
**The role of human disturbance in the dynamics and
distribution of sand forest in and around Tembe
Elephant Park, KwaZulu-Natal.**

by

Ronwyn Brereton-Stiles

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Abstract

This study investigated the nature and effects of a number of human 'disturbances' on the spatial distribution and dynamics of sand forest in and around Tembe Elephant Park (TEP), Maputaland, South Africa. The first disturbance investigated was that of fire and its role in determining the spatial patterning of sand forest at the landscape level. Secondly human disturbance was investigated in the form of utilisation of forest products and the effects of this on the dynamics of sand forest as a whole as well as on individual species.

Sand forest in this area was restricted to deep white sands and occurred as patchy strips with a north-south orientation within a mosaic of grassland and wooded grassland. An abrupt forest-grassland boundary was evident in these patches. Two alternatives were investigated as causal factors of the observed patterning: firstly, that sand forest boundaries could be set by underlying soil conditions and thus mosaic components were static; secondly that patches could be remnants of larger tracts of forest, which were fragmented or maintained by past disturbances such as fires. In the absence of these disturbances, patches should be able to expand. It was found that mosaic components did not differ significantly between altitude (used as a surrogate for soil moisture) which could imply that distribution patterns are not solely governed by soil determinants. Prevailing wind direction and intensity over the dry (fire) season were found to be strongly southerly and northerly and this is considered to be the direction for fragmentation and maintenance of north-south orientated strips.

Evidence of bush clumping in the grassland occurred around *Dialium schlecteri* nuclei. This process appears to be slow as, although evidence of thickening in fire-protected areas occurred in aerial photographs over time, it is gradual. The removal of fire in the grassland should lead to the development of sand forest clumps.

The dynamics of sand forest in terms of composition and size-class distributions was compared between a marginally disturbed site used by people south of the reserve and an unharvested site within the reserve from which elephants had been excluded. Overall dynamics were found to be similar between the sites although certain species showed significantly higher densities of seedlings in disturbed sites

than in protected sites. Canopy dominants were found to have low levels of seedling recruitment and an analysis of the 'grain' of sand forest showed it to have a coarse grain relative to other forest types in KwaZulu-Natal. These findings imply that relatively large gaps may be needed within sand forest in order to allow for regeneration of canopy species.

Four types of human use of sand forest products were investigated in the context of their sustainability: medicinal, craft and fuelwood sales and hut building. A number of plant products were harvested for the medicinal trade. Of the species investigated, the bark of *Cassipourea mossambicensis* appeared to be harvested unsustainably and this species has been seriously impacted outside the reserve. Crafters targeted *Cleistanthus schlecteri* for the manufacture of bowls for sale along the roadside. A model of a population of these trees adjacent to the main craft stalls revealed that reproductively viable adult trees would be depleted within 25 years. This indicated that craft manufacture was unsustainable. *Newtonia hildebrandtii* was the most commonly sold fuelwood along the roadside. Sellers mainly used deadwood and turnover rates of bundles sold was extremely slow. Thus at the time of the study (1997) fuelwood sale appeared to be sustainable. The main framework of huts built was composed of thin understorey and subcanopy sand forest woody species. Strong evidence of resprouting occurred in these species and species composition of huts was similar to an earlier study undertaken in 1982. This suggested that impact on forest dynamics was not substantial for this type of use.

In conclusion, management and utilisation of sand forest needs to be within the dynamics and regeneration capacity of this forest and its constituent species. For example I predict that an absence of fire will lead to thickening of woody vegetation and a decline of grasslands. Canopy species may require large gaps for regeneration to take place. Use of plant products for commercial purposes (e.g. *C. mossambicensis* for bark and *C. schlecteri* for crafts) is unsustainable given the slow growth rates of the forest. Although sale of firewood appeared to be sustainable at the time of the study, with increasing demand from tourists, live trees may increasingly be used and this industry could soon be problematic. Utilisation of trees for domestic purposes appeared to be sustainable as sand forest species were resilient resprouters. However, commercial use of this forest type was felt to be unsustainable. Species found to be most at risk were *C. mossambicensis*, *C. schlecteri*, and *N. hildebrandtii*.

Chapter 1

General Introduction

The precarious state of tropical deciduous forests is a cause of growing global concern and has possibly been underplayed due to focus on the calamity that is occurring in tropical rain forests (Lerdau *et al.* 1991). Dry deciduous forests once made up an estimated 40% of the forest area in the tropics (Murphy & Lugo 1986) and occurred over large areas of Central and South America, Africa, India, southeast Asia and Australia (Gerhardt & Hytteborn 1992). However they have been exposed to severe, large-scale changes, through cutting of valuable trees for the international market, clearing for agriculture and pastures, and accidental and intentional fires (Swaine 1992). Moreover, tropical dry forest areas continue to support a larger human population than do the humid forests. These people who are reliant on the forests' resources are increasingly losing access to traditional foods and medicines (Lerdau *et al.* 1991). In Central America for instance, less than 2 % of the tropical dry forests have remained in an intact state, and less than 0.1 % have any kind of conservation status (Janzen 1988). If a global strategy for the conservation of dry deciduous forests is not implemented with immediate effect, it is felt that "this biome will soon be lost" (Lerdau *et al.* 1991).

Sand forest in South Africa is a tropical deciduous forest type. Despite the fact that 39 % of its total area is under some form of protection (Geldenhuys & MacDevette 1989), there is a need for it to be afforded urgent conservation priority. This is due to a number of factors. Firstly, it is also subject to high levels of use by rural populations (Geldenhuys & MacDevette 1989; Midgley *et al.* 1997; Cunningham 1995) and it thus appears to be in a similar predicament to tropical dry forests world-wide. Clearing of trees for agriculture, commercial exploitation of forest products for medicines, crafts, fuelwood and construction is rapidly increasing with the demands of an escalating human population in South Africa (Cunningham 1985; 1997; 2001; Plates 1 and 2).

Secondly, sand forest experiences a severely limited distribution within South Africa. It is restricted to the Maputaland coastal plain in north-eastern KwaZulu-

Natal (Midgley *et al.* 1997) and covers an estimated total area of only 5 986 ha (Geldenhuys & MacDevette 1989). It occurs as a thin, north-south-orientated patchy belt which runs from the western shores of Lake St Lucia in the south to the Mozambique border in the north (Kirkwood & Midgley 1999). Its presence in South Africa represents the most southerly extension of its range, as it occurs to the north in adjacent countries such as Mozambique (Midgley *et al.* 1997).

A third factor that calls for consideration is its uniqueness within the context of other South African forests, both in terms of its species composition and its plant vital attributes. Compared to other South African forests, which have poor regional and local endemism (White 1983), sand forest supports relatively high numbers of endemic and uncommon species (Matthews *et al.* 1999). Also it possesses a conspicuous component of deciduous and semi-deciduous species, as well as those with compound leaves and wind-dispersed propagules (Midgley *et al.* 1997; Plate 3). This pattern differs from that of other South African forests which have predominantly simple-leaved, evergreen species which mainly possess fleshy-fruits (Midgley *et al.* 1995a).

The fourth factor of concern in sand forest conservation is the marked absence of published literature on its floristics and dynamics. Thus in order to develop a framework for sand forest research it may be useful to investigate it within the context of other forest types in South Africa. White (1983) argued that southern African forests are associated with two phytochoria: an Afromontane archipelago-like regional centre of endemism (which extends to the north-eastern African uplands) and the Tonga-Pondoland regional mosaic (which is largely restricted to the eastern coastal belt of South Africa). On a regional scale, forests in KwaZulu-Natal have been separated into two basic groups (MacDevette *et al.* 1989): the interior (Afromontane) and the coastal (Indian Ocean or Tongaland-Pondoland). Sand forest has been assigned to the coastal grouping which also comprises four other forest types, namely riverine, swamp, dune and coastal plane (or lowland) forests. The coastal group is associated with subtropical climates while the Afromontane types are distributed in cooler temperate climates.

The management of this unique and threatened forest type, is largely dependent on the effectiveness of its management within the reserve network of KwaZulu-Natal. About 38.8% of the estimated 5 986 ha covered by sand forest falls within formal conservation areas (Geldenhuys & MacDevette 1989).

However, research indicates that the current 'non-interference' management regime applied to forests within reserves in South Africa may be inhibiting regeneration of forest species (MacDevette *et al.* 1994; Midgley *et al.* 1995c). By 'non-interference' I mean that managers have actively protected forests within reserves against large-scale disturbances such as fires, as they fear that these cause harm to the function of forest processes or may alter the 'natural' species composition.

A range of research findings mainly on the forest and woodland communities within KwaZulu-Natal, have pointed to the possibility that both their current distribution within the landscape and their inherent species composition may be determined by the disturbance caused by past human activities (Feeley 1980; Hall 1984; Geldenhuys & MacDevette 1989; Everard *et al.* 1994; Midgley *et al.* 1995c; Van Wyk *et al.* 1996; Von Maltitz *et al.* 1996; Hoffman 1997; West *et al.* 2000; 2001; Bond & Midgley 2001).

This theory is supported from two major fronts. Firstly, a host of archaeological evidence exists of the long history of human inhabitation of the Maputaland coastal plain of both Stone and Iron Age (Bruton *et al.* 1980; Hall & Vogel 1978; Feeley 1980; Hall 1980; 1984). It is argued that the inherent land use practices of these Stone and Iron Age communities had considerable effect on the composition of forest, woodland and grassland. Secondly increasing evidence exists that the removal of disturbances from forests (e.g. large herbivores, fire and human utilisation) has resulted in a change in their structural composition and dynamics (e.g. Van Wyk *et al.* 1996; Von Maltitz *et al.* 1996).

In terms of evidence of the former, Stone Age hunter-gatherers are known to have burned vegetation to manipulate game movements and to stimulate new growth of geophytes and other plants as their primary food source (Hall 1984; Deacon 1992). Scholes & Walker (1993) argue that these activities would have increased the natural fire frequencies from anything from 100 000 to 10 000 years BP which would have had considerable impact on the vegetation.

The ensuing Iron Age agriculturalists were thought to have moved into the south-eastern parts of the sub-continent by AD 290, where they were successfully established by the eighth century (Feeley 1980). They made use of extensive burning to clear grassland and woodland areas suitable for agriculture and grazing for cattle (Hall 1984). These practices have been continued in northern Maputaland into more

recent centuries and up to the present time (e.g. local Tembe-Thonga inhabitants in and around sand forest; Cunningham 1988, and rural Zulu farmers in coastal dune forests; Von Maltitz *et al.* 1996). This evidence suggests that the presence of human disturbance has been a long-term component of the eastern seaboard of KwaZulu-Natal.

The second line of evidence occurs from studies of the forests themselves. Certain coastal forests that had a strong associated history of human disturbance or the presence of mega-herbivores such as elephants (e.g. dune forest; Von Maltitz *et al.* 1996; and coastal lowland forest, van Wyk *et al.* 1996) showed a shift in canopy dominants resulting from the removal of these disturbance factors. The dominant canopy species of 'undisturbed' forest had very low, if any, representation in the sub-canopy and understorey layers, which were dominated by a cohort of 'shade-tolerant' potential canopy species (van Wyk *et al.* 1996). The canopy species were found to be 'shade-intolerant', which suggests that their presence resulted from establishment in a high light environment provided by large canopy gaps. They therefore predicted that in the absence of a major disturbance event, these non-regenerating canopy species would be lost from the system.

Evidence from other dry tropical forests (e.g. West African forests; Swaine *et al.* 1992) suggested that fire had a potent influence on the determination of forest composition. They ascribed the disparity amongst forests in the composition of canopy and sub-canopy trees, to the differences in the severity and frequency of fires to which they were exposed.

Recent research on the regeneration of woody species shows a growing appreciation for the strategy employed by certain plants or even forest types to persist within the landscape following disturbance (Bond & Midgley 2001). Sprouting ability can have major impacts on plant populations, providing a reduction in turnover rates and minimising the effects of disturbance and damage (Plate 4). Dependence on seeds for population maintenance might be negligible for resprouters (Bond & Midgley 2001). In a range of southern African forests, Kruger *et al.* (1997) found that forests which are short in stature, are dominated by trees that regenerate by resprouting, while trees of tall forests regenerate primarily through seedling production. They argue that resprouters are disadvantaged within tall forests, where the ability to grow tall is critical for potential canopy species. Resprouters divert resources to developing, maintaining and protecting a bud-bank instead of devoting it

to vertical growth. In contrast, trees that produce many seedlings within a forest environment can divert resources to maximise rates of vertical growth to a single stem. Kruger *et al.* (1997) went as far as to say that forests dominated by resprouters should receive relatively less conservation priority than tall reseeders-dominated forests, where changes in herbivory patterns, disturbance and predation would influence composition more strongly.

In this thesis I was interested in investigating sand forest dynamics in the context of human disturbance and in an area where human interference had been removed. I was hoping that the findings would provide useful guidelines for sand forest management and for further research. I also wanted to gain an understanding of the subsistence and commercial use of sand forest by local people in a rural context, as I was concerned that increasing commercialisation of forest products coupled with growing human demand, may be threatening the existence of remaining sand forest patches outside protected areas. Also, I felt it was important to attempt to document a component of local people's biological and cultural knowledge of sand forest, as this knowledge is rapidly disappearing as they rely increasingly on modern alternatives.

Thesis structure

Of central interest to this study is whether past disturbances have shaped the sand forests present in Maputaland today, and if so, what the management implications are. Can lessons be learned from the dynamics of forests where local people continue to affect the disturbance conditions? Can sand forest be grouped with other forests in KwaZulu/Natal according to their functional types and does this have implications for management? Which species are of value to local people living in and around sand forest? At what point is disturbance too much?

In Chapter 2, the factors determining the occurrence of sand forest as part of a mosaic within the landscape are explored. The question asked is whether the observed patchiness of sand forest within the mosaic is a result of fragmentation by large-scale disturbances such as fire? If so, is there evidence of recovery and succession of woody species returning to forest? Or conversely, is the distribution of sand forest fragments determined by a corresponding set of environmental conditions, such as soil type, which predetermine the size and shape of patches and ratios of composite habitat types?

In Chapter 3, an attempt is made to compare sand forest dynamics in terms of species composition, size-class distribution and grain between forest utilised by humans to that within a protected area. An attempt is made to conceptualise these findings within the context of other South African forest types.

In Chapter 4, a closer look is taken at several types of human use taking place in sand forest outside the protected area. The aims of this chapter are to describe and quantify four types of use, namely the harvesting of plant parts of species used on the medicinal trade, the manufacture and sale of crafts, the collection and sale of fuelwood, and the use of forest laths and poles for the construction of huts. The response of individual species to this damage was explored in order to provide a framework for the sustainable use of sand forest.

In the synthesis of Chapter 5, recommendations are discussed for the management and research of sand forest occurring both within and outside protected areas.

Study sites

The study was undertaken in and adjacent to Tembe Elephant Park (hereafter referred to as TEP), which is located in the southern reaches of the Mozambique coastal plain, Maputaland, South Africa (27°02'S, 32°25'E). It represents the northern boundary of sand forest distribution in the province. The park itself covers an area of 30 013 ha, and has an average altitude of 80 m above sea level with its highest elevation at 129 m asl. The fieldwork component of the study was conducted between February 1997 and March 1998.

Three sites were chosen, each with different intensities of human and animal disturbance (Figure 1). All sites supported a mosaic of sand forest, wooded grassland and open grassland patches. An enclosed 200 ha section of the park (Site 1; Figures 1 and 2; Plate 5), situated on its southern boundary was chosen as a site of low disturbance. Human use of the forest had been absent at least since the declaration of TEP in 1983, although evidence from aerial photography (Plates 5 and 8) indicates that no settlement occurred in this section of forest since at least 1942. The section was surrounded by an electric fence in the early 1990's for the exclusion of elephants and was felt to be representative of sand forest elsewhere in the park (W. Matthews, pers. comm.). The most common ungulates present at this site included suni, red and

grey duiker, bush pig, impala and nyala. As carnivore predators occur at low densities within the park, a 'predator-simulation' culling programme is employed for the limited offtake of impala and nyala, although smaller ungulates such as suni and duiker species are not removed (F. Myburgh pers. comm.).

Site 1 served as a control for comparison with an unprotected patch of sand forest within a communal section of land south of the park (Site 2; Figure 1). This section lay adjacent to Site 1 and was of approximately equivalent area to Site 1. These two sites were separated by a tar road and were deemed to be comparable in terms of vegetation, soil type, elevation and climate. Main uses of the forest by local inhabitants at Site 2 included selective pole removal for building purposes and furniture construction, dead wood removal for fuel for both domestic use and for local sales. Additionally the forest species were used for medicinal purposes both by local *izangoma* (diviners) and *izinyanga* (herbalists) as well as by commercial gatherers. Grassland and wooded grassland areas between sand forest patches were burned annually for subsistence agriculture. Cattle were not grazed within Site 2 possibly due to the long distances to the nearest water source. Overall disturbance to sand forest was felt to be low to moderate as few people actually lived in forest patches but inhabited surrounding grassland and wooded grassland areas. As no surveys of ungulate densities had been carried out at Site 2 prior to those conducted in this study, population status of these animals was unknown.

Site 3 was located approximately 12 km due west of Site 2, also within communal land and comprised an area of about 100 ha (Figure 1). This site was chosen because forest use by local inhabitants was relatively more intensive than at Site 2. In addition to the use types described for Site 2, trees were felled for the manufacture of crafts, which were sold *in situ* at informal roadside craft markets. Also, slash and burn agricultural activities were conducted within the sand forest itself and whole trees were chopped down and burned to make way for the cultivation for crops such as maize. Sections of forest had also been cleared for the construction of homesteads. The soil type, elevation and climate were assumed to be comparable to those found at Sites 1 and 2. However, a larger proportion of sand forest was dominated by mature stands of *Newtonia hildebrandtii* and *Cleistanthus schlecteri* than at Sites 1 and 2.

Craft stalls and fuelwood sale points investigated in this study occurred on the 15.3 km section of road between TEP gate (located adjacent to the south-eastern

corner of Site 1) in the east and Phondweni store in the west (Figure 1; the store lies just east of where the road crosses the Pongola river).

▪ Climate

The region experiences a dry sub-tropical climate with wet, humid summers and a dry winter season. Mean monthly rainfall for the park is 235 mm for the dry season (April to September) and 531 mm for the wet season (October-March) with an annual mean total of 766 mm. Relative humidity between November and February exceeds 70%. Annual mean maximum temperature ranges from $25.3 \pm 31.1^\circ \text{C}$, and the annual mean minimum range is $11.5 \pm 21.7^\circ \text{C}$.

Data on prevailing winds from Ndumo Game Reserve, which lies to the west of Tembe (Figure 1), show that winds are predominantly north-east in the dry season and south-west during the wet season. Within Tembe, maximum wind velocities of 51.5 km/hour for N, NE, S and SW have been recorded.

▪ Soils

Soils within TEP are mainly porous, sandy and low nutrient Tertiary and Quaternary deposits (Hobday 1965; von M. Harmse 1978; Maud 1980). Marine transgressions and regressions since the late Cretaceous have formed these deposits into dune ridges orientated along a north-south axis. Wind activity during the Pleistocene reworked existing material and deposited further sand until the dunes were stabilised with the onset of vegetation (Hobday 1965).

Most of the coastal plane in Maputaland is covered in leached sandy soils with low agricultural potential (Maud 1980). Most soils are dystrophic, i.e. show signs of high levels of leaching and are relatively acidic [$\text{pH}(\text{water}) \pm 6$]. The main soil types are dystic regosols, which are moderate, to well-drained acidic soils found in elevated places such as dune crests and slopes. Humic gleysols, which are wet, acidic sands with an abnormal accumulation of organic matter, occur to a lesser extent in depressions (areas with a high water table; Matthews *et al.* 1999).

▪ Vegetation

TEP and areas to its immediate west and south are situated in the transitional zone between the Tropical and Sub-Tropical Regions (Moll 1977), which consists of floodplains, a mosaic of sand and riverine forests, swamp, open and closed woodland, palmveld and pure stands of grassland. Acocks (1975) classifies this area as lying within the Tropical Bush and Lowveld Savanna (Veld Type 10) and part of the Coastal Tropical Forest (Veld Type 1). MacDevette *et al.* (1989) however, reclassified sand forest as a tropical dry forest. The sand forest within and around TEP falls within the Eastern sand forest type, which occurs on deep white sands (Kirkwood & Midgley 1999). The latter study found Eastern sand forest to be subdivided into groups, characterised by the presence or absence of the Lebombo wattle, *Newtonia hildebrandtii*. *Cleistanthus schlecteri* was also found to be a common canopy dominant. Characteristic sub-canopy trees are: *Cola greenwayi*, *Drypetes arguta* and *Tricalysia lanceolata*. Preferential tree species include *Balanites maughamii*, *Cola greenwayi*, *Dialium schlecteri*, *Dovyalis zeyheri*, *Drypetes arguta*, *Erythrophleum lasianthum*, *Cirewia microthyrsa*, *Haplocoelum gallense*, *Hyperacanthus amoenus*, *Leptactina delagoensis*, *Manilkara discolor*, *Ochna arborea*, *O. natalitia*, *Oxyanthus latifolius*, *Psydrax locupules*, *P. fragrantissima*, *Ptaeroxylon obliquum*, *Strychnos henningsii*, *Suregada zanzibariensis*, *Toddaliopsis bremekampii* and *Vitex ferruginea* subsp. *amboniensis* (Kirkwood & Midgley 1999).

Common tree species of wooded grassland corridors between sand forest patches include: *Acacia burkei*, *Azelia quanzensis*, *Albizia adianthifolia*, *Combretum molle*, *Dialium schlecteri*, *Garcinia livingstonei*, *Hymenocardia ulmoides*, *Pteleopsis myrtifolia*, *Spirostachys africana*, *Strychnos spinosa*, *S. madagascariensis* and *Terminalia sericea*.

▪ Management of TEP

TEP was administered by the government, under the KwaZulu Department of Nature Conservation (formerly the KwaZulu Bureau of Natural Resources) until the end of 1997. At this stage it was amalgamated with the Natal Parks Board to form a new parastatal organisation, the KwaZulu-Natal Nature Conservation Service (NCS).

renamed KZN Wildlife in 2001. I have referred to the organisation as the NCS throughout this thesis.

- **Pers. comm.**

Information obtained from a personal source deemed to have the relevant expertise in that particular field, has been acknowledged as a 'pers. comm.'. The details of each person acknowledged are documented separately at the end of the 'References' section of the thesis.

Plates: 1 - 5

(overleaf)



Plate 1 Clearing of sand forest for subsistence agriculture, showing a *Newtonia hildebrandtii* tree in the process of being burned.



Plate 2 Local resident, Ehckazitha Gwala holding up the yellow taproot of an *isibhangalala* plant (*Salacia* sp.), which is in high demand on the medicinal trade for use as an aphrodisiac.



Plate 3 *Hymenocardia ulmoides*, a common sand forest tree, shown here with a profusion of its wind-dispersed propagules.



Plate 4 An example of strong resilience by *Erythrophloeum lasianthum* to severe ringbarking of all three main stems. The leaves in the lower quarter of the photograph are multiple sprouts being produced from a small unharvested section at the base of the stem, as is the thin central shoot. The presence of three stems suggests former coppicing following damage.

N ↑

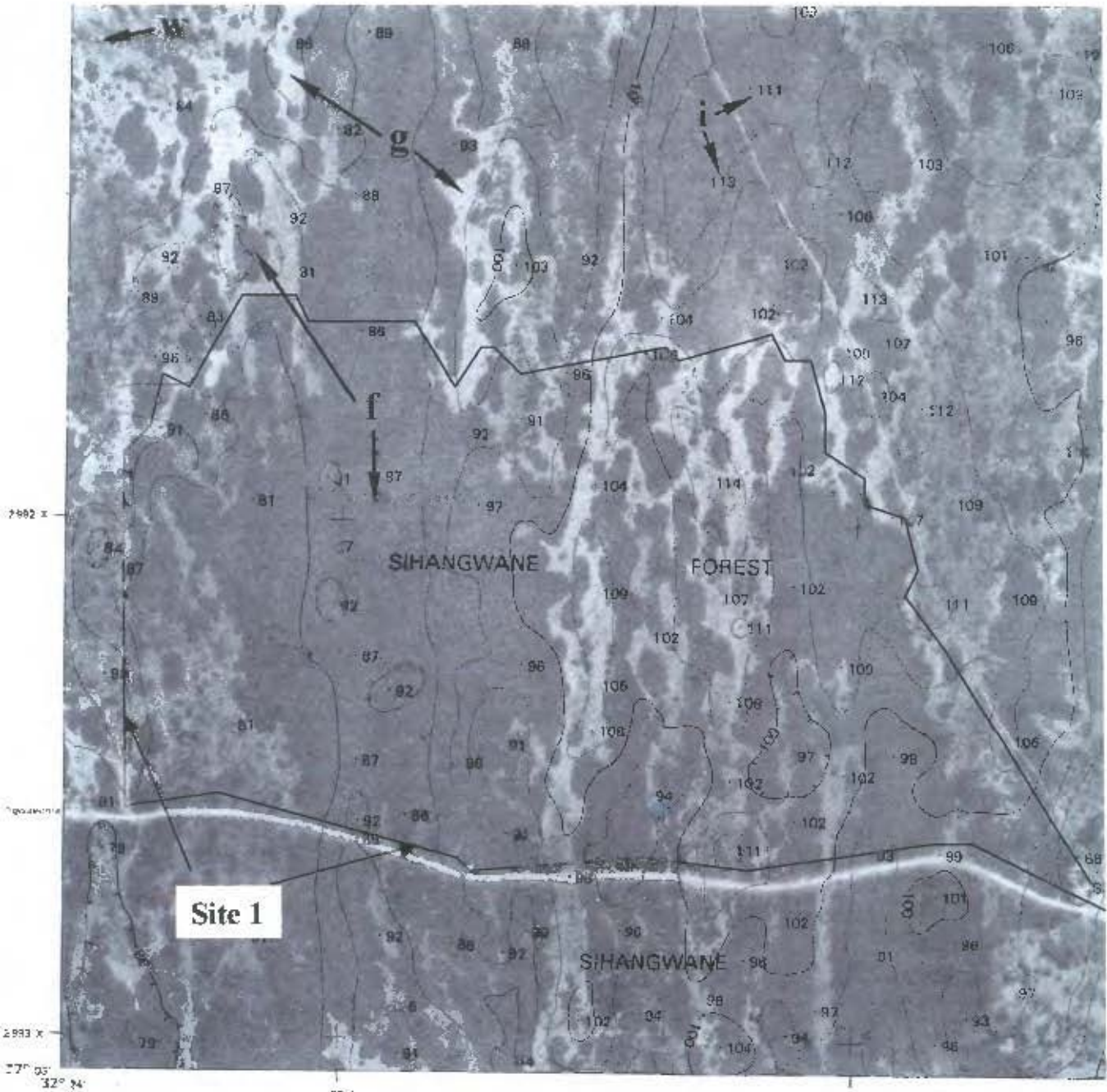


Plate 5 A 1:10 000 orthophotograph (2732 AB 4 of 1971) of the area to become Tembe Elephant Park in 1983 (north of the road running east-west to the south of the photograph) showing the north-south orientated sand forest patches (f), wooded grassland (w) and grassland (g). Isoheight values (i) are indicated (m asl). The boundary of the elephant enclosure plot (Site 1) is demarcated.

Figures: 1 - 2

(overleaf)

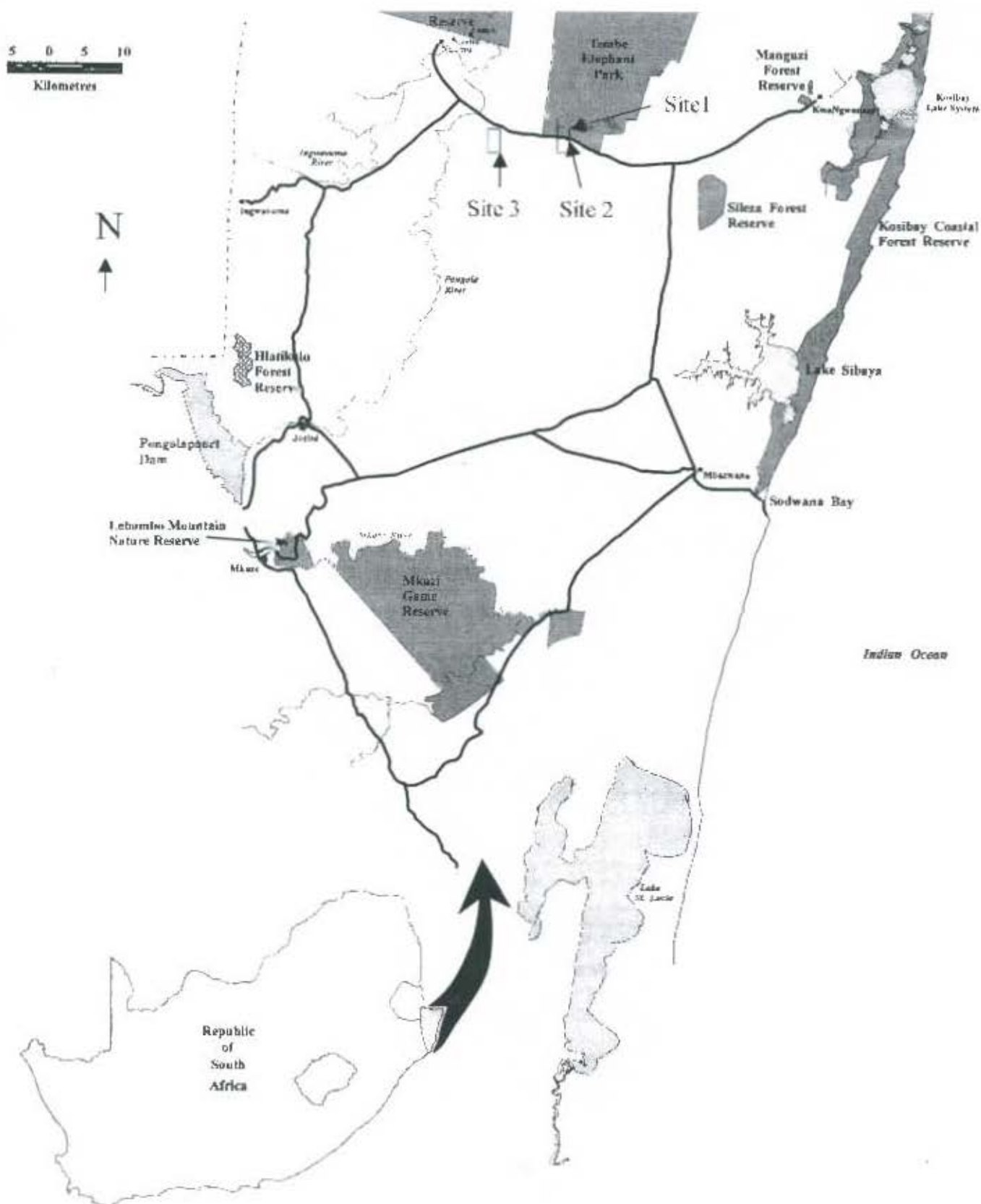


Figure 1 Map of Tembe Elephant Park (TEP) within the context of Maputaland and South Africa. Study sites 1-3 are indicated. Wood sellers and crafters sold their wares on the section of road between the south-eastern corner of Site 1 (opposite TEP entrance gate) to just east of the Pongola river.

Chapter 2

Sand forest patchiness in Tembe Elephant Park; environmental determinism or landscape disturbance?

Abstract

The patchiness of sand forest within a mosaic of grassland and wooded grassland in Tembe Elephant Park may have been determined by environmental constraints such as soil type. Alternatively patches could be remnants of larger tracts of forest, which were fragmented or maintained by past disturbances such as fires. Both hypotheses were investigated.

In order to test the environmental determinism hypothesis, the altitude at which the various vegetation types occurred (i.e. sand forest, wooded grassland and grassland) was used as an indicator of soil moisture. The assumption was that dune crests had deeper and thus effectively drier soils than did lower-lying areas, which was more conducive to the establishment of patches of sand forest than were moister low-lying areas. Isoheight values on orthophotographs of the study area were compared to the presence of the three vegetation types. No significant differences occurred between vegetation type and the altitude at which they occur. This suggests that the observed distribution of sand forest within the landscape is not merely a function of soil depth and thus of soil type or moisture.

In order to test the disturbance hypothesis, the shape and orientation of patches were analysed and it was found that 110 of 111 patches sampled were orientated with their longest axis lying on a NNE to NNW plane. Additionally, forest patches had an average ratio of 2.6 between the longest and shortest axis. This indicates that patches were shaped as narrow strips with a length 2.6 fold greater on average than the width.

The orientation of patches was similar to the prevailing southerly wind direction, measured as a product of wind intensity, duration and frequency over the dry season (May – September). Wind information over these months was used as an indicator of the most likely path and intensity of fires. Although other disturbance

factors such as browsing by elephants could cause forest fragmentation, these were not addressed in this study. The results suggest that patch shape and orientation were possibly determined and maintained by fires, rather than by underlying soil constraints.

The ability for forest patches to expand is inherent to the theory that they are predominantly governed by landscape disturbance as opposed to being predetermined by set environmental factors. Evidence of expansion and thickening of bush clumps within adjacent grassland patches occurred. Certain sand forest canopy species (e.g. *Dialium schlecteri*) appeared to act as a nucleus for this bush aggregation. Results of a DECORANA ordination also pointed to a successional gradient from open grassland through bush clumps to sand forest. Additionally comparisons of aerial photographs between 1942 and 1996 revealed thickening of woody vegetation within fire-protected grassland adjacent to sand forest patches over this time. This process of thickening however appeared to be slow and was ascribed to possible slow growth rates of plants given the dry sandy soil conditions.

The conclusions from the study were therefore that sand forest patches are not fixed in the landscape by predetermined environmental parameters such as soil type or moisture. Instead, they appear to be able to expand within the matrix by a process of nucleation and succession governed by the frequency of disturbances such as fire.

Keywords: Aerial photograph, *Dialium schlecteri*, fire, grassland, wooded grassland, Maputaland, mosaic, nucleation, orthophotograph, sand forest, succession, Tembe Elephant Park.

Introduction

Sand forest is a semi-deciduous tropical dry forest (Kirkwood & Midgley 1999) associated with relict dune ridges formed by Quaternary aeolian deposits (Maud 1980). In Maputaland (north-eastern KwaZulu-Natal), sand forest is distributed in a narrow belt from the western shores of Lake St. Lucia in the south into southern Mozambique in the north (Moll & White 1978). Aerial and orthophotographs of the northern Maputaland region indicate that sand forest is characteristically patchy and occurs as a mosaic of sand forest patches, wooded and open grassland (e.g. Plate 5). Both larger and smaller sand forest patches have clearly defined forest-grassland boundaries and appear to be shaped in long, north-south orientated strips, lying parallel to the east coastline.

Mosaics may be seen as fairly static components of the landscape, created and set by fixed environmental determinants, such as soil type and moisture (Brown & Archer 1989; Furley 1992). These factors may give rise to site-specific germination and survival of individuals of the composite vegetation types (Yeaton & Manzanares 1986) and thus the ability of different components of the mosaic to spread is site limited. Alternatively, mosaic patterns may not be fixed but may be part of a dynamic process of expansion and contraction depending on, for example, the time since the previous disturbance (e.g. Manders *et al.* 1992). For instance, observed patchiness of forest or closed woodland within savanna may have resulted from disturbance agents such as fire, which fragment larger sections of woody vegetation, leaving remnant patches of the original within savanna (Backéus 1992; Gignoux *et al.* 1997). If left undisturbed, woody vegetation may then expand to its original size by means of successional processes.

The process of 'nucleation' (Yarranton & Morrison 1974), is considered an important driving force in mosaic distribution pattern (Holmgren *et al.* 1994). According to this theory, the presence of trees or shrubs in the grassland creates favourable micro-sites for other species and so facilitates the establishment of further woody plants around them (Yeaton & Manzanares 1986). The process has been extensively documented in the literature (e.g. Smith & Goodman 1987; Archer *et al.* 1988; Brown & Archer 1989; Vetaas 1992; von Maltitz *et al.* 1996), and has been used to explain the transformation of open grassland, or savanna into to a more closed

canopy community. The actual mechanisms involved in the nucleation process may vary considerably from passive facilitation, such as the provision of bird-perching sites for seed dispersal (Franco-Pizaña *et al.* 1996; Cowling *et al.* 1997), to more direct facilitation such as enhanced soil conditions (Godínez-Alvarez & Valiente-Banuet 1998), shading (Cowling *et al.* 1997), or protection from fire (Skowno *et al.* 1999).

As little published literature is available on sand forest *per se*, few explanations exist to account for the observed mosaic pattern. Moll & White (1978) stated that sand forest was restricted to the sandy ridges of relict north-south dunes, accounting for their observed north-south orientation. Ward (1981) hypothesised that distribution patterns of sand forest plants result from the higher soil moisture level provided by an impermeable hardpan horizon, between 4 and 20m below the surface, which 'traps' water at depths accessible to their roots (Tinley 1971). This horizon, which was formed by Port Durnford sediments of the Mid-Pleistocene (Maud 1980), is thought to favour woody species by providing them with a competitive advantage over grass species by means of deeper water sources inaccessible to shallower roots of grasses. Thus soil moisture conditions are thought to play the major role in the relative distribution of sand forest within the mosaic.

Similarly, Tinley & Van Riet (1981) attributed the mosaic phenomenon to underlying soil conditions with forest patches being confined to strips of 'unique fine grained sand'. Abrupt changes on either side of these strips to 'medium grained sands', was evoked as the underlying determinate controlling the sharp change between savanna and forest. Most recently, Matthews *et al.* (1999), attributed the distribution of plant communities predominantly to soil moisture as determined by the depth of the water table, in turn a function of topography. They found that sand forest in their study area occurred on elevated dune ridges. They postulated that reduced surface moisture levels gave them a competitive advantage over grassland and woody grassland, which dominated more lower-lying, mesic areas.

Thus, the patchiness of sand forest has been attributed to being a product of stable factors such as underlying soil patterning, which confine constituent vegetation types to static strips. Patches are expected to be relatively fixed features in the landscape. For the purpose of this study, this theory will be referred to as the *soil moisture hypothesis* which proposes that sand forest patches are restricted to deep, relatively dry soils i.e. predominantly on dune crests and slopes, whereas lower-lying

areas will favour the establishment of grassland and woody grassland. Sand forest patches are shaped in a north-south orientation due to the north-south orientation of underlying relict dune ridges.

Alternatively, the hypothesis will be investigated that sand forest patches are not fixed features within the mosaic but instead are a part of dynamic process and are capable of expanding and contracting over time. This theory will be referred to as the *remnant / recovery hypothesis* which proposes that sand forest patches are remnants of larger forest stands that were fragmented in the past by large-scale disturbances such as fire. They are orientated in north-south strips as this is the major directional path of fire, as it is driven north by predominantly southerly winds. Although large herbivores such as elephants could also play a role in fragmentation of forest patches and influencing mosaic positioning through heavy browsing activities, this factor was not included in the study.

Study site

The fieldwork component of the study was undertaken in TEP in Site 1 (Figures 1 and 2; Chapter 1). However, for the aerial and orthophotograph analysis, the remainder of the park in which sand forest occurred was incorporated.

Methods

▪ Orthophotograph analysis

❖ *Altitude versus vegetation distribution*

The distribution of sand forest patches in relation to altitude was investigated. If the soil moisture hypothesis is correct, sand forest patches should predominate in high-lying areas while wooded grassland and grassland should be found more commonly in low-lying regions (Figure 1).

In order to test this, five orthophotographs (ref nos. 2732 AB 3, 4, 5, 8, 10; scale 1:10 000; Plate 8) were used which depicted the south-western section of TEP and incorporated Site 1 (e.g. Plate 5). Isoheight contours (m asl) were displayed on all orthophotographs. Observed vegetation was divided into three types: grassland.

wooded grassland and sand forest (Plate 5). Sections of grassland (g) were defined as areas on the orthophotograph where only grassland and no woody vegetation occurred. Wooded grassland (w) was defined as grassland with the presence of woody vegetation not aggregated into solid clumps (i.e. individual trees were visible). Sand forest (f) was defined as large consolidated patches of trees. Smaller patches, which were of the same texture on the orthophotographs as the larger patches of sand forest, were included as sand forest (f). For each isoheight value recorded, a note was made of the vegetation type where it occurred (i.e. g, w, or f). This gave an indication of the altitude at which each type occurred. Altitudes were compared for each of the three types using an Anova.

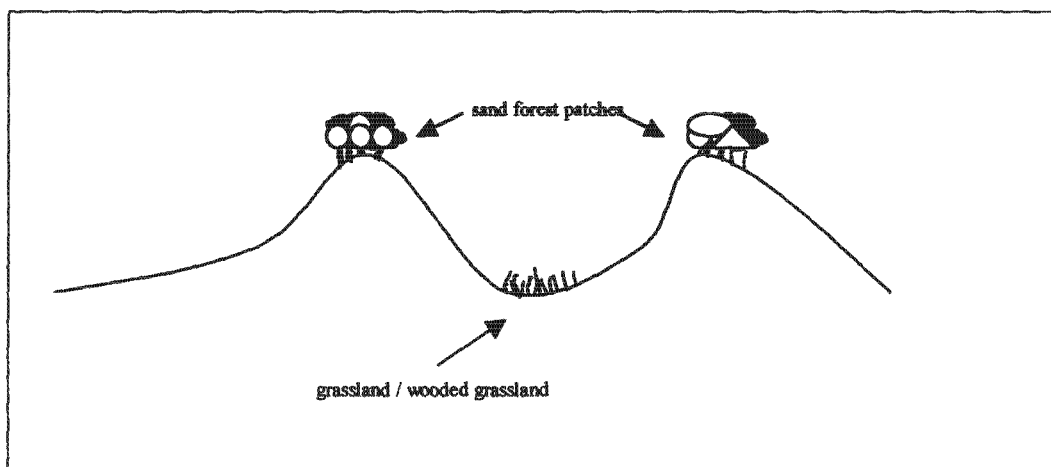


Figure 1 Soil moisture hypothesis: sand forest patches are synonymous with the drier soils of dune crests, while grassland is associated with moister soils of lower-lying areas.

❖ *Patch orientation versus wind direction*

In order to test the remnant / recovery hypothesis, the orientation of forest patches to the predominant wind direction were investigated. If patches are controlled by fires, their north-south orientation could be the result of a predominantly north or south direction taken by fires (Figure 2).

○ *Wind analysis*

Data of wind direction, duration and intensity for the dry season (May to September) were obtained for 23 years (1966 – 1988), as an indication of the most

likely direction of intense fires. Initially, May to August were chosen as the months of lowest rainfall (Kirkwood & Midgley 1999) and considered to be the fire season i.e. dry conditions coupled with high fuel loads of dead and moribund vegetation. Fires over this period are thus more likely to be of a sufficient intensity to damage and alter vegetation than those in the wet season where low fuel loads and moist conditions inhibit intensity (Smith & Tainton 1985). In northern Maputaland, high velocity Berg winds conducive to the spread of fire are common in September (F. Myburgh pers. comm.) and this month was thus included in the analysis.

Records were obtained from the closest weather station with wind data records (Makatini) approximately 50 km south of the study area. The station had records of wind intensities (m/s) and duration (frequency/1000) taken three times per day every day of the month for these years. These data were available for each of the eight cardinal points: N, NE, E, SE, S, SW, W, NW.

For the purpose of the study, wind intensity and duration for each cardinal point were averaged for the five chosen months and then these two factors were multiplied together. It was reasoned that a wind of both high intensity and duration would be more likely to drive a fire capable of the fragmentation of woody vegetation than one of lower intensity and duration. These results were then converted into a length (mm) and plotted on a diagram to provide a visual indication of dominant wind direction, intensity and speed for each cardinal point.

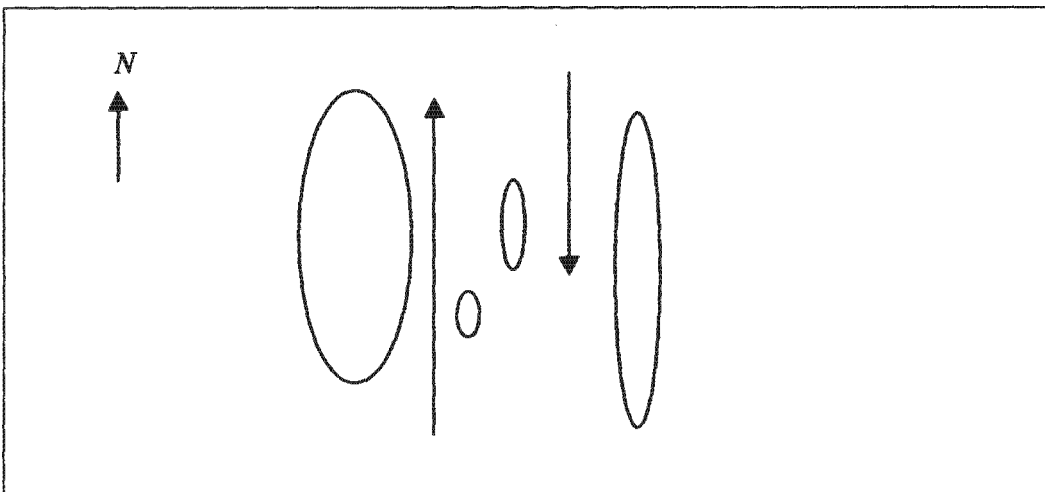


Figure 2 Remnant / recovery hypothesis (aerial view of mosaic). Arrows indicate the proposed direction of fire. Oval shapes represent sand forest patches within grassland.

○ *Shape and orientation of sand forest patches*

It was reasoned that if patches lie within the same orientation as the path of fire, then it is likely that fire is the agent responsible for their observed form and position in the landscape. The shape and orientation of the patches were documented in order to determine their shape as well as their orientation relative to north. Orthophotographs of the study area were used to measure the patch dimensions. A discrete forest patch (f) was defined as a cluster of woody plants of the same texture as the larger, continuous sand forest patches and entirely, or almost entirely, surrounded by grassland or wooded grassland. Orthophotographs used were 2732 AB 3, 4 and 8 (1:10 000) and were selected on the basis of their high proportion of discrete forest patches relative to other orthophotographs. Discrete patches of the larger forest patches were unusual and thus only smaller patches could be used for measurements. Larger patches that were not discrete (i.e. not completely surrounded by grassland or wooded grassland) were orientated along a similar plane.

In order to document the shape of the patch, i.e. to determine whether patches are long and thin or short and round, all discrete forest patches on the orthophotographs were measured and a ratio of their north-south: east-west axis was determined. Ratios of higher values indicated longer, thinner patches than smaller ratios. A ratio > 1 indicated that a forest patch had its longest axis orientated in a north-south direction, while a ratio < 1 would show that the longest axis of the patch was lying east-west.

Additionally, the orientation of each forest patch relative to north was calculated by measuring the smallest angle between a line drawn through True North on the orthophotograph and a line taken through the longest axis of the patch. The intercept between the two lines was positioned at the centre of the patch. True North was taken to be 0° and thus if a patch had a smallest angle between True North and the line drawn through the longest axis between -44.9° and $+45^\circ$ (i.e. NW to NE) it was considered to be positioned in a north-south orientation. Intercept angles between -90° and -45.1° (W to NW) and between 45.1° and 90° (NE to E) were considered to indicate that a patch had an east-west orientation.

The average orientation was then plotted onto the wind rose in order to provide a comparison between the dominant wind direction and the angle of patches.

▪ **Vegetation sampling**

If the remnant/recovery hypothesis is to be tested to describe mosaic dynamics of sand forest, evidence for nucleation and bush clump development in the grassland should be present. The sand forest species, *Dialium schlecteri* (Caesalpiniaceae) was used to investigate trends of succession between grassland (Plate 6), smaller clumps and sand forest patches. This species was chosen as plot data in studies of forest regeneration dynamics showed it to be the most common canopy species in sand forest patches (see Chapter 3) and it was found to occur in the adjacent grassland.

❖ *Size-class analysis*

According to the remnant / recovery hypothesis, larger patches of sand forest could be remnants of continuous forest that was fragmented. Alternatively, they could have developed through the aggregation of woody plants. Smaller bush clumps in the grassland could be the initiators of the nucleation process and thus be at an earlier successional phase than larger patches. Individual trees of developing patches are thus anticipated to have smaller size classes than equivalent species in large remnant patches.

Searches were made for *D. schlecteri* observed in the three habitat types until sample size was deemed to be adequate for the purpose of analysis. *D. schlecteri* occurring singly in the grassland were considered to be those individuals completely surrounded by grass and occurring at least 2.5 m from other woody vegetation. Bush clumps containing *D. schlecteri*, were defined as discreet aggregations of woody vegetation with a longest axis of 1-10 m, and completely surrounded by grassland (i.e. not connected to a forest patch). Clumps larger than 10 m in length were excluded. *D. schlecteri* were recorded in sand forest patches of a minimum of 25 m in length.

Measurements were taken of all stem diameters for small shrubs while diameter at breast height (dbh) was recorded for larger trees. An individual was considered to have more than one stem if the height of the first branching of its main stem was between 0-10 cm above the ground. Diameters used were then classed as follows: (1) 1-2 cm; (2) 3-6 cm; (3) 7-10 cm; (4) 11-20 cm; (5) 21-40 cm; (6) 41-60 cm; (7) 61 cm + and displayed graphically. For the purpose of the analysis, sizes were reduced to two diameter classes: (1) small (1-6 cm) and (2) large (7-61+ cm).

Large and small size-classes were compared between the three vegetation types using a chi-square test.

❖ *Stem number analysis*

I assumed that in terms of the remnant / recovery hypothesis, nucleus trees in the grassland could either be survivors of the initial fragmentation, or invaders of either sand forest or wooded grassland species. Multi-stemmed shrubs and trees could indicate resprouting from recent fire damage (Bond & van Wilgen 1996; Bond & Midgley 2001). Thus an individual with a large number of stems is likely to have recovered from a previous disturbance, while a single-stemmed individual is more likely to have recruited directly from seed (Kruger *et al.* 1997). Number of stems was therefore noted for each individual in the three habitat types and designated into the following size-classes: (1) 1-2 stems; (2) 3-5; (3) 6-8; (4) 9-12 and displayed as a histogram. Differences in stem number were compared between habitat types using an Anova.

▪ **Sand forest succession**

❖ *Aerial photographic analysis*

Three aerial photographs of the study site of the years 1942 (Job 661; Strip 6/6011), 1970 (Job 167; Strip 6/786) and 1996 (Job 985A, Strip 6/0165; Plate 8) were analysed visually to compare vegetation composition and density of the study area. If sand forest patches are restricted by underlying soil determinants, they should not be able to change or expand in the short term. Alternatively, if the remnant/recovery hypothesis is to be supported, it is expected that evidence of vegetation within the mosaic should be able to change. In the absence of fires an increase in woody vegetation would be expected as well as evidence of bush-clumping occurring from the earliest photograph to the latest.

Sections of vegetation on the 1942 and 1970 aerial photographs (blocks 1a and b on Plate 8a and blocks 2a on Plate 8b) considered likely to be protected from fire (as they were buffeted by patches of sand forest) were identified. These were then marked for comparison in the 1996 photograph (Plate 8c). Additionally, a patch of

sand forest surrounded by small homesteads and fields in Plate 8a (block 1c) was compared with the same section in Plates 8b and 8c.

For fire to be evoked as a major determinant of the observed patterning, evidence of large-scale fires in the past would be required. Natural fires induced by lightning strikes are deemed to be rare as there has been no record of this in TEP from 1991 to date (F. Myburgh, pers. comm.). A literature search was conducted to ascertain the extent to which people occurred in the area in the past. The presence of people within the region would imply a history of fire (Feely 1980).

❖ *Ordination of plots*

Succession has been documented in the literature with the use of ordination methods (e.g. von Maltitz *et al.* 1996; van Wyk *et al.* 1996). According to facilitation theory, pioneer species in the open grassland provide an enhanced environment for the establishment of grassland and forest woody species. As the clump develops and the micro-environment becomes more similar to larger sand forest patches, more sand forest species are expected to appear and woody grassland species are expected to drop out. It is expected that woody species in larger clumps should be more similar to those in sand forest patches than to those in the grassland. Additionally, it is expected that species of smaller size classes of bush clumps (i.e. the latest recruits), should be more similar to adult species of forest patches than adult species of bush clumps.

Three broad vegetation types were identified within the study area: grassland (less than 20% woody cover), wooded grassland (20-60% woody cover in grassland), and forest (80-100% woody cover within sand forest patches).

Circular plots with a radius of 11.28 m (400 m²) were randomly sampled in the three habitat types: 10 in grassland, 10 in wooded grassland and 25 in forest. The diameter at breast height (dbh) was measured and recorded for all woody tree species with dbh $\geq$ 10 cm. Trees with a dbh < 10 cm were categorised by height either as small trees (height $\geq$ 200 cm), or as understorey shrubs (height = 30 – 199 cm). In order to ascertain whether species invading developing clumps were more similar to sand forest species than to those in the grassland, each plot was separated into two subplots: one that contained trees between 30 cm in height and 9.99 cm dbh, and one with trees $\geq$ 10 cm dbh. Only woody plants were used in the analysis and climbers and herbs were excluded.

A polythetic divisive classification was carried out using TWINSpan (Hill 1979a), which separates plots on the basis of total species composition (Kent & Koker 1992). The programme was run with defaults. All woody species were included in the analysis and their presence or absence was used as importance values. A detrended correspondence analysis was performed using the computer programme DECORANA (Hill 1979b).

While sampling, it was observed that mature *D. schlecteri* forest individuals were showing signs of deterioration and many were infested with termites. This was interpreted to indicate that *D. schlecteri* trees within the forest were dying. In order to document this, for each individual encountered in the forest, an estimate was made of the total percentage of the tree (both stem and canopy) that was non-living.

Results

▪ Orthophotograph analysis

❖ *Altitude versus vegetation type*

No significant ($p > 0.05$) differences (Anova; $F = 2.39$) occurred between isoheight values for grassland, wooded grassland and sand forest (Table 1).

Table 1 Results of altitude data of the 3 habitat types: grassland (g); wooded grassland (w) and forest (f). Altitudes were obtained from isoheight values (m asl) on orthophotographs of the study area.

Test	Altitude (m)		
	g	w	f
N	117	445	552
min	42	38	41
max	118	112	129
range	76	74	88
mean	83.63	79.51	81.26
SD	10.00	11.90	12.38

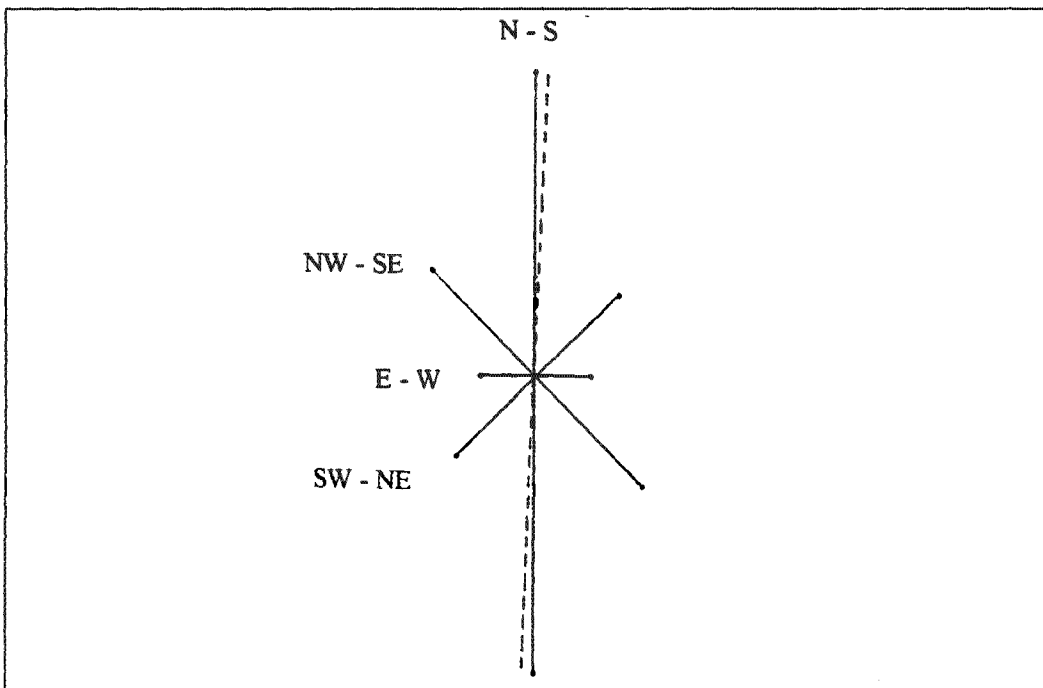
▪ Wind direction versus patch orientation

The product ' vf ' of wind intensity, v (m/s) and duration, f (frequency/1000) over the dry season months were as follows (from highest to lowest; Table 2).

Table 2 Wind intensity and duration for the main cardinal points, including combined strengths of opposite cardinal points.

	Cardinal points							
	S	N	NW	SE	SW	NE	E	W
	936.3	460.3	411.7	315.6	197.7	336.8	167.6	102.4
Length (cm)	7.8		4.0		3.0		1.5	

Southerly winds were clearly dominant in intensity and duration, followed by northerly winds. The $\sqrt{v}$ results for each opposing cardinal point were then added (e.g. N added to S; NW added to SE etc.) and these results were converted to lengths (cm). These measurements (Figure 3) show that N-S is the most likely direction of intense fire, with a length almost double that of the NW-SE direction.

**Figure 3** Wind rose showing the direction of winds in Maputaland measured as a product of duration and intensity (see text) over 23 years for the months May to September. The average orientation of the patches is indicated with a broken line.

Forest patches had an average ratio of 2.6 between the longest and shortest axis (range = 1.2 - 5.78; $SD = 0.95$). This indicates that patches were shaped as narrow strips with a length 2.6 fold greater on average than the width.

Of the 111 patches measured, 110 were orientated on a north-south axis and 1 patch was orientated on an east-west axis. The latter patch was almost round in shape with a ratio of 0.9 between the longest and shortest axis. N-S patches ($N = 110$) were all orientated between -22.5° and 22.5° from true North (i.e. between NNW and NNE respectively). Patches orientated between -22.5° and 0° ($N = 45$), had a mean orientation of -7.4° (range = $-1^\circ \pm -21^\circ$; $SD = 5.69$), while patches between 0° and 22.5° ($N = 61$) had a mean orientation of 8.48° (range = $1^\circ \pm 29^\circ$; $SD = 5.67$). Four patches were orientated at exactly 0° from North. Both positive and negatively orientated patches had an average orientation 1.7° from True North ($N = 110$) excluding the patch orientated east-west, and an average orientation of 2.3° from True North ($N = 111$) including the patch orientated east-west. Average orientation values were plotted (Figure 3). Due to this strong trend of north-south orientation of patches, no statistical analysis could be used to compare forest patch orientation to wind direction.

▪ **Nucleation**

❖ *Stem sizes*

Stem diameters of *D. schlecteri* differed ($p < 0.001$) significantly between those in grassland, in bush clumps and in sand forest (chi-squared). *D. schlecteri* occurring singly in grassland had the smallest stems, while those in small bush clumps had stems of intermediate sizes. Those in forest all had stem diameters greater than 20 cm in diameter (Figure 4). There was a general absence of *D. schlecteri* individuals representing 11-19 cm dbh size-class.

❖ *Multi-stemmedness*

Number of stems of *D. schlecteri* in grassland, bush clumps and forest showed significant ($p < 0.05$) differences ($F = 5.37$; Anova). Isolated individuals in the grassland displayed a higher degree of multi-stemmedness than those within bush clumps. *D. schlecteri* within sand forest displayed the least number of stems, although still had a degree of multi-stemmedness (Figure 5).

▪ Succession

The results of the TWINSpan classification (Appendices 1 and 2) resulted in the identification of 6 relevant divisions of sub-plots. The first division (eigenvalue = 0.690) separated the vegetation into forest plots (E) and non-forest plots (B and G). Forest plots were characterised by the presence of *Drypetes arguta*, *D. natalensis* and *Cleistanthus schlecteri*, while B and G plots were characterised by the presence of *Acacia burkei*, *Strychnos madagascariensis* and *S. spinosa*. *D. schlecteri* was a non-preferential species, i.e. it occurred in both forest and non-forest plots.

Forest plots were further divided into canopy and sub-canopy sub-plots (Division 2, eigenvalue = 0.398), the former defined by the presence of *D. schlecteri*, *Newtonia hildebrandtii*, *C. schlecteri* and *Balanites maughamii* and the latter characterised by the presence of *D. arguta*, *Toddaliopsis bremekampii* and *Leptactina delagoensis*. Forest canopy sub-plots were further divided (Division 4, eigenvalue = 0.297) into two communities. The first community described 18 of the 25 canopy sub-plots and was defined by the presence of *D. schlecteri*, *Psydrax fragrantissima* and *Erythrophleum lasianthum*. The second community described only 7 of the 25 plots and characterised by the presence of *Wrightia natalensis* and *Strychnos decussata*. Forest sub-canopy sub-plots were separated into two (Division 5, eigenvalue = 0.201), with *C. schlecteri* and *Memecylon sousae* characterising the first and *Brachylaena huillensis* and *O. natalitius*, the second.

For bush and grassland plots (Division 3, eigenvalue = 0.436), plot BJ6 was separated from the rest. The BJ6 plot was characterised of *Commiphora neglecta* and *Tarenna littoralis*, while the other plots, by *D. schlecteri*, *S. madagascariensis* and *S. spinosa*. B and G plots were further divided (Division 6, eigenvalue = 0.409) into sub-canopy and canopy sub-plots. Subcanopy subplots were defined by the presence of *D. schlecteri*, *Euclea natalensis* and *O. natalitius*, while canopy sub-plots had *Acacia burkei* as the indicator species.

The scatter diagram produced from the DECORANA ordination of the canopy and sub-canopy subplots, indicated that most of the variation is explained by Axis 1, with developing bush clumps to the right and sand forest patches to the left on the axis (Figure 6). Subcanopy subplots lie consistently toward the right of the canopy sub-

plots on the trajectory and a movement from developing, through bush clumps, to sand forest is fairly consistent in both canopy and sub-canopy plots.

Mature plots (B and G) separated out from BJ and GJ, which were more similar to forest plots. The second axis of the detrended correspondence analysis separates sub-canopy plots (J) from mature forest plots (E).

❖ *Senility*

Sizes of *D. schlecteri* within forest plots ranged from 30.7 – 186.6 cm dbh (N = 58). Most (51.7 %) individuals sampled were 50-90% dead (Figure 7).

▪ **Aerial photograph analysis**

There is evidence of thickening of woody vegetation within the woody grassland in fire-protected areas from 1942 (Plate 8a, blocks 1a and b) to 1996 (Plate 8c, equivalent blocks). Similarly a thickening of sand forest patches in the grassland occurs in block 2a (Plates 8b and c). Recovery appears to be slow. Burned areas and old homesteads are evident in block 1c of the 1942 photograph (Plate 8a), which are not present in equivalent sections of the 1970 and 1996 photographs (Plate 8b and c). Parts of this sand forest patch within this block were removed between 1942 and 1970, most likely by the inhabitants that used to reside there. No recovery of this sand forest patch has occurred.

Discussion

▪ **Landscape patterning of sand forest**

Several pointers suggests that the observed mosaic patterning in TEP is part of a dynamic process as outlined by the remnant-recovery hypothesis and is not completely fixed in space by set environmental variables (soil moisture hypothesis). Sand forest patches were found over the same altitudes as the other components of the matrix (woody grassland and grassland habitats). From this I infer that the observed patterning of the sand forest community within the mosaic is not a function of underlying soil conditions as suggested by Tinley & Van Riet (1981) or by soil water

availability (Matthews *et al.* 1999). Thus the north-south orientated dune ridges are not the main causal determinant of mosaic positioning or forest patch shape.

I suggest that fires driven in a southerly or northerly direction, and of sufficient intensity to fragment large sections of sand forest, are the main agents responsible for the observed patterning. The results show that southerly winds over the dry season are greatest for the region both in duration and intensity, followed by northerly winds. This implies that the most destructive fires during the dry season would be driven either in a southerly or a northerly direction. As sand forest is short and has a component of semi-deciduous species (Kirkwood & Midgley 1999) canopy burn would be fuelled by moribund leaf material and exposed branches.

The maintenance of the grass component following a fragmentation event would depend on the frequency and intensity of subsequent fires to suppress recovery of trees through resprouting and formation of bush clumps (Menaut *et al.* 1990). Subsequent fires would be channelled by relative ease of passage, along existing and newly developed north-south grassland 'corridors' between forest patches and maintain the observed sharp forest-grassland boundary (Matthews *et al.* 1999; Plate 7). The more frequent the fire, the more likely it would be for the grass corridors to be maintained, as fire generally promotes the maintenance of grassland and suppresses recovery of woody vegetation (Menaut *et al.* 1990; San-Jose & Montes 1997; Plate 9). This could account for the similarity in shape of forest patches observed between the 1942 and 1997 aerial photographs (Plates 8a and 8c).

Matthews *et al.* (1999) suggest that grasslands are primary features and not secondary (or anthropogenically induced) and propose that 'natural' fires were a common feature of the northern Maputaland region. I propose that natural fires are relatively rare in Maputaland and that past anthropogenic use of fire is largely responsible for the current mosaic.

The presence of both Stone and Iron Age man has been extensively documented in the Maputaland region (Bruton *et al.* 1980; Hall & Vogel 1978; Feely 1980; Hall 1980; 1984). Stone Age hunter-gatherers are known to have burned vegetation to manipulate game movements and to stimulate new growth of geophytes as their primary food source (Hall 1984). Scholes & Walker (1993) argue that these activities would have increased the natural fire frequencies from anything from 100 000 to 10 000 years BP which would have considerable impact on the vegetation. The ensuing Iron Age agriculturalist made use of extensive burning to clear grassland

and woodland areas suitable for agriculture and grazing for cattle (Hall 1984). In early 2002, lumps of charcoal were discovered in several sites within mature sand forest patches in southern TEP (e.g. in the vicinity of 'KwaH'; see Figure 2 of Chapter 1) at depths of up to one metre below the forest floor surface (K. Catapano, unpublished data 2002)). This evidence suggests that the presence of human-induced fires have been a long-term component of mosaic dynamics in northern Maputaland and is not a recent phenomenon.

In more modern times the rapidly increasing population of local Tembe-Thonga inhabitants in and around sand forest make use of slash and burn agricultural techniques and burn to enhance conditions for cattle grazing (Cunningham 1988a). Between 1983 and 1996 with the establishment of TEP, annual block burns were carried out at the end of the dry season. Fire-breaks were burned around sand forest patches to prevent them from igniting. From 1997 to date, random point burns have been used in the reserve, also at the end of the dry season (F. Myburgh pers. comm.).

▪ Nucleation

The results suggest evidence of nucleation and clumping in the study area, which lends support for the remnant/recovery hypothesis. In a fire-prone environment, 'escape' of small trees in the grassland to larger sizes through resprouting, may be facilitated substantially by the establishment of other woody species around them (Skowno *et al.* 1999). These 'bush clumps' would provide small shrubs protection from factors such as browsing and fire. Results of the study confirm this, as *D. schlecteri* showed significant increases in stem sizes from single plants in the grassland, through those within bush clumps to those in sand forest.

In terms of the remnant/recovery hypothesis, nuclei trees in the grassland could either be survivors of the initial fragmentation, or invaders from sand forest or wooded grassland species. Multi-stemmed shrubs and trees are likely to indicate resprouting from past disturbance (Keeley 1992a; 1992b; Bond 1997; Kruger *et al.* 1997; Plate 10). Thus small, multi-stemmed *D. schlecteri* in the grassland could be survivors of forests which were destroyed by past fragmentation events. Their relatively small stature may not reflect a young age, but may show that they have been suppressed in the grassland by subsequent disturbance events (Bond & van Wilgen 1996).

Alternatively the presence of small individuals of *D. schlecteri* in the grassland could show that they have recruited from seeds produced by adult trees in adjacent sand forest patches. Fruits of *D. schlecteri* trees have a sweet, powdery flesh and surround a hard *Acacia*-like seed, which is eaten and dispersed by animals and birds (Palgrave 1984). The rock-hard testa of the seed could require heat shock or smoke from fires to initiate germination, or processing through an animal gut (Jäger *et al.* 1996; Keith 1997; Godínez-Alvarez & Valiente-Banuet 1998; Keeley & Fotheringham 1998). If recruitment is occurring, the absence of small size-class *D. schlecteri* in the forest implies that it takes place almost exclusively within the grassland and not *in situ* in the forest.

Although less multi-stemmed than individuals in bush clumps and grassland, *D. schlecteri* still has a degree of multi-stemmedness within forest which also suggests that large multi-stemmed trees were not produced from seedlings in a forest environment, but may have survived the rigours of disturbance within the surrounding grassland. If this is the case, the significant reduction in stems from individuals in the grassland to those within the forest may indicate a natural process of self-thinning (Bond & Midgley 2001), rather than showing that trees recruited in a forest environment.

▪ Succession

Results of the detrended correspondence analysis suggested a successional gradient or a transition in composition from grassland through woodland trees to forest. The direction suggested that canopy species in the grassland and wooded grassland (e.g. *A. burkei*), were the initiators and provide an environment for the next stage in the succession, i.e. the establishment of smaller individuals of species more similar to sand forest species. Interestingly, the two bush plots where no clumping or nucleation had taken place and trees still occurred as fairly separate entities, were more similar to bush canopy sub-plots than the others.

In TEP, other woody plants were found to be part of clumps and possibly serve as nuclei e.g. *Acacia burkei*, *S. madagascariensis* and *Terminalia sericea* (Appendix 1). These species, however, were absent from sand forest plots and display similar properties to nucleus plants documented elsewhere (e.g. *Prosopis glandulosa*; Archer *et al.* 1988), which facilitate clumping in the grassland but do not

occur in the forest. They are likely to be shade-intolerant pioneers and although may initiate aggregation, are not able to survive within the context of the forest where they are over-topped and rapidly out-competed for light by forest species.

D. schlecteri displays a different pattern, in that its presence in the grassland may serve as an initiator of clumping, but it remains to become a canopy dominant within the forest. *D. schlecteri* is from the Caesalpiniaceae, a family comprising genera which are not true forest species (Pooley 1993). The observed clumping phenomenon and dominance of *D. schlecteri* in sand forest plots suggests that much of the sand forest within the study area is a product of the proposed clumping phenomenon. Thus, patches of sand forest dominated by the *D. schlecteri*-dominated community in TEP can be seen as a closed woodland. Sub-canopy forest species such as *D. arguta*, *D. natalensis*, *C. greenwayi* and *T. bremekampii* recruit in to this shaded context.

Other sand forest species were found to occur both within forest patches and singly within the grassland (e.g. *P. myrtifolia*, *H. ulmoides* and *P. fragrantissima*). These species, however, all displayed a degree of seedling recruitment within the forest and thus differed from *D. schlecteri* (see Chapter 3). The extent to which such species behave as nuclei requires further investigation.

According to aerial photographs of the study area there is evidence of thickening and clumping of woody vegetation in woody grassland patches deemed to be protected from fire over the 55 years period between photographs. However re-growth seems to be slow when compared to growth rates cited for similar systems elsewhere. In a one such study, release from fire resulted in the transformation of savanna into closed woodland in a matter of two years (Prins & van der Jeugd 1993). The slow changes observed in the sand forest mosaic could imply that growth rates of woody species are relatively slow, possibly as a consequence of sandy soils and low moisture levels. Also, the regular burns continue as part of the reserve management policy. This, combined with the slow growth rates of sand forest could cause the observed slow progress of succession.

Conclusion

The mosaic patterning within TEP appears to be, in part, the result of past forest fragmentation by fire, possibly induced by humans who have a long presence in

the area. The maintenance of the status quo, i.e. a component of sand forest, grassland and wooded grassland within the study area, may need to be achieved through manipulation of the burning regime within the reserve. Hot, intense fires could fragment existing sand forest patches and increase the ratio of grassland in the matrix. Large individuals of *D. schlecteri* may survive the removal of the forest and persist as small, multi-stemmed individuals in the grassland. Intense fires in the grassland will preclude the development of bush clumps and will keep *D. schlecteri* as small stunted trees.

In the absence of fire, small multi-stemmed individuals will increase in size and aggregation of woody trees will take place. In the continued absence of fires, these clumps could expand and merge with adjacent sand forest patches. Core sections of *D. schlecteri*-dominated sand forest, i.e. those with large mature *D. schlecteri* individuals, are expected to change in composition as *D. schlecteri* senesces and drops out of the system. This may cause an alteration of the floristic communities currently found in the study site. An implication for reserve managers and researchers may be to decide on appropriate burning regimes in order to manipulate the functioning of these systems to best serve the ideals of conservation of sand forest.

The model proposed in this study is preliminary and should be tested with a detailed analysis of the soil type and moisture found in the different mosaic components described. The effects of other disturbance factors on mosaic patterning, such as browsing of sand forest vegetation by elephants, also need to be investigated.

Plates: 6 - 10

(overleaf)



Plate 6 A section of grassland situated between sand forest patches, with Nina Veenstra, Adam West and Arthea Kisch.



Plate 7 Bruce Anderson standing at the abrupt grassland-forest boundary of a recently burned patch of sand forest.

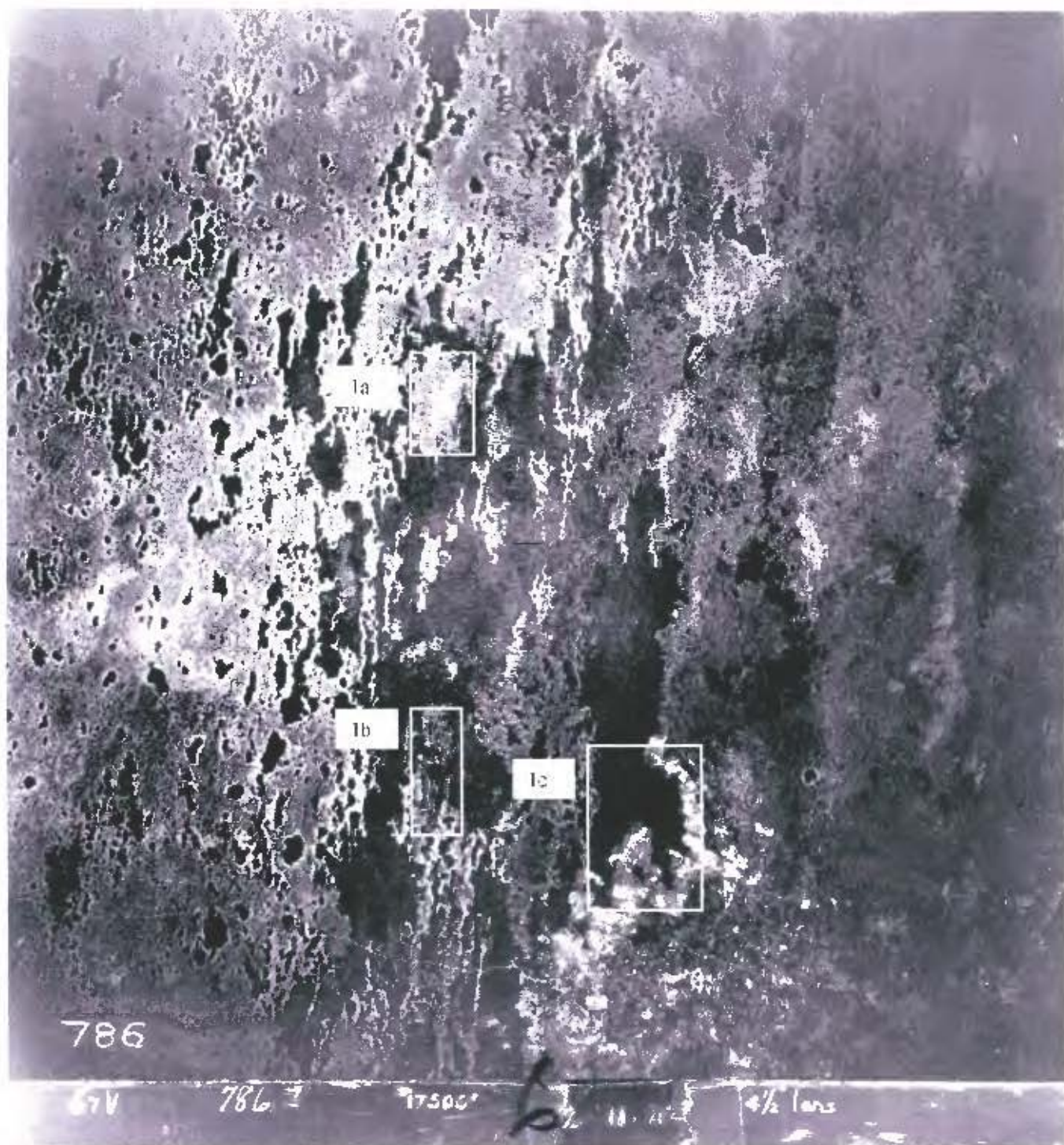


Plate 8a A 1:45 000 aerial photograph (Job 167; Strip 6/786 of 1942) of the area to become Tembe Elephant Park in 1983 (north of the sand road running east-west to the south of the photograph). Dark sections show sand forest patches (see Plate 5). Note the areas of sparse grass cover, particularly in the north-western section of the photograph. Compare vegetation in blocks 1a and b to that in blocks 1a and b in the 1996 photograph (Plate 8c). The small white patches which occur in and around the section of sand forest indicated within block 1c are likely to be areas inhabited and cleared by local Tembe-Tonga people. Compare the sand forest patch in this block to that in block 1c of Plate 8b and 8c.

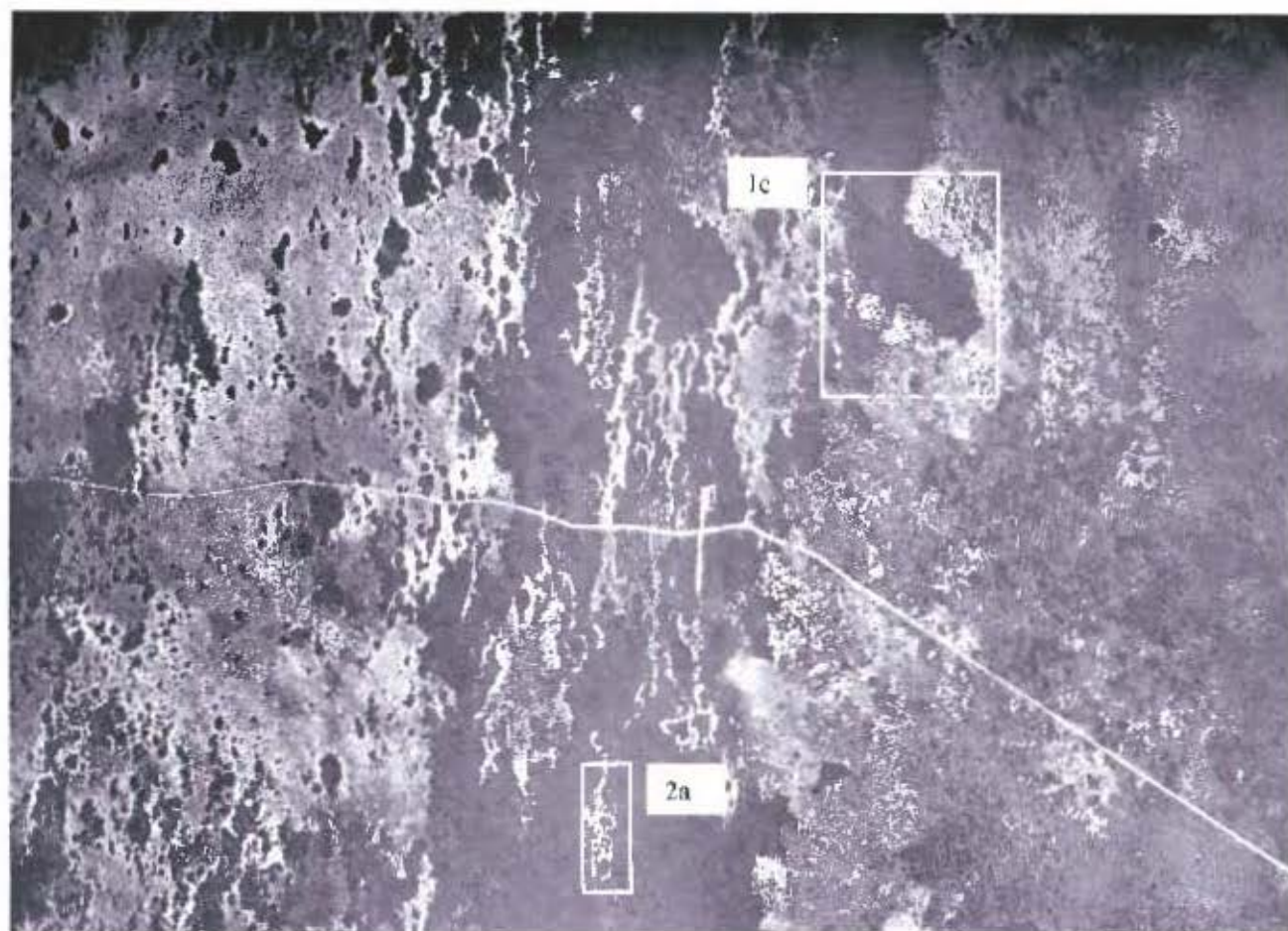


Plate 8b A 1:30 000 aerial photograph (Job 661; Strip 6/6010 of 1970) of the area to become Tembe Elephant Park (north of the sand road running east-west). Compare vegetation within the block annotated 1c in this photograph with 1c in Plates 8a and 8c. Compare vegetation in block 2a with that in block 2a in Plate 8c.

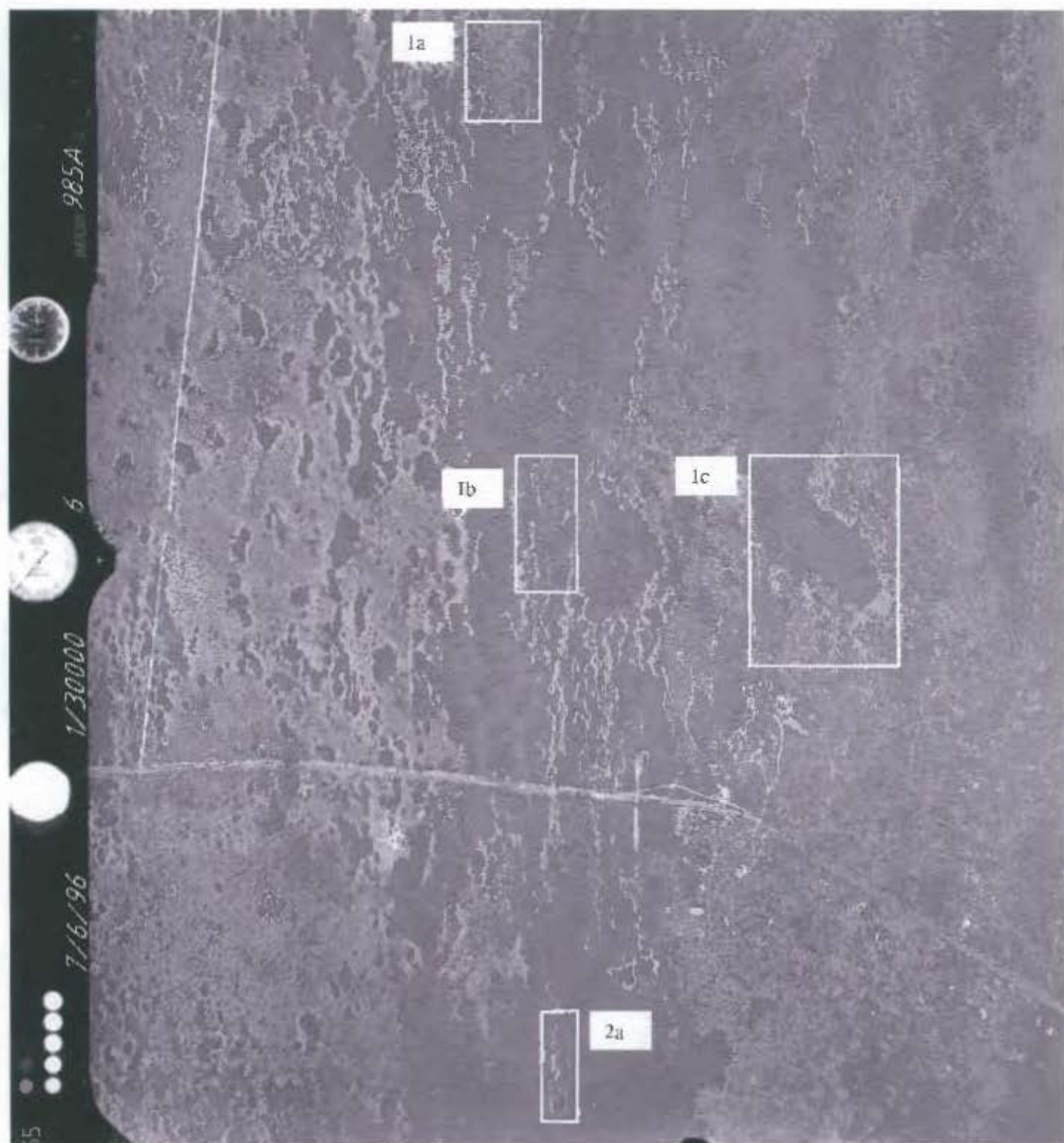


Plate 8c A 1:30 000 aerial photograph (Job 985A; Strip 6/0165 of 1996) of TEP (situated north of the tar road and to the east of the sand road running north-south). Compare vegetation in blocks 1a-c with that in the equivalent blocks in Plate 8a and in 1c with Plate 8b. Compare vegetation in block 2a with that in block 2a in Plate 8b.



Plate 9 The remains of a recently burned sand forest patch. Note the flush of new grasses that have established beneath the woody stems.



Plate 10 A multi-stemmed shrub in the grassland coppicing from the base following burning.

Figures: 4 - 7

(overleaf)

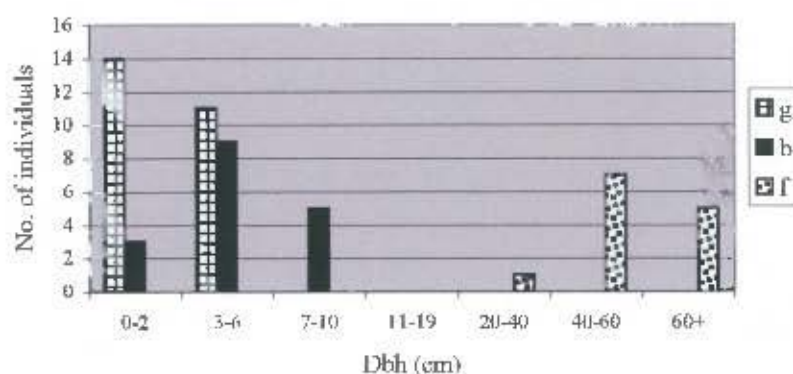


Figure 4 Sizes (cm dbh) of *D. schlechteri* individuals within grassland (g), bush clumps (b) and sand forest (f).

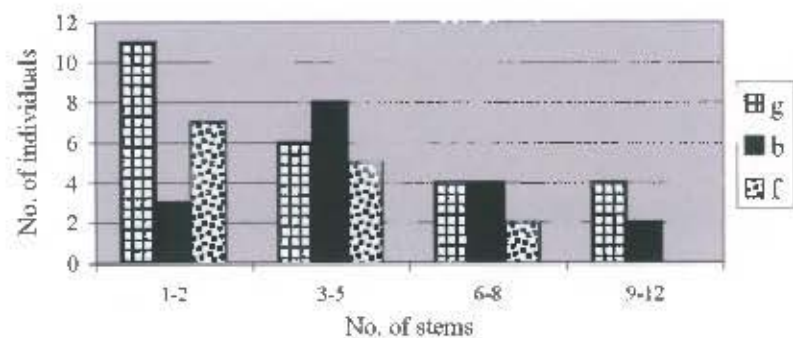


Figure 5 Number of stems of *D. schlechteri* trees in grassland (g), bush clumps (b) and sand forest (f).

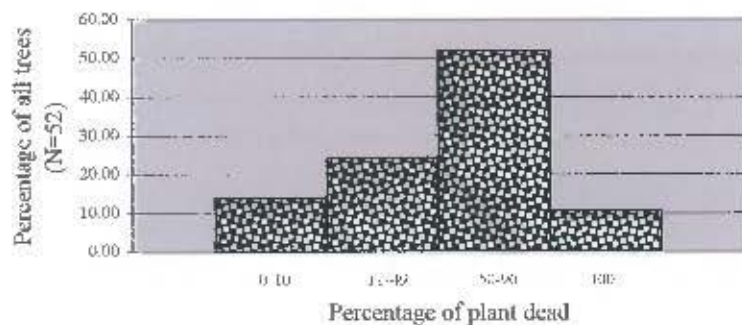


Figure 7 Percentage of total *D. schlechteri* individuals (> 10 cm dbh) in forest plots at Site 1 found in the various senility categories (see text).

Appendices: 1 - 2

(overleaf)

Appendix 1a TWINSPAN two-way table showing presence of species per plot at Site 1 within forest, grassland and bush plots. Community groupings are indicated by the numbers below and to the right of the table.

233223323322222333344444455644455665566655666845 6 1777117778881117111 777 18
01838794031256792456234015693679585612348907012384 7672341656702445880235789134019291

[illegible][illegible]

Appendix 1b i) Order of species derived from the TWINSpan classification (see Appendix 1a).

35	hymulm	49	psyfra	52	ptemyr	75	vitamb	3	afzqua
12	casmos	26	drynat	6	balmau	7	bosfoe	14	clesch
27	erylas	30	eupgra	34	hapgal	38	lanant	40	mandis
42	newhil	76	wrinat	15	colgre	16	commku	24	dioinh
41	memsou	51	ptaobl	59	strhen	25	dryarg	36	hypmic
39	lepdel	65	tarsup	68	todbre	20	croste	32	grecaf
43	ocharb	62	surzan	8	brahui	69	tricap	33	gremic
44	ochbar	64	tarlit	46	oxylat	48	physpp	71	trilan
10	canset	18	comneg	50	psyloc	70	trijun	5	albfor
45	ochnat	22	diasch	66	tecger	74	veplan	2	acrnat
9	bricat	13	claani	19	comzey	21	deiobl	23	diccin
29	eucnat	37	laglas	54	rhugue	55	sapint	58	strdec
72	undshr	77	zancap	78	zizmuc	4	albadi	11	canspi
28	eucdiv	31	garliv	60	strmad	63	tarjun	73	vaninf
17	commol	47	pavsch	53	pyrhys	56	sclcaf	57	spiafr
61	strspi	67	terser	1	acabur				

Appendix 1b ii) Order of plots derived from the TWINSpan classification (see Appendix 1a)

20	E1	31	E2	38	E3	23	E12	28	E17
37	E25	39	E4	24	E13	30	E19	33	E21
21	E10	22	E11	25	E14	26	E15	27	E16
29	E18	32	E20	34	E22	35	E23	36	E24
42	E7	43	E8	44	E9	40	E5	41	E6
45	EJ1	56	EJ2	59	EJ22	63	EJ3	46	EJ10
47	EJ11	49	EJ13	55	EJ19	58	EJ21	65	EJ5
66	EJ6	51	EJ15	52	EJ16	53	EJ17	64	EJ4
68	EJ8	69	EJ9	50	EJ14	57	EJ20	60	EJ23
61	EJ24	62	EJ25	83	GJ8	48	EJ12	54	EJ18
67	EJ7	6	B5	17	BJ7	72	G6	73	G7
74	G9	11	BJ10	16	BJ6	75	GJ1	76	GJ10
77	GJ2	80	GJ5	82	GJ7	84	GJ9	14	BJ4
15	BJ5	18	BJ8	78	GJ3	10	BJ1	12	BJ2
13	BJ3	5	B4	7	B6	8	B7	9	B9
1	B1	3	B2	4	B3	70	G1	71	G10
79	GJ4	2	B10	19	BJ9	81	GJ6		

Appendix 2 Species used in the TWINSpan classification and their codes.

Code	Species
acabur	<i>Acacia burkei</i>
acrnat	<i>Acridocarpus natalitius</i> var. <i>linearifolius</i>
afzqua	<i>Afzelia quanzensis</i>
albadi	<i>Albizia adianthifolia</i>
albfor	<i>Albizia forbesii</i>
balmau	<i>Balanites maughamii</i>
bosfoe	<i>Boscia foetida</i> subsp. <i>Rehmanniana</i>
brahui	<i>Brachylaena huillensis</i>
bricat	<i>Bridelia cathartica</i>
canset	<i>Canthium setiflorum</i>
canspi	<i>Canthium spinosum</i>
casmos	<i>Cassipourea mossambicensis</i>
claani	<i>Clausena anisata</i>
clesch	<i>Cleistanthus schlechteri</i>
colgre	<i>Cola greenwayi</i>
commku	<i>Combretum mkuzense</i>
commol	<i>Combretum molle</i>
comneg	<i>Commiphora neglecta</i>
comzey	<i>Combretum zeyheri</i>
croste	<i>Croton steenkampianus</i>
deiobl	<i>Deinbollia oblongifolia</i>
diasch	<i>Dialium schlechteri</i>
diccin	<i>Dichrostachys cinerea</i> subsp. <i>Africana</i>
dioinh	<i>Diospyrus inhacaensis</i>
dryarg	<i>Drypetes arguta</i>
drynat	<i>Drypetes natalensis</i>
erylas	<i>Erythrophleum lasianthum</i>
eucdiv	<i>Euclea divinorum</i>
eucnat	<i>Euclea natalensis</i> subsp. <i>rotundifolia</i>
eupgra	<i>Euphorbia grandidens</i>
garliv	<i>Garcinia livingstonei</i>
grecaf	<i>Grewia caffra</i>
gremic	<i>Grewia microthyrsa</i>
hapgal	<i>Haplocoelum gallense</i>
hymulm	<i>Hymenocardia ulmoides</i>
hypmic	<i>Hyperacanthus microphyllus</i>
laglas	<i>Lagynias lasiantha</i>
lanant	<i>Lannea antiscorbutica</i>
lepdel	<i>Leptactina delagoensis</i>
mandis	<i>Manilkara discolor</i>
memsou	<i>Memecylon sousae</i>
newhil	<i>Newtonia hildebrandtii</i> var. <i>hildebrandtii</i>

Appendix 2 continued.

Code	Species
ocharb	<i>Ochna arborea</i>
ochbar	<i>Ochna barbosae</i>
ochnat	<i>Ochna natalitia</i>
oxylas	<i>Oxyanthus latifolius</i>
pavsch	<i>Pavetta schumanniana</i>
physpp	<i>Phyllanthus spp.</i>
psyfra	<i>Psydrax fragrantissima</i>
psyloc	<i>Psydrax locuples</i>
ptaobl	<i>Ptaeroxylon obliquum</i>
ptemyr	<i>Pтелиopsis myrtifolia</i>
pyrhys	<i>Pyrostria hystrix</i>
rhugue	<i>Rhus gueinzii</i>
sapint	<i>Sapium integerrimum</i>
scfcf	<i>Sclerocarya birrea subsp. caffra</i>
spiafr	<i>Spirostachys africana</i>
strdec	<i>Strychnos decussata</i>
strhen	<i>Strychnos henningsii</i>
strmad	<i>Strychnos madagascariensis</i>
strspi	<i>Strychnos spinosa</i>
surzan	<i>Suregada zanzibariensis</i>
tarjun	<i>Tarenna junodii</i>
tarlit	<i>Tarenna littoralis</i>
tarsup	<i>Tarenna supra-axillaris subsp. barbertonensis</i>
tecger	<i>Teclea gerradii</i>
terser	<i>Terminalia sericea</i>
todbre	<i>Toddaliopsis bremekampii</i>
tricap	<i>Tricalysia capensis</i>
trijun	<i>Tricalysia junodii</i>
trilan	<i>Tricalysia lanceolata</i>
undshr	understorey shrub (unidentified species in B and G)
vaninf	<i>Vangueria infausta</i>
veplan	<i>Vepris lanceolata</i>
vitamb	<i>Vitex ferruginea subsp. amboniensis</i>
wrinat	<i>Wrightia natalensis</i>
zancap	<i>Zanthoxylon capense</i>
zizmuc	<i>Ziziphus mucronata subsp. mucronata</i>

CHAPTER 3

Floristics and dynamics of sand forest in and around Tembe Elephant Park.

Abstract

The floristics and demographics of sand forest was assessed and compared between Tembe Elephant Park (Site 1) and two disturbed communal areas neighbouring the reserve (Sites 2 and 3). The assessment and comparison between sites was based on: 1) floristics (species composition and richness), 2) dynamics (grain and demographics), and 3) the densities of ungulate browsers.

1) *Floristics*: Based on a TWINSpan classification and a DECORANA ordination of all plots, three main communities were identified, a sub-canopy community and two canopy communities. No major differences occurred between sand forest plots at either site and thus it appeared that harvesting had not altered overall species composition at Site 2. However species richness and stem densities increased at Site 2 could reflect the increased harvesting at this site. 2) *Dynamics*: The relatively long ordination length between centroids of sub-canopy and canopy subplots indicated that sand forest is a 'coarse-grained' forest type. Canopy species displayed size-class distribution curves similar to those of other coarse-grained forests in KwaZulu-Natal, in that they had higher proportions of large stems per species than they did smaller stems. This may suggest that these species require higher light levels in the form of large gaps for seedlings to establish successfully. 3) *Browsing*: Significantly lower densities of small antelope browsers occurred at Site 2 than at Site 1.

Keywords: browsing pressure, DECORANA, disturbance, forest dynamics, grain, KwaZulu-Natal, Maputaland, regeneration, small ungulate, sand forest, tropical dry forest, TWINSpan.

Introduction

In northern Maputaland, local Tembe-Thonga people living in and around sand forest, use forest products as poles and laths for hut and fence construction, traditional medicines and fuel wood (Cunningham 1989). Additionally, an increasing commercialisation of forest products has taken place, particularly in terms of the medicinal trade (Cunningham & Davis 1997), but also in the form of informal road-side craft and fuelwood markets (R. Kyle pers. comm.). A rapid increase in population densities of these inhabitants over recent years (Matthews *et al.* 1999) has been a cause for concern given the limited distribution of this forest type (Kirkwood & Midgley 1999). Studies have shown that this growing dependence on forest products in South Africa has resulted in a decrease of species richness in certain KwaZulu-Natal forests (Geldenhuys & MacDevette 1989).

About 38.8% of the estimated 5 986 ha covered by sand forest falls within formal conservation areas (Geldenhuys & MacDevette 1989). Thus it may seem that this forest type is generally protected from rising harvesting pressure outside reserve boundaries. However, increasing evidence suggests that a lack of regeneration exists in many KwaZulu-Natal forests within the reserve network (Everard *et al.* 1994; Midgley *et al.* 1995c; van Wyk *et al.* 1996; West *et al.* 2001). This may imply that factors required for regeneration are no longer present. The extent to which this may be true for sand forest is unknown, as although progress is being made towards a broad descriptive account of this forest type (e.g. Kirkwood & Midgley 1999), there is a notable absence of published information on its dynamics. The trend evident in KwaZulu-Natal forests has highlighted the need for a closer understanding of the dynamics and regeneration requirements of sand forest to ensure sustainable and effective management.

▪ Forest dynamics

Forest dynamics has been expressed as depending on the life history or degree of shade-tolerance of constituent species and on the level of forest disturbance (Midgley *et al.* 1990; Midgley *et al.* 1995c). The level of shade-tolerance of species would determine the ability of species to grow and reproduce under different degrees

of light dictated by level of canopy closure. Thus shade-tolerant species would show high regeneration success in a shaded environment provided by a closed canopy, while shade-intolerant species would be optimised in the higher levels of light provided by large forest gaps (Midgley *et al.* 1990; Everard *et al.* 1994). However, species do not simply display one type of shade-tolerance or the other, but occur along a continuum of light dependence (Everard *et al.* 1995).

The degree of disturbance within a forest could range from large-scale processes such as fires, hurricanes, or clearing for agriculture (Cunningham 1985; Veblen *et al.* 1992) to small-scale events, such as tree-falls or pole removal (Uhl *et al.* 1988; Everard *et al.* 1995; Midgley *et al.* 1995b). Thus it follows that manipulation of disturbance regimes would favour one type of species over another. It may be that whole forests are dominated either by shade-tolerant or shade-intolerant species. If this can be determined, then very simplistically, implementation of appropriate disturbance regimes may enable maintenance of regenerative processes within these forests.

▪ Grain

An attempt has been made to group forests in South Africa into such management entities based on this combination of shade-tolerance and scale of disturbance (Midgley *et al.* 1990; Everard *et al.* 1994). The term used to define these groups is that of 'grain'. A forest exhibiting a 'fine' grain would be one whose dominant canopy species are shade-tolerant and thus regenerate *in situ*. Species composition of the canopy is therefore very similar to that of the sub-canopy and the scale of variation is 'fine'. Level of disturbance required for successful recruitment is minimal or unnecessary. Alternatively 'coarse'-grained forests which have a canopy layer dominated by shade-intolerant species, will have most recruitment occurring within randomly located gaps. Thus larger differences exist between species of the canopy and those of sub-canopy layer at the plot level, scale of variation will be large or 'coarse'. Hence the term 'coarse-grained' has been used to define these forests.

Two broad categories of KwaZulu-Natal forests exist, namely 'coastal' types, which predominate on the eastern seaboard, and 'Afromontane' types, restricted to the cooler mountainous interior (Geldenhuys & MacDevette 1989). Research on forests of these types to date has suggested that forests which are grouped within the coastal

type (e.g. Dukuduku coastal lowlands forest; van Wyk *et al.* 1996) are more likely to be coarse-grained than are the Afromontane forest types, which tend to be fine-grained (e.g. Knysna Afromontane forest; Midgley *et al.* 1990). Thus, researchers argue that current species composition and community structure of coastal forests may have been influenced by ‘disturbance’ of patches by humans and large herbivores such in the past (van Wyk *et al.* 1996). Evidence in some of these forests (such as in coastal lowlands and dune forests on the eastern seaboard of KwaZulu-Natal) suggests that by removing these factors, processes such as the regeneration of canopy species may be impeded, resulting in a loss of species from the system (van Wyk *et al.* 1996).

Based on its species composition as well as its distribution in low-lying areas on the eastern seaboard of KwaZulu-Natal, sand forest has been grouped with the coastal forest types (see Chapter 1). On the basis of a preliminary analysis of a range of KwaZulu-Natal forests, it appeared that sand forests were relatively coarse-grained (Everard *et al.* 1995). Other preliminary evidence points to the possible relatively coarse-grained nature of sand forest. Midgley *et al.* (1995d) related leaf attributes of a range of southern African forest species (specific leaf area (SLA), and leaf nitrogen concentration) to their life-history strategy. They found that certain sand forest canopy species displayed leaf attributes synonymous with relatively faster-growing, shade-intolerant species i.e. relatively high nitrogen levels and high SLA. Two sand forest canopy species, the deciduous legume, *Erythrophleum lasianthum* as well as *Wrightia natalensis*, displayed amongst the highest SLA in their study.

▪ Plant vital attributes

As demonstrated in the SLA study (Midgley *et al.* 1995d), attempts are increasingly being made to group species of similar functional type according to their ‘plant vital attributes’ (Nobel & Slatyr 1980). As sand forest is unique within the context of South African forests in terms of some of these vital attributes (e.g. relatively high degree of wind-dispersed propagules and high deciduousness amongst species), a closer investigation of these features may provide clues into its dynamic strategies.

▪ **Browsing**

Another factor that could influence size-class distribution of species within a forest is that of herbivory. Ungulate browsing pressure has been cited as an important factor controlling the success of seedling establishment and growth within forests and woodland environments (e.g. Belsky 1984; Bergström 1992; Prins & Jeugd 1993). It is likely that some formally protected areas could have relatively high stocking rates of vertebrate herbivores, because of the recent absence of human hunting and in some cases, low numbers of carnivore predators. Reserves with high browser densities could expose sand forest seedlings to a possible disadvantage relative to unprotected areas where stocking rates are likely to be lower. No data to date exist on densities of ungulates in sand forest outside reserves.

Aims

Few data are available on the effects of human utilisation on the composition and diversity of sand forest, or of the life history strategies of component species. This lack of information makes it difficult to know the appropriate management approach necessary to maintain its biodiversity and function. Thus, the aims of the study are to provide a preliminary analysis of the dynamics and floristics of sand forest in and around Tembe Elephant Park. From the findings of the research, a framework for management will be developed with recommendations on the possible degree of disturbance required to maintain sand forest processes within reserves.

The main questions asked are as follows:

▪ **Floristics**

- ❖ What floristic communities occur within sand forest and do they differ between harvested and unharvested sites?
 - ❖ Does species richness differ with land-use?
 - ❖ What are the 'plant vital attributes' of sand forest species and do these differ between plant communities?
-

▪ **Dynamics**

- ❖ Does sand forest have a ‘course grain’ in relation to other forests in KwaZulu-Natal as is suggested by preliminary studies?
- ❖ What are the demographics of sand forest based on size-class distributions of key species? Can size-class distributions be used to group species into their functional type?
- ❖ Do size-class distributions differ between harvested and unharvested sites?
- ❖ Can the successional strategies of species be understood from this information?

▪ **Browsing**

- ❖ Do small ungulate browsers play a role in determining seedling survival of sand forest species?

Study sites

All three sites were used in this study (see Chapter 1 for details). Site 1 was located within Tembe Elephant Park and was protected from human and elephant disturbance. Sand forest at this site was thus relatively undisturbed although sand forest at Site 2 had, and was being, moderately disturbed by humans (i.e. stems of trees were being harvested for poles and harvesting was taking place for the medicinal trade). Sand forest at Site 3 had, and was being, highly disturbed (e.g. sections of forest had, and were being, cleared for subsistence agriculture).

Methods

▪ Sampling strategy

❖ *Forest plots*

Species and size-class data were collected from sand forest plots at Sites 1 and 2 in order to compare forest without and with human use respectively. Data were recorded from standard 0.04 ha (400 m²) circular plots (radius 11.28 m), which were randomly located in stands of sand forest at both sites (Plate 11). Twenty-five plots were sampled at Site 1 and 22 at Site 2. At each plot the average height (m) of the canopy was estimated and recorded. The diameter at breast height (dbh) was recorded for all woody tree species with dbh ≥ 10 cm. Diameters of stems of a plant were measured separately if they branched off from the primary stem from 0-10 cm above ground level. Plants with stems < 10 cm dbh were categorised either as small trees (height ≥ 200 cm) or as understorey shrubs (height = 30 – 199 cm).

Plants < 30 cm in height were ignored because it was unclear whether these individuals would progress beyond the seedling stage. High mortality rates of seedlings of certain species were found to occur within the initial few months following establishment (pers. obs.) and for this reason it was felt that plots sampled during the wet season, when most species recruit, would show significantly higher seedling abundances than plots sampled during the dry season. For the purpose of this study, establishment was considered to have been successful only once an individual had attained a height of at least 30 cm.

Only woody plants were used in the analysis, thus climbers and herbs were excluded. Common understorey species deemed not to be potential occupants of canopy or sub-canopy layers e.g. *Croton pseudopulchellus*, *Monanthotaxis caffra*, *Monodora junodii* and *Salacia leptoclada*, were also excluded from the survey. A new species of *Phyllanthus* was documented in the region and at the time of submission had not been named. It is thus referred to as *Phyllanthus* sp. throughout this study.

In order to document the plant vital attributes of each species, a note was made of the type of propagule (wind-dispersed, dry, fleshy or leguminous) and the type of

leaf (evergreen or deciduous; compound or simple) using information in Palgrave (1984) and Pooley (1993). These factors were tabulated to allow for comparison between species in order to provide insights into their dynamic strategies.

Nine plots were sampled at Site 3 in sections of highly disturbed sand forest dominated by *N. hildebrandtii* and *C. schlecteri* canopy trees. An equivalent section of forest in terms of community structure was not available in the exclosure plot at Site 1. The nearest site deemed similar within the reserve was a section of forest near 'Kwa-H' (see Figure 2, Chapter 1), which lay adjacent to the exclosure plot. However, this section showed signs of elephant utilisation and it was felt that this additional disturbance factor rendered it an adequate control site. Thus this section was not sampled in this study. However, plot data from Site 3 were used to indicate differences in dominance of different community types (see Analysis section of Methods, this chapter).

❖ *Transects*

Additionally, transects were sampled at Sites 1 and 2 to supplement plot data for size-class distributions of 4 common canopy species: *Balanites maughamii*, *Cleistanthus schlecteri*, *Erythrophleum lasianthum*, *Newtonia hildebrandtii*, and the smaller species, *Cassipourea mossambicensis*.

Transects were laid 40 m apart in a north-south direction due to the north-south orientation of the sand forest patches. Transects were 4m wide and of varying lengths (see Results section), which were determined by the length of the patch. Size-class data were recorded for all individuals of the selected species encountered.

Additional transects were sampled in the same manner at Site 3 to enable a comparison of size-classes of *N. hildebrandtii* and *C. schlecteri* at this site with its higher levels of human use.

○ *N. hildebrandtii* seedling transects

High densities of *N. hildebrandtii* seedlings were found during sampling at Site 3 in highly disturbed and cleared areas within the forest. Seedlings occurred on a wide sand road leading to a homestead, within areas cleared for agriculture that had subsequently been abandoned before cultivation had taken place, and in sections

cleared to make way for homesteads (Plates 12 and 13). Four meter wide transects of varying lengths were sampled in these disturbed areas where seedlings were found in order to determine localised seedling densities. The five transects sampled were 5, 10, 15, 30 and 40m in length respectively giving a total area sampled of 500 m². Number of seedlings and heights (cm) were recorded in four of the transects.

The purpose of this survey was merely to document the size-class and local densities of the seedlings within transects and not to use these data to calculate overall densities of *N. hildebrandtii* at Site 3. This was due to the fact that the seedlings sampled on these transects were not found within forest, but in cleared areas in and adjacent to *N. hildebrandtii* – dominated sand forest. Searches for *N. hildebrandtii* seedlings were also conducted in Tembe Elephant Park on and adjacent to, a wide sand road that had been within a mature stand of sand forest dominated by *N. hildebrandtii* and *C. schlecteri* (Gowanini Loop road at the site of 'Kwa-H'; see Figure 2 in Chapter 1). This section of forest was deemed to be equivalent to the forest at Site 3 in terms of species composition, size-classes of trees and the presence of the tourist sand road.

❖ *Faecal survey*

Surveys of faecal distribution patterns may serve as an indicator of the abundances and home ranges of browsers (Koster & Hart 1984; McClanahan 1986; Plumtree & Harris 1995). In my study, information on antelope scat densities was collected as an indicator of the presence and relative abundance of small ungulates at Site 1 and Site 2. The purpose of the survey was to determine whether densities of browsers differed between sites as they may have implications for recruitment success of certain species. Data were collected along eight parallel north-south orientated transects (120 m x 3 m) positioned 30 m apart, in forest patches within Site 1 and Site 2. Each pile of faecal pellets was recorded as a single data point. The species of the animal responsible for the droppings was identified using guidelines in Smithers (1983). This method served as an indicator of browsing pressure with the assumption that high densities of dropping piles indicated frequent visitation of browsers to sand forest patches.

▪ Analysis

Question 1: Floristics

❖ *Classification and ordination of communities*

Species composition of sand forest at Sites 1 and 2 was compared by classification and ordination of the plot data set. A polythetic divisive classification was carried out using TWINSpan (Hill 1979a), which separates plots on the basis of total species composition (Kent & Koker 1992). Number of stems was used as importance values for the input matrix. For the TWINSpan algorithm, all options were set at default, and pseudospecies cut levels were set at 0, 5, 10 and 40.

For gradient analysis purposes, the data set used in the TWINSpan classification was ordinated with the detrended correspondence analysis (DCA) subroutine of the programme DECORANA (Hill 1979b). Presence of species per plot was used as importance values in the analysis. TWINSpan community groupings were then superimposed on the scatter plot.

Initial classification and ordination of the data set showed no clear community groupings (Figure 1). It was felt that the presence of relatively high numbers of sub-canopy species was obscuring the effect of canopy species, which were fewer in number. For this reason, each plot was separated into two subplots: one that contained stems ≥ 30 cm height – 9.99 cm dbh and one that contained stems of dbh ≥ 10 cm. The classification and ordination was then reanalysed using these subplots.

In order to find which species dominated at the various sites in terms of stem diameter, total dbh was calculated for each species in canopy subplots (i.e. subplots containing stems with dbh ≥ 10 cm) at the three sites.

❖ *Species richness*

In order to see whether harvested sand forest (Site 2) differed in species richness to that of protected forest (Site 1), the number of species and the number of stems per plot was compared between Sites 1 and 2 using a Mann-Whitney *U*-test. As species richness could be influenced by number of stems per plot (Sheil *et al.* 1999) the

number of species per plot was regressed against the number of stems per plot, to determine whether a relationship existed.

❖ **Plant vital attributes**

Question 2: Grain

Two methods were used to investigate grain:

❖ ***Multivariate analysis***

Each plot sampled at Site 1 was separated into a canopy subplot (trees ≥ 10 cm dbh) and a sub-canopy subplot (stems ≥ 30 cm in height trees to dbh < 10 cm) as in the TWINSpan analysis above. Only potential canopy species were used in the analysis and those deemed to be strictly sub-canopy species were discarded. Only plot data from Site 1 were used in the analysis in order to avoid the possible confounding effects of the different disturbance regime at Site 2.

The data set used was ordinated using the detrended correspondence analysis (DCA) subroutine of the programme DECORANA (Hill 1979b). Presence of species per plot was used as importance values in the analysis.

The centroid for all canopy plots was calculated and the distance between this value and the centroid value for all sub-canopy plots was determined. The scale of variation between plots should be larger in a coarse-grained than in a fine-grained forest. Thus, a large distance would indicate that canopy and sub-canopy plots were very different to each other and would imply a 'coarse-grained' forest. If the scale of variation was small, there would only be a short distance between centroids and the forest would be considered 'fine-grained'. Values defining coarse and fine grain were compared to those found by Everard *et al.* (1994) for a range of KwaZulu-Natal forests.

❖ ***Analysis of size-class distribution curves***

The second, less direct approach to assess grain, was an analysis of the size-class distribution curves of the common species of sand forest plots. Size-class

distributions of species may provide insights into the dynamic strategy of a species within the forest type. If a similar size-class pattern predominated amongst canopy species within a particular forest, it may indicate that they have a similar reproductive strategy which would dictate forest grain. For instance, in a fine-grained forest, one would expect to find that most canopy species have a size-class distribution that would fit a negative exponential function (inverse J-shaped curve), i.e. there should be a preponderance of small size-classes relative to larger ones (Everard *et al.* 1994). Species displaying this size structure may possibly be shade tolerant climax species. In more coarse-grained forests, size-class distributions of various species would differ according to their position on the hierarchy of competition for light (degree of shade tolerance). Species with proportionally low numbers of seedlings may be shade-intolerant pioneers i.e. species dependent on a degree of disturbance for regeneration (van Wyk *et al.* 1996). Light-demanding species which will only survive in gaps, may have a total absence of smaller size-classes in forest which has had a long absence of disturbance. Shade-intolerant species with lower light requirements may display flatter curves indicating higher recruitment success than the previous species.

Size-class distributions could also provide an indication of disturbance regime. Shade-intolerant species would be expected to display higher levels of recruitment within a disturbed environment due to greater light availability. Shade-tolerant species on the other hand, would be competitively advantaged in lower light conditions and thus may have lower recruitment success in large gaps which are dominated by shade-intolerant pioneers. These differences would be reflected in size-class distribution curves between disturbed and protected sites.

Thus in order to assess size-class distributions as indicators of grain in terms of shade-tolerance and relative disturbance between sites, a number of analyses were carried out using size-class distributions of 13 common canopy and sub-canopy species obtained from plot and transect data at all sites. Sizes were classed as follows: 1. 30–199 cm in height; 2. 200 cm in height – 9.99 cm dbh; 3. 10-19.99 cm dbh; 4. 20-29.99; 5. 30-39.99; 6. 40-49.99; 7 50-59.99; 8. 60-69.99; 9. 70+ cm dbh. Histograms based on these classes were produced for each species. This provided the basis for the development of the shapes (outlined below).

Size-class data for each species were reduced into two broad categories, namely 'small' (stems < 10 cm dbh) and 'large' (stems $\geq$ 10 cm dbh). In order to assess whether these patterns differed between the protected forest at Site 1 and the

disturbed forest (Sites 2 and 3), small and large ratios for each species was compared between Site 1 and Site 2 for each of these species using a chi-squared test. For *C. schlecteri* and *N. hildebrandtii* size-class information for Sites 2 and 3 were combined and compared with that of Site 1 using the same test.

The size-class distribution curves that were obtained from the histograms developed were then categorised into four main shapes (Figure 2) using a visual assessment and the ratios of large to small size-classes. This provided a means for an analysis of the shade-tolerance of each species and also provided a means of comparing curves between sites.

Type 1 and 2 curves had proportionally more smaller individuals in the size-classes (i.e. those between 30 cm height and > 10 cm dbh) than larger classes (those of $\text{dbh} \geq 10$ cm).

Type 1 curves have an inverse-J shape but have few larger size-classes: in a) curves, large size-classes (≥ 10 cm dbh) are completely absent and thus a ratio cannot be calculated; b) curves are similar to a) except a few large size-classes (≥ 10 cm dbh) are present although generally only in size-classes 3-4. Thus ratios of small : large trees are high ($\geq 4.0 : 1$). I interpret Type 1 curves to represent individuals which are either inherently smaller in size- and thus are naturally restricted to the sub-canopy, or if they are canopy species, they are likely to be pioneers. Alternatively, larger size-classes could be absent if they were specifically targeted by harvesters.

Type 2 c) curves are those which still have more small than large individuals (i.e. ratios > 1) but the balance is almost equal (1.0 – 3.99). Curve c) has a fairly even spread of the first few size-classes with an absence of the more mature classes. This may represent species with a fairly even spread of size-classes (i.e. a shade-intolerant species with low light requirements). Absence of large sizes may indicate that it is inherently a small tree that will not attain canopy status.

Type 3 and 4 curves represented species that had proportionally more large size-classes than smaller (i.e. ratios < 1). Type 3 curves represented those species that had a far greater disparity between small and large classes than did Type 4 species and therefore had ratios close or equal to zero (0 – 0.2).

Type 3 d) curves represent species with the complete absence of smaller size-classes (ratios of 0 – 0.09), while e) shows species with a few small size-classes (ratios of 0.10 – 0.30). These curves may represent species in an environment which is not conducive to successful establishment of seedlings. These species could be

shade-intolerant pioneers which recruited into a large disturbed area. Reduction of light levels subsequent to establishment has inhibited further recruitment.

Small size-classes of Type 4 species have small : large ratios ratio $\geq 0.31 - 0.99$. Smaller ratios indicate a greater difference between the smaller and larger size-classes. This may either be because certain species grow to very large sizes and thus have individuals in more larger size-classes than other species, or that they have relatively large numbers of small size-classes. This confounds the ability to connect ratios to curve shape and thus in this case, species in Type 4 were divided visually between curves f) and g).

Curve f) represents species with a large number of individuals in smaller size-class, but other classes are well represented. Curve g) is a bell-shaped curve with most individuals occurring in the central size-classes.

Absences of individuals in central size-classes could either indicate inadequate recruitment conditions in the past or active removal of those particular classes.

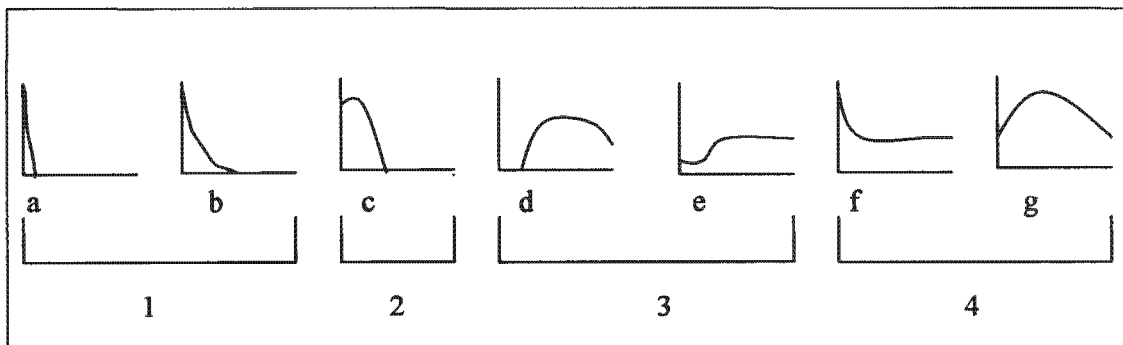


Figure 2 Variations on 4 types of size-class distributions. (1). Inverse J-shaped (curves a and b); (2). The first few size-classes are even in number and then a sudden reduction in larger classes occurs (curve c) (3). No small size-classes present (curve d) or a few size-classes (curve e) (4). Flatter curves with small and large size-classes represented fairly equally (curves f and g).

❖ *Comparison of ungulate densities between Sites 1 and 2*

In order to assess the densities of ungulate browsers between Site 1 and Site 2, scat piles obtained from transects were summed for each ungulate species and relative percentages were calculated. As no droppings of ungulate browsers occurred at Site 2, a statistical analysis was not possible.

Results

▪ **Floristics**

❖ **Species richness**

The number of species per plot was significantly ($p = 0.00$) greater at Site 2 than at Site 1 (Mann-Whitney U -test; $U = 123.5$). The average number of species per plot at Site 1 was 19.2 ($SD = 4.6$) and 25.2 ($SD = 6.1$) at Site 2 (Figure 3). The number of stems per plot was also significantly ($p = 0.00$) greater at Site 2 than at Site 1 (Mann-Whitney U -test; $U = 85$). Site 2 had an average of 565 stems per plot ($SD = 266.4$), while Site 1 had an average of 304.8 stems per plot ($SD = 94.8$). Results of the correlation between stem and species numbers per plot (Figure 4a) indicate a low correlation between these two variables ($R = 0.432$) at Site 1, while a higher correlation ($R = 0.397$) existed between the two at Site 2 (Figure 4b).

❖ **Canopy height**

The average height of the canopy for sand forest within plots was low at 10.41 m ($SD = 1.02$).

❖ **Classification of communities**

Three main communities were identified based on the TWINSpan and DECORANA analyses of subplot data; namely one grouping comprising the sub-canopy subplots and two groupings comprising the canopy subplots (Figure 5). As annotations on individual subplots on the DCA diagram (Figure 5) are not easy to see due to strong clustering of plots, a dendrogram was drawn from the TWINSpan analysis to allow individual subplots to be viewed (Figure 5).

The main community separation (TWINSpan division 1; eigenvalue = 0.485) occurred between canopy and sub-canopy subplots and was defined by the presence of the common sub-canopy species *Drypetes arguta* (2) in the sub-canopy subplots (Appendix 1; Figures 5 and 6). Species composition within subplots of this group was very similar. This is evidenced by the narrow distribution range of these subplots

on the first DCA (Figure 5). These subplots were sub-divided into two further groups (eigenvalue 0.144) consisting predominantly of subplots from Site 2 on the one hand and a mixture of Site 1 and 2 subplots on the other (Figure 5). Indicator species for the Site 2 sub-canopy group were *Hymenocardia ulmoides* (3), *Psydrax locuples* (1), *Ochna natalitius* (1), *Tarenna supra-axillaris* subsp. *barbertonensis* (1), *T. littoralis* (1), *Tricalysia junodii* (1), *Strychnos henningsii* (2) and *Haplocoelum gallense* (1).

Canopy sub-plots were divided into two main groups (eigenvalue 0.299) according to the presence of *Cleistanthus schlecteri* (2) and *Cola greenwayi* (1) on the one hand and *Dialium schlecteri* (1), *Erythrophleum lasianthum* (1) and *Hymenocardia ulmoides* (1) on the other. Canopy subplots of both groups were positioned over a larger distance on the DCA ordination trajectory (Figure 5) than were subplots of the sub-canopy group suggesting a greater mix of canopy species within subplots. The *C. schlecteri* grouping was represented almost exclusively by Site 1 plots (Figure 6) while the *D. schlecteri* group had a mixture of both Site 1 and Site 2 plots (Figures 5 and 6).

One exception to the sub-canopy subplot community was EJ17, which was situated just outside this group to the right on the DCA ordination axis and was thus incorporated with the *D. schlecteri* community group (Figure 5). This subplot had 8 stems of *C. schlecteri* and this possibly accounts for its positioning on the axis, as all other species were similar to those found in other sub-canopy subplots.

The dominant species in terms of total dbh at Site 1 were *D. schlecteri* (460 cm), followed by *N. hildebrandtii* (365.5 cm) and *C. schlecteri* (268.6 cm). At Site 2, *D. schlecteri* was also the most dominant species (357.4 cm), followed by *B. maughamii* (241.1 cm) and *E. lasianthum* (176.6 cm). Of the 9 plots sampled at Site 3, *N. hildebrandtii* dominated (211.6 cm), followed by *C. schlecteri* (203.3 cm) and *Albizia forbesii* (110.9 cm; Table 1).

▪ Grain

❖ Ordination length

Results of the TWINSpan classification and DECORANA ordination of potential canopy species only (Appendices 2 and 3), showed that sub-canopy subplots were clearly separated from canopy subplots (Figure 7). Mean distance between the

centroid of sub-canopy subplots and the centroid of canopy subplots was 131.45 ordination units. This distance was greater than that displayed by Dukuduku, a relatively coarse-grained coastal lowlands forest, which was 85.6 ordination units (Everard *et al.* 1994).

❖ *Demographics*

Initial size-class distribution curves based on the nine classes, showed that in the unharvested forest (Site 1), five of the seven canopy species did not display the inverse-J curve typical of shade-tolerant species (Figure 8a). This indicates low recruitment of the main canopy species. *H. ulmoides* and *P. myrtifolia* however, showed high recruitment in smaller size-classes relative to larger classes. Subcanopy species, had higher recruitment success (Figure 8b).

Three of the five canopy species analysed, namely *D. schlecteri*, *E. lasianthum* and *N. hildebrandtii*, showed significant increases in small size classes from the unharvested site to the harvested sites (Table 1). *N. hildebrandtii* had significantly ($p < 0.05$) more small than large classes at Sites 2 than at Site 1 (chi-square). This difference was greater ($p < 0.001$) when Site 3 was included in the comparison. *E. lasianthum* also had significantly ($p < 0.001$) more small than large size classes between Site 1 and Site 2 as did *D. schlecteri* ($p < 0.05$). *B. maughamii* and *C. schlecteri*, however showed no differences in size classes between sites.

Of the sub-canopy species, only *C. mossambicensis* showed differences between the sites. Numbers of large sizes of classes of this species were significantly ($p < 0.001$) less in the communal forest than within the reserve (Site 1 had 109 small 51 large trees; Site 2 had 86 small and 14 large trees). No comparisons were possible for *B. huillensis*, *D. arguta* and *T. bremekampii* as they did not have individuals with 'large' size-classes.

Size-class distributions of the 13 common canopy and sub-canopy species (Figure 8) were assigned to the curve types described above (see Figure 2) according to shape and ratios of small : large size classes (Table 3). Curves of species whose size-class distributions differed significantly between sites in terms of the chi-squared analysis, i.e. those of *N. hildebrandtii*, *C. mossambicensis* and *E. lasianthum* (Table 2) are shown in Figure 9.

Type 1 a) curves were represented by *D. arguta*, *T. bremekampii* and *B. huillensis*. Curves were the same for both Sites 1 and 2. As neither of these species had any individuals in the large size-classes (i.e. ≥ 10 cm dbh), no ratios could be calculated. Type 1 b) curves were displayed by *C. greenwayi*, *D. natalensis*, *H. ulmoides*, *P. myrtifolia* at both sites, while *C. mossambicensis* showed this type of curve only at Site 2. Small : large ratios ranged between 6.14 and 68.67 (Table 3).

A type 2 c) curve was displayed by *C. mossambicensis* at Site 1 with a small/large ratio of 2.14. The difference in curves displayed by *C. mossambicensis* between the 2 sites resulted from the depletion of size-class 3 for individuals of this species at Site 2 (Figure 8; Figure 9).

Type 3 d) curves were displayed by *N. hildebrandtii* (ratio = 0) and *E. lasianthum* (ratio = 0.06) at Site 1. A 3 e) curve was displayed each by *D. schlecteri* (ratio = 0.18) and by *B. maughamii* (ratio = 0.30) at Site 1 and by *N. hildebrandtii* at Site 2 (ratio = 0.11).

B. maughamii and *N. hildebrandtii* showed a Type 4 f) curve at Site 2 at Site 3 respectively. Type 4 g) curves were shown by *C. schlecteri* at all 3 sites and *D. schlecteri* and *E. lasianthum* at Site 2. Ratios ranged between 0.37 (*E. lasianthum*) and 0.66 (*C. schlecteri* at Site 2).

○ *N. hildebrandtii* seedling transects

Total number of *N. hildebrandtii* seedlings for the 500m² area sampled was 358, giving an average density of 0.7 individuals per m² and an average density per transect of 71.6 (*SD* = 64.3). Heights of seedlings were recorded for four of the transects (Figure 10). Results of their size-class distributions (Figure 11) indicated a wide spread of size-classes with 115 seedlings of 5-59 cm in height, 34 of 60-119 cm and 32 of 120 – 299 cm in height. No seedlings were found at the equivalent section of forest at Kwa-H within TEP.

▪ Ungulate browsing densities

The droppings of three antelope species were identified along transects at Site 1 (Figure 12). Average density (piles/m²) per transect was 0.04 (*SD* = 0.02). Only one dropping pile (vervet monkey) was found along the equivalent transects at Site 2.

Discussion

The low average height of sand forest (± 10 m) is similar to that of other coastal forests in KwaZulu-Natal and those elsewhere in South Africa, which are generally shorter on average than the Afromontane group (e.g. data in Kruger *et al.* 1997). This height also falls within the parameters of dry deciduous forests, which occur in other parts of Africa (e.g. West Africa; Swaine 1992).

▪ Community classification

No strongly defined groupings of canopy species occurred in sand forest within the study sites. This indicates a high mixing of canopy species which may result from the homogenous environment. The community dominated by *D. schlecteri* was the most commonly observed community type and was represented by plots of both sites (Figures 5 and 6). No clear separation occurred between Site 1 and Site 2 canopy plots of this group which suggests that species composition had not been altered significantly by human disturbance at Site 2. The possible mechanism responsible for the formation of these *D. schlecteri*-dominated sand forest patches, has been outlined in Chapter 2.

The second canopy community observed was dominated by *C. schlecteri* and *D. schlecteri* trees were mainly absent from these plots. Possible mechanisms responsible for the formation of this community will need further investigation, although insights may be gained from the regeneration strategy of *C. schlecteri* which are discussed below.

The clear separation of sub-canopy from canopy subplots (Figure 6) indicates that these two groups comprise a markedly different suite of species. This suggests that canopy species have limited representation in the sub-canopy and thus have presently low recruitment success. Unlike canopy plots, sub-canopy plots displayed a strong similarity to each other in terms of species composition, which indicates that the effects of harvesting at Site 2 had not altered the general floristics of the sand forest sub-canopy. The dominance of evergreen species in the sub-canopy layer and the presence of deciduous species in canopy plots (Appendix 2), is in keeping with the pattern displayed in other dry tropical forests which have a 'deciduous canopy layer

and an evergreen understorey' (e.g. forests in West Africa; Swaine 1992). However, the predominance of deciduousness within the forest is unique within the South African context where most forests are dominated by evergreen species (Midgley *et al.* 1997).

Although general floristics of sand forest did not appear to differ strongly between Site 1 and Site 2 plots, the significantly higher number of species per plot at Site 2 may indicate that changes are occurring at a finer scale. An increase in species richness has previously been observed in heavily logged forests (e.g. Bornean tropical rainforest, Cannon *et al.* 1998) and may indicate that the higher disturbance levels are providing opportunities for recruitment of species which would be relatively unsuccessful in undisturbed forest. Differences in species richness should thus be viewed cautiously and the types of species being added to the system as a consequence of increased disturbance would need to be assessed individually. An increase in pioneers could indicate degradation of the forest (Sheil *et al.* 1999). Also the significantly higher numbers of stems at Site 2 than at Site 1 are likely to be an effect of the prolific sprouting following harvesting (see Chapter 4). As a relationship existed between number of stems and species at Site 2 (Figure 4b) which was not apparent at Site 1 (Figure 4a), harvesting pressure could be causing the observed increase in species richness at Site 2 (e.g. Sheil *et al.* 1999).

▪ Grain

The ordination length between canopy and sub-canopy centroids of the multivariate analysis of grain exceeded that of all other coastal forests in KwaZulu-Natal (Everard *et al.* 1994). This indicates that a large difference exists between the species composition of these 2 subplot types relative to other coastal forests. This in turn suggests that sand forest has a coarse-grain and indicates that dominant canopy species display little or no *in situ* regeneration. The strong grouping of sub-canopy subplots in the TWINSpan classification and DCA ordination, may also indicate that canopy species show low recruitment at the level of the forest as a whole and not only at the plot level. This pattern contrasts markedly with typical fine-grain forests such as the Afromontane Knysna forest whose canopy species have an abundance of recruits (Midgley *et al.* 1990).

Analysis of size-class data of the most common canopy species confirmed this analysis as most had very few individuals in smaller size-classes in undisturbed forest (Site 1; Figure 8a). This may indicate that these species are shade-intolerant and thus require higher levels of light for successful establishment than do shade-tolerant species. However, the differences in the size-class curves of these species may also indicate that their light requirements may range along a continuum. This may have implications for their recruitment success under different light regimes.

Three groups, based on size-class distribution curves were identified within canopy species. Species of the first group (namely *E. lasianthum*, *D. schlecteri* and *N. hildebrandtii*) may be the most light-demanding on the continuum. They displayed low or no recruitment at Site 1 (Type 3 curves; Table 3), where light levels are assumed to be relatively low due to an absence of human disturbance. Thus the low densities of seedlings of these species may suggest that large enough gaps are not available at this site to allow for successful recruitment. Additionally, all three species showed significant increases in smaller size-classes at the more disturbed Site 2 and in the case of *N. hildebrandtii*, at Site 3 (Tables 2), where light levels are assumed to be greater. These species have compound leaves (Appendix 2) which suggest relatively high SLA common to more light-demanding species (Midgley *et al.* 1995d) and may thus be pioneer species.

However, unlike *D. schlecteri*, *N. hildebrandtii* was not found invading grassland patches adjacent to sand forest (see Chapter 1). In this study, high densities of *N. hildebrandtii* seedlings were only evident in large cleared open sites within *N. hildebrandtii*-dominated sand forest at Site 3. No recruitment was found in a similar community within the reserve. Also, the wide range of size-classes of the *N. hildebrandtii* seedlings observed along these Site 3 transects (Figure 11) indicates that several cohorts existed at that particular site. Thus recruitment was not a ‘once-off’ event but appears to have occurred over several successive years. Evidence from other dry tropical forests also indicates that recruitment by canopy species was ‘most pronounced in large forest gaps’ (Skoglund 1992). Thus the absence of recruitment of *N. hildebrandtii* in TEP may be the absence of large forest gaps.

The second group of canopy species were deemed to be less light-demanding than were the previous group. This group comprised *B. maughamii* and *C. schlecteri* which displayed more even size-class distribution curves at Site 1 (Table 3). This suggests that they may be tolerant of lower light conditions than are species of the

previous group. Also, they showed no significant increase from the reserve to harvested sites (Table 2), which may confirm that they are not reliant on higher light levels for recruitment success. In the case of *C. schlechteri*, its absence from grassland plots (Chapter 2) suggests that it is restricted to sand forest. It may thus be a secondary successor which recruits into forest once it has been established by pioneer species. Similarly, *B. maughamii* was found to be a secondary successional species in KwaZulu-Natal coastal lowlands forest (van Wyk *et al.* 1996) and it possibly displays a similar behaviour within sand forest.

The third group of canopy species displayed far higher levels of recruitment than did the other canopy species which may suggest that they have the lowest light requirements within the continuum. Both species (*H. ulmoides* and *P. myrtifolia*) are wind-dispersed and are able to invade grassland adjacent to sand forest patches (Chapter 2). In the coastal lowlands forest study (i.e. van Wyk *et al.* 1996), *H. ulmoides* appeared to be strictly a pioneer species with an absence of *in situ* recruitment in the forest. Sand forest may thus have relatively higher light availability than does coastal lowland forest as this species showed high recruitment success within the forest.

Species in sub-canopy plots (e.g. *Drypetes* sp. and *T. bremekampii*) appeared to display characteristics more typical of other forests in South Africa (i.e. fleshy fruits, simple and evergreen leaves). In other forests (e.g. the Dukuduku coastal lowland forest researched by van Wyk *et al.* (1996)), canopy species with these features are thought to be shade-tolerant climax species and thus constitute the third and final successional phase. Canopy species with these features are relatively few in sand forest (Appendix 2) where these characteristics are normally found in sub-canopy species.

▪ Browsing

Results in this study showed an absence of small ungulate browsers at Site 2. It is likely that hunting of these species by local people has caused their eradication from these unprotected areas. The extent to which the browsers present in TEP influence seedling survival will require further investigation. The fact that certain species in this study displayed higher recruitment levels at Site 2 may be argued to be a response to the release from browsing pressure. However, certain factors indicate

that this may not be the case. For instance, it is unlikely that the increase in seedlings of *E. lasianthum* at Site 2 can be ascribed to browsing, as this species has been shown to be unpalatable to antelope (Palgrave 1984). Similarly the increase in recruitment success of *N. hildebrandtii* from Site 2 to Site 3 would eliminate the possibility of a browsing effect. Additionally, species such as *B. maughamii* and *C. schlecteri* showed no enhanced recruitment success at Site 2. Thus, at this stage it appears that recruitment success is more strongly dependent on light-dependency of individual species than on browsing pressure.

Conclusion

This analysis is based on a non-experimental and descriptive synopsis of sand forest dynamics and is thus subject to interpretation. For example, I have documented a general absence of seedlings in protected relative to disturbed areas. My suggestion that disturbance may be necessary would require experimental validation. However, if my predictions are true, these would have management implications for sand forest within TEP, given the apparent coarse grain of this forest. Greater disturbance levels in the form of large gaps may therefore be required to allow regeneration of sand forest canopy species.

Plates: 11 - 13

(overleaf)



Plate 11 Adam West assisting with sampling of a 400m² sand forest plot outside the reserve.



Plate 12 Numerous seedlings of *Newtonia hildebrandtii* which occurred at highly disturbed sites were shown to us by two local craftsmen. The craftsmen are shown here with Jeremy Midgley, each holding a seedling.



Plate 13 Ideal conditions for the establishment of *N. hildebrandtii* seedlings? This recently cleared homestead within the sand forest was one of the sites where numerous *N. hildebrandtii* seedlings occurred. Shown here from left to right, are the owner of the homestead, Nonhlanhla Khumalo and Mark Botha.

Figures: 1; 3 - 12

(overleaf)

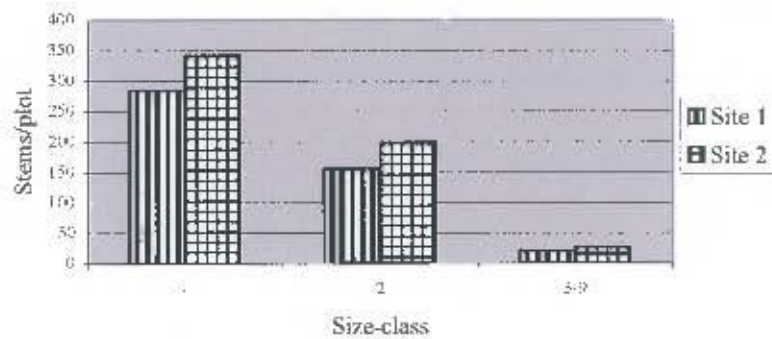


Figure 3 Average number of stems per plot at Site 1 and Site 2. Size-class 1 = 30 - 199 cm height; 2 = 200 cm in height - 9.99 cm dbh; 3-9 = 10-70+ cm dbh.

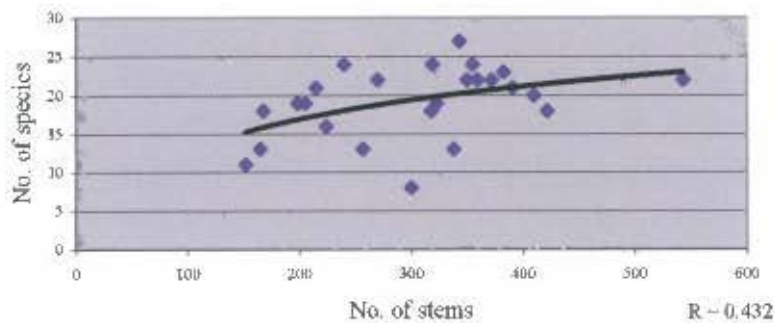


Figure 4a Correlation comparing number of stems per plot with number of species per plot at Site 1. Equation of the trendline: $y = 6.0819\ln(x) - 15.325$.

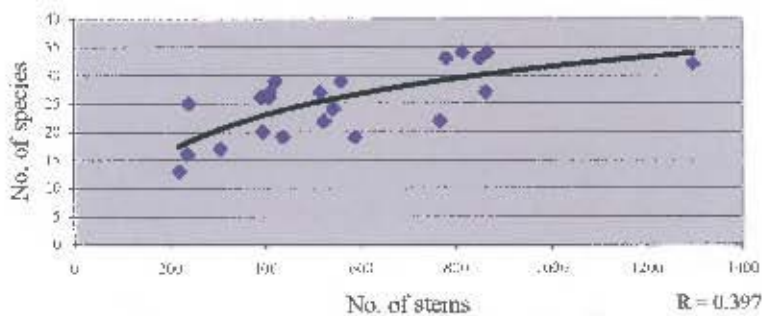


Figure 4b Correlation comparing number of stems per plot with number of species per plot at Site 2. Equation of the trendline: $y = 9.3297\ln(x) - 32.964$.

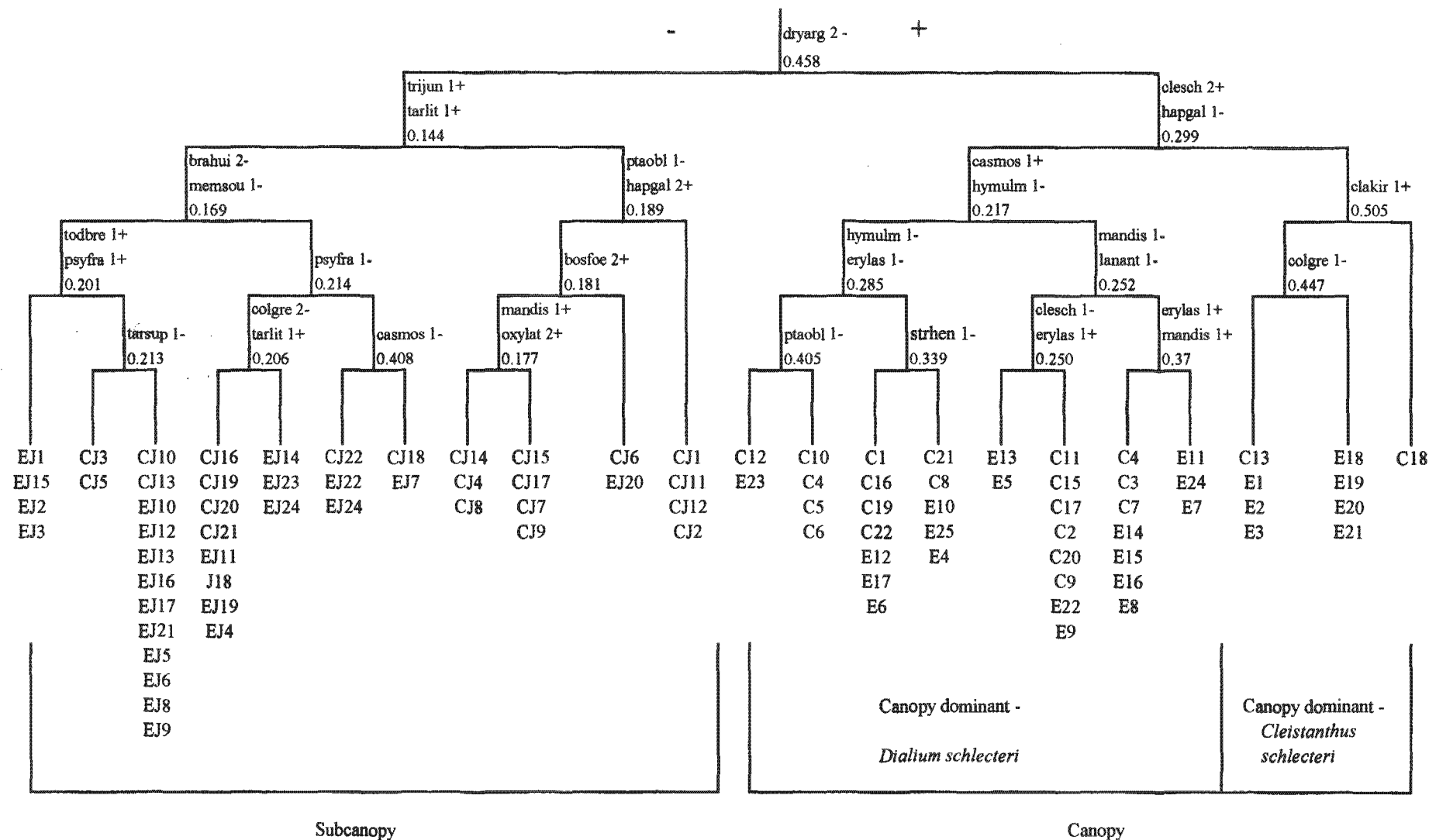


Figure 6 Dendrogram showing the TWINSpan classification to 5 levels of forest plots at Site 1 (C) and Site 2 (E). Canopy subplots (E and C) consist of stems > 10cm dbh, while EJ and CJ sub-plots consist of stems > 30 cm in height - 9.99 cm dbh.

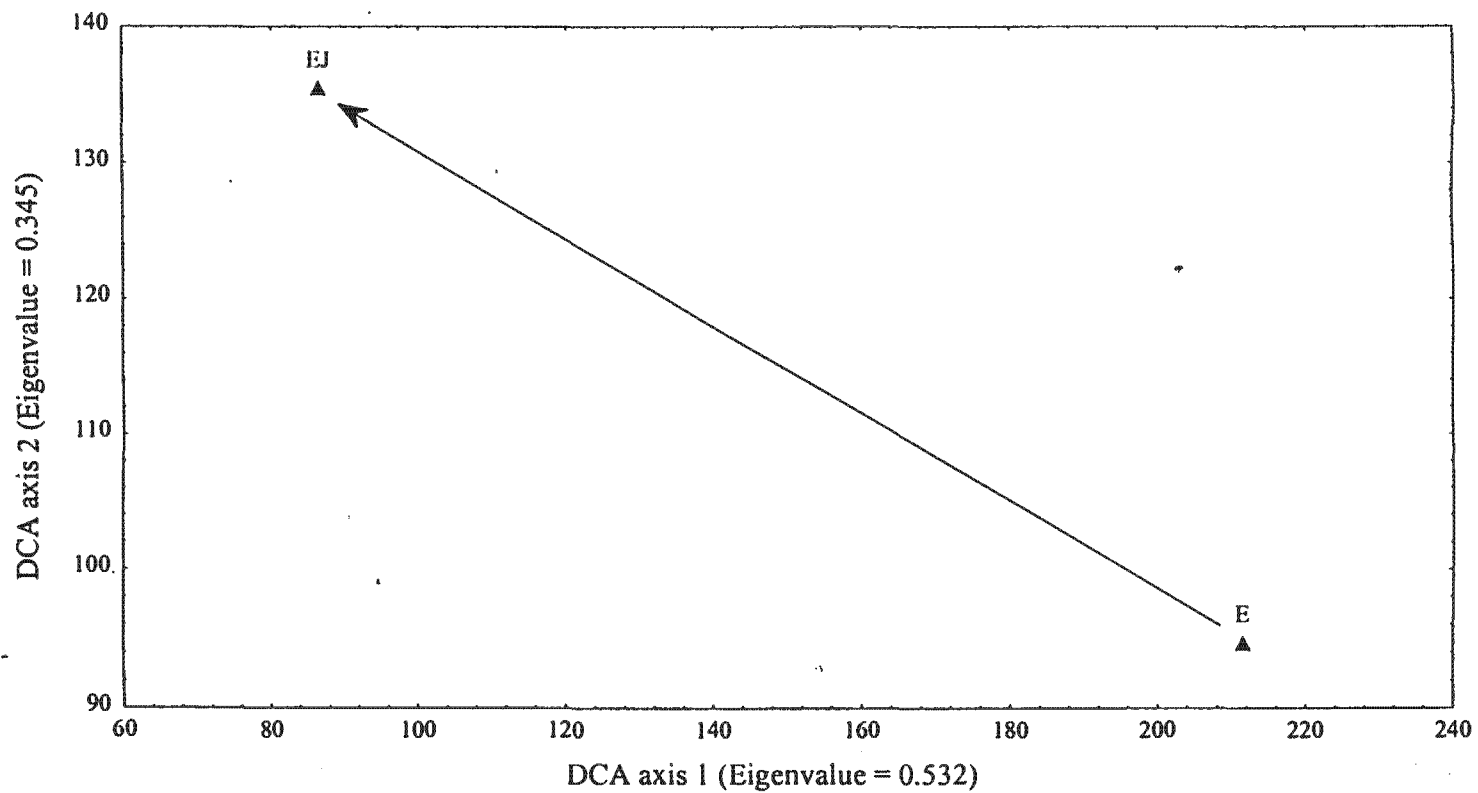


Figure 7 The ordination length between the 'E' and 'EJ' centroids is indicated (see text for methodology). Only potential canopy species were used in the ordination (Appendix 2).

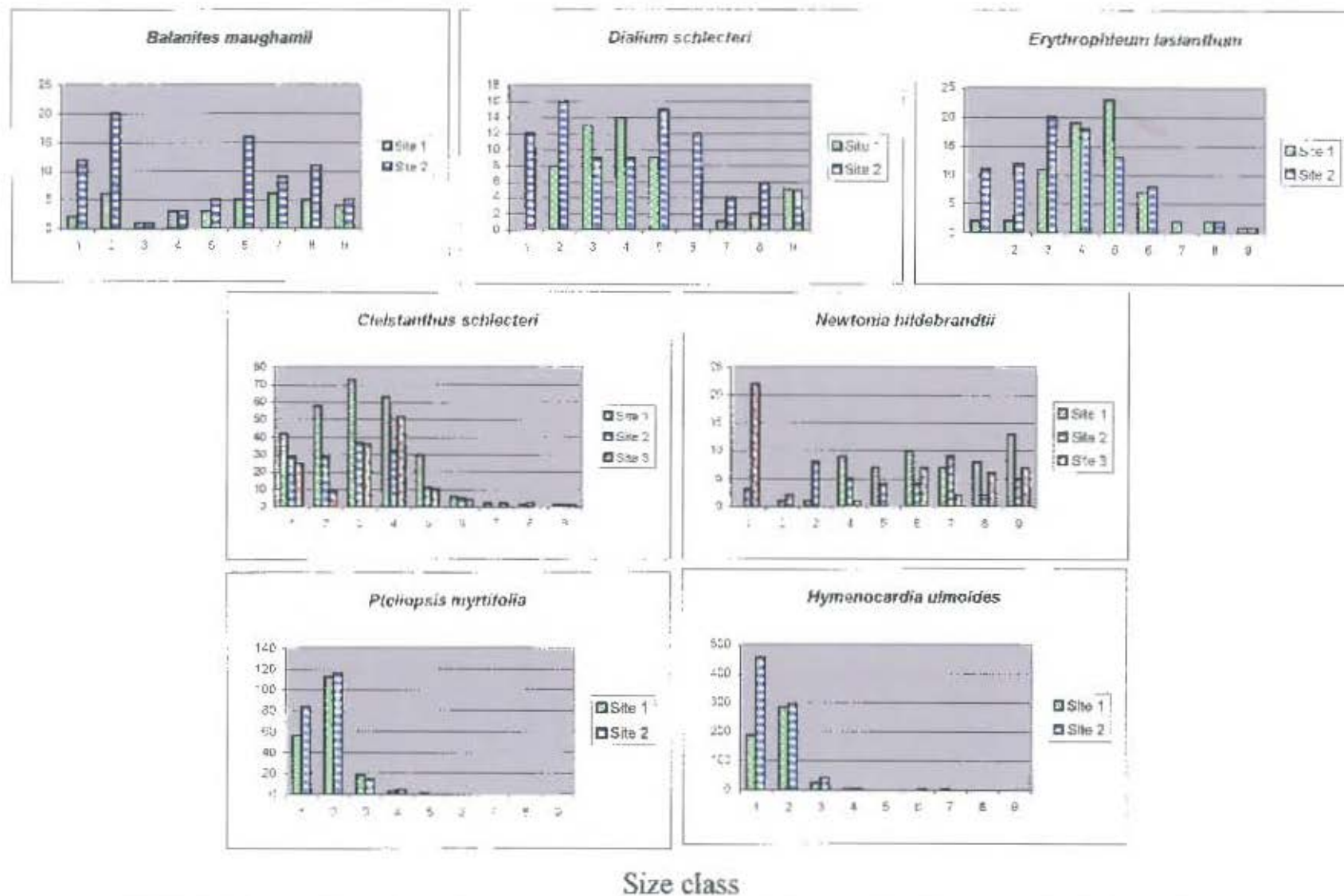


Figure 8a Size class distributions of common sand forest canopy species at Site 1, Site 2 and Site 3. Size classes: 1. 30-199 cm in height; 2. 200 cm in height - 0.99 cm dbh; 3. 10-19.99 cm dbh; 4. 20-29.99cm dbh; 5. 30-39.99 cm dbh; 6. 40-49.99 cm dbh; 7. 50-59.99 cm dbh; 8. 60-69.99 cm; 9. 70+ cm dbh.

Number of individuals

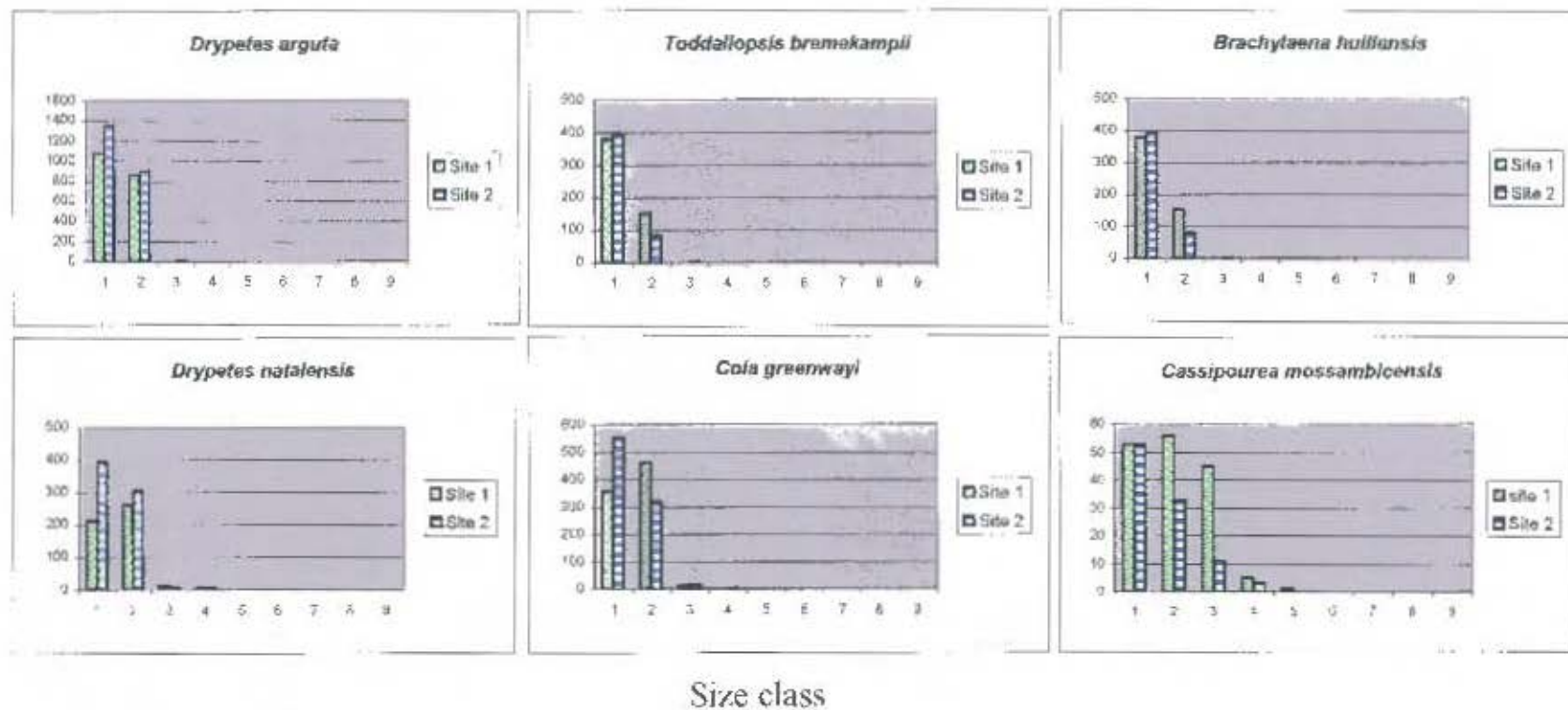
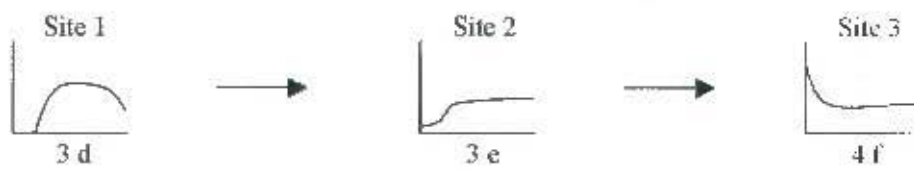


Figure 8b Size-class distributions of sand forest species at Site 1 and Site 2 (See Figure 8a for size class codes).

N. hildebrandtii



C. mossambicensis



E. lasianthum



Figure 9 Size class distributions of *Newtonia hildebrandtii*, *Erythrophloeum lasianthum* and *Cassipourea mossambicensis* showed significant differences between those within the reserve (Site 1) and those within disturbed forest (Sites 2 and 3).

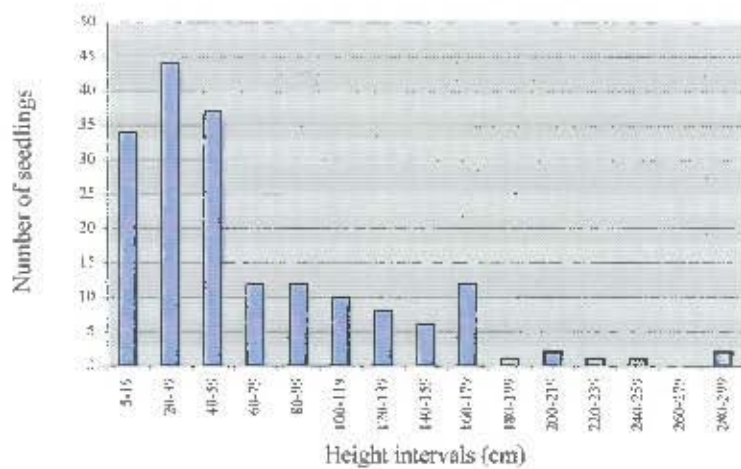


Figure 11 The size-class distribution heights (cm) of 182 *Newtonia hildebrandtii* seedlings found on four of the five seedling transects at Site 3.

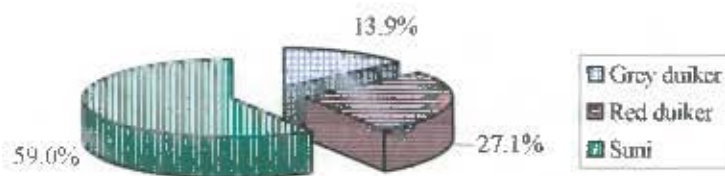


Figure 12 Chart showing percentage occurrence of dropping piles made by grey duiker, red duiker and suni along eight transects at Site 1.

Tables 1 - 3

(overleaf)

Table 1 The relative dominance of species of dbh ≥ 10 cm in 25 plots at Site 1 and 22 at Site 2 is shown from most to least dominant. Dominance in this case is measured in terms of total dbh (cm). Additionally, data from the 9 plots sampled at Site 3 are shown.

Site 1		Site 2		Site 3	
Species	Total dbh	Species	Total dbh	Species	Total dbh
diasch	460.0	diasch	357.4	newhil	211.6
newhil	365.5	balmau	241.1	clesch	203.3
clesch	268.6	erylas	176.6	albfor	110.9
balmau	186.2	hymulm	121.6	ptemyr	88.2
mandis	158.6	eupgra	113.5	lanant	41.7
erylas	157.7	clesch	107.1	eupgra	41.0
hymulm	152.6	psyfra	92.5	colgre	39.6
drynat	148.7	mandis	77.6	wrinat	35.0
psyfra	141.3	bosfoe	75.8	strhen	33.8
ptemyr	126.4	strhen	74.3	crograt	26.4
hapgal	106.6	newhil	72.5	balmau	25.1
dryarg	74.7	colgre	72.0	commku	24.6
eupgra	74.2	drynat	70.6	ptaobl	23.3
bosfoe	71.6	ptemyr	70.3	diasch	20
casmos	62.0	lanant	67.7	mandis	16
ochnat	56.4	afzqua	67.6	dryarg	11
afzqua	50.9	hapgal	66.2	hymulm	11
lanant	47.7	vitamb	58.8	afzqua	0
colgre	47.4	wrinat	57.2	bosfoe	0
ptaobl	41.7	casmos	50.4	brahui	0
strhen	40.6	dryarg	37.3	casmos	0
wrinat	29.7	ptaobl	36.5	clakir	0
commku	29.5	albfor	36.3	commneg	0
vitamb	29.4	dioinh	27.7	dioinh	0
memsou	27.4	tecger	24.2	drynat	0
dioinh	17.2	eucnat	22.0	erylas	0
psyloc	13	veplan	21.0	eucnat	0
albfor	10	memsou	17.0	hapgal	0
commneg	10	tabmon	16.9	memsou	0
brahui	0	brahui	16.2	ochnat	0
clakir	0	strdec	14.7	psyfra	0
eucnat	0	clakir	10	psyloc	0
strdec	0	ochnat	8	strdec	0
tabmon	0	commku	0	tabmon	0
tecger	0	commneg	0	tecger	0
veplan	0	psyloc	0	veplan	0

Table 2 Results of a chi-squared test comparing large (≥ 10 cm dbh) and small (> 30 cm height - 9.99 cm dbh) individuals of 11 dominant species in protected (Site 1) and unprotected forest (Sites 2 and 3).

Sites compared	Species	Chi-square	P	Significance
1 with 2	<i>B. maughamii</i>	0.285	0.09	NS
1 with 2	<i>C. greenwayi</i>	0.17	0.678	NS
1 with 2	<i>C. mossambicensis</i>	10.49	0.0012	$P < 0.05$
1 with 2	<i>C. schlechteri</i>	0.5	0.481	NS
1 with 2 and 3	<i>C. schlechteri</i>	0.97	0.324	NS
1 with 2	<i>D. natalensis</i>	2.6	0.107	NS
1 with 2	<i>D. schlechteri</i>	4.62	0.032	$P < 0.05$
1 with 2	<i>E. lasianthum</i>	11.95	0.0006	$P < 0.001$
1 with 2	<i>H. ulmoides</i>	0.26	0.608	NS
1 with 2	<i>N. hildebrandtii</i>	5.6	0.018	$P < 0.05$
1 with 2 and 3	<i>N. hildebrandtii</i>	21.76	0.0000	$P < 0.001$
1 with 2	<i>P. myrtifolia</i>	1.27	0.260	NS

Table 3 The ratios of small trees (30 cm height - < 10 cm dbh) to large trees (≥ 10 cm dbh) at Sites 1 - 3 indicated with the shape of the relevant curve (see text). Four types of curves are assigned. Ratios of small : large trees are as follows: Type 1 ≥ 4.0 ; Type 2 = 1.0 - 3.99; Type 3 = 0 - 0.30; Type 4 = 0.31 - 0.99. Asterisks serve to highlight those species whose shapes changed between the various sites. A dash (-) in the ratio column indicates an absence of individuals in the large tree size class (≥ 10 cm dbh) and thus division was not possible.

Species	Change	Site 1		Site 2		Site 2 + 3	
		small/large	curve	small/large	curve	small/large	curve
dryarg		-	1a	-	1a		
rodbre		-	1a	-	1a		
brahui		-	1a	-	1a		
colgrc		68.67	1b	58.4	1b		
drynat		29.50	1b	53.85	1b		
hymulm		17.48	1b	17.90	1b		
ptemyr		8.84	1b	11.11	1b		
clesch		0.57	4g	0.66	4g	0.48	4g
diasch	*	0.18	3c	0.47	4g		
erylas	*	0.06	3d	0.37	4g		
newhil	*	0	3d	0.11	3c	0.47	4f
casmoc	*	2.14	2c	6.14	1b		
balmau		0.30	3c	0.64	4f		

Appendices: 1 - 2

(overleaf)

Appendix 1a TWINSpan two-way table showing species occurrence and abundance per plot (number of stems) at Site 1 and Site 2. Community groupings are indicated by the numbers below and to the right of the table.

111 114561246646 11256 125556466 45655551 7788342277778999933337788788388392342344482223 6
78918158364162495379232996600128717556345780 06188047134783013403562909556747228939124123564402

[illegible]

Appendix 1b i) Order of species from the TWINSpan classification (see Appendix 1a).

38	ochnat	2	albadi	9	claani	18	dovlon	21	eryema
23	eucdiv	49	tarjun	51	tarsup	14	comneg	36	ocharb
39	oxylat	50	tarlit	55	trijun	56	trilan	27	gremic
42	psyloc	7	canset	30	hypmic	53	todbre	54	tricap
6	brahui	15	croste	26	grecaf	40	physpp	19	dryarg
32	lepdel	37	ochbar	47	surzan	60	zancap	34	memsou
52	tecger	12	colgre	13	commku	20	drynat	29	hymulm
17	dioinh	46	strhen	57	veplan	41	psyfra	43	ptaobl
44	ptemyr	8	casmos	48	tabmon	24	eucnat	25	eupgra
33	mandis	3	albfor	5	bosfoe	28	hapgal	58	vitamb
31	lanant	45	strdec	59	wrinat	1	afzqua	4	balmau
16	diasch	22	erylas	35	newhil	10	clakir	11	clesch

Appendix 1b ii) Order of plots from the TWINSpan classification (see Appendix 1a).

70	EJ1	76	EJ15	81	EJ2	88	EJ3	38	CJ3
40	CJ5	24	CJ10	27	CJ13	71	EJ10	73	EJ12
74	EJ13	77	EJ16	78	EJ17	83	EJ21	90	EJ5
91	EJ6	93	EJ8	94	EJ9	30	CJ16	33	CJ19
35	CJ20	36	CJ21	72	EJ11	79	EJ18	80	EJ19
89	EJ4	75	EJ14	85	EJ23	86	EJ24	37	CJ22
84	EJ22	87	EJ25	32	CJ18	92	EJ7	28	CJ14
39	CJ4	43	CJ8	29	CJ15	31	CJ17	42	CJ7
44	CJ9	41	CJ6	82	EJ20	23	CJ1	25	CJ11
26	CJ12	34	CJ2	4	C12	60	E23	2	C10
17	C4	18	C5	19	C6	1	C1	8	C16
11	C19	15	C22	48	E12	53	E17	66	E6
14	C21	21	C8	46	E10	62	E25	64	E4
49	E13	65	E5	3	C11	7	C15	9	C17
12	C2	13	C20	22	C9	59	E22	69	E9
6	C14	16	C3	20	C7	50	E14	51	E15
52	E16	68	E8	47	E11	61	E24	67	E7
5	C13	45	E1	56	E2	63	E3	54	E18
55	E19	57	E20	58	E21	10	C18		

Appendix 2 Sand forest canopy species (c) used in the DCA analysis measuring ordination distance between canopy and sub-canopy plots. Data were taken from the 25 plots sampled at Site 1. An indication is given as to whether species are deciduous or semi-deciduous (d) or evergreen (e) and whether leaves are simple (sim) or compound (com). Also the type of propagules of each species are indicated as either wind-dispersed (w), fleshy (f), legume (l) or dry (dr).

Species	c	d; e	com; sim	w; f; l; dr	Species continued	c	d; e		w; f; l; dr
<i>Albizia adianthifolia</i>		d	com	l	<i>Lagynius lasiantha</i>		e	sim	f
<i>Albizia forbesii</i>	c	d	com	l	<i>Leptactina delagoensis</i>		e	sim	f
<i>Azelia quanzensis</i>	c	d	com	dr	<i>Manilkara discolor</i>	c	e	sim	f
<i>Balanites maughamii</i>	c	d	com	f	<i>Memecylon sousae</i>		e	sim	f
<i>Boscia foetida</i>	c	e	sim	f	<i>Newtonia hildebrandtii</i>	c	d	com	w
<i>Brachylaena huillensis</i>		e	sim	dr	<i>Ochna arborea</i>		e	sim	f
<i>Canthium setiflorum</i>		e	sim	f	<i>Ochna barbosae</i>		d	sim	f
<i>Cassipourea mossambicensis</i>	c	e	sim	f	<i>Ochna natalitia</i>		e	sim	f
<i>Clausena anisata</i>		e	com	f	<i>Oxyanthus latifolius</i>		e	sim	f
<i>Cladostemon kirkii</i>		e	sim	dr	<i>Pavetta schumanniana</i>		d	sim	f
<i>Cleistanthus schlecteri</i>	c	d	sim	f	<i>Phyllanthus spp.</i>		d	com	f
<i>Cola greenwayi</i>		e	sim	f	<i>Psyrax fragrantissima</i>		e	sim	f
<i>Combretum mkuzense</i>	c	d	sim	w	<i>Psyrax locuples</i>		e	sim	f
<i>Commiphora neglecta</i>	c	d	sim	f	<i>Ptaeroxylon obliquum</i>		d	com	w
<i>Croton steenkampianus</i>		e	sim	dr	<i>Pтелиopsis myrtifolia</i>	c	e	sim	w
<i>Dialium schlecteri</i>	c	d	com	l	<i>Strychnos decussata</i>	c	e	sim	f
<i>Diospyrus inhacaensis</i>	c	e	sim	f	<i>Strychnos heningsii</i>	c	e	sim	f
<i>Dovyalis longispina</i>		e	sim	f	<i>Suregada zanzibariensis</i>		e	sim	f
<i>Drypetes arguta</i>		e	sim	f	<i>Tabernaemontana elegans</i>		e	sim	f
<i>Drypetes natalensis</i>		e	sim	f	<i>Tarenna littoralis</i>		e	sim	f
<i>Erythroxylum emarginatum</i>		e	sim	f	<i>Tarenna supra-axillaris</i>		e	sim	f
<i>Erythrophleum lasianthum</i>	c	e	com	l	<i>Teclea gerradii</i>		e	sim	f
<i>Euclea divinorum</i>		e	sim	f	<i>Toddaliopsis bremekampii</i>		e	sim	f
<i>Euclea natalensis</i>		e	sim	f	<i>Tricalysia capensis</i>		e	sim	f
<i>Euphorbia grandidens</i>	c			f	<i>Tricalysia junodii</i>		e	sim	f
<i>Grewia caffra</i>		d	sim	f	<i>Tricalysia lanceolata</i>		e	sim	f
<i>Grewia microthyrsa</i>		e	sim	f	<i>Vepris lanceolata</i>		e	sim	f
<i>Haplocoelum gallense</i>		e	sim	f	<i>Vitex amboniensis</i>	c	e	sim	f
<i>Hymenocardia ulmoides</i>	c	e	sim	w	<i>Wrightia natalensis</i>	c	d	sim	w
<i>Hyperacanthus microphyllus</i>		e	sim	f	<i>Zanthoxylon capense</i>		d	com	f
<i>Lannea antiscorbutica</i>	c	d	com	f					

Chapter 4

An investigation of human utilisation of sand forest around Tembe Elephant Park, northern KwaZulu-Natal

Abstract

In northern Maputaland, sand forest products are harvested by local Tembe-Thonga people for a range of domestic uses and increasingly, as a source of income. The study aimed to describe four types of human utilisation of sand forest and to document the response of sand forest species to this damage. Use types were: (1) harvesting of plants for the medicinal trade, (2) harvesting and sale of crafts, (3) sale of fuelwood, and (4) harvesting of laths and poles for hut construction. Several techniques were employed to investigate these use types and included market surveys, interviews and ecological surveys. The findings for each are as follows:

(1) Medicinal trade: Six study species were chosen due to their popularity in the medicinal trade: *Erythrophleum lasianthum* (Caesalpiniaceae), *Balanites maughamii* (Balanitaceae), *Cassipourea mossambicensis* (Rhizophoraceae), *Acridocarpus natalitius linearifolius* (Malpighiaceae), *Schlecterina mitostemmatoides* (Passifloraceae) and *Synaptolepis kirkii* (Thymelaeaceae). Surveys of the former three species in sand forest adjacent to Tembe Elephant Park showed heavy bark utilisation. Bark-use of *B. maughamii* appears to be sustainable as low mortality of harvested trees resulted. Use of *C. mossambicensis* for bark is thought to be unsustainable as high mortalities occurred and resprouting was limited. Although *E. lasianthum* generally resprouted in response to bark-removal, mortalities occurred which indicates that harvesting at current levels may not be viable. No significant difference occurred between densities per plot of *A. natalitius* and *S. kirkii* at the harvested site and the site within TEP, although densities per plot of *S. mitostemmatoides* were significantly higher in the harvested site. A possible explanation could be that a higher availability of light at the disturbed site could favour the recruitment success of this species.

(2) Crafts: Bowls were the main craft sold and provided crafters with an average of about R713.00 per person per month. Most crafts sold were made of *C.*

schlecteri wood. Damage assessment surveys of *C. schlecteri* trees indicated that they commonly resprouted. Results of a matrix model predicting structure of the harvested *C. schlecteri* population sampled, showed it to be dominated by short coppicing trees and young saplings after a 25 year period, if harvesting rates were assumed to be constant. Thus, the craft industry appears to be unsustainable for *C. schlecteri* trees.

(3) Fuelwood sales: Deadwood of *N. hildebrandtii* was the most commonly sold fuelwood type. Sellers only generated an average income of about R25.00 per person per month due to slow turnover rates of bundles. Only 4.4 % of *N. hildebrandtii* trees sampled had died as a result of harvesting. Additionally availability of deadwood below *N. hildebrandtii* trees at the harvested site was similar to levels within the unharvested forest (TEP). This evidence suggests that the sale of fuelwood was sustainable at levels of use present at the time of the study.

(4) Hut building: *Drypetes* sp. were the main species used as laths, while *Hymenocardia ulmoides* was favoured for poles. An average of 19.3 laths and poles were cut per plot. All species harvested resprouted following the removal of one or more stems. Also the significantly higher number of stems per plot at the harvested site (Chapter 3) may be a response to harvesting. This indicates that this resource is sustainable at the harvesting rates which occurred at the time of the study.

Sand forest appears to be similar to other 'coarse grained' forests in KwaZulu-Natal, in that its canopy dominants produce very few seedlings *in situ* (Chapter 3). This may suggest that its primary regenerative strategy is resprouting, as plant resources are being channelled into vegetative reproduction rather than into reseedling. They may be capable of surviving intense harvesting by coppicing following damage.

Keywords: crafts, fuelwood, hut construction, laths, Maputaland, medicinal trade, persistence, poles, sand forest, seeder, sprouter.

Introduction

In northern Maputaland, local Tembe-Thonga people living in and around sand forest, use indigenous species for various purposes such as poles and laths for hut and fence construction, traditional medicines and fuelwood (Cunningham 1989). A rapid increase in population densities of these inhabitants over recent years (Matthews *et al.* 1999) coupled with the commercialisation of certain sand forest species (Cunningham & Davis 1997) has been a cause for concern given the limited distribution of this forest type in South Africa (Kirkwood & Midgley 1999). The sale of certain sand forest species that are limited in distribution to Maputaland is taking place at large scales in the medicinal trade (Cunningham & Davis 1997). Since 1995, local craft and fuelwood markets have 'sprung up' along the main tourist route connecting northern Maputaland's sand forest zone to main urban centres (e.g. Richards Bay, Durban and Johannesburg) and Mozambique (R. Kyle pers. comm.). A strategic plan by national government (the Lebombo Spatial Development Initiative) to develop northern Maputaland for eco-tourism is underway. This is expected to significantly increase the number of tourists to the region and to southern Mozambique.

The shift from subsistence use to commercial sale, results in larger volumes of plants being harvested, and a higher frequency and intensity of harvesting (Cunningham 2001). This can have important implications for resource management of sand forest. For example, if targeted species become locally threatened, a greater responsibility is placed on the success of protected areas to ensure their continued survival. Also, local rural communities can be adversely affected by the reduction in highly valued plants through over-exploitation by commercial gatherers (Cunningham 2001).

For this reason it is crucial to ascertain which species are being targeted and why people harvest them. The availability of targeted plants within an area needs to be known as well as their inherent ability to recover from various levels of harvesting. Additionally, it is important to know what types of utilisation are taking place, how much and the responses of plants to use.

A factor essential to determine human impacts to a forest is the inherent resilience of individual species to harvesting under various types and intensities of

harvesting. A crucial factor is whether species are able to survive damage through resprouting and 'persist' in the landscape, or whether they are unable to resprout and tend to die following damage such as harvesting (Bond & Midgley 2001). Species likely to persist after damage are those that divert resources to developing, maintaining and protecting a bud-bank (Milton 1988; Bond & Midgley 2001). As their main reproductive strategy is to resprout, dependence on seeds for population maintenance generally becomes negligible. Thus these 'sprouters' are generally relatively slow growing as energy is invested into solid structural development and survival (Piñero *et al.* 1982; Kruger *et al.* 1997). On the other hand, poor resprouters are those which channel energy into seed production and maximising vertical growth (Kruger *et al.* 1997). These 'seeders' have a relatively high proportion of seedlings and fewer larger trees.

Kruger *et al.* (1997) suggested that whole forests could be grouped according to whether they were likely to be dominated by seeders or sprouters. They found that tall forests are mainly dominated by seeders which presumably out-competed relatively shorter sprouters in attaining occupancy of small gaps in the forest canopy. Similarly, short forests were dominated by sprouters where harsher conditions and higher levels of disturbance precluded tall reseeded trees.

Thus, given the short stature of sand forest and relatively low number of seedlings produced by dominant canopy species (see Chapter 3), it is likely that most species are geared towards a 'resprouter' strategy. They are expected to persist rather than perish when damaged.

The aims of the study are to provide a description of the human use of key sand forest species within the proximity of Tembe Elephant Park and to note their responses at an individual and a population level. Additionally, the commercial value to rural Tembe-Thonga inhabitants will be investigated.

Although sand forest resources are used for a wide range of purposes (Cunningham 1985), 4 of the main use types are addressed in this study; harvesting of plant parts for sale on the medicinal trade, manufacture and sale of crafts, gathering and sale of fuel wood and construction of huts.

- **An overview of the types of use of sand forest within the context of southern Africa**

❖ *Medicinal trade*

The major driving force behind the commercialisation of sand forest plants deemed to possess medicinal properties, is the rapidly increasing multi-million rand medicinal trade in Southern Africa. Although trade in medicinal plants has possibly been occurring for several centuries there has been an unprecedented increase in commercial exploitation since the 1960s (Cunningham 1988b).

This growth can be ascribed to 3 main factors. Firstly a rapidly growing, rapidly urbanising population of black South Africans to whom traditional medicines are important for medicinal and magical purposes (Cunningham & Davis 1997). The number of people in South Africa has increased eight times from 5.1 million in 1904 (Grobelaar 1985) to approximately 44.7 million in 2000 (as projected by Bulatao *et al.* 1990) with rapid urbanisation of the predominantly rural majority, occurring at a rapid rate particularly over the past 50 years (Hoffman 1997). The demand for traditional medicines is particularly high in urban centres, such as Johannesburg, Durban, Welkom and Vryheid as well as in numerous other smaller cities and towns (Cunningham 1993). In a survey in Soweto, Holdstock (1978) estimated that 80-85 % of inhabitants consult traditional practitioners. This number may be as high as 100 % for people in rural areas (Cunningham & Davis 1997).

The perpetuation of this urgent demand for traditional medicines by South Africans in an urban context where western biomedicine is available, seems incongruous. The explanation lies in the different approaches of western and traditional African medicine to health and disease. Western medicine takes a narrower approach, and treats ailments as biochemical imbalances of the body. Traditional medicine's view is broader, and disease and misfortune are seen as imbalances in the social environment (Ngubane 1977; Cunningham & Davis 1997). The belief is that nothing happens by chance but is subject to influence by other people or ancestral spirits (*amadlozi*; Hammond-Tooke 1989) and that the root cause must be determined and avoided. In overcrowded urban environments, the need for protection and cleansing from 'pollution' through proximity to undesirable people and

courses (Ngubane 1977), is greater than in rural areas. This may account for the fact that of the four major plant preparations sold, three (*imbiza*, *ubulawu* and *ikhubalo*) are used to rid the body of 'pollution' and the fourth (*intelezi*) protects the body or household from this pollution after it has been cleansed (Cunningham 1989; Cunningham & Davis 1997). Colours of plant parts (e.g. roots, flowers or bark) are significant in this context, particularly white (purification) pink or red (consolidation, intensification) and black (protection, cooling, strengthening; Hammond-Tooke 1989; Cunningham & Davis 1997). Thus plants which display these colours are more likely to be targeted than others (e.g. the white lignotuber of *Synaptolepis kirkii* (Thymelaeaceae)), which is used primarily as an emetic (Appendix 1).

A second reason that the need for medicinal plant use is growing with the increasing population in South Africa, is due to the relative abundance and accessibility of traditional healers compared to western doctors. In rural 'homelands' in South Africa, Savage (1985) showed that overall medical doctor to total population ratio was 1: 17 400 in 1976, with ratios as low as 1: 119 000 people in QwaQwa and 1: 30 000 people in Lebowa in 1982. In contrast, traditional practitioner to total population ratios are high. In Swaziland, for example, the ratio was estimated at 1:100 people (Green 1985) and in Venda, between 1: 720 and 1: 1200 people (Arnold & Gulumian 1984). The custom of consulting traditional herbalists (*izinyanga*) and diviners (*izangoma*) is thus being maintained in the cities.

Thirdly, high rates of unemployment and poor education standards are common in many parts of KwaZulu/Natal. Local indigenous plant resources with economic value are therefore sold by gatherers to obtain an income (Cunningham & Davis 1997) and are also cheaper for the consumer than are western medicines.

These insights are crucial to an understanding of the potent driving forces behind the large-scale use and sale of medicinal plants. They provide an understanding of the complexities involved in devising appropriate management strategies to ensure sustainability.

Another factor of concern is that the shift from local towards commercial use of medicinal plants has caused a change from a sustainable method of harvesting by local users to far more destructive practices employed by commercial gatherers. Cultural beliefs and norms of traditional healers have been inherently orientated towards ensuring the long-term harvesting potential of the plant (Mavi 1994). Certain rituals are adhered to when collecting medicines with the belief that failure to do so

will render the collected material ineffective. For example, when collecting bark, healers do not ring-bark trees but take the bark only from one side. Also, they only remove a small proportion of root material, and they do not harvest from a plant previously used by another traditional healer (Mavi 1994). Commercial gatherers, however, do not adhere to any of these practices and tend to remove most or all of the desired plant part.

Little recent data exist on the sand forest species being used or quantities of plant material being harvested or the impacts of these activities on the distribution patterns of sand forest species in northern Maputaland. Whether commercial harvesting techniques are causing death of individuals or a reduction in densities is unknown.

❖ *Craft industry*

The craft industry has placed an additional demand on forest products in northern Maputaland. Road-side craft stalls have been a recent development in this area (Plate 14). The main products sold are wooden bowls which are constructed from sand forest hardwood trees (Plate 15). Evidence from South Africa shows that craft construction in rural communities is usually labour intensive with low financial returns (Cunningham & Davis 1997). However, it provides a source of income to hundreds of thousands of rural families (Cunningham & Davis 1997). The quantities used and the sustainability of this use on sand forest in northern Maputaland has not hitherto been assessed or quantified.

❖ *Fuelwood*

Fuelwood is still used for cooking and warmth by the majority of South Africa's rural population (Eberhard 1990; Shackleton 1994b) and accounts for over half of the domestic energy used in South Africa (Basson 1987). It is estimated that many rural households will continue to be partially or wholly dependent on fuelwood for a further 20 – 30 years (Kotze 1993).

Harvesting of fuelwood by rural people is often species specific (Shackleton 1993a) and deadwood which is more easily accessible, is generally favoured over livewood (Shackleton & Prins 1992; Clarke *et al.* 1996). However, the high localised

demand for deadwood in the immediate vicinity of settlements can frequently not be met and has resulted in rural communities resorting to the more energy-demanding practice of harvesting of livewood (Grundy *et al.* 1993; Shackleton 1994a; Sundriyal *et al.* 1994).

Despite the current electrification drive in South Africa (Shackleton 1994b), few homesteads within the northern Maputaland region have electricity and are thus likely to be using fuelwood as their predominant energy source. In the vicinity of TEP, the sale of fuelwood by local people was initiated approximately 2 years prior to my study (R. Kyle pers. comm.; Plate 16). This creates an added demand on sand forest deadwood over and above its use as a source of domestic fuel. Preliminary investigations have shown that the local people have a preference for certain species of wood (Hanekom & Kyle, unpublished data). However, no data exist on whether deadwood has become scarce to the extent that live trees are being chopped down for sale by wood sellers. Additionally, the availability of deadwood of targeted species has not hitherto been investigated.

❖ *Hut building*

Building styles vary considerably in southern Africa, often reflecting local natural resources, which possibly influence design preferences of different cultures (Cunningham & Davis 1997). This is evidenced on a local scale in northern Maputaland where Tembe-Thonga hut styles range from those constructed predominantly of sand forest poles and laths to those made mainly of *Phragmites* reeds (Cunningham and Gwala 1986).

Along with fuelwood, fencing and building materials account for the highest volume of plant material used annually (Liengme 1983). However, the numbers of laths and poles used in hut construction will vary according to the building style. *Phragmites* reed huts, for example, offset the use of poles and result in lower wood consumption for construction (0.16 to 0.18 t family⁻¹yr⁻¹ in northern Maputaland) than those huts consisting of laths and poles (0.23 t family⁻¹yr⁻¹ in mopane savanna of the Northern Province; Cunningham 1989).

In part, building style determines the destructive potential to the surrounding vegetation. A study in northern Namibia, for example showed that a single homestead including palisade fencing consisted of 7 700 poles and required the

removal of more than 100 m³ of construction wood from the surrounding woodland (Erkiila & Siiskonen 1992). Mean timber volume was estimated at 1.22 m³ for Tsonga huts in mopane savanna in the Northern Province which was substantially lower than that used in Namibian hut construction (Liengme 1983; Cunningham & Davis 1997).

Of the huts in and around sand forest near TEP in northern Maputaland, 56 % of walls were predominantly constructed of interwoven hardwood laths (Plate 17), while 39 % of walls were constructed from *Phragmites* reeds (Cunningham 1985). Five per cent had walls constructed from stones or pieces of branch. The average number of laths per home was high (1400-2000 laths; Cunningham 1985). Poles were used as the support systems for the huts and were 4-9 cm in diameter. Laths were 1.5 - 3 cm in diameter and were woven horizontally and vertically to construct the walls of huts. They were also used to make the framework for the roof, which was subsequently covered in thatch consisting of grass or sedge. Although Cunningham (1985) documented the numbers of sand forest laths and poles and species used for hut construction, no data exists on the response of sand forest species to this damage.

In this study, I asked the following:

1. Which species are being targeted for the medicinal trade, fuelwood sale, crafts and hut building and which size classes?
2. What is the extent of the damage to individual trees as result of the various uses?
3. Are they able to recover from damage by resprouting?
4. Is harvesting sustainable?
5. In the case of fuelwood and craft sales, what is the industry worth to a seller?

The use types investigated are outlined below in more detail and are described within a framework of the broader concerns of Southern Africa to provide a context for the study.

Study site

The 3 study sites described in Chapter 1 were used in this study i.e. Site 1 (exclosure within TEP; no human use), Site 2 (equivalent site south of TEP and adjacent to Site 1; relatively low human use) and Site 3 (12 km west of the reserve; relatively high human use). In addition, the craft stalls and wood sale points which occurred along the 13.3 km section of road between the TEP gate (Sihangwane) and a point 2 km east of the store at Phondweni on the eastern side of the Pongola bridge, were included in the study (see Figure 1 in Chapter 1).

Methods

▪ Medicinal use of plants

Six sand forest species were selected for closer study, as they were suspected to be the main species utilised for sale in the southern African medicinal trade (A. Cunningham, pers. comm.). Additionally, evidence at the study sites outside TEP suggested that these species were specifically targeted by commercial gatherers for the purpose of sale (B. Gwala pers. comm.). Few recent data were available on densities of these particular species outside TEP or the extent of damage to, and response of, utilised individuals. The species chosen were: *Balanites maughamii* (Balanitaceae), *Cassipourea mossambicensis* (Rhizophoraceae), *Erythrophleum lasianthum* (Caesalpiniaceae), all woody trees, *Acridocarpus natalensis linearifolius* (Malpighiaceae), a scandent shrub or climber endemic to northern Maputaland, *Schlechterina mitostemmatoides* (Passifloraceae) and *Synaptolepis kirkii* (Thymelaeaceae), both herbaceous plants (Appendix 1; Plates 18 and 19).

Transects were sampled at Site 2 for *E. lasianthum*, *B. maughamii* and *C. mossambicensis*. *Cleistanthus schlechteri* and *Newtonia hildebrandtii*, common sand forest canopy trees (see Chapter 3), which were not allegedly used in the medicinal trade (B. Gwala pers. comm.), were included in these transects in order to provide a comparison of amounts and types of utilisation of these species to that of the former three. In addition, transects were sampled for these 2 species at Site 3. As most sand forest species are used for medicinal or magical purposes by local people (B. Gwala

pers. comm.), the aim of the comparison was to investigate the degree of commercial as opposed to local use. In terms of bark utilisation for instance, removal of more than 10 % of bark below 2 m in height on the trunk of a tree, may indicate commercial gathering for the medicinal trade, as opposed to < 10 % removal which could show local use (Cunningham 2001). The plot data from Site 2 (see Methods section, Chapter 3) was used to supplement transect data for all 5 species. As *D. schlecteri* was the dominant canopy species in plots at Site 2 (see Chapter 3) and is not allegedly used in the medicinal trade (B. Gwala pers. comm.), it was also included to provide a comparison of its utilisation with that of *E. lasianthum*, *B. maughamii* and *C. mossambicensis*.

The aim of the survey was to ascertain the current status of these species in terms of their size-class distribution, density, amounts and types of human-induced damage, and the responses of each individual to this utilisation. A damage/response assessment was undertaken for each of the above 6 species encountered (see Box 1). The response categories outlined in Box 1 were developed in an attempt to isolate the different responses of the species to the various types and amounts of damage.

Transects were laid 40 m apart in a north-south direction (due to the north-south orientation of the sand forest patches). Transects (T) were 5 m wide and of varying lengths, determined by the length of the sand forest patch (Table 1). Fifteen transects were sampled at Site 2 and were on average 227.3 m in length ($SD = 145.6$), while 4 transects were sampled at Site 3 and were on average 262.9 m in length ($SD = 134.6$; Table 1).

Box 1 Damage / response assessment

Damage to individual trees was noted and recorded as follows:

Bark: Individual trees were classed according to the percentage of bark that had been removed by gatherers. Only human damage was considered and damage by animals such as porcupine and bush pig was not recorded. Casual bark-slashes used by gatherers to confirm a tree identification were ignored. Damage categories indicated below, were those used by Cunningham (2001). An additional class (5) was added:

0 = no removal

1 = 1-10 %; (usually by traditional healers or local use)

2 = 11-25 %; (usually scarce species in high local demand or small-scale, emerging commercial trade)

3 = 26-50 %; (generally from popular, open access species in commercial trade)

4 = 51-75 %; (extensive bark removal; popular species in large-scale commercial trade, easy and open access)

5 = 75-90 %; bark from branches also removed

6 = ring-barked (any percentage); leads to death regardless of amounts

7 = total debarking; all bark removed including bark on branches; trees may be felled

Stem: The number of cut stems or branches was recorded.

Roots: The proportion of roots removed from a tree was estimated according to the methods laid out in Cunningham (2001; pp. 141). Root removal is useful only for recent damage as soil could fill the hole from where the roots were extracted, obscuring evidence of damage.

Responses of individuals were noted and classed as follows:

S = resprouting from the base of the stem, or damaged area

N = no resprouting

These classes were combined with either of the following:

D = >30 % of the individual is dead (based on a visual assessment of both stem and canopy)

H = <30 % of the individual is dead (the tree as a whole is healthy)

DD = the tree is dead

For example, if an individual had resprouted following bark removal, but 40 % of the tree appeared to be dead (including stem and canopy), the class 'SD' was used.

A different method was used to assess the use of *A. natalitius linearifolius*, *S. kirkii* and *S. mitostemmatoides*. As the roots are used in the medicinal trade for all these three species (Appendix 1), it was likely that a gatherer would remove the entire

individual to obtain the root matter in order to make it viable for sale in the medicinal trade (Cunningham 2001). Thus the commercial use of these species would probably lead to their mortality and leave no evidence of the plant behind. For this reason densities of these species were compared inside TEP (Site 1) where no harvesting was allowed, with those outside the reserve (Site 2), where harvesting for the medicinal trade occurred. For the purpose of this study, it was assumed that densities of these three species within Site 1 were optimal as they were not subject to removal by human gatherers. Thus if densities at Site 2 were similar to, or greater than, those which occurred at Site 1, it was assumed that no substantial damage by gatherers had been incurred to the populations of these species.

In order to test this, 21 and 22 circular plots (400m²) were randomly sampled in patches of sand forest at Site 1 and Site 2 respectively. Within each plot, all of the study species encountered were recorded and classified by height as seedlings (5 – 29 cm), understorey (30 – 200 cm) or sub-canopy (200+ cm) shrubs. Average numbers of individuals per plot were calculated and results were compared between Site 1 and Site 2 using a Mann-Whitney *U*-test.

▪ Craft manufacture and sale

The main aim of this investigation was to attempt to predict the impact of the local craft industry on the demographics of sand forest species used. Stalls were situated along a 15.3 km section of road between the TEP gate and the store at Phondweni on the eastern side of the Pongola bridge. Five of the 6 crafts stalls which occurred along this section of road were included in the study. Stall 6 was excluded as it had been initiated only a few weeks prior to the study and was felt not to be representative. A number of approaches were used to investigate resource use. This was because previous studies have shown that the use of a single method to quantify resource use may be misleading as results sometimes differ according to the technique employed (Muir 1990; Shackleton 1993b; Cunningham 2001).

❖ *Phase 1 – Preliminary investigation*

○ *Stall surveys*

A survey was conducted of all merchandise displayed for sale at 5 stalls over a 2 day period in October 1997. The type (e.g. bowl, walking stick etc.), sale price and species used, were recorded for each craft. Wooden bowls were classed either as large (length > 70 cm) or small (length < 70 cm).

○ *Preliminary discussions*

The *induna* (local headman) of the Sihangwane community (opposite the main entrance to TEP) was approached to request a bilingual member of his community to facilitate in interactions with sellers. The woman chosen and her family were well known in the area and this aided in reducing suspicion of sellers. Preliminary discussions were held with crafters in order to aid in the development of a questionnaire.

❖ *Phase 2*

○ *Questionnaires*

A questionnaire was designed based on the information gained from Phase 1 (Appendix 2a). Crafters from 5 stalls within the study area were then interviewed during October and November of 1997. The questionnaire was translated verbally from English into Zulu, for each crafter by the interpreter. Similarly, responses from crafters were translated from Zulu into English and recorded on the questionnaire sheets. Each crafter was interviewed separately to prevent influence from other crafters.

- *Income generated*

Results of the questionnaires and the stall surveys were used to calculate the average number of crafts sold per month and per annum, the average income generated per month and per annum and the number of trees cut of relevant species. Averages were calculated for each crafter, for each stall and for all stalls. As crafters were asked for numbers of bowls that they sold during an average month, it was assumed that these responses make allowance for seasonal fluctuations.

- ❖ *Phase 3*

- *Transect data*

As initial results showed a high preference for *C. schlecteri* in the manufacture of bowls, 4 transects to enumerate this species were sampled at Site 3 where most craft sales were taking place (see methods outlined above). The purpose was to assess the densities, size-class distributions, types and amounts of harvesting of this species and its response to damage.

- *Matrix model to predict size class structure of a population of C. schlecteri trees*

In order to gain quantitative insight into the demographics as a consequence of the utilisation of the *C. schlecteri* population at Site 3 over time, a stage-based population projection matrix was developed. Transect data from Site 3 were used for the model (Desmet *et al.* 1996).

The section of forest sampled, estimated to cover an area of approximately 100 ha., was assumed to be in walking distance of 2 craft stalls and thus used by approximately 13 crafters (Appendix 2b).

A simple matrix, based on the life-history of 138 *C. schlecteri* individuals being divided into 5 stages was used: (1) Mature seedlings and young saplings (30 cm – 200 cm height). (2) Mature, harvestable saplings (> 200 cm height, dbh < 10 cm) and trees of other size classes which had been cut down at the base but had

resprouted. (3) Young trees which had not yet reached reproductive age (10 – 19.99 cm dbh). (4) Mature reproductive trees (20 – 29.99 cm). (5) Mature reproductive trees (> 30 cm dbh).

The approach used was similar to that of Desmet *et al.* (1996), where values are determined for stage specific fecundity (F); for the probability of surviving and remaining in the same stage per time period (R); and for the probability of surviving and growing into the next stage class or any other stage class (G) per time interval (t ; Lefkovitch 1965).

The time interval (t), used for the model was 5 years. This was assumed to be adequate to represent the observed demographics of *C. schlecteri* and it was felt to be short enough to allow for the identification of recently cut and dead *C. schlecteri* trees. Consequently the calculated transition probabilities are expressed as the probability of a transition occurring during that time period. The derived transition matrix was used to show the effects of harvesting over 5 time periods, i.e. a total of 25 years. A constant rate of harvesting was assumed for this time.

The annual growth increment (G) was set at 0.5 cm diameter per year, which was obtained from results of carbon dating of a *C. schlecteri* tree of known size (D. Kirkwood, unpublished data). This growth rate of 2 - 2.5 cm per 5 years means that an individual would take 4-5 cycles to grow through a 10 cm diameter class. Thus the probability of an individual being promoted to the next level (G) was set at 0.2 (G), which was assumed to be constant for all stage classes.

The probability of trees remaining within a particular stage class (R), was calculated by incorporating natural and induced mortality. The probability of trees experiencing natural mortality was that calculated from the observed in the field for each stage class. A dead tree in a particular size class was considered to have died by natural means if no sign of human damage was present. Similarly, cutting-induced mortality probabilities were calculated from the observed for each stage class. Cutting-induced mortalities were considered to be dead trees with stems that had been cut off near the base. No damaged or cut trees were observed from stage class 1 and it was therefore assumed that harvesting only occurred in trees of stage classes 2-5. It is likely that size classes of trees cut for craft manufacture would be 20 cm dbh and greater, while trees harvested for building and fencing material were assumed to include trees of 200 cm in height to 20 cm dbh.

It was assumed that only trees of stage classes 4 and 5 were able to produce seedlings (*F*) which would enter stage class 1. Trees whose stems were chopped off at the base and had resprouted were designated to stage class 2.

- **Wood sale**

- ❖ *Sale point surveys*

A total of 20 wood sale points were found along the same section of road as craft stalls. A survey was conducted at all sale points in order to quantify amounts, species used and price of bundles displayed for sale. For each bundle, a size was allocated based on its price: large (R10.00), medium (R5.00) and small (R2.50). The number of pieces per bundle type averaged ± 80 -120 pieces for large, ± 30 -70 pieces for medium and ± 10 -20 pieces for small bundles (Hanekom & Kyle, unpublished data). Throughout the text, the term 'species pile' is used to define a bundle of fuelwood made up of a particular sand forest species.

- ❖ *Questionnaires*

Interviews were conducted with 18 wood sellers from the various road-side sale points. A questionnaire was used and verbally translated as with the crafters' interviews (Appendix 3a).

- *Quantities of fuelwood sold*

Results of the questionnaire and the wood stall survey were used to calculate number of bundles of the various species sold, and the financial gains for the sales per seller. As wood sellers were asked to estimate an average number of woodpiles sold each month, it was assumed that seasonal fluctuations in sales were taken into account. The purpose of these calculations was to ascertain the financial value of the wood sales for each seller in order to understand the value of this economy to an individual. For ease of reference, the methods used are detailed in the 'Results' section of this chapter.

❖ *Transects for N. hildebrandtii*

As preliminary evidence indicated that *N. hildebrandtii* was overwhelmingly the most common species sold, data from the 15 transects at Site 2 and the 4 transects at Site 3 (see methods above) was included in the investigation. The purpose of the transect data were to provide an indication of the availability of trees of this species, its size class distribution and the number of trees showing evidence of harvesting for fuelwood use.

❖ *Deadwood piles of N. hildebrandtii*

In addition, the amounts of deadwood of *N. hildebrandtii* available for use as fuel within an unharvested area (Site 1) and within an area considered to be harvested (Sites 2 and 3) were investigated. The amount of deadwood found below each *N. hildebrandtii* tree encountered along transects at Sites 1, 2 and 3 (see Methods section Chapter 3) was recorded. The amounts were quantified by estimating the number of large (R10.00) piles that could be made up from all the pieces of deadwood found on the forest floor beneath the canopy. A greater density of deadwood was expected in the reserve where no harvesting took place, than at Sites 2 and 3 where deadwood was removed. In order to compare the amounts between sites, number of woodpiles were converted from proportions to whole units by multiplying them four. Resultant figures were then rounded off to the nearest unit. Numbers were compared using a Mann-Whitney *U*-test.

▪ **Hut-building material**

❖ *Hut surveys*

The aim of the survey was to provide a synopsis of species used for hut construction and their response to harvesting. Previous researchers had documented the species of laths and poles used in hut construction in the study area in 1982 (Cunningham 1985). Thus an assessment of species present in huts in 1997 was undertaken in order to serve as a comparison with this earlier study. Changes in species used could infer changes in species availability.

Eleven huts were surveyed to ascertain the species used as laths and as poles in construction. Three different building styles were included in the survey and were classed as follows: 1 = stones (a framework of interwoven laths and upright poles, with stones filling the gaps), 2 = laths (constructed predominantly of interwoven laths with a framework of poles), and 3 = reed (mainly reed thatch with a framework of poles). One hut of Type 1 was sampled, 5 of Type 2 and 5 of Type 3. For each hut of Types 1 and 2, two walls were sub-sampled. Additionally two piles of poles, which had been collected by local people for use as building material, were found in the forest (Plate 20). Each pole and lath was identified to species level.

❖ *Poles and laths from Site 2*

As no data were available on the mortality and resprouting ability of sand forest species in response to harvesting for hut construction, a survey within the forest was undertaken to ascertain numbers and size classes cut and their responses.

Data from the 22 plots sampled at Site 2 (see Methods section, Chapter 3) were used to determine the number of poles harvested and species targeted in sand forest patches at Site 2. As poles used for housing were found to have a dbh of less than 10 cm, only trees with dbh < 10 cm were used in the investigation. At each 400 m² circular plot, a sub-sample of a quarter of the plot (100 m²) was used. Woody species were recorded in size classes as either understorey (30 – 200 cm height) or sub-canopy (height > 200 cm; dbh < 10 cm). For each individual, the number of stems was recorded and a note was made of whether or not the stem or branch had been cut. The response was classed as follows: 0 = no coppicing; 1 = 1 – 3 sprouts; 2 = 4 + sprouts. For a dead individual, a note was made of whether or not it had been cut and if possible, it was identified to species level.

The average number of stems/ha⁻¹ (30 cm ht to < 10 cm dbh) was compared between Sites 1 and 2 using a chi-squared test. This size class was considered to reflect the sizes and poles targeted for laths and poles. The purpose of the analysis was to test the hypothesis that trees will persist by resprouting following being cut for pole removal by local people (Site 2). This should be evidenced by a greater number of pole-sized stems at Site 2 than at Site 1 where no harvesting occurred.

Results

▪ Medicinal species

All six species sampled at Sites 2 and 3 showed evidence of utilisation (Table 3). Use ranged in intensity and type between species as is detailed below.

❖ *Bark*

B. maughamii, *C. mossambicensis* and *E. lasianthum* showed clear evidence of bark-removal, while *C. schlecteri*, *D. schlecteri* and *N. hildebrandtii* were not targeted by commercial harvesters for bark (Table 4; Box 1). Of the 50 *B. maughamii* trees sampled with dbh > 10 cm, 68 % had evidence of bark removal (Table 5). Half the trees sampled had between 26 and 75 % of their bark removed below 2 m. Of those harvested, 91.2 % did not coppice but trees remained 'healthy' i.e. less than 30 % of each tree was dead (Table 4). Only one incident of total bark removal was recorded for this species and this resulted in mortality.

Of the 100 live *C. mossambicensis* trees sampled (Table 5), 86 were less than 10 cm dbh and of these, only 2.3 % had experienced bark removal (Table 6). The sizes used ranged between 6 cm dbh and 26 cm dbh. Of trees larger than 10 cm dbh, 42.9 % had evidence of bark harvesting (Table 6). Most (81.8 %) *C. mossambicensis* trees found dead (N = 22) had experienced bark removal (Table 6; Plate 21). Sizes used ranged between 5 cm dbh and 29 cm dbh. Of the 26 trees used (both live and dead), only 1 individual had 1-10 % bark removed (Type 1) and only 1 had 11-25 % (Type 2). Otherwise 46.2 % were completely bark-stripped which resulted in death (Table 4). A further 30.8 % had had 75-90 % of their bark removed and of these 62.6 % had died. The balance (37.5 %) showed no evidence of sprouting and more than 30 % of each tree was dead. Only 3 of the 26 harvested trees sprouted and of these, the 2 which were 'healthy' had had less than 50 % bark removed (Table 4).

Of the 42 *E. lasianthum* trees sampled, 59.7 % had evidence of bark-removal (Table 5). Most bark-removal (28 %) was of Type 1 (i.e. 1-10 % removed). Thirteen of the 25 trees debarked resprouted, although 11 of these had more than 30 % of the

tree dead. Twenty-four per cent of the trees available were completely bark-stripped and of these 66.7 % resprouted, while the balance (33.3 %) died (Table 4).

❖ *Other medicinal species*

Results of the Mann-Whitney *U*-test indicated that there was no significant ($p = 0.618$) difference in densities per plot of *A. natalitius linearifolius* ($U = 210.5$) between the two sites, or of *S. kirkii* ($p = 0.2$; $U = 167$). However, a significant ($p = 0.0001$) difference occurred between sites of densities per plot of *S. mitostemmatoides* which was poorly represented at Site 1 (Figure 1).

▪ *Crafts*

Of the 15 crafters interviewed at 5 stalls, all were men (Appendix 2b; Plate 22). All crafters mentioned *C. schlecteri* as their first choice when asked to name the species they most commonly used and all named *A. forbesii* as their second choice. Of the species considered third choice, 53.3 % named *Spirostachys africana*, 6.7 % named *Albizia petersiana*, 6.7 % named *Brachylaena huillensis*, while 53.3 % had no suggestions. *B. huillensis* and *Brachylaena zeyheri* were each mentioned by 6.7 % of respondents as species they would use as a fourth choice, while 86.7 % had no suggestions. All said that there were many seedlings of *C. schlecteri* available in the forest.

The average time taken to find *C. schlecteri* was 45 min ($SD = 33.9$). All crafters said they chopped the entire tree down at the base and 86.7 % of crafters used a chainsaw. Only 1 crafter sold his goods at other markets. All crafters said that crafts were bought both by tourists and by local community members Appendix 2b).

The stall survey found that bowls accounted for 84.4 % of crafts (Table 7). Bowls made of *C. schlecteri* were the most common on display (80 % of available), followed by *A. forbesii* (5.5 % of available; Table 8).

❖ *Commercial value of crafts to sellers and numbers of crafts sold*

○ *Step 1: Average price per bowl.*

The average price for a small bowl (< 70 cm in length) was calculated as the total value of all small bowls (R3 306.00) displayed at the 5 stalls sampled divided by the total number of small bowls (57). Similarly the average price for a big bowl (> 70 cm in length) was calculated as the total value of all big bowls (R565.00) displayed at the 5 stalls divided by the total number of big bowls (4). Average price of the 'Other' crafts was calculated in a similar way, where total value was R338.00 and total number was 18. The average price for small bowls was R58.00 ($SD = 18.57$; min = 15; max = 110; $N = 57$) and R141.25 for large bowls ($SD = 20.16$; min = 120; max = 165; $N = 4$). Crafts other than bowls were relatively few in number (15.6 % of all crafts; Table 7), had a low average price (R18.89; $SD = 14.5$; min = 5; max = 55) and were made from small branches rather than whole trees (Appendix 2b), and thus were not considered in the following calculations.

○ *Step 2: Proportion of constituent species.*

In order to calculate the relative proportion of the various species used for bowls, the number of each craft type sold at the various stalls was added and the number of large bowls was doubled to convert them to small bowl units. The relative proportions of all constituent species were then calculated (Table 8). Bowls of species other than *C. schlechteri* (92 %) and *A. forbesii* (6 %), were pooled into group 'Other' (2 %).

○ *Step 3. Number of bowls sold per person*

In order to ascertain the average income generated per person, a sale rate of 5.4 small bowls/crafter/month and 2.8 large bowls/crafter/month was used based on results of the interviews (Appendix 2b)

The proportions of constituent species per 5.4 small bowls were ascertained from the previously calculated ratios (Step 1) and these were multiplied by the average price of small bowls (R58.00). This gave an average income per crafter for

the sale of 5.4 small and 2.8 large bowls (Table 10) which was calculated per month and per annum. To obtain an average income per stall, these totals were multiplied by the average number of sellers who sold their goods from the same stall (1.63; $SD = 1.42$; (Appendix 2b). According to these calculations, an average of 5.4 small bowls and 2.8 large bowls were sold per person per month (Table 10). As these had an average value of R313.20 and R399.74 each respectively, the income generated was approximately R713 per person per month and R8555 per person per annum (Table 10).

- Step 4: Number of trees chopped down.

To determine the number of trees of *C. schlecteri* felled, the average number of trees chopped down per week (1.97; $SD = 1.42$; Appendix 2b) was multiplied by four to obtain an average number of trees of each species chopped down per month (7.9; Table 11). The proportions of the various species available (Step 1) were calculated as proportions of this total per month. Thus, of the 7.9 trees felled per person per month, 7.2 of these would be *C. schlecteri* trees (Table 11). Thus an average of 44.4 *C. schlecteri* trees would be felled per stall per month, given that an average of 6.1 are sold per stall (Appendix 2b).

- Step 5: The value of a tree in bowl units

An estimate of the average monetary value of one tree to a crafter was calculated using bowl units. If an average of 8.8 small bowls can be made from one tree of approximately 30 cm dbh (Appendix 2b), and a small bowl has an average price of R58.00, then a tree used for the manufacture of small bowls is worth R510.40. Similarly, the average number of big bowls which can be made from one tree is 5.4 (Appendix 2b), and with an average price of R141.25, the average value of the tree is R762.75. If *C. schlecteri* trees alone are considered, in terms of small bowl units, one *C. schlecteri* tree would have an average value of R469.57 (calculated as 92 % of the total tree value of R510.40). In terms of big bowl units, one tree would be valued at R701.73 (calculated as 92 % of the average value of one tree of R762.72).

o Step 6: Potential income versus actual income per person per month

Considering only small bowls, if each crafter fells an average of 7.9 trees per month, he can potentially make an average of 69.5 small bowls per month (calculated as 8.8 small bowls per tree x 7.9 trees). If he managed to sell all of these bowls each month, he would make an average of R4032.16 (calculated as the product of 69.52 bowls and the average price of one bowl of R58.00). However, average monthly income per crafter for the sale of small bowls was only R313.20 (Table 10).

❖ *Matrix model*

The calculated probabilities for the transition matrix are presented in (a) of Table 2 (see text for details of stage classes 1-5) with the corresponding symbols shown in (b). The population vector, as based on the observed size class distribution, is presented in (c).

Table 2 (a) The derived transition matrix for *C. schlechteri*. (b) The matrix cell reference labels for the transition matrix. (c) The observed stage distribution of the sampled population of *C. schlechteri*.

		1	2	3	4	5
(a)	1	0.8	0	0	0.5	0.5
	2	0.2	0.8	0.15	0.1	0.18
	3	0	0.2	0.45	0	0
	4	0	0	0.2	0.62	0
	5	0	0	0	0.2	0.5
(b)	1	R1	0	0	F4	F5
	2	G1	R2	F3	F4	F5
	3	0	G2	R3	0	0
	4	0	0	G3	R4	0
	5	0	0	0	G3	R4
(c)		Trees per class				
	1	25				
	2	22				
	3	26				
	4	46				
	5	11				

Numbers of live *C. schlechteri* trees counted in Transects 1-4 were 25, 64, 21 and 28 respectively. Of the size classes available for cutting (Stages 2-5), 26 trees were

cut down near the base (23.0 % of available) and of these, 69.2 % were vigorously resprouting from the old stem (Plate 23), while 30.8 % had died.

The population growth rate (λ) was fairly constant for each time period ($t_{1-2} = 1.06$; $t_{2-3} = 1.09$; $t_{3-4} = 0.98$; $t_{4-5} = 1.05$). Stage class 1 initially increased but levelled off between T_4 and T_5 (Figure 2). There was a general increase in numbers of trees of stage class 2 over the 25 years, while numbers of mature reproductive *C. schlecteri* trees (stage classes 3-5) declined.

▪ Wood sales

❖ Questionnaires

Of the 18 sellers interviewed over 20 selling locations, all were women (Appendix 3b). *N. hildebrandtii* was mentioned as the most popular species for sale by 69.2 % of sellers, while *C. schlecteri*, *P. obliquum* and *S. madagascariensis* were the most popular for 15.4 %, 7.7 % and 7.7 % of sellers respectively. A total of 8 species were mentioned as being used for sale (Appendix 3b). In response to the question of which alternative species would be used if the 8 species mentioned disappeared from the area completely, a total of 6 species were named: *Acacia burkei* (22.2 % of respondents), *Sapium integerrimum* (11.1 %), *Terminalia sericea* (11.1 %), *Albizia petersiana* (5.6 %), *C. schlecteri* (5.6 %) and *Strychnos madagascariensis* (5.6 %). The remaining crafters (38.9 %) had no suggestions. Other alternatives suggested over and above the initial one were: *Albizia adianthifolia*, *Acacia tortilis*, *A. burkei*, *Hymenocardia ulmoides*, *S. africana*, *S. madagascariensis* and *T. sericea* (1 suggestion per species).

A total of 77 % of sellers did not use the preferred species for personal use, but used any dead wood in the vicinity of their homestead (Appendix 3b). Of the most popular species (*N. hildebrandtii*), 8 respondents said the wood was easy to find, while 9 said that trees of this species were scarce; 9 said they use available deadwood, while 5 said they sometimes burned live trees to fell them as well as using deadwood. Sellers took on average 1.6 hours to find accessible *N. hildebrandtii* fuelwood (min = 1.7 hrs; max = 3 hrs; $SD = 1.0$; Appendix 3b).

❖ *Stall surveys*

Results of the wood sale survey showed that a total of 7 species were used for fuel at the 20 sale points (Table 12). Substantially more *N. hildebrandtii* was sold as fuelwood than any other species and accounted for 73.9% of the wood displayed for sale. It appeared at 19 of the 20 selling points (Table 12). The next most common species available for sale was *C. schlechteri*. However it was sold at only 2 of the 20 stalls. Fuelwood was sold predominantly in large R10.00 bundles with fewer medium (R5.00) and small (R2.50) bundles sold (Table 13).

❖ *Income generated and number of piles sold*

To determine a) the average income generated by each wood seller per month and b) the number of species piles per stall, the following calculations were made:

○ *Step 1: Average price per species pile.*

From the wood pile survey, the total number of species piles of each price category was counted. This gave a figure for the total value (R) of each species at all 20 stalls (Table 13). This value was divided by the total number of piles of each species to attain the average price per species pile. (Table 14; Table 15).

○ *Step 2: Proportions of species piles sold*

The proportions of each species pile sold were calculated by converting all piles into large (R10.00) units. It was estimated that a small (R2.50) pile was a third of the size of a large bundle, while a medium (R5.00) pile was half the size of a large bundle. Thus the number of small and medium bundles was divided by 3 and by 2 respectively, to attain the number of large (R10.00) bundles available for sale.

The total number of all these species piles were added giving a total of 316 large piles sold for the 20 stalls (Table 12). The percentage of the total represented by each species was calculated (Table 12). *N. hildebrandtii* wood was found to account for 73.9 % of all bundles, while *C. schlechteri* accounted for 20.9 %.

○ *Step 3: Number of each species pile sold per month*

An assumption was made that the proportional availability of species piles displayed at stalls (e.g. *N. hildebrandtii* 73.9 %) was the proportion that would be sold each month. This was felt to be reasonable as tourist buyers from other parts of the country are unlikely to have species preferences and will thus be inclined to purchase according to availability. An average sale rate of 3.1 bundles per person per month was used from the results of the questionnaire (Appendix 3b). The proportion of species bundles constituting this number was calculated (Table 14). For example, of the 3.1 bundles sold, 2.3 piles of *N. hildebrandtii* will be sold as it constitutes 73.9 % availability. This figure was then multiplied by the average price of each species pile (attained from Step 1). These were then added to attain the total amount made (R) on average per person per month and multiplied by 12 to attain the annual income Table 15).

As an average of 6.5 sellers sold wood at each sale point (Appendix 3b), the monthly income per person was multiplied by this number, in order to obtain a monthly income per stall per month.

○ *Step 4: Average number of species piles sold*

The number of species piles constituting the 3.1 sold per person month, were multiplied by 6.5 (average number of sellers per stall) to obtain the number sold per stall per month. This in turn was multiplied by 12 to obtain the average number sold per year (Table 14).

The results of the calculations showed that an average of about R25.00 is generated per person per month from the sale of fuelwood or an average annual income per person of R301.00 (Table 14). On average the monthly income generated per stall for the sale of wood is R163.00, which translates to R1954.00 per stall annually.

An average of 178.0 species piles of *N. hildebrandtii* were sold per stall per year, which generates an average annual income of R1349.00 per stall (Table 15).

❖ *N. hildebrandtii* live tree damage

Of the 68 *N. hildebrandtii* trees encountered at Sites 2 and 3, a total of 6 had been damaged (8.8 %). Of these 6 damaged trees, 1 at Site 2 had between 1-10 % bark removed and although no resprouting was evident, no death had resulted to any part of the tree (Table 12; Table 16).

❖ *N. hildebrandtii* deadwood availability

Number of deadwood piles below *N. hildebrandtii* did not differ ($p = 0.35$) significantly between the three sites (Mann-Whitney *U*-test; $U = 521.5$), although slightly more deadwood was found beneath trees at Site 3 than at the other sites (Table 17).

Table 17 Potential number of large (R10.00) fuelwood piles estimated from pieces of deadwood below the canopy of *N. hildebrandtii* encountered along transects at the 3 sites.

Location	Ave no. R10.00 bundles per tree	SD	No. trees sampled	Total piles per site
Site 1	0.6	0.6	27	15.7
Site 2	0.5	1.1	24	13.1
Site 3	1.7	2.0	26	40.5

❖ *Other damage to species*

Other damage such as cutting of branches and stems was found to be minor (Tables 18 and 19). One instance of root removal was recorded for *C. mossambicensis*, where approximately 80% of the roots of a tree had been removed. This tree was also totally bark-stripped.

▪ **Hut-building material**

❖ *Hut survey*

The species used most commonly as a lath for hut construction in both the 1982 and this study was *Drypetes* sp., with *Tricalysia* sp., and *H. ulmoides* as the next

most commonly used (Table 20). *H. ulmoides* and *P. myrtifolia* were the most commonly used species for poles (Table 20).

❖ *Forest plots*

The average number of poles cut per plot at Site 2 of trees 30 cm height – dbh < 10 cm (Size classes 1 and 2) was 19.3 per 0.04 ha. plot ($SD = 15.7$). All species resprouted following cutting, while 93.6 % of size class 1 stems and 95.2 % of size class 2 stems resprouted following cutting (Table 21). Most species of both sub-canopy and understorey shrubs were single- rather multi-stemmed individuals (Figure 3).

▪ *Species documentation*

During the study, the Zulu or Thonga names used by local people for the various species were documented (Appendix 4).

Discussion

▪ **Medicinal plant use**

The amounts of bark removed from *B. maughamii* in most cases were greater than that predicted to be used purely for local use (Box 1; Cunningham 2001). This indicates that bark of *B. maughamii* at Site 2 was being utilised for commercial sale.

Despite the large number of *B. maughamii* trees which were harvested for bark, as well as the large amounts of bark removed, no adverse physical effects to individuals was observed. Only one of the 34 individuals damaged resprouted following bark removal. Adverse effects of bark removal to individuals of this species could possibly take forms other than that investigated in this study, such as a reduction in seed output. The apparent indifference of *B. maughamii* to bark removal, could possibly be the result of the relatively large sizes attained by this species (approximately 10-12 m; pers. obs.) and thus proportionately less of the total bark is removed than smaller species. Also the characteristically fluted stem could be advantageous to the species in that it provides several grooves where bark cannot

easily be accessed. These could protect the tree against total ringbarking. When total bark removal did occur mortality resulted.

E. lasianthum was also popular with commercial bark gatherers, although it appeared to be more vulnerable to bark removal than *B. maughamii* and even relatively low amounts of bark removal resulted in death to parts of an individual tree. Unlike *B. maughamii*, however, a large proportion of the debarked trees resprouted as a response to bark removal. This was expected for this species as it displays characteristics of a sprouter (low seedling recruitment; see Chapter 3; Kruger *et al.* 1997). A large proportion (67%) of individuals that were completely debarked, resprouted (e.g. Plate 2), although the balance died. It is likely that *E. lasianthum* can sustain up to Type 5 bark removal and still be able to resprout. However, its increasing vulnerability to mortality as a result of death to parts of the plant needs further investigation. Additionally, as few smaller size classes are available (Chapter 3), mortality of adult trees will result in a significant dent to the population.

Of the three species investigated, *C. mossambicensis* appeared to be the most heavily exploited by gatherers for bark removal. Only two individuals had between 1-25 % bark removed while the remaining trees harvested had between 75 and 100 % bark removed. This high percentage of bark removal per individual indicates that *C. mossambicensis* was used almost exclusively by commercial gatherers and was in high demand for sale in the medicinal trade.

The predominance of individuals in the smaller size classes, implies that *C. mossambicensis* may be a shade-tolerant 'seeder' and channel reproductive efforts into seedling production as opposed to resprouting (Everard *et al.* 1994; Kruger *et al.* 1997). Although proportions of all size classes harvested is low (8 %), it is relevant that 42.9 % of all trees of 10 cm dbh and greater had evidence of bark harvesting, while 81.8 % of the 22 dead trees had been completely bark-stripped often including removal of bark on branches (pers. obs.). As ease of identification of dead trees decreases with time since mortality due to the onset of decay (Cunningham 2001), it is likely that a larger number of dead trees were present at the site than could be identified. Thus mortality rates may be more severe than were shown by this study. With the increasing demand for this product as the medicinal trade expands (Cunningham & Davis 1997), it is likely that the proportion of use will increase.

At the time of the study (1997), the relative abundance of smaller unharvested size classes which are left unharvested would be important as they could replace

larger size classes which had died as a result of harvesting. However, a critical factor in the continued survival of this species would be the size at which reproductive maturity is attained. As bark harvesting occurred in trees 5 cm dbh and greater in size, if trees are not able to reproduce before attaining this size class, it is unlikely that *C. mossambicensis* will survive much longer in an unprotected context. This needs further investigation.

Only 1 tree sampled had had a proportion of its roots removed. As it had also been completely bark-stripped and was dead, it is likely that mortality would have resulted even if no root removal had occurred. Thus it was not possible to ascertain the response of *C. mossambicensis* to the effects of root removal.

The significantly higher densities per plot of *S. mitostemmatoides* at Site 2 (harvested) than at Site 1 (unharvested) was unexpected. Higher light availability at the disturbed site (Site 2) may favour the recruitment success of this species. Further research on the optimal environmental and disturbance preferences of these species would be required. Alternatively, the higher browsing pressure by relatively larger populations of small ungulates at Site 1 (see Chapter 3), could inhibit success of seedling establishment. Thus it may be necessary to erect small ungulate enclosure fences within the reserve to enable a more accurate comparison of these species at the two sites in the future.

The relatively higher densities of all three species at Site 2 than at Site 1 suggest that no substantial impact by medicinal gatherers had occurred on populations at Site 2 at the time of the study (see assumptions in the Methods section). Densities of these species however, would need to be continually monitored in order to detect any change in this trend.

▪ Crafts

Results of both the questionnaires and the stall surveys showed that *C. schlecteri* was strongly favoured as the primary species used for craft manufacture. *A. forbesii* was clearly the second choice in both cases, while few other species were favoured. *C. schlecteri* appears to be a vigorous resprouter. However, given the slow growth rates of this species, the harvesting of trees at observed levels, both for craft manufacture as well as for other uses, appears to be unsustainable.

The modelled population structure of *C. schlecteri* within the 25 years following the study, is predicted to be dominated by resprouting stumps, while reproductive adult trees would decline dramatically. Although population growth rate (λ) remained fairly constant between time intervals in the model, the number of trees in the utilised stage classes declined. This decline in mature reproductive trees led to a subsequent reduction in the rate of seedling production, to the extent that numbers in stage class 1 were constant over the last 2 time intervals (Figure 2). It is likely that subsequent years would lead to a declining number of seedlings produced with the decline of reproductively viable trees until the resprouting trees had reached reproductive maturity once more.

In terms of income generated from small bowls, it appears that at current levels of manufacture and sale, crafters are gaining substantially less than they could potentially earn. Average monthly income per crafter generated from the sale of small bowls was calculated at approximately R313.00, while if each tree was used to manufacture and sell all bowls which could potentially be made from each tree felled, an average monthly of around R4032.00 could be generated. Thus a discrepancy of some R3720.00 exists between potential and actual earnings per person per month. This could be the result of the inefficient tools used to craft the bowls resulting in wastage of wood, or harvested individuals being discarded due to damage by termites. An increase in efficiency of use of each tree felled needs to occur in order to limit unnecessary wastage.

I suggest that discussions between TEP officials and the relevant communities be initiated in order to establish structures which could be responsible for regulating harvesting, investigating alternatives and facilitating craft training.

▪ Wood sales

As has been found in other studies (e.g. Shackleton 1993a), wood sellers favoured particular species as fuelwood. The strong preference for *N. hildebrandtii* shown both in the interviews with sellers as well as from records of the wood pile surveys, could be cause for concern given the potential for elimination or significant reduction of trees targeted for fuelwood use (Grundy *et al.* 1993). If this was the case, TEP would be one of the few sources of protection for this species within northern

Maputaland. Given the low seedling availability of this species within the reserve, the future success of this species locally, could be compromised.

However at the levels of use observed, both of live trees and of deadwood material, the results of this study suggest that the sale of *N. hildebrandtii* wood is sustainable. Use of live trees appeared to be low and in fact of all the available *N. hildebrandtii* trees sampled at both sites, only about 4 % had been burned. Of the approximately 9 % of *N. hildebrandtii* trees found that had been chopped down or cut, all were alive and vigorously resprouting, indicating a high degree of resilience to harvesting. As deadwood availability of *N. hildebrandtii* did not differ significantly between sites, this could indicate that deadwood was still readily accessible.

Moreover, despite large numbers of piles at many of the selling points, the turnover of woodpiles is exceptionally low, as is the income generated per seller per month. However, as with the sale of crafts, it is likely that the sale of fuelwood will intensify in the future with the influx of tourists to the region. Also, a proportion of the wood sellers indicated that they would sometimes burn down a tree if no deadwood was available. This harvesting technique would presumably become more common given increasing demand.

I suggest that as with crafts, reserve officials should initiate discussions with wood sellers in order to identify mutually beneficial alternatives and to establish a means to fix number of sellers at a feasible level. The importance of restricting harvesting to deadwood should be stressed and the use of a broader range of species should be encouraged.

From personal observations during this survey I noticed that species sold appeared to reflect the availability of species in the vicinity. Wood sellers near Site 3, where *N. hildebrandtii* was more common, walked shorter distances to obtain it and sold it almost exclusively. On the other hand, sellers near Site 2 where *N. hildebrandtii* was less common, walked longer distances to find it and were prone to sell a wider range of species. This, however, would need further investigation.

Sellers themselves identified a large number of alternatives to what they were already selling (e.g. *A. adianthifolia*, *A. petersiana*, *A. burkei*, *A. tortilis*, *S. integerrimum*, and *T. sericea*) and almost all said they used a broader range of species for their own domestic purposes (Appendix 3b).

Also, as local sellers are not aware of the needs and preferences of tourists, they assume that visitors have similar knowledge and preference for particular species

as they do themselves. Although *N. hildebrandtii* may be the best fuelwood available, a wide range of other species may be just as appropriate for the needs of tourists. Once sellers were aware of this they could be encouraged to sell a wider range of species. Thus the potential exists for the inclusion of a far wider range of species for sale.

As deadwood is preferred over livewood due to its relative ease of access (Shackleton & Prins 1992; Clarke *et al.* 1996), an experiment could be initiated in the reserve to assess the rate at which deadwood is generated (e.g. Shackleton 1998). Production rates of deadwood serve to provide an indication of the amounts that may be harvested from a designated area in order to maintain a constant, renewable supply. Sellers could facilitate in the experiment by removing deadwood from permanent *N. hildebrandtii*-dominated plots at fixed time intervals in order to ascertain how rapidly the deadwood is reproduced.

Large tracts of *N. hildebrandtii*-dominated forest were being cleared for subsistence agriculture by local people in and around Site 3. Some of this deadwood could be used for sale to offset the use of *N. hildebrandtii* trees in the forest.

▪ Hut-building

The use of species as laths for hut building has remained similar to those used in 1982 (Cunningham 1985), with *Drypetes* sp. dominating as the favourite hardwood lath, followed by *Tricalysia* sp. and *H. ulmoides* (Table 20). This is an indication that the qualities necessary for an effective lath (strength and flexibility) are present in these species.

Cunningham (1985) maintained that species used for laths reflects their relative abundances in sand forest. However, clear selectivity occurs against *T. bremekampii* which is the second most abundant understorey (Size class 1) and sub-canopy (Size class 2) individual in plots; following *Drypetes* sp., which were the most abundant (Figure 3). *T. bremekampii* accounts for only 0.2 % of laths used in hut-building (1997), while it was not recorded in the 1982 study. The low number of cut stems of this species also reflects this disparity when compared to the relatively high number of *Drypetes* sp. found cut in forest plots at Site 2 (Table 21). Also *D. inhacaensis* proved to be specifically targeted in both studies accounting for 2.6 % and 3 % of laths used in 1997 and 1982 respectively, despite very low availability

within the forest (Figure 3). This could indicate that population sizes may be low due to over-utilisation of this species. However, abundances in unharvested forest at Site 1 yielded similar densities of this species, so this is unlikely.

In terms of use of poles, *H. ulmoides* was clearly selected for, and accounted for 22.9 % of all available poles used, followed *P. myrtifolia* (12.3 %) and *C. schlecteri* (11.4 %; Table 20). These species are possibly selected for their strength and durability as support structures for poles in building. *C. greenwayi* which was the third most abundant species in sub-canopy plots, following *Drypetes* sp. and *T. bremekampii* (Figure 3) was not selected for pole use, possibly indicating the unsuitability of this species for construction (Table 20). This could indicate that the qualities necessary for an effective lath (flexibility, strength, straightness of stem and resistance to borers) are present in these species.

The strong resprouting responses shown by all species harvested for poles and laths at Site 2, could indicate that human utilisation is resulting in the significantly higher stem densities per plot at Site 2 than at Site 1 (see Results in Chapter 3). Thus, despite high numbers of laths (1400-2000) being used per homestead as was found in Cunningham's study (1985), the results of this study indicate that at current harvesting levels, use of laths and poles from sand forest appears to be sustainable due to the resprouting ability of species used.

Conclusion

Of the variety of uses investigated, it appears that most sand forest tree species have the ability to resprout following damage. Notable exceptions appear to be *C. mossambicensis*, which is possibly a 'seeder' as opposed to a 'sprouter' and *B. maughamii* which may be relying on structural strength to persist in response to damage. Also, little information was obtained for *N. hildebrandtii* as few instances of moderate damage were encountered, as individuals were either left unharvested, or they were burned down. However, any level of cutting produced a strong sprouting response. Similarly, both *E. lasianthum* and *C. schlecteri* resprouted vigorously in response to severe levels of damage. Thus on the whole, it is likely that sand forest is dominated by 'sprouters' rather than 'reseeders' and is compatible with Kruger *et al.* (1997)'s model of a short forest.

Plates: 14 - 23

(Overleaf)



Plate 14 A typical road-side craft stall approximately 7 km west of Tembe Elephant Park displaying bowls for sale.



Plate 15 A bowl crafted out of *Cleistanthus schlecterii* wood. Floor polish is used to seal the wood and to give it a shiny appearance.



Plate 16 A road-side fuelwood sale point displaying mainly *Newtonia hildebrandtii* wood characterised by its rich red-brown colour.



Plate 17 A small hut with walls constructed of interwoven latas harvested from sand forest.



Plate 18 A tall *Balanites maughamii* tree growing just south of the TEP fence and as a consequence having suffered considerable bark-stripping by commercial gatherers.



Plate 19 *Acridocarpus natalensis* var *linearifolius*, a Maputaland endemic, in full flower. Children place pieces of the long leaves under their tongues to prevent their teacher from punishing them for being late for school.



Plate 20 A pile of sand forest poles recently cut by local people for hut and fence construction. These piles may be left for days in the forest and will be left untouched by other community members.



Plate 21 A severely bark-stripped *Cassipourea mossambicensis* tree which died as a result. After stripping the trunk, commercial gatherers appeared to have climbed up the tree in order to remove all the bark from its branches.



Plate 22 Crafters chop the bowls into shape using a rough hoe-like tool. The pile of wood chippings beneath this crafter has been generated over many months of bowl construction.



Plate 23 A crafter standing at a recently chopped *Cleistanthus schlecteri* tree. The profusion of green leaves to the left of the photograph are the sprouts growing from its base. The thinner, unharvested stem is most likely a response to previous damage.

Figures: 1 - 3

(overleaf)

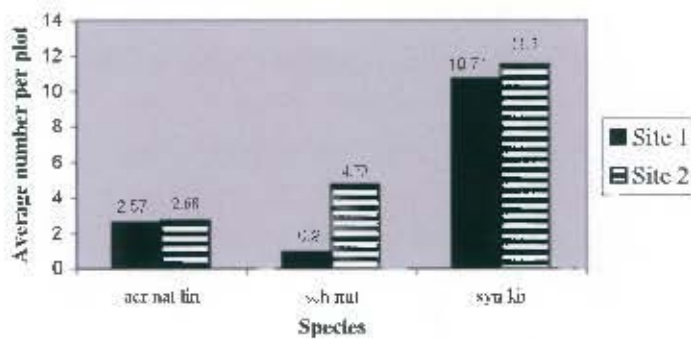


Figure 1 a Average density of *Acridocarpus natalitius* (encoded 'acr nat lin'), *Schlechterina mitostemmatis* ('sch mit') and *Synaptolepis kirkii* ('syn kir') seedlings (5-30 cm in height) per 400m² plot sampled at Site 1 (21 plots) and Site 2 (22 plots).

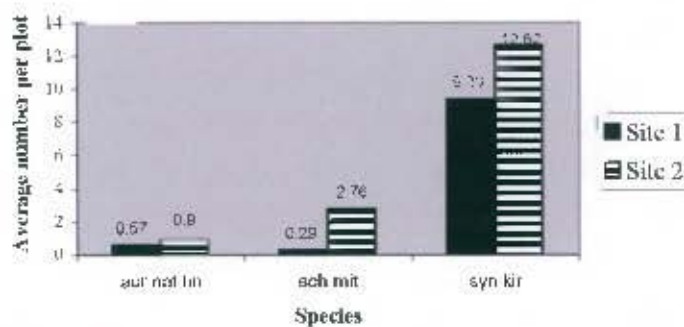


Figure 1 b Average density of *Acridocarpus natalitius*, *Schlechterina mitostemmatis* and *Synaptolepis kirkii* seedlings (5-30 cm in height) per 400m² plot sampled at Site 1 (21 plots) and Site 2 (22 plots).

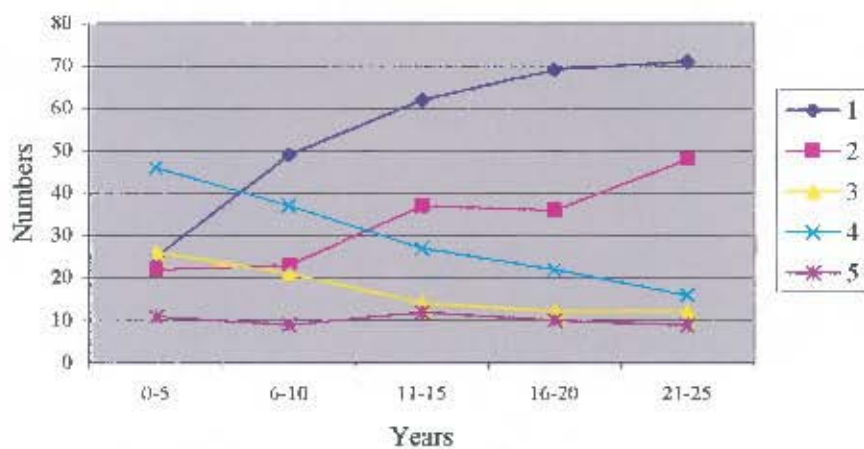


Figure 2 The projected matrix of the number of *Cleistanthus schlecteri* trees per stage classes 1-5 (see text) over a 25 year period. Data were obtained from transects at Site 3.

Tables 1; 3 – 16; 18 - 21

(overleaf)

Table 1 The lengths of 15 transects at Site 2 for *Balanites maughamii*, *Cassipourea mossambicensis*, *Cleistanthus schlecteri*, *Erythrophloeum lasianthum* and *Newtonia hildebrandtii* are specified (all 5 m in width). Similarly, the lengths of 4 transects (also 5 m in width), sampled at Site 3 for *N. hildebrandtii* and *C. schlecteri* are shown. The area of each transect at both sites is indicated.

Transect	Transects at Site 2		Transects at Site 3	
	Length (m)	Area (m ²)	Length (m)	Area (m ²)
T1	121	605	101.5	507.5
T2	153.5	767.5	430.5	2152.5
T3	103	515	249.5	1247.5
T4	121.5	607.5	270	1350
T5	154.5	772.5		
T6	180	900		
T7	526.5	2632.5		
T8	130.5	652.5		
T9	240	1200		
T10	123.5	617.5		
T11	548.5	2742.5		
T12	301	1505		
T13	102.5	512.5		
T14	282	1410		
T15	321	1605		

Table 3 A summary of the damage survey is shown of species sampled at Site 2 (transects and plots) and at Site 3 (transects). The percentage of both live and dead 'available' individuals (i.e. those with a dbh > 10 cm; column 'N') that had any form of damage by humans, is indicated in column '% Damaged'. For *C. mossambicensis* individuals of all size classes are included. Types of damage were bark and root removal, stem cutting or burning of the tree. Dead plants are indicated as a percentage of those available in column '% Dead of available'.

Species	% Damaged	N	% Dead of available
<i>B. maughamii</i>	68	50	3.8
<i>B. maughamii</i> (dead)	100	2	
<i>C. mossambicensis</i>	10	100	18.0
<i>C. mossambicensis</i> (dead)	81.8	22	
<i>C. schlecteri</i>	21.4	192	9.9
<i>C. schlecteri</i> (dead)	57.1	21	
<i>D. schlecteri</i>	6.6	60	11.8
<i>D. schlecteri</i> (dead)	0	8	
<i>E. lasianthum</i>	59.5	42	10.6
<i>E. lasianthum</i> (dead)	60	5	
<i>N. hildebrandtii</i>	15	60	11.8
<i>N. hildebrandtii</i> (dead)	37.5	8	

Table 4 Amounts of bark removed (Damage codes 1-7) from individuals of the species indicated. For all species other than *Cassipourea mossambicensis* only individuals of dbh > 10 cm are indicated, while all size classes are indicated for *C. mossambicensis*. Responses to this damage are indicated (Response codes) as a percentage of the total for each damage type. Total response types per species are indicated in bold (see text for codes). Data taken from all plot and transect data within the unprotected forest sites. No evidence of bark removal was found for *Cleistanthus schlecteri*.

Species	Damage codes	Response codes (%)					N
		DD	ND	NH	SD	SII	
<i>Balanites maughanii</i> No. bark-stripped = 34 No. available (dbh > 10cm) = 50	1 (1-10%)	0	0	100	0	0	8
	2 (11-25%)	0	0	100	0	0	6
	3 (26-50%)	0	0	100	0	0	9
	4 (51-75%)	0	0	87.5	0	12.5	8
	5 (75-90%)	0	0	100	0	0	1
	6 (any % ringbark)	0	0	100	0	0	1
	7 (tot bark removal)	100	0	0	0	0	1
<i>Cassipourea mossambicensis</i> No. bark-stripped = 26 No. available = 100 live; 22 dead	1	0	0	0	0	100	1
	2	100	0	0	0	0	1
	3	33	0	50	0	50	2
	4	0	50	0	50	0	2
	5	62.6	37.5	0	0	0	8
	6	0	0	0	0	0	0
	7	100	0	0	0	0	12
<i>Dialium schlecteri</i> No. bark-stripped = 2 No. available (dbh > 10cm) = 60	1	0	0	50	0	50	2
	2	0	0	0	0	0	0
	3	0	0	0	0	0	0
	4	0	0	0	0	0	0
	5	0	0	0	0	0	0
	6	0	0	0	0	0	0
	7	0	0	0	0	0	0
<i>Erythrophloeum lasianthum</i> No. bark-stripped = 25 No. available (dbh > 10cm) = 42	1	0	28.6	28.6	14.3	28.6	7
	2	0	0	100	0	0	2
	3	20	0	0	60	20	5
	4	0	0	33.3	66.7	0	3
	5	0	0	0	100	0	1
	6	0	100	0	0	0	1
	7	33.3	0	0	66.7	0	6
<i>Newtonia hildebrandtii</i> No. bark-stripped = 1 No. available (dbh > 10cm) = 60	1	0	0	100	0	0	1
	2	0	0	0	0	0	0
	3	0	0	0	0	0	0
	4	0	0	0	0	0	0
	5	0	0	0	0	0	0
	6	0	0	0	0	0	0
	7	0	0	0	0	0	0

Damage/response codes (from Box 1 in Methods)

S = resprouting from the base of the stem, or damaged area

N = no resprouting

These classes were combined with either of the following.

D = >30 % of the individual is dead (based on a visual assessment of both stem and canopy)

II = <30 % of the individual is dead (the tree as a whole is healthy)

DD = the tree is dead

Table 5 Bark removal: Availability of species at Site 2 (plots; transects) and Site 3 (transects) showing their size-classes. The number of dead individuals of *C. mossambicensis* shown for the various size classes. Size classes are as follows: 1. 30 cm – 200 cm in height; 2. 200 cm in height – 9.9 cm dbh; 3. 10-19.9 cm dbh; 4. 20-29.9; 5. 30-39.9; 6. 40-49.9; 7 50-59.9; 8. 60-69.9; 9. 70+ cm dbh. The 'no. available' for bark removal were the total number of trees with dbh > 10 cm for all species other than *C. mossambicensis*, where all size classes were used. 'No. bark damaged' total number found with bark removal (Table 4); '% damage of available' = percentage of trees of the number available which had had bark removed. See Appendix 4 for species codes used.

Size class	Site 2					Site 2	Site 3
	balmau	casmos	xcasmos	dtasch	erylas	newhil	
1	12	53	0	12	11	3	22
2	20	33	6	16	12	1	2
3	1	11	11	9	20	8	0
4	3	3	4	9	18	5	1
5	5		0	15	13	4	0
6	16		1	12	8	4	7
7	9			4	0	9	2
8	11			6	2	2	6
9	5			5	1	5	7
no. available (including dead)	50	100	22	60	42	37	23
no. bark-stripped	34	8	18	2	25	1	0
% bark stripped of available	68	8	81.8	3.3	59.5	2.7	0

Table 6 The size classes (dbh) of *C. mossambicensis* targeted for bark removal by gatherers at Site 2.

<i>C. mossambicensis</i>	No. available	No. bark-stripped	% bark-stripped
Live < 10 cm dbh	86	2	2.3
Live > 10 cm dbh	14	6	42.9
Total	100	8	8
Dead < 10 cm dbh	6	6	100
Dead > 10 cm dbh	16	12	75
Total	22	18	81.8

Table 7 The average number of each craft type displayed per stall is shown. A total number of 109 crafts were displayed at 5 stalls.

Bowls (84.4%)		Other (15.6 %)			
small	large	walking stick	eating utensil	assegaai	axe
17	1.4	2.2	0.6	0.2	0.4

Table 8 The species used as materials for the various types of crafts displayed at the 5 craft stalls are shown as a percentage of the total.

Species	Bowls		Other
	small	large	
<i>Albizia adianthifolia</i>	5.5	0	0
<i>Brachylaena huillensis</i>	0	0	0.9
<i>Cleistanthus schlecteri</i>	70.6	6.4	10.1
ikoti (unknown species)	0	0	2.8
<i>Spirostachys africana</i>	0.9	0	0.9
unknown species	0.9	0	0.9
Total % (N = 109)	84.4		15.6

Table 9 To calculate the proportions of species used as material for bowls, the number of large bowls at the 5 stalls surveyed were converted to medium bowl units by dividing numbers of large bowls by 2. These numbers were added and proportions of constituent species are displayed. See Appendix 4 for species codes.

Species	No. of bowls				% total
	small	large	large x2	total no.	
albfor	6	0	0	6	6
brahui	0	0	0	0	0
clesch	77	7	14	91	92
ikoti (unknown)	0	0	0	0	0
spiafr	1	0	0	1	1
unknown	1	0	0	1	1
Total	85	7	14	99	100

Table 10 Total income generated by crafters from the sale of medium and large bowls (other products are excluded). All prices shown in rands (R). See Appendix 4 for species codes.

Species used	no. sold/mnth	ave value	no. sold/mnth	ave value	income/person		income/per stall	
	small	small (R=8 ea.)	large	large (R=14.25 ea.)	per mnth	per yr	per mnth	per yr
cleis	4.97	288.14	2.60	367.76	655.90	7870.83	4020.68	48248.19
albfor	0.32	18.79	0.17	23.98	42.78	513.32	262.22	3146.62
other	0.11	6.26	0.06	7.99	14.26	171.11	87.41	1048.87
Total	5.4	313.20	2.8	399.74	712.94	8555.25	4370.31	52443.68

Table 11 The numbers of trees cut of each species for tray manufacture. It is assumed that 'other' crafts (e.g. walking sticks etc.) do not require the cutting down of a tree, as crafters indicated that branches are used for these types of crafts. See Appendix 4 for species codes.

Species used	Per person	Per stall		
	trees/mnth	trees/mnth	trees/yr	trees/5yrs
cleis	7.2	44.4	533	5333
albfor	0.5	2.9	35	348
other	0.2	1.0	12	116
Total	7.9	48.3	580	5797

Table 12 Number of bundles of wood (in units of large bundles) recorded for species at the 20 selling points from FEP gate to Phondweni store. Numbers of medium and small bundles were estimated to be half and a third of the size of a large bundle respectively. Thus numbers of medium and small bundles were divided by 2 and 3 respectively, in order to convert them into large bundle units). The percentage of bundles represented by each of the 7 species is shown. See Appendix 4 for species codes used in this table.

	SPECIES							
LOCATION	acabur	balmau	clesch	newhil	ptaobl	strmad	terser	TOTAL
1				26				26
2				65	17			82
3			0.17		0.08	0.08		0.33
4			1		9.33			10.33
5	0.5		0.5		28.67			29.67
6					10.67			10.67
7					8			8
8					2			2
9					51.67			51.67
10					5.33		1.33	6.67
11					5			5
12					6			6
13					4			4
14					4			4
15					2.33			2.33
16					10.67			10.67
17							4	4
18					16.67			16.67
19				1	16		0.33	26
20					10			10
Total no.	0.5	1.7	66	233.4	0.1	0.3	14	316
PERCENT	0.2	0.5	20.9	73.9	0.03	0.1	4.4	100

Table 13 Number of wood piles found of the various sizes (large, medium and small) at all stalls for each species. See Appendix 4 for species codes.

Species	No. of piles				Prices (R)			
	small	medium	large	N	R2, 50	R5, 00	R10, 00	Tot value
acabur			1	1	0	0	10	10
balmau	2	0	2	4	5	0	20	25
clesch			66	66	0	0	660	660
newhil	21	131	183	335	52.5	655	1830	2537.5
ptaobl	1			1	2.5	0	0	2.5
strmad		1		1	0	5	0	5
terser		6	12	18	0	30	120	150

Table 14 Calculated values of the number of bundles (converted to units of large, R10. 00 bundles) of each species sold over the time frames indicated. Total bundles sold per person per month (3.09) was attained from the interview responses. Proportions of species were attained from proportions of bundles of the various species available (Table 15). See Appendix 4 for species codes.

species	Sold per month			Sold per yr	
	per person	per stall	all stalls	per stall	all stalls
terser	0.14	0.89	17.80	10.68	213.56
strmad	0.003	0.02	0.42	0.25	5.08
ptaobl	0.001	0.01	0.11	0.06	1.27
newhil	2.28	14.84	296.72	178.03	3560.64
clesch	0.65	4.19	83.90	50.34	1006.79
balmau	0.016	0.11	2.12	1.27	25.42
acabur	0.005	0.03	0.64	0.38	7.63
Total	3.09	20.1	401.7	241.0	4606.8

Table 15 The average income per month per person and per sale point, is shown both as a total and as a proportion for each species pile. Figures obtained are from sources detailed in text (see Results). Calculations are explained in text (see Results).

Species	cost (R; all piles)	total no. piles	ave price/pile	proportions	%spp sold	Income per person (R)		Income per stall (R)	
						per month	per year	per month	per year
terser	150	18	8.33	4.43	0.14	1.14	13.69	7.42	88.98
strmad	5	1	5	0.11	0.003	0.02	0.20	0.11	1.27
ptaobl	2.5	1	2.5	0.03	0.001	0.00	0.02	0.01	0.16
newhil	2537.5	335	7.57	73.87	2.28	17.29	207.47	112.38	1348.53
clesch	660	66	10	20.89	0.65	6.45	77.45	41.95	503.40
balmau	25	4	6.25	0.53	0.02	0.10	1.22	0.66	7.95
acabur	10	1	10	0.16	0.005	0.05	0.59	0.32	3.81
tot	3390	426	7.09	100.00	3.09	25.05	300.63	162.84	1954.09

Table 16 Damaged trees encountered along transects at Site 2 and Site 3 are indicated. None of the *N. hildebrandtii* trees (N = 4) found in the 22 plots sampled at Site 2 were damaged. Types of damage are indicated as follows: b = bark removal, s = entire stem cut near the base, f = burned, c = branch cut. In the case of bark removal, the percentage removed is shown, while the dbh of the branch cut is shown. The dbh of damaged trees are indicated. The responses of trees to this damage are shown using the following sprouting types: 0 = no sprouting; 1 = mild resprouting (1-3 shoots); 2 = vigorous resprouting (4 + shoots). The response codes shown are described in Box 1.

Site	Live/Dead	Damage type	Dbh of tree (cm)	Sprouting type	Response code
2	L	s	13	2	SH
2	L	c (9 cm dbh)	42	2	SH
2	L	s	13	2	SH
2	L	s	16	2	SH
2	L	b (1-10 %)	53	0	NH
3	D	f	35	0	DD
3	D	f	73	0	DD
3	D	f	40	0	DD
3	L	c (10 cm dbh)	55	2	SH

Table 18 The number of branches cut from the species surveyed at Site 2 (transect and plot data) and Site 3 (transect data). Cut branches which coppiced are indicated as a percentage of the total number of trees cut. Data for *N. hildebrandtii* are shown in Table 16.

Species	No. branches cut	Coppiced (%)	Did not coppice (%)
<i>B. maughamii</i>	0	-	-
<i>C. mossambicensis</i>	1	0	100
<i>C. schlechteri</i>	13	69.23	30.77
<i>D. schlechteri</i>	2	50	50
<i>E. lasianthum</i>	1	100	0

Table 19 Number of stems cut of study species at Site 2 (plots and transects) and at Site 3 (transects) showing dbh (cm) and responses. Number of stems cut of *C. schlechteri* individuals was not included. Data for *N. hildebrandtii* are shown in Table 16.

Species	Dbh (cm)	No. stems cut	Response code
<i>B. maughamii</i>	60+	1	DD
<i>C. mossambicensis</i>	10-20	1	SH
<i>E. lasianthum</i>	<10	1	SH

Table 20 Species used as laths and poles for the 11 huts surveyed in this study (1997) are compared with a survey of a bundles of laths cut from sand forest for hut-building in 1982 (Cunningham 1985). Laths were classed as individuals with diameter < 3 cm while poles had a diameter between 4 – 9 cm. Poles surveyed included the 11 huts as well as bundles of cut poles cut by local people for hut construction. The percentage of the total number of laths and poles surveyed constituted by each species is shown. For the 1997 study, species not used as poles but used for laths and vice-versa are indicated as 'not used' in the relevant column. See Appendix 4 for the species codes used in this table.

Laths				Poles	
1997		1982		1997	
Species (32)	% (N=493)	Species (22)	% (N=388)	Species (35)	% (N=481)
dryang	30.8	dry spp	41.1	hymulm	22.9
hymulm	13.6	trispp	21.9	ptemyr	12.3
trispp	11.7	hymulm	8.9	clesch	11.4
drynat	7.1	monjun	8.9	trispp	11.2
brahui	5.3	dioinh	3.0	brahui	8.7
gremic	3.7	cro spp	2.4	ptaobl	6.7
ptemyr	3.2	hypamo	2.4	dioinh	3.1
dioinh	2.6	vangu	2.4	dryang	3.1
lepdel	2.2	wrinat	1.8	diasch	2.3
tarspp	1.6	colnat	1.5	drynat	2.3
uvacaf	1.6	hapgal	0.9	hapgal	1.9
laglas	1.4	moncaf/uvassp	0.9	casmos	1.5
ptaobl	1.4	diasch	0.9	eucalypt	1.5
mancon	1.4	gremic	0.9	larspp	1.5
wrinat	1.4	brahui	0.6	mandis	1.0
clesch	1.2	clesch	0.3	pavede	1.0
ochnat	1.2	sallep	0.3	surzan	1.0
pavede	1.2	strmit	0.3	albfor	0.8
strdec	1.0	strhen	0.3	sallep	0.8
grecaf	0.8	catobo	0.3	strdec	0.8
plearm	0.8	incawu	0.3	clegla	0.4
colgre	0.6			futhan	0.4
cropse	0.6			newhil	0.4
diasch	0.6			ochnat	0.4
monjun	0.6			todbre	0.4
mandis	0.4			balmau	0.2
casmos	0.4			castra	0.2
vitamb	0.4			erylas	0.2
gremon	0.2			gremic	0.2
lankir	0.2			lepdel	0.2
strmad	0.2			monjun	0.2
todbre	0.2			psyfra	0.2
albfor	not used			mancon	0.2
clegla	not used			khulan	0.2
eucalypt	not used			wrinat	0.2
hapgal	not used			colgre	not used
newhil	not used			cropse	not used
sallep	not used			grecaf	not used
surzan	not used			gremon	not used
				laglas	not used
				lankir	not used
				plearm	not used
				strmad	not used
				uvacaf	not used
				vitamb	not used

Table 21a Responses to harvesting of sub-canopy trees (dbh < 10 cm; height > 200 cm). Nineteen species were used of 45 available in the 22 plots sampled at Site 2. Of all individuals damaged, only 4.8% showed no evidence of resprouting. Response codes: 0 = no resprouting; 1 = 1-3 shoots; 2 = 4 or more shoots (also used in Table 21b). See Appendix 4 for species codes.

Species	Responses of sub-canopy trees			N
	0	1	2	
colgre	0	1	5	6
dryarg	2	8	22	32
drynat	1	4	6	11
gemic	0	0	1	1
hymulm	0	2	4	6
hypmic	0	1	0	1
lepdcl	0	0	1	1
memsou	0	1	0	1
ocharb	0	1	0	1
ochnat	0	0	1	1
psyfra	1	0	2	3
psyloc	0	0	1	1
plaobl	0	1	1	2
ptemyr	0	3	1	4
strhen	0	3	0	3
tarlit	0	0	1	1
todbre	0	2	1	3
tricap	0	1	3	4
wrinat	0	0	1	1
N	4	28	51	83

Table 21b Responses to cutting of understorey trees (height = 30 – 200 cm). Of the 55 species available in the plots, 16 were cut. Only 6.4 % of damaged trees showed no evidence of resprouting. See Appendix 4 for species codes.

Species	Responses of understorey trees			N
	0	1	2	
canset	0	0	2	2
colgre	0	1	4	5
dryarg	1	1	8	10
drynat	0	1	3	4
hymulm	0	0	2	2
lepdcl	0	0	1	1
mandis	0	1	0	1
psyfra	0	1	1	2
psyloc	0	0	2	2
ptemyr	0	2	1	3
surzan	0	1	0	1
tarlit	0	1	1	2
todbre	1	0	2	3
tricap	1	3	1	5
trijun	0	1	2	3
trilan	0	1	0	1
N	3	14	30	47

Appendices: 1 - 4

(overleaf)

Appendix 1 A summary of the main medicinal uses for the study species. Plant parts used are also indicated.

Species (Family)	Parts used	Main use
<i>Scientific name</i> (Family); English name(s); Zulu name(s)		
<i>Balanites maughamii</i> (Balanitaceae) Torchwood, Green Thorn; umNulu, uGobendlovu	bark, roots	The tree is thought to have magical properties. An emetic is prepared from the roots and bark and is used to ward off evil spirits from the homestead (Palgraves 1984).
<i>Cassipourea mossambicensis</i> (Rhizophoraceae) Sand onionwood; uMemezi	bark	The bark is used as an 'umemezi', or skin lightener (B. Gwala, pers. comm.).
<i>Erythrophleum lasianthum</i> (Caesalpiniaceae) Swazi Ordeal Tree; umKhwangu, umBhemise	bark	The bark, which is poisonous, is ground to make snuff for the treatment of headaches and colds (Palgrave 1984).
<i>Acridocarpus natalitius</i> var. <i>linearifolius</i> (Malpighiaceae) Moth fruit; umaBhophu	roots	The plant is known as an <i>intelezi</i> , a name given to all charms and plants used against evil (Pooley 1993). Its red-brown roots are used to improve crop yields, stop approaching danger or to stop evidence being given against one in a court of law (Cunningham 1997). It is also used as a love charm (Palgrave 1984).
<i>Synaptolepis kirkii</i> (Thymelaeaceae) uVuma	roots	The white lignotubers is used primarily as an emetic (cleanser) for a range of purposes; also used as an aphrodisiac (Hutchings 1996). An important ingredient in an <i>ubulawu</i> mix used by diviners to facilitate the interpretation of dreams (Cunningham 1997)
<i>Schlechterina mitostemmatoides</i> (Passifloraceae) iHlalanyosi lehlathi	roots	Roots used as charms to bring prosperity and protection (Hutchings 1996)

Appendix 2a Craft Questionnaire

Date	Questionnaire no.	Stall no.

Crafter information

Interviewer to circle the appropriate block:

1. Gender of crafter:

(1) Male	(2) Female
----------	------------

Interviewer to ask the following questions - responses to be indicated by circling the appropriate block or filling in the answer where appropriate.

2. How many crafters sell their wares at this stall?

No.	
-----	--

Harvesting

3. When you go to harvest wood for your craft industry, do you harvest with other people (1) or alone (2)?

(1) In a group	(2) Alone
----------------	-----------

4. Do you choose particular species which are more appropriate for use as craft materials (1), or do use any species (2).

(1) Preferred species	(2) No preferred species
-----------------------	--------------------------

5. If your answer for the previous question was (1), rank the 4 species you use most frequently in order, with 'Species (1)' being the species used most regularly and Species (4) being the species used least regularly of the four.

(Note to the interviewer: If the answer for the previous question is (2), questions 5 - 8 can be ignored).

Species (1)	
Species (2)	
Species (3)	
Species (4)	

6. Are there many (1) seedlings of Species 1 in the forest where you harvest or very few (2)?

(1) Many	(2) Few
----------	---------

7. Indicate how long it takes you to walk from your stall to the preferred tree species you use for craft manufacture.

Time:	mins
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8. If the tree species you are looking for is more than 30 minutes' walk away, would you continue to search until you found what you are after (1), or would you choose another, less preferable species that is in the immediate vicinity (2)?

(1) Continue to search	(2) Choose another species
------------------------	----------------------------

9. Do you chop down the whole tree (1), or do you cut off branches only and leave the rest of the tree alive (2)?

(1) Whole tree	(2) Branches
----------------	--------------

10. If you answered (1) for the previous question, have you ever cut down a tree and discovered that the wood was damaged? Yes (1) or No (2).

(Note to the interviewer: If the answer for the previous question was (2), questions 10 and 11 can be ignored).

(1) Yes	(2) No
---------	--------

11. If your previous answer was (1), do you abandon the tree completely (1), use the branches for craft manufacture (2), use the wood for some other purpose (3), or both the latter 2 purposes (4)?

(1) Abandon tree	(2) Use branches for craft manufacture	(3) Use wood for other purposes	(4) Both (2) + (3)
------------------	--	---------------------------------	--------------------

12. Name the type of tool you use to harvest your material: chain-saw (1), bush knife or axe (2), both chain-saw and bush knife/axe (3), or other (4).

(1) Chain-saw	(2) Bush knife or Axe	(3) 1 + 2	(4) Other
---------------	-----------------------	-----------	-----------

13. How many trees do you chop down for the purpose of craft manufacture per week?

No.	
-----	--

Manufacture and sale

14. How many big trays (length > 70 cm) do you think can be made from 1 tree?

No.	
-----	--

15. How many small trays (length < 70 cm) do you think can be made from 1 tree?

No.	
-----	--

16. How many big trays do you make on average per week?

No. of big trays made:		per week
------------------------	--	----------

17. How many small trays do you make on average per week?

No. of small trays made:		per week
--------------------------	--	----------

18. How many big trays do you sell on average per month?

No. of big trays sold:		per month
------------------------	--	-----------

19. How many small trays do you sell on average per month?

No. of small trays sold:		per month
--------------------------	--	-----------

20. Do you sell at this stall exclusively (1) or do you sell your products at other markets (2)?

(1) This stall only	(2) Other markets
---------------------	-------------------

21. If your answer for the above question is (2), indicate the percentage of your crafts that you sell per month at other markets.

Percentage sold at other markets per month		%
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22. Do you have regular buyers who order goods from you? Yes (1) or No (2).

(1) Yes	(2) No
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23. Are your most regular buyers members of your local community (1), tourists or tour operators (2), both (3) or other (4)?

(1) Local people	(2) Tourists	(3) Both (1) + (2)	(4) Other
------------------	--------------	--------------------	-----------

Appendix 2b Summary of responses to craft questionnaires of 15 crafters interviewed individually at the 5 stalls.

Crafter information

1. 100% of crafters were males (N = 15)
2. An average of 6.13 people sold wares at each craft stall ($SD = 1.73$)

Harvesting

3. 86.7% of crafters harvested in groups
4. 100% of crafters chose specific species (response 1) as craft material
5. Ranked species

Species 1	%	Species 2	%
<i>Cleistanthus schlecteri</i>	100	<i>Albizia forbesii</i>	100

Species 3	%	Species 4	%
<i>Spirostachys africana</i>	53.3	No suggestions	86.7
No suggestions	33.3	<i>Brachylaena huillensis</i>	6.7
<i>Albizia forbesii</i>	6.7	<i>Berchemia zeyheri</i>	6.7
<i>Brachylaena huillensis</i>	6.7		

6. 100% of crafters said there were many (response 1) seedlings of Species 1 in the forest.
7. The average time taken to find the preferred species was 45 mins ($SD = 33.91$).
8. 100% of crafters said they would continue walking longer than 30 mins to find their preferred species (response 1).
9. 100% of crafters said they chopped the whole tree down (answer 1) as opposed to cutting off branches only.
10. 100% of crafters said they had previously chopped down a tree to find that the wood had been damaged.
11. 100% of crafters said that in the circumstances outlined in Q10, they would use the branches of the tree to manufacture smaller crafts.
12. A chain-saw alone (1) was used by 13.33%, a bush knife or axe (2) were used by 20.0%, and a combination (3) was used by 66.67% of crafters. No other (4) tools were used.
13. Mean no. of trees chopped down per week = 1.97 ($SD = 1.42$)

Manufacture and sale

14. Mean no. of big bowls able to be made per tree = 5.4 ($SD = 1.99$)
15. Mean no. of small bowls able to be made per tree = 8.8 ($SD = 4.71$)
16. Mean no. of big bowls able to be made per week = 1.63 ($SD = 1.01$)
17. Mean no. of small bowls able to be made per week = 4.23 ($SD = 1.72$)
18. Mean no. of big bowls sold per month = 2.83 ($SD = 1.87$)
19. Mean no. of small bowls sold per month = 5.4 ($SD = 3.68$)
20. 93.33% of crafters sold their wares nowhere else (response 1); 6.67% sold crafts elsewhere.
21. Crafters who did not sell goods locally estimated that 30% of their stock was sold elsewhere i.e. only 2 % of all stock was sold outside the study area.
22. 26.67 crafters said they had regular buyers (response 1).
23. 100% of crafters said that both tourists and local community members (response 3) regularly bought their crafts.

Appendix 3a Firewood sale questionnaire.

Date	Questionnaire no.	Site no.

Information about wood seller

[Interviewer to circle the appropriate block]

1. Age of seller:

(1) 5-9 yrs	(2) 10-19 yrs	(3) 20-34 yrs	(4) 35-49 yrs	(5) 50+ yrs
-------------	---------------	---------------	---------------	-------------

2. Gender:

(1) Male	(2) Female
----------	------------

[Interviewer to ask the following questions of the wood sellers - responses to be indicated by circling the appropriate block or by filling in the answer where appropriate]

3. Rank the four species you collect for sale most frequently in order, with Species (1) being the species collected most regularly and Species (4) being the species collected least regularly.

Species (1)	
Species (2)	
Species (3)	
Species (4)	

4. For each species chosen in Question 3, indicate by means of an X, whether it is abundant (1) or scarce (2).

	Abundant (1)	Scarce (2)
Species (1)		
Species (2)		
Species (3)		
Species (4)		

5. For each species chosen in Question 3, indicate by means of an X, whether you only ever chop up and/or gather dead wood from the tree (1), or whether you also burn live trees in order to make them accessible for use as firewood (2).

	Dead only (1)	Burn live trees (2)
Species (1)		
Species (2)		
Species (3)		
Species (4)		

6. Indicate how long in minutes it takes you to find each species chosen in Question 3. Time indicated should reflect the length of time it takes you to walk from your starting point to the appropriate tree.

	Time taken (mins)
Species (1)	
Species (2)	
Species (3)	
Species (4)	

7. How many bundles do you gather per week?

No.	
-----	--

8. How many bundles do you sell per month?

No.	
-----	--

9. How many other people sell wood at this selling point?

No.	
-----	--

10. When you cook for yourself or your family, do you use the wood you sell as firewood (1), or do you simply select whichever dead wood is available in the vicinity (2)?

(1) Specific wood chosen	(2) Any wood
--------------------------	--------------

11. If all the species you currently use for sale as firewood disappeared from the area, and you wished to continue selling, which species would you sell?

Alternative species	
---------------------	--

Appendix 3b Summary of responses to wood sale questionnaires of 18 separately interviewed sellers over 20 selling locations.

1. Ages of sellers were as follows: 5-9 yrs = 0; 10-19 yrs = 3; 20-34 yrs = 8; 35 – 49 yrs = 5; 50+ yrs = 2.

2. Gender: Female = 100%

3. Species were ranked by sellers as follows:

Species 1	%	Species 2	%
<i>Newtonia hildebrandtii</i>	69.2	no selection	12.5%
<i>Cleistanthus schlecteri</i>	15.4	<i>Cleistanthus schlecteri</i>	27.8
<i>Ptaeroxylon obliquum</i>	7.7	<i>Strychnos madagascariensis</i>	27.8
<i>Strychnos madagascariensis</i>	7.7	<i>Newtonia hildebrandtii</i>	11.1
		<i>Terminalia sericea</i>	11.1
		<i>Balanites maughamii</i>	5.6

Species 3	%	Species 4	%
no selection	50	no selection	61.1
<i>Cleistanthus schlecteri</i>	16.7	<i>Cleistanthus schlecteri</i>	11.1
<i>Newtonia hildebrandtii</i>	16.7	<i>Terminalia sericea</i>	11.1
<i>Strychnos madagascariensis</i>	5.6	<i>Ptaeroxylon obliquum</i>	5.6
<i>Terminalia sericea</i>	0.2	<i>Spirostachys africana</i>	5.6
		<i>Strychnos madagascariensis</i>	5.6

4 – 5. Responses to Questions 4 – 5 are summarised below. For Questions 4 and 5, the number of responses to each option is indicated.

Species	Q 4 - quantity		Q 5 – harvest method	
	many (1)	few (2)	chop (1)	burn (2)
<i>Balanites maughamii</i>	0	1	1	0
<i>Cleistanthus schlecteri</i>	7	7	9	5
<i>Dialium schlecteri</i>	1	0	1	0
<i>Newtonia hildebrandtii</i>	8	9	9	8
<i>Ptaeroxylon obliquum</i>	1	1	2	0
<i>Spirostachys africana</i>	0	1	1	0
<i>Strychnos madagascariensis</i>	6	2	6	2
<i>Terminalia sericea</i>	3	3	4	2

6. For Question 6, the average time (hrs) taken, standard deviation, and minimum and maximum time are displayed.

Q6 – Time to find species				
Species	ave	SD	min	max
<i>Balanites maughamii</i>	3			
<i>Cleistanthus schlecteri</i>	1.49	0.95	0.5	3
<i>Dialium schlecteri</i>	2			
<i>Newtonia hildebrandtii</i>	1.62	1.01	0.17	3
<i>Ptaeroxylon obliquum</i>	0.75	0.35	0.5	0.75
<i>Spirostachys africana</i>	1			
<i>Strychnos madagascariensis</i>	1.31	0.80	0.5	3
<i>Terminalia sericea</i>	3	1.8	1	3

7. Average number of bundles gathered per week = 5 (SD = 3.65)

8. Average number of bundles sold per month = 3.09 (SD = 2.7)

9. Average number of sellers per stall = 6.5 (SD = 3.88)

10. 77.78% of sellers did not use the species they sold as firewood for their own cooking purposes, while 16.67% used the wood they had collected for sale.

11. Alternatives:

Species	%
no suggestions	38.89
<i>Acacia burkei</i>	22.22
<i>Sapium integerrimum</i>	11.11
<i>Terminalia sericea</i>	11.11
<i>Albizia petersiana</i>	5.56
<i>Cleistanthus schlecteri</i>	5.56
<i>Strychnos madagascariensis</i>	5.56

Other alternatives suggested over and above the initial one were: *A. adianthifolia*, *A. burkei*, *A. tortilis*, *H. ulmoides*, *S. africana*, *S. madagascariensis* and *T. sericea* (1 suggestion per species).

Appendix 4 A list of Zulu and Thonga names in use in the study area for the species indicated. Local names which differed slightly or completely to those found in Pooley (1994) are indicated as 'd'.

Code	Species	Zulu / Thonga names	Pooley
acabur	<i>Acacia burkei</i>	umKhaya	
acator	<i>Acacia tortilis</i>	iShoba-lendlovu	d
acrnat	<i>Acridocarpus natalitius</i> var. <i>linearifolius</i>	umaBhopha	
albadi	<i>Albizia adianthifolia</i>	iGowane	d
albfor	<i>Albizia forbesii</i>	umFomoshane, umNala	
albpet	<i>Albizia petersiana</i> subsp. <i>evansii</i>	umNala / amNala	
balmau	<i>Balanites maughamii</i>	uMnulu / uGobandlovu	d
berzey	<i>Berchemia zeyheri</i>	umNeyi	
brahui	<i>Brachylaena huillensis</i>	iGqeba / iPhahlalenhathi	d
canset	<i>Canthium setiflorum</i>	isiPilokojwana	d
casmos	<i>Cassipourea mossambicensis</i>	uMemezi	d
castra	<i>Cassine transvaalensis</i>	iNqotha	
cle gla	<i>Clerodendrum glabrum</i>	umNukalembaba	
clesch	<i>Cleistanthus schlechteri</i>	umZithi	
colgre	<i>Cola greenwayi</i>	umQhosho	
cropse	<i>Croton pseudopulchellus</i>	uHubeshane	
diasch	<i>Dialium schlechteri</i>	umThiba	
dioinh	<i>Diospyros inhacensis</i>	isiThomane	
dryarg	<i>Drypetes arguta</i>	umKushwane-lendoda	d
drynat	<i>Drypetes natalensis</i>	umKushwane-lesifazane	d
erylas	<i>Erythrophleum lasianthum</i>	umBhemise / umKhwangu	
eucalypt	<i>Eucalyptus</i> sp.	iGumtree	
grecaf	<i>Grewia caffra</i>	iSaka	
gremic	<i>Grewia microthyrsa</i>	isiMunywane	d
gremon	<i>Grewia monticola</i>	isiPhane	
hapgal	<i>Haplocoelum gallense</i>	iThambo	
hymulm	<i>Hymenocardia ulmoides</i>	iTsatsalatsane	
laglas	<i>Lagynias lasiantha</i>	isiPilokojwane	
lanant	<i>Lannea antiscorbutica</i>	uMganikomo	
lankir	<i>Landolphia kirkii</i>	umBhungwa	
lepdel	<i>Leptactina delagoensis</i>	umBhangwalehlathi	d
mandis	<i>Manilkara discolor</i>	anNywebe/ umNwebe	
mancon	<i>Manilkara concolor</i>	umNqambo	
mardis	<i>Margaritaria discoidea</i>	uPata	
memsou	<i>Memecylon sousae</i>	usiPhulamathambo	d
monjun	<i>Monodora junodii</i>	umKotshi, umDlankawu	d
newhil	<i>Newtonia hildebrandtii</i> var. <i>hildebrandtii</i>	umFomothi	
ochnat	<i>Ochna natalitius</i>	umShelelo	d
pavede	<i>Pavetta edentula</i>	isiMuncwane	
plearm	<i>Plectroniella armata</i>	isiKhwakhwane	
psyfra	<i>Psydrax fragrantissima</i>	umKukulaketelo-wasemagcekeni-omnyama	d
psyloc	<i>Psydrax locupules</i>	umKukulaketelo-lehlathi-omnyama	d
ptaobl	<i>Ptaeroxylon obliquum</i>	umThathi	
ptemyr	<i>Pteleopsis myrtifolia</i>	uMwandla	
sallep	<i>Salacia leptoclada</i>	uHlangahomu	d

Appendix 4 continued.

Code	Species	Zulu / Thonga names	Pooley
sapint	<i>Sapium integerrimum</i>	umDlampunzi, umHlepha	
schmit	<i>Schlechterina mitostemmatoides</i>	iHlalanyosi-omhlophe	
spiafr	<i>Spirostachys africana</i>	umThombothi	
strdec	<i>Strychnos decussata</i>	umPhathankosi	d
strmad	<i>Strychnos madagascariensis</i>	umKwakwa	
surzan	<i>Suregada zanzibariensis</i>	umDlankawu	
synkir	<i>Synaptolepis kirkii</i>	uVuma-omhlophe	
tarlit	<i>Tarenna littoralis</i>	ukuKulaketelo	d
tarsup	<i>Tarenna supra-axillaris</i> subsp. <i>barbertonensis</i>	umKukulaketelo-lehlathi-omhlophe	d
todbre	<i>Toddaliopsis bremekampii</i>	iNtane	
triccap	<i>Tricalysia capensis</i>	umBhangwe-wehlathi-omude	d
tricjun	<i>Tricalysia junodii</i>	umBhangwe-wehlathi-omfishane	d
khoti	Unknown 1	iKhoti	
futhan	Unknown 2	umaFuthane	
khulan	Unknown 3	umaKhulane	
uvacaf	<i>Uvaria caffra</i>	iNkonjane	
vitamb	<i>Vitex ferruginea</i> subsp. <i>amboniensis</i>	umPhenduka	
wrinat	<i>Wrightia natalensis</i>	umPengende	

Chapter 5

General Discussion and Conclusion

This study set out to investigate the nature of sand forest dynamics both internally and at the level of the landscape. It also aimed to explore the role played by disturbance in determining the observed distribution of forest patches, its species composition and dynamic functioning. Another of its intentions was to assess the use and disturbance of sand forest by local people, as well as to ascertain the value of forest resources for subsistence use. Finally, it aimed to look at implications of these findings for sand forest management both within and outside TEP.

In this synopsis, I assess the findings of the study and suggest future research opportunities and management implications for sand forest within TEP. Also, I outline what I view to be amongst the main problems which could inhibit the sustainable use of sand forest in the future and propose possible approaches to overcome them.

• Summary of research findings

The findings of this study (Chapters 2 and 3) indicate that sand forest patches within the mosaic of grassland and wooded grassland are possibly remnants of past fires. These fragments may expand in size in the long-term absence of fire by a successional process where certain forest species such as *Dialium schlechteri* invade intermediate grassland patches. Here, along with other trees in the grassland, they act as nuclei for the process of bush clumping. As bush clumps expand they provide an environment suitable for the recruitment of additional sand forest species, which leads to the formation of patches of sand forest. These patches appear to have *D. schlechteri* as the most common canopy species.

Another canopy community occurred within sand forest, which was dominated by *Cleistanthus schlechteri*. Based on its fairly even size-class distribution curve and absence from grassland patches, *C. schlechteri* is possibly a secondary successor within sand forest. It also demonstrated a strong sprouting response to damage. Thus its

success as a canopy dominant may be the result of these two factors, although further research on this species would be required to clarify this.

Results of ordination and classification of forest plots, suggested that the species composition of forest plots inside the reserve did not differ for the most part to those in an equivalent area outside the reserve (Site 2). This was possibly because the intensity of disturbance within the forest at this communal site was fairly low, as sand forest patches were used mainly for the harvesting of individual trees and no clearing for agriculture was taking place. In terms of the dynamics however, certain species displayed differences in size-class distribution between the sites. Significantly higher densities of seedlings of *Newtonia hildebrandtii* occurred at both disturbed sites outside the reserve (Sites 2 and 3) compared to Site 1 inside. This points to the possibility that recruitment of this species occurs more readily in highly disturbed sites than in undisturbed sites. Additionally, *Cassipourea mossambicensis* had substantially fewer individuals of intermediate size-classes. However, this probably resulted from the preferred use of these sizes by commercial gatherers for bark removal.

The forest as a whole was shown to be 'coarse-grained' and is thus synonymous with others grouped as 'coastal forests' within KwaZulu-Natal (Geldenhuys & MacDevette 1989). These forests were surmised to be characterised by species that are dependent on a degree of disturbance to regenerate and, like sand forest, their species composition may be the result of human disturbance in the past (Everard *et al.* 1994; van Wyk *et al.* 1996). Such forests appear to be dominated by canopy species that are shade-intolerant, produce low numbers of seedlings and are possibly reliant on vegetative reproduction as opposed to regeneration by seedlings.

If these findings are accurate, they have significant implications for sand forest protected in reserves under 'non-interference' management regimes, as canopy species may require intermittent large-scale disturbances for their continued regeneration, either by resprouting following damage or by reseedling in open areas. If these conditions are not present within the reserve, the continued survival of such species may be undermined.

The investigation of a range of human uses showed that *N. hildebrandtii* was being targeted for fuelwood sales. This study found that sellers appeared to be using available deadwood for sale, and burning of *N. hildebrandtii* trees was rare. However

a number of sellers indicated that they did burn trees when deadwood was not available and thus further investigation and monitoring is needed.

C. schlecteri was the species most used for the manufacture of crafts. Despite a demonstrated capacity to resprout following felling for building material and crafts, this study found that the use of *C. schlecteri* appeared to be unsustainable. This was based on the number of stalls that were operating at the time of the study (1997). A recent count of stalls along the same section of road shows an increase from the 6 that were operational in 1997 to 21 in May 2001 (Table 1). A total of 14 new craft stalls selling trays were counted, of which 11 occurred in the 8 km stretch of road between Tembe Elephant Park and Mtikini store where no stalls had been present in 1997. Interestingly only 3 new stalls had been established on the 5.3 km section between Mtikini and the last stall (2 km east of Phondweni), which indicates a possible market saturation driven either by social territories of crafters or by availability of trees. Only one stall had an alternative product to bowls and sold traditional fish trap baskets (*isifonya*).

Part of the initial section of road (TEP to Mtikini) falls into the Site 2 study area where relatively few *C. schlecteri* trees were encountered (see Chapter 3). Thus it would be interesting to see whether species other than *C. schlecteri* and *Albizia forbesii* are being targeted as is occurring at Site 3. It is likely that species such as *Spirostachys africana* and *Brachylaena huillensis*, are being used, as they were identified by crafters in interviews as being good craft material.

▪ **Future research and management recommendations for implementation in TEP**

If a more ‘interference’-based management strategy is to be implemented for sand forest within TEP, further research and experimentation would be necessary to determine the scale and frequency of disturbances required.

❖ ***D. schlecteri*-dominated sand forest patches**

In order to promote the successional process (from grassland to bush clumps through to forest), if that was deemed to be in keeping with the objectives of the reserve, it would be necessary to create long-term fire exclosures within the western

sections of TEP. I suggest that the existing elephant enclosure (Site 1) be used as a control in order to exclude heavy browsing. Additional sites would be necessary as comparisons. These could be monitored over time using permanent vegetation plots, GIS mapping as well as aerial photographic analysis. As change in the mosaic appears to be extremely gradual, fire exclusion plots should be seen as a permanent features of the reserve and written into the management plan.

Other questions need further investigation. One is: how did the short multi-stemmed individuals in the grassland get there to begin with? Were they formerly adults in a forest patch that was destroyed by fire and persisted by resprouting from remaining underground parts? Or did they recruit into the grassland by seed dispersed from mature *D. schlecteri* trees in a nearby forest patch?

To investigate the latter possibility, evidence would be required of the presence of single-stemmed *D. schlecteri* shrubs in the grassland. This would indicate that recruitment from seed in the grassland could occur. The fact that all small shrubs were multi-stemmed in this study may only indicate that the study area was subject to a similar burning regime. Thus, if small single-stemmed *D. schlecteri* shrubs had occurred in the grassland, they may have been damaged and resprouted accounting for the absence of single-stemmed shrubs. Other grassland patches within the reserve should be searched for single-stemmed seedlings and shrubs, particularly those areas that have been excluded from fires.

Secondly, an experiment to test the germination requirements of *D. schlecteri*'s hard, *Acacia*-like seed could indicate whether the gut contents of a monkey or elephant are sufficient to break the testa or whether heat shock or smoke is required to activate the process (e.g. Dixon *et al.* 1995; Keith 1997; Keeley & Fotheringham 1998). Thus, if recruitment were taking place in the grassland, the necessity for burning to trigger germination would be more adequately understood. I suspect that seedling recruitment does occur given the profusion of edible fruits produced which attract a range of dispersers including elephants (Pooley 1993), birds, monkeys and people (pers. obs.).

❖ *Succession between the two canopy community types?*

As communities in certain forest types appear to be linked along a successional continuum, with one community being the climax of another or others

(e.g. in coastal lowland forest; van Wyk *et al.* 1996), this may be the case for sand forest. In other words, the possibility exists that *D. schlechteri* community is the pioneering stage of a *C. schlechteri* climax community. This question would need to be answered by further research.

The arguments presented in this study suggest that *D. schlechteri*-dominated community may represent an earlier successional community while that dominated by *C. schlechteri*, may be a more secondary community of forest development. Most adult *D. schlechteri* individuals in patches of the *D. schlechteri* community type were found to be senescent (Figure 7; Chapter 2). Recruitment of this species within the forest was limited and was mainly restricted to intermediate grassland patches. Thus this community type appears to be similar to the 'core' forest community described for a coastal lowlands forest (van Wyk *et al.* 1996). In their study the 'core' forest was constituted of canopy species deemed to be primary successors with a notable absence of regeneration within the forest. Like *D. schlechteri*, these canopy species appeared to invade the disturbed grassland areas outside the forest. In the absence of disturbance, it was deemed that this community type had a limited life-span. This is likely to be the case for the *D. schlechteri* community in sand forest.

As *C. schlechteri* appears to be a secondary successor, further research would be necessary to determine whether it invades these *D. schlechteri*-dominated patches or whether this former community is formed by independent mechanisms.

❖ *N. hildebrandtii* – dominated sand forest patches

Newtonia hildebrandtii was identified as one of the canopy dominants in this study. Evidence suggested that its origin in the forest could be the result of recruitment into large disturbed sites, such as in sections of forest at Site 3 that had been burned and cleared for subsistence agriculture.

Although this study has emphasised the role played by disturbances such as fire in the recruitment success of sand forest species, the leached oligotrophic sands on which they grow would also certainly influence their survival strategies. We uprooted three of the *N. hildebrandtii* seedlings found at Site 3 and found that a seedling of about 30 cm in height possessed a taproot approximately three times its length (Plate 24). The occurrence of a taproot suggests that *N. hildebrandtii* is equipped to overcome moisture deficiencies in the upper profile and thus its survival

is primarily dependent on sufficient light levels. Further studies on the depth of soil moisture would be required to investigate this further.

The almost total lack of regeneration of *N. hildebrandtii* within the reserve may be cause for serious concern. I suspect that *N. hildebrandtii* is reliant on episodic recruitment events for regeneration. The lack of seedlings and the dense wood of these sand forest giants could indicate that its strategy is structural persistence (Bond & Midgley 2001; Plate 25). In other words it survives as long as possible by being resilient to damage and produces a profusion of wind-dispersed seeds every season on the chance that the conditions optimal for seed germination and seedling survival will occur in the immediate surroundings. As preliminary ageing tests indicate that *N. hildebrandtii* trees are extremely slow growing (approximately 0.25 cm/yr; D. Kirkwood, unpublished data), turnover rates are likely to be occurring in intervals of hundreds of years.

○ *Experimental plots*

These theories need to be tested experimentally in order to guide future management strategies for sand forest. One experiment would be the creation of large gaps within *N. hildebrandtii*-dominated patches of forest. The resprouting capacity of adult trees, the growth increments of all individuals, as well as the recruitment and survival of seedlings should be closely monitored over a number of years.

The impacts of browsing should also be investigated. Results from the study indicated that there are a higher number of small ungulates within the reserve than outside. The role played by small ungulates in seedling survival success and growth could be controlled for by treatments such as the erection of animal enclosure fencing within a number of some of the experimental plots. Additionally the impact of browsing on resprouting trees could also be monitored.

The effects of the burning on the recruitment success of *N. hildebrandtii* could also be tested as part of the experiment. Strong hydrophobia of soils within the forests (pers. obs.) may point to the existence of elements within the soils that inhibit seedling recruitment. These might even be a mechanism employed by a shade-intolerant 'persisting pioneer' such as *N. hildebrandtii* to prevent being overtopped by secondary plant successors. Thus burning treatments could be incorporated as part of the experiment in order to find whether soils in burnt sections are more conducive to

the establishment of seedlings than unburned sections. As experimental plots could take several years to reveal results that translate into management decisions, it is crucial that these experiments be initiated as soon as possible.

I disagree with the suggestion by Kruger *et al.* (1997) that forests dominated by sprouting trees require less conservation priority due to their ability to survive disturbance. Resprouting forests may be at more risk as most of their regenerative potential is invested in their individual structures rather than in a seedling bank safety net. Thus if they are harvested in ways that cause death, they could be lost altogether from the system. For instance, if *N. hildebrandtii* trees senesce, die and are not replaced, there are no smaller individuals to replace them. The virtual extinction in KwaZulu-Natal of the popular medicinal tree, *Warburgia salutaris* (Cunningham 2001), deemed to be a potent sprouter, is evidence of this.

❖ *C. mossambicensis*

The harvesting of *C. mossambicensis* bark for the medicinal trade appears to be resulting in high mortality rates in unprotected forest (Chapters 3 and 4). Experiments, using trees within the reserve, could be undertaken to ascertain the maximum quantity of bark that should be removed from *C. mossambicensis* after which resprouting no longer takes place. Individuals of size classes of 5-20 cm dbh in particular, should be used as these are the sizes that appear to be targeted by commercial gatherers for bark removal.

▪ **Approaches to sand forest conservation outside reserves**

Management of sand forest within reserves may be relatively simple compared to that outside the reserve. I attended a seminar in Cape Town in 1998 where Richard Leakey emphasised the crucial role played by reserves in Africa for the protection of ecosystem processes and biodiversity so rapidly disappearing at the hand of humans. He went on to say that reserves should be protected at all costs and not be made available to subsistence harvesters for utilisation. He felt that the inevitability of protected areas being transformed into oases within a desert of environmental degradation should encourage conservationists not to waste resources attempting to conserve 'doomed' communal areas. These are powerful sentiments

and are popular within some conservation circles where local inhabitants are seen as the enemy of a successful protection plan for biodiversity.

❖ *The problems*

From my experience of the social and ecological workings of Maputaland during my time there, I found its problems to be complex. A 'quick-fix' solution to conservation of sand forest outside reserves is thus unlikely to succeed. These problems appeared to at odds with the development of sustainable plan for sand forest outside reserves and they need to be understood before possible solutions can be arrived at. The following are amongst those that I found to be particularly concerning:

○ *Communal land ownership*

The first possible inhibiting factor to sustainable resource use is the communal ownership of land in Maputaland. This gives rise to the scenario where fellow community members have to compete with one another for limited communal resources. Thus an individual is disadvantaged by restricting his use of the natural resources available within his community's territory, as a fellow community member will remove them if he does not. This 'tragedy of the commons' dilemma (Hardin 1968) was played out both in the harvesting of *C. schlecteri* trees for craft manufacture as well as in the commercial gathering of medicinal plants. In the former instance, a crafter had to cut down as many trees as possible given that the resource was limited and possibly in non-renewable supply. If he did not exploit this resource, the crafters in the next stall would remove the best trees and he would lose out financially. There was thus no incentive for him to leave the trees unharvested. On the contrary, there was an urgency for him to fell as many as possible. The marked increase in the number of craft stalls, each one manufacturing the same product, indicates that competition for the resource is intense.

It would appear that the only solution for the alleviation of this problem would be for each individual to obtain a privately-owned section of land which he could manage as he felt appropriate. However, it is unlikely that the traditional

system of land tenure will be changed in the foreseeable future and thus other solutions need to be found.

○ *Consequences of poverty*

A second problem is the poverty under which most families in northern Maputaland live. High unemployment rates, poor levels of education, lack of skills training, and the loss of jobs of migrant workers from urban centres, places the onus on local resources to provide 'green security' (Cunningham & Davis 1997) to serve as a buffer against extreme poverty. The immediacy of basic survival is understandably prioritised over consideration of the needs of future generations. Traditional practices that have been undertaken sustainably for generations are becoming unsustainable with modern day population pressures.

○ *Belief systems*

The cultural and religious beliefs of the people of Maputaland and South Africa at large, coupled with the need for employment, are the potent forces driving the multi-million rand trade in medicinal plants. The need to be cleansed, protected from evil and given power (Cunningham & Davis 1997), are sought in the medicinal and magical properties of plants. Until a revolution occurs in cultural and religious beliefs, and alternative employment opportunities are found for people selling plants commercially, the exploitation of sand forest plants will be perpetuated.

○ *Poor law enforcement outside reserves*

Another problem issue is the poor law enforcement capacity within South Africa, and particularly in Maputaland where, for a host of reasons such as limited funding, staff and resources, as well as internal corruption, formal policing is restricted. Although national laws are in place to protect over-harvesting and sale of endangered species, sale and transport of large bags of plant parts takes place daily and these activities are largely unchallenged. Additionally, the trade in medicinal plants has been informally recognised by the government and markets in urban centres are encouraged. The dilemma of rural people relying on this 'green security'

to make a livelihood in a country with high unemployment rates coupled with the strong cultural and medical needs of South Africans, has possibly motivated the loosening of controls. This led Osborne *et al.* (1994) to conclude that the trade in traditional medicines poses 'an enigma of the South African situation to which it is difficult to find a solution' (Cunningham & Davis 1997).

These sentiments are echoed for all aspects of human resource use by many people in conservation circles, particularly those working on the ground close to the sobering realities of these problems. Formal conservation agencies in KwaZulu-Natal such as the NCS, are suffering major cuts in government funding which limits their capacity to develop solutions for the over-exploitation of plants outside protected areas. The reduction in funding is paradoxical given the emphasis placed by the government on the development of a thriving eco-tourism economy in South Africa. Instead, large-scale staff retrenchments are currently taking place and these, coupled with voluntary resignations, have resulted in a loss of expertise and experience from conservation organisations. Those remaining are left with a skeleton staff and limited operating budgets which restrict their capacity to take on major community conservation endeavours beyond the borders of their reserves.

- *Differing perceptions of the role of protected areas*

Also, there is a perception that harvesting of sand forest products by local people within a protected area will detract from the reserve's goals of the protection of biodiversity and maintenance of ecosystem functioning. Local people on the other hand, seem resentful of reserves from which, in many cases, they have been removed in the past. Some appear to see these protected areas as land that is rightfully theirs from which they deserve certain benefit, particularly as they are usually in marginal areas of low agricultural potential while reserves appear to have a bounty of natural resources. These disparities may be inherent (e.g. poor sandy soils around TEP) or induced (e.g. removal of antelope through hunting). This perception has been demonstrated over the past 4 years by the multiple land claims put forward by local people in their quest to win back ownership of protected areas such as Ndumo Game Reserve, TEP's neighbour to the west.

- *More economically competitive land-use alternatives*

Although Maputaland has relatively less transformed land than other parts of South Africa, unprotected areas are under increasing pressure from alternative land-use options such as forestry and mining. These possibilities are attractive to local community members who stand to gain returns for rental of their land as well as employment opportunities. Great pressure is therefore being placed on protected areas as well as on communally owned land to be economically competitive as land-use options. Thus if support for conservation is not gained by local communities and by the government, it is likely that these areas will be lost.

As I see it, these core problems will need to be addressed and overcome if a viable conservation plan is to be established for sand forest both outside and inside TEP.

❖ *The solutions*

The perception of formal conservation in South Africa has undergone a series of changes this century from a strongly preservationist approach, where local people were excluded from reserves, to the initiation of skills training and education programmes for reserve 'neighbours', to the current phase of joint participatory management involving all parties. The thinking inherent in this latter approach is for conservation and local communities to develop mutually beneficial partnerships to formulate solutions to optimally manage the environment incorporating both protected and surrounding areas. Although this type of thinking may take many more years to permeate into conservation circles across the spectrum, I do not believe it is the sole solution. The combination of all three approaches may be necessary and wisdom is required as to which are most useful under a given set of circumstances. As I see it, the key to sand forest conservation is the development of a multi-faceted regional plan that taps into all resources in the region and involves as wide a sphere of concerned and affected parties as possible.

○ *Eco-tourism*

Creative strategies that are implemented elsewhere in Southern Africa, such as the CAMPFIRE programme in Zimbabwe, can give insights into potential

solutions for Maputaland (Cunningham 2001). Although possibly not directly applicable in the South African context, the basic concept of programmes such as CAMPFIRE is that natural resources are given a monetary value to individuals within a community, over and above the value gained from them if they were used purely for subsistence purposes. This provides incentive for people to reduce subsistence use in favour of these alternative benefits.

- *Eco-tourism as an alternative land-use option*

Eco-tourism as a land-use form could provide this scenario. It is a highly preferable alternative to the more destructive options such as dune mining or forestry. Also local communities stand to benefit from developments that are established either on their own land or on land in protected areas neighbouring them. The nature of the benefit may range widely and will depend on the type of eco-tourism development that is established there. On the one end of the scale, communities could receive a community levy, generally a percentage of the tourist entry fees of a reserve (e.g. communities surrounding TEP). On the other end of the scale, a community could donate their land for the creation of a new reserve and thus be shareholders and partners in the development (e.g. proposals for the Greater St Lucia Wetland Park).

A major opportunity exists to optimise on these types of ventures, given the larger goals for the Maputaland region, which is currently being developed as an eco-tourism destination by the national government's Lebombo Spatial Development Initiative (LSDI) programme. Although most of these developments are planned for the coastal regions within the Greater St Lucia Wetland Park, which lies east of the sand forest zone, the whole region will stand to benefit from the influx of tourists to the area and increased development opportunities. The aim of this scheme is an integrated development plan between the private sector, local communities, the SDI and the NCS, whereby private sector developers are invited to set up eco-tourism ventures at certain designated sites, primarily within protected areas. Local communities have been incorporated in the development plan and those neighbouring the sites will receive a share of the income generated and will be given employment opportunities. Also, community conservation areas (CCAs) are being established (e.g. at Lake Sibaya), where communities are contributing their land to the formation of a conservation area.

Thus as owners of the land desired by tourism developers, local communities are increasingly being viewed as key role players. Far from communal ownership being part of the problem, it suddenly becomes part of the solution. A single community member could never be in a position to offer up sufficient land for a tourist development on his own, but as part of community, he can receive benefits.

In terms of the ramifications of this strategy for the conservation of sand forest, plans are underway in the area south of TEP (incorporating part of Site 2) to establish a 4000 ha reserve (Tshanini Game Reserve) which will possibly be linked to TEP in the future. This eco-tourism development involves partnerships between conservation authorities, private investors and the local community as the landowners. Conservation will gain from the increased protection afforded to sand forest, while the community will receive employment opportunities, skills training and a share in the reserve's income as shareholders. According to this study (see Chapters 3 and 4), other than species targeted for the medicinal trade, this section of sand forest did not appear to be under immediate threat and was in fact comparable in terms of species diversity and dynamic functioning to forest within TEP (Site 1). However, with human pressure mounting in other sections of sand forest (e.g. Site 3), for subsistence agriculture and the range of other uses investigated in this thesis, the protection afforded to this additional section of forest will safe-guard it against these mounting pressures.

○ *Skills development and use of local knowledge*

Other benefits to communities may be the provision of jobs and training within tourist developments. This is the case in Tembe Safaris, a private tourist lodge within TEP, where cooks and local guides from the community are trained to assist in the running of the camp. Skills training received could stand them in good stead for future employment.

Thus the expertise of local people with their vast knowledge of the bush is being recognised and channelled into an employment opportunity that will benefit all parties. Botanical experts such as Bhekazitha Gwala who assisted in this particular project, would be an invaluable asset to a tourist venture, either within TEP or in the new Tshanini Game Reserve. Guided trails where people from the community expound on the Zulu and Thonga names of sand forest species and their uses would

provide an exceptional experience for visitors to the area. At the same time, the guides themselves would benefit financially. This could not only aid in keep the rapidly dwindling local knowledge systems alive (Cunningham 1986; 1994; Mavi 1994), but it would provide local people a tangible benefit for ensuring the survival of sand forest.

For these reasons I tend to disagree with Richard's Leakey's viewpoint that local people should not be involved in conservation. On the contrary, I believe that if they are not seen as key partners in environmental conservation initiatives, and if reserves are not made more competitively viable land-use options, sand forest and existing reserves will be lost.

○ *Co-management*

Although eco-tourism is one solution, not all communal areas are viable for such enterprises. There is thus a great need for formal conservation agencies, the government, researchers and NGO's to collaborate with communities to find methods of sand forest management that will be advantageous to all involved groups. This strategy of 'co-management' has been implemented successfully in KwaZulu-Natal (e.g. Harris *et al.* 1996), the Transkei (Dr. G. Calvo-Ugarteburu pers. comm.) as well as in other parts of Africa (e.g. Baran & Tous 1999). Co-management committees should be established by the NCS in each community with delegates from all affected parties. Committee establishment could be motivated for by emphasising the goal common to all of them, namely to ensure that sand forest resources will be available at optimum levels on a permanent basis. If this goal is accomplished, all parties stand to benefit. For the conservation sector, the protection of biodiversity and ecosystem processes will be achieved. For eco-tourism developers, the maintenance of an 'unspoilt' environment in areas surrounding their reserves will create greater potential for the generation of revenue in the form of a continued influx of tourists. For the local community, plant products will be available at optimal levels for harvesting and employment opportunities will increasingly exist. These committees would initially provide a forum for 'cross-pollination' of ideas (Cunningham 1994) between all stakeholders in order to find creative solutions that can be of mutual benefit. From there, an integrated co-management strategy could be developed for sand forest in their area that would be implemented jointly.

Evidence of the potential for this type of strategy was highlighted during interactions with various sectors of the local community during my time in Maputaland. Traditional healers expressed great concern at the unsustainable harvesting practices of commercial gatherers and at the subsequent increase in rarity of many important medicinal and forest species. As a powerfully influential sector of rural societies, traditional healers share ideals of sustainable utilisation with conservation organisations, as healers stand to lose income if resources are depleted. Additionally an *induna* (headman) of one of the local communities at Site 3 expressed great concern over the influx of outsiders (particularly medicinal gatherers and people using poles for building material), into the forest under his jurisdiction and he was strongly opposed to the unlawful removal of his resources. He felt the solution would be to set up community policing patrols to protect his resources from destruction by outsiders.

○ *Training, policing, management and business development*

A range of activities could be undertaken through these co-management forums, including training, policing, resource management and business development. For instance, training workshops could be held where traditional healers and conservation officials advise commercial gatherers in their communities on techniques of sustainable harvesting to ensure their long-term employment as gatherers. In the case of *C. mossambicensis*, for example, the gatherers could be advised on amounts of bark that can be removed to allow the continued survival of these trees, based on results of research within TEP. A policing forum could be established for each community, incorporating members of the community hierarchy, *sangomas*, *inyangas* and NCS officials to ensure policies are being adhered to. This could include the development of a permit system stipulating amounts and types of plant material that may be removed. Large cultivation projects for species such as *C. mossambicensis*, *S. mitostemmatoides* and *A. natalitius* should be initiated both inside and outside reserves that would offset the over-use of indigenous plants.

Additionally, local communities could be exposed to the wide range of crafts that could be made as alternatives to bowls, which would be sustainable as a long-term employment option. For instance the sale of traditional fish traps (*isifonya*; Pooley 1980) could be a highly lucrative alternative due to their popularity with

tourists. As they are constructed of small sticks of a range of species (Pooley 1993), they are a far more sustainable alternative to bowl manufacture. Another option that is becoming increasingly popular, particularly in urban centres, is the construction of crafts from waste products such as plastic bags. Not only is the material easily accessible and does not cost anything, but crafters would also help alleviate the litter problem around local stores.

Conservation representatives on co-management committees could act as a resource to link community members to employment opportunities or training workshops for skills development. Local communities are often unaware of initiatives such as the LSDI craft training programme, cultivation courses for traditional healers such as those run by Silverglen Nursery in Durban or permaculture workshops by NGO's such as Trees for Africa or Abelimi Bhezekhaya (Farmers of the Home). Additionally, NGO's that offer training in the initiation of small business ventures for local people could be invited to train people on how to establish and run a businesses. A primary target group could be the crafters and wood sellers who are involved in exploiting sand forest products commercially in order to offset their reliance on local resources.

Continued funding for existing environmental education centres (e.g. the NCS centre neighbouring Ndumo Game Reserve) should constantly be sought. The work of highly experienced and dedicated NCS staff members to promote awareness of conservation principles to local communities and schools is invaluable for the future survival of the forest. These officials play a crucial role in providing awareness of the various problems in Maputaland and could assist in transforming people's thinking in terms of the necessity for sustainable harvesting practices and management of sand forest.

○ *Joint research and monitoring*

In terms of research, a collaborative venture could be initiated as has previously been undertaken by researchers in the area (e.g. Cunningham 1985; Kyle *et al.* 1997), where local people are employed to monitor the use or sale of various resources. A number of crafters could be employed to count the number, types and sizes of crafts sold each month over a number of years. This data would then incorporate seasonal fluctuations and could be used to obtain more accurate

predictions on the rates at which crafts are sold, and the consequent impact on the forest. A similar system may be used for wood sellers. This should be combined with monitoring of availability of the *C. schlechteri* and *N. hildebrandtii* trees by trained researchers. Management decisions could be formulated from these records. This should take place as soon as possible particularly as results from this study suggest that the use of *C. schlechteri* trees was unsustainable at 1997 use levels.

As *N. hildebrandtii* is the species most targeted for wood sales, an experiment involving local people could be undertaken within the reserve, modelled on other such studies in South Africa (e.g. Shackleton 1998). In his particular project, Shackleton established a number of permanent plots in 3 protected areas. Members of the neighbouring community were invited to enter the reserves at the end of September each year and to remove all deadwood they deemed useful as fuelwood. Amounts were weighed and the process was repeated for 3 consecutive years. The aim of the project was to ascertain the quantity of deadwood that could be produced each year. This experiment could be repeated in TEP to enable an assessment of sustainable wood removal rates if harvesting was allowed within the reserve.

Similarly, experiments to ascertain sustainable harvesting rates could be conducted within TEP, where trees are experimentally cut down and their rates of recovery monitored. Local community members, who have had years of experience of observing the effects of harvesting on trees, could be involved in the experimentation. This information could provide insights as to the development of a sustainable harvesting strategy.

○ *Project funding*

Thus there are many opportunities to improve sand forest management outside and inside reserves. In order to implement these proposals, an integrated forum would need to be set up for the development of a strategic overall plan to ensure projects are in keeping with the conservation objectives for the region. The forum would provide support and direction for the various endeavours once they have been established. It is unlikely that the NCS has adequate manpower or finances available to give full attention to the strategies I have proposed and these recommendations may therefore seem naive. It would thus be necessary for relevant staff members within the organisation to apply for funding from the government or

the private sector for the employment of a number of full-time project co-ordinators to implement these ventures. I myself am currently working on such a co-management project with subsistence fishers on the Maputaland coast. In my particular case a researcher within the NCS identified the need for the project, secured funding from an NGO for its running costs. I think this approach could be successfully applied to sand forest. A range of organisations could be approached. The government for instance, has a substantial poverty relief fund that is made available to projects that provide employment and skills training to unemployed people. Several NGO's such the Green Trust (WWFSA), fund projects aimed at community conservation initiatives. Also large corporate firms often have an environmental division and these could be approached for project funding.

▪ **And finally**

Although the solutions may be 'difficult to find' (Osborne *et al.* 1994), and this summary is an over-simplification of the issues at stake, I feel that ways forward for sand forest conservation do exist. But they need to be urgently and aggressively addressed. Implementers must seek to find the tenuous balance between too much and too little disturbance on either side of the reserve fence. If the *status quo* is allowed to continue, it is likely that sand forest in Maputaland may join the fate of other tropical dry forests worldwide and become 'of interest only to palaeoecologists' (Lerdau *et al.* 1991; Plate 26).

Plates: 24 - 26

(overleaf)



Plate 24 The lengthy tap root of a small *Newtonia hildebrandtii* seedling is evidence of the severe water limitations of its sandy environment.



Plate 25 A fallen giant. This large (110 cm dbh) senescent *N. hildebrandtii* tree was found lying on the forest floor within the reserve. Note the sturdy sprouts it has sent out from the main trunk.



Plate 26 *Newtonia hildebrandtii* forest (background) giving way to subsistence agriculture. Note the white sandy soils.

Table: 1

(overleaf)

Table 1 Distances between craft stalls measured in May 2001 on the same road surveyed in 1997. Distances are measured from the TEP gate (0 km) to Phondweni town (15.3 km) in an E-W direction. All craft stalls that were not present in 1997 are indicated as 'new'. The position of the stall selling isifonyo baskets is indicated (**).

Landmarks	Distance (km)	Kms from TEP	Stall no.	Old / new
TEP	0	0		
	4.2	4.2	1	new
	0.3	4.5	2	new
	0.3	4.8	3	new
	0.02	4.82	4	new
	0.08	4.9	5	new
	0.2	5.1	6	new
	0.3	5.4	7	new
	0.3	5.7	8	new
	0.3	6	9	new
	0.6	6.6	10	new
	0.2	6.8	11	new
Mfikini hill	1.2	8	12	old
	1	9	13	new
	0.2	9.2	14	new
	0.4	9.6	15	old
**	0.6	10.2		new
	0.4	10.6	16	old
	0.7	11.3	17	new
	0.8	12.1	18	old
	1.1	13.2	19	old
	0.1	13.3	20	old
Phondweni	2	15.3		

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- Dr Anthony Cunningham (1997): Ethnobotanist with specialisation in traditional plant use in the Tembe area of northern Maputaland.
- Dr Gugu Calvo-Ugarteburu (2001): Manager of the Coffee Bay subsistence fishing co-management project in the Eastern Cape (University of Umtata).
- Miss Kathleen G. Catapano (2002): MSc. thesis in prep: "Soil carbon isotopes and carbon cycling rates reveal history and dynamics of sand forests in Maputaland, South Africa", Dartmouth College, U.S.A.
- Mr Bhekezitha Gwala (1997/8): Local Tembe-Thonga resident of the study area and expert on traditional plant use. Assistant to Dr A. Cunningham during the fieldwork component of his DPhil conducted in northern Maputaland.
- Mr Donovan Kirkwood (2001): PhD thesis in prep: "Floristics and dynamics of sand forest in KwaZulu-Natal, South Africa", University of Cape Town, South Africa.
- Dr Scotty Kyle (2001): Regional Resource Ecologist (NCS) for the northern Maputaland Region.
- Mr Wayne Matthews (2001): Regional Ecologist (NCS) for the northern Maputaland Region.
- Mr Ferdi Myburgh (2001): Conservation manager (NCS) within the Ndumo-Tembe complex from 1991 to present.