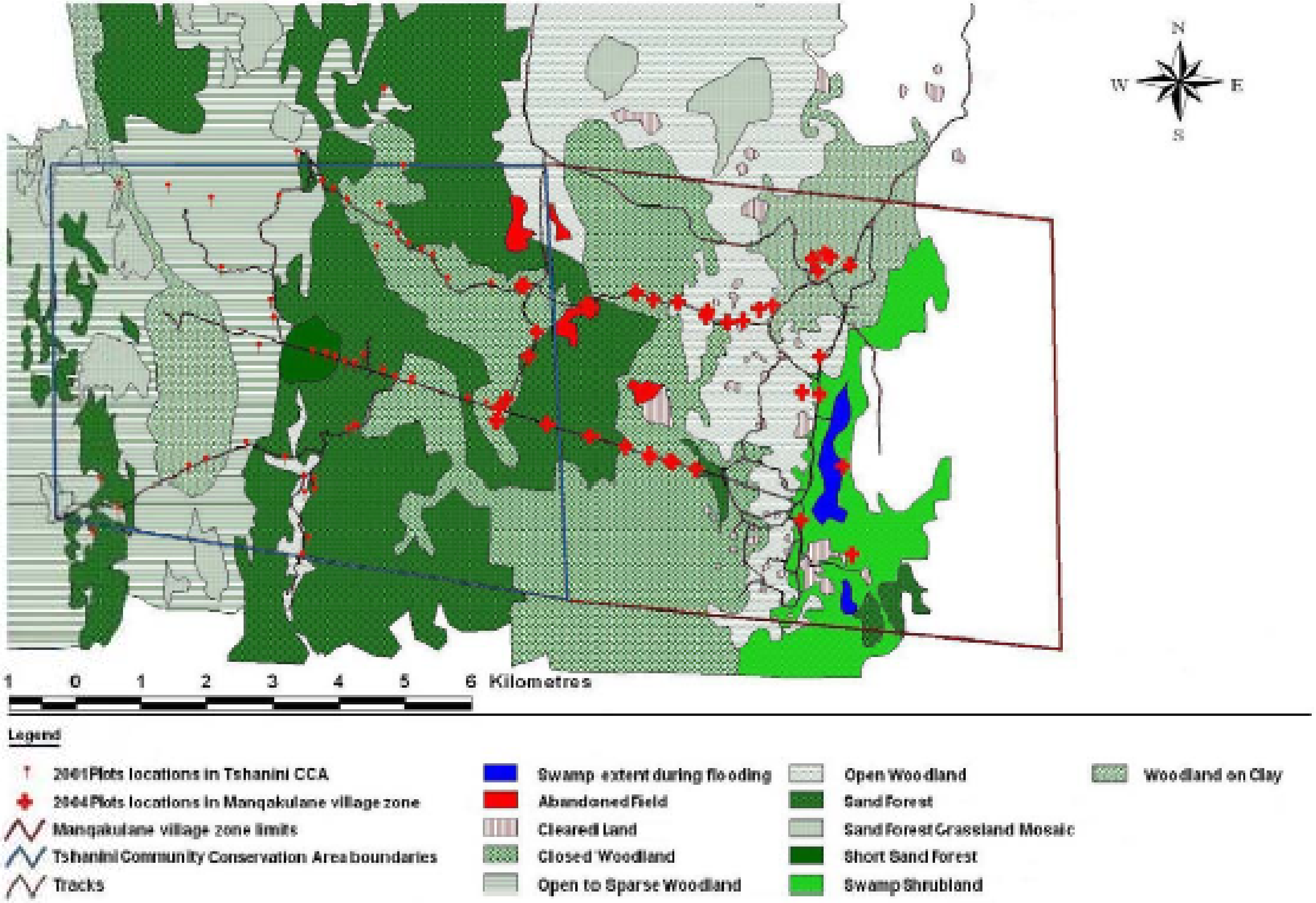

Figure 2: The location of 2001 survey plots in Tshanini Community Conservation Area, and 2004 survey plots in the village zone of the community of Manqakulane, Maputaland, northern KwaZulu-Natal, South Africa (map adapted from Gaugris 2004).

Figure 3: Aspects of the sandy tracks in the community of Manqakulane during surveys of 2001 (top) in Tshanini Community Conservation Area, and surveys of 2004 (bottom) in the village zone. Photos by J. Gaugris: Maputaland, northern KwaZulu-Natal, South Africa.

Figure 4: Aspects of vehicle tracks in Tembe Elephant Park. A tourist track in the western sparse woodland section (top left), a management track along the northern fence line with Mozambique (top right), note Mozambique to the left of the fence in the picture, and a tourist track through a Tall Sand Forest patch (bottom). Photos by J. Gaugris: Maputaland, northern KwaZulu-Natal, South Africa.

Figure 5: Laying out a plot in Tshanini Community Conservation Area during the surveys of 2001. Photo by J. Gaugris: Maputaland, northern KwaZulu-Natal, South Africa.

and width of the plot were noted. Following the environmental regulations of Tembe, no permanent plot marking was done. Therefore, a small descriptive sketch of the prominent features encountered along the plot was drawn to ensure some degree of repeatability in the future. The plots were walked on the one side of the rope first, measuring all woody individuals rooted within a set distance from the rope, regardless of the size of the individual. On the return leg, the other side was walked, measuring all woody individuals rooted within a set distance from the rope but measuring at least 0.4 m in height.

Measurements

In the present study only woody species were measured. Woody plants were defined as all plants with an erect to scrambling growth form and with a ligneous trunk. This definition therefore included some liana.

All woody individuals that met the above criteria encountered in the plots were recorded, identified (genus and species) and measured. The numbers of live and dead stems were counted and their diameters measured at the point where the stem becomes regular above the basal swelling. This was done using vernier callipers for plants with diameters up to 20 cm, for larger plants three graduated plastic rods held at right angles in such a manner as to form a large calliper were used instead. The tree height and the height to the base of the canopy (defined for the purpose of this study as the height where the larger lowest branches were found) were then measured, followed by the widest canopy diameter (D1) and the diameter of the canopy perpendicular to it (D2). Largest lower branches were regarded as the first branches supporting at least 10% of a tree’s overall canopy. Standing dead trees were also measured, while fallen dead trees were tentatively reconstructed to give an estimate of the size and space occupied by the tree before it died and fell. The researcher and his assistant trained themselves to reliably gauge tree height in various environments prior to sampling in order to ensure the constancy and reliability of the measurements. Tree height was measured by using gradated plastic rods that can be set together to form a total length of 6 m (Figure 6).

In the plots evaluating the herbivore utilisation of the vegetation, each woody plant measured was also evaluated for signs of herbivore utilisation or natural damage. Akin to writing the history of the utilisation for each measured plant, any alteration or damage to the tree as a whole (canopy, trunk and roots) was labelled, described, and quantified by age class. For each utilisation episode, an index of canopy removal at the time of damage was estimated to indicate how much of the canopy was removed at the

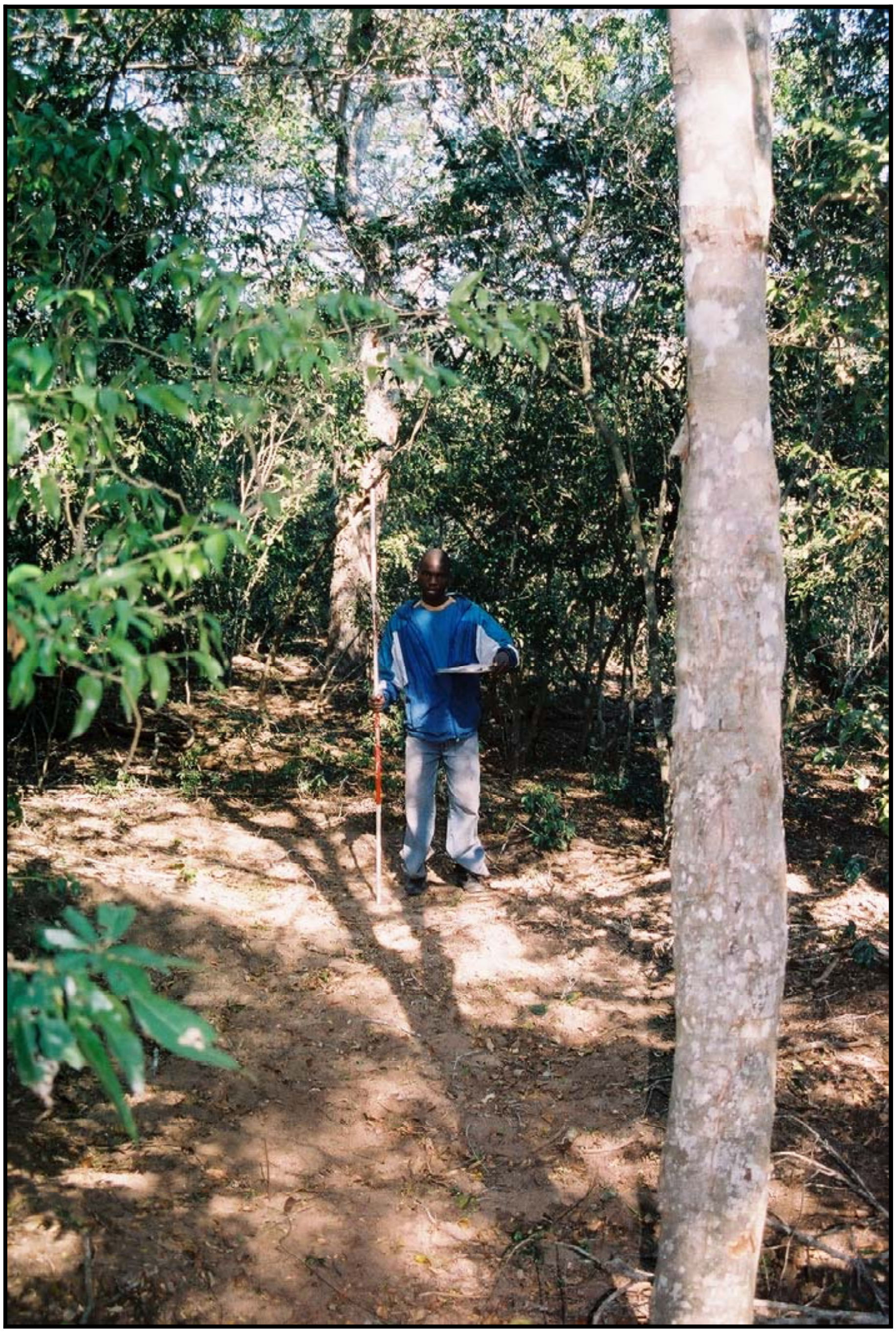

Figure 6: Measuring tree heights in a small elephant refuge (see Shannon 2001) in a Sand Forest patch of Tembe Elephant Park during the surveys of 2004. Note the ground cleared by elephant trampling. Photo by J. Gaugris: Maputaland, northern KwaZulu-Natal, South Africa.

time of the utilisation. Whenever possible, the agent responsible for the utilisation episode was identified to its species. While elephant *Loxodonta africana* (Blumenbach 1797) damage was easily recognised, the identification of other species often proved impossible, and the class of agent responsible for the damage was noted instead. The other herbivores were classified in four classes ranging from: insects, small herbivore mammals, medium herbivore mammals and large herbivore mammals. Human-related utilisation and natural damage were usually the most recognisable events during the field surveys, although the latter proved unclear once the analysis was over. Personal judgement of the researcher based on discussion with his assistant was used to define all these criteria.

Data capture in the field

The fieldwork team consisted of three people. The researcher and an assistant measured the plants and evaluated the utilisation by herbivores or man and the third person captured the data directly on site using a notebook computer. A portable table and chair allowed this person to capture the data comfortably in the field, and to follow the researcher and his assistant within the plot (Figure 7). This method saved a considerable amount of time and allowed on site data checks to be made and therefore considerably reduced the chances of data input errors frequently associated with capturing the data from survey sheets. The data were entered directly in Microsoft Excel spreadsheets designed for these surveys. Battery life shortcomings of notebook computers were overcome by using a portable power supply that could be recharged at the research facility every evening.

Maps and vegetation units described

As a result of the fine-scale mosaic character of the vegetation the units within which the plots appear on the maps, they do not always correspond with their present allocation. Rather than using the maps, the description of the vegetation communities made by Matthews *et al.* (2001) and Gaugris *et al.* (2004) were used to define the units within which the plot should be classified.

Fieldwork phase, important aspects and the lighter side

Doing fieldwork in northern Maputaland was not always easy. The dense to virtually impenetrable vegetation is for one extremely unsuited to such practice. The sight of a thick wall of green leaves when contemplating where to set out a line for the plots was sometimes very discouraging and made one wish for having chosen a

Figure 7: Portable office in the middle of Tembe Elephant Park during the surveys of 2004. Due to the presence of a group of elephants nearby the data capture person remained near the vehicle in case a speedy retreat would have been needed. Photo by J. Gaugris: Maputaland, northern KwaZulu-Natal, South Africa.

research site where tree density was measured in single digits per square kilometre. The animals (in decreasing order of annoyance: ticks, wasps, ants, caterpillars, elephants, lions and buffaloes) were most unfriendly and never missed an opportunity to give the team a harder time, especially when crawling through the Short Sand Forest.

This should not detract from the fact that northern Maputaland is a magnificent place and doing fieldwork in this region was a pleasure for most of the time. From the friendly people to the beautiful landscapes and amazing wildlife (especially when observed from a comfortably safe distance), the fieldwork phase was a thoroughly enjoyable experience and a great learning curve for the whole team. Some aspects merit further mention and are presented below.

The assistants

The present study would not have been as thorough and complete without the invaluable input from two exceptionally knowledgeable young men from the Manqakulane community. Thabani and Sabelo Mthembu are brothers and were the field assistants for the 2001 and 2004 surveys respectively. Their skills at identifying and recognising local trees as well as signs of various animals in the bush were of exceptional help. These field research phases provided them with a working and training opportunity and allowed them to interact with a mix of cultures and genders un-habitual to them and thus broadened their views considerably. Besides the enjoyable aspect of a meeting and understanding a different culture, the value of working with local people in the field cannot be ignored and allowed a great wealth of additional information to be collected. Their eye for detail in the field is nearly beyond the limits of understanding.

Caroline Vasicek played the un-envious role of data capture assistant during the 2004 fieldwork phase. My companion, friend and fellow researcher endured stressful moments behind the notebook in some of the most inaccessible places of Tembe Elephant Park. Capturing all the information directly in the field saved considerable time, allowed the addition of many comments on the spot that later helped to refine the analysis, but also avoided many errors. This method of data recording is recommended whenever it is safely and logistically possible.

Time and field encounters

Research in Maputaland during the 2001 surveys was greatly affected by the abundant rainfall that year, and took much longer than expected as many days and sometimes weeks were written off due to rain. Even when the rain had stopped it was sometimes necessary to wait an additional day or two for the vegetation to dry up a bit, thereby avoiding much unpleasant time spent crawling through wet bushes. The 2004 surveys were not too affected by rainfall, but the safety factors of working in a park where large and dangerous animals occur did sometimes take a toll. Some sites had to be visited several times as the team was kept off by various animals that did not take kindly to sharing their space with three noisy (as noisy as possible) people, especially around water holes and the Muzi Swamp. Noise was identified as a good helper to keep animals aware of the team's presence and to avoid any further interactions. Working noisily kept the peace most of the time, only on three occasions was a speedy escape needed from a total of 141 potential sites for encounters sampled in 2004. Working silently led to trouble at an alarming rate, and required a sometimes un-elegant escape on seven of 25 surveys sites of 2001.

Of distances, coffee breaks, food, vehicles and how it affects time, and money

Over the two study periods, an average of 51.22 km was driven every day for what amounted to 11 months in 2001 and nine months in 2004. Accommodation had to be paid for these periods for the researcher and his assistants. Coffee breaks were highly needed after every two plots sampled (Figure 8), and so were regular snacks. Snacks had an additional value for the local assistants. People in the northern Maputaland region cannot afford to eat more than one meal per day, and in most cases this meal is rarely nutritious enough to fulfil the body's dietary and energy requirements. When working in the rural community the effect of the lack of food was initially not noticeable as workdays rarely exceeded six hours and the assistants stayed home afterwards. However, when the distance from the community increased, the duration of workdays often exceeded six hours and the assistants could not cope with their usual food intake. While having regular snacks appears common sense to most, small but rich and sweet snacks were needed in addition to a solid breakfast and large lunches and dinners to keep Thabani and Sabelo through a normal day's work of a regular well-fed person. The vehicle used did not break down (thankfully) and saved the team long walks, but driving in the community area, off, but especially on roads meant many punctures. The people have a peculiar way of cutting down trees along the tracks, but leaving the stumps with sharp edges at exactly the right angle to pierce

Figure 7: A mid-morning coffee break after emerging from a sample plot in the Sand Forest of Tembe Elephant Park during the surveys of 2004. Photo by J. Gaugris: Maputaland, northern KwaZulu-Natal, South Africa.

straight through even the most robust tyres. All these aspects can be summarized by the fact that research takes time, and as the adage goes, money. The cost of doing extensive fieldwork research should not be underestimated.

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CHAPTER 4

THE SAND FOREST OF TEMBE ELEPHANT PARK AND ENVIRONS, MAPUTALAND, SOUTH AFRICA

Abstract

Maputaland in northeast KwaZulu-Natal of South Africa is considered a Centre of Plant Endemism, and the region has been included in the recently declared Maputaland – Pondoland – Albany hotspot of biodiversity. The Sand Forest vegetation has been labelled the most valuable vegetation type in this region due to the extensive list of endemics it harbours. Although a recognised and valuable vegetation type, it is poorly documented and its dynamics and structure are not well understood. To improve our knowledge of Sand Forest structure, the present study investigated the tree assemblages in the Sand Forest of Tembe Elephant Park, which protects the largest tracts of intact Sand Forest in South Africa. A total of 59 plots were sampled and analysed by using classification and ordination methods. The results suggest that Sand Forest is a complex assemblage of at least three different tree communities, with an additional two variations in one of the communities. These findings imply that the current descriptions of Sand Forest have to be revised and that future descriptions should consider at least three distinct tree assemblages of a community nature, that are floristically and structurally different, while sharing a large pool of common species.

Keywords

Forest structure, Intermediate Sand Forest, Maputaland, Sand Forest, Short Sand Forest, Tall Sand Forest, tree assemblages

Introduction

The forest biome in South Africa is the smallest biome in the country (Low and Rebelo 1998). The classification of this biome has recently been revised and eight zonal forest groups were distinguished in addition to one azonal forest group. Sand Forest is part of the Tropical Dry Forest group, which is found in Maputaland (Licuati Sand Forest) and in some parts of the Kruger National Park in South Africa (Nwambyia Sand Forest) (Mucina and Rutherford 2006). The conservation of forests in South Africa is difficult because their distribution is patchy, and therefore large networks of interconnected patches are needed so that their species diversity, but essentially their dynamics are conserved (Midgley *et al.* 1990; Everard *et al.* 1994; Everard *et al.* 1995; Low and Rebelo 1998; Van Rensburg *et al.* 2000b; Lawes *et al.* 2004).

Licuati Sand Forest (hereafter referred to as Sand Forest) is confined to the Maputaland region of South Africa, which is part of the Maputaland – Pondoland – Albany hotspot of biodiversity (Mucina and Rutherford 2006; Smith *et al.* 2006) and is also recognised as the Maputaland Centre of Plant Endemism (Van Wyk 1996; Van Wyk and Smith 2001). A study by Kirkwood and Midgley (1999) investigated the variations of Sand Forest throughout northern Maputaland, and established the presence of at least two variants, with eastern Sand Forest represented in Tembe Elephant Park, Sileza Nature Reserve, Phinda Game Reserve, and False Bay and Western Sand Forest occurred in Ndumo Game Reserve and Mkuzi Game Reserve. Each of these variants was further subdivided into several subtypes representative of local variations. As expected, Sand Forest shows a high level of plant but also animal endemism, and is considered as the rarest but also most valuable vegetation type in northern Maputaland (Van Wyk and Smith 2001; Matthews 2006; Botes *et al.* 2006). While the importance of Sand Forest has been clearly established, studies describing its structure remain preliminary (Matthews *et al.* 1999; Matthews *et al.* 2001; Izidine *et al.* 2003; Brookes 2004; Gaugris *et al.* 2004) and the descriptions of its dynamics are based on conjecture (Matthews 2006) and often contradictory (Van Rensburg *et al.* 2000a). The phytogeographic affinities and similarities of Sand Forest with Afromontane and Coastal forests (Van Rensburg *et al.* 1999; Matthews *et al.* 2001) suggest that Sand Forest may be a relict of previous climate conditions and it is considered, at best, as "in stasis" (Matthews 2006). Consensus appears to have been reached that under the current climatic conditions, Sand Forest may devolve into woodlands (Van Rensburg *et al.* 1999; Van Rensburg *et al.* 2000b; Matthews 2006; Botes *et al.* 2006).

While there has been a recent surge in studies regarding Maputaland, few have actually investigated vegetation structure and dynamics directly (Guldemond and Van Aarde In Press; Gaugris and Van Rooyen In Press). Most studies have either ignored forests (Morgenthal *et al.* 2006; Patrick and Ellery In Press), or investigated the animal component (Morley 2005; van Eeden 2005; Botes *et al.* 2006; Guldemond and Van Aarde In Press), or the human aspect (Brookes 2004; Chao 2004; Kloppers 2004; Peteers 2005; Gaugris *et al.* 2007), or considered general conservation issues (Smith *et al.* 2006).

The present paper utilises data collected for a study investigating the utilisation of woody plants by herbivores and man in northern Maputaland to classify the tree communities of Sand Forest in the Tembe Elephant Park. The floristic and structural composition of the Sand Forest tree assemblages were investigated by using a phytosociological approach, as validated recently by another study in Africa (Backeus *et al.* 2006). Based on the success of studies analysing tree assemblages (Fashing and Mwangi Gathua 2004; Hitimana *et al.* 2004), it is hoped that the present analysis will provide an altogether more comprehensive insight into the Sand Forest structure and floristics than has yet been documented, especially since this paper presents the most intensive sampling effort in Tembe Sand Forest to date. To improve our understanding further, the Sand Forest data from the phytosociological studies by Matthews *et al.* (2001) and Gaugris *et al.* (2004), were included in an ordination along with data from the present study.

Study area and general aspects of Sand Forest

The Tembe Elephant Park (Tembe) was created in 1983 with the dual purpose of conserving the region's rare Sand Forests and the remnants of the Maputaland coastal African elephant *Loxodonta africana* (Blumenbach 1797) population (Matthews 2006; Morley 2005; Guldemond and Van Aarde In Press). The park is approximately 30 000 ha in extent and is covered by a mix of woodlands of varying densities in the midst of which patches of Sand Forest occur. Tembe conserves the largest portion of the Sand Forest vegetation in South Africa (Matthews *et al.* 2001). However, the conflicting nature of the park's conservation aims has recently been questioned, as elephants utilise the Sand Forest, and doubt exists as to whether the Sand Forest can sustain such a level of constant animal disturbance (Matthews *et al.* 2001; Botes *et al.* 2006; Guldemond and Van Aarde In Press).

Although the Sand Forest is rare in South Africa, it appears more widespread in neighbouring Mozambique (Izidine *et al.* 2003; Matthews 2006). Nevertheless, the degree of endemism and abundance of rare species (Matthews *et al.* 2001) justify conserving Sand Forest in South Africa. Sand Forest has high levels of α and β diversity (Matthews 2006), implicating that conserving Sand Forest is not a simple matter, as large tracts of land, holding many patches of the vegetation type will be required in order to conserve a representative sample of such a diverse vegetation type (Matthews 2006).

Currently, Sand Forest in Maputaland is regarded as comprised of two floristically linked, but structurally different subcommunities (Matthews *et al.* 2001; Izidine *et al.* 2003; Gaugris *et al.* 2004), namely the Short Sand Forest and the Tall Sand Forest, for which the names of Licuáti Thicket and Licuáti Forest were recently proposed for classification purposes (Izidine *et al.* 2003; Mucina and Rutherford 2006). The Short Sand Forest was described as a short (5 – 6 m high), dense, single layer, thicket-like vegetation, while Tall Sand Forest reached canopy heights of 12 m, with emergents at 15 m, and displayed a typical multi-layered forest structure (Matthews *et al.* 2001; Izidine *et al.* 2003; Gaugris *et al.* 2004; Matthews 2006; Mucina and Rutherford 2006).

Peculiarities of Sand Forest are that it grows in a relatively low rainfall area, atypical of forest, on homogeneous, deep, nutrient poor, acidic (pH 5 – 6) sandy substratum (Matthews *et al.* 2001; Matthews 2006). Rainfall, mist, and soil moisture content have been proposed as important mechanisms regulating the persistence of Sand Forest (Matthews 2006).

Despite the apparent wealth of knowledge on Sand Forest, there have been relatively few in depth studies on the vegetation type and many of the hypotheses advanced rest on little actual and verified knowledge and remain untested (Matthews 2006). In the northern Maputaland area where Tembe is situated, only nine 10 m x 10 m plots were sampled for the phytosociological classification of Tembe's 3 020 ha of Sand Forest (Matthews *et al.* 2001), five 10 m x 10 m plots for the 25 ha of Sand Forest in Sileza Nature Reserve, which lies 20 km east of Tembe (Matthews *et al.* 1999), and 18 plots of 30 m x 30 m for the 1 045 ha of Sand Forest in the Tshanini Community Conservation Area, which lies 6 km south of Tembe (Gaugris *et al.* 2004).

Methods

Fieldwork

The research was conducted in Tembe during the dry winter period of 2004 (May to October). Due to management restrictions, plot placement was limited to areas alongside the road network of the park. Therefore, plots in Tembe were placed at least 50 m away from little-used management tracks and at least 100 m away from more established tourist tracks to avoid road-induced bias as much as possible. The outcome of this sampling strategy was that the northern section of Tembe, less extensively accessible by road than the southern section, could not be sampled in the same intensity.

The exact geographical coordinates (map datum: WGS 84, Lat-Long coordinates) of all plots were recorded by using a Global Positioning System (GPS) device. Transect length and width varied based on the general vegetation density. All woody plants (defined here as plants with an erect to scrambling growth form and with a ligneous trunk) ≥0.4m height and ≥1.0 cm stem diameter encountered in plots were identified to the species and measured, while those of dimensions below the above cut-offs were only measured along one half of the plot area. The study methodology used was designed to evaluate vegetation structure and herbivory levels, and the aspects presented here therefore represent a portion of the larger study. A total of 59 plots were sampled in the Sand Forest of Tembe.

For each woody plant the following measurements were recorded: a) tree height; b) the height to the base of the canopy (defined as the height where the larger lowest branches supporting at least 10% of the canopy were found); c) the largest canopy diameter (D1) and the diameter of the canopy perpendicular to it (D2) and e) stem circumference. Plant heights were measured by using six gradated 1 m long plastic poles that could be assembled to form one single pole. In the forest, trees higher than 6 m were visually evaluated using the poles as guidelines. The researcher and assistant trained themselves to reliably gauge tree height in a series of environments prior to sampling. Stem diameters of larger trees were measured at 100 cm above ground whenever possible, while for smaller plants the measurements were taken at the point where stem diameter becomes regular above the basal swelling. Measurements of stems up to 20 cm diameter were taken with vernier callipers, while larger trees were measured by using three plastic rods held at right angles in such a manner as to form a large calliper. The diameter dimension was subsequently read on the gradated rod. All trunks, alive or dead, were measured for diameter. Data were captured in Microsoft Excel spreadsheets, on site in the field by using a notebook computer, thereby saving time and allowing on site data checks.

Data analysis

Some limitations of the present analysis must be stated from the outset. The main objective of the study was to investigate current levels of vegetation utilisation by mammalian herbivores and the emphasis was on obtaining data of common rather than rare plant species, by conducting many small plots (Sutherland 1996). Therefore, the methodology does not lend itself to a rulebook phytosociological study. The phytosociological classification presented here is based solely on trees and woody plants such as lianas and small shrubs and not the whole range of plant forms normally associated with a phytosociological study. Additionally, the subsample presented here excluded the woodlands, is restricted to Tembe Sand Forest, and represents only one fifth of the regional vegetation sample of the present study.

The captured data were checked for errors and assembled in a single data file, subsequently transformed into a Microsoft Access database for ease of utilisation and analysis. This procedure was rendered possible by software designed by Mr Bruce

Page (School of Life and Environmental Sciences, University of Natal, Durban, South Africa).

Classification

The canopy cover of each species per plot was calculated as a percentage of the plot area. These canopy cover percentage values were converted into Braun-Banquet cover-abundance values for each tree species, according to the Braun-Blanquet cover-abundance scale of Mueller-Dombois and Ellenberg (1974) (Table 1). These calculated values represent overestimates of cover, because it was not possible to compensate for overlap between canopies of different individuals. The species and their cover-abundance values were used to create a matrix that could be analysed following Braun-Blanquet procedures using the TURBOVEG and MEGATAB computer packages (TURBOVEG for Windows version 1.97, Hennekens and Schaminee 2001). This classification system was used to investigate the differences between Sand Forest communities in terms of tree species composition.

To describe the structure of each vegetation unit in the classification, the density of woody individuals in each of the following height classes were calculated:

- undergrowth: individuals from 0 – 5 m tall
- first layer: individuals from 5 – 8 m tall
- second layer: individuals from 8 – 10 m tall
- canopy: individuals > 10 m tall
- emergents: individuals > 12 m tall
- tall emergents: individuals > 14 m tall
- very large trees: individuals > 16 m tall.

Ordinations: Tembe Elephant Park 2004 data

For exploratory purposes, to complement the classification (Kent and Coker 1996), the data were considered fit for application in a correspondence analysis (CA) indirect gradient ordination. The CA was performed by using the CANOCO for Windows version 4.52 software package (Ter Braak 2003). The CA parameters were set for an analysis without data transformation on the ordination values equivalents of the Braun-Blanquet cover-abundance values (see Table 1), focusing on inter-sample distance, no species of sample weight were specified, and no down-weighting of rare species were applied. A set of two CA ordinations was conducted. First by using the complete data set for Tembe Elephant Park collected in 2004. Then by using the data set restricted to a selection of Sand Forest plots (see classification results)

Table 1: *Braun Blanquet cover-abundance values (Mueller-Dombois and Ellenberg 1974) and their percentage cover equivalents used in the present study to classify the Sand Forest in the Tembe Elephant Park area, Maputaland, northern KwaZulu-Natal, South Africa*

Braun Blanquet cover-abundance value	Equivalent percentage cover (%)	Ordination values
r	0.1	1
+	0.9	2
1	2.0	3
2m	4.0	4
2a	8.5	5
2b	19.0	6
3	37.5	7
4	62.5	8
5	87.5	9

Ordinations: All data of Tembe and environs

Another ordination was performed, but with additional data from previous studies incorporated. The Sand Forest sections of the phytosociological tables from the studies of Tembe Elephant Park in 1996 by Matthews *et al.* (2001) and Tshanini Community Conservation Area in 2001 by Gaugris *et al.* (2004) were incorporated after all non-woody species were omitted. Because the present study overestimated cover - abundance, the cover-abundance values of the two additional data sets were artificially strengthened by one level (i.e. a cover abundance value of 2a became a 2b). A CA ordination with the same parameters as above was performed.

Results

A total of 59 plots and 105 species were analysed from the 2004 sample of Sand Forest vegetation in Tembe and 7 201 individual trees were sampled in the Sand Forest association, 1 430 of which were multi-stemmed, representing 19.86% of the sample. A total of 171 of the sampled trees were dead, representing 2.37% of the sample.

Classification

The classification of the 2004 woody Sand Forest species data strongly suggested the presence of at least three vegetation units that could be seen as communities in the Sand Forest association of Tembe Elephant Park. These units were to a large extent diffuse and represented a gradual transition from the left to the right of the phytosociological table with a large amount of species shared between units. Some units could be defined more by the absence of species groups than the presence of diagnostic species. The first unit or community 1 was represented by 16 plots, the second unit or community 2 was represented by 32 plots, while the third unit or community 3 was represented by 11 plots.

A total of 71 woody species were fitted satisfyingly into the species groups that define the three vegetation communities. The remainder of species could not be classified satisfyingly and are therefore presented in species group K as non-classified species (Table 2).

Community 1 was defined by *Strychnos decussata* and *Afzelia quanzensis* in species group C, and two variations of the community were found. The first variation was defined by *Manilkara concolor* in species group A, while the second variation was defined by *Cavacoa aurea* and *Dalbergia obovata* in species group B (Table 2). The species groups E, F and I were not represented within community 1, but links with

Table 2: The classification of Tembe Elephant Park Sand Forest woody species assemblages, Maputaland, northern KwaZulu-Natal, South Africa

Plot Number	113	190	192	200	199	203	114	206	3	193	196	204	81	82	69	28	198	189	182	187	88	63	95	201	184	183	58	110	178	195	186	109	105	188	191	194	17	179	16	180	18	7	205	181	185	67	31	9	49	112	30	86	13	111	26	6	60	71	4
	Community 1																**Community 2**																																**Community 3**										
	1.1								**1.2**																																																		
Species group A																																																											
1 *Manilkara concolor*	.	5	r	3	.	.	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
2 *Dovyalis zeyheri*	.	.	.	a	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3 *Ekebergia capensis*	3	.	.	.	.	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
4 *Mystroxylon aethiopicum*	.	5	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
5 *Coddia rudis*	b	1	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
6 *Sclerocroton integerrimus*	.	.	5	r	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	m	.	.	.	.	.	+	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
7 *Erythroxylum emarginatum*	1	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
8 *Cladostemon kirkii*	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Species group B																																																											
1 *Cavacoa aurea*	.	.	.	.	.	.	.	5	.	.	.	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	a	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
2 *Dalbergia obovata*	.	.	.	.	.	.	.	+	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3 *Ochna barbosae*	b	.	.	.	.	.	.	.	.	b	.	.	5	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5	.	.
4 *Elaeodendron croceum*	.	.	.	.	.	.	.	3	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
5 *Canthium armatum*	.	.	.	.	.	.	.	.	.	a	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.
Species group C																																																											
1 *Strychnos decussata*	5	b	.	5	5	.	.	5	5	5	a	5	5	5	a	.	.	.	.	.	.	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5	.	.	.	.	.	.	.	.	.	.	5	.	.	.
2 *Afzelia quanzensis*	.	.	5	5	.	.	.	5	.	5	.	.	.	.	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3 *Ochna arborea*	.	m	.	.	.	b	4	.	.	.	.	.	a	+	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
4 *Spirostachys africana*	.	.	.	5	5	.	r	.	r	.	.	.	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
5 *Euclea natalensis*	+	r	.	.	m	.	r	r	+	.	+	.	.	.	a	.	.	.	.	.	.	.	.	.	r	.	.	.	1	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
6 *Lagynias lasiantha*	.	5	.	.	.	.	.	a	.	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
7 *Grewia caffra*	.	.	+	.	.	.	.	.	.	.	.	.	.	.	1	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
8 *Erythrococca berberidea*	.	.	.	r	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
9 *Rothmannia fischeri*	.	.	.	.	3	1	.	5	.	.	.	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Species group D																																																											
1 *Balanites maughamii*	.	.	.	5	m	.	5	5	5	.	.	.	.	5	.	.	.	5	5	.	b	b	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
2 *Tarenna supra-axilaris*	3	.	.	4	b	a	.	b	.	.	.	.	.	.	.	b	b	.	4	.	.	.	.	.	+	.	m	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4
3 *Diospyros inhacaensis*	.	.	b	5	a	.	.	4	.	.	a	.	.	.	3	4	.	.	.	.	5	.	.	5	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
4 *Dovyalis longispina*	r	4	.	r	.	.	.	.	.	.	+	.	.	+	+	.	r	+	.	.	.	.	.	.	.	b	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
5 *Acalypha glabrata*	+	1	b	a	1	.	m	3	r	.	.	.	.	4	.	a	.	.	.	a	.	.	.	b	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.
Species group E																																																											
1 *Combretum celastroides*	.	.	.	.	.	.	.	.	.	.	.	5	.	.	.	.	.	.	m	3	.	.	5	1	5	.	.	5	b	.	5	5	m	b	b	4	b	.	.	.	.	.	.	.	.	.	.	.	3	.	.	3	.	.	.	.	5	.	.
2 *Pseudobersama mossambicensis*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	m	.	.	.	1	.	+	.	.	4	.	.	3	.	.	.	.	m	.	.	b	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3 *Brachylaena elliptica*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	+	.	.	.	.	+	1	.	.	.	+	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Species group F																																																											
1 *Combretum mkuzense*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	4	3	5	5	5	4	m	a	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
2 *Monanthotaxis caffra*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Species group G																																																											
1 *Newtonia hildebrandtii*	.	.	r	5	.	.	.	5	.	.	5	.	.	5	5	.	.	.	5	.	.	.	.	5	5	5	.	5	5	.	5	r	.	5	.	5	.	5	5	5	5	5	5	5	5	5	5	5	.	.	.	.	.	.	.	.	.	+	.
2 *Wrightia natalensis*	.	.	.	.	.	5	.	.	.	.	5	.	5	a	.	.	.	5	.	5	5	.	5	5	.	.	3	.	.	.	.	.	.	.	5	.	.	5	.	5	5	.	.	5	5	5	.	5	.	.	.	.	.	.	.	.	.	.	.
3 *Vepris lanceolata*	m	.	a	5	a	.	+	b	r	a	5	r	.	+	4	5	+	+	.	4	.	.	.	.	.	.	.	+	a	r	.	.	.	r	5	.	.	m	.	.	.	.	.	.	.	r	.	.	.	.	.	1	.	.	.	.	.	r	.
4 *Zanthoxylum leprieurii*	.	b	.	.	.	.	.	.	.	.	.	m	.	.	.	.	.	.	3	4	.	.	.	.	+	3	.	r	a	.	.	.	.	.	.	.	.	m	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
5 *Suregada zanzibariensis*	.	.	a	.	.	1	.	r	.	4	.	+	.	.	.	.	+	.	a	.	.	a	.	.	+	.	3	.	b	.	.	.	.	.	+	.	m	.	.	.	.	.	.	.	.	.	m	1	.	.	.	1	.	.	.	.	.	.	.
Species group H																																																											
1 *Uvaria lucida*	+	.	b	+	a	a	.	r	.	b	.	m	4	.	.	.	m	r	3	m	.	b	+	+	a	+	b	b	.	a	b	.	.	.	b	a	.	.	+	+	.	a	b	m	m	.	.	.	5	+	4	b	b	a	+	.	.	.	.
2 *Boscia filipes*	.	4	.	5	b	3	.	.	.	4	m	.	.	5	+	.	.	5	1	.	.	5	.	5	3	.	5	5	b	.	5	.	.	.	.	.	.	3	.	5	4	.	5	5	.	.	.	.	.	1	m	5	a	.	.	.	.	.	.
3 *Monodora junodii*	5	3	5	.	.	3	.	.	.	4	.	3	.	.	3	.	3	5	b	.	.	.	3	5	4	.	+	.	3	.	.	b	.	b	.	.	.	r	.	b	3	.	3	a	.	.	.	3	.	.	.	.	.	b	4	.	.	.	.
4 *Hyperacanthus microphyllus*	.	3	.	a	.	4	.	+	.	.	m	r	.	.	a	.	.	1	1	5	m	.	.	1	+	5	.	1	b	a	.	.	1	m	a	.	.	.	.	a	.	.	b	m	.	5	.	.	.	m	.	4	.	a	.	.	.	.	.
5 *Vitex harveyana*	.	b	5	.	5	r	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	5	.	5	.	.	.	.	a	.	.	.	.	3	.	.	.	.	.	5	.	.	.	.	.	.	.	.	.
Species group I																																																											
1 *Brachylaena huillensis*	.	.	5	.	.	.	.	.	3	5	.	.	.	.	.	.	.	4	1	b	.	m	r	.	m	1	.	a	.	4	3	a	b	.	.	b	.	1	.	b	.	r	.	5	.	5	r	r	b	m	3	b	5	m	3	b	5	.	3
2 *Vitex ferruginea*	.	.	.	.	.	.	.	.	5	.	.	.	.	.	.	.	.	.	.	.	.	.	5	.	.	.	.	a	.	.	.	.	5	.	.	5	.	5	.	.	.	5	.	.	.	.	.	.	.	.	.	4	.	.	.	5	.	.	4
3 *Cassipourea mossambicensis*	.	+	.	.	5	.	.	.	.	.	.	.	.	.	.	.	+	5	.	.	4	m	+	.	+	5	.	a	m	.	5	.	5	b	4	.	.	1	.	.	.	3	+	4	.	.	.	.	.	.	4	+	.	.	.	.	4	.	5
4 *Croton steenkampianus*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	a	.	.	.	.	.	.	.	r	.	m	+	.	1	.	.	.	.	1	.	1	.	.	.	m	+	.	.	a	.	.	r	a	.	r	.	.	.	.	.
5 *Pavetta lanceolata*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	b	m	.	.	b	.	.	.	.	.	.	a	.	.	.	a	.	m	.	+	a	.	.	.	.	+	.	4	.	m	b	b	.	4	.	.	m	a
6 *Burchellia bubalina*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5	.	.	.	.	.	4	.	.	.	5	.	.	.	.	.	.	.	.	.	.	.	.	m	.	a	.	.	.	.	.	a	.	3	.	.	.	m	.	.	.	3	.	.
7 *Ochna natalitia*	b	.	.	.	.	.	.	.	.	4	.	.	.	.	.	.	.	.	.	5	.	.	.	+	.	.	.	.	.	.	.	.	.	.	5	.	.	.	.	.	.	a	.	m	.	.	.	.	.	r	.	.	.	.	b	.	3	.	.
Species group J																																																											
1 *Drypetes arguta*	5	4	b	a	5	5	3	b	5	.	b	a	5	5	m	3	5	b	5	5	5	5	5	4	5	5	5	b	5	.	5	3	b	5	5	5	5	5	3	m	5	.	5	b	5	a	5	5	5	3	5	5	5	.	5	5	5	5	b
2 *Pteleopsis myrtifolia*	4	5	5	5	r	5	.	.	4	.	.	5	5	3	5	5	5	5	5	5	.	5	5	.	.	5	5	5	4	5	5	5	5	5	.	5	5	5	.	5	.	5	5	5	.	.	.	.	5	.	5	5	5	a	5	5	3	5	5
3 *Dialium schlechteri*	.	5	.	5	5	5	r	5	5	5	.	5	5	5	a	5	5	5	5	.	5	5	5	.	5	.	5	5	3	5	r	.	5	5	.	.	5	.	5	5	5	5	5	r	5	5	5	.	5	5	.	5	5	.	5	a	.	r	5
4 *Croton pseudopulchellus*	.	1	3	.	1	+	.	.	a	5	r	+	4	.	.	.	5	3	3	5	3	+	m	b	5	3	.	+	3	5	5	a	1	b	4	3	r	4	1	4	5	5	+	4	b	3	1	a	5	a	5	3	4	3	5	b	+	b	4
5 *Toddaliopsis bremekampii*	3	3	b	b	b	1	.	4	b	3	b	+	5	b	3	.	a	4	3	.	4	+	4	a	5	.	4	.	4	.	.	m	a	b	5	.	b	b	.	m	3	.	4	4	3	.	b	+	.	m	3	4	3	.	.	b	5	m	b
6 *Cola greenwayi*	.	1	5	r	m	.	5	a	3	.	5	5	5	5	.	.	5	.	5	5	5	3	5	5	5	5	4	3	4	3	3	.	.	b	5	5	5	5	5	5	5	5	+	5	5	5	5	5	5	.	5	a	.	.	+	5	5	5	.
7 *Hymenocardia ulmoides*	m	5	4	5	5	5	5	5	3	.	.	.	5	.	.	r	.	5	.	.	5	5	5	a	5	b	5	5	+	5	.	3	5	m	a	5	5	.	3	1	+	.	5	3	.	4	.	.	5	+	3	m	5	3	b	+	5	5	4
8 *Cleistanthus schlechteri*	.	5	.	.	4	3	.	.	.	.	.	5	.	5	.	.	5	5	b	5	.	.	5	5	5	5	.	4	5	5	5	5	5	5	.	.	5	5	5	5	5	.	.	5	5	5	m	5	5	5	5	5	.	5	5	5	r	5	.
9 *Ptaeroxylon obliquum*	5	5	.	5	5	.	5	.	5	.	5	.	5	.	5	5	5	b	5	5	5	r	r	5	5	r	.	3	4	.	r	5	.	5	r	.	.	b	.	r	b	5	.	r	3	3	5	.	5	.	a	.	3	.	.	.	b	r	.
10 *Strychnos henningsii*	a	m	5	4	b	.	4	5	.	.	5	4	.	4	3	.	5	.	.	5	5	3	m	3	.	.	.	.	b	m	.	.	a	m	5	5	4	.	.	.	.	a	.	.	.	.	.	5	4	.	5	5	+	.	.	5	.	5	5
11 *Manilkara discolor*	.	5	.	.	.	m	.	.	5	.	1	+	.	.	.	.	.	.	.	.	5	r	5	.	.	.	.	5	.	.	5	.	5	5	.	.	5	.	.	.	.	5	5	5	.	5	5	.	.	.	5	5	5	.	.	5	.	.	.
12 *Drypetes natalensis*	5	.	5	a	a	.	.	4	3	5	3	.	+	.	.	r	5	4	5	.	5	.	.	5	.	.	m	5	+	.	5	r	.	r	+	5	.	.	.	.	3	.	b	m	.	3	+	r	5	.	.	a	.	.	5	b	5	.	5
13 *Salacia leptoclada*	1	a	+	+	+	b	m	a	.	.	+	a	4	+	m	4	1	a	b	b	.	+	.	.	+	m	+	.	m	+	3	.	+	1	b	a	1	1	1	1	.	.	1	a	.	+	a	m	.	+	+	m	1	+	b	.	3	1	m
14 *Haplocoelum foliolosum*	.	5	.	4	5	.	.	a	.	5	b	5	5	r	+	.	r	.	.	m	5	m	.	1	5	.	.	a	5	.	.	.	.	4	5	.	a	.	.	.	m	.	5	5	5	.	4	.	.	.	.	.	5	.	.	5	5	5	.
15 *Psydrax obovata*	5	3	4	.	a	3	.	.	.	.	.	.	5	.	.	.	.	.	r	.	+	.	.	5	.	.	.	5	r	.	.	5	5	.	5	5	5	a	.	a	.	.	5	5	.	.	.	.	.	5	.	.	5	5	b	.	5	.	5
16 *Tricalysia junodii*	+	b	.	+	.	+	.	+	+	.	+	1	+	r	+	a	.	1	+	m	.	+	.	.	m	+	+	+	.	.	+	.	+	+	+	.	.	.	1	r	+	+	.	b	+	.	+	+	.	.	b	+	.	.	r	1	.	r	.
17 *Psydrax locuples*	5	+	r	.	r	+	.	.	4	r	.	.	.	.	1	5	r	.	5	.	.	.	.	.	r	r	.	r	r	.	b	3	.	.	r	.	.	.	.	m	.	1	a	r	.	.	.	r	.	+	.	.	3	.	.	b	.	.	r
18 *Oxyanthus latifolius*	.	.	a	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	m	.	.	.	.	.	.	.	.	a	.	.	.	.	.	1	.	.
19 *Strychnos gerrardii*	.	.	.	.	.	.	5	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	3	.	.	b	+	a	.	.	.	.	5	.	.	.	.	.	.	+	.	.	.	.	.	.	5	.	.	.	a	.	.	.	.	.
20 *Grewia microthyrsa*	.	b	b	.	.	r	.	.	.	.	.	.	3	.	b	.	.	m	.	.	5	a	.	.	.	.	.	.	.	.	.	.	b	.	4	m	+	a	.	a	.	a	m	a	.	.	.	.	5	m	4	3	a	3	.	.	.	.	.
21 *Tricalysia delagoensis*	.	m	a	b	1	5	.	.	.	.	.	.	5	.	a	.	.	.	+	.	b	a	.	.	.	.	.	.	a	m	.	.	a	.	.	.	.	a	.	.	.	.	b	.	.	.	a	3	.	.	.	+	.	b	.	.	a	.	.
22 *Uvaria caffra*	.	.	m	.	.	.	.	.	.	.	.	.	+	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	a	.	.	.	.	.	.	r	.	4	.	.	.	.	b	m	.	.	.	4	r	5	.	b	.	.	.	a	a	.
23 *Leptactina delagoensis*	.	.	.	.	m	m	1	.	.	b	.	.	.	.	.	b	+	a	+	.	.	.	.	.	m	b	m	a	.	.	b	1	.	a	.	.	.	b	.	b	.	.	m	a	1	.	.	.	.	m	.	.	.	b	.	.	.	.	.
24 *Erythrophleum lasianthum*	.	.	.	.	5	5	.	.	5	.	.	.	.	.	.	5	.	.	.	.	+	.	.	.	.	5	5	5	5	.	.	.	.	5	.	.	5	4	.	.	+	5	.	.	.	.	5	5	.	.	.	.	.	5	5	5	5	.	.
25 *Tricalysia lanceolata*	.	.	.	.	.	.	3	+	.	.	.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	.	a	1	.	.	.	.	+	.	.	.	.	.	.	1	.	m	.	b	.	.	.	.	.	.	r	1	3	b	1	.	.	.	4
26 *Brachylaena discolor*	+	.	.	.	.	r	.	.	b	+	a	.	.	.	r	1	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	+	+	1	+	.	b	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	a	.	+
27 *Tabernaemontana elegans*	.	.	.	m	.	.	.	.	3	3	r	.	.	.	.	5	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	a	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	m	.	.	1	.	.
Species group K																																																											
1 *Acridocarpus natalitius*	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
2 *Carissa bispinosa*	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	m	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3 *Dichrostachys cinerea*	.	b	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
4 *Catunaregam taylorii*	.	.	m	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
5 *Pavetta catophylla*	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
6 *Rubiacea spp.*	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
7 *Schlechterina mitostemmatoides*	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.
8 *Ziziphus mucronata*	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
9 *Schotia brachypetala*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.
10 *Rhus gueinzii*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
11 *Clausena anisata*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
12 *Commiphora neglecta*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
13 *Rhus dentata*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
14 *Canthium setiflorum*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
15 *Tarenna junodii*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	m	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3
16 *Canthium spp.*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	a	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.
17 *Elaeodendron transvaalense*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
18 *Canthium suberosum*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
19 *Combretum apiculatum*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5	.	.	.	.	.	.	.	.	.	.
20 *Bridelia cathartica*	.	.	.	.	.	a	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	b	.	.	.	.	.	.	.	m	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
21 *Deinbollia oblongifolia*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
22 *Grewia inaequilatera*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
23 *Euphorbia grandidens*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	.	.	4	.	.	.	.	.	.
24 *Craibia zimmermannii*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.
25 *Eugenia natalitia*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.
26 *Zanthoxylum capense*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.
27 *Combretum molle*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	b
28 *Tarenna pavetoides*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	b

community 2 were obvious within species groups D (*Balanites maughamii*) and G (*Newtonia hildebrandtii* and *Vepris lanceolata*). It appeared that links with communities 2 and 3 existed within species group H (*Uvaria lucida* and *Boscia filipes*). Community 1 had the highest number of woody species sampled in a plot (30 species) and the highest mean number of woody species per plot (mean = 21, SE = 1.26). Compared to the other communities it also had the highest density of trees in the canopy (Table 3), but the lowest density of trees in the undergrowth. The number of emergents and tall emergents in community 1 was much higher than in the other two communities, and it appeared possible to place the upper reaches of the canopy at a height of 12 to 14 m.

Community 2 is defined by a common pool of species shared with community 1 such as *Newtonia hildebrandtii* and *Wrightia natalensis* from species group G, but also two distinct variations. These variations are defined by species groups E (*Combretum celastroides*) and F (*Combretum mkuzense*). Community 2 had the second highest mean number of woody species sampled per plot (mean = 18.62, SE = 0.75) and the highest number of species in one plot was 28 species. The total density of woody species per hectare was lowest in this community (Table 3), where the upper reaches of the canopy could be placed between 10 and 12 m.

Community 3 was the most non-descript group, and was defined by an absence of species groups A to G rather than the presence of any variation. A link with community 2 was clearly present in species group I (e.g. *Brachylaena huillensis*), while species group H (*Uvaria lucida*) linked all three vegetation subcommunities. A total of 29 species from groups A to G (78.37% of species) were absolutely not represented within community 3. This community had the lowest mean number of sampled woody species per plot (mean = 15.72, SE = 0.95) and the highest number of woody species in one plot was 22 woody species. The woody species in plots that defined community 3 remained short, with a dense undergrowth and first layer, and the upper reaches of the canopy that could be located between 8 and 10 m. Trees seldom reached heights greater than 10 m, although the presence of scattered taller trees (*Cleistanthus schlechteri, Dialium schlechteri, Erythrophleum lasianthum*) with broad canopies and reaching heights of 10 to 12 m was noted.

One common species groups was defined: species group J, where *Drypetes arguta*, *Pteleopsis myrtifolia, Dialium schlechteri, Croton pseudopulchellus, Toddaliopsis bremekampii, Cola greenwayi, Hymenocardia ulmoides, Cleistanthus schlechteri, Ptaeroxylon obliquum* and *Strychnos henningsii* appeared ubiquitous, with generally high cover-abundance values.

Table 3: The presence of sampled woody individuals in the three communities, in various height classes. Tembe Elephant Park, Maputaland, northern KwaZulu-Natal, South Africa

Communities	spread of sampled woody species in various height segments of the Sand Forest of Tembe Elephant park													
	Undergrowth 0 to 5 m		First layer 5 to < 8 m		Second layer 8 to < 10 m		Canopy ≥ 10 m		Emergents ≥ 12 m		Tall emergents ≥ 14 m		Very large trees ≥ 16 m	
	Density (ind per ha)	% of sample	Density (ind per ha)	% of sample	Density (ind per ha)	% of sample	Density (ind per ha)	% of sample	Density (ind per ha)	% of sample	Density (ind per ha)	% of sample	Density (ind per ha)	% of sample
Community 1	6359	78.50	1097	13.54	359	4.43	269	3.32	124	1.53	77	0.95	4	0.05
Community 2	6494	83.83	757	9.78	315	4.07	164	2.12	56	0.73	11	0.14	2	0.02
Community 3	8464	83.81	1238	12.25	280	2.77	90	0.89	27	0.27	9	0.09	0	0.00

Ordinations

The first CA ordination based on the full 2004 Tembe Elephant Park Sand Forest data set produced high Eigen values to explain the first three axes along which the data were presented (Table 4). Along the first axis two main clusters appeared (Figure 1). The cluster on the right of axis 1, in the positive values contained 14 plots (87.5%) of community 1. On the left, in the negative values, the plots from communities 2 and 3 appeared undistinguishable and the picture was too cluttered to determine a pattern. Because community 1 appeared distinct, and most of the variation was explained along axis 1, the plots that defined cluster 1 were removed and a second ordination run to uncover possible underlying pattern (restricted data set).

The second CA ordination based on the restricted data set produced similarly high Eigen values (Table 4). Most of the difference appeared along axis 2 (Figure 2). Cluster one (top) contained eight plots of community 3 in the classification. Cluster two (bottom) represented the plots from community 2. However, the distinction between the two clusters remained tentative and somewhat inconclusive.

The third CA ordination, using the additional data from the studies of 1996 in Tembe Elephant Park by Matthews *et al.* (2001) and 2001 in Tshanini Community Conservation Area by Gaugris *et al.* (2004) revealed some interesting aspects (Figure 3). The Eigen values were high and most of the data appeared to be explained along axis 1 (Table 4). The data set from the present study, collected in 2004, appeared to the left of axis 1, mostly within the negative values along axis 1, and stretched along axis 2. The data set from Matthews *et al.* (2001), representing data that were sampled in 1996, was located between the 0 and 1 values along axis 1. Within this cluster, the Tall (dark red dots) and Short (dark green dots) Sand Forest subcommunities in the study by Matthews *et al.* (2001) were fairly well separated. The data set from Tshanini Community Conservation Area sampled in 2001 appeared on the right of axis 1 in two distinct sub-clusters. The sub-cluster furthest to the right represented the Short Sand Forest community described by Gaugris *et al.* (2004), and the other sub-cluster represents the Tall Sand Forest community.

Discussion

The most obvious results from the present study were the three distinct woody species assemblages (communities 1 to 3) presented in Table 2 and further confirmed by the first two ordinations (Figures 1 and 2). It is proposed that these three groups should be recognised as communities among the Sand Forest association of Tembe. The presence of a gradient of woody species assemblages, that can be subdivided into

Table 4: *The eigen values and inertia for the various correspondence analysis ordinations performed on the Sand Forest data sets (full and restricted) in Tembe Elephant Park, and for Maputaland, including a study of Tembe Elephant Park in 1996 (Matthews et al. 2001) and a study of Tshanini Community Conservation Area in 2001 (Gaugris et al. 2004)*

Ordination	Eigen values for the following axes			Inertia
	First Axis	Second Axis	Third Axis	
1) Full 2004 Tembe Elephant Park data set	0.29	0.26	0.24	4.61
2) Restricted 2004 Tembe Elephant Park data set	0.28	0.23	0.22	3.43
3) Northern Maputaland data set	0.46	0.27	0.21	5.76

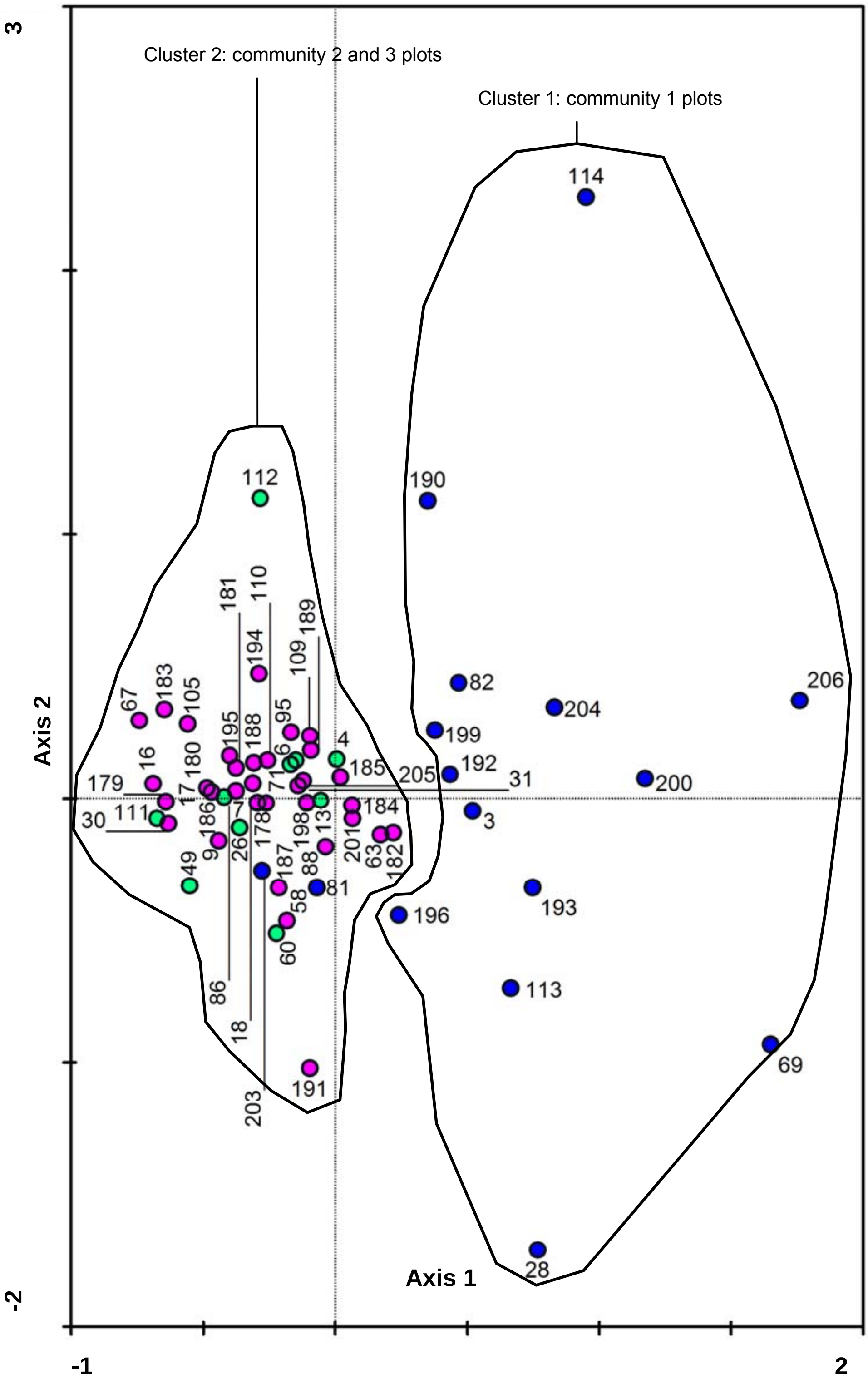

Figure 1: The graphical resolution of the correspondence analysis ordination applied on the 2004 Sand Forest woody species assemblages in Tembe Elephant Park, Maputaland, northern KwaZulu-Natal, South Africa.

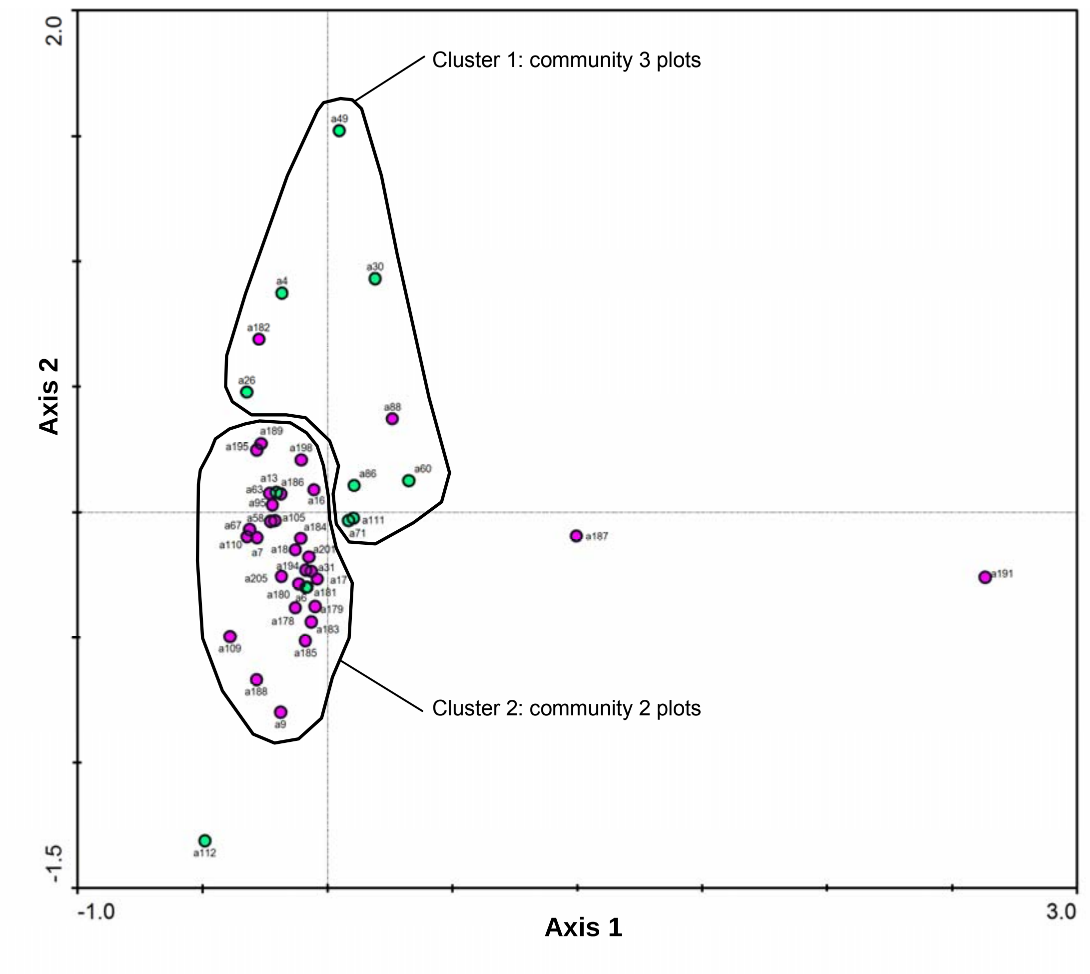

Figure 2: The graphical resolution of the correspondence analysis ordination applied on the 2004 restricted Sand Forest woody species in Tembe Elephant Park. The plots from community 1 were removed from the data for this analysis. Maputaland, northern KwaZulu-Natal, South Africa.

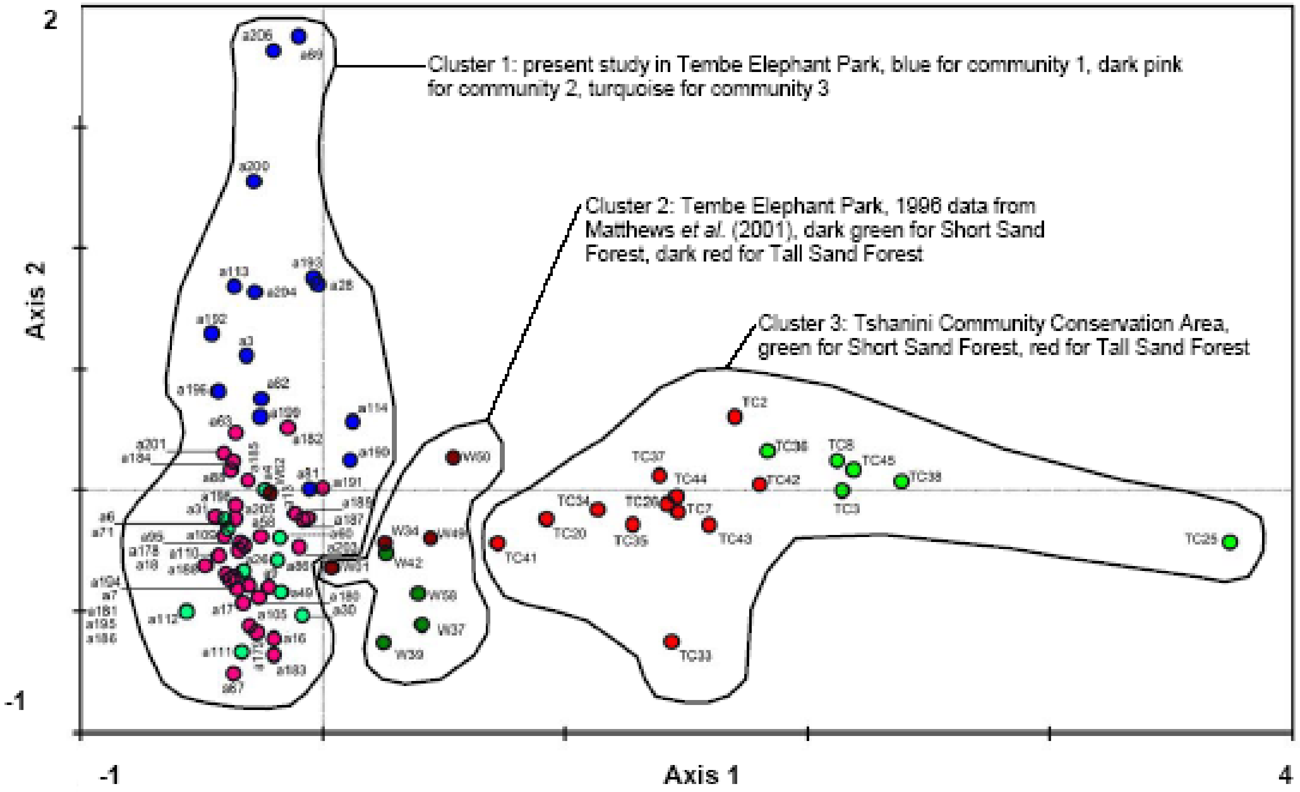

Figure 3: The graphical resolution of the correspondence analysis ordination applied on Sand Forest woody species, for the present study data set (plot number preceded by “a”), the data set from Matthews *et al.* (2001) (plot number preceded by “W”) and the data set from Gaugris *et al.* (2004) (plot number preceded by “TC”) in Maputaland, northern KwaZulu-Natal, South Africa. The clusters drawn represent the assemblages defined by the relevant authors.

at least three communities, with variations inside two of the communities is a new result in the suite of studies conducted on Sand Forest, which had so far only demonstrated the presence of two communities: the Tall and Short Sand Forest communities (Matthews *et al.* 1999; Matthews *et al.* 2001; Izidine *et al.* 2003; Gaugris *et al.* 2004). Communities 1 and 2 appeared further sub-divisible into two separate sub-groups each. Additionally, the delineation of Short Sand Forest as described in the previous studies was not as clear-cut as previously thought. Community 3 had the lowest canopy height of the three subcommunities with a canopy layer established between 8 and 10 m. This height was approximately 3 m higher than described previously, and it could be argued that such a height no longer fits the term of Thicket as described by previous studies (Matthews *et al.* 2001; Izidine *et al.* 2003). Perhaps the most interesting aspect from the classification was the clear gradient between the three subcommunities, with obvious links between each of them. This classification lends some credence to the hypothesis advanced by Gaugris *et al.* (2004) that Short Sand Forest evolves into Tall Sand Forest in time, and that the different forms are stages in a successional sequence.

The results from the ordinations offered further evidence of the strong ties between these three communities. The first ordination brought forward that community 1 was clearly distinct from the other two (Figure 1), while the second ordination (Figure 2) separated communities 2 and 3, but in a somewhat unsatisfactory manner. It appeared that communities 2 and 3 had many similarities in terms of cover-abundance and confirmed the ill-defined distinctions seen at the classification level.

The results from the third ordination (Figure 3) were most interesting and three aspects were noteworthy. The first aspect represented a timeline in Tembe. The most recent study in Tembe (2004) showed a clear cluster to the left of the scatter plot while the cluster from the study (1996) eight years previously, was clearly in the centre of the scatter plot. Because both studies sampled the Sand Forest in Tembe Elephant Park, and fire is not considered an agent of change in Tembe Elephant Park's Sand Forest (Matthews 2006), the differences observed most likely reflect changes associated with eight years of increasing animal utilisation. The second aspect, and possibly a confirmation of the above hypothesis, was the position most noticeably to the right of the scatter plot of the Tshanini Community Conservation Area cluster, representing data collected in 2001. Again fire was not considered and agent of disturbance in the Sand Forest of that area. Furthermore, this community reserve was under no animal utilisation pressure and human utilisation was excluded through tribal decisions (Gaugris 2004; Gaugris *et al.* 2004). The cluster from Tshanini Community

Conservation Area should therefore be considered to represent Sand Forest under no utilisation. It appeared therefore possible to describe axis 1 as a gradient in time and intensity of utilisation.

The third aspect was the position of the Short and Tall Sand Forest groups within the clusters of Matthews *et al.* (2001) and Gaugris *et al.* (2004). The vertical position (on axis 2) of these groups, which were reasonably well separated in both studies, was to an extent concordant with the vertical position of the plots representing communities 2 and 3 of the present study, while the plots of community 1 were higher along Axis 2 (Figure 3). It appeared possible that under mounting animal utilisation pressure, the Short and Tall Sand Forest described by Matthews *et al.* (2001) evolved to such an extent that the two communities have become much less discernable. Community 1 appeared as an altogether new form of Sand Forest, previously un-described.

The situation in 2004 therefore reflected Sand Forest as being a mosaic of the same forest type at different stages of evolution as proposed by Gaugris *et al.* (2004) and Gaugris and Van Rooyen (In Press) and that the dynamics were largely driven by the various utilisation regimes that Sand Forest was subjected to. This mosaic nature was described for tropical rain forests in other studies (Whitmore and Burslem 1996; Burslem and Whitmore 1999). The implications of such changes in time and of the mosaic pattern are in favour of a dynamic vegetation type rather than a vegetation type “in stasis” as described by several authors for the Sand Forest (Van Rensburg *et al.* 1999; Van Rensburg *et al.* 2000a; Matthews 2006).

At present the successional pathway is believed to encompass three types of Sand Forest communities. The sequence commences with the Short Sand Forest or Licuati Thicket, as described for Tembe Elephant Park from the 1996 sample (Matthews *et al.* 2001), Tshanini Community Conservation Area from the 2001 sample (Gaugris *et al.* 2004), and in southern Mozambique (Izidine *et al.* 2003). Through a combination of time, utilisation, and possibly the opening of gaps in the canopy of the Short Sand Forest, it evolves into community 2 described in the present classification. Community 2 appeared related to the Tall Sand Forest or Licuati Forest described by previous studies (Matthews *et al.* 2001; Izidine *et al.* 2003; Gaugris *et al.* 2004; Mucina and Rutherford 2006). With time and possibly continued disturbance as described above, this community progresses into community 3. The above hypothesis is well defended by the classification in the present study as well as the third ordination.

Based on the above results a revision of the nomenclature followed by previous studies in the South African side of Maputaland (Matthews *et al.* 2001; Gaugris *et al.*

2004) was deemed necessary. The present study therefore proposes the following revised community names:

- The *Brachylaena huillensis – Drypetes arguta* Short Sand Forest community (for community 3)
- The *Newtonia hildebrandtii – Cola greenwayi* Intermediate Sand Forest community (for community 2)
- The *Strychnos decussata – Afzelia quanzensis* Tall Sand Forest community (for community 1)

For their inherent descriptive values, the Short and Tall Sand Forest names remain in the present classification. However, the Tall Sand Forest now has a new meaning. The Short Sand Forest terminology described by previous authors was retained to describe the shortest form of this vegetation type, although it is now applicable to areas that may no longer be termed thicket like. It is here considered to represent a Short Sand Forest in transition due to intense animal utilisation.

The Intermediate Sand Forest is used to replace the Tall Sand Forest described in previous studies (Matthews *et al.* 2001; Izidine *et al.* 2003; Gaugris *et al.* 2004; Mucina and Rutherford 2006). It is intermediate in height, appeared most widespread (greatest number of plots) and could be a possible transition between Short and Tall states.

The community described as Tall Sand Forest represented a newly described unit of the Sand Forest vegetation. It is possibly the most mature stage of this forest type at present.

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CHAPTER 5

AN ANALYSIS OF THE INFLUENCE OF HERBIVORES AND MAN ON VEGETATION STRUCTURE: A CASE STUDY IN MAPUTALAND, SOUTH AFRICA

Abstract

The Maputaland region is part of the Maputaland – Pondoland – Albany hotspot of biodiversity. In communal land human pressure places strain on the natural resources of the region, but recent studies have also indicated that in conservation land the measures applied in the early 1980s no longer have the desired effect as animal populations have increased to such levels that they might have an observable negative impact on vegetation structure. A size and height class analysis investigated the horizontal and vertical structure of 21 vegetation units in Maputaland. Similar vegetation units under different utilisation pressure (human utilisation, herbivore utilisation, no utilisation) were compared. The results clearly indicated changes in stem diameter size class distribution as a result of human and animal utilisation, although the vertical structure remained unchanged. The canopies of all vegetation units were more open in utilised areas. In human dominated areas, this led to an overabundance of smaller woody plants whereas in animal utilised areas under formal conservation, these agents appeared to control the regeneration of woody plant species and possibly lead succession towards a sparse woodland system. The absence of utilisation in woodlands increased stand density and canopy closure. For the rare Sand Forest vegetation, an increased diversity and possibly stimulated dynamics were observed in areas under animal utilisation. However, recent increases in animal populations, especially elephants, appeared problematic. Sand Forest in non-utilised areas appeared more homogenous. The study presents the first quantification of change in vegetation structure due to animals or people in northern Maputaland and the first indication of the speed at which natural processes may influence the vegetation in the region.

Keywords

Animal utilisation, horizontal structure, human utilisation Maputaland, size class distribution, Sand Forest, vertical structure, woodlands

Introduction

Disturbance of natural ecosystems by people and herbivores are at the centre of many conservation debates. People utilise vegetation and therefore, depending on the level of utilisation it may lead to general vegetation change, degradation and fragmentation of ecosystems, or even extirpation of species (Kinnaird *et al.* 2003; Schmidt-Soltau 2003; Kupfer *et al.* 2004; Peteers 2005; Rudel 2006; Ndangalasi *et al.* 2007). While animals are usually the object of conservation measures, the effects of animal concentrations in confined areas can also be detrimental to vegetation in similar ways (Barnes 2001; Bond and Loffell 2001; Hornberg 2001; Tedonkeng Pamo and Tchamba 2001; Brits *et al.* 2002; Mapaure and Campbell 2002; Mosugelo *et al.* 2002; Shaw *et al.* 2002; Fashing and Mwangi Gathua 2004; Sheil and Salim 2004; Western and Maitumo 2004; Wiseman *et al.* 2004; Van Aarde and Jackson 2007; Western In Press). Yet, vegetation, animals and people have co-existed for millennia, and appear to be interdependent in terms of maintaining biodiversity, and ecosystem services (Kameri-Mbote and Cullet 1997; Laurance 1999; Perrings and Lovett 1999; Schmidt-Soltau 2003; Ticktin 2004b; Ward 2004; Ickowitz 2006; O'Connor *et al.* 2007). It is recognised that while disturbance is an essential factor to produce biodiversity rich matrix environments, too much disturbance reduces biodiversity through landscape destruction, while insufficient disturbance reduces biodiversity through homogenisation (Maisels *et al.* 2001; Moegenburg and Levey 2002; Gillson *et al.* 2003; Paul *et al.* 2004; Bell and Donnelly 2006; Chapman *et al.* 2006; Degen *et al.* 2006; Herrerias-Diego *et al.* 2006; Lindenmayer *et al.* 2006; Lindenmayer and Noss 2006; Spies *et al.* 2006; Stouffer *et al.* 2006; Ndangalasi *et al.* 2007). A problem therefore occurs when an agent, biological, anthropogenic or climatic, or a combination thereof, but also lack thereof, influences the vegetation in an unnatural way, leading to the above problems.

For conservation to be efficient, it is now accepted that reserve networks including large ecological reserves work best (Cabeza and Moilanen 2001; Reyers *et al.* 2002; Pressey *et al.* 2003; Lindenmayer *et al.* 2006; Rouget *et al.* 2006). However, due to the limited size of the world’s conservation areas (12% of the world land surface) and social acceptance of conservation concepts by local people (Brooks *et al.* 2006; West and Brockington 2006), it is obvious that much, if not the majority of conservation efforts have to be devoted to non-conserved areas (Sutherland 2003; Lindenmayer *et al.* 2006; Smith *et al.* 2006). The latter is especially important to preserve a variety of natural habitats under anthropogenic disturbance regimes, to retain landscape heterogeneity, and to regain biodiversity in areas where disturbance led to habitat destruction, but also to improve the output of natural and managed systems, and control resource extraction (Perrings and Lovett 1999; Decocq *et al.* 2004; Ticktin 2004a; Ticktin 2004b; Degen *et al.* 2006; Lindenmayer *et al.* 2006; Rouget *et al.* 2006; Rudel 2006; Wagner *et al.* 2006; Naughton-Treves *et al.* 2007).

It is therefore important to establish the quality of natural systems and to detect changes at both landscape and local level, within and outside conserved areas (Lindenmayer *et al.* 2006). Understanding natural system dynamics will allow more informed decisions to be taken (Lawes and Obiri 2003; Boudreau *et al.* 2005; Wagner *et al.* 2006). Ideally this knowledge comes from long-term studies and monitoring (Condit *et al.* 1998) and when such longitudinal studies are not available, they should be initiated. Initially, management decisions will rest on the available knowledge but these can be adapted and refined as additional information is gleaned (Condit *et al.* 1998; Boudreau and Lawes 2005; Lindenmayer *et al.* 2006; Smith *et al.* 2006).

To evaluate plant community structure and condition, static stem size distribution profiles provide interesting and useful insight in many facets of tree population structure, but are of little use to accurately assess the future plant community growth (Condit *et al.* 1998; Niklas *et al.* 2003). However, this method is often used to assess the growth potential of a community because of its ease of use (Condit *et al.* 1998; Obiri *et al.* 2002; Boudreau *et al.* 2005), and because it is often the only information available about a specific plant community. A significant relationship has been established between the slope of a linear regression fitted to the size structure of a community or a population, and its ecological condition (Niklas *et al.* 2003). Communities with highly negative slope values have been significantly linked with growing populations, whereas the reverse is true for communities with flatter or less negative slopes values (Niklas *et al.* 2003). Additionally, a link has been established between the position of the mean diameter of the trees in a population, termed “centroid”, and the size class distribution midpoint. A centroid skewed to the left of the midpoint indicates a young and growing community, whereas one skewed to the right indicates an older, relatively undisturbed community (Niklas *et al.* 2003).

Two analyses are reported on in the present study. The first analysis, to evaluate the state of the vegetation units was a classic size class distribution regression analysis based on the spread of stem diameter values of woody plants in each unit evaluated (hereafter referred to as the SCD analysis or horizontal structure). The second regression analysis, to increase the usefulness of available data and hopefully complement the results from the SCD analysis, was based on the height class distribution of the trees in each vegetation unit. It is hoped that this latter analysis (hereafter referred to as the HCD analysis or vertical structure) will add another dimension to the study of the structure of each unit.

In this paper the horizontal and vertical vegetation structure at three sites within a similar environment were compared. One site, the Tembe Elephant Park (Tembe) is under conservation rule and represents a situation where animals are the main disturbance. The Tshanini Community Conservation Area (Tshanini) is under as low human utilisation as is possible in the region due to its remoteness and difficulty of access and wild animals have been removed. The third site, the Manqakulane Rural Community (Manqakulane), is where people have relocated at a known date, and used the natural habitat since. While long-term studies of the area are unavailable, studying similar vegetation types within one geographical region but under different utilisation regimes allows us to gain an understanding of the processes operating at the different sites (Poorter *et al.* 1996; Chapman and Chapman 1997; Chapman *et al.* 1999), and hopefully bypasses some of the restrictions of classical size class distribution analyses (Condit *et al.* 1998; Boudreau *et al.* 2005).

Study area

Northern Maputaland is a region where long-term studies on vegetation dynamics are conspicuously absent (Gaugris 2004; Guldemond 2006; Matthews 2006; Smith *et al.* 2006). The region lies in the northern portion of the recently identified Maputaland - Pondoland - Albany hotspot of biodiversity (Smith *et al.* 2006). It harbours a rich range of endemic plant and animal species, many of which are rare and endangered (Van Wyk and Smith 2001; Matthews 2006). The region consists mainly of a sandy plain interspersed with ancient littoral dunes. It is covered by an open to closed woodland, with patches of Sand Forest and the Muzi Swamp running along the eastern boundary (Matthews *et al.* 2001; Gaugris *et al.* 2004).

Maputaland lies in a transition zone between the tropics to the north, and the subtropics to the south. The summers are hot, wet, and humid, while the winters are cool to warm and dry. Tembe received a mean annual rainfall of 721 mm in the period from 1981 to 2003 (Matthews 2006).

Tembe Elephant Park was created in 1983 to preserve the remnants of the Maputaland coastal African elephant *Loxodonta africana* (Blumenbach 1797) population as well as the rare Sand Forest vegetation (Morley 2005; Matthews 2006), and given to the then KwaZulu-Natal Bureau of Natural Resources to manage. Since 1983, little development occurred in the park and its main purpose was to preserve the region’s rare wildlife (KwaZulu Natal-Nature Conservation Services 1997; Browning 2000). The park has also served as a barrier to protect the local people from elephants raiding their crops.

Due to poaching in Mozambique the northern boundary of the park was closed in 1989, thus preventing animals from moving out of the park. Animal populations subsequently increased in numbers without the option of migrating along the Maputaland coastal plain seasonally (Morley 2005; Guldemond and Van Aarde In Press). There is now concern about the potential damage to the vegetation in the park due to the confined animal populations, especially elephants, a phenomenon observed elsewhere in southern Africa (Lombard *et al.* 2001; Guldemond and Van Aarde In Press; Van Aarde and Jackson 2007).

Tembe is the largest ecological reserve for northern Maputaland, and protects the largest share of the Sand Forest vegetation (Matthews 2006; Smith *et al.* 2006). However, the region around and south of the park is considered of high conservation value and most suitable for conservation purposes due to the low agricultural value of the land (Eeley *et al.* 2001; Matthews 2006; Smith *et al.* 2006). This intrinsic value is threatened by human population growth in the region, because of the pressure it exerts on natural resources, especially wood (Kloppers 2001; Peteers 2005; Gaugris *et al.* 2007). Although at present this demographic growth and its effect appear limited to areas along the road network (Brookes 2004), it is anticipated that it may lead to the utilisation of increasingly vast sections of land, thus endangering the natural ecological processes in this region (Brookes 2004; Matthews 2006; Smith *et al.* 2006).

The land of the community of Manqakulane is situated 6 km south of Tembe Elephant Park and in 2004 was comprised of 778 permanent residents (Peteers 2005). During the course of the year 2000, this community officially allocated of a portion of their tribal land to become a game reserve now gazetted as the Tshanini Community Conservation Area. This area was described extensively in Gaugris (2004) and appears to be the most representative “pristine” fragment of original northern Maputaland vegetation outside a formal conservation area. In Tshanini utilisation of wood resources by man has been low to insignificant since 1992, a date when the community people relocated their village from the eastern boundary of Tshanini to its current position along the Muzi Swamp (Gaugris 2004). While this move released Tshanini from human utilisation, it transferred a considerable pressure on the habitat surrounding the new village location as people cleared land for households and fields (Gaugris 2004; Peteers 2005; Gaugris *et al.* 2007).

The effect of man on the vegetation in a rural community is evaluated within the village area of the Manqakulane community. Utilisation of resources within communal land is governed by tribal laws that restrict the use of resources to those that are available within the tribal land of that particular community (Gaugris *et al.* 2007). Tarr *et al.* (2006) and Gaugris *et al.* (2007) found that people from the rural communities in northern Maputaland use resources available nearest to their households, rarely travelling further than 3 km to gather natural resources, which is consistent with other studies in KwaZulu-Natal and South Africa (Brookes 2004; Lawes *et al.* 2004; Boudreau *et al.* 2005; Peteers 2005; Gaugris *et al.* 2007; Madubansi and Shackleton 2007).

A total of 11 vegetation units (Table 1) were sampled within the three study areas. Whenever possible names follow the classification presented in Matthews *et al.* (2001). The Tall Sand Forest described in Matthews *et al.* (2001) and Gaugris *et al.* (2004) is here called Intermediate Sand Forest, as the Tall Sand Forest description is applied to a new type of Sand Forest unit recognised during the present sampling of Tembe and described in Chapter 4 of the present study. However, it does not occur in Manqakulane and Tshanini. Two additional communities viz. *Afzelia quanzensis* clumps and *Afzelia quanzensis* forest on sand were also described in the present study for the first time. These communities did not fit any of the established descriptions, and expert opinion was used to name them, despite the lack of data to prove their status adequately.

Material and Methods

Rectangular plots of varying length and width, depending on vegetation density, were used to obtain abundance and size class distribution data of woody species in the three sites studied. A total of 254 transects were conducted, of which 48 were in Tshanini, 42 in Manqakulane, and the remainder in Tembe. The data were captured by using Microsoft Excel and then compiled into a database in Microsoft Access.

Stem diameter measurements of woody plants were classified into 12 classes of varying diameter width for the SCD analysis (>0 to <1 cm, 1 to <2 cm, 2 to <4 cm, 4 to <6 cm, 6 to <10 cm, 10 to <14 cm, 14 to <20 cm, 20 to <26 cm, 26 to <34 cm, 34 to <42 cm, 42 to <52 cm, ≥52 cm). The tree height measurements at the vegetation unit level were similarly classified into eight classes of varying heights (>0 to <0.1 m, 0.1 to <0.5 m, 0.5 to <1.5 m, 1.5 to <3.0 m, 3.0 to <5.0 m, 5.0 to <8.0 m, 8.0 to <12 m, ≥12 m). The variations in diameter and height were used to accommodate approximately equal numbers of individuals in each class with increasing size because the number of individuals generally declines with size (Condit *et al.* 1998; Lykke 1998; Boudreau *et al.* 2005). The size and height classes were selected after a review of stem diameters and tree heights observed in the region (Pooley 1997; Matthews *et al.* 2001; Brookes 2004; Gaugris 2004). The number of individuals in each size or height class is divided by the width of the class (number of cm per class) to obtain a mean number of individuals per unit of measurement for each class (Condit *et al.* 1998) before calculating the density

Table 1: Vegetation units of the study area in Maputaland, northern KwaZulu-Natal, South Africa

Code	Abbreviation	Community Name	Synonym in other studies
1		Sand Forest association	
1.1	AQ	*Afzelia quanzensis* subassociation	Newly described in the present study
1.1.1	AQC	*Afzelia quanzensis* clumps	Newly described in the present study
1.1.2	AQF	*Afzelia quanzensis* forest	Newly described in the present study
1.2	SF	Sand Forest subassociation	
1.2.1	SSF	Short Sand Forest	Short Sand Forest in Matthews *et al.* (2001) and Gaugris *et al*. (2004)
1.2.2	ISF	Intermediate Sand Forest	Tall Sand Forest in Matthews *et al.* (2001) and Gaugris *et al*. (2004)
1.2.3	TSF	Tall Sand Forest	Newly described in the present study, replaces TSF of Matthews *et al.* (2001) and Gaugris *et al*. (2004)
2	CW	Closed Woodland association	
2.1.0	CWT	Closed Woodland Thicket	Described as such in Matthews *et al*. (2001) and as Closed Woodland in Gaugris *et al.* (2004)
2.2.0	CWC	Closed Woodland on Clay	Described as such in Matthews *et al.* (2001) and as Woodland on Clay in Gaugris *et al*. (2004)
2.3.0	CWS	Closed Woodland on Sand	Described as such in Matthews *et al.* (2001) and as Open Woodland on Sand in Gaugris *et al.* (2004)
3	OW	Open Woodland association	
3.1.0	OWS	Open Woodland on Sand	Described as such in Matthews *et al.* (2001) and as Sparse Woodland on Sand in Gaugris *et al.* (2004)
3.2.0	OWAH	Open Woodland on Abandoned Household sites	Newly described in the present study
4	SW	Sparse Woodland association	
4.1.0	SWS	Sparse Woodland on Sand	Described as such in Matthews *et al*. (2001)

(Di) per size and height class per vegetation unit in each study site. The class midpoint (Mi) for each diameter and height size class was set as the halfway measurement for each size class (Condit *et al.* 1998).

Once Di and Mi were established, normal logarithmic transformations (Condit *et al.* 1998) of the type ln(Di+1) and ln(Mi+1) were used to standardize the data (Lykke 1998; Niklas *et al.* 2003; Boudreau *et al.* 2005) before calculating the least square linear regressions fitting the data. The value of 1 was added as some size class bins could be empty (Lykke 1998; Boudreau *et al.* 2005). For each vegetation unit a regression was calculated with ln(Mi+1) values as independent variable and ln(Di+1) values as dependent variable (Condit *et al.* 1998; Lykke 1998; Boudreau *et al.* 2005). The slopes of these regressions are referred to as SCD slopes for the diameter-based regressions and HCD slopes for the height-based regressions.

Two regressions were calculated per analysis for each vegetation unit. The initial regression encompassed the full data set (hereafter referred to as the complete analysis), while the second regression was restricted to the last ten diameter size classes or seven height size classes (hereafter referred to as the restricted analysis), thus removing a potential bias from weather induced sudden seedling germination because not all surveys were conducted in the same year (Yeh *et al.* 2000; Niklas *et al.* 2003). For each regression, the location, year of sample, slope, intercept, r^2-value, standard error, significance of F, numerator degrees of freedom, number of size classes over which the regression was calculated and the centroid are indicated. The centroid represents the mean diameter or height at the unit level, and the size/height class in which it is located is indicated.

An analysis of covariance (ANCOVA) F-test was used to compare the regression slopes and intercepts between comparable vegetation units on different sites by using the linear regression comparison tool in GraphPad PRISM 4 software (Windows version, GraphPad Software, San Diego California USA, www.graphpad.com). This analysis begins by comparing the slopes of the regressions, and should there be no significant difference between the slopes, it evaluates the degree of difference between the Y-axis intercepts. When the slopes are similar, a pooled slope value is given. Should there be no significant difference established at the Y-axis intercept comparison level, a pooled Y-axis intercept value is also presented. Should there be no significant difference at either slope or Y-axis intercept levels, the vegetation in the sites compared can be described through the pooled slope and pooled Y-axis intercept.

Results

Only seven of the 11 vegetation units identified were compared across the sites. The SCD and HCD slopes for all communities are presented in Tables 2 and 3 respectively. A total of 22 regressions were calculated on the complete SCD analysis, F was highly significant in all regressions, and the r^2-values for 21 of these regressions was >0.80, and 0.75 for the remaining regression. All regressions of the restricted SCD analysis were highly significant while a total of 18 regressions had r^2-values >0.80, the remaining values being 0.48, 0.70 and 0.77 (Table 2).

The complete HCD analysis performed weakly, with only four regressions where the r^2-value was greater than 0.80 (Table 3). However, F remained significant for all but six of the regressions. The restricted HCD analysis performed better with 16 regressions with r^2-values >0.80, while only three regressions were not significant. Only the HCD analysis of the Closed Woodland Thicket in Tshanini could not be resolved satisfactorily with either method.

The SCD slopes and Y-axis intercepts of all Tshanini vegetation units were steeper/higher in the restricted analysis than in the complete analysis, reflecting a lower abundance of trees in size classes 1 and 2 than in the size classes following them. This was also the case for the Short and Tall Sand Forest in Tembe. All remaining SCD slopes and Y-axis intercepts were shallower/lower in the restricted analysis than in the complete analysis, thus reflecting a greater abundance of trees in size classes 1 and 2 than in the size classes following them (Table 2).

The opposite pattern held true for the HCD analysis, whereby all but two of the HCD slopes and Y-axis intercepts were steeper/higher in the restricted analysis than in the complete analysis. The two units for which the above did not hold true were the Short and Intermediate Sand Forest units of Tshanini, although the slope only differed marginally in the Intermediate Sand Forest case (Table 3). The latter two units had SCD slopes showing a dearth of small diameter trees, while the HCD slopes indicated the opposite. The Sand Forest units of Tembe and the woodland units of Tshanini showed a dearth of small size classes in both horizontal and vertical structures. However, the woodlands of Tembe and Manqakulane, and the *Afzelia quanzensis* association of Tembe showed an abundance of small trees in the horizontal structure that was not reflected at the vertical level.

The SCD centroid of communities in Tshanini shifted by one size class upwards for all but the Short Sand Forest unit, where it shifted by two size classes upwards (Table 2) between the complete and restricted SCD analysis. The SCD centroid of all other communities shifted by two to four size classes from the complete to restricted

Table 2: Results of the stem diameter class distribution (SCD) analysis by vegetation unit, for the full data set and data set restricted to the largest ten size classes (size class is abbreviated as SC)

VT	Vegetation unit (abbr.)*	Location	Year of sample	Number of Individuals sampled	Regression analysis of SCDs by using the full data set							Regression analysis of SCDs by using a data set restricted to SC 3 to SC 12						
					Slope	Intercept	r^2	Standard error	F	Df_d	Centroid location	Slope	Intercept	r^2	Standard error	F	Df_d	Centroid location
VT 01.1.0[a]	AQ	TEP	2004	297	-1.64	8.54	0.88	0.77	71.50 **	10	SC 2	-1.21	7.20	0.84	0.50	43.15 **	8	SC 5
VT 01.1.1	AQC	TEP	2004	96	-1.77	8.59	0.89	0.78	81.18 **	10	SC 1	-1.28	7.03	0.86	0.49	49.50 **	8	SC 5
VT 01.1.2	AQF	TEP	2004	201	-1.55	8.49	0.84	0.84	54.38 **	10	SC 2	-1.15	7.23	0.77	0.61	26.29 **	8	SC 5
VT 01.2.1	SSF	TCCA	2001	2411	-2.37	11.24	0.97	0.52	329.89 **	10	SC 2	-2.66	12.18	0.98	0.41	314.26 **	8	SC 4
VT 01.2.1	SSF	TEP	2004	896	-1.93	10.11	0.98	0.36	458.80 **	10	SC 2	-2.03	10.43	0.98	0.30	342.60 **	8	SC 4
VT 01.2.2	ISF	TCCA	2001	2883	-1.86	9.21	0.97	0.44	276.21 **	10	SC 3	-2.15	10.15	0.99	0.23	633.37 **	8	SC 4
VT 01.2.2	ISF	TEP	2004	4632	-1.87	9.77	0.98	0.36	414.20 **	10	SC 2	-1.87	9.78	0.95	0.40	161.80 **	8	SC 5
VT 01.2.3	TSF	TEP	2004	1779	-1.62	10.02	0.95	0.44	214.20 **	10	SC 3	-1.82	10.70	0.95	0.40	149.70 **	8	SC 5
VT 02.1.0	CWT	TCCA	2001	4126	-2.13	9.54	0.96	0.56	229.01 **	10	SC 2	-2.38	10.33	0.99	0.17	1496.90 **	8	SC 3
VT 02.1.0	CWT	TEP	2004	117	-1.87	8.73	0.88	0.88	71.54 **	10	SC 2	-1.66	8.04	0.77	0.87	27.17 **	8	SC 5
VT 02.1.0	CWT	MRC	2004	1170	-2.87	12.28	0.92	1.06	116.20 **	10	SC 2	-2.03	9.57	0.95	0.43	163.64 **	8	SC 5
VT 02.2.0	CWC	TEP	2004	2015	-1.87	8.99	0.98	0.35	463.97 **	10	SC 2	-1.74	8.58	0.96	0.33	202.23 **	8	SC 5
VT 02.2.0	CWC	MRC	2004	186	-2.17	9.80	0.75	1.58	29.80 **	10	SC 2	-1.58	7.88	0.48	1.59	7.27 **	8	SC 5
VT 02.3.0	CWS	TCCA	2001	3915	-2.09	9.31	0.98	0.39	458.71 **	10	SC 2	-2.18	9.61	0.99	0.16	1331.26 **	8	SC 3
VT 02.3.0	CWS	TEP	2004	1999	-1.90	9.28	0.99	0.27	817.51 **	10	SC 2	-1.89	9.23	0.97	0.29	302.95 **	8	SC 5
VT 02.3.0	CWS	MRC	2004	819	-2.11	9.77	0.96	0.53	248.45 **	10	SC 2	-1.81	8.79	0.95	0.38	166.75 **	8	SC 4
VT 03.1.0	OWS	TCCA	2001	4663	-2.09	8.59	0.98	0.40	428.47 **	10	SC 2	-2.17	8.84	0.98	0.29	399.72 **	8	SC 3
VT 03.1.0	OWS	TEP	2004	4202	-1.69	7.94	0.94	0.55	153.27 **	10	SC 2	-1.36	6.85	0.91	0.42	78.74 **	8	SC 5
VT 03.1.0	OWS	MRC	2004	149	-3.02	11.38	0.93	1.07	126.88 **	10	SC 1	-2.72	10.38	0.85	1.11	44.36 **	8	SC 5
VT 03.2.0	OWAH	MRC	2004	995	-2.16	8.91	0.93	0.77	125.74 **	10	SC 2	-1.80	7.72	0.86	0.69	49.56 **	8	SC 4
VT 04.1.0	SWS	TEP	2004	654	-2.26	8.82	0.89	0.98	83.65 **	10	SC 2	-1.59	6.65	0.86	0.61	49.28 **	8	SC 4
VT 04.1.0	SWS	MRC	2004	176	-2.18	8.88	0.86	1.12	60.04 **	10	SC 1	-1.66	7.19	0.70	1.05	18.35 **	8	SC 5

Notes: VT 01.1.0[a] is a combination of VT 01.1.1 and VT 01.1.2 calculated for practical purposes as it proved difficult to distinguish the two subcommunities at the analysis level

TCCA	Tshanini Community Conservation Area	**	Highly significant ($p \le 0.01$)
TEP	Tembe Elephant Park	*	Significant ($p \le 0.05$)
MRC	Manqakulane Rural Community	-	Not significant ($p > 0.05$)
(abbr.)*	Abbreviated form, see Table 1 for details		

Table 3: Results of the height class distribution (HCD) analysis by vegetation unit for the full data set and data set restricted to the largest six classes (height class is abbreviated as HC)

VT	Vegetation unit (abbr.)*	Location	Year of sample	Number of individuals sampled	Regression analysis of HCDs by using the full data set							Regression analysis of HCDs by using a data set restricted to HC 2 to HC 8						
					Slope	Intercept	r^2	Standard error	F	Df_d	Centroid location	Slope	Intercept	r^2	Standard error	F	Df_d	Centroid location
VT 01.1.1	AQC	TEP	2004	96	-0.48	5.77	0.03	3.02	0.17 -	6	HC 3	-2.28	9.38	0.94	0.57	77.90 **	5	HC 3
VT 01.1.2	AQF	TEP	2004	201	-1.52	8.85	0.69	1.08	13.47 *	6	HC 3	-2.11	10.03	0.94	0.52	78.58 **	5	HC 3
VT 01.2.1	SSF	TCCA	2001	2411	-2.76	10.53	0.62	2.31	9.68 *	6	HC 3	-2.67	10.37	0.52	2.52	5.40 -	5	HC 4
VT 01.2.1	SSF	TEP	2004	896	-1.67	8.94	0.54	1.65	6.97 *	6	HC 3	-2.42	10.45	0.80	1.18	20.29 **	5	HC 4
VT 01.2.2	ISF	TCCA	2001	2883	-1.69	8.15	0.52	1.71	6.58 *	6	HC 4	-1.68	8.14	0.44	1.88	3.87 -	5	HC 4
VT 01.2.2	ISF	TEP	2004	4632	-1.53	8.70	0.57	1.41	8.01 *	6	HC 3	-2.26	10.16	0.88	0.81	37.74 **	5	HC 3
VT 01.2.3	TSF	TEP	2004	1779	-0.82	8.26	0.21	1.67	1.62 -	6	HC 3	-1.79	10.22	0.94	0.46	72.04 **	5	HC 4
VT 02.1.0	CWT	TCCA	2001	4126	-1.46	6.72	0.27	2.53	2.27 -	6	HC 4	-1.97	7.74	0.35	2.61	2.74 -	5	HC 4
VT 02.1.0	CWT	TEP	2004	117	-1.11	6.01	0.12	3.25	0.79 -	6	HC 3	-2.97	9.75	0.87	1.12	33.75 **	5	HC 3
VT 02.1.0	CWT	MRC	2004	1170	-4.08	12.84	0.93	1.23	74.92 **	6	HC 2	-4.16	13.00	0.90	1.34	46.50 **	5	HC 2
VT 02.2.0	CWC	TEP	2004	2015	-2.11	8.56	0.70	1.46	14.25 **	6	HC 3	-2.81	9.96	0.89	0.98	39.86 **	5	HC 3
VT 02.2.0	CWC	MRC	2004	186	-2.27	9.58	0.83	1.08	30.10 **	6	HC 3	-2.91	10.87	1.00	0.19	1108.73 **	5	HC 3
VT 02.3.0	CWS	TCCA	2001	3915	-1.98	7.94	0.53	1.97	6.85 *	6	HC 4	-2.36	8.69	0.56	2.05	6.32 *	5	HC 4
VT 02.3.0	CWS	TEP	2004	1999	-1.68	8.06	0.43	2.06	4.50 *	6	HC 3	-2.68	10.08	0.80	1.33	19.45 **	5	HC 3
VT 02.3.0	CWS	MRC	2004	819	-2.44	9.45	0.86	1.07	35.55 **	6	HC 3	-3.00	10.58	0.97	0.56	140.46 **	5	HC 3
VT 03.1.0	OWS	TCCA	2001	4663	-2.57	7.94	0.71	1.76	14.47 **	6	HC 4	-2.93	8.65	0.71	1.82	12.47 *	5	HC 4
VT 03.1.0	OWS	TEP	2004	4202	-1.81	7.30	0.51	1.88	6.32 *	6	HC 3	-2.87	9.43	0.94	0.73	74.60 **	5	HC 3
VT 03.1.0	OWS	MRC	2004	149	-2.29	7.82	0.26	4.07	2.14 -	6	HC 3	-4.70	12.65	0.97	0.87	140.36 **	5	HC 3
VT 03.2.0	OWAH	MRC	2004	995	-2.55	8.71	0.89	0.97	47.11 **	6	HC 3	-3.10	9.80	0.98	0.39	309.87 **	5	HC 3
VT 04.1.0	SWS	TEP	2004	654	-2.76	8.46	0.75	1.69	18.21 **	6	HC 3	-3.76	10.47	0.99	0.31	726.33 **	5	HC 3
VT 04.1.0	SWS	MRC	2004	176	-2.11	6.56	0.31	3.38	2.65 -	6	HC 3	-4.13	10.62	0.99	0.49	339.70 **	5	HC 3

Notes:				
	TCCA	Tshanini Game Reserve	**	Highly significant ($p \leq 0.01$)
	TEP	Tembe Elephant Park	*	Significant ($p \leq 0.05$)
	MRC	Manqakulane Rural Community	-	Not significant ($p > 0.05$)
	(abbr.)*	Abbreviated form, see Table 1 for details		

analysis (Table 2). The greatest shift in size classes (four upwards) was observed in the *Afzelia quanzensis* clumps of Tembe, and in the open and sparse woodlands on sand of Manqakulane.

The HCD centroid of the complete and restricted analyses remained within the same height class for most units except the Sand Forest where it shifted upwards by one height class in the Short Sand Forest units of Tembe and Tshanini, and in the Tall Sand Forest unit of Tembe.

Because no significant differences were found between any of the sites regarding the HCD regressions, the regression results presentation will further only focus on the SCD regressions. Additionally, only the centroids of the restricted analyses will be used for the presentation of results, and therefore when the term centroid is used, the centroid for the restricted analysis is relevant.

The Short Sand Forest unit is present in Tembe and Tshanini. The slope and Y-axis intercepts of both SCD analyses in Tshanini were significantly steeper/greater than in Tembe (Table 2, 4). The SCD centroid was located in size class 4 in Tshanini and Tembe (Table 2), while the HCD centroid is located in height class 4 for both sites (Table 3). The graphical resolutions of the complete and restricted SCD analyses appear in Figure 1.

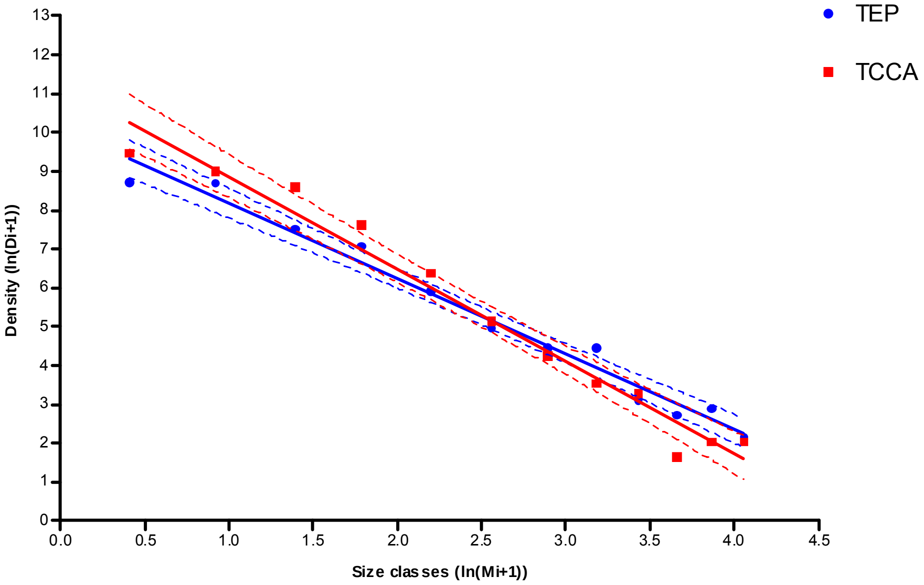
The Intermediate Sand Forest unit is also present in Tembe and Tshanini. The slopes of the regressions were similar in both sites for the complete and restricted SCD analyses (Tables 2, and 4), but the Y-axis intercept of the complete and restricted SCD analyses were significantly higher in Tembe than in Tshanini (Table 2). In effect, the SCD analysis of Tembe represented a greater abundance of trees of all sizes than in Tshanini (Figure 2). The SCD/HCD centroids in Tshanini were located within size/height class 4, but the SCD centroid was located within size class 5 and the HCD centroid within height class 3 in Tembe. The centroid positions showed a greater contribution of large diameter trees in Tembe, while there appeared to be a greater contribution from tall trees in Tshanini.

The Closed Woodland Thicket unit occurs on all three study sites. The three sites appeared similar in both SCD and HCD slopes and Y-axis intercepts (Tables 4 and 5, restricted analyses). However, when considering the abundance of the smaller diameter trees (complete SCD analysis), only Tembe and Tshanini were similar, while the slope and Y-axis intercepts of Manqakulane were significantly steeper/greater (Tables 2 and 4). The SCD centroid for Tshanini was located within size class 3, but within size class 5 for the two other sites (Table 2). The HCD centroid was located within height class 4 in Tshanini, height class 3 in Tembe and height class 2 in

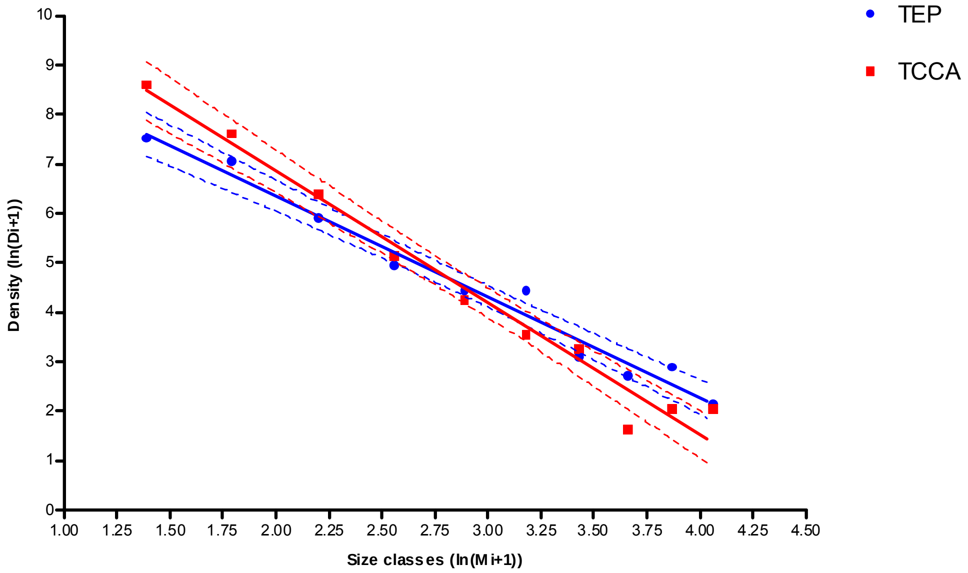
Table 4: The stem diameter class distribution (SCD) slopes and Y-axis intercepts for the comparable vegetation units of the three study sites, Maputaland, South Africa

Comparison levels			Slope comparison						Y-axis intercept comparison						Final outcome
VT	Units (Abbr.)*	Sites compared	F value		Df_n	Df_d	P value	Pooled slope	F value		Df_n	Df_d	P value	Pooled Intercept	
FULL DATA SET															
VT 01.2.1	SSF	TEP / TCCA	7.59	**	1	20	0.01	-	-		-	-	-	-	Different
VT 01.2.2	ISF	TEP / TCCA	0.00	*ns*	1	20	0.92	-1.86	9.98	**	1	21	<0.01	-	Different
VT 02.1.0	CWT	TEP / TCCA / MRC	5.74	**	2	30	<0.01	-	-		-	-	-	-	Different
		TEP / TCCA	0.94	*ns*	1	20	0.34	-2.01	0.29	*ns*	1	21	0.60	9.14	Similar
		TCCA / MRC	6.06	*	1	20	0.02	-	-		-	-	-	-	Different
		TEP / MRC	8.25	**	1	20	0.01	-	-		-	-	-	-	Different
VT 02.2.0	CWC	TEP / MRC	0.54	*ns*	1	20	0.47	-2.02	0.01	*ns*	1	21	0.92	9.40	Similar
VT 02.3.0	CWS	TEP / TCCA / MRC	1.21	*ns*	2	30	0.31	-2.04	4.06	*	2	32	0.03	-	Different
		TEP / TCCA	2.38	*ns*	1	20	0.31	-2.00	9.80	**	1	21	0.01	-	Different
		TEP / MRC	1.93	*ns*	1	20	0.18	-2.01	0.07	*ns*	1	21	0.79	9.54	Similar
		TCCA / MRC	0.03	*ns*	1	20	0.87	-2.04	4.42	*	1	21	0.05		Different
VT 03.1.0	OWS	TEP / TCCA / MRC	13.90	**	2	30	<0.01	-	-		-	-	-	-	Different
		TEP / TCCA	5.36	*	1	20	0.03	-	-		-	-	-	-	Different
		TEP / MRC	19.52	**	1	20	<0.01	-	-		-	-	-	-	Different
		TCCA / MRC	10.69	**	1	20	<0.01	-	-		-	-	-	-	Different
VT04.1.0	SWS	TEP / MRC	0.04	*ns*	1	20	0.84	-2.22	0.37	*ns*	1	21	0.55	8.86	Similar
RESTRICTED DATA SET															
VT 01.2.1	SSF	TEP / TCCA	11.15	**	1	16	<0.01	-	-		-	-	-	-	Different
VT 01.2.2	ISF	TEP / TCCA	2.60	*ns*	1	16	0.12	-2.01	7.52	**	1	17	0.01	-	Different
VT 02.1.0	CWT	TEP / TCCA / MRC	2.94	*ns*	2	24	0.07	-2.03	1.50	ns	2	26	0.25	1.31	Similar
VT 02.2.0	CWC	TEP / MRC	0.08	*ns*	1	16	0.78	-1.66	0.18	*ns*	1	21	0.67	8.23	Similar
VT 02.3.0	CWS	TEP / TCCA / MRC	3.26	*ns*	2	24	0.06	-1.96	5.78	*	2	26	<0.01	-	Different
		TEP / TCCA	5.70	*	1	16	0.03	-	-		-	-	-	-	Different
		TEP / MRC	0.18	*ns*	1	16	0.68	-1.85	2.29	*ns*	1	17	0.15	9.02	Similar
		TCCA / MRC	5.83	*	1	16	0.03	-	-		-	-	-	-	Different
VT 03.1.0	OWS	TEP / TCCA / MRC	6.96	**	2	24	<0.01	-	-		-	-	-	-	Different
		TEP / TCCA	18.64	**	1	16	<0.01	-	-		-	-	-	-	Different
		TEP / MRC	9.73	**	1	16	<0.01	-	-		-	-	-	-	Different
		TCCA / MRC	1.67	*ns*	1	16	0.21	-2.45	0.02	*ns*	1	17	0.99	9.62	Similar
VT04.1.0	SWS	TEP / MRC	0.02	*ns*	1	16	0.88	-1.62	0.85	*ns*	1	17	0.37	6.92	Similar

Notes:		
	**	Highly significant ($p \le 0.01$)
	*	Significant ($p \le 0.05$)
	ns	Not significant ($p > 0.05$)
	(abbr.)*	Abbreviated form, see Table 1 for details

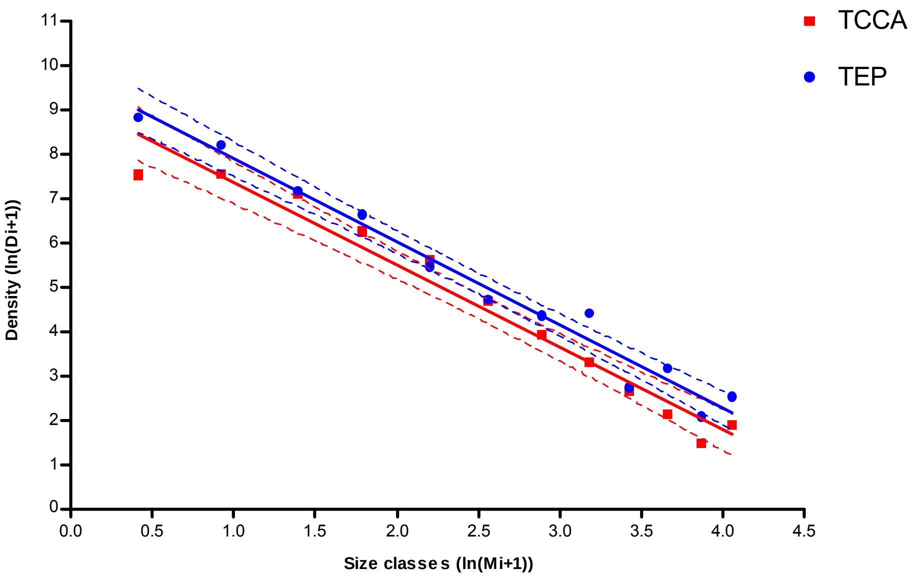


(a) SSF complete SCD analysis

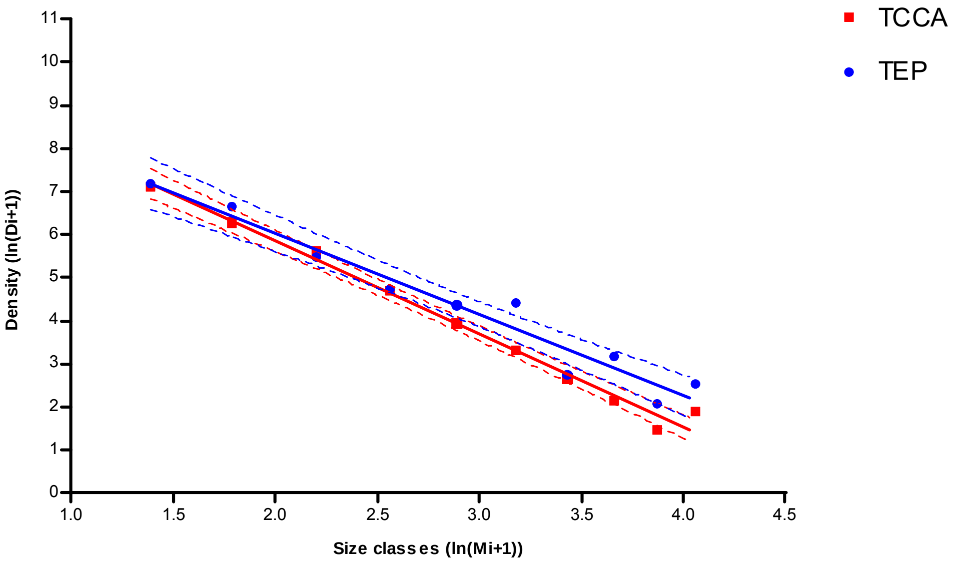


(b) SSF restricted SCD analysis

Figure 1: Stem diameter size class distribution in the Short Sand Forest (SSF) in Tembe Elephant Park (TEP) and Tshanini Community Conservation Area (TCCA). (a) A linear regression on all 12 size classes, (b) linear regression excluding the smallest two size classes. The dotted lines represent the 95% confidence intervals.



(a) ISF complete SCD analysis



(b) ISF restricted SCD analysis

Figure 2: Stem diameter size class distribution in the Intermediate Sand Forest (ISF) in Tembe Elephant Park (TEP) and Tshanini Community Conservation Area (TCCA). (a) A linear regression on all 12 size classes, (b) linear regression excluding the smallest two size classes. The dotted lines represent the 95% confidence intervals.

Manqakulane (Table 3). The graphical resolution of the SCD analysis (Figure 3) confirmed that most of the difference lied in the smaller size classes, while the larger size classes were similar.

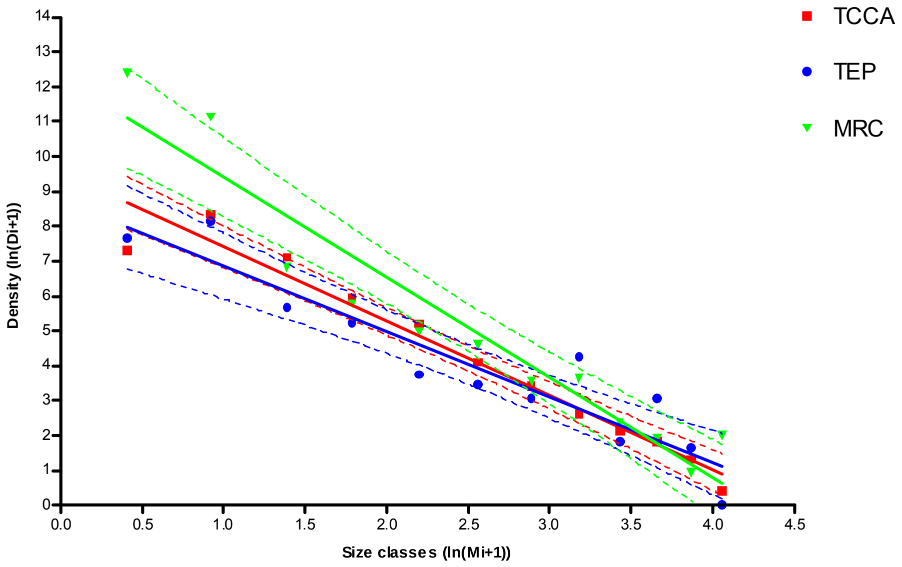
The Closed Woodland on Clay unit occurs only in Tembe and Manqakulane. The SCD slopes and Y-axis intercepts of Manqakulane and Tembe (Tables 4 and 5) did not differ significantly and the pooled slopes and Y-axis intercepts could therefore be used to describe the SCD curve shapes of both sites (Tables 4). The SCD centroid was located within size class 5 in both sites and the HCD centroid within height class 3 in both sites as well.

The Closed Woodland on Sand unit occurs on all three sites. The SCD slopes and Y-axis intercepts of Manqakulane and Tembe were similar, while the slope and Y-axis intercepts of Tshanini were significantly different from the two other sites (Table 4, Figure 4). The SCD centroids were located within size class 3 for Tshanini, size class 5 for Tembe and size class 4 for Manqakulane (Table 2). The HCD centroid of Tshanini was located within height class 4, while those of Tembe and Manqakulane were located within height class 3 (Table 3). In effect, density in larger size classes in Tshanini appeared lower than in both other sites while the smaller size classes appeared better represented.

The Open Woodland on Sand unit occurs on all three sites. The horizontal structure (SCD analysis) of the three sites showed that Tshanini and Manqakulane were similar (restricted analysis), while Tembe differed from both (Table 4, Figure 5). The steepest SCD slope and highest Y-axis intercept were found within Manqakulane, while the slope became progressively shallower and the Y-axis intercept lower in the Tshanini and Tembe sites successively (Table 2). The SCD centroids were located within size class 3 for Tshanini and within size class 5 for Tembe and Manqakulane (Table 2). The HCD centroid of Tshanini was located in height class 4, and those of Tembe and Manqakulane were located within height class 3 (Table 3). The Manqakulane site lacked individuals in the greater size classes, while the Tembe site seemed to have a greater abundance of larger trees than the Tshanini site (Figure 5).

The last comparison possible was within the Sparse Woodland on Sand unit found in Tembe and Manqakulane. The SCD analysis revealed that there were no differences between the two sites in either SCD or HCD levels (Tables 4 and 5). The SCD centroid of Tembe was located within size class 4 while that of Manqakulane was located within size class 5 (Table 2). The HCD centroids of Tembe and Manqakulane were both located within height class 3 (Table 3)

(a) CWT complete SCD analysis



(b) CWT restricted SCD analysis

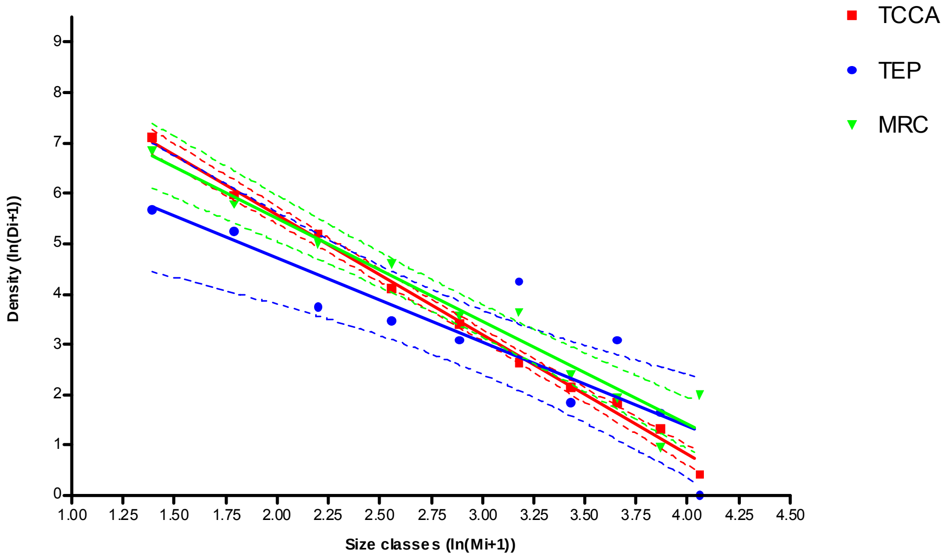
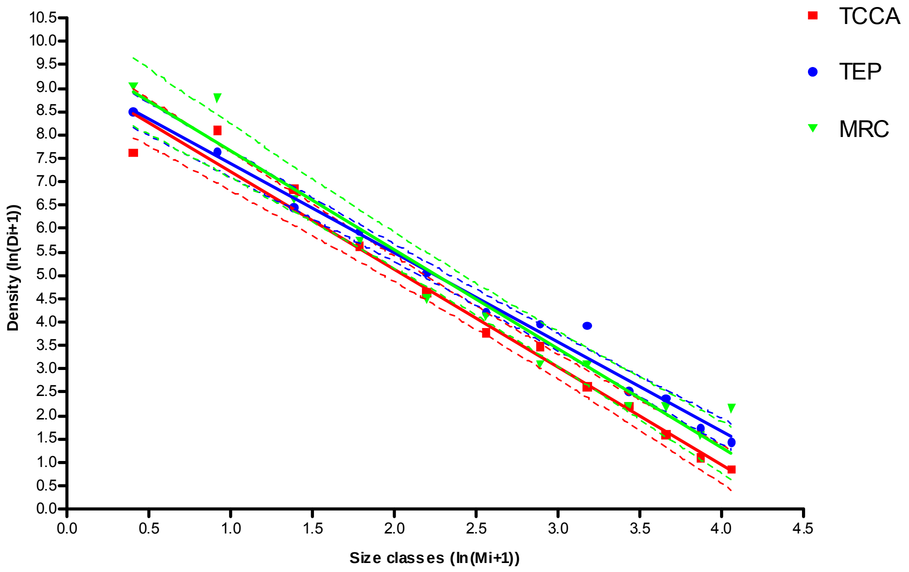


Figure 3: Stem diameter size class distribution in the Closed Woodland Thicket (CWT) in Tembe Elephant Park (TEP), Tshanini Community Conservation Area (TCCA) and the Manqakulane village zone area (MRC). (a) A linear regression on all 12 size classes, (b) linear regression excluding the smallest two size classes. The dotted lines represent the 95% confidence intervals.

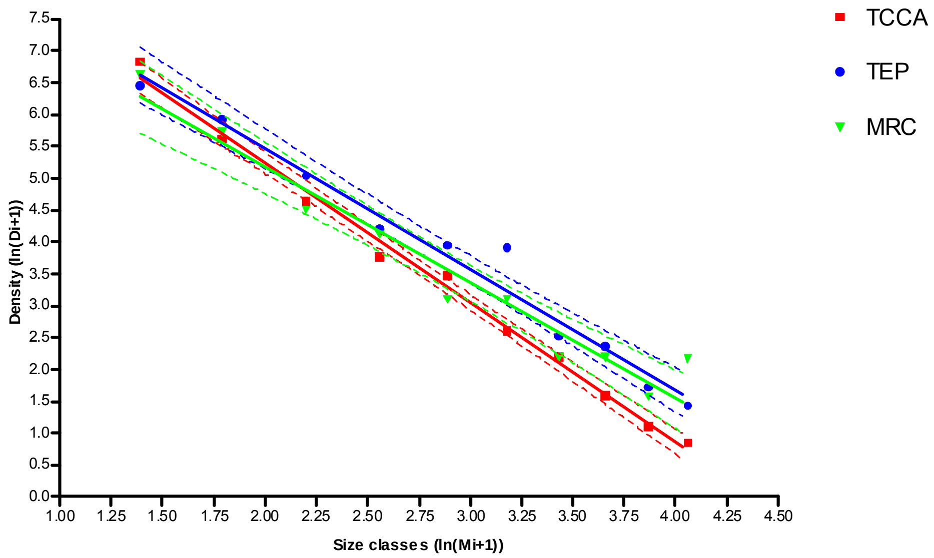
Table 5: The height class distribution (HCD) slopes and Y-axis intercepts for the comparable vegetation units of the three study sites, Maputaland, South Africa

Comparison levels				Slope comparison					Y-axis intercept comparison					Final outcome
VT	Units (abbr.)*	Sites compared	Validity[a]	F value	Df_n	Df_d	P value	Pooled slope	F value	Df_n	Df_d	P value	Pooled Intercept	
FULL DATA SET														
VT 01.2.1	SSF	TEP / TCCA	X	1.00 *ns*	1	12	0.34	-2.21	0.01 *ns*	1	13	0.91	9.73	Similar
VT 01.2.2	ISF	TEP / TCCA	X	0.03 *ns*	1	12	0.86	-1.61	1.04 *ns*	1	13	0.33	8.43	Similar
VT 02.1.0	CWT	TEP / TCCA / MRC	-	2.91 *ns*	2	18	0.08	-2.21	2.60 *ns*	2	20	0.10	8.52	Similar
VT 02.2.0	CWC	TEP / MRC	X	0.05 *ns*	1	12	0.82	-2.19	1.68 *ns*	1	13	0.22	9.07	Similar
VT 02.3.0	CWS	TEP / TCCA / MRC	X	0.32 *ns*	2	18	0.73	-2.03	0.54 *ns*	1	20	0.59	8.48	Similar
VT 03.1.0	OWS	TEP / TCCA / MRC	-	0.12 *ns*	2	18	0.88	-2.22	0.05 *ns*	2	20	0.95	7.69	Similar
VT04.1.0	SWS	TEP / MRC	-	0.20 *ns*	1	12	0.66	-2.44	0.62 *ns*	1	13	0.45	7.51	Similar
RESTRICTED DATA SET														
VT 01.2.1	SSF	TEP / TCCA	-	0.04 *ns*	1	10	0.84	-2.54	0.21 *ns*	1	11	0.65	10.40	Similar
VT 01.2.2	ISF	TEP / TCCA	-	0.38 *ns*	1	10	0.55	-1.96	2.28 *ns*	1	11	0.16	9.14	Similar
VT 02.1.0	CWT	TEP / TCCA / MRC	X	1.77 *ns*	2	15	0.20	-3.03	1.84 *ns*	2	17	0.19	10.16	Similar
VT 02.2.0	CWC	TEP / MRC	-	0.05 *ns*	1	10	0.82	-2.85	4.31 *ns*	1	11	0.06	10.41	Similar
VT 02.3.0	CWS	TEP / TCCA / MRC	-	0.24 *ns*	2	15	0.79	-2.67	0.95 *ns*	1	17	0.41	9.78	Similar
VT 03.1.0	OWS	TEP / TCCA / MRC	X	3.38 *ns*	2	15	0.06	-3.49	1.49 *ns*	2	17	0.25	10.24	Similar
VT04.1.0	SWS	TEP / MRC	X	1.98 *ns*	1	10	0.19	-3.94	3.57 *ns*	1	11	0.09	10.54	Similar

Notes:		
	**	Highly significant ($p \leq 0.01$)
	*	Significant ($p \leq 0.05$)
	ns	Not significant ($p > 0.05$)
	Validity[a]	a X sign represents the data set where F was the most significant and r^2-values reflected the best fit of the data, the X marked analysis should be selected for discussion
	(abbr.)*	Abbreviated form, see Table 1 for details

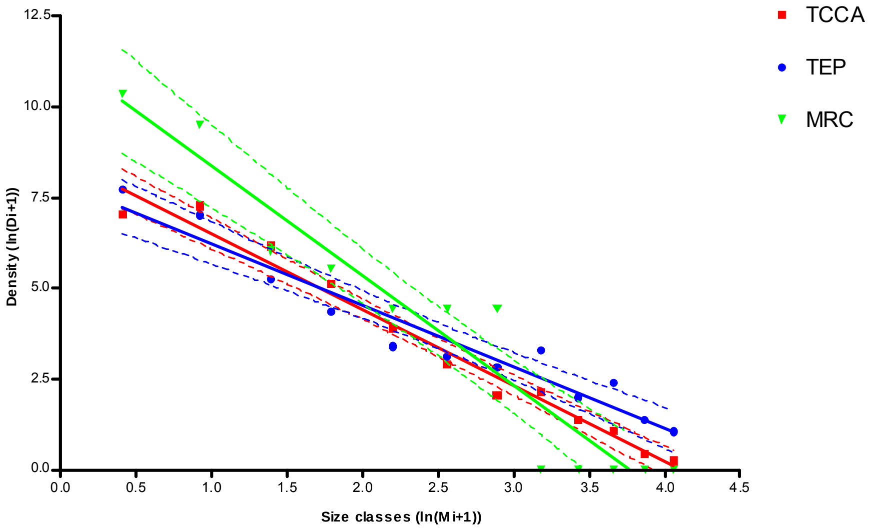


(a) CWS complete SCD analysis

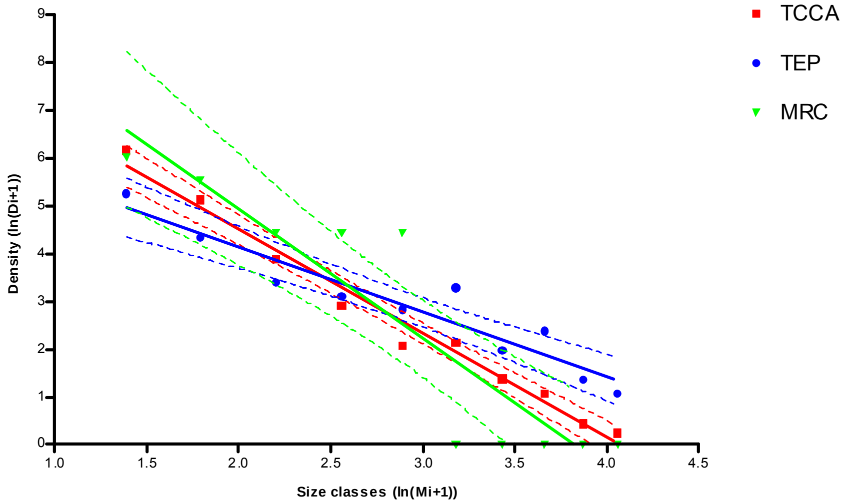


(b) CWS restricted SCD analysis

Figure 4: Stem diameter size class distribution in the Closed Woodland on Sand (CWS) in Tembe Elephant Park (TEP), Tshanini Community Conservation Area (TCCA) and the Manqakulane village zone area (MRC). (a) A linear regression on all 12 size classes, (b) linear regression excluding the smallest two size classes. The dotted lines represent the 95% confidence intervals.



(a) OWS complete SCD analysis



(b) OWS restricted SCD analysis

Figure 5: Stem diameter size class distribution in the Open Woodland on Sand (OWS) in Tembe Elephant Park (TEP), Tshanini Community Conservation Area (TCCA) and the Manqakulane village zone area (MRC). (a) A linear regression on all 12 size classes, (b) linear regression excluding the smallest two size classes. The dotted lines represent the 95% confidence intervals.

In essence, there appeared to be a clear difference in horizontal structure between the sites. From the five possible comparisons between Tembe and Tshanini, a similarity was only observed for the Closed Woodland Thicket unit. The woodlands of Tembe and Manqakulane were similar, except for the Open Woodland on Sand, while the three comparable woodlands of Tshanini and Manqakulane differed only in the Closed Woodland on Sand. The vertical structure of the three sites was not different.

Discussion

It is evident that the size class structure of vegetation units in Tshanini is markedly different from their counterparts in Tembe and Manqakulane. Gaugris *et al.* (2004) established a remarkable similarity in floristic composition between the Tembe and Tshanini sites but reported that cover-abundance of species varied significantly. Such heterogeneity among sites of similar vegetation types is not unknown, and is often linked to various modes of utilisation such as the presence/absence of animals, especially elephants (Sheil and Salim 2004; Babweteera *et al.* 2007), or the importance of traditional and commercial human activities (Poorter *et al.* 1996; Chapman and Chapman 1997; Chapman *et al.* 1997; Fashing and Mwangi Gathua 2004; Sheil and Salim 2004).

Besides the underlying geology and edaphic factors, vegetation in Africa is controlled by a fine balance of disturbances in the form of animal utilisation (Sheil and Salim 2004; Babweteera *et al.* 2007; O'Connor *et al.* 2007), climate (Lindenmayer *et al.* 2006; O'Connor *et al.* 2007), fire (Bond *et al.* 2003; Bond and Keeley 2005; Bond *et al.* 2005; Banda *et al.* 2006a) and people (Omeja *et al.* 2004; Boudreau and Lawes 2005; Banda *et al.* 2006b; Degen *et al.* 2006; Lindenmayer *et al.* 2006; Lindenmayer and Noss 2006; Ndangalasi *et al.* 2007). The balance between all of these elements varies continuously in time and place and represents the basis for the observed biodiversity (Gillson *et al.* 2003). While it appears that all elements are needed to maintain a high level of heterogeneity conducive to rich biodiversity (Perrings and Lovett 1999), the dominance of one or several of these elements can have the opposite effect (Chapman *et al.* 1997; Western and Maitumo 2004; Banda *et al.* 2006b; Western In Press). The overwhelming presence of man can have associated effects such as the confinement, reduction and even extirpation of animal populations (Babaasa 2000; Maisels *et al.* 2001; Babweteera *et al.* 2007).

To explain the differences in the present study, it is important to look at the above elements. Yeh *et al.* (2000) contend that when study sites are within a 7 km radius from a weather station, then the climate attributes of all sites within that area are similar. In the present study the close proximity (6 – 7 km radius) of all three sites in space most likely rules out climatic factors particular to one site as an explanation for these differences. Additionally, there is no climatic event of catastrophic nature recorded since 1989, or even 1983 (Matthews 2006; Guldemond and Van Aarde In Press), and therefore the most likely answer lies in the influence of fire, herbivores and man.

Fire is a semi-controlled element in the woodlands of Tembe (Matthews 2006), but an uncontrolled and frequent event in Manqakulane and Tshanini, and is applied especially to stimulate grass re-growth for cattle grazing (Gaugris *et al.* 2004). Repeated fire leads to low fuel loads, which in the absence of animals, favour tree re-growth (Western and Maitumo 2004; Ickowitz 2006; Western In Press). In the presence of animals, the tree component in African woodlands is contained and the tree-grass balance is maintained. However, when the animal component exceeds the density that the system can sustain, especially grazers, the combination of fire and high animal density leads to a shift from closed to open or sparse woodlands (Salvatori *et al.* 2001; Walpole *et al.* 2004; Western and Maitumo 2004; Western In Press).

Rural people in Africa use trees mainly as sources of firewood, charcoal and building (Banks *et al.* 1996; Lawes *et al.* 2004; Boudreau *et al.* 2005; Banda *et al.* 2006b; Naughton-Treves *et al.* 2007; Ndangalasi *et al.* 2007), and will deforest areas for cultivation (Ickowitz 2006). Rural people usually deplete the stocks of various animal populations (Maisels *et al.* 2001; Banda *et al.* 2006b; Laurance *et al.* 2006), which can have further detrimental effects on vegetation dynamics (Maisels *et al.* 2001; Babweteera *et al.* 2007). The effect of people on vegetation through shifting cultivation is temporary, provided it remains non-commercial, and vegetation communities tend to recover after use, as long as the soil seed bank has remained and soil nutrients have not been depleted (Colón and Lugo 2006; Ickowitz 2006; Karlowski 2006). The above described effects are encountered in the Manqakulane area as well as in Tshanini. As such, the absence of wild animals in Manqakulane and Tshanini was diagnosed (Gaugris 2004; Gaugris *et al.* 2004; Guldemond and Van Aarde In Press), as well as the abandonment of fields on the eastern boundary of Tshanini (Gaugris 2004), where natural woodland vegetation appears to be coming back (Open Woodland on Abandoned Household site unit in the present study, see Table 1)

In the present study, differences between the three sites appear in three forms. The first noticeable difference is between complete and restricted analyses, in the horizontal and vertical structures. The most common case (case 1, 13 units) showed a shallower SCD slope in the restricted analysis than in the complete analysis;

associated with the opposite in the HCD analysis (the slope is steeper in the restricted analysis). The second most common case (case 2, six units) showed a steeper slope in the restricted analysis than in the complete analysis in both SCD and HCD analyses. The third case (case 3, two units) had a steeper restricted analysis SCD slope than the complete analysis, but a shallower restricted analysis HCD slope than in the complete analysis.

Case 1 implies an abundance of small trees, which are not found in the smallest height class of the HCD analysis. This represents an abundance of small but relatively tall trees. The latter is quite typical of an increased light availability where species compete for light by growing tall fast (Poorter *et al.* 1996; Myers *et al.* 2000; Paul *et al.* 2004). This pattern is only documented in the Tembe and Manqakulane sites, especially in the woodlands, but also in the *Afzelia quanzensis* unit. While light availability could explain such a phenomenon in forest or thicket, in the woodlands it is most likely a result of growth of some woody species stimulated by the opening of the canopy by fire (Banda *et al.* 2006a; Karlowski 2006), large mammals (Western In Press), or people (Schwartz and Caro 2003; Boudreau *et al.* 2005) or a combination thereof.

In case 2, the dearth of small individuals found in the SCD is also found in the HCD and implies either removal of seedlings by animals, or a limited recruitment due to unfavourable conditions such as shading for light demanding pioneer species (Everard *et al.* 1994; Everard *et al.* 1995; Poorter *et al.* 1996; Obiri *et al.* 2002; Lawes and Obiri 2003; Schwartz and Caro 2003; Fashing and Mwangi Gathua 2004; Boudreau *et al.* 2005; Lawes and Chapman 2006). This particular case is found in Tembe's Sand Forest units and Tshanini's woodlands.

In case 3, there is a dearth of the smallest individuals in the horizontal structure that contrasts with an abundance of small individuals in the vertical structure. This particular case was associated with the abundance of semi-woody scrambling plants such as lianas, whereby size classes can be large, but height classes remain low (Fashing and Mwangi Gathua 2004; Lawes and Chapman 2006). This type of structure can limit the growth of seedlings and saplings of other species. Gaugris (2004) described in the Sand Forest units of Tshanini a ground layer of liana such as *Uvaria lucida* and *Uvaria caffra,* and vines such as *Rhoicissus revoilii* sprawling on the Sand Forest floor, which was not described for Tembe (Matthews *et al.* 2001). This particular feature suggests that in the absence of animals, a ground cover may develop in the Sand Forest

The next type of difference lies in the centroid's shift. To an extent this particular feature corroborates the above-mentioned differences in the SCD/HCD slopes. The centroid (or mean stem diameter/height location) is predicted to increase as the proportion of large individuals increases (Lawes and Obiri 2003; Niklas *et al.* 2003). In the present study the shift of the centroid position between the complete and restricted analyses was expected to represent the contribution of the smallest individuals in the size/height class distribution structure. While the change in SCD centroid location between the full and restricted analysis were largely within similar size or height classes at the different sites, the SCD centroid shift was lowest in Tshanini, therefore indicating a lower contribution of smallest individuals to the size class distributions than at other sites. The large SCD centroid shift at the other sites therefore indicates a greater contribution of the smaller individuals, and therefore a higher recruitment rate. One explanation is that vegetation units of Tshanini, especially the woodlands, are less disturbed than those of Manqakulane and Tembe (Gaugris 2004). Support of this explanation lies in the different years in which the sites in Tembe and Manqakulane (2004) and Tshanini were sampled (2001). Tshanini was sampled one year after abnormally high rainfall, which was expected to stimulate regeneration but did not, while Tembe and Manqakulane were sampled during a dry spell, which was expected to have the opposite effect (Brokaw and Busing 2000; Niklas *et al.* 2003; Babaasa *et al.* 2004; Matthews 2006).

Furthermore, in all but one instances, the restricted analysis SCD centroid of vegetation units in Tshanini are located within a lower size class than in Tembe and Manqakulane, while the HCD centroid is located in a higher size class (except short Sand Forest, where it is within the same size class). A logical deduction is that there is a greater abundance of tall trees with smaller diameters in Tshanini than in Tembe and Manqakulane. This particular aspect hints at a greater competition for light (Babaasa *et al.* 2004) in Tshanini, and therefore the assumption that canopies in Tembe and Manqakulane have more gaps than in Tshanini, following utilisation either by man or herbivores (Condit *et al.* 1998; Boudreau *et al.* 2005).

The final type of difference is expressed in the statistical comparisons of the SCD slopes and Y-axis intercepts between different sites. Both the complete and restricted analyses show remarkably well that Tshanini is different from both Tembe and Manqakulane and that the woodlands of the latter two sites appear remarkably similar. Only in the case of the Closed Woodland Thicket restricted analysis are the three sites similar. In the woodlands the following hypothesis is proposed: based on a review of literature, a combination of animal utilisation and fire management in Tembe, and people utilisation through shifting agriculture and utilisation of trees for firewood and building wood in Manqakulane have modified the structure of Closed Woodland Thicket, Closed Woodland on Clay, Open Woodland on Sand, and Sparse Woodland on Sand. The large pools of smaller individuals, the steep slopes, and the SCD and HCD centroids generally skewed to the left of the size class distributions (towards smaller size classes) all hint at communities where disturbance is an active process (Condit *et al.* 1998; Niklas *et al.* 2003; Gaugris and Van Rooyen In Press), whereas these appear less clear cut for the Tshanini site.

The Sand Forest units offer a perplexing situation. The Short Sand Forest communities of the two sites are distinctly different, with that of Tshanini having a much steeper SCD slope and higher Y-axis intercept. It is therefore assumed that in Tshanini, Short Sand Forest is at an earlier successional stage than in Tembe (Denslow 1995; Babaasa *et al.* 2004). The Intermediate Sand Forests also differ but in the opposite direction and there appear to be a generally greater abundance of trees in all size classes in Tembe than in Tshanini. This particular aspect can possibly be linked to thinning, which in association with normal natural mortality in areas of low disturbance is recognised to lower tree density (Niklas *et al.* 2003). However, the latter does not totally conform to the theory, which would require a shift in the centroid to the right, as “average stem diameter increases with increasing maximum stem diameter” (Gaugris 2004). Moreover, since density of trees in the Intermediate Sand Forest of Tembe is higher than in Tshanini, it can be equally be assumed that the self-thinning limit has not yet been reached for Tshanini. Other alternatives are that the general lower density in Tshanini represents a less mature and more active vegetation community, or it may also represent a ghost of human harvesting activities before the 1992 move of the village in the east. The lack of old harvesting marks (Lindenmayer *et al.* 2006) does not weigh in favour of the latter theory, although it cannot be fully discarded.

Alternatively, the increase in numbers in the Intermediate Sand Forest in Tembe could be the result of disturbance in forests. Canopy gaps are created by elephants in the Sand Forest of Tembe (Shannon 2001; Matthews 2006) and it appears possible that increased light levels, or a greater light continuum (Van Rensburg *et al.* 1999; McGeogh *et al.* 2002) leads to an increased density of species throughout. The higher density of larger trees in Tembe can however not be explained satisfyingly in such manner as the time scales implied are much longer than those debated within the present study. The perceived fragility of Sand Forest in the current climatic context (Matthews 2006) implies that the larger the gaps, the more prone to fire and destruction the Sand Forest will become and theory indicates that larger gaps may also favour species regeneration suites different from the current assemblage (Brokaw and Busing 2000; Babaasa *et al.* 2004; Karlowski 2006).

The current size of gaps in Sand Forest remains to be determined, although Shannon (2001) established the presence of two gap types, termed refuges, where elephants opened the Sand Forest canopy either severely or in a minor way. It is contended that until relatively recently the elephant population in Tembe might have contributed to a more diverse Sand Forest, however, the differences observed in other communities and a review of literature on the subject beg the question: until when (Van Rensburg *et al.* 1999; Matthews 2006)?

In conclusion, a difference at the unit level between similar vegetation types in three locations and under different utilisation regimes has been established for this part of Maputaland. It appears clear that people and animals influence the vegetation in a distinctive and rapid manner as the differences presented here are expected to represent the changes in vegetation unit structure over a period of less than thirty years. These results corroborate previous conclusions regarding the canopy opening and woody species modification effect of elephants on woodlands in Tembe (Guldemond and Van Aarde In Press) but go against other conclusions by the same authors. Most notably, there is an effect of herbivores on Sand Forest and all woodland units, not restricted to the open woodlands, but also areas outside conserved areas under human influence are most likely to be in a highly disturbed state. More importantly these results present the first systematic quantification of changes between vegetation communities under different utilisation regimes in Maputaland and provide the first estimate of the time scale at which processes take place.

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CHAPTER 6

A SPECIES LEVEL ANALYSIS OF THE EFFECT OF HERBIVORES AND MAN ON THE SAND FOREST VEGETATION OF MAPUTALAND, NORTHERN KWAZULU-NATAL, SOUTH AFRICA

Abstract

Sand Forest in the northern Maputaland region of KwaZulu-Natal in South Africa is deemed the most valuable, but also probably the most complex vegetation type of this part of the Maputaland – Pondoland – Albany hotspot of biodiversity. Its structure and dynamics have been provisionally described but the descriptions remain mostly speculative. The current human population growth in that region called for an in-depth investigation of the forest structure and dynamics in order to evaluate the most successful conservation options available. It appears that Sand Forest is a complex assemblage of at least three tree communities defined by different canopy and subcanopy levels. It is dominated by fine-grained species with an ideal population structure (inverse J-shaped) and therefore can be considered a fine-grained forest. The three communities appear to define a gradient in grain and may represent successional stages of the Sand Forest sub-association as a whole. The forest regeneration appears dependent on the creation of small canopy gaps either by natural processes or elephants, while the creation of large gaps seems to lead to a successional change to woodland. Management of conservation areas where Sand Forest occurs should therefore concentrate efforts on regulating animal populations to levels that provide gap properties that favour forest regeneration.

Keywords

Elephant, fine-grain forest, gaps, Sand Forest, size class distribution, succession, vegetation dynamics

Introduction

The structure and dynamics of African forests remain relatively poorly documented. The number of long-term studies on large plots, allowing a good understanding of forest dynamics and structure is limited to a few sites in Central and East Africa (Condit 1995; Hitimana *et al.* 2004; Ndangalasi *et al.* 2007). In general, information is most often gathered through a single survey, describing size class frequencies (Condit *et al.* 1998; Obiri *et al.* 2002), which provide a largely static representation of the plant populations at the time of study. To gain an understanding of dynamics, repeated surveys would be needed (Obiri *et al.* 2002; Lawes and Obiri 2003).

Because such punctual surveys are often the only source of information available (Obiri *et al.* 2002; Lawes and Obiri 2003; Niklas *et al.* 2003), a range of techniques have been devised to derive as much knowledge as possible from simple size class distributions. These techniques range from fitting a regression slope to the size class distributions and discussing the steepness of the slope (Poorter *et al.* 1996; Lykke 1998; Lawes and Obiri 2003; Niklas *et al.* 2003), evaluating the position of the mean diameter of the population (Niklas *et al.* 2003), and determining the grain of forests and species (Midgley *et al.* 1990; Everard *et al.* 1994; Everard *et al.* 1995; Obiri *et al.* 2002; Lawes and Obiri 2003). Although these methods do not replace long-term studies, the combination of these methods allows forestry practitioners to make some inferences on population dynamics (Obiri *et al.* 2002; Lawes and Obiri 2003; Niklas *et al.* 2003; Boudreau *et al.* 2005).

The importance of such analyses is emphasised by the traditional value of forests for poor rural people. Rural people utilise forests freely to obtain a large range of products, thereby saving the few cash resources for other uses (Madubansi and Shackleton 2006; Shackleton *et al.* 2007). Even in South Africa where alternative sources of energy have been provided to rural households, the contribution of firewood for heating and cooking has remained unchanged, while the new energy has been used for luxury items (Madubansi and Shackleton 2006; Shackleton and Shackleton 2006; Madubansi and Shackleton 2007). Despite such government programmes for development in the more advanced countries, the utilisation of natural resources by rural people remains essential to survival, and in areas of high demographic growth the sustainability of resources becomes questionable (Shackleton 1993; Banks *et al.* 1996; Shackleton 1998; Emanuel *et al.* 2005; Shackleton *et al.* 2005). In these areas, valuing the wealth represented by the resource base is essential, but understanding the limits imposed by the dynamics of the resource base is critical to ensure its future (Obiri *et al.* 2002; Lawes and Obiri 2003; Boudreau and Lawes 2005; Boudreau *et al.* 2005; Emanuel *et al.* 2005; Pote *et al.* 2006).

In Maputaland, the trend in demographic growth is upwards (Kloppers 2001; Matthews 2006; Peteers 2005; Jones 2006) and while resource utilisation until present appears, for the most part, to have been limited (Brookes 2004; Gaugris *et al.* 2004; Gaugris *et al.* 2007), it has become clear that the modernisation of society is shifting the utilisation patterns towards increased clearing of land for the creation of new households as the number of residents per households decreases (Peteers 2005).

Additionally, in the past six years Maputaland has emerged as a new tourism destination in South Africa, and therefore the natural demographic growth in the region is likely to be increased by immigration of people towards the economic hubs of Maputaland to benefit from tourism-related activities (Matthews 2006; Peteers 2005). The present state of affairs calls for an evaluation of the natural resource base, and its dynamics.

The study area encompasses two sites in the remote, rural, and poor northern Maputaland region of KwaZulu-Natal in South Africa (-26.85 ° to -27.15 ° South and 032.35 ° to 032.60 ° East). Site one is located in Tembe Elephant Park (Tembe), site two in the neighbouring Manqakulane rural community (6 km south of the southern fence of Tembe), where the Tshanini Community Conservation Area lies (Tshanini). These selection of these two sites allowed an analysis of the effect of herbivores, especially the African elephant *Loxodonta africana* (Blumenbach 1797), on individual tree species by comparing Tembe (with herbivores) to a control area (Tshanini) where utilisation by people and herbivores was low to nil (Gaugris *et al.* 2004).

The effect of herbivores on Sand Forest is a much-debated topic since the late 1990s, but it is undermined by a blatant lack of reliable and in-depth information on the Sand Forest structure and dynamics. Despite being a unique, valuable and important vegetation type, Sand Forest remains a poorly documented forest type in South Africa. The sum of recent available knowledge on this vegetation unit rests on a cumulative total of 31 plots (5 + 8 + 18 plots) surveyed by three separate studies (Matthews *et al.* 1999; Matthews *et al.* 2001; Gaugris and Van Rooyen In Press). The need for additional knowledge is essential for understanding the structure and dynamics of such a special vegetation type, and the influence that animals may have.

In the present study, the objectives were to present new and more extensive information on the Sand Forest structure, but also to discuss the potential effect of herbivores. To present these aspects, the size class distributions of woody species from the Sand Forest vegetation, under differing utilisation regimes during the 15 years prior to the present study, were evaluated. The range of techniques available for single surveys were utilised and expanded to present the woody species population structures at both sites, but also to compare them between sites and evaluate the influence of herbivores on the woody species population structure. It is hoped that these comparisons will allow a better understanding of the influence of herbivores on the sensitive Sand Forest.

Study area

The study area is situated in the Maputaland coastal plain at nearly equal distance from the sea to the east and the Lebombo Mountain Range to the west. The Maputaland coastal plain consists of a sandy plain interspersed with ancient littoral dunes, vegetated by open to closed woodlands, with patches of the rare Sand Forest vegetation. The Muzi Swamp runs along the eastern side of the study area (Matthews *et al.* 2001; Gaugris *et al.* 2004). The region experiences hot, wet, and humid summers, while winters are cool to warm and dry. The mean annual rainfall for the region was 721 mm in the period from 1981 to 2003 (Matthews 2006).

The creation of Tembe in 1983 stemmed from a desire to conserve the region's remaining wildlife and protect the biodiversity rich Sand Forest vegetation from utilisation by people. The park's 30 000 ha were fenced in two stages, the South African sides in 1983, followed by the northern border with Mozambique in 1989. The conservation policy for Tembe has been one of low tourism development, and the park's main purpose was to preserve the region's rare vegetation and wildlife rather than attract mass tourism (KwaZulu-Natal — Nature Conservation Services 1997; Browning 2000). As a consequence, Tembe has received little tourism for most of its lifespan and the conservation principle has been criticised as it does not provide enough economic returns for the neighbouring communities. A thorough description of Tembe appears in Matthews *et al.* (2001).

Tshanini Game Reserve was established in 2000 on the western 2 420 ha section of tribal land of the Manqakulane Community. It was renamed Tshanini Community Conservation Area and gazetted in December 2005. Until 1992 this land was used by the people, supplying them with building material, firewood, grazing and hunting grounds, fruit and honey, while some areas on the eastern side were cleared for subsistence cultivation. However, in 1992, the people moved eastwards to the Muzi Swamp area where a government-installed water supply and better soils promised an easier life (Gaugris 2004). Tshanini has been relatively untouched since that date, protected by the people's desire to turn it into a conservation area (Gaugris *et al.* 2004). Tshanini is fully described in Gaugris *et al.* (2004).

A total of five Sand Forest vegetation units were sampled in the two study sites (Table 1). Three new vegetation types were sampled in Tembe, namely a new type of Sand Forest vegetation (presented in Chapter 4 of the present study), and the *Afzelia quanzensis* clumps and *Afzelia quanzensis* forest. The latter two are not described by Matthews *et al.* (2001) or Gaugris *et al.* (2004), and expert opinion was used to name them, despite the lack of data to prove their status adequately.

Table 1: Sand Forest types of the study area in Maputaland, northern KwaZulu-Natal, South Africa

Code	Abbreviation	Community name	Synonym in other studies
1		Sand Forest association	
1.1	AQ	*Afzelia quanzensis* subassociation	Newly described in the present study
1.1.1	AQC	*Afzelia quanzensis* clumps	Newly described in the present study
1.1.2	AQF	*Afzelia quanzensis* forest	Newly described in the present study
1.2	SF	Sand Forest subassociation	
1.2.1	SSF	Short Sand Forest	Short Sand Forest in Matthews *et al.* (2001) and Gaugris *et al*. (2004)
1.2.2	ISF	Intermediate Sand Forest	Tall Sand Forest in Matthews *et al.* (2001) and Gaugris *et al*. (2004)
1.2.3	TSF	Tall Sand Forest	Newly described in the present study, replaces TSF of Matthews *et al.* (2001) and Gaugris *et al*. (2004)

Methods

In the present study, rectangular plots of varying length and width, depending on the vegetation density, were used to obtain abundance and size class distribution data of tree species in the two sites studied. A total of 254 plots were surveyed in the region, of which 59 plots were sampled in the Sand Forest in Tembe and 18 plots in that of Tshanini. The data were captured in Microsoft Excel spreadsheets and then compiled into a Microsoft Access database.

A classic species based size class distribution regression analysis on the spread of stem diameter values of woody plants (hereafter referred to as the SCD analysis) in each vegetation unit was conducted. The limitations of such analyses for obtaining information on population dynamics are acknowledged (Condit *et al.* 1998; Niklas *et al.* 2003). However, it is expected that the range of other factors evaluated in the present study, such as centroid location, contribution of smaller size classes, subcanopy and canopy densities, frequency, and the fact that two study sites are compared, one of which is considered a control area, will contribute to a much improved insight in the species population structure and possibly dynamics of Sand Forest vegetation.

Stem diameter measurements of woody plants (for multi-stemmed individuals only the largest stem diameter was included for calculations) were classified into 12 size classes of varying diameter width measured in centimetres (>0 to <1 cm, 1 to <2 cm, 2 to <4 cm, 4 to <6 cm, 6 to <10 cm, 10 to <14 cm, 14 to <20 cm, 20 to <26 cm, 26 to <34 cm, 34 to <42 cm, 42 to <52 cm, ≥ 52 cm). The variations in diameter segments were used to accommodate approximately equal numbers of individuals in each size class with increasing size because the number of individuals generally declines with size (Condit *et al.* 1998; Lykke 1998). The size classes were selected after a careful review of the stem diameters observed in the region (Brookes 2004; Gaugris 2004; Gaugris and Van Rooyen In Press).

The number of individuals in each size class is divided by the width of the class to obtain a mean number of individuals per diameter unit in each class (Condit *et al.* 1998) before calculating the density (Di) per size class per vegetation unit per species in each study site. The stem density per species per vegetation unit was calculated to reflect species frequency in the plots to avoid the density dilution observed in habitat density calculations (Lawes and Obiri 2003). The class midpoint (Mi) was set as the halfway measurement for each size class for each diameter size class (Condit *et al.* 1998).

Once Di and Mi were established, normal logarithmic transformations (Condit *et al.* 1998) of the type ln(Di+1) and ln(Mi+1) were used to standardize the data (Niklas *et al.* 2003) before calculating the least square linear regressions fitting the data. The value of 1 was added as some size classes' bins were not represented (Lykke 1998). The regressions were calculated with ln(Mi+1) values as the independent variable and ln(Di+1) values as the dependent variable (Condit *et al.* 1998; Lykke 1998). The slopes of these regressions are referred to as SCD slopes.

The minimum number of individuals sampled to perform a reliable regression analysis was set at 30 (hereafter referred to as the full analysis) (Niklas *et al.* 2003). Regressions were also calculated for species with a sampled number of individual comprised from 10 to 29 (hereafter referred to as the limited analysis) as some authors consider it a sufficient sample size (Condit *et al.* 1998; Lykke 1998). However, these species are treated separately and greater attention is paid to the significance of F and the r^2 values when they are considered. Diameter size classes up to the largest size class with individuals present are included in the regressions; larger, empty size classes are omitted. For each regression, the site, vegetation unit, species, slope, Y-axis intercept, r^2 value, significance of F, number of size classes over which the regression was calculated and the number of individuals sampled are indicated.

A link has been established between the position of the mean diameter of the species population structure, termed "centroid", and the size class distribution midpoint. A centroid skewed to the left of the midpoint indicates a young and growing population, whereas one skewed to the right indicates an older, relatively undisturbed population (Niklas *et al.* 2003). In the present study, the centroid is calculated in two ways. Centroid 1 represents the centroid position when the whole data set including all 12 size classes is analysed; whereas centroid 2 is calculated on a data set restricted to size classes ranging from 3 to 12 to remove the potential effect of weather on seedling germination. The species size class distribution centroid (centroid 1) represents the mean diameter at the species population level, and the diameter size class in which it is located is therefore indicated (Niklas *et al.* 2003). The location of centroid 2 is more meaningful, as it establishes the mean diameter of the established tree strata (Niklas *et al.* 2003). The magnitude of the shift from centroid 1 to centroid 2 indicates the relative importance of small individuals at the time of the study.

The subcanopy and canopy densities per species were also calculated. In the present study, these correspond to the sum of densities per species for the size classes 3 to 6 for the subcanopy category, thereby removing all the seedlings and saplings from the analysis, and the size classes 7 to 12 for the canopy category. The frequency of occurrence for each species in each vegetation unit was calculated as the percentage of plots in which it occurred per vegetation unit (Lawes and Obiri 2003). The use of subcanopy and canopy densities, associated with the frequency of occurrence allows the determination of species grain.

The graphical model of Lawes and Obiri (2003) to determine the grain of species by plotting canopy density on the X-axis and subcanopy density on the Y-axis, is used to define which species are fine, coarse, or intermediate-grained. The model appears in Figure 1, and ln-transformed values were used to facilitate reading due to high densities and large density variations observed in the study area sites. The same critical lower bounds for canopy, subcanopy and frequency of occurrence levels as Lawes and Obiri (2003) were used. These authors evaluated a range of forests from the Eastern Cape and KwaZulu-Natal provinces of South Africa using this model, and it was deemed judicious to use the same limits to allow comparison at the regional level. These boundaries were 10 and 30 individuals per ha for the canopy and subcanopy levels respectively, and a minimum of 50% frequency of occurrence in the sampled plots for a species to be considered fit for selection in the model. Grain is further determined by the position of species in the scatter plot within the above boundaries, and the relative position above (intermediate to fine-grain) or below (intermediate to coarse-grain) a line that represents equal densities at canopy and subcanopy levels. Frequency of occurrence was not represented graphically as it was already provided in the previous analysis.

A convenient grouping of the species in three Types depending on the steepness of the slope is presented. The Types are:

- Type 1, species with slopes steeper or equal to half that of the vegetation unit (calculated on all individuals of all species, see Chapter 5) evaluated in the particular utilisation regime. These species show good regeneration.
- Type 2, species with slopes shallower than half that of the vegetation unit evaluated in the particular utilisation regime, but steeper than a threshold fixed at a slope coefficient of -0.15 (Lykke 1998).
- Type 3, species with slopes shallower than the above threshold or with positive slope coefficients.

Finally, the slopes and Y-axis intercepts of regressions were compared for species found within the same vegetation unit but under different utilisation regimes by means of an analysis of covariance (ANCOVA) by using the GraphPad PRISM 4 software (Windows version, GraphPad Software, San Diego California USA, www.graphpad.com). This analysis first compares the regressions slopes, and should there be no significant difference between slopes, the Y-axis intercepts are then compared. When slopes are similar, a pooled slope value is given, and when Y-axis intercepts are similar, a pooled Y-axis intercept value is presented. Should there be no significant difference at either slope or Y-axis intercept levels, the species present in the two sites, can be described through the pooled slope and Y-axis intercept.

Results

In Tshanini 79 woody species were inventoried and in Tembe105 species. A total of 57 Sand Forest woody species met the criterion for analysis with 55 of these found within the Intermediate Sand Forest, while 33 of them were recorded in the Short Sand Forest.

Short Sand Forest

A total of 22 species were analysed in the Short Sand Forest in Tshanini (Table 2). The species from the full analysis in general had steep slopes, with only 12.50% of species with a flat or positive slope coefficient (*Monodora junodii* and *Boscia filipes*). Important species for household buildings, such as *Brachylaena huillensis* or *Ptaeroxylon obliquum* (Gaugris *et al.* 2007) had steep slope coefficients. However, while the latter species was ubiquitous in this vegetation unit and occurs in great abundance in the subcanopy and canopy levels, the former species was relatively rare (33.33% frequency of occurrence, Table 2) and was only found in the subcanopy.

The most abundant species in the subcanopy in this vegetation unit in Tshanini appeared to be *Hymenocardia ulmoides*, followed by *Psydrax locuples*, while the canopy stratum was dominated by a mixture of *Dialium schlechteri, Ptaeroxylon obliquum* and *Pteleopsis myrtifolia*. The first mentioned can grow into a fairly large tree (Pooley 1997), and represents the most abundant large tree found in the canopy. The other large canopy tree is *Cleistanthus schlechteri*, although it was found at much lower densities in the canopy. In general, most species found at both canopy and subcanopy levels showed a pyramidal structure whereby the subcanopy density was greater than the canopy density.

In the limited analysis, three species of shrubs showed a shallow or positive slope coefficient, denoting struggling populations (Table 2). *Spirostachys africana* is a woodland species (Pooley 1997; Gaugris 2004), and its canopy density was also higher than the subcanopy density.

Mean SCD centroid 2 for both full and limited analyses was located within size class 4 (Table 2). Mean centroid 1 was located within size class 3 in the full analysis

Table 2: Detail of species level size class distribution (SCD) regressions, including statistical significance, the range of size classes (SC) used, number of individuals sampled, centroid 1 position (full data set) centroid 2 position (size classes 3 - 12), subcanopy and canopy density, frequency of occurrence in sample plots, and species grain. The information presented is for the common species for which 30 or more individuals were sampled (full analysis) and those for which 10 to 29 individuals were sampled (limited analysis) of the Short Sand Forest in Tshanini Community Conservation Area, Maputaland, northern KwaZulu-Natal, South Africa

Analysis	Species	Slope	Intercept	R^2	Standard error	F		Degrees of freedom	SC range	Number of individuals	Centroid 1 in SC	Centroid 2 in SC	Subcanopy density (individuals / ha)	Canopy density (individuals / ha)	Frequency of occurrence (%)	Species grain
Community Level	**Community SCD**	**-2.37**	**11.24**	**0.97**	**0.52**	**329.89**	**	**10**	**12**	**2411**						
Full	*Acalypha glabrata*	-1.54	8.18	0.46	1.16	0.85	-	1	3	239	02	03	517	0	50.00	***NA***
Full	*Boscia filipes*	-0.13	2.93	0.00	2.05	0.03	-	6	8	48	05	05	733	33	83.33	Fine
Full	*Brachylaena huillensis*	-2.21	7.29	0.76	0.92	6.22	-	2	4	62	02	04	133	0	33.33	***NA***
Full	*Cleistanthus schlechteri*	-0.93	5.12	0.71	0.62	14.78	**	6	8	41	05	05	483	67	16.67	Fine (*NA*)
Full	*Dialium schlechteri*	-1.06	5.74	0.58	1.01	9.57	*	7	9	80	05	05	1050	150	83.33	Fine
Full	*Drypetes arguta*	-1.25	7.13	0.90	0.30	18.63	*	2	4	115	02	03	833	0	100.00	***NA***
Full	*Grewia microthyrsa*	-0.55	4.59	0.04	2.10	0.07	-	2	4	41	03	03	250	0	100.00	***NA***
Full	*Hymenocardia ulmoides*	-2.71	9.13	0.78	1.58	25.43	**	7	9	298	03	03	3467	17	100.00	Fine
Full	*Hyperacanthus microphyllus*	-0.95	3.87	0.11	2.62	0.63	-	5	7	57	03	03	767	17	100.00	Fine
Full	*Monodora junodii*	1.46	1.31	0.27	1.94	1.13	-	3	5	33	04	04	483	0	100.00	***NA***
Full	*Psydrax locuples*	-1.91	8.11	0.87	0.81	48.65	**	7	9	205	03	04	2150	100	83.33	Fine
Full	*Ptaeroxylon obliquum*	-2.17	8.30	0.85	1.02	39.60	**	7	9	508	02	05	483	133	100.00	Fine
Full	*Pteleopsis myrtifolia*	-1.63	7.08	0.75	1.04	21.34	**	7	9	126	04	04	1567	100	100.00	***NA***
Full	*Salacia leptoclada*	-2.88	8.11	0.85	0.88	11.42	-	2	4	77	02	03	300	0	100.00	***NA***
Full	*Toddaliopsis bremekampii*	-0.88	6.47	0.27	1.16	1.13	-	3	5	153	03	03	1917	0	83.33	***NA***
Full	*Uvaria caffra*	-0.55	3.47	0.03	2.73	0.13	-	4	6	44	03	03	500	0	100.00	***NA***
						Mean SCD centroid location for common species:					03	04				
Limited	*Coddia rudis*	-1.50	5.75	0.97	0.20	28.16	-	1	3	20	02	03	83	0	66.67	***NA***
Limited	*Croton steenkampianus*	4.10	-0.65	0.55	2.59	1.21	-	1	3	17	03	03	100	0	100.00	***NA***
Limited	*Euclea natalensis*	-1.46	5.33	0.76	0.81	15.72	*	5	7	29	03	05	117	17	50.00	Fine
Limited	*Margaritaria discoidea*	0.89	1.66	0.13	1.90	0.44	-	3	5	23	04	04	367	0	50.00	***NA***
Limited	*Ochna arborea*	0.57	1.99	0.04	2.16	0.14	-	3	5	18	03	03	200	0	83.33	***NA***
Limited	*Spirostachys africana*	-0.88	3.95	0.44	1.23	8.01	*	10	12	22	06	08	100	117	50.00	Intermediate
						Mean SCD centroid location for common species:					04	04				

SC	Size Class
**	Highly significant ($p \leq 0.01$)
*	Significant ($p \leq 0.05$)
-	Not significant ($p > 0.05$)
NA	Not applicable, following the species grain, it indicates that while grain could be determined, the frequency of occurrence is too low to warrant inclusion in the model

and size class 4 in the limited one. There was no major shift between the positions of mean centroid 1 and 2 in both analyses.

A total of 18 species were analysed in the Short Sand Forest in Tembe (Table 3). The species *Croton pseudopulchellus* and *Cola greewayi* have the highest subcanopy densities, while the latter also had the highest canopy density. *Brachylaena huillensis* was present in most plots (80.00%), at a higher density than in Tshanini. However, *Dialium schlechteri, Psydrax locuples* and *Pteleopsis myrtifolia*, were present in greater abundance in Tshanini than in Tembe where they were classified within the restricted analysis, and the SCD curve slope coefficients for the first and second species belonged to Type 3. The subcanopy density for *Dialium schlechteri* was lower than its canopy density.

The species classified in the full analysis all showed steep SCD curve coefficients (100.00% of species within Type 1, Table 4), while 45.50% of species in the limited analysis fell within Type 3. Mean centroid 2 fell within size class 4 in the full analysis and size class 5 in the limited analysis, whereas centroid 1 is located in size class 3 and 5 within the full and limited analyses respectively. There is no major shift between the positions of mean centroid 1 and 2 in both analyses.

A comparison of SCD slope coefficients and Y-axis intercepts between the species found within the full analysis (Table 5) at the two sites showed that out of five species in common, only *Drypetes arguta* showed a significant difference at the Y-axis intercept level, with a higher value for the Tshanini site. No species were shared between the limited analyses (Table 5), while three species (*Dialium schlechteri, Psydrax locuples* and *Pteleopsis myrtifolia*) could be compared across analyses (Table 5). The SCD slopes of all three species were significantly different between sites. *Dialium schlechteri* had a positive slope in Tembe, while it was negative and steep in Tshanini, *Psydrax locuples* fell within Type 1 in Tshanini and Type 3 in Tembe, and *Pteleopsis myrtifolia* was classified within Type 1 in Tshanini but in Type 2 in Tembe. This represented a total of eight species compared, four of which showed significant differences in SCD curve shape.

Intermediate Sand Forest

A total of 36 species were analysed in the Intermediate Sand Forest in Tshanini (Table 6). Most species in the full analysis could be classified within Type 1, with a steep slope (Table 4), while the bulk of species in the limited analysis fell within Types 2 and 3. Mean centroid 2 was located within size class 5 for both analyses, while mean centroid 1 was located within size classes 4 and 5 for the full and limited analyses

Table 3: Detail of species level size class distribution (SCD) regressions, including statistical significance, the range of size classes (SC) used, number of individuals sampled, centroid 1 position (full data set) centroid 2 position (size classes 3 - 12), subcanopy and canopy density, frequency of occurrence in sample plots, and species grain. The information presented is for the common species for which 30 or more individuals were sampled (full analysis) and those for which 10 to 29 individuals were sampled (limited analysis) of the Short Sand Forest in Tembe Elephant Park, Maputaland, northern KwaZulu-Natal, South Africa

Analysis	Species	Slope	Intercept	R^2	Standard error	F		Degrees of freedom	SCD range	Number of individuals	Centroid 1 in SC	Centroid 2 in SC	Subcanopy density (individuals / ha)	Canopy density (individuals / ha)	Frequency of occurrence (%)	Species grain
Community Level	**Community SCD**	**-1.92**	**9.91**	**0.98**	**0.30**	**646.82**	**	**10**	**12**	**850**						
Full	*Brachylaena huillensis*	-1.81	6.53	0.83	0.87	28.41	**	6	8	31	03	05	245	19	80.00	Fine
Full	*Cola greenwayi*	-1.35	6.59	0.87	0.55	40.22	**	6	8	63	04	05	660	151	60.00	Fine
Full	*Croton pseudopulchellus*	-2.96	9.90	0.89	0.84	24.93	*	3	5	247	02	03	1264	0	80.00	***NA***
Full	*Drypetes arguta*	-1.66	7.04	0.95	0.40	113.92	**	6	8	59	04	05	698	57	70.00	Fine
Full	*Hymenocardia ulmoides*	-1.54	5.99	0.71	1.02	15.05	**	6	8	31	04	04	453	19	80.00	Fine
Full	*Salacia leptoclada*	-3.11	8.63	0.90	0.85	26.50	*	3	5	65	02	03	321	0	60.00	***NA***
Full	*Toddaliopsis bremekampii*	-1.50	6.31	0.74	0.88	13.92	*	5	7	41	03	04	566	19	60.00	Fine
						Mean SCD centroid location for common species:					03	04				
Limited	*Dialium schlechteri*	0.2	0.73	0.12	0.88	1.37	-	10	12	14	09	09	75	189	80.00	Intermediate
Limited	*Drypetes natalensis*	-1.1	5.28	0.87	0.50	48.32	**	7	9	24	05	05	245	94	80.00	Fine
Limited	*Erythrophleum lasianthum*	0.0	0.99	0.00	1.18	0.01	-	10	12	10	09	09	19	151	80.00	Coarse
Limited	*Ochna natalitia*	-0.4	3.92	0.32	0.53	1.43	-	3	5	12	03	04	189	0	50.00	***NA***
Limited	*Pavetta lanceolata*	2.6	0.34	0.50	1.96	2.02	-	2	4	20	03	03	302	0	40.00	***NA***
Limited	*Psydrax locuples*	-0.07	2.47	0.00	1.52	0.01	-	4	6	10	04	05	170	0	60.00	***NA***
Limited	*Psydrax obovata*	-0.34	3.06	0.04	1.80	0.23	-	6	8	28	05	05	472	38	40.00	Fine (*NA*)
Limited	*Pteleopsis myrtifolia*	-0.57	3.96	0.65	0.46	13.10	**	7	9	23	06	06	226	170	90.00	Fine
Limited	*Tricalysia junodii*	-2.98	7.80	1.00	0.00	0.00	-	0	2	28	01	***NA***	0	0	60.00	***NA***
Limited	*Tricalysia lanceolata*	0.15	2.95	0.00	2.64	0.00	-	2	4	16	03	03	245	0	50.00	***NA***
Limited	*Vepris lanceolata*	-1.11	3.81	0.23	1.97	1.51	-	5	7	13	03	05	94	38	30.00	Fine (*NA*)
						Mean SCD centroid location for common species:					05	05				

SC	Size Class
**	Highly significant ($p \leq 0.01$)
*	Significant ($p \leq 0.05$)
-	Not significant ($p > 0.05$)
NA	Not applicable, when behind species grain, it indicates that while grain could be established, the frequency of occurrence precludes inclusion in the model

Table 4: The percentage of species with Type 1 to 3 slopes for the Sand Forest vegetation of Tembe Elephant Park (TEP) and Tshanini Community Conservation Area (TCCA), for the full (≥ 30 individuals sampled) and limited (10 - 29 individuals sampled) analyses, Maputaland, northern KwaZulu-Natal, South Africa. The total number of species (No spp) for analyses by vegetation unit or sub-unit is indicated in the top line of each analysis

Analysis	Type	Percentage of species per Type by vegetation units and sites					
		Short Sand Forest		Intermediate Sand Forest		Tall Sand Forest	*Afzelia quanzensis* clumps
		TCCA	TEP	TCCA	TEP	TEP	TEP
	No spp →	16	7	22	21	12	2
Full		(%)	(%)	(%)	(%)	(%)	(%)
	Type 1	50.00	100.00	59.09	80.95	100.00	100.00
	Type 2	37.50	0.00	27.27	9.52	0.00	0.00
	Type 3	12.50	0.00	13.64	9.52	0.00	0.00
	No spp →	6	11	14	14	16	8
Limited		(%)	(%)	(%)	(%)	(%)	(%)
	Type 1	33.30	27.27	7.14	35.71	31.25	62.50
	Type 2	16.70	27.27	50.00	21.43	25.00	12.50
	Type 3	50.00	45.45	42.86	42.86	43.75	25.00
	No spp →	22	18	36	35	28	10
Combined		(%)	(%)	(%)	(%)	(%)	(%)
	Type 1	45.45	55.56	38.89	62.86	60.71	70.00
	Type 2	31.82	16.67	36.11	14.29	14.29	10.00
	Type 3	22.73	27.78	25.00	22.86	25.00	20.00

Type 1	slopes steeper or equal to half that of the vegetation unit evaluated
Type 2	slopes shallower than half that of the vegetation unit evaluated but steeper than - 0.15
Type 3	slopes shallower than - 0.15 coefficient or with positive slope coefficients

Table 5: A comparison of size class distribution (SCD) slope coefficients and Y-axis intercepts within species and analyses (F = Full analysis, L = Limited Analysis) in comparable Sand Forest vegetation unit in the study sites Tembe Elephant Park (TEP) and Tshanini Community Conservation Area (TCCA), Maputaland, northern KwaZulu-Natal, South Africa

		Species	Comparison levels		Slope Comparison						Intercept Comparison						Outcome	Note*
VT	Vegetation unit		Sites compared	Analysis	F value		Df $_n$	Df $_d$	P value	Pooled slope	F value		Df $_n$	Df $_d$	P value	Pooled Intercept		
VT 01.2.1	Short Sand Forest	*Brachylaena huillensis*	TEP / TGR	F / F	0.20	-	1	8	0.67	-1.87	0.21	-	1	9	0.66	6.74	Similar	-
		Drypetes arguta	TEP / TGR	F / F	1.06	-	1	8	0.33	-1.60	5.29	*	1	9	0.05	-	Different	-
		Hymenocardia ulmoides	TEP / TGR	F / F	2.77	-	1	13	0.12	-2.20	1.39	-	1	14	0.26	7.69	Similar	-
		Salacia leptoclada	TEP / TGR	F / F	0.05	-	1	5	0.83	-3.03	0.20	-	1	6	0.67	8.41	Similar	-
		Toddaliopsis bremekampii	TEP / TGR	F / F	0.56	-	1	8	0.48	-1.32	3.33	-	1	9	0.10	6.44	Similar	-
		Dialium schlechteri	TEP / TGR	L / F	11.15	**	1	17	<0.01	-	-		-	-	-	-	Different	X
		Psydrax locuples	TEP / TGR	L / F	6.40	*	1	11	0.03	-	-		-	-	-	-	Different	X
		Pteleopsis myrtifolia	TEP / TGR	L / F	7.58	*	1	14	0.02	-	-		-	-	-	-	Different	-
																	-	-
VT 01.2.2	Intermediate Sand Forest	*Brachylaena huillensis*	TEP / TGR	F / F	0.58	-	1	13	0.46	-1.55	29.11	**	1	14	<0.01	-	Different	-
		Cleistanthus schlechteri	TEP / TGR	F / F	0.05	-	1	19	0.82	-0.44	0.19	-	1	20	0.66	3.13	Similar	-
		Cola greenwayi	TEP / TGR	F / F	7.91	*	1	16	0.01	-	-		-	-	-	-	Different	-
		Croton pseudopulchellus	TEP / TGR	F / F	5.51	*	1	10	0.04	-	-		-	-	-	-	Different	-
		Dialium schlechteri	TEP / TGR	F / F	28.13	**	1	19	<0.01	-	-		-	-	-	-	Different	-
		Drypetes arguta	TEP / TGR	F / F	1.06	-	1	11	0.32	-1.90	1.17	-	1	12	0.30	7.37	Similar	-
		Haplocoelum foliolosum	TEP / TGR	F / F	0.55	-	1	17	0.47	-1.02	0.59	-	1	18	0.45	4.04	Similar	-
		Hymenocardia ulmoides	TEP / TGR	F / F	1.20	-	1	16	0.29	-1.61	1.64	-	1	17	0.22	6.25	Similar	-
		Hyperacanthus microphyllus	TEP / TGR	F / F	0.97	-	1	10	0.35	-0.82	4.14	-	1	11	0.07	3.62	Similar	-
		Monodora junodii	TEP / TGR	F / F	0.02	-	1	9	0.88	0.30	0.14	-	1	10	0.72	1.34	Similar	-
		Newtonia hildebrandtii	TEP / TGR	F / F	2.22	-	1	20	0.15	-0.06	0.22	-	1	21	0.64	1.02	Similar	-
		Ptaeroxylon obliquum	TEP / TGR	F / F	2.94	-	1	16	0.11	-1.18	5.08	*	1	17	0.04	-	Different	-
		Pteleopsis myrtifolia	TEP / TGR	F / F	0.00	-	1	16	0.98	-0.63	0.26	-	1	17	0.62	3.62	Similar	-
		Salacia leptoclada	TEP / TGR	F / F	1.48	-	1	7	0.26	-2.84	0.07	-	1	8	0.80	7.32	Similar	-
		Toddaliopsis bremekampii	TEP / TGR	F / F	0.06	-	1	14	0.81	-2.04	0.38	-	1	15	0.55	7.07	Similar	-
		Uvaria caffra	TEP / TGR	F / F	0.78	-	1	8	0.40	-1.23	0.01	-	1	9	0.91	4.21	Similar	-
		Balanites maughamii	TEP / TGR	L / L	7.89	*	1	20	0.01	-	-		-	-	-	-	Different	-
		Grewia microthyrsa	TEP / TGR	L / L	0.03	-	1	6	0.87	-0.33	0.00	-	1	7	0.99	2.28	Similar	-
		Zanthoxylum leprieuri	TEP / TGR	L / L	1.79	-	1	8	0.22	-0.43	1.11	-	1	9	0.32	1.97	Similar	-
		Boscia filipes	TEP / TGR	F / L	0.93	-	1	15	0.35	-0.18	1.48	-	1	16	0.24	1.60	Similar	X
		Psydrax locuples	TEP / TGR	F / L	3.6	-	1	12	0.08	-1.61	9.97	*	1	13	0.01	-	Different	-
		Strychnos henningsii	TEP / TGR	F / L	2.32	-	1	9	0.16	-0.12	1.03	-	1	10	0.33	1.78	Similar	-
		Suregada zanzibariensis	TEP / TGR	L / F	0.29	-	1	6	0.61	-0.58	0.02	-	1	7	0.89	2.58	Similar	X

**	Highly significant ($p \leq 0.01$)
*	Significant ($p \leq 0.05$)
-	Not significant ($p > 0.05$)
Note*	analyses marked with an X were conducted on regression slopes where F was not significant in at least one site

Table 6: Detail of species level size class distribution (SCD) regressions, including statistical significance, the range of size classes (SC) used, number of individuals sampled, centroid 1 position (full data set) centroid 2 position (size classes 3 - 12), subcanopy and canopy density, frequency of occurrence in sample plots, and species grain. The information presented is for the common species for which 30 or more individuals were sampled (full analysis) and those for which 10 to 29 individuals were sampled (limited analysis) of the Intermediate Sand Forest in Tshanini Community Conservation Area, Maputaland, northern KwaZulu-Natal, South Africa

Analysis	Species	Slope	Intercept	R^2	Standard error	F	Degrees of freedom	SC range	Number of individuals	Centroid 1 in SC	Centroid 2 in SC	Subcanopy density (individuals / ha)	Canopy density (individuals / ha)	Frequency of occurrence (%)	Species grain
Community Level	**Community SCD**	**-1.86**	**9.21**	**0.97**	**0.44**	**276.21 ****	**10**	**12**	**2883**						
Full	*Acalypha glabrata*	-1.48	5.45	0.52	1.03	2.20 -	2	4	97	02	03	130	0	91.67	***NA***
Full	*Boscia filipes*	-0.44	2.47	0.13	1.28	1.03 -	7	9	50	05	05	140	13	58.33	Fine
Full	*Brachylaena huillensis*	-1.39	4.18	0.87	0.47	27.85 **	4	6	33	03	05	37	0	8.33	***NA***
Full	*Cleistanthus schlechteri*	-0.47	3.14	0.49	0.58	8.59 *	9	11	90	07	07	113	143	75.00	Intermediate
Full	*Cola greenwayi*	-0.30	3.18	0.03	1.84	0.18 -	6	8	172	05	05	490	30	75.00	Fine
Full	*Croton pseudopulchellus*	-1.22	4.05	0.29	1.73	1.62 -	4	6	68	03	03	127	0	58.33	***NA***
Full	*Dialium schlechteri*	-1.01	4.44	0.84	0.53	47.90 **	9	11	96	05	06	160	70	100.00	Fine
Full	*Drypetes arguta*	-2.13	7.57	0.91	0.67	48.74 **	5	7	392	03	04	560	3	83.33	***NA***
Full	*Euclea natalensis*	-1.63	4.53	0.75	0.92	15.19 *	5	7	44	03	05	13	7	75.00	***NA***
Full	*Haplocoelum foliolosum*	-1.13	4.37	0.89	0.45	53.94 **	7	9	62	05	06	87	30	75.00	Fine
Full	*Hymenocardia ulmoides*	-1.72	6.36	0.93	0.53	113.75 **	8	10	197	04	05	393	17	91.67	Fine
Full	*Hyperacanthus microphyllus*	-1.38	5.26	0.68	0.86	8.37 *	4	6	107	03	04	203	0	100.00	***NA***
Full	*Manilkara concolor*	0.35	1.06	0.11	0.97	0.61 -	5	7	35	05	05	103	10	16.67	Fine
Full	*Monodora junodii*	0.24	1.32	0.04	1.20	0.20 -	5	7	48	05	05	150	3	66.67	***NA***
Full	*Newtonia hildebrandtii*	0.16	0.40	0.08	0.69	0.84 -	10	12	34	09	09	33	80	58.33	Intermediate
Full	*Psydrax locuples*	-1.94	6.08	0.94	0.53	88.47 **	6	8	113	03	04	127	3	58.33	***NA***
Full	*Ptaeroxylon obliquum*	-1.40	5.36	0.99	0.17	745.42 **	8	10	108	04	05	140	33	83.33	Fine
Full	*Pteleopsis myrtifolia*	-0.64	3.56	0.49	0.76	7.66 *	8	10	90	06	06	190	80	100.00	Fine
Full	*Salacia leptoclada*	-2.52	6.76	0.87	0.90	25.66 **	4	6	150	02	03	163	0	83.33	***NA***
Full	*Suregada zanzibariensis*	-0.42	2.27	0.08	1.40	0.44 -	5	7	31	04	04	80	3	58.33	***NA***
Full	*Toddaliopsis bremekampii*	-2.07	7.25	0.89	0.90	70.90 **	9	11	397	03	04	717	3	100.00	***NA***
Full	*Uvaria caffra*	-0.86	3.67	0.21	1.51	1.05 -	4	6	63	03	03	153	0	100.00	***NA***
					Mean SCD centroid location for common species:					04	05				
Limited	*Balanites maughamii*	0.08	0.28	0.06	0.38	0.66 -	10	12	14	10	10	10	37	41.67	Coarse
Limited	*Mystroxylon aethiopicum*	-0.24	1.67	0.07	0.95	0.43 -	6	8	20	05	05	50	10	66.67	Fine
Limited	*Coddia rudis*	-1.79	4.80	0.98	0.20	39.31 -	1	3	29	02	03	17	0	50.00	***NA***
Limited	*Grewia microthyrsa*	-0.50	2.48	0.10	1.11	0.22 -	2	4	13	03	03	17	0	41.67	***NA***
Limited	*Hippocratea delagoensis*	1.08	0.36	0.36	1.19	1.66 -	3	5	29	04	04	93	0	58.33	***NA***
Limited	*Margaritaria discoidea*	-0.68	2.48	0.57	0.48	4.00 -	3	5	11	04	05	20	0	33.33	***NA***
Limited	*Ochna arborea*	-0.11	1.14	0.02	0.78	0.10 -	5	7	10	05	05	27	3	50.00	***NA***
Limited	*Rhus gueinzii*	-0.87	2.87	0.81	0.42	21.02 **	5	7	14	04	05	20	3	58.33	***NA***
Limited	*Rothmannia fischeri*	-0.07	1.27	0.01	0.79	0.06 -	7	9	24	06	06	50	27	58.33	Fine
Limited	*Spirostachys africana*	0.19	-0.09	0.26	0.40	3.08 -	9	11	12	08	08	7	33	33.33	Coarse (*NA*)
Limited	*Strychnos henningsii*	0.54	0.61	0.20	0.89	0.74 -	3	5	12	04	04	33	0	25.00	***NA***
Limited	*Tarenna litoralis*	-0.31	2.20	0.15	0.61	0.53 -	3	5	14	03	04	33	0	25.00	***NA***
Limited	*Vitex ferruginea*	-0.32	1.81	0.19	0.64	1.19 -	5	7	15	05	05	37	7	33.33	***NA***
Limited	*Zanthoxylum leprieuri*	-0.18	1.32	0.04	0.83	0.22 -	5	7	11	04	05	27	3	58.33	***NA***
					Mean SCD centroid location for common species:					05	05				

SC	Size Class
**	Highly significant ($p \leq 0.01$)
*	Significant ($p \leq 0.05$)
-	Not significant ($p > 0.05$)
NA	Not applicable, when behind species grain, it indicates that while grain could be established, the frequency of occurrence precludes inclusion in the model

respectively. There was no major shift between the positions of mean centroid 1 and 2 in both analyses.

Most species in the full analysis had a pyramidal population structure with a subcanopy density of individuals greater than the canopy density, except for *Cleistanthus schlechteri* and *Newtonia hildebrandtii* where the opposite was true (Table 6). This was confirmed in the latter species by the positive curve slope coefficient. The canopy level was dominated by these two species together with *Dialium schlechteri* and *Pteleopsis myrtifolia*, while the subcanopy level was dominated by *Toddaliopsis bremekampii, Drypetes arguta* and *Cola greenwayi.*

In the limited analysis, *Balanites maughamii* showed an inverted pyramid population structure, confirmed by a positive SCD slope coefficient, as did *Spirostachys africana*. Most species classified in this analysis had relatively low density values and did not appear much in the canopy level of the forest except for the above-mentioned species.

Large individuals in size class 12 were sampled for both *Balanites maughamii* and *Newtonia hildebrandtii* (Table 6). Large trees classified in size class 11 were found in the populations of *Cleistanthus schlechteri, Dialium schlechteri,* and *Toddaliopsis bremekampii,* while trees classified in size class 10 were found for *Hymenocardia ulmoides, Ptaeroxylon obliquum* and *Pteleopsis myrtifolia*.

A total of 42 species were analysed in the Intermediate Sand Forest in Tembe (Table 7). The majority of species in the full analysis could be classified into Type 1 (Table 4), while in the limited analysis the majority of species were in Type 3, followed by Type 1. Mean centroid 2 was located within size class 5 for both analyses, while mean centroid 1 was located within size classes 4 and 5 for the full and limited analyses respectively. There was no major shift between the positions of mean centroid 1 and 2 in both analyses.

The subcanopy level of the Intermediate Sand Forest in Tembe (full analysis, Table 7) was dominated by species such as *Croton pseudopulchellus, Drypetes arguta, Cola greenwayi* and *Hymenocardia ulmoides*. The canopy level was dominated by *Cleistanthus schlechteri, Pteleopsis myrtifolia* and *Dialium schlechteri*. Large (size classes 10 and 11) to very large (size class 12) individuals were sampled in a range of species. The population structure of three large canopy trees (*Cleistanthus schlechteri, Dialium schlechteri, Newtonia hildebrandtii*) of this community showed an inverse pyramid shape; whereby the subcanopy density was lower than the canopy density, but other species showed a regular pyramidal population structure.

Table 7: Detail of species level size class distribution (SCD) regressions, including statistical significance, the range of size classes (SC) used, number of individuals sampled, centroid 1 position (full data set) centroid 2 position (size classes 3 - 12), subcanopy and canopy density, frequency of occurrence in sample plots, and species grain. The information presented is for the common species for which 30 or more individuals were sampled (full analysis) and those for which 10 to 29 individuals were sampled (limited analysis) of the Intermediate Sand Forest in Tembe Elephant Park, Maputaland, northern KwaZulu-Natal, South Africa

Analysis	Species	Slope	Intercept	R^2	Standard error	F		Degrees of freedom	SC range	Number of individuals	Centroid 1 in SC	Centroid 2 in SC	Subcanopy density (individuals / ha)	Canopy density (individuals / ha)	Frequency of occurrence (%)	Species grain
Community Level	**Community SCD**	**-1.87**	**9.77**	**0.98**	**0.36**	**414.20**	**	**10**	**12**	**4632**						
Full	*Brachylaena huillensis*	-1.59	5.79	0.96	0.41	196.36	**	9	11	123	03	05	125	21	64.86	Fine
Full	*Cassipourea mossambicensis*	-1.27	4.38	0.88	0.49	44.06	**	6	8	40	04	05	58	9	45.95	***NA***
Full	*Cleistanthus schlechteri*	-0.42	3.12	0.54	0.49	11.58	**	10	12	119	07	08	125	222	81.08	Intermediate
Full	*Cola greenwayi*	-1.84	7.50	0.96	0.45	262.70	**	10	12	461	04	05	703	140	83.78	Fine
Full	*Croton pseudopulchellus*	-3.33	9.84	0.93	0.97	77.45	**	6	8	1241	02	03	971	3	100.00	***NA***
Full	*Croton steenkampianus*	-2.83	6.74	0.85	0.84	5.54	-	1	3	76	02	03	21	0	35.14	***NA***
Full	*Dialium schlechteri*	0.15	0.78	0.08	0.63	0.89	-	10	12	59	09	09	24	152	75.68	Coarse
Full	*Drypetes arguta*	-1.73	7.22	0.90	0.62	52.00	**	6	8	440	04	05	898	46	97.30	Fine
Full	*Drypetes natalensis*	-1.22	4.75	0.95	0.29	119.69	**	6	8	69	04	05	104	24	54.05	Fine
Full	*Haplocoelum foliolosum*	-0.97	3.82	0.82	0.57	45.79	**	10	12	47	05	07	46	43	48.65	Fine (*NA*)
Full	*Hymenocardia ulmoides*	-1.50	6.13	0.95	0.42	138.10	**	8	10	197	04	05	332	79	81.08	Fine
Full	*Hyperacanthus microphyllus*	-0.55	2.50	0.14	1.44	0.97	-	6	8	41	04	04	107	6	54.05	***NA***
Full	*Leptactinia delagoensis*	-1.42	4.61	0.53	1.10	3.33	-	3	5	47	03	03	88	0	40.54	***NA***
Full	*Monodora junodii*	0.38	1.34	0.07	1.23	0.30	-	4	6	36	04	04	100	0	40.54	***NA***
Full	*Newtonia hildebrandtii*	-0.27	1.65	0.12	0.92	1.38	-	10	12	41	10	11	6	100	56.76	Coarse
Full	*Psydrax obovata*	-0.60	3.52	0.48	0.65	5.65	-	6	8	73	05	06	137	43	48.65	Fine (*NA*)
Full	*Ptaeroxylon obliquum*	-0.96	3.75	0.65	0.83	14.68	**	8	10	57	04	06	64	30	72.97	Fine
Full	*Pteleopsis myrtifolia*	-0.63	3.69	0.60	0.60	11.83	**	8	10	100	06	07	88	164	70.27	Intermediate
Full	*Salacia leptoclada*	-3.37	8.10	0.96	0.58	67.92	**	3	5	200	02	03	100	0	78.38	***NA***
Full	*Strychnos henningsii*	-0.32	2.34	0.25	0.58	2.00	-	6	8	37	05	06	76	30	51.35	Fine
Full	*Toddaliopsis bremekampii*	-0.83	6.69	0.8649	0.779	32.021	**	5	7	223	02	03	208	1	75.68	***NA***
Full	*Tricalysia delagoensis*	-0.70	2.74	0.20	1.47	1.52	-	6	8	34	04	04	73	3	35.14	***NA***
Full	*Tricalysia junodii*	-4.00	7.64	0.87	1.12	13.61	-	2	4	159	01	04	9	0	62.16	***NA***
Full	*Uvaria caffra*	-1.61	4.75	0.97	0.26	120.32	**	4	6	35	03	04	43	0	32.43	***NA***
Full	*Uvaria lucida*	-2.45	6.91	0.95	0.57	88.10	**	5	7	197	02	04	94	3	67.57	***NA***
Full	*Vepris lanceolata*	-1.46	4.33	0.90	0.51	53.16	**	6	8	30	03	05	24	3	32.43	***NA***
						Mean SCD centroid location for common species:					04	05				

Table 7: continued

Limited	*Balanites maughamii*	-0.43	1.69	0.44	0.62	7.83	*	10	12	12	07	07	18	12	13.51	Intermediate (*NA*
Limited	*Boscia filipes*	0.03	0.85	0.00	0.85	0.01	-	8	10	28	06	06	52	33	48.65	Fine (*NA*)
Limited	*Brachylaena discolor*	-2.55	5.50	0.96	0.40	42.99	*	2	4	27	02	03	12	0	18.92	***NA***
Limited	*Burchellia bubalina*	-0.10	1.80	0.03	0.49	0.08	-	3	5	13	04	04	33	0	16.22	***NA***
Limited	*Combretum celastroides*	-0.07	1.44	0.01	0.80	0.06	-	6	8	28	05	05	67	15	43.24	Fine (*NA*)
Limited	*Erythrophleum lasianthum*	-0.31	1.39	0.32	0.56	4.75	-	10	12	14	08	09	3	33	29.73	Coarse (*NA*)
Limited	*Grewia microthyrsa*	-0.27	2.19	0.04	1.25	0.15	-	4	6	28	04	05	73	0	48.65	***NA***
Limited	*Manilkara discolor*	0.13	0.43	0.11	0.47	1.18	-	10	12	28	09	09	18	67	43.24	Coarse (*NA*)
Limited	*Pavetta lanceolata*	-1.1	3.67	0.44	1.03	2.33	-	3	5	29	03	03	67	0	35.14	***NA***
Limited	*Psydrax locuples*	-1.2	3.78	0.79	0.69	23.03	**	6	8	23	03	05	18	3	40.54	***NA***
Limited	*Strychnos decussata*	0.4	-0.05	0.31	0.63	2.70	-	6	8	16	06	06	37	12	8.11	Fine (*NA*)
Limited	*Strychnos gerrardii*	-0.2	1.67	0.06	1.08	0.33	-	5	7	16	04	05	37	6	18.92	***NA***
Limited	*Suregada zanzibariensis*	-0.9	3.13	0.61	0.63	4.61	-	3	5	16	03	03	37	0	27.03	***NA***
Limited	*Tricalysia lanceolata*	-0.4	2.54	0.11	0.90	0.24	-	2	4	12	03	03	18	0	18.92	***NA***
Limited	*Wrightia natalensis*	0.3	-0.29	0.45	0.42	7.28	*	9	11	19	09	09	3	55	40.54	Coarse (*NA*)
Limited	*Zanthoxylum leprieuri*	-1.04	3.09	0.64	0.63	5.37	-	3	5	12	03	04	18	0	18.92	***NA***
										Mean SCD centroid location for common species:	05	05				

SC	Size Class
**	Highly significant (p ≤ 0.01)
*	Significant (p ≤ 0.05)
-	Not significant (p > 0.05)
NA	Not applicable, when behind species grain, it indicates that while grain could be established, the frequency of occurrence precludes inclusion in the model

The species within the limited analysis also had some large individuals, and inverse pyramid population structures. In general, these species appeared to have shallower SCD slopes (Table 7).

A comparison of SCD slope coefficients and Y-axis intercepts of species found at both sites within the full analysis (Table 5) showed that five of the 16 species had different SCD slope coefficients or Y-axis intercepts. The important species for construction *Brachylaena huillensis* had a higher Y-axis intercept and greater density values in Tembe than in Tshanini, moreover its presence was established in nearly two thirds of the plots. However, the reverse applied for *Dialium schlechteri*, where the Tembe population had a positive slope coefficient. Only three species were comparable within the limited analyses (Table 5), and differences between sites occurred for *Balanites maughamii* with the Tembe population of this species in a better shape than its Tshanini counterpart. Only four species could be compared across analyses (Table 5) and only *Psydrax locuples* differed at the Y-axis intercept level.

Tall Sand Forest

This vegetation unit was newly identified in the present study (see Chapter 4), and no comparable vegetation units were established outside Tembe at that time. The main features of this unit are presented below for their own interest.

A total of 29 species were analysed in the Tall Sand Forest (Table 8). The most striking feature (full analysis) appeared in the subcanopy density of some species such as *Cola greenwayi, Drypetes arguta, Vepris lanceolata* and *Toddaliopsis bremekampii*, that exceeded 800 individuals per ha and appeared consistently in more than 80.00% of plots. While these species appeared to dominate the lower strata of this unit, *Cola greenwayi, Cleistanthus schlechteri* and *Dialium schlechteri* dominated the canopy level, but were found in less plots.

All species on the full analysis were classified in Type 1, while the majority of species in the limited analysis were classified in Type 3 followed by Type 1 (Table 4). *Cleistanthus schlechteri, Dialium schlechteri* and *Newtonia hildebrandtii* had inverse pyramid population structures, and the former and latter species had positive slope coefficients (Table 8). Mean centroid 2 was located within size class 4 for the full analysis and within size class 6 for the limited analysis. The latter clearly denotes the abundance of large trees in this vegetation unit. Mean centroid 1 was located within size classes 3 and 5 for the full and limited analyses respectively. There was no major shift between the positions of mean centroid 1 and 2 in both analyses.

Table 8: Detail of species level size class distribution (SCD) regressions, including statistical significance, the range of size classes (SC) used, number of individuals sampled, centroid 1 position (full data set) centroid 2 position (size classes 3 - 12), subcanopy and canopy density, frequency of occurrence in sample plots, and species grain. The information presented is for the common species for which 30 or more individuals were sampled (full analysis) and those for which 10 to 29 individuals were sampled (limited analysis) of the Tall Sand Forest in Tembe Elephant Park, Maputaland, northern KwaZulu-Natal, South Africa

Analysis	Species	Slope	Intercept	R^2	Standard error	F	Degrees of freedom	SC range	Number of individuals	Centroid 1 in SC	Centroid 2 in SC	Subcanopy density (individuals / ha)	Canopy density (individuals / ha)	Frequency of occurrence (%)	Species grain
Community Level	**Community SCD**	**-1.54**	**10.30**	**0.96**	**0.41**	**223.22** **	**10**	**12**	**1038**						
Full	*Acalypha glabrata*	-2.80	8.14	0.96	0.46	75.01 **	3	5	88	02	03	340	0	73.33	***NA***
Full	*Cola greenwayi*	-1.65	7.90	0.91	0.58	69.84 **	7	9	193	04	05	1811	321	86.67	Fine
Full	*Croton pseudopulchellus*	-2.46	7.01	0.70	1.71	13.69 *	6	8	75	02	04	151	19	46.67	Fine
Full	*Drypetes arguta*	-1.52	6.96	0.74	0.88	14.44 *	5	7	97	03	04	1208	38	100.00	Fine
Full	*Drypetes natalensis*	-1.20	5.58	0.87	0.52	46.35 **	7	9	38	05	05	415	94	66.67	Fine
Full	*Haplocoelum foliolosum*	-0.98	4.63	0.38	1.53	5.42 *	9	11	47	05	06	358	132	80.00	Fine
Full	*Ptaeroxylon obliquum*	-1.01	5.34	0.83	0.54	38.71 **	8	10	45	05	07	245	226	66.67	Fine
Full	*Salacia leptoclada*	-2.22	7.21	0.92	0.47	24.30 *	2	4	51	02	03	170	0	100.00	***NA***
Full	*Toddaliopsis bremekampii*	-1.40	6.53	0.71	0.80	9.99 *	4	6	67	03	04	811	0	93.33	***NA***
Full	*Tricalysia junodii*	-3.19	6.75	0.63	1.98	5.18 -	3	5	46	01	05	19	0	66.67	***NA***
Full	*Uvaria lucida*	-3.75	8.97	0.98	0.37	110.42 **	2	4	152	01	03	113	0	66.67	***NA***
Full	*Vepris lanceolata*	-1.63	7.06	0.86	0.68	37.99 **	6	8	96	03	04	1038	57	93.33	Fine
						Mean SCD centroid location for common species:				03	04				
Limited	*Balanites maughamii*	-0.47	2.39	0.16	1.39	1.85 -	10	12	12	08	09	94	75	53.33	Fine
Limited	*Boscia filipes*	0.00	1.78	0.00	1.31	0.00 -	6	8	10	05	06	113	57	53.33	Fine
Limited	*Cavacoa aurea*	-1.50	5.65	0.77	0.86	19.96 **	6	8	26	04	05	226	38	20.00	Fine (*NA*)
Limited	*Cleistanthus schlechteri*	0.45	0.38	0.25	0.97	3.37 -	10	12	21	08	08	113	283	40.00	Intermediate (*NA*)
Limited	*Dalbergia obovata*	***NA***	***NA***	***NA***	***NA***	***NA*** -	***NA***	1	13	01	***NA***	0	0	20.00	***NA***
Limited	*Dialium schlechteri*	-0.42	3.20	0.29	0.83	4.11 -	10	12	24	08	09	151	264	80.00	Intermediate
Limited	*Diospyros inhacaensis*	-0.92	4.30	0.46	1.05	5.11 -	6	8	19	05	05	264	19	60.00	Fine
Limited	*Dovyalis longispina*	-1.58	5.28	0.75	0.75	8.86 -	3	5	18	02	04	94	0	53.33	***NA***
Limited	*Euclea natalensis*	-2.17	5.51	0.34	2.22	1.03 -	2	4	18	02	04	57	0	60.00	***NA***
Limited	*Hymenocardia ulmoides*	-1.22	5.20	0.74	0.84	22.92 **	8	10	28	05	06	283	113	66.67	Fine
Limited	*Monodora junodii*	0.21	1.72	0.02	1.51	0.12 -	6	8	19	06	06	245	94	40.00	Fine (*NA*)
Limited	*Newtonia hildebrandtii*	0.86	-1.15	0.64	0.82	17.45 **	10	12	25	10	10	0	58	53.33	***NA***
Limited	*Pteleopsis myrtifolia*	-0.49	3.01	0.27	0.93	3.00 -	8	10	14	07	07	113	94	73.33	Fine
Limited	*Rothmannia fischerii*	1.17	-0.20	0.63	0.88	8.57 *	5	7	13	06	06	208	38	33.33	Fine (*NA*)
Limited	*Strychnos decussata*	0.23	1.15	0.03	1.45	0.26 -	8	10	18	06	06	189	151	80.00	Fine
Limited	*Strychnos henningsii*	-0.31	3.64	0.16	0.75	1.14 -	6	8	29	05	05	434	75	100.00	Fine
Limited	*Tricalysia delagoensis*	0.65	1.63	0.07	1.88	0.24 -	3	5	11	03	04	113	0	26.67	***NA***
						Mean SCD centroid location for common species:				05	06				

SC	Size Class
**	Highly significant ($p \leq 0.01$)
*	Significant ($p \leq 0.05$)
-	Not significant ($p > 0.05$)
NA	Not applicable, when behind species grain, it indicates that while grain could be established, the frequency of occurrence precludes inclusion in the model

Afzelia quanzensis unit

The *Afzelia quanzensis* unit is also a new vegetation unit established during the present study. While *Afzelia quanzensis* was the characteristic species usually forming the canopy of this vegetation unit, was not the most abundant species. The subcanopy was dominated by a stand of *Vepris lanceolata* (Table 9). Mean centroid 1 was located within size class 3 for both analyses and mean centroid 2 within size class 7 for the full analysis and within size class 5 for the limited analysis. There was a major shift between the positions of mean centroid 1 and 2 in the full analysis (four size classes changes), and a shift of two size classes in the limited analysis.

Results of the limited analysis showed that the subcanopy level was shared by *Diospyros inhacaensis, Drypetes arguta, Drypetes natalensis* and *Euclea natalensis*. The canopy level was shared by *Vepris lanceolata* and *Dialium schlechteri* with some emergents from *Cola greenwayi* and *Diospyros inhacaensis*. In general, this community was of a fairly low stature, reaching heights of 8 to 10 m for the larger trees.

The two species in the full analysis belonged to Type 1, and so did most species in the limited analysis, although there were two species in Type 3 (*Ochna barbosae* and *Dialium schlechteri*).

Grain of species and communities

The grain of species was noted for all species for which it was possible to identify grain by using the general model presented in Figure 1. The graphical identification of grain appears in Figures 2 – 11 for the various vegetation units (compare Tables 2, 3, 6, 7, 8 and 9). Most species were fine-grained (Table 10), and therefore all vegetation units sampled here were considered fine-grained (Table 10). The Sand Forest Association in general was a fine-grained forest. Interestingly, the species classified as coarse or intermediate-grained were usually those that grow into large canopy trees such as the canopy trees that define the Sand Forest (*Newtonia hildebrandtii, Cleistanthus schlechteri, Balanites maughamii, Erythrophleum lasianthum* and *Dialium schlechteri*). However, they represented the minority in terms of the number of species classified.

In general, there were more species with a fine-grain character in Tshanini than in Tembe. However, the Tall Sand Forest in Tembe had a definitive fine-grain character and had the most species classified.

Table 9: Detail of species level size class distribution (SCD) regressions, including statistical significance, the range of size classes (SC) used, number of individuals sampled, centroid 1 position (full data set) centroid 2 position (size classes 3 - 12), subcanopy and canopy density, frequency of occurrence in sample plots, and species grain. The information presented is for the common species for which 30 or more individuals were sampled (full analysis) and those for which 10 to 29 individuals were sampled (limited analysis) of the <u>*Afzelia quanzensis*</u> *clumps vegetation unit in Tembe Elephant Park, Maputaland, northern KwaZulu-Natal, South Africa*

Analysis	Species	Slope	Intercept	R^2	Standard error	F	Degrees of freedom	SC range	Number of individuals	Centroid 1 in SC	Centroid 2 in SC	Subcanopy density (individuals / ha)	Canopy density (individuals / ha)	Frequency of occurrence (%)	Species grain
Community Level	**Community SCD**	**-1.64**	**8.54**	**0.88**	**0.77**	**71.50 ****	**10**	**12**	**297**						
Full	*Haplocoelum foliolosum*	-1.34	4.33	0.32	2.27	3.82 -	8	10	31	02	08	50	50	66.67	Fine
Full	*Vepris lanceolata*	-1.50	7.49	0.87	0.62	39.22 **	6	8	31	04	05	1100	250	100.00	Fine
						Mean SCD centroid location for common species:				03	07				
Limited	*Cola greenwayi*	-0.92	.38	0.12	2.59	0.83 -	6	8	12	03	05	100	50	66.67	Fine
Limited	*Dialium schlechteri*	0.03	07	0.00	1.75	0.00 -	9	11	10	07	08	167	333	66.67	Intermediate
Limited	*Diospyros inhacaensis*	-1.92	13	0.76	1.14	18.98 **	6	8	19	03	05	450	50	66.67	Fine
Limited	*Drypetes arguta*	-2.07	54	0.77	0.91	10.31 *	3	5	28	02	04	450	0	66.67	***NA***
Limited	*Drypetes natalensis*	-0.72	34	0.10	2.07	0.58 -	5	7	15	03	05	350	0	33.33	***NA***
Limited	*Euclea natalensis*	-2.03	65	0.90	0.65	46.88 **	5	7	26	02	05	350	0	66.67	***NA***
Limited	*Monanthotaxis caffra*	***NA***	***NA***	***NA***	***NA***	***NA***	***NA***	1	11	01	***NA***	0	0	33.33	***NA***
Limited	*Ochna barbosae*	4.95	-0.48	0.44	3.91	0.77 -	1	3	11	02	03	222	0	66.67	***NA***
Limited	*Toddaliopsis bremekampii*	-1.47	6.77	0.72	0.67	5.12 -	2	4	14	02	03	300	0	66.67	***NA***
						Mean SCD centroid location for common species:				03	05				

SC	Size Class
**	Highly significant ($p \leq 0.01$)
*	Significant ($p \leq 0.05$)
-	Not significant ($p > 0.05$)
NA	Not applicable, when behind species grain, it indicates that while grain could be established, the frequency of occurrence precludes inclusion in the model

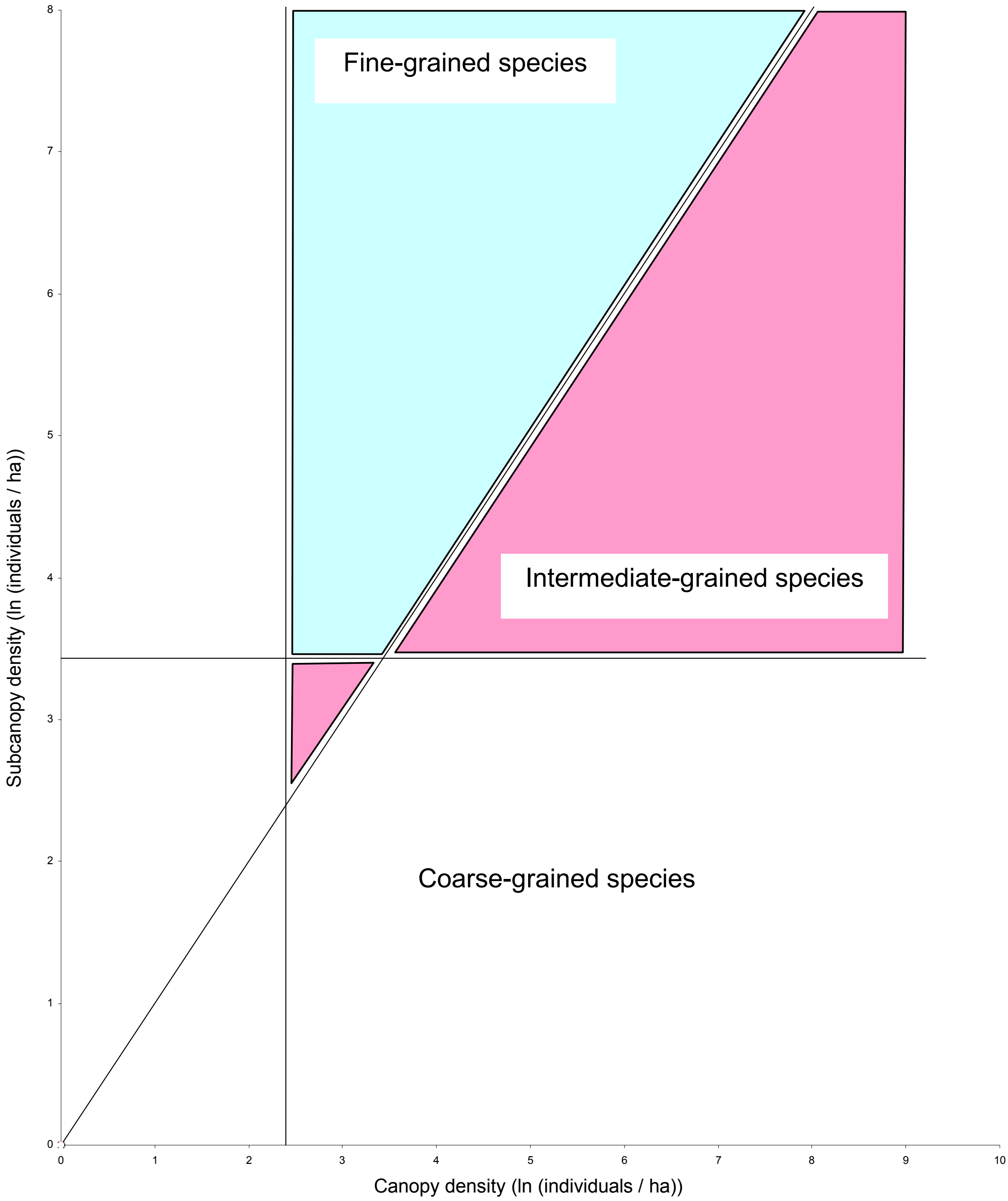

Figure 1: The graphical grain determination model based on canopy density (X-axis) and subcanopy density (Y-axis) used to evaluate tree species grain in the two study sites in KwaZulu-Natal, South Africa. Values are ln-transformed to improve readability. The model is adapted from Lawes and Obiri (2003).

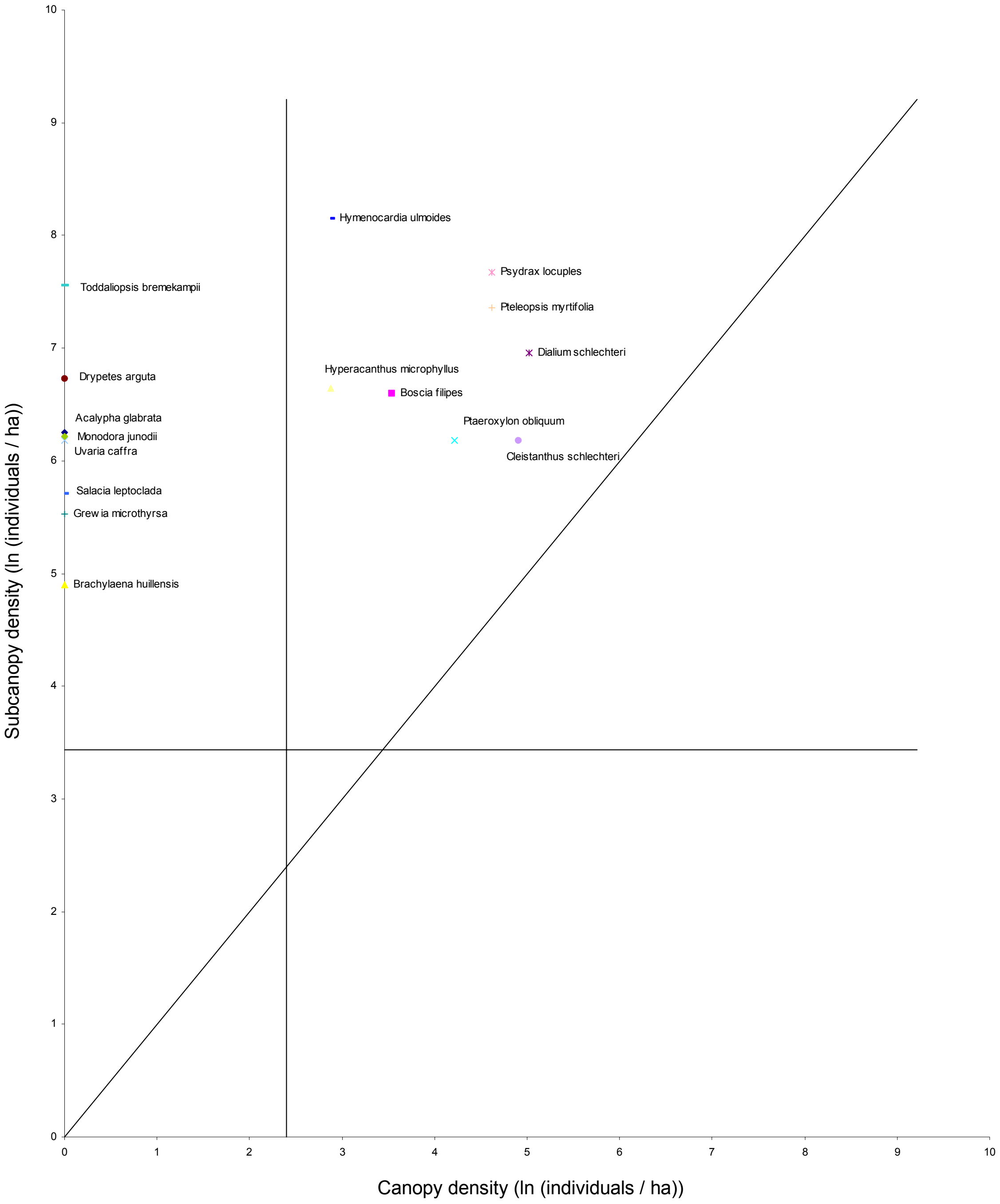

Figure 2: The grain of Short Sand Forest woody species for which at least 30 individuals were sampled in Tshanini Community Conservation Area, KwaZulu-Natal, South Africa. Values have been ln-transformed to improve readability.

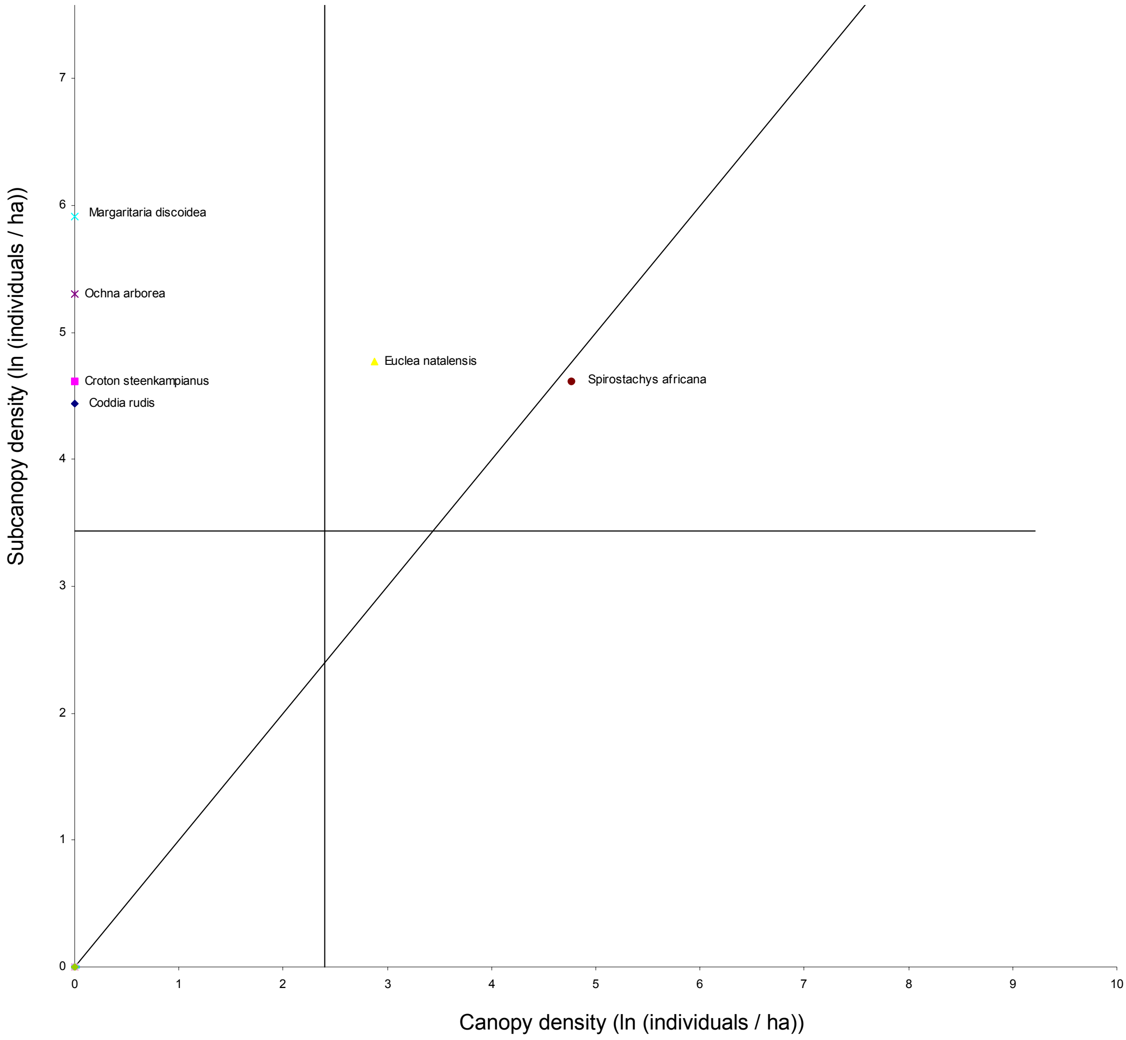

Figure 3: The grain of Short Sand Forest woody species for which 10 to 29 individuals were sampled in Tshanini Community Conservation Area, KwaZulu-Natal, South Africa. Values have been ln-transformed to improve readability.

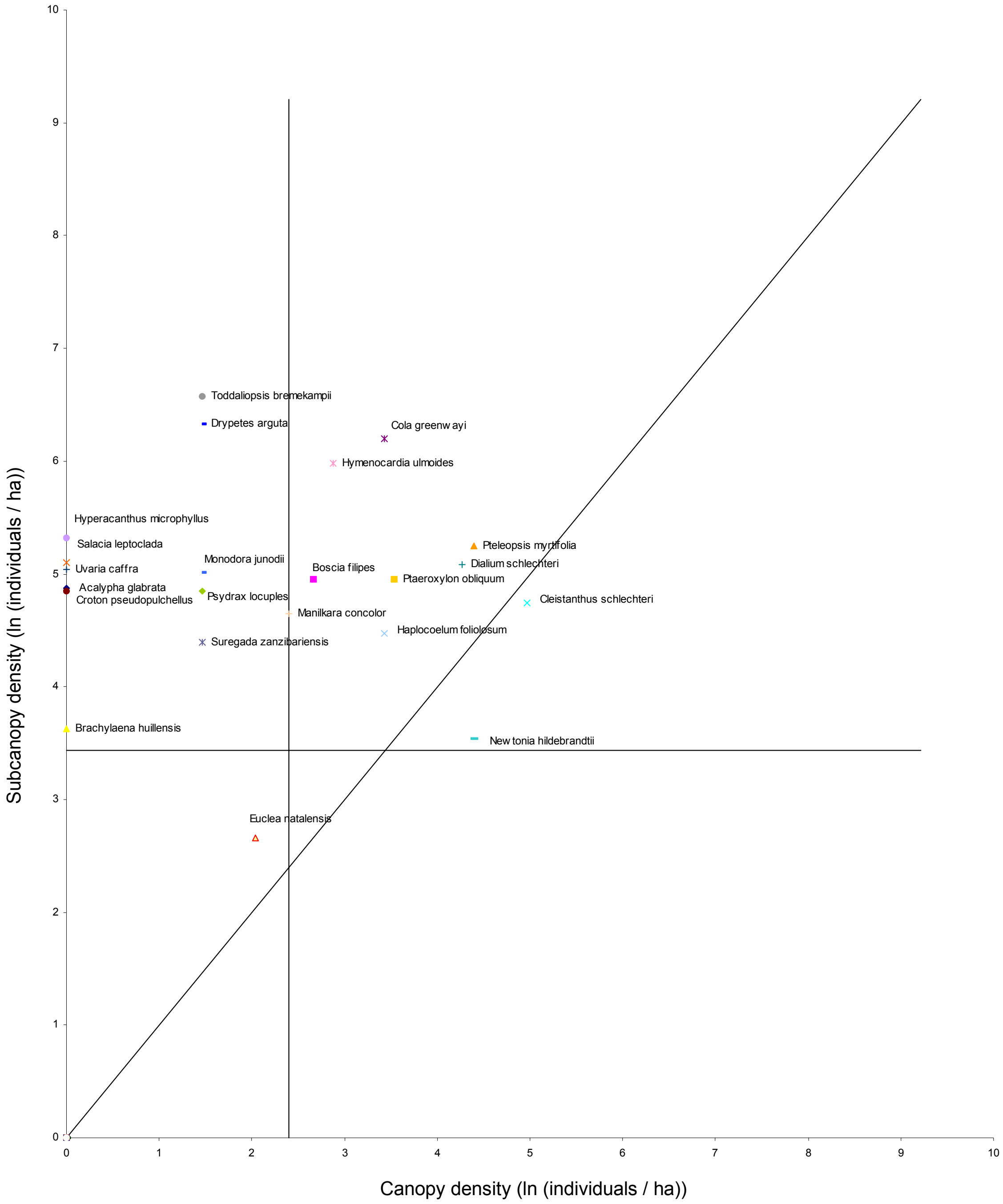

Figure 4: The grain of Intermediate Sand Forest woody species for which at least 30 individuals were sampled in Tshanini Community Conservation Area, KwaZulu-Natal, South Africa. Values have been ln-transformed to improve readability.

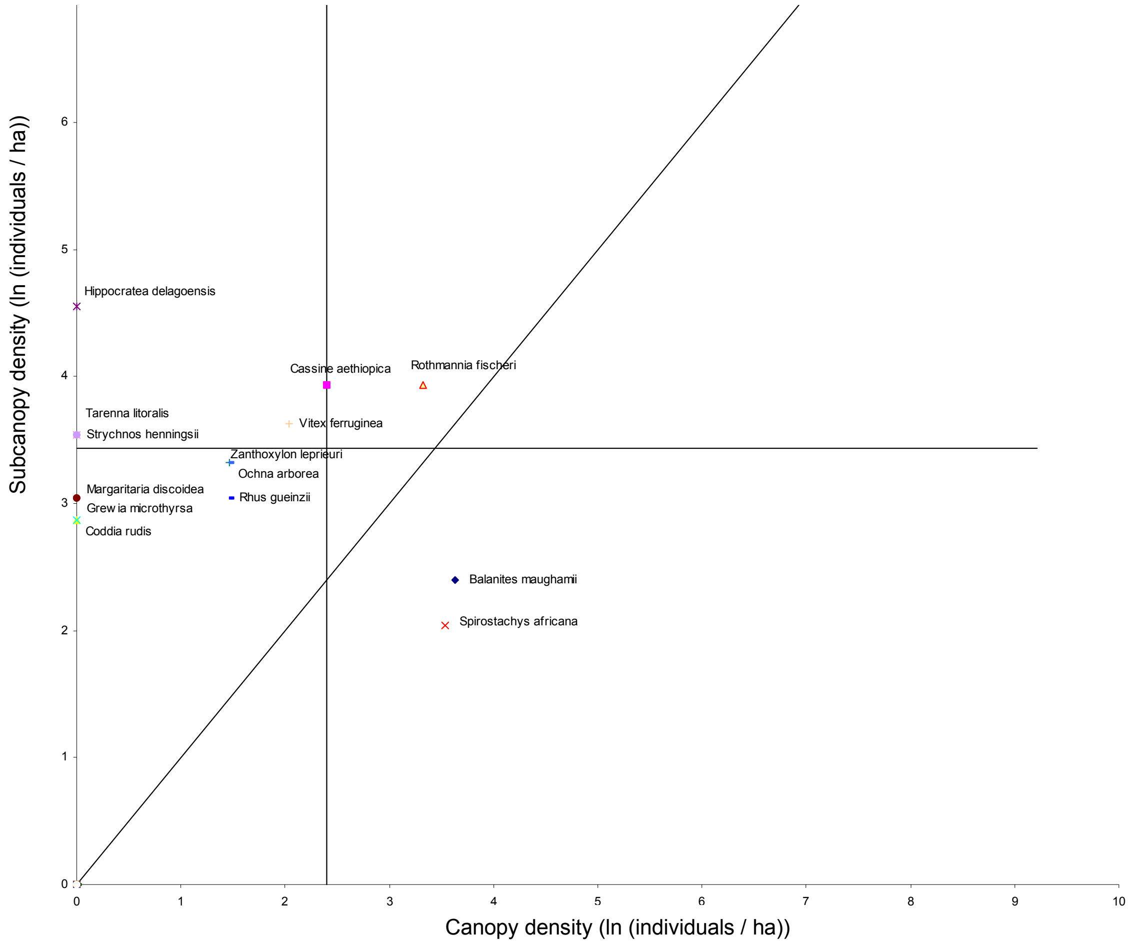

Figure 5: The grain of Intermediate Sand Forest woody species for which 10 to 29 individuals were sampled in Tshanini Community Conservation Area, KwaZulu-Natal, South Africa. Values have been ln-transformed to improve readability.

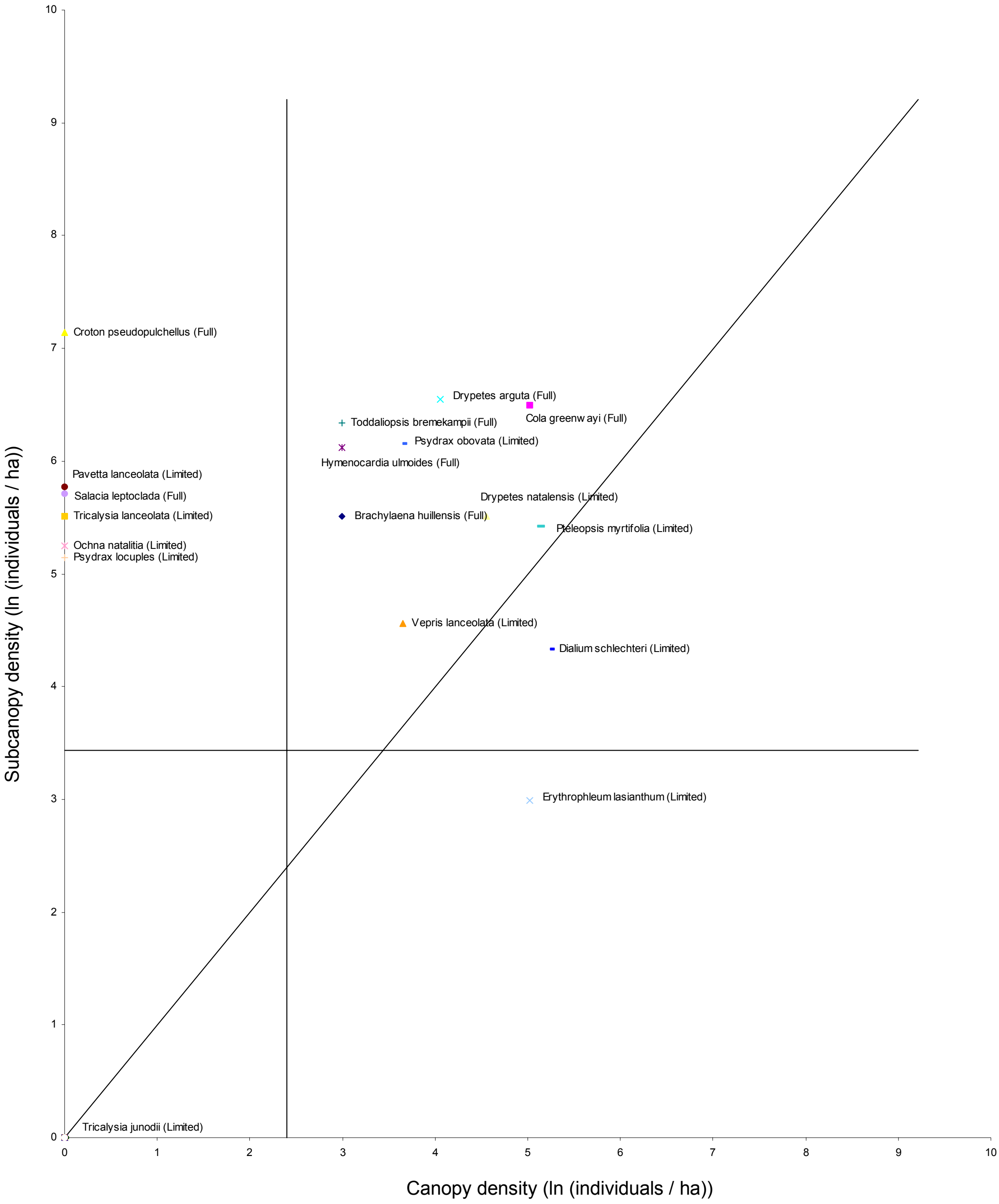

Figure 6: The grain of Short Sand Forest woody species sampled in Tembe Elephant Park, KwaZulu-Natal, South Africa. Values have been ln-transformed to improve readability. The full analysis represents species for which at least 30 individuals were sampled, while the limited analysis represents species for which only 10 to 29 individuals were sampled.

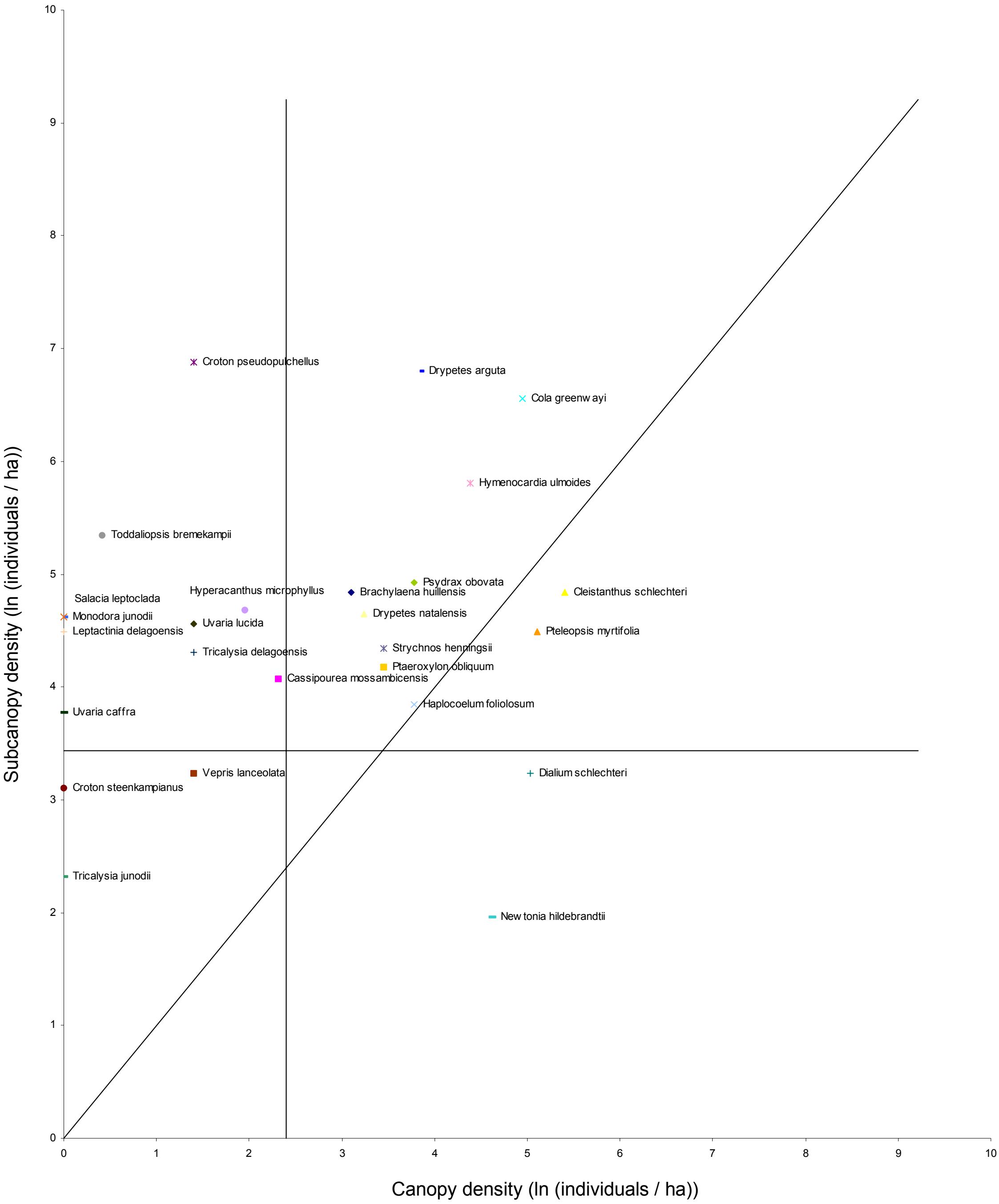

Figure 7: The grain of Intermediate Sand Forest woody species for which at least 30 individuals were sampled in Tembe Elephant Park, KwaZulu-Natal, South Africa. Values have been ln-transformed to improve readability.

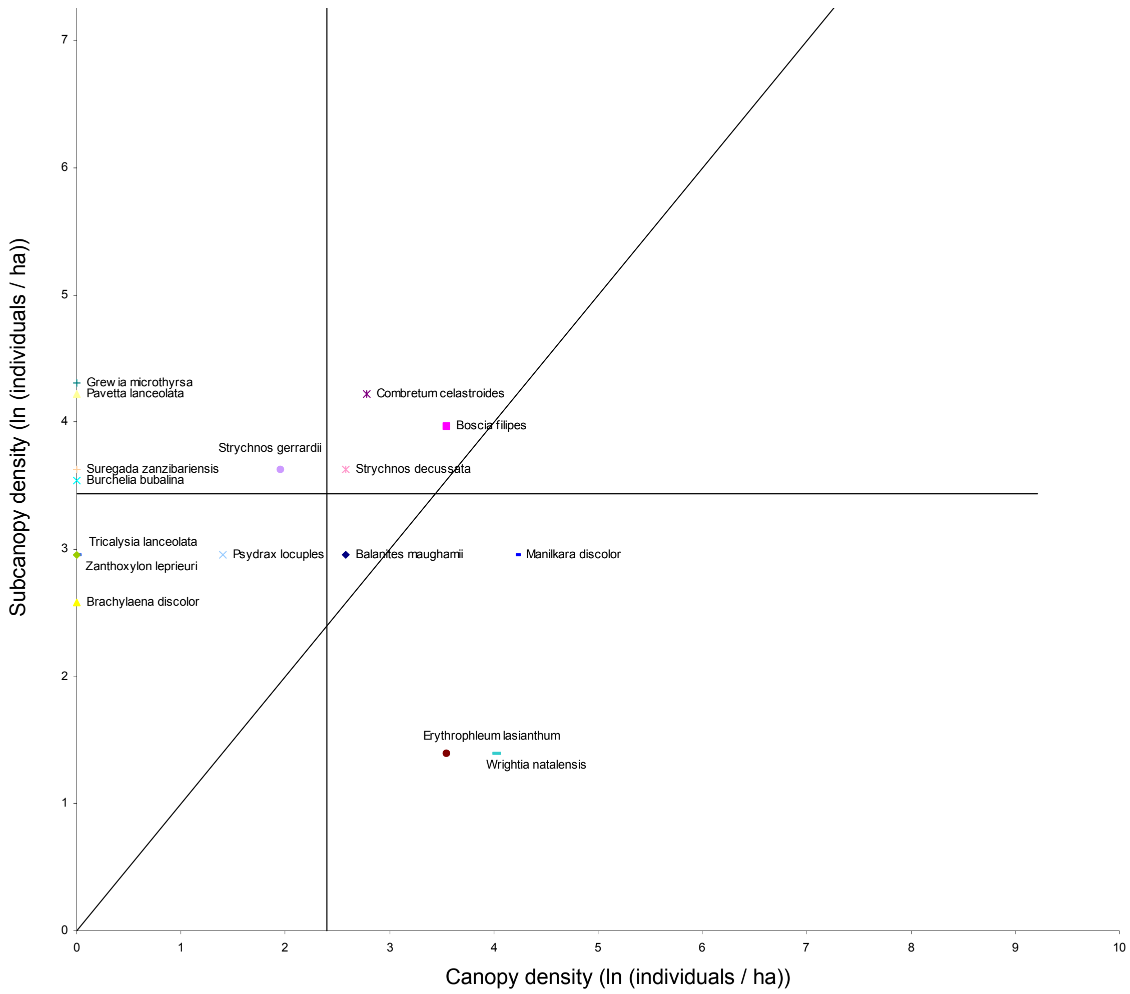

Figure 8: The grain of Intermediate Sand Forest tree species for which 10 to 29 individuals were sampled in Tembe Elephant Park, KwaZulu-Natal, South Africa. Values have been ln-transformed to improve readability.

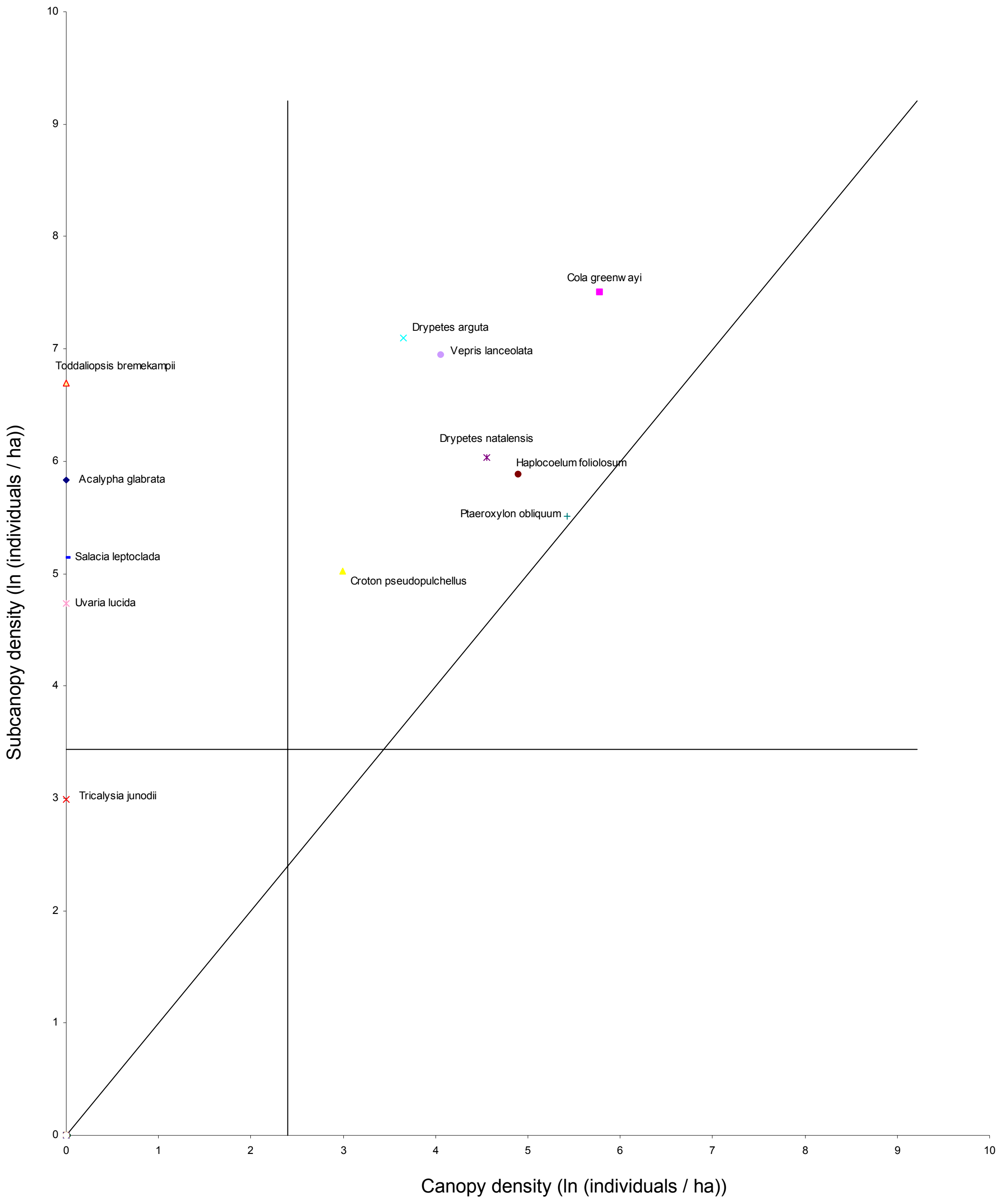

Figure 9: The grain of Tall Sand Forest woody species for which at least 30 individuals were sampled in Tembe Elephant Park, KwaZulu-Natal, South Africa. Values have been ln-transformed to improve readability.

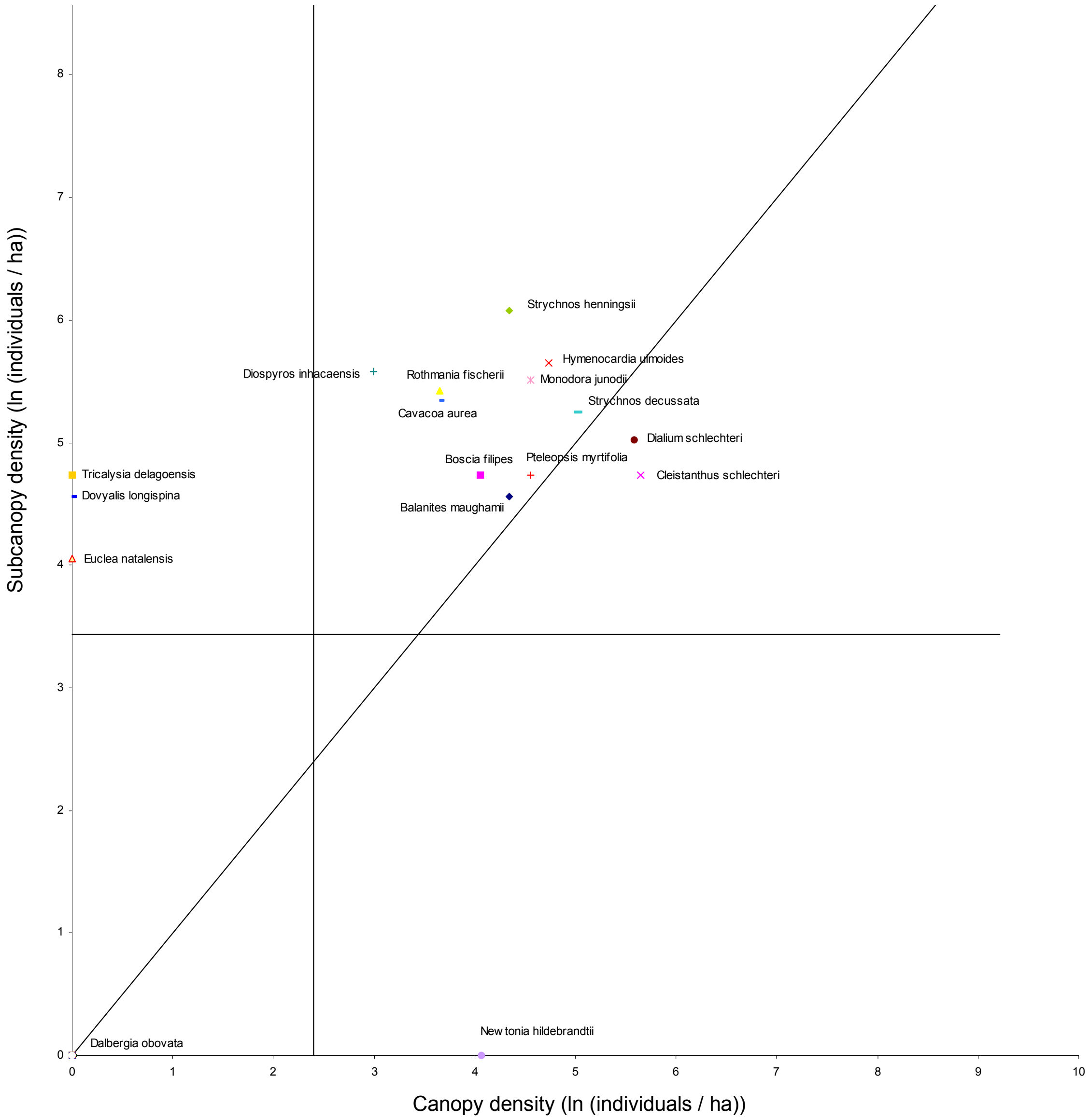

Figure 10: The grain of Tall Sand Forest woody species for which 10 to 29 individuals were sampled in Tembe Elephant Park, KwaZulu-Natal, South Africa. Values have been ln-transformed to improve readability.

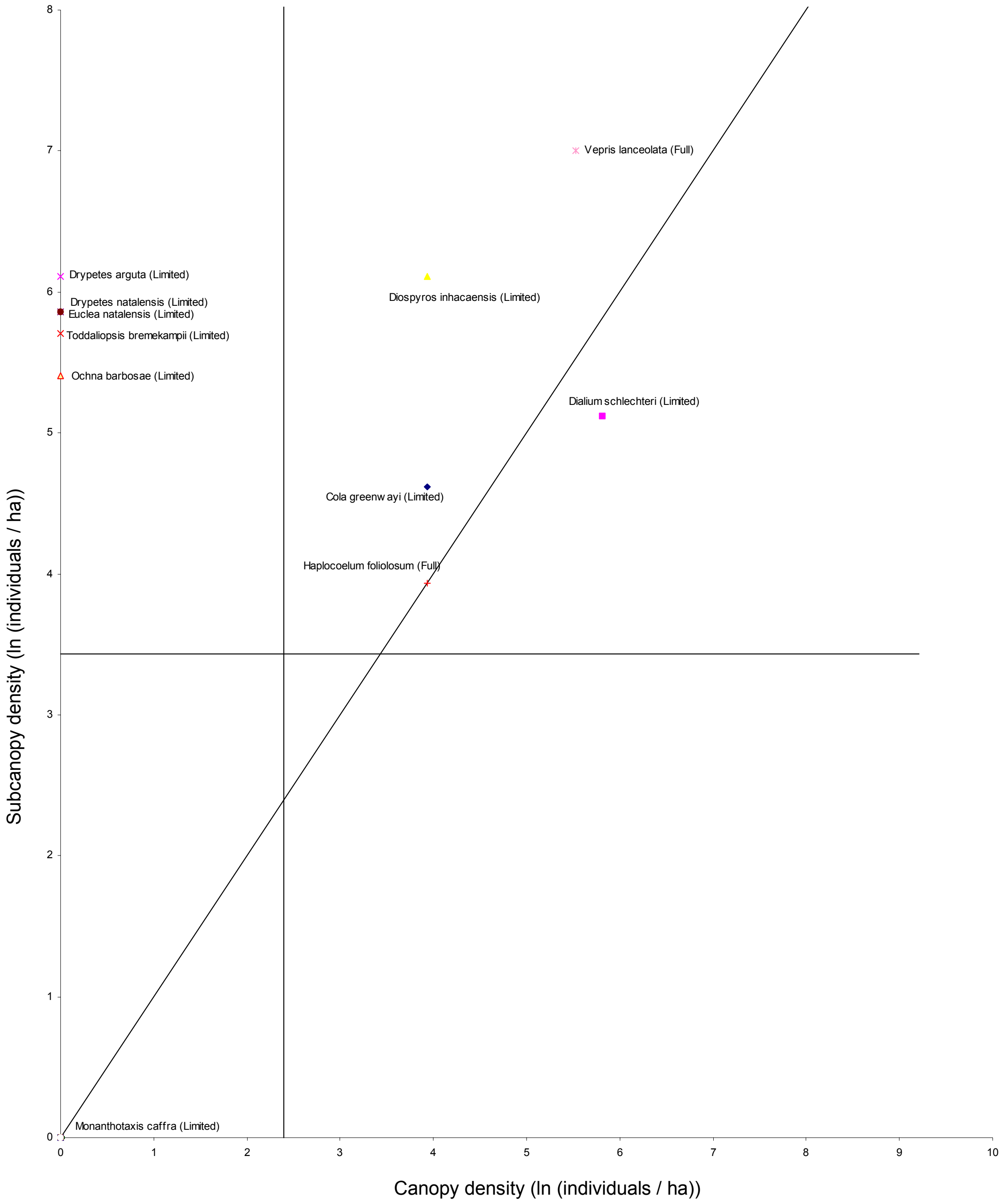

Figure 11: The grain of *Afzelia quanzensis* clumps community woody species sampled in Tembe Elephant Park, KwaZulu-Natal, South Africa. Values have been ln-transformed to improve readability. The full analysis represents species for which at least 30 individuals were sampled, while the limited analysis represents species for which only 10 to 29 individuals were sampled.

Table 10: The number of species by grain category and the derived community grain for the various vegetation units of Tshanini Community Conservation Area (TCCA) and Tembe Elephant Park (TEP), Maputaland, northern KwaZulu-Natal, South Africa

Grain	Number of species per grain category by vegetation units and sites					
	Short Sand Forest		Intermediate Sand Forest		Tall Sand Forest	*Afzelia quanzensis* clumps
	TCCA	TEP	TCCA	TEP	TEP	TEP
Fine	7	6	9	7	14	4
Intermediate	1	1	2	2	1	1
Coarse	0	1	1	2	0	0
	Derived status of the vegetation unit or sub-unit					
Fine	X	X	X	X	X	X
Intermediate	-	-	-	-	-	-
Coarse	-	-	-	-	-	-

Discussion

The general perception from the present study was that there was a remarkable similarity between the two sites at most levels. From the species that could be compared, 50.00% had similar SCD structures in the Short Sand Forest , while 69.56% of species had similar SCD structures in the Intermediate Sand Forest. Both sites appeared to have a majority of their most common species populations (full analysis, Table 4) classified within Type 1, representing self-sustaining populations (Everard *et al.* 1994; Lykke 1998; Niklas *et al.* 2003). The less abundant species (limited analysis, Table 4) were generally found more within Type 3, which represents flat or positive slopes, indicating potentially declining populations (Lykke 1998) or mature long-lived early successional species that have survived up to the present (Condit *et al.* 1998). Looking at a combined value for both analyses (Table 4), it was clear that Type 1 dominated in nearly all sites, while Type 2 was equally important in the Intermediate Sand Forest of Tshanini.

Moreover, in both analyses the centroids were generally skewed to the left of the size class distributions, which confirmed that these populations had good regenerative potential (Niklas *et al.* 2003), further confirmed by mostly pyramidal population structures. A similarity between sites at the phytosociological level was already highlighted by (Gaugris *et al.* 2004), and the present study confirmed this similarity.

Differences in abundance between the two sites were observed in three common species, *Drypetes arguta, Dialium schlechteri* and *Pteleopsis myrtifolia,* in the Short Sand Forest, while *Toddaliopsis bremekampii* and *Hymenocardia ulmoides* were similar. The differences in the Short Sand Forest indicate that common species populations in Tshanini are in better condition than in Tembe. In the Intermediate Sand Forest, differences were observed within five common species while the other five shared species were similar. In the Intermediate Sand Forest, *Cola greenwayi* and *Croton pseudopulchellus* had steeper slopes and higher Y-axis intercepts in Tembe than in Tshanini, denoting healthier populations (Lykke 1998; Niklas *et al.* 2003; Boudreau *et al.* 2005) although the Tshanini populations were not declining. However, the other three common species found to be different were in better shape in Tshanini than in Tembe, especially in the case of *Dialium schlechteri* where the population in Tembe showed a positive slope coefficient. While these differences are weak, it appears that common species have begun to show differences and that populations in Tshanini appear closer to the ideal population structure defined by a range of authors

(Everard *et al.* 1994; Everard *et al.* 1995; Peters 1996; Niklas *et al.* 2003) than in Tembe.

An interesting case was that of *Brachylaena huillensis*, which was a relatively abundant species at both canopy and subcanopy levels in the Intermediate Sand Forest of Tembe (Table 7), but rare (frequency < 10.00%) and only found at the subcanopy level in Tshanini (Table 6). This is the most highly sought after species for building construction by local people (Gaugris *et al.* 2007), and its abundance in Tshanini is suspiciously low. Selective extraction of this species in the past appears a relatively credible option to explain its low abundance and its absence from the canopy level.

It is not always possible to pinpoint a particular reason for differences at the species level. Variations could be linked to natural variations in the forest, without a particular influence from either man or herbivores (Chapman *et al.* 1997; Burslem and Whitmore 1999; Chapman *et al.* 1999), but also to either of these elements separately or their absence altogether (Chapman and Chapman 1997; Babaasa 2000; Maisels *et al.* 2001; Mosugelo *et al.* 2002; Babaasa *et al.* 2004; Western and Maitumo 2004; Boudreau *et al.* 2005; Banda *et al.* 2006; Botes *et al.* 2006; Western In Press), as Tembe is influenced by animals and not by people, while Tshanini has not been influenced by either since 1992 (Gaugris 2004).

Fire, although a noteworthy agent in Africa (Bond *et al.* 2003; Bond and Keeley 2005; Bond *et al.* 2005) appears an unlikely candidate here as Sand Forest in both sites has not burned in a significant manner recently (Gaugris 2004; Matthews 2006), and the small burned patches currently appear to be regenerating as woodlands (Matthews 2006), and were therefore not included in this sample. The close proximity of the two sites in space also most likely rules out climatic factors particular to one site as an explanation to these differences (Yeh *et al.* 2000). Additionally, no disturbance of climatic or catastrophic nature as defined by Whitmore and Burslem 1996, or Burslem and Whitmore (1999), has been recorded since 1989, or even 1983 (Matthews 2006; Guldemond 2006), and therefore the most likely answer lies in the influence of herbivores and man.

The fact that people and fire are eliminated from Tembe as disturbance agents indicates that the differences observed between the two sites are potentially attributable to an influence from herbivores. However, at this stage it appears equally possible that the lack of any disturbance agent in Tshanini could explain these differences. A similar situation was observed in Cameroon by Maisels *et al.* (2001). Woody species in Tshanini are more evenly spread between Types 1 and 2 than in

Tembe. Type 2 species have less steep distributions, but are not flat, and are defined as species with shrinking populations in the sense that the regeneration pool is diminished (Condit *et al.* 1998; Niklas *et al.* 2003). As canopies close in mature forests, the abundance of smaller trees becomes lower as the light continuum in the subcanopy decreases (Poorter *et al.* 1996; Babaasa *et al.* 2004), but when gaps are opened, the abundance of such small classes usually increases (Babaasa *et al.* 2004). The size of gaps is influential, as the regeneration of Type 1 species occurs mainly in minor gaps such as branch breaks but Type 3 species need substantially larger gaps (Everard *et al.* 1994; Everard *et al.* 1995).

Because Type 3 species in Tembe and Tshanini show relatively poor regeneration with inverse pyramidal structures, and because the abundance of Type 3 species was more or less similar at both sites (Table 4), the hypothesis that these species are long-lived early successional species that persist in the canopy level and regenerate irregularly (Everard *et al.* 1994; Everard *et al.* 1995; Poorter *et al.* 1996; Burslem and Whitmore 1999) appears most likely. If the hypothesis holds true, then sampling in the present study did not encounter signs of large Type 3 favourable gaps, which concurs with the author’s personal observations. The spread of Type 1 and 2 species is therefore interesting in the sense that it could represent the presence of small Type 1 favourable gaps in Tembe, whereas they are less frequent in Tshanini. Again personal observation concurs with this option, and no gaps were sampled in Tshanini, whereas gaps were represented in the sampling in Tembe. It is however important to note that Type 1 species can also regenerate without gaps or otherwise in transient gaps, such as quickly replaced broken branches (Burslem and Whitmore 1999), it appears therefore also possible that some gaps may not have been obviously noticeable during the sampling. Canopy gaps in the Sand Forest of Tembe have been described as elephant refuges of two sizes (Shannon 2001). A grade 2 refuge represents a small opening of the canopy, but a grade 1 refuge represents large clearings of 20 m diameter and larger. Both refuges represent what is commonly known as gaps, and it appears likely that both refuge types will contribute to an increased level of direct light penetration to the subcanopy level (grade 1 refuge), or an improved light continuum throughout the subcanopy level (grade 2 refuge). The hypothesis that elephants are creating gaps in the Sand Forest could contribute to the greater proportion of tree species classified in Type 1 in Tembe.

While differences are difficult to explain, a tentative account of Sand Forest structure and dynamics appears possible. The Short Sand Forest is defined as a dense thicket-like vegetation of short stature, rarely exceeding 8 m in height (Matthews *et al.*

2001; Izidine *et al.* 2003; Gaugris and Van Rooyen In Press) or 10 m as defined in the present study (see chapter 4). In the present study it is shown that the subcanopy density often exceeds 800 individuals per hectare for a range of medium to large sized woody species that appear to be in a short form in this particular unit. These species are *Croton pseudopulchellus, Dialium schlechteri, Drypetes arguta, Hymenocardia ulmoides, Psydrax locuples, Pteleopsis myrtifolia* and *Toddaliopsis bremekampii.* The upper canopy is dominated by some of these species, although at a much lower density than the subcanopy level, and apart from *Cleistanthus schlechteri* and *Dialium schlechteri,* which emerge above the uniformly low canopy, there are no other real large canopy trees. Nearly all species have pyramidal population structures whereby the subcanopy density is greater than the canopy density, and some woodland species, such as *Spirostachys africana,* occur in the canopy. The centroid location skewed to the left indicates a young and dynamic subcommunity (Niklas *et al.* 2003), while the size class range rarely exceeds size class 9, indicating that not many trees have reached their potential stem diameter. The lack of major shift in size classes between the locations of centroids 1 and 2 indicates that small individuals do not contribute disproportionately to the observed size class distributions.

The Intermediate Sand Forest, previously described as Tall Sand Forest (Matthews *et al.* 2001; Gaugris *et al.* 2004; Gaugris and Van Rooyen In Press), has been reclassified as Intermediate Sand Forest as it appears to form a link between the Short Sand Forest and a new unit called Tall Sand Forest in this study. The subcanopy density rarely exceeds 400 individuals per hectare for any species, and the bulk of species have densities within the 100 to 300 individuals per hectare. This unit has the highest species count and reaches heights of 12 m with emergents around 15 m (see Matthews *et al.* 2001, Gaugris *et al.* 2004, Gaugris and Van Rooyen in press). The size class range is complete, with many species found in the large to very large size classes (size classes 10 to 12). Interestingly, some of these large trees are also the emergents from the Short Sand Forest, such as *Dialium schlechteri, Hymenocardia ulmoides, Psydrax locuples, Pteleopsis myrtifolia* and *Toddaliopsis bremekampii,* and new species have appeared in the canopy, such as *Brachylaena huillensis, Cola greenwayi, Newtonia hildebrandtii* and *Ptaeroxylon obliquum*. The centroid location is closer to the middle of the size class distribution, thus indicating the presence of large and mature trees, but still an abundance of smaller trees.

The Tall Sand Forest described in the present study (see Chapter 4) shows another picture altogether. The unit has a tall tree stratum of 12 to 15 m and a second lower canopy at 10 m. In terms of density this unit is characterised by the reappearance of subcanopy densities in excess of 1000 individuals per ha for some species (*Cola greenwayi, Drypetes arguta, Vepris lanceolata*), while larger trees such as *Cleistanthus schlechteri, Dialium schlechteri, Newtonia hildebrandtii* and *Ptaeroxylon obliquum* dominate the canopy. The centroid position of species encountered the most shows a blatant skew to the left, while the centroid position of species encountered least often shows a centroid located in the middle of the size class distribution, thus indicating the most mature stage encountered as yet. Individuals in the large to very large size classes in the latter group are commonplace. The shift observed between mean centroid positions shows that the species found most often are influenced by seedlings and saplings, indicating potentially good recruitment (Niklas *et al.* 2003), while the species found least often, have problematic size class distributions as evidenced by a number of flat or shallow slope coefficients.

The descriptions above illustrate clear distinctions in the Sand Forest structure, with the presence of various layers at different heights, as well as a wealth of species groups in different successional stages. Additionally, the Short and Intermediate Sand Forest were found to potentially harbour a greater number of species (Pers. Obs.: although this is an impression rather than a demonstrated fact, due to unequal sample sizes between the vegetation units) than the Tall Sand Forest, thereby potentially indicating a more mature forest stage for the last subcommunity (Burslem and Whitmore 1999). This diversity observed in Sand Forest bears similarities to a hypothesis of Burslem and Whitmore (1999) describing what could be a successional transition from Short to Tall Sand Forest: a suite of species appears in the Short Sand Forest and is maintained in the Intermediate Sand Forest stage. The Intermediate Sand Forest stage leads to the establishment of a tall (12 – 15 m) canopy of large trees (Tall Sand Forest), while the undergrowth goes through another change as light conditions are modified once this tall canopy has emerged.

The species level comparisons portray a relatively different picture than the vegetation unit level comparisons presented in the previous chapter. As such the comparable species of the Short and Intermediate Sand Forest are mostly similar in terms of slope and Y-axis intercepts, but the unit level comparisons displayed significant differences between the comparable Sand Forest units of the two sites. However, in the present part of the study, relatively few of the species that were analysed could be compared. Only eight species (24.24%) were comparable from a total of 33 species analysed for the Short Sand Forest across both sites, and 23 species (42.81%) compared from a total of 55 species analysed across both sites for the Intermediate Sand Forest. This remarkable similarity at the comparable species level should be interpreted with caution as the majority of common species could not be compared between the two sites. It appears most likely that differences at the unit level must be linked to these other species. The implications of this difference are far reaching, as it appears that common species of the two sites now exhibit such differences in abundance that they can no longer be compared. Although there is no statistical comparison presented, the impossibility to compare such species between the two sites attests the difference at the common species level.

The concept of grain originates from forestry ecology in South Africa (Midgley *et al.* 1990; Everard *et al.* 1994; Everard *et al.* 1995), and represents a spatial analysis comparing number of individuals of a species at the subcanopy and canopy levels (Everard *et al.* 1994; Everard *et al.* 1995; Obiri *et al.* 2002; Lawes and Obiri 2003). The grain of a species indicates the scale of regeneration of the species. Coarse-grained species have relatively few individuals in the subcanopy level compared to the canopy level, while the reverse holds true for fine-grained species (Obiri *et al.* 2002; Lawes and Obiri 2003). Coarse-grained species are believed to regenerate over large areas at low densities, and may not withstand intense utilisation. Fine-grained species have well-balanced subcanopy and canopy levels that reflect a typical inverse J-shaped distribution, which is considered the ideal population structure (Obiri *et al.* 2002; Lawes and Obiri 2003).

The grain of species and communities established in the present study must be evaluated in conjunction with the classification into Types (Everard *et al.* 1994; Everard *et al.* 1995; Obiri *et al.* 2002). A wealth of Type 1 species and an abundance of the same species at both subcanopy and canopy levels define fine-grained forests (Everard *et al.* 1994; Everard *et al.* 1995). As such it is therefore fairly conclusive that Sand Forests are fine-grained forests (Tables 4 and 10).

A definition of fine-grained forests is needed before developing the Sand Forest case further. Fine-grained forests are defined as populated by shade-tolerant fine-grained species, where the scale of variation from patch to patch is small (Midgley *et al.* 1990; Everard *et al.* 1994; Everard *et al.* 1995). The scale of variation in the concept of grain applies to “the scale at which normal dynamic regeneration processes occur” (Everard *et al.* 1995) while patch is loosely used to define structures that range from a few acres to hundreds of hectares or more. Based on such assumptions, it appears possible that small patches of forest can exist as sustainable entities (Everard *et al.* 1995). Moreover, a small scale of variation means that small gaps are sufficient to ensure successful regeneration of species. However, the grain of a forest concept does not include other processes that contribute to regeneration, such as pollination and seed dispersal, which are thought to function at a different scale altogether (Everard *et al.* 1995; Maisels *et al.* 2001; Babweteera *et al.* 2007; O'Connor *et al.* 2007).

In terms of dynamics, the fine-grain pattern indicates that at the patch level, even small, Sand Forest is likely to sustain and regenerate itself. However, the diversity observed in avian species assemblages (Van Rensburg *et al.* 2000) and the indications from dung beetles used as indicators of forest condition and disturbance (Van Rensburg *et al.* 1999; McGeogh *et al.* 2002; Botes *et al.* 2006) suggest that diversity between patches is such that many patches over a large area are required to conserve the dynamics of Sand Forest in general, and that these forests are susceptible to over-utilisation by man and elephants. The present study supports the notion that elephants are important agents affecting Sand Forests dynamics through the creation of small gaps and associated changes in the light continuum. However, in a small and confined reserve where elephant populations increase in numbers (Morley 2005; Guldemond 2006), the risk that elephants will open larger gaps increases (O'Connor *et al.* 2007). Large gaps are most likely to provoke a change in the forest dynamics or a successional change to woodlands altogether (Van Rensburg *et al.* 1999; Van Rensburg *et al.* 2000). It has also been documented that Sand Forest species do not regenerate well in large gaps created by fire (Matthews 2006). However, the absence of disturbance, observed in Tshanini, shows that species distribution curves possibly change from Type 1 to Type 2 and bring the forest closer to an intermediate grain, the problem with the last statement being that it is contrary to grain theory (Everard *et al.* 1995). In the Intermediate Sand Forest therefore it appears that absence of disturbance is potentially as much of a problem as over-disturbance.

Large frequent gaps define large-scale disturbance that drive coarse-grained forests (Everard *et al.* 1994; Everard *et al.* 1995). In the event of such regular disturbance it has been hypothesised that forests could become coarse-grained as coarse-grained shade intolerant species out-compete the fine-grained shade tolerant species. The observation by Matthews (2006) on fire and Sand Forest could be likened to the process of transformation from fine-grained forest to a coarse-grained forest, except that in this case a woodland appears to replace the forest, although this author and several others have considered the closed woodlands of Tembe and Tshanini as forest-like units (Van Rensburg *et al.* 2000; Gaugris *et al.* 2004). Interesting questions would be to see whether under a continued small-scale disturbance the closed woodlands of this region would progress to a forest, would this forest be similar in species composition to Sand Forest, and whether the transition would follow a Short to Tall Sand Forest succession?

Note on the methodology

The distinction between a full and a limited analysis used in the present study was based on an initial perception that regressions would work better at the full than the limited level. This somewhat cumbersome distinction proved true with regards to the regressions. However, the distinction proved particularly useful in separating the analysis in two parts that represented different tree dynamics. In terms of species evaluated in the limited analysis, it appears that the low number of individuals encountered was information in itself and it allowed a better understanding of the dynamics of the forest as a whole. While the statistical significance of the regressions is an important aspect of mathematical integrity, to overlook the species where regressions were not significant would have limited the ability to perceive patterns in the dynamics of this area. It appears therefore important to recommend that future studies in this field do not discard species with low abundance on the proviso that statistical significance was not met.

Conclusion

The present study contradicts previous studies that classified Sand Forest as coarse to intermediate-grained forests (Everard *et al.* 1995; Gaugris and Van Rooyen In Press). These previous studies were based on considerably smaller sample sizes, and it appears that they did not pick up the regional levels of variations. The new perception presented here appears strongly supported by documented evidence and does explain Sand Forest character fairly well. The fine-grain character is a positive sign for Sand Forest conservation as it simplifies its management, and suggests that in Tembe and Tshanini, managers should concentrate on controlling the animal populations to ensure the presence of regular creation of small canopy gaps.

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CHAPTER 7

A SPECIES LEVEL ANALYSIS OF THE EFFECT OF HERBIVORES AND MAN ON THE STRUCTURE, AND DYNAMICS OF WOODLAND VEGETATION OF MAPUTALAND, NORTHERN KWAZULU-NATAL, SOUTH AFRICA

Abstract

The woodlands of Maputaland are under utilisation pressure in both conserved and non-conserved areas, due to the mounting densities of mammals in the former areas, and the increasing human utilisation of natural vegetation in the rural areas. The conservation of this biodiversity rich region requires a better understanding of the vegetation dynamics. To fill this gap in knowledge, the structure of the woodland vegetation is evaluated on three sites through a classical size class distribution analysis, reinforced by the determination of species centroids, the comparisons of size class distributions between sites, and the determination of community grain, a forestry concept here provisionally applied to woodlands. One site had animals as the main disturbance agent; humans filled this role in a second site, while the third site was not disturbed by either since 1992. The three sites have been under their respective disturbance regimes for comparable periods. The results show a pattern of utilisation similar to those described for other areas in Southern, Eastern, and Central Africa where woodlands are over-utilised by man in rural areas, and woodland are destroyed by elephants in the confined conserved areas. The grain model performed successfully for the woodlands of the region and the results obtained are coherent with grain theory. The woodlands of Maputaland are mostly fine-grained forest-like vegetation units, and they follow the dynamics of fine-grained forests closely. The implications of grain for conservation are discussed.

Keywords

Elephant, fine-grain, forest grain, human utilisation, Maputaland, rural community, size class distribution, vegetation dynamics, woodlands

Introduction

Savanna woodlands are a dominant feature of the African landscape (Bond and Keeley 2005; Pote *et al.* 2006). The woodlands have evolved under a delicate balance of fire, animal and people-related disturbance in association with climate variations (Bond *et al.* 2005). As such, woodlands form an important resource base for rural African people (Perrings and Lovett 1999; Naughton-Treves *et al.* 2007; Shackleton *et* *al.* 2007), and are the most represented landscapes in famous conservation areas of central, east and southern Africa (Leuthold 1996; Eckhardt *et al.* 2000; Dudley *et al.* 2001; Mosugelo *et al.* 2002; Walpole *et al.* 2004; Van Aarde and Jackson 2007; Western In Press). Under low human demographic pressure, where wildlife populations roam freely, woodlands are resilient (Perrings and Lovett 1999; Walpole *et al.* 2004; Western In Press), and able to support large but temporary surges of utilisation. In systems where demographic pressure is high, such as in conserved areas where animal densities have increased to levels that threaten the ecological capacity of the reserves, human – wildlife conflicts are rife, and woodland landscapes tend to change (Leuthold 1996; Naughton-Treves 1998; Gillson *et al.* 2003; Walpole *et al.* 2004; Western In Press).

Under intense wildlife utilisation, especially linked to high African elephant *Loxodonta africana* (Blumenbach 1797) densities, woodlands have been documented to change into grasslands (Leuthold 1996; Western In Press), while under low densities, woodlands become denser, the canopy level becomes continuous, and potentially evolve into forests (Walpole *et al.* 2004; Western and Maitumo 2004). Effects from human utilisation are more complex and varied. Where people are few, and agriculture limited to shifting cultivation, but where hunting removes wildlife from the landscape, woodlands have changed into forests (Ickowitz 2006). Where human density is high, wildlife is usually hunted to local extinction, and and when harvesting is limited to lying dead wood and standing pole-sized trees, gradients of plant utilisation are observed away from villages (Schwartz and Caro 2003; Banda *et al.* 2006a; Banda *et al.* 2006b). In these areas there is usually a wealth of seedlings and saplings but large trees contain a gap in the pole-sized classes. While the gap in size classes may become a sustainability issue, there is often sufficient regeneration to perpetuate the woodland type albeit with a changed structure (Luoga *et al.* 2002). Problems occur when pressure from commercial harvesting is added, as is the case for charcoal and precious timber species (Luoga *et al.* 2002; Schwartz *et al.* 2002; Schwartz and Caro 2003; Caro *et al.* 2005). In those instances, selective harvest of species for precious timber can lead to local extirpation of all commercially valuable woody species, thus changing species composition (Luoga *et al.* 2002; Schwartz *et al.* 2002; Ticktin 2004). Charcoal production, which is especially pronounced along easily accessible routes (Kirubi *et al.* 2000; Okello *et al.* 2001) leads to the harvesting of a wide range of species, to such an extent that it results in severe changes in the woodland's structure (Naughton-Treves *et al.* 2007).

As a whole it is widely acknowledged that woodlands in Africa are a valuable, if not essential, resource for rural people in Africa (Shackleton *et al.* 2007). In South Africa this importance has remained unchanged by development programmes. Despite the recent implementation of a free electrical supply to rural areas by the government, it appears that at least 80% of rural households utilise firewood for cooking and heating as they did before the electrification programme (Madubansi and Shackleton 2006; Madubansi and Shackleton 2007). In rural areas where demographic growth is high, the sustainability of the natural woodland vegetation utilisation becomes questionable (Shackleton 1993; Shackleton 1998; Shackleton *et al.* 2005).

Woodlands and forests of Maputaland are intricately interwoven, diverse vegetation units. They share many species, and it is often not clear whether some woodlands are the result of Sand Forest deterioration or whether they are the precursor to Sand Forest (Van Rensburg *et al.* 2000; Gaugris 2004; Botes *et al.* 2006; Matthews 2006). In protected areas, it is documented that both Sand Forest and woodlands are deteriorating due to high animal densities (Matthews 2006; Guldemond and Van Aarde In Press), while outside conserved areas, numerous questions have been raised with regards to the potential destruction of these ecosystems by people (Tarr *et al.* 2004; Peteers 2005; Smith *et al.* 2006; Gaugris *et al.* 2007). In order to avoid further woodland destruction, the conservation authorities in KwaZulu-Natal, South Africa are encouraging rural communities to protect parts of their land and to practice sustainable resource utilisation (KwaZulu-Natal Nature Conservation Services 1997; Gaugris 2004; Peteers 2005; Matthews 2006).

In northern Maputaland the problem is exacerbated by the rapid demographic growth rate (Kloppers 2001; Matthews 2006; Peteers 2005; Jones 2006) and while resource utilisation until present was limited (Brookes 2004; Gaugris *et al.* 2004; Gaugris *et al.* 2007), land clearing for the creation of new households and fields is increasing. Reasons are twofold, on the one hand modernisation of rural society leads to a lower number of residents per households, while the arrival of new people by immigration increases and fuels the preponderance of this phenomenon (Peteers 2005). In addition, since 2000, Maputaland has become a favourite tourism destination in South Africa and southern Mozambique, which recently provoked the migration of people towards economic hubs of Maputaland as tourism-related activities and businesses have flourished (Peteers 2005; Matthews 2006).

Because of the demographic growth observed in the Maputaland region, and the recent debates that animal populations in formally protected areas have reached saturation and begun to damage the ecosystems that sustain them, information is needed on the current state of vegetation structure and to understand the underlying dynamics. The aims of the present study were therefore to investigate the effect of two different landscape shaping agents: large herbivores (especially elephants) and man on the population structure and dynamics of woody species. The study area encompassed three sites in the remote, rural, and poor northern Maputaland region of KwaZulu-Natal, South Africa (-26.85 ° to -27.15 ° South and 032.35 ° to 032.60 ° East) which have been under differing utilisation regimes during the past 15 years. Site one was located in Tembe Elephant Park (Tembe), sites two and three in the neighbouring Manqakulane rural community (6 km south of the southern fence of Tembe), where one site was located within the Manqakulane Rural Community village rule area (Manqakulane) and the other site in the Tshanini Community Conservation Area (Tshanini). Utilisation by either agents was low to nil in the Tshanini Community Conservation Area (Gaugris *et al.* 2004) and it could therefore be used as a control to compare the other sites.

The woody species resource base on the three sites was evaluated by using a range of techniques. These techniques range from a species level size class distribution regression analysis (Poorter *et al.* 1996; Lykke 1998; Lawes and Obiri 2003; Niklas *et al.* 2003), evaluating the position of the mean stem diameter of populations (Niklas *et al.* 2003), to determining the grain of species (Midgley *et al.* 1990; Everard *et al.* 1994; Everard *et al.* 1995; Obiri *et al.* 2002; Lawes and Obiri 2003). Although these methods do not replace long-term studies, the combination of these methods allows forestry practitioners to make some inferences on population dynamics (Obiri *et al.* 2002; Lawes and Obiri 2003; Niklas *et al.* 2003; Boudreau *et al.* 2005).

Study area

The study area is situated in the Maputaland coastal plain nearly midway from the sea to the east and the Lebombo Mountain Range to the west. This plain is intersected by ancient littoral dune cordons aligned in a north – south direction, and it is vegetated by open to closed woodlands, with patches of Sand Forest. The Muzi Swamp, underlain by clay soils, runs along the eastern side of the study area (Matthews *et al.* 2001; Gaugris *et al.* 2004). The region is hot, wet, and humid in summer, but winters are cool and dry. The region is relatively arid with a mean annual rainfall of 721 mm from 1981 to 2003 (Matthews 2006).

Tembe Elephant Park was created in 1983 to conserve the region's remaining wildlife and protect the diverse Sand Forest vegetation from utilisation by people. The park covers 30 000 ha and while the South African sides were fenced by 1983, full closure of the northern border with Mozambique occurred in 1989. The main purpose of Tembe was not to attract mass tourism (KwaZulu-Natal Nature Conservation Services 1997; Browning 2000) and therefore Tembe received few tourists between 1983 and 2001, which has elicited resentment from neighbouring communities as few economic returns accrued to them. A thorough description of Tembe appears in Matthews *et al.* (2001).

Tshanini Community Conservation Area is a remarkable achievement of the Manqakulane rural community. Already in 1992, the people from this community set aside the 2 420 ha section of tribal land that was launched as Tshanini Game Reserve in 2000, renamed and gazetted as Tshanini Community Conservation Area by end of 2005. Before the 1992 decision, people used the land to collect building material, firewood, fruit and honey, but also for cattle grazing and some hunting, while some areas on the eastern side were cultivated. In 1992, following the installation of a safe water supply along the Muzi Swamp, the people moved eastwards (Gaugris 2004). Tshanini has been protected by tribal rules since that date and therefore little human utilisation has taken place (Gaugris *et al.* 2004). Tshanini is described in Gaugris *et al.* (2004).

Manqakulane represents the land east of Tshanini (*ca.* 2 500 ha in total), comprised of the village zone where people are now living, but also the portion of free land between the village itself and Tshanini (Gaugris 2004; Gaugris *et al.* 2007). Both sections fall under tribal rule authority for the use of land and natural resources. Tribal rules can be likened to utilisation pressure within a restricted area. Tribal rules preclude harvesting in a neighbouring community's land, which would be considered trespass and may call for compensation (Kloppers 2001; Gaugris 2004). A total of 778 permanent residents lived in 124 households in the Manqakulane sector in 2004 (Peteers 2005) scattered along a broad north-south axis, parallel and to the west of the Muzi Swamp. The Manqakulane population has remained relatively stable over the past 10 years, in stark contrast to the regional population (Peteers 2005). However, the number of households increased considerably, thereby implying that land was cleared and natural vegetation utilised intensively for the construction of new households. A thorough description of the Manqakulane community village zone appears in Gaugris *et al.* (2007) and Peteers (2005).

Methods

A total of 6 vegetation units were sampled in the three study sites (Table 1). Rectangular plots of varying length and width, depending on the vegetation density, were used to obtain abundance and distribution data of woody species in the three sites studied. A total of 105 plots were located in the woodland units of Tembe, all plots (42) in Manqakulane were within woodland units, while the woodlands of Tshanini were represented in 30 plots from the total Tshanini sample. The data were captured in Microsoft Excel spreadsheets and then compiled into a Microsoft Access database.

A classic species based size class distribution regression analysis on the spread of stem diameter values of woody species in each vegetation unit evaluated (hereafter referred to as the SCD analysis) was conducted. The limitations of such analyses for obtaining population dynamics information are acknowledged (Condit *et al.* 1998; Niklas *et al.* 2003). However, it is expected that the range of other factors evaluated in the present study, such as centroid location, contribution of smaller size classes, subcanopy and canopy densities, frequency, and the fact that three study sites including a control area are evaluated, will contribute to a much improved insight in the species population structures and possibly dynamics. The core of the methodology followed in the present chapter is identical to that of the previous chapter and is therefore not repeated here. Only the determination of grain is presented below as it differed from the previous chapter in several important aspects.

The graphical model of Lawes and Obiri (2003) to determine the grain of species by plotting canopy density on the X-axis and subcanopy density on the Y-axis, was used to define which species are fine, coarse, or intermediate-grained species. The model appears in Figure 1, and ln-transformed values were used to facilitate reading due to high densities and large density variations observed in the study area. The same critical lower bounds for canopy, subcanopy and frequency of occurrence levels as Lawes and Obiri (2003) are used. These authors evaluated a range of forests from the Eastern Cape and KwaZulu-Natal provinces of South Africa using this model, and it was deemed judicious to use the same limits to allow comparison at the regional level. These boundaries are 10 and 30 individuals per ha for the canopy and subcanopy levels respectively, and a minimum of 50% frequency of occurrence in the sampled plots. Frequency of occurrence was not represented graphically as it was already provided in the SCD analysis. The above boundary limits were used for the Closed Woodlands units as the latter have been identified as forest-like units (Gaugris 2004). For comparative purposes, the concept was applied to the Open and Sparse

Table 1: Vegetation units of the study area in Maputaland, northern KwaZulu-Natal, South Africa

	Code	Abreviation	Community Name	Synonym in other studies
2		CW	Closed Woodland association	
	2.1.0	CWT	Closed Woodland Thicket	Described as such in Matthews *et al.* (2001), and as Closed Woodland in Gaugris *et al.* (2004)
	2.2.0	CWC	Closed Woodland on Clay	Described as such in Matthews *et al.* (2001), and as Woodland on Clay in Gaugris *et al.* (2004)
	2.3.0	CWS	Closed Woodland on Sand	Described as such in Matthews *et al.* (2001), and as Open Woodland on Sand in Gaugris *et al.* (2004)
3		OW	Open Woodland association	
	3.1.0	OWS	Open Woodland on Sand	Described as such in Matthews *et al.* (2001), and as Sparse Woodland on Sand in Gaugris *et al.* (2004)
	3.2.0	OWAH	Open Woodland on Abandoned Household sites	Newly described in the present study
4		SW	Sparse Woodland association	
	4.1.0	SWS	Sparse Woodland on Sand	Described as such in Matthews *et al.* (2001)

Woodlands units, but the canopy boundary was relaxed to 5 and 3 individuals per ha respectively.

Results

Closed Woodland Thicket

The Closed Woodland Thicket was not well represented in Tembe, and was therefore not sampled intensively. Only three species fulfilled the analysis minimum number of individuals' criteria employed (Table 2) and it was therefore difficult to make further comparisons between Tembe and other comparable vegetation units in Tshanini and Manqakulane. The three species were classified within Type 1 (Table 3). Mean centroid 2 was located within size class 5 in both analyses, and mean centroid 1 was located within size classes 4 and 3 in the full and limited analyses respectively.

In Tshanini, this unit appeared well represented with 44 species evaluated (Table 4). The majority of species were classified in Type 1 in the full analysis (Table 3) but the limited analysis showed a vast majority of species within Type 3 (Table 3). The mean centroid 2 positions reflected a bias to the left of the centre of the SCD range in both analyses and no major shift in size classes occurred from the positions of centroid 1 to centroid 2.

The subcanopy level was dominated by *Acacia burkei, Pteleopsis myrtifolia, Sclerocarya birrea* and *Strychnos madagascariensis* (Table 4) and the canopy was dominated by the same species found as large to very large trees (size classes 10 to 12) except for *Pteleopsis myrtifolia*, and with the addition of *Terminalia sericea*. Typical species of the subcanopy level included *Bridelia cathartica, Dichrostachys cinerea, Euclea natalensis, Grewia microthyrsa, Strychnos spinosa, Tabernaemontana elegans* and *Vangueria infausta*. The population structure of all woody species found within both subcanopy and canopy levels were pyramidal, represented by a large subcanopy component and a small canopy component. The pyramidal structure and the centroid skewed to the left reinforced the assumption that regenerative processes are strong.

In Manqakulane, this unit was represented by 24 species (Table 5), all classified within Type 1 (Table 3). The mean centroid 2 position reflected a bias to the left of the centre of the SCD range in both analyses, which was belied by a major shift in size classes that occurred between the positions of mean centroids 1 and 2 (Table 5), indicating a large influence of seedlings and saplings.

The subcanopy was dominated by Acacia *burkei, Euclea natalensis, Zanthoxylum capense* and *Commiphora neglecta. Acacia burkei* was still the dominant component at the canopy level, but shared it with *Dialium schlechteri, Euclea*

Table 2: Detail of species level size class distribution (SCD) regressions, including statistical significance, the range of size classes (SC) used, number of individuals sampled, centroid 1 position (full data set) centroid 2 position (size classes 3 - 12), subcanopy and canopy density, frequency of occurrence in sample plots, and species grain. The information presented is for the common species for which 30 or more individuals were sampled (full analysis) and those for which 10 to 29 individuals were sampled (limited analysis) of the Closed Woodland Thicket in Tembe Elephant Park, Maputaland, northern KwaZulu-Natal, South Africa

Analysis	Species	Slope	Intercept	R^2	Standard error	F	Degrees of freedom	SC range	Number of individuals	Centroid 1 in SC	Centroid 2 in SC	Subcanopy density (individuals / ha)	Canopy density (individuals / ha)	Frequency of occurrence (%)	Species grain
Community Level	**Community SCD**	**-2.13**	**9.54**	**0.96**	**0.56**	**229.01** **	**10**	**12**	**117**						
Full	*Tabernaemontana elegans*	-1.35	6.41	0.49	1.45	5.77 -	6	8	30	04	05	750	167	100.00	Fine
						Mean SCD centroid location for common species:				04	05				
Limited	*Sclerocroton integerrimus*	-1.74	5.74	0.49	1.86	5.81 -	6	8	11	03	06	125	42	100.00	Fine
Limited	*Psydrax locuples*	-3.08	8.58	0.73	1.30	2.69 -	1	3	24	02	03	83	0	100.00	***NA***
						Mean SCD centroid location for common species:				03	05				

SC	Size Class
**	Highly significant (p ≤ 0.01)
*	Significant (p ≤ 0.05)
-	Not significant (p > 0.05)
NA	Not applicable, following the species grain, it indicates that while grain could be determined, the frequency of occurrence is too low to warrant inclusion in the model

Table 3: Detail of species level size class distribution (SCD) regressions, including statistical significance, the range of size classes (SC) used, number of individuals sampled, centroid 1 position (full data set) centroid 2 position (size classes 3 - 12), subcanopy and canopy density, frequency of occurrence in sample plots, and species grain. The information presented is for the common species for which 30 or more individuals were sampled (full analysis) and those for which 10 to 29 individuals were sampled (limited analysis) of the Closed Woodland Thicket in Tshanini Community Conservation Area, Maputaland, northern KwaZulu-Natal, South Africa

Analysis	Species	Slope	Intercept	R^2	Standard error	F		Degrees of freedom	SC range	Number of individuals	Centroid 1 in SC	Centroid 2 in SC	Subcanopy density (individuals / ha)	Canopy density (individuals / ha)	Frequency of occurrence (%)	Species grain
Community Level	**Community SCD**	**-2.13**	**9.54**	**0.96**	**0.56**	**229.01**	**	**10**	**12**	**4126**						
Full	*Acacia burkei*	-1.07	5.08	0.94	0.32	146.04	**	9	11	203	05	06	283	105	100.00	Fine
Full	*Albizia adianthifolia*	-0.80	3.09	0.29	1.03	1.23	-	3	5	31	03	03	50	0	30.00	***NA***
Full	*Bridelia cathartica*	-1.86	5.71	0.76	1.03	15.69	*	5	7	150	03	04	183	8	50.00	***NA***
Full	*Catunaregam taylori*	-0.78	3.41	0.11	1.77	0.39	-	3	5	68	03	03	73	0	60.00	***NA***
Full	*Cleistanthus schlechteri*	-1.09	3.96	0.42	1.61	7.24	*	10	12	571	02	07	25	13	20.00	Intermediate (*NA*)
Full	*Clerodendrum glabrum*	-0.41	2.59	0.23	0.67	1.20	-	4	6	34	04	04	70	0	20.00	***NA***
Full	*Coddia rudis*	-2.41	5.08	0.99	0.12	187.12	*	1	3	35	01	03	10	0	70.00	***NA***
Full	*Combretum molle*	-0.83	3.44	0.40	1.07	3.96	-	6	8	67	04	04	123	5	80.00	***NA***
Full	*Deinbollia oblongifolia*	-1.50	5.66	0.72	0.65	2.55	-	1	3	118	02	03	53	0	70.00	***NA***
Full	*Dialium schlechteri*	-1.32	4.46	0.73	0.85	16.04	**	6	8	72	04	04	133	3	50.00	***NA***
Full	*Dichrostachys cinerea*	-2.39	7.10	0.92	0.64	45.95	**	4	6	270	02	04	178	0	50.00	***NA***
Full	*Euclea natalensis*	-1.65	5.74	0.89	0.64	57.87	**	7	9	174	03	05	150	23	100.00	Fine
Full	*Gardenia volkensii*	-2.13	4.84	0.95	0.36	37.70	*	2	4	32	02	03	15	0	50.00	***NA***
Full	*Grewia caffra*	-0.45	3.44	0.11	0.93	0.25	-	2	4	49	03	03	65	0	40.00	***NA***
Full	*Grewia microthyrsa*	-1.95	6.54	0.86	0.57	12.52	-	2	4	220	02	03	143	0	50.00	***NA***
Full	*Hymenocardia ulmoides*	-1.74	5.24	0.86	0.74	36.35	**	6	8	87	03	04	98	3	60.00	***NA***
Full	*Lippia javanica*	1.70	1.38	0.24	2.09	0.32	-	1	3	55	02	03	33	0	10.00	***NA***
Full	*Margaritaria discoidea*	-0.36	3.30	0.02	1.95	0.02	-	1	3	47	02	03	13	0	70.00	***NA***
Full	*Gymnosporia senegalensis*	-1.07	3.40	0.36	1.39	2.81	-	5	7	53	03	04	73	8	30.00	***NA***
Full	*Pteleopsis myrtifolia*	-1.26	5.76	0.37	1.34	1.77	-	3	5	335	03	03	465	0	50.00	***NA***
Full	*Sclerocroton integerrimus*	-0.89	3.27	0.55	0.78	6.13	-	5	7	35	04	05	50	3	50.00	***NA***
Full	*Sclerocarya birrea*	-1.26	5.18	0.88	0.58	73.88	**	10	12	174	05	05	298	43	60.00	Fine
Full	*Spirostachys africana*	-0.61	2.53	0.31	1.10	4.11	-	9	11	47	05	05	58	15	50.00	Fine
Full	*Strychnos madagascariensis*	-1.21	5.33	0.72	0.89	20.35	**	8	10	249	05	05	460	53	100.00	Fine
Full	*Strychnos spinosa*	-1.34	4.82	0.88	0.58	59.14	**	8	10	101	04	04	158	13	100.00	Fine
Full	*Tabernaemontana elegans*	-1.05	4.27	0.68	0.76	12.57	*	6	8	90	04	05	118	13	80.00	Fine
Full	*Terminalia sericea*	-0.93	3.83	0.55	1.03	10.80	**	9	11	111	05	06	135	40	70.00	Fine
Full	*Vangueria infausta*	-0.92	4.18	0.46	0.81	2.57	-	3	5	80	03	03	140	0	90.00	***NA***
Full	*Vitex ferruginea*	-1.11	3.81	0.51	1.22	7.17	*	7	9	72	03	04	83	3	50.00	***NA***
Full	*Xylotheca kraussiana*	-2.47	6.59	1.00	0.00	0.00	-	0	2	137	01	***NA***	0	0	100.00	***NA***
						Mean SCD centroid location for common species:					03	04				

Table 3:continued

	Limited	*Acridocarpus natalitius*	2.69	-0.64	0.72	1.16	2.61	-	1	3	16	03	03	25	0	60.00	***NA***
	Limited	*Ancylanthos monteiroi*	-1.01	4.18	1.00	0.00	0.00	-	0	2	27	01	***NA***	0	0	30.00	***NA***
	Limited	*Balanites maughamii*	-0.08	0.69	0.02	0.68	0.18	-	9	11	16	06	06	25	15	40.00	Intermediate (*NA*)
	Limited	*Bridelia micrantha*	0.75	-0.21	0.30	0.94	1.30	-	3	5	10	04	04	25	0	10.00	***NA***
	Limited	*Canthium armatum*	-0.32	1.75	0.18	0.56	0.66	-	3	5	10	03	04	18	0	40.00	***NA***
	Limited	*Commiphora neglecta*	-1.23	3.19	0.69	0.67	6.65	-	3	5	15	03	04	10	0	20.00	***NA***
	Limited	*Diospyros inhacaensis*	0.94	-0.36	0.62	0.59	4.94	-	3	5	11	04	04	28	0	30.00	***NA***
	Limited	*Ehretia obtusifolia*	-0.07	1.07	0.01	0.98	0.03	-	5	7	17	04	05	38	3	40.00	***NA***
	Limited	*Psydrax locuples*	-1.15	3.19	0.88	0.35	21.14	*	3	5	15	03	04	15	0	70.00	***NA***
	Limited	*Rhus gueinzii*	-0.10	1.45	0.00	1.61	0.01	-	3	5	20	03	04	33	0	60.00	***NA***
	Limited	*Tarenna junodii*	0.06	1.90	0.00	1.71	0.00	-	1	3	14	02	03	5	0	10.00	***NA***
	Limited	*Tricalysia lanceolata*	1.52	1.52	1.00	0.00	0.00	-	0	2	10	02	***NA***	0	0	10.00	***NA***
	Limited	*Zanthoxylum leprieuri*	0.05	2.66	0.00	1.38	0.00	-	1	3	27	02	03	15	0	50.00	***NA***
	Limited	*Ziziphus mucronata*	0.00	0.69	0.00	0.79	0.00	-	7	9	18	06	06	40	5	70.00	***NA***
									Mean SCD centroid location for common species:			03	04				

SC	Size Class
**	Highly significant (p ≤ 0.01)
*	Significant (p ≤ 0.05)
-	Not significant (p > 0.05)
NA	Not applicable, following the species grain, it indicates that while grain could be determined, the frequency of occurrence is too low to warrant inclusion in the model

Table 4: Detail of species level size class distribution (SCD) regressions, including statistical significance, the range of size classes (SC) used, number of individuals sampled, centroid 1 position (full data set) centroid 2 position (size classes 3 - 12), subcanopy and canopy density, frequency of occurrence in sample plots, and species grain. The information presented is for the common species for which 30 or more individuals were sampled (full analysis) and those for which 10 to 29 individuals were sampled (limited analysis) of the Closed Woodland Thicket in the Manqakulane Rural Community Village zone, Maputaland, northern KwaZulu-Natal, South Africa

Analysis	Species	Slope	Intercept	R^2	Standard error	F	Degrees of freedom	SC range	Number of individuals	Centroid 1 in SC	Centroid 2 in SC	Subcanopy density (individuals / ha)	Canopy density (individuals / ha)	Frequency of occurrence (%)	Species grain
Community Level	**Community SCD**	**-2.87**	**12.28**	**0.92**	**1.06**	**116.20** **	**10**	**12**	**1170**						
Full	*Acacia burkei*	-1.84	7.29	0.82	1.06	40.47 **	9	11	36	03	06	331	110	78.57	Fine
Full	*Carissa tetramera*	-6.18	12.87	0.83	1.92	4.99 -	1	3	67	01	03	63	0	35.71	***NA***
Full	*Clausena anisata*	-7.77	14.60	0.93	1.45	13.78 -	1	3	176	01	03	47	0	85.71	***NA***
Full	*Coddia rudis*	-4.25	10.90	0.68	2.02	2.13 -	1	3	38	02	03	126	0	85.71	***NA***
Full	*Dialium schlechteri*	-2.19	7.99	0.72	1.72	25.57 **	10	12	64	01	07	94	63	85.71	Fine
Full	*Euclea natalensis*	-2.64	9.20	0.62	2.30	11.39 *	7	9	171	01	06	252	63	100.00	Fine
Full	*Monanthotaxis caffra*	-6.00	11.08	0.77	2.40	6.70 -	2	4	34	01	04	16	0	92.86	***NA***
Full	*Psydrax locuples*	-3.93	10.24	0.79	1.80	15.50 *	4	6	44	01	05	63	0	92.86	***NA***
Full	*Xylotheca kraussiana*	-1.94	9.91	1.00	0.00	0.00 -	0	2	37	01	***NA***	0	0	92.86	***NA***
Full	*Zantoxylum capense*	-3.59	10.47	0.94	0.79	67.71 **	4	6	60	01	04	331	0	92.86	***NA***
							Mean SCD centroid location for common species:			01	05				
Limited	*Brachylaena discolor*	-3.9	9.59	0.96	0.64	75.66 **	3	5	21	01	04	94	0	42.86	***NA***
Limited	*Canthium armatum*	-4.3	9.57	0.84	1.53	15.89 *	3	5	13	01	04	47	0	64.29	***NA***
Limited	*Carissa bispinosa*	-5.7	10.89	1.00	0.25	257.19 *	1	3	17	01	03	31	0	21.43	***NA***
Limited	*Catunaregam taylori*	-4.0	9.43	0.89	1.04	16.25 -	2	4	11	01	03	63	0	35.71	***NA***
Limited	*Commiphora neglecta*	-2.5	8.35	0.92	0.74	55.38 **	5	7	24	02	05	252	0	35.71	***NA***
Limited	*Deinbollia oblongifolia*	-3.93	9.70	0.88	1.18	22.21 *	3	5	17	02	04	79	0	71.43	***NA***
Limited	*Dovyalis longispina*	-5.03	10.35	0.61	2.80	1.55 -	1	3	14	02	03	16	0	42.86	***NA***
Limited	*Grewia caffra*	-2.21	6.07	0.44	2.46	3.87 -	5	7	19	01	04	142	0	92.86	***NA***
Limited	*Haplocoelum foliolosum*	-2.99	8.40	0.85	1.13	22.60 **	4	6	13	02	04	94	0	42.86	***NA***
Limited	*Manilkara concolor*	-5.47	10.68	0.75	2.16	3.08 -	1	3	12	01	03	16	0	42.86	***NA***
Limited	*Ochna natalitia*	-2.15	9.59	1.00	0.00	0.00 -	0	2	24	01	***NA***	0	0	71.43	***NA***
Limited	*Rhus gueinzii*	-4.19	9.54	0.79	1.75	11.47 *	3	5	16	01	04	63	0	78.57	***NA***
Limited	*Strychnos madagascariensis*	-1.88	6.48	0.61	1.56	9.51 *	6	8	12	03	06	110	16	50.00	Fine
Limited	*Strychnos spinosa*	-3.60	9.26	0.80	1.33	7.92 -	2	4	15	01	04	94	0	42.86	***NA***
							Mean SCD centroid location for common species:			01	04				

SC	Size Class
**	Highly significant ($p \leq 0.01$)
*	Significant ($p \leq 0.05$)
-	Not significant ($p > 0.05$)
NA	Not applicable, following the species grain, it indicates that while grain could be determined, the frequency of occurrence is too low to warrant inclusion in the model

Table 5: The percentage of species with Type 1 to 3 slopes for the Sand Forest vegetation of Tembe Elephant Park (TEP), the Manqakulane Rural Community village zone (MRC) and Tshanini Community Conservation Area (TCCA), for the full (≥ 30 individuals sampled) and limited (10 - 29 individuals sampled) analyses, northern Maputaland, KwaZulu-Natal, South Africa. The total number of species (No spp) for analyses by vegetation unit or sub-unit is indicated in the top line of each analysis

Analysis	Type	Vegetation units and sites													
		Closed Woodland Thicket			Closed Woodland on Clay		Closed Woodland on Sand			Open Woodland on Sand			Open Woodland on abandoned household site	Sparse Woodland on Sand	
		TEP	TCCA	MRC	TEP	MRC	TEP	TCCA	MRC	TEP	TCCA	MRC	MRC	TEP	MRC
	No spp →	1	30	10	25		18	26	8	27	19	1	13	6	2
Full		(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
	Type 1	100.00	60.00	100.00	88.00	-	88.89	76.92	100.00	92.59	73.68	100.00	100.00	83.33	100.00
	Type 2	0.00	36.67	0.00	8.00	-	11.11	19.23	0.00	7.41	21.05	0.00	0.00	0.00	0.00
	Type 3	0.00	3.33	0.00	4.00	-	0.00	3.85	0.00	0.00	5.26	0.00	0.00	16.67	0.00
	No spp →	2	14	14	25		25	13	20	15	14	0	7	2	1
Limited		(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
	Type 1	100.00	14.29	100.00	52.00	66.67	64.00	30.77	80.00	40.00	14.29	-	71.43	50.00	100.00
	Type 2	0.00	14.29	0.00	36.00	16.67	28.00	38.46	10.00	40.00	35.71	-	28.57	50.00	0.00
	Type 3	0.00	71.43	0.00	12.00	16.67	8.00	30.77	10.00	20.00	50.00	-	0.00	0.00	0.00
	No spp →	3	44	24	50	6	43	39	28	42	33	1	20	8	3
Combined		(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
	Type 1	100.00	45.45	100.00	70.00	66.67	74.42	61.54	85.71	73.81	48.48	100.00	90.00	75.00	100.00
	Type 2	0.00	29.55	0.00	22.00	16.67	20.93	25.64	7.14	19.05	27.27	0.00	10.00	12.50	0.00
	Type 3	0.00	25.00	0.00	8.00	16.67	4.65	12.82	7.14	7.14	24.24	0.00	0.00	12.50	0.00

Type 1	slopes steeper or equal to half that of the vegetation unit evaluated
Type 2	slopes shallower than half that of the vegetation unit evaluated but steeper than - 0.15
Type 3	slopes shallower than - 0.15 coefficient or with positive slope coefficients

natalensis and to a lesser degree *Strychnos madagascariensis*. The SCD range indicated that some large to very large trees were identified, but the bulk of species did not exceed size class 6 (Table 5).

A total of 16 comparisons were performed and half showed different population structures (Table 6). All Tshanini species populations had shallower slopes and lower Y-axis intercepts than their Manqakulane counterparts. Only *Psydrax locuples* was comparable between Tembe and Manqakulane, and the slopes and Y-axis intercepts were similar.

Closed Woodland on clay

This vegetation unit only occured in Manqakulane and Tembe. There is the possibility of a small area with underlying clay soils in Tshanini (Gaugris *et al.* 2004), but it was not investigated. Some 50 species were evaluated in Tembe (Table 7) but Manqakulane was only represented by five species in the limited analysis (Table 7). Most species of both sites fell within Type 1 (Table 3), and some in Type 2 and 3. The mean centroid 2 position for both sites indicated a slight skew to the left, but a large shift occured between the positions of mean centroids 1 and 2 for Manqakulane, indicating a large regeneration cohort, while no major shift was observed in Tembe.

In Manqakulane, *Dialium schlechteri* was an important species, present in subcanopy and canopy levels at fairly high densities. *Margaritaria discoidea* was an abundant subcanopy component.

In Tembe the SCD range indicated that a variety of size classes were found, including large to very large trees. The distribution of species in this vegetation unit appeared patchy or clustered with frequency of occurrences rarely exceeding 60%. The most ubiquitous species were *Euclea natalensis* (present in 91% of plots) and *Vepris lanceolata* (present in 68% of plots). *Acacia burkei, Schotia brachypetala, Spirostachys africana, Terminalia sericea, Afzelia quanzensis* and *Sclerocarya birrea* dominated the canopy level in the patches they occurred in, either alone or in co-dominance. *Combretum molle, Spirostachys africana* and *Terminalia sericea* were the most abundant subcanopy woody species in these patches. The bulk of the species sampled occurred at densities that ranged from 50 to 90 individuals per hectare at the subcanopy level.

The two species that could be compared (*Dialium schlechteri* and *Euclea natalensis)* had similar population structures in the two sites (Table 6).

Table 6: *A comparison of size class distribution (SCD) slope coefficients and Y-axis intercepts within species and analyses (F = Full analysis, L = Limited Analysis) in comparable Woodland vegetation units in the study sites Tembe Elephant Park (TEP), the Manqakulane Rural Community village zone (MRC) and Tshanini Community Conservation Area (TCCA), Maputaland, northern KwaZulu-Natal, South Africa*

Comparison levels					Slope Comparison					Intercept Comparison					Meaning	Note*
VT	Vegetation unit	Species	Sites compared	Datasets	F value	Df $_n$	Df $_d$	P value	Pooled slope	F value	Df $_n$	Df $_d$	P value	Pooled Intercept		
VT 02.1.0	Closed Woodland Thicket	*Acacia burkei*	MRC / TGR	F / F	6.42 *	1	18	0.02	-	-	-	-	-	-	Different	-
		Coddia rudis	MRC / TGR	F / F	0.40 -	1	2	0.59	-3.33	15.9 *	1	3	0.03	-	Different	-
		Dialium schlechteri	MRC / TGR	F / F	1.64 -	1	16	0.22	-1.93	6.03 *	1	17	0.03	-	Different	-
		Euclea natalensis	MRC / TGR	F / F	1.48 -	1	14	0.24	-2.15	2.99 -	1	15	0.10	7.47	Similar	-
		Tabernaemontana elegans	TEP / TGR	F / F	0.22 -	1	12	0.64	-1.20	7.69 *	1	13	0.02	-	Different	-
		Psydrax locuples	TEP / TGR	L / L	2.81 -	1	4	0.17	-1.52	28.03 **	1	5	<0.01	-	Different	-
		Commiphora neglecta	MRC / TGR	L / L	4.63 -	1	8	0.06	-1.52	40.38 **	1	9	<0.01	-	Different	-
		Rhus gueinzii	MRC / TGR	L / L	5.91 -	1	6	0.05	-2.14	3.57 -	1	7	0.10	5.50	Similar	-
		Canthium armatum	MRC / TGR	L / L	6.02 -	1	5	0.06	-1.58	0.91 -	1	6	0.38	3.92	Similar	-
		Catunaregam taylori	MRC / TGR	L / F	3.21 -	1	5	0.13	-1.92	3.03 -	1	6	0.13	5.87	Similar	X
		Deinbollia oblongifolia	MRC / TGR	L / F	2.00 -	1	4	0.23	-3.45	3.24 -	1	5	0.13	8.45	Similar	X
		Grewia caffra	MRC / TGR	L / F	0.59 -	1	7	0.47	-1.89	0.11 -	1	8	0.75	5.35	Similar	-
		Psydrax locuples	TEP / TGR / MRC	L / L / F	2.56 -	2	8	0.17	-2.89	6.00 *	2	10	0.02	-	Different	-
		1) *Psydrax locuples*	MRC / TGR	L / F	5.04 -	1	7	0.06	-2.87	8.94 *	1	8	0.02	-	Different	-
		2) *Psydrax locuples*	MRC / TEP	F / L	0.10 -	1	5	0.76	-3.82	0.45 -	1	6	0.53	9.80	Similar	-
		3) *Psydrax locuples*	TEP / TGR	L / L	2.81 -	1	4	0.17	-1.52	28 **	1	5	<0.01	-	Different	-
		Strychnos madagascariensis	MRC / TGR	L / F	1.21 -	1	14	0.29	-1.46	0.12 -	1	15	0.73	5.80	Similar	X
		Strychnos spinosa	MRC / TGR	L / F	8.12 *	1	11	0.02	-	-	-	-	-	-	Different	-
		Sclerocroton integerrimus	TEP / TGR	L / F	0.93 -	1	11	0.35	-1.38	1.46 -	1	12	0.25	4.62	Similar	X
VT 02.2.0	Closed Woodland on Clay	*Dialium schlechteri*	TEP / MRC	F / L	0.50 -	1	15	0.49	-1.20	0.00 -	1	16	0.99	4.35	Similar	-
		Euclea natalensis	TEP / MRC	F / L	1.09 -	1	8	0.33	-2.44	0.00 -	1	9	0.97	7.14	Similar	X
VT 02.3.0	Closed Woodland on Sand	*Combretum molle*	TEP / TGR	F / F	3.04 -	1	14	0.10	-1.20	0.00 -	1	15	0.95	4.52	Similar	-
		Deinbollia oblongifolia	TEP / MRC	F / F	0.00 -	1	3	0.99	-3.21	6.91 -	1	4	0.06	7.10	Similar	-
		Dialium schlechteri	TEP / TGR	F / F	0.29 -	1	17	0.60	-1.27	21.1 **	1	18	<0.01	-	Different	-
		Dichrostachys cinerea	MRC / TGR	F / F	0.00 -	1	8	0.98	-2.06	9.47 *	1	9	0.01	-	Different	-
		Euclea natalensis	TEP / MRC / TGR	F / F / F	3.21 -	2	13	0.07	-1.76	2.72 -	2	15	0.10	5.84	Similar	-
		Psydrax locuples	TEP / MRC / TGR	F / F / F	1.95 -	2	11	0.19	-2.08	1.35 -	2	13	0.29	5.55	Similar	-
		Sclerocroton integerrimus	TEP / TGR	F / F	0.25 -	1	13	0.63	-1.23	0.16 -	1	14	0.69	4.25	Similar	-
		Spirostachys africana	TEP / TGR	F / F	3.87 -	1	16	0.07	-0.93	3.42 -	1	17	0.08	3.79	Similar	-
		Strychnos madagascariensis	TEP / TGR	F / F	3.17 -	1	16	0.09	-1.19	7.70 *	1	17	0.01	-	Different	-
		Strychnos spinosa	TEP / MRC / TGR	F / F / F	1.03 -	2	18	0.38	-1.71	3.43 -	2	20	0.05	5.69	Similar	-
		Tabernaemontana elegans	TEP / TGR	F / F	0.03 -	1	13	0.86	-0.99	8.94 *	1	14	0.01	-	Different	-
		Catunaregam taylori	MRC / TGR	L / L	0.16 -	1	4	0.71	-2.23	41.22 **	1	5	<0.01	-	Different	-
		Commiphora neglecta	TEP / MRC	L / L	5.64 *	1	12	0.04	-	-	-	-	-	-	Different	-
		Coddia rudis	MRC / TGR	L / L	0.36 -	1	3	0.59	-1.04	0.05 -	1	4	0.83	3.42	Similar	-
		Ptaeroxylon obliquum	TEP / TGR	L / L	0.03 -	1	11	0.86	-1.04	0.00 -	1	12	0.99	3.01	Similar	-
		Rhus gueinzii	TEP / TGR	L / L	2.99 -	1	9	0.12	-1.10	1.15 -	1	10	0.31	3.37	Similar	-
		Sclerocarya birrea	MRC / TGR	L / L	0.92 -	1	20	0.35	-0.74	8.04 **	1	21	<0.01	-	Different	-
		Acacia burkei	MRC / TGR	F / L	0.94 -	1	20	0.34	-1.33	0.14 -	1	21	0.71	5.51	Similar	-
		Bridelia cathartica	MRC / TGR	L / F	0.10 -	1	8	0.76	-1.41	16.45 **	1	9	<0.01	-	Different	X
		Clausena anisata	TEP / MRC	L / F	0.20 -	1	2	0.70	-3.78	9.60 -	1	3	0.05	7.36	Similar	-
		Deinbollia oblongifolia	TEP / TGR / MRC	F / L / F	1.91 -	2	4	0.26	-3.19	7.75 *	2	6	0.02	-	Different	-
		1) *Deinbollia oblongifolia*	TEP / TGR	F / L	41.9 *	1	2	0.02	-	-	-	-	-	-	Different	-
		2) *Deinbollia oblongifolia*	MRC / TEP	F / F	0.95 -	1	3	0.40	-3.62	7.23 -	1	21	0.05	7.47	Similar	-

Table 6: continued

		3) *Deinbollia oblongifolia*	MRC / TGR	F / L	1.07	-	1	3	0.38	-2.78	12.94	*	1	4	0.02	-	Different	-
		Dalbergia obovata	MRC / TGR	L / F	0.28	-	1	3	0.64	-3.35	0.65	-	1	4	0.46	6.95	Similar	-
		Dialium schlechteri	TEP / TGR / MRC	F / F / L	6.19	**	2	21	<0.01	-	-	-	-	-	-	-	Different	-
		1) *Dialium schlechteri*	TEP / TGR	F / F	0.29	-	1	17	0.60	-1.27	21.15	**	1	18	<0.01	-	Different	-
		2) *Dialium schlechteri*	MRC / TEP	L / F	9.90	**	1	12	<0.01	-	-	-	-	-	-	-	Different	-
		3) *Dialium schlechteri*	MRC / TGR	L / F	8.22	*	1	13	0.01	-	-	-	-	-	-	-	Different	-
		Canthium armatum	MRC / TGR	L / F	1.91	-	1	6	0.73	-2.16	3.30	-	1	7	0.11	6.16	Similar	X
		Spirostachys africana	TEP / TGR / MRC	F / F / L	2.47	-	2	22	0.11	-1.09	1.23	-	2	24	0.31	4.20	Similar	-
		Strychnos madagascariensis	TEP / TGR / MRC	F / F / L	1.42	-	2	26	0.26	-1.19	3.99	*	2	28	0.03	-	Different	-
		1) *Strychnos madagascariensis*	TEP / TGR	F / F	3.17	-	1	16	0.09	-1.19	7.70	*	1	17	0.01	-	Different	-
		2) *Strychnos madagascariensis*	MRC / TEP	L / F	1.01	-	1	17	0.33	-1.10	0.77	-	1	18	0.39	4.52	Similar	-
		3) *Strychnos madagascariensis*	MRC / TGR	L / F	0.60	-	1	19	0.45	-1.27	3.54	-	1	20	0.07	5.30	Similar	-
		Terminalia sericea	MRC / TGR	L / F	5.76	*	1	15	0.03	-	-	-	-	-	-	-	Different	X
		Dichrostachys cinerea	TEP / TGR / MRC	L / F / F	2.63	-	2	13	0.11	-1.45	6.26	*	2	15	0.01	-	Different	X
		1) *Dichrostachys cinerea*	TEP / TGR	L / F	3.32	-	1	9	0.10	-1.20	2.18	-	1	10	0.17	3.59	Similar	X
		2) *Dichrostachys cinerea*	MRC / TEP	F / L	2.87	-	1	9	0.12	-1.19	10.46	**	1	10	<0.01	-	Different	X
		3) *Dichrostachys cinerea*	MRC / TGR	F / F	0.00	-	1	8	0.98	-2.06	9.47	*	1	9	0.01	-	Different	-
		Tabernaemontana elegans	TEP / TGR	F / F	0.03	-	1	13	0.86	-0.99	8.94	**	1	14	<0.01	-	Different	-
VT 03.1.0	en Woodland on Sand	*Acacia burkei*	TEP / TGR	F / F	0.21	-	1	20	0.65	-0.87	1.57	-	1	21	0.22	3.65	Similar	-
		Catunaregam taylori	TEP / TGR	F / F	0.12	-	1	5	0.74	-3.00	0.72	-	1	6	0.43	6.15	Similar	-
		Combretum molle	TEP / TGR	F / F	0.38	-	1	16	0.54	-1.03	0.91	-	1	17	0.35	3.66	Similar	-
		Dialium schlechteri	TEP / TGR	F / F	2.31	-	1	16	0.15	-1.06	0.16	-	1	17	0.69	3.64	Similar	-
		Sclerocroton integerrimus	TEP / TGR	F / F	0.75	-	1	14	0.40	-0.78	0.08	-	1	15	0.78	2.79	Similar	-
		Strychnos madagascariensis	TEP / TGR	F / F	0.39	-	1	18	0.54	-1.30	0.87	-	1	19	0.36	5.12	Similar	-
		Strychnos spinosa	TEP / TGR	F / F	0.82	-	1	15	0.38	-1.31	0.00	-	1	16	0.99	4.45	Similar	-
		Terminalia sericea	TEP / TGR	F / F	11.84	**	1	19	<0.01	-	-	-	-	-	-	-	Different	-
		Vangueria infausta	TEP / TGR	F / F	5.83	*	1	14	0.03	-	-	-	-	-	-	-	Different	-
		Mundulea sericea	TEP / TGR	L / L	0.00	-	1	3	0.99	0.16	6.77	-	1	4	0.06	1.29	Similar	-
		Tabernaemontana elegans	TEP / TGR	L / L	0.22	-	1	13	0.65	-0.46	0.17	-	1	14	0.68	1.53	Similar	-
		Albizia adianthifolia	TEP / TGR	L / F	6.96	*	1	20	0.02	-	-	-	-	-	-	-	Different	-
		Albizia versicolor	TEP / TGR	F / L	2.04	-	1	17	0.17	-0.27	3.66	-	1	18	0.07	1.15	Similar	-
		Dichrostachys cinerea	TEP / TGR	F / L	8.56	*	1	11	0.01	-	-	-	-	-	-	-	Different	-
		Euclea natalensis	TEP / TGR	F / L	2.55	-	1	7	0.15	-1.41	4.08	-	1	8	0.08	3.70	Similar	-
		Grewia microthyrsa	TEP / TGR	L / F	0.80	-	1	2	0.47	-1.65	5.03	-	1	3	0.11	4.48	Similar	-
		Gymnosporia senegalensis	TEP / TGR	F / L	1.97	-	1	5	0.22	-1.64	6.40	*	1	6	0.04	-	Different	-
		Hymenocardia ulmoides	TEP / TGR	L / F	2.67	-	1	9	0.14	-1.61	14.49	**	1	10	<0.01	-	Different	-
		Psydrax locuples	TEP / TGR	F / L	7.89	*	1	4	0.05	-	-	-	-	-	-	-	Different	X
		Rhus gueinzii	TEP / TGR	F / L	5.22	*	1	9	0.05	-	-	-	-	-	-	-	Different	X
		Spirostachys africana	TEP / TGR	F / L	1.37	-	1	18	0.26	-0.67	0.15	-	1	19	0.70	2.18	Similar	-
VT 04.1.0	Sparse Woodland on Sand	*Dichrostachys cinerea*	TEP / MRC	F / F	0.07	-	1	5	0.80	-3.96	1.19	-	1	6	0.32	9.36	Similar	-

**	Highly significant (p ≤ 0.01)
*	Significant (p ≤ 0.05)
-	Not significant (p > 0.05)
Note*	analyses marked with an X were conducted on regression slopes where F was not significant in at least one site

Table 7: *Detail of species level size class distribution (SCD) regressions, including statistical significance, the range of size classes (SC) used, number of individuals sampled, centroid 1 position (full data set) centroid 2 position (size classes 3 - 12), subcanopy and canopy density, frequency of occurrence in sample plots, and species grain. The information presented is for the common species for which 30 or more individuals were sampled (full analysis) and those for which 10 to 29 individuals were sampled (limited analysis) of the Closed Woodland on Clay in the sites: Tembe Elephant Park (TEP) and Manqakulane Rural Community Village zone (MRC); Maputaland, northern KwaZulu-Natal, South Africa*

Analysis	Species	Slope	Intercept	R^2	Standard error	F		Degrees of freedom	SC range	Number of individuals	Centroid 1 in SC	Centroid 2 in SC	Subcanopy density (individuals / ha)	Canopy density (individuals / ha)	Frequency of occurrence (%)	Species grain
<u>TEP site</u>																
Community Level	**Community SCD**	**-1.87**	**8.99**	**0.98**	**0.35**	**463.97**	**	**10**	**12**	**2015**						
Full	*Acacia burkei*	-0.96	4.33	0.82	0.57	44.25	**	10	12	84	06	08	80	107	59.09	Intermediate
Full	*Acacia gerrardii*	-1.58	4.82	0.84	0.69	25.38	**	5	7	44	03	05	54	0	27.27	***NA***
Full	*Acalypha glabrata*	-2.09	5.86	0.87	0.65	20.46	*	3	5	55	02	03	74	0	4.55	***NA***
Full	*Berchemia zeyheri*	-1.32	4.47	0.86	0.57	35.94	**	6	8	39	04	05	70	7	22.73	***NA***
Full	*Canthium armatum*	-1.99	5.44	0.90	0.54	26.55	*	3	5	40	02	04	37	0	45.45	***NA***
Full	*Catunaregam taylori*	-1.40	4.54	0.32	1.50	0.94	-	2	4	38	02	04	23	0	36.36	***NA***
Full	*Clausena anisata*	-2.90	6.44	0.95	0.49	37.64	*	2	4	58	02	03	40	0	40.91	***NA***
Full	*Coddia rudis*	-2.03	5.51	0.81	0.81	12.57	*	3	5	45	02	03	57	0	54.55	***NA***
Full	*Combretum molle*	-1.19	4.45	0.93	0.34	81.99	**	6	8	46	04	05	101	3	50.00	***NA***
Full	*Dialium schlechteri*	-1.58	5.07	0.95	0.39	109.72	**	6	8	49	03	05	67	7	54.55	***NA***
Full	*Dichrostachys cinerea*	-2.45	5.71	0.82	0.93	13.87	*	3	5	39	02	03	40	0	45.45	***NA***
Full	*Diospyros dichrophylla*	-3.08	6.77	1.00	0.00	0.00	-	0	2	59	01	***NA***	0	0	27.27	***NA***
Full	*Euclea nataler*	-2.20	6.67	0.92	0.67	71.74	**	6	8	162	02	05	84	3	90.91	***NA***
Full	*Gymnosporia s galensis*	-1.77	4.86	0.78	0.69	7.09	-	2	4	32	02	03	37	0	27.27	***NA***
Full	*Hymenocardia oides*	-1.76	4.59	0.49	1.63	3.80	-	4	6	38	02	06	20	0	4.55	***NA***
Full	*Monanthotaxis ra*	-2.81	6.17	1.00	0.00	0.00	-	0	2	37	01	***NA***	0	0	22.73	***NA***
Full	*Ochna nataliti*	-2.34	5.56	0.99	0.16	236.46	**	2	4	34	02	03	23	0	31.82	***NA***
Full	*Psydrax locupl*	-1.99	5.68	0.80	0.80	12.32	*	3	5	66	02	04	60	0	54.55	***NA***
Full	*Schotia brachy la*	-0.76	2.89	0.46	1.05	8.37	*	10	12	33	05	09	7	34	31.82	Coarse (*NA*)
Full	*Senna petersianna*	1.48	1.89	0.25	1.75	0.34	-	1	3	36	02	03	47	0	9.09	***NA***
Full	*Spirostachys africana*	-1.23	5.34	0.93	0.44	124.03	**	10	12	126	05	07	188	90	50.00	Fine
Full	*Strychnos madagascariensis*	-1.15	3.96	0.75	0.78	23.92	**	8	10	35	03	07	27	10	40.91	Intermediate (*NA*)
Full	*Strychnos spinosa*	-1.30	4.45	0.89	0.47	49.90	**	6	8	37	04	05	57	10	63.64	Fine
Full	*Terminalia sericea*	-0.81	3.66	0.85	0.42	58.81	**	10	12	54	06	07	107	50	40.91	***NA***
Full	*Vepris lanceolata*	-1.85	5.82	0.97	0.34	200.06	**	6	8	74	03	04	90	3	68.18	***NA***
						Mean SCD centroid location for common species:					03	05				
Limited	*Acacia nilotica*	-0.86	2.55	0.50	0.95	7.09	*	7	9	12	04	08	3	7	18.18	***NA***
Limited	*Acacia robusta*	-0.69	2.55	0.53	0.82	11.36	**	10	12	17	06	09	10	17	36.36	Coarse (*NA*)
Limited	*Afzelia quanzensis*	0.10	0.31	0.05	0.60	0.48	-	10	12	19	08	08	30	34	45.45	Intermediate (*NA*)
Limited	*Balanites maughamii*	-0.61	2.31	0.91	0.25	98.61	**	10	12	11	06	07	20	7	36.36	Intermediate (*NA*)
Limited	*Bridelia cathartica*	-0.62	3.28	0.41	0.61	2.06	-	3	5	26	03	04	64	0	50.00	***NA***
Limited	*Commiphora neglecta*	-2.33	4.72	0.91	0.52	21.17	*	2	4	15	01	04	7	0	22.73	***NA***
Limited	*Croton pseudopulchellus*	-1.81	4.76	0.86	0.60	18.04	*	3	5	24	02	04	27	0	13.64	***NA***
Limited	*Diospyros inhacaensis*	-1.04	3.26	0.87	0.39	34.39	**	5	7	14	04	05	30	0	13.64	***NA***
Limited	*Dovyalis longispina*	-2.18	4.28	0.66	1.13	3.95	-	2	4	10	02	04	3	0	31.82	***NA***
Limited	*Erythroxylum delagoense*	-1.12	3.57	0.84	0.52	31.25	**	6	8	18	04	05	34	3	40.91	***NA***
Limited	*Euclea divinorum*	-1.07	2.99	0.70	0.73	14.15	**	6	8	11	03	05	17	3	27.27	***NA***
Limited	*Grewia caffra*	-2.41	5.17	0.89	0.68	24.65	*	3	5	25	02	04	13	0	45.45	***NA***
Limited	*Grewia spp.*	-2.36	4.43	0.75	1.01	5.84	-	2	4	11	01	04	3	0	4.55	***NA***

Table 7: continued

Limited	*Maytenus nemorosa*	***NA***	***NA***	***NA***	***NA***	***NA***	-	***NA***	1	11	01	***NA***	0	0	4.55	***NA***
Limited	*Ochna barbosae*	-0.69	2.70	0.37	0.73	1.77	-	3	5	12	03	04	23	0	13.64	***NA***
Limited	*Pavetta gardeniifolia*	9.16	-3.71	1.00	0.00	0.00	-	0	2	21	02	***NA***	0	0	13.64	***NA***
Limited	*Pteleopsis myrtifolia*	-1.17	3.51	0.85	0.51	35.11	**	6	8	15	03	05	17	3	13.64	***NA***
Limited	*Rhus gueinsii*	-1.68	4.64	0.90	0.56	42.87	**	5	7	26	03	04	34	0	59.09	***NA***
Limited	*Sclerocarya birrea*	-0.08	0.67	0.02	0.72	0.16	-	9	11	10	08	09	7	20	27.27	***NA***
Limited	*Scutia myrtina*	-1.90	4.57	0.91	0.49	29.90	*	3	5	17	02	04	13	0	22.73	***NA***
Limited	*Tabernaemontana elegans*	-0.73	2.94	0.88	0.32	56.76	**	8	10	22	06	07	40	17	54.55	Fine
Limited	*Tricalysia lanceolata*	-0.60	3.03	0.15	0.97	0.18	-	1	3	10	02	03	10	0	18.18	***NA***
Limited	*Vernonia colorata*	-1.16	3.72	0.45	1.17	3.21	-	4	6	28	03	04	47	0	22.73	***NA***
Limited	*Warburgia salutaris*	-0.45	1.81	0.18	1.01	1.35	-	6	8	11	04	05	20	3	4.55	***NA***
Limited	*Zanthoxylum capense*	-1.35	3.58	0.76	0.74	16.07	*	5	7	15	02	05	13	0	27.27	***NA***
Limited	*Ziziphus mucronata*	-0.5	2.16	0.45	0.80	8.02	*	10	12	15	06	08	17	13	45.45	***NA***
										Mean SCD centroid location for common species:	04	05				
MRC site																
Community Level	**Community SCD**	**-2.1**	**9.80**	**0.75**	**1.58**	**29.80**	**	**10**	**12**	**186**						
Limited	*Carissa tetramera*	-4.18	9.65	1.00	0.00	0.00	-	0	2	19	01	***NA***	0	0	50.00	***NA***
Limited	*Dalbergia obovata*	-2.76	5.95	0.21	3.97	0.52	-	2	4	13	01	04	83	0	50.00	***NA***
Limited	*Dialium schlechteri*	-1.02	3.90	0.25	2.13	3.03	-	9	11	10	03	08	167	83	50.00	Fine
Limited	*Euclea natalensis*	-3.90	8.81	0.49	2.91	1.93	-	2	4	15	01	04	83	0	100.00	***NA***
Limited	*Margaritaria discoidea*	-2.61	8.98	0.91	0.60	20.37	*	2	4	26	02	03	417	0	50.00	***NA***
										Mean SCD centroid location for common species:	02	05				

SC	Size Class
**	Highly significant (p ≤ 0.01)
*	Significant (p ≤ 0.05)
-	Not significant (p > 0.05)
NA	Not applicable, following the species grain, it indicates that while grain could be determined, the frequency of occurrence is too low to warrant inclusion in the model

Closed Woodland on sand

This vegetation unit was well-represented on all sites. A total of 43, 39 and 28 species were evaluated in Tembe, Tshanini and Manqakulane respectively (Tables 8, 9 and 10). In all three sites the majority of species fell within Type 1, but the percentages were highest in Manqakulane, followed by Tembe, and then Tshanini (Table 5). In the three sites the mean centroid 2 location fell either within size classes 4 or 5 (Tables 8 – 10). In Tembe and Tshanini a minor shift between mean centroids 1 and 2 locations was observed but in Manqakulane there was a noticeable shift in size classes between the positions of mean centroids 1 and 2 (Table 10)

The subcanopy level of this unit in Tembe was dominated by *Dialium schlechteri, Canthium armatum* and *Vepris lanceolata*. The first and last of these species also formed an important part of the canopy, accompanied by *Combretum molle, Spirostachys africana, Strychnos madagascariensis, Tabernaemontana elegans, Acacia burkei* and *Afzelia quanzensis* in what appeared to be a fairly diverse canopy stratum.

In Tshanini this unit's subcanopy was dominated by *Acacia burkei, Albizia adianthifolia, Hymenocardia ulmoides, Pteleopsis myrtifolia, Strychnos madagascariensis* and *Terminalia sericea*. The canopy level was dominated by *Acacia burkei*, the ubiquitous *Strychnos madagascariensis*, and *Terminalia sericea* (Table 9). Quite a range of trees reached large to very large sizes. The fruit bearing *Sclerocarya birrea* occurred in low but equal densities at subcanopy and canopy levels, while some large forest trees (*Cleistanthus schlechteri*) were observed within this vegetation type.

The subcanopy in Manqakulane was dominated by *Acacia burkei, Dichrostachys cinerea, Strychnos spinosa, Bridelia cathartica, Strychnos madagascariensis, Tabernaemontana elegans* and *Terminalia sericea* (Table 10). The canopy level was dominated by *Acacia burkei, Strychnos spinosa, Sclerocarya birrea, Spirostachys africana* and *Strychnos madagascariensis*. Interestingly, the woody species where large individuals were sampled were either large shady trees (*Acacia burkei* and *Acacia robusta*) or edible fruit bearing trees (*Sclerocarya birrea* and *Strychnos madagascariensis*) (Pooley 1997).

A total of 28 species were compared between the sites and 14 (50%) had different population structures (Table 6). The differences at the species slope level revealed that slopes were usually steepest in Manqakulane, followed by Tembe, and then Tshanini. However most differences observed were at the Y-axis intercept level (eight of the 14 different species), where the Y-axis intercepts was usually highest in Manqakulane, then Tembe then Tshanini.

Table 8: Detail of species level size class distribution (SCD) regressions, including statistical significance, the range of size classes (SC) used, number of individuals sampled, centroid 1 position (full data set) centroid 2 position (size classes 3 - 12), subcanopy and canopy density, frequency of occurrence in sample plots, and species grain. The information presented is for the common species for which 30 or more individuals were sampled (full analysis) and those for which 10 to 29 individuals were sampled (limited analysis) of the Closed Woodland on Sand in Tembe Elephant Park, Maputaland, northern KwaZulu-Natal, South Africa

Analysis	Species	Slope	Intercept	R^2	Standard error	F		Degrees of freedom	SC range	Number of individuals	Centroid 1 in SC	Centroid 2 in SC	Subcanopy density (individuals / ha)	Canopy density (individuals / ha)	Frequency of occurrence (%)	Species grain
Community Level	**Community SCD**	**-1.90**	**9.28**	**0.99**	**0.27**	**817.51**	**	**10**	**12**	**1999**						
Full	*Canthium armatum*	-2.42	7.25	0.89	0.70	23.53	*	3	5	145	02	03	269	0	61.90	***NA***
Full	*Clausena anisata*	-4.09	6.89	1.00	0.07	1860.41	*	1	3	36	02	05	5	0	33.33	***NA***
Full	*Combretum molle*	-0.96	4.02	0.81	0.51	30.38	**	7	9	38	05	06	82	37	42.86	Fine (*NA*)
Full	*Dalbergia obovata*	-3.19	6.62	0.96	0.49	45.59	*	2	4	58	01	03	18	0	38.10	***NA***
Full	*Deinbollia oblongifolia*	-3.20	6.28	0.98	0.29	56.85	-	1	3	30	01	03	9	0	23.81	***NA***
Full	*Dialium schlechteri*	-1.3	5.54	0.96	0.32	188.66	**	8	10	100	05	06	233	50	90.48	Fine
Full	*Euclea natalensis*	-2.1	6.64	0.89	0.74	39.14	**	5	7	161	02	05	96	0	95.24	***NA***
Full	*Monanthotaxis caffra*	-4.2	6.65	0.89	1.02	8.40	-	1	3	37	01	03	5	0	33.33	***NA***
Full	*Psydrax locuples*	-1.8	5.50	0.84	0.72	21.78	**	4	6	51	03	05	68	0	57.14	***NA***
Full	*Sclerocroton integerrimus*	-1.3	4.54	0.79	0.79	30.67	**	8	10	40	03	06	46	5	61.90	***NA***
Full	*Sideroxylon inerme*	-1.39	4.85	0.90	0.50	51.36	**	6	8	41	04	05	82	14	23.81	Fine (*NA*)
Full	*Spirostachys africana*	-1.29	5.01	0.77	0.82	27.04	**	8	10	73	04	06	114	32	33.33	Fine (*NA*)
Full	*Strychnos decussata*	-0.69	3.06	0.20	1.52	1.77	-	7	9	44	04	05	169	5	38.10	***NA***
Full	*Strychnos madagascariensis*	-0.92	4.00	0.70	0.66	16.67	**	7	9	43	05	07	78	41	42.86	Fine (*NA*)
Full	*Strychnos spinosa*	-1.42	4.62	0.82	0.69	28.01	**	6	8	34	03	05	46	9	61.90	***NA***
Full	*Tabernaemontana elegans*	-0.95	4.09	0.74	0.63	19.74	**	7	9	48	05	06	110	32	66.67	Fine
Full	*Tricalysia junodii*	***NA***	***NA***	***NA***	***NA***	***NA***	-	***NA***	1	30	01	***NA***	0	0	9.52	***NA***
Full	*Tricalysia lanceolata*	-2.19	5.72	0.87	0.75	27.50	**	4	6	39	02	04	37	0	38.10	***NA***
Full	*Vepris lanceolata*	-1.48	6.48	0.97	0.28	180.07	**	6	8	203	04	05	420	32	76.19	Fine
						Mean SCD centroid location for common species:					03	05				

Table 8: continued

Limited	*Acacia burkei*	-0.60	2.66	0.41	0.90	6.98	*	10	12	25	07	09	23	50	66.67	Coarse
Limited	*Afzelia quanzensis*	0.12	0.72	0.05	0.65	0.53	-	10	12	28	08	08	64	64	47.62	Fine (*NA*)
Limited	*Azima tetracantha*	***NA***	***NA***	***NA***	***NA***	***NA***	-	***NA***	1	28	01	***NA***	0	0	4.76	***NA***
Limited	*Brachylaena discolor*	-3.03	4.49	0.50	2.10	1.00	-	1	3	11	01	03	5	0	23.81	***NA***
Limited	*Coddia rudis*	-0.75	3.03	0.20	1.10	0.49	-	2	4	11	03	03	18	0	28.57	***NA***
Limited	*Cola greenwayi*	-1.76	4.70	0.72	0.80	5.24	-	2	4	19	02	03	23	0	9.52	***NA***
Limited	*Commiphora neglecta*	-0.47	2.72	0.37	0.64	3.52	-	6	8	28	05	05	110	9	33.33	***NA***
Limited	*Croton pseudopulchellus*	-2.37	5.52	0.65	1.22	1.83	-	1	3	25	02	03	9	0	14.29	***NA***
Limited	*Dichrostachys cinerea*	-0.61	2.09	0.16	1.37	0.96	-	5	7	11	03	05	18	0	33.33	***NA***
Limited	*Diospyros dichrophylla*	-5.01	6.52	1.00	0.00	0.00	-	0	2	16	01	***NA***	0	0	19.05	***NA***
Limited	*Diospyros inhacaensis*	-1.37	3.96	0.81	0.66	20.81	**	5	7	15	03	04	37	0	33.33	***NA***
Limited	*Dovyalis longispina*	-2.04	5.07	0.92	0.45	21.67	*	2	4	21	02	04	18	0	52.38	***NA***
Limited	*Grewia caffra*	-2.53	5.38	0.85	0.87	16.94	*	3	5	24	02	04	9	0	52.38	***NA***
Limited	*Grewia microthyrsa*	-1.39	4.01	0.79	0.58	11.48	*	3	5	15	03	03	37	0	42.86	***NA***
Limited	*Hymenocardia ulmoides*	-1.26	3.52	0.64	0.92	8.94	*	5	7	13	03	05	18	0	23.81	***NA***
Limited	*Mundulea sericea*	-0.76	2.62	0.22	1.51	1.66	-	6	8	22	03	04	64	5	9.52	***NA***
Limited	*Ochna natalitia*	-3.69	6.47	0.98	0.39	42.46	-	1	3	27	01	03	5	0	57.14	***NA***
Limited	*Pavetta gardeniifolia*	-2.08	4.57	0.56	1.50	3.87	-	3	5	18	02	05	9	0	23.81	***NA***
Limited	*Ptaeroxylon obliquum*	-1.08	3.08	0.62	0.89	9.60	*	6	8	12	03	07	9	5	9.52	***NA***
Limited	*Rhus gueinsii*	-1.37	4.01	0.85	0.57	27.81	**	5	7	16	03	05	27	0	38.10	***NA***
Limited	*Rothmania fischerii*	0.76	-0.35	0.48	0.77	4.60	-	5	7	15	05	05	68	0	23.81	***NA***
Limited	*Suregada zanzibariensis*	-0.70	3.30	0.49	0.58	2.90	-	3	5	17	03	04	46	0	33.33	***NA***
Limited	*Tecoma capensis*	-3.21	5.48	1.00	0.00	0.00	-	0	2	13	01	***NA***	0	0	4.76	***NA***
Limited	*Terminalia sericea*	-0.26	1.52	0.15	0.77	1.79	-	10	12	17	08	08	32	37	33.33	Intermediate (*NA*)
Limited	*Tricalysia delagoensis*	-1.31	3.63	0.70	0.78	9.21	*	4	6	12	03	04	27	0	38.10	***NA***
Limited	*Zanthoxylum capense*	-1.33	4.39	0.90	0.36	27.47	*	3	5	23	03	04	46	0	28.57	***NA***
						Mean SCD centroid location for common species:					03	05				

SC	Size Class
**	Highly significant (p ≤ 0.01)
*	Significant (p ≤ 0.05)
-	Not significant (p > 0.05)
NA	Not applicable, following the species grain, it indicates that while grain could be determined, the frequency of occurrence is too low to warrant inclusion in the model

Table 9: Detail of species level size class distribution (SCD) regressions, including statistical significance, the range of size classes (SC) used, number of individuals sampled, centroid 1 position (full data set) centroid 2 position (size classes 3 - 12), subcanopy and canopy density, frequency of occurrence in sample plots, and species grain. The information presented is for the common species for which 30 or more individuals were sampled (full analysis) and those for which 10 to 29 individuals were sampled (limited analysis) of the Closed Woodland on Sand in Tshanini Community Conservation Area, Maputaland, northern KwaZulu-Natal, South Africa

Analysis	Species	Slope	Intercept	R^2	Standard error	F		Degrees of freedom	SC range	Number of individuals	Centroid 1 in SC	Centroid 2 in SC	Subcanopy density (individuals / ha)	Canopy density (individuals / ha)	Frequency of occurrence (%)	Species grain
Community Level	**Community SCD**	**-2.09**	**9.31**	**0.98**	**0.39**	**458.71**	**	**10**	**12**	**3915**						
Full	*Acacia burkei*	-1.25	5.27	0.96	0.32	248.69	**	10	12	198	05	06	151	89	77.78	Fine
Full	*Albizia adianthifolia*	-1.82	5.89	0.72	1.32	20.51	**	8	10	344	03	03	276	9	66.67	***NA***
Full	*Boscia filipes*	3.86	-0.73	0.61	2.13	1.58	-	1	3	78	03	03	80	0	11.11	***NA***
Full	*Bridelia cathartica*	-1.35	4.10	0.87	0.46	27.90	**	4	6	42	03	04	42	0	22.22	***NA***
Full	*Combretum molle*	-1.44	5.01	0.86	0.64	43.96	**	7	9	125	03	05	100	13	100.00	Fine
Full	*Dialium schlechteri*	-1.21	4.26	0.84	0.64	47.61	**	9	11	75	04	05	53	16	77.78	Fine
Full	*Dichrostachys cinerea*	-2.07	5.48	0.89	0.66	32.18	**	4	6	89	02	04	36	0	55.56	***NA***
Full	*Euclea natalensis*	-1.27	4.31	0.62	1.04	9.86	*	6	8	85	03	05	58	9	44.44	***NA***
Full	*Gardenia volkensii*	-2.1	4.77	0.70	1.02	4.66	-	2	4	40	02	03	9	0	55.56	***NA***
Full	*Grewia caffra*	-0.7	3.84	0.05	2.26	0.05	-	1	3	79	02	03	11	0	33.33	***NA***
Full	*Grewia microthyrsa*	-3.6	7.75	0.91	0.96	29.54	*	3	5	279	01	03	22	0	88.89	***NA***
Full	*Hymenocardia ulmoides*	-1.6	5.82	0.82	0.94	35.35	**	8	10	235	03	04	398	4	55.56	***NA***
Full	*Lippia javanica*	-3.0	5.80	0.50	2.09	0.99	-	1	3	72	02	03	2	0	22.22	***NA***
Full	*Margaritaria discoidea*	-1.5	4.09	0.54	1.05	2.35	-	2	4	34	02	03	11	0	66.67	***NA***
Full	*Mundulea sericea*	-3.18	7.02	0.85	1.09	17.06	*	3	5	163	02	03	56	0	44.44	***NA***
Full	*Psydrax locuples*	-1.02	3.39	0.45	0.92	2.49	-	3	5	31	03	03	36	0	44.44	***NA***
Full	*Pteleopsis myrtifolia*	-2.13	6.88	0.80	1.13	23.35	**	6	8	401	03	04	407	7	77.78	***NA***
Full	*Sclerocroton integerrimus*	-1.02	3.76	0.32	1.46	2.38	-	5	7	99	03	04	122	13	77.78	Fine
Full	*Spirostachys africana*	-0.56	2.58	0.33	0.92	4.01	-	8	10	57	05	07	49	24	11.11	Fine (*NA*)
Full	*Strychnos madagascariensis*	-1.37	5.76	0.91	0.51	96.14	**	9	11	278	05	05	369	82	100.00	Fine
Full	*Strychnos spinosa*	-1.57	5.42	0.89	0.53	41.28	**	5	7	138	03	04	131	11	100.00	Fine
Full	*Tabernaemontana elegans*	-1.03	3.11	0.55	0.98	7.37	*	6	8	31	04	05	18	7	66.67	***NA***
Full	*Terminalia sericea*	-1.63	6.01	0.88	0.69	60.30	**	8	10	298	03	05	182	36	77.78	Fine
Full	*Vangueria infausta*	-1.29	4.74	0.45	1.16	2.47	-	3	5	105	03	03	100	0	100.00	***NA***
Full	*Vitex ferruginea*	-2.15	5.48	0.76	0.89	6.27	-	2	4	78	02	03	22	0	66.67	***NA***
Full	*Xylotheca kraussiana*	-4.28	7.46	1.00	0.00	0.00	-	0	2	152	01	***NA***	0	0	88.89	***NA***
										Mean SCD centroid location for common species:	03	04				

Table 9: continued

Limited	*Albizia versicolor*	0.03	0.58	0.00	0.84	0.01	-	5	7	11	04	04	22	2	11.11	***NA***
Limited	*Ancylanthos monteiroi*	-1.63	3.88	0.54	1.05	1.17	-	1	3	20	02	03	4	0	44.44	***NA***
Limited	*Brachylaena elliptica*	-0.83	2.46	0.34	1.15	2.53	-	5	7	24	03	06	7	4	33.33	***NA***
Limited	*Catunaregam taylori*	-1.99	4.21	0.81	0.67	4.30	-	1	3	20	02	03	4	0	55.56	***NA***
Limited	*Cleistanthus schlechteri*	-0.67	2.27	0.63	0.66	16.67	**	10	12	16	05	09	4	4	11.11	***NA***
Limited	*Coddia rudis*	-1.70	4.10	0.93	0.31	14.26	-	1	3	24	02	03	11	0	55.56	***NA***
Limited	*Combretum mkuzense*	0.60	0.51	0.25	0.85	0.98	-	3	5	16	04	04	31	0	11.11	***NA***
Limited	*Deinbollia oblongifolia*	-1.7	4.08	0.95	0.28	19.22	-	1	3	20	02	03	7	0	44.44	***NA***
Limited	*Gymnosporia senegalensis*	0.5	1.51	0.07	1.46	0.077	-	1	3	16	02	03	9	0	33.33	***NA***
Limited	*Ptaeroxylon obliquum*	-0.9	2.93	0.66	0.70	9.56	*	5	7	20	03	05	13	2	22.22	***NA***
Limited	*Rhus gueinzii*	-0.6	2.55	0.60	0.51	5.90	-	4	6	19	04	05	24	0	44.44	***NA***
Limited	*Sclerocarya birrea*	-0.6	2.42	0.75	0.44	29.98	**	10	12	28	07	08	20	22	66.67	Coarse
Limited	*Strychnos henningsii*	2.2	-0.38	0.57	1.37	1.32	-	1	3	14	03	03	16	0	22.22	***NA***
										Mean SCD centroid location for common species:	03	05				

SC	Size Class
**	Highly significant (p ≤ 0.01)
*	Significant (p ≤ 0.05)
-	Not significant (p > 0.05)
NA	Not applicable, following the species grain, it indicates that while grain could be determined, the frequency of occurrence is too low to warrant inclusion in the model

Table 10: Detail of species level size class distribution (SCD) regressions, including statistical significance, the range of size classes (SC) used, number of individuals sampled, centroid 1 position (full data set) centroid 2 position (size classes 3 - 12), subcanopy and canopy density, frequency of occurrence in sample plots, and species grain. The information presented is for the common species for which 30 or more individuals were sampled (full analysis) and those for which 10 to 29 individuals were sampled (limited analysis) of the Closed Woodland on Sand in the Manqakulane Rural Community Village zone, Maputaland, northern KwaZulu-Natal, South Africa

Analysis	Species	Slope	Intercept	R^2	Standard error	F		Degrees of freedom	SC range	Number of individuals	Centroid 1 in SC	Centroid 2 in SC	Subcanopy density (individuals / ha)	Canopy density (individuals / ha)	Frequency of occurrence (%)	Species grain
Community Level	**Community SCD**	**-2.11**	**9.77**	**0.96**	**0.53**	**248.45**	**	**10**	**12**	**819**						
Full	*Acacia burkei*	-1.41	5.74	0.91	0.56	99.15	**	10	12	33	04	06	191	38	70.00	Fine
Full	*Coddia rudis*	-3.20	8.01	0.90	0.78	18.30	-	2	4	39	02	03	76	0	50.00	***NA***
Full	*Deinbollia oblongifolia*	-3.22	7.71	0.86	0.95	12.34	-	2	4	30	02	03	38	0	60.00	***NA***
Full	*Dichrostachys cinerea*	-2.06	6.77	0.81	0.89	17.20	*	4	6	39	03	04	268	0	90.00	***NA***
Full	*Euclea natalensis*	-3.27	8.36	0.98	0.34	99.47	**	2	4	57	01	03	89	0	90.00	***NA***
Full	*Psydrax locuples*	-2.95	7.22	0.76	1.51	12.47	*	4	6	33	02	05	38	0	70.00	***NA***
Full	*Strychnos spinosa*	-2.00	6.80	0.82	1.04	32.01	**	7	9	48	03	05	217	38	90.00	Fine
Full	*Zanthoxylum capense*	-2.64	7.47	0.94	0.59	64.90	**	4	6	45	02	04	102	0	60.00	***NA***
						Mean SCD centroid location for common species:					02	04				
Limited	*Acacia robusta*	-1.39	4.74	0.62	1.36	16.65	**	10	12	20	03	06	51	13	10.00	Fine (*NA*)
Limited	*Balanites maughamii*	1.58	4.03	1.00	0.00	0.00	-	0	2	13	02	***NA***	0	0	10.00	***NA***
Limited	*Brachylaena discolor*	-2.65	6.33	1.00	0.09	380.52	*	1	3	11	01	03	25	0	30.00	***NA***
Limited	*Bridelia cathartica*	-1.48	5.50	0.83	0.60	19.47	*	4	6	20	03	04	166	0	80.00	***NA***
Limited	*Canthium armatum*	-1.90	5.08	0.42	1.83	2.17	-	3	5	11	02	05	25	0	50.00	***NA***
Limited	*Catunaregam taylori*	-2.29	6.66	0.96	0.38	71.09	**	3	5	22	02	04	102	0	20.00	***NA***
Limited	*Clausena anisata*	-3.46	7.83	0.85	0.99	5.90	-	1	3	27	01	03	25	0	50.00	***NA***
Limited	*Commiphora neglecta*	-1.76	5.72	0.69	1.25	13.13	*	6	8	25	03	05	102	13	50.00	Fine
Limited	*Dalbergia obovata*	-3.72	7.47	0.92	0.74	12.13	-	1	3	16	01	03	13	0	10.00	***NA***
Limited	*Dialium schlechteri*	-2.57	6.92	0.85	0.98	22.21	**	4	6	25	02	04	76	0	90.00	***NA***
Limited	*Diospyros dichrophylla*	-1.79	6.99	1.00	0.00	0.00	-	0	2	28	01	***NA***	0	0	30.00	***NA***
Limited	*Erythroxylum delagoense*	-2.37	6.65	0.93	0.52	40.62	**	3	5	21	02	03	102	0	50.00	***NA***
Limited	*Monanthotaxis caffra*	-4.63	7.55	1.00	0.00	***NA***	-	0	2	12	01	***NA***	0	0	50.00	***NA***
Limited	*Ochna natalitia*	-1.61	6.70	1.00	0.00	***NA***	-	0	2	23	01	***NA***	0	0	60.00	***NA***
Limited	*Sclerocarya birrea*	-0.87	4.02	0.53	1.03	11.33	**	10	12	22	06	09	89	89	60.00	Fine
Limited	*Spirostachys africana*	-1.64	5.34	0.59	1.45	8.48	*	6	8	21	03	06	89	38	50.00	Fine
Limited	*Strychnos madagascariensis*	-1.19	4.88	0.84	0.66	52.12	**	10	12	21	05	07	140	51	70.00	Fine
Limited	*Tabernaemontana elegans*	-1.66	5.24	0.60	1.34	7.41	*	5	7	18	03	04	166	0	50.00	***NA***
Limited	*Terminalia sericea*	-0.46	2.52	0.12	1.37	0.99	-	7	9	12	05	05	127	13	50.00	Fine
Limited	*Xylotheca kraussiana*	0.44	5.58	1.00	0.00	0.00	-	0	2	27	02	***NA***	0	0	80.00	***NA***
						Mean SCD centroid location for common species:					02	05				

SC	Size Class
**	Highly significant (p ≤ 0.01)
*	Significant (p ≤ 0.05)
-	Not significant (p > 0.05)
NA	Not applicable, following the species grain, it indicates that while grain could be determined, the frequency of occurrence is too low to warrant inclusion in the model

Open Woodland on sand

This particular vegetation unit was well-represented in Tembe (42 species, Table 11) and Tshanini (33 species, Table 12), but poorly so in Manqakulane where only one species was within the full analysis from only one plot (Table 12).

In Tembe, most species were classified within Type 1 (Table 3). Mean centroid 2 was skewed to the left for the full scope analysis and in the middle of the range for the limited analysis. There was a small shift in size classes between the positions of mean centroids 1 and 2. The subcanopy level of this unit was dominated by *Strychnos madagascariensis* and *Terminalia sericea*, with some patches of dense *Vepris lanceolata* undergrowth (Table 11). In the canopy, large to very large trees of the same species occurred, with the addition of *Acacia burkei, Sclerocroton integerrimus,* and *Spirostachys africana*.

In Tembe some species had particularly obvious anomalous population structures. *Albizia adianthifolia* was absent at the subcanopy level (Table 11), and scarce at canopy level, occurring only in some places. In Tshanini this species was abundant at the subcanopy level, and was found in most plots (see Table 12). Another two such species were *Garcinia livingstonei* and *Sclerocarya birrea*, where the mean centroid 2 location was skewed to the right, inverse pyramidal population structures and low frequency of occurrence were also observed.

In Tshanini, only *Grewia caffra* was classified within Type 3 (Table 3), and the majority of species fell within Type 1 in the full analysis. Half of the species in the limited analysis fell within Type 3. Mean centroid 2 position indicated an obvious left bias in the population in both sets of analyses, and there was no major shift in size classes between the positions of mean centroids 1 and 2. The subcanopy was populated by *Pteleopsis myrtifolia, Strychnos madagascariensis* and *Terminalia sericea*, with some dense patches of *Grewia caffra*. A mix of large *Acacia burkei, Strychnos madagascariensis* and *Terminalia sericea* trees formed the canopy, while some large *Albizia adianthifolia* and *Spirostachys africana* were also found (Table 12). There were no obvious defects in population structure in this vegetation unit, species with flat or positive slope coefficients did not reach sizes that would make it obvious with the current subcanopy and canopy cut-off points.

Some 21 species were compared between Tembe and Tshanini and eight (38%) had different structures. Within the full analysis, only *Terminalia sericea* and *Vangueria infausta* had different slope coefficients (Table 6). In the cross analyses species comparisons, five species had different population structures between Tembe and Tshanini (Table 6). The most noticeable species in this group was *Albizia*

Table 11: Detail of species level size class distribution (SCD) regressions, including statistical significance, the range of size classes (SC) used, number of individuals sampled, centroid 1 position (full data set) centroid 2 position (size classes 3 - 12), subcanopy and canopy density, frequency of occurrence in sample plots, and species grain. The information presented is for the common species for which 30 or more individuals were sampled (full analysis) and those for which 10 to 29 individuals were sampled (limited analysis) of the Open Woodland on Sand in Tembe Elephant Park, Maputaland, northern KwaZulu-Natal, South Africa

Analysis	Species	Slope	Intercept	R^2	Standard error	F		Degrees of freedom	SC range	Number of individuals	Centroid 1 in SC	Centroid 2 in SC	Subcanopy density (individuals / ha)	Canopy density (individuals / ha)	Frequency of occurrence (%)	Species grain
Community Level	**Community SCD**	**-1.69**	**7.94**	**0.94**	**0.55**	**153.27**	**	**10**	**12**	**4202**						
Full	*Acacia burkei*	-0.91	3.89	0.78	0.61	35.48	**	10	12	198	06	08	55	66	62.00	Intermediate
Full	*Albizia versicolor*	-0.34	1.46	0.79	0.23	36.80	**	10	12	31	08	09	11	14	40.00	Coarse (*NA*)
Full	*Brachylaena discolor*	-1.54	4.32	0.77	0.61	6.84	-	2	4	75	02	03	22	0	28.00	***NA***
Full	*Carissa bispinosa*	-5.67	7.69	1.00	0.00	0.00	-	0	2	206	01	***NA***	0	0	12.00	***NA***
Full	*Catunaregam taylori*	-2.89	6.17	0.93	0.66	38.66	**	3	5	198	01	04	9	0	38.00	***NA***
Full	*Clausena anisata*	-3.49	5.81	0.93	0.66	13.41	-	1	3	77	01	03	2	0	20.00	***NA***
Full	*Combretum molle*	-0.97	3.62	0.89	0.41	76.63	**	9	11	103	05	06	40	15	66.00	Fine
Full	*Commiphora neglecta*	-1.79	3.90	0.86	0.54	12.01	-	2	4	36	02	03	6	0	24.00	***NA***
Full	*Dalbergia obovata*	-4.90	6.85	0.95	0.81	17.58	-	1	3	163	01	03	1	0	14.00	***NA***
Full	*Dialium schlechteri*	-0.96	3.34	0.82	0.56	46.82	**	10	12	74	03	05	34	3	56.00	***NA***
Full	*Dichrostachys cinerea*	-2.12	5.94	0.83	0.94	24.45	**	5	7	335	02	04	56	0	74.00	***NA***
Full	*Diospyros dichrophylla*	-3.36	6.72	1.00	0.00	0.00	-	0	2	221	01	***NA***	0	0	28.00	***NA***
Full	*Euclea natalensis*	-1.61	4.41	0.96	0.31	128.33	**	5	7	82	03	04	28	0	52.00	***NA***
Full	*Gymnosporia senegalensis*	-2.61	6.12	0.79	0.99	7.39	-	2	4	211	02	03	24	0	28.00	***NA***
Full	*Monanthotaxis caffra*	***NA***	***NA***	***NA***	***NA***	***NA***	-	***NA***	1	61	01	***NA***	0	0	4.00	***NA***
Full	*Ozoroa englerii*	-1.29	3.22	0.86	0.43	17.81	*	3	5	31	03	03	14	0	38.00	***NA***
Full	*Parinari capensis*	-3.81	5.34	0.91	0.82	10.32	-	1	3	57	01	03	1	0	6.00	***NA***
Full	*Pavetta catophylla*	***NA***	***NA***	***NA***	***NA***	***NA***	-	***NA***	1	57	01	***NA***	0	0	2.00	***NA***
Full	*Pavetta gardeniifolia*	-3.94	7.19	1.00	0.00	0.00	-	0	2	269	01	***NA***	0	0	20.00	***NA***
Full	*Psydrax locuples*	-1.99	4.11	0.88	0.60	21.90	*	3	5	40	02	04	4	0	34.00	***NA***
Full	*Rhus gueinsii*	-1.03	2.89	0.73	0.66	16.43	**	6	8	34	03	04	9	1	38.00	***NA***
Full	*Sclerocroton integerrimus*	-0.88	3.05	0.77	0.56	26.76	**	8	10	64	05	07	23	8	48.00	Intermediate (*NA*)
Full	*Spirostachys africana*	-0.87	2.69	0.52	0.97	8.71	*	8	10	81	03	07	4	6	18.00	Coarse (*NA*)
Full	*Strychnos madagascariensis*	-1.25	4.92	0.92	0.45	104.45	**	9	11	304	04	06	115	25	92.00	Fine
Full	*Strychnos spinosa*	-1.20	4.22	0.82	0.65	37.56	**	8	10	156	04	06	40	10	64.00	Fine
Full	*Terminalia sericea*	-0.95	4.51	0.81	0.57	44.05	**	10	12	385	06	07	158	115	90.00	Fine
Full	*Vangueria infausta*	-0.50	1.91	0.49	0.54	5.66	-	6	8	37	05	05	30	1	58.00	***NA***
Full	*Vepris lanceolata*	-1.00	2.86	0.77	0.57	20.41	**	6	8	32	03	05	750	167	24.00	Fine (*NA*)
Full	*Zanthoxylum capense*	-1.96	3.86	0.74	0.94	8.68	-	3	5	35	02	05	1	0	32.00	***NA***
						Mean SCD centroid location for common species:					03	05				

Table 11: continued

Limited	*Albizia adianthifolia*	-0.44	1.47	0.38	0.71	6.15	*	10	12	22	05	12	0	4	18.00	***NA***
Limited	*Antidesma venosum*	-0.09	0.48	0.26	0.20	3.59	-	10	12	12	07	08	6	5	16.00	Intermediate (*NA*)
Limited	*Bridelia cathartica*	-0.43	2.08	0.47	0.34	1.75	-	2	4	21	03	04	11	0	20.00	***NA***
Limited	*Canthium armatum*	-1.56	3.36	0.65	0.84	3.65	-	2	4	27	02	03	4	0	18.00	***NA***
Limited	*Deinbollia oblongifolia*	-1.62	2.95	1.00	0.00	0.00	-	0	2	11	01	***NA***	0	0	16.00	***NA***
Limited	*Garcinia livingstonei*	-0.33	1.32	0.49	0.42	9.72	*	10	12	26	07	09	4	15	34.00	Coarse (*NA*)
Limited	*Grewia microthyrsa*	-0.57	2.45	0.08	1.31	0.09	-	1	3	25	02	03	4	0	30.00	***NA***
Limited	*Grewia tenuinervis*	***NA***	***NA***	***NA***	***NA***	***NA***	-	***NA***	1	15	01	***NA***	0	0	2.00	***NA***
Limited	*Hymenocardia ulmoides*	-1.03	2.51	0.84	0.36	16.25	*	3	5	17	03	04	6	0	18.00	***NA***
Limited	*Hyphaene coriacea*	-0.15	0.77	0.12	0.47	1.12	-	8	10	18	06	06	14	3	18.00	***NA***
Limited	*Mundulea sericea*	0.17	0.97	0.06	0.50	0.12	-	2	4	13	03	04	8	0	16.00	***NA***
Limited	*Ochna natalitia*	-2.75	4.22	1.00	0.00	672169.72	**	1	3	24	01	03	1	0	32.00	***NA***
Limited	*Sclerocarya birrea*	0.00	0.28	0.00	0.35	0.00	-	10	12	22	09	09	7	15	34.00	Coarse (*NA*)
Limited	*Senna petersianna*	-1.38	2.96	1.00	0.00	***NA***	-	0	2	13	01	***NA***	0	0	2.00	***NA***
Limited	*Tabernaemontana elegans*	-0.49	1.63	0.71	0.35	17.45	**	7	9	19	05	05	11	3	20.00	***NA***
Limited	*Xylotheca kraussiana*	-3.47	4.65	1.00	0.00	0.00	-	0	2	25	01	***NA***	0	0	26.00	***NA***
										Mean SCD centroid location for common species:	04	06				

SC	Size Class
**	Highly significant (p ≤ 0.01)
*	Significant (p ≤ 0.05)
-	Not significant (p > 0.05)
NA	Not applicable, following the species grain, it indicates that while grain could be determined, the frequency of occurrence is too low to warrant inclusion in the model

Table 12: Detail of species level size class distribution (SCD) regressions, including statistical significance, the range of size classes (SC) used, number of individuals sampled, centroid 1 position (full data set) centroid 2 position (size classes 3 - 12), subcanopy and canopy density, frequency of occurrence in sample plots, and species grain. The information presented is for the common species for which 30 or more individuals were sampled (full analysis) and those for which 10 to 29 individuals were sampled (limited analysis) of the Open Woodland on Sand in the sites: Tshanini Community Conservation Area (TCCA) and the Manqakulane Rural Community Village zone (MRC); Maputaland, northern KwaZulu-Natal, South Africa

Analysis	Species	Slope	Intercept	R^2	Standard error	F		Degrees of freedom	SC range	Number of individuals	Centroid 1 in SC	Centroid 2 in SC	Subcanopy density (individuals / ha)	Canopy density (individuals / ha)	Frequency of occurrence (%)	Species grain
<u>**TCCA site**</u>																
Community Level	**Community SCD**	**-2.09**	**8.59**	**0.98**	**0.40**	**428.47**	**	**10**	**12**	**4663**						
Full	*Acacia burkei*	-0.83	3.42	0.88	0.38	75.57	**	10	12	138	06	07	36	41	81.82	Intermediate
Full	*Albizia adianthifolia*	-1.23	4.19	0.73	0.96	26.44	**	10	12	215	03	04	48	3	90.91	***NA***
Full	*Brachylaena elliptica*	-1.36	3.07	0.69	0.82	8.81	*	4	6	34	02	05	3	0	36.36	***NA***
Full	*Catunaregam taylori*	-3.19	6.15	0.90	0.77	18.23	-	2	4	171	01	03	5	0	63.64	***NA***
Full	*Combretum molle*	-1.1	3.72	0.78	0.66	24.55	**	7	9	114	03	05	47	5	90.91	***NA***
Full	*Dialium schlechteri*	-1.3	4.16	0.94	0.34	96.08	**	6	8	120	03	05	35	6	63.64	Fine
Full	*Gardenia volkensii*	-1.4	3.31	0.84	0.55	21.50	**	4	6	34	02	04	5	0	63.64	***NA***
Full	*Grewia caffra*	3.0	-0.01	0.62	1.71	3.33	-	2	4	553	03	03	430	0	18.18	***NA***
Full	*Grewia microthyrsa*	-2.7	6.51	0.76	1.05	3.25	-	1	3	320	02	03	17	0	63.64	***NA***
Full	*Hymenocardia ulmoides*	-1.7	5.02	0.89	0.65	50.14	**	6	8	173	02	03	43	1	72.73	***NA***
Full	*Margaritaria discoidea*	-1.55	3.39	0.38	1.38	0.61	-	1	3	34	02	03	2	0	36.36	***NA***
Full	*Pteleopsis myrtifolia*	-1.85	5.93	0.87	0.85	52.10	**	8	10	534	02	03	136	1	72.73	***NA***
Full	*Sclerocroton integerrimus*	-0.62	2.42	0.46	0.70	5.12	-	6	8	67	04	05	49	2	81.82	***NA***
Full	*Strychnos madagascariensis*	-1.34	5.31	0.95	0.36	184.52	**	9	11	417	04	05	228	33	100.00	Fine
Full	*Strychnos spinosa*	-1.44	4.73	0.92	0.48	77.11	**	7	9	191	03	04	75	4	90.91	***NA***
Full	*Terminalia sericea*	-1.65	6.00	0.94	0.51	136.42	**	9	11	658	03	05	148	24	90.91	Fine
Full	*Tricalysia delagoensis*	-0.38	4.10	1.00	0.00	0.00	-	0	2	102	01	***NA***	0	0	9.09	***NA***
Full	*Vangueria infausta*	-1.20	4.20	0.83	0.63	39.69	**	8	10	166	04	04	96	2	100.00	***NA***
Full	*Vitex ferruginea*	-0.39	3.20	0.02	1.87	0.02	-	1	3	108	02	03	11	0	72.73	***NA***
Full	*Xylotheca kraussiana*	-4.68	6.99	0.99	0.31	112.32	-	1	3	179	01	03	1	0	100.00	***NA***
						Mean SCD centroid location for common species:					03	04				

Table 12: continued

Limited	*Albizia versicolor*	-0.14	0.70	0.10	0.45	0.81	-	7	9	16	05	06	10	4	54.55	***NA***
Limited	*Ancylanthos monteiroi*	0.65	1.95	1.00	0.00	0.00	-	0	2	22	02	***NA***	0	0	27.27	***NA***
Limited	*Brachylaena huilensis*	-1.15	2.24	0.76	0.47	6.40	-	2	4	12	02	03	3	0	36.36	***NA***
Limited	*Dichrostachys cinerea*	-0.88	2.39	0.82	0.43	28.22	**	6	8	22	03	05	4	1	63.64	***NA***
Limited	*Euclea natalensis*	-0.50	2.05	0.10	1.12	0.21	-	2	4	29	03	03	8	0	36.36	***NA***
Limited	*Hyperacanthus microphyllus*	-0.72	2.17	0.42	0.59	0.71	-	1	3	17	02	03	6	0	27.27	***NA***
Limited	*Lippia javanica*	0.93	0.22	0.15	1.52	0.18	-	1	3	13	02	03	3	0	9.09	***NA***
Limited	*Gymnosporia senegalensis*	-1.12	2.68	0.56	0.81	3.81	-	3	5	27	03	03	10	0	18.18	***NA***
Limited	*Mundulea sericea*	0.16	1.71	0.31	0.17	0.45	-	1	3	24	03	03	11	0	27.27	***NA***
Limited	*Psydrax locuples*	0.70	0.59	0.41	0.59	0.69	-	1	3	12	03	03	5	0	9.09	***NA***
Limited	*Rhus gueinzii*	0.01	0.76	0.00	0.30	0.00	-	3	5	13	04	04	10	0	54.55	***NA***
Limited	*Spirostachys africana*	-0.5	1.77	0.66	0.48	19.23	**	10	12	20	04	05	6	1	27.27	***NA***
Limited	*Tabernaemontana elegans*	-0.4	1.41	0.69	0.30	13.09	*	6	8	18	05	06	9	2	36.36	***NA***
Limited	*Vangueria esculenta*	0.4	-0.16	0.50	0.39	2.99	-	3	5	10	04	04	9	0	54.55	***NA***
						Mean SCD centroid location for common species:					03	04				
<u>MRC site</u>																
Community Level	**Community SCD**	**-3.02**	**11.38**	**0.93**	**1.07**	**126.88**	**	**10**	**12**	**149**						
Full	*Carissa bispinosa*	-3.76	11.65	1.00	0.00	0.00	-	0	2	86	01	***NA***	0	0	100.00	***NA***
						Mean SCD centroid location for common species:					01	***NA***				

Notes:

SC = Size Class

**	Highly significant
*	Significant
-	Not significant
NA	Not applicable

adianthifolia, which had a shallower slope and a lower Y-axis intercept in Tembe, with a centroid (restricted data set) totally skewed to the right, indicating a population where only mature trees were left. The centroid position for the full data set revealed a small bias to the left, but the subcanopy density indicated a dearth of the small size classes.

Open Woodland on Abandoned Household sites

This particular unit was recognised to separate the vegetation growing on old household sites and abandoned fields from surrounding vegetation in Manqakulane. The species found in this vegetation unit were atypical for the characteristic Open Woodland surrounding vegetation. The “open” prefix is used here in the structural sense, because the mix of species ranges between Closed Woodland Thicket and Sparse Woodland on Sand. A total of 20 species were evaluated (Table 13), the majority of which were classified in Type 1 (Table 3). Mean centroid 2 was either centrally located (limited analysis) or slightly skewed to the left. However, there was a major shift in size classes (three size classes upwards) between the positions of mean centroids 1 and 2, indicating a strong influence of seedlings and saplings on the populations (Table 13).

No very large trees (size class 12) were sampled, but some were sampled in the classes immediately below (Table 13). These large trees were the fruiting species *Sclerocarya birrea, Strychnos madagascariensis* and *Strychnos spinosa*, while the other large trees were the shade providing *Dialium schlechteri* and *Trichilia emetica*. The subcanopy was dominated by *Dichrostachys cinerea*, *Strychnos spinosa* and *Acacia burkei*. This vegetation unit was unique to Manqakulane and had no equivalent in the Tshanini and Tembe.

Sparse Woodland on sand

This vegetation unit only occured in Tembe and Manqakulane. In Manqakulane only three species (Table 14) were evaluated, with *Dichrostachys cinerea* and *Gymnosporia senegalensis* in the full analysis and *Sclerocarya birrea* in the limited analysis. The first species dominated the subcanopy while the last species was prevalent at the canopy level. *Sclerocarya birrea* was found in equal densities at subcanopy and canopy levels. All three species belonged to Type 1 (Table 3) and mean centroid 2 for the full analysis was biased to the left. There were large shifts in size classes between the positions of mean centroids 1 and 2, indicating an influence of seedlings and saplings on the populations.

Table 13: Detail of species level size class distribution (SCD) regressions, including statistical significance, the range of size classes (SC) used, number of individuals sampled, centroid 1 position (full data set) centroid 2 position (size classes 3 - 12), subcanopy and canopy density, frequency of occurrence in sample plots, and species grain. The information presented is for the common species for which 30 or more individuals were sampled (full analysis) and those for which 10 to 29 individuals were sampled (limited analysis) of the Open Woodland on Abandoned Household site in the Manqakulane Rural Community Village zone, Maputaland, northern KwaZulu-Natal, South Africa

Analysis	Species	Slope	Intercept	R^2	Standard error	F	Degrees of freedom	SC range	Number of individuals	Centroid 1 in SC	Centroid 2 in SC	Subcanopy density (individuals / ha)	Canopy density (individuals / ha)	Frequency of occurrence (%)	Species grain
Community Level	**Community SCD**	**-2.16**	**8.91**	**0.93**	**0.77**	**125.74** **	**10**	**12**	**995**						
Full	*Acacia burkei*	-1.56	5.31	0.93	0.49	87.29 **	7	9	41	03	05	123	5	78.57	***NA***
Full	*Bridelia cathartica*	-2.37	6.28	0.91	0.68	39.57 **	4	6	42	02	04	49	0	64.29	***NA***
Full	*Canthium armatum*	-2.08	6.12	0.79	0.78	7.61 -	2	4	42	02	03	59	0	21.43	***NA***
Full	*Deinbollia oblongifolia*	-2.57	7.30	1.00	0.00	***NA*** -	0	2	71	01	***NA***	0	0	64.29	***NA***
Full	*Dichrostachys cinerea*	-2.78	7.89	0.96	0.51	95.88 **	4	6	144	02	04	137	0	85.71	***NA***
Full	*Diospyros dichrophylla*	-6.40	8.20	1.00	0.00	0.00 -	0	2	30	01	***NA***	0	0	28.57	***NA***
Full	*Gymnosporia senegalensis*	-2.33	6.26	0.96	0.39	69.79 **	3	5	39	02	04	59	0	35.71	***NA***
Full	*Margaritaria discoidea*	-2.83	7.28	0.97	0.41	92.98 **	3	5	74	02	04	59	0	78.57	***NA***
Full	*Sclerocarya birrea*	-1.32	4.86	0.81	0.78	38.43 **	9	11	41	04	07	59	29	71.43	Fine
Full	*Strychnos madagascariensis*	-1.2	4.59	0.90	0.50	84.01 **	9	11	34	04	06	69	15	57.14	Fine
Full	*Strychnos spinosa*	-1.8	6.31	0.92	0.65	89.00 **	8	10	83	03	05	127	10	92.86	Fine
Full	*Tabernaemontana elegans*	-1.9	5.66	0.92	0.48	34.82 **	3	5	30	02	04	49	0	64.29	***NA***
Full	*Terminalia sericea*	-2.1	6.15	0.89	0.78	48.13 **	6	8	55	02	05	54	5	35.71	***NA***
						Mean SCD centroid location for common species:				02	05				
Limited	*Dialium schlechteri*	-0.77	2.68	0.52	0.90	9.68 *	9	11	11	06	09	5	20	50.00	Coarse
Limited	*Euclea natalensis*	-2.27	5.41	0.79	1.06	15.04 *	4	6	21	02	05	15	0	71.43	***NA***
Limited	*Grewia caffra*	-4.51	6.47	1.00	0.00	0.00 -	0	2	12	01	***NA***	0	0	35.71	***NA***
Limited	*Ochna natalitia*	-1.34	5.09	1.00	0.00	0.00 -	0	2	15	01	***NA***	0	0	64.29	***NA***
Limited	*Trichilia emetica*	-0.68	2.88	0.56	0.73	11.32 **	9	11	19	06	08	25	39	71.43	Coarse
Limited	*Xylotheca kraussiana*	-3.21	6.42	0.63	1.72	1.67 -	1	3	24	02	03	5	0	71.43	***NA***
Limited	*Zanthoxylum capense*	-2.62	6.02	0.99	0.21	163.18 **	2	4	23	02	03	25	0	50.00	***NA***
						Mean SCD centroid location for common species:				03	06				

SC	Size Class
**	Highly significant ($p \le 0.01$)
*	Significant ($p \le 0.05$)
-	Not significant ($p > 0.05$)
NA	Not applicable, following the species grain, it indicates that while grain could be determined, the frequency of occurrence is too low to warrant inclusion in the model

Table 14: Detail of species level size class distribution (SCD) regressions, including statistical significance, the range of size classes (SC) used, number of individuals sampled, centroid 1 position (full data set) centroid 2 position (size classes 3 - 12), subcanopy and canopy density, frequency of occurrence in sample plots, and species grain. The information presented is for the common species for which 30 or more individuals were sampled (full analysis) and those for which 10 to 29 individuals were sampled (limited analysis) of the Sparse Woodland on Sand in the sites: Tembe Elephant Park (TEP) and Manqakulane Rural Community Village zone (MRC); Maputaland, northern KwaZulu-Natal, South Africa

Analysis	Species	Slope	Intercept	R^2	Standard error	F		Degrees of freedom	SC range	Number of individuals	Centroid 1 in SC	Centroid 2 in SC	Subcanopy density (individuals / ha)	Canopy density (individuals / ha)	Frequency of occurrence (%)	Species grain
<u>TEP site</u>																
Community Level	**Community SCD**	**-2.26**	**8.82**	**0.89**	**0.98**	**83.65**	**	**10**	**12**	**654**						
Full	*Catunaregam taylori*	-2.66	7.65	1.00	0.00	***NA***	-	0	2	54	01	***NA***	0	0	42.86	***NA***
Full	*Dichrostachys cinerea*	-4.11	9.15	0.79	1.71	11.50	*	3	5	143	02	04	46	0	85.71	***NA***
Full	*Parinari capensis*	0.92	6.35	1.00	0.00	0.00	-	0	2	130	02	***NA***	0	0	28.57	***NA***
Full	*Pavetta gardeniifolia*	-2.94	8.15	1.00	0.00	0.00	-	0	2	77	01	***NA***	0	0	28.57	***NA***
Full	*Strychnos madagascariensis*	-2.09	6.89	0.89	0.78	46.89	**	6	8	73	02	05	120	19	100.00	Fine
Full	*Terminalia sericea*	-1.93	6.87	0.85	0.91	39.04	**	7	9	78	03	05	333	37	100.00	Fine
					Mean SCD centroid location for common species:						02	05				
Limited	*Acacia burkei*	-1.4	4.87	0.71	1.13	22.45	**	9	11	24	03	05	74	9	57.14	Fine
Limited	*Carissa bispinosa*	***NA***	***NA***	***NA***	***NA***	***NA***	-	***NA***	1	11	01	***NA***	0	0	14.29	***NA***
Limited	*Carissa tetramera*	***NA***	***NA***	***NA***	***NA***	***NA***	-	***NA***	1	20	01	***NA***	0	0	14.29	***NA***
Limited	*Combretum molle*	-0.7	4.52	0.33	0.73	0.49	-	1	3	13	02	03	46	0	71.43	***NA***
					Mean SCD centroid location for common species:						02	04				
<u>MRC site</u>																
Community Level	**Community SCD**	**-2.18**	**8.88**	**0.86**	**1.12**	**60.04**	**	**10**	**12**	**176**						
Full	*Dichrostachys cinerea*	-3.67	9.55	0.95	0.61	38.65	*	2	4	52	01	03	169	0	100.00	***NA***
Full	*Gymnosporia senegalensis*	-5.64	10.26	0.93	1.06	13.71	-	1	3	67	01	03	34	0	50.00	***NA***
					Mean SCD centroid location for common species:						01	03				
Limited	*Sclerocarya birrea*	-1.17	4.67	0.39	1.77	5.87	*	9	11	13	05	08	102	102	50.00	Fine
					Mean SCD centroid location for common species:						05	08				

SC	Size Class
**	Highly significant ($p \leq 0.01$)
*	Significant ($p \leq 0.05$)
-	Not significant ($p > 0.05$)
NA	Not applicable, following the species grain, it indicates that while grain could be determined, the frequency of occurrence is too low to warrant inclusion in the model

In Tembe, ten species were evaluated (Table 14). The unit was dominated by a low stratum of *Dichrostachys cinerea, Strychnos madagascariensis, Terminalia sericea, Acacia burkei* and *Combretum molle*, while the canopy level was a mix of *Strychnos madagascariensis* and *Terminalia sericea*. Mean centroid 2 locations indicated some bias to the left, but there were large shifts in size classes between the positions of mean centroids 1 and 2. Only the populations of *Dichrostachys cinerea* could be compared between sites and they were similar (Table 6).

Grain of species and communities

The grain of species was noted for all species for which it was possible to identify grain by using the general model presented in Figure 1 (Figures 2 – 20). Most species that could be classified according to the grain model were fine-grained (Table 15), and therefore most vegetation units sampled here were considered fine-grained (Table 15). However, the Closed Woodland on Clay and Open Woodland on Sand of Tembe were intermediate-grained vegetation units, as were the Open Woodland on Abandoned Household sites unit in Manqakulane and the Closed Woodland Thicket in Tshanini. In contrast to the grain model presented by Lawes and Obiri (2002), the species for which grain could be established, but for which frequency of occurrence in the plots should have precluded their inclusion in the model, were also used to determine the woodland communities' grain.

Discussion

The woodlands of northern Maputaland are subjected to many different influences and it is obvious that man and wildlife have had a shaping influence. From the present results it appears that the main effect of both agents is an increase in the regeneration levels, and steeper species size class distribution curves, with a shortening of the range of the curves, especially with regards to the effect of man. This effect can most likely be linked to the opening of the canopies by man or large herbivores where the canopy opening stimulates the growth of lower strata, as documented in west, east and southern Africa for wildlife (Tafangenyasha 1997; Tedonkeng Pamo and Tchamba 2001; Mosugelo *et al.* 2002; Western and Maitumo 2004) and man (Lykke 1998; Schwartz and Caro 2003; Shackleton *et al.* 2005; Backeus *et al.* 2006)

In the case of Manqakulane, woody species re-growth is certainly not controlled by wildlife, as most species but the smallest antelopes have been hunted to local extinction (Guldemond and Van Aarde In Press), but also not by cattle and goats,

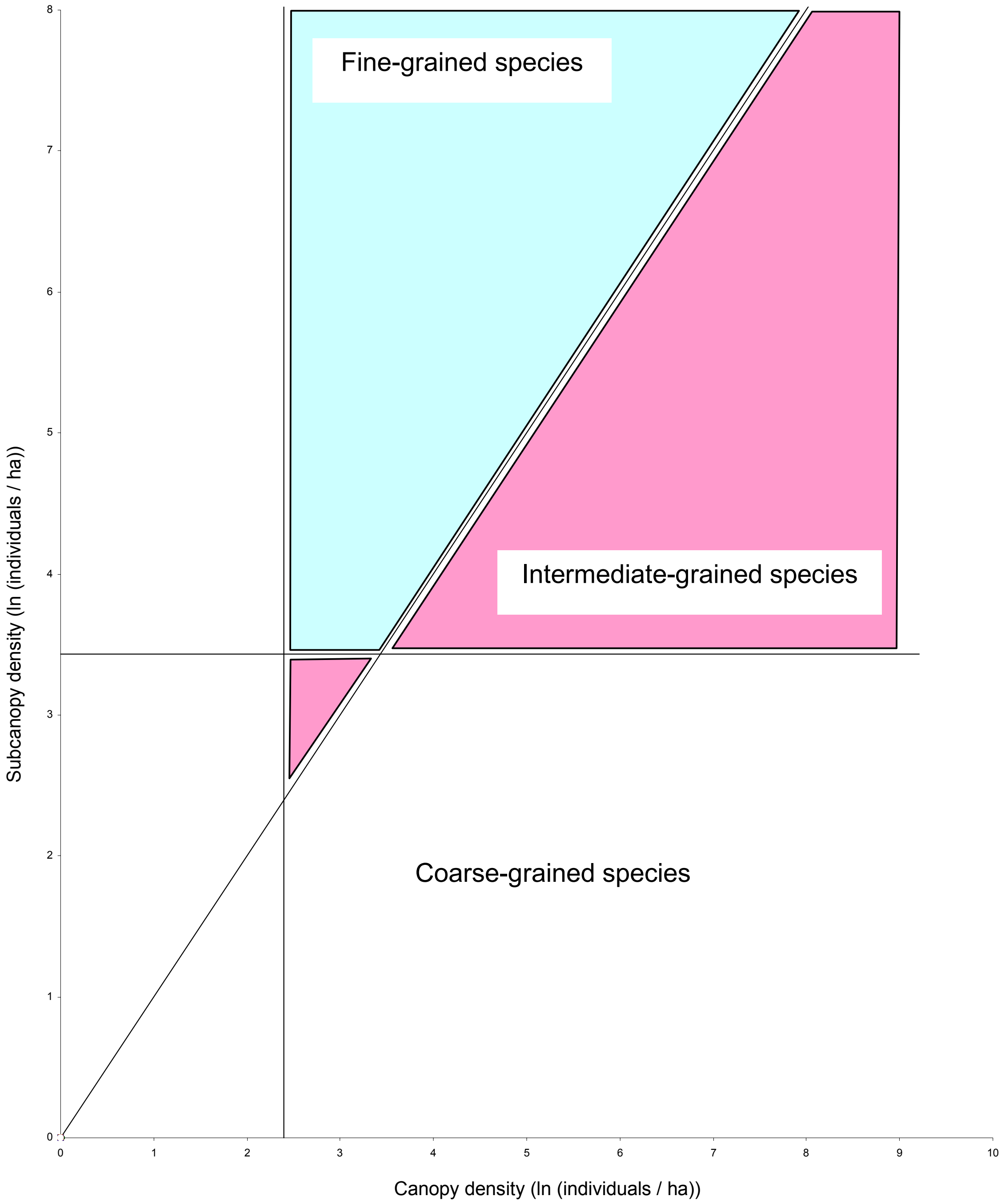

Figure 1: The graphical grain determination model based on canopy density (X-axis) and subcanopy density (Y-axis) used to evaluate tree species grain in the three study sites in KwaZulu-Natal, South Africa. Values are ln-transformed to improve readability. The model is adapted from Lawes and Obiri (2003).

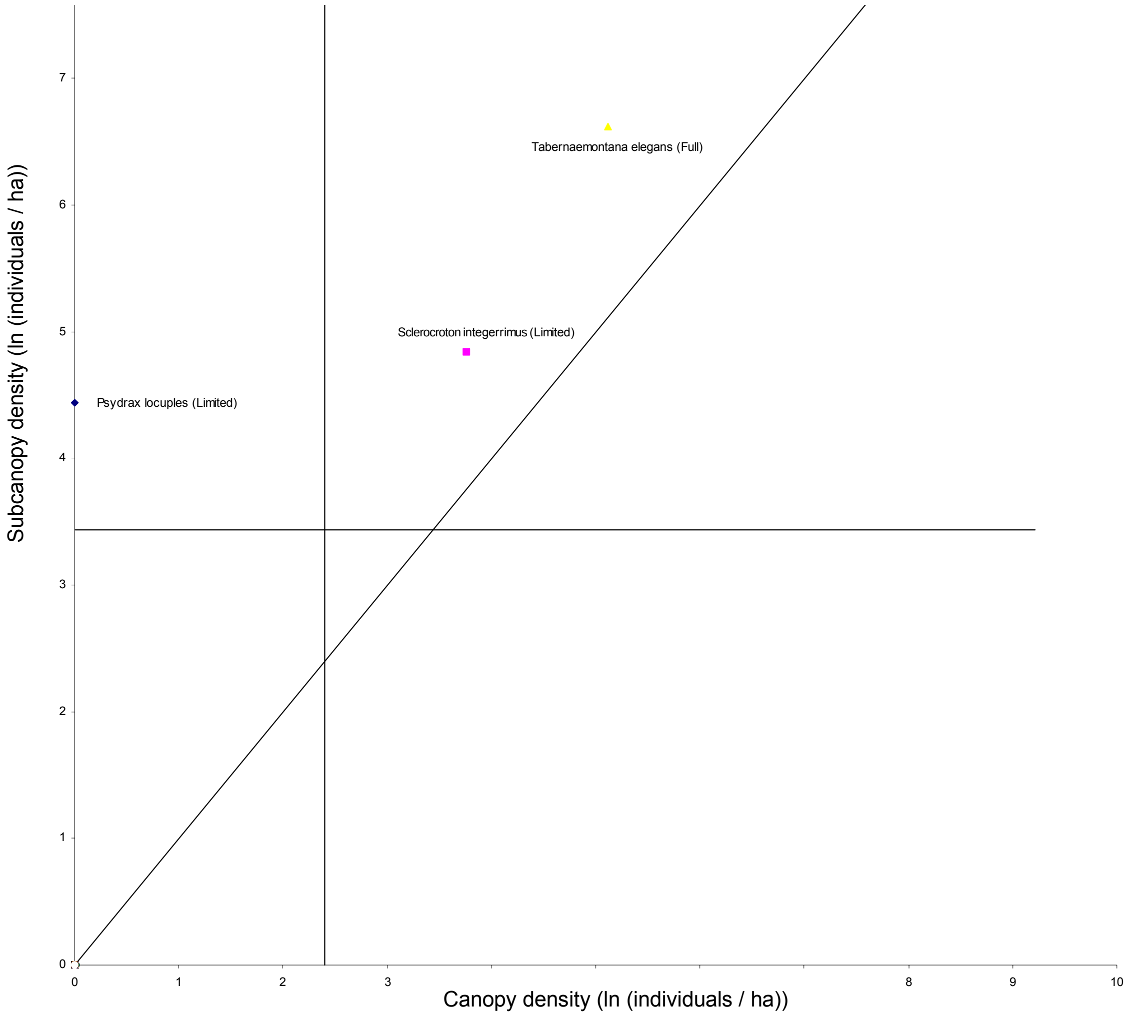

Figure 2: The grain of Closed Woodland Thicket woody species sampled in Tembe Elephant Park, KwaZulu-Natal, South Africa. Values have been ln-transformed to improve readability. The full analysis represents species for which at least 30 individuals were sampled, while the limited analysis represents species for which only 10 to 29 individuals were sampled.

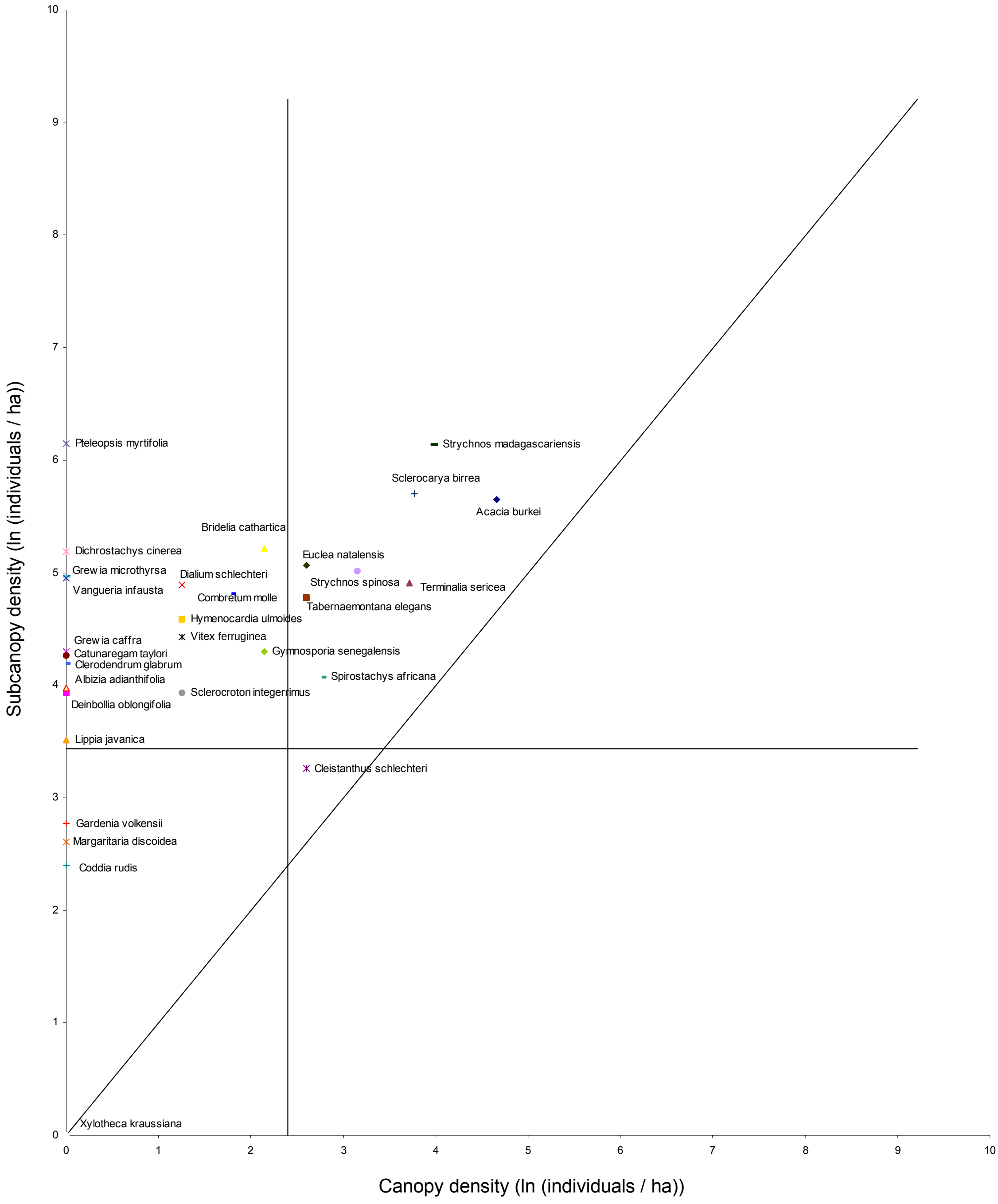

Figure 3: The grain of Closed Woodland Thicket woody species for which at least 30 individuals were sampled in Tshanini Community Conservation Area, KwaZulu-Natal, South Africa. Values have been ln-transformed to improve readability.

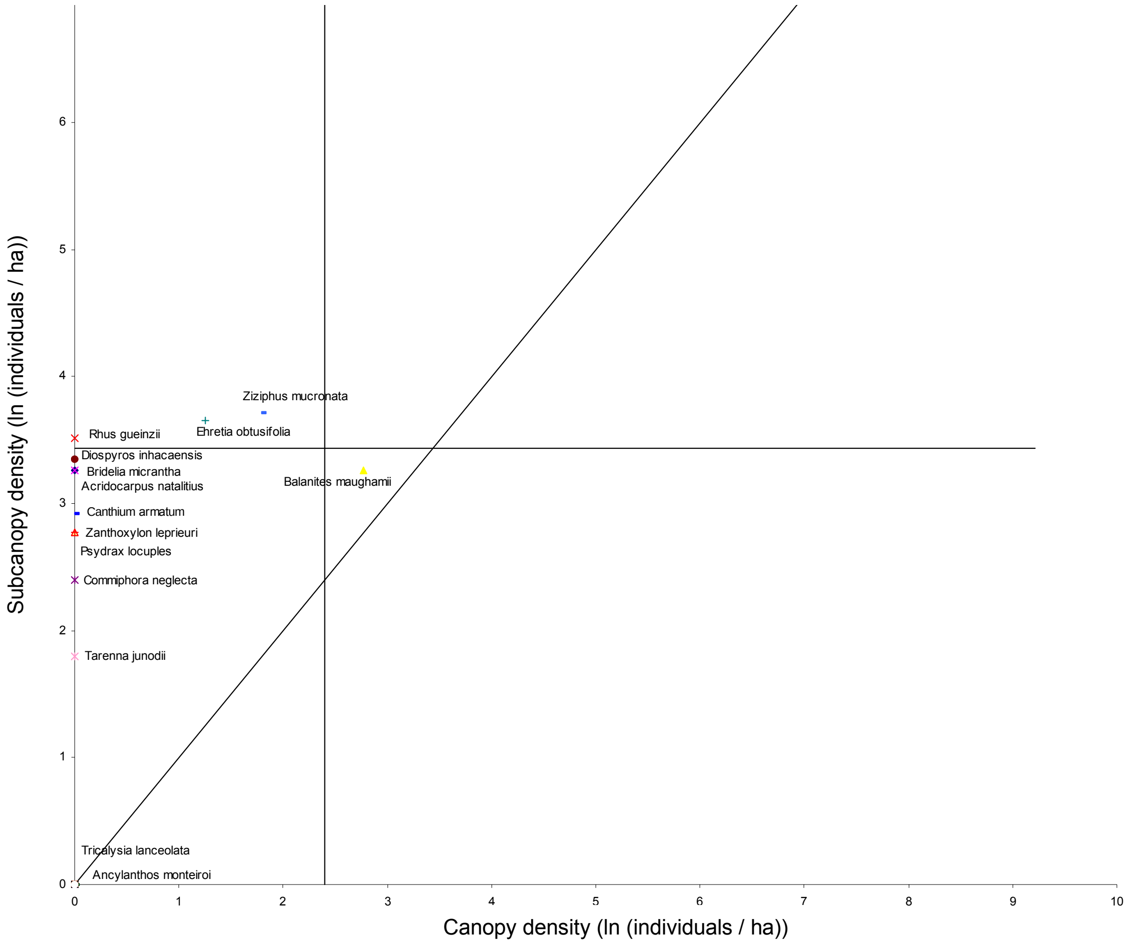

Figure 4: The grain of Closed Woodland Thicket woody species for which 10 to 29 individuals were sampled in Tshanini Community Conservation Area, KwaZulu-Natal, South Africa. Values have been ln-transformed to improve readability.

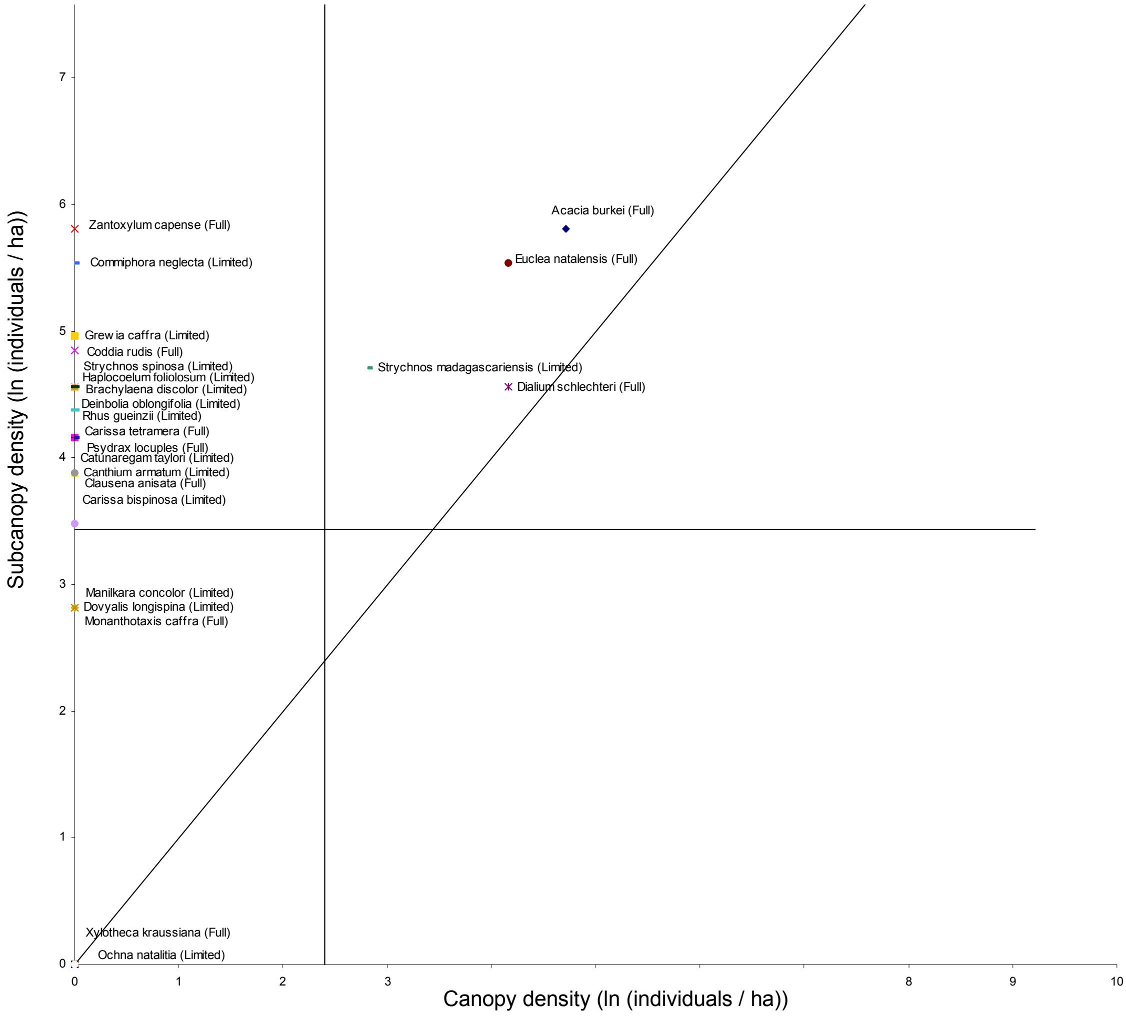

Figure 5: The grain of Closed Woodland Thicket woody species sampled in Manqakulane rural community village zone area, KwaZulu-Natal, South Africa. Values have been ln-transformed to improve readability. The full analysis represents species for which at least 30 individuals were sampled, while the limited analysis represents species for which only 10 to 29 individuals were sampled.

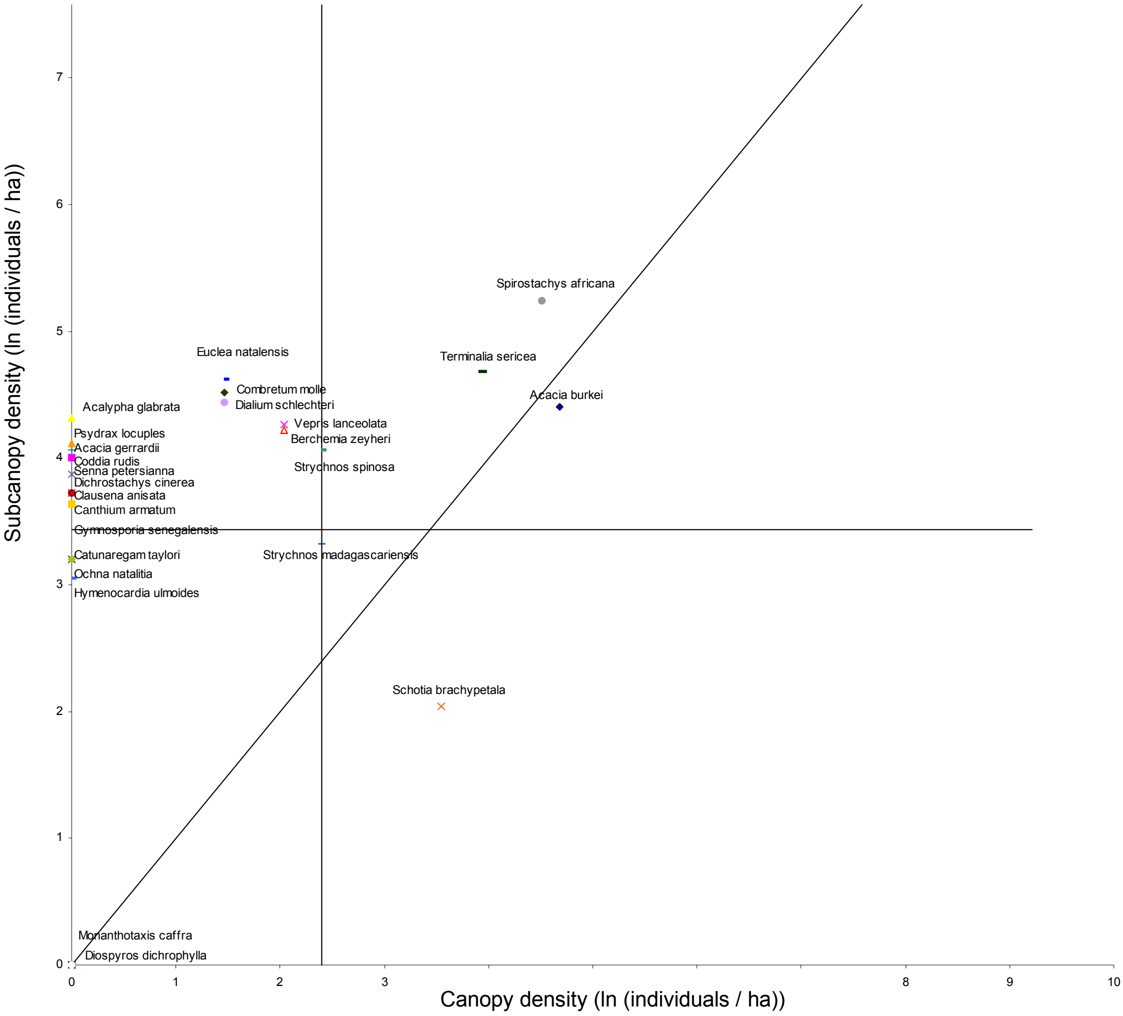

Figure 6: The grain of Closed Woodland on Clay woody species for which at least 30 individuals were sampled in Tembe Elephant Park, KwaZulu-Natal, South Africa. Values have been ln-transformed to improve readability.

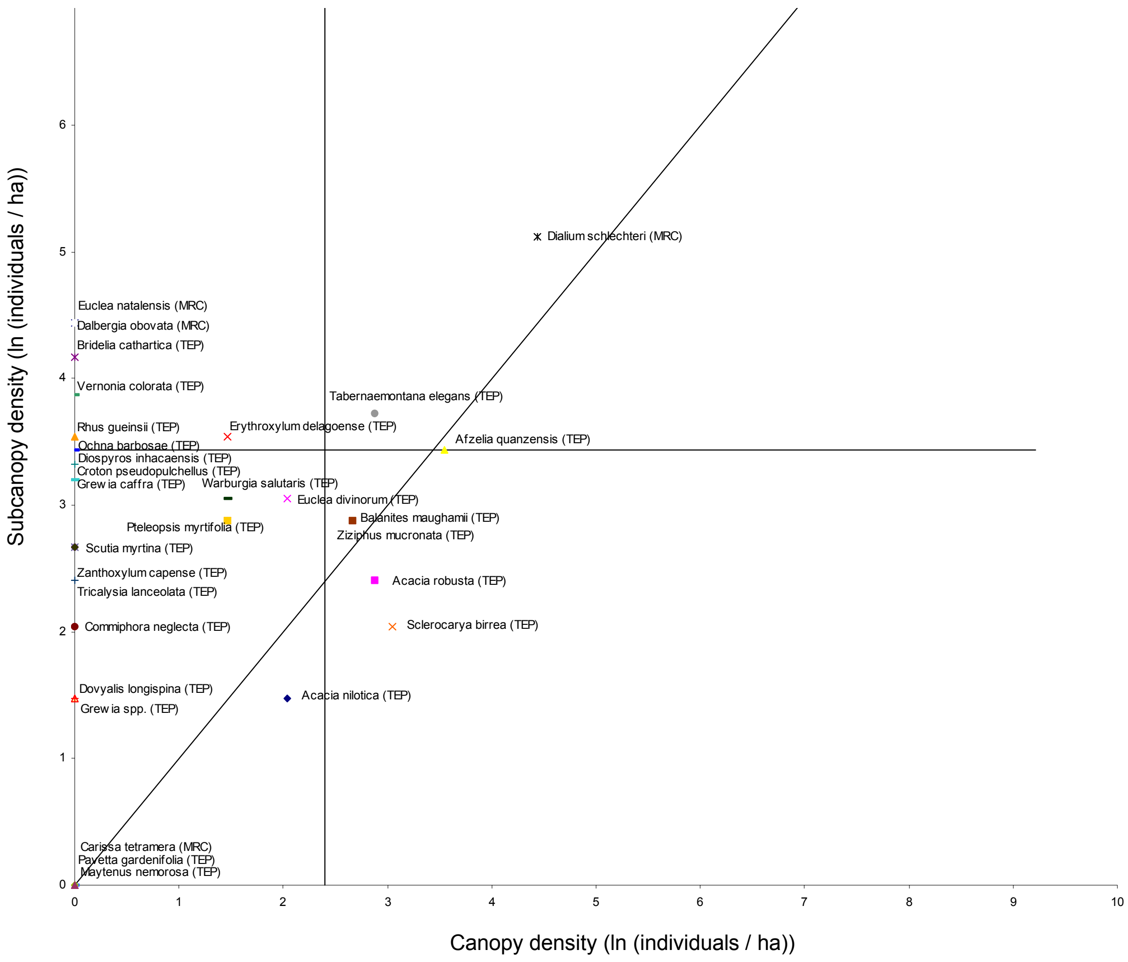

Figure 7: The grain of Closed Woodland on Clay woody species for which 10 to 29 individuals were sampled in Tembe Elephant Park (TEP) and Manqakulane Rural Community (MRC) village area, KwaZulu-Natal, South Africa. Values have been ln-transformed to improve readability.

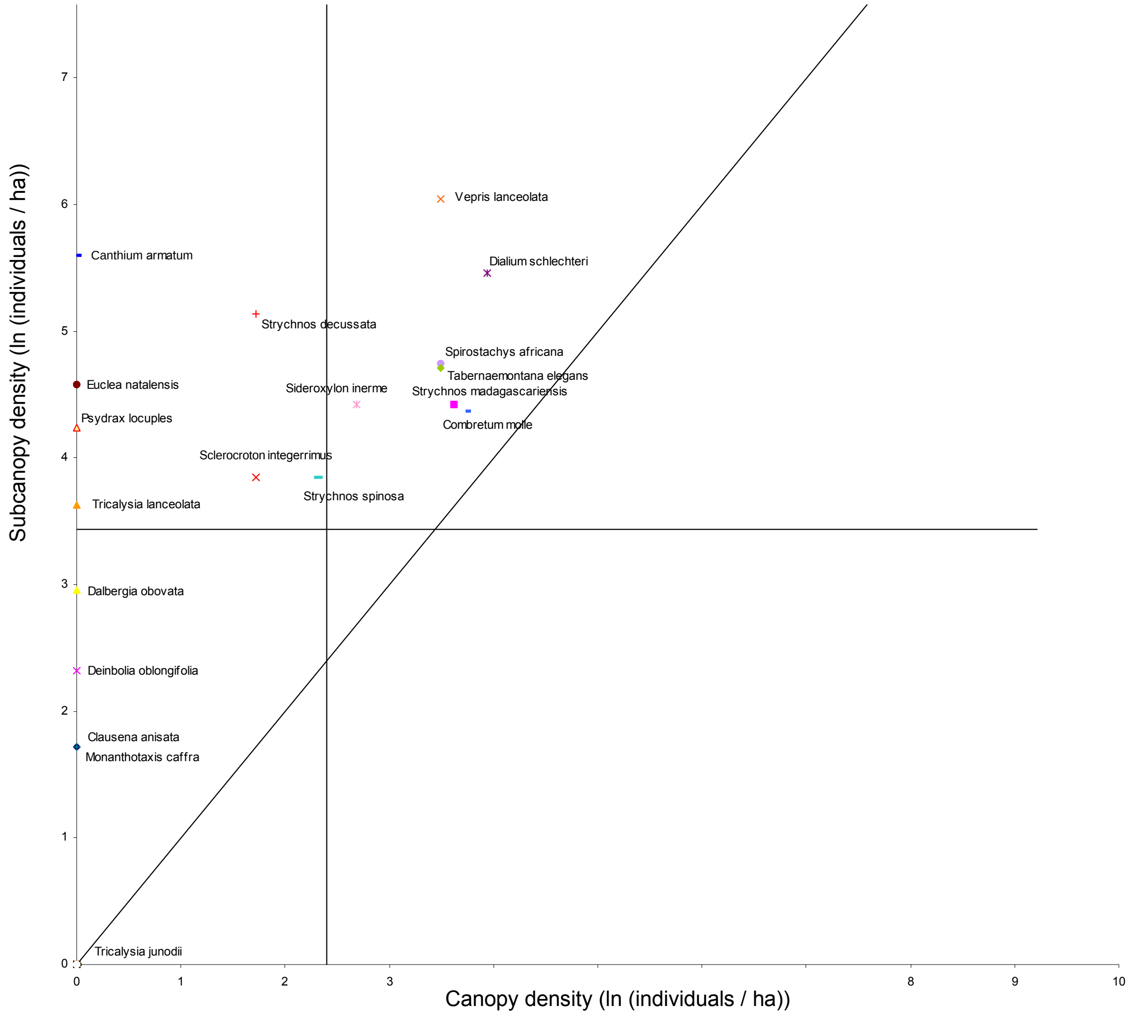

Figure 8: The grain of Closed Woodland on Sand woody species for which at least 30 individuals were sampled in Tembe Elephant Park, KwaZulu-Natal, South Africa. Values have been ln-transformed to improve readability.

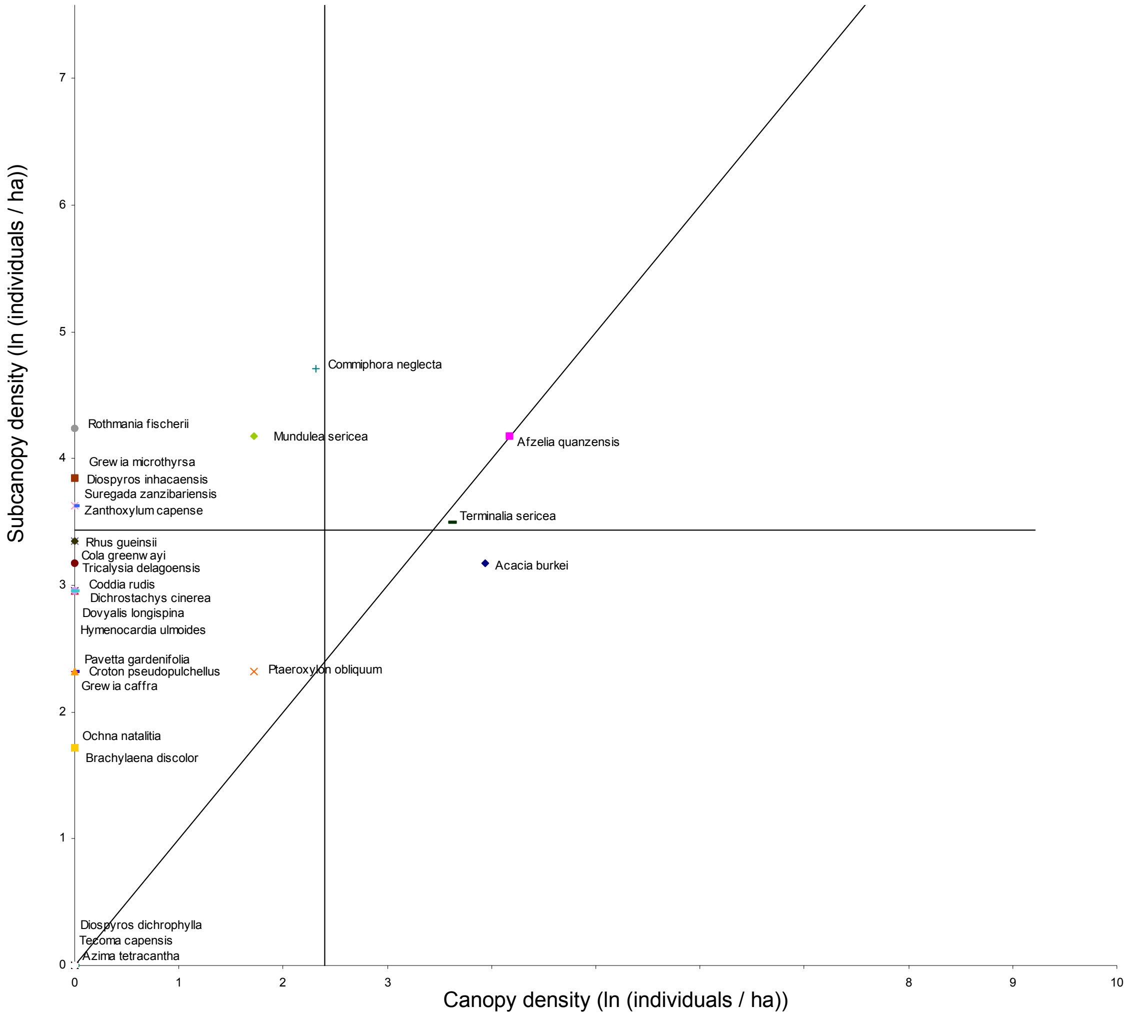

Figure 9: The grain of Closed Woodland on Sand woody species for which 10 to 29 individuals were sampled in Tembe Elephant Park, KwaZulu-Natal, South Africa. Values have been ln-transformed to improve readability.

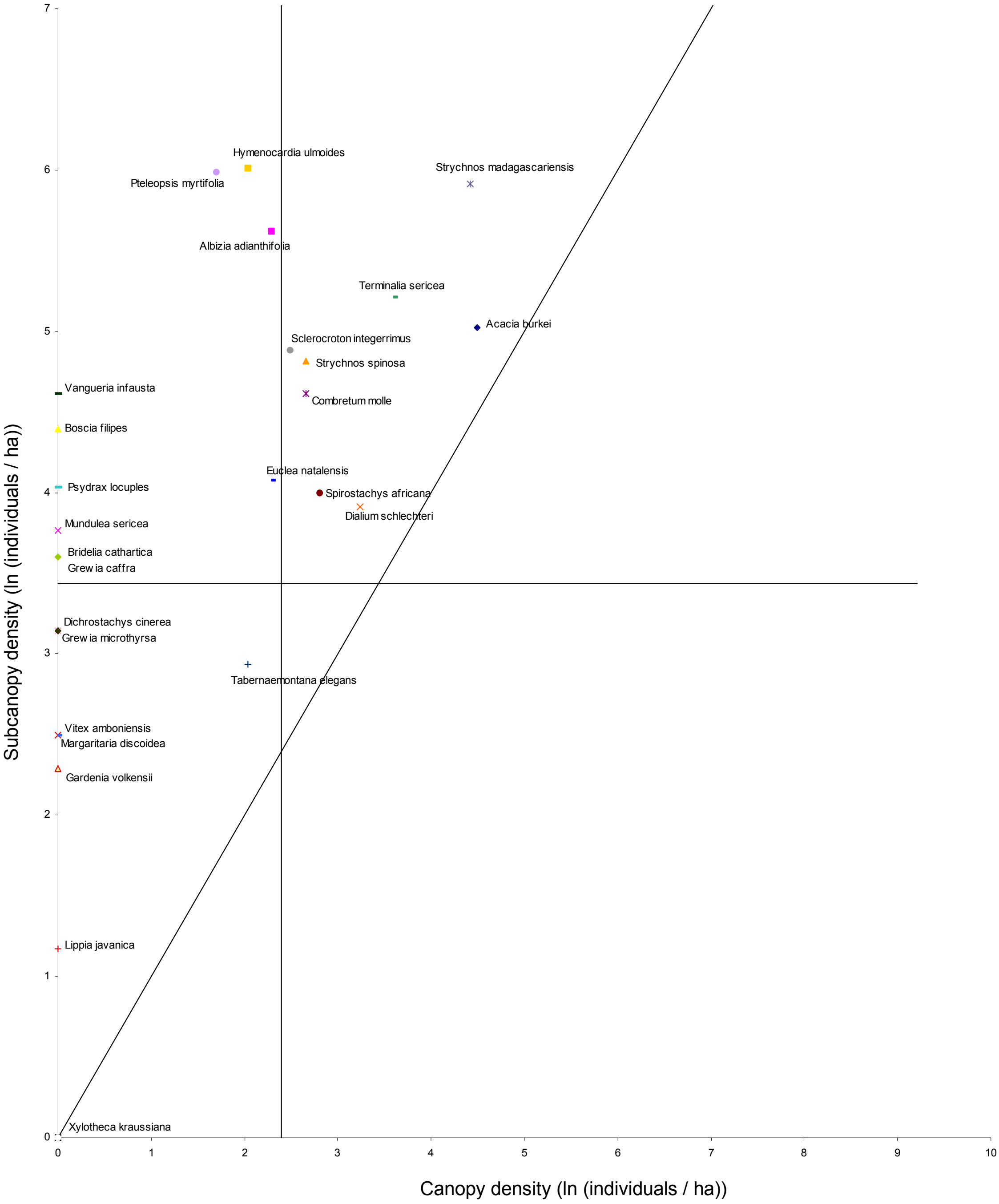

Figure 10: The grain of Closed Woodland on Sand woody species for which at least 30 individuals were sampled in Tshanini Community Conservation Area, KwaZulu-Natal, South Africa. Values have been ln-transformed to improve readability.

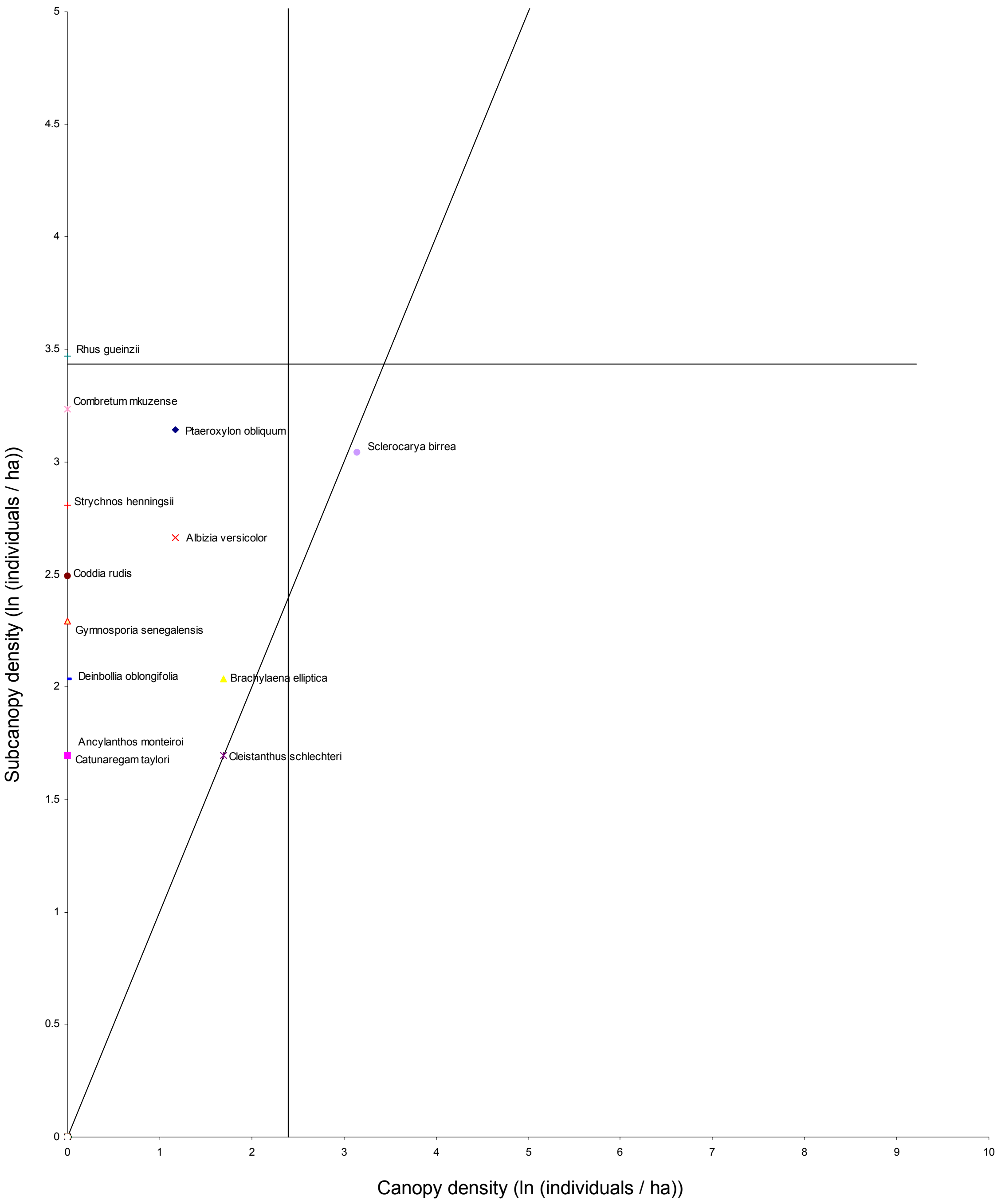

Figure 11: The grain of Closed Woodland on Sand woody species for which 10 to 29 individuals were sampled in Tshanini Community Conservation Area, KwaZulu-Natal, South Africa. Values have been ln-transformed to improve readability.

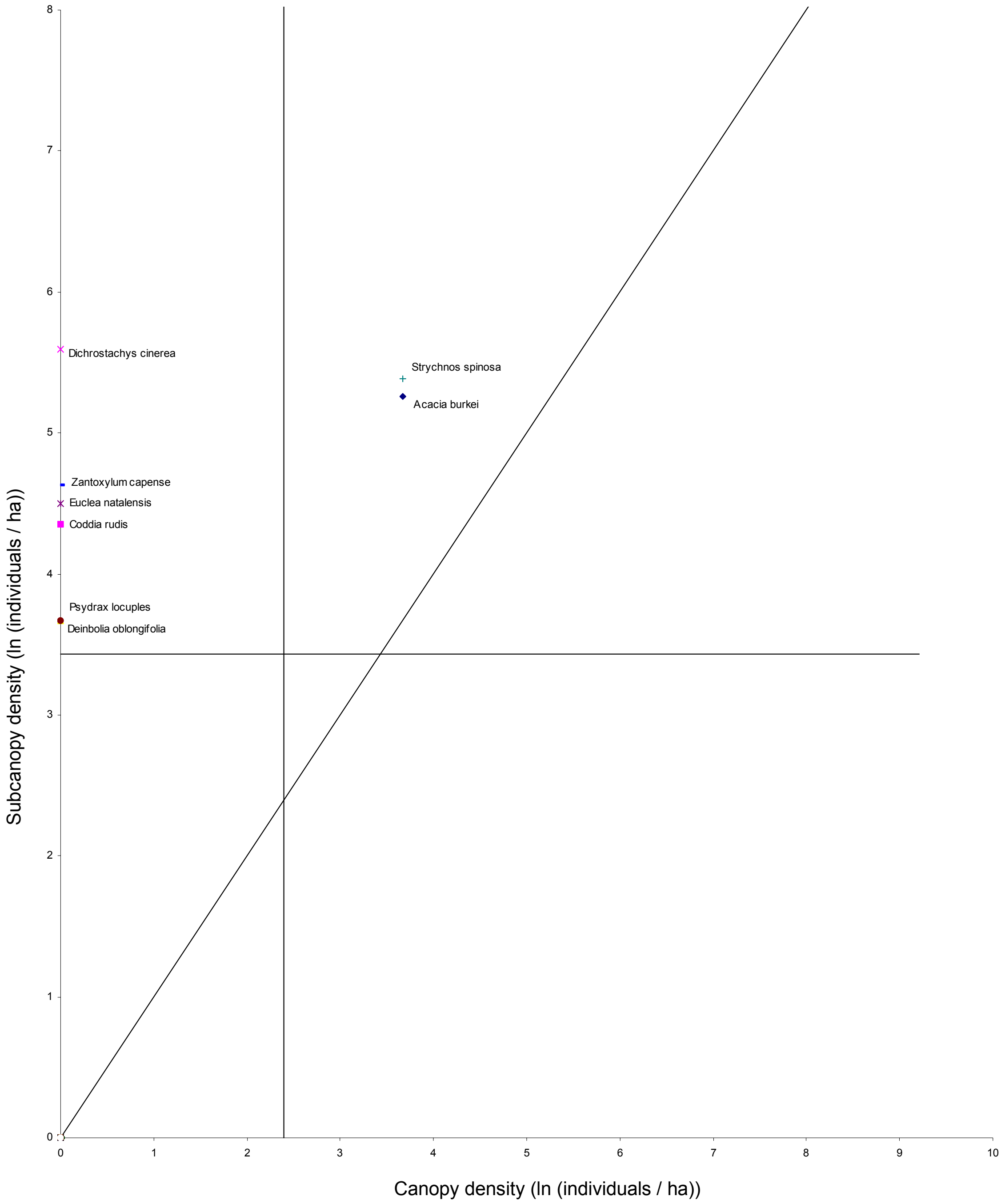

Figure 12: The grain of Closed Woodland on Sand woody species for which at least 30 individuals were sampled in the Manqakulane Rural Community village zone, KwaZulu-Natal, South Africa. Values have been ln-transformed to improve readability.

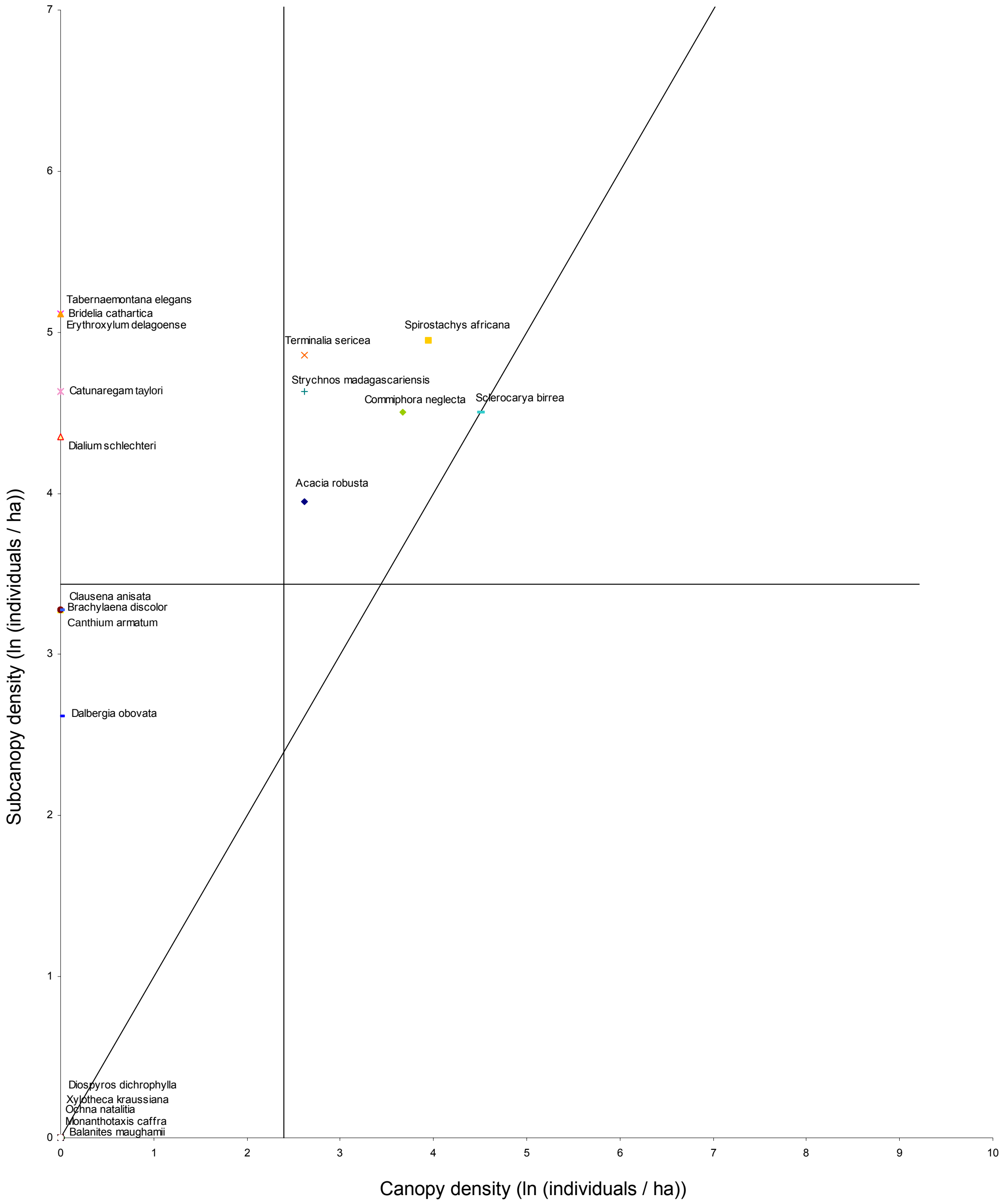

Figure 13: The grain of Closed Woodland on Sand tree species for which 10 to 29 individuals were sampled in the Manqakulane Rural Community village zone, KwaZulu-Natal, South Africa. Values have been ln-transformed to improve readability.

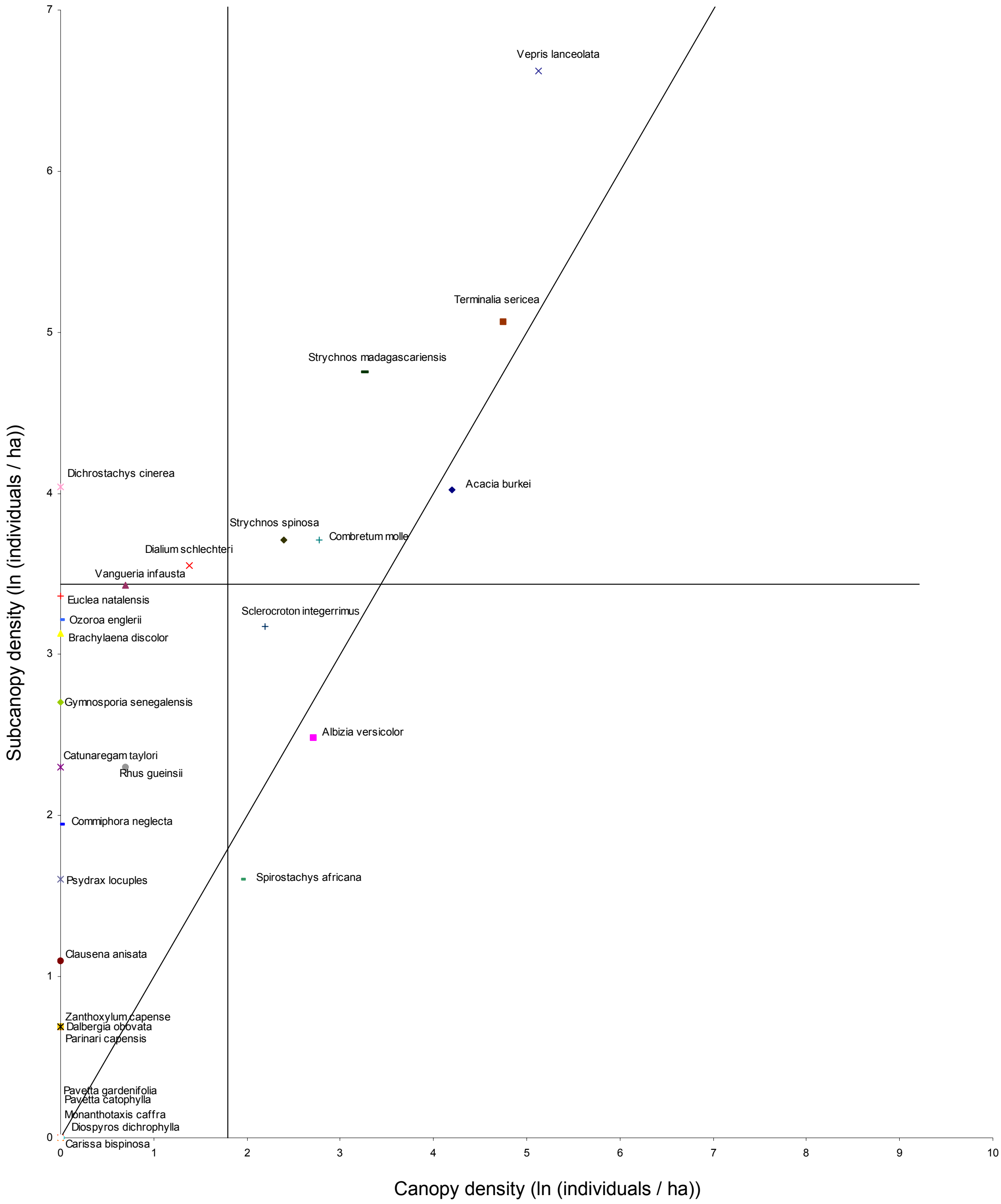

Figure 14: The grain of Open Woodland on Sand woody species for which at least 30 individuals were sampled in Tembe Elephant Park, KwaZulu-Natal, South Africa. Values have been ln-transformed to improve readability. The lower boundary for canopy density has been relaxed to 5 individuals per ha.

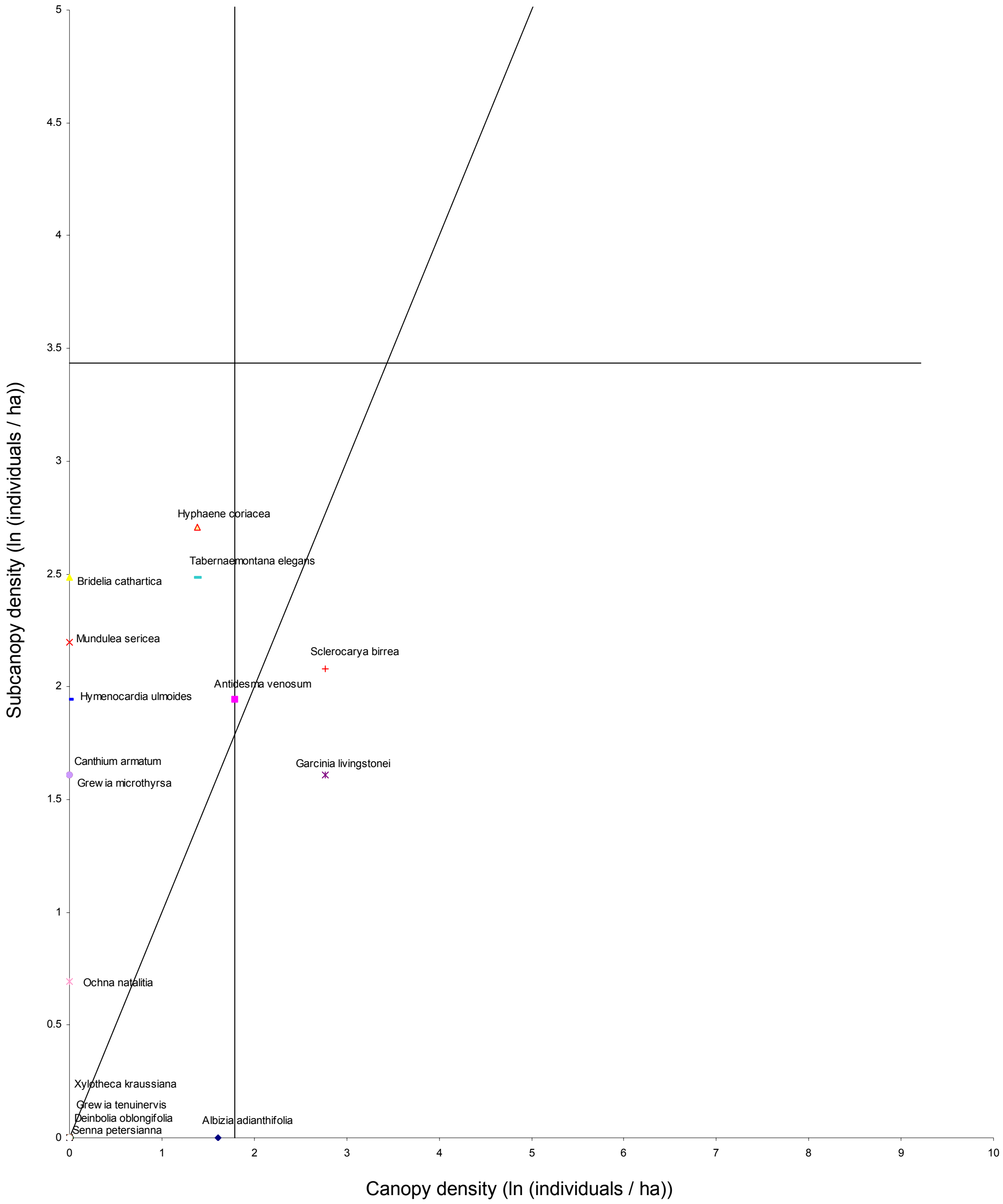

Figure 15: The grain of Open Woodland on Sand woody species for which 10 to 29 individuals were sampled in Tembe Elephant Park, KwaZulu-Natal, South Africa. Values have been ln-transformed to improve readability. The lower boundary for canopy density has been relaxed to 5 individuals per ha.

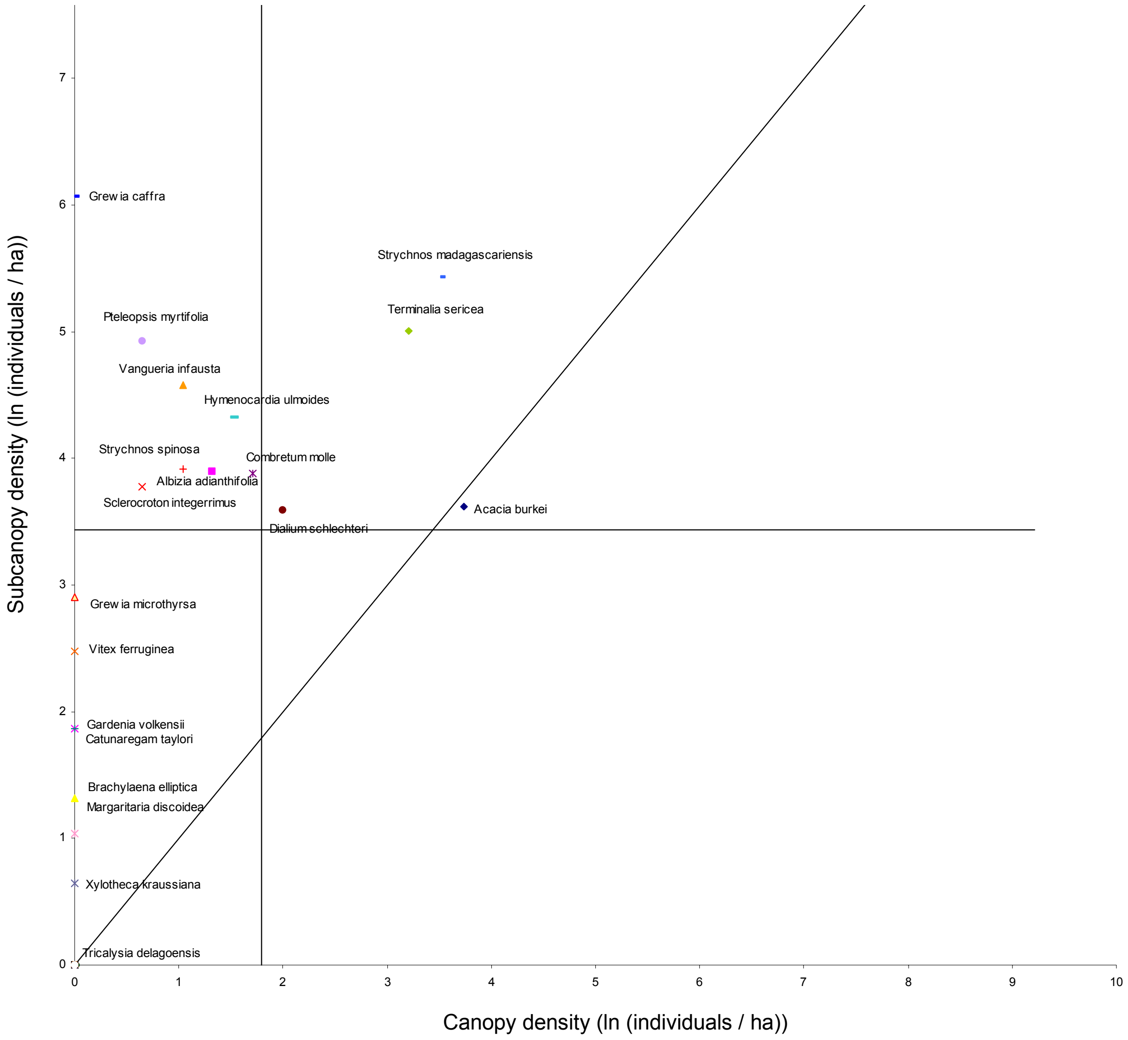

Figure 16: The grain of Open Woodland on Sand woody species for which at least 30 individuals were sampled in Tshanini Community Conservation Area, KwaZulu-Natal, South Africa. Values have been ln-transformed to improve readability. The lower boundary for canopy density has been relaxed to 5 individuals per ha.

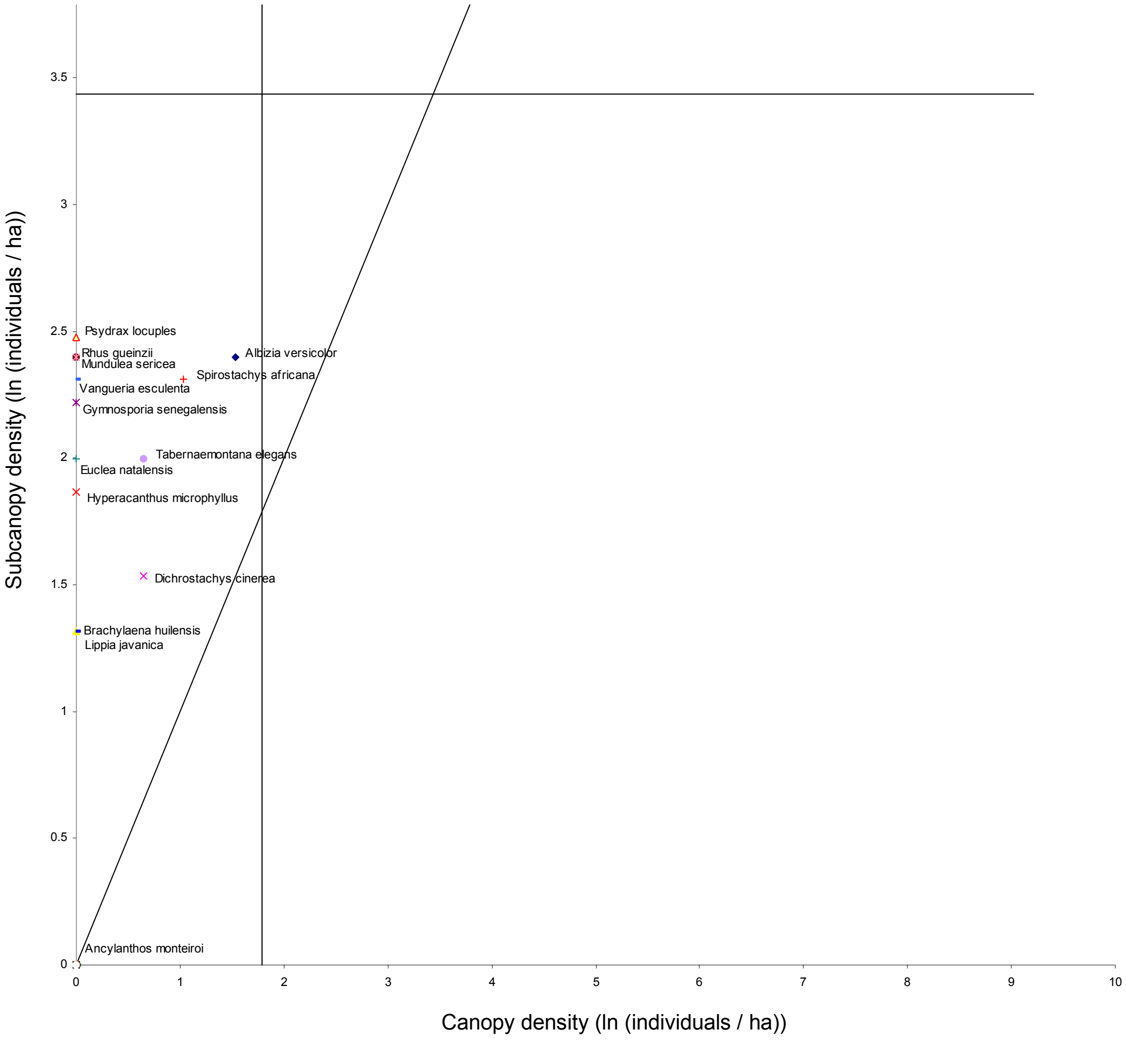

Figure 17: The grain of Open Woodland on Sand woody species for which 10 to 29 individuals were sampled in Tshanini Community Conservation Area, KwaZulu-Natal, South Africa. Values have been ln-transformed to improve readability. The lower boundary for canopy density has been relaxed to 5 individuals per ha.

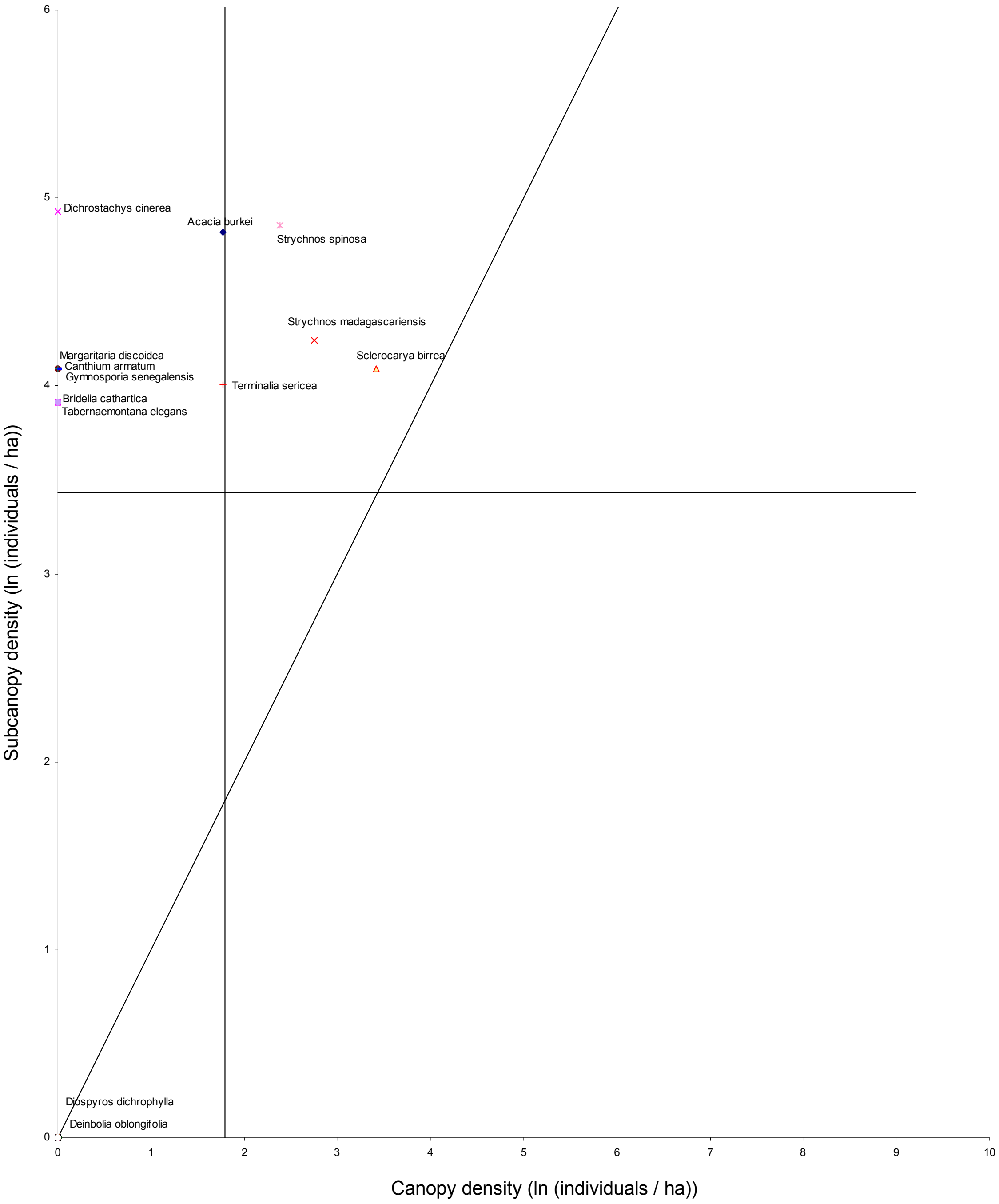

Figure 18: The grain of Open Woodland on Abandoned Household sites woody species for which at least 30 individuals were sampled in Manqakulane Rural Community village zone, South Africa. Values have been ln-transformed to improve readability. The lower boundary for canopy density has been relaxed to 5 individuals per ha.

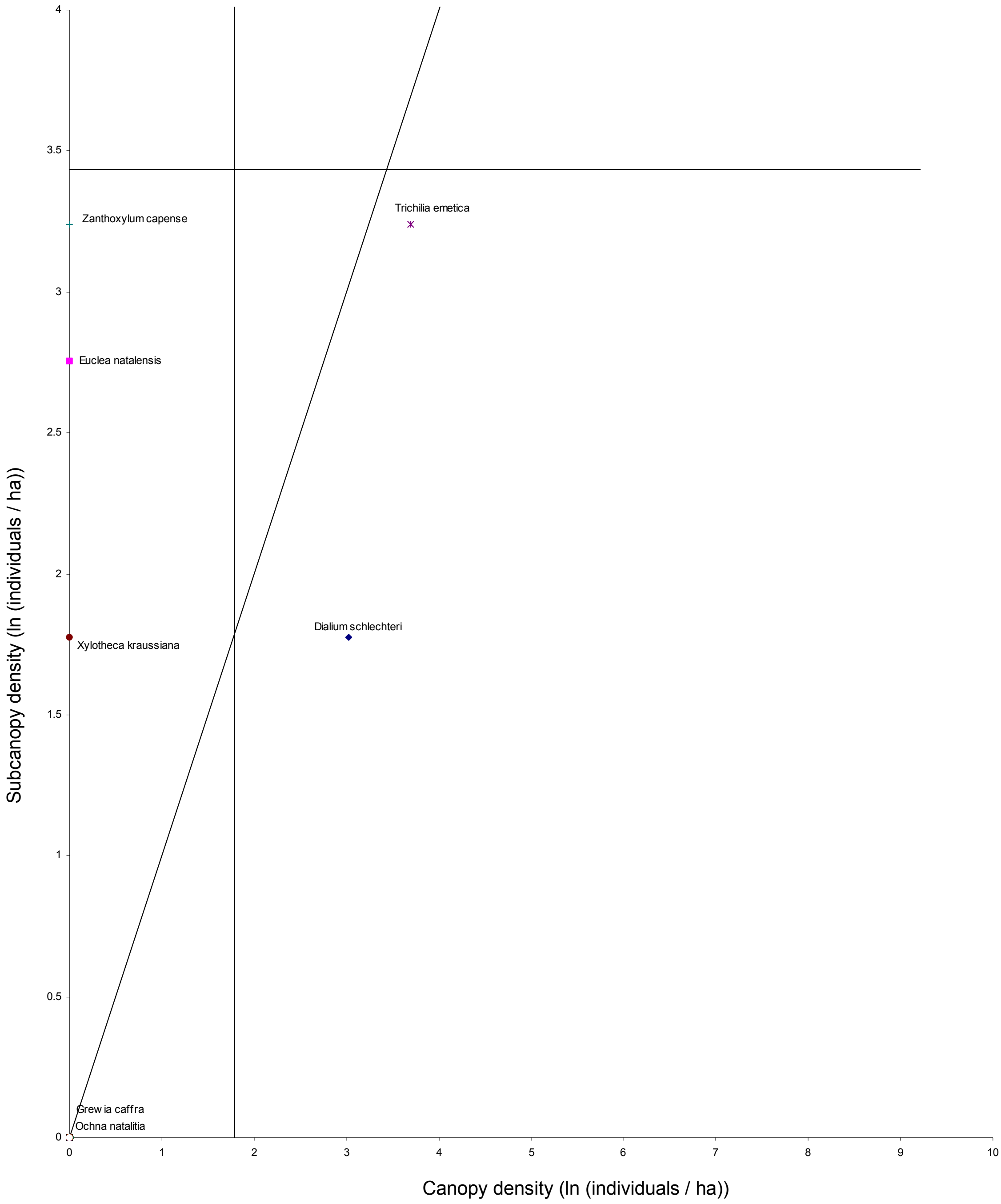

Figure 19: The grain of Open Woodland on Abandoned Household sites woody species for which 10 to 29 individuals were sampled in Manqakulane Rural Community village zone, South Africa. Values have been ln-transformed to improve readability. The lower boundary for canopy density has been relaxed to 5 individuals per ha.

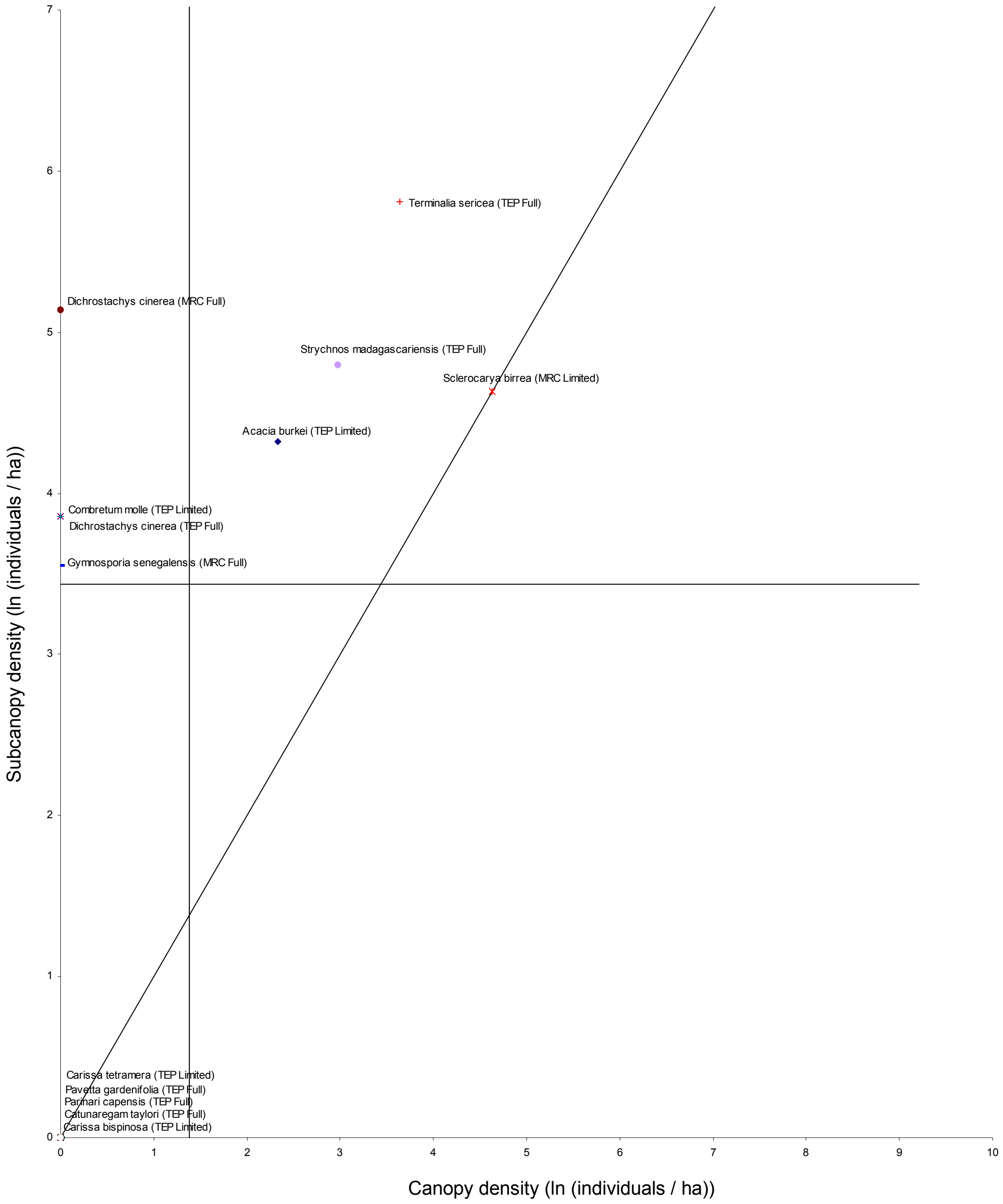

Figure 20: The grain of Sparse Woodland on Sand woody species sampled in the Tembe elephant Park (TEP) and Manqakulane Rural Community (MRC) village zone, KwaZulu-Natal, South Africa. Values have been ln-transformed to improve readability. The lower boundary for canopy density has been relaxed to 3 individuals per ha. The full analysis represents species for which at least 30 individuals were sampled, while the limited analysis represents species for which only 10 to 29 individuals were sampled.

Table 15: The number of species by grain category and the derived community grain for the various vegetation units of Tshanini Community Conservation Area (TCCA), the Manqakulane Rural Community village zone (MRC) and Tembe Elephant Park (TEP), Maputaland, northern KwaZulu-Natal, South Africa

Grain	Number of species per grain category by vegetation units and sites													
	Closed Woodland Thicket			Closed Woodland on Clay		Closed Woodland on Sand			Open Woodland on Sand			Open Woodland on abandoned household site	Sparse Woodland on Sand	
	TEP	TCCA	MRC	TEP	MRC	TEP	TCCA	MRC	TEP	TCCA	MRC	MRC	TEP	MRC
Fine	2	1	4	3	1	3 (5)	7 (1)	7 (1)	4 (1)	3	0	3	3	1
Intermediate	0	0 (2)	0	1 (3)	0	0	0	0	1 (2)	1	0	0	0	0
Coarse	0	0	0	0 (2)	0	1	0	0	0 (4)	0	0	2	0	0
	Derived status of the vegetation unit or sub-unit													
Fine	X	-	X	-	X	X	X	X	-	X	-	-	X	X
Intermediate	-	X	-	X	-	-	-	-	X	-	-	X	-	-
Coarse	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Note: The numbers between brackets correspond to the number of species for which grain was determined but where frequency of occurrence precluded their inclusion in the grain model which occur in low numbers as the climate appears unfavourable for the latter, and better cattle grazing fields occur in the hygrophilous grasslands further east (Gaugris 2004; Matthews 2006; Peteers 2005; Gaugris *et al.* 2007). The strong influence of seedlings and saplings on the shape of the curves as indicated by the shifts in centroid positions as well as the steepness of the slopes (Niklas *et al.* 2003) can be attributed to the absence or low abundance of limiting mammalian herbivores and the presence of man. Of note is that many large trees remain in Manqakulane, especially those species that provide fruit or shade. This could be explained by the reluctance to cut these trees, a fact documented in rural areas of west, central and east Africa (Lykke 1998; Luoga *et al.* 2002; Banda *et al.* 2006b) but also in South Africa (Shackleton *et al.* 2005). However, there appears to be a gap between the lower size classes and the larger ones, which corresponds to the size classes utilised for household building observed in this rural community (Gaugris *et al.* 2007). While untested in the present study, the link is obvious, and documented by other studies (Obiri *et al.* 2002; Boudreau *et al.* 2005).

In Tembe, the influence of mammals is more difficult to discern than that of man in Manqakulane, but differences appear in terms of centroid locations. In general, the Tembe woodland sites have populations of woody species with a centroid either slightly biased to the left or in a central position of the SCD range. This indicates mature populations (Niklas *et al.* 2003). However, a shift of at least two size classes frequently observed in mean centroids 1 and 2 positions shows some influence from seedlings and saplings on the curve shape, indicating that recruitment is potentially stimulated (Everard *et al.* 1995; Lykke 1998; Niklas *et al.* 2003) in a more active manner than in the Tshanini site where the shift was usually only one size class. Because the sites are geographically so close to each other, climatic conditions are considered similar (see Yeh *et al.* 2000), and because human influence in Tshanini and Tembe is controlled (Gaugris 2004; Matthews 2006), the remaining shaping agents for Tembe and Tshanini woodlands are either herbivores or fire.

The centroid location biased to the right means that many large individuals contribute to the population structure (Niklas *et al.* 2003). In Tembe this statement could be biased due to the fact that a range of the smaller size classes must be utilised by herbivores or removed by fire, thus reducing the influence of smaller size classes on the centroid location. This bias in Tembe appears possible because in the absence of animals in Tshanini, the centroids for that site are biased to the left with little influence from seedlings and saplings to the curve shapes as evidenced by the minimal changes in centroid positions between the two analyses. Fire as shaping agent occurs in both Tshanini and Tembe, although at a higher frequency in the former (Gaugris *et al.* 2004;

Matthews 2006; Guldemond and Van Aarde In Press). But as it appears to have little effect on the population curves in Tshanini (seedling germination and sapling growth can also be induced by fire events (Barnes 2001; Ickowitz 2006)), it appears possible to deduce that its effect in Tembe should be similar, and therefore that animals are most likely the shaping agent in Tembe. This impression is reinforced by the case of some species that seem to be on the verge of disappearing in Tembe (especially in the Open Woodland on sand vegetation unit), whereas populations of the same species in Tshanini are healthy. If this trend continues Tembe faces the risk that herbivores, and especially elephants, will bring some species to local extinction by repeated utilisation, as has been documented elsewhere (Guldemond and Van Aarde In Press; O'Connor *et al.* 2007).

In general, species in Tshanini are healthy and regenerating well, even those species classified within Type 3 have fairly high densities at both subcanopy and canopy levels. The species of Type 3 are usually found within the limited analysis and often grow into large trees. Large, long-lived (>200 years) woody species are known to establish a strong canopy level and a sufficient but somewhat episodic recruitment through the subcanopy (Everard *et al.* 1994; Everard *et al.* 1995; Peters 1996; Condit *et al.* 1998; Burslem and Whitmore 1999), which could therefore explain the flat or even positive slopes, indicating both long-term scales of regeneration and mature species (Lykke 1998; Niklas *et al.* 2003). These species are by nature less numerous than others as only a few large trees are necessary to form a closed canopy (Peters 1996; Burslem and Whitmore 1999), and the fact that they were classified within the limited analysis does not appear to warrant a particular concern.

The evaluation of grain of species undertaken in the present study contributes some interesting views. However, some limitations of the use of the model must be stated, as it was not used in the classical way. The model was tentatively applied to woodlands by Gaugris (2004) in Tshanini during a previous study and its application to woodlands therefore remains largely invalidated. In addition, the concept was here divided in two aspects, the grain of the unit was defined by all species where grain could be determined, and therefore did not take into consideration the frequency of occurrence as required in the forest application (Lawes and Obiri 2003). The frequency of occurrence is here only considered of interest for utilisation purposes, which are discussed below. Another restriction applies, in the sense that unit grain rests on a few species for which grain is determined, and it may therefore lead to wrong assumptions in some instances.

Species grain should preferably always be evaluated in conjunction with the size class distributions (Obiri *et al.* 2002; Lawes and Obiri 2003). A wealth of Type 1 species and an abundance of the same species at both subcanopy and canopy levels define fine-grained vegetation communities in forests (Everard *et al.* 1994; Everard *et al.* 1995). As such, the fine-grained character of some of the vegetation units evaluated here could be fairly conclusively shown (Tables 3 and 15). The implications of fine-grain forests are that natural processes of regeneration of shade-tolerant species are based on small-scale processes, and therefore that regular small-scale disturbance is required to maintain the vegetation structure (Midgley *et al.* 1990; Everard *et al.* 1994; Everard *et al.* 1995; Obiri *et al.* 2002; Lawes and Obiri 2003). Coarse-grained species are on the other side of the scale, and regenerate poorly under frequent small scale disturbance regimes, but rather require relatively frequent large scale disturbance, such as the opening of large gaps, to maintain their populations (Midgley *et al.* 1990; Everard *et al.* 1994; Everard *et al.* 1995; Obiri *et al.* 2002; Lawes and Obiri 2003). Given the absence of disturbance, coarse-grained forests are thought to evolve into fine-grained ones as shade-tolerant species progressively replace the shade-intolerant ones (Everard *et al.* 1994; Everard *et al.* 1995).

Closed Woodland units of Tshanini have been recognised as forest like (Gaugris 2004; Gaugris *et al.* 2004), and it is expected that the grain model should therefore work well when applied to the Closed Woodland units in general. However, a problem occurs for the grain theory in the case of Open and Sparse Woodland units, where the gap concept that drives grain theory would not be relevant anymore. The gap concept relies on the assumption that there are gap-demanders (light sensitive germination, fast growing, regular fruiting, dormant seed bank) (Burslem and Whitmore 1999) and non-gap-demanders (light insensitive germination, slow growing, irregular fruiting, sapling bank), but Open and Sparse Woodland species are not gap-limited. The grain concept in these woodlands could indicate the frequency at which disturbances that trigger favourable conditions for regeneration occur.

In terms of management and conservation, the implications of an intermediate to fine-grain status for the woodlands in the region are therefore a good sign, as it simplifies their management considerably. It appears possible that regular small disturbances by animals and man that do not destroy the canopy significantly are tolerable and even desirable, up to a level (Everard *et al.* 1994; Everard *et al.* 1995). In the case of Tembe, the Closed Woodland on clay and Open Woodland on sand are intermediate-grained communities, whereas the Tshanini or Manqakulane equivalents are fine-grained. It can be hypothesised that elephants may have broken the canopy to such an extent that the species composition of these woodlands is changing towards a coarse-grained composition.

The grain theory balances the Manqakulane situation rather well (Table 15), where under human utilisation, the canopy remains, thus keeping the fine-grain character, but the undergrowth becomes utilised. As a layer of the subcanopy is removed, the ground layer benefits from added space and light and the result is a noticeably increased regeneration pattern (Babaasa *et al.* 2004; Hitimana *et al.* 2004; Boudreau and Lawes2005). The latter should however be monitored carefully, as the abundance of young individuals for woody species such as *Dichrostachys cinerea* could also be the beginning of bush encroachment. The grain theory remains valid for the Manqakulane Open Woodland on Abandoned Household sites unit. In that case, the clearing of woodlands for cultivation and households is a canopy-breaking disturbance, which is maintained by recurrent human activity. Once human activity ceases, it appears logical that shade intolerant species would first re-colonise the sites, followed by the shade tolerant cohort (Poorter *et al.* 1996; Colón and Lugo 2006; Karlowski 2006). An interesting indication offered by this theory is that it has taken less than 20 years to regenerate intermediate-grained woodland, which appears relatively rapid.

In Tshanini, the Closed Woodland Thicket is an intermediate grain vegetation type (Table 15), while the same unit is fine-grained in both Tembe and Manqakulane. The grain status in Tembe is well corroborated by the spread of species in Types (Table 3), indicating that the community grain should be correct. Additionally, the spread of species in the various groups is reminiscent of mature tree populations in the absence of disturbance (Burslem and Whitmore 1999; Niklas *et al.* 2003). The situation is intriguing and somehow contradictory as in Tshanini, disturbances have been eliminated from the system since 1992 (Gaugris 2004), and fire is also thought to have had a limited influence. According to the grain theory, the logical resulting unit should have been a fine-grained one. A hypothesis is proposed that in the absence of disturbance, the closure of the canopy has allowed new shade-tolerant species to develop and a new situation is evolving altogether, whereby a fine-grained Closed Woodland Thicket has started a transition towards a forest state. The hypothesis is reinforced by the facts that some forest species (Table 3) appear to regenerate well in the subcanopy (*Cleistanthus schlechteri, Dialium schlechteri, Hymenocardia ulmoides, Pteleopsis myrtifolia*), but also occur in the canopy (*Balanites maughamii, Cleistanthus schlechteri, Dialium schlechteri, Hymenocardia ulmoides*). Moreover, this unit differed the most from its equivalent units in Tembe and Manqakulane (Table 6).

In general, the grain model appears to have worked successfully when applied to a woodland environment. The situations tested mostly agree with the theory, and it appears a useful tool to determine the type of dynamics that drive woodland communities. The success of the model for the Closed Woodland units in the present study is possibly inherent to the fact that they are closely related to forests. However, the concept seems to work in Open and Sparse Woodland units as well. But in those instances, it appears possible that the grain does not necessarily reflect the frequency and intensity of gap-formation but rather the frequency with which recruitment occurs. In occurrence, fine-grained species seem to find suitable conditions for recruitment continuously whereas coarse-grained species have limited opportunities and pulsed recruitment. The nature of these limited opportunities is difficult to determine at present but some options such as a temporary and simultaneous release from fire and grazing or favourable climatic conditions appear possible.

From the present study it appears that the influence of man and herbivores on the vegetation has taken quite a toll on areas where their presence is limited either by tribal rules or fences. The effects of man and herbivore utilisation can be described as "classical" and have been documented in several papers and reviews (Perrings and Lovett 1999; Ticktin 2004; Wiseman *et al.* 2004; Guldemond 2006; Ickowitz 2006; O'Connor *et al.* 2007). The method to deal with the wildlife utilisation aspect should be based on documented evidence that reduced populations of herbivores, especially elephants, have led to spectacular recoveries of woodlands in short time spans in affected areas elsewhere (Western and Maitumo 2004; Western In Press). However, to discuss these methods would be beyond the scope of the present paper.

With regards to human utilisation, the issue is far more complex, as development is an inalienable right of rural people (Perrings and Lovett 1999). The attitude of many communities is however, favourable to conserving sections of land that have no agricultural value (Gaugris 2004). In this region of Maputaland it is particularly fortunate that this very same land harbours the biodiversity rich woodlands and Sand Forest that make Maputaland special (Eeley *et al.* 2001; Smith *et al.* 2006). This represents the most easily accessible solution to preserving the natural landscapes of Maputaland. The implications of fine-grained communities further enhance the options as it allows the controlled but sustained utilisation of resources (Lawes and Obiri 2003).

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CHAPTER 8

AN OVERVIEW OF WOODY VEGETATION UTILISATION IN TEMBE ELEPHANT PARK, KWAZULU-NATAL, SOUTH AFRICA

Abstract

A survey of woody plant species utilisation by elephants, large, medium and small browsers, man and natural damage, was conducted in nine vegetation units of Tembe Elephant Park, Maputaland, KwaZulu-Natal, South Africa. The study was conducted primarily to assess the risk from elephant utilisation for the conservation of the rare and diverse Sand Forest. Canopy removal was evaluated within two age ranges, (a) recent, 12 months prior to the study and (b) old, more than 12 months prior to the study. The overall density of utilisation was also evaluated. Results show that recent canopy removal by medium and small browsers was intensive, followed by elephant utilisation. However, older canopy removal values showed that elephant utilisation marks accumulated and that trees were utilised repeatedly preventing them from recovering. The overall density of utilisation showed that medium and small browsers removed the regeneration class, while elephants opened gaps in the canopy at a rapid rate. The extent of natural damage events appeared linked and possibly amplified by elephant utilisation. We conclude that the vegetation units conserved in Tembe Elephant Park are endangered by a combination of canopy removal by elephant utilisation and sapling removal by small and medium browsers. This browsing pressure could lead to the degradation of woodland to grassland as was found in east Africa under high densities of animals.

Keywords

Browsers, elephants, Maputaland, Sand Forest, tree utilisation, woodland

Introduction

A number of ecological problems have been documented relating to the over-concentration of animals, whether the area is small and unfenced (Walpole *et al.* 2004; Western In Press) or large and fenced (Eckhardt *et al.* 2000; Mosugelo *et al.* 2002). Among them is the often-observed transformation of a woodland landscape into shrubby grassland, or the suppression of woody vegetation growth (Bond and Loffell 2001; Western and Maitumo 2004; Wiseman *et al.* 2004). The problem of growing animal populations confined to small reserves in Africa, and to a greater extent in South Africa, has come to the forefront of conservation issues recently, because public, scientific, and conservation opinions are divided on the way to manage this problem (Van Aarde *et al.* 1999; Lombard *et al.* 2001; Van Aarde and Jackson 2007), especially when charismatic animals such as the African elephant *Loxodonta africana* (Blumenbach 1797) are concerned.

The effect of growing animal populations is of particular importance when the vegetation in these reserves is rare, rich in biodiversity, and unlikely to recover from intense utilisation (Lombard *et al.* 2001; Guldemond and Van Aarde In Press; O'Connor *et al.* 2007). This is the case in Tembe Elephant Park, a 300 km^2 reserve in Maputaland where animal populations have been confined by fences since 1989, and where the Sand Forest occurs. Sand Forest is considered one of the most valuable vegetation types of the Maputaland – Pondoland – Albany hotspot of biodiversity found along the east coast of southern Mozambique and South Africa (Van Wyk 1996; Van Wyk and Smith 2001; Matthews 2006; Morley 2005; Guldemond and Van Aarde In Press). Tembe Elephant Park was created with the dual mandate of preserving Sand Forest and the last remnants of the Maputaland coastal plain elephant population (Matthews 2006).

The elephant population was estimated at 179 animals in 2004 (Morley 2005), and was expected to exceed 200 individuals by 2006, and there is now concern that such numbers are affecting the Sand Forest (Guldemond and Van Aarde In Press), but also the forest-like woodlands (Van Rensburg *et al.* 2000; Gaugris 2004) of the region. There is growing fear that these changes could be irreversible due to the delicate ecological balance that controls Maputaland's vegetation dynamics (Van Rensburg *et al.* 2000; Matthews 2006).

The present study investigates the utilisation of the woody vegetation by large herbivore browsers in Tembe Elephant Park to determine the current level of utilisation. Canopy removal and overall utilisation of woody species are investigated and quantified within two different periods. Because elephant management is such a contentious issue, elephant utilisation is explored in depth and the changes observed in woody species utilisation since a similar study in 1994 are discussed.

Study area

The study area is situated in Maputaland, northern KwaZulu-Natal, South Africa (-26.85° to -27.15° South and 032.35° to 032.60° East). Tembe Elephant Park covers an area of 30 000 ha and was proclaimed in 1983 after negotiations with the local tribal authorities. The management of the park was given to the then KwaZulu-Natal Bureau of Natural Resources. The park was subsequently completely fenced in 1989. Little tourist development has occurred in the park and its main purpose was to preserve the region's rare wildlife (Kwazulu-Natal Nature Conservation Services 1997; Browning 2000). The park has also served as a barrier to protect the local people from elephants raiding their crops. A full description of the topography, geology, soils, climate and vegetation of Tembe Elephant Park is provided in Matthews *et al.* (2001).

The park is characterised by a sandy plain interspersed with ancient littoral dunes with the Muzi Swamp running along the eastern boundary. It is covered by an Open to Closed Woodland, with patches of Short Intermediate and Tall Sand Forest. Maputaland lies on the southern boundary of the tropical zone. The summers are hot, wet, and humid, while the winters are cool to warm and dry. Tembe Elephant Park received a mean annual rainfall of 721 mm in the period from 1981 to 2003 (Matthews 2006).

Methods

Fieldwork

Surveys were done during the dry winter period of 2004 (May to October). Rectangular plots were placed at least 50 m away from little-used management tracks and at least 100 m away from more established tourist tracks to avoid road-induced bias as much as possible. While the southern portion of the park is relatively well covered by the road network, the northern part is less accessible and could not be sampled in the same detail as the rest of the park. The exact geographical coordinates (map datum: WGS 84, Lat-Long coordinates) of the middle point of all plots were recorded by using a Global Positioning System (GPS) device.

Only woody species were evaluated and no other plant forms were recorded. Woody plants in the present study were defined as all plants with an erect to scrambling growth form and with a ligneous trunk. The methodology was designed to evaluate the vegetation structure and the utilisation of vegetation by herbivores. Both aspects were evaluated in 135 plots. Plot dimensions were density-dependent and varied from a minimum of 15 m by 2 m to a maximum length of 45 m by a 19 m width. Extremely dense stands of Short Sand Forest called for shorter and narrower lines than the less dense Tall Sand Forest stands. By following this approach a similar amount of information was gathered for most plots.

Plots were subdivided in two subsamples. All the woody plants with a height ≥ 0.4 m were sampled in the whole area defined by the plot's dimensions, while those smaller than the defined cut-off were sampled in an area restricted to half that of the full plot size. This was done by dividing the plot in two equal halves along its length and walking the first half recording both subsamples, while only woody species of heights ≥ 0.4 m were sampled on the return leg. All woody individuals encountered in either subsample were recorded, identified and measured. The genus and species name were noted for each plant. The numbers of live and dead stems were counted and their diameters measured at the level where the stem became regular above the basal swelling. The plant height and the height to the base of the canopy (defined as the height where the larger lowest branches supporting at least 10% of the canopy are found) were then measured, followed by the largest canopy diameter (D1) and the diameter of the canopy perpendicular to it (D2). Standing dead trees were also measured, while fallen dead trees were imaginary reconstructed to estimate the size and space occupied by the tree before it died and fell.

The herbivore or human utilisation of the vegetation was evaluated for each plant. Any change or damage to the plant, i.e. canopy, trunk and roots, were considered. The following parameters were evaluated for each plant (see Table 1 for details of various items, note that Table 1 is informative, and all types and states possibilities are presented, although they were not all utilised in the field):

- the state of the plant
- the type of damage / utilisation
- the presumed agent for the observed damage / utilisation
- the age of the damage
- the estimated percentage of material removed (canopy / bark / roots) by damage / utilisation
- the growth response to the damage / utilisation

Whenever possible each utilisation episode was scored separately.

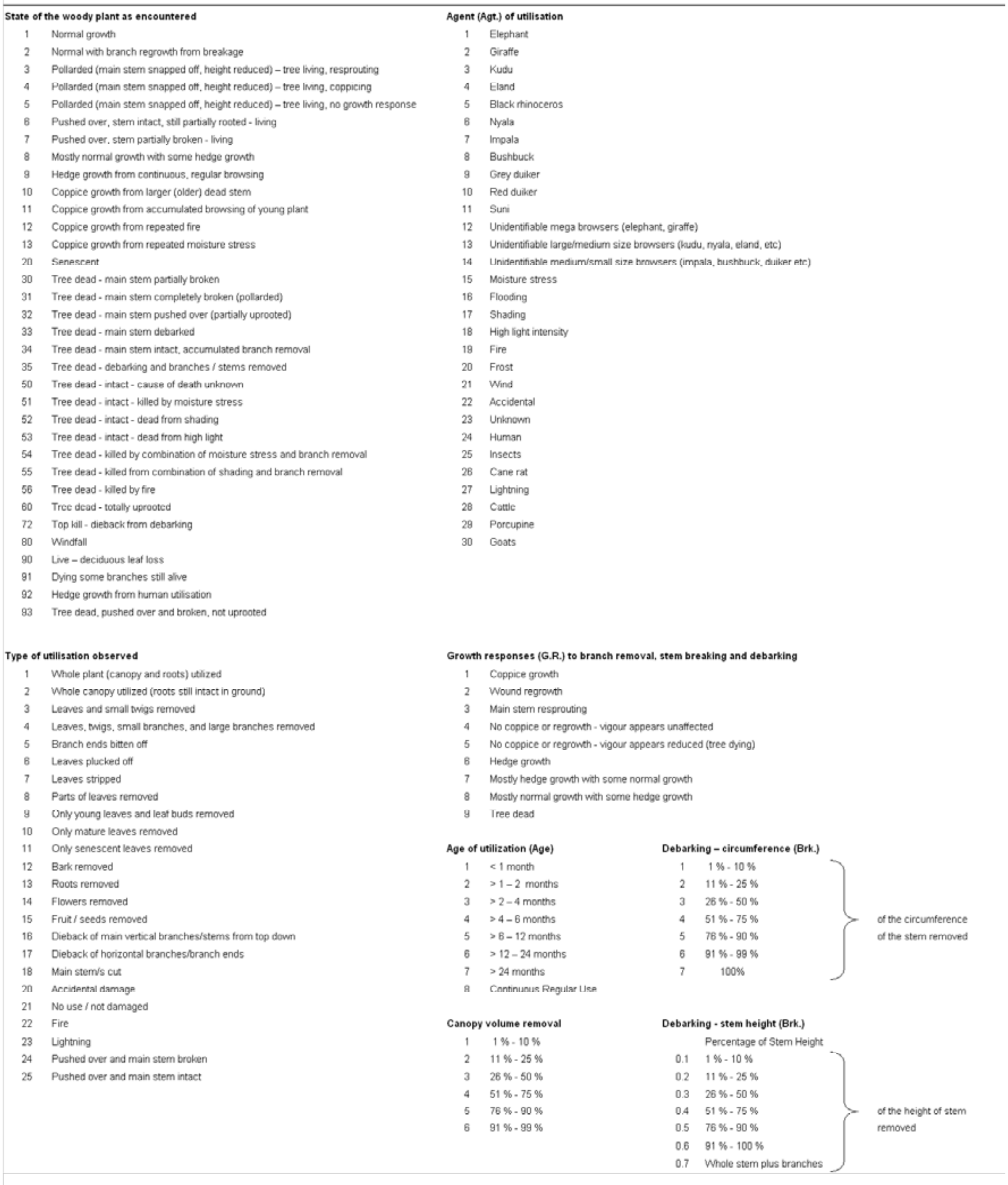
Data analysis

The data were captured in Microsoft Excel spreadsheets and subsequently transformed into a database in Microsoft Access for ease of utilisation and analysis. Software designed by Mr Bruce Page (School of Life and Environmental Sciences, University of Natal, Durban, South Africa) was used to design the queries to analyse the vegetation utilisation aspects.

The analyses presented further below in this section were conducted independently for different agents. Agents were classified on the basis of the height of utilisation rather than body size *per se*. The following categories of agents were recognised:

- elephant

Table 1 Codes used for evaluating the utilisation of vegetation by browsers, man and natural damage in Tembe Elephant Park, the coding is derived from a code database used for other studies in KwaZulu-Natal, Northern Maputaland, South Africa, and only the codes relevant to the present study are displayed



	State of the woody plant as encountered
1	Normal growth
2	Normal with branch regrowth from breakage
3	Pollarded (main stem snapped off, height reduced) – tree living, resprouting
4	Pollarded (main stem snapped off, height reduced) – tree living, coppicing
5	Pollarded (main stem snapped off, height reduced) – tree living, no growth response
6	Pushed over, stem intact, still partially rooted - living
7	Pushed over, stem partially broken - living
8	Mostly normal growth with some hedge growth
9	Hedge growth from continuous, regular browsing
10	Coppice growth from larger (older) dead stem
11	Coppice growth from accumulated browsing of young plant
12	Coppice growth from repeated fire
13	Coppice growth from repeated moisture stress
20	Senescent
30	Tree dead - main stem partially broken
31	Tree dead - main stem completely broken (pollarded)
32	Tree dead - main stem pushed over (partially uprooted)
33	Tree dead - main stem debarked
34	Tree dead - main stem intact, accumulated branch removal
35	Tree dead - debarking and branches / stems removed
50	Tree dead - intact - cause of death unknown
51	Tree dead - intact - killed by moisture stress
52	Tree dead - intact - dead from shading
53	Tree dead - intact - dead from high light
54	Tree dead - killed by combination of moisture stress and branch removal
55	Tree dead - killed from combination of shading and branch removal
56	Tree dead - killed by fire
60	Tree dead - totally uprooted
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

	Agent (Agt.) of utilisation
1	Elephant
2	Giraffe
3	Kudu
4	Eland
5	Black rhinoceros
6	Nyala
7	Impala
8	Bushbuck
9	Grey duiker
10	Red duiker
11	Suni
12	Unidentifiable mega browsers (elephant, giraffe)
13	Unidentifiable large/medium size browsers (kudu, nyala, eland, etc)
14	Unidentifiable medium/small size browsers (impala, bushbuck, duiker etc)
15	Moisture stress
16	Flooding
17	Shading
18	High light intensity
19	Fire
20	Frost
21	Wind
22	Accidental
23	Unknown
24	Human
25	Insects
26	Cane rat
27	Lightning
28	Cattle
29	Porcupine
30	Goats

	Type of utilisation observed
1	Whole plant (canopy and roots) utilized
2	Whole canopy utilized (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

	Growth responses (G.R.) 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

	Age of utilization (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

	Debarking – circumference (Brk.)	
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%	

	Canopy volume removal
1	1 % - 10 %
2	11 % - 25 %
3	26 % - 50 %
4	51 % - 75 %
5	76 % - 90 %
6	91 % - 99 %

	Debarking - stem height (Brk.)	
	Percentage of Stem Height	
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	

- undetermined large browsers (giraffe *Giraffa camelopardalis* (Linnaeus), elephant)
- undetermined medium browsers (such as: kudu *Tragelaphus strepsiceros* (Pallas), eland *Tragelaphus oryx* (Pallas), black rhinoceros *Diceros bicornis* (Linnaeus))
- undetermined small browsers (such as: suni *Neotragus moschatus* (Von Dueben), red duiker *Cephalophus natalensis* (A. Smith), common duiker *Sylvicapra grimmia* (Linnaeus), nyala *Tragelaphus angasii* (Gray), impala *Aepyceros melampus* (Lichtenstein), bushbuck *Tragelaphus scriptus* (Pallas))
- man
- natural damage (all cases where the above agents could not be identified positively or where a natural cause such as wind, drought, fire, lightning, light conditions, was deemed the most likely reason for the observed damage).

A distinction was made in the analysis between utilisation events that only affected the canopy volume and those that represented overall utilisation events, which represented a combination of all utilisation events, including canopy removal but also bark damage, stem or branch breakages, uprooting and other damages as listed in Table 1. A further distinction was made to evaluate the canopy volume removal events in time, and two periods were considered. Recent events represented all events within the 12 months prior to when fieldwork started, while old events represented all events that took place more than 12 months prior to the date when fieldwork started. The overall utilisation events were not qualified in terms of time of utilisation / damage events as above for canopy removal, due to the difficulty linked to reliably estimate and represent a combined age of some of the utilisation / damage events other than canopy removals.

The number of woody species utilised by an agent by vegetation unit was evaluated, and expressed as a percentage of the total number of species sampled in that vegetation unit. The number of woody species was evaluated and expressed for recent and old canopy volume removal events as well as for overall utilisation events.

Plants were then classified into eight height classes (>0 to <0.1 m, 0.1 to <0.5 m, 0.5 to <1.5 m, 1.5 to <3.0 m, 3.0 to <5.0 m, 5.0 to <8.0 m, 8.0 to <12 m, ≥12 m) selected to be representative of the local vegetation structure evaluated in previous studies (Matthews *et al.* 2001; Gaugris 2004). The range of height classes that may potentially be utilised by an agent was evaluated as the range of height classes where any utilisation event was documented for that agent at any time in the present study, and formed the basis for calculating the total number of height classes available to that agent. The total number of height classes available for an agent was calculated for all woody species in a vegetation unit and represented the total number of height classes available in a vegetation unit during the two periods defined above.

The canopy volume available and canopy volume removal per height class per woody species in a vegetation unit were estimated by using the method of Walker (1976) for estimating the percentage of the canopy volume removed. The number of height classes where canopy removal events by an agent were observed was counted at the vegetation unit level and expressed as a percentage of the total number of height classes available to that agent. The number of height classes where at least 50% of the canopy volume was removed and the number of height classes where 100% of the canopy was removed were then established at the vegetation unit level. These numbers were then represented as percentages of height classes utilised in a vegetation unit where these canopy removal thresholds had been met within the range of available height classes to the agent considered.

The total density of individuals and the density of utilised individuals by an agent were calculated for all woody species in a vegetation unit, and a total density of woody individuals available and total density of utilised woody individuals per height class was derived for each woody species. The sums of these densities were used to represent available and utilised densities at the vegetation unit level. The ratio of utilised density to available density was expressed as an overall utilisation percentage value per height class per vegetation unit. The number of height classes where utilisation by the agent occurred was calculated and presented as a percentage of the available height classes to the agent by vegetation unit. The number of height classes where at least 50% of all woody individuals in one species were used and where 100% of all woody individuals in one species were used were calculated and similarly expressed as percentages of utilised height classes reaching these thresholds of the total number height classes available to the agent.

Woody species selection by agent

Similar counts of number of height classes utilised by agent as above were made, for recent and old canopy removal as well as overall utilisation, but restricted to the woody species level. The total number of height classes utilised per agent (canopy volume and overall utilisation), woody species and vegetation unit, the number of height classes where utilisation is at least 50% and 100% (canopy volume and overall utilisation) were counted. In order to rank the utilisation of these woody species, they were classified in decreasing order of total number of height classes used, total number of height classes where utilisation was at least 50% and the number of height classes where utilisation was 100%. For practical reasons only the first ten most utilised woody species by agent were presented in this manuscript. However, the complete list of woody species utilised by agent by vegetation unit is available from the author on request.

Elephant utilisation evaluation

The case of elephant utilisation was evaluated in further detail. The overall recent and old canopy removals per woody species were calculated as the percentage of canopy removed (all height classed included) from the total available canopy (all height classes sampled were included) at park level, and the species were ranked by order of canopy removal intensity. A similar park level evaluation was done for the overall utilisation. These results were presented in relation to the 13 species documented as heavily utilised in 1994 by Matthews and Page (in Prep). These authors classified the 13 species into three groups. Group 1 included species for which canopy removal was ≥ 50%, group 2 included species for which canopy removal was ≥ 25% but < 50%, and group 3 included species for which canopy removal ranged from ≥ 10% to < 25%. In order to document the utilisation by vegetation unit, the above analysis was repeated at the vegetation unit level.

Results

The new Sand Forest classification presented in Chapter 1 of the present study was followed. A total of 12 915 woody plants were evaluated in this study, and 168 woody species were sampled, or 84% of the woody species known to occur in Tembe Elephant Park (Tembe Herbarium Collection Records).

Sand Forest association

In the Sand Forest association and the *Afzelia quanzensis* clumps, medium and small browsers affected the greatest number of woody species as far as recent canopy removal was concerned (Table 2). Small browsers also appeared to utilise most woody species from the *Afzelia quanzensis* clumps. Recent canopy removal values showed that elephants and large browsers utilised less species than the medium and small browsers.

The older canopy removal values showed that the greatest number of woody species where utilisation marks remain was from elephants and natural damage. The

Table 2: The number of species utilised by various agents in the Sand Forest association of Tembe Elephant Park, Maputaland, northern KwaZulu-Natal, South Africa. Values are given for canopy removal (number of species where a percentage of canopy volume (CV) was removed) for the two periods evaluated (Recent: within 12 months prior to the study and Old: > 12 months prior to the study) and for the overall utilisation (O U), including all utilisation events, but time was undetermined

Vegetation unit →			***Afzelia quanzensis* clumps (VT 01.1.1)**		**Short Sand Forest (VT 01.2.1)**		**Intermediate Sand Forest (VT 01.2.2)**		**Tall Sand Forest (VT 01.2.3)**	
No of Species sampled →			25		60		71		53	
No of Species used by	Age	Type	Number	(%)	Number	(%)	Number	(%)	Number	(%)
Elephant	Recent	CV	2	8.00	17	28.33	26	36.62	17	32.08
	Old	CV	5	20.00	39	65.00	37	52.11	23	43.40
	All ages	O U	7	28.00	43	71.67	38	53.52	31	58.49
Large Browsers	Recent	CV	0	0.00	0	0.00	0	0.00	0	0.00
	Old	CV	0	0.00	1	1.67	0	0.00	1	1.89
	All ages	O U	0	0.00	1	1.67	0	0.00	1	1.89
Medium Browsers	Recent	CV	5	20.00	25	41.67	33	46.48	20	37.74
	Old	CV	3	12.00	11	18.33	20	28.17	8	15.09
	All ages	O U	5	20.00	28	46.67	37	52.11	27	50.94
Small Browsers	Recent	CV	19	76.00	25	41.67	35	49.30	20	37.74
	Old	CV	0	0.00	2	3.33	4	5.63	0	0.00
	All ages	O U	19	76.00	25	41.67	38	53.52	22	41.51
Man	Recent	CV	0	0.00	0	0.00	0	0.00	0	0.00
	Old	CV	0	0.00	2	3.33	4	5.63	0	0.00
	All ages	O U	0	0.00	2	3.33	5	7.04	0	0.00
Natural Damage	Recent	CV	0	0.00	12	20.00	17	23.94	5	9.43
	Old	CV	10	40.00	47	78.33	51	71.83	28	52.83
	All ages	O U	10	40.00	51	85.00	52	73.24	29	54.72

marks of utilisation from medium and small browsers were less noticeable after 12 months, especially in the case of small browsers where the number of woody species showing signs of canopy removal disappeared altogether or was greatly reduced. In the Short Sand Forest for example, the number of species utilised by small browsers was reduced from 41.67% to 3.33% (Table 2).

The overall utilisation also showed that elephants used the greatest number of woody species in the Sand Forest association and that small browsers are the greatest users in the *Afzelia quanzensis* clumps. However, in the Sand Forest association, marks from natural damage appeared to affect more woody species than any of the other agents respectively (Table 2).

No recent canopy removal was recorded as being from human activities, and only old signs of activity were observed (see Table 2). The human utilisation in Tembe Elephant Park was ancient and no longer clearly visible. Human activity was only observed along the boundaries of Tembe Elephant Park, and sites within the park were free from human influence.

From an examination of the percentage of height classes utilised by the agent, in the Sand Forest association, elephants utilised from 4.17% to 24.27% of the available height classes in terms of canopy removal, in the past 12 months (Table 3). There were hardly any signs of recent or old height class canopy removal by the large browsers group. The medium browsers utilised from 11.11% to 25.91% of height classes available to them during the 12 months prior to the study. The small browsers used the greatest part of the canopy available to them in the Sand Forest, with up to 60.47% of the height classes available to them showing signs of utilisation (Table 3). Recent canopy removal by way of natural damage was relatively low but up to 12.05% of the sampled height classes were affected (Table 3).

In terms of old canopy removal, marks from small and medium browsers disappeared with time as their share of utilisation was halved or fell below 1.0% of the available height classes (Table 3). However, the signs of elephant use appeared to persist for much longer and even to accumulate over time, as evidenced by the way the number of height classes utilised by elephant was higher for the old period throughout the Sand Forest association, as high as 38.96% of the available height classes for the Short Sand Forest. Canopy removal has reached high levels, and up to 9.65% of height classes in the Tall Sand Forest showed signs that utilisation had removed at least 50% of the height class canopy volume, while a further 2.63% of height classes were documented having suffered complete canopy removal (Table 3).

Table 3: The number and percentage of height classes (HC) utilised by the various agents in the Sand Forest association of Tembe Elephant Park, Maputaland, northern KwaZulu-Natal, South Africa. The number of height classes utilised is represented in three ways, a total number of height classes utilised within the range utilised by the agent, the number of height classes in that range where utilisation of at least 50% of the height class was observed for at least one species, and the number of height classes where 100% of individuals in one height class were utilised for at least one species. Values are given for canopy removal utilisation events (CV) for the two periods evaluated (Recent: within 12 months prior to the study and Old: > 12 months prior to the study) and for the overall utilisation (O U), including all utilisation events, but time was undetermined

Agent	Range of height classes used	Age	Type	Vegetation units																											
				***Afzelia quanzensis* clumps (VT 01.1.1)**							**Short Sand Forest (VT 01.2.1)**							**Intermediate Sand Forest (VT 01.2.2)**							**Tall Sand Forest (VT 01.2.3)**						
				NHCS*	Total HC utilisation (No)	(%)	HC use where > 50 % of HC used (No)	(%)	HC use where 100% of HC used (No)	(%)	NHCS*	Total HC utilisation (No)	(%)	HC use where > 50 % of HC used (No)	(%)	HC use where 100% of HC used (No)	(%)	NHCS*	Total HC utilisation (No)	(%)	HC use where > 50 % of HC used (No)	(%)	HC use where 100% of HC used (No)	(%)	NHCS*	Total HC utilisation (No)	(%)	HC use where > 50 % of HC used (No)	(%)	HC use where 100% of HC used (No)	(%)
Elephant	**02 - 07**	Recent	CV	48	2	4.17	0	0.00	0	0.00	154	19	12.34	0	0.00	0	0.00	206	50	24.27	0	0.00	0	0.00	114	23	20.18	0	0.00	0	0.00
		Old	CV	48	5	10.42	0	0.00	0	0.00	154	60	38.96	6	3.90	1	0.65	206	77	37.38	8	3.88	0	0.00	114	35	30.70	11	9.65	3	2.63
		All ages	O U	48	7	14.58	7	14.58	4	8.33	154	67	43.51	42	27.27	20	12.99	206	86	41.75	29	14.08	9	4.37	114	47	41.23	36	31.58	23	20.18
Large Browsers	**03 - 06**	Recent	CV	36	0	0.00	0	0.00	0	0.00	125	0	0.00	0	0.00	0	0.00	164	0	0.00	0	0.00	0	0.00	90	0	0.00	0	0.00	0	0.00
		Old	CV	36	0	0.00	0	0.00	0	0.00	125	1	0.80	0	0.00	0	0.00	164	0	0.00	0	0.00	0	0.00	90	1	1.11	0	0.00	0	0.00
		All ages	O U	36	0	0.00	0	0.00	0	0.00	125	1	0.80	0	0.00	0	0.00	164	0	0.00	0	0.00	0	0.00	90	1	1.11	0	0.00	0	0.00
Medium Browsers	**02 - 06**	Recent	CV	45	5	11.11	1	2.22	0	0.00	146	32	21.92	1	0.68	0	0.00	193	50	25.91	2	1.04	0	0.00	109	26	23.85	2	1.83	0	0.00
		Old	CV	45	3	6.67	1	2.22	0	0.00	146	12	8.22	1	0.68	0	0.00	193	28	14.51	2	1.04	0	0.00	109	8	7.34	2	1.83	0	0.00
		All ages	O U	45	5	11.11	4	8.89	2	4.44	146	35	23.97	12	8.22	10	6.85	193	64	33.16	17	8.81	11	5.70	109	40	36.70	21	19.27	11	10.09
Small Browsers	**01 - 05**	Recent	CV	43	26	60.47	0	0.00	0	0.00	130	43	33.08	1	0.77	0	0.00	173	68	39.31	1	0.58	0	0.00	96	30	31.25	0	0.00	0	0.00
		Old	CV	43	1	2.33	0	0.00	0	0.00	130	0	0.00	0	0.00	0	0.00	173	4	2.31	0	0.00	0	0.00	96	0	0.00	0	0.00	0	0.00
		All ages	O U	43	27	62.79	26	60.47	21	48.84	130	43	33.08	21	16.15	10	7.69	173	72	41.62	32	18.50	11	6.36	96	32	33.33	23	23.96	12	12.50
Man	**02 - 07**	Recent	CV	48	0	0.00	0	0.00	0	0.00	154	0	0.00	0	0.00	0	0.00	206	0	0.00	0	0.00	0	0.00	114	0	0.00	0	0.00	0	0.00
		Old	CV	48	0	0.00	0	0.00	0	0.00	154	1	0.65	1	0.65	1	0.65	206	7	3.40	1	0.49	1	0.49	114	0	0.00	0	0.00	0	0.00
		All ages	O U	48	0	0.00	0	0.00	0	0.00	154	2	1.30	0	0.00	0	0.00	206	8	3.88	1	0.49	0	0.00	114	0	0.00	0	0.00	0	0.00
Natural Damage	**01 - 08**	Recent	CV	49	0	0.00	0	0.00	0	0.00	163	15	9.20	1	0.61	1	0.61	224	27	12.05	0	0.00	0	0.00	121	5	4.13	0	0.00	0	0.00
		Old	CV	49	14	28.57	1	2.04	1	2.04	163	90	55.21	2	1.23	1	0.61	224	123	54.91	3	1.34	1	0.45	121	46	38.02	0	0.00	0	0.00
		All ages	O U	49	14	28.57	13	26.53	9	18.37	163	96	58.90	78	47.85	45	27.61	224	128	57.14	90	40.18	44	19.64	121	49	40.50	33	27.27	21	17.36

NHCS* = Number of height classes sampled in the range used by the agent

HC = Height Classes

No = Number

Old signs of human utilisation show that some canopy removal took place in the past. The impression is given that human utilisation implied the complete removal of available height classes (Table 3) as evidenced by the complete removal of height classes in the Short and Intermediate Sand Forest. Signs of canopy removal from natural damage showed that like elephants, natural damage marks appeared to accumulate over time, and up to 55.21% of the available height classes were scarred in the Short Sand Forest. Natural damage had the highest percentage of complete canopy removal within height classes in most of the Sand Forest association (Table 3).

In terms of the overall utilisation, the values mirrored that of the old canopy removal, although the percentage of height classes used was usually higher for all agents. This was especially valid with regards to percentages of height classes where utilisation was documented to affect 50% to 100% individuals in height classes. Elephants completely utilised up to 20.18% (Table 3, Tall Sand Forest) of the height classes available to them. In general, the values for natural damage were even higher, indicating that many entire trees must have been damaged by this mechanism (Table 3).

Woodland vegetation group

With regards to the woodland communities, the number of woody species utilised recently was once again greatest for small and medium browsers followed by elephant (Table 4). The small browsers used more species in the Closed Woodland Thicket and Sparse Woodland on Sand than any other agent, and used at least 50% of woody species available in all woodland units. Natural damage affected less woody species than other agent related utilisation in most instances, except for man and large browsers.

With regards to old canopy removal, the number of woody species used by elephants was greater than recent removals and remained visible (Table 4), while the signs of utilisation by medium and small browsers were less or disappearing. Signs of natural damage to woody species were abundant and more than 50% of woody species showed signs of old natural damage in the Closed Woodland on Sand.

The overall utilisation of woody species showed that elephants used mainly the Closed Woodland on Clay and on Sand and Open Woodland on Sand (more than 50% of available woody species, Table 4). A similar picture emerged for the medium browsers, while the overall woody species utilisation by small browsers was consistently higher than 50% of sampled woody species in all woodland units. Natural

Table 4: *The number of species utilised by various agents in the Woodland association of Tembe Elephant Park, Maputaland, northern KwaZulu-Natal, South Africa. Values are given for canopy removal (number of species where a percentage of canopy volume (CV) was removed) for the two periods evaluated (Recent: within 12 months prior to the study and Old: > 12 months prior to the study) and for the overall utilisation (O U), including all utilisation events, but time was undetermined*

Vegetation Unit →			**Closed Woodland Thicket (VT 02.1.0)**		**Closed Woodland on Clay (VT 02.2.0)**		**Closed Woodland on Sand (VT 02.3.0)**		**Open Woodland on Sand (VT 03.1.0)**		**Sparse Woodland on Sand (VT 04.1.0)**	
No of Species sampled →			29		116		115		92		40	
No of Species used by	Age	Type	Number	(%)	Number	(%)	Number	(%)	Number	(%)	Number	(%)
Elephant	Recent	CV	5	17.24	54	46.55	40	34.78	30	32.61	4	10.00
	Old	CV	10	34.48	62	53.45	62	53.91	42	45.65	11	27.50
	All ages	O U	12	41.38	69	59.48	66	57.39	47	51.09	10	25.00
Large Browsers	Recent	CV	0	0.00	1	0.86	5	4.35	11	11.96	0	0.00
	Old	CV	0	0.00	1	0.86	0	0.00	4	4.35	0	0.00
	All ages	O U	0	0.00	3	2.59	5	4.35	14	15.22	1	2.50
Medium Browsers	Recent	CV	8	27.59	66	56.90	60	52.17	43	46.74	11	27.50
	Old	CV	5	17.24	35	30.17	37	32.17	23	25.00	4	10.00
	All ages	O U	8	27.59	89	76.72	78	67.83	60	65.22	15	37.50
Small Browsers	Recent	CV	16	55.17	79	68.10	76	66.09	72	78.26	21	52.50
	Old	CV	1	3.45	2	1.72	4	3.48	2	2.17	2	5.00
	All ages	O U	16	55.17	82	70.69	80	69.57	73	79.35	22	55.00
Man	Recent	CV	1	3.45	1	0.86	3	2.61	0	0.00	0	0.00
	Old	CV	0	0.00	0	0.00	1	0.87	0	0.00	1	2.50
	All ages	O U	1	3.45	2	1.72	4	3.48	0	0.00	1	2.50
Natural Damage	Recent	CV	1	3.45	28	24.14	20	17.39	38	41.30	7	17.50
	Old	CV	8	27.59	56	48.28	63	54.78	43	46.74	14	35.00
	All ages	O U	8	27.59	59	50.86	67	58.26	52	56.52	16	40.00

damage affected more than 50% of woody species available in the same vegetation units that the elephants and small to medium browsers used.

There were recent signs of human utilisation of woodland vegetation types, as evidenced by a number of species for which canopy removal was documented in the Closed Woodlands. No human utilisation was observed in the Open or Sparse Woodland on Sand.

In terms of recent canopy removal, small browsers appeared to utilise the greatest number of height classes (Table 5). Values for the medium browsers were slightly lower, and those for elephant utilisation even less. Utilisation by large browsers was seldom encountered. Man utilised the canopy in some height classes in the three closed woodlands, but hardly contributed to the total of utilisation. A noticeable number of height classes had their canopies reduced through natural damage, especially in the Open Woodland on Sand, where 31.14% of available height classes were affected. A number of height classes had their canopies fully removed in the Closed Woodland on Sand and Clay, the Open Woodland on Sand and the Sparse Woodland on Sand (Table 5).

Old canopy removal events followed similar trends as for the Sand Forest, whereby signs of utilisation by medium and small browsers tended to disappear (Table 5), whereas signs of utilisation from elephants and natural damage were emphasised. The canopies from 0.58% to 4.00% of height classes in the Closed Woodlands and the Open Woodland on Sand were completely removed by elephant. Natural damage canopy removal affected approximately a third of height classes throughout the Woodlands. Signs of old canopy removal by large browsers and man were low.

The overall utilisation of height classes values were generally higher than those for canopy removal and the percentage of height classes where all individual were used was noticeably higher especially by elephants (20.00%) in Closed Woodland Thicket, and by natural damage (19.48%) in Sparse Woodland on Sand (Table 5). Small browsers completely utilised height classes in more than 10.00% of the available total throughout the woodland group (Table 5). Utilisation by man and large browsers was low in general (Table 5).

Woody species selection by agent

A summary of the 10 (whenever possible) most utilised woody species by vegetation unit was presented for the different agents in Tables 6 (elephant), 7 (large browsers), 8 (medium browsers), 9 (small browsers), 10 (man) and 11 (natural damage).

Table 5: The number and percentage of height classes (HC) utilised by the various agents in the Woodland association of Tembe Elephant Park, Maputaland, northern KwaZulu-Natal, South Africa. The number of height classes utilised is represented in three ways, a total number of height classes utilised within the range utilised by the agent, the number of height classes in that range where utilisation of at least 50% of the height class was observed for at least one species, and the number of height classes where 100% of individuals in one height class were utilised for at least one species. Values are given for canopy removal utilisation events (CV) for the two periods evaluated (Recent: within 12 months prior to the study and Old: > 12 months prior to the study) and for the overall utilisation (O U), including all utilisation events, but time was undetermined

Agent	Range of height classes used	Age	Type	Vegetation units																				
				Closed Woodland Thicket (VT 02.1.0)							**Closed Woodland on Clay (VT 02.2.0)**							**Closed Woodland on Sand (VT 02.3.0)**						
				NHCS*	Total HC utilisation		HC use where > 50 % of HC used		HC use where 100% of HC used		NHCS*	Total HC utilisation		HC use where > 50 % of HC used		HC use where 100% of HC used		NHCS*	Total HC utilisation		HC use where > 50 % of HC used		HC use where 100% of HC used	
					(No)	(%)	(No)	(%)	(No)	(%)		(No)	(%)	(No)	(%)	(No)	(%)		(No)	(%)	(No)	(%)	(No)	(%)
Elephant	**02 - 07**	Recent	CV	50	9	18.00	0	0.00	0	0.00	342	90	26.32	3	0.88	1	0.29	332	70	21.08	2	0.60	0	0.00
		Old	CV	50	17	34.00	3	6.00	2	4.00	342	130	38.01	8	2.34	2	0.58	332	110	33.13	18	5.42	3	0.90
		All ages	O U	50	21	42.00	15	30.00	10	20.00	342	151	44.15	92	26.90	49	14.33	332	128	38.55	78	23.49	34	10.24
Large Browsers	**03 - 06**	Recent	CV	41	0	0.00	0	0.00	0	0.00	261	1	0.38	0	0.00	0	0.00	262	5	1.91	0	0.00	0	0.00
		Old	CV	41	0	0.00	0	0.00	0	0.00	261	1	0.38	0	0.00	0	0.00	262	0	0.00	0	0.00	0	0.00
		All ages	O U	41	0	0.00	0	0.00	0	0.00	261	3	1.15	0	0.00	0	0.00	262	5	1.91	2	0.76	1	0.38
Medium Browsers	**02 - 06**	Recent	CV	50	16	32.00	0	0.00	0	0.00	333	131	39.34	5	1.50	0	0.00	317	115	36.28	2	0.63	0	0.00
		Old	CV	50	11	22.00	0	0.00	0	0.00	333	55	16.52	5	1.50	0	0.00	317	56	17.67	2	0.63	0	0.00
		All ages	O U	50	14	28.00	9	18.00	6	12.00	333	189	56.76	105	31.53	51	15.32	317	145	45.74	60	18.93	34	10.73
Small Browsers	**01 - 05**	Recent	CV	43	24	55.81	0	0.00	0	0.00	321	150	46.73	0	0.00	0	0.00	317	145	45.74	1	0.32	0	0.00
		Old	CV	43	1	2.33	0	0.00	0	0.00	321	2	0.62	0	0.00	0	0.00	317	4	1.26	1	0.32	0	0.00
		All ages	O U	43	26	60.47	18	41.86	15	34.88	321	156	48.60	74	23.05	37	11.53	317	153	48.26	78	24.61	45	14.20
Man	**02 - 07**	Recent	CV	50	1	2.00	0	0.00	0	0.00	342	1	0.29	0	0.00	0	0.00	332	3	0.90	0	0.00	0	0.00
		Old	CV	50	0	0.00	0	0.00	0	0.00	342	0	0.00	0	0.00	0	0.00	332	1	0.30	0	0.00	0	0.00
		All ages	O U	50	1	2.00	0	0.00	0	0.00	342	2	0.58	1	0.29	1	0.29	332	4	1.20	0	0.00	0	0.00
Natural Damage	**01 - 08**	Recent	CV	51	2	3.92	0	0.00	0	0.00	364	48	13.19	6	1.65	5	1.37	373	36	9.65	8	2.14	7	1.88
		Old	CV	51	16	31.37	0	0.00	0	0.00	364	107	29.40	8	2.20	5	1.37	373	132	35.39	12	3.22	7	1.88
		All ages	O U	51	17	33.33	9	17.65	6	11.76	364	119	32.69	50	13.74	25	6.87	373	134	35.92	74	19.84	49	13.14

Agent	Range of height classes used	Age	Type	Vegetation units													
				Open Woodland on Sand (VT 03.1.0)							**Sparse Woodland on Sand (VT 04.1.0)**						
				NHCS*	Total HC utilisation		HC use where > 50 % of HC used		HC use where 100% of HC used		NHCS*	Total HC utilisation		HC use where > 50 % of HC used		HC use where 100% of HC used	
					(No)	(%)	(No)	(%)	(No)	(%)		(No)	(%)	(No)	(%)	(No)	(%)
Elephant	**02 - 07**	Recent	CV	254	52	20.47	0	0.00	0	0.00	74	5	6.76	0	0.00	0	0.00
		Old	CV	254	96	37.80	8	3.15	1	0.39	74	16	21.62	2	2.70	0	0.00
		All ages	O U	254	107	42.13	65	25.59	36	14.17	74	17	22.97	8	10.81	6	8.11
Large Browsers	**03 - 06**	Recent	CV	188	12	6.38	0	0.00	0	0.00	48	1	2.08	0	0.00	0	0.00
		Old	CV	188	4	2.13	0	0.00	0	0.00	48	0	0.00	0	0.00	0	0.00
		All ages	O U	188	15	7.98	1	0.53	0	0.00	48	1	2.08	0	0.00	0	0.00
Medium Browsers	**02 - 06**	Recent	CV	246	91	36.99	0	0.00	0	0.00	72	18	25.00	4	5.56	2	2.78
		Old	CV	246	40	16.26	0	0.00	0	0.00	72	4	5.56	1	1.39	0	0.00
		All ages	O U	246	122	49.59	44	17.89	21	8.54	72	20	27.78	8	11.11	7	9.72
Small Browsers	**01 - 05**	Recent	CV	243	145	59.67	3	1.23	0	0.00	73	34	46.58	0	0.00	0	0.00
		Old	CV	243	14	5.76	0	0.00	0	0.00	73	5	6.85	0	0.00	0	0.00
		All ages	O U	243	148	60.91	71	29.22	30	12.35	73	34	46.58	26	35.62	11	15.07
Man	**02 - 07**	Recent	CV	254	0	0.00	0	0.00	0	0.00	74	0	0.00	0	0.00	0	0.00
		Old	CV	254	0	0.00	0	0.00	0	0.00	74	1	1.35	0	0.00	0	0.00
		All ages	O U	254	0	0.00	0	0.00	0	0.00	74	1	1.35	0	0.00	0	0.00
Natural Damage	**01 - 08**	Recent	CV	273	85	31.14	6	2.20	3	1.10	77	12	15.58	8	10.39	1	1.30
		Old	CV	273	109	39.93	10	3.66	4	1.47	77	23	29.87	4	5.19	0	0.00
		All ages	O U	273	132	48.35	63	23.08	23	8.42	77	32	41.56	22	28.57	15	19.48

NHCS* = Number of height classes sampled in the range used by the agent
HC = Height Classes
No = Number

Table 6: *The 10 woody species most utilised by elephants in Tembe Elephant Park, by vegetation unit and age of damage (for canopy volume removal only). Values given reflect the number of height classes (HC) where utilisation was reported (HC 01), as well as the number of height classes where utilisation was > 50% (HC 02) and 100% (HC 03) of canopy removed or number of individuals utilised within a height class, and the highest height class where damage was observed (HC 04). Species highlighted in red represent situations where at least one height class was completely utilised. Maputaland, northern KwaZulu-Natal, South Africa*

Number	Vegetation unit	Taxa	Canopy Volume removal < 12 months				Taxa	Canopy Volume removal > 12 months				Taxa	Overall Utilisation			
			HC 01*	HC 02*	HC 03*	HC 04*		HC 01*	HC 02*	HC 03*	HC 04*		HC 01*	HC 02*	HC 03*	HC 04*
1	VT 01.1.1	*Ochna barbosae*	1	0	0	05	*Afzelia quanzensis*	1	0	0	07	*Boscia filipes*	1	1	1	04
2	VT 01.1.1	*Tabernaemontana elegans*	1	0	0	05	*Boscia filipes*	1	0	0	04	*Manilkara concolor*	1	1	1	05
3	VT 01.1.1	-	-	-	-	-	*Manilkara concolor*	1	0	0	05	*Ochna barbosae*	1	1	1	05
4	VT 01.1.1	-	-	-	-	-	*Sclerocroton integerrimus*	1	0	0	05	*Sclerocroton integerrimus*	1	1	1	05
5	VT 01.1.1	-	-	-	-	-	*Vepris lanceolata*	1	0	0	04	*Afzelia quanzensis*	1	1	0	07
6	VT 01.1.1	-	-	-	-	-	-	-	-	-	-	*Tabernaemontana elegans*	1	1	0	05
7	VT 01.1.1	-	-	-	-	-	-	-	-	-	-	*Vepris lanceolata*	1	1	0	04
1	VT 01.2.1	*Brachylaena huillensis*	2	0	0	04	*Pteleopsis myrtifolia*	3	1	0	07	*Brachylaena huillensis*	4	1	0	06
2	VT 01.2.1	*Strychnos henningsii*	2	0	0	05	*Salacia leptoclada*	3	1	0	06	*Pteleopsis myrtifolia*	3	3	0	07
3	VT 01.2.1	*Cassipourea mossambicensis*	1	0	0	05	*Brachylaena huillensis*	3	0	0	06	*Psydrax obovata*	3	1	1	06
4	VT 01.2.1	*Cola greenwayi*		0	0	05	*Cola greenwayi*	3	0	0	06	*Salacia leptoclada*	3	1	1	06
5	VT 01.2.1	*Croton pseudopulchellus*		0	0	03	*Hymenocardia ulmoides*	3	0	0	06	*Cola greenwayi*	3	1	0	06
6	VT 01.2.1	*Hymenocardia ulmoides*		0	0	04	*Psydrax obovata*	3	0	0	06	*Hymenocardia ulmoides*	3	1	0	06
7	VT 01.2.1	*Lagynias lasiantha*		0	0	05	*Brachylaena discolor*	2	1	1	06	*Cleistanthus schlechteri*	2	2	1	07
8	VT 01.2.1	*Leptactina delagoensis*		0	0	04	*Cleistanthus schlechteri*	2	0	0	07	*Lagynias lasiantha*	2	2	1	05
9	VT 01.2.1	*Manilkara discolor*	1	0	0	05	*Dialium schlechteri*	2	0	0	06	*Strychnos henningsii*	2	2	1	05
10	VT 01.2.1	*Pavetta lanceolata*	1	0	0	04	*Drypetes arguta*	2	0	0	06	*Vitex ferruginea*	2	2	1	06
1	VT 01.2.2	*Cola greenwayi*	4	0	0	06	*Cola greenwayi*	5	0	0	06	*Cola greenwayi*	5	0	0	06
2	VT 01.2.2	*Drypetes arguta*	4	0	0	06	*Brachylaena huillensis*	4	1	0	06	*Haplocoelum foliolosum*	4	3	1	06
3	VT 01.2.2	*Dialium schlechteri*	3	0	0	07	*Hymenocardia ulmoides*	4	0	0	06	*Brachylaena huillensis*	4	0	0	06
4	VT 01.2.2	*Haplocoelum foliolosum*	3	0	0	05	*Grewia microthyrsa*	3	1	0	05	*Drypetes arguta*	4	0	0	06
5	VT 01.2.2	*Hymenocardia ulmoides*	3	0	0	06	*Psydrax obovata*	3	1	0	06	*Hymenocardia ulmoides*	4	0	0	06
6	VT 01.2.2	*Balanites maughamii*	2	0	0	05	*Ptaeroxylon obliquum*	3	1	0	06	*Erythrophleum lasianthum*	3	3	2	06
7	VT 01.2.2	*Boscia filipes*	2	0	0	05	*Cleistanthus schlechteri*	3	0	0	07	*Ptaeroxylon obliquum*	3	3	1	06
8	VT 01.2.2	*Brachylaena huillensis*	2	0	0	05	*Croton pseudopulchellus*	3	0	0	04	*Grewia microthyrsa*	3	3	0	05
9	VT 01.2.2	*Burchellia bubalina*	2	0	0	05	*Dialium schlechteri*	3	0	0	07	*Strychnos decussata*	3	2	1	06
10	VT 01.2.2	*Cassipourea mossambicensis*	2	0	0	06	*Drypetes arguta*	3	0	0	05	*Strychnos henningsii*	3	2	1	06

Table 6 continued

1	VT 01.2.3	*Cola greenwayi*	3	0	0	05	*Cola greenwayi*	4	0	0	06	*Cola greenwayi*	4	2	0	06
2	VT 01.2.3	*Drypetes arguta*	2	0	0	05	*Balanites maughamii*	2	1	1	07	*Ptaeroxylon obliquum*	3	3	0	06
3	VT 01.2.3	*Ptaeroxylon obliquum*	2	0	0	05	*Cleistanthus schlechteri*	2	1	1	06	*Balanites maughamii*	2	2	2	07
4	VT 01.2.3	*Strychnos gerrardii*	2	0	0	06	*Ptaeroxylon obliquum*	2	1	0	06	*Pteleopsis myrtifolia*	2	2	2	06
5	VT 01.2.3	*Vepris lanceolata*	2	0	0	05	*Pteleopsis myrtifolia*	2	1	0	06	*Strychnos gerrardii*	2	2	2	06
6	VT 01.2.3	*Acalypha glabrata*	1	0	0	04	*Acalypha glabrata*	2	0	0	05	*Cleistanthus schlechteri*	2	2	1	06
7	VT 01.2.3	*Cladostemon kirkii*	1	0	0	05	*Drypetes arguta*	2	0	0	05	*Psydrax obovata*	2	2	1	06
8	VT 01.2.3	*Erythroxylum emarginatum*	1	0	0	04	*Psydrax obovata*	2	0	0	06	*Strychnos decussata*	2	2	1	06
9	VT 01.2.3	*Hymenocardia ulmoides*	1	0	0	03	*Strychnos decussata*	2	0	0	06	*Strychnos henningsii*	2	1	1	05
10	VT 01.2.3	*Lagynias lasiantha*	1	0	0	05	*Strychnos henningsii*	2	0	0	05	*Drypetes arguta*	2	1	0	05
1	VT 02.1.0	*Euclea natalensis*	5	0	0	07	*Euclea natalensis*	4	0	0	07	*Euclea natalensis*	5	3	0	07
2	VT 02.1.0	*Afzelia quanzensis*	1	0	0	06	*Tabernaemontana elegans*	4	0	0	06	*Tabernaemontana elegans*	4	1	1	06
3	VT 02.1.0	*Grewia microthyrsa*	1	0	0	04	*Terminalia sericea*	2	1	1	06	*Sclerocroton integerrimus*	2	2	2	06
4	VT 02.1.0	*Rothmannia fischeri*	1	0	0	06	*Albizia adianthifolia*	1	1	1	06	*Terminalia sericea*	2	2	1	06
5	VT 02.1.0	*Sclerocroton integerrimus*	1	0	0	05	*Rhus gueinzii*	1	1	0	05	*Afzelia quanzensis*	1	1	1	06
6	VT 02.1.0	-	-	-	-	-	*Afzelia quanzensis*	1	0	0	06	*Albizia adianthifolia*	1	1	1	06
7	VT 02.1.0	-	-	-	-	-	*Combretum molle*	1	0	0	06	*Grewia microthyrsa*	1	1	1	04
8	VT 02.1.0	-	-	-	-	-	*Psydrax locuples*	1	0	0	04	*Rhus gueinzii*	1	1	1	05
9	VT 02.1.0	-	-	-	-	-	*Sclerocroton integerrimus*	1	0	0	06	*Rothmania fischeri*	1	1	1	06
10	VT 02.1.0	-	-	-	-	-	*Sclerocarya birrea*	1	0	0	04	*Sclerocarya birrea*	1	1	1	04
1	VT 02.2.0	*Afzelia qu ensis*	4	1	0	07	*Spirostachys africana*	5	0	0	07	*Sclerocarya birrea*	5	5	4	07
2	VT 02.2.0	*Acacia bu*	4	0	0	07	*Strychnos spinosa*	5	0	0	06	*Terminalia sericea*	5	3	2	07
3	VT 02.2.0	*Sclerocarya birrea*	3	1	1	07	*Terminalia sericea*	5	0	0	07	*Strychnos spinosa*	5	3	1	06
4	VT 02.2.0	*Dialium schlechteri*	3	0	0	06	*Schotia brachypetala*	4	1	0	07	*Tabernaemontana elegans*	5	3	1	06
5	VT 02.2.0	*Psydrax locuples*	3	0	0	05	*Acacia burkei*	4	0	0	07	*Acacia burkei*	5	2	0	07
6	VT 02.2.0	*Pteleopsis myrtifolia*	3	0	0	06	*Afzelia quanzensis*	4	0	0	07	*Spirostachys africana*	5	0	0	07
7	VT 02.2.0	*Tabernaemontana elegans*	3	0	0	04	*Euclea natalensis*	4	0	0	07	*Afzelia quanzensis*	4	4	3	07
8	VT 02.2.0	*Terminalia sericea*	3	0	0	06	*Sclerocarya birrea*	4	0	0	07	*Schotia brachypetala*	4	3	1	07
9	VT 02.2.0	*Vepris lanceolata*	3	0	0	05	*Tabernaemontana elegans*	4	0	0	06	*Euclea natalensis*	4	0	0	07
10	VT 02.2.0	*Vernonia colorata*	3	0	0	05	*Vepris lanceolata*	4	0	0	06	*Vepris lanceolata*	4	0	0	06
1	VT 02.3.0	*Bridelia cathartica*	4	0	0	06	*Afzelia quanzensis*	4	1	0	07	*Dialium schlechteri*	5	1	0	07
2	VT 02.3.0	*Tabernaemontana elegans*	4	0	0	06	*Tabernaemontana elegans*	4	1	0	06	*Sideroxylon inerme*	4	3	1	07
3	VT 02.3.0	*Erythroxylum delagoense*	3	0	0	05	*Bridelia cathartica*	4	0	0	06	*Strychnos spinosa*	4	3	1	06
4	VT 02.3.0	*Strychnos decussata*	3	0	0	06	*Commiphora neglecta*	4	0	0	06	*Afzelia quanzensis*	4	3	0	07
5	VT 02.3.0	*Strychnos madagascariensis*	3	0	0	06	*Dialium schlechteri*	4	0	0	07	*Bridelia cathartica*	4	3	0	06
6	VT 02.3.0	*Acacia burkei*	3	0	0	07	*Vepris lanceolata*	4	0	0	06	*Dichrostachys cinerea*	4	3	0	05
7	VT 02.3.0	*Afzelia quanzensis*	3	0	0	07	*Acacia burkei*	3	0	0	07	*Tabernaemontana elegans*	4	3	0	06
8	VT 02.3.0	*Sideroxylon inerme*	3	0	0	07	*Combretum molle*	3	0	0	06	*Commiphora neglecta*	4	1	0	06

Table 6 continued

9	VT 02.3.0	*Margaritaria discoidea*	2	0	0	04	*Canthium armatum*	3	0	0	05	*Vepris lanceolata*	4	0	0	06
10	VT 02.3.0	*Ximenia caffra*	2	0	0	04	*Psydrax locuples*	3	0	0	06	*Strychnos madagascariensis*	3	3	0	06
1	VT 03.1.0	*Terminalia sericea*	4	0	0	06	*Albizia versicolor*	5	2	0	07	*Albizia versicolor*	5	4	3	07
2	VT 03.1.0	*Acacia burkei*	3	0	0	07	*Acacia burkei*	5	0	0	07	*Strychnos madagascariensis*	5	3	1	06
3	VT 03.1.0	*Combretum molle*	3	0	0	06	*Strychnos madagascariensis*	5	0	0	06	*Acacia burkei*	5	2	0	07
4	VT 03.1.0	*Strychnos madagascariensis*	3	0	0	05	*Terminalia sericea*	5	0	0	07	*Terminalia sericea*	5	2	0	07
5	VT 03.1.0	*Acacia robusta*	2	0	0	06	*Vangueria infausta*	4	1	1	06	*Vangueria infausta*	4	3	1	06
6	VT 03.1.0	*Albizia versicolor*	2	0	0	05	*Combretum molle*	4	0	0	06	*Sclerocarya birrea*	4	3	0	07
7	VT 03.1.0	*Antidesma venosum*	2	0	0	06	*Dichrostachys cinerea*	4	0	0	05	*Sclerocroton integerrimus*	4	2	1	06
8	VT 03.1.0	*Commiphora neglecta*	2	0	0	04	*Sclerocroton integerrimus*	4	0	0	06	*Combretum molle*	4	2	0	06
9	VT 03.1.0	*Dichrostachys cinerea*	2	0	0	03	*Sclerocarya birrea*	4	0	0	07	*Dichrostachys cinerea*	4	1	0	05
10	VT 03.1.0	*Garcinia livingstonei*	2	0	0	05	*Antidesma venosum*	3	1	0	06	*Acacia robusta*	3	3	2	07
1	VT 04.1.0	*Terminalia sericea*	2	0	0	05	*Strychnos madagascariensis*	4	0	0	05	*Strychnos madagascariensis*	4	1	0	05
2	VT 04.1.0	*Acacia burkei*	1	0	0	04	*Strychnos spinosa*	2	1	0	04	*Terminalia sericea*	3	1	0	05
3	VT 04.1.0	*Dichrostachys cinerea*	1	0	0	03	*Terminalia sericea*	2	0	0	05	*Acacia burkei*	2	1	1	05
4	VT 04.1.0	*Strychnos spinosa*	1	0	0	00	*Vangueria infausta*	1	1	0	04	*Strychnos spinosa*	2	1	1	04
5	VT 04.1.0	-	-	-	-	-	*Acacia burkei*	1	0	0	05	*Albizia adianthifolia*	1	1	1	07
6	VT 04.1.0	-	-	-	-	-	*Albizia adianthifolia*	1	0	0	07	*Dialium schlechteri*	1	1	1	06
7	VT 04.1.0	-	-	-	-	-	*Dialium schlechteri*	1	0	0	06	*Syzigium cordatum*	1	1	1	06
8	VT 04.1.0	-	-	-	-	-	*Dichrostachys cinerea*	1	0	0	03	*Vangueria infausta*	1	1	1	04
9	VT 04.1.0	-	-	-	-	-	*Euclea natalensis*	1	0	0	07	*Dichrostachys cinerea*	1	0	0	03
10	VT 04.1.0	-	-	-	-	-	*Syzigium cordatum*	1	0	0	06	*Ximenia caffra*	1	0	0	03

VT 01.1.1 = *Afzelia quanzensis* clumps
VT 01.2.1 = Short Sand Forest
VT 01.2.2 = Intermediate Sand Forest
VT 01.2.3 = Tall Sand Forest
VT 02.1.0 = Closed Woodland Thicket
VT 02.2.0 = Closed Woodland on Clay
VT 02.3.0 = Closed Woodland on Sand
VT 03.1.0 = Open Woodland on Sand
VT 04.1.0 = Sparse Woodland on Sand

Table 7: The 10 woody species most utilised by large browsers in Tembe Elephant Park, by vegetation unit and age of damage (for canopy volume removal only). Values given reflect the number of height classes (HC) where utilisation was reported (HC 01), as well as the number of height classes where utilisation was > 50% (HC 02) and 100% (HC 03) of canopy removed or number of individuals utilised within a height class, and the highest height class where damage was observed (HC 04). Species highlighted in red represent situations where at least one height class was completely utilised. Maputaland, northern KwaZulu-Natal, South Africa

Number	Vegetation unit	Taxa	Canopy Volume removal < 12 months				Taxa	Canopy Volume removal > 12 months				Taxa	Overall Utilisation			
			HC 01*	HC 02*	HC 03*	HC 04*		HC 01*	HC 02*	HC 03*	HC 04*		HC 01*	HC 02*	HC 03*	HC 04*
	VT 01.2.1	-	-	-	-	-	*Cola greenwayi*	1	0	0	05	*Cola greenwayi*	1	0	0	05
	VT 01.2.3	-	-	-	-	-	*Afzelia quanzensis*	1	0	0	06	*Afzelia quanzensis*	1	1	1	06
1	VT 02.2.0	*Strychnos madagascariensis*	1	0	0	05	*Spirostachys africana*	1	0	0	04	*Combretum molle*	1	0	0	05
	VT 02.2.0	-	-	-	-	-	-	-	-	-	-	*Spirostachys africana*	1	0	0	04
	VT 02.2.0	-	-	-	-	-	-	-	-	-	-	*Strychnos madagascariensis*	1	0	0	05
1	VT 02.3.0	*Ancylanthos monteiroi*	1	0	0	04	-	-	-	-	-	*Ancylanthos monteiroi*	1	1	1	04
2	VT 02.3.0	*Dialium schlechteri*	1	0	0	04	-	-	-	-	-	*Trichilia emetica*	1	1	0	06
3	VT 02.3.0	*Canthium armatum*	1	0	0	04	-	-	-	-	-	*Dialium schlechteri*	1	0	0	04
4	VT 02.3.0	*Trichilia emetica*	1	0	0	06	-	-	-	-	-	*Canthium armatum*	1	0	0	04
5	VT 02.3.0	*Vepris lanceolata*	1	0	0	06	-	-	-	-	-	*Vepris lanceolata*	1	0	0	06
1	VT 03.1.0	*Strychnos spinosa*	2	0	0	05	*Brachylaena discolor*	1	0	0	03	*Strychnos spinosa*	2	0	0	05
2	VT 03.1.0	*Acacia burkei*	1	0	0	04	*Combretum molle*	1	0	0	05	*Lagynias lasiantha*	1	1	0	04
3	VT 03.1.0	*Brachylaena elliptica*	1	0	0	04	*Terminalia sericea*	1	0	0	05	*Acacia burkei*	1	0	0	04
4	VT 03.1.0	*Commiphora neglecta*	1	0	0	04	*Vepris lanceolata*	1	0	0	04	*Brachylaena discolor*	1	0	0	03
5	VT 03.1.0	*Dichrostachys cinerea*	1	0	0	04	-	-	-	-	-	*Brachylaena elliptica*	1	0	0	04
6	VT 03.1.0	*Garcinia livingstonei*	1	0	0	04	-	-	-	-	-	*Combretum molle*	1	0	0	05
7	VT 03.1.0	*Hymenocardia ulmoides*	1	0	0	03	-	-	-	-	-	*Commiphora neglecta*	1	0	0	04
8	VT 03.1.0	*Lagynias lasiantha*	1	0	0	04	-	-	-	-	-	*Dichrostachys cinerea*	1	0	0	04
9	VT 03.1.0	*Strychnos madagascariensis*	1	0	0	04	-	-	-	-	-	*Garcinia livingstonei*	1	0	0	04
10	VT 03.1.0	*Terminalia sericea*	1	0	0	04	-	-	-	-	-	*Hymenocardia ulmoides*	1	0	0	03
1	VT 04.1.0	*Terminalia sericea*	1	0	0	05	-	-	-	-	-	*Terminalia sericea*	1	0	0	05

VT 01.2.1 = Short Sand Forest
VT 01.2.3 = Tall Sand Forest
VT 02.2.0 = Closed Woodland on Clay
VT 02.3.0 = Closed Woodland on Sand
VT 03.1.0 = Open Woodland on Sand
VT 04.1.0 = Sparse Woodland on Sand

Table 8: *The 10 woody species most utilised by medium browsers in Tembe Elephant Park, by vegetation unit and age of damage (for canopy volume removal only). Values given reflect the number of height classes (HC) where utilisation was reported (HC 01), as well as the number of height classes where utilisation was > 50% (HC 02) and 100% (HC 03) of canopy removed or number of individuals utilised within a height class, and the highest height class where damage was observed (HC 04). Species highlighted in red represent situations where at least one height class was completely utilised. Maputaland, northern KwaZulu-Natal, South Africa*

Number	Vegetation unit	Taxa	Canopy Volume removal < 12 months				Taxa	Canopy Volume removal > 12 months				Taxa	Overall Utilisation			
			HC 01*	HC 02*	HC 03*	HC 04*		HC 01*	HC 02*	HC 03*	HC 04*		HC 01*	HC 02*	HC 03*	HC 04*
1	VT 01.1.1	*Tabernaemontana elegans*	1	1	0	03	*Tabernaemontana elegans*	1	1	0	03	*Catunaregam spinosa*	1	1	1	04
2	VT 01.1.1	*Catunaregam spinosa*	1	0	0	04	*Catunaregam spinosa*	1	0	0	04	*Psydrax locuples*	1	1	1	04
3	VT 01.1.1	*Ochna barbosae*	1	0	0	04	*Ochna barbosae*	1	0	0	04	*Tabernaemontana elegans*	1	1	0	03
4	VT 01.1.1	*Psydrax locuples*	1	0	0	04	-	-	-	-	-	*Tricalysia lanceolata*	1	1	0	04
5	VT 01.1.1	*Tricalysia lanceolata*	1	0	0	04	-	-	-	-	-	*Ochna barbosae*	1	0	0	04
1	VT 01.2.1	*Tricalysia junodii*	3	0	0	04	*Brachylaena huillensis*	2	0	0	05	*Tricalysia junodii*	3	1	0	04
2	VT 01.2.1	*Brachylaena huillensis*	2	0	0	05	*Pteleopsis myrtifolia*	1	1	0	02	*Oxyanthus latifolius*	2	1	1	04
3	VT 01.2.1	*Oxyanthus latifolius*	2	0	0	04	*Acalypha glabrata*	1	0	0	02	*Pavetta lanceolata*	2	1	1	04
4	VT 01.2.1	*Pavetta lanceolata*	2	0	0	04	*Burchelia bubalina*	1	0	0	04	*Tricalysia lanceolata*	2	1	1	04
5	VT 01.2.1	*Salacia leptoclada*	2	0	0	04	*Cassine papillosae*	1	0	0	05	*Brachylaena huillensis*	2	0	0	05
6	VT 01.2.1	*Tricalysia lanceolata*	2	0	0	04	*Combretum molle*	1	0	0	04	*Salacia leptoclada*	2	0	0	04
7	VT 01.2.1	*Pteleopsis myrtifolia*	1	1	0	02	*Croton pseudopulchellus*	1	0	0	03	*Acalypha glabrata*	1	1	1	02
8	VT 01.2.1	*Acalypha glabrata*	1	0	0	02	*Hymenocardia ulmoides*	1	0	0	04	*Cassine papillosae*	1	1	1	05
9	VT 01.2.1	*Burchelia bubalina*	1	0	0	04	*Ochna natalitia*	1	0	0	05	*Combretum molle*	1	1	1	04
10	VT 01.2.1	*Cassine papillosae*	1	0	0	05	*Psydrax obovata*	1	0	0	05	*Drypetes natalensis*	1	1	1	03
1	VT 01.2.2	*Croton pseudopulchellus*	4	0	0	05	*Croton pseudopulchellus*	4	0	0	05	*Croton pseudopulchellus*	4	0	0	05
2	VT 01.2.2	*Drypetes arguta*	3	0	0	05	*Drypetes arguta*	3	0	0	05	*Drypetes arguta*	4	0	0	05
3	VT 01.2.2	*Hymenocardia ulmoides*	3	0	0	06	*Cola greenwayi*	2	0	0	04	*Hymenocardia ulmoides*	4	0	0	06
4	VT 01.2.2	*Cola greenwayi*	2	0	0	04	*Monodora junodii*	2	0	0	05	*Cola greenwayi*	3	0	0	05
5	VT 01.2.2	*Haplocoelum gallense*	2	0	0	05	*Salacia leptoclada*	2	0	0	04	*Drypetes natalensis*	3	0	0	05
6	VT 01.2.2	*Monodora junodii*	2	0	0	05	*Deinbolia oblongifolia*	1	1	0	03	*Brachylaena discolor*	2	2	2	04
7	VT 01.2.2	*Pavetta lanceolata*	2	0	0	05	*Strychnos decussata*	1	1	0	04	*Boscia filipes*	2	2	1	05
8	VT 01.2.2	*Salacia leptoclada*	2	0	0	04	*Balanites maughamii*	1	0	0	04	*Balanites maughamii*	2	1	1	04
9	VT 01.2.2	*Suregada zanzibariensis*	2	0	0	04	*Boscia filipes*	1	0	0	03	*Cassipourea mossambicensis*	2	1	1	06
10	VT 01.2.2	*Toddaliopsis bremekampii*	2	0	0	05	*Brachylaena discolor*	1	0	0	04	*Monodora junodii*	2	1	1	05

Table 8 continued

1	VT 01.2.3	*Toddaliopsis bremekampii*	3	0	0	05	*Psydrax locuples*	1	1	0	04	*Balanites maughamii*	3	3	2	04
2	VT 01.2.3	*Grewia microthyrsa*	2	0	0	05	*Rhus gueinzii*	1	1	0	03	*Drypetes arguta*	3	0	0	05
3	VT 01.2.3	*Ptaeroxylon obliquum*	2	0	0	06	*Cola greenwayi*	1	0	0	04	*Toddaliopsis bremekampii*	3	0	0	05
4	VT 01.2.3	*Salacia leptoclada*	2	0	0	03	*Dialium schlechteri*	1	0	0	04	*Grewia microthyrsa*	2	2	2	05
5	VT 01.2.3	*Strychnos henningsii*	2	0	0	05	*Haplocoelum gallense*	1	0	0	04	*Drypetes natalensis*	2	1	1	05
6	VT 01.2.3	*Psydrax locuples*	1	1	0	04	*Hymenocardia ulmoides*	1	0	0	03	*Strychnos henningsii*	2	1	0	05
7	VT 01.2.3	*Rhus gueinzii*	1	1	0	03	*Ochna barbosae*	1	0	0	04	*Acalypha glabrata*	2	0	0	04
8	VT 01.2.3	*Cola greenwayi*	1	0	0	04	*Tricalysia lanceolata*	1	0	0	04	*Cola greenwayi*	2	0	0	04
9	VT 01.2.3	*Dialium schlechteri*	1	0	0	04	-	-	-	-	-	*Ptaeroxylon obliquum*	2	0	0	06
10	VT 01.2.3	*Grewia caffra*	1	0	0	04	-	-	-	-	-	*Salacia leptoclada*	2	0	0	03
1	VT 02.1.0	*Euclea natalensis*	4	0	0	06	*Euclea natalensis*	4	0	0	06	*Tabernaemontana elegans*	4	3	2	06
2	VT 02.1.0	*Tabernaemontana elegans*	4	0	0	06	*Tabernaemontana elegans*	3	0	0	06	*Euclea natalensis*	3	1	0	06
3	VT 02.1.0	*Combretum molle*	2	0	0	06	*Combretum molle*	2	0	0	06	*Combretum molle*	2	2	1	06
4	VT 02.1.0	*Rhus gueinzii*	2	0	0	05	*Rhus gueinzii*	1	0	0	04	*Lagynias lasiantha*	1	1	1	04
5	VT 02.1.0	*Lagynias lasiantha*	1	0	0	04	*Terminalia sericea*	1	0	0	05	*Rhus gueinzii*	1	1	1	04
6	VT 02.1.0	*Psydrax locuples*	1	0	0	03	-	-	-	-	-	*Sclerocarya birrea*	1	1	1	04
7	VT 02.1.0	*Sclerocarya birrea*	1	0	0	04	-	-	-	-	-	*Psydrax locuples*	1	0	0	03
8	VT 02.1.0	*Terminalia sericea*	1	0	0	05	-	-	-	-	-	*Terminalia sericea*	1	0	0	05
1	VT 02.2.0	*Tabernaemontana elegans*	5	0	0	06	*Spirostachys africana*	4	0	0	06	*Tabernaemontana elegans*	5	3	0	06
2	VT 02.2.0	*Rhus gueinzii*	4	1	0	05	*Berchemia zeyheri*	3	0	0	05	*Acacia burkei*	5	0	0	06
3	VT 02.2.0	*Plectroniella armata*	4	0	0	05	*Strychnos spinosa*	3	0	0	05	*Rhus gueinzii*	4	3	3	05
4	VT 02.2.0	*Scutia myrtina*	4	0	0	06	*Terminalia sericea*	3	0	0	05	*Scutia myrtina*	4	3	2	06
5	VT 02.2.0	*Spirostachys africana*	4	0	0	06	*Vepris lanceolata*	3	0	0	05	*Ziziphus mucronata*	4	2	2	06
6	VT 02.2.0	*Strychnos madagascariensis*	4	0	0	05	*Clerodendrum glabrum*	2	2	0	04	*Diospyros inhacaensis*	4	2	1	05
7	VT 02.2.0	*Strychnos spinosa*	4	0	0	05	*Rhus gueinzii*	2	1	0	03	*Plectroniella armata*	4	2	0	05
8	VT 02.2.0	*Ziziphus mucronata*	4	0	0	06	*Acacia gerrardii*	2	0	0	04	*Berchemia zeyheri*	4	1	0	05
9	VT 02.2.0	*Berchemia zeyheri*	3	0	0	05	*Euclea natalensis*	2	0	0	05	*Dialium schlechteri*	4	1	0	05
10	VT 02.2.0	*Euclea natalensis*	3	0	0	05	*Gymnosporia senegalensis*	2	0	0	04	*Spirostachys africana*	4	1	0	06
1	VT 02.3.0	*Sideroxylon inerme*	5	0	0	06	*Sideroxylon inerme*	4	0	0	06	*Tabernaemontana elegans*	5	3	0	06
2	VT 02.3.0	*Strychnos madagascariensis*	5	0	0	06	*Vepris lanceolata*	4	0	0	06	*Sideroxylon inerme*	5	1	0	06
3	VT 02.3.0	*Tabernaemontana elegans*	5	0	0	06	*Combretum molle*	3	0	0	05	*Dialium schlechteri*	5	0	0	06
4	VT 02.3.0	*Vepris lanceolata*	5	0	0	06	*Strychnos decussata*	3	0	0	05	*Vepris lanceolata*	5	0	0	06
5	VT 02.3.0	*Plectroniella armata*	4	0	0	05	*Strychnos madagascariensis*	3	0	0	05	*Plectroniella armata*	4	0	0	05
6	VT 02.3.0	*Sapium integerrimum*	4	0	0	06	*Tabernaemontana elegans*	3	0	0	06	*Sapium integerrimum*	4	0	0	06
7	VT 02.3.0	*Combretum molle*	3	0	0	05	*Diospyros inhacaensis*	2	1	0	04	*Strychnos madagascariensis*	4	0	0	05

Table 8 continued

8	VT 02.3.0	*Euclea natalensis*	3	0	0	05	*Dialium schlechteri*	2	0	0	05	*Hyperacanthus microphyllus*	3	3	2	05
9	VT 02.3.0	*Hymenocardia ulmoides*	3	0	0	05	*Psydrax locuples*	2	0	0	04	*Grewia caffra*	3	2	2	06
10	VT 02.3.0	*Hyperacanthus microphyllus*	3	0	0	05	*Tricalysia delagoensis*	2	0	0	05	*Diospyros inhacaensis*	3	2	1	05
1	VT 03.1.0	*Spirostachys africana*	4	0	0	06	*Dialium schlechteri*	3	0	0	05	*Spirostachys africana*	4	2	1	06
2	VT 03.1.0	*Strychnos madagascariensis*	4	0	0	05	*Dichrostachys cinerea*	3	0	0	04	*Acacia burkei*	4	1	0	05
3	VT 03.1.0	*Terminalia sericea*	4	0	0	06	*Strychnos madagascariensis*	3	0	0	05	*Albizia versicolor*	4	0	0	06
4	VT 03.1.0	*Dialium schlechteri*	3	0	0	05	*Strychnos spinosa*	3	0	0	05	*Combretum molle*	4	0	0	06
5	VT 03.1.0	*Dichrostachys cinerea*	3	0	0	04	*Terminalia sericea*	3	0	0	05	*Strychnos madagascariensis*	4	0	0	05
6	VT 03.1.0	*Garcinia livingstonei*	3	0	0	06	*Acacia burkei*	2	0	0	04	*Terminalia sericea*	4	0	0	06
7	VT 03.1.0	*Gymnosporia senegalensis*	3	0	0	04	*Bridelia cathartica*	2	0	0	05	*Tabernaemontana elegans*	3	2	2	05
8	VT 03.1.0	*Rhus gueinzii*	3	0	0	04	*Catunaregam spinosa*	2	0	0	05	*Bridelia cathartica*	3	2	1	05
9	VT 03.1.0	*Sapium integerrimum*	3	0	0	05	*Combretum molle*	2	0	0	05	*Sclerocarya birrea*	3	2	1	05
10	VT 03.1.0	*Sclerocarya birrea*	3	0	0	05	*Garcinia livingstonei*	2	0	0	05	*Garcinia livingstonei*	3	2	0	06
1	VT 04.1.0	*Euclea natalensis*	3	3	2	07	*Pteleopsis myrtifolia*	1	1	0	03	*Terminalia sericea*	3	1	0	05
2	VT 04.1.0	*Terminalia sericea*	3	0	0	05	*Acacia burkei*	1	0	0	04	*Combretum molle*	2	1	1	04
3	VT 04.1.0	*Strychnos madagascariensis*	2	0	0	05	*Dialium schlechteri*	1	0	0	04	*Acacia burkei*	2	0	0	04
4	VT 04.1.0	*Pteleopsis myrtifolia*	1	1	0	03	*Terminalia sericea*	1	0	0	04	*Dichrostachys cinerea*	2	0	0	03
5	VT 04.1.0	*Acacia burkei*	1	0	0	04	-	-	-	-	-	*Canthium inerme*	1	1	1	02
6	VT 04.1.0	*Dialium schlechteri*	1	0	0	04	-	-	-	-	-	*Dialium schlechteri*	1	1	1	04
7	VT 04.1.0	*Grewia microthyrsa*	1	0	0	04	-	-	-	-	-	*Grewia microthyrsa*	1	1	1	04
8	VT 04.1.0	*Hymenocardia ulmoides*	1	0	0	03	-	-	-	-	-	*Pteleopsis myrtifolia*	1	1	1	03
9	VT 04.1.0	*Hyphaene coriacea*	1	0	0	04	-	-	-	-	-	*Sclerocarya birrea*	1	1	1	03
10	VT 04.1.0	*Ozoroa englerii*	1	0	0	03	-	-	-	-	-	*Vangueria infausta*	1	1	1	04

VT 01.1.1 = *Afzelia quanzensis* clumps
VT 01.2.1 = Short Sand Forest
VT 01.2.2 = Intermediate Sand Forest
VT 01.2.3 = Tall Sand Forest
VT 02.1.0 = Closed Woodland Thicket
VT 02.2.0 = Closed Woodland on Clay
VT 02.3.0 = Closed Woodland on Sand
VT 03.1.0 = Open Woodland on Sand
VT 04.1.0 = Sparse Woodland on Sand

Table 9: *The 10 woody species most utilised by small browsers in Tembe Elephant Park, by vegetation unit and age of damage (for canopy volume removal only). Values given reflect the number of height classes (HC) where utilisation was reported (HC 01), as well as the number of height classes where utilisation was > 50% (HC 02) and 100% (HC 03) of canopy removed or number of individuals utilised within a height class, and the highest height class where damage was observed (HC 04). Species highlighted in red represent situations where at least one height class was completely utilised. Maputaland, northern KwaZulu-Natal, South Africa*

Number	Vegetation	Taxa	Canopy Volume removal < 12 months				Taxa	Canopy Volume removal > 12 months				Taxa	Overall Utilisation			
	unit		HC 01*	HC 02*	HC 03*	HC 04*		HC 01*	HC 02*	HC 03*	HC 04*		HC 01*	HC 02*	HC 03*	HC 04*
1	VT 01.1.1	*Ochna barbosae*	3	0	0	05	-	-	-	-	-	*Ochna barbosae*	3	3	1	05
2	VT 01.1.1	*Vepris lanceolata*	3	0	0	04	-	-	-	-	-	*Vepris lanceolata*	3	3	1	04
3	VT 01.1.1	*Monanthotaxis caffra*	2	0	0	03	-	-	-	-	-	*Bridelia cathartica*	2	2	2	04
4	VT 01.1.1	*Ochna natalitia*	2	0	0	03	-	-	-	-	-	*Tricalysia lanceolata*	2	2	2	04
5	VT 01.1.1	*Tricalysia lanceolata*	2	0	0	04	-	-	-	-	-	*Ochna natalitia*	2	2	1	03
6	VT 01.1.1	*Boscia filipes*	1	0	0	04	-	-	-	-	-	*Monanthotaxis caffra*	2	1	1	03
7	VT 01.1.1	*Bridelia cathartica*	1	0	0	03	-	-	-	-	-	*Boscia filipes*	1	1	1	04
8	VT 01.1.1	*Canthium setiflorum*	1	0	0	03	-	-	-	-	-	*Canthium setiflorum*	1	1	1	03
9	VT 01.1.1	*Carissa tetramera*	1	0	0	03	-	-	-	-	-	*Carissa tetramera*	1	1	1	03
10	VT 01.1.1	*Mystroxylon aethiopicum*	1	0	0	04	-	-	-	-	-	*Mystroxylon aethiopicum*	1	1	1	04
1	VT 01.2.1	*Salacia leptoclada*	4	0	0	05	*Tricalysia junodii*	1	0	0	02	*Tricalysia junodii*	4	2	1	05
2	VT 01.2.1	*Tricalysia junodii*	4	0	0	05	*Vepris lanceolata*	1	0	0	02	*Salacia leptoclada*	4	1	0	05
3	VT 01.2.1	*Brachylaena discolor*	3	0	0	06	-	-	-	-	-	*Brachylaena discolor*	3	2	2	06
4	VT 01.2.1	*Cola greenwayi*	3	0	0	04	-	-	-	-	-	*Tricalysia lanceolata*	3	2	1	04
5	VT 01.2.1	*Toddaliopsis bremekampii*	3	0	0	04	-	-	-	-	-	*Cola greenwayi*	3	1	0	04
6	VT 01.2.1	*Tricalysia lanceolata*	3	0	0	04	-	-	-	-	-	*Toddaliopsis bremekampii*	3	1	0	04
7	VT 01.2.1	*Brachylaena huillensis*	2	0	0	04	-	-	-	-	-	*Drypetes natalensis*	2	2	1	03
8	VT 01.2.1	*Croton pseudopulchellus*	2	0	0	03	-	-	-	-	-	*Croton pseudopulchellus*	2	1	0	03
9	VT 01.2.1	*Drypetes arguta*	2	0	0	03	-	-	-	-	-	*Brachylaena huillensis*	2	0	0	04
10	VT 01.2.1	*Drypetes natalensis*	2	0	0	03	-	-	-	-	-	*Drypetes arguta*	2	0	0	03
1	VT 01.2.2	*Cola greenwayi*	5	0	0	06	*Brachylaena huillensis*	1	0	0	03	*Drypetes arguta*	5	1	0	05
2	VT 01.2.2	*Drypetes arguta*	5	0	0	05	*Cola greenwayi*	1	0	0	02	*Cola greenwayi*	4	1	0	05
3	VT 01.2.2	*Drypetes natalensis*	4	0	0	05	*Tarenna junodii*	1	0	0	03	*Drypetes natalensis*	4	1	0	05
4	VT 01.2.2	*Tricalysia delagoensis*	4	0	0	06	*Tricalysia junodii*	1	0	0	02	*Hymenocardia ulmoides*	4	0	0	06
5	VT 01.2.2	*Brachylaena huillensis*	3	0	0	04	-	-	-	-	-	*Pavetta lanceolata*	3	1	1	04
6	VT 01.2.2	*Croton pseudopulchellus*	3	0	0	04	-	-	-	-	-	*Salacia leptoclada*	3	1	0	04
7	VT 01.2.2	*Hymenocardia ulmoides*	3	0	0	04	-	-	-	-	-	*Tricalysia delagoensis*	3	1	0	05
8	VT 01.2.2	*Salacia leptoclada*	3	0	0	04	-	-	-	-	-	*Uvaria caffra*	3	1	0	06
9	VT 01.2.2	*Toddaliopsis bremekampii*	3	0	0	05	-	-	-	-	-	*Brachylaena huillensis*	3	0	0	04
10	VT 01.2.2	*Balanites maughamii*	2	0	0	04	-	-	-	-	-	*Croton pseudopulchellus*	3	0	0	04

Table 9 continued

1	VT 01.2.3	*Drypetes arguta*	3	0	0	05	-	-	-	-	-	*Drypetes arguta*	3	1	0	05
2	VT 01.2.3	*Acalypha glabrata*	2	0	0	03	-	-	-	-	-	*Dovyalis longispina*	2	2	1	03
3	VT 01.2.3	*Cola greenwayi*	2	0	0	04	-	-	-	-	-	*Drypetes natalensis*	2	2	1	04
4	VT 01.2.3	*Dovyalis longispina*	2	0	0	03	-	-	-	-	-	*Ptaeroxylon obliquum*	2	2	1	04
5	VT 01.2.3	*Drypetes natalensis*	2	0	0	04	-	-	-	-	-	*Tricalysia junodii*	2	2	1	03
6	VT 01.2.3	*Hymenocardia ulmoides*	2	0	0	03	-	-	-	-	-	*Hymenocardia ulmoides*	2	1	1	03
7	VT 01.2.3	*Ochna barbosae*	2	0	0	04	-	-	-	-	-	*Acalypha glabrata*	2	1	0	03
8	VT 01.2.3	*Ptaeroxylon obliquum*	2	0	0	04	-	-	-	-	-	*Ochna barbosae*	2	1	0	04
9	VT 01.2.3	*Tricalysia junodii*	2	0	0	03	-	-	-	-	-	*Cola greenwayi*	2	0	0	04
10	VT 01.2.3	*Boscia filipes*	1	0	0	03	-	-	-	-	-	*Boscia filipes*	1	1	1	03
1	VT 02.1.0	*Euclea natalensis*	4	0	0	07	*Strychnos madagascariensis*	1	0	0	03	*Euclea natalensis*	5	0	0	07
2	VT 02.1.0	*Tabernaemontana elegans*	3	0	0	04	-	-	-	-	-	*Tabernaemontana elegans*	3	2	0	04
3	VT 02.1.0	*Grewia microthyrsa*	2	0	0	04	-	-	-	-	-	*Grewia microthyrsa*	2	2	2	04
4	VT 02.1.0	*Psydrax locuples*	2	0	0	04	-	-	-	-	-	*Strychnos madagascariensis*	2	2	2	03
5	VT 02.1.0	*Sclerocroton integerrimus*	2	0	0	04	-	-	-	-	-	*Sclerocroton integerrimus*	2	1	1	04
6	VT 02.1.0	*Acacia burkei*	1	0	0	02	-	-	-	-	-	*Psydrax locuples*	2	1	0	04
7	VT 02.1.0	*Coddia rudis*	1	0	0	03	-	-	-	-	-	*Acacia burkei*	1	1	1	02
8	VT 02.1.0	*Combretum molle*	1	0	0	05	-	-	-	-	-	*Coddia rudis*	1	1	1	03
9	VT 02.1.0	*Lagynias lasiantha*	1	0	0	03	-	-	-	-	-	*Combretum molle*	1	1	1	05
10	VT 02.1.0	*Margaritaria discoidea*	1	0	0	03	-	-	-	-	-	*Lagynias lasiantha*	1	1	1	03
1	VT 02.2.0	*Acacia gerrardii*	3	0	0	04	*Sclerocarya birrea*	1	0	0	03	*Psydrax locuples*	4	2	0	05
2	VT 02.2.0	*Acacia burkei*	3	0	0	04	*Strychnos madagascariensis*	1	0	0	03	*Lagynias lasiantha*	3	3	3	04
3	VT 02.2.0	*Berchemia zeyheri*	3	0	0	04	-	-	-	-	-	*Monanthotaxis caffra*	3	3	1	04
4	VT 02.2.0	*Elaeodendron croceum*	3	0	0	04	-	-	-	-	-	*Pteleopsis myrtifolia*	3	3	1	04
5	VT 02.2.0	*Catunaregam taylori*	3	0	0	04	-	-	-	-	-	*Tricalysia lanceolata*	3	2	1	04
6	VT 02.2.0	*Coddia rudis*	3	0	0	04	-	-	-	-	-	*Erythroxylum delagoense*	3	2	0	04
7	VT 02.2.0	*Dialium schlechteri*	3	0	0	04	-	-	-	-	-	*Grewia caffra*	3	2	0	04
8	VT 02.2.0	*Dichrostachys cinerea*	3	0	0	04	-	-	-	-	-	*Gymnosporia senegalensis*	3	2	0	04
9	VT 02.2.0	*Dovyalis longispina*	3	0	0	04	-	-	-	-	-	*Strychnos madagascariensis*	3	2	0	04
10	VT 02.2.0	*Erythroxylum delagoense*	3	0	0	04	-	-	-	-	-	*Bridelia cathartica*	3	1	1	04
1	VT 02.3.0	*Dialium schlechteri*	5	1	0	05	*Salacia leptoclada*	1	1	0	03	*Tabernaemontana elegans*	5	1	0	05
2	VT 02.3.0	*Combretum molle*	4	0	0	05	*Strychnos madagascariensis*	1	0	0	02	*Dialium schlechteri*	5	0	0	05
3	VT 02.3.0	*Dalbergia obovata*	4	0	0	04	*Strychnos spinosa*	1	0	0	03	*Erythroxylum delagoense*	4	3	3	06
4	VT 02.3.0	*Grewia microthyrsa*	4	0	0	06	*Vepris lanceolata*	1	0	0	02	*Grewia microthyrsa*	4	3	2	06
5	VT 02.3.0	*Psydrax locuples*	4	0	0	04	-	-	-	-	-	*Dalbergia obovata*	4	2	1	04

Table 9 continued

6	VT 02.3.0	*Strychnos madagascariensis*	4	0	0	05	-	-	-	-	-	*Psydrax locuples*	4	2	0	04
7	VT 02.3.0	*Tabernaemontana elegans*	4	0	0	05	-	-	-	-	-	*Combretum molle*	4	1	1	05
8	VT 02.3.0	*Acacia burkei*	3	0	0	04	-	-	-	-	-	*Vepris lanceolata*	4	0	0	05
9	VT 02.3.0	*Bridelia cathartica*	3	0	0	05	-	-	-	-	-	*Strychnos madagascariensis*	3	3	2	04
10	VT 02.3.0	*Coddia rudis*	3	0	0	04	-	-	-	-	-	*Mundulea sericea*	3	3	1	04
1	VT 03.1.0	*Garcinia livingstonei*	5	1	0	05	*Strychnos madagascariensis*	4	0	0	04	*Strychnos madagascariensis*	5	3	0	05
2	VT 03.1.0	*Strychnos madagascariensis*	5	0	0	05	*Coddia rudis*	2	0	0	03	*Garcinia livingstonei*	5	2	2	05
3	VT 03.1.0	*Acacia burkei*	4	0	0	04	*Psydrax locuples*	2	0	0	03	*Strychnos spinosa*	4	2	0	05
4	VT 03.1.0	*Albizia versicolor*	4	0	0	06	*Clausena anisata*	1	0	0	03	*Dichrostachys cinerea*	4	1	1	04
5	VT 03.1.0	*Combretum molle*	4	0	0	06	*Dichrostachys cinerea*	1	0	0	03	*Sclerocroton integerrimus*	4	1	0	05
6	VT 03.1.0	*Dichrostachys cinerea*	4	0	0	04	*Garcinia livingstonei*	1	0	0	02	*Acacia burkei*	4	0	0	04
7	VT 03.1.0	*Sclerocroton integerrimus*	4	0	0	05	*Spirostachys africana*	1	0	0	02	*Combretum molle*	4	0	0	06
8	VT 03.1.0	*Strychnos spinosa*	4	0	0	05	*Terminalia sericea*	1	0	0	03	*Terminalia sericea*	4	0	0	05
9	VT 03.1.0	*Terminalia sericea*	4	0	0	05	*Tricalysia lanceolata*	1	0	0	02	*Albizia versicolor*	3	2	1	04
10	VT 03.1.0	*Brachylaena discolor*	3	0	0	04	-	-	-	-	-	*Grewia caffra*	3	2	1	04
1	VT 04.1.0	*Strychnos madagascariensis*	4	0	0	04	*Euclea natalensis*	3	0	0	05	*Strychnos madagascariensis*	4	3	0	04
2	VT 04.1.0	*Acacia burkei*	3	0	0	04	*Strychnos madagascariensis*	2	0	0	03	*Acacia burkei*	3	2	0	04
3	VT 04.1.0	*Dichrostachys cinerea*	3	0	0	04	-	-	-	-	-	*Dichrostachys cinerea*	3	2	0	04
4	VT 04.1.0	*Catunaregam taylori*	2	0	0	03	-	-	-	-	-	*Catunaregam taylori*	2	2	1	03
5	VT 04.1.0	*Combretum molle*	2	0	0	03	-	-	-	-	-	*Combretum molle*	2	2	1	03
6	VT 04.1.0	*Dialium schlechteri*	2	0	0	05	-	-	-	-	-	*Pavetta gardenophylla*	2	2	1	03
7	VT 04.1.0	*Pavetta gardenophylla*	2	0	0	03	-	-	-	-	-	*Strychnos spinosa*	2	2	0	04
8	VT 04.1.0	*Strychnos spinosa*	2	0	0	04	-	-	-	-	-	*Terminalia sericea*	2	0	0	04
9	VT 04.1.0	*Terminalia sericea*	2	0	0	04	-	-	-	-	-	*Boscia filipes*	1	1	1	02
10	VT 04.1.0	*Boscia filipes*	1	0	0	02	-	-	-	-	-	*Canthium inerme*	1	1	1	03

VT 01.1.1 = *Afzelia quanzensis* clumps

VT 01.2.1 = Short Sand Forest

VT 01.2.2 = Intermediate Sand Forest

VT 01.2.3 = Tall Sand Forest

VT 02.1.0 = Closed Woodland Thicket

VT 02.2.0 = Closed Woodland on Clay

VT 02.3.0 = Closed Woodland on Sand

VT 03.1.0 = Open Woodland on Sand

VT 04.1.0 = Sparse Woodland on Sand

Table 10: The 10 woody species most utilised by man in Tembe Elephant Park, by vegetation unit and age of damage (for canopy volume removal only). Values given reflect the number of height classes (HC) where utilisation was reported (HC 01), as well as the number of height classes where utilisation was > 50% (HC 02) and 100% (HC 03) of canopy removed or number of individuals utilised within a height class, and the highest height class where damage was observed (HC 04). Species highlighted in red represent situations where at least one height class was completely utilised. Maputaland, northern KwaZulu-Natal, South Africa

Number	Vegetation	Taxa	Canopy Volume removal < 12 months				Taxa	Canopy Volume removal > 12 months				Taxa	Overall Utilisation			
	unit		HC 01*	HC 02*	HC 03*	HC 04*		HC 01*	HC 02*	HC 03*	HC 04*		HC 01*	HC 02*	HC 03*	HC 04*
1	VT 01.2.1	-	-	-	-	-	*Brachylaena huillensis*	1	0	0	04	*Brachylaena huillensis*	1	0	0	04
2	VT 01.2.1	-	-	-	-	-	*Croton pseudopulchellus*	1	1	1	05	*Croton pseudopulchellus*	1	0	0	05
1	VT 01.2.2	-	-	-	-	-	*Brachylaena huillensis*	3	1	1	06	*Brachylaena huillensis*	3	0	0	06
2	VT 01.2.2	-	-	-	-	-	*Hymenocardia ulmoides*	2	0	0	06	*Hymenocardia ulmoides*	2	0	0	06
3	VT 01.2.2	-	-	-	-	-	*Dialium schlechteri*	1	0	0	06	*Uvaria lucida*	1	1	0	06
4	VT 01.2.2	-	-	-	-	-	*Manilkara discolor*	1	0	0	06	*Dialium schlechteri*	1	0	0	06
5	VT 01.2.2	-	-	-	-	-	-	-	-	-	-	*Manilkara discolor*	1	0	0	06
1	VT 02.1.0	*Euclea natalensis*	1	0	0	04	-	-	-	-	-	*Euclea natalensis*	1	0	0	04
1	VT 02.2.0	*Vernonia colorata*	1	0	0	04	-	-	-	-	-	*Balanites maughamii*	1	1	1	07
2	VT 02.2.0	-	-	-	-	-	-	-	-	-	-	*Vernonia colorata*	1	0	0	04
1	VT 02.3.0	*Erythroxylum delagoense*	1	0	0	05	*Canthium armatum*	1	0	0	02	*Erythroxylum delagoense*	1	0	0	05
2	VT 02.3.0	*Grewia microthyrsa*	1	0	0	03	-	-	-	-	-	*Grewia microthyrsa*	1	0	0	03
3	VT 02.3.0	*Strychnos spinosa*	1	0	0	03	-	-	-	-	-	*Canthium armatum*	1	0	0	02
4	VT 02.3.0	-	-	-	-	-	-	-	-	-	-	*Strychnos spinosa*	1	0	0	03
1	VT 04.1.0	-	-	-	-	-	*Coddia rudis*	1	0	0	03	*Coddia rudis*	1	1	0	03

VT 01.2.1 = Short Sand Forest
VT 01.2.2 = Intermediate Sand Forest
VT 02.1.0 = Closed Woodland Thicket
VT 02.2.0 = Closed Woodland on Clay
VT 02.3.0 = Closed Woodland on Sand
VT 04.1.0 = Sparse Woodland on Sand

Table 11: The 10 woody species most utilised by natural damage in Tembe Elephant Park, by vegetation unit and age of damage (for canopy volume removal only). Values given reflect the number of height classes (HC) where utilisation was reported (HC 01), as well as the number of height classes where utilisation was > 50% (HC 02) and 100% (HC 03) of canopy removed or number of individuals utilised within a height class, and the highest height class where damage was observed (HC 04). Species highlighted in red represent situations where at least one height class was completely utilised. Maputaland, northern KwaZulu-Natal, South Africa

Number	Vegetation	Taxa	Canopy Volume removal < 12 months				Taxa	Canopy Volume removal > 12 months				Taxa	Overall Utilisation			
	unit		HC 01*	HC 02*	HC 03*	HC 04*		HC 01*	HC 02*	HC 03*	HC 04*		HC 01*	HC 02*	HC 03*	HC 04*
1	VT 01.1.1	-	-	-	-	-	*Dialium schlechteri*	4	1	1	07	*Dialium schlechteri*	4	4	3	07
2	VT 01.1.1	-	-	-	-	-	*Vepris lanceolata*	2	0	0	06	*Vepris lanceolata*	2	2	0	06
3	VT 01.1.1	-	-	-	-	-	*Afzelia quanzensis*	1	0	0	07	*Mystroxylon aethiopicum*	1	1	1	04
4	VT 01.1.1	-	-	-	-	-	*Mystroxylon aethiopicum*	1	0	0	04	*Sclerocarya birrea*	1	1	1	07
5	VT 01.1.1	-	-	-	-	-	*Ochna barbosae*	1	0	0	03	*Spirostachys africana*	1	1	1	05
6	VT 01.1.1	-	-	-	-	-	*Sclerocarya birrea*	1	0	0	07	*Strychnos decussata*	1	1	1	05
7	VT 01.1.1	-	-	-	-	-	*Spirostachys africana*	1	0	0	05	*Tabernaemontana elegans*	1	1	1	05
8	VT 01.1.1	-	-	-	-	-	*Strychnos decussata*	1	0	0	05	*Toddaliopsis bremekampii*	1	1	1	04
9	VT 01.1.1	-	-	-	-	-	*Tabernaemontana elegans*	1	0	0	05	*Afzelia quanzensis*	1	1	0	07
10	VT 01.1.1	-	-	-	-	-	*Toddaliopsis bremekampii*	1	0	0	04	*Ochna barbosae*	1	0	0	03
1	VT 01.2.1	*Erythrophleum lasianthum*	3	1	1	07	*Cola greenwayi*	4	0	0	06	*Pteleopsis myrtifolia*	4	4	1	07
2	VT 01.2.1	*Salacia leptoclada*	2	0	0	03	*Pteleopsis myrtifolia*	4	0	0	07	*Cola greenwayi*	4	3	0	06
3	VT 01.2.1	*Acalypha glabrata*	1	0	0	04	*Erythrophleum lasianthum*	3	1	1	07	*Salacia leptoclada*	4	2	1	05
4	VT 01.2.1	*Cassipourea mossambicensis*	1	0	0	06	*Brachylaena huillensis*	3	0	0	06	*Vepris lanceolata*	3	3	3	06
5	VT 01.2.1	*Hyperacanthus microphyllus*	1	0	0	04	*Cleistanthus schlechteri*	3	0	0	07	*Psydrax locuples*	3	3	2	06
6	VT 01.2.1	*Leptactina delagoensis*	1	0	0	04	*Dialium schlechteri*	3	0	0	07	*Cassipourea mossambicensis*	3	3	1	06
7	VT 01.2.1	*Pavetta lanceolata*	1	0	0	05	*Hymenocardia ulmoides*	3	0	0	06	*Cleistanthus schlechteri*	3	3	1	07
8	VT 01.2.1	*Pteleopsis myrtifolia*	1	0	0	04	*Psydrax locuples*	3	0	0	06	*Toddaliopsis bremekampii*	3	3	0	05
9	VT 01.2.1	*Toddaliopsis bremekampii*	1	0	0	03	*Psydrax obovata*	3	0	0	06	*Dialium schlechteri*	3	2	1	07
10	VT 01.2.1	*Tricalysia junodii*	1	0	0	03	*Ptaeroxylon obliquum*	3	0	0	06	*Hymenocardia ulmoides*	3	2	1	06
1	VT 01.2.2	*Drypetes arguta*	4	0	0	05	*Cleistanthus schlechteri*	5	0	0	08	*Cleistanthus schlechteri*	5	4	2	08
2	VT 01.2.2	*Cola greenwayi*	3	0	0	05	*Cola greenwayi*	5	0	0	06	*Cola greenwayi*	5	3	0	06
3	VT 01.2.2	*Drypetes natalensis*	2	0	0	04	*Hymenocardia ulmoides*	5	0	0	07	*Hymenocardia ulmoides*	5	3	0	07
4	VT 01.2.2	*Hymenocardia ulmoides*	2	0	0	04	*Brachylaena huillensis*	4	0	0	07	*Salacia leptoclada*	5	2	2	06
5	VT 01.2.2	*Pavetta lanceolata*	2	0	0	05	*Croton pseudopulchellus*	4	0	0	06	*Drypetes arguta*	5	2	0	06
6	VT 01.2.2	*Salacia leptoclada*	2	0	0	03	*Dialium schlechteri*	4	0	0	07	*Manilkara discolor*	4	4	2	07
7	VT 01.2.2	*Uvaria lucida*	2	0	0	05	*Drypetes arguta*	4	0	0	06	*Haplocoelum galense*	4	4	1	07
8	VT 01.2.2	*Brachylaena huillensis*	1	0	0	04	*Drypetes natalensis*	4	0	0	06	*Drypetes natalensis*	4	3	1	06
9	VT 01.2.2	*Croton pseudopulchellus*	1	0	0	04	*Haplocoelum foliolosum*	4	0	0	07	*Toddaliopsis bremekampii*	4	3	0	06
10	VT 01.2.2	*Deinbollia oblongifolia*	1	0	0	03	*Manilkara discolor*	4	0	0	07	*Dialium schlechteri*	4	2	2	07

Table 11 continued

1	VT 01.2.3	*Balanites maughamii*	1	0	0	03	*Cola greenwayi*	3	0	0	06	*Vepris lanceolata*	4	2	1	06
2	VT 01.2.3	*Cola greenwayi*	1	0	0	04	*Dialium schlechteri*	3	0	0	06	*Dialium schlechteri*	3	3	1	06
3	VT 01.2.3	*Toddaliopsis bremekampii*	1	0	0	05	*Newtonia hildebrandtii*	3	0	0	08	*Newtonia hildebrandtii*	3	2	0	08
4	VT 01.2.3	*Vepris lanceolata*	1	0	0	03	*Vepris lanceolata*	3	0	0	06	*Cola greenwayi*	3	1	0	06
5	VT 01.2.3	*Ziziphus mucronata*	1	0	0	02	*Acalypha glabrata*	2	0	0	05	*Grewia microthyrsa*	2	2	2	05
6	VT 01.2.3	-	-	-	-	-	*Cleistanthus schlechteri*	2	0	0	07	*Tricalysia lanceolata*	2	2	1	06
7	VT 01.2.3	-	-	-	-	-	*Drypetes arguta*	2	0	0	05	*Cleistanthus schlechteri*	2	2	0	07
8	VT 01.2.3	-	-	-	-	-	*Grewia microthyrsa*	2	0	0	05	*Toddaliopsis bremekampii*	2	2	0	05
9	VT 01.2.3	-	-	-	-	-	*Monodora junodii*	2	0	0	06	*Acalypha glabrata*	2	1	1	05
10	VT 01.2.3	-	-	-	-	-	*Ptaeroxylon obliquum*	2	0	0	07	*Balanites maughamii*	2	1	1	08
1	VT 02.1.0	*Euclea natalensis*	2	0	0	05	*Euclea natalensis*	4	0	0	07	*Euclea natalensis*	5	0	0	07
2	VT 02.1.0	-	-	-	-	-	*Psydrax locuples*	3	0	0	05	*Psydrax locuples*	3	1	0	05
3	VT 02.1.0	-	-	-	-	-	*Acacia burkei*	2	0	0	06	*Acacia burkei*	2	2	2	06
4	VT 02.1.0	-	-	-	-	-	*Tabernaemontana elegans*	2	0	0	06	*Tabernaemontana elegans*	2	2	1	06
5	VT 02.1.0	-	-	-	-	-	*Terminalia sericea*	2	0	0	06	*Terminalia sericea*	2	1	0	06
6	VT 02.1.0	-	-	-	-	-	*Mystroxylon aethiopicum*	1	0	0	04	*Mystroxylon aethiopicum*	1	1	1	04
7	VT 02.1.0	-	-	-	-	-	*Combretum molle*	1	0	0	06	*Combretum molle*	1	1	1	06
8	VT 02.1.0	-	-	-	-	-	*Sclerocarya birrea*	1	0	0	04	*Sclerocarya birrea*	1	1	1	04
1	VT 02.2.0	*Acacia burkei*	7	4	4	07	*Acacia burkei*	7	4	4	07	*Acacia burkei*	5	2	0	07
2	VT 02.2.0	*Coddia rudis*	4	2	1	04	*Spirostachys africana*	5	0	0	07	*Spirostachys africana*	5	2	0	07
3	VT 02.2.0	*Dialium schlechteri*	4	0	0	06	*Coddia rudis*	4	2	1	04	*Warburgia salutaris*	4	3	3	06
4	VT 02.2.0	*Strychnos spinosa*	3	0	0	05	*Warburgia salutaris*	4	0	0	06	*Dialium schlechteri*	4	0	0	06
5	VT 02.2.0	*Bridelia cathartica*	2	0	0	05	*Acacia robusta*	3	0	0	06	*Sclerocarya birrea*	3	3	1	07
6	VT 02.2.0	*Catunaregam taylori*	2	0	0	04	*Combretum molle*	3	0	0	05	*Acacia robusta*	3	2	2	06
7	VT 02.2.0	*Combretum molle*	2	0	0	05	*Euclea natalensis*	3	0	0	07	*Croton pseudopulchellus*	3	2	1	05
8	VT 02.2.0	*Croton pseudopulchellus*	2	0	0	04	*Ochna barbosae*	3	0	0	05	*Schotia brachypetala*	3	2	1	07
9	VT 02.2.0	*Canthium armatum*	2	0	0	04	*Ochna natalitia*	3	0	0	05	*Vepris lanceolata*	3	2	1	06
10	VT 02.2.0	*Tricalysia lanceolata*	2	0	0	04	*Sclerocarya birrea*	3	0	0	07	*Catunaregam taylori*	3	1	0	05
1	VT 02.3.0	*Spirostachys africana*	6	3	3	07	*Spirostachys africana*	6	3	3	07	*Vepris lanceolata*	5	3	0	07
2	VT 02.3.0	*Strychnos madagascariensis*	6	3	3	06	*Strychnos madagascariensis*	6	3	3	06	*Dialium schlechteri*	4	3	1	07
3	VT 02.3.0	*Canthium armatum*	3	0	0	05	*Vepris lanceolata*	5	0	0	07	*Commiphora neglecta*	4	3	0	06
4	VT 02.3.0	*Albizia versicolor*	2	1	1	06	*Afzelia quanzensis*	4	1	0	07	*Sideroxylon inerme*	4	2	1	07
5	VT 02.3.0	*Acacia robusta*	2	1	0	07	*Combretum molle*	4	0	0	06	*Afzelia quanzensis*	4	1	0	07
6	VT 02.3.0	*Bridelia cathartica*	2	0	0	04	*Dialium schlechteri*	4	0	0	07	*Combretum molle*	4	1	0	06
7	VT 02.3.0	*Commiphora neglecta*	2	0	0	04	*Sideroxylon inerme*	4	0	0	07	*Spirostachys africana*	4	1	0	07
8	VT 02.3.0	*Afzelia quanzensis*	1	0	0	07	*Albizia versicolor*	3	1	1	07	*Bridelia cathartica*	4	0	0	06

Table 11 continued

9	VT 02.3.0	*Acalypha glabrata*	1	0	0	04	*Acacia burkei*	3	0	0	07	*Haplocoelum galense*	3	3	3	06
10	VT 02.3.0	*Acacia burkei*	1	0	0	07	*Bridelia cathartica*	3	0	0	06	*Toddaliopsis bremekampii*	3	3	3	05
1	VT 03.1.0	*Acacia burkei*	7	2	2	07	*Acacia burkei*	7	2	2	07	*Terminalia sericea*	6	3	1	07
2	VT 03.1.0	*Terminalia sericea*	6	0	0	07	*Albizia versicolor*	5	0	0	07	*Albizia versicolor*	6	1	0	07
3	VT 03.1.0	*Albizia versicolor*	5	0	0	07	*Terminalia sericea*	5	0	0	07	*Sclerocarya birrea*	5	3	1	07
4	VT 03.1.0	*Combretum molle*	4	0	0	05	*Vangueria infausta*	4	1	1	06	*Acacia burkei*	5	3	0	07
5	VT 03.1.0	*Strychnos madagascariensis*	4	0	0	05	*Combretum molle*	4	1	0	06	*Ziziphus mucronata*	5	3	0	06
6	VT 03.1.0	*Zanthoxylum capense*	3	1	1	05	*Catunaregam taylori*	4	0	0	05	*Combretum molle*	5	1	0	06
7	VT 03.1.0	*Catunaregam taylori*	3	0	0	04	*Dichrostachys cinerea*	4	0	0	05	*Catunaregam taylori*	4	2	1	05
8	VT 03.1.0	*Dialium schlechteri*	3	0	0	05	*Rhus gueinziinzii*	4	0	0	05	*Dichrostachys cinerea*	4	2	1	05
9	VT 03.1.0	*Dichrostachys cinerea*	3	0	0	04	*Sclerocroton integerrimus*	4	0	0	06	*Rhus gueinziinzii*	4	2	1	05
10	VT 03.1.0	*Gymnosporia senegalensis*	3	0	0	04	*Sclerocarya birrea*	4	0	0	07	*Strychnos spinosa*	4	2	0	05
1	VT 04.1.0	*Euclea natalensis*	3	3	1	05	*Dialium schlechteri*	3	1	0	06	*Terminalia sericea*	4	3	0	05
2	VT 04.1.0	*Dichrostachys cinerea*	3	1	0	04	*Strychnos madagascariensis*	3	0	0	05	*Strychnos madagascariensis*	4	2	0	05
3	VT 04.1.0	*Terminalia sericea*	2	1	0	03	*Terminalia sericea*	3	0	0	05	*Dialium schlechteri*	3	3	3	06
4	VT 04.1.0	*Combretum molle*	1	1	0	02	*Brachylaena discolor*	2	2	0	04	*Euclea natalensis*	3	3	2	07
5	VT 04.1.0	*Crotalaria monteiroi*	1	1	0	03	*Acacia burkei*	2	0	0	04	*Dichrostachys cinerea*	3	0	0	04
6	VT 04.1.0	*Mundulea sericea*	1	1	0	03	*Dichrostachys cinerea*	2	0	0	03	*Brachylaena discolor*	2	2	2	04
7	VT 04.1.0	*Strychnos madagascariensis*	1	0	0	05	*Vitex ferruginea*	1	1	0	03	*Mundulea sericea*	2	2	1	03
8	VT 04.1.0	-	-	-	-	-	*Albizia adianthifolia*	1	0	0	07	*Combretum molle*	2	1	1	03
9	VT 04.1.0	-	-	-	-	-	*Combretum molle*	1	0	0	03	*Acacia burkei*	2	0	0	04
10	VT 04.1.0	-	-	-	-	-	*Euclea natalensis*	1	0	0	07	*Albizia adianthifolia*	1	1	1	07

VT 01.1.1 = *Afzelia quanzensis* clumps
VT 01.2.1 = Short Sand Forest
VT 01.2.2 = Intermediate Sand Forest
VT 01.2.3 = Tall Sand Forest
VT 02.1.0 = Closed Woodland Thicket
VT 02.2.0 = Closed Woodland on Clay
VT 02.3.0 = Closed Woodland on Sand
VT 03.1.0 = Open Woodland on Sand
VT 04.1.0 = Sparse Woodland on Sand

Elephant utilisation evaluation

The overall percentage of canopy removal by species for the recent and old periods, and for the overall utilisation was presented in Table 12. More than 10% of the canopy was removed for seven species during the past 12 months, while canopy removal exceeded 10% for 65 species (39.15% of sampled species) during the old period. More significantly, canopy removal was greater than 40% for nine species, and greater than 50% for five of these species. Overall utilisation was ≥ 10% for 99 species, and > 50% for 29 of these species, meaning that more than 50% of the available individuals were used for each of these woody species. For comparative purposes the old canopy removal value was used to compare results with the 1994 study, because recent canopy removal only documented one year of utilisation. *Albizia versicolor* remained a highly utilised species and was still classified within group 1, with in excess of 80% of the canopy removed, whereas *Terminalia sericea* and *Albizia adianthifolia* canopy utilisation was lower and they fell within group 2. *Sclerocarya birrea, Spirostachys africana* and *Afzelia quanzensis* had less than 10% of their available canopy removed and therefore could no longer be classified into the original groups. The remainder of species initially described were now within group 3. The values for overall utilisation indicated that elephants utilised 127 species, or 75.60% of the sampled woody species (1994 study value was 66.00%).

The species level analysis by vegetation units showed that recent canopy removal was generally below 10% in the Sand Forest association except for the Tall Sand Forest unit where three species had nearly 40% of their canopy removed (Table 13) but old canopy removal exceeded 10% for almost half of the utilised species (Table 14), with remarkably high values for six species of the Tall Sand Forest unit. Recent canopy removal in the Woodlands (Table 15) exceeded 10% for two (50.00% of utilised species in the vegetation unit), nine (16.66%), seven (17.50%) and four (12.90%) species in the Closed Woodland Thicket, Closed Woodland on Clay, Closed Woodland on Sand, and Open Woodland on Sand respectively. *Phyllanthus reticulatus* was particularly utilised by elephants recently, as 94.50% of its canopy was removed in the Closed Woodland on Clay. Old signs of canopy removal (Table 16) showed that canopy removal was > 10% for the majority of utilised species in the Woodlands (55.55% in Closed Woodland Thicket and Closed Woodland on Clay, 69.35% in Closed Woodland on Sand, 62.79% in Open Woodland on Sand, and 70.00% in Sparse Woodland on Sand). The Closed Woodland on Sand had the most species where canopy removal was > 50% (9.67% of utilised species). *Albizia versicolor* was most

Table 12: *The recent (12 months prior to the study) and old (>12 months prior to the study) canopy removal values due to elephant utilisation, as well as the overall utilisation of woody species linked to elephant utilisation, the values represent the percentage of the canopy removed or the overall utilisation of woody species by elephant action for all vegetation units combined in Tembe Elephant Park, Maputaland, northern KwaZulu-Natal, South Africa. Species are ranked by decreasing order of overall utilisation*

Utilisation rank	Recent canopy volume removal (percentage of available canopy removed)			Old canopy volume removal (percentage of available canopy removed)			Overall utilisation (percentage of trees utilised)		
1	*Phyllanthus reticulatus*		94.50	*Lannea antiscorbutica*		94.77	*Bridelia micrantha*		100.00
2	*Cladostemon kirkii*		21.63	*Albizia versicolor*	1	82.65	*Cladostemon kirkii*		100.00
3	*Cordia caffra*		17.50	*Mystroxylon aethiopicum*		73.37	*Cordia caffra*		100.00
4	*Clausena anisata*		14.97	*Dalbergia obovata*		53.27	*Lannea antiscorbutica*		100.00
5	*Tarenna supra-axilaris*		11.82	*Ptaeroxylon obliquum*		50.04	*Lantana rugosa*		100.00
6	*Vangueria infausta*		11.68	*Brachylaena discolor*		49.31	*Phyllanthus reticulatus*		100.00
7	*Erythroxylum delagoense*		10.95	*Antidesma venosum*		44.56	*Syzygium cordatum*		100.00
8	*Berchemia zeyheri*		9.68	*Leptactina delagoensis*		40.59	*Trichilia emetica*	3	87.91
9	*Chaetacme aristata*		9.22	*Ximenia caffra*		40.16	*Albizia versicolor*	1	82.95
10	*Gardenia volkensii*		8.92	*Canthium inerme*		35.73	*Ekebergia capensis*		82.76
11	*Sideroxylon inerme*		8.65	*Tarenna junodii*		29.83	*Erythroxylum emarginatum*		80.00
12	*Zanthoxylum leprieuri*		8.39	*Zanthoxylum leprieuri*		28.75	*Vitex ferruginea*		62.34
13	*Ochna barbosae*		7.72	*Ziziphus mucronata*		28.29	*Ochna arborea*		60.00
14	*Tricalysia lanceolata*		7.19	*Brachylaena elliptica*		25.92	*Gardenia volkensii*		60.00
15	*Psydrax locuples*		6.77	*Terminalia sericea*	1	24.76	*Sclerocarya birrea*	2	59.30
16	*Ziziphus mucronata*		6.77	*Erythroxylum emarginatum*		24.06	*Afzelia quanzensis*	3	58.97
17	*Erythroxylum emarginatum*		6.01	*Trichilia emetica*	3	23.28	*Ximenia caffra*		58.89
18	*Deinbollia oblongifolia*		5.68	*Kraussia floribunda*		23.17	*Manilkara discolor*		58.26
19	*Brachylaena discolor*		5.52	*Ehretia obtusiflora*		23.11	*Strychnos henningsii*		57.92
20	*Bridelia cathartica*		5.15	*Garcinia livingstonei*		22.22	*Chaetacme aristata*		57.14
21	*Lantana rugosa*		5.00	*Sclerocroton integerrimus*		22.16	*Antidesma venosum*		54.52
22	*Strychnos henningsii*		4.02	*Dovyalis longispina*		21.67	*Cassipourea mossambicensis*		51.67
23	*Garcinia livingstonei*		3.75	*Peltophorum africanum*		21.27	*Ptaeroxylon obliquum*		49.25
24	*Boscia filipes*		3.64	*Strychnos madagascariensis*	2	20.49	*Garcinia livingstonei*		48.44
25	*Ochna natalitia*		3.48	*Strychnos henningsii*		20.47	*Vangueria infausta*		47.62
26	*Albizia versicolor*	1	3.47	*Tabernaemontana elegans*		19.98	*Craibia zimmermannii*		47.09
27	*Vernonia colorata*		3.45	*Albizia adianthifolia*	1	19.70	*Warburgia salutaris*		46.67
28	*Lagynias lasiantha*		3.42	*Grewia microthyrsa*		19.51	*Wrightia natalensis*		46.12
29	*Strychnos spinosa*		3.04	*Strychnos spinosa*		19.42	*Tarenna supra-axilaris*		43.21
30	*Vitex ferruginea*		2.96	*Vernonia colorata*		18.80	*Acalypha sonderiana*		40.00
31	*Zanthoxylum capense*		2.83	*Schotia brachypetala*		18.68	*Clerodendrum glabrum*		39.40
32	*Combretum molle*	3	2.75	*Vangueria infausta*		18.57	*Lagynias lasiantha*		39.33
33	*Brachylaena elliptica*		2.75	*Hymenocardia ulmoides*	3	18.29	*Margaritaria discoidea*		37.41
34	*Leptactina delagoensis*		2.52	*Strychnos decussata*		18.05	*Strychnos decussata*		36.97
35	*Cassipourea mossambicensis*		2.46	*Commiphora neglecta*		17.78	*Acacia robusta*	3	36.65
36	*Strychnos madagascariensis*	2	2.42	*Rhus gueinzii*		17.60	*Monodora junodii*		36.58
37	*Acalypha sonderiana*		2.30	*Bridelia micrantha*		17.50	*Ziziphus mucronata*		36.51
38	*Elaeodendron transvaalense*		2.25	*Bridelia cathartica*		17.43	*Terminalia sericea*	1	36.14
39	*Afzelia quanzensis*	3	2.20	*Acalypha sonderiana*		17.43	*Vernonia colorata*		35.09
40	*Manilkara discolor*		2.13	*Ochna arborea*		16.71	*Peltophorum africanum*		34.78
41	*Schotia brachypetala*		1.98	*Pavetta gardenophylla*		15.38	*Burchellia bubalina*		34.40
42	*Euclea natalensis*		1.95	*Grewia spp.*		14.61	*Pseudobersama mossambicensis*		34.09
43	*Terminalia sericea*	1	1.91	*Monodora junodii*		14.33	*Boscia filipes*		33.80
44	*Drypetes arguta*		1.86	*Pteleopsis myrtifolia*		14.12	*Erythroxylum delagoense*		33.36
45	*Manilkara concolor*		1.78	*Wrightia natalensis*		14.11	*Tabernaemontana elegans*		33.29
46	*Trichilia emetica*	3	1.76	*Acacia gerrardii*		14.09	*Ehretia obtusiflora*		32.79
47	*Tricalysia delagoensis*		1.75	*Mundulea sericea*		13.99	*Erythrophleum lasianthum*		31.93
48	*Warburgia salutaris*		1.66	*Canthium setiflorum*		13.79	*Manilkara concolor*		30.83
49	*Suregada africana*		1.66	*Euclea divinorum*		13.16	*Tricalysia delagoensis*		30.24
50	*Margaritaria discoidea*		1.64	*Ochna natalitia*		12.95	*Grewia microthyrsa*		29.99
51	*Acacia gerrardii*		1.61	*Dialium schlechteri*	2	12.69	*Pteleopsis myrtifolia*		29.68
52	*Syzygium cordatum*		1.54	*Sideroxylon inerme*		12.34	*Bridelia cathartica*		29.17
53	*Burchellia bubalina*		1.44	*Cassipourea mossambicensis*		12.29	*Cleistanthus schlechteri*		27.32
54	*Hymenocardia ulmoides*	3	1.30	*Combretum molle*	3	12.23	*Balanites maughamii*		27.28
55	*Sclerocarya birrea*	2	1.28	*Cola greenwayi*		12.05	*Suregada africana*		26.67
56	*Antidesma venosum*		1.24	*Acacia nilotica*		12.05	*Sideroxylon inerme*		26.55
57	*Sclerocroton integerrimus*		1.20	*Euclea natalensis*		11.27	*Strychnos spinosa*		26.50
58	*Canthium setiflorum*		1.15	*Syzigium cordatum*		11.13	*Combretum molle*	3	26.10
59	*Hyphaene coriacea*		1.14	*Erythrophleum lasianthum*		11.07	*Sclerocroton integerrimus*		25.75
60	*Diospyros inhacaensis*		1.10	*Vitex ferruginea*		10.91	*Erythrococca berberidae*		25.10
61	*Haplocoelum foliolosum*		1.04	*Chaetacme aristata*		10.55	*Rothmania fischeri*		25.00
62	*Rhus gueinzii*		1.00	*Acacia robusta*	3	10.38	*Eugenia natalitia*		25.00
63	*Hyperacanthus microphyllus*		0.93	*Acacia burkei*	2	10.16	*Tarenna junodii*		24.87
64	*Cola greenwayi*		0.91	*Elaeodendron transvalense*		10.04	*Strychnos gerrardii*		24.87
65	*Grewia microthyrsa*		0.91	*Cleistanthus schlechteri*		10.03	*Hymenocardia ulmoides*	3	24.85
66	*Pseudobersama mossambicensis*		0.90	*Sclerocarya birrea*	2	9.79	*Combretum celastroides*		23.98

Table 12 continued

67	*Toddaliopsis bremekampii*		0.89	*Psydrax locuples*		9.07	*Mystroxylon aethiopicum*		23.63
68	*Strychnos gerrardii*		0.85	*Erythroxylum delagoense*		9.01	*Acacia burkei*	2	23.51
69	*Dichrostachys cinerea*		0.79	*Dichrostachys cinerea*		8.96	*Tricalysia lanceolata*		23.24
70	*Monodora junodii*		0.77	*Hyphaene coriacea*		8.74	*Brachylaena huillensis*		22.98
71	*Dialium schlechteri*	2	0.77	*Erythrococca berberidae*		8.56	*Leptactina delagoensis*		22.69
72	*Psydrax obovata*		0.77	*Diospyros inhacaensis*		8.52	*Psydrax obovata*		22.22
73	*Ximenia caffra*		0.75	*Drypetes arguta*		8.06	*Haplocoelum foliolosum*		22.13
74	*Canthium armatum*		0.70	*Tricalysia delagoensis*		8.00	*Dialium schlechteri*	2	22.11
75	*Tabernaemontana elegans*		0.69	*Brachylaena huillensis*		7.43	*Albizia adianthifolia*	1	20.93
76	*Acacia burkei*	2	0.60	*Boscia filipes*		7.34	*Strychnos madagascariensis*	2	20.60
77	*Brachylaena huillensis*		0.56	*Ekebergia capensis*		6.82	*Diospyros inhacaensis*		20.18
78	*Ptaeroxylon obliquum*		0.56	*Balanites maughamii*		6.71	*Acacia nilotica*		20.16
79	*Commiphora neglecta*		0.55	*Pseudobersama mossambicensis*		6.43	*Schotia brachypetala*		18.82
80	*Erythrococca berberidae*		0.53	*Combretum celastroides*		6.41	*Commiphora neglecta*		18.75
81	*Catunaregam taylori*		0.51	*Spirostachys africana*	3	6.31	*Suregada zanzibariensis*		16.51
82	*Spirostachys africana*	3	0.47	*Haplocoelum foliolosum*		5.99	*Newtonia hildebrandtii*		16.03
83	*Acalypha glabrata*		0.46	*Burchellia bubalina*		5.70	*Cola greenwayi*		16.01
84	*Coddia rudis*		0.45	*Lagynias lasiantha*		5.64	*Rhus gueinzii*		15.89
85	*Vepris lanceolata*		0.43	*Afzelia quanzensis*	3	5.57	*Elaeodendron croceum*		15.87
86	*Dalbergia obovata*		0.43	*Psydrax obovata*		5.34	*Drypetes arguta*		15.83
87	*Rothmannia fischeri*		0.35	*Tricalysia lanceolata*		5.25	*Grewia spp.*		14.93
88	*Pavetta lanceolata*		0.28	*Drypetes natalensis*		5.16	*Toddaliopsis bremekampii*		14.71
89	*Wrightia natalensis*		0.28	*Salacia leptoclada*		4.89	*Acacia gerrardii*		14.59
90	*Croton pseudopulchellus*		0.28	*Manilkara discolor*		4.52	*Drypetes natalensis*		14.27
91	*Acacia robusta*	3	0.27	*Uvaria lucida*		4.22	*Spirostachys africana*	3	13.60
92	*Balanites maughamii*		0.22	*Toddaliopsis bremekampii*		4.16	*Canthium setiflorum*		12.81
93	*Suregada zanzibariensis*		0.14	*Newtonia hildebrandtii*		4.16	*Kraussia floribunda*		12.60
94	*Tricalysia junodii*		0.13	*Clerodendrum glabrum*		4.13	*Elaeodendron transvalense*		12.00
95	*Pteleopsis myrtifolia*		0.11	*Strychnos gerrardii*		4.03	*Canthium armatum*		11.95
96	*Strychnos decussata*		0.09	*Zanthoxylum capense*		3.95	*Uvaria lucida*		11.45
97	*Grewia spp.*		0.04	*Suregada africana*		3.78	*Psydrax locuples*		10.68
98	*Mundulea sericea*		0.03	*Catunaregam taylori*		3.58	*Vepris lanceolata*		10.46
99	*Cleistanthus schlechteri*		0.02	*Ochna barbosae*		3.26	*Canthium inerme*		10.00
100	*Drypetes natalensis*		0.01	*Manilkara concolor*		3.03	*Ochna barbosae*		9.95
101	*Erythrophleum lasianthum*		0.00	*Margaritaria discoidea*		2.93	*Zanthoxylum capense*		9.94
102	*Uvaria lucida*		0.00	*Croton pseudopulchellus*		2.65	*Mundulea sericea*		9.92
103				*Canthium armatum*		2.37	*Uvaria caffra*		8.63
104				*Hyperacanthus microphyllus*		2.05	*Berchemia zeyheri*		8.33
105				*Uvaria caffra*		2.02	*Hyphaene coriacea*		8.14
106				*Gardenia volkensii*		1.96	*Dichrostachys cinerea*		7.78
107				*Ozoroa englerii*		1.93	*Acalypha glabrata*		7.60
108				*Suregada zanzibariensis*		1.79	*Hyperacanthus microphyllus*		7.32
109				*Eugenia natalitia*		1.75	*Euclea natalensis*		7.12
110				*Berchemia zeyheri*		1.75	*Clausena anisata*		6.36
111				*Craibia zimmermannii*		1.73	*Ochna natalitia*		5.86
112				*Tarenna supra-axilaris*		1.63	*Pavetta lanceolata*		5.18
113				*Vepris lanceolata*		1.58	*Brachylaena elliptica*		5.03
114				*Acalypha glabrata*		1.49	*Croton pseudopulchellus*		4.95
115				*Rothmania fischeri*		1.07	*Brachylaena discolor*		4.60
116				*Clausena anisata*		1.01	*Combretum mkuzense*		4.49
117				*Coddia rudis*		0.79	*Ozoroa englerii*		4.19
118				*Elaeodendron croceum*		0.61	*Euclea divinorum*		3.75
119				*Warburgia salutaris*		0.21	*Salacia leptoclada*		3.07
120				*Combretum mkuzense*		0.03	*Dalbergia obovata*		2.58
121							*Coddia rudis*		2.34
122							*Zanthoxylum leprieuri*		1.88
123							*Pavetta gardenophylla*		1.69
124							*Dovyalis longispina*		1.65
125							*Deinbollia oblongifolia*		1.36
126							*Catunaregam taylori*		0.75
127							*Tricalysia junodii*		0.53

Note: the values in the highlighted boxes to the right of the species names represent the rankings of overall woody species utilisation in the form of canopy removal from elephant observed by Matthews and Page (In prep) during a similar study conducted in 1994. Species were ranked in three groups based on the canopy volume removal observed at that stage, a rank of 1 was given to species where canopy volume removal was ≥ 50%, a rank of 2 was given to species where observed canopy removal varied from ≥ 25% to 49%, while a rank of 3 represented species where observed canopy removal ranged from ≥ 10% to 24%. The bold lines in the column separate these groups in the current sample.

Table 13: *The recent (within 12 months prior to the study) woody species canopy volume removal linked to elephant utilisation observed in the Sand Forest association of Tembe Elephant Park, Maputaland, northern KwaZulu-Natal, South Africa, in 2004. The woody species are ranked by canopy volume removal intensity at the vegetation unit level*

Utilisation rank	Recent canopy removal in the *Afzelia quanzensis* clumps (percentage of available canopy removed)		Recent canopy removal in the Short Sand Forest (percentage of available canopy removed)		Recent canopy removal in the Intermediate Sand Forest (percentage of available canopy removed)		Recent canopy removal in the Tall Sand Forest (percentage of available canopy removed)	
1	*Tabernaemontana elegans*	3.53	*Tricalysia lanceolata*	15.09	*Boscia filipes*	5.38	*Erythroxylum emarginatum*	37.50
2	*Ochna barbosae*	3.40	*Leptactina delagoensis*	8.41	*Strychnos henningsii*	4.86	*Tarenna supra-axilaris*	37.50
3			*Tricalysia delagoensis*	3.97	*Burchellia bubalina*	3.28	*Psydrax locuples*	37.46
4			*Lagynias lasiantha*	3.19	*Cassipourea mossambicensis*	2.88	*Cladostemon kirkii*	21.63
5			*Manilkara discolor*	2.94	*Manilkara discolor*	1.95	*Lagynias lasiantha*	14.44
6			*Psydrax obovata*	2.37	*Hymenocardia ulmoides*	1.72	*Tricalysia lanceolata*	7.33
7			*Cassipourea mossambicensis*	2.34	*Grewia microthyrsa*	1.46	*Cola greenwayi*	7.28
8			*Tarenna supra-axilaris*	2.17	*Drypetes arguta*	1.45	*Drypetes arguta*	6.85
9			*Strychnos henningsii*	1.91	*Haplocoelum foliolosum*	1.35	*Vepris lanceolata*	6.13
10			*Drypetes arguta*	1.57	*Tricalysia delagoensis*	1.19	*Toddaliopsis bremekampii*	5.07
11			*Suregada zanzibariensis*	1.47	*Pseudobersama mossambicensis*	0.90	*Strychnos gerrardii*	5.00
12			*Brachylaena huillensis*	0.68	*Toddaliopsis bremekampii*	0.74	*Manilkara concolor*	4.75
13			*Cola greenwayi*	0.66	*Suregada zanzibariensis*	0.48	*Leptactina delagoensis*	4.54
14			*Pavetta lanceolata*	0.35	*Brachylaena huillensis*	0.44	*Strychnos henningsii*	3.37
15			*Vitex ferruginea*	0.13	*Cola greenwayi*	0.42	*Hymenocardia ulmoides*	2.19
16			*Croton pseudopulchellus*	0.09	*Tricalysia junodii*	0.37	*Ptaeroxylon obliquum*	0.77
17			*Hymenocardia ulmoides*	0.08	*Wrightia natalensis*	0.29	*Acalypha glabrata*	0.23
18					*Dialium schlechteri*	0.24		
19					*Croton pseudopulchellus*	0.20		
20					*Pavetta lanceolata*	0.14		
21					*Balanites maughamii*	0.14		
22					*Pteleopsis myrtifolia*	0.05		
23					*Cleistanthus schlechteri*	0.03		
24					*Drypetes natalensis*	0.02		
25					*Strychnos decussata*	0.02		
26					*Erythrophleum lasianthum*	0.01		

Table 14: *The old (more than 12 months prior to the study) woody species canopy volume removal linked to elephant utilisation observed in the Sand Forest association of Tembe Elephant Park, Maputaland, northern KwaZulu-Natal, South Africa, in 2004. The woody species are ranked by canopy volume removal intensity at the vegetation unit level*

Utilisation	Old canopy removal in the		Old canopy removal in the		Old canopy removal in the		Old canopy removal in the	
	Afzelia quanzensis clumps		Short Sand Forest		Intermediate Sand Forest		Tall Sand Forest	
rank	(percentage of available canopy removed)		(percentage of available canopy removed)		(percentage of available canopy removed)		(percentage of available canopy removed)	
1	*Sclerocroton integerrimus*	37.50	*Tarenna junodii*	94.50	*Leptactina delagoensis*	58.56	*Ekebergia capensis*	94.50
2	*Boscia filipes*	17.50	*Uvaria caffra*	82.50	*Erythroxylum emarginatum*	37.50	*Ptaeroxylon obliquum*	77.15
3	*Manilkara concolor*	17.50	*Monodora junodii*	37.84	*Strychnos decussata*	34.97	*Schotia brachypetala*	76.56
4	*Vepris lanceolata*	0.45	*Newtonia hildebrandtii*	37.50	*Grewia microthyrsa*	30.48	*Tricalysia delagoensis*	62.50
5			*Strychnos decussata*	24.52	*Cassipourea mossambicensis*	24.77	*Boscia filipes*	61.84
6			*Strychnos henningsii*	22.96	*Strychnos henningsii*	21.15	*Haplocoelum foliolosum*	60.54
7			*Cleistanthus schlechteri*	18.78	*Hymenocardia ulmoides*	20.54	*Balanites maughamii*	22.17
8			*Ochna natalitia*	18.73	*Tricalysia lanceolata*	19.61	*Pteleopsis myrtifolia*	20.90
9			*Vitex ferruginea*	17.83	*Dialium schlechteri*	17.70	*Ochna arborea*	17.48
10			*Combretum celastroides*	17.50	*Suregada zanzibariensis*	17.12	*Strychnos decussata*	17.06
11			*Boscia filipes*	16.68	*Ptaeroxylon obliquum*	16.01	*Strychnos henningsii*	15.92
12			*Ptaeroxylon obliquum*	16.66	*Brachylaena huillensis*	14.71	*Drypetes arguta*	11.95
13			*Pteleopsis myrtifolia*	15.30	*Wrightia natalensis*	14.38	*Psydrax obovata*	9.75
14			*Tricalysia lanceolata*	13.24	*Pteleopsis myrtifolia*	12.96	*Cola greenwayi*	6.58
15			*Erythrophleum lasianthum*	12.89	*Monodora junodii*	12.35	*Acalypha glabrata*	5.97
16			*Cola greenwayi*	12.82	*Cola greenwayi*	12.29	*Manilkara concolor*	5.00
17			*Drypetes natalensis*	12.56	*Burchellia bubalina*	11.18	*Cleistanthus schlechteri*	4.86
18			*Dialium schlechteri*	11.78	*Salacia leptoclada*	10.79	*Leptactina delagoensis*	4.78
19			*Hymenocardia ulmoides*	10.83	*Tricalysia delagoensis*	7.78	*Monodora junodii*	4.48
20			*Lagynias lasiantha*	10.75	*Cleistanthus schlechteri*	7.27	*Hymenocardia ulmoides*	2.52
21			*Drypetes arguta*	10.40	*Haplocoelum foliolosum*	7.22	*Toddaliopsis bremekampii*	0.80
22			*Toddaliopsis bremekampii*	5.17	*Drypetes arguta*	6.45	*Salacia leptoclada*	0.16
23			*Cassipourea mossambicensis*	5.00	*Pseudobersama mossambicensis*	6.43	*Strychnos gerrardii*	0.05
24			*Wrightia natalensis*	4.75	*Combretum celastroides*	5.82		
25			*Grewia microthyrsa*	4.64	*Psydrax obovata*	5.68		
26			*Manilkara discolor*	4.58	*Uvaria lucida*	4.84		
27			*Psydrax obovata*	4.26	*Manilkara discolor*	4.17		
28			*Croton pseudopulchellus*	3.74	*Toddaliopsis bremekampii*	3.92		
29			*Salacia leptoclada*	2.67	*Erythrophleum lasianthum*	3.40		
30			*Tarenna supra-axilaris*	2.28	*Boscia filipes*	3.07		
31			*Combretum molle*	1.62	*Drypetes natalensis*	3.05		
32			*Burchellia bubalina*	1.39	*Hyperacanthus microphyllus*	2.83		
33			*Psydrax locuples*	1.39	*Vitex ferruginea*	2.07		
34			*Uvaria lucida*	1.29	*Eugenia natalitia*	1.75		
35			*Haplocoelum foliolosum*	1.25	*Uvaria caffra*	1.04		
36			*Balanites maughamii*	0.76	*Croton pseudopulchellus*	0.95		
37			*Brachylaena huillensis*	0.72	*Newtonia hildebrandtii*	0.85		
38			*Vepris lanceolata*	0.72				
39			*Acalypha glabrata*	0.35				

Table 15: The recent (within 12 months prior to the study) woody species canopy volume removal linked to elephant utilisation observed in the Woodland association of Tembe Elephant Park, northern Maputaland, KwaZulu-Natal, South Africa, in 2004. The woody species are ranked by canopy volume removal intensity at the vegetation unit level.

Utilisation rank	Recent canopy removal in the Closed Woodland Thicket (percentage of available canopy removed)		Recent canopy removal in the Closed Woodland on Clay (percentage of available canopy removed)		Recent canopy removal in the Closed Woodland on Sand (percentage of available canopy removed)		Recent canopy removal in the Open Woodland on Sand (percentage of available canopy removed)		Recent canopy removal in the Sparse Woodland on Sand (percentage of available canopy removed)	
1	*Grewia microthyrsa*	17.26	*Phyllanthus reticulatus*	94.50	*Brachylaena discolor*	58.13	*Commiphora neglecta*	26.90	*Dichrostachys cinerea*	0.72
2	*Afzelia quanzensis*	11.56	*Vitex ferruginea*	31.94	*Albizia versicolor*	21.99	*Cordia caffra*	17.50	*Terminalia sericea*	0.58
3	*Rothmania fischeri*	5.00	*Monodora junodii*	25.50	*Gardenia volkensii*	18.74	*Canthium setiflorum*	14.23	*Acacia burkei*	0.52
4	*Sclerocroton integerrimus*	2.50	*Clausena anisata*	20.08	*Ochna barbosae*	16.41	*Vangueria infausta*	10.91	*Strychnos spinosa*	0.30
5			*Vangueria infausta*	19.36	*Antidesma venosum*	15.77	*Brachylaena elliptica*	9.06		
6			*Erythroxylum delagoense*	18.43	*Chaetacme aristata*	14.67	*Zanthoxylum leprieuri*	8.77		
7			*Ochna barbosae*	12.73	*Hyperacanthus microphyllus*	10.30	*Acacia gerrardii*	7.31		
8			*Hyphaene coriacea*	11.15	*Vernonia colorata*	9.08	*Garcinia livingstonei*	7.28		
9			*Ochna natalitia*	10.05	*Sideroxylon inerme*	8.84	*Syzigium cordatum*	4.51		
10			*Berchemia zeyheri*	9.68	*Deinbollia oblongifolia*	8.41	*Dalbergia obovata*	2.99		
11			*Ptaeroxylon obliquum*	9.57	*Bridelia cathartica*	7.69	*Afzelia quanzensis*	2.99		
12			*Psydrax locuples*	8.77	*Balanites maughamii*	7.44	*Bridelia cathartica*	2.49		
13			*Ziziphus mucronata*	8.36	*Terminalia sericea*	7.04	*Vepris lanceolata*	2.36		
14			*Sclerocroton integerrimus*	7.53	*Strychnos spinosa*	5.89	*Acacia robusta*	2.29		
15			*Strychnos madagascariensis*	6.47	*Combretum molle*	5.80	*Ziziphus mucronata*	2.15		
16			*Euclea natalensis*	6.42	*Vangueria infausta*	5.19	*Strychnos madagascariensis*	1.72		
17			*Combretum molle*	6.10	*Erythroxylum delagoense*	4.34	*Terminalia sericea*	1.64		
18			*Pteleopsis myrtifolia*	5.77	*Ximenia caffra*	4.19	*Trichilia emetica*	1.41		
19			*Garcinia livingstonei*	5.40	*Psydrax locuples*	3.51	*Hymenocardia ulmoides*	1.07		
20			*Lantana rugosa*	5.00	*Dialium schlechteri*	3.03	*Antidesma venosum*	0.99		
21			*Zanthoxylum capense*	4.52	*Strychnos madagascariensis*	2.46	*Euclea natalensis*	0.83		
22			*Dialium schlechteri*	4.18	*Trichilia emetica*	2.37	*Sclerocarya birrea*	0.81		
23			*Diospyros inhacaensis*	4.15	*Acalypha sonderiana*	2.30	*Sclerocroton integerrimus*	0.74		
24			*Rhus gueinzii*	4.02	*Zanthoxylum capense*	2.23	*Combretum molle*	0.71		
25			*Sclerocarya birrea*	3.82	*Margaritaria discoidea*	1.78	*Strychnos spinosa*	0.57		
26			*Afzelia quanzensis*	3.54	*Afzelia quanzensis*	1.73	*Acacia burkei*	0.32		
27			*Tarenna supra-axilaris*	3.13	*Acacia burkei*	1.50	*Brachylaena discolor*	0.19		
28			*Haplocoelum foliolosum*	3.12	*Hymenocardia ulmoides*	1.24	*Catunaregam taylori*	0.11		
29			*Strychnos spinosa*	3.05	*Tabernaemontana elegans*	0.93	*Dichrostachys cinerea*	0.09		
30			*Croton pseudopulchellus*	2.94	*Canthium armatum*	0.78	*Albizia versicolor*	0.08		

Table 15 continued

31	*Manilkara discolor*	2.67	*Sclerocroton integerrimus*	0.74	*Mundulea sericea*	0.05
32	*Dichrostachys cinerea*	2.40	*Tricalysia lanceolata*	0.69		
33	*Elaeodendron transvalense*	2.27	*Tricalysia delagoensis*	0.53		
34	*Schotia brachypetala*	2.04	*Ziziphus mucronata*	0.41		
35	*Suregada africana*	1.72	*Spirostachys africana*	0.32		
36	*Warburgia salutaris*	1.66	*Strychnos decussata*	0.28		
37	*Vernonia colorata*	1.19	*Dichrostachys cinerea*	0.13		
38	*Catunaregam taylori*	1.15	*Vepris lanceolata*	0.13		
39	*Coddia rudis*	1.08	*Euclea natalensis*	0.04		
40	*Bridelia cathartica*	0.81	*Dalbergia obovata*	0.01		
41	*Vepris lanceolata*	0.69				
42	*Balanites maughamii*	0.66				
43	*Spirostachys africana*	0.59				
44	*Erythrococca berberidae*	0.57				
45	*Acacia burkei*	0.56				
46	*Acacia gerrardii*	0.54				
47	*Acalypha glabrata*	0.52				
48	*Terminalia sericea*	0.51				
49	*Canthium armatum*	0.45				
50	*Toddaliopsis bremekampii*	0.36				
51	*Tabernaemontana elegans*	0.21				
52	*Acacia robusta*	0.17				
53	*Suregada zanzibariensis*	0.09				
54	*Grewia spp.*	0.04				

Table 16: The old (more than 12 months prior to the study) woody species canopy volume removal linked to elephant utilisation observed in the Woodland association of Tembe Elephant Park, northern Maputaland, KwaZulu-Natal, South Africa, in 2004. The woody species are ranked by canopy volume removal intensity at the vegetation unit level.

Utilisation rank	Recent canopy removal in the Closed Woodland Thicket (percentage of available canopy removed)		Recent canopy removal in the Closed Woodland on Clay (percentage of available canopy removed)		Recent canopy removal in the Closed Woodland on Sand (percentage of available canopy removed)		Recent canopy removal in the Open Woodland on Sand (percentage of available canopy removed)		Recent canopy removal in the Sparse Woodland on Sand (percentage of available canopy removed)	
1	*Terminalia sericea*	76.22	*Mystroxylon aethiopicum*	80.09	*Albizia versicolor*	95.25	*Albizia versicolor*	70.87	*Vangueria infausta*	62.50
2	*Rhus gueinzii*	72.94	*Toddaliopsis bremekampii*	44.84	*Lannea antiscorbutica*	94.77	*Ximenia caffra*	70.64	*Strychnos spinosa*	61.40
3	*Albizia adianthifolia*	19.74	*Haplocoelum foliolosum*	37.40	*Terminalia sericea*	66.65	*Antidesma venosum*	45.33	*Terminalia sericea*	30.36
4	*Psydrax locuples*	18.36	*Trichilia emetica*	36.31	*Strychnos gerrardii*	64.74	*Trichilia emetica*	41.42	*Strychnos madagascariensis*	23.09
5	*Sclerocroton integerrimus*	16.33	*Grewia microthyrsa*	35.38	*Manilkara discolor*	62.50	*Canthium inerme*	37.49	*Ximenia caffra*	21.44
6	*Tabernaemontana elegans*	7.37	*Albizia versicolor*	34.91	*Dalbergia obovata*	62.10	*Zanthoxylum leprieuri*	30.06	*Albizia adianthifolia*	17.50
7	*Afzelia quanzensis*	5.29	*Manilkara discolor*	34.82	*Vangueria infausta*	49.39	*Ziziphus mucronata*	29.66	*Syzygium cordatum*	14.44
8	*Sclerocarya birrea*	4.51	*Pteleopsis myrtifolia*	32.99	*Cassipourea mossambicensis*	44.82	*Strychnos madagascariensis*	22.70	*Dialium schlechteri*	9.16
9	*Combretum molle*	1.89	*Ziziphus mucronata*	29.55	*Hymenocardia ulmoides*	44.27	*Acacia gerrardii*	22.65	*Acacia burkei*	0.32
10			*Elaeodendron croceum*	27.47	*Dovyalis longispina*	43.93	*Strychnos spinosa*	21.74	*Dichrostachys cinerea*	0.12
11			*Chaetacme aristata*	26.41	*Balanites maughamii*	37.48	*Peltophorum africanum*	21.37		
12			*Terminalia sericea*	24.73	*Brachylaena elliptica*	37.39	*Strychnos decussata*	19.36		
13			*Ehretia obtusiflora*	24.59	*Schotia brachypetala*	37.07	*Garcinia livingstonei*	18.19		
14			*Strychnos spinosa*	21.03	*Mystroxylon aethiopicum*	36.83	*Albizia adianthifolia*	18.01		
15			*Strychnos madagascariensis*	19.68	*Mundulea sericea*	35.05	*Rothmania fischeri*	17.50		
16			*Schotia brachypetala*	17.70	*Hyphaene coriacea*	32.56	*Bridelia micrantha*	17.50		
17			*Erythroxylum delagoense*	17.51	*Sclerocroton integerrimus*	30.22	*Vangueria infausta*	17.13		
18			*Cassipourea mossambicensis*	17.50	*Garcinia livingstonei*	27.21	*Terminalia sericea*	16.81		
19			*Euclea natalensis*	16.55	*Croton pseudopulchellus*	25.88	*Sclerocarya birrea*	16.21		
20			*Vernonia colorata*	16.31	*Kraussia floribunda*	25.85	*Sclerocroton integerrimus*	16.05		
21			*Grewia spp.*	14.96	*Tabernaemontana elegans*	25.68	*Acacia robusta*	14.83		
22			*Sclerocarya birrea*	14.66	*Vernonia colorata*	25.03	*Afzelia quanzensis*	14.07		
23			*Euclea divinorum*	13.16	*Diospyros inhacaensis*	23.84	*Dialium schlechteri*	13.79		
24			*Tabernaemontana elegans*	12.73	*Bridelia cathartica*	23.18	*Spirostachys africana*	13.36		
25			*Acacia gerrardii*	12.50	*Dichrostachys cinerea*	22.90	*Combretum molle*	12.58		
26			*Vangueria infausta*	12.43	*Rhus gueinzii*	22.36	*Tabernaemontana elegans*	11.72		
27			*Acacia robusta*	12.43	*Cola greenwayi*	20.94	*Psydrax locuples*	10.30		
28			*Boscia filipes*	12.41	*Pavetta gardenophylla*	20.38	*Acacia burkei*	8.25		
29			*Acacia burkei*	12.33	*Commiphora neglecta*	18.57	*Dichrostachys cinerea*	7.16		
30			*Acacia nilotica*	12.05	*Ozoroa englerii*	18.27	*Syzygium cordatum*	4.75		

Table 16 continued

31	*Combretum molle*	12.05	*Acalypha sonderiana*	17.43	*Hymenocardia ulmoides*	4.68
32	*Zanthoxylum capense*	11.83	*Strychnos spinosa*	17.32	*Grewia microthyrsa*	4.16
33	*Bridelia cathartica*	10.64	*Strychnos madagascariensis*	16.21	*Gardenia volkensii*	3.75
34	*Elaeodendron transvalense*	10.12	*Canthium setiflorum*	15.36	*Brachylaena discolor*	2.59
35	*Psydrax locuples*	10.09	*Acacia burkei*	15.09	*Mundulea sericea*	2.01
36	*STRY SPEC*	9.75	*Combretum molle*	15.03	*Euclea natalensis*	1.78
37	*Erythrococca berberidae*	9.19	*Ochna barbosae*	13.54	*Bridelia cathartica*	1.50
38	*Catunaregam taylori*	8.67	*Ziziphus mucronata*	13.17	*Vepris lanceolata*	1.44
39	*Garcinia livingstonei*	6.55	*Euclea natalensis*	13.06	*Combretum mkuzense*	0.96
40	*Ochna natalitia*	6.33	*Psydrax locuples*	13.03	*Ozoroa englerii*	0.90
41	*Croton pseudopulchellus*	5.90	*Ximenia caffra*	12.84	*Pteleopsis myrtifolia*	0.87
42	*Spirostachys africana*	5.84	*Sideroxylon inerme*	12.58	*Rhus gueinzii*	0.84
43	*Afzelia quanzensis*	5.72	*Trichilia emetica*	10.96	*Commiphora neglecta*	0.02
44	*Dichrostachys cinerea*	5.51	*Tricalysia delagoensis*	8.15		
45	*Ochna barbosae*	5.26	*Acacia robusta*	6.09		
46	*Ptaeroxylon obliquum*	4.88	*Lagynias lasiantha*	5.27		
47	*Balanites maughamii*	4.59	*Spirostachys africana*	3.82		
48	*Clerodendrum glabrum*	4.50	*Afzelia quanzensis*	3.75		
49	*Hymenocardia ulmoides*	4.40	*Margaritaria discoidea*	3.18		
50	*Dialium schlechteri*	4.17	*Albizia adianthifolia*	2.74		
51	*Suregada africana*	3.92	*Canthium armatum*	2.44		
52	*Strychnos decussata*	2.59	*Dialium schlechteri*	2.06		
53	*Canthium armatum*	2.34	*Vepris lanceolata*	1.90		
54	*Sclerocroton integerrimus*	2.23	*Craibia zimmermannii*	1.74		
55	*Rhus gueinzii*	2.19	*Erythroxylum delagoense*	1.43		
56	*Tarenna supra-axilaris*	2.03	*Chaetacme aristata*	1.22		
57	*Coddia rudis*	1.87	*Tricalysia lanceolata*	1.05		
58	*Sideroxylon inerme*	1.87	*Strychnos decussata*	0.91		
59	*Berchemia zeyheri*	1.75	*Sclerocarya birrea*	0.78		
60	*Clausena anisata*	1.35	*Zanthoxylum capense*	0.65		
61	*Acalypha glabrata*	1.01	*Rothmania fischeri*	0.57		
62	*Vepris lanceolata*	0.82	*Grewia microthyrsa*	0.17		
63	*Warburgia salutaris*	0.21				

heavily utilised in the Closed and Open Woodlands on Sand (> 70.00% canopy removal)

Discussion

The degree of utilisation of the vegetation by browsers in Tembe Elephant Park was rather intense. While elephant utilisation of trees is easily observed and has previously been recorded (Van Rensburg *et al.* 2000; Matthews 2006; Guldemond and Van Aarde In Press), browsing by medium and small herbivores in Tembe Elephant Park was equally intense, if not more so in some instances. However, with regards to canopy removal, there is a major difference in the way the agents affect the vegetation. While medium and small browsers utilise many of the available height classes, their actions leave little durable signs of utilisation as demonstrated by the decrease in old damage marks. The more permanent marks were some broken branches from animals such as kudu or nyala (van Eeden 2005). Elephants on the other hand leave a long-lasting mark on the vegetation. Elephants usually defoliate by breaking branches, and sometimes by breaking secondary or main stems, or even uprooting whole trees (O'Connor *et al.* 2007). These marks accumulate over time as evidenced by the higher percentage of height classes utilised in the old canopy removal.

In all Woodland vegetation units and to a lesser extent in the Sand Forest association, small and medium browsers utilised all individuals in a sizeable portion of the available height classes. Considering the size of these browsers, it is most likely that the height classes completely utilised are the smaller ones, especially those important for recruitment, such as seedlings and saplings. This could potentially limit future recruitment of woody species (Shaw *et al.* 2002; Western and Maitumo 2004), although the present study is not in measure to prove it.

The interesting question from the above is whether the utilisation levels are sustainable or not. Other studies have shown that herbivory by small mammals is usually not a limiting factor, although it may slow down regeneration in cases of high densities (Barnes 2001; Walpole *et al.* 2004; Western and Maitumo 2004). In Kenya, in the Masaai Mara National Reserve, 73% of woody species were utilised by small browsers, and although they were not believed to have an effect on regeneration, they were thought to be responsible for changes in species abundance, by facilitating some invasive species (Walpole *et al.* 2004). The levels of overall utilisation by small and medium browsers in Tembe Elephant Park are approaching such values, and therefore the risk that further small and medium browser population increases would lead to homogenisation of some vegetation units cannot be discarded. The homogenisation of

Open Woodlands through elephant action in Tembe Elephant Park is discussed by (Guldemond 2006) and the present study contends that this process could be aided by the current level of herbivory by small browsers.

Elephant utilisation, as is well known, can be destructive (O'Connor *et al.* 2007; Van Aarde and Jackson 2007). Elephants can shape landscapes and modify the ecological balance of an environment by removing trees, thus creating conditions more suitable for the herbaceous layer, which in turn becomes more fire-prone (Western and Maitumo 2004; Birkett and Stevens-Wood 2005; O'Connor *et al.* 2007). The implications of elephant utilisation are far reaching and need to be evaluated carefully when an environment has specific conservation needs. In the present study, elephants have removed some height classes for selected species completely. Unless the tree is completely uprooted and utilised, most tree species recover from the utilisation event, either by re-sprouting or coppicing. In time, the material removed during the utilisation event is usually replaced. A problem occurs when a subsequent utilisation happens before the previous one has been completely replaced. In that situation, the tree is under greater stress, and if the utilisation is repeated regularly, hedging occurs. The tree can be prevented from producing flowers and fruits in the normal way, and due to its reduced size, it becomes more susceptible to utilisation by other browsers or damage from fire (Styles and Skinner 2000; Barnes 2001; Bond and Loffell 2001; Birkett and Stevens-Wood 2005).

In the forest and possibly a closed woodland environment, canopy gaps are a driving mechanism for succession and are usually created through natural damage such as wind, lightning, or the fall of a large old tree (Brokaw and Busing 2000; Paul *et al.* 2004; Karlowski 2006). Depending on the size of the gap, it is subsequently re-colonised by pioneer or late secondary species favoured by the access to light (Babaasa *et al.* 2004; Karlowski 2006). In the case of Sand Forest, the constant occurrence of small canopy gaps is thought to be the way Sand Forest regenerates (Matthews 2006), and the sensitivity of Sand Forest is such that large gaps are thought to favour re-growth of a suite of species different from Sand Forest (Matthews 2006). Elephants are able to remove height classes of tall trees by pushing them over. Although the action can be likened to gap creation (O'Connor *et al.* 2007), the main difference lies in the frequency of the event. The present study shows that the scars of elephant utilisation events accumulate, or in other words that the interval between events is insufficient for the plants to recover. The elephant population in Tembe Elephant Park grows at a rate of 4.6% per year (Morley 2005), and unless management decisions are taken, the population will continue to grow until it supposedly regulates itself (Van Aarde *et al.* 1999; Van Aarde and Jackson 2007). However, the level of self-regulation for Tembe Elephant Park is yet unknown. The present study therefore assumes that the elephant population will continue to grow, especially as the environment is suitable for young elephant growth (Mosugelo *et al.* 2002; Stokke and du Toit 2002; Smit *et al.* In Press), and becomes even more suitable as adult elephants push over more trees and stimulate re-growth at a low level (Stokke and du Toit 2002). With the current indication that utilisation events accumulate, and the above assumption with regards to elephant population growth, it appears straightforward that utilisation of vegetation by elephants will increase, and will become a problem as described for other areas (Western and Maitumo 2004; Van Aarde and Jackson 2007), if it has not already.

In an unfenced environment as idealised by the metapopulation concept, natural migratory movements of animal populations, following rainfall and food availability, should avail plants time to recover after an utilisation event (Van Aarde and Jackson 2007). Likewise, low animal population numbers should ensure that repeated use should be a rare event, and not the norm. However, in Tembe Elephant Park, the fences have restricted such migratory movements for elephants, and the size of the park does not allow simulated migratory movements for elephants (Van Aarde and Jackson 2007). It therefore appears logical that repeated utilisation events would occur. The implications in Tembe Elephant Park, especially in the Sand Forest, are that an abnormally high rate of canopy gaps are created, which is considered a threat to the Sand Forest conservation (Matthews 2006). Elephant damage in the woodland environment will probably lead to a succession towards a grassland environment. Elephant impact on woodlands in Tembe Elephant Park showed that elephants created a more heterogeneous Closed Woodland environment but homogenised the Open Woodland with a risk of forcing a succession towards Sparse Woodland (Guldemond and Van Aarde In Press). This risk is increased in Tembe Elephant Park by the presence of smaller browsers. Similar conditions have been shown to facilitate the succession from woodland to grassland in East Africa (Western and Maitumo 2004; Birkett and Stevens-Wood 2005).

The values for old canopy volume removal described in Table 12 reveal a change in utilisation levels of the 13 species described as most utilised in 1994. Apart from *Albizia versicolor*, for which canopy removal is extreme, most other species are now within group 3. Two possible explanations could be given, one option is that utilisation of these species has decreased altogether, while the other more plausible option would indicate that as abundance of these species has decreased due to elephant utilisation since the 1994 study, and because of this lower abundance the utilisation has consequently become less. The purpose of the present paper is descriptive and a comparison of the results is not attempted here, however, the second option appears most likely as the abundance of some of the species utilised was documented as having fallen dramatically (see Chapters 6 and 7).

An interesting aspect in the present study is the intensity of utilisation-like events caused by natural damage. The latter, includes all natural phenomenon that can potentially break or even kill trees (wind, fire, lightning, moisture conditions, light conditions, disease, etc.), which are part of a natural system under normal conditions but also following some catastrophic events (Condit 1995; Whitmore and Burslem 1996; Lindenmayer *et al.* 2006). In the forests and woodlands of Tembe Elephant Park, it appears that utilisation-like events from natural damage affect a considerable number of species and also accumulate over time (Tables 2, 3, 4, 5) as in the case of animal utilisation (Kraft *et al.* 2004; Conybeare 2004; Sheil and Salim 2004). This accumulation is important in the Sand Forest and although lower in the woodlands, it remains a concern. In the Short Sand Forest, the percentage of available height classes removed completely nears 30.00% (Table 3). This value is extremely high for a vegetation type where wind should not have much effect due to the lack of tall trees that could break and fall, and where fire hardly occurs (Izidine *et al.* 2003; Matthews 2006). However, the abundance of plants and the height of this vegetation type make it particularly suited to elephant utilisation as has also been observed in Addo Elephant Park thicket vegetation (Lombard *et al.* 2001; Matthews 2006). In the present study the hypothesis is proposed that animals and elephants in fact induce some of the utilisation-like events contributed to natural damage.

Conclusion

An overview of the utilisation of woody vegetation in the Tembe elephant Park is presented. While the scope of this paper is descriptive, potentially serious problems are highlighted. In particular, it appears that elephant utilisation is creating gaps at an un-natural rhythm, and combined with intense herbivory from the smaller browsers, this process could force succession of Closed and Open Woodlands towards Sparse Woodlands, and Sand Forest towards Woodlands. While the gaps created by elephants are part of the natural dynamics of the vegetation of Maputaland, the current rate of disturbance appears alarmingly high as evidenced by the percentage of height classes that have been completely removed. The present study therefore concludes that elephant utilisation in Tembe Elephant Park is problematic, especially combined with the current utilisation level of other browsing agents. Management authorities of Tembe Elephant Park are strongly advised to take measures in order to limit animal population growth, but also to force elephants out of sections of the park for periods long enough to allow a recovery of the vegetation to a level where canopy removed by utilisation is replaced before subsequent utilisation occurs.

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CHAPTER 9

AN OVERVIEW OF WOODY VEGETATION UTILISATION IN THE MANQAKULANE RURAL COMMUNITY, KWAZULU-NATAL, SOUTH AFRICA

Abstract

A survey of woody species utilisation by small browsers, insects, man and natural damage, was conducted in six woodland vegetation units found in the village area of the land of the Manqakulane rural community, Maputaland, KwaZulu-Natal, South Africa. The study was conducted primarily to assess vegetation use by people in rural areas of this part of the Maputaland – Pondoland – Albany hotspot of biodiversity. Canopy removal was evaluated for two age ranges, (a) recent, 12 months prior to the study and (b) old, more than 12 months prior to the study. Overall utilisation was also evaluated but without age ranges. The results showed that utilisation levels by people were high, with canopy removal concentrated around the village area where woodlands are cleared for agriculture and the construction of households. Intense use of edible fruit-bearing woody species was also documented, and could be unsustainable. Insect herbivory affected up to 60% of woody species and canopy removal by defoliation appeared the most likely utilisation. Insects also completely removed more than 9% of height classes in a sparse woodland unit and proved a significant agent of woody species utilisation. Finally there appeared to be a link between natural damage and human utilisation of the area, as it appeared doubtful that all utilisation documented as natural damage could be explained by natural causes

Keywords

Browsers, insects, Maputaland, people, rural communities, woody species utilisation

Introduction

Woodlands and forests are important sources of free natural products that support the livelihoods of rural communities in Africa (Hillring 2006; Shackleton *et al.* 2007). In South Africa, the importance of these products, also called non-timber forest products (NTFP) is primarily the liberation of scarce cash resources for the purchase of products and services that cannot be obtained from the environment, such as education and health benefits (Shackleton and Shackleton 2006; Shackleton *et al.* 2007). The use of NTFP resources by rural and poor communities was initially thought to be a solution for introducing the concept of sustainable utilisation to rural people.

This belief was based on that fact that rural people are aware of the resources and know that when all resources are harvested life becomes increasingly difficult, and that by guiding them through the steps of utilising the resource base in a more sustainable manner, rural people would be agreeable to the restrictions imposed. It was hoped that associated to the development of a sustainable utilisation conscience among rural people, the greater goal of conservation would benefit by default (Arnold and Pérez 2001; Ickowitz 2006). However, poor planning of the resource use has led to problems of resource regeneration and therefore sustainability was threatened (Gram 2001; Janse and Ottitsch 2003; Ticktin 2004). In some cases where utilisation provided the expected financial benefits, people suddenly had the financial means to purchase tools for timber harvesting and thereby threatened the woodland and forest conservation altogether, because the value of timber products and the ease of harvesting proved superior to any potential returns from NTFP (Christensen 2004; Ticktin 2004; Ickowitz 2006).

Maputaland is a region shared by Mozambique and South Africa, and is comprised of a coastal plain that spreads from Maputo in Mozambique, southwards to the St-Lucia estuary in South Africa, and is wedged between the Indian Ocean to the east and the Lebombo Mountain Range to the west (Matthews 2006; Smith *et al.* 2006). The region is considered as possibly the second richest in biodiversity in South Africa (Eeley *et al.* 2001; Matthews 2006; Smith *et al.* 2006), and as such Maputaland has been included in the Maputaland – Pondoland – Albany hotspot of biodiversity (Smith *et al.* 2006). Areas are declared hotspots because they harbour exceptional biodiversity that is under threat from human activities and a growing human population (Brooks *et al.* 2002; Jha and Bawa 2006). The population of Maputaland has indeed grown significantly over the past 20 years (Browning 2000) and recently has been boosted by immigration towards the region fast becoming a tourism centre (Matthews 2006; Peteers 2005).

Because the levels of human population growth and associated vegetation utilisation are threatening the ecology of Maputaland, it is important to evaluate the extent and potential effects as soon as possible. In the present study, the levels of woody species utilisation in a rural community are evaluated for four main agents, i.e. small browsers, insects, people and natural damage. The number of woody species and height classed used by each agent by vegetation unit is evaluated to present a preliminary overview of utilisation in the northern Maputaland region.

Study area

The study area is situated in northern Maputaland, KwaZulu-Natal, South Africa (-26.85º to -27.15º South and 32.35º to 32.60º East). Six kilometres south of the southern fence of Tembe Elephant Park lies the land of the rural community of Manqakulane, which is composed of two sections: a community village (Manqakulane) and its commons to the east and the Tshanini Community Conservation Area (Tshanini) to the west (Gaugris 2004). The village and its associated communal land is spread over approximately half of the tribal land, *ca*. 2 500 ha, of the community of Manqakulane (Gaugris *et al.* 2007), while Tshanini represents the other half at 2 420 ha. A complete description of the community of Manqakulane and Tshanini is presented in Gaugris (2004). Tshanini will not be evaluated further in this chapter.

The overlying geology of the study site is the result of a succession of marine transgressions during the Miocene and Pleistocene eras and the dune cordons that cross the Maputaland Coastal Plain along a north – south axis are ancient littoral dunes (Matthews 2006). This predominantly sandy substratum is covered by an Open to Closed Woodland, with patches of Short and Tall Sand Forest, while clay cells have developed in low-lying areas and hold semi-permanent water bodies such as the Muzi Swamp running along the eastern boundary of the Tembe Elephant Park and Manqakulane (Matthews *et al.* 2001). Maputaland represents the southern limit of the tropical zone, and summers are hot, wet, and humid, and winters are cool to warm and dry. The mean annual rainfall for the region as measured at the Sihangwane weather station in the Tembe Elephant Park is 721 mm in the period from 1981 to 2003 (Matthews 2006).

In 1992, the Manqakulane community people moved from their previous settlement, centrally located within their tribal land, on the eastern boundary of Tshanini, and resettled further east along the Muzi Swamp area where the government installed a safe water supply, and where soils lend themselves to agriculture (Gaugris 2004). This is where the village area of the community is now situated, spread along a north-south axis. A total of 778 people were living permanently in that area in 2004 while the total number of community people consisted of an additional 120 people currently working elsewhere in South Africa (Peteers 2005). The utilisation of hardwood species by people for house construction is documented in Gaugris *et al.* (2007).

Methods

The methodology used is identical to that of the previous chapter and is therefore not repeated in its entirety. Only the relevant aspects are presented below.

Fieldwork

Only woody species were evaluated and no other plant forms were recorded. Woody plants in the present study are defined as all plants with an erect to scrambling growth form and with a ligneous trunk. The methodology was designed to evaluate the vegetation structure and the utilisation of vegetation by a range of agents. Both aspects were evaluated in 42 plots. Plot dimensions were density-dependent and varied from a minimum of 15 m by 2 m to a maximum length of 45 m by 19 m. Extremely dense vegetation such as Closed Woodland Thicket called for shorter and narrower lines than the less dense Open Woodlands. By following this approach a similar amount of information was gathered for most plots.

Data analysis

The canopy removal and overall utilisation of woody species by agents analyses were conducted independently for the following agents (see Table 1 for details):

- undetermined small browsers (such as: suni *Neotragus moschatus* (Von Dueben), red duiker *Cephalophus natalensis* (A. Smith), common duiker *Sylvicapra grimmia* (Linnaeus), nyala *Tragelaphus angasii* (Gray), impala *Aepyceros melampus* (Lichtenstein), bushbuck *Tragelaphus scriptus* (Pallas))
- insects (utilisation by insects was recorded with the help of local assistants able to differentiate utilisation patterns by such agents from small browsing mammals)
- man
- natural damage (all cases where the above agent categories could not be identified positively or where a natural cause such as wind, drought, fire, lightning, light conditions, was deemed the most likely reason for the observed damage).

Tree species selection by agent

For practical reasons only the first ten most utilised woody species by agent were presented in this manuscript. However, the complete list of woody species height classes utilised by agent by vegetation unit is available from the author on request.

Table 1: Codes used for evaluating the utilisation of vegetation by browsers, man and natural damage in Manqakulane community, the coding is derived from a co database used for other studies in KwaZulu-Natal, Northern Maputaland, South Africa, and only the codes relevant to the present study are displayed

State of the woody plant as encountered	
1	Normal growth
2	Normal with branch regrowth from breakage
3	Pollarded (main stem snapped off, height reduced) – tree living, resprouting
4	Pollarded (main stem snapped off, height reduced) – tree living, coppicing
5	Pollarded (main stem snapped off, height reduced) – tree living, no growth response
6	Pushed over, stem intact, still partially rooted - living
7	Pushed over, stem partially broken - living
8	Mostly normal growth with some hedge growth
9	Hedge growth from continuous, regular browsing
10	Coppice growth from larger (older) dead stem
11	Coppice growth from accumulated browsing of young plant
12	Coppice growth from repeated fire
13	Coppice growth from repeated moisture stress
20	Senescent
30	Tree dead - main stem partially broken
31	Tree dead - main stem completely broken (pollarded)
32	Tree dead - main stem pushed over (partially uprooted)
33	Tree dead - main stem debarked
34	Tree dead - main stem intact, accumulated branch removal
35	Tree dead - debarking and branches / stems removed
50	Tree dead - intact - cause of death unknown
51	Tree dead - intact - killed by moisture stress
52	Tree dead - intact - dead from shading
53	Tree dead - intact - dead from high light
54	Tree dead - killed by combination of moisture stress and branch removal
55	Tree dead - killed from combination of shading and branch removal
56	Tree dead - killed by fire
60	Tree dead - totally uprooted
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

Agent (Agt.) of utilisation	
1	Elephant
2	Giraffe
3	Kudu
4	Eland
5	Black rhinoceros
6	Nyala
7	Impala
8	Bushbuck
9	Grey duiker
10	Red duiker
11	Suni
12	Unidentifiable mega browsers (elephant, giraffe)
13	Unidentifiable large/medium size browsers (kudu, nyala, eland, etc)
14	Unidentifiable medium/small size browsers (impala, bushbuck, duiker etc)
15	Moisture stress
16	Flooding
17	Shading
18	High light intensity
19	Fire
20	Frost
21	Wind
22	Accidental
23	Unknown
24	Human
25	Insects
26	Cane rat
27	Lightning
28	Cattle
29	Porcupine
30	Goats

Type of utilisation observed	
1	Whole plant (canopy and roots) utilized
2	Whole canopy utilized (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

Growth responses (G.R.) 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

Age of utilization (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

Debarking – circumference (Brk.)		
1	1 % - 10 %	of the circumfere of the stem rem
2	11 % - 25 %	
3	26 % - 50 %	
4	51 % - 75 %	
5	76 % - 90 %	
6	91 % - 99 %	
7	100%	

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

Debarking - stem height (Brk.)		
	Percentage of Stem Height	
0.1	1 % - 10 %	of the height of s 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	

Results

A new woodland unit was described in Manqakulane, the Open Woodland on Abandoned Household Sites. This unit on old household sites and old fields was markedly different form the surrounding natural vegetation and has not previously been described by Gaugris (2004) or Matthews *et al.* (2001). A total of 3 632 trees and shrubs were evaluated in the surveys, with a total of 80 woody species sampled.

Number of tree species utilised

As expected, there were no signs of utilisation from medium or large browsers, or African elephants *Loxodonta africana* (Blumenbach 1797). However, small browsers were present in Manqakulane as evidenced by some utilisation observed on some woody species. Recent signs of utilisation were only observed in the Open Woodland on Abandoned Household Sites (Table 2). Old signs of utilisation were observed in the latter and also in the Closed Woodland Thicket. Some of the survey sites in these two vegetation types were placed the furthest away from the community village in the direction of Tshanini. Overall, the number of species found to be utilised by small browsers was low.

In terms of canopy removal, people from the community utilised 4.55% to 16.39% of the available woody species within the 12 months prior to the fieldwork (Table 2). The most utilised vegetation units were the Closed Woodland Thicket, the Closed Woodland on Sand and the Sparse Woodland on Sand. The older utilisation values showed that the most utilised vegetation units in terms of number of woody species were the Closed Woodland on Sand, Open Woodland on Abandoned Household Sites, and Closed Woodland on Clay. In terms of overall utilisation, the Open Woodland on Abandoned Household Sites, the Closed Woodland Thicket, and the Closed Woodland on Sand were the most utilised vegetation units, with values in excess of 50% of the woody species utilised.

The overall occurrence of natural damage was exceptionally high in the Closed Woodland Thicket, while the Open Woodland on Abandoned Household Sites, the Sparse Woodland and Closed Woodland on Sand also showed signs of intensive utilisation. Natural damage appeared mostly in the form of canopy removal more than 12 months prior to the fieldwork (Table 2).

An interesting feature observed in the Manqakulane site was insect herbivory. Due to the extremely low numbers of small mammals in Manqakulane, it proved possible and feasible in time as well as sampling effort to actually distinguish between small browser herbivory and insect herbivory. However, insect herbivory was only

Table 2: The number of species utilised by various agents in the Woodland association of Manqakulane Rural Community, Maputaland, northern KwaZulu-Natal, South Africa. Values are given for canopy removal (number of species where a percentage of canopy volume (CV) was removed) for the two periods evaluated (Recent: within 12 months prior to the study and Old: > 12 months prior to the study) and for the overall utilisation (O U), including all utilisation events, but time was undetermined

Vegetation unit →			**Closed Woodland Thicket (VT 02.1.0)**		**Closed Woodland on Clay (VT 02.2.0)**		**Closed Woodland on Sand (VT 02.3.0)**		**Open Woodland on Sand (VT 03.1.0)**		**Open Woodland on Abandoned Household Sites (VT 03.2.0)**		**Sparse Woodland on Sand (VT 04.1.0)**	
No of Species sampled →			61		37		53		22		60		19	
No of Species used by	Age	Type	Number	(%)	Number	(%)	Number	(%)	Number	(%)	Number	(%)	Number	(%)
Small Browsers	Recent	CV	0	0.00	0	0.00	0	0.00	0	0.00	2	3.33	0	0.00
	Old	CV	2	3.28	0	0.00	0	0.00	0	0.00	1	1.67	0	0.00
	All ages	O U	2	3.28	0	0.00	0	0.00	0	0.00	2	3.33	0	0.00
Insects	Recent	CV	37	60.66	9	24.32	32	60.38	4	18.18	30	50.00	6	31.58
	Old	CV	na	na	na	na	na	na	na	na	na	na	na	na
	All ages	O U	45	73.77	9	24.32	35	66.04	6	27.27	35	58.33	8	42.11
Man	Recent	CV	10	16.39	3	8.11	8	15.09	1	4.55	5	8.33	2	10.53
	Old	CV	21	34.43	16	43.24	26	49.06	8	36.36	27	45.00	8	42.11
	All ages	O U	32	52.46	18	48.65	28	52.83	8	36.36	32	53.33	8	42.11
Natural Damage	Recent	CV	15	24.59	0	0.00	17	32.08	1	4.55	19	31.67	0	0.00
	Old	CV	42	68.85	13	35.14	25	47.17	5	22.73	28	46.67	11	57.89
	All ages	O U	46	75.41	13	35.14	28	52.83	6	27.27	36	60.00	11	57.89

na: not applicable

distinguishable as a recent feature, and therefore no data were available for old canopy removal by this agent. In terms of number of woody species utilised, insect herbivory proved remarkably high in the Closed Woodland Thicket, Closed Woodland on Sand, and Open Woodland on Abandoned Household Sites (Table 2) with up to 60.66% of the woody species affected in the former (Table 2).

Number of height classes utilised

Small browsers were scarce, and recent utilisation marks were only found within the Open Woodland on Abandoned Household Sites. In that unit they utilised the canopy in 1.31% of the height classes available to them within the past 12 months and utilisation by small animals confined to canopy removal (Table 3). Old signs of utilisation by small browsers were observed in the Closed Woodland Thicket.

The people in the Manqakulane had a noteworthy effect on the vegetation. In the 12 months preceding the study, people utilised the canopy in 2.94% to 6.25% of the available height classes (Table 3). However, the older marks bore testimony of a greater use in the past with 15.46% (Closed Woodland Thicket) to 40.63% (Sparse Woodland on Sand) of height classes where canopy was removed in the past (Table 3). Overall utilisation values reveal that canopy removal was possibly the only form of utilisation in the Open and Sparse Woodland on Sand, but that all woody plant individuals in more than 10.00% and up to 21.88% of available height classes bore utilisation marks from people in four of the woodland units (Table 3).

Recent canopy removal through natural damage was absent in the Closed Woodland on Clay and Sparse Woodland on Sand, while visible but low (<10% of height classes utilised) in the Closed Woodland Thicket and Open Woodland on Sand, and in excess of 10.00% of height classes utilised in the remaining two units (Table 3). For older utilisation signs, canopy removal was observed in 17.14% (Open Woodland on Sand) to 51.52% (Sparse Woodland on Sand) of height classes, and was generally high (Table 3). The overall utilisation values mirrored the above but were slightly higher. However, the percentage of height classes that showed utilisation of all woody individuals was considerable and exceeded 10.00% of the available height classes for four units (Table 3).

Insect herbivory signs where observed in >10.00% of height classes in all vegetation units with a high of 33.73% of height classes being used in the Open Woodland on Abandoned Household Sites (Table 3). The overall utilisation of height classes showed that insect herbivory affected all woody individuals in a range of height

Table 3: The number and percentage of height classes (HC) utilised by the various agents in the Woodland association of Manqakulane Rural Community, Maputaland, northern KwaZulu-Natal, South Africa. The number of height classes utilised is represented in three ways, a total number of height classes utilised within the range utilised by the agent, the number of height classes in that range where utilisation of at least 50% of the height class was observed for at least one species, and the number of height classes where 100% of individuals in one height class were utilised for at least one species. Values are given for canopy removal utilisation events (CV) for the two periods evaluated (Recent: within 12 months prior to the study and Old: > 12 months prior to the study) and for the overall utilisation (O U), including all utilisation events, but time was undetermined

Agent	Range of height classes used	Age	Type	Vegetation Units																				
				Closed Woodland Thicket (VT 02.1.0)							**Closed Woodland on Clay (VT 02.2.0)**							**Closed Woodland on Sand (VT 02.3.0)**						
				NHCS*	Total HC utilisation (No)	(%)	HC use where > 50 % of HC used (No)	(%)	HC use where 100% of HC used (No)	(%)	NHCS*	Total HC utilisation (No)	(%)	HC use where > 50 % of HC used (No)	(%)	HC use where 100% of HC used (No)	(%)	NHCS*	Total HC utilisation (No)	(%)	HC use where > 50 % of HC used (No)	(%)	HC use where 100% of HC used (No)	(%)
Small Browsers	**01 - 05**	Recent	CV	208	0	0.00	0	0.00	0	0.00	74	0	0.00	0	0.00	0	0.00	166	0	0.00	0	0.00	0	0.00
		Old	CV	208	2	0.96	0	0.00	0	0.00	74	0	0.00	0	0.00	0	0.00	166	0	0.00	0	0.00	0	0.00
		All ages	O U	208	2	0.96	0	0.00	0	0.00	74	0	0.00	0	0.00	0	0.00	166	0	0.00	0	0.00	0	0.00
Insects	**01 - 07**	Recent	CV	228	72	31.58	1	0.44	0	0.00	79	9	11.39	0	0.00	0	0.00	177	62	35.03	1	0.56	0	0.00
		Old	CV	228	na	na	na	na	na	na	79	na	na	na	na	na	na	177	na	na	na	na	na	na
		All ages	O U	228	94	41.23	39	17.11	14	6.14	79	11	13.92	7	8.86	4	5.06	177	69	38.98	20	11.30	6	3.39
Man	**02 - 07**	Recent	CV	207	11	5.31	2	0.97	0	0.00	78	3	3.85	0	0.00	0	0.00	164	9	5.49	1	0.61	1	0.61
		Old	CV	207	32	15.46	2	0.97	0	0.00	78	19	24.36	4	5.13	1	1.28	164	52	31.71	3	1.83	0	0.00
		All ages	O U	207	47	22.71	20	9.66	10	4.83	78	22	28.21	21	26.92	17	21.79	164	56	34.15	25	15.24	14	8.54
Natural Damage	**01 - 08**	Recent	CV	228	20	8.77	0	0.00	0	0.00	79	0	0.00	0	0.00	0	0.00	178	23	12.92	4	2.25	4	2.25
		Old	CV	228	81	35.53	9	3.95	5	2.19	79	15	18.99	0	0.00	0	0.00	178	51	28.65	7	3.93	4	2.25
		All ages	O U	228	95	41.67	54	23.68	29	12.72	79	15	18.99	12	15.19	10	12.66	178	56	31.46	26	14.61	12	6.74

Agent	Range of height classes used	Age	Type	Vegetation Units																				
				Open Woodland on Sand (VT 03.1.0)							**Open Woodland on Abandoned Household Sites (VT 03.2.0)**							**Sparse Woodland on Sand (VT 04.1.0)**						
				NHCS*	Total HC utilisation (No)	(%)	HC use where > 50 % of HC used (No)	(%)	HC use where 100% of HC used (No)	(%)	NHCS*	Total HC utilisation (No)	(%)	HC use where > 50 % of HC used (No)	(%)	HC use where 100% of HC used (No)	(%)	NHCS*	Total HC utilisation (No)	(%)	HC use where > 50 % of HC used (No)	(%)	HC use where 100% of HC used (No)	(%)
Small Browsers	**01 - 05**	Recent	CV	34	0	0.00	0	0.00	0	0.00	153	2	1.31	0	0.00	0	0.00	33	0	0.00	0	0.00	0	0.00
		Old	CV	34	0	0.00	0	0.00	0	0.00	153	1	0.65	0	0.00	0	0.00	33	0	0.00	0	0.00	0	0.00
		All ages	O U	34	0	0.00	0	0.00	0	0.00	153	2	1.31	0	0.00	0	0.00	33	0	0.00	0	0.00	0	0.00
Insects	**01 - 07**	Recent	CV	35	4	11.43	0	0.00	0	0.00	166	56	33.73	0	0.00	0	0.00	33	6	18.18	0	0.00	0	0.00
		Old	CV	35	na	na	na	na	na	na	166	na	na	na	na	na	na	33	na	na	na	na	na	na
		All ages	O U	35	6	17.14	3	8.57	0	0.00	166	65	39.16	16	9.64	10	6.02	33	9	27.27	5	15.15	3	9.09
Man	**02 - 07**	Recent	CV	34	1	2.94	0	0.00	0	0.00	150	5	3.33	0	0.00	0	0.00	32	2	6.25	0	0.00	0	0.00
		Old	CV	34	10	29.41	2	5.88	0	0.00	150	53	35.33	5	3.33	2	1.33	32	13	40.63	3	9.38	1	3.13
		All ages	O U	34	10	29.41	8	23.53	5	14.71	150	64	42.67	40	26.67	27	18.00	32	13	40.63	8	25.00	7	21.88
Natural Damage	**01 - 08**	Recent	CV	35	1	2.86	0	0.00	0	0.00	166	38	22.89	10	6.02	5	3.01	33	0	0.00	0	0.00	0	0.00
		Old	CV	35	6	17.14	3	8.57	0	0.00	166	60	36.14	11	6.63	6	3.61	33	17	51.52	6	18.18	0	0.00
		All ages	O U	35	7	20.00	6	17.14	5	14.29	166	72	43.37	32	19.28	16	9.64	33	17	51.52	14	42.42	6	18.18

NHCS* = Number of height classes sampled in the range used by the agent
HC = Height Classes
No = Number

classes in all units but the Open Woodland on Sand, with a high of 9.09% of height classes fully utilised in the Sparse Woodland on Sand (Table 3).

Tree species selection by agent

Small browser utilisation in Manqakulane was diagnosed in only four woody species (Table 4). These tree species showed utilisation signs, but there were no indications that height classes were excessively utilised.

Human utilisation of a selection of woody species was expectedly high. *Dialium schlechteri*, a good firewood species (Gaugris 2004), was one of the most utilised plants in three vegetation units (Closed Woodland Thicket, Closed Woodland on Clay, Open Woodland on Abandoned Household Sites, Table 5), where one to three height classes were removed. The edible fruit bearing species *Strychnos madagascariensis, Strychnos spinosa* and *Sclerocarya birrea* were heavily utilised, especially the former species, where signs of full height classes utilisation or at least 50% use of a height class were found in all vegetation units (Table 6). *Hyphaene coriacea* is a species of predilection for the production of palm wine (ubusulu), and in all three vegetation units where utilisation was documented, all individuals were utilised.

An interesting feature was the intensity at which *Sclerocarya birrea* appeared to be damaged through natural events in the Closed Woodland on Sand, Open Woodland on Abandoned Household Sites, and Sparse Woodland on Sand (see Table 6). As this is a species preferred by people, a question is raised whether human use of the species engenders a premature and aggravated damage and possibly death of trees of this species. The effect appeared particularly striking in the Closed Woodland on Sand where canopy removal-like events, recent and old, have affected 50% to 100% of individuals in at least four height classes.

Insect utilisation preferences appeared for the following species: *Zanthoxylum capense* and *Deinbollia oblongifolia* in the three Closed Woodland units, *Strychnos madagascariensis* and *Sclerocarya birrea* in the Closed Woodland on Sand, Open Woodland on Abandoned Household Sites, and Sparse Woodland on Sand (Table 7).

Discussion

An obvious deduction from this study is the low or lack of impact of small to large mammals outside formally conserved areas in northern Maputaland. The reasons are most likely linked to human hunting pressure over the past 20 years (Kloppers 2001; Gaugris 2004). The only signs of small mammal presence were observed in the areas furthest away form the community village, close to the eastern boundary of

Table 4: The 10 woody species most utilised by small browsers in Manqakulane Rural Community, by vegetation unit and age of damage (for canopy volume removal only). Values given reflect the number of height classes (HC) where utilisation was reported (HC 01), as well as the number of height classes where utilisation was > 50% (HC 02) and 100% (HC 03) of canopy removed or number of individuals utilised within a height class, and the highest height class where damage was observed (HC 04). Species highlighted in red represent situations where at least one height class was completely utilised. Maputaland, northern KwaZulu-Natal, South Africa

Number	Vegetation unit	Taxa	Canopy Volume removal < 12 months				Taxa	Canopy Volume removal > 12 months				Taxa	Overall Utilisation			
			HC 01*	HC 02*	HC 03*	HC 04*		HC 01*	HC 02*	HC 03*	HC 04*		HC 01*	HC 02*	HC 03*	HC 04*
1	VT 02.1.0	-	-	-	-	-	*Dovyalis longispina*	1	0	0	02	*Dovyalis longispina*	1	0	0	02
2	VT 02.1.0	-	-	-	-	-	*Strychnos spinosa*	1	0	0	04	*Strychnos spinosa*	1	0	0	04
1	VT03.2.0	*Acacia burkei*	1	0	0	02	*Terminalia sericea*	1	0	0	02	*Acacia burkei*	1	0	0	02
2	VT03.2.0	*Terminalia sericea*	1	0	0	02	-	-	-	-	-	*Terminalia sericea*	1	0	0	02

VT 02.1.0 = Closed Woodland Thicket

VT 03.2.0 = Open Woodland on Abandoned Household Sites

Table 5: *The 10 woody species most utilised by man in Manqakulane Rural Community, by vegetation unit and age of damage (for canopy volume removal only). Values given reflect the number of height classes (HC) where utilisation was reported (HC 01), as well as the number of height classes where utilisation was > 50% (HC 02) and 100% (HC 03) of canopy removed or number of individuals utilised within a height class, and the highest height class where damage was observed (HC 04). Species highlighted in red represent situations where at least one height class was completely utilised. Maputaland, northern KwaZulu-Natal, South Africa*

Number	Vegetation unit	Taxa	Canopy Volume removal < 12 months				Taxa	Canopy Volume removal > 12 months				Taxa	Overall Utilisation			
			HC 01*	HC 02*	HC 03*	HC 04*		HC 01*	HC 02*	HC 03*	HC 04*		HC 01*	HC 02*	HC 03*	HC 04*
1	VT 02.1.0	*Zanthoxylum capense*	2	0	0	04	*Dialium schlechteri*	3	0	0	07	*Strychnos madagascariensis*	3	2	1	05
2	VT 02.1.0	*Canthium setiflorum*	1	1	0	04	*Strychnos spinosa*	3	0	0	05	*Dialium schlechteri*	3	2	0	07
3	VT 02.1.0	*Ptaeroxylon obliquum*	1	1	0	03	*Terminalia sericea*	2	1	0	06	*Strychnos spinosa*	3	1	1	05
4	VT 02.1.0	*Carissa tetramera*	1	0	0	04	*Acacia burkei*	2	0	0	06	*Terminalia sericea*	3	0	0	06
5	VT 02.1.0	*Clausena anisata*	1	0	0	02	*Bridelia cathartica*	2	0	0	05	*Zanthoxylum capense*	3	0	0	06
6	VT 02.1.0	*Monanthotaxis caffra*	1	0	0	02	*Dichrostachys cinerea*	2	0	0	05	*Bridelia cathartica*	2	1	0	05
7	VT 02.1.0	*Strychnos madagascariensis*	1	0	0	05	*Euclea natalensis*	2	0	0	06	*Euclea natalensis*	2	1	0	06
8	VT 02.1.0	*Terminalia sericea*	1	0	0	05	*Strychnos madagascariensis*	2	0	0	05	*Strychnos gerrardii*	2	1	0	06
9	VT 02.1.0	*Tricalysia capensis*	1	0	0	03	*Zanthoxylum capense*	2	0	0	06	*Acacia burkei*	2	0	0	06
10	VT 02.1.0	*Xylotheca kraussiana*	1	0	0	03	*Lagynias lasiantha*	1	1	0	04	*Dichrostachys cinerea*	2	0	0	05
1	VT 02.2.0	*Dialium schlechteri*	1	0	0	06	*Dialium schlechteri*	2	0	0	05	*Dialium schlechteri*	3	3	2	06
2	VT 02.2.0	*Hyphaene coriacea*	1	0	0	04	*Ehretia obtusiflora*	2	0	0	03	*Ehretia obtusiflora*	2	2	1	03
3	VT 02.2.0	*Margaritaria discoidea*	1	0	0	03	*Euclea natalensis*	2	0	0	06	*Euclea natalensis*	2	2	1	06
4	VT 02.2.0	-	-	-	-	-	*Acacia burkei*	1	1	1	06	*Acacia burkei*	1	1	1	06
5	VT 02.2.0	-	-	-	-	-	*Psydrax locuples*	1	1	0	03	*Balanites maughamii*	1	1	1	07
6	VT 02.2.0	-	-	-	-	-	*Rhus gueinzii*	1	1	0	05	*Canthium setiflorum*	1	1	1	03
7	VT 02.2.0	-	-	-	-	-	*Strychnos madagascariensis*	1	1	0	05	*Hyphaene coriacea*	1	1	1	04
8	VT 02.2.0	-	-	-	-	-	*Balanites maughamii*	1	0	0	07	*Psydrax locuples*	1	1	1	03
9	VT 02.2.0	-	-	-	-	-	*Canthium setiflorum*	1	0	0	03	*Pteleopsis myrtifolia*	1	1	1	05
10	VT 02.2.0	-	-	-	-	-	*Dalbergia obovata*	1	0	0	03	*Rhus gueinzii*	1	1	1	05
1	VT 02.3.0	*Dichrostachys cinerea*	2	0	0	04	*Sclerocarya birrea*	4	0	0	07	*Sclerocarya birrea*	4	4	2	07
2	VT 02.3.0	*Rhus gueinzii*	1	1	1	05	*Strychnos spinosa*	4	0	0	05	*Catunaregam taylori*	4	1	0	05
3	VT 02.3.0	*Brachylaena discolor*	1	0	0	04	*Catunaregam taylori*	3	1	0	05	*Strychnos spinosa*	4	1	0	05
4	VT 02.3.0	*Catunaregam taylori*	1	0	0	02	*Erythroxylum delagoense*	3	1	0	05	*Trichilia emetica*	3	3	3	06
5	VT 02.3.0	*Deinbollia oblongifolia*	1	0	0	03	*Terminalia sericea*	3	1	0	06	*Terminalia sericea*	3	2	1	06
6	VT 02.3.0	*Dialium schlechteri*	1	0	0	03	*Dichrostachys cinerea*	3	0	0	05	*Strychnos madagascariensis*	3	1	1	06
7	VT 02.3.0	*Sclerocarya birrea*	1	0	0	04	*Strychnos madagascariensis*	3	0	0	06	*Erythroxylum delagoense*	3	1	0	05
8	VT 02.3.0	*Spirostachys africana*	1	0	0	05	*Trichilia emetica*	3	0	0	06	*Dichrostachys cinerea*	3	0	0	05
9	VT 02.3.0						*Acacia burkei*	2	0	0	05	*Lagynias lasiantha*	2	1	1	05
10	VT 02.3.0						*Bridelia cathartica*	2	0	0	04	*Spirostachys africana*	2	1	1	06

Table 5 continued

1	VT 03.1.0	*Strychnos madagascariensis*	1	0	0	03	*Brachylaena discolor*	2	1	0	04	*Hyphaene coriacea*	2	2	2	04
2	VT 03.1.0	-	-	-	-	-	*Hyphaene coriacea*	2	0	0	04	*Brachylaena discolor*	2	2	0	04
3	VT 03.1.0	-	-	-	-	-	*Strychnos madagascariensis*	1	1	0	03	*Balanites maughamii*	1	1	1	03
4	VT 03.1.0	-	-	-	-	-	*Balanites maughamii*	1	0	0	03	*Combretum molle*	1	1	1	05
5	VT 03.1.0	-	-	-	-	-	*Combretum molle*	1	0	0	05	*Euclea natalensis*	1	1	1	04
6	VT 03.1.0	-	-	-	-	-	*Euclea natalensis*	1	0	0	04	*Grewia microthyrsa*	1	1	0	04
7	VT 03.1.0	-	-	-	-	-	*Grewia microthyrsa*	1	0	0	04	*Strychnos madagascariensis*	1	0	0	03
8	VT 03.1.0	-	-	-	-	-	*Xylotheca kraussiana*	1	0	0	03	*Xylotheca kraussiana*	1	0	0	03
1	VT 03.2.0	*Acacia robusta*	1	0	0	04	*Strychnos spinosa*	4	0	0	06	*Dialium schlechteri*	5	5	3	07
2	VT 03.2.0	*Margaritaria discoidea*	1	0	0	03	*Terminalia sericea*	4	0	0	07	*Terminalia sericea*	5	3	3	07
3	VT 03.2.0	*Tricalysia delagoensis*	1	0	0	04	*Trichilia emetica*	4	0	0	07	*Trichilia emetica*	4	4	1	07
4	VT 03.2.0	*Trichilia emetica*	1	0	0	07	*Dichrostachys cinerea*	3	0	0	05	*Sclerocarya birrea*	4	3	1	07
5	VT 03.2.0	*Xylotheca kraussiana*	1	0	0	02	*Euclea natalensis*	3	0	0	05	*Strychnos spinosa*	4	1	1	06
6	VT 03.2.0	-	-	-	-	-	*Gymnosporia senegalensis*	3	0	0	05	*Strychnos madagascariensis*	3	3	1	06
7	VT 03.2.0	-	-	-	-	-	*Sclerocarya birrea*	3	0	0	06	*Euclea natalensis*	3	1	1	05
8	VT 03.2.0	-	-	-	-	-	*Strychnos madagascariensis*	3	0	0	06	*Gymnosporia senegalensis*	3	1	1	05
9	VT 03.2.0	-	-	-	-	-	*Dialium schlechteri*	2	1	1	07	*Dichrostachys cinerea*	3	1	0	05
10	VT 03.2.0	-	-	-	-	-	*Spirostachys africana*	2	1	0	07	*Spirostachys africana*	2	2	2	07
1	VT 04.1.0	*Acacia gerrardii*	1	0	0	03	*Acacia gerrardii*	2	2	1	04	*Hyphaene coriacea*	2	2	2	03
2	VT 04.1.0	*Strychnos madagascariensis*	1	0	0	03	*Strychnos madagascariensis*	2	1	0	05	*Acacia gerrardii*	2	2	1	04
3	VT 04.1.0	-	-	-	-	-	*Dichrostachys cinerea*	2	0	0	03	*Sclerocarya birrea*	2	1	1	05
4	VT 04.1.0	-	-	-	-	-	*Hyphaene coriacea*	2	0	0	03	*Strychnos madagascariensis*	2	1	1	05
5	VT 04.1.0	-	-	-	-	-	*Sclerocarya birrea*	2	0	0	05	*Dichrostachys cinerea*	2	0	0	03
6	VT 04.1.0	-	-	-	-	-	*Gymnosporia senegalensis*	1	0	0	02	*Phoenix reclinata*	1	1	1	04
7	VT 04.1.0	-	-	-	-	-	*Phoenix reclinata*	1	0	0	04	*Ziziphus mucronata*	1	1	1	04
8	VT 04.1.0	-	-	-	-	-	*Ziziphus mucronata*	1	0	0	04	*Gymnosporia senegalensis*	1	0	0	02

VT 02.1.0 = Closed Woodland Thicket
VT 02.2.0 = Closed Woodland on Clay
VT 02.3.0 = Closed Woodland on Sand
VT 03.1.0 = Open Woodland on Sand
VT 03.2.0 = Open Woodland on Abandoned Household Sites
VT 04.1.0 = Sparse Woodland on Sand

Table 6: The 10 woody species most damaged through natural damage in Manqakulane Rural Community, by vegetation unit and age of damage (for canopy volume removal only). Values given reflect the number of height classes (HC) where utilisation was reported (HC 01), as well as the number of height classes where utilisation was > 50% (HC 02) and 100% (HC 03) of canopy removed or number of individuals utilised within a height class, and the highest height class where damage was observed (HC 04). Species highlighted in red represent situations where at least one height class was completely utilised. Maputaland, northern KwaZulu-Natal, South Africa

Number	Vegetation unit	Taxa	Canopy Volume removal < 12 months				Taxa	Canopy Volume removal > 12 months				Taxa	Overall Utilisation			
			HC 01*	HC 02*	HC 03*	HC 04*		HC 01*	HC 02*	HC 03*	HC 04*		HC 01*	HC 02*	HC 03*	HC 04*
1	VT 02.1.0	*Euclea natalensis*	3	0	0	05	*Dialium schlechteri*	4	1	0	07	*Euclea natalensis*	5	2	0	06
2	VT 02.1.0	*Zanthoxylum capense*	3	0	0	05	*Acacia burkei*	4	0	0	05	*Acacia burkei*	4	4	1	07
3	VT 02.1.0	*Grewia caffra*	2	0	0	05	*Bridelia cathartica*	4	0	0	06	*Commiphora neglecta*	4	3	0	06
4	VT 02.1.0	*Acacia burkei*	1	0	0	05	*Commiphora neglecta*	4	0	0	07	*Dialium schlechteri*	4	2	1	07
5	VT 02.1.0	*Carissa tetramera*	1	0	0	00	*Dichrostachys cinerea*	3	2	1	05	*Zanthoxylum capense*	4	2	0	06
6	VT 02.1.0	*Catunaregam taylori*	1	0	0	04	*Catunaregam taylori*	3	0	0	04	*Bridelia cathartica*	4	0	0	05
7	VT 02.1.0	*Clausena anisata*	1	0	0	04	*Clausena anisata*	3	0	0	06	*Dichrostachys cinerea*	3	3	1	06
8	VT 02.1.0	*Coddia rudis*	1	0	0	05	*Euclea natalensis*	3	0	0	06	*Strychnos gerrardii*	3	2	2	06
9	VT 02.1.0	*Combretum molle*	1	0	0	05	*Strychnos gerrardii*	3	0	0	06	*Catunaregam taylori*	3	2	1	05
10	VT 02.1.0	*Deinbollia oblongifolia*	1	0	0	03	*Xylotheca kraussiana*	3	0	0	04	*Coddia rudis*	3	1	1	05
1	VT 02.2.0	-	-	-	-	-	*Dialium schlechteri*	2	0	0	06	*Rhus rhemanianna*	2	2	2	05
2	VT 02.2.0	-	-	-	-	-	*Rhus rhemanianna*	2	0	0	05	*Dialium schlechteri*	2	2	1	06
3	VT 02.2.0	-	-	-	-	-	*Acacia gerrardii*	1	0	0	05	*Balanites maughamii*	1	1	1	07
4	VT 02.2.0	-	-	-	-	-	*Balanites maughamii*	1	0	0	07	*Pteleopsis myrtifolia*	1	1	1	05
5	VT 02.2.0	-	-	-	-	-	*Bridelia cathartica*	1	0	0	02	*Rhus gueinzii*	1	1	1	05
6	VT 02.2.0	-	-	-	-	-	*Carissa bispinosa*	1	0	0	03	*Strychnos madagascariensis*	1	1	1	05
7	VT 02.2.0	-	-	-	-	-	*Deinbollia oblongifolia*	1	0	0	03	*Strychnos spinosa*	1	1	1	05
8	VT 02.2.0	-	-	-	-	-	*Pteleopsis myrtifolia*	1	0	0	05	*Tabernaemontana elegans*	1	1	1	04
9	VT 02.2.0	-	-	-	-	-	*Rhus gueinzii*	1	0	0	05	*Trichilia emetica*	1	1	1	06
10	VT 02.2.0	-	-	-	-	-	*Strychnos madagascariensis*	1	0	0	05	*Carissa bispinosa*	1	1	0	03
1	VT 02.3.0	*Sclerocarya birrea*	4	4	4	05	*Sclerocarya birrea*	6	4	4	07	*Acacia burkei*	4	2	1	07
2	VT 02.3.0	*Bridelia cathartica*	2	0	0	05	*Strychnos madagascariensis*	4	1	0	06	*Strychnos madagascariensis*	4	2	1	06
3	VT 02.3.0	*Erythroxylum delagoense*	2	0	0	03	*Acacia burkei*	4	0	0	07	*Sclerocarya birrea*	3	2	2	07
4	VT 02.3.0	*Zanthoxylum capense*	2	0	0	04	*Bridelia cathartica*	3	0	0	05	*Bridelia cathartica*	3	2	0	05
5	VT 02.3.0	*Acacia burkei*	1	0	0	02	*Catunaregam taylori*	3	0	0	05	*Dichrostachys cinerea*	3	2	0	05
6	VT 02.3.0	*Acacia robusta*	1	0	0	03	*Dichrostachys cinerea*	3	0	0	05	*Terminalia sericea*	3	2	0	06
7	VT 02.3.0	*Carissa bispinosa*	1	0	0	03	*Strychnos spinosa*	3	0	0	05	*Strychnos spinosa*	3	1	1	05
8	VT 02.3.0	*Dalbergia obovata*	1	0	0	04	*Terminalia sericea*	3	0	0	06	*Catunaregam taylori*	3	1	0	05
9	VT 02.3.0	*Deinbollia oblongifolia*	1	0	0	03	*Combretum molle*	2	1	0	05	*Erythroxylum delagoense*	3	1	0	05
10	VT 02.3.0	*Dichrostachys cinerea*	1	0	0	04	*Acacia robusta*	2	0	0	08	*Trichilia emetica*	2	2	1	06

Table 6 continued

1	VT 03.1.0	*Brachylaena discolor*	6	4	2	07	*Euclea natalensis*	2	0	0	04	*Euclea natalensis*	2	1	1	04
2	VT 03.1.0	-	-	-	-	-	*Acacia burkei*	1	1	0	06	*Acacia burkei*	1	1	1	06
3	VT 03.1.0	-	-	-	-	-	*Combretum molle*	1	1	0	03	*Combretum molle*	1	1	1	03
4	VT 03.1.0	-	-	-	-	-	*Vangueria infausta*	1	1	0	03	*Tabernaemontana elegans*	1	1	1	05
5	VT 03.1.0	-	-	-	-	-	*Tabernaemontana elegans*	1	0	0	05	*Vangueria infausta*	1	1	1	03
6	VT 03.1.0	-	-	-	-	-						*Brachylaena discolor*	1	1	0	03
7	VT 03.1.0	-	-	-	-	-										
1	VT 03.2.0	*Trichilia emetica*	6	4	3	07	*Trichilia emetica*	6	4	3	07	*Sclerocarya birrea*	7	4	2	07
2	VT 03.2.0	*Sclerocarya birrea*	6	4	2	07	*Sclerocarya birrea*	6	3	2	07	*Trichilia emetica*	6	4	2	07
3	VT 03.2.0	*Dichrostachys cinerea*	4	0	0	04	*Acacia burkei*	4	0	0	05	*Acacia burkei*	5	1	0	05
4	VT 03.2.0	*Canthium armatum*	3	0	0	04	*Dichrostachys cinerea*	4	0	0	05	*Dichrostachys cinerea*	5	1	0	05
5	VT 03.2.0	*Acacia burkei*	2	0	0	04	*Strychnos spinosa*	4	0	0	05	*Strychnos spinosa*	4	2	0	05
6	VT 03.2.0	*Gymnosporia senegalensis*	2	0	0	04	*Tabernaemontana elegans*	4	0	0	05	*Tabernaemontana elegans*	4	1	1	05
7	VT 03.2.0	*Margaritaria discoidea*	2	0	0	04	*Terminalia sericea*	4	0	0	07	*Terminalia sericea*	3	2	0	04
8	VT 03.2.0	*Strychnos spinosa*	2	0	0	03	*Gymnosporia senegalensis*	3	0	0	05	*Gymnosporia senegalensis*	3	1	0	05
9	VT 03.2.0	*Tecoma capense*	1	1	0	04	*Canthium armatum*	2	1	0	04	*Canthium armatum*	3	0	0	04
10	VT 03.2.0	*Ziziphus mucronata*	1	1	0	04	*Brachylaena discolor*	2	0	0	05	*Brachylaena discolor*	2	2	1	05
1	VT 04.1.0	-	-	-	-	-	*Dichrostachys cinerea*	3	1	0	04	*Sclerocarya birrea*	3	3	0	05
2	VT 04.1.0	-	-	-	-	-	*Sclerocarya birrea*	3	1	0	05	*Dichrostachys cinerea*	3	2	1	04
3	VT 04.1.0	-	-	-	-	-	*Acacia gerrardii*	2	0	0	04	*Acacia gerrardii*	2	2	0	04
4	VT 04.1.0	-	-	-	-	-	*Gymnosporia senegalensis*	2	0	0	03	*Gymnosporia senegalensis*	2	1	1	03
5	VT 04.1.0	-	-	-	-	-	*Acacia burkei*	1	1	0	03	*Acacia burkei*	1	1	1	03
6	VT 04.1.0	-	-	-	-	-	*Phoenix reclinata*	1	1	0	04	*Phoenix reclinata*	1	1	1	04
7	VT 04.1.0	-	-	-	-	-	*Tabernaemontana elegans*	1	1	0	03	*Strychnos madagascariensis*	1	1	1	05
8	VT 04.1.0	-	-	-	-	-	*Vangueria infausta*	1	1	0	04	*Vangueria infausta*	1	1	1	04
9	VT 04.1.0	-	-	-	-	-	*Euclea natalensis*	1	0	0	03	*Euclea natalensis*	1	1	0	03
10	VT 04.1.0	-	-	-	-	-	*Garcinia livingstonei*	1	0	0	03	*Tabernaemontana elegans*	1	1	0	03

VT 02.1.0 = Closed Woodland Thicket
VT 02.2.0 = Closed Woodland on Clay
VT 02.3.0 = Closed Woodland on Sand
VT 03.1.0 = Open Woodland on Sand
VT 03.2.0 = Open Woodland on Abandoned Household Sites
VT 04.1.0 = Sparse Woodland on Sand

Table 7: The 10 woody species most utilised by insects in Manqakulane Rural Community, by vegetation unit and age of damage (for canopy volume removal only). Values given reflect the number of height classes (HC) where utilisation was reported (HC 01), as well as the number of height classes where utilisation was > 50% (HC 02) and 100% (HC 03) of canopy removed or number of individuals utilised within a height class, and the highest height class where damage was observed (HC 04). Species highlighted in red represent situations where at least one height class was completely utilised. Maputaland, northern KwaZulu-Natal, South Africa

Number	Vegetation unit	Taxa	Canopy Volume removal < 12 months				Taxa	Overall Utilisation			
			HC 01*	HC 02*	HC 03*	HC 04*		HC 01*	HC 02*	HC 03*	HC 04*
1	VT 02.1.0	*Zanthoxylum capense*	5	0	0	06	*Acacia burkei*	5	2	1	07
2	VT 02.1.0	*Acacia burkei*	4	0	0	07	*Zanthoxylum capense*	5	1	0	06
3	VT 02.1.0	*Bridelia cathartica*	4	0	0	05	*Terminalia sericea*	4	4	1	06
4	VT 02.1.0	*Euclea natalensis*	4	0	0	06	*Bridelia cathartica*	4	2	0	05
5	VT 02.1.0	*Canthium armatum*	3	1	0	04	*Commiphora neglecta*	4	1	0	05
6	VT 02.1.0	*Carissa bispinosa*	3	0	0	04	*Euclea natalensis*	4	1	0	06
7	VT 02.1.0	*Clausena anisata*	3	0	0	03	*Clausena anisata*	4	0	0	04
8	VT 02.1.0	*Psydrax locuples*	3	0	0	04	*Brachylaena discolor*	3	2	0	05
9	VT 02.1.0	*Albizia adianthifolia*	2	0	0	05	*Carissa bispinosa*	3	2	0	04
10	VT 02.1.0	*Brachylaena discolor*	2	0	0	04	*Deinbollia oblongifolia*	3	1	0	04
1	VT 02.2.0	*Canthium setiflorum*	1	0	0	03	*Grewia caffra*	2	2	2	05
2	VT 02.2.0	*Dalbergia obovata*	1	0	0	03	*Dialium schlechteri*	2	1	1	06
3	VT 02.2.0	*Deinbollia oblongifolia*	1	0	0	03	*Canthium setiflorum*	1	1	1	03
4	VT 02.2.0	*Dialium schlechteri*	1	0	0	02	*Dalbergia obovata*	1	1	0	03
5	VT 02.2.0	*Ehretia obtusiflora*	1	0	0	00	*Ehretia obtusiflora*	1	1	0	03
6	VT 02.2.0	*Grewia caffra*	1	0	0	03	*Rhus gueinzii*	1	1	0	03
7	VT 02.2.0	*Kraussia floribunda*	1	0	0	03	*Deinbollia oblongifolia*	1	0	0	03
8	VT 02.2.0	*Rhus gueinzii*	1	0	0	03	*Kraussia floribunda*	1	0	0	03
9	VT 02.2.0	*Zanthoxylum capense*	1	0	0	03	*Zanthoxylum capense*	1	0	0	03
1	VT 02.3.0	*Acacia burkei*	4	0	0	05	*Strychnos madagascariensis*	5	2	1	06
2	VT 02.3.0	*Bridelia cathartica*	4	0	0	05	*Bridelia cathartica*	4	2	0	05
3	VT 02.3.0	*Dichrostachys cinerea*	4	0	0	05	*Zanthoxylum capense*	4	2	0	05
4	VT 02.3.0	*Zanthoxylum capense*	4	0	0	05	*Acacia burkei*	4	0	0	05
5	VT 02.3.0	*Coddia rudis*	3	0	0	04	*Dichrostachys cinerea*	4	0	0	05
6	VT 02.3.0	*Euclea natalensis*	3	0	0	04	*Sclerocarya birrea*	3	2	0	07
7	VT 02.3.0	*Psydrax locuples*	3	0	0	04	*Spirostachys africana*	3	1	0	06
8	VT 02.3.0	*Strychnos madagascariensis*	3	0	0	05	*Coddia rudis*	3	0	0	04
9	VT 02.3.0	*Deinbollia oblongifolia*	2	0	0	03	*Euclea natalensis*	3	0	0	04
10	VT 02.3.0	*Dialium schlechteri*	2	0	0	04	*Psydrax locuples*	3	0	0	04

Table 7 continued

1	VT 03.1.0	*Brachylaena discolor*	1	0	0	04	*Brachylaena discolor*	1	1	0	04
2	VT 03.1.0	*Combretum molle*	1	0	0	05	*Combretum molle*	1	1	0	05
3	VT 03.1.0	*Dalbergia obovata*	1	0	0	03	*Dalbergia obovata*	1	1	0	03
4	VT 03.1.0	*Grewia microthyrsa*	1	0	0	04	*Grewia microthyrsa*	1	0	0	04
5	VT 03.1.0	-	-	-	-	-	*Hymenocardia ulmoides*	1	0	0	03
6	VT 03.1.0	-	-	-	-	-	*Xylotheca kraussiana*	1	0	0	03
1	VT 03.2.0	*Dichrostachys cinerea*	4	0	0	04	*Terminalia sericea*	4	1	1	07
2	VT 03.2.0	*Strychnos madagascariensis*	4	0	0	05	*Dichrostachys cinerea*	4	0	0	04
3	VT 03.2.0	*Strychnos spinosa*	4	0	0	05	*Strychnos madagascariensis*	4	0	0	05
4	VT 03.2.0	*Euclea natalensis*	3	0	0	04	*Strychnos spinosa*	4	0	0	05
5	VT 03.2.0	*Ochna natalitia*	3	0	0	07	*Ochna natalitia*	3	1	1	07
6	VT 03.2.0	*Sclerocarya birrea*	3	0	0	04	*Sclerocarya birrea*	3	1	0	04
7	VT 03.2.0	*Terminalia sericea*	3	0	0	04	*Euclea natalensis*	3	0	0	04
8	VT 03.2.0	*Albizia adianthifolia*	2	0	0	03	*Trichilia emetica*	3	0	0	07
9	VT 03.2.0	*Commiphora neglecta*	2	0	0	04	*Commiphora neglecta*	2	2	1	04
10	VT 03.2.0	*Deinbollia oblongifolia*	2	0	0	03	*Albizia adianthifolia*	2	1	1	03
1	VT 04.1.0	*Garcinia livingstonei*	1	0	0	03	*Sclerocarya birrea*	2	1	0	05
2	VT 04.1.0	*Sclerocarya birrea*	1	0	0	02	*Trichilia emetica*	1	1	1	02
3	VT 04.1.0	*Strychnos madagascariensis*	1	0	0	03	*Xylotheca kraussiana*	1	1	1	02
4	VT 04.1.0	*Trichilia emetica*	1	0	0	02	*Ziziphus mucronata*	1	1	1	04
5	VT 04.1.0	*Xylotheca kraussiana*	1	0	0	02	*Garcinia livingstonei*	1	1	0	03
6	VT 04.1.0	*Ziziphus mucronata*	1	0	0	04	*Acacia gerrardii*	1	0	0	03
7	VT 04.1.0	-	-	-	-	-	*Dichrostachys cinerea*	1	0	0	03
8	VT 04.1.0	-	-	-	-	-	*Strychnos madagascariensis*	1	0	0	03

VT 02.1.0 = Closed Woodland Thicket
VT 02.2.0 = Closed Woodland on Clay
VT 02.3.0 = Closed Woodland on Sand
VT 03.1.0 = Open Woodland on Sand
VT 03.2.0 = Open Woodland on Abandoned Household Site
VT 04.1.0 = Sparse Woodland on Sand

Tshanini. It would seem that the local people have hunted all small mammals within a 2 km zone around the core community village. The Closed Woodland Thicket and Open Woodland on Abandoned Household Sites have a dense undergrowth and these conditions are the most favourable for these small mammals, by providing cover and abundant food (van Eeden 2005). Van Eeden (2005) evaluated small mammals' occurrence in Tshanini and established that only suni and red duiker occurred in the area.

Human utilisation of the area is remarkably high and appears destructive. The number of height classes fully utilised is alarming, and it seems that canopy removal by humans tend to have a cumulative effect on the vegetation. As expected, the units where most of the older signs of utilisation are found were the Open Woodland on Abandoned Household Sites but also the Sparse Woodland on Sand and the Closed Woodland on Clay. The former, as indicated by its name is an open woodland vegetation phase, where the vegetation is recovering from a range of man-induced utilisation (Gaugris 2004; Peteers 2005). The latter two occupy the area where most of the local people relocated after 1992, when the government installed a safe water supply along the western side of the Muzi Swamp (Gaugris 2004; Peteers 2005).

The Closed Woodland on Clay is found along the eastern and western sides of the Muzi Swamp and in addition to being close to the safe water supply, the tall trees provide much-needed shade in summer (Gaugris 2004). Most households are therefore settled within this woodland type, but also on the first dune cordon in a westerly direction, where a mixture of Open and Sparse Woodland on Sand occurs (Gaugris 2004). However, due to the nature of the latter vegetation unit the need to remove trees to settle a household is lower and could therefore explain the reduced impact observed there. Moreover, the Open Woodland on Sand is rich in fruit bearing trees and it is possible that the extensive use of this unit is linked to such a form of utilisation.

The recent signs of utilisation identified in the Closed Woodland Thicket go against statements that people rarely travel further than 2 km to harvest building material (Brookes 2004; Gaugris *et al.* 2007). This observation could be associated with either of two events or both. Tshanini was fenced at the end of 2005, and during most of the year prior to that event, teams of workers from the community were sent to clear the fence lines. It appears highly likely that some of the recent utilisation observed is linked to that event, as the people would have been equipped with harvesting equipment and would have used the access roads to the reserve. The fence line clearing most likely brought the people further away than they would normally do, and they have used the opportunity to harvest trees in that vegetation unit for firewood or the building of households. The alternative option is that tree species used for the construction of households have been so depleted in the vicinity of the village that the people are actually forced to walk the extra distance to reach this vegetation unit. Such a pattern of utilisation has been observed in several places in South Africa (Banda *et al.* 2006; Shackleton *et al.* 2007). However, the actual tree species utilisation values in Table 5 do not support this hypothesis fully. The most utilised species in the Closed Woodland Thicket are the fruit bearing *Strychnos* species, and *Dialium schlechteri*, which is utilised more for firewood or non-habitation buildings such as maize stores (Gaugris *et al.* 2007). The straight poles of smaller *Terminalia sericea*, and medium sized *Euclea natalensis* are currently used for house building although their short durability is not a preferred feature (Gaugris *et al.* 2007), while the thorny branches of *Acacia burkei* and *Dichrostachys cinerea* are used for firewood or as cattle-proof fences around cultivated fields.

The tree species utilisation analysis (Table 5) reveals that people do indeed use fruit bearing trees extensively, although it was not unexpected (Emanuel *et al.* 2005; Shackleton *et al.* 2007). The values also show that the utilisation could potentially be unsustainable in the long-term, especially for the species where utilisation exceeds the 50% of a height class utilisation mark in more than one height class. Several studies that evaluated non-timber forest product utilisation established that in most instances the use was not sustainable, as the removal of parts of the plants, and sometimes the reproductive systems led to much reduced flowering and fruiting and regeneration (Fredericksen *et al.* 1999; Ticktin 2004; Shackleton *et al.* 2005). The utilisation of *Hyphaene coriacea* for the production of palm wine appears particularly destructive. The stems of the trees are cut at approximately breast height, thereby removing the whole canopy. While the latter explains the noticeably high utilisation level for that species, it also highlights a major problem with the sustainable utilisation of this species. Every time a tree is cut for producing palm wine, the flowering part of the plant is removed, and there is no further potential for sexual reproduction and genetic mixing.

The utilisation due to natural damage is a puzzling issue. Natural damage appears to affect a large percentage of woody species, and greatly affects a large percentage of height classes as well. Furthermore, the natural damage appears to have an accumulative nature, whereby plants seem to have insufficient time to recover between utilisation events. The latter is most uncharacteristic of natural disturbance damage (Whitmore and Burslem 1996; Burslem and Whitmore 1999). One option could be the human-induced burning of the bush, especially in Open and Sparse Woodland units (Gaugris *et al.* 2004). The local people burn the vegetation to induce fresh grass growth towards the end of the dry season, in order to feed the cattle. The author observed numerous fires, left uncontrolled. The practice is regular and annual burning of the same vegetation units was observed. Due to the human utilisation of these vegetation units, some of the tree canopy is removed and conditions are favourable for the development of a dense herbaceous layer, thus generating high fuel loads and hot, intense fires. The latter has been documented in east Africa and elsewhere (Franklin *et al.* 2000; Kauffman *et al.* 2003; Schwartz and Caro 2003) and could potentially be the one important reason for the high level of natural damage observed. Another option could be linked to the opening of the vegetation for fields and households (Colón and Lugo 2006), which changes conditions at all levels of the woody species' canopies (Gerwing 2002; Okuda *et al.* 2003; Schwartz and Caro 2003; Paul *et al.* 2004). The changes include increased light and temperature, which could have a bearing on the ability of some species to survive especially when such changes are extensive and lead to constant absence of vegetation at several levels.

The level of insect herbivory observed is an interesting aspect in the present study. The number of woody species used by insects is high (>60% in three vegetation units) and damage consists mostly of defoliation, but also the removal of some height classes. In a study in east Africa, it was established that insects caused the greatest damage to the seedlings of *Acacia* species, but also that insect herbivory was greater in areas where mammals larger than rodents were absent (Shaw *et al.* 2002), while another study measured the effect of arthropods at 20.00% removal of the net primary productivity (Chapman *et al.* 2006). Insects are an often overlooked agent, but the utilisation levels observed proves that it must be included in the larger picture when considering the sustainable utilisation of the vegetation in a region. It appears possible that insect herbivory is exacerbated in the Manqakulane area due to the lack of small browsers (Shaw *et al.* 2002).

Conclusion

An overview of the utilisation of woodland vegetation outside protected areas and in a remote part of northern Maputaland is presented. The levels of utilisation observed indicated that rural people were utilising the vegetation at an alarmingly high rate, especially around settled areas. Insect herbivory was observed and evaluated as a non-negligible agent in the utilisation of vegetation, while natural damage was believed to be largely aggravated by the human utilisation methods. The conservation of natural vegetation of northern Maputaland outside conserved areas appears a difficult task as modernisation of the rural society has led to the opening of clearings for new households characterised by smaller families. This society change is taking a remarkable toll on the surrounding vegetation and it appears judicious to focus future conservation efforts on enticing people to set aside non-farmed land such as Tshanini and to evaluate the potential of agro-forestry to provide building material in a sustainable manner.

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CHAPTER 10

THE UTILISATION OF WOODY VEGETATION BY ELEPHANTS IN TEMBE ELEPHANT PARK, MAPUTALAND, SOUTH AFRICA

Abstract

The utilisation of vegetation and particularly trees in enclosed small reserves where elephant populations are confined is a contentious conservation issue. In Tembe Elephant Park in Maputaland, the biodiversity rich Sand Forest is considered the most valuable feature to conserve, yet it is considered at risk from increasing elephant utilisation of the park's vegetation. The mean canopy removal by elephants across the park was therefore studied over a recent period including the last 12 months prior to the study and an older period for all events prior to the past 12 months. The intensity of utilisation was also evaluated in relation to the distance to water. Results show that utilisation patterns have shifted in the recent period and a significant decrease in utilisation intensity is correlated to an increasing distance from water points in the park. Recent and old utilisation patterns are discussed.

Keywords

Canopy removal, elephant, Maputaland, Sand Forest, watering point distance, woodlands

Introduction

Tembe Elephant Park, in South Africa's Maputaland region, is home to a confined and growing population of African elephant *Loxodonta africana* (Blumenbach 1797)(Morley 2005). The park was initially created in 1983 to protect the last remnants of the elephant population in Maputaland, and to conserve the biodiversity rich Sand Forest vegetation, home to many endemic plants and animals (Matthews *et al.* 2001; Matthews 2006; Guldemond 2006; Guldemond and Van Aarde In Press).

The destructive effect of growing elephant populations on the vegetation and particularly on trees, is well documented (Leuthold 1996; Hall *et al.* 1997; Mosugelo *et al.* 2002; Western and Maitumo 2004; de Beer *et al.* 2006; Mtui and Owen-Smith 2006; Guldemond and Van Aarde In Press; Van Aarde and Jackson 2007; Western In Press) and is of paramount importance in small and fenced reserves (Lombard *et al.* 2001; Guldemond 2006; Guldemond and Van Aarde In Press; Van Aarde and Jackson 2007), where the animals are not afforded the space to roam.

The impact of elephants in Tembe Elephant Park and especially on the Sand Forest is a hotly debated subject (Van Rensburg *et al.* 1999a; Van Rensburg *et al.* 1999b; McGeogh *et al.* 2002; Gaugris *et al.* 2004; Matthews 2006; Botes *et al.* 2006; Guldemond and Van Aarde In Press). The elephant population in Tembe Elephant Park has been documented to utilise the vegetation in a destructive manner and the preponderance of visual damage was noted to be increasing (Morley 2005; Guldemond and Van Aarde In Press). While there is no clear change in terms of forest tree species composition (Gaugris *et al.* 2004), the general impression is that elephant utilisation will probably damage the Sand Forest, a forest type considered in "suspended animation" (Matthews 2006) due to its apparent lack of recruitment and expansion (Van Rensburg *et al.* 1999a; Van Rensburg *et al.* 1999b; Matthews *et al.* 2001; McGeogh *et al.* 2002; Matthews 2006; Botes *et al.* 2006). However, the study by (Guldemond and Van Aarde In Press) contradict the above perceptions. They established that while elephants clearly affected tree species, the effect of these mammals was not yet detrimental at the community level.

In the present study we aim to provide additional insight on the level of utilisation of the various vegetation units by elephant in Tembe Elephant Park. The impact of elephants in Tembe Elephant Park is investigated at the park level, and in different sectors of the park, as well as by vegetation unit. A correlation between distance to permanent water points and utilisation intensity is also attempted.

Study area

Tembe Elephant Park is situated in Maputaland, northern KwaZulu-Natal, South Africa (-26.85 º to -27.15 º South and 032.35 º to 032.60 º East) and a thorough description of the study area appears in Matthews *et al.* (2001).

The park consists mainly of a sandy plain interspersed with ancient littoral dunes. It is covered by an Open to Closed Woodland, with patches of Short, Intermediate and Tall Sand Forest and the Muzi Swamp running along the eastern boundary (Matthews *et al.* 2001). Mean annual rainfall for the period from 1981 to 2003 is 721 mm in Matthews (2006). The summers are hot; with a mean mid-day temperature of 31°C in January. The winters are cool to warm, with a mean mid-day temperature of 24°C in July, and with June, July and August the coldest months. The total rainfall at the study site was measured at a high of 1391 mm in 2000, followed by an above average rainfall year of 904 mm in 2001. However, rainfall dropped to 246 mm in 2002 and 343 mm in 2003. More rain was received in 2004, with 623 mm precipitation. This was a noticeable reduction in rainfall over the four years preceding the present study, and a switch from exceptionally high rainfall in 2000, to a drought situation during most of 2003. Only waterholes with permanent water were used to measure distance from plot to the nearest waterhole (see below).

The Tembe Elephant Park has a confined elephant population (Morley 2005; Guldemond and Van Aarde In Press), which was estimated at 179 animals (95% confidence interval of 136 – 233) in 2001, and growing at 4.64% per year (Morley 2005). At the above estimated growth rate, the population at the time of the present study (2004) had most likely exceeded 200 animals (204 animals, 95% confidence interval of 156 – 266).

Methods

A total of 107 rectangular plots of varying length and width were sampled to evaluate the intensity of woody plant species utilisation by browsing herbivores throughout the park in 2004. In this manuscript only the utilisation by African elephant is evaluated. The plots were laid out at least 100 m from tourist tracks and 50 m from less used management tracks. Management restrictions at the time of the study forced the lay out of plots within the network of roads. The park is divided in two sections: a southern section (approximately 1/3 of the park) where tourists can visit the park through a fairly well-developed network of sandy tracks accessible to 4x4 vehicles, and a northern section considered a wilderness area where tourist visits are prohibited and where a minimalist network of management tracks allows access.

Each plot was subdivided in two subsamples. All trees with a height ≥ 0.4 m were sampled in the whole area defined by the plot dimensions, while those inferior to the defined cut-off mark were sampled in an area restricted to half that of the full plot size. All woody individuals encountered were identified to the species and measured. For each tree, the numbers of live and dead stems were counted and their diameters measured. The tree height and the height to the base of the canopy (defined as the height where the larger lowest branches are found) were measured, followed by the largest canopy diameter (D1) and the diameter of the canopy perpendicular to it (D2).

The level of utilisation by herbivores of each tree was evaluated. Any alteration or damage to the tree as a whole (canopy, trunk and roots) was labelled, described, quantified and aged (<12 months or >12 months since utilisation event). For each utilisation episode, an index of canopy removal at the time of damage was estimated to describe how much of the canopy was removed at the time of the utilisation, ranking from 1 (>0 to 10%), 2 (11% to 25%), 3 (26% to 50%), 4 (51% to 75%), 5 (76% to 90%), 6 (91% to 99%) to 7 (100%). Whenever possible, the animal responsible for the utilisation was identified. If positive identification proved impossible, the herbivore class most likely responsible for the utilisation was noted. The herbivores were classified in five classes ranging from: insects, small herbivore mammals, medium herbivore mammals, undetermined large herbivore mammals and elephants. Expert knowledge and judgement was used to define all these criteria. In the present manuscript only the elephant utilisation aspect will be discussed

The data were captured in Microsoft Excel spreadsheets. A triple error checking procedure was followed. These occurred during capture, back at the research facility while creating back-ups of the day's data, and before formatting once fieldwork was completed. All the data sets were assembled in a single information file and subsequently transformed into a Microsoft Access database for ease of utilisation and analysis.

Afzelia quanzensis clumps and Closed Woodland Thicket vegetation groups are not well represented in the Tembe Elephant Park sample and therefore not analysed further. The Sparse and Open Woodlands on Sand are grouped for further analysis

Queries were written to calculate a mean percentage canopy removal by elephant utilisation value for each plot for the following two periods:

- Recent: period of 12 months prior to when sampling started in May 2004
- Old: period preceding the recent period.

The mean canopy volume removal value was calculated from the midpoint percentage values of the 1 – 7 scale used in the field. The mean canopy volume removal utilisation value is then calculated at the vegetation unit level, and for each period described above.

The distance of each plot to permanent waterholes (at the time of study) was measured using Arc View GIS 3.2a, and we applied Spearman correlations (using Graph Pad Prism Version 4.00 for Windows, GraphPad Software, San Diego California USA, www.graphpad.com) between the mean canopy removal utilisation values and the distance to the nearest permanent waterhole of each plot. Correlations were calculated at the park’s level, and for the Sand Forest association, the Closed Woodland on Clay unit, the Closed Woodland on Sand unit, and the combined Open and Sparse Woodland units. Least square linear regressions were calculated for each of the above levels to illustrate the spread of data.

The park was then subdivided in four sectors (Figure 1):

- the southeast Muzi Swamp sector, with permanent water in the Muzi Swamp
- the northeast Muzi Swamp sector, with permanent water in the Muzi Swamp

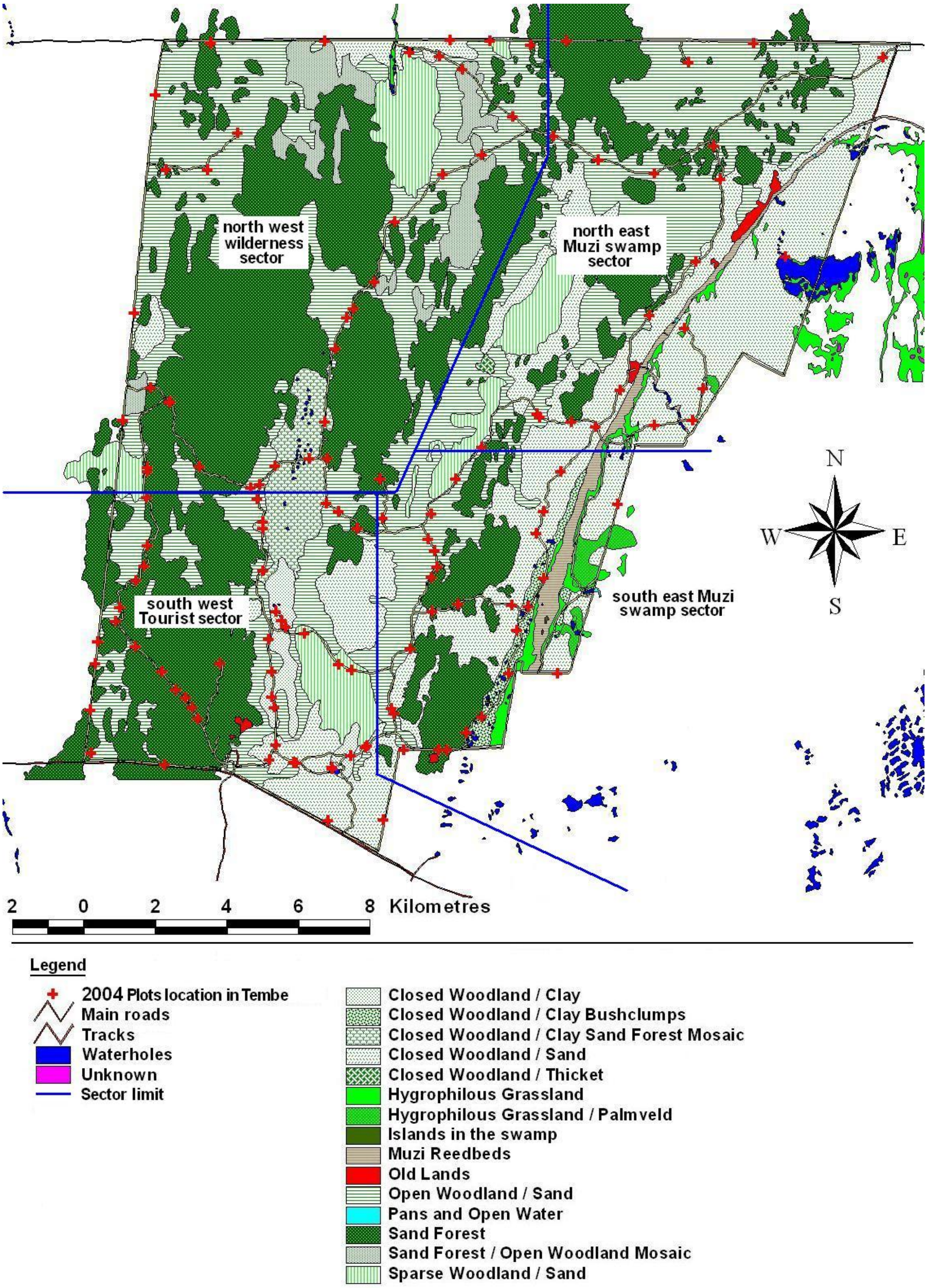

Figure 1: The sector limits used to calculate the distance to water and elephant utilisation relationship in Tembe Elephant Park, surveys of 2004. Maputaland, northern KwaZulu-Natal, South Africa (map adapted from Matthews *et al*. 2001).

- the southwest tourist sector, with permanent water in the Mahlasela hide and Vukazini Pan
- the northwest wilderness sector, with permanent water in the Enzinaleni Pans and northwest pans.

The mean canopy utilisation for each of the above sectors was calculated as the mean of the plots located within a sector for each of the two periods.

Results

From 107 plots sampled, 42 plots (39.25%) had no sign of recent elephant canopy removal, while only five plots (4.67%) had no recorded canopy removal in the old period (Table 1, Figure 2). A total of three plots (2.80%, one in Closed Woodland on Sand, one in Open Woodland on Sand and one in Sparse Woodland on Sand) showed no recorded signs of recent or old elephant utilisation.

The mean canopy utilisation values of the recent period were all smaller than those of the old period, but show that based on the 1 – 7 scale used in the present study, canopy removal during the recent period ranged between 10.67% and 23.47% of the available canopy. The Sand Forest and Closed Woodlands had more of their canopy removed than the Open and Sparse Woodland (Table 2) and the level of canopy removal for the Closed Woodland units was higher than the mean for the park. The older canopy removal utilisation values ranged from 27.23% in the Open and Sparse Woodland to 39.38% in the Closed Woodland on Sand unit. The maximum canopy removal values observed in a plot for the old period were 95.00% in the Sand Forest association and 83.00% for the Closed Woodland on Sand unit. The canopies of two plots (one in the Sparse Woodland unit and one in the Open Woodland unit) were completely removed during the past 12 months (utilisation index of 7 (100.00%), Table 2).

The correlations show that at the park level there was a significant negative relationship between distance to water and mean canopy utilisation during the recent period, whereby mean canopy removal values decreased with increasing distance to water (Table 3). A similar relationship was established for the Closed Woodland on Clay vegetation during the old period, and in the combined Open and Sparse Woodland on Sand vegetation group during the recent period (Table 3).

The regression analysis confirmed the relationships established above for Tembe Elephant Park at the park level (Figure 3), and for the Closed Woodland on Clay vegetation, but not for the combined Open and Sparse Woodland vegetation (Table 4).

Table 1: The number of transects that were not utilised by elephants in Tembe Elephant Park, by vegetation group, in the recent (<12 months) and old periods (>12 months) prior to the study. Maputaland, South Africa

	Total number of transects sampled	Number of transects not utilised by elephant	
		Recent canopy removal	Old canopy removal
Tembe Elephant Park (overall)	107	42	5
Afzelia quanzensis clumps	1	0	0
Sand Forest	26	8	0
Closed Woodland Thicket	1	0	0
Closed Woodland on Clay	15	1	0
Closed wooodland on Sand	16	2	1
Open Woodland on Sand	43	27	2
Sparse Woodland on Sand	5	4	2

NB: *Afzelia quanzensis* clumps and Closed Woodland Thicket vegetation groups are not well represented in this sample and therefore not analysed further. The Sparse and Open Woodlands on Sand are grouped for further analysis

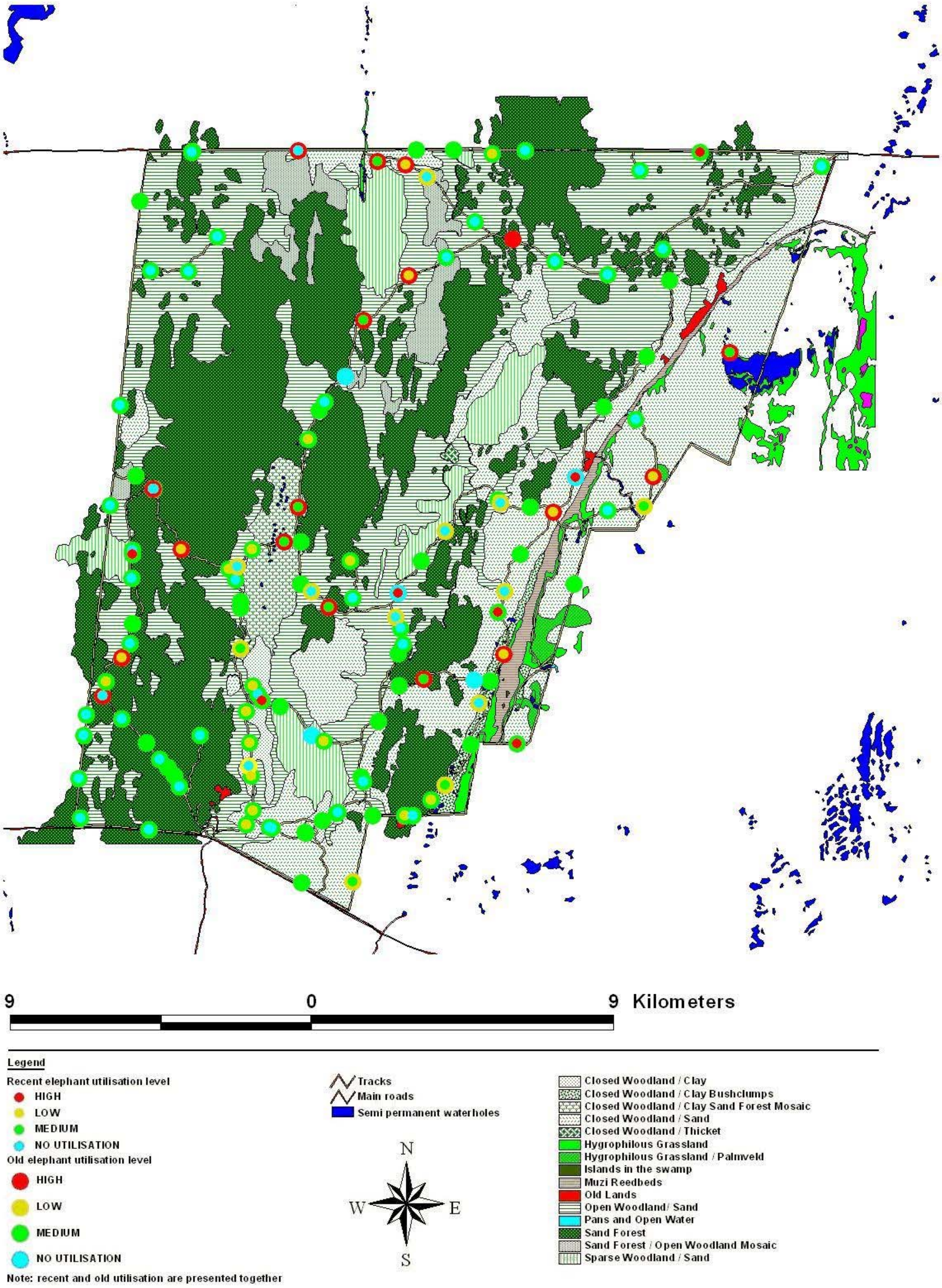

Figure 2: The recent and old elephant utilisation intensity (No utilisation = 0% canopy removal, low utilisation = 1% to 25% canopy removal, medium utilisation = 26% to 75% canopy removal, high utilisation = >75% canopy removal) observed in Tembe Elephant Park Maputaland, northern KwaZulu-Natal, South Africa, surveys of 2004. Recent (12 months prior to fieldwork) and old (>12 months prior to fieldwork) utilisation are presented together, circles that are homogenously coloured represent no change in utilisation intensity over the 12 months prior to the study. (map adapted from Matthews *et al.* 2001)

Table 2: The mean percentage canopy removal by elephants for Tembe Elephant Park and the various vegetation groups or units of the park. Maputaland, South Africa

Site and Vegetation type	Recent canopy removal					Old canopy removal					Mean distance from transect to water by vegetation group				
	Mean	SE	Min	Max	Count	Mean	SE	Min	Max	Count	Mean	SE	Min	Max	Count
Tembe Elephant Park (overall situation)	14.78	2.05	0	100	107	31.34	1.84	0	95	107	2.58	0.16	0.10	8.26	107
Sand Forest	13.81	2.37	0	38	26	34.33	4.09	6	95	26	3.22	0.28	0.77	8.26	26
Closed Woodland on Clay	23.47	6.00	0	83	15	28.17	3.80	6	63	15	0.88	0.18	0.10	2.38	15
Closed Woodland on Sand	21.69	4.60	0	63	16	39.38	5.21	0	83	16	1.14	0.21	0.27	3.58	16
Open and Sparse Woodland on Sand	10.67	3.56	0	100	48	27.23	2.38	0	63	48	3.26	0.23	0.45	6.46	48

Table 3: The Spearman correlations between distance to water and elephant utilisation intensity for Tembe Elephant Park, at the park level and in the various vegetation communities, for recent (<12 Months) and old (12 months) utilisation

		Recent elephant utilisation		Old Elephant utilisation	
	Number of XY Pairs	Spearman r	P (2-tailed)	Spearman r	P (2-tailed)
Tembe Elephant Park (overall situation)	107	-0.47	<0.01 **	0.01	0.88
Sand Forest	26	-0.09	0.67	0.31	0.12
Closed Woodland on Clay	15	-0.30	0.28	-0.71	<0.01 **
Closed Woodland on Sand	16	-0.30	0.25	-0.08	0.77
Open and Sparse Woodland on sand	48	-0.43	<0.01 **	0.25	0.09

** highly significant

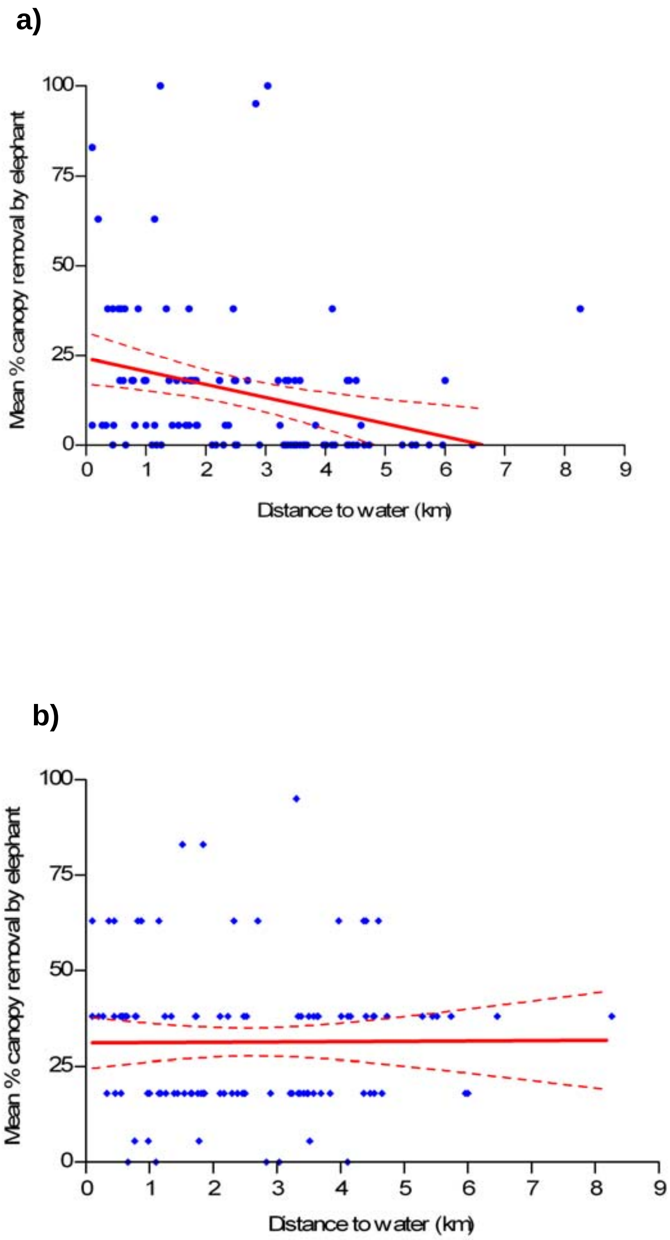

Figure 3: An overview of the percentage of canopy removal (CR) by elephants in Tembe Elephant Park (TEP), Maputaland, northern KwaZulu-Natal, South Africa, in the two periods studied (a): recent or 12 months prior to the study; b): old or >12 months before the study.

Table 4: Summary of the least square regressions fitted to the mean canopy utilisation and distance to water data for Tembe Elephant Park and the various vegetation units within the park Maputaland, South Africa

	Tembe Elephant Park		Sand Forest		Closed Woodland on Clay		Closed Woodland on Sand		Open and Sparse Woodland on Sand	
	Recent utilisation	Old utilisation	Recent utilisation	Old utilisation	Recent utilisation	Old utilisation	Recent utilisation	Old utilisation	Recent utilisation	Old utilisation
Slope	-3.66	0.08	0.72	2.57	-14.72	-14.37	-6.67	-0.16	-3.61	1.84
Y-axis intercept	24.25	31.13	11.48	26.05	36.43	40.82	29.30	39.56	22.44	21.23
r^2	0.08	0.00	0.01	0.03	0.19	0.46	0.09	0.00	0.06	0.03
F	9.71	0.01	0.18	0.78	3.13	11.07	1.42	0.00	2.72	1.54
DF_n	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
DF_d	105.00	105.00	24.00	24.00	13.00	13.00	14.00	14.00	46.00	46.00
P value	<0.01	0.94	0.68	0.39	0.10	<0.01	0.25	0.98	0.11	0.22
Deviation from zero	**	ns	ns	ns	ns	**	ns	ns	ns	ns

ns Not significant

** Highy significant ($p \leq 0.01$)

The northwest and southwest sectors had the highest number of plots not utilised by elephants (Table 5). The mean canopy removal in the recent period is highest in the eastern sectors (Table 5) and lowest in the western sectors. In the old period, mean canopy removal was highest in the northern and lowest in the southern sectors. The mean distance from plot to water was highest in the west and lowest in the east.

Discussion

The canopy utilisation of trees by elephants is highest in the Closed Woodlands, followed by the Sand Forest and the Open and Sparse Woodland during the recent period. The older period values show that utilisation was greatest in the Closed Woodland on Sand, followed by Sand Forest, Closed Woodland on Clay and Open and Sparse Woodland. The results suggest elephants have concentrated on the Closed Woodlands on Clay and Sand during the recent drier period, where mean distance to permanent water holes was the lowest. The recent utilisation values indicate a gradient of utilisation away from permanent water (Table 2).

The level of utilisation in the recent period is between 10 and 24% of the potential maximum canopy removal. However, the level of utilisation in the older period is closer to 30% and up to 40%. It is believed that the former does not imply a decrease in canopy removal but rather represents a phenomenon described as accumulation of scars in several studies (Smallie and O'Connor 2000; Styles and Skinner 2000; Barnes 2001; Sheil and Salim 2004; Makhabu *et al.* 2006), which results in shaping of trees, a reduced canopy height and volume, and ultimately a greater sensitivity of trees to fire (Eckhardt *et al.* 2000; Lombard *et al.* 2001; Western and Maitumo 2004; Birkett and Stevens-Wood 2005; Western In Press). Such repeated utilisation of trees produces a “hedging” effect (Smallie and O'Connor 2000; Styles and Skinner 2000) that may be conducive to repeated breakages in a short time span in areas of intense utilisation. Hedged trees are more attractive to elephants, and in case of pronounced over-utilisation may lead to important physiognomic vegetation change (Smallie and O'Connor 2000; Styles and Skinner 2000; Lombard *et al.* 2001; Gadd 2002; Sheil and Salim 2004). While hedging has mainly been described for woodlands in southern Africa, the repeated use of trees by elephants has been documented in central and east African forests (Sheil and Salim 2004; Lawes and Chapman 2006) and a similar pattern of use has been observed in Europe and North America by moose *Alces alces* and various deer species (Hornberg 2001b; Hornberg 2001a; Joys *et al.* 2004; Kraft *et al.* 2004).

Table 5: The mean elephant canopy utilisation (% canopy removal) by sector in Tembe Elephant Park, and the mean distance from plot to water in each sector, Maputaland, South Africa

Sectors	Number of plots per sector	Number of not utilised plots per sector				Mean canopy use and distance from plot to water per sector											
		Recent		Old		Mean recent canopy utilisation by sector				Mean old canopy utilisation by sector				Mean distance (km) from plot to water by sector			
		Number	%	Number	%	Mean	SE	Min	Max	Mean	SE	Min	Max	Mean	SE	Min	Max
Southeast	21	3	14.29	3	14.29	30.86	6.60	0	100	30.79	4.30	0	63	1.80	0.40	0.10	8.26
Southwest	35	15	42.86	1	2.86	9.50	1.97	0	38	24.34	2.18	0	63	2.64	0.24	0.45	5.96
Northeast	17	5	29.41	0	0.00	17.41	4.35	0	63	40.65	4.85	18	83	2.16	0.36	0.27	4.65
Northwest	34	19	55.88	1	2.94	8.96	3.27	0	100	34.22	3.65	0	95	3.23	0.29	0.33	6.46

Elephants are water-dependent animals, and the provision of artificial permanent waterholes in many reserves has exacerbated the utilisation of trees by elephants due to the absence of natural plant refuges where water is scarce (Eckhardt *et al.* 2000; Guldemond 2006). The utilisation of the landscape by elephants varies, but in general is limited by water availability, with bulls usually ranging further than family herds but rarely further than 15 km from water (Eckhardt *et al.* 2000; Stokke and du Toit 2000; Tedonkeng Pamo and Tchamba 2001; Stokke and du Toit 2002; Smit *et al.* In Press). Elephant ranging behaviour appears to be influenced by rainfall and rainy season length (Dudley *et al.* 2001; de Beer *et al.* 2006), ambient temperature (Kinahan *et al.* 2007), and food resources availability during dry and wet periods (Babaasa 2000; Tedonkeng Pamo and Tchamba 2001; Stokke and du Toit 2002; Galanti *et al.* 2006; Guldemond 2006; Van Aarde and Jackson 2007; Smit *et al.* In Press).

In Tembe Elephant Park there are strong indications that utilisation patterns have changed recently. The increased intensity of utilisation closer to water appears noticeable at the park level (Table 3), and especially in the Open and Sparse Woodlands in the recent period (Table 3). Utilisation by elephants appears to have shifted from the northern sectors to the eastern sectors where the mean distance to water was the lowest, especially along the Muzi Swamp. The precipitation pattern in the region has changed from exceptionally high in 2000/2001, to near drought and drought from 2002 until 2004 (Gaugris 2004). The changed utilisation pattern observed in the park in general, coincides with the change in rainfall and the associated reduction of permanent water points. While in 2000 all water points of natural origin as well as man-made ones were filled to capacity and water was available throughout the park, as the drought set in, the natural waterholes dried up and only the Muzi Swamp contained permanent water. The man-made water holes of Mahlasela Pan and Vukazini Pan were kept full by management decisions, and the northwest waterhole still had water at the time of the study but was drying fast (Pers. obs.). It is suggested that due to the drought, elephants in Tembe Elephant Park utilised the eastern sectors of the park where permanent water was abundant in the Muzi Swamp, and restricted their movements to the western sectors and westernmost areas to short feeding forays.

The case of the Closed Woodland on Clay vegetation shows a reverse trend, whereby utilisation intensity decreased with distance in the old period, and is found relatively constant in the recent period. The clay cells are the areas where waterholes are common and occur mostly along the Muzi Swamp and along the eastern side of the centrally located Sihangwane dune cordon bisecting the park along a north-south axis (Matthews *et al.* 2001). It appears possible that clay areas along the Sihangwane dune cordon were utilised more heavily during the period of high rainfall due to their central location. This would have led to the observed effect as animals move from neighbouring vegetation types to the clay areas to drink, and possibly utilised these areas more intensively, as the clay soils vegetation is most likely more nutritious than on adjacent sandy soils (Matthews *et al.* 2001). As the natural waterholes of the central clay areas dried up with the drought, animals only used these areas for temporary feeding forays, without highly localised utilisation, thus explaining the absence of correlation between increased utilisation intensity and distance to water in the recent period.

In conclusion, it appears that a shift of vegetation utilisation by elephants has occurred in the Tembe Elephant Park during the last 12 months prior to the fieldwork for the present study due to the transition in precipitation regime, and now follows a gradient of utilisation related to the distance to water. The gradient is apparent at the community, sector and park levels and shows that over the 12 months prior to the present study's fieldwork, the canopy utilisation increased close to permanent water. These results are similar to those of other studies (Eckhardt *et al.* 2000; Stokke and du Toit 2000; Tedonkeng Pamo and Tchamba 2001; Stokke and du Toit 2002; Smit *et al.* In Press) but are of further interest due to the small size of the Tembe Elephant Park (300 km^2). The small size means that only a minor part of the park is further than 6 km from permanent water (Shannon 2001), which is well below the acknowledged maximum distance from water observed for bulls during dry season spells (Stokke and du Toit 2000; Mosugelo *et al.* 2002; Stokke and du Toit 2002; de Beer *et al.* 2006; O'Connor *et al.* 2007). Yet, a noticeable water dependence has been shown for elephants in Tembe despite the small distances involved. The conservation implications for management are interesting, as it appears that controlling the supply of water in the park could change utilisation patterns by elephants.

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CHAPTER 11: SYNTHESIS AND DISCUSSION

OF FORESTS, ELEPHANTS, AND MAN: A DELICATE BALANCE FOR THE CONSERVATION OF NORTHERN MAPUTALAND ON THE SOUTH AFRICAN - MOZAMBICAN BORDERLAND

Abstract

The conservation of the rare, diverse and valued vegetation of Maputaland, a region shared by South Africa and Mozambique, is investigated. Conservation options within areas under formal and informal protection, as well as within a human-dominated landscape are discussed after a short review of recent studies on the ecology and social aspects of the region. Animals and people have been the drivers of some major vegetation changes observed within the past 15 years and it is clear that the increasing utilisation pressure by these agents will soon lead to the loss of species, habitat and processes. However, results from a control area that has not been utilised by either agent in a similar time span also show that the influence of animal and human disturbance is an essential component of the northern Maputaland vegetation. Because most-tourist attracting mammalian species in conserved areas do not have threatened status on a global scale, it appears clear that conservation in the region should prioritize vegetation processes across the various landscapes and land-uses and options for unconventional conservation methods are evaluated and discussed. Non-tourism based conservation targets of sometimes-controversial social acceptability such as culling, carbon trade, and developing agro-forestry landscapes appear most likely to ensure that vegetation subsistence conservation targets would be met.

Keywords

Agro–forestry, conservation, elephant, Maputaland, Sand Forest, tourism, utilisation, vegetation

Introduction

In Maputaland as elsewhere in Africa, the processes that govern ecosystem maintenance are at risk from a growing human population (Laurance 1999; Matthews 2006). Until recently, Maputaland remained a little explored region, known for its richness in biodiversity (Van Wyk 1996; Van Wyk and Smith 2001; Smith *et al.* 2006). This diversity was thought to be significantly conserved in the network of parks and reserves in Maputaland (Van Rensburg *et al.* 2000b; Van Wyk and Smith 2001), but recent evaluation of the success of conservation management of mammals in

Maputaland suggests that large herbivore populations are reaching densities that endanger habitat maintenance and diversity governing processes in similar ways as people (Morley 2005; Botes *et al.* 2006; Guldemond 2006). The organisations charged with the management of conservation areas have therefore reached a stage where informed decisions need to be made and management actions should follow suit. Based on a synthesis of current ecological knowledge from recent studies in the region and that gained in the present study, the challenges that lie ahead are explored and some solutions discussed.

A review of results from recent studies on the ecology of Maputaland

1) Conservation planning

A suite of studies based on Geographic Information Systems (GIS) have classified the region as a conservation priority in South Africa. These studies have also noted that human pressure is likely to jeopardise the conservation of ecological processes in the near future (Eeley *et al.* 2001; Reyers *et al.* 2001; Reyers *et al.* 2002; Jones 2006; Smith *et al.* 2006). The main identified threat was the large and unutilised tracts of land available because traditional subsistence farming has proved unsuccessful, but where the soils lend themselves to technologically-aided modern agricultural practices (e.g. drip irrigation) unavailable to the rural and poor majority of the population. Such modern agricultural practices could prove economically more viable than conservation and would result in forest clearing and fragmentation to open fields for mechanised and irrigated agricultural practices as observed elsewhere (Boltz *et al.* 2001; Muchagata and Brown 2003; de Barros Ferraz *et al.* 2004).

2) Vegetation

A set of phytosociological studies evaluated the floristic composition of three sites in northern Maputaland namely Sileza Nature Reserve (SNR) (Matthews *et al.* 1999), Tembe Elephant Park (Tembe) (Matthews *et al.* 2001) and Tshanini Community Conservation Area (Tshanini) (Gaugris *et al.* 2004). The former two studies concentrated on areas conserved by the conservation authorities of the KwaZulu-Natal province of South Africa and subject to animal utilisation, while the latter one investigated a community-based conservation initiative subject to no utilisation. The three studies presented an assemblage of woodlands and Sand Forest, remarkable in floristic similarity. However, further analysis of dung beetle and avian assemblages in terms of patch variation revealed a great disparity in the species composition between patches (Van Rensburg *et al.* 2000b), thereby requiring conservation on a larger scale to preserve the ecosystem processes within these vegetation communities. Comparisons between Tembe and Tshanini revealed that species composition was remarkably similar, but species abundance was assumed to have changed due to the effect of large herbivores in Tembe. However, it appeared difficult to ascertain where the most representative original vegetation state lay, as both sites have been submitted to treatments that differed from the natural state that prevailed before demographic pressure and animal extirpation changed the conditions.

Based on a synthesis of the studies in Tembe and SNR Matthews (2006) presented several hypotheses regarding Sand Forest. He suggested that Sand Forest was a community in stasis as a result of meteorological conditions that have prevailed over the past 1 800 years and was only able to sustain itself as long as it remained undamaged. Sand Forest grows in mist-prone areas on self-modified hydrophobic soil. Moreover the hypothetical allelopathic characteristics of the Sand Forest compounds found in the soil could preclude the development of a conspicuous ground layer. The majority of plant species disseminate by fleshy fruits, most likely animal dispersed, while woody species of Sand Forest appear to grow older than woodland woody species. The most likely origin of Sand Forest is that its precursor is Dune Forest, which subsequently evolved in a separate functioning system with a different species composition to become the present day Sand Forest (Matthews 2006).

Two other phytosociological studies investigated the vegetation of Maputaland further south. One concentrated on a flood plain system and found that the vegetation communities were arranged along an inundation-sedimentation gradient (Patrick and Ellery In Press). The other study evaluated the grasslands and woodlands of northern Maputaland north and east of Mkhuze Game Reserve in the Makhathini flats plain but disregarded the forests (Morgenthal *et al.* 2006).

Wooded grasslands of Maputaland are the other most exciting vegetation type of Maputaland and are described as the evolutionary result of a fire controlled system (Matthews 2006).

A study in southern Mozambique described the vegetation of the Licuati Forest Reserve. The presence of a thicket-like vegetation that rarely exceeds 5 m in height, called Licuati Thicket and that of a taller vegetation called Licuati Forest were recorded. These two vegetation types have been identified as equivalents to the vegetation types previously called Short and Tall Sand Forest in South Africa (Izidine *et al.* 2003).

3) Human plant utilisation

Plant utilisation by people in rural and unprotected areas has been highlighted as a concern and several studies have identified and quantified utilisation by local people in an effort to provide information to develop management plans for their sustainable utilisation. One such study evaluated the influence of reed harvesting on reed bed quality in the Muzi Swamp (Tarr *et al.* 2004). An aspect of the results suggested that harvesting should be limited to the dormant winter period in order to allow nutrient reserves to be transferred to the rootstock in the late summer. Harvesting for firewood, crafts, medicinal purposes and building wood have also been evaluated. One study concentrated on areas along the main road that links the towns of Ingwavuma and KwaNgwanase and found that surprisingly few signs of utilisation were visible. Removal was mostly for local purposes and utilisation decreased significantly along a gradient away from villages (Brookes 2004). An in-depth study evaluated the amount of wood used for household buildings. It was estimated that the harvesting needs of 800 people in a rural community for the eight years following study in 2004 would be at least 28 147 wall laths, 1 416 roof laths, 628 main posts, and 477 main beams per year (Gaugris *et al.* 2007). The potential to develop a finished product to sell with added value, through assembling prefabricated wood and reed hut panels by using surplus reed and wood harvest available was also investigated (Tarr *et al.* 2006).

Several studies of a more sociological nature have evaluated the value of natural resources for rural people of the region and showed that while there were clear signs of modernisation of society in northern Maputaland, the utilisation of natural resources in the region was essential to the survival of rural families (Kloppers 2001; Kloppers 2004; Peteers 2005).

4) Effects of animals on vegetation

The African elephant *Loxodonta Africana* (Blumenbach 1797) population of Tembe was estimated, using scientifically accepted methods, at 179 individuals in 2004, with a confidence interval allowing for a range of individuals from 136 to 233 (95% confidence interval) (Morley 2005), and estimated to grow at 4.64% per year since 1989. A study on elephant impact at the micro-, meso- and macro-scales was conducted in and around Tembe (Guldemond 2006). This study established that elephants had an effect at the micro-scale by increasing the heterogeneity of closed woodlands but homogenising open woodlands. There was little effect at the meso-scale when comparing communities inside park and outside the park, while at the macro-scale levels, elephants did not appear to follow a landscape selection pattern. A study on elephant movement patterns across Tembe showed definitive routes within the park, and that elephants created themselves refuges in the Sand Forest and created canopy gaps in doing so (Shannon 2001). A study on smaller herbivores documented the plant species preferences of these animals and some aspects of their ecology in Maputaland inside and outside conserved areas (van Eeden 2005). Studies using dung beetles and birds as indicators of elephant or human impact inside and outside Tembe revealed a significant influence of both agents in reducing the diversity of these indicators (Van Rensburg *et al.* 1999; Van Rensburg *et al.* 2000a; McGeogh *et al.* 2002; Botes *et al.* 2006).

A synthesis of insight gained from the present study

In the present study some hypotheses on the ecology and dynamics of Maputaland are revisited. For the most part, previous hypotheses were not substantiated by quantitative data, whereas the present study is possibly the first to provide quantitative data whereby our insight into the dynamics of the region's woodlands and forests can be advanced. The analysis of the functioning of these ecosystems is further strengthened by investigating the systems on their own and under the influence of mammals or people. The aspects revealed by the present study are summarised and discussed in their context.

1) The Sand Forest diversity in structure and woody species assemblages

Sand Forest remains a largely unknown and unexplored vegetation type. The present study re-defined the groups of Tall and Short Sand Forest by separating them through a newly interpreted Intermediate Sand Forest subcommunity. The evidence obtained from Tembe defined three communities at the floristic and structural levels. However, considering the ordination of these communities with their counterparts in Tshanini revealed that a larger number of units should be considered, as the Short Sand Forest of Tshanini (Gaugris *et al.* 2004) was remarkably different from the Tembe one and might be more related to the Licuati Thicket defined by (Izidine *et al.* 2003) in Mozambique, where trees were rarely noted to emerge from the 5 – 6 m thicket-like canopy.

The implications of the present results are numerous. It appears that Sand Forest is definitely a more complex and possibly dynamic system than has been believed until present. The variations in the forest have been described before at the species level (Matthews *et al.* 1999; Van Rensburg *et al.* 2000a; Van Rensburg *et al.* 2000b; Matthews *et al.* 2001; Izidine *et al.* 2003; Matthews 2006), but the distinctions in structure are new and lend themselves to debating the fact that Sand Forest could be a mosaic of different stages of the same vegetation type, represented by the dominance of different species guilds and structural features (Whitmore and Burslem 1996; Burslem and Whitmore 1999). Another implication is that Sand Forest, although apparently static in size over the past 50 years (Matthews 2006), is actually a diverse, active and self-sustaining vegetation type that derives its exceptional diversity from the mosaic of patches at different structural stages representing successional pathways between one structure and another (Burslem and Whitmore 1999). This runs contrary to hypotheses presented so far.

2) The state and dynamics of woodlands and Sand Forest under different utilisation regimes

The horizontal and vertical structure of similar vegetation units in Tembe, Tshanini and the Manqakulane community village area (Manqakulane) were evaluated in terms of size class distributions and centroid locations. All vegetation units within sites where human (Manqakulane) and animal (Tembe) utilisation have prevailed since 1990 showed evidence of active regeneration possibly stimulated by canopy gaps and an increased light continuum, while in Tshanini regeneration appeared reduced and the understory was more typical of a closed canopy situation in the woodlands. It is hypothesised that the observed differences are the results of 15 to 30 years under different land-use.

A species level analysis of the same vegetation units revealed that the majority of woody species evaluated had relatively steep slopes and a minority of larger trees had shallower slopes. The results indicate an overall good to excellent regenerative potential with exceptions for some species that appear to have been eliminated by utilisation through a particular agent, most notably the *Albizia* species and *Sclerocarya birrea*. This analysis revealed that woody species populations appeared more mature in Tshanini than in Tembe or Manqakulane, although there were not enough large trees to completely fulfil the criteria for mature populations. Moreover and contrary to previous findings, fine-grain processes appear to lead the dynamics of the region’s woodlands and forests. These processes are dominated by non-gap-demanding processes or by the creation of small-scale gaps on a relatively frequent basis that maintain species diversity and regeneration. It appeared obvious that while animals and people played a role in maintaining these vegetation units in the past, however, the current utilisation pressure by either agent was likely to jeopardise the vegetation condition as patterns of utilisation become more characteristic of larger scale disturbance suitable for coarse-grained forests. The absence of disturbance was identified as provoking a change towards coarser grain in Tshanini, but it may also be one of the potential requirements for succession from woodland to forest to happen.

The present study represents the first large-scale vegetation study that investigated the abundance and distribution of woody species in this region of Maputaland and attempted to offer some insight of its dynamics. Previous studies relied on much smaller sample sizes (Matthews *et al.* 1999; Matthews *et al.* 2001; Gaugris *et al.* 2004; Gaugris and Van Rooyen In Press) and did not detect as many nuances in the region's vegetation. The current study, although it reveals many more facets to the northern Maputaland vegetation, remains incomplete, as long-term studies on the growth and mortality rates are essential to obtain a more in-depth view of the overarching dynamics (Condit *et al.* 1998). Nevertheless, the results indicate many aspects that run against hypotheses presented before. The most controversial issue remains the fact that Sand Forest now appears as a dynamic, regeneration prone unit that is intricately linked to the presence of a disturbance agent for the maintenance of its diversity and regeneration processes.

3) The impact of animals and people

The impact of the utilisation of vegetation by people and animals in Maputaland has been debated over the past 10 years and while a general consensus has recently been reached that both agents now have a negative effect on vegetation dynamics (Matthews 2006; Morley 2005; Botes *et al.* 2006; Guldemond 2006), the present study is the first attempt at quantifying these effects. Utilisation was mostly in the form of canopy removal by a range of animals and people, associated with what has been referred to as natural damage. The numbers of woody species used by these agents in their respective areas of influence were high. For elephants and natural damage scars appeared to accumulate, and a new element identified was the observation of utilisation / canopy removal for all woody individuals within a range of height classes. In Tembe it was established that elephants open the canopy while smaller mammals slow down regeneration, thus increasing the grass layer, especially in woodlands, and therefore increasing the influence of fire. This could lead to a "classical" woodland to scrubland to grassland successional progression, typical of abnormally high animal densities in restricted areas such as was observed in East Africa 20 to 30 years ago (Western and Maitumo 2004). In Manqakulane a similarly intense canopy removal by people was established, leading to a somewhat similar successional pathway. Finally, a study of elephant mean utilisation levels over a recent and old period showed active landscape selection in relation to a distance to water gradient during the recent drought years of 2004 and 2005.

The results of the present study corroborate hypotheses proposed in other studies (Van Rensburg *et al.* 1999; Van Rensburg *et al.* 2000a; Matthews 2006; Botes *et al.* 2006; Guldemond 2006), but more importantly indicate that intensely disturbing patterns observed elsewhere in Africa (Walpole *et al.* 2004; Western and Maitumo 2004; Colón and Lugo 2006; Karlowski 2006) are activated and likely to develop fully in Maputaland should no management action be taken. The implications for the conservation authorities are straightforward as these effects have been observed elsewhere in Southern and Eastern Africa, but solutions have also been found and proven successful.

To conclude, the main point in the present study was the documented proof that Sand Forest and Woodlands of Maputaland are active vegetation groups, and that their biodiversity is linked to animal and human agents. However, the survival of these biodiverse ecosystems is dependent upon limiting the repeated large-scale effects of people outside conserved areas and herbivore mammals, especially elephants, in conserved areas. Considering that most large herbivores in Tembe are not in immediate danger of extinction and are well represented within South Africa by a host of other equally or more numerous subpopulations, the present study suggests that the conservation of the vegetation should become the priority for the Tembe management team.

Sand Forest and Woodland dynamics and their management

Most studies to date would question the Sand Forest as described in the present study because it was seen as a vestigial remnant of a long gone era when climate was wetter and more propitious to its expansion (Van Rensburg *et al.* 2000a; Matthews 2006). Most observations by prior studies indicate that Sand Forest does not regenerate after large scale disturbance and that woodland and Sand Forest similarities in species composition and even sometimes structure are the result of a unidirectional change from a forest to woodland state (Van Rensburg *et al.* 2000a). The implications of such a successional pathway imply that forest loss is irreversible under present conditions.

A rapid look at human and animal presence in the region is needed before discussing the implications of the above and the present study further. Organised human presence in Maputaland is well-documented for the period from 1502 until present (Kloppers 2001). The presence of people prior to this date is certain, although much less is known about it (Kloppers 2004; Matthews 2006; Peteers 2005). It is believed that iron age communities populated Maputaland as early as 290 AD, while signs of human presence date back from 110 000 years (Peteers 2005). The animals of the region have been hunted by people for as long as their presence in the region has been documented (Kloppers 2001; Peteers 2005). The human and animal presence in Maputaland therefore represents a very long association of these two agents with the vegetation of the region. Such long-standing associations are known to have interrelated effects, especially the shaping of vegetation by uninterrupted human societies over a long period of time (Ickowitz 2006). In such human-dominated rural societies the progression from forest to woodland or woodland to forest have been documented over history (Ickowitz 2006). The present state of most west, central and east African wooded landscapes appears to be 1800 – 2000 years old, and wherever paleo-palynologists, archaeologists and biologists have worked together, there is mounting evidence that human societies have shaped the advance and retreat of forests and woodlands during this era (Ickowitz 2006). Due to the long-term presence of people in Maputaland it appears doubtful that they would not have had such a shaping influence, especially considering that fire appears to have been a management tool since early ages (Matthews 2006; Peteers 2005).

Due to the implications of such long-term interactions affecting ecological processes that span centuries to millennia (Whitmore and Burslem 1996; Chapman *et al.* 1997; Burslem and Whitmore 1999; White and Jentsch 2001) statements regarding current (50 – 100 years prior to study time) woodland to forest or forest to woodland successional pathways in Maputaland as inferred by the studies referred to above should be done with caution. However, what appears undisputed is that animals and people have been and remain part of the dynamics of the region’s vegetation and should probably not be separated from the system.

The consequences of the fine-grain character have been discussed in the relevant sections, but a further interest is that managers need to focus on guaranteeing a level of disturbance that allows patches of vegetation to be utilised and recover thereafter. The implications for such management are most likely limiting the number of animals in conservation areas, and creating and thereafter controlling a rotational harvesting system for human utilisation. Defining the levels that promote fine-grain processes remains unknown for Maputaland conservation. However, the present study has clearly established that current levels are untenable and are promoting changes that are considered undesirable for the conservation of the vegetation in Maputaland. Therefore, it is suggested that the 2004 population of 179 elephants in the 30 000 ha of

Tembe (Morley 2005), the numbers of other herbivores for 2004 in Tembe and 778 people in 124 households on the 2 500 ha of Manqakulane for 2004 (Peteers 2005) most likely represent values that exceed the threshold for maintaining the region's vegetation dynamics. These densities of agent per ha or km^2 could be included into conservation planning systems as indicators of forced forest to woodland to grassland succession (Smith *et al.* 2006).

Because the above values indicate undesired problems in the making, it is logical to accept that either lower animal numbers or restricted human access to resources is required. Setting these numbers will be a difficult task, as the conflicting interests of tourism and conservation (Matthews 2006) will have to be considered in conserved areas while those of people's needs and conservation's needs will need to be taken into account in non-conserved areas (Gaugris 2004; Gaugris *et al.* 2007).

Because the three sites studied have been under their respective agent's influences for known periods, it can be assumed that the differences observed are the results of a minimum of 12 years influences or lack thereof in Manqakulane and Tshanini or 15 years for Tembe. These values are absolute minimums and are most likely not representative of the real time span, which is probably closer to double these values. In effect animal populations' movements in this area of northern Maputaland were confined within Tembe since 1983 (Matthews 2006), while since 1975, people from the Manqakulane community already utilised the Manqakulane area before they settled there permanently in 1992 (Peteers 2005). The changes observed are therefore most likely derived from a period of 21 – 29 years influence of the agents. The situations observed in the present study represent the end results of a succession of elements and their accumulated effects over a period that spans approximately a quarter of a century. It appears likely that the success of direct conservation measures in Tembe and by default conservation measures in Tshanini and its implied restrictive effects for Manqakulane since the 1989 – 1992 timelines have exacerbated the progression towards its current state. It appears also likely that recent increases in animal densities in Tembe and in human population in Manqakulane could have had exponential effects on the vegetation. In this situation, it may be that only the past five to eight years represent a problem timeline. However, for reliability, the above-defined 12 – 15 years timeline should rather be considered as the accurate reading.

As a guideline it would be recommended to investigate the animal numbers of Tembe from the selected timeline as a threshold that management actions should possibly consider as non-damaging to vegetation dynamics of the region. The elephant population in 1989 was estimated to have ranged from 124 to 152 individuals (or 0.41

to 0.50 elephant km^{-2}) (Morley 2005), which is significantly more than presented in previous other studies (Klingelhoeffer 1987; Matthews and Page In Prep). These studies were considered inaccurate due to the bias of Tembe's elephant population in favour of bulls, which was established during the most recent study (Morley 2005). The human population in Manqakulane at that time is unknown. However, the population is thought not to have changed significantly since 1996 due to emigration towards main access roads (Peteers 2005). An educated approximation would therefore place the population of the community between 250 and 500 people. The animal numbers from this period in Tembe are documented by regular large herbivore estimates undertaken by the regional ecologist of Tembe (Matthews 2000). The report available to the present study made clear that surveys were conducted in 1990 and 1994. Animal population estimates from these reports should probably be used to determine and re-evaluate thresholds of animal densities for Tembe.

A further note on elephant impact concerns the accumulation of scars on the woody species. Such scars due to elephant utilisation have been documented in other studies and the repeated scarring often led to the death of many woody species utilised (Conybeare 2004; Sheil and Salim 2004). A similar study in Tembe, conducted in 1995 did not note the level of scarring as in the present study (Matthews and Page In Prep) and it appears highly likely that should scars have been present, it would have been recorded and discussed. It is therefore assumed that the study by those authors reflected a situation that would not have harmed vegetation processes and reinforces the opinion that animal numbers from the 1990 – 1992 timelines should be seriously considered as optimal management guidelines to ensure the persistence of vegetation. It is important to realise that based on the present study's results and deductions, the above number of elephants from the 1990 – 1992 period is suggested as a threshold that ensures vegetation persistence and not as the ecological carrying capacity of Tembe for elephants. Recent studies (Morley 2005; Guldemond and Van Aarde In Press) show that elephants in Tembe have yet to reach the level of density-dependent regulation of the population assumed to represent the ecological capacity of the system for this agent (O'Connor *et al.* 2007). It is interesting to note that the above number of elephants represents an animal density of 0.41 to 0.50 elephant per km^2, which is remarkably close to the density responsible for density-dependent auto-regulation assumed to be active in Kruger National Park in South Africa (0.374 elephant per km^2) (Van Aarde *et al.* 1999). However, several flaws plague the auto-regulation concept, not least of which are that self-regulation mechanisms remain highly hypothetical (O'Connor *et al.* 2007). Another facet is that self-regulation is most likely linked to rainfall and food availability (O'Connor *et al.* 2007), both of which are much higher in the Maputaland region than in the Kruger National Park. Finally another problem with keeping an elephant population as close as possible to a static predetermined number is that it is not desirable (Van Aarde and Jackson 2007) because it opposes the non-equilibrium principle now accepted to rule African savannas. Some implications and solutions for this particular aspect are discussed in the next section.

The level of accumulated canopy removal observed and considered as scars in the present study begs the question of defining a boundary between utilisation and damage. The fact that signs of utilisation accumulate suggests that insufficient time is available between utilisation events to allow the recovery of the plants affected. In an open ecosystem, such accumulation of utilisation events may be observable over a short period, but the intrinsic quality of the system allows the animals to move to a different area as soon as any of their food selection criteria are no longer met (O'Connor *et al.* 2007). The likelihood of a return to an area that was previously utilised is low when sufficient habitat of suitable quality is encountered (O'Connor *et al.* 2007; Van Aarde and Jackson 2007). In the areas defined as closed systems due to fences or anthropogenic pressure, where such free-ranging is by definition excluded, and where utilisation accumulates to form scars (Van Aarde *et al.* 1999), it appears important that the notion of damage to the vegetation should supersede that of utilisation of the vegetation. The Oxford English Dictionary defines damage as “physical harm reducing the value, operation, or usefulness of something”. In the context of Tembe the above definition appears fitting as it seems that utilisation of the vegetation is reducing the value thereof. It is therefore suggested that conservation authorities should thrive to eliminate damage of the vegetation.

Conservation and the elephant question in the Transfrontier context

A transfrontier conservation area (TFCA) agreement has been signed between Mozambique, Swaziland and South Africa for the creation of the Lubombo TFCA. The planned development of this project is to re-establish a wildlife corridor (Futi Corridor) between the Maputo Elephant Reserve (MER) in Mozambique, Tembe and Ndumo Game Reserves in South Africa and Swaziland’s Hlane National Park and Mlawula and Ndzinda Game Reserves (Kloppers 2001). The most influential aspect of this linkage would be to allow elephant populations of Tembe and MER, estimated to represent 384 individuals in total in 2004 (Morley 2005), to roam freely in a landscape approaching 180 000 ha for the MER – Futi Corridor – Tembe system. The size of this system would certainly guarantee a gap in time before elephant populations have increased to a degree that once again threatens the ecology of northern Maputaland. Assuming the lower density option as recommended above by the present study (0.41 elephant km^{-2}) based on Morley's (2005) results and the upper growth rate described for these populations of 4.64% per year (Morley 2005), a period of 15 to 16 years appears necessary to reach the recommended lower limit, calling for an elephant population in the 700 to 800 individuals for the system. Due to the greater diversity of environments offered by the larger system, it may be possible that a greater density of elephants could be supported before vegetation becomes damaged. Nevertheless, while these estimates remain over-simplistic, the problem remains the same as the larger conservation area thus created remains a closed system, and effects are only delayed by 15 – 30 years depending on the pathway chosen.

The further opening of this greater system towards yet another conservation area is an appealing option for the conservationist mind. Such an option would necessitate corridors to be opened between the conserved areas as well as active protection. Alternatively, such linkages could be acting as sinks and conserved areas acting as sources, as implied in the southern African global elephant metapopulation framework (Van Aarde and Jackson 2007) However, some aspects need consideration before further discussing the issue.

The first issue is one of economic feasibility and desirability. Southern Mozambique, especially the region around the capital city of Maputo and the N4 highway that links Johannesburg and Pretoria in the Gauteng province of South Africa, is an economically active region that has an undeniable attraction for Mozambican people searching for employment opportunities (Kloppers 2001; Kloppers 2004). It is expected that the renewed interest in Maputo as a major harbour for the Indian Ocean coastline, and the agricultural potential of the inland area will provoke a considerable influx of people along an east – west axis from Maputo towards Komatipoort, the South African borderpost on the N4 highway (Kloppers 2001; Kloppers 2004). This highway is of particular economic importance as it links the harbour of Maputo to the economic powerhouse of South Africa, namely the cities of Johannesburg and Pretoria. It is therefore most likely that within the 15 – 30 years timeframe considered, this development axis will represents a real barrier to the development of a wildlife corridor that would link the Kruger – Gaza – Gonarezhou TFCA shared by South Africa, Mozambique and Zimbabwe to the Lubombo TFCA. Such an economic development would probably negate any wildlife corridor linkage possibility in the short- to medium-term future (15 to 50 years) as it appears doubtful that politicians of developing countries would limit their options in one of the most economically favourable areas of the country (West and Brockington 2006). The only way such a linkage would succeed would be to prove that economic benefits from the wildlife corridor would exceed the economic value of development in the region (Cairncross 2004), which appears unlikely.

Should such a wildlife corridor be developed, another issue lies in controlling the safety of people and wildlife through such a human populated landscape. Elephants and other wildlife avoid human populated areas (Walpole *et al.* 2004; Banda *et al.* 2006; Buij *et al.* 2007). In the absence of guaranteed security throughout the wildlife corridor, wildlife movements through the corridor will be reduced to such a low level that the desired effects of density reduction are unlikely to be achieved. Indeed some wildlife will be lost to the sink represented by the corridor. But wildlife reaction to such hunting in other parts of Africa (Hall *et al.* 1997; Maisels *et al.* 2001; Buij *et al.* 2007) suggests that the desired elephant metapopulation ideal, that of a sink harvesting equilibrating the growth from the source population (Van Aarde and Jackson 2007), would not be reached, and therefore the source population would most likely continue to grow. In addition, what is needed for wildlife is equally necessary for people and guaranteed human safety from wildlife needs to be ensured (O'Connell-Rodwell *et al.* 2000) while crop safety and crop loss compensation needs negotiating (Naughton-Treves 1998; Schmidt-Soltau 2003). The short- to medium-term implications of such a corridor in this part of southern Africa imply an “old style” preservation of the link between two conservation areas by fencing in potentially valuable land (O'Connell-Rodwell *et al.* 2000), to the detriment of local rural people (Kameri-Mbote and Cullet 1997; Perrings and Lovett 1999). The term for advocating such a system without favourable and immediate economic return is called “political suicide” (Christensen 2004b; Christensen 2004a).

From the above it appears therefore unlikely that a wildlife corridor would be established in the near future to connect the Lubombo TFCA to another conservation system further north. Another two options of enlarging the system should be investigated. One consists in opening Tembe towards Tshanini, and creating a larger community run concession-like area south of Tembe. This option affords a widening of the system by 10 000 to 20 000 ha before land valuable to people and densely settled zones are encountered (Patrick and Ellery In Press; Smith *et al.* 2006). The short- to long-term attractiveness and value of this option for vegetation subsistence and the wildlife management point of view appears rather low. The second option consists of linking the MER to the Maputaland Coastal Marine Reserve and the St Lucia Wetlands Biosphere Reserve along the Indian Ocean coastline in South Africa. However, similar problems will be encountered with this option as those described above with the presence of the towns of KwaNgwanase in South Africa and Ponta de Ouro in Mozambique in economic expansion and presenting a serious obstacle if not quite as considerable as the one considered above.

This review of options for further expansion shows that intrinsically the Lubombo TFCA may become a closed system in the near future, and failure to consider this aspect will lead conservation authorities to encounter the same problems as today, but at a larger scale, within 15 to 30 years. An option to consider lies in the creation of botanical reserves within the conserved areas (Lombard *et al.* 2001). Although the concept is attractive, the most efficient way to ensure the long-term effect of such reserves lies in adequate elephant-proof fencing (O'Connell-Rodwell *et al.* 2000). The Tshanini situation probably corresponds most closely to a botanical reserve, and while the vegetation is undoubtedly in excellent condition (Gaugris *et al.* 2004), the absence of elephants and other mammals does not appear as the panacea. The direct implication means that regular changes of the botanical reserve boundaries would be needed to ensure that the required disturbance level is reached for most patches. Fencing is not aesthetically pleasing, is ecologically debatable, represents a considerable economic cost to establish and maintain subsequently (Borrini-Feyerabend 1997), but more importantly in this case it does not solve the core issue of the problem. In the Lubombo TFCA context, the use of botanical reserves is therefore suggested as one tool to limit elephant impact on vegetation if needed, but its cost should be carefully considered and weighed against the cost of measures that are more likely to solve the problem. Similarly, long distance translocation is not considered, because it has little value for rural communities, because most southern African conservation areas have reached saturation, and because prospects for translocation further north in Africa are prohibitively expensive as well as unethical because the safety of the animals could be less than adequate (Van Aarde and Jackson 2007). However, short distance (highly localised) translocation is discussed further below.

Solutions to the problem are therefore most likely to be found in a population control method. Because levels of density-dependent auto-regulation of the elephant population are not obvious and remain to be established, even for systems of a much greater size than considered here (Van Jaarsveld *et al.* 1999; O'Connor *et al.* 2007; Van Aarde and Jackson 2007), it seems most unlikely that auto-regulation mechanisms of the MER – Futi Corridor – Tembe elephant population would be stimulated by a population size of 700 to 800 individuals. The option of managing the southern African global elephant population as a metapopulation makes allowance for using the elephant locally as a resource, pending that its conservation is assured through the metapopulation concept elsewhere in the subcontinent (Van Aarde and Jackson 2007). It is the resource aspect that appears the most promising in the current context.

Rural communities need to benefit from conservation in order to ensure continued support for conservation action. This definition, although very simplified and wide, represents the essence of conservation objectives since the era of “old style” preservationist policy has been considered politically inappropriate (Wilkie *et al.* 2006). As such the use of wildlife in general, and elephant in particular, needs to benefit neighbouring communities in a significant way. Wildlife population reduction can be achieved through culling, hunting, and contraception. The latter has been described as viable for small populations on limited areas where repeated treatment is economically feasible, but the long-term consequences on treated animals’ behaviour is unknown (Van Aarde and Jackson 2007). Moreover, contraception is an expensive means of controlling wildlife populations that can hardly be presented as a benefit for neighbouring rural communities.

Culling and hunting are therefore the two most likely options. Both of them are fraught with social controversy (Van Aarde and Jackson 2007), but benefits from such activities are undeniable (Chardonnet 1992) and costs can be relatively limited once a proper structure has been established (Schmidt-Soltau 2003). One of the most criticized issues of these activities lies in the concept of reducing wildlife populations towards a set number of animals. As a starting point, conservation authorities need to accept the underlying condition that because elephant management is within a metapopulation framework, the loss of the isolated and small Tembe and MER regional subpopulations (O'Connor *et al.* 2007) does not represent a threat to the conservation of elephants on the southern African subcontinent as much larger subpopulations (>2000 individuals) exist and are increasing (Morley 2005; O'Connor *et al.* 2007; Van Aarde and Jackson 2007). Moreover, according to several viability studies, the Tembe and MER subpopulations are below the recognised threshold for long-term genetic maintenance (Van Jaarsveld *et al.* 1999; Sanderson 2006) of elephant populations (> 500 individuals) and their loss does not appear critical. However, it is relatively easy to maintain genetic diversity through exchanges between subpopulations (Morley 2005). Loss of the subpopulations is not contemplated in the present case, but it was deemed important to highlight their relatively unimportant status and further justify the possibility to utilise the population for other purposes.

The scientific and economic issues with the culling of elephants in the Kruger National Park in South Africa during the period from 1967 to 1996 were mostly linked with population dynamics disruption, the stimulation of population growth, the creation of static population numbers, and finally the economic cost of logistics to cull and process in excess of 17 000 elephants over that period of time (Van Aarde *et al.* 1999; Van Aarde and Jackson 2007). However, the main difference with the Tembe and MER subpopulations is that the scale of the subpopulation is nowhere close to that of Kruger National Park, and that in Tembe vegetation conservation has been considered more important than elephant conservation. In the following section the discussion concentrates on the Tembe population, as the Tembe and MER systems are not yet linked. Bringing the Tembe elephant population down to its 1990 level represents the culling/hunting of approximately 100 individuals. This number can be hunted (marketing of bulls) / culled (family groups) relatively easily in terms of logistics (Chardonnet 1992), and its economic processing including the sale of hunts and the sale of meat and elephant derived products will most likely offset the initial costs over a short to medium term timeframe and offer an added economic incentive, yet absent (Chardonnet 1992). Elephant population fluctuations at the scale of Tembe are probably limited to the 50 – 200 individuals range within 30-year cycles while for the MER – Futi Corridor – Tembe scale, the range of fluctuations could be allowed between 100 and 800 individuals within 40 years. At these scales it would be worthwhile evaluating whether such variations may be identified as large scale temporal variation that in principle follow the non-equilibrium theory, while at the same time conserving the system's vegetation.

The acceptability of such practices has been debated recently with regards to tourism appeal. Tourists want to see large herbivores, and it appears clear that thresholds of tourism appeal need to be considered. The combination of forests, woodlands, hygrophilous grasslands and swamps that form the intricate vegetation landscape of Maputaland is of great scenic beauty and much of its biodiversity is of great interest to niche tourism such as botanists, birders, insect enthusiasts, and people in quest of elusive mammals. This niche market offers high economic returns for areas where big game tourism is less of an option (Schmidt-Soltau 2003; Kiss 2004; Vande Weghe 2004; Meadows 2006). This begs the question for the development of a network of reserves with tourism infrastructures designed for tourism options that suit the ecological criteria of the region. It appears regrettable to sacrifice the ecological quality of many ecosystems in the name of large game mass tourism. These areas exist and are already famous, the point of creating more appears hardly justified when most problems of these areas are yet to be solved (Vande Weghe 2004). Moreover, the costs of ecosystem management for tourism purposes should in future be compared to the income potential from using the ecosystem value for non-tourism purposes such as ecosystem services (Perrings and Lovett 1999), carbon sequestration and carbon release avoidance (Smith and Applegate 2004; Glenday 2006), and the recent willingness of developed countries and some philanthropists to pay for conservation instead of trying to make conservation pay for itself (Ellison 2003; Ellison and Daily 2003).

To conclude, the present study suggests the management of the Tembe elephant population and that of the greater Lubombo TFCA system once it is created by allowing fluctuations within the vegetation subsistence thresholds by the use of hunting and culling (preferably culling for ethical reasons when elephant family groups are targeted), for economic gain. It is also recommended that new forms of financial contributions enumerated above should be considered and integrated to complement or even replace traditional tourism revenues. It would be regrettable if social acceptability of such practices should dictate its non-use when no obviously viable alternative solution has been presented. It is also suggested that management goals should be aimed at an overarching degree of biodiversity conservation for regional and highly endemic ecosystem preservation and not just a single species of doubtful conservation status.

Conservation in a human-dominated rural landscape

The present study was able to quantify the level of utilisation of the vegetation in the rural community of Manqakulane. This community differs from other communities studied before in the Tembe region because of its location, which is further away from the main paved road from Ingwavuma to KwaNgwanase. Most other communities previously evaluated were situated along that road (Browning 2000; Brookes 2004; Tarr *et al.* 2004; Botes *et al.* 2006; Guldemond and Van Aarde In Press) and most likely demonstrated the effects of development through the access road to Maputaland until late 2002. This road was then supplanted by a newly built access road from the south, from Hluhluwe to Phelindaba and onwards to KwaNgwanase. Besides the geographical distance from a main road, the most notable difference for this rural community lies in the relative stability of its population base since 1996 (Peteers 2005).

Despite this relatively stable population base, the community is nevertheless undergoing a visible modernisation through the increase in number of households, reduction of number of occupants per household and a slight increase in the utilisation of modern materials for household construction (Gaugris 2004; Peteers 2005; Gaugris *et al.* 2007). In this modernisation process a high utilisation of natural resources is evident. The most promising and noteworthy trait of this community is demonstrated by the presence of Tshanini, a dream born in 1992, established in 2000 (Els and Matthews 2001), and gazetted in 2005. The example set by the Manqakulane people is now drawing attention from their neighbours, especially since their old dream has become a fenced-off area with official recognition. Two important aspects need to be considered to make Tshanini a success, ecologically, financially and for the benefit of Maputaland conservation. However, an underlying assumption needs to be presented before developing these aspects. Any development of the nature described below will need the security and safety offered by good governance at the country, provincial and regional level (Christensen 2004a), but also the help offered by children and adult education as well as health and sanitation infrastructure development (Schmidt-Soltau 2003).

The first aspect is to ensure that people in the community derive a financial benefit from the sacrifice of land demonstrated by the presence of Tshanini (Ellison 2003; Ellison and Daily 2003). This needs to be investigated in the way described for Tembe and the Lubombo TFCA. The site of Tshanini in itself has little attraction except for its scenic beauty and the lack of large and dangerous mammals that allow unworried wanderings through the forest. Geographically Tshanini is at a serious disadvantage from the direct competition of Tembe in terms of tourism, but also in that it does not offer a different landscape. Moreover, Tshanini is small, the access road to the site is difficult for most vehicles, and Tshanini does not have any infrastructure for receiving overnight tourists unless they are fully self-sufficient. It is therefore rather sad, albeit realistic, to state that Tshanini, although a conservation success story demonstrating the willingness of rural communities to participate in conservation, is unlikely to offset the costs of standard tourism infrastructure development in its current form (Kiss 2004), and it remains doubtful that should such an infrastructure be developed it would become profitable, as such ventures typically need 10 – 15 years and up to 30 years, to effect viable returns when they are successful (Perrings and Lovett 1999; Schmidt-Soltau 2003; Kiss 2004). In that respect, financial benefits must be returned to local people through innovative conservation systems, and as pointed out in some cases, ecotourism has sometimes less returns and conservation value than pure conservation (Kiss 2004).

Because Tshanini is a reality, it is important to demonstrate further that profits can be obtained so that other rural communities are drawn to the process (Kiss 2004). The most obvious route lies in exploring the potential for securing payments for conservation (Ellison 2003) and possibly entering the carbon trade in the form of credits for not releasing carbon (Smith and Applegate 2004; Glenday 2006). Another, older but demonstrated route would be the use of Tshanini as a hunting area for the region's wildlife. Ideally Tshanini should first be enlarged to ensure the fair chase ethics are respected (Chardonnet 1992), but the combination of conservation payments and carbon trade may trigger sufficient interest for other rural communities to join in the process and envisage the enlargement of Tshanini. In the hunting context, it would be necessary to effect small scale translocations from Tembe to Tshanini. As such the inclusion of one or several elephants for a period of a few months should be investigated to ensure that ecological processes of Tshanini forests and woodlands are maintained.

The second aspect, to be developed at the same time represents the development of a modern agricultural landscape based on organic farming (van Mansvelt *et al.* 1998) and sustainable and indigenous agro-forestry principles (Sanchez and Leakey 1997; Matson and Vitousek 2006). This aspect will be developed through securing soil fertility, intensifying and diversifying land-use, and enabling policies to facilitate land tenure, access to credit, infrastructure development, research, marketing and access to markets (Sanchez and Leakey 1997). The present study recommends the approach of an agro–forestry landscape because it has recently been demonstrated that it increases the quality of life and allows better overall conservation results in the development context (Berger *et al.* 2003). Additionally, it is considered a good human governed landscape to limit the effects of fragmentation and can maintain the biodiversity of a region by serving as a corridor landscape between wild systems (Kursten 2000; Nyhus and Tilson 2004; Wagner *et al.* 2006).

In conclusion, the present study suggests motivating other rural communities to follow the example set by the Manqakulane people, and the creation of a larger community-based conservation area should be envisaged, but with a different conservation target than Tembe. The development of such areas must coincide with the upliftment of rural populations and an amelioration of the overall quality of life starting with assured food security while keeping an enjoyable landscape to live in.

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