CHAPTER 4

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

Abstract

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

Keywords

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

Introduction

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

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

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

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

Study area and general aspects of Sand Forest

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

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

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

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

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

Methods

Fieldwork

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

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

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

Data analysis

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

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

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

Classification

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

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

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

Ordinations: Tembe Elephant Park 2004 data

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

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

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

Ordinations: All data of Tembe and environs

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

Results

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

Classification

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

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

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

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

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

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

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

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

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

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

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

Ordinations

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

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

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

Discussion

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

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

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

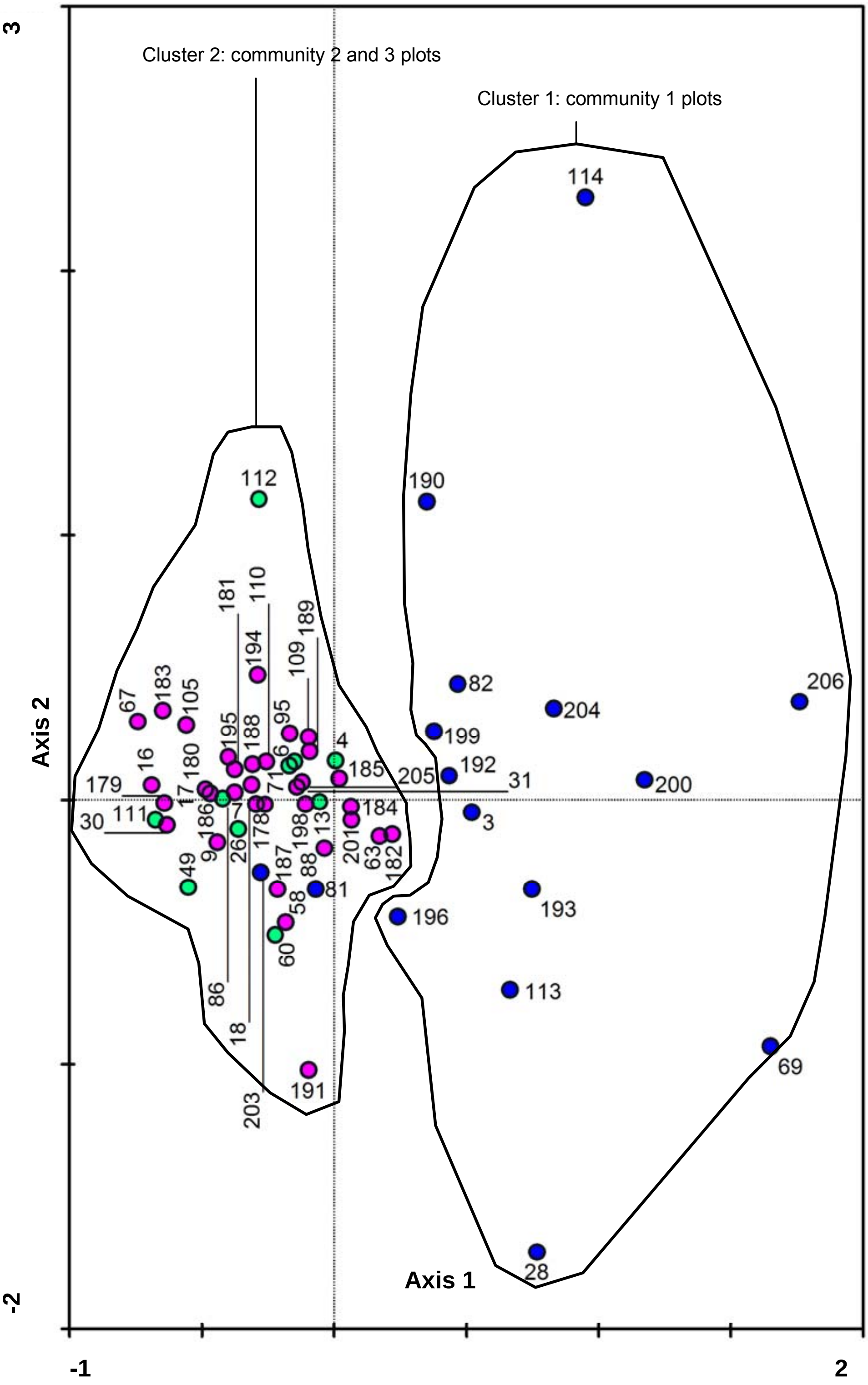

Figure 1: The graphical resolution of the correspondence analysis ordination applied on the 2004 Sand Forest woody species assemblages in Tembe Elephant Park, Maputaland, northern KwaZulu-Natal, South Africa.

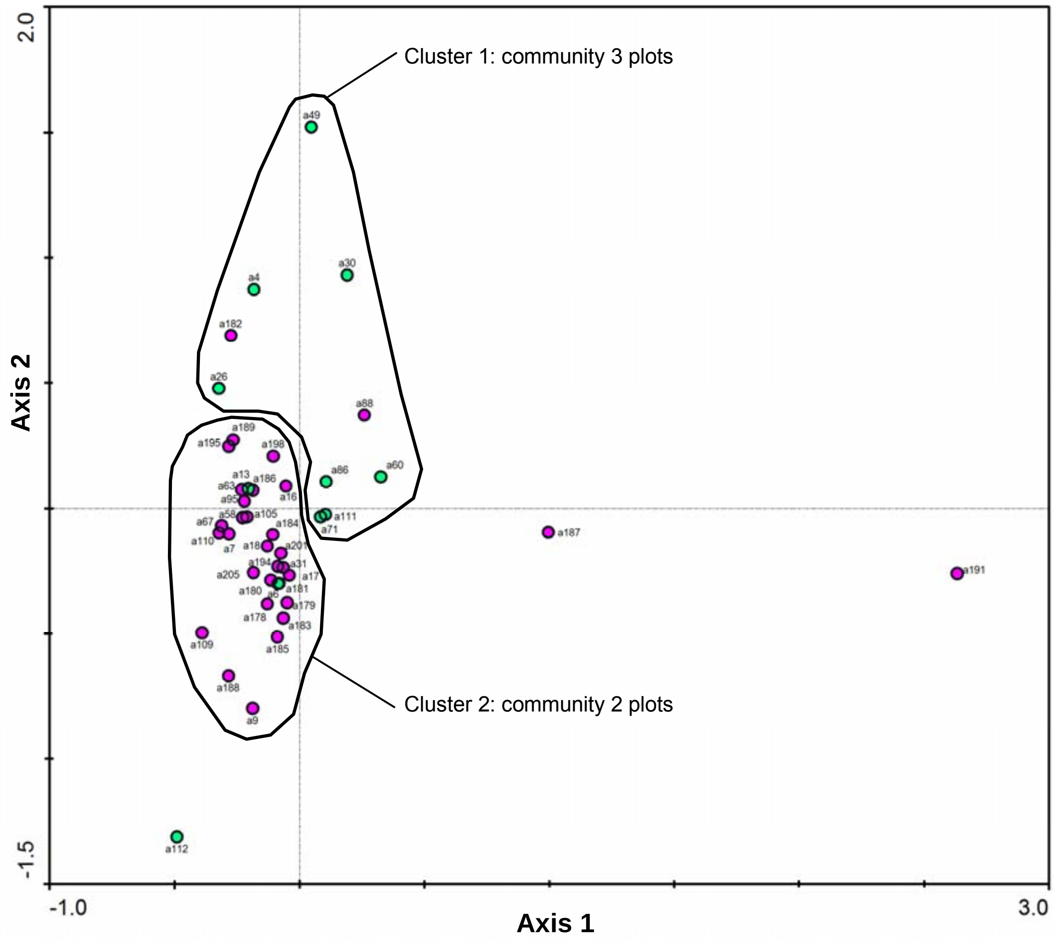

Figure 2: The graphical resolution of the correspondence analysis ordination applied on the 2004 restricted Sand Forest woody species in Tembe Elephant Park. The plots from community 1 were removed from the data for this analysis. Maputaland, northern KwaZulu-Natal, South Africa.

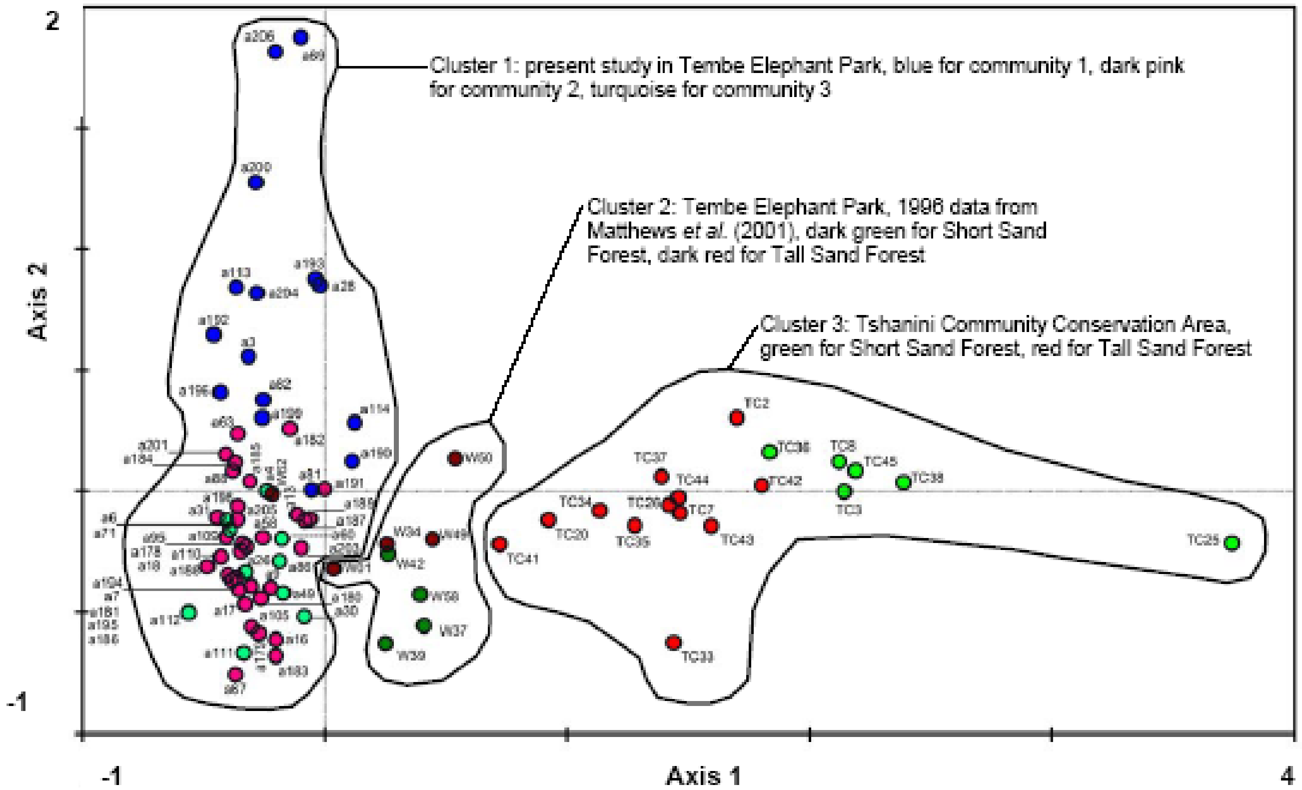

Figure 3: The graphical resolution of the correspondence analysis ordination applied on Sand Forest woody species, for the present study data set (plot number preceded by "a"), the data set from Matthews *et al.* (2001) (plot number preceded by "W") and the data set from Gaugris *et al.* (2004) (plot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

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

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

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

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

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

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

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

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

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

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

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

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

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

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