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An ecological evaluation of the sustainability of bark harvesting of medicinal plant species in the Venda region, Limpopo province, South Africa

by

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Submitted in fulfillment of the requirements for the degree

Philosophiae Doctor

In the Faculty of Natural and Agricultural Sciences

Department of Plant Science

University of Pretoria

Pretoria

Supervisor: Prof. M.W. van Rooyen

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Dedication

This work is dedicated to my biological parents, Tshamano Sarah and the late Maanda Andries Tshisikhawe.

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DECLARATION

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

SIGNATURE:………………………………………………….

DATE:…………………………………………………………

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ABSTRACT

An ecological evaluation of the sustainability of bark harvesting of medicinal plant species in the Venda region, Limpopo province, South Africa

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Milingoni Peter Tshisikhawe

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The study evaluated the extent and threat of bark harvesting of plant species for medicinal purposes in the Venda region and investigated possibilities of the sustainability of these practices. Approximately 30% of the woody plant species in Venda were found to have medicinal properties in their bark, but only about 12% of these species are commonly traded in muthi shops in the region. Fifty-eight medicinal plant species are commonly harvested for medicinal properties in their bark and found in muthi shops in the region. These 58 species were scored for the possible threat of bark harvesting to the species' survival using 20 ecologically relevant plant population traits. The most vulnerable species were *Adansonia digitata, Adenia spinosa, Albizia adianthifolia, Albizia versicolor, Brackenridgea zanguebarica, Croton megalobotrys,* and *Warburgia salutaris.* Of these species *Brackenridgea*

zanguebarica and *Warburgia salutaris* are amongst the ten most traded medicinal plant species in Venda region.

Elaeodendron transvaalense and *Brackenridgea zanguebarica*, the two species investigated in detail in this study, were amongst the most commonly traded medicinal plant species in Venda region. Analysis of size class distributions showed that both species had growing and healthy populations, exhibiting J-shaped population curves, centroids left-skewed from the midpoint of the size class distribution, and a fine-grained status. However, size-class distributions in both species revealed certain classes that needed monitoring since they were negatively affected by bark harvesting. Adult individuals of *B. zanguebarica* showed a high degree of bark regeneration as a response to bark removal from medicine men. The crown health status of *E. transvaalense* was generally good although some individuals, contributing 9% of the sample, had dead crowns. A linear relationship was noticed between areas harvested and stem circumference, which is understandable considering the large surface area of harvestable bark on bigger individuals. Matrix modeling of *E. transvaalense* revealed that the vegetative stage should be targeted for management action.

An assessment of the adequacy of the Brackenridgea Nature Reserve, an initiative aimed at protecting *Brackenridgea zanguebarica,* revealed that the reserve size is not enough for conservation of a viable population. The method flagged out potential growth habitat for *B. zanguebarica* around the current reserve, which could be incorporated to enlarge the conservation area, which could be incorporated to enlarge the conservation area. Four different scenarios were analysed on how best to conserve the species. Assuming a 50% reduction in human-related activities, such as cultivation, harvesting and livestock grazing, it is recommended that the reserve be enlarged from its current 110 ha to 366 ha to maintain a viable population into the future.

Finally, the study recommended the adoption of an integrated approach to achieve sustainability of bark harvesting in the Venda region. Only by selecting best practices from both indigenous and conventional conservation techniques will the conservation of natural resources that are of important to local communities, be successful. An action plan that will involve the formation of an association by all stakeholders interested in the sustainable utilization of natural resources must be developed. The association must be governed by a constitution with a clear mission statement and the harvesting of natural resources should be done in line with a collection policy.

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CHAPTER 1

INTRODUCTION

1.1 Thematic background

Sustainable use of the vegetation, both extractive and non-extractive, is a dynamic process towards which one strives in order to maintain biodiversity and to enhance ecological and socio-economic services, recognizing that the greater the equity and degree of participation in governance, the greater the likelihood is of achieving these objectives for present and future generations (IUCN 2001). The sustainable use of a natural resource will be determined, to a large extent by the interaction between biological, social and economic factors.

Dzerefos and Witkowski (2001) define sustainable harvesting of natural resources as the removal of a natural resource without depleting it or compromising its ability to regenerate. Sustainable harvesting of medicinal resources is critical to the survival of indigenous forests (Hartshorn 1995, Obiri *et al.* 2002, Hamilton 2003, Shukla and Gardner 2006, Bhattarai *et al.* 2010, Njoroge *et al.* 2010). Quantifying levels of sustainable harvesting requires planning and monitoring (Laurance 1999, Obiri *et al.* 2002). It is therefore important for conservation authorities to take the initiative to form partnerships with local people and to promote a sense of ownership rather than exclusion from protected areas (Dzerefos and Witkowski 2001). It is also emphasized that adjusting the harvestable size-class intervals according to the size of the mature tree is necessary to avoid recommending the use of particularly those naturally small tree species that may be currently harvested (Obiri *et al*. 2002).

The high number of plant species that are used for medicinal purposes should be acknowledged, with approximately 28% (between 50 000 and 80 000) of plant species worldwide reported to have ethnomedicinal use (Farnsworth and Soejarto 1991, Van Seters 1995, Louhaichi *et al*. 2011). These plant species are being used in various human cultures around the world for medicinal purposes and many of them are subjected to uncontrolled local and external trade. The contribution of unsustainable harvesting to annual extinction rate is indeed a matter of great concern as it could imply the loss of potential drugs against incurable conditions such as dementia, cancer, influenza or AIDS (Rates 2001, Gurib-Fakim 2006, McChesney *et al.* 2007).

According to Van Eck *et al.* (1997), people living in rural areas have learned through many years of experience to use natural resources sustainably. It has also been found that throughout Africa the gathering of medicinal plants was traditionally restricted to traditional medical practitioners. However, due to a number of factors traditional medical practitioners currently also involve the services of their trainees or middlemen in the collection of medicinal material.

According to Hartshorn (1995) and Boudreau *et al.* (2005), modern forest management systems are intended to focus on balancing the needs of users against the regeneration ecology and growth or supply of the resource base to ensure the sustainable use and conservation of forest resources. To develop optimum harvesting systems it is essential to understand the effects of harvesting on the composition and structure of the residual population, which is the base of the natural resource. It is against this background that even in harvesting of medicinal plants the balance between supply and demand needs to be maintained. The ecosystem needs to be maintained through monitoring of populations if the subsistence of people's activities is to be achieved.

Currently, in most African forests subsistence harvesting of natural resources is not effectively managed and unsustainable harvesting rates are defined by various factors such as short-term needs of consumers, power of traditional authorities, size of the consumer community, availability of suitable tree stem sizes, and forest size and accessibility (Oates 1999, Boudreau *et al.* 2005).

1.2 Problem statement and rationale for the study

For any resource, a relationship exists between resource capital, i.e. the resource population size, and the sustainable rate of harvest (Boudreau *et al.* 2005, Stewart 2009). Sustainable harvesting of medicinal resources can be achieved if people only harvest what they need for treatment. The impact of gathering medicinal material on the plant population is also influenced by factors such as the part of the plant harvested, with root and bark harvesting being the most harmful forms of harvesting (Williams *et al.* 2007). It is also influenced by factors such as frequency of harvesting, time or season of harvesting in relation to the developmental stage of the plant.

The high percentage of indigenous medicinal plant material traded in the Venda region in the form of roots and bark is a cause for concern, because these forms of harvesting have the largest negative effect on the plant. Sixty one percent of the medicinal plant material traded in the Venda region is in the form of roots, while bark material contributes 15 percent, with 22 percent of whole plants and 2% for leaves and fruits (Tshisikhawe 2002).

The bark of many different forest and woodland tree species in the Venda region are used, although a relatively small number are in high demand and intensively used (Tshisikhawe 2002). Intense and frequent harvesting of the bark from species with a high market demand often results in ring-barking of trees. The trees subsequently die, and the species become rare over time. This practice is obviously unsustainable and will almost certainly result in the extinction of many forest and woodland tree species (Diederichs *et al.* 2002). The trend towards increased commercialization of medicinal plants in South Africa has compounded the problem and resulted in overharvesting and in some cases near-extinction of some valued indigenous species (Newton and Vaughan 1996, Williams *et al.* 2000, Tshisikhawe 2002, Botha *et al.* 2004a, 2004b).

Elaeodendron transvaalense Jacq. and *Brackenridgea zanguebarica* Oliv. are some of the medicinal plant species that are facing a serious threat of extirpation in the Venda region. These species are amongst some of the medicinal plant species commonly traded in Venda muthi shops (Tshisikhawe 2002). In both species the bark from the stem as well as the roots are preferred and harvested for medicinal purposes.

Elaeodendron transvaalense is a medicinal plant that is used in the treatment of a number of ailments. Among its many uses the species is used in the treatment of any stomach disorder in a patient (Mabogo 1990, Tshisikhawe 2002). It is often believed that its application can be helpful in cleaning the blood of a patient from any foreign material. Traditional healers therefore refer to the species as "mukuvhazwivhi" which when literally translated means "sin-washer" because of its ability of cleaning any foreign material that may be in the patient's blood system (Mabogo 1990, Tshisikhawe 2002). When a species such as *E. transvaalense*, is used as a generalist its many uses force collectors to collect its medicinal material in bulk, which can put the species under severe threat of overexploitation and consequently local extinction.

Brackenridgea zanguebarica, which is only found in the Thengwe area of Limpopo province (Palgrave 1988, Raimondo *et al.* 2009) is also a very important medicinal plant species in South Africa as a whole (Van Wyk *et al.* 1997, Tshisikhawe 2002). Records on its collection from the Thengwe tribal authority indicate that the plant is collected by users who come from as far as KwaZulu-Natal (Tshisikhawe 2002). Its uses are mainly magical, although it can also be used for a number of medical conditions such as treatment of wounds, worms, amenorrhea, swollen ankles and aching hands (Tshisikhawe 2002). In Venda the plant is commonly known as 'mutavhatsindi'. The name implies that the plant is a property of the 'Vhatavhatsindi' clan found within the Vhavenda tribe. They believe it is their sole responsibility to protect the plant, which they regard as a present from God (Ramaliba pers comm.[1]).

[1] Ramaliba, Traditional Healer, Thohoyandou, South Africa, Communication 2007

Williams (1996) has recorded the plant in the Witwatersrand muthi trade where it was only referred to as 'hlabasindi'. Muthi traders in Witwatersrand have ranked the plant species second to *Siphonochilus aethiopicus* 'isiPhephetho' in terms of scarcity.

1.3 Study aim and objectives

The aim of this study was firstly to evaluate the extent, severity and threat of bark harvesting on plant species in the Venda region. Thereafter the study focused on two species, viz. *Elaeodendron transvaalense* and *Brackenridgea zanguebarica*, and assessed the impact caused by harvesting medicinal material on the population of these two species. These two species were selected because, in spite of both having their bark harvested for medicinal purposes, there are many underlying differences. Although *Elaeodendron transvaalense* is not common it has a wide distribution. It is regarded as a generalist with many medicinal uses. Furthermore, it occurs in areas where there is open access to these plants and harvesting is not controlled. In contrast, *Brackenridgea zanguebarica* has a very restricted distribution in South Africa and it is classified as Critically Endangered in South Africa (Raimondo *et al.* 2009). Furthermore, it has more specific uses and harvesting is controlled by strict measures.

The project aimed to answer the following questions:

i. What is the overall state of bark harvesting in the Venda region?
ii. Is sustainable harvesting of *E. transvaalense* and *B. zanguebarica* achievable considering the harvesting pattern?
iii. How can sustainable bark harvesting of indigenous plants be achieved or maintained?

iv. Is the size of the Brackenridgea Nature Reserve large enough to adequately conserve the species?

v. What recommendations can be proposed on the integrated management of these two species in the Venda region?

To answer the key questions the following objectives were set:

i. to estimate the extent of bark harvesting for medicinal purposes in the Venda region,
ii. to determine the vulnerability of species commonly used for bark harvesting in the Venda region,
iii. to determine the size class distribution of the two species and size classes targeted for harvesting,
iv. to use sensitivity analysis from matrix model to establish the key life-history stages, which are in most need of conservation measures, of *Elaeodendron transvaalense*,
v. to investigate the adequacy of the Brackenridge Nature Reserve for the conservation of *B. zanguebarica*,
vi. to compare current with past harvesting in the Brackenridge Nature Reserve and recommend better management approach.

1.4 Structure of the dissertation

The dissertation starts with a general introduction in Chapter 1, and literature review in Chapter 2. The study area, as well as materials and methods are covered in Chapter 3. Chapters 4 to 7, which are to be submitted for publication in various scientific journals, present the results and discussion of the investigation. Chapter 4 evaluates the overall extent and threat of bark harvesting in the Venda region and the effects of trade in medicinal plant species in the region. Chapter 5 and Chapter 6 investigate the population biology of *Elaeodendron transvaalense* and *Brackenridgea zanguebarica* respectively. Chapter 7 evaluates the conservation efforts of *Brackenridgea zanguebarica* in the Brackenridgea Nature Reserve. A general synthesis with management recommendations is provided in Chapter 8. Finally, all the references cited in the dissertation were compiled in one chapter (Chapter 9). The main body of this dissertation is presented in the form of papers and therefore each chapter has been prepared as a free-standing unit. As a consequence, it is inevitable that there will be some repetition between chapters.

References

BHATTARAI, S., CHAUDHARY, R.P., QUAVE, C.L. AND TAYLOR, R.S.I. 2010. The use of medicinal plants in the trans-Himalayan arid zone of Mustang District, Nepal. *Journal of Ethnobiology and Ethnomedicine* **6: 14-24.**

BOTHA, J., WITKOWSKI, E.T.F. AND SHACKLETON, C.M. 2004a. Market profiles and trade in medicinal plants in the Lowveld, South Africa. *Environmental Conservation* **31: 38-46**.

BOTHA, J., WITKOWSKI, E.T.F., AND SHACKLETON, C.M. 2004b. The impact of commercial harvesting on *Warburgia salutaris* ('pepper-bark tree') in Mpumalanga, South Africa. *Biodiversity and Conservation* **13: 1675-1698.**

BOUDREAU, S., LAWES, M.J., PIPER, S.E. AND PHADIMA, L.J. 2005. Subsistence harvesting of pole-size understorey species from Ongoye Forest Reserve, South Africa: Species preference, harvest intensity, and social correlates. *Forest Ecology and Management* **216: 149-165.**

DIEDERICHS, N., GELDENHUYS, C. AND MITCHELL, D. 2002. The first legal harvesters of protected medicinal plants in South Africa. *Science in Africa: Africa's first on-line science magazine*. November 2002.

DZEREFOS, C.M. AND WITKOWSKI, E.T.F. 2001. Density and potential utilization of medicinal grassland plants from Abe Bailey Nature Reserve, South Africa. *Biodiversity and Conservation* **10: 1875-1896.**

FARNSWORTH, N.R. AND SOEJARTO, D.D. 1991. Global importance of medicinal plants. In: Akerele, O., Heywood, V. and Synge, H. (Eds.) Conservation of medicinal plants, pp. 25-42. Cambridge University Press, Cambridge.

GURIB-FAKIM, A. 2006. Medicinal Plants: Traditions of yesterday and drugs of tomorrow. *Molecular Aspects of Medicines* **27: 1-93.**

HAMILTON, A. 2003. Medicinal plants and conservation: issues and approaches. Paper presented to International Plants Conservation Unit, World Wide Wildlife Foundation, UK.

HARTSHORN, G.S. 1995. Ecological basis for sustainable development in Tropical forests. *Annual Review of Ecology and Systematics* **26: 155-175.**

IUCN. 2001. Analytic framework for assessing factors that influence sustainability of uses of wild living natural resources. Technical Advisory Committee. IUCN SSC Sustainable Use Specialist Group.

LAURANCE, W.F. 1999. Reflections on the tropical deforestation crisis. *Biological Conservation* **91:109-117.**

LOUHAICHI, M., SALKINI, A.K., ESTITA, H.E. AND BELKHIR, S. 2011. Initial assessment of medicinal plants across the Libyan Mediterranean coast. *Advances in Environmental Biology***5: 359-370.**

MABOGO, D.E.N. 1990. The ethnobotany of the Vhavenda. Master of Science dissertation, University of Pretoria, Pretoria, South Africa.

McCHESNEY, J.D., VENKATARAMAN, S.K. AND HENRI, J.T. 2007. Plant natural products: Back to the future or into extinction? *Phytochemistry* **68:2015-2022.**

NEWTON, D.J. AND VAUGHAN, H. 1996. South Africa's *Aloe ferox* plant, parts and derivatives industry. TRAFFIC East/Southern Africa Publishers. Johannesburg, South Africa.

NJOROGE, G.N., KAIBUI, I.M., NJENGA, P.K. AND ODHIAMBO, P.O. 2010. Utilization of priority medicinal plants and local people's knowledge on their conservation status in arid lands of Kenya (Muringi District). *Journal of Ethnobiology and Ethnomedicine* **6: 22-29**.

OATES, J.F. 1999. Myth and Reality in the Rainforest - How Conservation Strategies are Failing in West Africa. University of California Press, Berkeley.

OBIRI, J., LAWES, M. AND MUKOLWE, M. 2002. The dynamics and sustainable use of high-value tree species of the coastal Pondoland forests of the Eastern Cape Province, South Africa. *Forest Ecology and Management* **166: 131-148.**

PALGRAVE, K.C. 1988. Trees of Southern Africa. 4th edition. Struik Publishers. Cape Town, South Africa.

RAIMONDO, D., VON STADEN, L., FODEN, W., VICTOR, J.E., HELME, N.A., TURNER, R.C., KAMUNDI, D.A. AND MANYAMA, P.A. 2009. Red list of South African Plants. *Strelitzia* **25.** South African National Biodiversity Institute, Pretoria.

RATES, S.M.K. 2001. Plants as source of drugs. *Toxicon* **39: 603-613.**

SHUKLA, S. AND GARDNER, J. 2006. Local knowledge in community-based approaches to medicinal plant conservation: lessons from India. *Journal of Ethnobiology and Ethnomedicine* **2: 20-24**.

STEWART, K. 2009. Effects of bark harvest and other human activity on populations of African cherry *(Prunus africana)* on Mount Oku, Cameroon. *Forest Ecology and Management* **258: 1121-1128.**

TSHISIKHAWE, M.P. 2002. Trade of indigenous medicinal plants in the Northern Province, Venda region: their ethnobotanical importance and sustainable use. Master of Science dissertation, University of Venda, Thohoyandou, South Africa.

VAN ECK, H., HAM, C. AND VAN WYK, G. 1997. Survey of indigenous tree uses and preferences in the Eastern Cape Province. *Southern African Forestry Journal* **180: 61-64.**

VAN SETERS, A.P. 1995. Forest based medicines in traditional and cosmopolitan health care. Rainforest Medical Foundation, The Netherlands.

VAN WYK, B.E., VAN OUDTSHOORN, B. AND GERICKE, N. 1997. Medicinal plants of South Africa. Briza Publications, Pretoria, South Africa.

WILLIAMS, V.L. 1996. The Witwatersrand muthi trade. *Veld and Flora* **3: 12-14.**

WILLIAMS, V.L., BALKWILL, K. AND WITKOWSKI, E.T.F. 2000. Unraveling the commercial market for medicinal plants and plant parts on the Witwatersrand, South Africa. *Economic Botany* **54: 310-327.**

WILLIAMS, V.L., WITKOWSKI, E.T.F. AND BALKWILL, K. 2007. The relationship between bark thickness and diameter at breast height for six tree species used medicinally for bark in South Africa. *South African Journal of Botany* **73: 449-465.**

CHAPTER 2

LITERATURE REVIEW

2.1 Historical development and current state of medicinal plant use

Traditional medicine derived from indigenous plants has always played a role in the healthcare of indigenous people of Africa and in particular of South Africa (World Health Organization 2002, Tabuti *et al.* 2003). It continues to play an important role in the health of the Vhavenda people. The utilization of indigenous plants for medicinal purposes has many facets, which have developed with the advancement of mankind over the years.

Howell and Mesher (1997) argue that our ancestors developed an elaborate set of unwritten rules about how people can interact with their land. These rules were taught from an early age as part of storytelling. The most important rules have to do with the scale of harvesting natural resources. People were taught to only take what they needed. Unnecessary harm of any living creature would bring swift chastisement. Everyone was therefore brought up with this code of ethics instilled into them from infancy. This kind of practice reflected a very strong conservation ethic.

Tree resources, like any other natural resource, have always been used by indigenous people. According to Mabogo (1990) plants have been used by the Vhavenda people as a source of food and beverages, oils, polishes and dyes, medicines, firewood, crafts, rustic work and construction of huts and kraals. Vhavenda people harvested a considerable amount of medicines from the forest. They used these medicines to treat themselves relatively free of charge, although some patients were required to pay varying amounts in the form of livestock, grain or money. Some medicines were exchanged for other valuable articles or other medicines, especially with people from other parts of the country where such medicines were unavailable or unknown.

Von Malitz and Shackleton (2004) argue that historical information, as indicated by the persistence of many customary practices for the management of natural resources today, suggests that the systems incorporating local codified rules, taboos and norms were used in part to govern the use of forest and woodland resources from the earliest time. The chiefs and tribal authorities were generally responsible for setting and enforcing resource controls and regulations. Chieftancies were powerful institutions that were respected and obeyed by local people, and had absolute authority. According to Williams *et al.* (2000), strict customary conservation practices which regulated plant collection times and quantities were respected and adhered to. However, the demand for medicinal plant material has increased with the advent of urbanization and the consequent commercialization of traditional health care.

In the past, harvesting of medicinal plants was an activity for the traditional medical practitioners. Religious beliefs and norms instituted by, for example, local traditional healers also influenced resource use. The importance of these norms is corroborated by Mabogo (1990) who indicated that in Venda, taboos and superstitions that existed around certain plant species prevented them from being overexploited. For instance, the collection of medicinal material from *Brackenridgea zanguebarica* has to be done by a naked person. Some forests were also proclaimed as sacred and entrance is reserved to people from a specific clan. Sacred forests were surrounded by myths, which made it difficult for people from other clans to utilize their resources. Even the collection of commodities such as firewood and fruits were prohibited from sacred forest sites.

Currently, because of the expanding trade in medicinal plant products people who may not necessarily be traditional healers are also involved in harvesting of medicinal material (Tshisikhawe 2002, Botha *et al.* 2004a, 2004b). In most cases these commercial traders of indigenous medicinal material are not familiar with the rituals associated with the collection of such material. Engaging middlemen in the collection of medicinal material poses a serious threat of overexploitation to medicinal plant species.

Harvesting of medicinal material has therefore become a domain of untrained, and often indifferent, commercial gatherers who do not have other sources of income. In some cases medicinal plant material is harvested and transported to urban areas for trade. Harvesting of medicinal plants for trade in order to meet the urban demand is an environmentally destructive activity (Williams *et al.* 2000). According to Kohira and Ninomiya (2003), such socioeconomic activities cause large tracts of primary forest to become degraded and fragmented. Patches of remaining forests inevitably become small and their future uncertain as a result of such socioeconomically driven reasons. The tree communities in those remnant patches are likely to suffer greater ecological stresses and ultimately contain species that decline for reasons other than natural forest dynamics (Kohira and Ninomiya 2003).

2.2 The concept of sustainable use

The Chiang Mai Declaration of 1988played a major role in acknowledging the use of medicinal plant material in the health care of the majority of the population in most developing countries. It also noted that the loss of certain medicinal plant species and reduced supply of other important plant species through unsustainable harvesting would have a direct impact on human health and wellbeing (Bodeker 1995). There is no question that unsustainable extraction methods, involving excessive debarking or the felling of entire trees, are currently threatening plant species and indigenous forests (Cunningham and Mbenkum 1993, Hartshorn 1995, Hamilton 2003, Lawes *et al.* 2004, Njoroge *et al.* 2010). This is ascribed to the fact that the demand has become so high that these unfavourable practices are becoming common. The increase in demand is partly due to an increase in trade of medicinal plant materials.

According to Robinson (1993), the specific objectives of the World Conservation Strategy are to maintain ecological processes and life support systems, to support biological diversity, and to ensure that the use of natural resources is sustainable. The focus is therefore on the natural environment and human dependence on our environment. The World Conservation Strategy therefore promulgated the concept of conservation through sustainable development and explicitly recognizes the sustainable concept (Heywood and Iriondo 2003, Abensperg-Traun 2009, Jackson and Kennedy 2009). Sustainable development being defined as ‘development that meets the needs of the present without compromising the ability of future generations to meet their own needs (World Commission on Environment and Development 1987).

The Convention on Biological Diversity (CBD) also stipulates three broad objectives which are to conserve and sustainably use biological diversity while fairly and equitably sharing the benefits that accrue from the use of its genetic resources (Puppim de Oliveira *et al.* 2011). Throughout its history the CBD has provided quantifiable and intrinsic values, benefits and services upon which human societies depend materially, culturally, aesthetically and spiritually (Harrop and Pritchard 2011).

South Africa has more than 3 000 medicinal plant species (Dladla 2001). The demand for muthi is likely to increase and exceed supply because of population growth and the increasing level of urbanization since most urban dwellers rely on muthi markets for their indigenous medicinal materials. Furthermore, trade in traditional herbs and medicine is booming as many unemployed people turn to the selling of muthi for their livelihood (Williams *et al.* 2007). The boom in muthi trade is aided by the fact that approximately 80 percent of South Africans rely on traditional healing (Steenkamp 2003, Van Staden 2008, Williams *et al.* 2007).

In African countries with high rural population densities and small cities, the gathering of medicinal plant products is expected to be small scale but with a high frequency, and where a species is popular and supplies are low due to habitat destruction and agricultural expansion, the tree will suffer a "death of thousand cuts" rather than once-off ring-barking due to commercial harvesting.

Sustainability is seen, not as a fixed ideal state or an end point, but as a process of attempting to improve the management of systems through learning, understanding and better use of knowledge (Marschke and Berkes 2005). In understanding sustainability it is therefore also important to understand the ecological processes that take place in a forest such as gap dynamics, dispersal and regeneration. These ecological processes are influenced by a numbers of factors that in turn can also be influenced by human activities. The use of resources should be in such a way that allows stable harvest rates into perpetuity (Etnier 2007). In wooded environments the unwanted eco-impacts on natural resources may also include exploitation of trees for fuel wood (Kuniyal 2002). Moreover, the factors affecting ecological processes in forest ecosystems are not static but fluctuate in space and time, thereby contributing to a unique biodiversity (Osho 1996, Kohira and Ninomiya 2003).

2.3 Size-class distribution

The first step in developing sustainable harvesting strategies is to gain an understanding of the population structure of the species (Everard *et al.* 1994, Obiri *et al*. 2002, Lawes and Obiri 2003, Gaugris and Van Rooyen 2007). It is therefore important to understand the life span and life history strategies of a species before subjecting the population to modelling techniques. A tree's life history strategies provide critical information for understanding its population dynamics and for estimating the regeneration cycle and turnover in a forest ecosystem. In general, the population growth rate of woody plants depends more heavily on the survival of adult individuals than on fecundity or growth (Kurokawa *et al.* 2003). Information on how a plant population is regenerating gives valuable data for resource management purposes and is widely used in planning for sustainable management.

Size-class distributions are commonly used as a tool for understanding plant population dynamics for trees (Lykke 1998, Condit *et al.* 1998, Niklas *et al.* 2003a, 2003b). To compile a size-class distribution of a population, individuals within a sample population are grouped into size classes based on stem diameter, stem circumference or stem length. Size-class distributions are regarded as a way of understanding plant population structure as well as the stability in the population (Cunningham 2001, Shaukat *et al.* 2012). The size class distribution reflects the reproductive capacity, the recruitment of new individuals (relative to mortality rate) into the population, the chance of plants in one size class surviving into the next size class as well as the prevalence of disturbance regimes (Shaukat *et al.* 2012).

2.4 Matrix modeling

According to the IUCN (2001) the use of natural resources is a part of human nature. Making use sustainable on the other hand is controversial and a challenge, and requires forms of control and regulations. One popular approach to managing the use of natural resources involves combining the efforts of local communities and management institutions to create models that not only guarantee the continued existence of these resources, but also satisfy the food and income requirements of the communities.

Matrix population models have become popular and powerful tools for investigating the dynamics of age or stage-structured populations (Caswell 2001, Oli 2003). Not only are these models valuable as a tool for basic ecological research but they have gained acceptance and popularity with increasing applications in wildlife management and conservation biology (Link and Doherty 2002, Crone *et al.* 2011). Caswell (2001) has indicated that matrix population models provide linkages between the individual and the population as a whole. The link is built around a simple description of a life cycle. It is therefore important to acknowledge that individual organisms are born, grow, mature, reproduce and die. Each event is however surrounded by risks, which are influenced by the environment in which the individuals find themselves.

With the aid of these models it can be determined whether and at what level a species can be harvested sustainably (Pfab and Scholes 2004, Ndangalasi 2007). By subjecting the matrix to sensitivity and elasticity analysis they can indicate the relative importance of different transitions for maintaining population growth rate (De Kroon *et al.* 2000). Elasticity analysis isolates those matrix elements or life history processes that are most sensitive to change whereas sensitivity analysis is regarded as a scenario testing of those sensitive life history processes (Desmet *et al.* 1996).

According to Jensen (1995) the matrix model was initially developed by Lewis in 1942 and improved upon by Leslie 1945 and furthermore in 1948, to describe changes in population age structure over time. The earliest matrix models (Lebreton 2005) consider a discrete time step and age classes covering intervals equal to the time step (Lebreton 2005). Leslie modified his matrix model to describe population growth in a limited environment (Pykh and Efremova 2000). However, the Leslie matrix model has been of limited use in ecology because it models exponential population growth. Since then, several density-dependent matrix models have been developed (Jensen

1995, Zhao *et al.* 2005, Namaalwa *et al.* 2005). However, these density-dependent models are complex and require detailed knowledge of the species concerned.

According to Loibel *et al.* (2006), modeling techniques are important in population studies because of mainly two reasons. Firstly, modeling is an important tool in trying to understand how environmental uncertainties affect the population growth. Secondly, the models can be used to forecast the population's behaviour as well as to estimate their extinction risk and other statistics connected with the population extinction. A picture of what future generations may look like may be obtained by multiplying the probability matrix by the present state of the population. Matrix modeling can therefore give an idea as to whether the population is growing or declining. It outlines how different life aspects of the life cycle interact. Through experimental manipulation matrix models can help in examining the 'what if scenarios' outside the ranges of observed conditions (Crone *et al.* 2011).

The use of matrix modeling systems in plant ecology is often based on short-term data which are limited in developing an understanding long-term stochastic population dynamics. The use of long-term data (e.g. 20 years of data) is regarded as a strength in stochastic matrix modeling (Pfab and Scholes 2004). It may also require a lot of computation time in cases where detailed physiological processes are simulated (Porte and Bartelink 2002, Crone *et al.* 2011). In South Africa matrix modeling has not often been used to investigate the sustainability of harvesting a particular species. It has been used in assessing the sustainable harvesting of *Sclerocarya birrea* fruits and also in the population dynamics of *Pterocarpus angolensis* (Desmet *et al.* 1996, Emanuel *et al.* 2005). However, in the case of *Sclerocarya birrea* fruits, management of other uses within the broader landscape was found to be important in maintaining yields of fruit harvesting. In their study on *Pterocarpus angolensis* Desmet *et al*. (1996) found that the most important requirement for the survival of these populations was the continued presence of mature, reproductive individuals. These were the very size classes being targeted for felling.

Wiegand *et al.* (1999) observed that understanding the population dynamics of a long-lived species is enhanced by an integrated approach of field studies and modeling. None of these approaches can provide a complete view on its own however; they can mutually promote each other's findings. Population matrix models take advantage of the fact that the life cycle of any tree species can be divided into a few stage classes and the associated probability of moving from one stage class to the next (Cunningham 2001).

2.5 Plant conservation target areas

Sustainability of natural resources use is part of sustainable management which is seen as an elusive goal of conservation. In implementing an effective conservation plan which should lead to sustainable management much effort should be devoted to resolving the scientific, technical, sociological and economic issues (Heywood and Iriondo 2003). The protection of biodiversity, particularly of vascular plant species should be done through adequate reserve systems. Such reserve systems should consider viable population of all species throughout their natural range (Burgman *et al.* 2001).

One of the central issues in conservation science is to determine how much needs to be protected (Poiani *et al.* 2000, Sanderson *et al.* 2002, Svancara *et al.* 2005, Tear *et al*. 2005). Many methods have been proposed to answer this question, but no universally accepted method has yet been developed. The method for setting conservation targets for any plant species developed by Burgman *et al.* (2001) may be particularly useful when there are insufficient data or time to conduct a formal population viability analysis. In this method the regional targets are used to assess the effectiveness of current conservation areas and development of new conservation management plans (Gaugris and Van Rooyen 2010). The method has only been applied once in a South African setting (Gaugris and Van Rooyen 2010). Setting of targets may help a great deal in conservation efforts of species to achieve viable populations.

References

ABENSPERG-TRAUN, M. 2009.*CITES,* sustainable use of wild species and incentive-driven conservation in developing countries, with an emphasis on southern Africa. *Biological Conservation* **142: 948-963.**

BODEKER, G.C. 1995. Introduction: Medicinal plants for Conservation and Healthcare. Institute of Health Sciences, University of Oxford, Oxford.

BOTHA, J., WITKOWSKI, E.T.F. AND SHACKLETON, C.M. 2004a. Market profiles and trade in medicinal plants in the Lowveld, South Africa. *Environmental Conservation* **31: 38-46**.

BOTHA, J., WITKOWSKI, E.T.F. AND SHACKLETON, C.M. 2004b. The impact of commercial harvesting on *Warburgia salutaris* ('pepper-bark tree') in Mpumalanga, South Africa. *Biodiversity and Conservation* **13: 1675-1698.**

BURGMAN, M.A., POSSINGHAM, H.P., LYNCH, J.J., KEITH, D.A., McCARTHY, M.A., HOPPER, S.D., DRURY, W.L., PASIOURA, J.A. AND DEVRIES, R.J. 2001. A method for setting the size of plant conservation target areas. *Conservation Biology* **15: 603-616.**

CASWELL, H. 2001. Matrix population models: construction, analysis and interpretation. Sinauer Associates, Sunderland.

CONDIT, R., SUKUMAR, R., HUBBEL, S. AND FOSTER, R. 1998. Predicting population trends from size distributions: a direct test in a tropical tree community. *American Naturalist* **152: 495-509.**

CRONE, E.E., MENGES, E.S., ELLIS, M.M., BIERZYCHUDEK, P., EHRLEN, J., KAYE, T.N, KNIGHT, T.M. LESICA, P., MORRIS, W.F., OOSTERMEIJER, G., QUINTANA-ASCENCIO, P.F., STANLEY, A.,

TICKTIN, T., VALVERDE, T. AND WILLIAMS, J.L. 2011. How do plant ecologists use matrix population models? *Ecology Letters* **14: 1–8.**

CUNNINGHAM, A.B. 2001. Applied ethnobotany: people, wild plant use and conservation. Earthscan Publication, London.

CUNNINGHAM, A.B. AND MBENKUM, F.T. 1993. Sustainability of harvesting *Prunus africana* bark in Cameroon. People and Plants Working Paper, 2. UNESCO, Paris, France.

DE KROON, H., VAN GROENENDAEL, J. AND EHRLEN, J. 2000. Elasticities: A review of methods and model limitations. *Ecology* **81: 607-618.**

DESMET, P.G., SHACKLETON, C.M. AND ROBINSON, E.R. 1996. The population dynamics and life-history attributes of a *Pterocarpus angolensis* DC. population in the Northern Province, South Africa. *South African Journal of Botany* **62: 160-166.**

DLADLA, S. 2001. Muthi Trade Boom: Unemployment finds refuge in traditional world. *Sunday World,* South Africa.p.19.

EMANUEL, P.L., SHACKLETON, C.M. AND BAXTER, J.S. 2005. Modelling the sustainable harvest of *Sclerocarya birrea* subsp. *caffra* fruits in the South African lowveld. *Forest Ecology and Management* **214: 91-103.**

ETNIER, M.A. 2007. Defining and identifying sustainable harvests of resources: Archeological examples of pinniped harvests in the eastern North Pacific. *Journal for Nature Conservation* **15: 196-207.**

EVERARD, D.A., VAN WYK, G.F. AND MIDGLEY, J.J. 1994. Disturbance and the diversity of forests in Natal, South Africa: lessons for their utilisation. *Strelitzia* **1: 275-285.**

GAUGRIS, J.Y. AND VAN ROOYEN, M.W. 2007. The structure and harvesting potential of the sand forest in Tshanini Game Reserve, South Africa. *South African Journal of Botany* **73: 611–622.**

GAUGRIS, J.Y. AND VAN ROOYEN, M.W. 2010. Evaluating the adequacy of reserves in the Tembe–Tshanini Complex: a case study in Maputaland, South Africa. *Oryx* **44: 399–410.**

HAMILTON, A. 2003. Medicinal plants and conservation: issues and approaches. Paper presented to International Plants Conservation Unit, World Wide Wildlife Foundation, UK.

HARROP, S.R. AND PRITCHARD, D.J. 2011. A hard instrument goes soft: The implications of the Convention on Biological Diversity's current trajectory. *Global Environmental Change* **21: 474-480.**

HARTSHORN, G.S. 1995. Ecological basis for sustainable development in Tropical forests. *Annual Review of Ecology and Systematics* **26: 155-175.**

HEYWOOD, V.H. AND IRIONDO, J.M. 2003. Plant Conservation: old problems, new perspectives. *Biological Conservation* **113: 321-335.**

HOWELL, J. AND MESHER, K. 1997. Taking care of each other: The relationship between the *Labrador metis* and the environment. Workshop on traditional and western scientific environmental knowledge. Northwest River, Labrador. September 10-11.

IUCN 2001. Analytic framework for assessing factors that influence sustainability of uses of wild living natural resources. Technical Advisory Committee. IUCN SSC Sustainable Use Specialist Group, Washington D.C. USA.

JACKSON, P.W. AND KENNEDY, K. 2009. The Global Strategy for Plant Conservation: a challenge and opportunity for the international community. *Trends in Plant Science* **14: 578-580.**

JENSEN, A.L. 1995. Simple density-dependent matrix model for population projection. *Ecological Modelling* **77: 43-48.**

KOHIRA, M. AND NINOMIYA, I. 2003. Detecting tree populations at risk for forest conservation management: using single-year vs. long-term inventory data. *Forest Ecology and Management* **174: 423-435.**

KUNIYAL, J.C. 2002. Mountain expedition: minimizing the impact. *Environmental Impact Assessment Review* **22: 561-581.**

KUROKAWA, H., YISHIDA, T., NAKAMURA, T., LAI, J. AND NAKASHIZUKA, T. 2003. The age of tropical rain-forest canopy species, Borneo ironwood *(Eusideroxylon zwageri)*, determined by ^{14}C dating. *Journal of Tropical Ecology* **19: 1-7.**

LAWES, M.J., EELEY, H.A.C., SHACKLETON, C.M. AND GEACH, B.G.S. 2004. Indigenous forests and woodlands in South Africa: Policy, People and Practice. University of KwaZulu-Natal Press, Pietermaritzburg, South Africa.

LAWES, M.J. AND OBIRI, J.A.F. 2003. Using the spatial grain of regeneration to select harvestable tree species in subtropical forest. *Forest Ecology and Management* **184: 105-114.**

LEBRETON, J.D. 2005. Age, stages, and the role of generation time in matrix models. *Ecological Modelling* **188: 22-29.**

LINK, W.A. AND DOHERTY, P.F. 2002. Scaling in sensitivity analysis. *Ecology* **83: 3299-3305.**

LOIBEL, S., DO VAL, J.B.R. AND ANDRADE, M.G. 2006. Inference for the Richards growth model using Box and Cox transformation and bootstrap techniques. *Ecological Modelling* **191: 501-512.**

LYKKE, A.M., 1998. Assessment of species composition change in savanna vegetation by means of woody plants' size class distributions and local information. *Biodiversity and Conservation* **7: 1261-1275.**

MABOGO, D.E.N. 1990. The Ethnobotany of the Vhavenda. M.Sc. dissertation, University of Pretoria, Pretoria, South Africa.

MARSCHKE, M. AND BERKES, F. 2005. Local level sustainability planning for livelihoods: A Cambodian experience. *International Journal of Sustainable Development and World Ecology* **12: 21-33.**

NAMAALWA, J., EID, T. AND SANKHAYAN, P. 2005. A multi-species density-dependent matrix growth model for the dry woodlands of Uganda. *Forest Ecology and Management* **213: 312-327.**

NDANGALASI, H.J., BITARIHO, R. AND DOVIE, D.B.K. 2007. Harvesting of non-timber forest products and implications for conservation in two montane forests of East Africa. *Biological Conservation* **134: 242-250.**

NIKLAS, K.J., MIDGLEY, J.J. AND RAND, R.H. 2003a. Size-dependent species richness: trends within plant communities and across latitude. *Ecology Letters* **6: 631-636.**

NIKLAS, K.J., MIDGLEY, J.J. AND RAND, R.H. 2003b. Tree size frequency distributions, plant density, age and community disturbance. *Ecology Letters* **6: 405-411.**

NJOROGE, G.N., KAIBUI, I.M., NJENGA, P.K. AND ODHIAMBO, P.O. 2010. Utilization of priority medicinal plants and local people’s knowledge on their conservation status in arid lands of Kenya (Muringi District). *Journal of Ethnobiology and Ethnomedicine* **6: 22-29**.

OBIRI, J., LAWES, M. AND MUKOLWE, M. 2002. The dynamics and sustainable use of high value tree species of the coastal Pondoland forests of the Eastern Cape Province, South Africa. *Forest Ecology and Management* **166: 131-148.**

OLI, M.K. 2003. Partial life-cycle models: how good are they? *Ecological Modelling* **169: 313-325.**

OSHO, J.S.A. 1996. Modelling the tree population dynamics of the most abundant species in a Nigerian tropical rain forest. *Ecological Modelling* **89: 175-181.**

PFAB, M.F. AND SCHOLES, M.A. 2004. Is the collection of *Aloe peglerae* from the wild sustainable? An evaluation using stochastic population modeling. *Biological Conservation* **118: 695-701.**

POIANI, K.A., RICHTER, B.D., ANDERSON, M.G. AND RICHTER, H. 2000. Biodiversity conservation at multiple scales: functional sites, landscapes and networks. *BioScience* **50: 133-146.**

PORTE, A. AND BARTELINK, H.H. 2002. Modelling mixed forest growth: a review of models for forest management. *Ecological Modelling* **150: 141-188.**

PUPPIM DE OLIVEIRA, J.A., BALABAN, O., DOLL, C.N.H., MORENO-PENARANDA, R., GASPARATOS, A., IOSSIFOVA, D. AND SUWA, A. 2011. Cities and biodiversity: Perspectives and governance challenges for implementing the convention on biological diversity (CBD) at the city level. *Biological Conservation* **144: 1302-1313.**

PYKH, Y.A. AND EFREMOVA, S.S. 2000. Equilibrium, stability and chaotic behavior in Leslie matrix models with different density-dependent birth and survival rates. *Mathematics and Computers in Simulation* **52: 87-112.**

ROBINSON, J.G. 1993. The limits to caring: sustainable living and the loss of biodiversity. *Conservation Biology* **7: 20-28.**

SANDERSON, E.W., REDFORD, K.H., VEDDER, A., COPPOLILLO, P.B. AND WARD, S.E. 2002. A conceptual model for conservation planning based on landscape species requirements. *Landscape and Urban Planning* **58: 41-56.**

SHAUKAT, S.S., AZIZ, S., AHMED, W. AND SHAHZAD, A. 2012. Population structure, spatial pattern and reproductive capacity of two semi-desert undershrubs *Senna holosericea* and *Fagonia indica* in Pakistan. Pakistan Journal of Botany **44: 1-9.**

STEENKAMP, V. 2003. Traditional herbal remedies used by South African women for gynaecological complaints. *Journal of Ethnopharmacology* **86: 97-108.**

SVANCARA, L.K., BRANNON, R., SCOTT, J.M., GROVES, C.R., NOSS, R.F. AND PRESSEY, R.L. 2005. Policy-driven versus evidence-based conservation: a review of political targets and biological needs. *BioScience* **55: 989-995.**

TABUTI, J.R.S., DHILLION, S.S. AND LE, K.A. 2003. Traditional medicine in Bulamogi county, Uganda: its practitioners, users and viability. *Journal of Ethnopharmacology* **85: 119-129.**

TEAR, T.H., KAREIVA, P., ANGERMEIER, P.L., COMER, P., CZECH, B., KAUTZ, R., LANDON, L., MEHLMAN, D., MURPHY, K., RUCKELSHAUS, M., SCOTT, J.M. AND WILHERE, G. 2005. How much is enough? The recurrent problem of setting measurable objectives in conservation. *BioScience* **55: 835 – 849.**

TSHISIKHAWE, M.P. 2002. Trade of indigenous medicinal plants in the Northern Province, Venda region: their ethnobotanical importance and sustainable use.

M.Sc. Dissertation, University of Venda for Science and Technology, Thohoyandou, South Africa.

VAN STADEN, J. 2008. Ethnobotany in South Africa. *Journal of Ethnopharmacology* **119: 329-330.**

VON MALTITZ, G.P. AND SHACKLETON, S.E. 2004. Use and management of forests and woodlands in South Africa: stakeholders, institutions and processes from past to present. In: Lawes, M.J., Eeley, H.A., Shackleton, C.M. & Geach, B.G. (eds). *Indigenous forests and woodlands in South Africa: policy people and practice*. pp. 109-135. University of KwaZulu-Natal Press, Pietermaritzburg.

WIEGAND, K., JELTSCH, F. AND WARD, D. 1999. Analysis of the population dynamics of *Senegalia* trees in the Negev desert, Israel with a spatial-explicit computer simulation model. *Ecological Modelling* **117: 203-224.**

WILLIAMS, V.L., BALKWILL, K. AND WITKOWSKI, E.T.F. 2000. Unraveling the commercial market for medicinal plants and plant parts on the Witwatersrand, South Africa. *Economic Botany* **54: 310-327.**

WILLIAMS, V.L., BALKWILL, K. AND WITKOWSKI, E.T.F. 2007. Size-class prevalence of bulbous and perennial herbs sold in the Johannesburg medicinal plant markets between 1995 and 2001. *South African Journal of Botany* **73: 144-155.**

WORLD COMMISSION ON ENVIRONMENT AND DEVELOPMENT 1987.Our common future. Oxford University Press, Oxford.

WORLD HEALTH ORGANIZATION. 2002. Traditional Medicine Strategy 2002 – 2005. Traditional Medicine Strategy. www.who.int/medicines/publications/ traditionslpolicy/index.html.

ZHAO, D., BORDERS, B. AND WILSON, M. 2005. A density-dependent matrix model for bottomland hardwood stands in the Lower Mississippi Alluvial Valley. *Ecological Modelling* **184: 381-395.**

CHAPTER 3

STUDY AREA, MATERIAL AND METHODS

3.1 Study area

The study on populations of the two sampled medicinal plant species, *viz.* *Elaeodendron transvaalense* Jacq. and *Brackenridgea zanguebarica* Oliv. was conducted in the Venda region, which is found within the Vhembe District Municipality of the Limpopo province, South Africa. The Venda region is situated in the northern part of the Limpopo province. It lies between $23^{\circ}45'$ and $25^{\circ}15'$S and $29^{\circ}50'$ and $31^{\circ}30'$E. It is within the tropics and the warmest period is from October to February with a cool period between April and August (Figure 3.1a and 3.1b).

The winters are generally mild and frost sometimes occurs only in the southern valleys (Jordaan and Jordaan 1987). Mean annual rainfall in the Tshirolwe area (data from the closest weather station at Siloam, Weather Bureau 1998) is 390 mm, whereas it is 688 mm at Thengwe (data from the closest weather station at Tshandama, Weather Bureau 1998). The extreme maximum and minimum temperature recorded for Siloam are 40.5°C and -1.5°C respectively and the comparable temperatures for Tshandama are 43.2°C and -3.4°C respectively (Weather Bureau 1998). The mean temperatures and precipitation of Tshirolwe and Thengwe study areas are indicated in the Walter diagrams in Figure 3.1 (a) and (b).

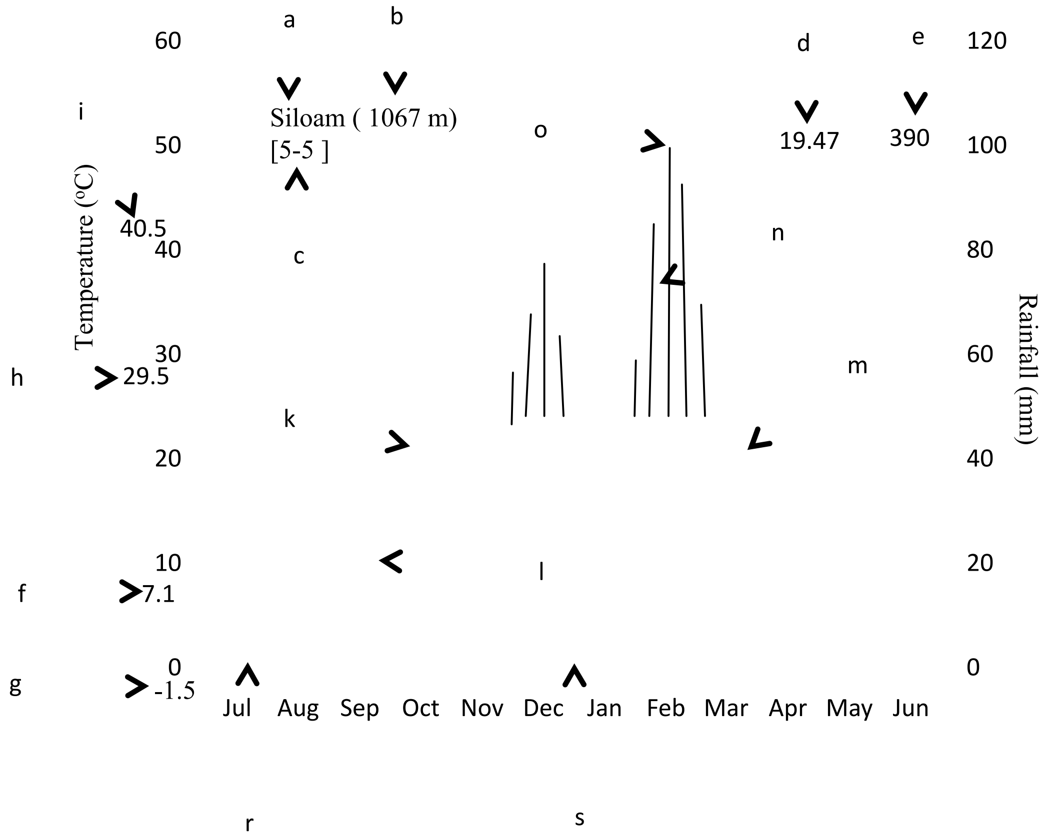

Figure 3.1 (a): Climate diagram, following Walter and Lieth's (1960-1967) convention, for the Tshirolwe study area as represented by the Siloam Weather Station (data obtained from Weather Bureau 1998).

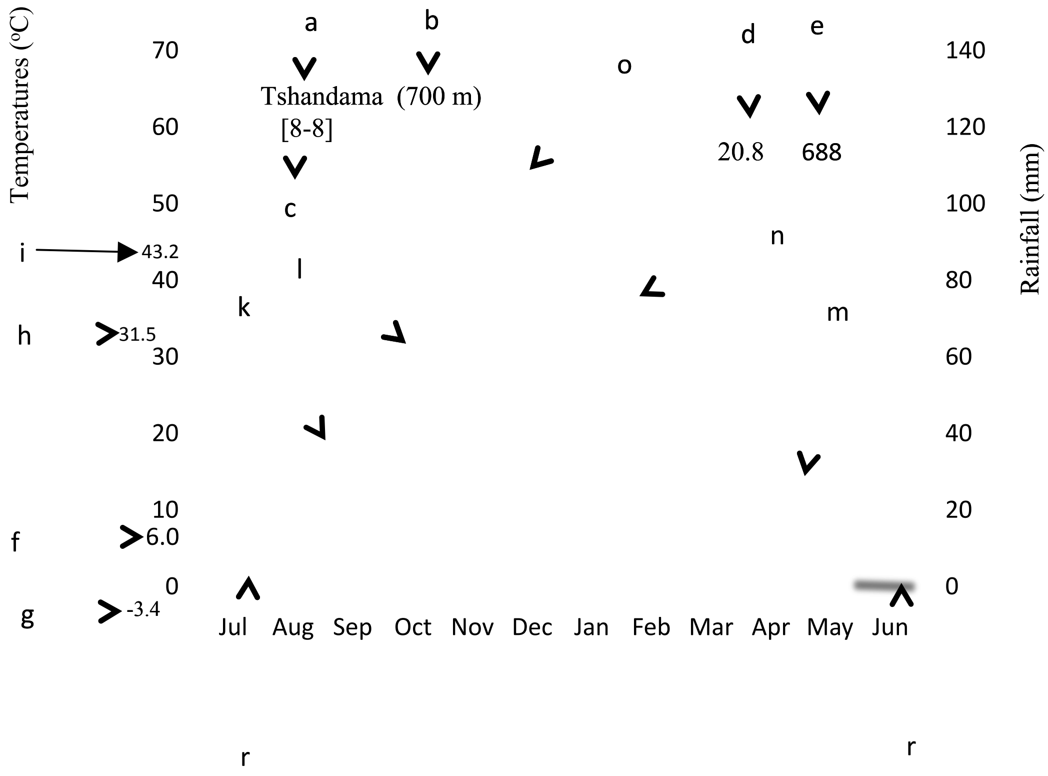

Figure 3.1 (b): Climate diagram, following Walter and Lieth's (1960-1967) convention, for the Thengwe study area as represented by the Tshandama Weather Station (data obtained from Weather Bureau 1998).

The Walter diagram is explained as follows:

a. Weather station
b. Altitude (m above sea level)
c. Number of years of observation [temperature – rainfall]
d. Mean annual temp (°C)
e. Mean annual rainfall (mm)
f. Mean daily minimum temperature of coldest month (°C)
g. Absolute minimum temperature (°C)
h. Mean daily maximum temperature of hottest month (°C)
i. Absolute maximum temperature (°C)
j. Mean daily temperature fluctuation (°C)
k. Curve for mean monthly temperature (°C)
l. Curve for mean monthly precipitation (mm)
m. Dry season
n. Wet season
o. Per humid season – mean monthly precipitation >100 mm

q. Cold season: mean daily min <0°C
r. Months with absolute min less than 0°C
s. Mean duration of frost free period

The Thengwe study area is wetter than the Tshirolwe study area and has more months with a mean precipitation of greater than 100 mm as compared to the Tshirolwe study area (Figure 3.1(a) and 3.1(b)). The wet season of the Thengwe study area is also longer than that of the Tshirolwe study area.

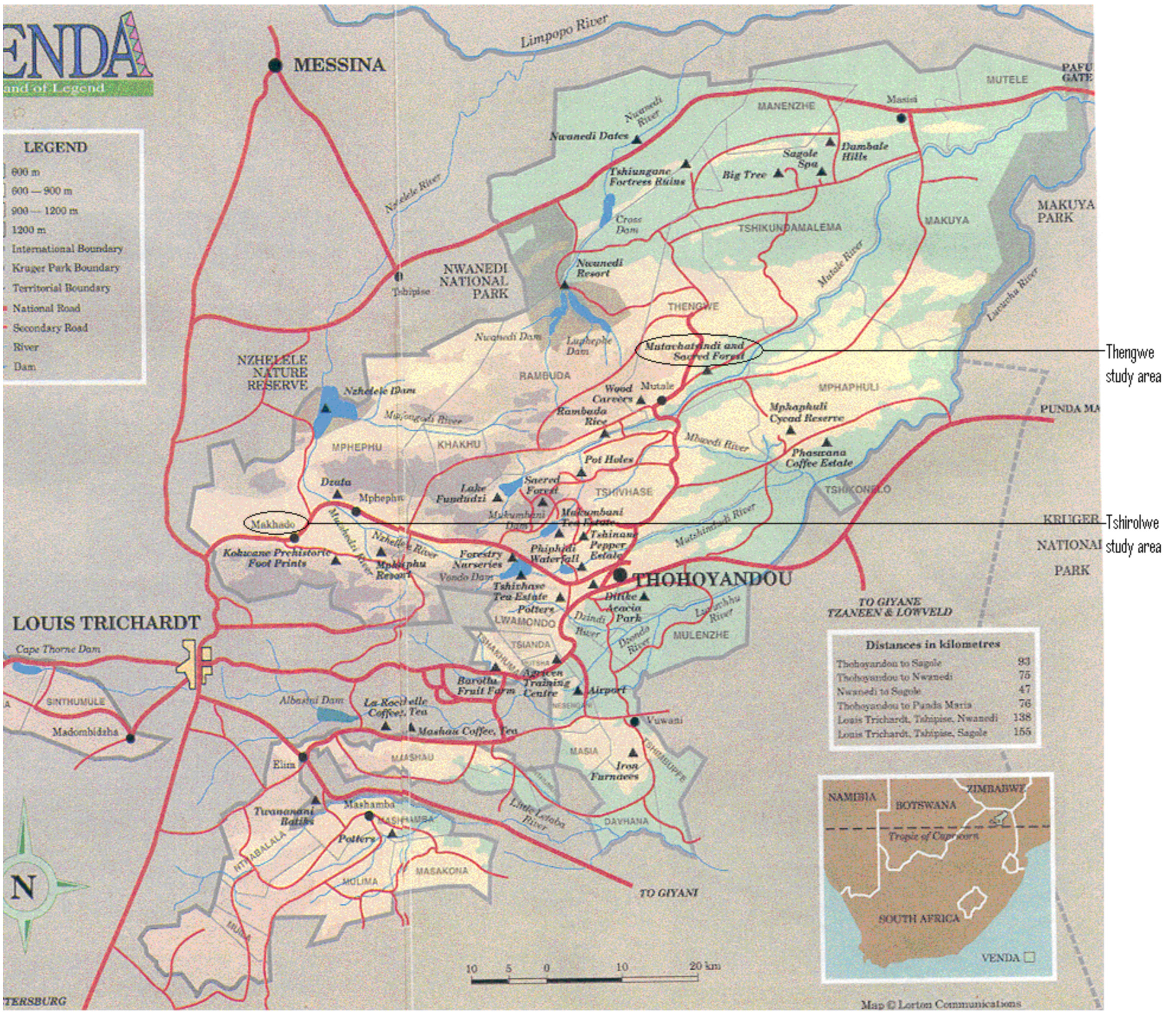

Figure 3.2: A map of the Venda region showing the Tshirolwe and Thengwe study areas that were sampled during the 2004 and 2005 data collection of *Elaeodendron transvaalense* and *Brackenridgea zanguebarica* populations (Lorton communications undated).

Both study areas indicated in Figure 3.2 fall within the savanna biome (Low and Rebelo1996, Rutherford and Westfall 1986). Raventos *et al.* (2004) have indicated that savannas are very important tropical ecosystems characterized by co-dominance of herbaceous vegetation and less abundant trees and shrubs. According to Acocks's (1953, 1988) vegetation map this savanna was classified as Sourish Mixed Bushveld, whereas Low and Rebelo (1996) classified it as part of the Soutpansberg Arid Mountain Bushveld, which occurs on the dry, hot, rocky slopes and summits of the Soutpansberg Mountains.

According to the more detailed vegetation map of Mucina *et al.* (2005) the vegetation type at the two study sites differs. The Tshirolwe study area falls in the Soutpansberg Mountain Bushveld (SVcb21), which is characterized by low to high mountains. The vegetation has a dense tree layer with a grass layer that is poorly developed. Its topographic diversity has made the Soutpansberg Mountain Bushveld a mosaic of sharply contrasting kinds of vegetation within limited areas (Mucina and Rutherford 2006). The Soutpansberg Mountain Bushveld is regarded as vulnerable with approximate 21% of the area being transformed, 14% under cultivation and 6% under forestry and only 2% formally conserved. Furthermore, the rural human population density is high, especially in the eastern lower-lying parts. The Thengwe study area falls in the VhaVenda Miombo (SVcb 22, Mucina and Rutherford 2006). This is a very small and unique vegetation unit found within the eastern extension of the Soutpansberg Mountain Bushveld. No part of this unit is formally conserved and it is heavily impacted by grazing, wood-collecting and agriculture.

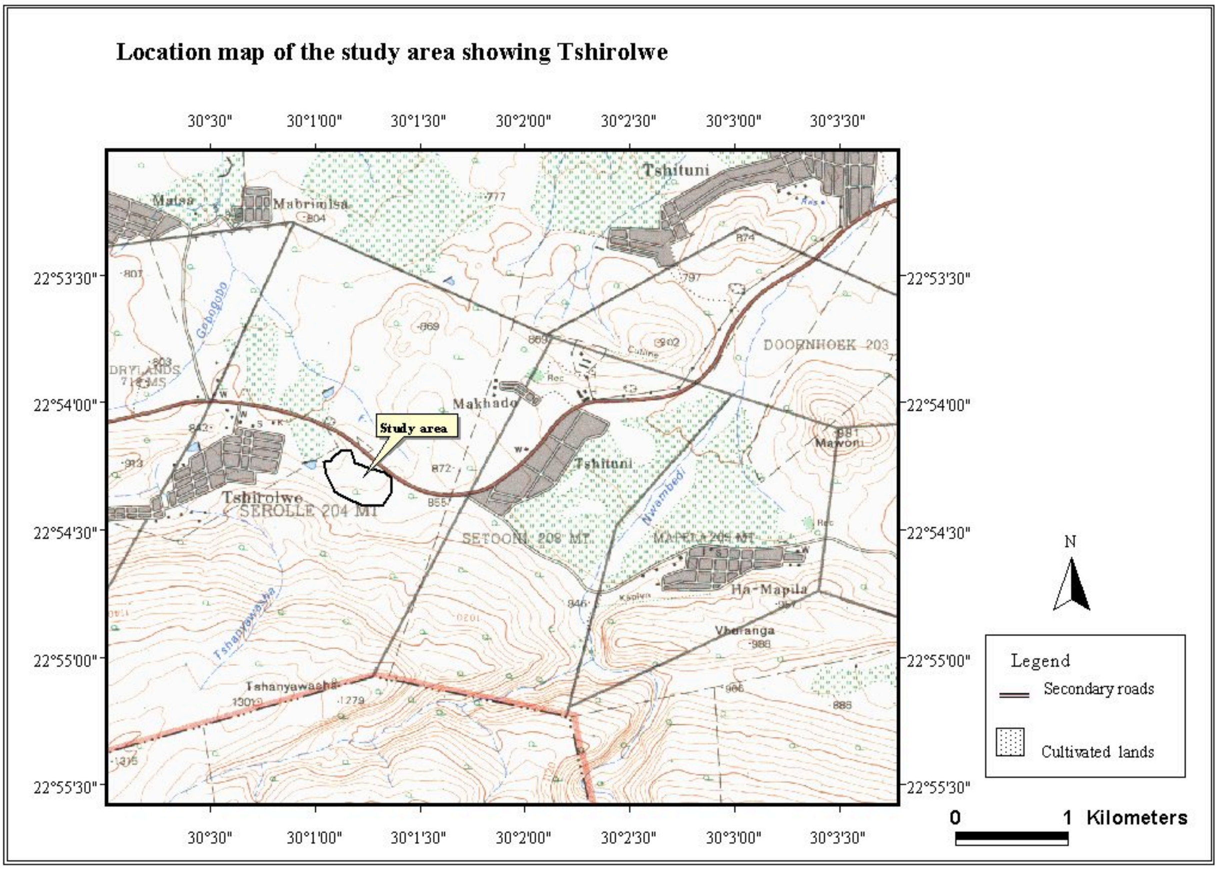

Figure 3.3: A location map showing the Tshirolwe study area.

The selection of the study areas was based on the availability of the populations of species that were being investigated. The study on the *Elaeodendron transvaalense* population was done at Tshirolwe (Figure 3.3), which is situated approximately 55 km to the west of Thohoyandou. The Tshirolwe study area had a large population of *E. transvaalense.* The Tshirolwe population of *E. transvaalense* is in a communal area where there is free access to it by the communities around it.

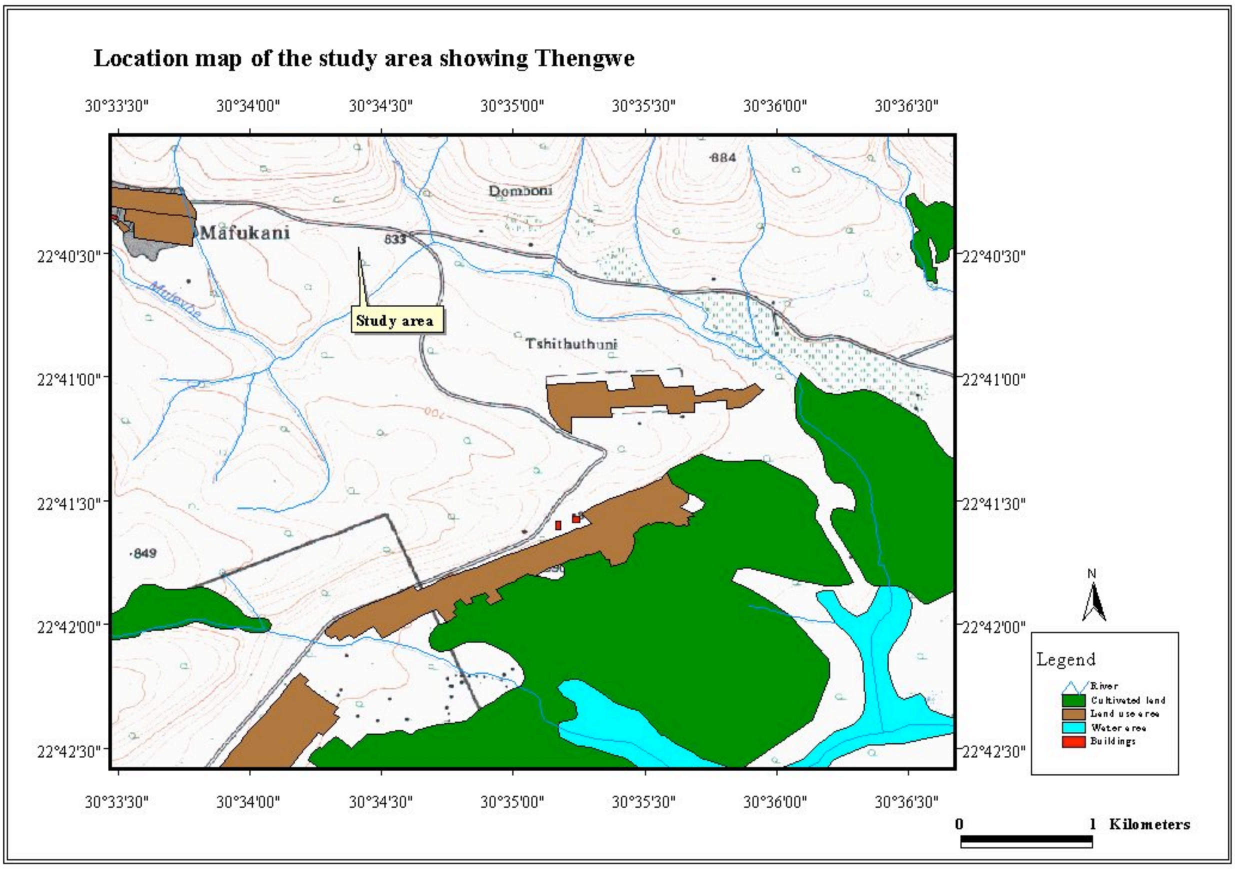

Figure 3.4: A location map showing the Thengwe study area.

The Thengwe study area, which is indicated in Figure 3.4, had a good representative *Brackenridgea zanguebarica* population. In South Africa *B. zanguebarica* has only been recorded in the Thengwe area. (Palgrave 1988). The study was done on an area adjacent to the Brackenridgea Nature Reserve, which has been established by the Department of Economic Development, Environment and Tourism as an initiative towards the conservation of the species. Access into the study area is monitored by the Thengwe traditional authority.

3.2 Description of the species investigated

3.2.1 Elaeodendron transvaalense

Elaeodendron transvaalense is a shrub or small, multi-branched tree, usually around 5m in height but it may reach 10 m or more (Palgrave 1988). The leaves are often clustered on reduced lateral shoots, with the terminal ones sometimes apparently 3-whorled. The leathery leaves are narrowly elliptic to oblong, green to greyish-green, and hairless. The leaf margins are particularly prominently toothed in juvenile growth or sucker shoots with the petiole up to 5 mm long (van Wyk and van Wyk 1997). The small greenish-white flowers are in stalked axillary clusters. The fruit is a drupe, which is round to oval, up to 15 mm in diameter, cream and yellowish when ripe. According to van Wyk *et al.* (1997) the bark is generally smooth and has a very characteristic pale, grey colour.

Elaeodendron transvaalense is found distributed mainly in Limpopo, Mpumalanga and along the coastal region of KwaZulu-Natal. It further extends into the southern parts of Zimbabwe as well as the northern parts of Botswana. The species is also found in Namibia (Mannheimer and Curtis 2009). The stem is debarked for medicinal purposes as is evident in Figure 3.5.

Figure 3.5: An *Elaeodendron transvaalense* tree showing bark removal from the stem in the Tshirolwe study area.

3.2.2 *Brackenridgea zanguebarica*

Brackenridgea zanguebarica (Figure 3.6) is a deciduous shrub or small tree, which occurs in the bushveld or along the forest margins. The bark is rough or corky with a bright yellow pigment in the dead outer layers. The leaves are elliptic to obovate, glossy dark green above, paler green below, hairless, with numerous lateral and tertiary veins prominent on both sides. Margins are finely toothed with each tooth tipped by a minute gland (van Wyk and van Wyk 1997). According to Netshiungani and van Wyk (1980), these glands found along the margins of the lamina, are a characteristic that can be used to differentiate *B. zanguebarica* from other members of the Ochnaceae family. Another characteristic, which differentiates members of *Brackenridgea* genus from the *Ochna* genus, is the presence of the yellow pigment in the bark.

Figure 3.6: *Brackenridgea zanguebarica* showing leathery-coated seeds exposed from ruptured fruits in the Thengwe study area.

Brackenridgea zanguebarica is mostly found in Zimbabwe and Mozambique and some parts of Zambia (Palgrave 1988). In South Africa it is found only in the northern part of Limpopo at Thengwe. Although it may be found in large numbers in other parts of Africa, South Africa only boast a very small population of this species.

3.3 Methods

3.3.1 Population studies

Data were collected using both qualitative and quantitative surveying research methods.

Belt transects of 100 m x 5 m were set out in the Tshirolwe and Thengwe study areas where the above-mentioned plant species were being harvested for medicinal purposes. A 100 m rope marked at 2 m intervals was laid out and a tape measure was used in measuring out 2.5 m on both sides of the 100 m rope as a way of validating those individuals that were growing on the margin of the transect as indicated in Figure 3.7. The size of transects was adopted as a way of careful management of sampling.

A transect is an elongated sample plot in which the vegetational data are recorded in the order that plant individuals are encountered (Phillips 1959, Hill *et al.* 2005). Transects were randomly distributed across the study area in order to obtain a representative sample of the population. The position of the start of each transect was recorded using a 12 channel Garmin Global Positioning System (GPS). The direction of transects were randomly selected and made to follow a straight line in order to eradicate bias. Transects were not allowed to overlap in order to avoid sampling of the same individual more than once. The number of transects was dictated by the number of individuals present in them. Sampling continued until in excess of 150 individuals had been sampled. In the Tshirolwe study area eleven transects in which

Elaeodendron transvaalense individuals were sampled were laid out. In the Thengwe study area seven transects in which *Brackenridgea zanguebarica* individuals were sampled were laid out.

Figure 3.7: A layout of a transect with a hundred meter rope and a tape measure measuring out the 2.5 m width on the both sides of the 100 m rope in a *Brackenridgea zanguebarica* sampling area.

In each transect all individuals of *Elaeodendron transvaalense* and *Brackenridgea zanguebarica* in their respective study areas were measured with reference to the following parameters:

a) Stem circumference (in cm) of the tree above the basal swelling was recorded using a tape measure. In multi-stemmed individuals the thickest stem was measured and number of stems was noted. Measurements on seedlings were done immediately on the aboveground part of the stem with vernier calliper.

b) Heights of the individuals (in m) were measured using a calibrated height rod and a tape measure was used on seedlings. In multi-stemmed individuals the height of the tallest branch was recorded.

c) Bark harvesting intensity was recorded with a sliding scale estimation of 0 to 5. Estimates of bark harvesting were made in relation to the expected unharvested stem. The classes of the sliding scale were interpreted as follows:

0 - no harvest at all,

1 - traces of bark removal (approximately 1 – 25% removal),

2 - light bark removal (approximately >25 – 50% removal),

3 - moderate bark removal (approximately >50 – 75% removal),

4 - severe bark removal (approximately >75 – 99% removal),

5 -100% removal of bark around the stem.

d) The area harvested (i.e. length x width of harvested area) was also measured.

e) Crown health assessment was also done on each individual using a sliding scale of 0 to 5. Crown health is regarded as a good indication of overall tree health (Sunderland and Tako 1999). Crown health was estimated as the percentage of the crown that shown sign of damage. The classes of the sliding scale were interpreted as follows:

0 - no crown at all,

1 – severe crown damage (approximately >75 – 99% damage),

2 – moderate crown damage (approximately >50 – 75% damage),

3 – light crown damage (approximately >25 – 50% damage),

4 – traces of crown damage (approximately 1 – 25% damage),

5 – healthy crown.

f) Adult trees were marked and their stem circumference measured again after 12 months to determine an annual growth rate in stem circumference.

g) An estimate of seed production was also obtained from individuals of all different size classes of each species. Seed production was estimated by counting seeds on one branch and multiplying by the number of similar sized branches on the tree.

Stem circumference data were used to produce a size-class distribution for each species. The size-class distribution data were analyzed in several ways to obtain the maximum information (Condit *et al.* 1998, Lykke 1998, Niklas *et al.* 2003) and to establish whether harvesting was sustainable (Obiri *et al.* 2002). Further detail on these analyses is provided in Chapters 5 and 6.

For the matrix model, the population was divided into three stage classes namely; seedling, vegetative and flowering. The entries for the matrices were then derived based on the three stage classes. This was done following procedures as set out in Desmet *et al*. (1996), Ebert (1999), Caswell (2001), and Stewart (2001). The derived transition matrix was used to explore the viability of the population when subjected to different harvesting strategies and the most sensitive stage identified. Management recommendations were made based on model results.

The results of data collected on the *Brackenridgea zanguebarica* population were also compared with the results of previous research done on the same population (Todd *et al.* 2004). For a valid comparison, the current data were converted to the same size class intervals as for the published data. This comparison gave a clear picture on the development of the *B. zanguebarica* population as reflected in Chapter 6.

3.3.2 Evaluating reserve adequacy of the *Brackenridgea zanguebarica* reserve

The Burgman *et al.* (2001) method together with a modification proposed by Gaugris and Van Rooyen (2010) was used to evaluate the adequacy of the Brackenridgea Nature Reserve in protecting a viable population of *Brackenridgea zanguebarica* in Chapter 7. The method helps in setting conservation goals by providing a transparent means of incorporating the knowledge of experts into processes of identifying and setting conservation priorities (Burgman *et al.* 2001). The methodology is described fully in Chapter 7 and is therefore not repeated here.

References

ACOCKS, J.P.H. 1953. Veld Types of South Africa (vegetation map). *Memoirs of the Botanical Survey of South Africa* **28: 1-192.**

ACOCKS, J.P.H. 1988. Veld Types of South Africa. 3rd edition. *Memoirs of the Botanical Survey of South Africa*. No. **57**.

BURGMAN, M.A., POSSINGHAM, H.P., LYNCH, J.J., KEITH, D.A., McCARTHY, M.A., HOPPER, S.D., DRURY, W.L., PASIOURA, J.A. AND DEVRIES, R.J. 2001. A method for setting the size of plant conservation target areas. *Conservation Biology* **15: 603-616.**

CASWELL, H. 2001. Matrix population models: construction, analysis and interpretation. Sinauer Associates, Sunderland.

CONDIT, R., SUKUMAR, R., HUBBEL, S. AND FOSTER, R. 1998. Predicting population trends from size distributions: a direct test in a tropical tree community. *American Naturalist* **152: 495-509.**

DESMET, P.G., SHACKLETON, C.M. AND ROBINSON, E.R. 1996. The population dynamics and life-history attributes of a *Pterocarpus angolensis* DC. population in the Northern Province, South Africa. *South African Journal of Botany* **62:160-166.**

EBERT, T.A. 1999. Plant and animal populations: methods in demography. Academic Press, San Diego.

GAUGRIS, J.Y. AND VAN ROOYEN, M.W. 2010. Evaluating the adequacy of reserves in the Tembe-Tshanini Complex: a case study in Maputaland, South Africa. *Oryx* **44: 399-410.**

HILL, D.A., FASHAM, M., TUCKER, G., SHEWRY, M. AND SHAW, P. 2005. Handbook of biodiversity methods: survey, evaluation and monitoring. Cambridge University Press, Cambridge.

JORDAAN, S.P. AND JORDAAN, A. 1987. The Republic of Venda: The insight series. De Jager-HAUM Publishers. Pretoria, South Africa.

LORTON COMMUNICATIONS. Venda Land of Legend. Undated. Creda Press.

LOW, A.B. AND REBELO, A.G. 1996. Vegetation of South Africa, Lesotho and Swaziland. A companion of the vegetation map of South Africa, Lesotho and Swaziland. Department of Environmental Affairs and Tourism, Pretoria, South Africa.

LYKKE, A.M., 1998. Assessment of species composition change in savanna vegetation by means of woody plants' size class distributions and local information. *Biodiversity and Conservation* **7: 1261-1275.**

MANNHEIMER, C. AND CURTIS, B. 2009. Le Roux and Mueller's field guide to the trees and shrubs of Namibia. MacMillan Education Namibia, Windhoek.

MUCINA, L., RUTHERFORD, M.C. AND POWRIE, L.W. (Eds.) 2005. Vegetation map of South Africa, Lesotho and Swaziland, 1 : 1 000 000 scale sheet maps. South African National Biodiversity Institute, Pretoria.

MUCINA, L. AND RUTHERFORD, M.C. (eds). 2006. The vegetation of South Africa, Lesotho and Swaziland. *Strelitzia 19.* South African National Biodiversity Institute, Pretoria.

NETSHIUNGANI, E.N. AND VAN WYK, A.E. 1980. MUTAVHATSINDI – mysterious plant from Venda. *Veld and Flora* **66:87-89**

NIKLAS, K.J., MIDGLEY, J.J. AND RAND, R.H. 2003. Tree size frequency distributions, plant density, age and community disturbance. *Ecology Letters* **6: 405-411.**

OBIRI, J., LAWES, M. AND MUKOLWE, M. 2002. The dynamics and sustainable use of high value tree species of the coastal Pondoland forests of the Eastern Cape Province, South Africa. *Forest Ecology and Management* **166: 131-148.**

PALGRAVE, K.C. 1988. Trees of Southern Africa. 4th edition. Struik Publishers. Cape Town, South Africa.

PHILLIPS, E.A. 1959. Methods of vegetation study. Holt, Rinehart and Winston. New York, USA.

RAVENTOS, J., SEGARRA, J. AND ACEVEDO, M.F. 2004. Growth dynamics of tropical savanna grass species using projection matrices. *Ecological Modelling* **174: 85-101.**

RUTHERFORD, M.C. AND WESTFALL, R.H. 1986. Biomes of Southern Africa: an objective characterisation. *Memoirs of the Botanical Survey of South Africa* **54: 1-98.**

STEWART, K.M. 2001. The commercial bark harvest of the African cherry (*Prunus africana*) on Mount Oku, Cameroon: effects on traditional uses and population dynamics. PhD thesis. Florida International University.

SUNDERLAND, T.C.H. AND TAKO, C.T. 1999. The exploitation of *Prunus africana* on the island of Bioko, Equatorial Guinea. A report for People and Plants Initiatives, WWF-Germany and the IUCN/SSC Medicinal Plant Specialist Group.

TODD, C.B., KHOROMMBI, K., VAN DER WAAL, B.C. AND WEISSER, P.J. 2004. Conservation of woodland biodiversity: A complementary traditional approach and western approach towards protecting *Brackenridgea zanguebarica*. In: Indigenous forests and woodlands in South Africa – Policy, People and Practice. Eds. LAWES, M.J., EELEY, H.A.C., SHACKLETON, C.M. AND GEACH, B.G.S. University of Kwazulu-Natal Press, Durban, South Africa: 737-750.

VAN WYK, B.E., VAN OUDTSHOORN, B. AND GERICKE, N. 1997. Medicinal plants of South Africa. Briza Publications. Pretoria, South Africa.

VAN WYK, B. AND VAN WYK, P. 1997. Field guide to trees of Southern Africa. Struik Publishers. Cape Town, South Africa.

WALTER, H. AND LIETH, H. 1960-1967. Klimadiagramm Weltatlas. G. Fischer Verlag, Jena.

WEATHER BUREAU. 1998. *Climate of South Africa: Climate statistics up to 1990*. WB 42. Government Printer, Pretoria.

CHAPTER 4

AN EVALUATION OF THE EXTENT AND THREAT OF BARK HARVESTING IN THE VENDA REGION, LIMPOPO PROVINCE, SOUTH AFRICA

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Abstract

The medicinal flora of the Venda region consists of a variety of species, which may potentially provide therapeutic agents to treat different diseases. Bark use for medicinal purposes in southern Africa has been reported for approximately 30% of the woody species (153 species) in the Venda region. However, only 58 medicinal plant species are commonly harvested for the medicinal properties in their bark and found in muthi shops in the region. These 58 species were scored for the possible threat of bark harvesting to the species' survival using 20 ecologically relevant plant or population traits. The most vulnerable species were *Adansonia digitata, Adenia spinosa, Albizia adianthifolia, Albizia versicolor, Brackenridgea zanguebarica, Croton megalobotrys,* and *Warburgia salutaris. Brackenridgea zanguebarica and Warburgia salutaris* are amongst ten most traded medicinal plant species in Venda region.

An analysis of the pattern of trade in medicinal plants by local markets in the Venda region, indicated that the growing trade in indigenous medicinal plants in South Africa is posing a threat to the conservation of many plant species. Apart from pharmaceutical companies, trade in medicinal plants has become a way of making a living for some people. Indications are that bark harvesting may threaten the survival of some of the plant species, notably *Brackenridgea zanguebarica,* and *Warburgia salutaris*.

Keywords: Ethnobotanical trade, medicinal plant species, middlemen, traditional healers

4.1 Introduction

Nature is full of undiscovered medicines and valuable chemicals that can potentially be used in healthcare systems and save countless lives (Raskin *et al.* 2002, Gurib-Fakim 2006). Indigenous societies with their wealth of information about medicinal plant species have long understood the importance of a healthy ecosystem for a continued supply of natural resources. As long as people harvest only what they need for treatment, a balanced ecosystem in which populations are viable may be maintained, leading to sustainable harvesting of natural resources (Makoe 1994). However, as a result of growing market demands due to preference of traditional medicine, maintaining the ecosystem balance is currently becoming a problem. Therefore, the unsustainable way of bark harvesting practices for medicinal purposes could make species disappear and their chemical secrets that are probably only known by traditional healers, traders and indigenous societies, would be lost (Buenz 2005).

According to Makoe (1994), Credo Muthwa, who is a well-known traditional healer, believes that muthi shop runners are the ones who heavily exploit animals and plants. He indicated that owners of these outlets hire people who do not understand the traditional ethics of collecting medicines. Muthi is a term for traditional medicine in South Africa. It has been derived from the Zulu word for tree due to the fact that most traditional medicines are derived from trees.

Traditional medicine is regarded as an effective complement to the scientific forms of health care (alternative health care system) and inhabitants of some African countries still rely exclusively on plants as a source of medicine (Hostettmann *et al.* 2000, Lim

2005, Gurib-Fakim 2006, Nyika 2009). The traditional healer takes time to talk to the patient in a holistic way, trying to find out the patient's state of mind and the state of his/her relation with the family. In this way the traditional healer also renders a social service. According to Professor Ralph Kirsch of the Department of Medicine at the University of Cape Town Medical School, traditional healers are caring people, and extraordinarily skilled in psychotherapy and counseling (cited by Kale 1995). They are respected in their community, and regarded as counselors and leaders.

In South Africa most people still make use of traditional medicines for their physical and psychological health needs (Rabe and Van Staden 1997, Dold and Cocks 2002, Keirungi and Fabricius 2005). Especially in areas characterized by high unemployment and insufficient government health services there is a strong adherence to traditional belief systems. The use and reliance on traditional medicines should be acknowledged and accepted, as it cannot be wished away if and when western medicine becomes available. Eighty per cent of the population consulting traditional healers have been found to be firm believers in muthi (Newton 1997, Steenkamp 2003, Fennell *et al.* 2004, Jager 2005). One medical doctor, Dr N. Motlana believed that 99 per cent of patients consulted traditional healers before they would turn to western medicines (Levitz 1992).

To ensure sustainability it has been suggested that collectors of medicinal plant material should be regulated and advised on proper harvesting methods (Lewington 1993, Springfield *et al.* 2005). Furthermore, in order to promote sustainable utilization it is important to know the plant species that are used and harvested for commercialization. Phytochemical screening of medicinal plant parts is recommended to check the concentration levels of compounds within different parts of the plants. In some instances traders might be selling roots, whereas leaves of the same plant can be used to treat the same disease effectively (Zschocke *et al*. 2007, Shai *et al.* 2009). However, the sustainable harvesting practice that existed for millennia is only becoming a threat as a result of human population growth and its consequencial activities.

Most medicinal plant species from the Venda region are also sold outside Venda. For example, *Brackenridgea zanguebarica*, which in South Africa is confined to the Venda region, has been found to be very popular as a medicine (Netshiungani and Van Wyk, 1980). The bark of *B. zanguebarica* is well sought after beyond the borders of Venda and can be found in the stock of muthi sellers as far away as the Lowveld, Johannesburg, Pretoria or Durban (Williams 1996, Botha *et al.* 2007).

The objectives of the study were to:

i. to compile an inventory of indigenous woody plant species occurring in the Venda region with reported medicinal bark properties;
ii. to provide a list of the plant species most commonly traded for medicinal bark properties in Venda;
iii. to assess the vulnerability of the plant species commonly harvested for their bark in Venda;
iv. to assess the proportion of different plant parts traded within the markets; and
v. to determine the market value of indigenous plant species traded for their bark in the Venda region.

4.2 Study area

The study was conducted in South Africa, Venda region within the Vhembe District Municipality. Venda falls within the Soutpansberg region and is an area that is characterized by its great floristic diversity (Van Wyk and Smith 2001). This is also reflected in the large variety of vegetation types found in the region. According to Mucina and Rutherford (2006), the vegetation of Venda consists of the following vegetation types: Musina Mopane Bushveld, Limpopo Ridge Bushveld, Makhado Sweet Bushveld, Soutpansberg Mountain Bushveld, VhaVenda Miombo, Maluleke Sandy Bushveld, Granite Lowveld and Tzaneen Sour Bushveld.

The climate of Venda also makes the region a favourable growing place for many South African tree species with 535 woody plant species documented for the Soutpansberg (Hahn undated). In the northern region there are 25 to 30 rainy days per annum with rain mainly falling between December and February (50 mm to 75 mm per month), with less than 10 mm per month falling between May and September. The mean temperature ranges from 28°C in January to 15°C in July. Humidity in the area is ± 40 percent (Lorton communications undated).

4.3 Materials and methods

4.3.1 Overall assessment of species with potential medicinal bark use in the Venda region

A species list of the woody plant species occurring in the Venda region was compiled from the PRECIS database of the South African Biodiversity Institute (www:/ sibis.sanbi.org) and the tree list of the Soutpansberg (Hahn undated). The literature was consulted to find reports of bark use for medicinal purposes for each species (e.g. Watt and Breyer-Brandwijk 1962, Palgrave 1988, Mabogo 1990, Van Wyk *et al.* 1997, Venter and Venter 1996, Tshisikhawe 2002, Schmidt *et al.* 2002, Van Wyk 2008, Van Wyk and Van Wyk 2009, Mannheimer and Curtis 2009). Plant names used follow the electronic species list in Plants of South Africa version 3.0 (http://posa.sanbi.org).

4.3.2 Evaluation of trade in plant bark in the Venda region

Herbal shops around Thohoyandou and Sibasa were used to compile an inventory of the plant species that were sold and to assess a record of sales (Tshisikhawe 2002). Thohoyandou is regarded as the center of trade in the Venda region mainly due to the presence of government buildings, the University of Venda and businesses. Thohoyandou had five muthi shops in 1998 (Tshisikhawe 2002). Two traders in indigenous medicinal plants, a male and a female, in Thohoyandou (Mr Netshia[2] and Mrs Munyai[1]) were selected for intensive studies and interviews. At Sibasa two muthi shops, a main and a subsidiary were investigated (Mr Tuwani[1]). Data were obtained only from the targeted main shop as this served as a store for the subsidiary one.

The indigenous plant use activities in the region were assessed through visits and

[2] Mr Netshia, Traditional Healer, Thohoyandou, South Africa
Mrs Munyai, Traditional Healer, Thohoyandou, South Africa
Mr Tuwani, Traditional Healer, Sibasa, South Africa.

interviews with traders, traditional healers, and medicinal material gatherers (middlemen). Collection of voucher specimens, which were deposited at the University of Venda herbarium, was done in the company of a traditional healer who indicated their collecting areas and techniques.

4.3.3 Vulnerability of 58 species traded most for their medicinal bark properties in the Venda region

Table 4.1 lists the ecological and biological factors used to score the vulnerability of the 58 species harvested most commonly for their bark in the Venda region. These same factors can also be used to set conservation goals for species according to the method of Burgman *et al.* (2001). In Chapter 7 such an approach is pursued further for one species, *Brackenridgea zanguebarica*.

Each factor had two alternative states: the positive state related to species resilience and the negative one to species vulnerability. Each factor was investigated for a species and if it was possible to answer the question reliably then +1 was given for resilience or -1 for vulnerability. If the available knowledge of the species was insufficient to obtain a reliable answer a value of 0 was given to both resilience and vulnerability. The sum of all positive and negative scores was a measure of the vulnerability of the species. The maximum score for a species would be +20 if it scored positively on all the resilient ecological attributes. The lower the score, the more vulnerable the species would be to population declines with the minimum score -20 if it scored negatively on all the ecological attributes reflecting vulnerability.

Table 4.1: List of ecological factors used to score the vulnerability of the 58 species harvested most commonly for their bark in the Venda region

	Positive criteria	Negative criteria
1	Many large populations	Few small isolated populations
2	Widespread distribution	Restricted distribution
3	Habitat generalist	Habitat specialist
4	Not restricted to a temporal niche	Restricted to a temporal niche
5	Not subject to extreme habitat fluctuations	Subject to extreme habitat fluctuations
6	Vigorous post disturbance regeneration	Weak post disturbance regeneration
7	Rapid vigorous growth	Slow weak growth
8	Quickly achieves site dominance	Poor competitor
9	Short time to set first seed or propagules	Long time to set first seed or propagules
10	Long reproductive lifespan	Short reproductive lifespan
11	Reliable seed production	Unreliable seed production
12	High seed production	Low seed production
13	Long seed or propagule viability	Short seed or propagule viability
14	Good dispersal	Poor dispersal
15	Generally survives fire and and other damage	Generally killed by fire and other damage
16	Adapted to existing grazing, drought, fire-regime	Not adapted to existing grazing, drought, fire-regime
17	Able to coppice and resprout	Unable to coppice and resprout
18	Not exceptionally vulnerable to pathogens, diseases, insects, etc.	Exceptionally vulnerable to pathogens, diseases, insects, etc.
19	Not dependent on vulnerable mutualist	Dependent on vulnerable mutualist
20	Low degree of bark harvest	High degree of bark harvest

4.4 Results and discussion

4.4.1 Overall assessment of species with potential medicinal bark use in the Venda region

Four hundred and ninty eight woody plant species (excluding subspecies) were listed for the Venda region (PRECIS database and Hahn undated combined). Of these species, 30.7% (n = 158) have been reported to have medicinal properties in their bark. However, only 11.7% (n = 58) of these species are actively traded for their bark in muthi shops around Venda. Overall, it is estimated that in South Africa more than 700 plant species are actively traded for their medicinal purposes (Dold and Cocks 2002). Trade of bark for medicinal purposes in Venda therefore contributes 8.2% of total plant species traded for their medicinal purposes in South Africa. Percentage of total plant traded in Venda region is quite high when comparing its land area of 6 807 km^2 and that of the rest of South Africa of 1 219 090 km^2. Trade of medicinal plants in Venda region is therefore relatively high.

The Fabaceae is the most important family for its medicinal bark. The family constitutes 14.7% to all woody plant species (73 woody species) in Venda, but comprises 22.9% of those species with medicinal bark properties and contributes to 27.6% of the medicinal plant species traded for their bark. In contrast, the Rubiaceae is the second most important woody family in Venda (9.4% of all woody plant species, n = 47) but only 1.2% of the woody species with medicinal bark properties belong to the Rubiaceae.

4.4.2 Evaluation of trade

4.4.2.1 Plant parts and species most commonly traded

The traders interviewed were predominantly traditional healers by profession. They practiced their professions at home and sometimes at their shops. Occasionally, they employed other people like relatives, children, and wives to run the shops. This was in line with the tradition that traditional healers pass their knowledge orally through generations. On the other hand, the chain of knowledge may be broken if none of the family members become interested in the practice.

In Venda the trade of medicinal plant material is centralized in the central business district (CBD) as it is uncommon to find people trading in the rural areas. This might be attributed to the fact that in rural areas people go directly to traditional healers for consultation and muthi dispensation. The introduction and popularity of muthi shops in urban areas is a result of urban people still preferring traditional medicines.

The research information that was collated from three shops (one at Sibasa and two in Thohoyandou) showed that the plant material marketed in Thohoyandou and Sibasa muthi shops ranged from roots, bark, leaves, and fruits, and in some cases, the whole plant (Tshisikhawe 2002). Figure 4.1 summarizes the percentage contribution of different plant parts in the preparation of medicines from the three shops. The plant parts most preferred were roots since 61% of the medicinal plant species were traded in the form of roots. Twenty two percent of plant species were traded in the form of the whole plant, 15% in the form of stem bark, 1% in the form of fruits and the other 1% in the form of leaves (Tshisikhawe 2002).

In the Venda region roots were therefore the most important parts traded followed by the whole plant and bark. In the Lowveld, Botha *et al.* (2004) similarly reported that the greatest proportions of plant parts were roots, bark or the whole plant, with relatively small proportions of flowers, fruit, seeds and branches. In the Mpumalanga and Limpopo markets roots constituted 59.4% and 60.5% respectively of the stock, with the comparable values for bark being 23.0% in Mpumalanga and 6.2% in Limpopo (Botha *et al.* 2004). In the Witwatersrand muthi markets it was also found that most of the plant species were traded for their roots and bark although the leaves, stems, whole plants and bulbs were also sold (Williams 1996, Williams *et al.* 2000). In the Eastern Cape, trading in medicinal bark was very high and came second to roots (Dold and Cocks 2002). However, in Maputo, Mozambique more than 50% of plant species were traded for their roots and about 6% of medicinal material was traded in the form of bark (Krog *et al.* 2006). In Suriname, South America bark is harvested in a non-destructive manner and only contributes 6% of the material on the market, while roots are minor items that contribute 5% and are mostly aerial roots (Van Andel and Havinga 2008).

Trading of roots for medicinal purposes is not sustainable since it usually results in the destruction of plants. The removal of roots, whole plant or excessive use of fruits and seeds for medicinal purposes has a negative impact on plant population growth which may lead to a decline of maedicinal plants from the wild (Ghimire *et al.* 2008, Rokaya *et al.* 2010).

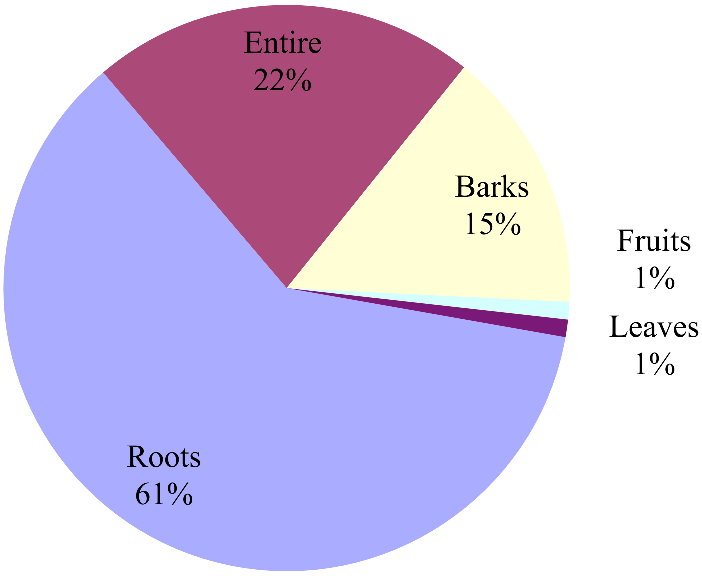

Figure 4.1: Contribution of plant parts to medicinal trade in Venda (adapted from Tshisikhawe 2002).

As indicated in Table 4.2 a total of 58 medicinal plant species are commonly harvested for their medicinal bark in Venda. In total 26 families were listed, with the Fabaceae being the most prominent family, contributing to 27.6% of these species. For 37 (63.8%) of these species only the bark is used, whereas for 17 (29.3%) of the species both the root and bark are used and for four (6.9%) of them the entire plant is used medicinally. In 79.3% of the species the bark has multiple uses and only in 20.7% does the species have only a single use. Most of the species are readily available in the wild (45 species; 77.6%), with 11 (19% of all listed species) of them being moderately available and only two (3.4%) of them, i.e. *Brackenridgea zanguebarica* and *Warburgia salutaris* having a low availability. Additionally, the latter two species also have multiple uses for their bark and are among the ten most traded species in the Venda region.

Table 4.2: Indigenous plant species most commonly traded around Venda for medicinal bark properties

Botanical names	**Common names** **E – English, V – Venda**	**Plant parts**	**Single/ multiple use**	**Availability**	**Remarks***
Adansonia digitata L.	Boabab (E), Muvhuyu (V)	Bark	Multiple	High	Bark contains phenolic compounds and is a use source of the new hypoglycemic compounds
Adenia spinosa Burtt Davy	Tshivhuyudumbu (V)	Bark	Multiple	Moderate	Contains cyanogenic compounds
Afzelia quanzensis Welw.	Pod mahogany (E), Mutokota (V)	Bark	Multiple	High	Bark contains compounds with therapeutic potential
Albizia adianthifolia (Shumach.) W. Wight	Flat-crown (E), Muelela (V)	Bark	Single	High	Bark contains large amounts of histamine and related imidazole compounds
Albizia versicolor Welw. *ex* Oliv.	Large-leaved false-thorn (E), Mutamba-pfunda (V)	Bark	Multiple	High	Bark contains 4.8% tannin
Annona senegalensis Pers.	Wild custard-apple (E), Muembe (V)	Root/Bark	Multiple	High	Contains four bioactive ent-kaurenoids (1-4).
Berchemia discolor (Klotsch) Hemsl.	Brown ivory (E), Munie (V)	Bark	Single	High	Bark contains prenylated flavonoids
Bolusanthus speciosus (Bolus) Harms	Tree wistaria (E), Mukambana (V)	Root/Bark	Multiple	High	Bark contains eight known isoflavonoids

Brackenridgea zanguebarica Oliv.	Mutavhatsindi (V)	Root/Bark	Multiple	Low	Bark contains phenolic compounds and differen flavanoids
Burkea africana Hook.	Wild seringa (E), Mufhulu (V)	Bark	Multiple	High	Bark contains tannin
Combretum molle R. Br. *ex* G. Don	Velvet bushwillow (E), Mugwiti (V)	Root/Bark	Multiple	High	Saponins, sericoside and tannins extracted
Commiphora marlothii Engl.	Paperbark corkwood (E), Mukarakara (V)	Bark	Single	Moderate	Bark contains three labile C22 octanordammare triterpenes compounds
Commiphora viminea Burtt Davy	Zebra-bark corkwood (E)	Root/Bark	Multiple	High	Pentacyclic triterpene extracted, strong antimicrobial activity
Croton gratissimus Burch. var. *gratissimus*	Lavender fever-berry (E), Mufholoro (V)	Bark	Multiple	High	Bark contains four cembranolides
Croton megalobotrys Muell. Arg.	Large fever-berry (E), Muruthu (V)	Bark	Multiple	High	Bark contains aristolochic acid I (1)
Cussonia spicata Thunb.	Common cabbage tree (E), Musenzhe (V)	Root/Bark	Multiple	High	Bark contains tannins
Dalbergia melanoxylon Guill. & Perr.	Zebrawood (E), Muuluri (V)	Bark	Single	Moderate	Contains antidiarrhetic compounds

Dichrostachys cinerea (L.) Wight & Arn. subsp. *africana* Brenan & Brummitt	Sickle bush (E), Murenzhe (V)	Root/Bark	Multiple	High	Epicatechin isolated
Diospyros mespiliformis Hochst. *ex* A. DC.	Jackal berry (E), Musuma (V)	Root/Bark	Single	High	Bark contains tannins
Dombeya rotundifolia (Hochst.) Planch. var. *rotundifolia*	Common wild pear (E), Tshiluvhari (V)	Bark	Multiple	High	Bark contains lupeol and β-sitosterol
Ekebergia capensis Sparrm.	Cape ash (E), Mutovuma (V)	Bark	Multiple	Moderate	Bark contains 7.23% tannin and used in treatme of heartburn and chest complaints
Elaeodendron transvaalense (Burtt Davy) R.H. Archer	Bushveld saffron (E), Mulumanamana (V)	Root/ bark	Multiple	Moderate	Used in treatment of venereal diseases and contains 13.4% catechol tannin
Elephantorrhiza elephantine (Burch.) Skeels	Dwarf Elephant-root (E), Gumululo (V)	Bark	Multiple	Moderate	Demonstrate anti-ehrlichial activity
Erythrina lysistemon Hutch.	Common coral tree (E), Muvhale (V)	Bark	Single	High	Antibacterial compound wighteone isolated fro bark
Euphorbia ingens E. Mey. *ex* Boiss.	Common tree euphorbia (E), Mukonde (V)	Root/Bark	Multiple	High	Contains poisonous latex with ichthyocidal properties

Faidherbia albida (Delile) A. Chev.	Ana tree (E)	Bark	Multiple	High	Contains compounds with anti-malarial activiti
Ficus ingens (Miq.) Miq.	Red-leaved rock fig (E), Tshikululu (V)	Bark	Multiple	High	Bark contains analgesic compounds
Ficus sansibarica Warb. subsp. *sansibarica*	Knobbly fig (E), Mutamvu (V)	Bark	Multiple	High	Contains phenolic compounds
Maerua angolensis DC. subsp. *angolensis*	Bead bean tree (E), Mutamba-na-mme (V)	Bark	Multiple	High	Contains compounds with hypoglycemic effect
Maerua cafra (DC.) Pax	Bush-cherry (E)	Root/Bark	Multiple	Moderate	Contains natural compounds similar to nicotine
Mundulea sericea (Willd.) A. Chev.	Cork-bush (E), Mukunda-ndou (V)	Bark	Single	High	Contains rotenone, deguelin, tephrosin, munduserone, and mundulone compounds
Ozoroa engleri R. Fern. & A. Fern.	White resin tree (E), Tshinungmafhi (V)	Bark	Multiple	High	Bark contains compounds with antimalarial properties
Parinari curatellifolia Planch. *ex* Benth.	Mobola plum (E), Muvhula (V)	Bark	Multiple	High	Bark contains silica crystals
Peltophorum africanum Sond.	Weeping wattle (E), Musese (V)	Bark	Multiple	High	Contains bergenin and norbergenin
Piliostigma thonningii (Schumach.) Milne-Redh.	Camel's foot (E), Mukolokota (V)	Root/Bark	Multiple	High	Bark rich in tannin

Pleurostylia capensis (Turcz.) Loes.	Coffee-pear (E), Murumelela (V)	Root/Bark	Multiple	High	Contains psychoactive compounds
Podocarpus latifolius (Thunb.) R.Br. *ex* Mirb.	Broad-leaf yellowwood (E), Muhovho-hovho (V)	Entire	Single	High	Contains 3-6% tannin
Pseudolachnostylis maprouneifolia Pax	Kudu berry (E), Mutondowa (V)	Bark	Multiple	High	Contains inhibitory effects of suramin
Pterocarpus angolensis DC.	Wild teak (E), Mutondo (V)	Bark	Multiple	High	Contains a high percentage tannin
Rapanea melanophloeos (L.) Mez.	Cape-beech (E), Tshikonwa (V)	Bark	Multiple	Moderate	Contains 12-15% tannin
Rauvolfia caffra Sond.	Quinine tree (E), Munadzi (V)	Bark	Multiple	High	Contains the alkaloid reserpine
Schotia brachypetala Sond.	Weeping boer-bean (E), Mulubi (V)	Bark	Multiple	High	Antibacterial fatty acids isolated
Sclerocarya birrea (A. Rich.) Hochst. subsp. *caffra* (Sond.) Kokwaro	Marula (E), Mufula (V)	Bark	Multiple	High	Bark contains 3.5-20.5% tannin
Searsia leptodictya (Diels) T.S. Yi, A.J. Mill & J. Wen.	Mountain karee (E), Mushakaladza (V)	Root/Bark	Single	High	Contains anti-cancer and anti-inflammatory compounds

Securidaca longepedunculata Fresen.	Violet tree (E), Mupesu (V)	Entire	Multiple	Moderate	Roots contain high percentage of methyl salicyl
Senegalia karroo Hayne	Sweet thorn (E), Muunga (V)	Bark	Multiple	High	Bark contains 19% tannin
Senegalia tortilis (Forssk.) Hayne subsp. *heteracantha* (Burch.) Brenan	Umbrella thorn (E), Muswu (V)	Bark	Single	High	Bark has a small amount of condensed tannins
Spirostachys africana Sond.	Tamboti (E), Muonze (V)	Bark	Multiple	High	Lipophilic compounds extracted
Strychnos madagascariensis Poir.	Black monkey orange (E), Mukwakwa (V)	Bark	Single	High	Contains tannins and other secondary compoun
Synadenium cupulare (Boiss.) L.C. Wheeler *ex* A.C. White, R.A. Dyer & B. Sloane	Dead-mans tree (E), Muswoswo (V)	Entire	Single	Moderate	Contains high amount of cyclooxygenase inhibitors
Syzygium cordatum Hochst. *ex* C. Krauss	Water berry (E), Mutu (V)	Root/Bark	Multiple	High	Leucodelphinidin and leucocyanidin detected ir bark
Syzygium guineense (Willd.) DC.	Water pear (E), Mutu-madi (V)	Bark	Multiple	High	Bark extract contains polyphenols, tannins and triterpens
Terminalia sericea Burch. *ex* DC.	Silver cluster-leaf (E), Mususu (V)	Entire	Multiple	High	Bark contains several pentacyclic triterpenoids

Trichilia dregeana Sond.	Forest Natal mahogany (E), Mutuhu (V)	Bark	Multiple	Moderate	Contains limonoids
Trichilia emetica Vahl subsp. *emetica*	Natal mahogany (E), Mutshikili (V)	Root/bark	Multiple	High	Contains limonoids
Warburgia salutaris (G. Bertol.) Chiov.	Pepper-bark tree (E), Mulanga (V)	Bark	Multiple	Low	Bark contains tannin, mannitol and muzigadial compounds
Wrightia natalensis Stapf	Saddle pod (E), Musunzi (V)	Root/bark	Multiple	High	Contains tyrosinase inhibitory potency compou
Zanthoxylum davyi (I. Verd.) P.G. Waterman	Knobwood (E), Munungu (V)	Bark	Multiple	High	Contain alkaloids pellitorine, hesperidin, lupeol and chelerythrine acetonate

*Sources: Von Breitenbach 1981, Palgrave 1988, Mabogo 1990, Hutchings 1996, Van Wyk *et al.* 1997, Venter and Venter 1996, Schmidt *et al.* 2002, Tshisikhawe 2002, Seigler 2003, Geyid *et al.* 2005, van Wyk 2008, Paraskeva 2008, van Wyk and van Wyk 2009, Mulaudzi *et al.* 2011.

Table 4.3 lists ten of the most commonly traded plant species in Venda. Five of these species are traded for their bark and/or roots, i.e. *Brackenridgea zanguebarica, Elaeodendron transvaalense, Pleurostylia capensis, Securidaca longepedunculata* and *Warburgia salutaris.* From Table 4.3 it is evident that species such as *Elaeodendron transvaalense* and *Pleurostylia capensis* are readily available to traders. The availability of these species in the wild is high irrespective of the fact that they are among the most sought after and noted medicinal plants.

Of all the medicinal plants recorded, it is only *Brackenridgea zanguebarica*, which is collected at the same place by all traders interviewed. The fact that commonly traded plant species in Table 4.3, with the exception of *Brackenridgea zanguebarica,* are collected at different localities indicates a low level of collection pressure. The spread of the collection area is a good sign in terms of species conservation, preservation and sustainability because it allows these plants enough time to regenerate between collection periods resulting in the removal of stress on such plants. Collection of medicinal plant materials is usually done in winter when people are free from farming activities (Mabogo 1990).

Table 4.3: Comparison in terms of availability and collection locality of ten medicinal plant species commonly traded in the three shops in Thohoyandou (adapted from Tshisikhawe, 2002)

BOTANICAL NAMES	**Mr Netshia**		**Mrs Munyai**		**Mr Tuwani**	
	***Origin**	**Av.**	**Origin**	**Av.**	**Origin**	**Av.**
Albizia anthelmintica	Shakadza, Makuya	Moderate	Makuya	Moderate	Ha-Mutele	Low
Brackenridgea zanguebarica	Thengwe	Very low	Thengwe	Very low	Thengwe	Very low
Elaeodendron transvaalense	Thengwe	Very high	Makuya	High	Makuya	Moderate
Maerua edulis	Shakadza	Moderate	Makuya	Moderate	Ha-Mutele	Low
Osyris lanceolata	Thononda, Thengwe	Low	Thengwe	Low	Makonde	Low
Pleurostylia capensis	Shakadza	High	Dzimauli	High	Makonde, Sambandou	Moderate
Salacia rehmannii	Thengwe, Linia	Moderate	Thengwe	Low	Gundani	Low
Securidaca longepedunculata	Matavhela	Low	Makuya	Moderate	Makonde	Low
Warburgia salutaris	Mudimeli, KNP	Low	Songozwi	Very low	KNP	Very low
Wrightia natalensis	Thengwe	Low	Makuya	High	Makuya	High

Av. = Availability KNP = Kruger National Park

* Origin - refers to places where the plant species are collected. The places differ from one collector to another although there might be some few overlapping in terms of their collection areas.

Collection by various collectors at the same locality, as is the case with *B. zanguebarica* results in pressure on the species. In addition, it indicates that this species is restricted to one area.

Price / quantity relationship can be used to estimate the value of the plant material since the relationship also indicates its importance and popularity as a medicine. Medicinal plant material was mostly traded in portions ranging from 4 to 850 g although some were sold in powdered form. It was clear that powdered plant material was the most expensive, but that not all traders offered powdered plant material (Table 4.4). For example, powdered *Elaeodendron transvaalense* material at Mr Netshia's shop was 22 times more expensive than the non-powdered form at Mrs Munyai's shop (Tshisikhawe 2002). The high cost of prepared materials is attributed to the time and energy spent during the collection, and grinding processes (Van Andel and Havinga 2008).

Of note was the large difference in price per mass at the different shops and that the ranking was not always consistent among the traders. The same trend was reported by Botha *et al.* (2007) for the Lowveld region of Limpopo and Mpumalanga. Availability also influences the price of medicinal plant material (Netshiluvhi 1999, Letsela *et al.* 2002) although Botha *et al*. (2007) found that there was no relationship between prices and perceptions of species availability. Some plant species are hard to find, because of scarcity or distance factors, which render them more expensive than those readily available. As indicated in Table 4.4 some plant species, in particular *Brackenridgea zanguebarica* and *Warburgia salutaris*, were found to be out of stock, because of their popularity, diverse uses and scarcity (Tshisikhawe 2002).

Table 4.4: Comparison of species price and frequency of use of the most commonly traded species around Thohoyandou and Sibasa (adapted from Tshisikhawe 2002)

Botanical names	**Price/mass (rand/gram) Mr Netshia**	**Price/mass (rand/gram) Mrs Munyai**	**Price/mass (rand/gram) Mr Tuwani**	**Total use frequency (demand/ supply)**
Albizia anthelmintica	1.76*	0.13	0.02	7
Brackenridgea zanguebarica	0.39	Out of stock	0.04	5
Elaeodendron transvaalense	2.88*	0.13	0.04	3
Maerua edulis	2.04*	Out of stock	0.02	3
Osyris lanceolata	0.11	0.41	0.04	6
Pleurostylia capensis	0.14	0.59	0.19	5
Salacia rehmannii	0.28	0.35	0.07	2
Securidaca longepedunculata	0.08	0.34	0.03	5
Warburgia salutaris	Out of stock	0.23	Out of stock	4
Wrightia natalensis	0.60	Out of stock	Out of stock	2

* = Powdered medicinal plant material

Price/mass index were calculated in rand per gram unit in all the three shops

Total use frequency was used to determine the supply and demand of the muthi market.

The scarcity of medicinal plants such as *Warburgia salutaris* and *Brackenridgea zanguebarica* as revealed in Table 4.3 is partly compensated for by the fact that they are not leading the list of plant species with the highest use frequency, although they are still among the most traded species. Total use frequency was obtained by consolidating reported medicinal use from all the traders. During consolidation similar uses on one species were recorded ones in order to produce use frequency ranking. Plants with the highest use frequencies are *Albizia anthelmintica* and *Osyris lanceolata*. *Brackenridgea zanguebarica* is ranked third together with *Pleurostylia capensis* and *Securidaca longepedunculata,* while *Warburgia salutaris* is ranked fourth.

An interesting aspect, which was evident in the muthi shops, was the interest in hemiparasites and epiphytes, for example *Viscum* species (nzunzu) amongst the traditional healers. The trade of hemiparasites and epiphytes is a new trend, and has also been noted by other researchers (Botha *et al*. 2001, 2004, 2007, Williams *et al*. 2010). During collection of medicinal material traditional healers showed great excitement when they find a hemiparasite or epiphyte rather than the plant species on which it grows. They believe that hemiparasites/epiphytes are very strong medicinally, compared to the plants on which they grow (Netshia pers comm.[3]).

Rituals observed during the collection include the spitting of saliva on the epiphytes before collecting. Performances of rituals are accompanied by invocations and praises to the ancestors. Interest in epiphytes may alleviate stress on affected plants that might be faced with extinction thereby giving them time to establish themselves again (Netshia pers. comm.[4]). However, the trade in parasitic species also has its dangers if rare parasitic species are overcollected e.g. *Hydnora africana*. It is clear that the trade of epiphytes and hemiparasites/parasites will increase due to their considered healing powers by the traditional healers.

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[3] Mr Netshia, Traditional Healer, Thohoyandou, South Africa, Communication 1998

[4] Mr Netshia, Traditional Healer, Thohoyandou, South Africa. Communication 1998.

4.4.2.2 Collectors of medicinal plants

Mr Netshia (pers. comm.) and Mr Tuwani[5] (pers. comm.) collect medicinal plant material themselves, whereas Mrs Munyai[6] (pers. comm.) depends on the middlemen in most cases. Traditional healers usually train their middlemen in terms of collecting rituals in order for them to get good quality medicinal plant material. In fact these middlemen end up helping people in their areas with minor problems.

According to Mrs Munyai, middlemen are only used in places difficult to access such as steep mountains in cases where the traditional healer may be a woman or an old person. However, middlemen have been found to have an effect on the price of material collected by them. From Table 4.4, it is clear that on average the price of unprepared medicinal material is high at Mrs Munyai's shop as she gets most of her material through the middlemen. Middlemen come at a cost and this cost is included in the cost of the medicine.

It should be noted that collection of medicinal material comes at a cost irrespective of middlemen involvement. The cost of collection is influenced by one or all of the following factors:

(i) Transport – The area of collection of medicinal material varies according to availability as well as the practitioner's knowledge of such species and habitat. To a practitioner with extensive knowledge on species distribution, the collecting distance increases with species depletion from one area. The

[5] Mr Tuwani, Traditional Healer, Sibasa, South Africa.
[6] Mrs Munyai, Traditional Healer, Thohoyandou, South Africa

increase in distance of collection brings about more transport cost, which is absorbed by the clients.

(ii) Consultation fee - Traditional healers believe that when they are away on collection trips a lot of clients are turned away. Therefore, thousands of rands are lost in consultation fee because of their absence. The longer the time they spend in the field looking for a particular medicine, the more expensive the medicine will be.

(iii) Middlemen fee - They collect medicinal material for traditional healers at a price. The price of middlemen is fair as they are needed only in conditions unfavourable to the traditional healer, for example when a female traditional healer needs a plant species which is found on top of a mountain, a young man is preferred as a middleman.

The effect of the middleman in the whole medicinal plant trading process should not be ignored. Their level of knowledge on rituals and their roles in the functioning of medicinal plants should be investigated. Usually middlemen start as assistants to traditional healers during collecting. It is only after understanding the collecting procedures that they qualify as collectors. Depending on the level of knowledge and understanding, the middlemen may be as good as traditional healers in collecting medicinal plant materials.

4.4.2.3 Exportation from the region

Some accounts of collectors from outside the Venda region were obtained from the Thengwe Territorial Council where *Brackenridgea zanguebarica* is collected through an interview with the headman (Nemafukani pers. comm.[7]). The account serves to establish the extent of trade and destinations to which plants are exported.

Medicinal plant materials are extensively exported from the Venda region. Although there are no proper official records of medicinal plant material collection at Thengwe Territorial Council on *Brackenridgea zanguebarica*, it was estimated that about a hundred traditional healers visit the area for collecting annually (Nemafukani pers. comm.). The headman reported that some collectors come from as far as KwaZulu-Natal, Gauteng and Mpumalanga Provinces which is about 1100, 500 and 400 km respectively from Venda region. According to the headman control measures for *Brackenridgea zanguebarica* collection have now been put in place. The observation by headman Nemafukani on the extent of exportation from Venda region is supported by Netshiungani and van Wyk (1980) and Williams (1996), who noted that *Brackenridgea zanguebarica* was even found in stocks of muthi sellers trading in Johannesburg and Pretoria.

4.4.2.4 Conservation and sustainability methods

Traditional healers still observe traditional rituals when collecting medicinal plant material. The cultural beliefs of the Vhavenda people towards *Brackenridgea zanguebarica* are the main factor in its conservation, and preservation (Netshiungani and van Wyk 1980).

Amongst some of the traditional rituals, traditional healers always make sure that they

[7] Mr Nemafukani, Headman Thengwe Territorial Council. Communication 1999.

leave behind a plant or population of plants that can regenerate and sustain it (Netshia pers comm.[8]). The success of their harvesting strategy is confirmed during their second visit to collecting areas. An indication that traditional healers always have conservation in mind when collecting can be seen from the confidence with which they show their collection sites. They are always sure that visiting their collecting areas can reveal the success of their conservation strategies and methods. For example, when collecting the roots they harvest only a few lateral roots from one plant and then go to the next. The area from where the roots had been collected is immediately covered again so that the plant should not die.

It is only with herbs that healers uproot the whole plant leaving some plants behind so that the population is sustained. The whole plant is preferably used as medicine in cases where herbaceous species are used. This avoids collection of a large number of plants and there is therefore, no waste/danger in uprooting the whole plant. Collection of leafy parts involves the collection of a few small branches from the plant. Rituals like spitting of saliva on the branches before being collected are often performed as is the case with hemiparasites/epiphytes. They believe that if such an act is not performed the medicine may not work effectively (Netshia pers comm.[9]).

Collection of bark involves removal of a few strips preferably from the stem. Traditional healers will never ring-bark the stem because they believe that for the medicine to be effective in healing, the plant it is removed from should not die. Traditional healer Credo Muthwa (cited in Makoe 1994) also confirmed the conservation of medicinal plants by traditional healers through collection rituals.

[8]Mr Netshia, Traditional Healer, Thohoyandou, South Africa. Communication 1998.
[9] Mr Netshia, Traditional Healer, Thohoyandou, South Africa. Communication 1998.

Muthwa believes that if you take all the roots and leave the tree rootless, then you are also killing the very patient you purport to help. According to Muthwa traditional healers from Botswana, Lebowa and Zimbabwe also confirm this traditional practice. In fact, to Credo Muthwa: "it is an insult to claim, or even suggest, that traditional healers play a role, active or sluggish, in the extinction of plants and animals".

In Venda, these traditional practices of saving the plant were noticed during voucher specimen collection field trips. According to Mabogo (1990), Venda traditional healers stress the need to avoid killing the plants from which the medicines are obtained. They believe that if a person kills the plant as a result of collecting the medicine from it, the medicine will kill the patient instead of healing such a patient. Leaving the roots exposed is therefore strictly forbidden. However, the increase in trade of medicinal plants which often include people who are not traditional healers has brought about harvesting techniques that do not conform to the rituals of traditional healers that promoted sustainable harvesting.

Conservation measures for *Brackenridgea zanguebarica,* since it is regarded as threatened, have been put in place by making a reserve around the population of this species. The conservation authorities and the headman make sure that collection of medicinal plant material from the reserve is done by a dedicated person from the tribal council under the supervision of reserve staff. Collection of medicinal plant material is only done outside the reserve and even this has been suspended since 1997 so that the trees are given time to recover. According to Nemafukani (pers. comm.), seedlings of this plant, which have established themselves in great numbers, will also have enough time to grow into mature plants. This will ensure a continuous and sustainable supply of medicinal material from the area if they can vegetatively develop and reach flowering stage. The territorial council arrests people found collecting medicinal material during the recovery period. Because of the fact that headmen from the areas where *Brackenridgea zanguebarica* is found are given a share in the cash generated, civic people in such areas also play a conservationist role by policing the area. This system of managing natural resources by involving traditional leaders and the community was found to be successful.

4.3.3 Vulnerability of 58 species traded most for their medicinal bark properties in the Venda region

Vulnerability is a descriptor of long term *in situ* effects on populations or ecosystems. It is considered a function of exposure to a stressor, effect and recovery potential (De Lange *et al.* 2010). A vulnerability/resilience score gives insight on those species that might be at risk since it assesses each species on a number of sensitive criteria.

In Table 4.5 the lower the vulnerability/resilience score, the more at risk such a species would be from overutilization. From Table 4.5 it can be seen that species such as *Adansonia digitata (8), Adenia spinosa (4), Albizia adianthifolia (9), Albizia versicolor (5), Brackenridgea zanguebarica (6), Croton megalobotrys (6),* and *Warburgia salutaris (8)* may be considered to be species at risk because of their low scores which are below 10. The three vulnerable species that stand out are *Albizia adianthifolia, Brackenridgea zanguebarica* and *Warburgia salutaris* which are also among the ten most traded species in Venda. On the other hand, the rest of the most traded species *Elaeodendron transvaalense (15), Pleurostylia capensis (18),* *Securidaca longepedunculata* (18) and *Wrightia natalensis* (19) all had high scores. *Osyris lanceolata, Maerua edulis* and *Salacia rehmannii* were not scored because they are not harvested for their bark.

It is important to note that vulnerability/resilience scores look at the totality of all the criteria and as such a species may have high degree of bark harvest thereby scoring negatively but be away from risk due to positive scores on other criteria. *Elaeodendron transvaalense (15), Peltophorum africanum (19), Pterocarpus angolensis (19), and Sclerocarya birrea* subsp. *caffra (18)* are some of those species with a high degree of bark harvesting but score positively on other criteria. Therefore bark harvesting alone cannot be used as a criterion of suggesting that the species is at risk.

Planning should be done in order to reduce or minimize holistic human-induced threats to biodiversity (Midgley and Thuiller 2007, De Lange *et al.* 2010, Gauthier *et al.* 2010). One way in which the threat of bark harvesting on the wild plant populations could be minimized would be by establishing medicinal plant gardens or botanic gardens. The medicinal plant garden staff must also develop comprehensive programs of environmental education to the public, which will help in stressing the need for plant conservation. The need for a time of recovery after a harvest and the capacity of some species to regenerate their bark, could be stressed by such environmental education initiatives.

Table 4.5: Vulnerability score for 58 plant species harvested for their bark in the Venda region

Botanical names	**Vulnerability score**
Senegalia karroo	17
Senegalia tortilis subsp. *heteracantha*	16
Adansonia digitata	8
Adenia spinosa	4
Afzelia quanzensis	15
Albizia adianthifolia	9
Albizia versicolor	5
Annona senegalensis	20
Berchemia discolor	20
Bolusanthus speciosus	11
Brackenridgea zanguebarica	6
Burkea africana	18
Combretum molle	18
Commiphora marlothii	20
Commiphora merkeri	20
Croton gratissimus var. *gratissimus*	11
Croton megalobotrys	6
Cussonia spicata	16
Dalbergia melanoxylon	17
Dichrostachys cinerea subsp. *africana*	20
Diospyros mespiliformis	16
Dombeya rotundifolia var. *rotundifolia*	17
Ekebergia capensis	16
Elaeodendron transvaalense	15
Elephantorrhiza elephantina	18
Erythrina lysistemon	19
Euphorbia ingens	18
Faidherbia albida	18

Ficus ingens	16
Ficus sansibarica subsp. *sansibarica*	16
Maerua angolensis subsp. *angolensis*	20
Maerua caffra	19
Mundulea sericea	19
Ozoroa engleri	19
Parinari curatellifolia	18
Peltophorum africanum	19
Piliostigma thonningii	18
Pleurostylia capensis	18
Podocarpus latifolius	20
Pseudolachnostylis maprouneifolia	20
Pterocarpus angolensis	19
Rapanea melanophloeos	20
Rauvolfia caffra	20
Schotia brachypetala	19
Sclerocarya birrea subsp. *caffra*	18
Searsia leptodictya	20
Securidaca longepedunculata	18
Spirostachys africana	19
Strychnos madagascariensis	18
Synadenium cupulare	18
Syzygium cordatum	19
Syzygium guineense	18
Terminalia sericea	20
Trichilia dregeana	18
Trichilia emetica subsp. *emetica*	18
Warburgia salutaris	8
Wrightia natalensis	19
Zanthoxylum davyi	20

Derivation of scores is provided in Appendix B

4.5 Conclusions

Although only a proportion of the potential plant species with medicinal properties were found in the muthi shops investigated, bark harvesting constitutes a very important component of the trade in medicinal plant species. Five out of the ten most traded species were used for their bark and among these five species the two scarcest species were counted, while one of them was only moderately available.

This study furthermore reported on the pattern of trade in medicinal plant species by local markets in the Venda region, Limpopo Province, South Africa. Venda in general and Thohoyandou and Sibasa in particular have few muthi trading shops. This is because the people trading in medicinal plant material are at the same time traditional healers who are able to collect medicinal plant material using their practicing certificates as their licenses.

It is recommended that initiatives such as the formation of the Brackenridgea Nature Reserve aimed at protection of *Brackenridgea zanguebarica* species be supported and expanded to include other threatened species. These reserves around communities of threatened medicinal plants must be supplemented by a propagation program of threatened species in medicinal plant gardens or botanic gardens. The medicinal plant garden staff must also develop comprehensive programs of environmental education to the public, which will help in stressing the need for plant conservation.

Bark harvesting is very prominent in certain species that are in demand such as *Brackenridgea zanguebarica* and *Elaeodendron transvaalense*. However, recovery from bark harvesting between the two species differ with *B. zanguebarica* showing a good healing strategy.

Trade in medicinal plants might be rife in Venda but it is important to note that most of the species whose bark is being traded are able to recover from the harvesting and their populations are able to sustain themselves. Trading with bark can be detrimental when the species involved has a small population with a restricted distribution because if the population is large and widely distributed the species has the potential of avoiding harvesting over the entire range. The good thing about species traded for their bark in Venda is that although negatively reported, overall the species involved in trade are able to recover from harvesting due to their large populations that are widely distributed.

4.6 Acknowledgements

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References

BOTHA, J., WITKOWSKI, E.T.F. AND SHACKLETON, C.M. 2001. An inventory of medicinal plants traded on the western boundary of the Kruger National Park. *Koedoe* **44: 7 – 46.**

BOTHA, J., WITKOWSKI, E.T.F. AND SHACKLETON, C.M. 2004. Market profiles and trade in medicinal plants in the Lowveld, South Africa. *Environmental Conservation* **31: 38-46**.

BOTHA, J., WITKOWSKI, E.T.F. AND SHACKLETON, C.M. 2007. Factors influencing prices of medicinal plants traded in the Lowveld, South Africa *International Journal of Sustainable Development and World Ecology* **14: 450-469.**

BUENZ, E.J. 2005. Country development does not presuppose the loss of forest resources for traditional medicine use. *Journal of Ethnopharmacology* **100: 118-123.**

BURGMAN, M.A., POSSINGHAM, H.P., LYNCH, J.J., KEITH, D.A., McCARTHY, M.A., HOPPER, S.D., DRURY, W.L., PASIOURA, J.A. AND DEVRIES, R.J. 2001. A method for setting the size of plant conservation target areas. *Conservation Biology* **15: 603-616.**

DE LANGE, H.J., SALA, S., VIGHI, M. AND FABER, J.H. 2010.Ecological vulnerability in risk assessment – A review and perspectives. *Science of the Total Environment* **408: 3871-3879.**

DOLD, A.P. AND COCKS, M.L. 2002. The trade in medicinal plants in the Eastern Cape Province, South Africa. *South African Journal of Science* **98:589-597.**

FENNELL, C.W., LINDSEY, K.L., McGAW, L.J., SPARG, S.G., STAFFORD, G.I.,

ELGORASHI, E.E., GRACE, O.M. AND VAN STADEN, J. 2004. Assessing African medicinal plants for efficacy and safety: pharmacological screening and toxicology. *Journal of Ethnopharmacology* **94: 205-217.**

GAUTHIER, P., DEBUSSCHE, M. AND THOMPSON, M.D. 2010. Regional priority setting for rare species based on a method combining three criteria. *Biological Conservation* **143: 1501-1509.**

GEYID, A., ABEBE, D., DEBELLA, A., MAKONNEN, Z., ABERRA, F., TEKA, F., KEBEDE, T., URGA, K., YERSAW, K., BIZA, T., MARIAM, B.H. AND GUTA, M. 2005. Screening of some medicinal plants of Ethiopia for their anti-microbial properties and chemical profiles. *Journal of Ethnopharmacology* **97: 421-427.**

GHIMIRE, S.K., GIMENEZ, O., PRADEL, R., MCKEY, D. AND AUMEERUDDY-THOMAS, Y. 2008. Demographic variation and population viability in a threatened Himalayan medicinal and aromatic herb Nardostachys grandiflora: matrix modelling of harvesting effects in two contrasting habitats. *Journal of Applied Ecology* **45: 41–51.**

GURIB-FAKIM, A. 2006. Medicinal Plants: Traditions of yesterday and drugs of tomorrow. *Molecular Aspects of Medicines* **27: 1-93.**

HAHN, N. Undated. Tree list of the Soutpansberg. Fantique Publishers, Pretoria.

HOSTETTMANN, K., MARSTON, A., NDJOKO, K. AND WOLLFENDER, J. 2000. The potential of African plants as a source of drugs. *Current Organic Chemistry* **4: 973-1010.**

HUTCHINGS, A. 1996. Zulu Medicinal Plants: An Inventory. University of Natal Press, Pietermaritzburg, South Africa.

JAGER, A.K. 2005. Is traditional medicine better off 25 years later? *Journal of*

Ethnopharmacology **100: 3-4.**

KALE, R. 1995. Traditional healers in South Africa: a parallel health care system. *BMJ* **310.**

KEIRUNGI, J. AND FABRICIUS, C. 2005. Selecting medicinal plants for cultivation at Nqabara on the Eastern Cape Wild Coast, South Africa. South African *Journal of Science* **101: 497-501.**

KROG, M., FALCAO, M.P. AND OLSEN, C.S. 2006. Medicinal plant markets and trade in Maputo, Mozambique. *Forest and Landscape* Working Papers no. 16-2006. Danish Centre for Forest, Landscape and Planning, KVL., Denmark.

LETSELA, T., WITKOWSKI, E.T.F. AND BALKWILL, K. 2002. Direct use values of communal resources in Bokong and Tsehlanyane in Lesotho: Whither the commons: *The International Journal of Sustainable Development and World Ecology* **9: 351–68.**

LEVITS, E. 1992.Traditional medicine - friend or foe? *Publico* **92.**

LEWINGTON, A. 1993. Medicinal plants and plants extracts: a review of their importation into Europe. *TRAFFIC International*.

LIM, M.K., SADARANGANI, P., CHAN, H.L. AND HENG, J.Y. 2005. Complementary and alternative medicine use in multiracial Singapore. *Complimentary Therapies in Medicine* **13: 16-24.**

LORTON COMMUNICATIONS. Venda: Land of Legend. Undated. Creda Press.

MABOGO, DEN. 1990. The ethnobotany of the Vhavenda. Master of Science dissertation. University of Pretoria, Pretoria, South Africa.

MAKOE, A. 1994.Muthi trade – affordable health care for our people. On track *Summer* **12-14.**

MANNHEIMER, C. AND CURTIS, B. 2009. Le Roux and Mueller's field guide to the trees and shrubs of Namibia. MacMillan Education Namibia, Windhoek.

MIDGLEY, G.F. AND THUILLER, W. 2007. Potential vulnerability of Namaqualand plant diversity to anthropogenic climate change. *Journal of Arid Environments* **70: 615-628.**

MUCINA, L. AND RUTHERFORD, M.C. 2006. The vegetation of South Africa, Lesotho and Swaziland. South African National Biodiversity Institute, Pretoria.

MULAUDZI, R.B., NDHALA, A.R., KULKARNI, M.G., FINNIE, J.F. AND VAN STADEN, J. 2011. Antimicrobial properties and phenolic contents of medicinal plants used by the Venda people for conditions related to venereal diseases. *Journal of Ethnopharmacology* **135:330-337.**

NETSHILUVHI, T.R. 1999. Demand, propagation and seedling establishment of selected medicinal trees. *South African Journal of Botany* **65: 331-338.**

NETSHIUNGANI, E.N. AND VAN WYK, A.E. 1980. Mutavhatsindi – mysterious plant from Venda. *Veld and Flora* **66: 87-89.**

NEWTON, D. 1997. Flora and fauna in the Medicine Cupboard. *Endangered Wildlife* **26.**

NYIKA, A. 2009. The ethics of improving African traditional medical practice: Scientific or African traditional research methods? *Acta Tropica* **112s: s32-s36.**

PALGRAVE, K.C. 1988. Trees of Southern Africa. 4th edition. Struik Publishers, Cape Town.

PARASKEVA, M.A. 2008. A phytochemical and pharmacological study of ten *Commiphora* species indigenous to South Africa. PhD thesis, University of Witwatersrand, Johannesburg.

RABE, T. AND VAN STADEN, J. 1997. Antibacterial activity of South African plants used for medicinal purposes. *Journal of Ethnopharmacology* **56: 81-87.**

RASKIN, I., RIBNICKY, D.M., KOMARNITSKY, S., ILIC, N., POULEV, A., BORISJUK, N., BRINKER, A., MORENO, D.A., RIPOLL, C., YAKOBY, N., O'NEAL, J.M., CORNWELL, T., PASTOR, I. AND FRIDLENDER, B. 2002. Plants and human health in the twenty-first century. *Trends in biotechnology* **20: 522-531.**

ROKAYA, M.B., MUNZBERGOVA, S. AND TIMSINA, B. 2010. Ethnobotanical study of medicinal plants from the Humla district of western Nepal. *Journal of Ethnopharmacology* **130: 485-504.**

SCHMIDT, E., LOTTER, M. AND McCLEALAND, W. 2002. Trees and shrubs of Mpumalanga and Kruger National Park. Jacana Publishers, Johannesburg, South Africa.

SEIGLER, D.S. 2003. Phytochemistry of *Senegalia-sensu lato. Biochemical Systematic and Ecology* **31: 845-873.**

SHAI, L.J., McGAW, L.J. AND ELOFF, J.N. 2009. Extracts of the leaves and twigs of the threatened tree *Curtisia dentata* (Cornaceae) are more active against *Candida albicans* and other microorganisms than the stem bark. *South African Journal of Botany* **75: 363-366.**

SPRINGFIELD, E.P., EAGLES, P.K.F. AND SCOTT, G. 2005. Quality assessment of South African herbal medicines by means of HPLC fingerprinting. *Journal of Ethnopharmacology* **101: 75-83.**

STEENKAMP, V. 2003. Traditional herbal remedies used by South African women for gynecological complaints. *Journal of Ethnopharmacology* **86:97-108.**

TSHISIKHAWE, MP. 2002. Trade of indigenous medicinal plants in the Northern Province, Venda region: their ethnobotanical importance and sustainable use. M.Sc. dissertation, University of Venda for Science and Technology, Thohoyandou, South Africa.

VAN ANDEL, T. AND HAVINGA, R. 2008. Sustainability of commercial medicinal plant harvesting in Suriname. *Forest Ecology and Management* **256: 1540-1545.**

VAN WYK, A.E. AND SMITH, G.F. 2001. Regions of floristic endemism in southern Africa: A review with emphasis on succulents. Umdaus Press, Pretoria.

VAN WYK, P. 2008. Field guide to the trees of the Kruger National Park. Struik Publishers, Cape Town, South Africa.

VAN WYK, B.E., VAN OUDTSHOORN, B. AND GERICKE, N. 1997. Medicinal plants of South Africa. Briza Publications, Pretoria, South Africa.

VAN WYK, B. AND VAN WYK, P. 2009. Field guide to trees of southern Africa. Struik Publishers, Cape Town, South Africa.

VENTER, F, AND VENTER, J-A.1996. Making the most of indigenous trees. Briza Publications, Pretoria, South Africa.

VON BREITENBACH, F. 1981. Standard names of trees in southern Africa (Part II). *Journal of Dendrology* **1: 84-94.**

WATT, J.M. AND BREYER-BRANDWIJK, M.G. 1962. The medicinal and poisonous plants of southern and eastern Africa: Being an account of their medicinal and other uses, chemical composition, pharmacological effects and toxicology in man and animal. 2nd edition. E. and S. Livingstone Publishers. Edinburgh, Scotland.

WILLIAMS, V.L. 1996. The Witwatersrand muthi trade. *Veld and Flora* **3:12-14.**

WILLIAMS, V.L., BALKWILL, K. AND WITKOWSKI, E.T.F. 2000. Unraveling the commercial market for medicinal plants and plant parts on the Witwatersrand, South Africa. *Economic Botany* **54: 310-327.**

WILLIAMS, V.L., FALCAO, M.P. AND WOJTASIK, E.M. 2010. *Hydnora abyssinica*: ethnobotanical evidence for its occurrence in southern Mozambique. *South African Journal of Botany* **77: 474-478**.

ZSCHOCKE, S., RABE, T. TAYLOR, J.L. JAGER, A.K. AND VAN STADEN, J. 2007.Plant part substitution – a way to conserve endangered medicinal plants. *Journal of Ethnopharmacology* **71: 281-292.**

CHAPTER 5

POPULATION BIOLOGY OF *ELAEODENDRON TRANSVAALENSE* JACQ. IN THE PRESENCE OF HARVESTING

Submitted to South African Journal of Botany (SAJB)

Abstract

Elaeodendron transvaalense is one of the medicinal plant species used very often by people in the Venda region. It is known to treat a variety of diseases. Due to its wide usage and importance to traditional healers it had found its way into the muthi markets and it is amongst seven most commonly traded plant species in the Venda region. The study investigated the impact of bark harvesting on the population structure of this species.

The study revealed that although the level of bark harvesting is high, the species appeared to be able to cope with the pressure since it is a fine-grained species. The population also showed the ability to regenerate as it exhibited an inverse J-shaped curve. The crown health status was generally good although some individuals, contributing 9% of the sample, had dead crowns, which are a cause for concern. A linear relationship was noticed between areas harvested and stem circumference, which is understandable considering the large surface area of harvestable bark on bigger individuals. Elasticity analysis revealed that the vegetative stage should be targeted for management action.

Keywords: Bark harvesting, matrix modeling, medicinal plants, muthi markets, population growth rate.

5.1 Introduction

In 1988 the Chiang Mai Declaration had noted that, since medicinal plants form the basis of medicines used by the majority of the population of most developing countries, the loss of certain medicinal plant species and reduced supply of other important plant species would have a direct impact on human health and wellbeing (Bodeker 1995).

Elaeodendron transvaalense is one of the medicinal plant species used very often by people around Venda. It is amongst seven medicinal plant species that are most commonly traded in muthi markets around Venda (Tshisikhawe 2002). In some parts of the country *Elaeodendron transvaalense* is at the same time, one of the medicinal plant species that is facing a serious threat of extirpation through over-harvesting of bark from stems.

Elaeodendron transvaalense is used for a variety of diseases and hence its reference by traditional healers as "mukuvhazwivhi" which literally translated means "sin-washer". The following are some of its medicinal uses (Mabogo 1990, van Wyk *et al.* 1997, Tshisikhawe 2002, Steenkamp 2003, Samie *et al.*2005, Bessong *et al*. 2005):

i. Cleaning of stomach from any disorder;
ii. Treatment of ulcers;
iii. Treatment of venereal diseases;
iv. Treatment of fungal infections;
v. Treatment of piles and haemorrhoids in humans and domestic animals;
vi. Treatment of dysmenorrhoea.

According to Mabogo (1990), van Wyk and Gericke (2000) and Tshikalange *et al.* (2008) the root or stem bark decoction or infusion is taken orally in cupfuls three to four times a day. The medicinal material is also prepared into a powder and taken as a tea or mixed with soft porridge.

Bessong *et al.* (2006) and Tshikalange *et al.* (2008) noted that *Elaeodendron transvaalense* showed 48.6 percent RNA-dependent-DNA polymerization (RDDP) activity inhibition of HIV-1 RT in the n-butanol fraction. The activity seems to be credited to the fact that many plant species said to be rich in sterols and sterolines have immuno-modulatory effects and boost the vitality of AIDS patients. The species also showed in vitro anti-HIV properties through the inhibition of both NF-kB and Tat proteins. According to Drewes *et al.* (1991) a new peltogynoid, (+)-11, 11-dimethyl-1,3,8,10-tetrahydroxy-9-methoxypeltogynan was obtained from the roots of *Elaeodendron transvaalense* along with other three pentacyclictriterpenes. A phenolic compound known as elaeocyanidin has also been isolated from the species (van Wyk *et al.* 1997).

Intense and frequent harvesting of bark from species with a high market demand often results in ring-barking of trees and the trees subsequently die, and the species becomes rare over time. Because of the demand of *E. transvaalense* as a medicine it is important to assess the effects of harvesting on its population structure. The population structure can be assessed by an analysis of the frequency distribution of stems across diameter classes (Lykke 1998, Condit *et al.* 1998, Niklas *et al.* 2003b, Lawes *et al.* 2004). The size class distribution data can also be used to assess the potential of the population for its sustainable use (Everard *et al.* 1994, Everard *et* *al.*1995, Obiri *et al.* 2002, Lawes and Obiri 2003, Gaugris and Van Rooyen 2007, Gaugris *et al.* 2007). Investigating the various aspects of the life cycle of a plant (e.g. age/size at flowering, seed output per size class) is crucial to gain an understanding of the dynamics of the population (Solbrig 1980). This knowledge can then be used to quantify the demographic variables of a population, which can be used in more refined analyses of the population, such as matrix analysis (Caswell 2001, Crone *et al.* 2011).

The objectives of the current study were to investigate the impacts of harvesting on a population of *Elaeodendron transvaalense* in the Venda region. Firstly, the population structure was examined and the extent of the harvesting was evaluated in terms of the size classes targeted and the effects on crown health and seed production. Secondly, a matrix analysis and elasticity analysis were performed to establish which size class contributed most to the population growth rate and should be targeted in future conservation efforts. Thirdly, the data were used to evaluate the potential for sustainable harvesting of the species by means of the grain concept.

5.2 Study area

Data on population parameters were collected from an *Elaeodendron transvaalense* population in the Tshirolwe area in the Venda region, Limpopo province (Figure 5.1). The Tshirolwe study area lies 38 km north of the town of Louis Trichardt and 50 km west of the town of Thohoyandou in the Vhembe District Municipality of the Limpopo province. The study area is a communal area, which is accessible to anyone and anything without any restriction. It lies within a 1 km distance from the settlements of Tshirolwe and Tshituni.

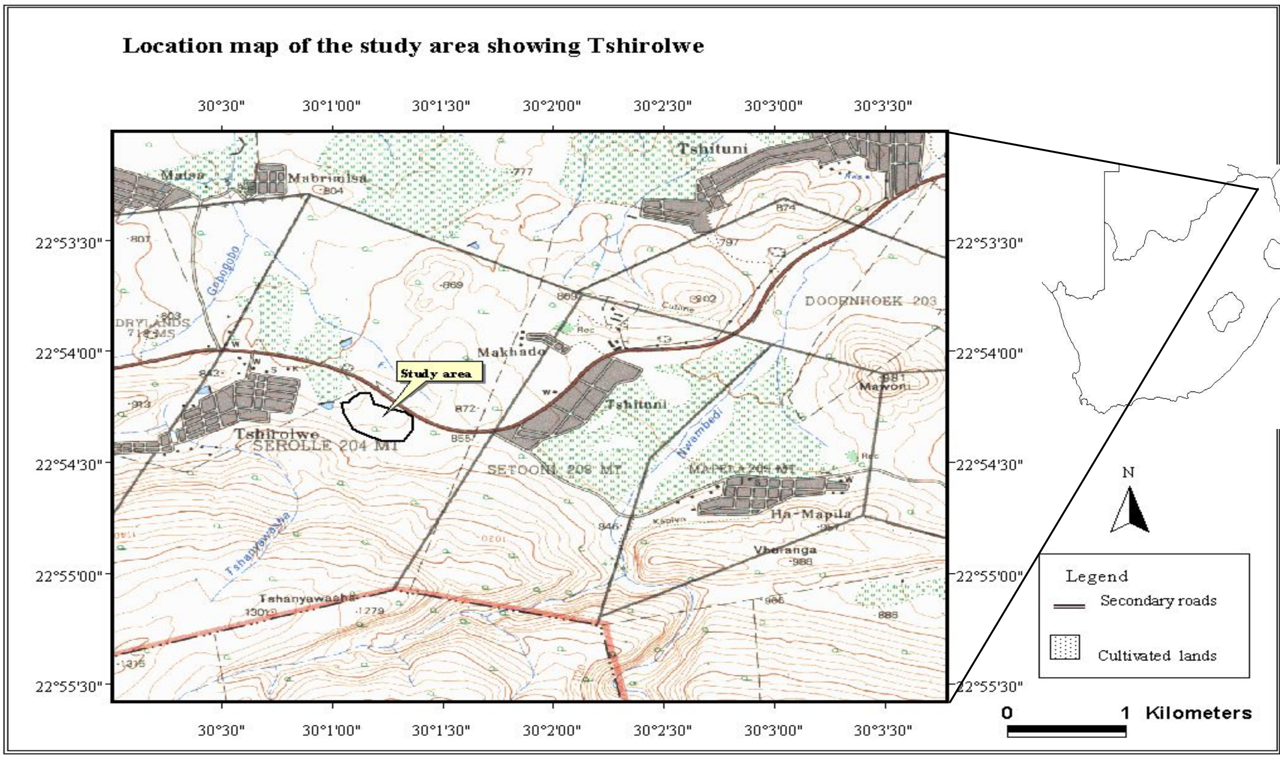

Figure 5.1: A location map showing the Tshirolwe study area where data on *Elaeodendron transvaalense* were collected in the 2004 and 2005 surveys.

According to Acocks (1988) the study area is part of the Northeastern Mountain Sourish Mixed Bushveld, whereas Mucina and Rutherford (2006) classify it as Soutpansberg Mountain Bushveld. The vegetation type is regarded as 'Vulnerable' with approximately 21% being transformed, mostly by cultivation (Mucina and Rutherford 2006). The area has a semi-arid climate with the rainfall pattern influenced by the Soutpansberg mountain range (Berger *et al.* 2003). It receives one cycle of rainfall that extends from October to March with the dry period extending from April to October. Frost is infrequent in the region.

The study area rests on the gneisses of the Limpopo belt and Bandelierkop Complex (Berger *et al.* 2003). It is situated within the Nzhelele-Formation, which is one of the seven units that constitute the Soutpansberg group of the volcano-sedimentary succession.

5.3 Materials and methods

Elaeodendron transvaalense, belonging to the family Celastraceae, is a shrub or small tree, which can sometimes reach a height of 10 to 15m. It is widespread, although not common, at low altitudes in open woodlands. It grows from KwaZulu-Natal, Swaziland, Mpumalanga and through the northern parts of South Africa into Mozambique, Zimbabwe, Botswana and Zambia. The bark, which is used medicinally, is pale grey and sometimes finely fissured and breaks up into small blocks especially in older individuals (Palgrave 1988, van Wyk 1996). Leaves are simple and usually set at twig terminals. The leaves are browsed upon by wildlife. Flowers are in a flat inflorescence and set from November to February. Fruits are borne in short clusters and are edible although not palatable. Fruit development is slow and they ripen from July to September.

Eleven transects of 100 m x 5 m were demarcated in order to sample the required data. The coordinates of each transect were recorded using a 12 channel Garmin Global Positioning System (GPS) (Garmin International, Kansas City). A rope was used to delineate the transects during data collection. No control transects were demarcated due to lack of unharvested population within the same environmental gradients. The following data were recorded on *E. transvaalense* individuals:

i. Stem circumference (in cm) – measured with a measuring tape above the basal swelling.

ii. Plant height (in m) – measured with a measuring tape and/or graduated height rod.

iii. Crown health – estimated using a 0 – 5-point scale as follows:

  0 - no crown at all,

  1 – severe crown damage,

  2 – moderate crown damage,

  3 – light crown damage,

  4 – traces of crown damage,

  5 – healthy crown.

iv. Bark removal area – breadth and width of harvested area measured with tape measure (in cm^2).

v. Seed count – seeds were counted from one branch of a tree and an estimate for the tree was made. The estimates were considered minimal estimates of total seed production (Schwartz *et al.* 2002).

For the size class analysis stem circumference measurements were classified into 13 size classes with 20 cm intervals. Natural logarithmic transformations of the density of the size classes (D) (Condit *et al.* 1998) of the type ln (D+1) and were used to transform the data (Niklas *et al.* 2003b) before calculating least square linear regressions. The value of 1 was added as some size class bins were not represented (Lykke 1998).

Figure 5.2: A research assistant measuring the debarked area on an *Elaeodendron transvaalense* stem in the Tshirolwe study area in the Venda region.

The mean circumference of the population, the "centroid", was calculated. A centroid skewed to the left of the midpoint of the size class distribution indicates a young and growing population, whereas one skewed to the right indicates an older, relatively undisturbed population (Niklas *et al.* 2003b).

To estimate the harvesting pressure on an individual plant, a ratio was calculated as the area harvested : the stem circumference. This ratio was used to examine the relationship between harvesting pressure and crown health.

Most of the parameters were sampled during a once-off survey. Stem circumferences of marked individuals were sampled again after one year in order to record the growth rate. The mean stem circumference growth increment of all individuals was calculated. A mean growth rate was also calculated for individuals up to a circumference of 60 cm, considered as the individuals representing the subcanopy level, and those above 60 cm in circumference, representing the canopy layer. These values could be used to estimate the ages of all the individuals sampled. However, it is acknowledged that because of phenotypic plasticity, size-class distributions cannot be readily converted into age class distributions (Silvertown and Charlesworth 2001).

The subcanopy and canopy densities were calculated as the sum of the number of individuals ≤ 60 cm circumference and larger than 60 cm circumference respectively. The use of subcanopy and canopy density, associated with frequency allows the grain of a species to be determined. The concept of species grain was developed for forests (Midgley *et al*. 1990); however, it has been successfully applied to woodlands by Gaugris *et al.* (2007) to establish which species could be harvested sustainably. The graphical model of Lawes and Obiri (2003) to determine species grain by plotting canopy density (X-axis) and subcanopy density (Y-axis) was used. The critical lower bounds for canopy and subcanopy density of 10 and 30 individuals per ha of Lawes and Obiri (2003) were retained in this study.

A stage-class matrix analysis was performed using three stages, namely: seedlings; juvenile, non-flowering plants; and mature, flowering plants. A Lefkovitz matrix was compiled with the upper row representing the fecundity, the diagonal the probability of remaining in the same stage and the sub-diagonal the probability of progressing into the next stage. The transition matrix was derived using the age of transitions of the oldest seedling and vegetative stages.

The matrix analysis was performed at the Institute of Biology of the University of Bergen in Norway using the Matlab computer package as this programme is regarded as the most appropriate package for these analyses (Caswell 2001). An elasticity analysis was subsequently performed (Caswell 2001, Norris and McCulloch 2003).

5.4 Results and discussion

5.4.1 Population structure

The size-class distribution of the *Elaeodendron transvaalense* population at Tshirolwe is illustrated in Figure 5.3. The population status resembles the typical reverse J-shaped curve. Three ideal types of size-class distribution can be recognized for tree populations (Peters 1996, Cunningham 2001). The typical reverse J-shaped curve or negative exponential curve indicates continuous recruitment of young stems, the bell-shaped curve indicates a lack of seedlings and young plants and the straight horizontal line indicates relatively low numbers of seedlings and young plants. In a closed-canopy environment the reverse J-shaped curve as displayed in Figure 5.3 is considered to indicate species which are tolerant to shade or competition while the bell-shaped curve or straight line curve will indicate shade-intolerant or competition-intolerant species. The fact that most of the adult individuals are harvested leaves the population in danger of not producing seeds due to poor health. In their study on *Pterocarpus angolensis* Desmet *et al*. (1996) found that the most important requirement for the survival of these populations was the continued presence of mature, reproductive individuals. It is also important for seedling size-class to recruit into adult size-classes without being harvested.

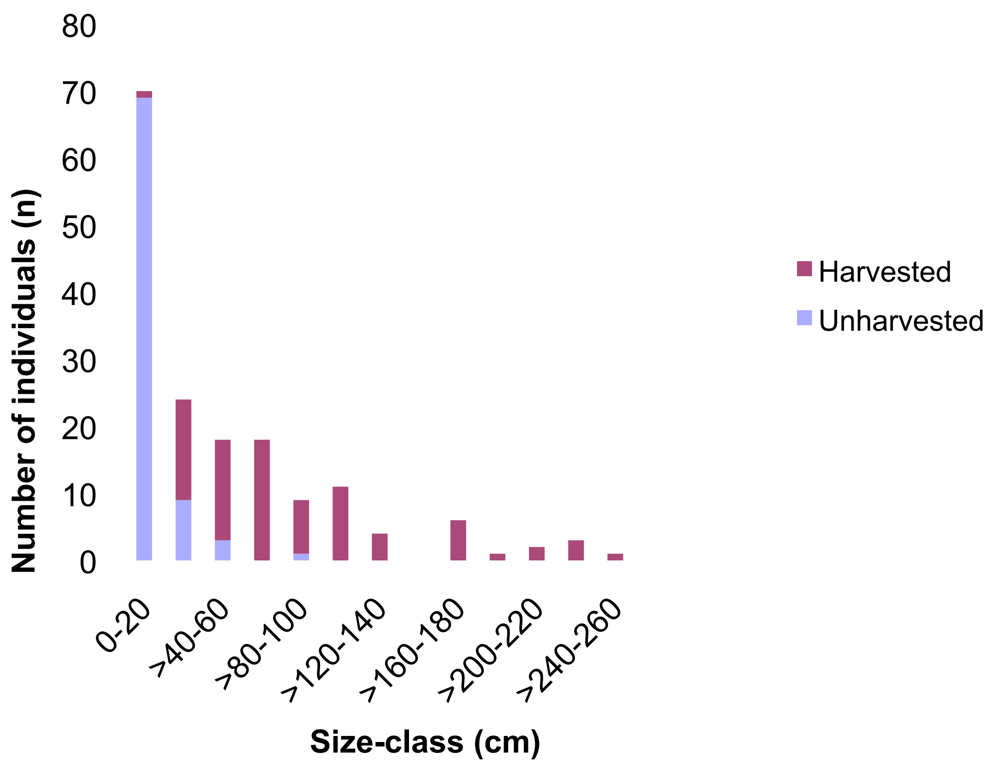

Figure 5.3: Size-class distribution of harvested and unharvested individuals in a population of *Elaeodendron transvaalense* sampled in 2004 at Tshirolwe, in the Venda region, Limpopo.

On a plant community level it has been established that the majority of species increasingly resides in the smallest size-class (Niklas *et al*. 2003a, Guedje *et al.* 2007) and that in fact species richness is a size-class dependent phenomenon. Large size-class individuals in rare species are found in small numbers thereby attributing to the rareness of the species. The fact that the *E. transvaalense* population sampled has few individuals in the large classes shows that it is not abundant and that it may become increasingly rare in the near future.

A high abundance of individuals in smaller size classes, which lead to an inverse J-shaped size class distribution, is generally regarded as an indicator of adequate regeneration and population maintenance (Peters 1996, Condit *et al.*1998, Lykke 1998, Niklas *et al.* 2003a, Ganesan and Siddappa 2004). The abundance of seedlings is therefore a manifestation of successful seed germination and establishment in the *E. transvaalense* population. The position of the centroid found to be 49.12 cm, which was left-skewed in relation to the midpoint of the circumference distribution of 130 cm stem circumference, confirmed the healthy status of the population.

It was clear that except for the smallest size class (0 – 20 cm), all the size classes had a high proportion of individuals harvested (Figure 5.3). In many size classes all individuals showed signs of harvesting.

The linear regression on the natural logarithm of the density in the size classes against the size class midpoint (Figure 5.4) produced a significant linear regression (r^2 = 0.678; y = -0.014x + 4.279; p= $5.38x10^{-4}$). The slope and Y-axis intercept of this equation can in future be used to compare other populations of *E. transvaalense* under different harvesting regimes. It can also be used to monitor and compare the same Tshirolwe population over time to detect changes in population structure (Gaugris and Van Rooyen 2011).

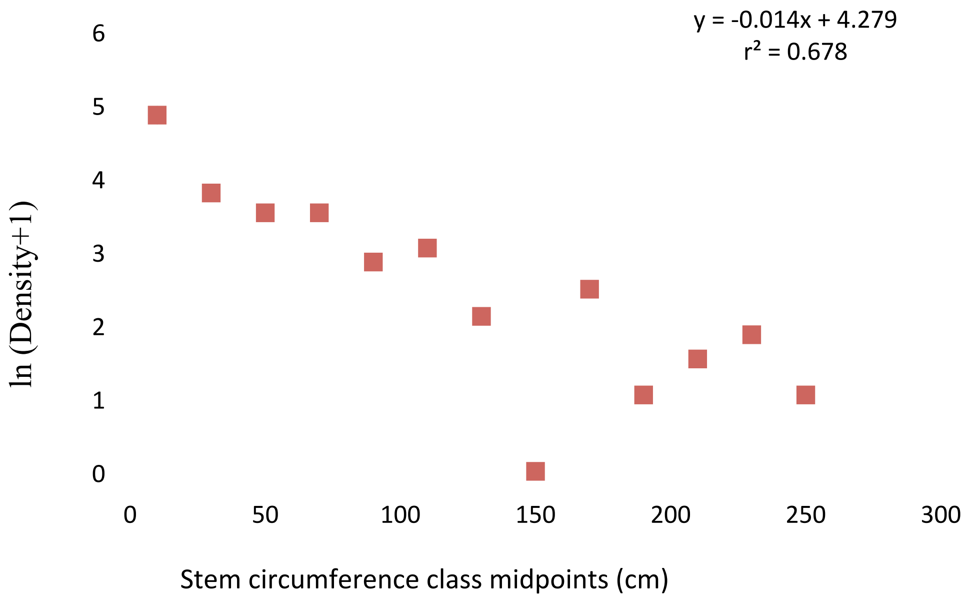

Figure 5.4: The regression of ln (D + 1) against stem circumference in a population of *Elaeodendron transvaalense* sampled in 2004 at Tshirolwe, in the Venda region, Limpopo.

Although long-term population monitoring data would be optimal to detect trends in population structure, Kohira and Ninomiya (2003) have indicated that there is merit in using the size-class distribution with single-year data. Furthermore, a range of techniques has been devised to obtain as much information as possible from single surveys. The assessment of population structure with single-year data gives an essential head start for conservation efforts with a small amount of resources.

There is a significant positive correlation between plant height and stem circumference until an optimum height is achieved as shown in Figure 5.5 (r^2 = 0.5682; y = 1.1295 ln(x) + 0.6714; p = 6.99 x 10^{-21}). Individuals of stem circumference between 10 cm and 40 cm achieved a maximum height of more than 8

m. Height of individuals is mostly affected by herbivory which was observed in the area.

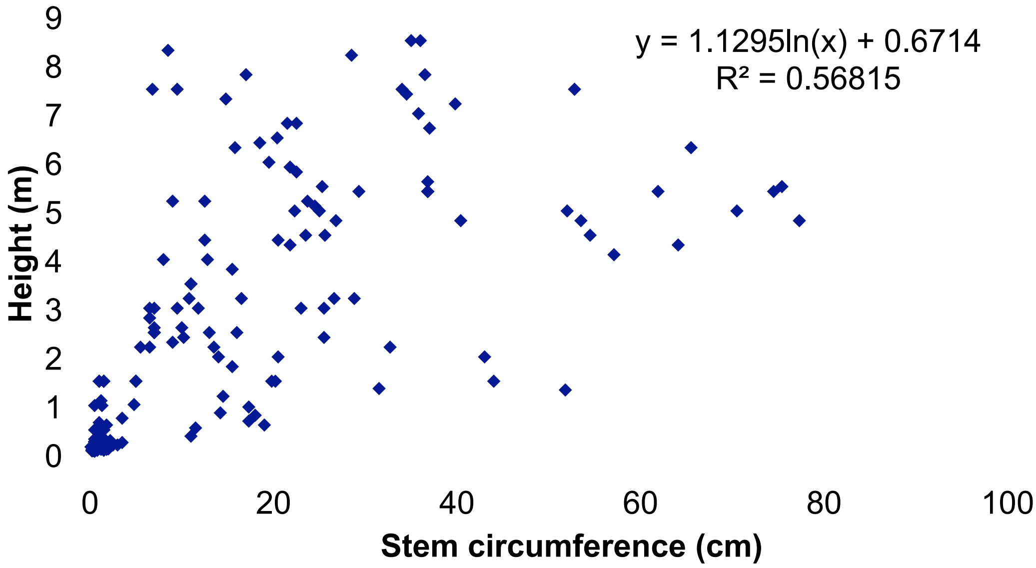

Figure 5.5: A logarithmic relationship between stem circumference and plant height in a population of *Elaeodendron transvaalense* sampled in 2004 at Tshirolwe, in the Venda region, Limpopo.

5.4.2 Harvesting

Forty eight percent of the *Elaeodendron transvaalense* individuals sampled were not harvested (Table 5.1; Figure 5.3). Most of the unharvested individuals were seedlings. The large number of unharvested seedlings indicates that the population should potentially be able to recover if harvesting intensity is reduced, although it still needs monitoring. In contrast, most of the larger size classes showed that 100% of the individuals had signs of harvesting.

Table 5.1: Extent of harvesting on *Elaeodendron transvaalense* individual trees in the Tshirolwe population sampled in 2004

Stem circumference size class (cm)	No. of harvested individuals	No. of unharvested individuals	Total number of individuals	Percentage of size class harvested	Total area harvested (m^2)	Mean area harvested per individual (m^2)
0-20	1	69	70	1.43	0.04	0.04
>20-40	15	9	24	62.5	1.12	0.07
>40-60	15	3	18	83.3	4.29	0.29
>60-80	18	0	18	100.0	12.21	0.68
>80-100	8	1	9	88.9	4.29	0.54
>100-120	11	0	11	100.0	9.89	0.90
>120-140	4	0	4	100.0	2.31	0.58
>140-160	0	0	0	0.0	0.00	0.00
>160-180	6	0	6	100.0	4.96	0.83
>180-200	1	0	1	100.0	1.99	1.99
>200-220	2	0	2	100.0	4.02	2.01
>220-240	3	0	3	100.0	4.94	1.68
>240-260	1	0	1	100.0	1.31	1.31

Some individuals showed severe bark removal with some of the individuals ending up dead due to harvesting pressure. Harvesting area increased with an increase in stem circumference (Table 5.1, Figure 5.6, $r^2 = 0.6219$ and $y = 0.1437x - 0.1662$). This is understandable because large trees have more available bark to harvest.

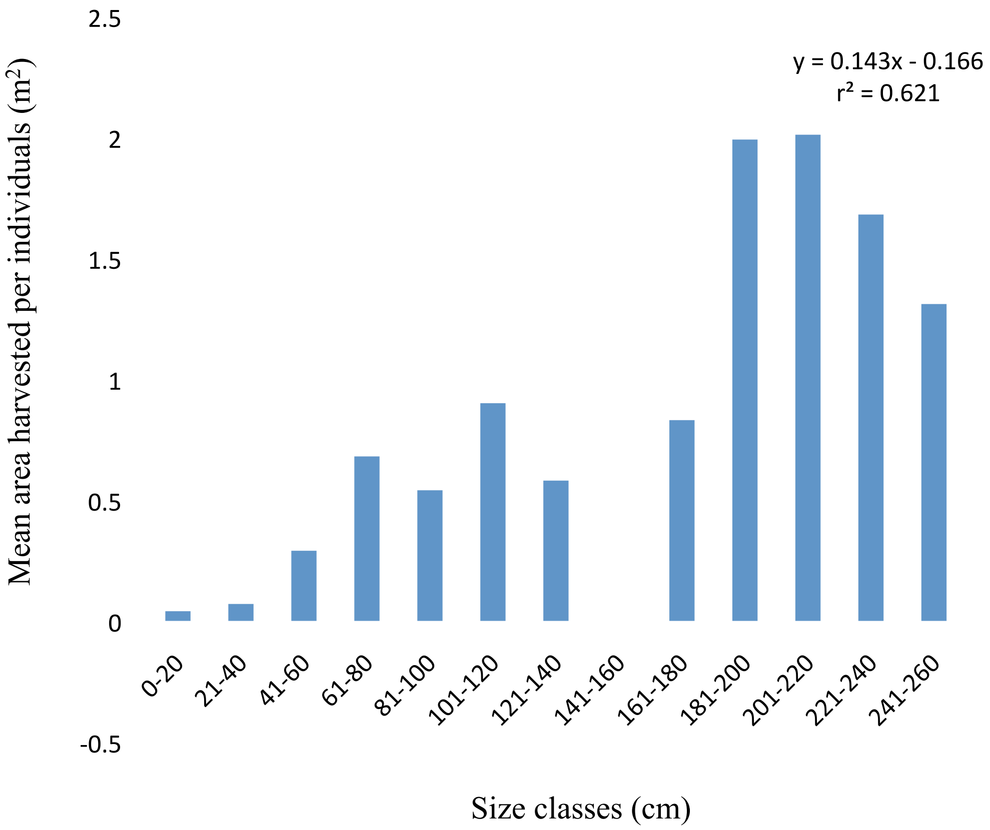

Figure 5.6: Relationship between the stem circumference classes and mean harvested area in a population of *Elaeodendron transvaalense* sampled in 2004 at Tshirolwe, in the Venda region, Limpopo.

Overharvesting could be the reason for the absence of any individuals either harvested or unharvested in the larger than 140 to 160 cm circumference size class in the studied *Elaeodendron transvaalense* population. The three size classes most affected by the bark removal practices were the >180-200, >200-220, and >220-240 cm circumference classes (Figure 5.6). These three size class categories also constituted 30% of the individuals that showed 100% crown mortality.

Figure 5.7: Stem size classes against ratio of the area: stem circumference in a population of *Elaeodendron transvaalense* sampled in 2004 at Tshirolwe, in the Venda region, Limpopo.

When the ratio of harvested area : stem circumference was plotted against the different size classes it was clear that some of the smaller size classes were experiencing the same high harvesting pressure as the larger ones. It is clear that harvesting of medicinal materials is also done on young individuals.

5.4.3 Crown health

Defoliation is widely used as an indicator for the vitality of forest trees and the degree of damage (Zierl 2004, Wang *et al.* 2007). Crown health was assessed on a 0 - 5-point scale with 0 indicating 100% crown mortality and 5 indicating a healthy crown (Sunderland and Tako 1999) and gave a good indication of overall tree health.

The crown health of the *Elaeodendron transvaalense* population was generally not in a good state (Figure 5.8). Ten percent (10%) of the *E. transvaalense* population crowns sampled was found to be completely dead. The death of a tree is regarded as an ultimate indicator of its non-vitality (Dobbertin and Brang 2001). Five percent (5%) had severe crown damage while 10% had moderate crown damage. Twenty-nine percent (29%) of the individuals sampled showed some traces of crown damage while 19% of individuals showed relatively healthy crowns. There was a weak negative relationship between the size of the individual and crown health (Figure 5.9; $r^2 = 0.1464$; $y = -0.0096x + 3.7846$; $p= 0.10171$) with most of the large individuals showing a poorer health status than the smaller individuals.

It is important to note that crown defoliation is a non-specific indicator of some underlying factors that may have caused stress for a tree. Total tree defoliation is a useful parameter in predicting year to year tree mortality (Dobbertin and Brang 2001).

Individuals with severe crown damage are likely to to die from stress that resulted in their defoliation.

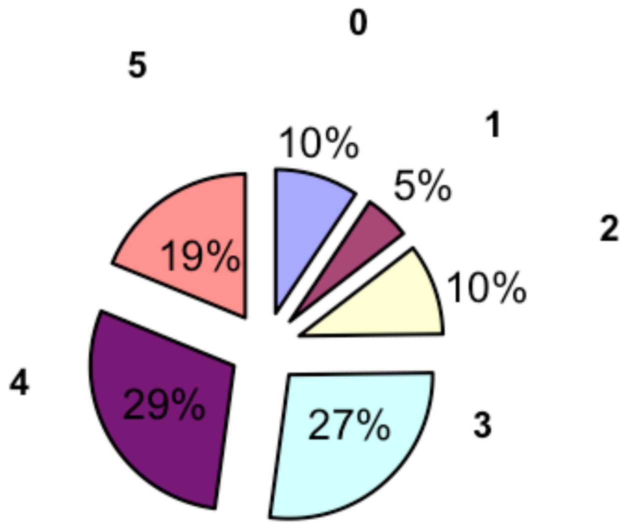

Figure 5.8: Crown health status of *Elaeodendron transvaalense* population in the Tshirolwe study area, Venda region, Limpopo, as determined by a survey in 2004. Crown health was assessed on a scale of 0–5 with 0 indicating 100% crown mortality and 5 indicating a healthy crown.

Although bark removal seemed to be the most likely factor contributing to the loss of crown health in the case of the Tshirolwe population, Zierl (2004) cautioned that it is important to devote more effort to the identification of other possible stress factors that may cause tree decline. In some cases the decline may be due to natural processes that involve environmental stresses such as water availability or exceptionally high or low temperatures (Zierl 2004).

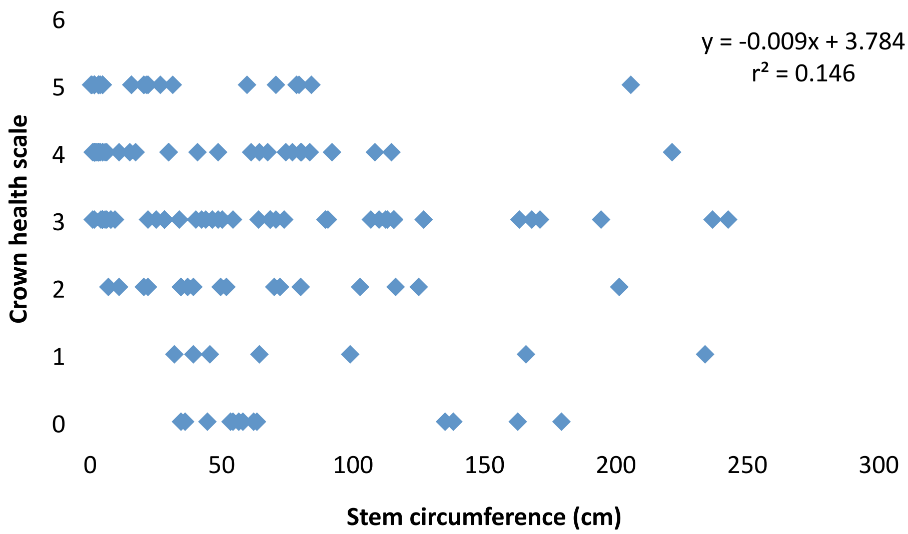

Figure 5.9: Stem circumference versus crown health status in a population of *Elaeodendron transvaalense* sampled in 2004 at Tshirolwe, in the Venda region, Limpopo.

In the Tshirolwe *E. transvaalense* population stress factors such as herbivory, trampling by livestock and wood harvesting for firewood were evident. The livestock observed in the study area were goats and cattle. In the population under study a number of seedlings were browsed on and the effect of herbivory on seedling survival will have to be monitored in future. Fortunately, the collection of wood for firewood, which is very prominent in the area, is only done for *E. transvaalense* after the individuals have died from ring-barking.

5.4.4 Regeneration

The relationship between seed production and the size of the plant as illustrated in Figure 5.10 indicated high seed production in middle-aged individuals of stem circumference of 50 cm to 150 cm as compared to older individuals with stem circumference of more than 150 cm to 250 cm. In general, irrespective of the few individuals bearing seeds, seedling establishment seemed to be good with a large number of seedlings observed.

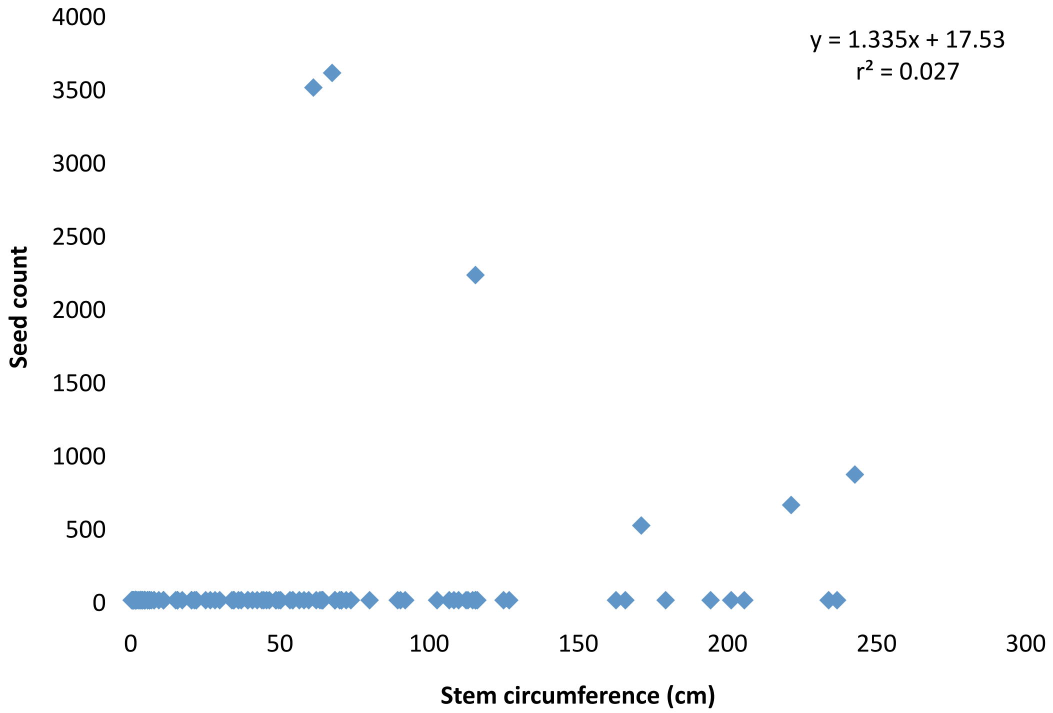

Figure 5.10: Stem circumference versus seed count as per individual.

Regeneration in a forest or woodland is an indicator of the wellbeing of the forest (Murthy *et al.* 2002). Studies relating to the regeneration of a specific species or the forest in general have always looked at the factors responsible for degradation. In spite of the large number of seedlings, the seedlings of *Elaeodendron transvaalense* were suppressed by herbivory. The effect of herbivory was largely counteracted by the ability of *E. transvaalense* to develop lignotubers (Figure 5.11) which store starch and enable the seedling to develop quickly after being browsed upon. The lignotuber is a storage organ, which resprouts vigorously when everything else above the ground has been destroyed by herbivores or fire. In the current study resprouts were generally classified as seedlings since it could only be established that they were resprouts after digging up the lignotuber. The classification of resprouts as seedlings could give a false impression of the success of regeneration by seeds. It is important to note that plant size is the most significant determinant of resprouting response (Neke *et al.* 2006)

Figure 5.11: An *Elaeodendron transvaalense* seedling resprout showing a well-developed lignotuber in the 2004 survey at the Tshirolwe, Limpopo study area.

The rate at which plant biomass is consumed by herbivores does not necessarily indicate control of plant standing crop by herbivores (Chase *et al.* 2000). Plants are able to compensate for losses to herbivory by regrowing tissues. Therefore the amount of plant biomass consumed by herbivores may have little to do with controlling effects of herbivores on plants. Maron and Crone (2006) also noted that in terms of consumer effects on plant abundance and distribution, demographic sensitivities alone may not provide accurate predictions on whether consumers that attack specific life stages of plants will have consequences on a population scale. The relative magnitude of the response of that particular life stage is also of importance.

5.4.5 Stem growth rate

When analysing the stem growth increment of *Elaeodendron transvaalense* a positive linear relationship was observed between the annual growth increments and stem circumference size (Figure 5.12; $r^2 = 0.8618$; $y = 0.0452x + 3.9228$; $p = 3.05 \times 10^{-12}$). The mean stem diameter increment for the entire sample was 2.57 cm per annum. Although this growth rate appears to be high it compares very well with growth rates of other woodland savanna species such as *Garcinia livingstonei* (2.6 cm/year), *Sclerocarya birrea* (1.33 cm/year) and *Albizia versicolor* (1.20 cm/year) as indicated in Gaugris *et al.* (2008).

In many tree species the growth rate of a tree changes with its life history (Kurokawa *et al.* 2003). Trees are expected to have their highest growth rate at middle size stages before growth is limited by the metabolic rate and reproduction. The mean stem circumference increment value of individuals in their vegetative stage was 5.74 cm (1.83 cm diameter increment) while it doubled to 10.56 cm (3.36 cm diameter increment) in the flowering stage (Figure 5.12). This however, showed that in *E.*

transvaalense the stem circumference growth rate continued to increase as circumference increased.

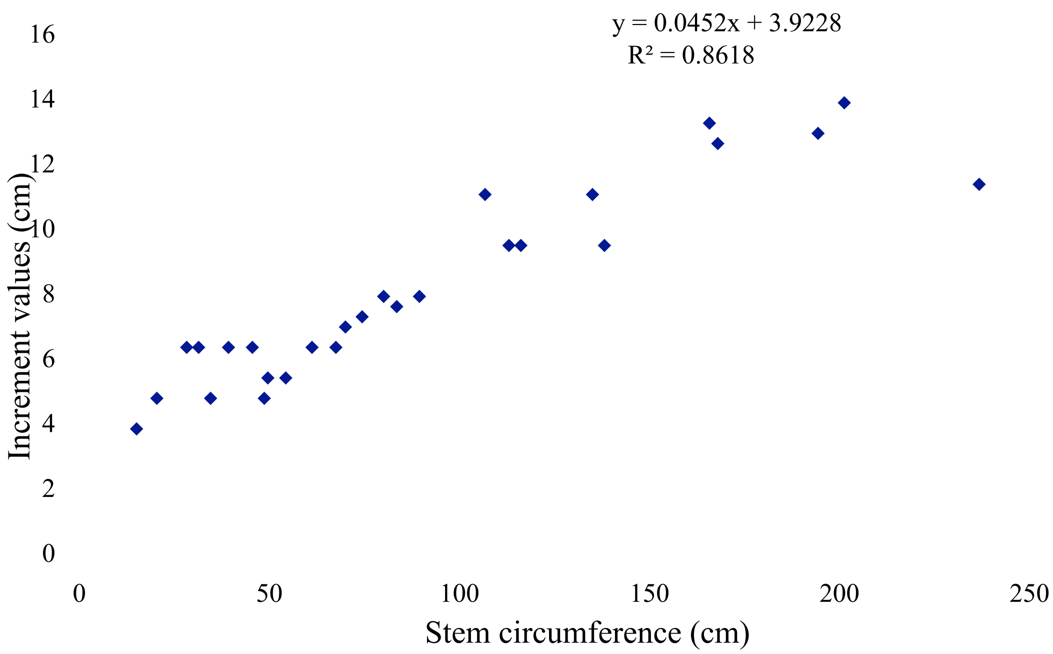

Figure 5.12: *Elaeodendron transvaalense* annual stem circumference increment as measured at Tshirolwe, Venda region between 2004 and 2005.

5.4.6 Population growth rate

A Lefkovitch transition matrix for structured populations was constructed (Giho and Seno 1997, Caswell 2001) with the population divided into three stages, namely: seedling, vegetative, and flowering stages. The stages were differentiated by stem circumference assuming that there was a relationship between age and stem circumference (Perryman and Olsen 2000, Suarez *et al.* 2008, Stoffberg *et al.* 2009).The diagonal values of the transition matrix were derived from the ages of individuals that were obtained from stem circumference increments. However, the matrix was derived with the assumption that all vegetative plants will reach flowering stage since there was no information on mortality.

After subjecting the matrix derived from *Elaeodendron transvaalense* data through the lambda script on the Matlab programme, lambda was found to be 1.041. When using a constant transition matrix for multiplication the prediction of future population size is generally of little relevance (Desmet *et al.* 1996, Morris and Doak 2002).

An elasticity analysis was performed to evaluate the relative importance of the population projection matrix cell entries and lower-level parameters on lambda. This analysis can be used to determine the stages of a species' life cycle that should be targeted for management action (Link and Doherty 2002, Norris and McCullogh 2003, Crone *et al.* 2011).

The elasticity analysis showed that the highest elasticity value was in the cell indicating the probability of a vegetative individual remaining in the vegetative stage, which had a value of 0.6420. This means that 64.2% of the influence on λ can be ascribed to this stage. It therefore indicates that for management purposes it can be important to put more effort into protecting plants that are in the vegetative stage.

5.4.7 Species grain

The species grain concept provides information on whether a tree species can potentially sustain moderate harvesting levels or whether it may not survive such harvesting (Obiri *et al.* 2002). This approach provides a useful framework upon which to base operational harvesting rates.

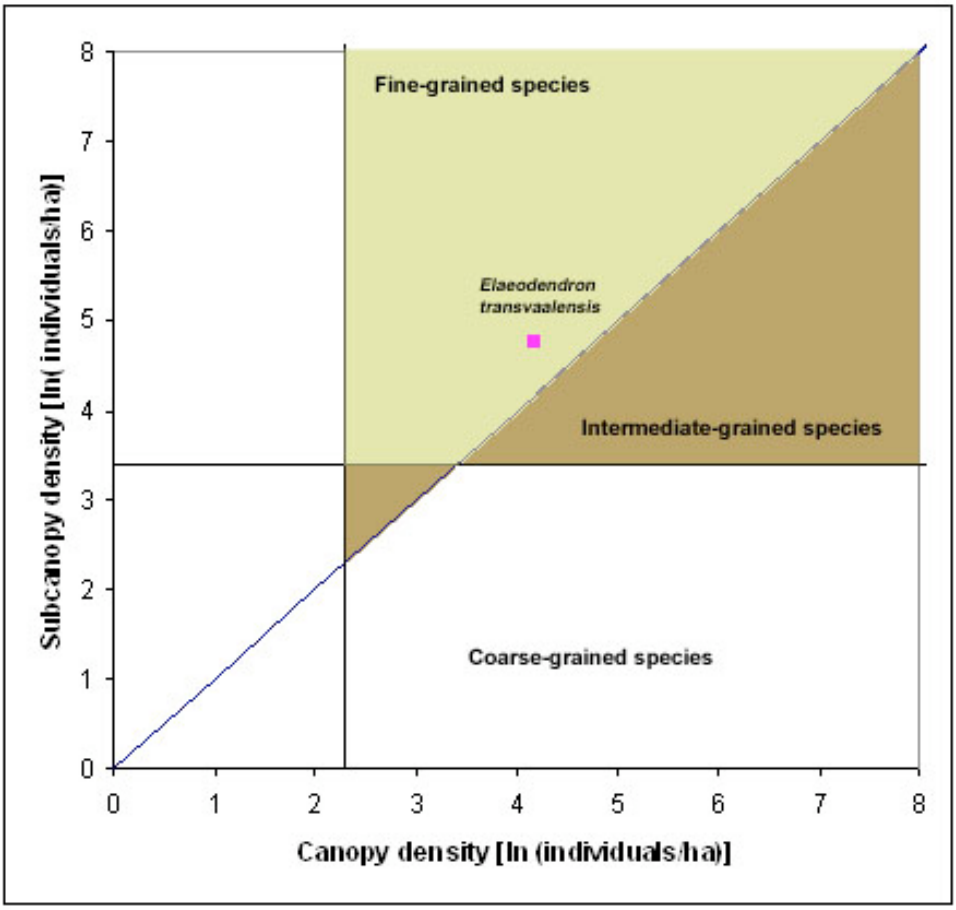

Figure 5.13: Species grain of the *Elaeodendron transvaalense* population of Tshirolwe from data collected in 2004.

The population of *Elaeodendron transvaalense* under study could be classified as a fine-grained species (Figure 5.13). According to Obiri *et al.* (2002) the species grain theory suggests that fine-grained species should be able to withstand moderate levels of use. It would therefore appear possible to harvest *E. transvaalense* sustainably. In the case of *E. transvaalense,* individuals are not used for construction or other purposes and bark-harvesting therefore represents the only form of harvest. Therefore with the proper harvesting techniques, *E. transvaalense* may survive such moderate harvesting.

5.5 Conclusions

The use of a size-class distribution analysis provided a practical field method for investigating the population structure of *Elaeodendron transvaalense* and illustrated the response of the population to harvesting pressures. The population showed a healthy population structure with an inverse J-shaped curve. Therefore, in spite of the current harvesting pressure the population was still showing good recruitment. The data collected during this once-off survey can be used for monitoring changes in the population structure over time in the presence of harvesting.

The study has shown that the exploitation of *E. transvaalense* by local people around Venda is currently very high. Despite the reasonable level of seedling establishment, the destruction rate of large trees is a point of concern. Bark harvesting for medicinal purposes is the major contributor to the loss of *E. transvaalense* individuals, since people only utilize it for firewood after it has died from debarking and is dry. Cultivation intervention should be considered to reduce the stress experienced by *E. transvaalense*.

The matrix analysis allows one to answer a number of questions that cannot be answered by simple calculations. However, to improve the analysis it is important to get repeated data on every individual in the population. Data should be recorded for many years in order to get a clear picture in terms of changes that occur. Data on mortality is especially needed to improve the parameterization of the cell entries in the transition matrix. This kind of information can also indicate the longevity of the individual.

5.6 Acknowledgements

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References

ACOCKS, J.P.H. 1988. Veld Types of South Africa. 3rd edition. *Memoirs of the Botanical survey of South Africa.* No. 57.

BERGER, K., CRAFFORD, J.E., GAIGHER, I., GAIGHER, M.J., HAHN, N. AND MACDONALD, I. 2003. A first synthesis of the environmental, biological and cultural assets of the Soutpansberg. Leach printers, Louis Trichardt, South Africa.

BESSONG, P.O., OBI, C.L., ANDREOLA, M.L., ROJAS, L.B., POUSEGU, L., IGUMBOR, E., MEYER, J.J.M., QUIDEAU, S. AND LITVAK, S. 2005. Evaluation of selected South African medicinal plants for inhibitory properties against human immunodeficiency virus type 1 reverse transcriptase and integrase. *Journal of Ethnopharmacology* **99: 83-91.**

BESSONG, P.O., ROJAS, L.B., OBI, L.C., TSHISIKHAWE, P.M. AND IGUMBOR, E.O. 2006.Further screening of Venda medicinal plants for activity against HIV type 1 reverse transcriptase and integrase. *African Journal of Biotechnology* **5: 526-528.**

BODEKER, G.C. 1995. Introduction: Medicinal plants for Conservation and Healthcare. Institute of Health Sciences, University of Oxford, Oxford, UK.

CASWELL, H. 2001. Matrix population models: Construction, Analysis and Interpretation. 2nd edition. Sinauer Associates, Inc. Publishers, Massachusetts, USA.

CHASE, J.M., LEIBOLD, M.A., DOWNING, A.L. AND SHURIN, J.B. 2000. The effects of productivity, herbivory, and plant species turnover in grassland and food webs. *Ecology* **81: 2485-2497.**

CONDIT, R., SUKUMAR, R., HUBBEL, S. AND FOSTER, R. 1998. Predicting population trends from size distributions: a direct test in a tropical tree community. *American Naturalist* **152: 495-509.**

CRONE, E.E., MENGES, E.S., ELLIS, M.M., BIERZYCHUDEK,P., EHRLEN, J., KAYE, T.N., KNIGHT, T.M., LESICA, P., MORIS, W.F., OOSTERMEIJER, G. QUINTANA-ASCENCIO, P.F., STANLEY, A., TICKTIN, T., VALVERDE, T. AND WILLIAMS, J.L. 2011. How do plant ecologists use matrix population models? *Ecology Letters* **14: 1–8.**

CUNNINGHAM, A.B. 2001. Applied ethnobotany: people, wild plant use and conservation. Earthscan Publication, London, UK.

DESMET, P.G., SHACKLETON, C.M. AND ROBINSON, E.R. 1996. The population dynamics and life-history attributes of a *Pterocarpus angolensis* DC. population in the Northern Province, South Africa. *South African Journal of Botany* **62:160-166.**

DOBBERTIN, M. AND BRANG, P. 2001. Crown defoliation improves tree mortality models. *Forest Ecology and Management* **141: 271-284.**

DREWES, S.E., MASHIMBYE, M.J., FIELD, J.S. AND RAMESAR, N. 1991. 11, 11-dimethyl-1,3,8,10-tetrahydroxy-9-methoxypeltogynan and three pentacyclictriterpenes from *Cassine transvaalense. Phytochemistry* **30: 3490-3493.**

EVERARD, D.A., MIDGLEY, J.J. AND VAN WYK, G.F. 1995. Dynamics of some forests in KwaZulu-Natal, South Africa, based on ordinations and size class distributions. *South African Journal of Botany* **61: 283-292.**

EVERARD, D.A., VAN WYK, G.F. AND MIDGLEY, J. J. 1994. Disturbance and the diversity of forests in Natal, South Africa: lessons for their utilisation. *Strelitzia* **1: 275-285.**

GANESAN, R. AND SIDDAPPA, S.R. 2004. Regeneration of *Amla*, an important non-timber forest product from Southern India. *Conservation and Society* **2: 365-375.**

GAUGRIS, J.Y. AND VAN ROOYEN, M.W. 2007. The structure and harvesting potential of the sand forest in Tshanini Game Reserve, South Africa. *South African Journal of Botany* **73: 611–622.**

GAUGRIS, J.Y. AND VAN ROOYEN, M.W. 2011. The effect of herbivores and humans on the Sand Forest species of Maputaland, northern KwaZulu-Natal, South Africa. *Ecological Research* **26: 365-376.**

GAUGRIS, J.Y., VASICEK, C.A. AND VAN ROOYEN, M.W. 2007. Selecting tree species for sustainable harvest and calculating their sustainable harvesting quota in Tshanini Conservation Area, Maputaland, South Africa. *Ethnobotany Research and Applications* **5: 373-389.**

GAUGRIS, J.Y., VAN ROOYEN, M.W. AND BOTHMA, J.P. 2008. Growth rate of selected woody species in the northern Maputaland, KwaZulu-Natal, South Africa. *South African Journal of Botany* **74: 85-92.**

GIHO, H. AND SENO, H. 1997. Transition matrix modelling on disturbance-controlled persistence of plant population. *Ecological Modelling* **94: 207-219.**

GUEDJE, N.M., ZUIDEMA, P.A., DURING, H., FOAHOM, B. AND LEJOLY, J. 2007. Tree bark as a non-timber forest product: The effect of bark collection on population structure and dynamics of *Garcinia lucida* Vesque. *Forest Ecology and Management* **240: 1-12.**

KOHIRA, M. AND NINOMIYA, I. 2003. Detecting tree populations at risk for forest conservation management: using single-year vs. long-term inventory data. *Forest Ecology and Management* **174: 423-435.**

KUROKAWA, H., YISHIDA, T., NAKAMURA, T., LAI, J. AND NAKASHIZUKA, T. 2003. The age of tropical rain-forest canopy species, Borneo ironwood *(Eusideroxylon zwageri)*, determined by ^{14}C dating. *Journal of Tropical Ecology* **19: 1-7.**

LINK, W.A. AND DOHERTY, P.F. 2002. Scaling in sensitivity analysis. *Ecology* **83: 3299-3305.**

LAWES, M.J. AND OBIRI, J.A.F. 2003. Using the spatial grain of regeneration to select harvestable tree species in subtropical forest. *Forest Ecology and Management* **184: 105-114.**

LAWES, M.J., EELEY, H.A.C., SHACKLETON, C.M. AND GEACH, B.G.S. 2004. Indigenous forests and woodlands in South Africa: Policy, People and Practice. University of KwaZulu-Natal Press, Pietermaritzburg.

LYKKE, A.M. 1998. Assessment of species composition change in savanna vegetation by means of woody plants' size class distributions and local information. *Biodiversity and Conservation* **7: 1261-1275.**

MABOGO, D.E.N. 1990. The ethnobotany of the Vhavenda. Master of Science dissertation, University of Pretoria, Pretoria.

MARON, J.L. AND CRONE, E. 2006. Herbivory: effects on plant abundance, distribution and population growth. *Proceedings of The Royal Botanical Society* **273: 2575-2584.**

MIDGLEY, J., SEYDACK, A., REYNELL, D. AND MCKELLY, D. 1990. Fine-grain pattern in southern Cape plateau forests. *Journal of Vegetation Science* **1: 539-546.**

MORRIS, W.F. AND DOAK, D.F. 2002. Quantitative conservation biology: theory and practice of population viability analysis. Sinauer Associates, Sunderland, Massachusetts.

MUCINA, L. AND RUTHERFORD, M.C. 2006.The vegetation of South Africa, Lesotho and Swaziland. South African National Biodiversity Institute, Pretoria.

MURTHY, I.K., MURALI, K.S., HEGDE, G.T., BHAT, P.R. AND RAVINDRANATH, N.H. 2002. A comparative analysis of regeneration in natural forests and joint forest management plantations in Uttara Kannanda district, Western Ghats. *Current Science* **83: 1358-1364.**

NEKE, K.S., OWEN-SMITH, N. AND WITKOWSKI, E.T.F. 2006. Comparative resprouting response of Savanna woody plant species following harvesting: the value of persistence. *Forest Ecology and Management* **232: 114-123.**

NIKLAS, K.J., MIDGLEY, J.J. AND RAND, R.H. 2003a. Size-dependent species richness: trends within plant communities and across latitude. *Ecology Letters* **6: 631-636.**

NIKLAS, K.J., MIDGLEY, J.J. AND RAND, R.H. 2003b. Tree size frequency distributions, plant density, age and community disturbance. *Ecology Letters* **6: 405-411.**

NORRIS, K. AND MCCULLOCH, N. 2003. Demographic models and the management of endangered species: a case study of the critically endangered Seychelle magpie robin. *Journal of Applied Ecology* **40: 890-899.**

OBIRI, J., LAWES, M. AND MUKOLWE, M. 2002. The dynamics and sustainable use of high value tree species of the coastal Pondoland forests of the Eastern Cape Province, South Africa. *Forest Ecology and Management* **166: 131-148.**

PALGRAVE, K.C. 1988. Trees of Southern Africa. 4th edition. Struik Publishers, Cape Town.

PERRYMAN, BL. AND OLSEN, R.A. 2000. Age-stem diameter relationships of big sagebrush and their management implications. *Journal of Range Management* **53: 342-346.**

PETERS, C.M. 1996. *The Ecology and Management of Non-Timber Forest Resources*. World Bank Technical Paper No. 332. Washington, D.C., U.S.A.

SAMIE, A., OBI, C.L., BESSONG, P.O. AND LALL, N. 2005. Activity profiles of fourteen selected medicinal plants from rural Venda communities in South Africa against fifteen clinical bacterial species. *African Journal of Biotechnology* **4: 1443-1451.**

SCHWARTZ, M.W., CARO, T.M. AND BANDA-SAKALA, T. 2002. Assessing the sustainability of harvest of *Pterocarpus angolensis* in Rukwa Region, Tanzania. *Forest Ecology and Management* **170: 259-269.**

SILVERTOWN, J. AND CHARLESWORTH, D. 2001. Plant population biology. 4th edition. Blackwell Science, Oxford.

SOLBRIG, O.T. 1980. Demography and evolution in plant populations. Blackwell Scientific Publishers, California.

STEENKAMP, V. 2003. Traditional herbal remedies used by South African women for gynecological complaints. *Journal of Ethnopharmacology* **86:97-108.**

STOFFBERG, G.H., VAN ROOYEN, M.W., VAN DER LINDE, M.T. AND GROENEVELD, H.T. 2009. Modelling dimensional growth of three street tree species in the urban forest of the City of Tshwane, South Africa. *Southern Forests* **71: 273-277.**

SUAREZ, M.L., RENISON, D., MARCORA, P. AND HENSON, I. 2008. Age-size-habitat relationships for *Polylepis australis*: dealing with endangered forest ecosystems. *Biodiversity & Conservation* **17: 2617- 2625.**

SUNDERLAND, T.C.H. AND TAKO, C.T. 1999.The exploitation of *Prunus africana* on the island of Bioko, Equatorial Guinea. A report for People and Plants Initiatives, WWF-Germany and the IUCN/SSC Medicinal Plant Specialist Group.

TSHIKALANGE, T.E., MEYER, J.J.M., LALL, N., MUNOZ, E., SANCHO, R., VAN DE VENTER, M. AND OOSTHUIZEN, V. 2008. *In vitro* anti-HIV-1 properties of ethnobotanically selected South African plants used in the treatment of sexually transmitted diseases. *Journal of Ethnopharmacology* **119:478-481.**

TSHISIKHAWE, M.P. 2002. Trade of indigenous medicinal plants in the Northern Province, Venda region: their ethnobotanical importance and sustainable use. M.Sc. dissertation, University of Venda for Science and Technology, Thohoyandou.

VAN WYK, P. 1996. Field guide to the trees of the Kruger National Park. Struik Publishers, Cape Town, South Africa.

VAN WYK, B.E., VAN OUDTSHOORN, B. AND GERICKE, N. 1997. Medicinal plants of South Africa. Briza Publications, Pretoria, South Africa.

VAN WYK, B.E. AND GERICKE, N. 2000. People's plants. Briza publications, Pretoria, South Africa.

WANG, Y., SOLBERG, S., YU, P., MYKING, T., VOGT, R.D. AND DU, S. 2007. Assessments of tree crown condition of two masson pine forests in the acid rain region in south China. *Forest Ecology and Management* **242: 530-540.**

ZIERL, B. 2004. A simulation study to analyze the relations between crown condition and drought in Switzerland. *Forest Ecology and Management* **188: 25-38.**

CHAPTER 6

POPULATION BIOLOGY OF *BRACKENRIDGEA ZANGUEBARICA* OLIV. IN THE PRESENCE OF HARVESTING

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Abstract

Intense and frequent harvesting of bark from species with a high market demand often result in ring-barking of trees. The trees subsequently die, and the species becomes rare over time. *Brackenridgea zanguebarica* is a species in demand not only because of its medicinal value but also because it is highly regarded for its magical value.

The species has a limited distribution and is found only at Thengwe in the whole of South Africa. The population structure of the species was investigated and the response of the species to harvesting pressure evaluated in order to gain an understanding of its survival strategies. In spite of the high demand for the species it seems to be surviving the harvesting pressure, possibly because of its fine-grained nature. *Brackenridgea zanguebarica* showed a healthy population structure with lots of seedlings. The adult individuals showed a high degree of bark regeneration as a response to bark removal from medicine men. The inverse J-shaped curve showed that the population is healthy although sharp decreases between diameter size classes were observed. Fewer older individuals have healthy crown covers since crown health status tends to decrease with increase in stem diameter.

Keywords: Bark harvesting, magical value, population structure, regeneration

6.1 Introduction

Brackenridgea zanguebarica Oliv. (Ochnaceae) has been used by the Venda people for millennia, mostly for magical purposes. Because of its magical uses the species is popularly known as the magic tree. According to Netshiungani and Van Wyk (1980), to the Vhavenda people, *B. zanguebarica* is also a plant of great medicinal importance. Some of the uses recorded in Netshiungani and van Wyk (1980), Van Wyk *et al*. (1997) Tshisikhawe (2002), and Todd *et al.* (2004) are the following:

i. to protect people against witchcraft;
ii. protecting the whole homestead from evil people;
iii. performing magical activities;
iv. treatment of wounds, worms, amenorrhea, swollen ankles and aching hands; and
v. discouraging opponents in sporting events such as soccer.

Brackenridgea zanguebarica has a wide range of biological activity against eukaryotic cells, bacteria and viruses (Moller *et al.* 2006). The species has a restricted distribution in South Africa and has been classified as Critically Endangered (CR) according to the IUCN Red List categories in South Africa (Raimondo *et al.* 2009). However, it occurs more widespread in southern African countries such as Zimbabwe and Zambia and its global IUCN Red List status is Least Concern (LC). Although plant numbers are limited in South Africa, its survival is mainly attributed to the cultural beliefs of the Vhavenda people when collecting it. Since the plant is found within the Vhatavhatsindi clan they believe for it to work as a medicine it has to be collected by a dedicated person from the clan. They also believe that the collector, who is not a dedicated member, can become sterile by touching the plant. Collection is also done by a naked person, which is usually during the dark to avoid being seen by passersby (Mabogo 1990). These are some of the beliefs that are still adhered to by people from the area as well as traditional healers, and it is only illegal collectors and people who do not know the culture that do not honour them. Middlemen, those that collect for the traditional healers and traders, do not adhere to these cultural beliefs since for them it is about making money through collecting large amounts of medicinal material.

Because of the ever-increasing demand of this species as medicine (Williams 1996, Tshisikhawe 2002, Botha 2004, Todd *et al.* 2004, Saidi and Tshipala-Rmatshimbila 2006) it is important to assess the effect of harvesting on its population structure. Knowledge of the size-class distribution, i.e. the frequency distribution of stems across diameter or circumference classes, can help in assessing the population for its sustainability (Lawes *et al.* 2004). However, because of phenotypic plasticity care should be taken when converting size-class distributions into age-class distributions (Silvertown and Charlesworth 2001). The aim of the study was therefore to understand the population biology of *Brackenridgea zanguebarica* in the presence of harvesting in a communal area.

6.2 Species and study area

Brackenridgea zanguebarica is a deciduous shrub or small tree, which occurs in the bushveld or along the forest margins (Palgrave 1988, Van Wyk and Van Wyk 1997). The bark is rough or corky with a bright yellow pigment in the dead outer layers of the stems. The leaves are elliptic to obovate, glossy dark green above, paler green below, hairless, with numerous lateral and tertiary veins prominent on both sides. Margins are finely toothed with each tooth tipped by a minute gland (Van Wyk and Van Wyk 1997). According to Netshiungani and Van Wyk (1980), these glands found along the margins of the lamina, are a characteristic that can be used to differentiate the species from other members of the Ochnaceae family.

Brackenridgea zanguebarica is the only member of the *Brackenridgea* genus that occurs in South Africa. The Thengwe population is also the only population of *B. zanguebarica* in South Africa. The bark of *B. zanguebarica* is collected and used as medicine although its main usage is for its magical properties. This bark is collected from the stems of standing trees as well as from roots.

Data on *Brackenridgea zanguebarica* was collected from the Venda region in the Thengwe study area (Figure 6.1). According to Acocks (1988) the vegetation type is a Sourish Mixed Bushveld. It is the veld type occupying an irregular belt between the sour types and the mixed types of the plains and valleys. Soil in this vegetation type is a sandy loam that was derived from sandstone (Cowling *et al.* 1997). The rainfall at Tshandama the closest weather station to Thengwe is 688 mm (Weather Bureau 1998).

The vegetation around the study area is classified as the VhaVenda Miombo by Mucina and Rutherford (2006). It is a unique vegetation unit and is limited to a very small area in the upper reaches of the Mbodi River Valley between Shakadza and

Mafukani. *Brachystegia spiciformis*, one of the most important and dominant species of miombo woodlands has its southernmost distribution in this vegetation unit.

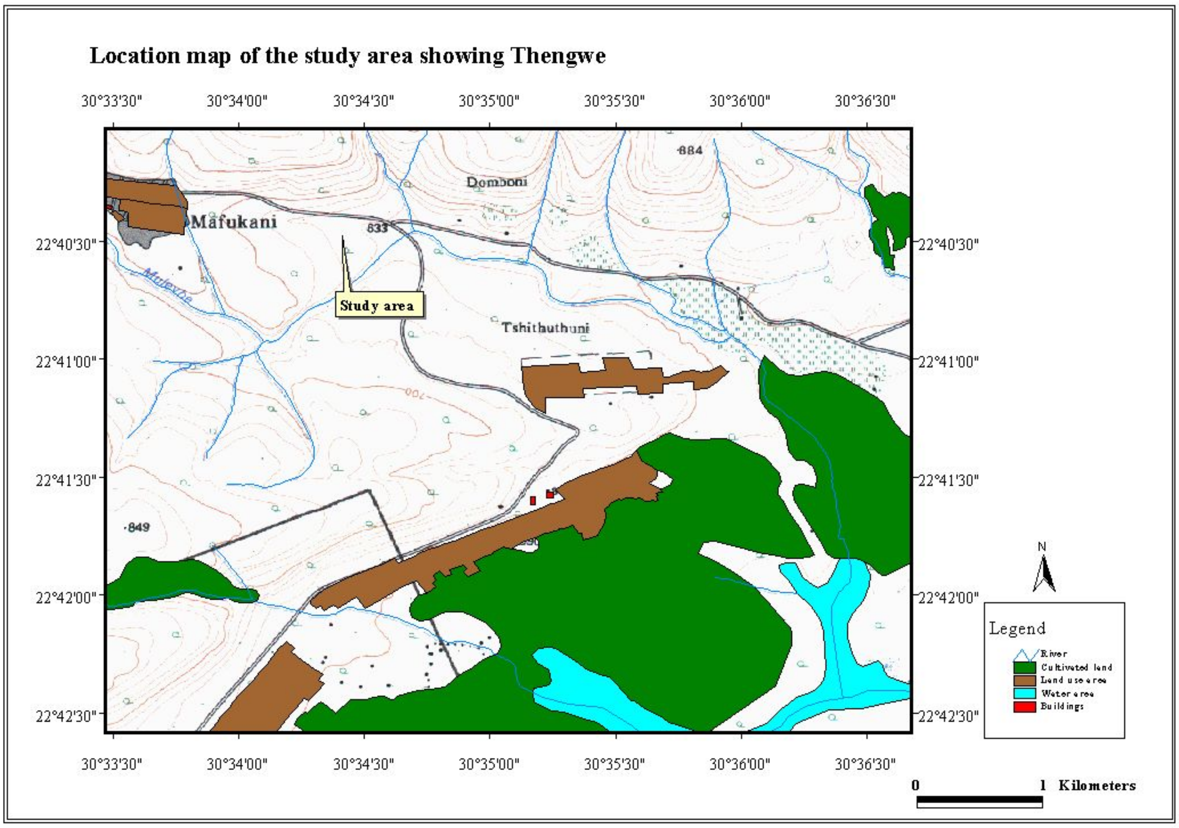

Figure 6.1: A location map showing the Thengwe study area where data on *Brackenridgea zanguebarica* was collected in 2004.

Accessibility in the Thengwe study area is strictly controlled by the local tribal authority. The local tribal authority makes sure that the population is not exploited by collectors of medicinal material. Collectors of medicinal material from *B. zanguebarica* are accompanied by people from the tribal offices who supervise the collection procedures. With the guidance of the local authorities, harvesters are allowed to chop down appropriate stems for collection of medicinal material.

Collection of medicinal material from *Brackenridgea zanguebarica* is done by a dedicated member of the Vhatavhatsindi clan who should be young and not yet sexually active or old enough to be no longer involved in such an activity. This is a way of ensuring that a collector who is sexually active is protected from becoming sterile based on the cultural belief system amongst the Vhatavhatsindi people. The Vhatavhatsindi people believe that the plant which is only found in their community is a gift from God and they are the sole custodian of the species hence its common name as 'mutavhatsindi' (Ramaliba pers comm.[10]). They also believe that for the medicine to be active, it should only be collected by a dedicated member from their clan.

The collection pattern is however being negatively affected by people who collect medicinal material in the absence of members of the tribal authority. These illegal collectors are people who do not observe the mythology associated with the Vhatavhatsindi clan (Ramaliba pers comm[1]).

6.3 Materials and methods

Seven 100 m x 5 m transects were demarcated in order to sample the required data. The coordinates of each transect were recorded using a Global Positioning System. A rope was used to delineate transects. No control transects were demarcated due to lack of unharvested population within the same environmental gradients. The following data were recorded on all *Brackenridgea zanguebarica* individuals encountered within transects:

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[10] Ramaliba, Traditional Healer, Thohoyandou, South Africa, Communication 2007

(i) Stem circumference (in cm) – measured with a measuring tape above the basal swelling. Stem circumference values were converted to diameter values for some calculations.

(ii) Crown health – estimated using a 0 – 5-point scale as follows:

0 - no crown at all,

1 – severe crown damage,

2 – moderate crown damage,

3 – light crown damage,

4 – traces of crown damage,

5 – healthy crown.

(iii) Bark removal area – estimated using a 0 - 5 point scale, with 0 indicating no removal and 5 indicating 100% removal of bark around the stem.

(iv) Height – Height of the trees was measured with a graduated height rod while for seedlings a measuring tape was used.

(v) Stem circumferences of marked individuals were sampled again after one year in order to record the growth rate.

Stem diameter measurements were classified into 6 size classes with 5 cm intervals for the purpose of the size class analysis. Natural logarithmic transformations of the density of the size classes (D) (Condit *et al.* 1998) of the type ln (D+1) were used to transform the data (Lykke 1998, Niklas *et al.* 2003) before calculating least square linear regressions.

The mean diameter of the population, the "centroid", was also calculated. According to Niklas *et al.* (2003) a centroid skewed to the left of the midpoint of the size class distribution indicates a young and growing population, whereas one skewed to the right indicates an older, relatively undisturbed population.

The statistical significance of the differences between the slope and intercept values of the size class distribution curves of different surveys were analyzed by an Analysis of covariance (Quinn and Keough 2002) in GraphPad Prism 4.03 for windows (GraphPad software, San Diego California, USA, www. Graphpad.com).

The subcanopy and canopy densities were calculated as the sum of the number of individuals ≤30 cm circumference and larger than 30 cm circumference respectively. The use of subcanopy and canopy density, associated with frequency allows the grain of a species to be determined. The concept of species grain was developed for forests (Midgley *et al.* 1990); however, it has been successfully applied to woodlands (Gaugris *et al.* 2007, Gaugris and van Rooyen 2007) to establish which species could be harvested sustainably. The graphical model of Lawes and Obiri (2003) to determine species grain by plotting canopy density (X-axis) and subcanopy density (Y-axis) was used. The critical lower bounds for canopy and subcanopy density of 10 and 30 individuals per ha of Lawes and Obiri (2003) for forested systems were retained in this study.

6.4 Results and discussion

6.4.1 Population structure

The analysis of the population structure of *B. zanguebarica* as shown in Figure 6.2

indicates a healthy population as displayed by the inverse J-shaped curve (Peters 1996, Cunningham 2001). It is encouraging that the population has a fair amount of young individuals in the diameter class of 0–5 cm (approximately 70% of the population). However, individuals of the 0-5 cm the diameter class find it difficult to survive to the next class in large number since it shows a more than 50% reduction in the next size class of >5-10 cm diameter which constitutes approximately 23% of the population. The high mortality experienced early in the life cycle is characteristic of most long-lived species that have been studied (Silvertown and Charlesworth 2001). The more than 50% reduction is also experienced in the development of individuals from the >5-10 cm diameter class to >10-15 cm diameter class (7% of the population). The population remained at 7% in the >15-20 cm diameter class as well. The relative frequency reduction trend in the different size classes concurred with that recorded by Todd *et al.* (2004) from data collected in 1990 and 1997.

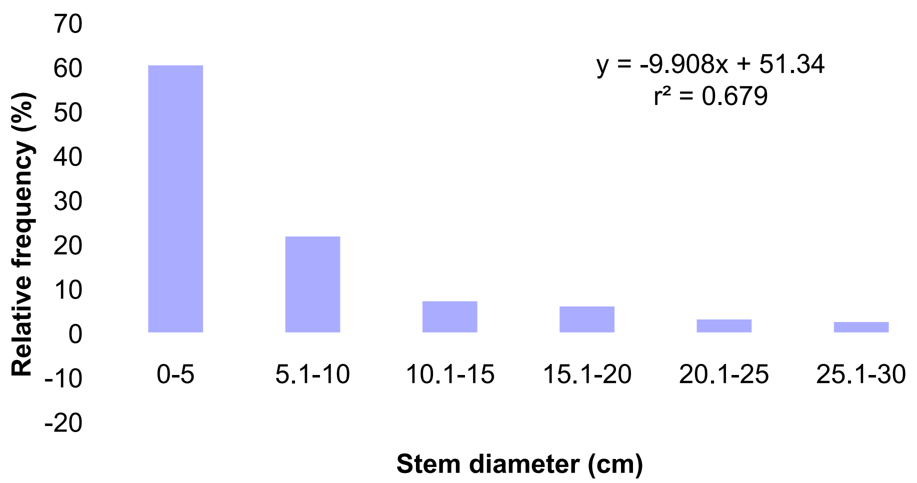

Figure 6.2: Size-class distribution of *Brackenridgea zanguebarica* from the Thengwe study area, Limpopo from data collected in 2004.

Todd *et al.* (2004) recorded 57% and 50% of individuals in the 0-5 cm which dropped in the >5–10 cm diameter class to 30% and 18% in 1990 and 1997 respectively. The population also decreased tremendously to 7% in the >15-20 cm diameter size class of 1990 while it remained at the same percentage of 18% in 1997. The *Brackenridgea zanguebarica* data of 2004 showed the presence of 3% of all individuals in the >20-25 cm diameter class as compared to 0% recorded in 1990 and 1997 data by Todd *et al.* (2004).

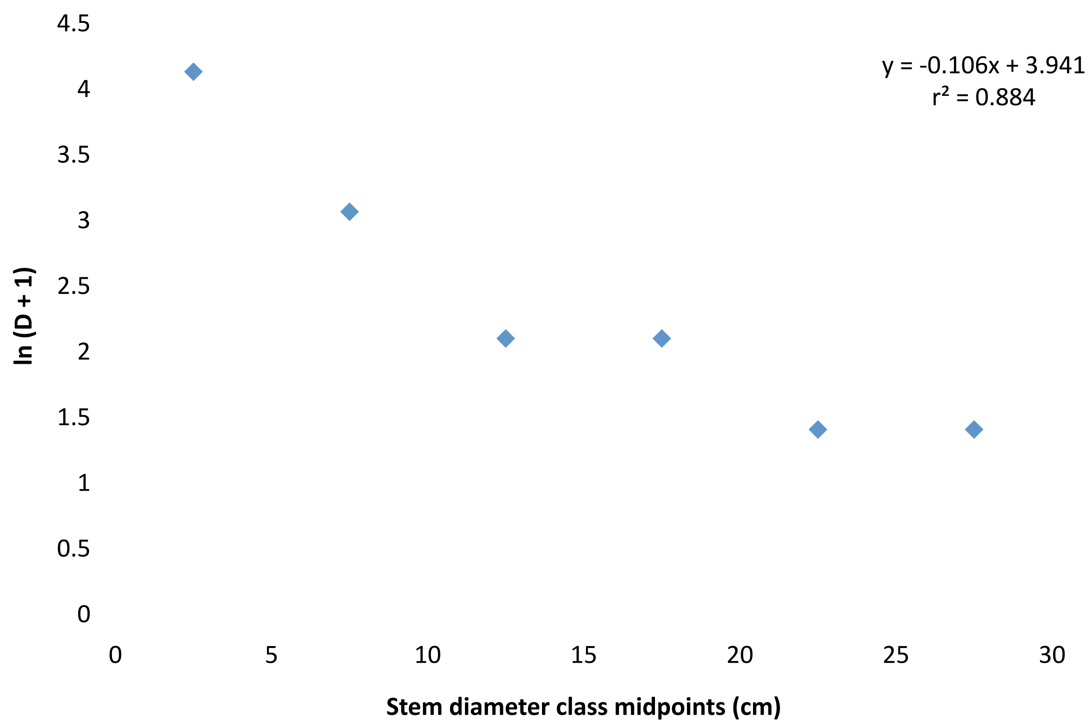

Figure 6.3: The regression of ln (D + 1) against stem diameter class midpoints for a *Brackenridgea zanguebarica* population from the Thengwe study area, Limpopo in 2004.

The position of the centroid (6.56 cm) was left-skewed in relation to the midpoint of stem diameter distributions (15.04 cm) and confirms the healthy status of the population in spite of harvesting. The linear regression on the natural logarithm of the density in the size classed against the size class midpoint (Figure 6.3) produced a significant linear regression ($r^2 = 0.8844$; $y = -0.1063x + 3.9419$; $p = 1.67 \times 10^{-3}$). The slope and Y-axis intercept of this equation can in future be used to compare other populations of *B. zanguebarica* under different harvesting regimes. It can also be used to compare the same Thengwe population over time to detect changes in population structure as has been done in Figure 6.4.

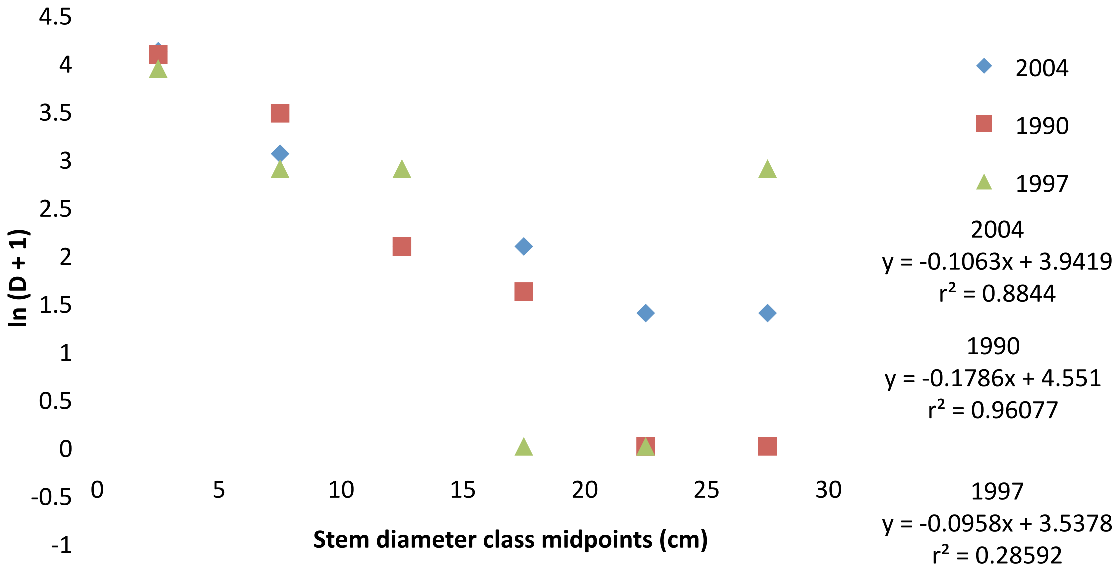

Figure 6.4: The regression of ln (D + 1) against stem diameter class midpoints for a *Brackenridgea zanguebarica* population from the Thengwe study area, Limpopo in 2004 compared to the regressions of data by Todd *et al.* (2004) in 1990 and 1997. (The 1st and 3rd points of 2004 data respectively overlapped with those of 1990 data).

The 2004 data were compared with those of Todd *et al.* (2004) in Figure 6.4. It is evident that the 1990 population regression had the steepest slope and the highest Y-intercept. An Analysis of Covariance indicated that the slope of the 1990 population was significantly steeper than that of the 2004 population ($p = 0.0253$), but that there was no significant difference in either slopes or intercepts between the 1990 and 1997 populations ($p = 0.3186$). There was also no significant difference in the slope or intercept between the 1997 and 2004 populations ($p = 0.8969$). It is therefore clear that significant changes have already occurred in the population since 1990 with the most noticeable difference being the presence of more large trees in 2004.

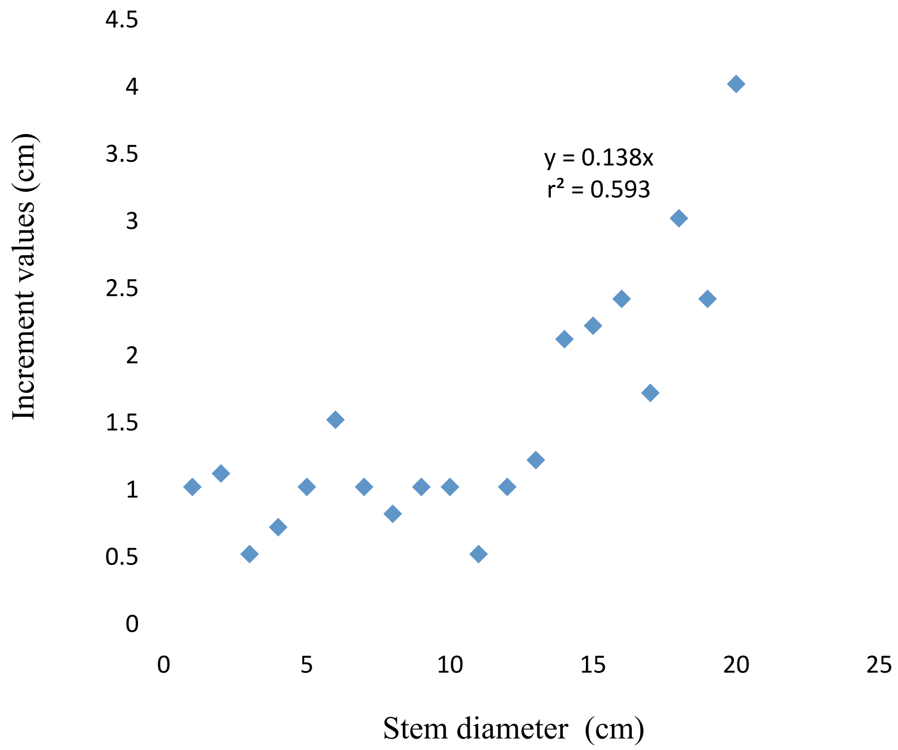

Figure 6.5: *Brackenridgea zanguebarica* annual stem circumference increment as measured at Thengwe, Venda region on data collected in 2004 and 2005.

Stem increment values of the *B. zanguebarica* population showed a linear regression as indicated in Figure 6.5 ($r^2 = 0.593$; $y = 0.138x$, linear regression forced through zero for it to be complete). The increment values were obtained from repeated sampling of stem circumference over two years. Because stem circumferences increments increase in proportion to stem size, individuals will remain longer within the smaller size classes than in larger size classes (provided that the size of all stem diameter classes is equal). For the 0 – 5 cm, >5 – 10 cm and >10 – 15 cm stem diameter classes the mean annual increase in circumference was 0.350 cm, 1.049 cm and 1.749 cm respectively. This translates into an individual remaining in the smallest size class (0 – 5 cm) for approximately 14 years, in the >5 – 10 cm size class for approximately 5 years and in the >10 – 15 cm size class for approximately 3 years.

6.4.2 Crown health

Crown health is regarded as a good indication of overall tree health (Sunderland and Tako 1999). Zierl (2004) has indicated that defoliation is widely used as an indicator for the vitality of forest trees and the degree of damage. The crown health status of *B. zanguebarica* population was found to be good since all the individuals showed a generally good health with the scale ranging from 3 to 5 (Figure 6.6; $r^2 = 0.702$, $y = 9.782x - 9.562$; $p = 2.92 \times 10^{-2}$).

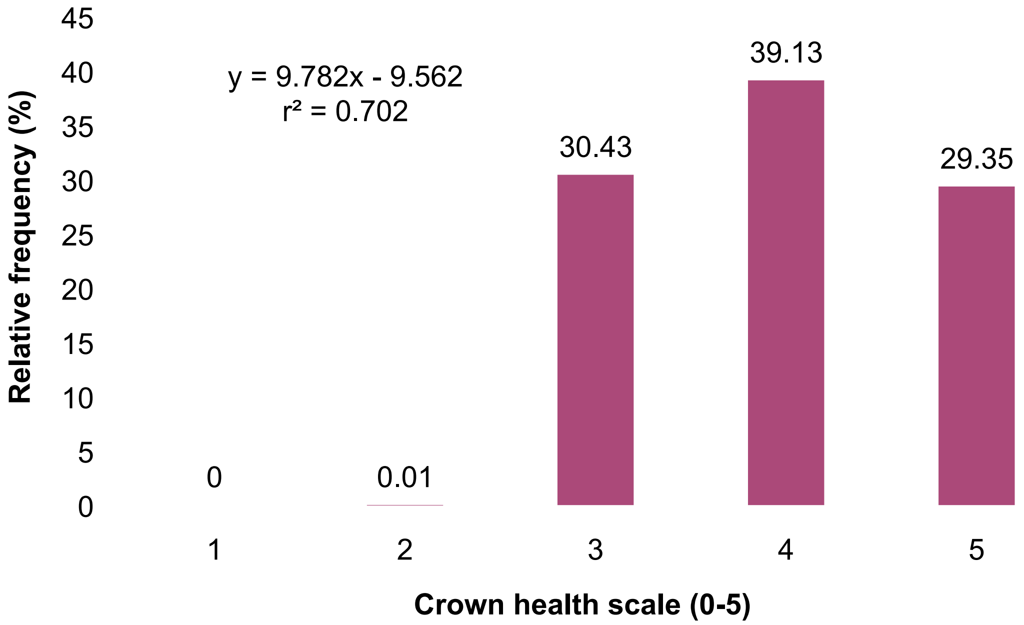

Figure 6.6: Crown health status of the *Brackenridgea zanguebarica* population in the Venda region, Limpopo, as determined by a survey in 2004. Crown health was assessed on a scale of 0-5 with 0 indicating 100% crown mortality and 5 indicating a healthy crown.

In spite of the intense harvesting pressure on the population, crown health status of the *B. zanguebarica* population was impressive considering the fact that none of the trees showed a crown status in the 0 category of the sliding scale. It shows that most of the individuals sampled have healthy canopies, which is a good sign of a well-managed population. As long as the stem is not ringbarked the species has the ability to regrow its bark and continue to have a healthy crown status.

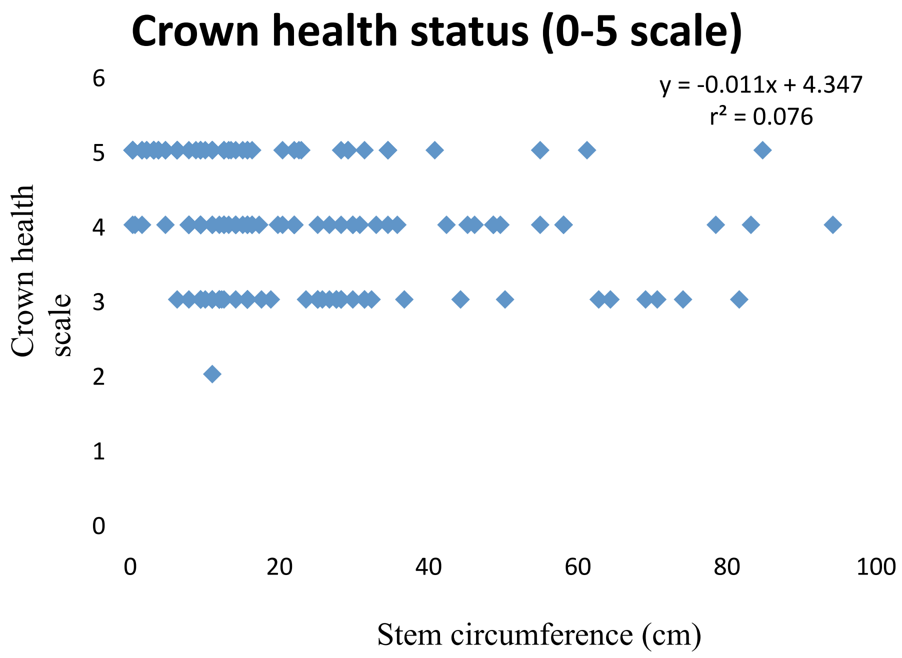

Figure 6.7: Correlation of crown health status and stem circumference of all individuals of *Brackenridgea zanguebarica* sampled in the Venda region, Limpopo, as determined by a survey in 2004.

A large number of individuals with stem circumferences of less than 40 cm showed healthy crowns (values 3, 4 and 5 on the sliding scale indicating only traces of crown damage or light crown damage). In general, crown health status deteriorated slightly with an increase in the stem circumference. Therefore, fewer older individuals have health crown covers as shown in Figure 6.7 ($r^2 = 0.076$, $y = -0.011x + 4.347$, $p = 2.4 \times 10^{-4}$).

6.4.3 Bark removal areas

To avoid ring-barking of trees the traditional authority accompanies medicinal material collectors to the field. However, ring-barking of trees still occurs due to the high level of illegal harvesting. At present the bark theft on *B. zanguebarica* has also extended into the Brackenridgea Nature Reserve despite the presence of conservation officials during the day.

Only 13% of the sample collected in 2004 as shown in Figure 6.8 showed some signs of bark removal with 1% of it showing 100% bark removal around the stem. Eighty-seven percent of the sample showed no signs of bark removal at all. This good harvesting practice is attributed to the close monitoring of medicinal material collection enforced by the local tribal authority. However, it should be noted that harvesters prefer collecting medicinal material through the removal of entire stems from *Brackenridgea zanguebarica* individuals and therefore the stems remaining on the plants do not show signs of bark removal. Investigating entire stem removal could not be done since it could have involved disturbing plants that could not be allowed.

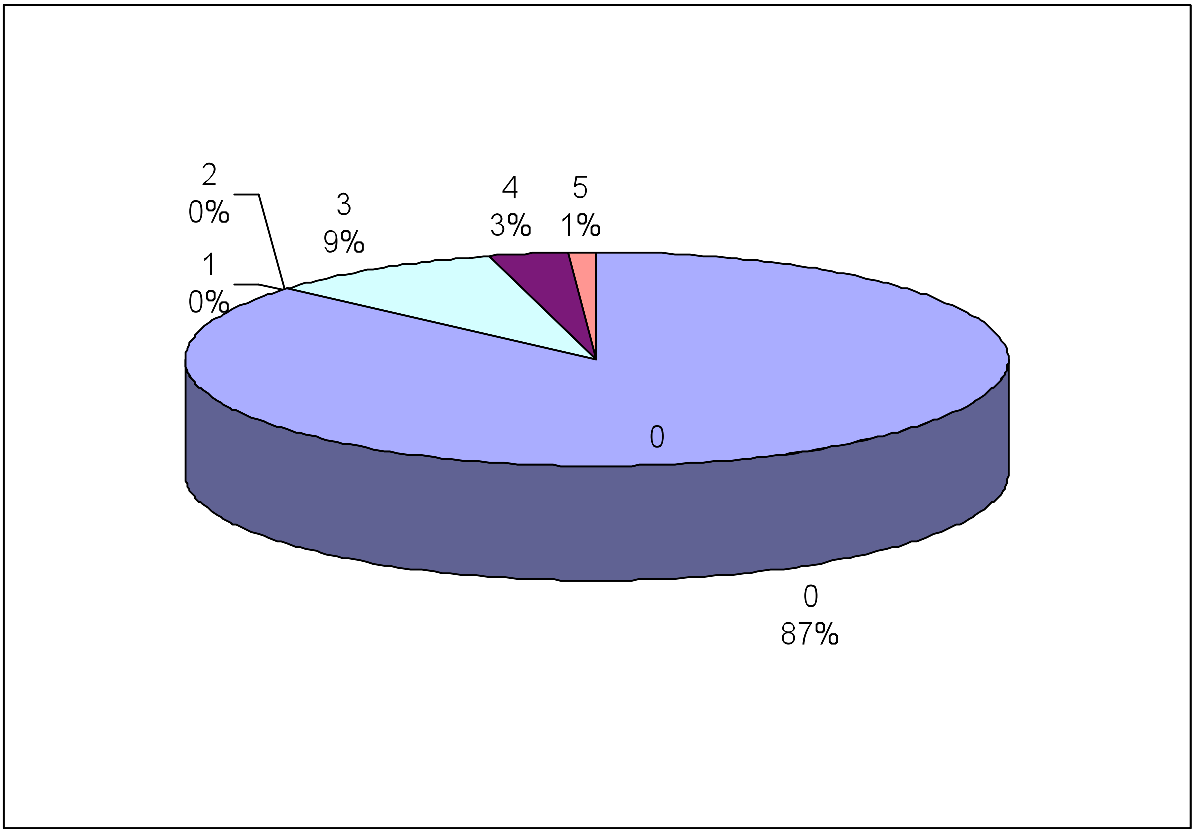

Figure 6.8: Bark removal estimates percentages on *B. zanguebarica* individuals from data collected in 2004 on a sliding scale of 0-5 with 0 indicating no removal and 5 indicating 100% removal of bark around the stem.

It is important to note the size classes of stems from which barks are mainly harvested. Harvesters prefer *Brackenridgea zanguebarica* individuals with stem circumference of >20 to 30 cm size classes as shown in Table 6.1. However, the number of individuals harvested in the >20-30 stem circumference class represented only 34.61% of the entire size class. The >60-70 cm and >70-10 cm stem circumference size classes showed the largest proportion of harvested individuals, i.e. 100% and 67% respectively (Table 6.1).

Table 6.1: Extent of harvesting on *Brackenridgea zanguebarica* individual trees through stem removal in data collected in 2004 at Thengwe study area

Stem circumference size class (cm)	No. of harvested individuals	No. of unharvested individuals	Total number of individuals	Percentage of size class harvested
0-10	1	58	59	1.69
>10-20	1	50	51	2.00
>20-30	9	17	26	34.61
>30-40	1	10	11	9.09
>40-50	2	6	8	25.00
>50-60	2	3	5	40.00
>60-70	4	0	4	100
>70-80	2	1	3	66.67
>80-90	1	2	3	33.33
>90-100	0	1	1	0

Although bark removal may contribute to the loss of crown health of forest species, it is important to devote more efforts to the identification of other possible stress factors that may cause forest decline. According to Zierl (2004), in some cases the decline may be due to natural processes that involve environmental stresses such as water availability or exceptionally high or low temperatures.

6.4.4 Regeneration

Tree species respond differently to bark harvesting in terms of coppice regrowth (Geldenhuys 2004). The *Brackenridgea zanguebarica* population at Thengwe has stumps of trees that have been chopped to ground level. Although the species has the potential to resprout through coppicing it is recommended not to cut the tree to ground level since it will always take a long time to regenerate to maturity. The cutting of stems for medicinal purposes should where possible be limited to individuals with multi-stems. Removing stems from multi-stemmed individuals helps in maintaining the population since the remaining stems will still produce seeds while the removed stem is regenerating.

Obiri *et al.* (2002) concede that management systems that marginally alter the resource availability and whose off-take patterns do not exceed resource regeneration should be encouraged. An optimal harvesting system should take into consideration the availability of harvestable materials, rate of use as well as their potential to regenerate and maintain the sustainability of the population.

Figure 6.9: Stem of *Brackenridgea zanguebarica* showing bark regeneration on a harvesting scar caused by illegal harvesters as pointed out by the researcher in the Brackenridgea Nature Reserve, Thengwe. (Photo: K Magwede, Samsung Digimax 130).

Brackenridgea zanguebarica shows the ability to regrow its bark after being harvested (Figure 6.9). According to Todd *et al.* (2004) the bark appears to grow back relatively quickly after being harvested by producing a surface callus from the wound callus. Bark recovery, leading to persistence of individuals and populations, is a species-dependent trait (Delvaux *et al.* 2009, 2010). This bark regeneration ability in *Brackenridgea zanguebarica* is very important for the survival of mature individuals within the population. Furthermore, it is important for a population to recover from the loss of exploited individuals through demographic processes that allows continuous recruitment and establishment of new seedlings (Guedje *et al.* 2007).

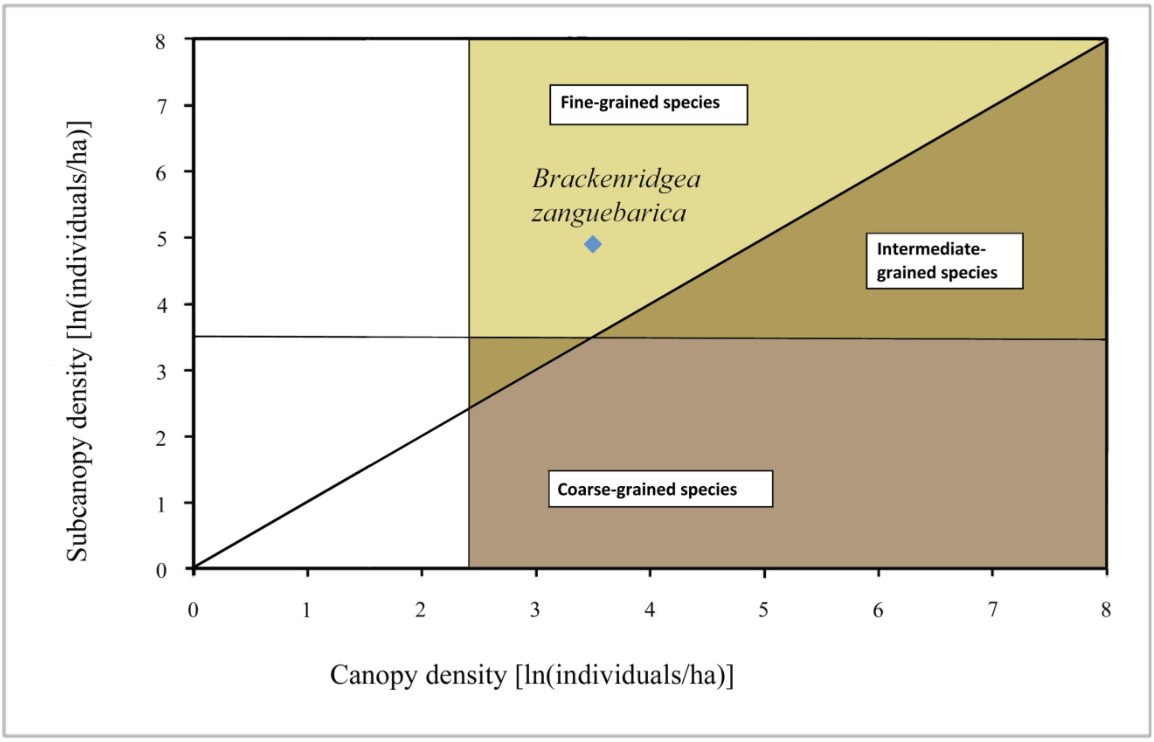

Figure 6.10: Species grain of the *Brackenridgea zanguebarica* population of Thengwe from data collected in 2004.

The *Brackenridgea zanguebarica* population from Thengwe study area could be classified as a fine-grained species (Figure 6.10). It would therefore appear possible to harvest this species sustainably provided more than 10 reproducing individuals are maintained in a hectare and 30 subcanopy individuals per hectare, since a ln value of above 2.3 on canopy density and 3.4 on subcanopy density indicate 10 and 30 individuals and above respectively in a hectare. *Brackenridgea zanguebarica* individuals are not used for construction or other purposes and bark-harvesting for medicinal purposes represents the only form of harvest. According to Obiri *et al.* (2002) the species grain theory suggests that fine-grained species should be able to withstand moderate levels of use, because these species show continuous recruitment of young individuals. Therefore with the proper harvesting techniques and close monitoring, *B. zanguebarica* may survive moderate harvesting levels.

6.5 Conclusions

The use of size-class distributions is regarded as a practical field method for assessing harvesting impacts and for illustrating the response of plant populations to harvesting pressure. Overall, the *Brackenridgea zanguebarica* population has been found to be healthy as shown in the distribution curve. However, a comparison with size class distribution curves from 14 years previously showed that significant changes had occurred in the size class distribution of the species and there were currently more large individuals. The species is able to regenerate from bark removal although it is important to analyze its response from repeated harvesting.

In the *B. zanguebarica* population the supervised removal of medicinal material through stem cutting does not seem to have a negative effect on the crowns of the remaining stems. Such kind of practice should be encouraged amongst the tribal authority since it helps in maintaining the physiognomic structure of the vegetation. However, it is becoming evident that illegal collectors of medicinal material do not follow the collection procedures recommended by the tribal authority. Although the species has the ability to regrow its bark after bark harvesting, this does not mean that bark can be indiscriminately harvested. It is therefore important to determine the harvesting limit of *Brackenridgea zanguebarica*.

6.6 Acknowledgements

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References

ACOCKS, J.P.H. 1988. Veld Types of South Africa. 3rd edition. *Memoirs of the Botanical survey of South Africa*. No. 57.

BOTHA, J., WITKOWSKI, E.T.F. AND SHACKLETON, C.M. 2004. Market profiles and trade in medicinal plants in the Lowveld, South Africa. *Environmental Conservation* **31: 38-46**.

CONDIT, R., SUKUMAR, R., HUBBEL, S. AND FOSTER, R. 1998. Predicting population trends from size distributions: a direct test in a tropical tree community. *American Naturalist* **152: 495-509.**

COWLING, R.M., RICHARDSON, D.M. AND PIERCE, S.M. 1997.Vegetation of Southern Africa. Cambridge University Press, Cambridge, United Kingdom.

CUNNINGHAM, A.B. 2001. Applied ethnobotany: people, wild plant use and conservation. Earthscan Publication, London, UK.

DELVAUX, C., SINSIN, B., DARCHAMBEAU, F. AND VAN DAMME, P. 2009. Recovery from bark harvesting of 12 medicinal tree species in Benin, West Africa. *Journal of Applied Ecology* **46: 703-712.**

DELVAUX, C., SINSIN, B., AND VAN DAMME, P. 2010. Impact of season, stem diameter and intensity of debarking on survival and bark re-growth pattern of medicinal tree species, Benin, West Africa. *Biological Conservation* **143: 2664-2671.**

GAUGRIS, J.Y. AND VAN ROOYEN, M.W. 2007. The structure and harvesting potential of the sand forest in Tshanini Game Reserve, South Africa. *South African Journal of Botany* **73: 611–622.**

GAUGRIS, J.Y., VASICEK, C.A. AND VAN ROOYEN, M.W. 2007. Selecting tree species for sustainable harvest and calculating their sustainable harvesting quota in Tshanini Conservation Area, Maputaland, South Africa. *Ethnobotany Research and Applications* **5: 373-389.**

GELDENHUYS, C.J. 2004. Bark harvesting for traditional medicine: from illegal resource degradation to participatory management. *Scandinavian Journal of Forest research* **19: 103-115.**

GUEDJE, N.M., ZUIDEMA, P.A., DURING, H., FOAHOM, B. AND LEJOLY, J. 2007. Tree bark as a non-timber forest product: The effect of bark collection on population structure and dynamics of *Garcinia lucida* Vesque. *Forest Ecology and Management* **240: 1-12.**

LAWES, M.J., EELEY, H.A.C., SHACKLETON, C.M. AND GEACH, B.G.S. 2004. Indigenous forests and woodlands in South Africa: Policy, People and Practice. University of Kwazulu-Natal Press, Pietermaritzburg.

LAWES, M.J. AND OBIRI, J.A.F. 2003. Using the spatial grain of regeneration to select harvestable tree species in subtropical forest. *Forest Ecology and Management* **184: 105-114.**

LYKKE, A.M. 1998. Assessment of species composition change in savanna vegetation by means of woody plants' size class distributions and local information. *Biodiversity and Conservation* **7: 1261-1275.**

MABOGO, D.E.N. 1990. The ethnobotany of the Vhavenda. Master of Science dissertation. University of Pretoria, Pretoria, South Africa.

MIDGLEY, J., SEYDACK, A., REYNELL, D. AND MCKELLY, D. 1990. Fine-grain pattern in southern Cape plateau forests. *Journal of Vegetation Science* **1: 539-546.**

MOLLER, M., SUSCHKE, U., NOLKEMPER, S., SCHNEELE, J., DISTL, M., SPORER, F., REICHLING, J. AND WINK, M. 2006. Antibacterial, antiviral, antiproliferative and apoptosis-inducing properties of *Brackenridgea zanguebarica* (Ochnaceae). *Journal of Pharmacy and Pharmacology* **58: 1131-1138.**

MUCINA, L. AND RUTHERFORD, M.C. 2006. The vegetation of South Africa, Lesotho and Swaziland. South African National Biodiversity Institute, Pretoria.

NETSHIUNGANI, E.N. AND VAN WYK, A.E. 1980. Mutavhatsindi - mysterious plant from Venda. *Veld and Flora.* September**: 87-90.**

NIKLAS, K.J., MIDGLEY, J.J. AND RAND, R.H. 2003. Tree size frequency distributions, plant density, age and community disturbance. *Ecology Letters* **6: 405-411.**

OBIRI, J., LAWES, M. AND MUKOLWE, M. 2002. The dynamics and sustainable use of high value tree species of the coastal Pondoland forests of the Eastern Cape Province, South Africa. *Forest Ecology and Management* **166: 131-148.**

PALGRAVE, K.C. 1988. Trees of Southern Africa. 4th edition. Struik Publishers, Cape Town.

PETERS, C.M. 1996. *The Ecology and Management of Non-Timber Forest Resources*. World Bank Technical Paper No. 332. Washington, D.C., U.S.A.

QUINN, G.P. AND KEOUGH, M.J. 2002. Experimental design and data analysis for biologists. Cambridge University Press, Cambridge.

RAIMONDO, D., VON STADEN, L., FODEN, W., VICTOR, J.E., HELME, N.A., TURNER, R.C., KAMUNDI, D.A. AND MANYAMA, P.A. 2009. Red list of

South African Plants. *Strelitzia 25.* South African National Biodiversity Institute, Pretoria.

SAIDI, T.A. AND TSHIPALA-RAMATSHIMBILA, T.V. 2006. Ecology and management of a remnant *Brachystegia spiciformis* (miombo) woodland in Northeastern Soutpansberg, Limpopo Province. *South African Geographical Journal* **88: 205-212.**

SILVERTOWN, J. AND CHARLESWORTH, D. 2001. Plant population biology. 4th edition. Blackwell Science.

SUNDERLAND, T.C.H. AND TAKO, C.T. 1999. The exploitation of *Prunus africana* on the island of Bioko, Equatorial Guinea.A report for People and Plants Initiatives, WWF-Germany and the IUCN/SSC Medicinal Plant Specialist Group.

TODD, C.B., KHOROMMBI, K., VAN DER WAAL, B.C. AND WEISSER, P.J. 2004. Conservation of woodland biodiversity: A complementary traditional approach and western approach towards protecting *Brackenridgea zanguebarica*. In: Indigenous forests and woodlands in South Africa – Policy, People and Practice. Eds. LAWES, M.J., EELEY, H.A.C., SHACKLETON, C.M. AND GEACH, B.G.S. University of Kwazulu-Natal Press, Durban, South Africa: 737-750

TSHISIKHAWE, M.P. 2002. Trade of indigenous medicinal plants in the Limpopo province, Venda region; their ethnobotanical importance and sustainable use. M.Sc dissertation, University of Venda for Science and Technology, Thohoyandou.

VAN WYK, B. AND VAN WYK, P. 1997. Field guide to trees of Southern Africa. Struik Publication, Cape Town, South Africa.

VAN WYK, B.E., VAN OUDTSHOORN, B. AND GERICKE, N. 1997. Medicinal plants of South Africa. Briza Publications, Pretoria, South Africa.

WEATHER BUREAU. 1998. *Climate of South Africa: Climate statistics up to 1990*. WB 42. Government Printer, Pretoria.

WILLIAMS, V.L. 1996. The Witwatersrand muthi trade. *Veld and Flora* **3: 12-14.**

ZIERL, B. 2004. A simulation study to analyze the relations between crown condition and drought in Switzerland. *Forest Ecology and Management* **188: 25-38.**

CHAPTER 7

IS THE PRESENT BRACKENRIDGEA NATURE RESERVE LARGE ENOUGH TO ENSURE THE SURVIVAL OF *BRACKENRIDGEA ZANGUEBARICA* Oliv.?

Submitted to Koedoe Journal

Abstract

The Brackenridgea Nature Reserve is a protected area that has been established by the provincial Limpopo Department of Economic Development, Environment and Tourism as a way of protecting the population of *Brackenridgea zanguebarica,* a species classified as Critically Endangered in South Africa according to the IUCN red data classification. In the whole of South Africa the species is found in only one small area around Thengwe in Venda. It is threatened with extinction due to its high demand as a medicinal plant. Some individuals occur outside the nature reserve for people to harvest under close monitoring by the local tribal authority. However, currently the population in the nature reserve is also being harvested illegally.

This study investigated the adequacy of the reserve to conserve the species using the Burgman et al. (2001) method. The method involves 12 steps to quantify the risk of the decline or possible extinction of the species and takes current human activities, disturbances and the viability of the population into consideration for setting a conservation target. From the results it is clear that more area is needed for the current population to survive beyond 50 years. Assuming the status quo it will require 974 ha for sustenance of the population whereas a 50% reduction in human-related activities, such as cultivation, harvesting and livestock grazing, will lower the required potential habitat to 366 ha.

Key words: Conservation, extinction, local tribal authority, nature reserve.

7.1 Introduction

The Brackenridgea Nature Reserve or better known as the Mutavhatsindi Nature Reserve is a protected area that was established in 1987 by the provincial Limpopo Department of Economic Development, Environment and Tourism in a proactive attempt of protecting the population of *Brackenridgea zanguebarica.* In the whole of South Africa the species is found in only one small area around Thengwe in Venda. It is threatened with extinction due to its high demand as a magical and medicinal plant species (Netshiungani & Van Wyk 1980) and is classified as Critically Endangered in South Africa (Plants of southern Africa version 3.0: an online checklist http://posa.sanbi.org).

When evaluating rare taxa it is important to understand the distribution, biology and threats in order to devise efficient strategies for their protection (Wessels *et al.* 1999, Lozana and Schwartz 2005). *Brackenridgea zanguebarica* is a long-lived woody plant species that can grow up to 7 m in height (Palgrave 1988, Van Wyk and Van Wyk 1997). It has a very narrow geographic distribution range in South Africa and occurs only in the Thengwe region within the Vhembe district municipality of Limpopo province. The species is locally used for magical and medicinal purposes (Netshiungani and Van Wyk 1980, Van Wyk *et al.* 1997) as well as building of animal enclosures and homesteads fences. Understanding the dynamics of the resource base is important to develop a sound management system for resource harvesting (Obiri *et al.* 2002). While taking cognizance of the traditional uses of the species it is important not to ignore all the other factors, which may limit its expansion because biodiversity loss may be attributed to a number of processes (Dengler 2009).

According to Todd *et al.* (2004), uncontrolled harvesting of *Brackenridgea zanguebarica* has led to a tremendous decrease in the population density of the species in the Brackenridgea Nature Reserve (Mutavhatsindi Nature Reserve – MNR). In 1990 the reserve contained 140 trees per hectare while in 1997 there were only 25 trees per hectare. The questions therefore arise (a) whether the current Brackenridgea Nature Reserve is adequate to ensure the survival of the species? and (b) if the reserve is inadequate what should the size of the targeted area be?

Protected areas are indispensible for conserving biodiversity as threats to biodiversity continue to increase globally (Millenium Ecosystem Assessment 2005). Traditionally the selection of conservation areas such as reserves in southern Africa and elsewhere in the world has been opportunistic (Pressey 1994, Sarkar *et al.* 2006), or focused upon large charismatic mammals of savanna woodland and grassland. Such an approach however resulted in over-representation of some features and omission of others. It is therefore important that future reserves be sensibly located with respect to the distribution of features such as habitat or species (Eeley *et al.* 2001, Pressey *et al.* 2003).

Systematic conservation planning is a young field and promotes a systematic process to reserve selection (Margules and Pressey 2000, Cabeza and Van Teeffelen 2009). At the same time systematic conservation planning should aim to ensure the long-term persistence of that diversity by sustaining key ecological and evolutionary processes

(Desmet *et al*. 2002, Cowling *et al*. 2003). Probably the best way of ensuring the long-term conservation is by minimizing the extinction risk of species.

Population viability analysis (PVA) is regarded as one of the cornerstones of conservation science and it has been traditionally used to estimate the minimum viable population for threatened taxa (Menges 2000, Pfab and Witkowski 2000, Beissinger and McCullough 2002). It has provided a framework to understanding how stochastic events and processes affect the chances of extinction of a species. PVA can play a role in determining whether the size of a reserve is large enough to conserve a particular species, but in general the data needed for a realistic PVA takes many years to gather (Menges 2000, Pfab and Scholes 2004). Furthermore, to estimate the extinction risk of a large number of species requires an immense database (Burgman *et al.* 2001, Cabeza and Van Teeffelen 2009) that is seldom available in developing countries such as South Africa. Consequently, when ecologically acceptable targets have to be set, conservationists are faced with a problem because they seldom have the time or budget for the detailed, long-term population viability analysis and habitat modeling.

In response to the general deficiency in time and data, Burgman *et al.* (2001) developed a method for setting conservation targets for plant species when a limited amount of relevant information is available. Burgman *et al.* (2001) are of the opinion that by using their method an adequate reserve system, which can conserve a viable population of a species, can be designed. However, they stress that in decision-making in terms of conserving species, it is important to come up with an appropriate model, which will support the decision, based on available information. They believe that many decisions are made even when there is insufficient time or data to develop models (Burgman *et al.* 2001). Planning for a single species, as it is the case with the Brackenridgea Nature Reserve, therefore requires a formal assessment of the risks posed by different factors.

The current study therefore aims to apply the methodology of Burgman *et al.* (2001) to assess if the size of the Brackenridgea Nature Reserve is currently large enough to conserve a viable population of *B. zanguebarica*. Several scenarios were run to investigate different levels of human-induced impact to derive the most promising and realistic target area to conserve the species.

7.2 Study area

The study was done in the Brackenridgea Nature Reserve, which is situated in the Vhembe District Municipality of the Limpopo province (Figure 7.1). The Vhembe region in which the Brackenridgea Nature Reserve is situated is a UNESCO declared biosphere as from 2009 and it form the core zone of the biosphere principles. The Brackenridgea Nature Reserve (BNR) is currently 110 hectares in size. The reserve was established as a way of conserving the population of *Brackenridgea zanguebarica,* which is found only in the Thengwe region in the whole of South Africa. Unfortunately, poaching of medicinal material within the reserve is currently the major threat to the population of *B. zanguebarica*.

The vegetation in and around the reserve is classified as the VhaVenda Miombo by Mucina and Rutherford (2006). It is a unique vegetation unit in South Africa and is limited to a very small area in the upper reaches of the Mbodi River Valley between Shakadza and Mafukani. Several species, amongst which *Brachystegia spiciformis* and *Brackenridgea zanguebarica,* find their southernmost distribution within this small miombo vegetation unit.

The Thengwe population of *B. zanguebarica* covers an area of approximately 2 500 ha (25 km^2) (Todd *et al.* 2004). Within the reserve *B. zanguebarica* is a dominant species of the *Brackenridgea zanguebarica* – *Digitaria sanguinalis* open scrub vegetation with emergent trees of up to 10 m high (Todd *et al.* 2004).The vegetation on the outside of the reserve is heavily degraded by overgrazing, wood-collecting, agriculture and alien invasion (Mucina and Rutherford 2006).

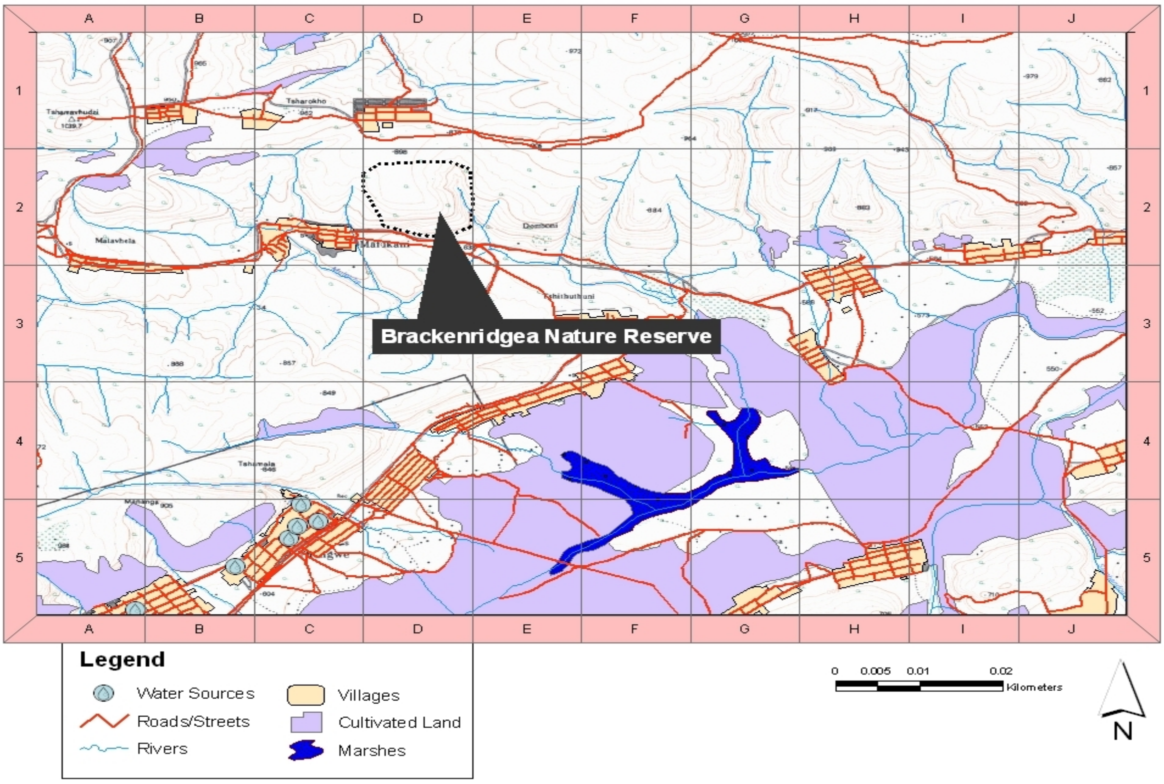

Figure 7.1: Grid map of the Thengwe region where the Brackenridgea Nature Reserve (boundary indicated by the black dotted line) is located.

7.3 Materials and Methods

For an easy assessment of the area the map of the region in which the study area is located was divided into fifty manageable grids. Each of the fifty grids constituted an area of 150 ha.

Sixteen plots of 50 x 10 m in size were sampled in the Brackenridgea Nature Reserve situated in cell D2 in order to obtain a quantitative measure of the density of the *Brackenridgea zanguebarica* population. The plots were constructed using 50 m tape measures, which were removed after sampling. The plots were constructed in an east-west direction of the Brackenridgea Nature Reserve at 10 m intervals. All *B. zanguebarica* individuals within each plot were counted and recorded. The following parameters were recorded for each individual: (i) the diameter measurements of all stems (in cm), (ii) the height measurement of the trees (in m), (iii) the height to the base of the canopy (where the largest lowest branches are) (in m), (iv) the diameter of the widest canopy section (in m), (v) and the diameter perpendicular to that of the widest canopy (in m).

Outside the reserve a total of seven transects of 100 m x 5 m were surveyed to obtain the same data for each individual tree. This survey was conducted in 2004 (Chapter 6). The transects sampled covered 3500 m^2 of the 100 ha surveyed communal area to the south-western side of the adjacent Brackenridgea Nature Reserve (Figure 7.1).

The method used for setting the conservation goals is that which was developed by Burgman *et al.* (2001) and modified by Gaugris and Van Rooyen (2010). This method accounts for processes that lead to a deterministic decline in a population as well as extinction from stochastic events. The approach can be used for setting preservation targets for any species, which may be of interest, when there is insufficient data or time to conduct a formal population viability analysis. The approach is intended to provide a framework within which knowledge of each species can be ordered and considered, as well as facilitating discussion about how best to set conservation targets in protecting species in a relatively transparent context.

Burgman *et al.* (2001)'s method is based on the following general rules related to extinction risk:

i. All populations face some risk of decline and extinction because they are exposed to the challenges of natural temporal and spatial variation, even in habitats protected from humans.

ii. To minimize the number of plant extinctions in the medium term, priorities for conservation should reflect the risks faced by different taxa or by the particular species.

iii. Disturbance regimes can be modeled as processes resulting in an expected proportion of habitat remaining available throughout the period over which risks are evaluated.

iv. Catastrophes can be implicated in the local extinction of many plant taxa or species, and conservation strategies can be developed to minimize the risk of global loss. Catastrophes are sudden collapses in population size, caused by extreme environmental events such as droughts, fires, floods and epidemics (Beissinger and McCullough 2002).

The Burgman *et al.* (2001) method, which was followed and adapted to suit the condition of the study, consists of 12 steps. A brief summary of these steps is provided to guide the reader.

STEP 1: The first step was to get a value for F, the minimum viable population size likely to persist demographic and environmental influences. This was defined by Burgman *et al.* (2001) as the population size that faces a 0.1% probability of falling below 50 adults at least once in the next 50 years, assuming no detrimental human effects. The bound of 50 adult individuals (Burgman *et al.* 2001), which is considered as an unacceptable small population size for any species, was adopted in this study. The F-value was obtained by applying the empirical method proposed by Gaugris and Van Rooyen (2010) for practitioners.

The F-value was established by making a scatter graph of tree species through plotting of their known F-values on the y-axis against their life expectancy on the x-axis. The following tree species with their F-values and their life expectancy (LE) were used to estimate F for *B. zanguebarica* since they are also woodland species: *Cleistanthus schlechteri* Hutch. (Euphorbiaceae, F = 536, LE = 250); *Newtonia hildebrandtii* (Vatke) Torre. (Leguminosae, F = 186, LE = 400); *Sclerocarya birrea* Hochst. (Anacardiaceae, F = 374, LE = 300); and *Hymenocardia ulmoides* Oliv. (Euphorbiaceae, F = 1068, LE = 150). As per expert knowledge the life expectancy of *Brackenridgea zanguebarica* was set at 150 years. By fitting the exponential function ($y = ae^{b(x)}$, where a and b are constants) to the graph derived from the F-value against life expectancy (Gaugris & Van Rooyen 2010) an F-value could be derived for *B. zanguebarica.*

Once the F-value had been established, the adjusted F-value as per local, present and future risk could be derived. The adjusted F-value is based on the available knowledge regarding the species and environmental factors against the list of 25 ecological factors (Table 7.2) with each factor having two alternative states: one related to the species resilience and the other one to the species vulnerability (Burgman *et al.* 2001, Gaugris and Van Rooyen 2010). Expert judgement is regarded sufficient to consider factors such as life history, demographics, disturbance response mechanisms and seed bank dynamics to establish the adjusted F-value. An all positive score of 25 was assumed to need zero adjustment and an all negative -25 score was assumed to need a 100% adjustment (equal to 2F) (Gaugris and Van Rooyen 2010).

STEP 2: In step 2 the populations which were experiencing similar sources and intensity of disturbance were identified. To accomplish this, the disturbance in each of the 50 grids was evaluated and classified into one of three classes: (i) sustainable (ii) light or (iii) heavy.

STEP 3: The potential *B. zanguebarica* habitat per disturbance region in the blocks was evaluated using knowledge from reconnaissance and fieldwork surveys.

STEP 4: In this step the potential habitat that was surveyed (ha) was mapped. The area mapped consisted of the 110 ha of the Brackenridgea Nature Reserve as well as the 100 ha in the adjacent communal land. Identification of these areas assists in pointing out potential areas for *B. zanguebarica* expansion.

STEP 5: Density of adults trees per ha (D) was established from data sampled inside the Brackenridgea Nature Reserve as well as on the outside of the reserve in communal land. All trees with a stem diameter of >10 cm were considered as mature, adult trees.

STEP 6: The preliminary minimum target area (Target area A_0) required for conservation was calculated as:

Target area A_0 = Adjusted F / D (in ha).

This step was to estimate a target area for protection based on background disturbance processes and does not consider other known disturbances that can be measured and planned for (Burgman *et al.* 2001).

STEP 7: In this step the percentage of land that remains in 50 years, after yearly disturbance is estimated (S). This assessment is done by considering all the activities that cause disturbances that may reduce the potential habitat of *B. zanguebarica*. It is assumed that small-scale disturbances are reversible and that the species will be able to recover from these within the 50-year period. The reduction in potential habitat was used to calculate an adjusted target area (A_1) as:

$A_1 = A_0 / S$ (in ha)

STEP 8: The area expected to be irreversibly damaged in the next 50 years (c_i) was evaluated by considering areas that may be irreversibly lost through human development activities and will not become available again (Burgman *et al.* 2001). The remaining area was used to refine the adjusted target area (A_2) as:

$A_2 = A_1 / (c - c_i)$ (in ha)

STEP 9: Compensation for expected density-reducing human related activities was achieved through adjustment of the target area per disturbance region and was expressed as r_i, the estimated percentage of remaining habitat (Burgman *et al.* 2001). The following four human related activities were considered: cultivation (through clearing of agricultural fields),), grazing (removal of seedlings and overall degradation of habitat), building (through wood use as fencing poles), and harvesting (through collection of medicinal material and collection of firewood from other species). For each of these activities a percentage habitat remaining is calculated and the product of these proportions is used for further refinement of the target area (A_3) as:

$A_3 = A_2 / r_i$ (in ha)

Four scenarios were assessed in order to determine which scenario could provide the best acceptable management option for *B. zanguebarica*. The four scenarios were as follows; (i) Scenario 1 looked at the current status of the species management, (ii) Scenario 2 was when grazing, which is one of the human-related activities, was removed from the management system, (iii) Scenario 3 investigated the effect of reducing all four human related activities by half, whereas (iv) Scenario 4 looked at the management system in which all the human-related activities had been entirely removed from the management system.

STEP 10: Identifying catastrophic events such as landslides, earthquakes and volcanic eruptions (Burgman *et al.* 2001), that are likely to affect the species' potential habitat was not carried out since such events are unexpected in the area. The area in which the *Brackenridgea zanguebarica* population is found has never suffered any recorded catastrophic event in the past years.

STEP 11: Combining targets across disturbance regions and defining a species/community target (Burgman *et al.* 2001).

STEP 12: Evaluation of habitat maps and evaluation of the adequacy of current strategies and set out objectives accounting for spatial and species constraints (Burgman *et al.* 2001). The ratio of available to required habitat is calculated for each of the grids.

7.4 Results and discussion

7.4.1 *Brackenridgea zanguebarica* population parameters

Burgman *et al.* (2001)'s method depends heavily on a reliable estimate of the population density (number of plants per unit area). Although it has to be acknowledged that in the absence of basic understanding of species-specific and site-specific population structure among other life history traits, density alone can contribute little towards knowledge on sustainability of a species (Schulze *et al.* 2008). A total of 121 *B. zanguebarica* individuals were recorded in the 16 transects (50 m x 10 m), sampled in the reserve translating into an overall density of 151.25 *Brackenridgea zanguebarica* individuals per ha. However, as indicated in Table 7.1 the density of young plants with a stem diameter of 10 cm and below was 90 individuals per ha, while that of adult individuals with stem diameter of more than 10 cm was 61 individuals per ha.

Outside the reserve to the density of plants was 489 plants per ha. Approximately 100 individuals per ha were adult plants and the rest were immature trees. The density in the communal land was higher than that in the nature reserve. This is due to the fact that sampling on communal land was done in 2004 when collectors were still following management controls set by the tribal authority whereas in the reserve it was done in 2007 when collectors were illegally collecting large quantities of bark inside the reserve.

Table 7.1: Density of young and adult categories of *Brackenridgea zanguebarica* individuals sampled in the Brackenridgea Nature Reserve

Stem diameter size class distribution					
Size classes (cm)	Mid class	Original frequency	Density (D) per ha	Ln (D+1)	Comment
0.0-2.0	1	0	0.0	0.000	Density of young trees =90.0 trees per ha
2.1-4.0	3	2	2.5	1.253	
4.1-6.0	5	26	32.5	3.512	
6.1-8.0	7	28	35.0	3.584	
8.1-10.0	9	16	20.0	3.045	
10.1-12.0	11	20	25.0	3.258	Flowering/fruiting threshold for mature trees
12.1-14.0	13	13	16.3	2.848	Density of adult trees = 61.3 trees per ha
14.1-16.0	15	7	8.8	2.277	
16.1-18.0	17	3	3.8	1.558	
18.1-20.0	19	2	2.5	1.253	
20.1-22.0	21	3	3.8	1.558	
22.1-24.0	23	0	0.0	0.000	
24.1-26.0	25	1	1.3	0.811	
26.1-28.0	27	0	0.0	0.000	

At the time of data gathering in 2007 the overall density (151 individuals per ha) was approximately the same as in 1990 (140 individuals per ha, data provided in Todd *et al.* 2004). However, the distribution among the size classes differed, with many more individuals in the 0 – 5 cm diameter size class in the 1990 survey. The fact that there were no individuals within the 0 - 2 cm stem diameter size class and very few in the >2 – 4 cm class (Table 7.1) is cause for concern because it shows that there is little recruitment of young individuals in the population and as such viability may not be achieved. However, the 2007 survey indicated many individuals in the stem diameter size classes from 4 – 20 cm.

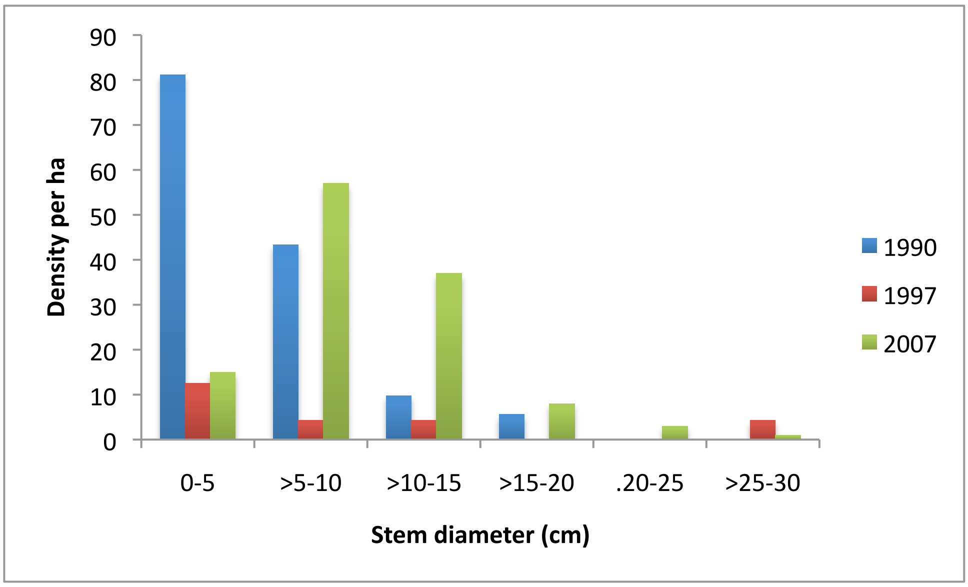

Figure 7.2: Changes in the size class distribution of *Brackenridgea zanguebarica* in the Brackenridgea Nature Reserve from 1990 to 2007 (1990 and 1997 from Todd unpublished data).

To see how long *B. zanguebarica* individuals remain in the different size classes the stem diameter increments measured on 20 individuals between 2004 and 2005 outside the reserve can be used. Because the stem circumferences increments increase in proportion to stem size (Figure 7.3), individuals will remain longer within the smaller size classes than in larger size classes (provided that the size of all stem diameter classes is equal). For the 0 – 5 cm, >5 – 10 cm and >10 – 15 cm stem diameter classes the mean annual increase in diameter was 0.350 cm, 1.049 cm and 1.749 cm respectively. This translates into an individual remaining in the smallest size class (0 – 5 cm) for approximately 14 years, in the >5 – 10 cm size class for approximately 5 years and in the >10 – 15 cm size class for approximately 3 years. The large number of individuals in the >10 – 15 cm class in 2007 could therefore be as a result of the large number of very small individuals recorded in 1990. However, at present there seems to be a problem with the recruitment of new individuals.

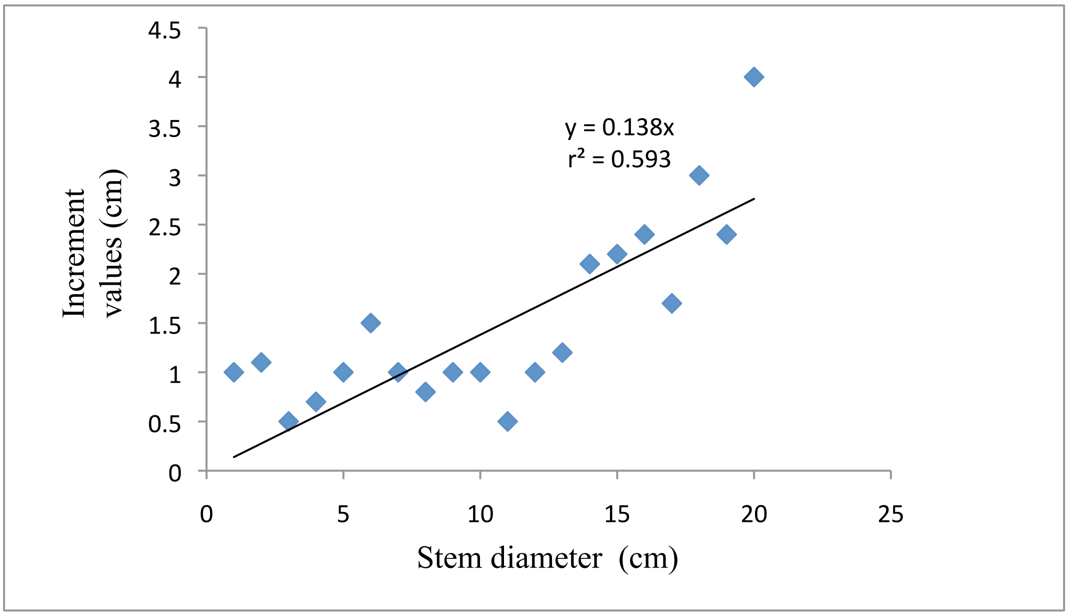

Figure 7.3: *Brackenridgea zanguebarica* annual stem circumference increment of 20 individuals as measured on the Thengwe population outside the Brackenridgea Nature Reserve, Venda region between 2004 and 2005. (Note intercept has been forced through zero).

7.4.2 Establishment of minimum core conservation area

Step 1: An F-value of 1071 individuals was obtained by applying the empirical method proposed by Gaugris and Van Rooyen (2010) for practitioners.

The percentage adjustment needed to the F-value was derived by calculating the ecological factor score for the species in Table 7.2. The ecological factor score of 6 needed an adjustment of 38% producing an adjusted F-value of 1478. It is important to note that an error which may have been brought about by establishing the adjusted F-value is compensated for in the method by a number of factors included in the assessment of the area.

Step 2 The viable conservation area can be easily influenced by local identified activities such as agricultural cultivation, livestock grazing, and extraction of building materials as well as harvesting of plants for medicinal purposes. An area of 7 500 ha was mapped into 50 cells of 150 ha each and assessed in terms of disturbance levels of either sustainable, light (human activity disturbances associated with resource harvesting and light grazing by livestock) or heavy (disturbances associated with building, cultivation and heavy grazing). Only five cells (A4, B4, C3, G2, and J1) showed a sustainable level of disturbance, while 20 cells showed a light disturbance level and 25 (50%) showed a heavy disturbance level.

Table 7.2: Determination of the ecological factor score and adjustment percentage of *Brackenridgea zanguebarica* in the Brackenridgea Nature Reserve area

Factors affecting the minimum population size (*F*)

	Positive criteria (indicator of resilience) (*F*+)	**Score (*F*+)**	**Negative criteria (indicator of vulnerability) (*F*-)**	**Score (*F*-)**
1	Many large populations	0	Few small isolated populations	-1
2	Widespread distribution	0	Restricted distribution	-1
3	Habitat generalist	0	Habitat specialist	-1
4	Not restricted to a temporal niche	0	Restricted to a temporal niche	-1
5	Not subject to extreme habitat fluctuations	0	Subject to extreme habitat fluctuations	0
6	No particular genetic vulnerability	0	Genetic vulnerability	0
7	Vigorous post disturbance regeneration	0	Weak post disturbance regeneration	-1
8	Rapid vigorous growth	1	Slow weak growth	0
9	Quickly achieves site dominance	1	Poor competitor	0
10	All life stages resilient	0	Particular life stages vulnerable	-1
11	Short time to set first seed or propagule	1	Long time to set first seed or propagule	0
12	Long reproductive lifespan	1	Short reproductive lifespan	0
13	Robust breeding system	0	Dysfunctional breeding system	-1
14	Readily pollinated	1	Not readily pollinated	0
15	Reliable seed production	1	Unreliable seed production	0
16	High seed production	1	Low seed production	0
17	Long seed or propagule viability	1	Short seed or propagule viability	0
18	Seed or propagule not exhausted by disturbance	1	Seed or propagule exhausted by disturbance	0
19	Good dispersal	0	Poor dispersal	-1
20	Generally survives fire and other damage	1	Generally killed by fire and other damage	0
21	Not adversely affected by pre-1600 disturbance*	0	Adversely affected by pre-1600 disturbance*	0
22	Adapted to existing grazing, drought, fire-regime	1	Not adapted to existing grazing, drought, fire-regime	0
23	Able to coppice and resprout	1	Unable to coppice and resprout	0
24	Not vulnerable to pathogens, diseases, insects, etc.	1	Vulnerable to pathogens, diseases, insects, etc.	0
25	Not dependent on vulnerable mutualist	1	Dependent on vulnerable mutualist	0
Total		**14**		**-8**
Ecological factor score {Efs = (*F*+) + (*F*-)}			**6**	
(*F*) value adjustment percentage based on the Ecological Factor Score {Efs +25 = +0% of (*F*), Efs 0 = +50% of (F), Efs -25 = +100% of (F)}			**+38%**	

* The pre-1600 disturbance represents any large scale, landscape shaping disturbance known to have occurred prior to the colonization of South Africa by European colonists

Step 3 The 110 ha which forms the Brackenridgea Nature Reserve as well as 100 ha of adjacent community land was sampled in order to gain insight into the potential habitat available. An estimation based on expert knowledge was done on areas where fieldwork based data was unavailable. Cells C2, D2, D3, E2, E3, and F2 exhibited a good potential of becoming good habitat for *B. zanguebarica*. It therefore means that such cells can be recommended for protection in order to allow for expansion of the current population. Small proportions of suitable habitat were also found in cells B2, C3, F3, G2 and G3. These fragmented cells can be protected from human activities through a network of corridors for the expansion of the population.

Step 4 Potential habitat surveyed amounted to 110 + 100 ha. As shown in Figure 7.2 there is a fairly healthy population within the reserve with high amount of mature individuals. The reduction in the number of seedlings since 1990 is however, cause for concern since it may lead to minimal recruitment of seedlings to vegetative and flowering stages. Continued monitoring of activities within the reserve must therefore be enforced in order to maintain the population in a viable state.

Step 5 A density of 61.25 matured individuals per hectare was obtained after surveying D2 cell in which the population of *B. zanguebarica* has been protected (Table 7.1). This density is higher than the density of 23 mature individuals per hectare as recorded in the 1990 census (Todd unpublished data). The reserve population seems to have improved through the conservation efforts provided by the provincial department. A density of 100 matured individuals per hectare was found in the adjacent community land in cell D3. Although the method allows different density values for the different disturbance regions, Burgman *et al.* (2001) suggest that it is preferable to use a single density value based on the most undisturbed habitat. In this study, that would represent the 61.25 individuals per ha for the Brackenridgea Nature Reserve.

Step 6 Target area or raw area (A_0) for reserve creation was established as a way of determining the minimum area required for conservation. It was calculated as (Burgman *et al.* 2001):

Target area (A_0) = Adjusted F/Density

The value of 24 ha was obtained as the minimum area required assuming that the population will be facing no threat. The Target Area (A_0) is a preliminary value that does not consider other known disturbances (Gaugris and Van Rooyen 2010).

Step 7 The human activity (sociological) layered map was used in determining the additional small-scale disturbances that can allow the species to recover in 50 years but reducing the potential habitat available (Burgman *et al.* 2001). All activities that affect the population were considered in determining the percentage of land that would be left (S) for potential habitat against the disturbed area (S_d). Different percentage of remaining areas has been recorded with an average of 68% as indicated in Table 7.3.

Step 8 Human activities that modify the soil structure and the presence of a seed bank were considered in evaluating the potential habitat that will be irreversibly lost within 50 years. The expansion of human settlements in the region is the main cause of these irreversible losses of habitat (Table 7.3). Expansion around the *B. zanguebarica* population should be limited to prevent seed bank loss.

Step 9 An evaluation of the effect of activities that will affect the species' density was achieved by adjusting the target area per disturbance region in compensation of expected density reducing human-related activities within the next 50 years (Gaugris and Van Rooyen 2010). The four prominent human activities which were considered were: Cultivation, grazing, building and harvesting. The four scenarios assessed in the study yielded the following results:

Scenario 1: Assessing the current status of the area revealed that 974 ha will be needed in order to maintain a viable population of *B. zanguebarica* (Table 7.3). This is if the situation is kept as it is with human related activities allowed to continue unabated. Cells B2, C2, C3, D2, D3, E2, E3, F2, F3, G2 and G3 that showed potential habitat constitute approximately 1650 ha which is more than the required 974 ha.

Table 7.3: *Brackenridgea zanguebarica* minimum conservation area size calculations using the Burgman *et al.* (2001) method

					Step 1	Step 2	Step 3		Step 4	Step 5	Step 6	Step 7			
	Cell	AREA (HA)	Percentage of block as potential habitat	Surface area of potential habitat in ha	Adjusted F value	Disturbance level	Potential *B. zanguebarica* habitat in the block		Potential habitat surveyed (ha)	Density of adults trees per ha (D)	A_0 = Adjusted F / D (in ha)	Percentage of land that remains in 50 years after yearly disturbance			
							%	ha				Disturbed (Sd)	Remaining (S)	Proportion	$A_1 = A_0/S$ (ha)
1	A1	150	0%	0	1478	HEAVY	0%	0	110	61.25	24.13	50%	50%	0.5	48.26
2	A2	150	0%	0	1478	HEAVY	0%	0	110	61.25	24.13	60%	40%	0.4	60.33
3	A3	150	0%	0	1478	HEAVY	0%	0	110	61.25	24.13	20%	80%	0.8	30.16
4	A4	150	0%	0	1478	SUSTAINABLE	0%	0	110	61.25	24.13	20%	80%	0.8	30.16
5	A5	150	0%	0	1478	LIGHT	0%	0	110	61.25	24.13	70%	30%	0.3	80.44
6	B1	150	0%	0	1478	HEAVY	0%	0	110	61.25	24.13	50%	50%	0.5	48.26
7	B2	150	10%	15	1478	HEAVY	5%	15	110	61.25	24.13	30%	70%	0.7	34.47
8	B3	150	0%	0	1478	HEAVY	0%	0	110	61.25	24.13	20%	80%	0.8	30.16
9	B4	150	0%	0	1478	SUSTAINABLE	0%	0	110	61.25	24.13	40%	60%	0.6	40.22
10	B5	150	0%	0	1478	HEAVY	0%	0	110	61.25	24.13	90%	10%	0.1	241.31
11	C1	150	0%	0	1478	HEAVY	0%	0	110	61.25	24.13	40%	60%	0.6	40.22
12	C2	150	75%	112.5	1478	HEAVY	70%	112.5	110	61.25	24.13	80%	20%	0.2	120.65
13	C3	150	20%	30	1478	SUSTAINABLE	15%	30	110	61.25	24.13	10%	90%	0.9	26.81
14	C4	150	0%	0	1478	LIGHT	0%	0	110	61.25	24.13	30%	70%	0.7	34.47
15	C5	150	0%	0	1478	HEAVY	0%	0	110	61.25	24.13	95%	5%	0.05	482.61
16	D1	150	0%	0	1478	HEAVY	0%	0	110	61.25	24.13	40%	60%	0.6	40.22
17	D2	150	80%	120	1478	LIGHT	80%	120	110	61.25	24.13	30%	70%	0.7	34.47
18	D3	150	45%	67.5	1478	LIGHT	50%	75	110	61.25	24.13	15%	85%	0.85	28.39
19	D4	150	0%	0	1478	HEAVY	0%	0	110	61.25	24.13	70%	30%	0.3	80.44
20	D5	150	0%	0	1478	HEAVY	0%	0	110	61.25	24.13	25%	75%	0.75	32.17
21	E1	150	0%	0	1478	LIGHT	0%	0	110	61.25	24.13	10%	90%	0.9	26.81
22	E2	150	80%	120	1478	LIGHT	80%	120	110	61.25	24.13	20%	80%	0.8	30.16
23	E3	150	50%	75	1478	LIGHT	50%	5	110	61.25	24.13	40%	60%	0.6	40.22

	Cell	AREA (HA)	Percentage of block as potential habitat	Surface area of potential habitat in ha	Step 1 Adjusted F value	Step 2 Disturbance level	Step 3 Potential *B. zanguebarica* habitat in the block %	Step 3 Potential *B. zanguebarica* habitat in the block ha	Step 4 Potential habitat surveyed (ha)	Step 5 Density of adults trees per ha (D)	Step 6 A_0 = Adjusted F / D (in ha)	Step 7 Percentage of land that remains in 50 years after yearly disturbance: Disturbed (Sd)	Remaining (S)	Proportion	$A_1 = A_0/S$ (ha)
24	E4	150	0%	0	1478	HEAVY	0%	0	110	61.25	24.13	50%	50%	0.5	48.26
25	E5	150	0%	0	1478	KIGHT	0%	0	110	61.25	24.13	10%	90%	0.9	26.81
26	F1	150	0%	0	1478	LIGHT	0%	0	110	61.25	24.13	10%	90%	0.9	26.81
27	F2	150	70%	105	1478	LIGHT	75%	75	110	61.25	24.13	10%	90%	0.9	26.81
28	F3	150	20%	30	1478	HEAVY	20%	30	110	61.25	24.13	60%	40%	0.4	60.33
29	F4	150	0%	0	1478	HEAVY	0%	0	110	61.25	24.13	15%	85%	0.85	28.39
30	F5	150	0%	0	1478	LIGHT	0%	0	110	61.25	24.13	10%	90%	0.9	26.81
31	G1	150	0%	0	1478	LIGHT	0%	0	110	61.25	24.13	10%	90%	0.9	26.81
32	G2	150	30%	45	1478	SUSTAINABLE	30%	45	110	61.25	24.13	5%	95%	0.95	25.40
33	G3	150	20%	30	1478	HEAVY	15%	30	110	61.25	24.13	25%	75%	0.75	32.17
34	G4	150	0%	0	1478	LIGHT	0%	0	110	61.25	24.13	5%	95%	0.95	25.40
35	G5	150	0%	0	1478	HEAVY	0%	0	110	61.25	24.13	35%	65%	0.65	37.12
36	H1	150	0%	0	1478	LIGHT	0%	0	110	61.25	24.13	10%	90%	0.9	26.81
37	H2	150	0%	0	1478	HEAVY	0%	0	110	61.25	24.13	15%	85%	0.85	28.39
38	H3	150	0%	0	1478	HEAVY	0%	0	110	61.25	24.13	70%	30%	0.3	80.44
39	H4	150	0%	0	1478	LIGHT	0%	0	110	61.25	24.13	10%	90%	0.9	26.81
40	H5	150	0%	0	1478	HEAVY	0%	0	110	61.25	24.13	60%	40%	0.4	60.33
41	I1	150	0%	0	1478	LIGHT	0%	0	110	61.25	24.13	10%	90%	0.9	26.81
42	I2	150	0%	0	1478	HEAVY	0%	0	110	61.25	24.13	40%	60%	0.6	40.22
43	I3	150	0%	0	1478	LIGHT	0%	0	110	61.25	24.13	10%	90%	0.9	26.81
44	I4	150	0%	0	1478	LIGHT	0%	0	110	61.25	24.13	10%	90%	0.9	26.81
45	I5	150	0%	0	1478	HEAVY	0%	0	110	61.25	24.13	25%	75%	0.75	32.17
46	J1	150	0%	0	1478	SUSTAINABLE	0%	0	110	61.25	24.13	5%	95%	0.95	25.40
47	J2	150	0%	0	1478	HEAVY	0%	0	110	61.25	24.13	40%	60%	0.6	40.22
48	J3	150	0%	0	1478	LIGHT	0%	0	110	61.25	24.13	20%	80%	0.8	30.16
49	J4	150	0%	0	1478	HEAVY	0%	0	110	61.25	24.13	30%	70%	0.7	34.47
50	J5	150	0%	0	1478	LIGHT	0%	0	110	61.25	24.13	30%	70%	0.7	34.47
Av					1478		10%		110	61.25	24.13	32%	68%	0.683	51.86

Table 3 continued

	Cell	Step 8		Step 9									Step 12			
		Area irreversibly damaged in the next 50 years through human activities		Compensation for density reducing activities (proportion of remaining habitat)								Product of density reducing activities (ri)	Ratio of available to required habitat			
		$1-C_i$	$A_2 = A_1/(1-C_i)$ (ha)	Cultivation	Remaining	Grazing	Remaining	Building	Remaining	Harvesting	Remaining		$A_3 = A_2/ri$	Required	Available	Ratio
1	A1	0.4	120.65	0.2	0.8	0.3	0.7	0.5	0.5	0.1	0.9	0.252	478.78	478.78	0	0.000
2	A2	0.4	150.82	0.4	0.6	0.3	0.7	0.3	0.7	0.3	0.7	0.206	732.83	732.83	0	0.000
3	A3	0.6	50.27	0.1	0.9	0.2	0.8	0.2	0.8	0.1	0.9	0.518	96.98	96.98	0	0.000
4	A4	0.7	43.09	0.1	0.9	0.1	0.9	0.1	0.9	0.2	0.8	0.583	73.89	73.89	0	0.000
5	A5	0.2	402.18	0.6	0.4	0.3	0.7	0.3	0.7	0.3	0.7	0.137	2931.32	2931.32	0	0.000
6	B1	0.4	120.65	0.4	0.6	0.3	0.7	0.3	0.7	0.3	0.7	0.206	586.26	586.26	0	0.000
7	B2	0.5	68.94	0.4	0.6	0.1	0.9	0.3	0.7	0.1	0.9	0.340	202.66	202.66	15	0.074
8	B3	0.6	50.27	0.1	0.9	0.1	0.9	0.2	0.8	0.2	0.8	0.518	96.98	96.98	0	0.000
9	B4	0.6	67.03	0.2	0.8	0.2	0.8	0.1	0.9	0.2	0.8	0.461	145.46	145.46	0	0.000
10	B5	0.2	1206.53	0.5	0.5	0.4	0.6	0.3	0.7	0.3	0.7	0.147	8207.69	8207.69	0	0.000
11	C1	0.3	134.06	0.3	0.7	0.3	0.7	0.3	0.7	0.2	0.8	0.274	488.55	488.55	0	0.000
12	C2	0.4	301.63	0.2	0.8	0.2	0.8	0.3	0.7	0.5	0.5	0.224	1346.57	1346.57	112.5	0.084
13	C3	0.6	44.69	0.2	0.8	0.2	0.8	0.1	0.9	0.2	0.8	0.461	96.98	96.98	30	0.309
14	C4	0.4	86.18	0.4	0.6	0.1	0.9	0.3	0.7	0.1	0.9	0.340	253.32	253.32	0	0.000
15	C5	0.2	2413.06	0.3	0.7	0.3	0.7	0.5	0.5	0.2	0.8	0.196	12311.54	12311.54	0	0.000
16	D1	0.3	134.06	0.2	0.8	0.2	0.8	0.4	0.6	0.2	0.8	0.307	436.39	436.39	0	0.000
17	D2	0.4	86.18	0.2	0.8	0.2	0.8	0.1	0.9	0.2	0.8	0.461	187.02	187.02	120	0.642
18	D3	0.5	56.78	0.1	0.9	0.1	0.9	0.1	0.9	0.1	0.9	0.656	86.54	86.54	75	0.867
19	D4	0.2	402.18	0.3	0.7	0.2	0.8	0.5	0.5	0.2	0.8	0.224	1795.43	1795.43	0	0.000
20	D5	0.2	160.87	0.2	0.8	0.2	0.8	0.6	0.4	0.2	0.8	0.205	785.50	785.50	0	0.000
21	E1	0.6	44.69	0.1	0.9	0.1	0.9	0.1	0.9	0.1	0.9	0.656	68.11	68.11	0	0.000
22	E2	0.3	100.54	0.1	0.9	0.1	0.9	0.1	0.9	0.1	0.9	0.656	153.25	153.25	120	0.783
23	E3	0.4	100.54	0.1	0.9	0.2	0.8	0.2	0.8	0.2	0.8	0.461	218.19	218.19	5	0.023

	Cell	Step 8: Area irreversibly damaged in the next 50 years through human activities		Step 9: Compensation for density reducing activities (proportion of remaining habitat)								Product of density reducing activities (ri	Step 12: Ratio of available to required habitat			
		$1-C_i$	$A_2 = A_1/(1-C_i)$ (ha)	Cultivation	Remaining	Grazing	Remaining	Building	Remaining	Harvesting	Remaining		$A_3 = A_2/ri$	Required	Available	Ratio
24	E4	0.2	241.31	0.6	0.4	0.3	0.7	0.4	0.6	0.4	0.6	0.101	2393.91	2393.91	0	0.000
25	E5	0.1	268.12	0.8	0.2	0.1	0.9	0.1	0.9	0.1	0.9	0.146	1838.94	1838.94	0	0.000
26	F1	0.7	38.30	0.1	0.9	0.1	0.9	0.2	0.8	0.1	0.9	0.583	65.68	65.68	0	0.000
27	F2	0.5	53.62	0.1	0.9	0.1	0.9	0.2	0.8	0.2	0.8	0.518	103.44	103.44	75	0.725
28	F3	0.4	150.82	0.4	0.6	0.2	0.8	0.3	0.7	0.2	0.8	0.269	561.07	561.07	30	0.053
29	F4	0.2	141.94	0.7	0.3	0.1	0.9	0.2	0.8	0.2	0.8	0.173	821.44	821.44	0	0.000
30	F5	0.2	134.06	0.6	0.4	0.1	0.9	0.1	0.9	0.1	0.9	0.292	459.74	459.74	0	0.000
31	G1	0.8	33.51	0.1	0.9	0.1	0.9	0.1	0.9	0.1	0.9	0.656	51.08	51.08	0	0.000
32	G2	0.7	36.29	0.3	0.7	0.2	0.8	0.1	0.9	0.2	0.8	0.403	90.00	90.00	45	0.500
33	G3	0.4	80.44	0.5	0.5	0.2	0.8	0.2	0.8	0.3	0.7	0.224	359.09	359.09	30	0.084
34	G4	0.2	127.00	0.4	0.6	0.1	0.9	0.1	0.9	0.1	0.9	0.437	290.36	290.36	0	0.000
35	G5	0.2	185.62	0.6	0.4	0.3	0.7	0.4	0.6	0.3	0.7	0.118	1578.40	1578.40	0	0.000
36	H1	0.8	33.51	0.1	0.9	0.1	0.9	0.1	0.9	0.1	0.9	0.656	51.08	51.08	0	0.000
37	H2	0.7	40.56	0.2	0.8	0.2	0.8	0.2	0.8	0.2	0.8	0.410	99.01	99.01	0	0.000
38	H3	0.5	160.87	0.3	0.7	0.3	0.7	0.5	0.5	0.3	0.7	0.172	938.02	938.02	0	0.000
39	H4	0.2	134.06	0.9	0.1	0.2	0.8	0.2	0.8	0.2	0.8	0.051	2618.34	2618.34	0	0.000
40	H5	0.3	201.09	0.5	0.5	0.3	0.7	0.4	0.6	0.4	0.6	0.126	1595.94	1595.94	0	0.000
41	I1	0.7	38.30	0.1	0.9	0.1	0.9	0.1	0.9	0.1	0.9	0.656	58.38	58.38	0	0.000
42	I2	0.6	67.03	0.3	0.7	0.2	0.8	0.4	0.6	0.3	0.7	0.235	284.99	284.99	0	0.000
43	I3	0.4	67.03	0.5	0.5	0.2	0.8	0.2	0.8	0.2	0.8	0.256	261.83	261.83	0	0.000
44	I4	0.2	134.06	0.7	0.3	0.1	0.9	0.1	0.9	0.1	0.9	0.219	612.98	612.98	0	0.000
45	I5	0.3	107.25	0.5	0.5	0.3	0.7	0.3	0.7	0.2	0.8	0.196	547.18	547.18	0	0.000
46	J1	0.8	31.75	0.1	0.9	0.1	0.9	0.1	0.9	0.1	0.9	0.656	48.39	48.39	0	0.000
47	J2	0.6	67.03	0.1	0.9	0.3	0.7	0.4	0.6	0.3	0.7	0.265	253.32	253.32	0	0.000
48	J3	0.7	43.09	0.4	0.6	0.2	0.8	0.1	0.9	0.2	0.8	0.346	124.68	124.68	0	0.000
49	J4	0.3	114.91	0.5	0.5	0.2	0.8	0.3	0.7	0.3	0.7	0.196	586.26	586.26	0	0.000
50	J5	0.3	114.91	0.4	0.6	0.1	0.9	0.1	0.9	0.1	0.9	0.437	262.71	262.71	0	0.000
Av		**0.428**	**183.85**	**0.33**	**0.67**	**0.19**	**0.81**	**0.24**	**0.76**	**0.20**	**0.80**	**0.35**	**974.73**	**974.73**	**13.15**	**0.083**

Table 7.3(a): The impact on area of minimum required habitat after removing grazing

	Cell	Step 9									Step 12			
		Compensation for density reducing activities(proportion of remaining habitat) Area expected to be irreversibly damaged in the next 50 years through human activities								Product of density reducing activities (ri)	Ratio of available to required habitat			
		Cultivation	Remaining	Grazing	Remaining	Building	Remaining	Harvesting	Remaining		$A_3 = A_2/ri$	Required	Available	Ratio
1	A1	0.2	0.8	0	1	0.5	0.5	0.1	0.9	0.36	335.15	335.15	0	0.000
2	A2	0.4	0.6	0	1	0.3	0.7	0.3	0.7	0.294	512.99	512.99	0	0.000
3	A3	0.1	0.9	0	1	0.2	0.8	0.1	0.9	0.648	77.58	77.58	0	0.000
4	A4	0.1	0.9	0	1	0.1	0.9	0.2	0.8	0.648	66.50	66.50	0	0.000
5	A5	0.6	0.4	0	1	0.3	0.7	0.3	0.7	0.196	2051.92	2051.92	0	0.000
6	B1	0.4	0.6	0	1	0.3	0.7	0.3	0.7	0.294	410.38	410.38	0	0.000
7	B2	0.4	0.6	0	1	0.3	0.7	0.1	0.9	0.378	182.39	182.39	15	0.082
8	B3	0.1	0.9	0	1	0.2	0.8	0.2	0.8	0.576	87.278	87.28	0	0.000
9	B4	0.2	0.8	0	1	0.1	0.9	0.2	0.8	0.576	116.37	116.37	0	0.000
10	B5	0.5	0.5	0	1	0.3	0.7	0.3	0.7	0.245	4924.61	4924.61	0	0.000
11	C1	0.3	0.7	0	1	0.3	0.7	0.2	0.8	0.392	341.99	341.99	0	0.000
12	C2	0.2	0.8	0	1	0.3	0.7	0.5	0.5	0.28	1077.26	1077.26	113	0.104
13	C3	0.2	0.8	0	1	0.1	0.9	0.2	0.8	0.576	77.58	77.58	30	0.387
14	C4	0.4	0.6	0	1	0.3	0.7	0.1	0.9	0.378	227.99	227.99	0	0.000
15	C5	0.3	0.7	0	1	0.5	0.5	0.2	0.8	0.28	8618.08	8618.08	0	0.000
16	D1	0.2	0.8	0	1	0.4	0.6	0.2	0.8	0.384	349.11	349.11	0	0.000
17	D2	0.2	0.8	0	1	0.1	0.9	0.2	0.8	0.576	149.62	149.62	120	0.802
18	D3	0.1	0.9	0	1	0.1	0.9	0.1	0.9	0.729	77.88	77.88	75	0.963
19	D4	0.3	0.7	0	1	0.5	0.5	0.2	0.8	0.28	1436.35	1436.35	0	0.000
20	D5	0.2	0.8	0	1	0.6	0.4	0.2	0.8	0.256	628.40	628.40	0	0.000
21	E1	0.1	0.9	0	1	0.1	0.9	0.1	0.9	0.729	61.30	61.30	0	0.000
22	E2	0.1	0.9	0	1	0.1	0.9	0.1	0.9	0.729	137.92	137.92	120	0.870
23	E3	0.1	0.9	0	1	0.2	0.8	0.2	0.8	0.576	174.56	174.56	5	0.029
24	E4	0.6	0.4	0	1	0.4	0.6	0.4	0.6	0.144	1675.74	1675.74	0	0.000
25	E5	0.8	0.2	0	1	0.1	0.9	0.1	0.9	0.162	1655.05	1655.05	0	0.000

	Cell	Step 9: Compensation for density reducing activities(proportion of remaining habitat) — Area expected to be irreversibly damaged in the next 50 years through human activities								Product of density reducing activities (ri)	Step 12: Ratio of available to required habitat			
		Cultivation	Remaining	Grazing	Remaining	Building	Remaining	Harvesting	Remaining		$A_3 = A_2/ri$	Required	Available	Ratio
26	F1	0.1	0.9	0	1	0.2	0.8	0.1	0.9	0.648	59.11	59.11	0	0.000
27	F2	0.1	0.9	0	1	0.2	0.8	0.2	0.8	0.576	93.10	93.10	75	0.806
28	F3	0.4	0.6	0	1	0.3	0.7	0.2	0.8	0.336	448.86	448.86	30	0.067
29	F4	0.7	0.3	0	1	0.2	0.8	0.2	0.8	0.192	739.30	739.30	0	0.000
30	F5	0.6	0.4	0	1	0.1	0.9	0.1	0.9	0.324	413.76	413.76	0	0.000
31	G1	0.1	0.9	0	1	0.1	0.9	0.1	0.9	0.729	45.97	45.97	0	0.000
32	G2	0.3	0.7	0	1	0.1	0.9	0.2	0.8	0.504	72.00	72.00	45	0.625
33	G3	0.5	0.5	0	1	0.2	0.8	0.3	0.7	0.28	287.27	287.27	30	0.104
34	G4	0.4	0.6	0	1	0.1	0.9	0.1	0.9	0.486	261.32	261.32	0	0.000
35	G5	0.6	0.4	0	1	0.4	0.6	0.3	0.7	0.168	1104.88	1104.88	0	0.000
36	H1	0.1	0.9	0	1	0.1	0.9	0.1	0.9	0.729	45.97	45.97	0	0.
37	H2	0.2	0.8	0	1	0.2	0.8	0.2	0.8	0.512	79.21	79.21	0	0.000
38	H3	0.3	0.7	0	1	0.5	0.5	0.3	0.7	0.245	656.62	656.62	0	0.000
39	H4	0.9	0.1	0	1	0.2	0.8	0.2	0.8	0.064	2094.67	2094.67	0	0.000
40	H5	0.5	0.5	0	1	0.4	0.6	0.4	0.6	0.18	1117.16	1117.16	0	0.000
41	I1	0.1	0.9	0	1	0.1	0.9	0.1	0.9	0.729	52.54	52.54	0	0.000
42	I2	0.3	0.7	0	1	0.4	0.6	0.3	0.7	0.294	227.99	227.99	0	0.000
43	I3	0.5	0.5	0	1	0.2	0.8	0.2	0.8	0.32	209.47	209.47	0	0.000
44	I4	0.7	0.3	0	1	0.1	0.9	0.1	0.9	0.243	551.68	551.68	0	0.000
45	I5	0.5	0.5	0	1	0.3	0.7	0.2	0.8	0.28	383.03	383.03	0	0.000
46	J1	0.1	0.9	0	1	0.1	0.9	0.1	0.9	0.729	43.55	43.55	0	0.000
47	J2	0.1	0.9	0	1	0.4	0.6	0.3	0.7	0.378	177.33	177.33	0	0.000
48	J3	0.4	0.6	0	1	0.1	0.9	0.2	0.8	0.432	99.75	99.75	0	0.000
49	J4	0.5	0.5	0	1	0.3	0.7	0.3	0.7	0.245	469.01	469.01	0	0.000
50	J5	0.4	0.6	0	1	0.1	0.9	0.1	0.9	0.486	236.44	236.44	0	0.000
Av		0.33	**0.67**	**0.19**	**0.81**	**0.24**	**0.76**	**0.20**	**0.80**	**0.35**	**708.48**	**708.48**	**13.15**	**0.097**

Table 7.3(b): The impact on area of minimum required habitat after reducing the four identified anthropogenic factors by half

	Cell	Step 9									Step 12			
		Compensation for density reducing activities(proportion of remaining habitat) Area expected to be irreversibly damaged in the next 50 years through human activities								Product of density reducing activities (ri)	Ratio of available to required habitat			
		Cultivation	Remaining	Grazing	Remaining	Building	Remaining	Harvesting	Remaining		$A_3 = A_2/ri$	Required	Available	Ratio
1	A1	0.1	0.9	0.2	0.9	0.3	0.8	0.1	1.0	0.545	221.36	221.36	0	0.000
2	A2	0.2	0.8	0.2	0.9	0.2	0.9	0.2	0.9	0.491	306.97	306.97	0	0.000
3	A3	0.1	1.0	0.1	0.9	0.1	0.9	0.1	1.0	0.731	68.77	68.77	0	0.000
4	A4	0.1	1.0	0.1	1.0	0.1	1.0	0.1	0.9	0.772	55.84	55.84	0	0.000
5	A5	0.3	0.7	0.2	0.9	0.2	0.9	0.2	0.9	0.430	935.54	935.54	0	0.000
6	B1	0.2	0.8	0.2	0.9	0.2	0.9	0.2	0.9	0.491	245.58	245.58	0	0.000
7	B2	0.2	0.8	0.1	1.0	0.2	0.9	0.1	1.0	0.614	112.34	112.34	15	0.134
8	B3	0.1	1.0	0.1	1.0	0.1	0.9	0.1	0.9	0.731	68.77	68.77	0	0.000
9	B4	0.1	0.9	0.1	0.9	0.1	1.0	0.1	0.9	0.693	96.79	96.79	0	0.000
10	B5	0.3	0.8	0.2	0.8	0.2	0.9	0.2	0.9	0.434	2783.23	2783.23	0	0.000
11	C1	0.2	0.9	0.2	0.9	0.2	0.9	0.1	0.9	0.553	242.55	242.55	0	0.000
12	C2	0.1	0.9	0.1	0.9	0.2	0.9	0.3	0.8	0.516	584.13	584.13	112.5	0.193
13	C3	0.1	0.9	0.1	0.9	0.1	1.0	0.1	0.9	0.693	64.52	64.52	30	0.465
14	C4	0.2	0.8	0.1	1.0	0.2	0.9	0.1	1.0	0.614	140.43	140.43	0	0.000
15	C5	0.2	0.9	0.2	0.9	0.3	0.8	0.1	0.9	0.488	4947.97	4947.97	0	0.000
16	D1	0.1	0.9	0.1	0.9	0.2	0.8	0.1	0.9	0.583	229.87	229.87	0	0.000
17	D2	0.1	0.9	0.1	0.9	0.1	1.0	0.1	0.9	0.693	124.44	124.44	120	0.964
18	D3	0.1	1.0	0.1	1.0	0.1	1.0	0.1	1.0	0.815	69.71	69.71	75	1.076
19	D4	0.2	0.9	0.1	0.9	0.3	0.8	0.1	0.9	0.516	778.85	778.85	0	0.000
20	D5	0.1	0.9	0.1	0.9	0.3	0.7	0.1	0.9	0.510	315.25	315.25	0	0.000
21	E1	0.1	1.0	0.1	1.0	0.1	1.0	0.1	1.0	0.815	54.86	54.86	0	0.000
22	E2	0.1	1.0	0.1	1.0	0.1	1.0	0.1	1.0	0.815	123.44	123.44	120	0.972
23	E3	0.1	1.0	0.1	0.9	0.1	0.9	0.1	0.9	0.693	145.18	145.18	5	0.034
24	E4	0.3	0.7	0.2	0.9	0.2	0.8	0.2	0.8	0.381	633.68	633.68	0	0.000
25	E5	0.4	0.6	0.1	1.0	0.1	1.0	0.1	1.0	0.514	521.20	521.20	0	0.000

	Cell	Step 9									Step 12			
		Compensation for density reducing activities(proportion of remaining habitat)								Product of density reducing activities (ri)	Ratio of available to required habitat			
		Area expected to be irreversibly damaged in the next 50 years through human activities												
		Cultivation	Remaining	Grazing	Remaining	Building	Remaining	Harvesting	Remaining		$A_3 = A_2/ri$	Required	Available	Ratio
26	F1	0.1	1.0	0.1	1.0	0.1	0.9	0.1	1.0	0.772	49.64	49.64	0	0.000
27	F2	0.1	1.0	0.1	1.0	0.1	0.9	0.1	0.9	0.731	73.35	73.35	75	1.022
28	F3	0.2	0.8	0.1	0.9	0.2	0.9	0.1	0.9	0.551	273.81	273.81	30	0.110
29	F4	0.4	0.7	0.1	1.0	0.1	0.9	0.1	0.9	0.500	283.79	283.79	0	0.000
30	F5	0.3	0.7	0.1	1.0	0.1	1.0	0.1	1.0	0.600	223.37	223.37	0	0.000
31	G1	0.1	1.0	0.1	1.0	0.1	1.0	0.1	1.0	0.815	41.147	41.147	0	0.000
32	G2	0.2	0.9	0.1	0.9	0.1	1.0	0.1	0.9	0.654	55.48	55.48	45	0.811
33	G3	0.3	0.8	0.1	0.9	0.1	0.9	0.2	0.9	0.516	155.78	155.78	30	0.193
34	G4	0.2	0.8	0.1	1.0	0.1	1.0	0.1	1.0	0.686	185.16	185.16	0	0.000
35	G5	0.3	0.7	0.2	0.9	0.2	0.8	0.2	0.9	0.405	458.77	458.77	0	0.000
36	H1	0.1	1.0	0.1	1.0	0.1	1.0	0.1	1.0	0.815	41.15	41.15	0	0.000
37	H2	0.1	0.9	0.1	0.9	0.1	0.9	0.1	0.9	0.656	61.81	61.81	0	0.000
38	H3	0.2	0.9	0.2	0.9	0.3	0.8	0.2	0.9	0.461	349.27	349.27	0	0.000
39	H4	0.5	0.6	0.2	0.9	0.1	0.9	0.1	0.9	0.379	354.02	354.02	0	0.000
40	H5	0.3	0.8	0.1	1.0	0.2	0.8	0.2	0.8	0.456	440.98	440.98	0	0.000
41	I1	0.1	1.0	0.1	1.0	0.1	1.0	0.1	1.0	0.815	47.025	47.025	0	0.000
42	I2	0.2	0.9	0.1	0.9	0.2	0.8	0.2	0.9	0.520	128.85	128.85	0	0.000
43	I3	0.3	0.8	0.1	0.9	0.1	0.9	0.1	0.9	0.547	122.60	122.60	0	0.000
44	I4	0.4	0.7	0.1	1.0	0.1	1.0	0.1	1.0	0.557	240.55	240.55	0	0.000
45	I5	0.3	0.8	0.2	0.9	0.2	0.9	0.1	0.9	0.488	219.91	219.91	0	0.000
46	J1	0.1	1.0	0.1	1.0	0.1	1.0	0.1	1.0	0.815	38.98	38.98	0	0.000
47	J2	0.1	1.0	0.2	0.9	0.2	0.8	0.2	0.9	0.549	122.07	122.07	0	0.000
48	J3	0.2	0.8	0.1	0.9	0.1	1.0	0.1	0.9	0.616	70.00	70.00	0	0.000
49	J4	0.3	0.8	0.1	0.9	0.2	0.9	0.2	0.9	0.488	235.62	235.62	0	0.000
50	J5	0.2	0.8	0.1	1.0	0.1	1.0	0.1	1.0	0.686	167.53	167.53	0	0.000
Av		0.165	**0.84**	**0.09**	**0.91**	**0.12**	**0.88**	**0.10**	**0.90**	**0.600**	**304.36**	**304.36**	**13.15**	**0.119**

Table 7.3(c): The impact on area of minimum required habitat when the four identified anthropogenic factors are removed

	Cell	Step 9									Step 12			
		Compensation for density reducing activities(proportion of remaining habitat) Area expected to be irreversibly damaged in the next 50 years through human activities								Product of density reducing activities (ri)	Ratio of available to required habitat			
		Cultivation	Remaining	Grazing	Remaining	Building	Remaining	Harvesting	Remaining		$A_3 = A_2/ri$	Required	Available	Ratio
1	A1	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	1.000	120.65	120.65	0	0.000
2	A2	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	1.000	150.82	150.82	0	0.000
3	A3	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	1.000	50.27	50.27	0	0.000
4	A4	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	1.000	43.09	43.09	0	0.000
5	A5	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	1.000	402.18	402.18	0	0.000
6	B1	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	1.000	120.65	120.65	0	0.000
7	B2	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	1.000	68.94	68.94	15	0.218
8	B3	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	1.000	50.27	50.27	0	0.000
9	B4	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	1.000	67.03	67.03	0	0.000
10	B5	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	1.000	1206.53	1206.53	0	0.000
11	C1	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	1.000	134.06	134.06	0	0.000
12	C2	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	1.000	301.63	301.63	113	0.373
13	C3	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	1.000	44.69	44.69	30	0.671
14	C4	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	1.000	86.18	86.18	0	0.000
15	C5	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	1.000	2413.06	2413.06	0	0.000
16	D1	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	1.000	134.06	134.06	0	0.000
17	D2	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	1.000	86.18	86.18	120	1.392
18	D3	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	1.000	56.78	56.78	75	1.321
19	D4	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	1.000	402.18	402.18	0	0.000
20	D5	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	1.000	160.87	160.87	0	0.000
21	E1	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	1.000	44.69	44.69	0	0.000
22	E2	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	1.000	100.54	100.54	120	1.194
23	E3	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	1.000	100.54	100.54	5	0.050
24	E4	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	1.000	241.31	241.31	0	0.000
25	E5	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	1.000	268.12	268.12	0	0.000

	Cell	Step 9									Step 12			
		Compensation for density reducing activities(proportion of remaining habitat) Area expected to be irreversibly damaged in the next 50 years through human activities								Product of density reducing activities (ri)	Ratio of available to required habitat			
		Cultivation	Remaining	Grazing	Remaining	Building	Remaining	Harvesting	Remaining		$A_3 = A_2/ri$	Required	Available	Ratio
26	F1	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	1.000	38.30	38.30	0	0.000
27	F2	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	1.000	53.62	53.62	75	1.399
28	F3	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	1.000	150.82	150.82	30	0.199
29	F4	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	1.000	141.94	141.94	0	0.000
30	F5	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	1.000	134.06	134.06	0	0.000
31	G1	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	1.000	33.51	33.51	0	0.000
32	G2	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	1.000	36.29	36.29	45	1.240
33	G3	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	1.000	80.44	80.44	30	0.373
34	G4	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	1.000	127.00	127.00	0	0.000
35	G5	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	1.000	185.62	185.62	0	0.000
36	H1	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	1.000	33.51	33.51	0	0.000
37	H2	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	1.000	40.56	40.56	0	0.000
38	H3	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	1.000	160.87	160.87	0	0.000
39	H4	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	1.000	134.06	134.06	0	0.000
40	H5	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	1.000	201.09	201.09	0	0.000
41	I1	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	1.000	38.30	38.30	0	0.000
42	I2	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	1.000	67.03	67.03	0	0.000
43	I3	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	1.000	67.03	67.03	0	0.000
44	I4	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	1.000	134.06	134.06	0	0.000
45	I5	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	1.000	107.25	107.25	0	0.000
46	J1	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	1.000	31.75	31.75	0	0.000
47	J2	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	1.000	67.03	67.03	0	0.000
48	J3	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	1.000	43.09	43.09	0	0.000
49	J4	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	1.000	114.91	114.91	0	0.000
50	J5	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	1.000	114.91	114.91	0	0.000
Av		0.0	**1.0**	0.0	**1.0**	0.0	**1.0**	0.0	**1.0**	**1**	**183.85**	**183.85**	**13.15**	**0.169**

Scenario 2: Changing some of the human activities may have a positive impact towards the conservation goal. The second scenario is to prohibit at least one human impacting activity from the area (Table 7.3a). Just by removing grazing from the area it can reduce the area to be conserved from 974 ha to 708 ha. Excluding herbivores from an area promotes seedling establishment of woody species (Angassa and Oba 2010). In addition, grazing and trampling decrease the number of plants, plant basal area, and the amount of dead plant material that acts as protective mulch (Zhou *et al.* 2010). Disturbances such as grazing and cultivation also affect evapotranspiration by altering vegetational canopy surface conductance, canopy structure, and soil water-holding capacity (Miao *et al.* 2009). However, some grazing related disturbances may be associated with increased plant abundance such as bush encroachment (McGeoch *et al.* 2008) and it is therefore important to make an assessment of each human impacting activity before suggesting exclusions. Human practices, such as harvesting for medicinal plant material, impacts forests at various levels (Sinha and Bawa 2002, Ghimire *et al.* 2005). Therefore, the creation of a protected area may facilitate the conservation of medicinal plant species by restricting access and extractive use that promote overexploitation (McGeoch *et al.* 2008). However, it has also been found that whenever the economic value of a natural resource carries more weight than the cultural value, traditional management of such a resource will fail to guarantee its sustainability (Saidi andTshipala-Ramatshimbila 2006).

Scenario 3: By reducing all four human activities (cultivation, grazing, building, and harvesting) by half, it can also reduce the area needed to be conserved by more than fifty percent (Table 7.3b). Reducing the impacts of human activities can increase the remaining unconserved land. Instead of targeting all 974 ha for conserving the species only 366 ha needs to be set aside for conserving the species. Under this scenario the communities can be allowed to carry on with their activities at a reduced rate. The challenge will only arise in the monitoring of the levels of utilization, which is to be reduced by half from the current level. The community depends on activities such as grazing and cultivation for their daily livelihoods and extending the reserve area from 110 ha to 366 ha is feasible since there is enough available potential habitat. In a reserve the harvesting for materials should continue in a sustainable manner. Proper management which allow for the harvesting of medicinal materials from *B. zanguebarica* within the reserve will have to be established and put in place.

Scenario 4: Bringing in a scenario of entirely removing all four human impacting activities through the increase of protected areas brings down the area needed for keeping a viable population of *B. zanguebarica* to 184 hectares (Table 7.3c). This is a significant decrease, which can theoretically be easily achieved by increasing the protected area from 110 hectares to 184 hectares. However, conservation is about sustainable utilization of resources and this scenario cannot work since it will not allow use of resources.

From the four scenarios assessed it is clear that the first scenario of keeping the status quo cannot allow for a viable population of *B. zanguebarica* since the 974 ha is too large to acquire amidst all the activities around the area. It is unlikely that the reserve size could be increased to include 14 of the cells (Figure 7.1) into the core zone of the biosphere, which can then be managed through the biosphere principles.

It is important to note that both habitats and species suffer from human pressures (Rodgers *et al.* 2010, Louette *et al.* 2011). It is therefore upon people to decrease or stop biodiversity loss. Exclusion of other human related activities as demonstrated in scenario two, three and four reduces the area required as potential habitat for allowing a viable population of *B. zanguebarica* to grow. Amongst these options, scenario 3 seems the most likely to succeed. Only an addition of 256bhactares in the form of reserve extention may result in enough potential habitat for conserving a viable population.

Step 10 Identifying catastrophic events that are likely to affect the potential habitat of the species was not conducted since the area has no records of any catastrophes.

Step 11 Combining targets areas across different regions and defining a species/community target was also not conducted since the method was applied on the only population of *B. zanguebarica* that exists within South Africa.

Step 12 During this step habitat maps were evaluated and a possible target conservation area proposed accounting for spatial and species-specific constraints. The Brackenridgea Nature Reserve, which is situated in cell D2 can easily be expanded into parts of cells C2, E2 and F2 to obtain the required 366 ha for conservation. Even parts of cells D3 and E3 on the other side of the road could be protected as another unit of the nature reserve. Where necessary, corridors will have to be implemented in an effort to mitigate fragmentation and conservation of biodiversity and allow for genetic movement (Hess and Fischer 2001). By expanding the reserve it will increase the available area of the species and the probability of the extinction of *Brackenridgea zanguebarica* in a larger reserve as compared to the present small reserve will be less (Pelletier 2000, Lienert 2004).

7.4.3 Factors threatening the survival of *Brackenridgea zanguebarica* population

7.4.3.1 Unsustainable harvesting practices

Poaching of medicinal material is currently the major threat to the population of *B. zanguebarica*. Although the reserve is guarded throughout the day, poachers still manage to gain entrance into the reserve after hours (Figure 7.4). According to Mr Maluta[11] poaching activities take place either early in the morning or late at night. When collecting the roots the poachers dig up the whole tree and collect all the roots leaving the stem lying on the ground. Collection of bark involves removal of all the

[11] Mr Maluta, Conservation Officer, Brackenridgea Nature Reserve, Personal Communication 2007

bark from the stem and leaving the plant to die from ring-barking. In the past harvesting of medicinal material was done by traditional healers who followed cultural taboos, which indirectly contributed to reduced harvesting pressure (Van Andel and Havinga 2008).

Figure 7.4: A researcher showing illegal harvesting of bark for medicinal purposes taking place inside the Brackenridgea Nature Reserve during the 2007 population density survey.

7.4.3.2 Settlement areas

The expansion of settlements as a result of intrinsic human population growth is posing a challenge to the *Brackenridgea zanguebarica* population, since clearing for such development does not take cognizance of the importance of the plant in most cases. The expanding periphery of the settlements close to the reserve decreases the area available for medicinal collection outside the reserve. The village to the western side of the reserve almost borders the fence of the reserve, while the one to the east is also expanding rapidly towards the reserve. This expansion is influenced by the topography of the region, i.e. the fact that the northward expansion of the village is hindered by a mountain, while southward expansion is prevented by the river. The village therefore forms a strip, which can only expand on the eastern and western sides.

7.4.3.3 Development ventures

The loss of natural resources is not inextricably tied to development (Buenz 2005) and managed development can be possible with minimal exploitation, or preferably the sustainable use, of natural resources. Development ventures in the area are in the form of roads and community businesses. The gravel road that used to service the area was tarred during 1989-90 as a way of promoting tourism in the area. This tarred road cuts through the population of *B. zanguebarica*. Although the development is more than welcomed, the resulting tarred road made access into the population much easier now than before. People can therefore easily park their cars by the side of the road and jump into the reserve or into the communal land and get away swiftly.

Some of the developments that are being made are in the form of business ventures where people are fencing areas close to the nature reserve in order to create recreational facilities. These areas that are being cordoned off for developments were in the past utilized by medicinal plants collectors as collection grounds. The claiming of certain areas for development activities is therefore reducing the collection areas of medicinal material.

7.5 Conclusions

In developing countries, where both funding and implementation capacity are limited, conservation planning needs to be scheduled, data driven and target directed (Margules & Pressey 2000, Visconti *et al*. 2010). A key issue to be resolved in conservation science remains the question of how much should be conserved (Sanderson *et al.* 2002, Tear *et al*. 2005). The Burgman *et al.* (2001) method holds promise in guiding conservation efforts in this regard. Although the authors claim that the method is quick and uses only information that is available, it is not a short-cut.

In conclusion, it is clear to note that the utilization of *Brackenridgea zanguebarica* from the Thengwe area for medicinal purposes cannot be stopped since the species is regarded an important medicinal plant and only located in one area in the whole of South Africa. It is therefore recommended that the area for conservation of *B. zanguebarica* be increased in order to increase the distribution of the species through the available potential habitat. Several cells which have enough potential for the growth of *B. zanguebarica* population can be included in the conservation plan. In a situation where a single reserve cannot be constructed by extension from the existing one, several smaller reserves can be created along potential growth habitat as long as corridors are kept in place. The creation of corridors between the different cells is important in ensuring the viability of the protected population.

It is important to note that all conservation managers face decisions regarding what actions to be taken in order to achieve conservation objectives (Pullin *et al.* 2004). Although most of the decisions might involve a level of uncertainty which might be minor, individual knowledge and experience may be good enough to make sound decisions.

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References

ANGASSA, A. AND OBA, G. 2010. Effects of grazing pressure, age of enclosures and seasonality on bush cover dynamics and vegetation composition in southern Ethiopia. *Journal of Arid Environments* **74: 111-120.**

BEISSINGER, S.R. AND MCCULLOUGH, D.R. 2002. Population viability analysis. The University of Chicago Press, Chicago, USA.

BUENZ, E.J. 2005. Country development does not presuppose the loss of forest resources for traditional medicine use. *Journal of Ethnopharmacology* **100: 118-123.**

BURGMAN, M.A., POSSINGHAM, H.P., LYNCH, J.J., KEITH, D.A., McCARTHY, M.A., HOPPER, S.D., DRURY, W.L., PASIOURA, J.A. AND DEVRIES, R.J. 2001. A method for setting the size of plant conservation target areas. *Conservation Biology* **15: 603-616.**

CABEZA, M. AND VAN TEEFFELEN, A.J.A. 2009. Strategies of reserve selection. Encyclopedia of Life Sciences. John Wiley & Sons, Chichester. DOI: 10.1002/9780470015902. a0021224.

COWLING, R.M., PRESSEY, R.L., ROUGET, M. AND LOMBARD, A.T. 2003.A conservation plan for a global biodiversity hotspot – the Cape Floristic Region, South Africa. *Biological Conservation* **112: 191−216.**

DENGLER, J. 2009. A flexible multi-scale approach for standardised recording of plant species richness patterns. *Ecological Indicators* **9: 1169-1178.**

DESMET, P.G., COWLING, R.M., ELLIS, A.G. AND PRESSEY, R.L. 2002. Integrating biosystematics data into conservation planning: Perspectives from Southern Africa’s Succulent Karoo. *Systematic Biology* **51: 317–330**.

EELEY, H.A.C., LAWES, M.J. AND REYERS, B. 2001. Priority areas for the conservation of subtropical indigenous forest in southern Africa: a case study from Kwazulu-Natal. *Biodiversity and Conservation* **10: 1221-1246.**

GAUGRIS, J.Y. AND VAN ROOYEN, M.W. 2010. Evaluating the adequacy of reserves in the Tembe–Tshanini Complex: a case study in Maputaland, South Africa. Fauna and Flora International, *Oryx* **44: 399–410.**

GHIMIRE, S.K., McKEY, D. AND AUMEERUDDY-THOMAS, Y. 2005. Conservation of Himalayan medicinal plants: Harvesting patterns and ecology of two threatened species, *Nardostachys grandiflora* DC and *Neopicrorhiza scrophulariiflora* (Pennell) Hong. *Biological Conservation* **124: 463-475.**

HESS, G.R. AND FISCHER, R.A. 2001. Communicating clearly about conservation corridors. *Landscape and Urban Planning* **55: 195-208.**

LIENERT, J. 2004. Habitat fragmentation effects on fitness of plant populations – a review. *Journal for Nature Conservation***12: 53-72.**

LOUETTE, G., ADRIAENS, D., ADRIAENS, P., ANSELIN, A., DEVOS, K., SANNEN, K., VAN LANDUYT, W., PAELINCKX, D. AND HOFFMANN, M. 2011. Bridging the gap between the Natura 2000 regional conservation status and local conservation objectives. *Journal for Nature Conservation* **19: 224-235.**

LOZANO, F.D. AND SCHWARTZ, M.W. 2005. Patterns of rarity and taxonomic group size in plants. *Biological Conservation* **126: 146-154.**

MARGULES, C.R. AND PRESSEY, R.L. 2000. Systematic conservation planning. *Nature* **405: 43–253.**

McGEOCH, L., GORDON, I. AND SCHMITT, J. 2008. Impacts of land use, anthropogenic disturbance, and harvesting on an African medicinal liana. *Biological Conservation* **141: 2218-2229.**

MENGES, E.S. 2000. Population viability analysis in plants: challenges and opportunities. *Trends in Ecology and Evolution* **15: 51-56.**

MIAO, H., CHEN, S., CHEN, J., ZHANG, W., ZHANG, P., WEI, L., HAN, X. AND LIN, G. 2009. Cultivation and grazing altered evapotranspiration and dynamics in Inner Mongolia steppes. *Agricultural and Forest Metereology* **149: 1810-1819.**

MILLENIUM ECOSYSTEM ASSESSMENT 2005. Ecosystems and human well-being: Biodiversity synthesis. World Resources Institute, Washington DC.

MUCINA, L. AND RUTHERFORD, M.C. (eds). 2006. The vegetation of South Africa, Lesotho and Swaziland. *Strelitzia 19.* South African National Biodiversity Institute, Pretoria.

NETSHIUNGANI, E.N. AND VAN WYK, A.E. 1980. Mutavhatsindi - mysterious plant from Venda. *Veld and Flora.* September**: 87-90.**

OBIRI, J., LAWES, M. AND MUKOLWE, M. 2002. The dynamics and sustainable use of high value tree species of the coastal Pondoland forests of the Eastern Cape Province, South Africa. *Forest Ecology and Management* **166: 131-148.**

PALGRAVE, K.C. 1988. Trees of Southern Africa. 4th edition. Struik Publishers, Cape Town.

PELLETIER, J.D. 2000. Model assessment of the optimal design of nature reserves for maximizing species longevity. *Journal of Theoretical Biology* **202: 25-32.**

PFAB, M.F. AND SCHOLES, M.A. 2004. Is the collection of *Aloe peglerae* from the wild sustainable? An evaluation using stochastic population modeling. *Biological Conservation* **118: 695-701.**

PFAB, M.F. AND WITKOWSKI, E.T.F. 2000. A simple population viability analysis of the critically endangered *Euphorbia clivicola* R.A. Dyer under four management scenarios. *Biological Conservation* **96: 263-270.**

PRESSEY, R.L. 1994. Ad hoc reservations: forward or backward steps in developing representative reserve systems? *Conservation Biology* **8: 662-668**.

PRESSEY, R.L., COWLING, R.M. AND ROUGET, M. 2003, Formulating conservation targets for biodiversity pattern and process in the Cape Floristic Region, South Africa. *Biological Conservation* **112: 99–127.**

PULLIN, A.S., KNIGHT, T.M., STONE, D.A. AND CHARMAN, K. 2004. Do conservation managers use scientific evidence to support their decision-making? *Biological Conservation* **119: 245-252.**

RODGERS, H.M., GLEW, L., HONZAK, M. AND HUDSON, M.D. 2010. Prioritizing key biodiversity areas in Madagascar by including data on human pressure and ecosystem services. *Landscape and Urban Planning* **96: 48-56.**

SAIDI, T.A. AND TSHIPALA-RAMATSHIMBILA, T.V. 2006. Ecology and management of a remnant of *Brachystegia spiciformis* (miombo) woodland in North Eastern Soutpansberg, Limpopo Province. *South African Geographical Journal* **88: 205-212.**

SANDERSON, E.W., REDFORD, K.H., VEDDER, A., COPPOLILLO, P.B. AND WARD, S.E. 2002. A conceptual model for conservation planning based on landscape species requirements. *Landscape and Urban Planning* **58: 41-56.**

SARKAR, S., PRESSEY, R.L., FAITH, D.P., MARGULES, C.R., FULLER, T., STOMS, D.M., MOFFET, A., WILSON, K.A., WILLIAMS, K.J., WILLIAMS, P.H. AND ANDELMAN, S. 2006. Biodiversity conservation planning tools: present status and challenges for the future. *Annual Reviews of Environment and Resources* **31: 123-159.**

SCHULZE, M., GROGAN, J., LANDIS, R.M. AND VIDAL, E. 2008. How rare is too rare to harvest? Management challenges posed by timber species occurring at low densities in the Brazilian Amazon. *Forest Ecology and Management* **256: 1443-1457.**

SINHA, A. AND BAWA, K.S. 2002. Harvesting techniques, hemiparasites and fruit production in two non-timber forest tree species in South India. *Forest Ecology and Management* **168: 289-300.**

TEAR, T.H., KAREIVA, P., ANGERMEIER, P.L., COMER, P., CZECH, B., KAUTZ, R., LANDON, L., MEHLMAN, D., MURPHY, K., RUCKELSHAUS, M., SCOTT, J.M. AND WILHERE, G. 2005. How much is enough? The recurrent problem of setting measurable objectives in conservation. *BioScience* **55: 835 – 849.**

TODD, C.B., KHOROMMBI, K., VAN DER WAAL, B.C. AND WEISSER, P.J. 2004. Conservation of woodland biodiversity: A complementary traditional approach and western approach towards protecting *Brackenridgea zanguebarica*. In: Indigenous forests and woodlands in South Africa – Policy, People and Practice. Eds. LAWES, M.J., EELEY, H.A.C., SHACKLETON, C.M. AND GEACH. B.G.S. University of KwaZulu-Natal Press, Durban, South Africa: 737-750

VAN ANDEL, T. AND HAVINGA, R. 2008. Sustainability of commercial medicinal plant harvesting in Suriname. *Forest Ecology and Management* **256: 1540-1545.**

VAN WYK, B. AND VAN WYK, P. 1997. Field guide to trees of Southern Africa. Struik Publication, Cape Town, South Africa.

VAN WYK, B.E., VAN OUDTSHOORN, B. AND GERICKE, N. 1997. Medicinal plants of South Africa. Briza Publications, Pretoria, South Africa.

VISCONTI, P., PRESSEY, R.L., SEGAN, D.B. AND WINTLE, B.A. 2010. Conservation planning with dynamic threats: the role of spatial design and priority setting for species' persistence. *Biological Conservation* **143: 756-767.**

WESSELS, K.J., FREITAG, S. AND VAN JAARSVELD, A.S. 1999. The use of land facets as biodiversity surrogates during reserve selection at a local scale. *Biological Conservation* **89: 21-38.**

ZHOU, Z.C., GAN, Z.T., SHANGGUAN, Z.P. AND DONG, Z.B. 2010. Effects of grazing on soil physical properties and soil erodibility in semiarid grassland of the Northern Loess Plateau (China). *Catena* **82: 87-91.**

CHAPTER 8

SYNTHESIS AND MANAGEMENT RECOMMENDATIONS

Abstract

The study on sustainability of some of the indigenous medicinal plant species traded in Venda region, Limpopo province of South Africa came about as a way of assessing bark harvesting impact on indigenous medicinal plants in Venda. Approx 31% of all woody species in the Venda region have been reported to have medicinal properties in their bark and many of these are traded in the muthi markets. Vulnerability scoring also revealed that there are a number of factors that renders a species vulnerable or resilient and was used to identify those species which are most threatened.

Studies on the impact of bark harvesting for medicinal purposes on *Elaeodendron transvaalense* and *Brackenridgea zanguebarica* revealed a high degree of overexploitation. Although their populations looked healthy it was clear to note that there are size classes that need to be protected in order for the populations to remain viable into the future.

Conservation efforts from all levels are highly welcomed since they are contributing in their own ways towards conservation of indigenous medicinal plants. It is therefore clear that an integrated approach of taking best conservation practices from western as well as indigenous systems can be the way to go. Formation of a Participatory Natural Resource Management Associations in areas where natural resources are being threatened by unsustainable harvesting practice can help in bringing together interested stakeholders into the mainstream of protecting such resources. Such associations should be governed by natural resource harvesting policy with clear objectives around documentation, monitoring and evaluation of harvesting. The policy should cover ecological, social, as well as economical concerns.

Key words: Harvesting impact, integrated management, sustainable harvesting

8.1 Introduction

The concepts of sustainability and sustainable development have come to the forefront of many ecological as well as political debates over the last few decades (Goodland 1995). Sustainable development has become a widely accepted concept, although it used to be regarded as a poorly defined one (Dernbach 2001; Kennedy 2001). Yet, achieving sustainability still remains a problem. Sustainable utilization of resources should be seen as a cornerstone of conservation instead of being seen merely as a way of alleviating pressure on our natural resources. For conventional conservation to be efficient, reserve networks including large ecological reserves work best. However, establishing protected areas is associated with many conflicting issues because of the incompatibility of land uses as a result of the high human population growth rate (Nantel *et al.* 1998, West and Brockington 2006, Gaugris and Van Rooyen 2010). It is therefore obvious that much, if not the majority of conservation efforts, have to be devoted to non-conserved areas (Smith *et al.* 2006). Regarding the latter it is especially important to retain landscape heterogeneity and to preserve a variety of natural habitats under anthropogenic disturbance regimes, but also to improve resource use and control resource extraction (Lindenmayer *et al.* 2006; Naughton-Treves *et al.* 2007).

The exploitation of *Elaeodendron transvaalense* and *Brackenridgea zanguebarica* for medicinal purposes is currently very high in the Venda region. Despite the reasonable number of seedlings that are established in both species, the destruction rate of large trees is a point of concern. For both species bark harvesting for medicinal purpose is the major contributor to the loss of mature individuals. In the case of *E. transvaalense* it is also used for firewood but this only occurs when it is dry. In the case of *B. zanguebarica* it is not used for anything else due to taboos associated with it (Netshia pers. comm.[12]). However, the taboos associated with it encourage men to use poles of the species for fencing so that women could not attempt to use the fence as firewood.

8.2 Discussion

8.2.1 Sustainable harvesting and conservation

The idea that conservation and sustainable use are linked together is now widely accepted as is the belief of the inextricable link that exists between our survival and that of other species around us (Salafsky *et al.* 2002, Heywood and Iriondo 2003). The World Conservation Strategy defines conservation as the management of human use of the biosphere so that it may yield the greatest sustainable benefit to present generations, while maintaining its potential to meet the needs and the aspirations of the future generation (IUCN/UNEP/WWF 1980). It is also acknowledged that human harvesting of natural resources is not the sole cause of extinctions. There are other major unintended and irreversible ecological consequences of human activities that may lead to species extinction, through biodiversity loss such as by habitat loss or as a result of global climate change (Fisher and Krutilla 1974, Johannes 2002, Brooks *et al.* 2002, Antoci *et al.* 2005).

The large amount of bark harvesting for medicinal purposes in Venda region as revealed in Chapter 4 is cause for concern. Of the 498 woody plant species listed for

[12] NETSHIA, L. 1998. Traditional healer. Thohoyandou, Limpopo province.

the Venda region 30.7% (n = 158 plant species) have been reported to have medicinal properties in their bark. However, only 11.7% (n = 58) of these species are actively traded for their bark in muthi shops around Venda. From the 58 species used for their bark only five species appeared on the list of species most commonly traded in Venda region (Tshisikhawe 2002).

The first step in determining the potential of sustainable bark harvesting of the species of Venda was therefore to assess each species by means of a vulnerability score so that measures can be taken to improve the protection and monitoring of the most vulnerable species by trying to reduce human induced biodiversity threats (Gauthier *et al.* 2010). What is consoling is to realize that 81% of the 58 medicinal plants harvested for their bark were not threatened since they showed high resilience score of above 15. However, 19% of the 58 medicinal plant species harvested for their bark were considered to be species at risk and it is this group of species that requires urgent inclusion into management protection plans.

Some of the problems of bark harvesting for medicinal purposes can be addressed by simply following the correct procedures of harvesting as well as by adhering to the myths associated with medicinal bark collection wherein traditional healers believe that killing the plant may result in patients not getting healed (Netshia pers. comm[13]. and Ramaliba pers. comm[14].). Promoting adherence to these myths amongst those who believe in them can go a long way in protecting biodiversity. Adherence to myths and taboos is also important to consider when proposing harvesting strategies because the use of bark for medicinal purposes is embedded in the mindsets of rural traditional

[13] NETSHIA, L. 1998. Traditional healer. Thohoyandou, Limpopo province.
[14]RAMALIBA, T.Z. 2007. Traditional healer.Thohoyandou, Limpopo province.

healers and they may not use leaves which are harvested in a less destructive way even when proved to have the same compounds when compared to barks (Zschocke *et al.* 2000a and b, Drewes *et al*. 2001, Geldenhuys 2004a).

Analyzing the population size class distribution of *Elaeodendron transvaalense* and *Brackenridgea zanguebarica* gave an insight on their status. In spite of the problems of inferring population dynamics from once off surveys (Condit *et al*. 1998, Boudreau *et al.* 2005)these surveys revealed size classes that needed careful attention and which are important in maintaining healthy populations (Chapters 5 and 6). This method of analyzing the population structure by a size class analysis if repeated after some years, as was the case with *Brackenridgea zanguebarica,* can help in understanding the dynamics of the population and checking whether significant differences between the size class regression curves could be detected through an analysis of covariance (Chapter 6).

The size class distribution analysis revealed some important features of the population structure of the species. It is important to have accurate counts of small individuals when the size class distribution of a species is investigated, because these individuals need to ensure the survival of the species. Both species investigated in the current study showed the ability to resprout from a lignotuber. In the current study resprouts were generally classified as seedlings since it could only be established that they were resprouts after digging up the lignotuber. The classification of resprouts as seedlings could give a false impression of the success of regeneration by seeds. It is however also important to consider small individuals whenever estimates on plant biodiversity are carried out. It has been found that such biodiversity estimates can seriously be jeopardized whenever surveys tend to neglect very small individuals such as the case in surveys of forested communities (Niklas *et al*. 2003).

There are some mechanisms whereby species can show a degree of resilience towards bark harvesting. The ability to coppice or resprout is regarded as one method to afford some resilience against bark harvesting (Botha *et al.* 2004, Geldenhuys 2004a). Another mechanism of resilience towards bark harvesting is the ability of the species to regrow its bark (Cunningham and Mbenkum 1993, Cunningham 1993, Delvaux *et al.* 2009). This ability has been shown to be species-specific (Fasola and Egunyomi 2005, Vermeulen 2006, Geldenhuys *et al.* 2007, Delvaux *et al.* 2009). Both *Elaeodendron transvaalense* and *Brackenridgea zanguebarica* show the ability to regrow their bark after being harvested. Bark regeneration is therefore very important for the survival of matured individuals within the population. There are a number of factors affecting the degree of bark regeneration. The intensity of the harvest seems to have a negative impact on the bark's regrowth potential. A relationship has also been demonstrated between tree size and bark regrowth, with larger trees more resilient to bark harvesting (Vermeulen and Geldenhuys 2004). Furthermore, the degree of bark regrowth depends on the harvesting technique (Delvaux *et al.* 2009). Removing a narrow strip of bark may improve the chances of healing the wound.

In spite of these mechanisms to improve the resilience of the species to bark harvesting, they do not guarantee sustainability of harvesting. As soon as the harvesting intensity exceeds the resilience capacity of the species it will be vulnerable to overharvesting. This has been demonstrated for *Prunus africana,* which has the ability to regrow its bark; however populations are declining due to commercial harvesting of this species in Cameroon (Cunningham and Mbenkum 1993, Stewart 2009).

The size class distribution analysis was complemented by a matrix analysis in the case of *Elaeodendron transvaalense.* Using matrix modelling as conducted with *E. transvaalense* population can help in making projections into the future, but even more important the elasticity analysis could indicate the most vulnerable stage in the life cycle. However, more sophisticated matrix modeling, such as incorporating density-dependence, generally needs vast amounts of data and many years of repeated data sampling (Pfab and Scholes 2004). In this project the matrix was derived from data collected in two years and with the assumption that all the plants will reach flowering stage since there was no information on mortality. Although matrix analysis is a rigorous method it may be too time consuming if employed in the evaluation of all species subjected to bark harvesting in Venda, since it requires a lot of data and more time. However, matrix modelling should in future be used in evaluating those species that were found to be most at risk after evaluating their vulnerability (Chapter 4).

For a species such as *Brackenridgea zanguebarica* with a restricted distribution and specific habitat requirements, it is important to protect it *in situ* since its distribution is influenced by the surrounding environmental conditions. To ensure the species' survival it is essential to protect a viable population. The Burgman method (Burgman *et al.* 2001, Gaugris and Van Rooyen, 2010) used in the evaluation of *B. zanguebarica* and its reserve requirement proved to be a good method although it depends largely on the expert's knowledge when making the assessment (Chapter 7). However, after evaluating the population with the Burgman *et al.* (2001) method and establishing the reserve adequacy of the Brackenridgea Nature Reserve it will still require protection efforts that are inclusive of all stakeholders. Including all the stakeholders in the management of this species is imperative, because some of the recommendations to protect *B. zanguebarica* will require community members to reduce some of their activities. The Burgman method (Burgman *et al.* 2001) is a valuable tool to set the size of target plant conservation areas only if the expert making the assessment has a good knowledge of the species and its requirements. However, because the method is time consuming it can only be used for evaluating special cases.

For sustainability to be achieved local resources should be controlled by local people. As is the case in Mafungabusi State Forest of Zimbabwe, involving local residents in management and control of protected areas has proved successful (Vermeulen 1996). The approach of co-management with tribal authorities of the woodland vegetation in which *Brackenridgea zanguebarica* is found is promoted as was suggested by officials from Water Affairs and Forestry Department (Saidi and Tshipala-Ramatshimbila 2006). This approach is appealing and extremely relevant since natural ecosystems are often closely associated with the history of human societies. The role of human communities should therefore be recognized because the future of ecosystems and human activities are closely intertwined (Thompson *et al.* 2011).

8.2.2 Indigenous conservation techniques

Indigenous conservation techniques are informed by indigenous knowledge, which is defined as accumulated knowledge, skill and technology of local people. It is derived from their direct interaction with the environment (Verlinden and Dayot 2005). Indigenous medicinal plants have always been harvested for medicinal purposes by traditional healers with reverence. The respect shown by these traditional healers through indigenous techniques has made it possible for many plant species to survive all these years of exploitation. Taboos, myths, beliefs and rituals are generally used in the protection of indigenous medicinal plants in the Venda region. This is generally practiced during the collection of all medicinal plant material by the traditional healers (Tshisikhawe 2005). As an example it should be noted that if traditional healers believe that a plant from which medicinal material is harvested should not be killed as a result of harvesting impact, since it may cause the medicinal material to be ineffective, then it means that they will always exercise extreme caution when harvesting such material. Whether the myth is true or not, adhering to it will always promote protection of the species concerned.

It is generally regarded as a taboo by traditional healers to ring-bark a medicinal plant, during collection of medicinal material. This taboo also applies to *Elaeodendron transvaalense* and *Brackenridgea zangueb*arica. This is due to the fact that if such a plant dies it is believed that the medicine may also become ineffective and even kill the patient instead of healing (Mabogo 1990). According to tradition, medicinal material from the stem may only be collected from opposite sides. Collection from the north facing side is accompanied by collection from the opposite southern side of the stem. If collection is done on the eastern side the same removal is done on the western side. Such a type of collection technique is further promoted by the belief held by traditional healers that winds which blow from different directions carry healing powers (Mabogo 1990). During collection of roots only lateral roots may be removed and the place from which they are removed should be covered again for the plant to be able to recover (Mabogo 1990, Tshisikhawe 2002).

Collection of medicinal material from *Brackenridgea zanguebarica* has always been accompanied by the performance of rituals (Netshiungani and Van Wyk 1980, Mabogo 1990, Netshia 1998 pers. comm.[15]). There is a dedicated person from the Vhatavhatsindi clan who is responsible for the collection of medicinal material from the plant since there is a belief amongst the Vhatavhatsindi people that the plant is a gift to them by their ancestors. Before collection they talk to the plant so that it knows that they have visited it and the fact that they would like to collect medicinal material from it in order to help the nation. If they need roots they also ask it to make their job easy by not hiding the roots from them (Ramaliba 2007 pers. comm.[16]).

It is also believed that if an unauthorized person collects medicinal material from the plant, such a person may become sterile if he or she was still sexually active (Netshia 1998 pers. comm.[17], Ramaliba 2007 pers. comm.[18]). Sometimes such a person may become insane. The nature of these indigenous techniques has scared people from coming into contact with *Brackenridgea zanguebarica* over the years.

[15] NETSHIA, L. 1998. Traditional healer. Thohoyandou, Limpopo province.
[16] RAMALIBA, T.Z. 2007. Traditional healer.Thohoyandou, Limpopo province.
[17] NETSHIA, L. 1998. Traditional healer. Thohoyandou, Limpopo province.
[18] RAMALIBA, T.Z. 2007. Traditional healer.Thohoyandou, Limpopo province.

Figure 8.1: A traditional healer (Dr TZ Ramaliba - standing) being assisted by a dedicated Mutavhatsindi person (locating the roots) who is responsible for the digging of medicinal material of *B. zanguebarica.*

Traditional woodland management is still seen as a good way of resource management in the area where the *Brackenridgea zanguebarica* population occurs (Saidi and Tshipala-Ramatshimbila 2006). The Department of Water Affairs and Forestry (currently the Department of Agriculture, Forestry and Fisheries) believe that co-management of the woodland with the tribal authorities can be the best way of protecting it. Community based approaches that build on local medicinal knowledge system of the species must be encouraged with supportive policies and legislative measures at provincial, national and global levels (Shukla and Gardner 2006). Co-management of natural resources is discussed in more detail under integrated management in section 8.2.4.

8.2.3 Conventional conservation techniques

Orthodox conservation techniques can also play a major role in conserving endangered species through law enforcement. Reserves have always played a pivotal role in conservation of biodiversity especially in areas where resources can still be obtained outside them. It is however becoming a challenge in situations where resources may be exhausted outside the reserve area.

The Vhembe district Municipality in which the two study sites, namely Tshirolwe and Thengwe, lie has been declared by UNESCO as a Biosphere region (UNESCO 2009). This programme of protecting biodiversity will also go a long way in promoting sustainable utilization of resources since all the inhabitants of the region will be guided by biosphere principles in their daily lives.

In the case of *Brackenridgea zanguebarica* the individuals outside the reserve have been depleted, even amidst law enforcement by the tribal authority. The tribal authority monitored the collection of medicinal materials from those *B. zanguebarica* individuals that were left outside the Brackenridgea Nature Reserve. They did that by accompanying collectors of medicinal material to the field and making sure that they collected enough, but in a sustainable way. They also monitored the development of the population by prohibiting collection to allow the population to recover. However, illegal collection of medicinal material has since occurred and depleted the population outside the reserve. Illegal collection of medicinal material, which is usually done during odd hours, has also extended into the reserve area and is now threatening the population of *B. zanguebarica* within the reserve.

An alternative conventional conservation technique would be *ex situ* conservation in botanical gardens or in medicinal plant gardens (Wiersum *et al.* 2006, Schippmann *et al.* 2006). In a botanical garden medicinal plant species that are being threatened with overharvesting can be propagated and taken good care off. The propagation programme within the botanical garden can extend its service to the community of users by providing them with seedlings to plant in their homestead. It is important to note that although traditional healers do not prefer to obtain medicinal materials from gardens they are willing and prepared to propagate medicinal plants in their own yards (Tshisikhawe 2002).

Some progress has been made towards improving the harvesting techniques applied to specific species. Depending on the extent and the rate of wound closure a strategy could be developed for those species that qualify for strip harvesting (Vermeulen 2006, Delvaux *et al.*2009). Key aspects of the harvest strategy would include strip width and length, harvest rotation, minimum diameter of harvested trees, percentage of the trees in the population to be exposed to bark harvesting and the number and rotation of strips on selected trees (Vermeulen 2006).

Even although it has been shown that leaves could contain the same compounds as bark (Zschocke *et al.* 2000a and b, Drewes *et al*. 2001, Geldenhuys 2004a) using the leaves for traditional medicine is not acceptable to the Venda traditional healer community. Traditional healers believe that if a plant is initially utilized for its medicinal bark such can hardly be substituted with leaves since they may not have the same strength.

A number of indigenous medicinal plant species have been successfully propagated after investigating a number of horticultural techniques on those species that may be difficult to propagate. To enhance the germination of woody plant species, a seed coat cracking pretreatment, as a way of breaking dormancy of hard-seeded species, improved germination by 62% (Netshiluvhi 1999). Tissue culture techniques have also successfully been used to propagate indigenous medicinal plants for commercial purposes (Rout *et al.* 2000). Micropropagation of indigenous medicinal plants is also seen as a way of protecting wild populations from overexploitation (Moyo *et al* 2011). Cultivation of medicinal plants may therefore in the long-term remove pressure from the forests and divert it to the production sites outside forest sites (Tshisikhawe 2002, Geldenhuys 2004b). While looking forward to this medium to long-term solution, efforts should focus on integrated management of the remaining populations of species that are threatened with harvesting as part of the short-term solution. The intergrated management should involve the use of western approach as well as the indigenous approach which is led by the tribal authority.

8.2.4 The integrated management of *Elaeodendron transvaalense* and *Brackenridgea zanguebarica*

The protection of *Elaeodendron transvaalense* and *Brackenridgea zanguebarica,* which are species in demand due to their medicinal value, will require an integrated management approach. The approach should draw best practices in conservation from western as well as indigenous conservation techniques. The system must also enjoy a buy in from the communities that are utilizing the plant resources. It therefore calls for ecological solidarity in the fight against their demise. The concept of ecological solidarity is based on the notion that individuals become united around a common goal and that they are conscious of their common interests and shared responsibility (Thompson *et al.* 2011). Ecological solidarity in this case will require the community to use the best of western as well as indigenous approach of conservation for the achievement of sustainable utilization of the resources that they need. Whether it is towards the use of natural resources, which may include the use of traditional medicine, to the protection of a threatened species, human societies can contribute to the preservation of biodiversity where no monetary value can be identified. Human communities must be reminded of them being part of nature and that the future of nature lies in their capable hands. Integrated conservation and development, which must involve all relevant stakeholders from the start, should therefore have multiple targets related to both conserving biodiversity and improving human welfare (Salafsky *et al*. 2002, Geldenhuys 2004b). Intergrated concept should allow for sustainable utilization of resources by community members.

This integrated conservation concept becomes relevant in the Vhembe District Municipality where the study of this research was based because of the area being accepted by UNESCO as a Vhembe Biosphere Reserve. It is acknowledged that UNESCO's Man and the Biosphere (MAB) strategy of implementing biosphere reserves might constitute an appropriate planning tool in as far as conservation is concerned. Zonations in biosphere reserves allow for traditional forest use areas, traditional agriculture and settlements, and recreational zones (Bucking 2003, Zafra-Calvo *et al.* 2010). In fact biosphere reserves are another model of integrating different types of forest protection and use together (Bucking 2003).

The biosphere concept therefore offers the communities and the whole fraternity of stakeholders within Vhembe District Municipality the opportunity to engage with one another in a holistic approach to conservation. The ecological solidarity concept within the biosphere can work very well with systematic conservation planning, since it will attempt to represent and maintain all the biodiversity within the Vhembe Biosphere region. Complementary systematic conservation planning will provide numerous benefits over the *ad hoc* planning approaches (Lombard *et al.* 2003, Sarkar *et al.* 2006, Zafra-Calvo *et al.* 2010). Conservation plans should ideally use approaches that combine land classification data with that of the species. Conservation planning should therefore not only concern the location and design of reserves that represent the biodiversity of a region, but it should at the same time enable the persistence of that diversity by sustaining key ecological and evolutionary processes (Desmet *et al*. 2002, Cowling *et al*. 2003). However, successful implementation will be possible only if the planning incorporates socio-economic considerations (Berliner 2005) and identification of a general need to develop conservation landscapes that allow the maintenance of biodiversity whilst minimising impacts on the livelihoods of local people (Driver *et al.* 2003).

The ecological solidarity concept will go well with community based natural resource management (CBNRM), which clearly affirms management system of resources that existed amongst indigenous communities. Because of their reliance on natural resources, indigenous communities adhered to management of resources approaches that were meted out by traditional institutions such as chiefs, headmen and healers (Fabricius 2004). Community participation form the core of CBNRM and it should enable them to regain control over natural resources while at the same time strengthening their decision making skills (Wainwright and Wehrmeyer 1998). The Thengwe tribal authority institutions will set boundaries that controlled natural resource utilization. Revival and adherence to these tribal institutions and their practices can play an important ecological role in promotion and sustenance of biodiversity. Carrying out rural development initiatives within a legal framework and effective institutional structures is one of the four components that need to be integrated in order to achieve sustainability of natural resource use. Other components to be integrated concern ecological, social, and economical aspects (Geldenhuys 2004a).

The integrated approach will therefore only prosper when commitment is provided by all sectors of the community. Failing to provide support by all the sectors concerned may lead to the downfall of the integrated management approach. Its strength is that everybody becomes the custodian of the natural resources in this people centered approach to resource management. Communication between different stakeholders is essential for the participatory management approach and the continued sustainability of natural resources (Geldenhuys 2004b). Any information generated on studies of natural resources should be shared amongst different stakeholders.

8.3 Conclusions and recommendations

It is clear that indigenous conservation techniques (ICT) and orthodox conservation play major roles in the conservation of indigenous medicinal plants. It is therefore important to acknowledge the two approaches in the conservation model that should be put into place by the Provincial Department of Environment and the tribal authority institutions of Thengwe and Tshirolwe where the study areas of *Brackenridgea zanguebarica* and *Elaeodendron transvaalense* were respectively located. Instead of focusing only on law enforcement initiatives, efforts should be made that will also focus on the mentality of the communities. People around Thengwe and Tshirolwe should be made to understand the real meaning of having a species that is considered to be rare growing in their area. The Provincial Department of Environment and the tribal authority institution should make the immediate communities feel the sense of ownership in reality.

The feeling of ownership within the Vhatavhatsindi clan in the case of *B. zanguebarica* must cascade down to every member of the community around the area where the species is growing. The information that the species is only found in the Thengwe area of Limpopo province in the whole of South Africa must be communicated to all members of surrounding communities in order for them to understand its place in global, national, provincial as well as local environmental management plans. It is also clear that expansion of Brackenrigea nature reserve by 256 ha is feasible and can go a long way in conserving the species. The research has demonstrated that there is enough potential habitat for the species to expand its distribution.

In the case of *E. transvaalense* the community around Tshirolwe must understand its importance in the healthcare system so that they can look after it with care since the species is used in most of the traditional remedies. Its many uses in traditional medicines offer it the opportunity of breaking into the pharmaceutical markets.

However, for it to get into pharmaceutical markets it will require large scale propagation in order not to deplete its population in the wild.

Propagation intervention is therefore necessary to reduce the stress experienced by both *E. transvaalense* and *B. zanguebarica* through harvesting of medicinal materials. Optimal conditions for propagation need to be established in order to produce enough seedlings that can be distributed to traditional healers who may be prepared to start their own medicinal plant gardens. The approach towards promotion of propagation of medicinal plants is encouraged by the fact that some of the traditional healers have already started introducing medicinal plants of interest to them amongst their crops in their home gardens (Tshisikhawe 2002). It is therefore important to inform people that our own welfare, the survival of other species and the resilience of global life support systems are all intertwined and at risk of extinction threats (Aronson *et al.* 2006). More than ever before it means that people are part of nature and must practice ecological conservation and restoration since it matters in our lives.

The development of an action plan is paramount in as far as the success of the protection and management of natural resources is concerned. In the case of *Brackenridgea zanguebarica*, the action plan should be developed as follows:

- Formation of an association – An association that will look at the conservation of species under threat must be formed. The terms of reference should involve the drafting of a constitution that will drive the process of participatory management of natural resources with specific focus on bark harvesting for medicinal purposes. The constitution for the association should have a clear mission and vision statement as well as a policy for sustainable integrated resource use. The policy should outline the do's and don'ts around harvesting of barks for medicinal purposes.

- Identification of stakeholders – Stakeholders with interest in the protection of natural resources should be identified and recruited to form part of the association. Relevant stakeholders that should be involved in the association include the Department of Water Affairs and Forestry, tribal authority, district and local municipalities, Brakenridgea Nature Reserve, academic and research institutions, traditional healers associations, art and craft associations, and other relevant NGOs operating around such resources. Stakeholders that will be drawn from different sectors of the community are expected to provide knowledge and skill in the management of natural resources.
- Mobilization of stakeholders –The formation of an association should be discussed with individual stakeholder groups for them to understand the need and endorse the process. Once all the stakeholders have bought into the idea the association can start convening and engage as a group.
- Investigation of mechanisms for local groups to co-operate – Local groups must have representation within the identified stakeholders. Their roles should also be accommodated within the harvesting policy for sustainable integrated resource use.
- Framework for planning and documentation of the project – the action plan on the protection of natural resources must be treated as a project that needs careful planning, documentation, monitoring and evaluation. The planning document should emphasized sustainable harvesting of natural resources which should be monitored continuously. Evaluation of the project will help in assessing the success of the sustainable resource use action plan.

- Sustainable harvesting – The emphasis is that resources should be utilized in a sustainable manner. In the case of medicinal plants such as *Elaeodendron transvaalense* and *Brackenridgea zanguebarica* it will be important to understand the ecology of such species for sustainable management of harvesting.
  - Scientific ecological studies that include quantification of the available resources, assessment of the growth rate of the species, as well as production rate will assist in strengthening the harvesting policy. Modelling will also help in projecting into the future in terms of assessing the future impacts of harvesting practice on the population.
  - The socio-economic survey will also help in understanding the demand of the resource for improvement of livelihood. Data from the socio-eonomic survey should flag out the demand of the species and it should help in determining the harvesting quota that should leave behind a viable population.
  - The demand and supply should be supplemented by best harvesting practice. Research on best harvesting practice of the species should inform the harvesting policy.
  - Alternative resources for medicinal materials such as botanical gardens, nurseries, and home gardens should be identified and developed.
  - Access into the forest should be regulated. The harvesting policy should outline the access policy which should include permit to use forest products obtainable from the association.
- Monitoring and evaluation – Harvesting impacts of medicinal materials should be monitored. Evaluation of the impacts should be based on the assessment of

harvesting techniques. Evaluation of the techniques should inform the continuation of such techniques or modification thereof. Simple and easy to apply techniques of assessing harvesting impacts should be developed. The technique should be able to collect and analyze enough data within a short period in a cost-effective manner.

- Funding proposals should be developed for submission to national and international funding institutions that champion biological diversity conservation initiatives.

In general, embracing the association of participatory management of natural resources by all the stakeholders can make such a plan of action a success. The model of action plan developed around the protection of *B. zanguebarica* can therefore be replicated in all the areas that require integrated approach of natural resource management.

References

ANTOCI, A., BORGHESI, S. AND RUSSU, P. 2005. Biodiversity and economic growth: Trade-offs between stabilization of the ecological system and preservation of natural dynamics. *Ecological Modelling* **189: 333-346.**

ARONSON, J., MILTON, S.J., BLIGNAUT, J.N. AND CLEWELL, A.F. 2006. Nature Conservation as if people mattered. *Journal for Nature Conservation* **14: 260-263.**

BERLINER, D. 2005, Systematic conservation planning for the forest biome of South Africa. Approach, methods and results of the selection of priority forests for conservation action, Water and Forestry Support Programme, Department of Water Affairs and Forestry, Pretoria.

BOTHA, J., WITKOWSKI, E.T.F. AND SHACKLETON, C.M. 2004. The impact of commercial harvesting on *Warburgia salutaris* ('pepper-bark tree') in Mpumalanga, South Africa. *Biodiversity and Conservation* **13: 1675–1698.**

BOUDREAU, S., LAWES, M.J., PIPER, S.E. AND PHADIMA, L.J. 2005. Subsistence harvesting of pole-size understorey species from Ongoye Forest Reserve, South Africa: species preference, harvest intensity, and social correlates. *Forest Ecology and Management* **216:149-165.**

BROOKS, T.M., MITTELMEIER, R.A., MITTELMEIER, C.G., DA FONSECA, G.A.B., RYLANDS, A.B., CONSTANT, W.R., FLICK, P., PILGRIM, J., OLDFIELD, S., MAGIN, G. AND HILTON-TAYLOR, C. 2002. Habitat loss and extinction in hotspots of biodiversity. *Conservation Biology* **16: 909-923.**

BUCKING, W. 2003. Are there threshold numbers for protected forests? *Journal of Environmental Management* **67: 37-45.**

BURGMAN, M.A., POSSINGHAM, H.P., LYNCH, J.J., KEITH, D.A., McCARTHY, M.A., HOPPER, S.D., DRURY, W.L., PASIOURA, J.A. AND DEVRIES, R.J. 2001. A method for setting the size of plant conservation target areas. *Conservation Biology* **15: 603-616.**

CONDIT, R., SUKUMAR, R., HUBBEL, S. AND FOSTER, R. 1998. Predicting population trends from size distributions: a direct test in a tropical tree community. *American Naturalist* **152: 495-509.**

COWLING, R.M., PRESSEY, R.L., ROUGET, M. AND LOMBARD, A.T. 2003.A conservation plan for a global biodiversity hotspot – the Cape Floristic Region, South Africa. *Biological Conservation* **112: 191−216.**

CUNNINGHAM, A.B. 1993. African medicinal plants: Setting priorities at the interface between conservation and primary healthcare. UNESCO, Paris.

CUNNINGHAM, A.B. AND MBENKUM, F.T. 1993. Sustainability of harvesting *Prunus africana* bark in Cameroon: a medicinal plant in international trade. UNESCO, Paris.

DELVAUX, C., SINSIN, B., DARCHAMBEAU, F. AND VAN DAMME, P. 2009. Recovery from bark harvesting of 12 medicinal tree species in Benin, West Africa. *Journal of Applied Ecology* **46:703-712.**

DERNBACH, J. 2001. From Rio to Johannesburg, Implementing Sustainable Development at the Global and Local Scale. Pp. 46-50 in Recommendations for Achieving Sustainable Communities, Science and Solutions. Report from the second National Conference on Science, Policy and Environment. National Council for Science and the Environment. Smithsonian National Museum of Natural History, Washington, DC.

DESMET, P.G., COWLING, R.M., ELLIS, A.G. AND PRESSEY, R.L. 2002. Integrating biosystematics data into conservation planning: Perspectives from Southern Africa's Succulent Karoo. *Systematic Biology* **51:317–330.**

DREWES, S.E., CROUCH, N.R., MASHIMBYE, M.J., DE LEEUW, B.M. AND HORN, M.M. 2001. A phytochemical basis for the potential use of *Warburgia salutaris* (pepper-bark tree) leaves in the place of bark. *South African Journal of Science* **97: 383–386.**

DRIVER, A., COWLING, R.M. AND MAZE, K.E. 2003.Planning for living landscapes: Perspectives and lessons from South Africa. Botanical Society of South Africa, Cape Town.

FABRICIUS, C. 2004. The fundamentals of community-base natural resource management. In Rights, Resources and Rural Development Community-based Natural Resource Management in Southern Africa. Eds. FABRICIUS, C., KOCH, E., MAGOME, H. AND TURNER, S. Earthscan Publishers, USA.

FASOLA, T.R. AND EGUNYOMI, A. 2005. Nigerian usage of bark in phytomedecine. *Ethnobotany Research and Applications* **3:73–77.**

FISHER, A.C. AND KRUTILLA, J.V. 1974. Valuing long run ecological consequences and irreversibilities. *Journal of Environmental Economics and Management* **1: 96-108.**

GAUGRIS, J.Y. AND VAN ROOYEN, M.W. 2010. Evaluating the adequacy of reserves in the Tembe–Tshanini Complex: a case study in Maputaland, South Africa. *Oryx* **44: 399–410.**

GAUTHIER, P., DEBUSSCHE, M. AND THOMPSON, M.D. 2010. Regional priority setting for rare species based on a method combining three criteria. *Biological Conservation* **143: 1501-1509.**

GELDENHUYS, C.J. 2004a. Meeting the demand for *Ocotea bullata* bark: implications for the conservation of high value and medicinal tree species. In: Indigenous forests and woodlands in South Africa – Policy, People and Practice. Eds. LAWES, M.J., EELEY, H.A.C., SHACKLETON, C.M. AND GEACH. B.G.S. University of Kwazulu-Natal Press, Durban, South Africa: **517-550.**

GELDENHUYS, C.J. 2004b. Bark harvesting for traditional medicine: from illegal resource degradation to participatory management. *Scandinavian Journal of Forest Research* **19: 103-115.**

GELDENHUYS, C.J., SYAMPUNGANI, S., MEKE, G.S. AND VERMEULEN, W.J. 2007. Response of different species to bark harvesting for traditional medicine in Southern Africa. In J.J. Bester, A.H.W. Seydack, T. Vorster, I.J. Van der Merwe AND S. Dzivhani (eds). Multiple Use Management of Natural Forests and Woodlands: Policy Refinement and Scientific Progress. pp. 55–62. Department of Water Affairs and Forestry, Pretoria, South Africa.

GOODLAND, R. 1995. The concept of environmental sustainability. *Annual Review of Ecology and Systematics* **26:1-24.**

HEYWOOD, V.H. AND IRIONDO, J.M. 2003. Plant conservation: old problems, new perspectives. *Biological Conservation* **113: 321-335.**

IUCN/UNEP/WWF. 1980. World Conservation Strategy: Living resource conservation for sustainable development. International Union for the Conservation of Nature, Gland.

JOHANNES, R.E. 2002. Did indigenous conservation ethics exist? *SPC Traditional Marine Resource Management and Knowledge Information Bulletin* **14: 3-7.**

KENNEDY, D. 2001. Sustainability: Problems, science and solutions. Pp. 35-39 in Recommendations for Achieving Sustainable Communities, Science and Solutions. Report from the second National Conference on Science, Policy and Environment. National Council for Science and the Environment. Smithsonian National Museum of Natural History, Washington, DC.

LINDENMAYER, D.B., FRANKLIN, J.F. AND FISCHER, J. 2006. General management principles and a checklist of strategies to guide forest biodiversity conservation. *Biological Conservation* **131: 433–441.**

LOMBARD, A.T., COWLING, R.M., PRESSEY, R.L. AND REBELO, A.G. 2003. Effectiveness of land classes as surrogates for species in conservation planning for the Cape Floristic Region. *Biological Conservation* **112: 45-62.**

MABOGO, D.E.N. 1990. The ethnobotany of the Vhavenda. Master of science thesis. University of Pretoria, Pretoria, South Africa.

MOYO, M., BAIRU, M.W., AMOO, S.O. AND VAN STADEN, J.2011.Plant biotechnology in South Africa: Micropropagation research endeavours, prospects and challenges. *South African Journal of Botany* **77: 996-1011.**

NANTEL, P., BOUCHARD, A., BROUILLET, L. AND HAY, S. 1998. Selection of areas for protecting rare plants with integration of land use conflicts: A case study for the west coast of Newfoundland, Canada. *Biological Conservation* **84: 223-234.**

NAUGHTON-TREVES, L., KAMMEN, D.M. AND CHAPMAN, C. 2007. Burning biodiversity: woody biomass use by commercial and subsistence groups in western Uganda's forests. *Biological Conservation* **134: 232-241.**

NETSHILUVHI, T.R. 1999. Demand, propagation and seedling establishment of selected medicinal trees. *South African Journal of Botany* **65: 331-338.**

NETSHIUNGANI, E.N. AND VAN WYK, A.E. 1980. Mutavhatsindi – mysterious plant from Venda. *Veld and Flora* **66: 87-89.**

NIKLAS, K.J., MIDGLEY, J.J. AND RAND, R.H. 2003. Size-dependent species richness: trends within plant communities and across latitude. *Ecology Letters* **6: 631-636.**

PFAB, M.F. AND SCHOLES, M.A. 2004. Is the collection of *Aloe peglerae* from the wild sustainable? An evaluation using stochastic population modelling. *Biological Conservation* **118: 695-701.**

ROUT, G.R., SAMANTARAY, S. AND DAS, P. 2000. *In vitro* manipulation and propagation of medicinal plants. *Biotechnology Advances* **18: 91-120.**

SAIDI, T.A. AND TSHIPALA-RAMATSHIMBILA, T.V. 2006. Ecology and management of remnant *Brachystegia spiciformis* (Miombo) woodland in north-eastern Soutpansberg, Limpopo Province. *South African Geographical Journal* **88: 205-212.**

SALAFSKY, N., MARGOLUIS, R., REDFORD, K.H. AND ROBINSON, J.G. 2002. Improving the practice of conservation: a conceptual framework and research agenda for conservation science. *Conservation Biology* **16: 1469-1479.**

SARKAR, S., PRESSEY, R.L., FAITH, D.P., MARGULES, C.R., FULLER, T., STOMS, D.M., MOFFET, A., WILSON, K.A., WILLIAMS, K.J., WILLIAMS, P.H. AND ANDELMAN, S. 2006. Biodiversity conservation planning tools: present status and challenges for the future. *Annual Reviews of Environment and Resources* **31: 123-159.**

SCHIPPMANN, U., LEAMAN, D. AND CUNNINGHAM, A.B. 2006. A comparison of cultivation and wild collection of medicinal and aromatic plants under sustainability aspects. In: BOGERS, R.J., CRAKER, L.E., LANGE, D. (eds).

Medicinal and aromatic plants, agricultural, commercial, ecological, legal, pharmacological and social aspects, pp. 75-95.Springer, Dordrecht, the Netherlands (Wageningen UR Frontis Series 17).

SHUKLA, S. AND GARDNER, J. 2006. Local knowledge in community based approaches to medicinal plant conservation: lessons from India. *Journal of Ethnobiology and Ethnomedicine* **2: 20-24.**

SMITH, R.J., GOODMAN, P.S. AND MATTHEWS, W. 2006. Systematic conservation planning: a review of perceived limitations and an illustration of the benefits, using a case study from Maputaland, South Africa. *Oryx* **40: 400–410.**

STEWART, K. 2009. Effects of bark harvest and other human activities on populations of the African cherry (Prunus africana) on Mount Oku, Cameroon. *Forest Ecology and Management* **258:1121-1128.**

THOMPSON, J.D., MATHEVET, R., DELANOE, O., GIL-FOURIE, C., BONNIN, M. AND CHEYLAN, M. 2011. Ecological solidarity as a conceptual tool for rethinking ecological and social interdependence in conservation policy for protected areas and their surrounding landscape. *Comptes Rendus Biologiques* **334: 412-419.**

TSHISIKHAWE, MP. 2002. Trade of indigenous medicinal plants in the Northern Province, Venda region: their ethnobotanical importance and sustainable use. M.Sc dissertation, University of Venda for Science and Technology, Thohoyandou, South Africa.

TSHISIKHAWE, M.P. 2005. Synthesis on medicinal plants of the Soutpansberg region.http://www.soutpansberg.com/workshop/synthesis/medicinalplants.htm

UNESCO. 2009. 22 new biosphere reserves selected by UNESCO. http://www.unesco.org

VERLINDEN, A. AND DAYOT, B. 2005. A comparison between indigenous environmental knowledge and a conventional vegetation analysis in north central Namibia. *Journal of Arid Environments* **62: 143-175.**

VERMEULEN, S.J. 1996. Cutting trees by local residents in a communal area and an adjacent state forest in Zimbabwe. *Forest Ecology and Management* **81: 101-111.**

VERMEULEN, W.J. 2006. Sustainable harvesting for medicinal use: matching species to prescriptions. In: J.J. BESTER, A.H.W. SEYDACK, T. VOSTER, I.J. VAN DER MERWE AND S. DZIVHANI (Eds) Multiple use management of natural forests and woodlands: policy refinements and scientific progress: Symposium on Natural forests and Savanna Woodlands, Symposium IV. http://www2.dwaf.gov.za/webapp/resourcecentre/Documents/ Reports/4259_Day1_session3_item4.pdf

VERMEULEN, W.J. AND GELDENHUYS, C.J. 2004. Experimental protocols and lessons learnt from strip harvesting of bark for medicinal use in the southern Cape forests. DIFID, UK.

WAINWRIGHT, W. AND WEHRMEYER, W. 1998.Success in integrating conservation and development? A study from Zambia. *World Development* **26: 933-944.**

WEST, P. AND BROCKINGTON, D. 2006. An anthropological perspective on some unexpected consequences of protected areas. *Conservation Biology* **20: 609–616.**

WIERSUM, K.F., DOLD, A.P., HUSSELMAN, M. AND COCKS, M. 2006.

Cultivation of medicinal plants as a tool for biodiversity conservation and poverty alleviation in the Amatola region, South Africa. In: BOGERS, R.J., CRAKER, L.E., LANGE, D. (eds). Medicinal and aromatic plants, agricultural, commercial, ecological, legal, pharmacological and social aspects, pp. 43-57.Springer, Dordrecht, the Netherlands (Wageningen UR Frontis Series 17).

ZAFRA-CALVO, N., CERRO, R., FULLER, T., LOBO, J.M., RODRIGUEZ, M.A. AND SARKAR, S. 2010. Prioritizing areas for conservation and vegetation restoration in post-agricultural landscapes: A biosphere reserve plan for Bioko, Equatorial Guinea. *Biological Conservation* **143: 787-794.**

ZSCHOCKE, S., DREWES, S.E., PAULUS, K., BAUER, R. AND VAN STADEN, J. 2000a. Analytical and pharmacological investigation of *Ocotea bullata* (black stinkwood) bark and leaves. *Journal of Ethnopharmacology* **71: 219–230.**

ZSCHOCKE, S., RABE, T., TAYLOR, J.L.S., JÄGER, A.K. AND VAN STADEN, J. 2000b.Plant part substitution – a way to conserve endangered medicinal plants? *Journal of Ethnopharmacology* **71: 281–292.**

CHAPTER 9

REFERENCES

ABENSPERG-TRAUN, M. 2009.*CITES,* sustainable use of wild species and incentive-driven conservation in developing countries, with an emphasis on southern Africa. *Biological Conservation* **142: 948-963.**

ACOCKS, J.P.H. 1953. Veld Types of South Africa. *Memoirs of the Botanical Survey of South Africa* **28: 1-192.**

ACOCKS, J.P.H. 1988. Veld Types of South Africa. 3rd edition. *Memoirs of the Botanical survey of South Africa*. No. 57.

ANGASSA, A. AND OBA, G. 2010. Effects of grazing pressure, age of enclosures and seasonality on bush cover dynamics and vegetation composition in southern Ethiopia. *Journal of Arid Environments* **74: 111-120.**

ANTOCI, A., BORGHESI, S. AND RUSSU, P. 2005.Biodiversity and economic growth: Trade-offs between stabilization of the ecological system and preservation of natural dynamics. *Ecological Modelling* **189: 333-346.**

ARONSON, J., MILTON, S.J., BLIGNAUT, J.N. AND CLEWELL, A.F. 2006. Nature Conservation as if people mattered. *Journal for Nature Conservation* **14: 260-263.**

BEISINGER, S.R. AND MCCULLOUGH, D.R. 2002. Population viability analysis. The University of Chicago Press, Chicago, USA.

BERGER, K., CRAFFORD, J.E., GAIGHER, I., GAIGHER, M.J., HAHN, N. AND MACDONALD, I. 2003. A first synthesis of the environmental, biological and cultural assets of the Soutpansberg. Leach printers, Louis Trichardt, South Africa.

BERLINER, D. 2005. Systematic conservation planning for the forest biome of South Africa. Approach, methods and results of the selection of priority forests for conservation action, Water and Forestry Support Programme, Department of Water Affairs and Forestry, Pretoria.

BESSONG, P.O., OBI, C.L., ANDREOLA, M.L., ROJAS, L.B., POUSEGU, L., IGUMBOR, E., MEYER, J.J.M., QUIDEAU, S. AND LITVAK, S. 2005. Evaluation of selected South African medicinal plants for inhibitory properties against human immunodeficiency virus type 1 reverse transcriptase and integrase. *Journal of Ethnopharmacology* **99: 83-91.**

BESSONG, P.O., ROJAS, L.B., OBI, L.C., TSHISIKHAWE, P.M. AND IGUMBOR, E.O. 2006. Further screening of Venda medicinal plants for activity against HIV type 1 reverse transcriptase and integrase. *African Journal of Biotechnology* **5: 526-528.**

BHATTARAI, S., CHAUDHARY, R.P., QUAVE, C.L. AND TAYLOR, R.S.I. 2010.The use of medicinal plants in the trans-Himalayan arid zone of Mustang District, Nepal. *Journal of Ethnobiology and Ethnomedicine* **6: 14-24.**

BODEKER, G.C. 1995. Introduction: Medicinal plants for Conservation and Healthcare. Institute of Health Sciences, University of Oxford, Oxford.

BOON, R. 2010. Pooley's trees of eastern South Africa: A complete guide. Flora and Fauna Publications Trust, Durban, South Africa.

BOTHA, J., WITKOWSKI, E.T.F. AND SHACKLETON, C.M. 2001. An inventory of medicinal plants traded on the western boundary of the Kruger National Park. *Koedoe* **44: 7 – 46.**

BOTHA, J., WITKOWSKI, E.T.F. AND SHACKLETON, C.M. 2004a. Market profiles and trade in medicinal plants in the Lowveld, South Africa. *Environmental Conservation* **31: 38-46**.

BOTHA, J., WITKOWSKI, E.T.F. AND SHACKLETON, C.M. 2004b. The impact of commercial harvesting on *Warburgia salutaris* ('pepper-bark tree') in Mpumalanga, South Africa. *Biodiversity and Conservation* **13: 1675–1698.**

BOTHA, J., WITKOWSKI, E.T.F. AND SHACKLETON, C.M. 2007. Factors influencing prices of medicinal plants traded in the Lowveld, South Africa *International Journal of Sustainable Development and World Ecology* **14: 450-469.**

BOUDREAU, S., LAWES, M.J., PIPER, S.E. AND PHADIMA, L.J. 2005. Subsistence harvesting of pole-size understorey species from Ongoye Forest Reserve, South Africa: Species preference, harvest intensity, and social correlates. *Forest Ecology and Management***216: 149-165.**

BROOKS, T.M., MITTELMEIER, R.A., MITTELMEIER, C.G., DA FONSECA, G.A.B., RYLANDS, A.B., CONSTANT, W.R., FLICK, P., PILGRIM, J., OLDFIELD, S., MAGIN, G. AND HILTON-TAYLOR, C. 2002. Habitat loss and extinction in hotspots of biodiversity. *Conservation Biology***16:** 909-923.

BUCKING, W. 2003. Are there threshold numbers for protected forests? *Journal of Environmental Management* **67: 37-45.**

BUENZ, E.J. 2005. Country development does not presuppose the loss of forest resources for traditional medicine use. *Journal of Ethnopharmacology* **100: 118-123.**

BURGMAN, M.A., POSSINGHAM, H.P., LYNCH, J.J., KEITH, D.A., McCARTHY, M.A., HOPPER, S.D., DRURY, W.L., PASIOURA, J.A. AND

DEVRIES, R.J. 2001. A method for setting the size of plant conservation target areas. *Conservation Biology* **15: 603-616.**

CABEZA, M. AND VAN TEEFFELEN, A.J.A. 2009. Strategies of reserve selection. Encyclopedia of Life Sciences. John Wiley & Sons, Chichester. DOI: 10.1002/9780470015902.a0021224.

CASWELL, H. 2001. Matrix population models: Construction, Analysis and Interpretation. 2nd edition. Sinauer Associates, Inc. Publishers, Massachusetts, USA.

CHASE, J.M., LEIBOLD, M.A., DOWNING, A.L. AND SHURIN, J.B. 2000. The effects of productivity, herbivory, and plant species turnover in grassland and food webs. *Ecology* **81: 2485-2497.**

CONDIT, R., SUKUMAR, R., HUBBEL, S. AND FOSTER, R. 1998. Predicting population trends from size distributions: a direct test in a tropical tree community. *American Naturalist* **152: 495-509.**

COWLING, R.M., PRESSEY, R.L., ROUGET, M. AND LOMBARD, A.T. 2003.A conservation plan for a global biodiversity hotspot – the Cape Floristic Region, South Africa. *Biological Conservation* **112: 191−216.**

COWLING, R.M., RICHARDSON, D.M. AND PIERCE, S.M. 1997.Vegetation of Southern Africa. Cambridge University Press, Cambridge, United Kingdom.

CRONE, E.E., MENGES, E.S., ELLIS, M.M., BIERZYCHUDEK, P., EHRLEN, J., KAYE, T.N, KNIGHT, T.M. LESICA, P., MORRIS, W.F., OOSTERMEIJER, G., QUINTANA-ASCENCIO, P.F., STANLEY, A., TICKTIN, T., VALVERDE, T. AND WILLIAMS, J.L. 2011. How do plant ecologists use matrix population models? *Ecology Letters* **14: 1–8.**

CUNNINGHAM, A.B. 1993. African medicinal plants: Setting priorities at the interface between conservation and primary healthcare. UNESCO, Paris.

CUNNINGHAM, A.B. 2001. Applied ethnobotany: people, wild plant use and conservation. Earthscan Publication, London.

CUNNINGHAM, A.B. AND MBENKUM, F.T. 1993. Sustainability of harvesting *Prunus africana* bark in Cameroon. People and Plants Working Paper, 2. UNESCO, Paris, France.

DE KROON, H., VAN GROENENDAEL, J. AND EHRLEN, J. 2000. Elasticities: A review of methods and model limitations. *Ecology* **81: 607-618.**

DE LANGE, H.J., SALA, S., VIGHI, M. AND FABER, J.H. 2010.Ecological vulnerability in risk assessment – A review and perspectives. *Science of the Total Environment* **408: 3871-3879.**

DELVAUX, C., SINSIN, B., AND VAN DAMME, P. 2010. Impact of season, stem diameter and intensity of debarking on survival and bark re-growth pattern of medicinal tree species, Benin, West Africa. *Biological Conservation* **143: 2664-2671.**

DELVAUX, C., SINSIN, B., DARCHAMBEAU, F. AND VAN DAMME, P. 2009. Recovery from bark harvesting of 12 medicinal tree species in Benin, West Africa. *Journal of Applied Ecology* **46:703-712.**

DENGLER, J. 2009. A flexible multi-scale approach for standardised recording of plant species richness patterns. *Ecological Indicators* **9: 1169-1178.**

DERNBACH, J. 2001. From Rio to Johannesburg, Implementing Sustainable Development at the Global and Local Scale. Pp. 46-50. In: Recommendations for Achieving Sustainable Communities, Science and Solutions. Report from the second National Conference on Science, Policy and Environment. National

Council for Science and the Environment. Smithsonian National Museum of Natural History, Washington, DC.

DESMET, P.G., COWLING, R.M., ELLIS, A.G. AND PRESSEY, R.L. 2002. Integrating biosystematics data into conservation planning: Perspectives from Southern Africa's Succulent Karoo. *Systematic Biology* **51: 317–330.**

DESMET, P.G., SHACKLETON, C.M. AND ROBINSON, E.R. 1996. The population dynamics and life-history attributes of a *Pterocarpus angolensis* DC. population in the Northern Province, South Africa. *South African Journal of Botany* **62:160-166.**

DIEDERICHS, N., GELDENHUYS, C. AND MITCHELL, D. 2002. The first legal harvesters of protected medicinal plants in South Africa. *Science in Africa: Africa's first on-line science magazine*. November 2002.

DLADLA, S. 2001. Muthi Trade Boom: Unemployment finds refuge in traditional world. *Sunday World,* South Africa. p.19.

DOBBERTIN, M. AND BRANG, P. 2001. Crown defoliation improves tree mortality models. *Forest Ecology and Management* **141: 271-284.**

DOLD, A.P. AND COCKS, M.L. 2002. The trade in medicinal plants in the Eastern Cape Province, South Africa. *South African Journal of Science* **98:589-597.**

DREWES, S.E., CROUCH, N.R., MASHIMBYE, M.J., DE LEEUW, B.M. AND HORN, M.M. 2001. A phytochemical basis for the potential use of *Warburgia salutaris* (pepper-bark tree) leaves in the place of bark. *South African Journal of Science* **97: 383–386.**

DREWES, S.E., MASHIMBYE, M.J., FIELD, J.S. AND RAMESAR, N. 1991. 11, 11-dimethyl-1,3,8,10-tetrahydroxy-9-methoxypeltogynan and three pentacyclictriterpenes from *Cassine transvaalense. Phytochemistry* **30: 3490-3493.**

DRIVER, A., COWLING, R.M. AND MAZE, K.E. 2003.Planning for living landscapes: Perspectives and lessons from South Africa. Botanical Society of South Africa, Cape Town.

DZEREFOS, C.M. AND WITKOWSKI, E.T.F. 2001. Density and potential utilization of medicinal grassland plants from Abe Bailey Nature Reserve, South Africa. *Biodiversity and Conservation* **10: 1875-1896.**

EBERT, T.A. 1999. Plant and animal populations: methods in demography. Academic Press, San Diego.

EELEY, H.A.C., LAWES, M.J. AND REYERS, B. 2001. Priority areas for the conservation of subtropical indigenous forest in southern Africa: a case study from Kwazulu-Natal. *Biodiversity and Conservation* **10: 1221-1246.**

EMANUEL, P.L., SHACKLETON, C.M. AND BAXTER, J.S. 2005. Modelling the sustainable harvest of *Sclerocarya birrea* subsp. *caffra* fruits in the South African lowveld. *Forest Ecology and Management* **214: 91-103.**

ETNIER, M.A. 2007. Defining and identifying sustainable harvests of resources: Archeological examples of pinniped harvests in the eastern North Pacific. *Journal for Nature conservation* **15: 196-207.**

EVERARD, D.A., MIDGLEY, J.J. AND VAN WYK, G.F. 1995. Dynamics of some forests in KwaZulu-Natal, South Africa, based on ordinations and size class distributions. *South African Journal of Botany* **61: 283-292.**

EVERARD, D.A., VAN WYK, G.F. AND MIDGLEY, J. J. 1994. Disturbance and the diversity of forests in Natal, South Africa: lessons for their utilisation. *Strelitzia* **1: 275-285.**

FABRICIUS, C. 2004. The fundamentals of community-base natural resource management. In Rights, Resources and Rural Development Community-based Natural Resource Management in Southern Africa. Eds. FABRICIUS, C., KOCH, E., MAGOME, H. AND TURNER, S. Earthscan Publishers, USA.

FARNSWORTH, N.R. AND SOEJARTO, D.D. 1991. Global importance of medicinal plants. In: Akerele, O., Heywood, V. & Synge, H. (Eds.) Conservation of medicinal plants, pp. 25-42. Cambridge University Press, Cambridge.

FASOLA, T.R. AND EGUNYOMI, A. 2005. Nigerian usage of bark in phytomedecine. *Ethnobotany Research and Application s***3:73–77.**

FENNELL, C.W., LINDSEY, K.L., McGAW, L.J., SPARG, S.G., STAFFORD, G.I., ELGORASHI, E.E., GRACE, O.M. AND VAN STADEN, J. 2004. Assessing African medicinal plants for efficacy and safety: pharmacological screening and toxicology. *Journal of Ethnopharmacology* **94: 205-217.**

FISHER, A.C. AND KRUTILLA, J.V. 1974. Valuing long run ecological consequences and irreversibilities. *Journal of Environmental Economics and Management***1: 96-108.**

GANESAN, R. AND SIDDAPPA, S.R. 2004. Regeneration of *Amla*, an important non-timber forest product from Southern India. *Conservation and Society* **2: 365-375.**

GAUGRIS, J.Y. AND VAN ROOYEN, M.W. 2007. The structure and harvesting potential of the sand forest in Tshanini Game Reserve, South Africa. *South African Journal of Botany* **73: 611–622.**

GAUGRIS, J.Y. AND VAN ROOYEN, M.W. 2010. Evaluating the adequacy of reserves in the Tembe-Tshanini Complex: a case study in Maputaland, South Africa. *Oryx* **44: 399-410.**

GAUGRIS, J.Y. AND VAN ROOYEN, M.W. 2011. The effect of herbivores and humans on the Sand Forest species of Maputaland, northern KwaZulu-Natal, South Africa. *Ecological Research* **26: 365-376.**

GAUGRIS, J.Y., VAN ROOYEN, M.W. AND BOTHMA, J.P. 2008. Growth rate of selected woody species in the northern Maputaland, KwaZulu-Natal, South Africa. *South African Journal of Botany* **74: 85-92.**

GAUGRIS, J.Y., VASICEK, C.A. AND VAN ROOYEN, M.W. 2007. Selecting tree species for sustainable harvest and calculating their sustainable harvesting quota in Tshanini Conservation Area, Maputaland, South Africa. *Ethnobotany Research and Applications* **5: 373-389.**

GAUTHIER, P., DEBUSSCHE, M. AND THOMPSON, M.D. 2010. Regional priority setting for rare species based on a method combining three criteria. *Biological Conservation* **143: 1501-1509.**

GELDENHUYS, C.J. 2004. Bark harvesting for traditional medicine: from illegal resource degradation to participatory management. *Scandinavian Journal of Forest research* **19: 103-115.**

GELDENHUYS, C.J. 2004. Meeting the demand for *Ocotea bullata* bark: implications for the conservation of high value and medicinal tree species. In: Indigenous forests and woodlands in South Africa – Policy, People and Practice. Eds. LAWES, M.J., EELEY, H.A.C., SHACKLETON, C.M. AND GEACH. B.G.S. University of Kwazulu-Natal Press, Durban, South Africa: 517-550.

GELDENHUYS, C.J., SYAMPUNGANI, S., MEKE, G.S. AND VERMEULEN, W.J. 2007. Response of different species to bark harvesting for traditional medicine in Southern Africa. In J.J. Bester, A.H.W. Seydack, T. Vorster, I.J. Van der Merwe AND S. Dzivhani (eds). Multiple Use Management of Natural Forests and Woodlands: Policy Refinement and Scientific Progress. pp. 55–62. Department of Water Affairs and Forestry, Pretoria, South Africa.

GEYID, A., ABEBE, D., DEBELLA, A., MAKONNEN, Z., ABERRA, F., TEKA, F., KEBEDE, T., URGA, K., YERSAW, K., BIZA, T., MARIAM, B.H. AND GUTA, M. 2005.Screening of some medicinal plants of Ethiopia for their anti-microbial properties and chemical profiles. *Journal of Ethnopharmacology* **97: 421-427.**

GHIMIRE, S.K., McKEY, D. AND AUMEERUDDY-THOMAS, Y. 2005. Conservation of Himalayan medicinal plants: Harvesting patterns and ecology of two threatened species, *Nardostachys grandiflora* DC and *Neopicrorhiza scrophulariiflora* (Pennell) Hong. *Biological Conservation* **124: 463-475.**

GHIMIRE, S.K., GIMENEZ, O., PRADEL, R., MCKEY, D. AND AUMEERUDDY-THOMAS, Y. 2008. Demographic variation and population viability in a threatened Himalayan medicinal and aromatic herb Nardostachys grandiflora: matrix modelling of harvesting effects in two contrasting habitats. *Journal of Applied Ecology* **45: 41–51.**

GIHO, H. AND SENO, H. 1997. Transition matrix modelling on disturbance-controlled persistence of plant population. *Ecological Modelling* **94: 207-219.**

GOODLAND, R. 1995. The concept of environmental sustainability. *Annual Review of Ecology and Systematics* **26:1-24.**

GUEDJE, N.M., ZUIDEMA, P.A., DURING, H., FOAHOM, B. AND LEJOLY, J. 2007. Tree bark as a non-timber forest product: The effect of bark collection on population structure and dynamics of *Garcinia lucida* Vesque. *Forest Ecology and Management* **240: 1-12.**

GURIB-FAKIM, A. 2006. Medicinal Plants: Traditions of yesterday and drugs of tomorrow. *Molecular Aspects of Medicines* **27: 1-93.**

HAHN, N. Undated. Tree list of the Soutpansberg. Fantique Publishers, Pretoria.

HAMILTON, A. 2003. Medicinal plants and conservation: issues and approaches. Paper presented to International Plants Conservation Unit, World Wide Wildlife Foundation, UK.

HARROP, S.R. AND PRITCHARD, D.J. 2011. A hard instrument goes soft: The implications of the Convention on Biological Diversity's current trajectory. *Global Environmental Change* **21: 474-480.**

HARTSHORN, G.S. 1995. Ecological basis for sustainable development in Tropical forests. *Annual Review of Ecology and Systematics* **26: 155-175.**

HESS, G.R. AND FISCHER, R.A. 2001. Communicating clearly about conservation corridors. *Landscape and Urban Planning* **55: 195-208.**

HEYWOOD, V.H. AND IRIONDO, J.M. 2003. Plant Conservation: old problems, new perspectives. *Biological Conservation* **113: 321-335.**

HILL, D.A., FASHAM, M., TUCKER, G., SHEWRY, M. AND SHAW, P. 2005. Handbook of biodiversity methods: survey, evaluation and monitoring. Cambridge University Press, Cambridge.

HOSTETTMANN, K., MARSTON, A., NDJOKO, K. AND WOLLFENDER, J. 2000. The potential of African plants as a source of drugs. *Current Organic Chemistry* **4: 973-1010.**

HOWELL, J. AND MESHER, K. 1997. Taking care of each other: The relationship between the *Labrador metis* and the environment. Workshop on traditional and western scientific environmental knowledge. Northwest River, Labrador. September 10-11.

HUTCHING, A. 1996. Zulu Medicinal Plants: An Inventory. University of Natal Press, Pietermaritzburg, South Africa.

IUCN 2001. Analytic framework for assessing factors that influence sustainability of uses of wild living natural resources. Technical Advisory Committee. IUCN SSC Sustainable Use Specialist Group, Washington D.C. USA.

IUCN/UNEP/WWF. 1980. World Conservation Strategy: Living resource conservation for sustainable development. International Union for the Conservation of Nature, Gland.

JACKSON, P.W. AND KENNEDY, K. 2009. The Global Strategy for Plant Conservation: a challenge and opportunity for the international community. *Trends in Plant Science* **14: 578-580.**

JAGER, A.K. 2005. Is traditional medicine better off 25 years later? *Journal of Ethnopharmacology* **100: 3-4.**

JENSEN, A.L. 1995. Simple density-dependent matrix model for population projection. *Ecological Modelling* **77: 43-48.**

JOHANNES, R.E. 2002. Did indigenous conservation ethics exist? *SPC Traditional Marine Resource Management and Knowledge Information Bulletin* **14: 3-7.**

JORDAAN, S.P. AND JORDAAN, A. 1987. The Republic of Venda: The insight series. De Jager-HAUM Publishers. Pretoria, South Africa.

KALE, R. 1995. Traditional healers in South Africa: a parallel health care system. *BMJ,* **310.**

KEIRUNGI, J. AND FABRICIUS, C. 2005. Selecting medicinal plants for cultivation at Nqabara on the Eastern Cape Wild Coast, South Africa. *South African Journal of Science* **101: 497-501.**

KENNEDY, D. 2001. Sustainability: Problems, science and solutions. Pp. 35-39 in Recommendations for Achieving Sustainable Communities, Science and Solutions. Report from the second National Conference on Science, Policy and Environment. National Council for Science and the Environment. Smithsonian National Museum of Natural History, Washington, DC.

KOHIRA, M. AND NINOMIYA, I. 2003. Detecting tree populations at risk for forest conservation management: using single-year vs. long-term inventory data. *Forest Ecology and Management* **174: 423-435.**

KROG, M., FALCAO, M.P. AND OLSEN, C.S. 2006. Medicinal plant markets and trade in Maputo, Mozambique. *Forest and Landscape* Working Papers no. 16-2006. Danish Centre for Forest, Landscape and Planning, KVL., Denmark.

KUNIYAL, J.C. 2002. Mountain expedition: minimizing the impact. *Environmental Impact Assessment Review* **22: 561-581.**

KUROKAWA, H., YISHIDA, T., NAKAMURA, T., LAI, J. AND NAKASHIZUKA, T. 2003. The age of tropical rain-forest canopy species, Borneo ironwood *(Eusideroxylon zwageri)*, determined by ^{14}C dating. *Journal of Tropical Ecology* **19: 1-7.**

LAURANCE, W.F. 1999. Reflections on the tropical deforestation crisis. *Biological Conservation* **91:109-117.**

LAURANCE, W.F., GOOSEM, M. AND LAURANCE, S.G.W. 2009. Impacts of roads and linear clearings on tropical forests. *Trends in Ecology and Evolution* **24: 659-669.**

LAWES, M.J. AND OBIRI, J.A.F. 2003. Using the spatial grain of regeneration to select harvestable tree species in subtropical forest. *Forest Ecology and Management* **184: 105-114.**

LAWES, M.J., EELEY, H.A.C., SHACKLETON, C.M. AND GEACH, B.G.S. 2004. Indigenous forests and woodlands in South Africa: Policy, People and Practice. University of KwaZulu-Natal Press. Pietermaritzburg, South Africa.

LEBRETON, J.D. 2005. Age, stages, and the role of generation time in matrix models. *Ecological Modelling* **188: 22-29.**

LETSELA, T., WITKOWSKI, E.T.F. AND BALKWILL, K. 2002. Direct use values of communal resources in Bokong and Tsehlanyane in Lesotho: Whither the commons: *The International Journal of Sustainable Development and World Ecology* **9: 351–68.**

LEVITS, E. 1992. Traditional medicine - friend or foe? *Publico* **92.**

LEWINGTON, A. 1993. Medicinal plants and plants extracts: a review of their importation into Europe. *TRAFFIC International*.

LIENERT, J. 2004. Habitat fragmentation effects on fitness of plant populations – a review. *Journal for Nature Conservation***12: 53-72.**

LIM, M.K., SADARANGANI, P., CHAN, H.L. AND HENG, J.Y. 2005. Complementary and alternative medicine use in multiracial Singapore. *Complimentary Therapies in Medicine* **13: 16-24.**

LINDENMAYER, D.B., FRANKLIN, J.F. AND FISCHER, J. 2006. General management principles and a checklist of strategies to guide forest biodiversity conservation. *Biological Conservation* **131: 433–441.**

LINK, W.A. AND DOHERTY, P.F. 2002. Scaling in sensitivity analysis. *Ecology* **83: 3299-3305.**

LOIBEL, S., DO VAL, J.B.R. AND ANDRADE, M.G. 2006. Inference for the Richards growth model using Box and Cox transformation and bootstrap techniques. *Ecological Modelling* **191: 501-512.**

LOMBARD, A.T., COWLING, R.M., PRESSEY, R.L. AND REBELO, A.G. 2003. Effectiveness of land classes as surrogates for species in conservation planning for the Cape Floristic Region. *Biological Conservation* **112: 45-62.**

LORTON COMMUNICATIONS. Venda: Land of Legend. Undated. Creda Press.

LOUETTE, G., ADRIAENS, D., ADRIAENS, P., ANSELIN, A., DEVOS, K., SANNEN, K., VAN LANDUYT, W., PAELINCKX, D. AND HOFFMANN, M. 2011. Bridging the gap between the Natura 2000 regional conservation status and local conservation objectives. *Journal for Nature Conservation* **19: 224-235.**

LOUHAICHI, M., SALKINI, A.K., ESTITA, H.E. AND BELKHIR, S. 2011. Initial assessment of medicinal plants across the Libyan Mediterranean coast. *Advances in Environmental Biology* **5: 359-370.**

LOW, A.B. AND REBELO, A.G. 1996. Vegetation of South Africa, Lesotho and Swaziland. A companion of the vegetation map of South Africa, Lesotho and Swaziland. Department of Environmental Affairs and Tourism. Pretoria, South Africa.

LOZANO, F.D. AND SCHWARTZ, M.W. 2005. Patterns of rarity and taxonomic group size in plants. *Biological Conservation* **126: 146-154.**

LYKKE, A.M., 1998. Assessment of species composition change in savanna vegetation by means of woody plants' size class distributions and local information. *Biodiversity and Conservation* **7: 1261-1275.**

MABOGO, D.E.N. 1990. The ethnobotany of the Vhavenda. Master of science thesis. University of Pretoria, Pretoria, South Africa.

MAKOE, A. 1994. Muthi trade – affordable health care for our people. On track *Summer* **12-14.**

MANNHEIMER, C. AND CURTIS, B. 2009. Le Roux and Mueller's field guide to the trees and shrubs of Namibia. MacMillan Education Namibia, Windhoek.

MARON, J.L. AND CRONE, E. 2006. Herbivory: effects on plant abundance, distribution and population growth. *Proceedings of The Royal Botanical Society* **273: 2575-2584.**

MARSCHKE, M. AND BERKES, F. 2005. Local level sustainability planning for livelihoods: A Cambodian experience. *International Journal of Sustainable Development and World Ecology* **12: 21-33.**

McCHESNEY, J.D., VENKATARAMAN, S.K. AND HENRI, J.T. 2007. Plant natural products: Back to the future or into extinction? *Phytochemistry* **68:2015-2022.**

McGEOCH, L., GORDON, I. AND SCHMITT, J. 2008. Impacts of land use, anthropogenic disturbance, and harvesting on an African medicinal liana. *Biological Conservation* **141: 2218-2229.**

MIAO, H., CHEN, S., CHEN, J., ZHANG, W., ZHANG, P., WEI, L., HAN, X. AND LIN, G. 2009. Cultivation and grazing altered evapotranspiration and dynamics in Inner Mongolia steppes. *Agricultural and Forest Metereology* **149: 1810-1819.**

MIDGLEY, G.F. AND THUILLER, W. 2007. Potential vulnerability of Namaqualand plant diversity to anthropogenic climate change. *Journal of Arid Environments* **70: 615-628.**

MIDGLEY, J., SEYDACK, A., REYNELL, D. AND MCKELLY, D. 1990. Fine-grain pattern in southern Cape plateau forests. *Journal of Vegetation Science* **1: 539-546.**

MOLLER, M., SUSCHKE, U., NOLKEMPER, S., SCHNEELE, J., DISTL, M., SPORER, F., REICHLING, J. AND WINK, M. 2006. Antibacterial, antiviral, antiproliferative and apoptosis-inducing properties of *Brackenridgea zanguebarica* (Ochnaceae). *Journal of Pharmacy and Pharmacology* **58: 1131-1138.**

MORRIS, W.F. AND DOAK, D.F. 2002. Quantitative conservation biology: theory and practice of population viability analysis. Sinauer Associates, Sunderland, Massachusetts.

MOYO, M., BAIRU, M.W., AMOO, S.O., VAN STADEN, J. 2011. Plant biotechnology in South Africa: Micropropagation research endeavours, prospects and challenges. *South African Journal of Botany* **77: 996-1011.**

MUCINA, L. AND RUTHERFORD, M.C. (eds). 2006. The vegetation of South Africa, Lesotho and Swaziland. *Strelitzia 19.* South African National Biodiversity Institute, Pretoria.

MUCINA, L., RUTHERFORD, M.C. AND POWRIE, L.W. (Eds.) 2005. Vegetation map of South Africa, Lesotho and Swaziland, 1 : 1 000 000 scale sheet maps. South African National Biodiversity Institute, Pretoria.

MULAUDZI, R.B., NDHALA, A.R., KULKARNI, M.G., FINNIE, J.F. AND VAN STADEN, J. 2011. Antimicrobial properties and phenolic contents of medicinal plants used by the Venda people for conditions related to venereal diseases. *Journal of Ethnopharmacology* **135:330-337.**

MURTHY, I.K., MURALI, K.S., HEGDE, G.T., BHAT, P.R. AND RAVINDRANATH, N.H. 2002. A comparative analysis of regeneration in natural forests and joint forest management plantations in Uttara Kannada district, Western Ghats. *Current Science* **83: 1358-1364.**

NAMAALWA, J., EID, T. AND SANKHAYAN, P. 2005. A multi-species density-dependent matrix growth model for the dry woodlands of Uganda. *Forest Ecology and Management* **213: 312-327.**

NANTEL, P., BOUCHARD, A., BROUILLET, L. AND HAY, S. 1998. Selection of areas for protecting rare plants with integration of land use conflicts: A case study for the west coast of Newfoundland, Canada. *Biological Conservation* **84: 223-234.**

NAUGHTON-TREVES, L., KAMMEN, D.M. AND CHAPMAN, C. 2007. Burning biodiversity: woody biomass use by commercial and subsistence groups in western Uganda's forests. *Biological Conservation* **134: 232-241.**

NDANGALASI, H.J., BITARIHO, R. AND DOVIE, D.B.K. 2007. Harvesting of non-timber forest products and implications for conservation in two montane forests of East Africa. *Biological Conservation* **134: 242-250.**

NEKE, K.S., OWEN-SMITH, N. AND WITKOWSKI, E.T.F. 2006. Comparative resprouting response of Savanna woody plant species following harvesting: the value of persistence. *Forest Ecology and Management* **232: 114-123.**

NETSHILUVHI, T.R. 1999. Demand, propagation and seedling establishment of selected medicinal trees. *South African Journal of Botany* **65: 331-338.**

NETSHIUNGANI, E.N. AND VAN WYK, A.E. 1980. Mutavhatsindi – mysterious plant from Venda. *Veld and Flora* **66: 87-89.**

NEWTON, D. 1997. Flora and fauna in the Medicine Cupboard. *Endangered Wildlife* **26.**

NEWTON, D.J. AND VAUGHAN, H. 1996. South Africa's *Aloe ferox* plant, parts and derivatives industry. TRAFFIC East/Southern Africa Publishers. Johannesburg, South Africa.

NIKLAS, K.J., MIDGLEY, J.J. AND RAND, R.H. 2003a. Size-dependent species richness: trends within plant communities and across latitude. *Ecology Letters* **6: 631-636.**

NIKLAS, K.J., MIDGLEY, J.J. AND RAND, R.H. 2003b. Tree size frequency distributions, plant density, age and community disturbance. *Ecology Letters* **6: 405-411.**

NJOROGE, G.N., KAIBUI, I.M., NJENGA, P.K. AND ODHIAMBO, P.O. 2010. Utilization of priority medicinal plants and local people's knowledge on their conservation status in arid lands of Kenya (Muringi District). *Journal of Ethnobiology and Ethnomedicine* **6: 22-29**.

NORRIS, K. AND MCCULLOCH, N. 2003. Demographic models and the management of endangered species: a case study of the critically endangered Seychelle magpie robin. *Journal of Applied Ecology* **40: 890-899.**

NYIKA, A. 2009. The ethics of improving African traditional medical practice: Scientific or African traditional research methods? *Acta Tropica* **112s: s32-s36.**

OATES, J.F. 1999. Myth and Reality in the Rainforest - How Conservation Strategies are Failing in West Africa. University of California Press, Berkeley.

OBIRI, J., LAWES, M. AND MUKOLWE, M. 2002. The dynamics and sustainable use of high-value tree species of the coastal Pondoland forests of the Eastern Cape Province, South Africa. *Forest Ecology and Management* **166: 131-148.**

OLI, M.K. 2003. Partial life-cycle models: how good are they? *Ecological Modelling* **169: 313-325.**

OSHO, J.S.A. 1996. Modelling the tree population dynamics of the most abundant species in a Nigerian tropical rain forest. *Ecological Modelling* **89: 175-181.**

PALGRAVE, K.C. 1988. Trees of Southern Africa. 4th edition. Struik Publishers. Cape Town, South Africa.

PARASKEVA, M.A. 2008. A phytochemical and pharmacological study of ten *Commiphora* species indigenous to South Africa. PhD thesis, University of Witwatersrand, Johannesburg.

PELLETIER, J.D. 2000. Model assessment of the optimal design of nature reserves for maximizing species longevity. *Journal of Theoretical Biology* **202: 25-32.**

PERRYMAN, BL. AND OLSEN, R.A. 2000. Age-stem diameter relationships of big sagebrush and their management implications. *Journal of Range Management* **53: 342-346.**

PETERS, C.M. 1996. *The Ecology and Management of Non-Timber Forest Resources*. World Bank Technical Paper No. 332. Washington, D.C., U.S.A.

PFAB, M.F. AND SCHOLES, M.A. 2004. Is the collection of *Aloe peglerae* from the wild sustainable? An evaluation using stochastic population modeling. *Biological Conservation* **118: 695-701.**

PFAB, M.F. AND WITKOWSKI, E.T.F. 2000. A simple population viability analysis of the critically endangered *Euphorbia clivicola* R.A. Dyer under four management scenarios. *Biological Conservation* **96: 263-270.**

PHILLIPS, E.A. 1959. Methods of vegetation study. Holt, Rinehart and Winston. New York, USA.

POIANI, K.A., RICHTER, B.D., ANDERSON, M.G. AND RICHTER, H. 2000. Biodiversity conservation at multiple scales: functional sites, landscapes and networks. *BioScience* **50: 133-146.**

PORTE, A. AND BARTELINK, H.H. 2002. Modelling mixed forest growth: a review of models for forest management. *Ecological Modelling* **150: 141-188.**

PULLIN, A.S., KNIGHT, T.M., STONE, D.A. AND CHARMAN, K. 2004. Do conservation managers use scientific evidence to support their decision-making? *Biological Conservation* **119: 245-252.**

PUPPIM DE OLIVEIRA, J.A., BALABAN, O., DOLL, C.N.H., MORENO-PENARANDA, R., GASPARATOS, A., IOSSIFOVA, D. AND SUWA, A. 2011. Cities and biodiversity: Perspectives and governance challenges for implementing the convention on biological diversity (CBD) at the city level. *Biological Conservation* **144: 1302-1313.**

PYKH, Y.A. AND EFREMOVA, S.S. 2000. Equilibrium, stability and chaotic behavior in Leslie matrix models with different density-dependent birth and survival rates. *Mathematics and Computers in Simulation* **52: 87-112.**

QUINN, G.P. AND KEOUGH, M.J. 2002. Experimental design and data analysis for biologists. Cambridge University Press, Cambridge.

RABE, T. AND VAN STADEN, J. 1997. Antibacterial activity of South African plants used for medicinal purposes. *Journal of Ethnopharmacology* **56: 81-87.**

RAIMONDO, D., VON STADEN, L., FODEN, W., VICTOR, J.E., HELME, N.A., TURNER, R.C., KAMUNDI, D.A. AND MANYAMA, P.A. 2009. Red list of

South African Plants. *Strelitzia* **25.** South African National Biodiversity Institute, Pretoria.

RASKIN, I., RIBNICKY, D.M., KOMARNITSKY, S., ILIC, N., POULEV, A., BORISJUK, N., BRINKER, A., MORENO, D.A., RIPOLL, C., YAKOBY, N., O'NEAL, J.M., CORNWELL, T., PASTOR, I. AND FRIDLENDER, B. 2002. Plants and human health in the twenty-first century. *Trends in biotechnology* **20: 522-531.**

RATES, S.M.K. 2001. Plants as source of drugs. *Toxicon* **39: 603-613.**

RAVENTOS, J., SEGARRA, J. AND ACEVEDO, M.F. 2004. Growth dynamics of tropical savanna grass species using projection matrices. *Ecological Modelling* **174: 85-101.**

ROBINSON, J.G. 1993. The limits to caring: sustainable living and the loss of biodiversity. *Conservation Biology* **7: 20-28.**

RODGERS, H.M., GLEW, L., HONZAK, M. AND HUDSON, M.D. 2010. Prioritizing key biodiversity areas in Madagascar by including data on human pressure and ecosystem services. *Landscape and Urban Planning* **96: 48-56.**

ROKAYA, M.B., MUNZBERGOVA, S. AND TIMSINA, B. 2010. Ethnobotanical study of medicinal plants from the Humla district of western Nepal. *Journal of Ethnopharmacology* **130: 485-504.**

ROUT, G.R., SAMANTARAY, S. AND DAS, P. 2000. *In vitro* manipulation and propagation of medicinal plants. *Biotechnology Advances* **18: 91-120.**

RUTHERFORD, M.C. AND WESTFALL, R.H. 1986. Biomes of Southern Africa. An objective characterisation. *Memoirs of the Botanical Survey of South Africa* **54: 1-98.**

SAIDI, T.A. AND TSHIPALA-RAMATSHIMBILA, T.V. 2006. Ecology and management of a remnant *Brachystegia spiciformis* (miombo) woodland in Northeastern Soutpansberg, Limpopo Province. *South African Geographical Journal* **88: 205-212.**

SALAFSKY, N., MARGOLUIS, R., REDFORD, K.H. AND ROBINSON, J.G. 2002. Improving the practice of conservation: a conceptual framework and research agenda for conservation science. *Conservation Biology* **16: 1469-1479.**

SAMIE, A., OBI, C.L., BESSONG, P.O. AND LALL, N. 2005. Activity profiles of fourteen selected medicinal plants from rural Venda communities in South Africa against fifteen clinical bacterial species. *African Journal of Biotechnology* **4: 1443-1451.**

SANDERSON, E.W., REDFORD, K.H., VEDDER, A., COPPOLILLO, P.B. AND WARD, S.E. 2002. A conceptual model for conservation planning based on landscape species requirements. *Landscape and Urban Planning* **58: 41-56.**

SARKAR, S., PRESSEY, R.L., FAITH, D.P., MARGULES, C.R., FULLER, T., STOMS, D.M., MOFFET, A., WILSON, K.A., WILLIAMS, K.J., WILLIAMS, P.H. AND ANDELMAN, S. 2006. Biodiversity conservation planning tools: present status and challenges for the future. *Annual Reviews of Environment and Resources* **31: 123-159.**

SCHIPPMANN, U., LEAMAN, D. AND CUNNINGHAM, A.B. 2006. A comparison of cultivation and wild collection of medicinal and aromatic plants under sustainability aspects. In: BOGERS, R.J., CRAKER, L.E., LANGE, D. (eds). Medicinal and aromatic plants, agricultural, commercial, ecological, legal, pharmacological and social aspects, pp. 75-95.Springer, Dordrecht, the

Netherlands (Wageningen UR Frontis Series 17).

SCHMIDT, E., LOTTER, M. AND McCLEALAND, W. 2002.Trees and shrubs of Mpumalanga and Kruger National Park. Jacana Publishers, Johannesburg, South Africa.

SCHULZE, M., GROGAN, J., LANDIS, R.M. AND VIDAL, E. 2008. How rare is too rare to harvest? Management challenges posed by timber species occurring at low densities in the Brazilian Amazon. *Forest Ecology and Management* **256: 1443-1457.**

SCHWARTZ, M.W., CARO, T.M. AND BANDA-SAKALA, T. 2002. Assessing the sustainability of harvest of *Pterocarpus angolensis* in Rukwa Region, Tanzania. *Forest Ecology and Management* **170: 259-269.**

SEIGLER, D.S. 2003. Phytochemistry of *Senegalia-sensu lato. Biochemical Systematic and Ecology* **31: 845-873.**

SHAI, L.J., McGAW, L.J. AND ELOFF, J.N. 2009. Extracts of the leaves and twigs of the threatened tree *Curtisia dentata* (Cornaceae) are more active against *Candida albicans* and other microorganisms than the stem bark. *South African Journal of Botany* **75: 363-366.**

SHAUKAT, S.S., AZIZ, S., AHMED, W. & SHAHZAD, A. 2012. Population structure, spatial pattern and reproductive capacity of two semi-desert undershrubs *Senna holosericea* and *Fagonia indica* in Pakistan. Pakistan Journal of Botany **44: 1-9.**

SHUKLA, S. AND GARDNER, J. 2006. Local knowledge in community based approaches to medicinal plant conservation: lessons from India. *Journal of Ethnobiology and Ethnomedicine* **2: 20-24.**

SILVERTOWN, J. AND CHARLESWORTH, D. 2001. Plant population biology. 4th edition. Blackwell Science, Oxford.

SINHA, A. AND BAWA, K.S. 2002. Harvesting techniques, hemiparasites and fruit production in two non-timber forest tree species in South India. *Forest Ecology and Management* **168: 289-300.**

SMITH, R.J., GOODMAN, P.S. AND MATTHEWS, W. 2006. Systematic conservation planning: a review of perceived limitations and an illustration of the benefits, using a case study from Maputaland, South Africa. *Oryx***40: 400–410.**

SOLBRIG, O.T. 1980. Demography and evolution in plant populations. Blackwell Scientific Publishers, California.

SPRINGFIELD, E.P., EAGLES, P.K.F. AND SCOTT, G. 2005. Quality assessment of South African herbal medicines by means of HPLC fingerprinting. *Journal of Ethnopharmacology* **101: 75-83.**

STEENKAMP, V. 2003. Traditional herbal remedies used by South African women for gynaecological complaints. *Journal of Ethnopharmacology* **86: 97-108.**

STEWART, K.M. 2001. The commercial bark harvest of the African cherry (*Prunus africana*) on Mount Oku, Cameroon: effects on traditional uses and population dynamics. PhD thesis. Florida International University.

STEWART, K. 2009. Effects of bark harvest and other human activity on populations of African cherry *(Prunus africana)* on Mount Oku, Cameroon. *Forest Ecology and Management* **258: 1121-1128.**

STOFFBERG, G.H., VAN ROOYEN, M.W., VAN DER LINDE, M.T. AND GROENEVELD, H.T. 2009. Modelling dimensional growth of three street tree species in the urban forest of the City of Tshwane, South Africa. *Southern Forests* **71: 273-277.**

SUAREZ, M.L., RENISON, D., MARCORA, P. AND HENSON, I. 2008. Age-size-habitat relationships for *Polylepis australis*: dealing with endangered forest ecosystems. *Biodiversity & Conservation 17: 2617- 2625*.

SUNDERLAND, T.C.H. AND TAKO, C.T. 1999. The exploitation of *Prunus africana* on the island of Bioko, Equatorial Guinea. A report for People and Plants Initiatives, WWF-Germany and the IUCN/SSC Medicinal Plant Specialist Group.

SVANCARA, L.K., BRANNON, R., SCOTT, J.M., GROVES, C.R., NOSS, R.F. AND PRESSEY, R.L. 2005. Policy-driven versus evidence-based conservation: a review of political targets and biological needs. *BioScience* **55: 989-995.**

TABUTI, J.R.S., DHILLION, S.S. AND LE, K.A. 2003. Traditional medicine in Bulamogi county, Uganda: its practitioners, users and viability. *Journal of Ethnopharmacology* **85: 119-129.**

THOMPSON, J.D., MATHEVET, R., DELANOE, O., GIL-FOURIE, C., BONNIN, M. AND CHEYLAN, M. 2011. Ecological solidarity as a conceptual tool for rethinking ecological and social interdependence in conservation policy for protected areas and their surrounding landscape. *Comptes Rendus Biologies* **334: 412-419.**

TODD, C.B., KHOROMMBI, K., VAN DER WAAL, B.C. AND WEISSER, P.J. 2004. Conservation of woodland biodiversity: A complementary traditional approach and western approach towards protecting *Brackenridgea zanguebarica*. In: Indigenous forests and woodlands in South Africa – Policy, People and Practice. Eds. LAWES, M.J., EELEY, H.A.C., SHACKLETON, C.M. AND GEACH, B.G.S. University of Kwazulu-Natal Press, Durban, South Africa: 737-750.

TSHIKALANGE, T.E., MEYER, J.J.M., LALL, N., MUNOZ, E., SANCHO, R., VAN DE VENTER, M. AND OOSTHUIZEN, V. 2008.*In vitro* anti-HIV-1 properties of ethnobotanically selected South African plants used in the treatment of sexually transmitted diseases. *Journal of Ethnopharmacology* **119:478-481.**

TSHISIKHAWE, M.P. 2002. Trade of indigenous medicinal plants in the Northern Province, Venda region: their ethnobotanical importance and sustainable use. M.Sc. dissertation, University of Venda, Thohoyandou, South Africa.

TSHISIKHAWE, M.P. 2005. Synthesis on medicinal plants of the Soutpansberg region. http://www.soutpansberg.com/workshop/synthesis/medicinal_plants.htm

UNESCO 2009. 22 new biosphere reserves selected by UNESCO. http://www.unesco.org

VAN ANDEL, T. AND HAVINGA, R. 2008. Sustainability of commercial medicinal plant harvesting in Suriname. *Forest Ecology and Management* **256: 1540-1545.**

VAN ECK, H., HAM, C. AND VAN WYK, G. 1997. Survey of indigenous tree uses and preferences in the Eastern Cape Province. *Southern African Forestry Journal* **180: 61-64.**

VAN SETERS, A.P. 1995. Forest based medicines in traditional and cosmopolitan health care. Rainforest Medical Foundation. The Netherlands.

VAN STADEN, J. 2008. Ethnobotany in South Africa. *Journal of Ethnopharmacology* **119: 329-330.**

VAN WYK, A.E. AND SMITH, G.F. 2001. Regions of floristic endemism in southern Africa: A review with emphasis on succulents. Umdaus Press, Pretoria.

VAN WYK, B. AND VAN WYK, P. 1997. Field guide to trees of Southern Africa. Struik Publishers. Cape Town, South Africa.

VAN WYK, B. AND VAN WYK, P. 2009. Field guide to trees of Southern Africa. Struik Publishers, Cape Town, South Africa.

VAN WYK, B.E. AND GERICKE, N. 2000. People's plants. Briza publications, Pretoria, South Africa.

VAN WYK, B.E., VAN OUDTSHOORN, B. AND GERICKE, N. 1997. Medicinal plants of South Africa. Briza Publications, Pretoria, South Africa.

VAN WYK, P. 1996. Field guide to the trees of the Kruger National Park. Struik Publishers, Cape Town, South Africa.

VAN WYK, P. 2008. Field guide to the trees of the Kruger National Park. Struik Publishers, Cape Town, South Africa.

VAN WYK, B., VAN WYK, P. AND VAN WYK B.E. 2008. Photo guide to trees of southern Africa. Briza publications, Pretoria, South Africa.

VENTER, F, AND VENTER, J-A.1996. Making the most of indigenous trees. Briza Publications, Pretoria, South Africa.

VERLINDEN, A. AND DAYOT, B. 2005. A comparison between indigenous environmental knowledge and a conventional vegetation analysis in north central Namibia. *Journal of Arid Environments* **62: 143-175.**

VERMEULEN, S.J. 1996. Cutting trees by local residents in a communal area and an adjacent state forest in Zimbabwe. *Forest Ecology and Management* **81: 101-111.**

VERMEULEN, W.J. 2006. Sustainable harvesting for medicinal use: matching species to prescriptions. In: J.J. BESTER, A.H.W. SEYDACK, T. VOSTER, I.J. VAN DER MERWE AND S. DZIVHANI (Eds) Multiple use management of natural forests and woodlands: policy refinements and scientific progress: Symposium on Natural forests and Savanna Woodlands, Symposium IV. http://www2.dwaf.gov.za/webapp/resourcecentre/Documents/ Reports/4259_Day1_session3_item4.pdf

VERMEULEN, W.J. AND GELDENHUYS, C.J. 2004. Experimental protocols and lessons learnt from strip harvesting of bark for medicinal use in the southern Cape forests. DIFID, UK.

VISCONTI, P., PRESSEY, R.L., SEGAN, D.B. AND WINTLE, B.A. 2010. Conservation planning with dynamic threats: the role of spatial design and priority setting for species' persistence. *Biological Conservation* **143: 756-767.**

VON BREITENBACH, F. 1981. Standard names of trees in southern Africa (Part II). *Journal of Dendrology* **1: 84-94.**

VON MALTITZ, G.P. AND SHACKLETON, S.E. 2004. Use and management of forests and woodlands in South Africa: stakeholders, institutions and processes from past to present. In: Lawes, M.J., Eeley, H.A., Shackleton, C.M. & Geach, B.G. (eds). *Indigenous forests and woodlands in South Africa: policy people and practice*. pp. 109-135. University of KwaZulu-Natal Press, Pietermaritzburg.

WAINWRIGHT, W. AND WEHRMEYER, W. 1998. Success in integrating conservation and development? A study from Zambia. *World Development* **26: 933-944.**

WALTER, H. AND LIETH, H. 1960-1967. Klimadiagramm Weltatlas. G. Fischer Verlag, Jena.

WANG, Y., SOLBERG, S., YU, P., MYKING, T., VOGT, R.D. AND DU, S. 2007. Assessments of tree crown condition of two masson pine forests in the acid rain region in south China. *Forest Ecology and Management* **242: 530-540.**

WATT, J.M. AND BREYER-BRANDWIJK, M.G. 1962. The medicinal and poisonous plants of southern and eastern Africa: Being an account of their medicinal and other uses, chemical composition, pharmacological effects and toxicology in man and animal. 2nd edition.E.and S. Livingstone Publishers. Edinburgh, Scotland.

WEATHER BUREAU. 1998. *Climate of South Africa: Climate statistics up to 1990*. WB 42. Government Printer, Pretoria.

WESSELS, K.J., FREITAG, S. AND VAN JAARSVELD, A.S. 1999. The use of land facets as biodiversity surrogates during reserve selection at a local scale. *Biological Conservation* **89: 21-38.**

WEST, P. AND BROCKINGTON, D. 2006. An anthropological perspective on some unexpected consequences of protected areas. *Conservation Biology* **20: 609–616.**

WIEGAND, K., JELTSCH, F. AND WARD, D. 1999. Analysis of the population dynamics of *Senegalia* trees in the Negev desert, Israel with a spatial-explicit computer simulation model. *Ecological Modelling* **117: 203-224.**

WIERSUM, K.F., DOLD, A.P., HUSSELMAN, M. AND COCKS, M.

2006.Cultivation of medicinal plants as a tool for biodiversity conservation and poverty alleviation in the Amatola region, South Africa. In: BOGERS, R.J., CRAKER, L.E., LANGE, D. (eds). Medicinal and aromatic plants, agricultural, commercial, ecological, legal, pharmacological and social aspects, pp. 43-57.Springer, Dordrecht, the Netherlands (Wageningen UR Frontis Series 17).

WILLIAMS, V.L. 1996. The Witwatersrand muthi trade. *Veld and Flora* **3: 12-14.**

WILLIAMS, V.L., BALKWILL, K. AND WITKOWSKI, E.T.F. 2000. Unraveling the commercial market for medicinal plants and plant parts on the Witwatersrand, South Africa. *Economic Botany* **54: 310-327.**

WILLIAMS, V.L., BALKWILL, K. AND WITKOWSKI, E.T.F. 2007. Size-class prevalence of bulbous and perennial herbs sold in the Johannesburg medicinal plant markets between 1995 and 2001. *South African Journal of Botany* **73: 144-155.**

WILLIAMS, V.L., FALCAO, M.P. AND WOJTASIK, E.M. 2010. *Hydnora abyssinica*: ethonobotanical evidence for its occurrence in southern Mozambique. *South African Journal of Botany* **77: 474-478**.

WILLIAMS, V.L., WITKOWSKI, E.T.F AND BALKWILL, K. 2007. The relationship between bark thickness and diameter at breast height for six tree species used medicinally for bark in South Africa. *South African Journal of Botany* **73: 449-465.**

WORLD COMMISSION ON ENVIRONMENT AND DEVELOPMENT 1987.Our common future. Oxford University Press, Oxford.

WORLD HEALTH ORGANIZATION. 2002. Traditional Medicine Strategy 2002 – 2005. Traditional Medicine Strategy.

www.who.int/medicines/publications/traditionslpolicy/index.html.

ZAFRA-CALVO, N., CERRO, R., FULLER, T., LOBO, J.M., RODRIGUEZ, M.A. AND SARKAR, S. 2010. Prioritizing areas for conservation and vegetation restoration in post-agricultural landscapes: A biosphere reserve plan for Bioko, Equatorial Guinea. *Biological Conservation* **143: 787-794.**

ZHAO, D., BORDERS, B. AND WILSON, M. 2005. A density-dependent matrix model for bottomland hardwood stands in the Lower Mississippi Alluvial Valley. *Ecological Modelling* **184: 381-395.**

ZHOU, Z.C., GAN, Z.T., SHANGGUAN, Z.P. AND DONG, Z.B. 2010. Effects of grazing on soil physical properties and soil erodibility in semiarid grassland of the Northern Loess Plateau (China). *Catena* **82: 87-91.**

ZIERL, B. 2004.A simulation study to analyze the relations between crown condition and drought in Switzerland. *Forest Ecology and Management* **188: 25-38.**

ZSCHOCKE, S., DREWES, S.E., PAULUS, K., BAUER, R. AND VAN STADEN, J. 2000a. Analytical and pharmacological investigation of *Ocotea bullata* (black stinkwood) bark and leaves. *Journal of Ethnopharmacology* **71: 219–230.**

ZSCHOCKE, S., RABE, T., TAYLOR, J.L.S., JÄGER, A.K. AND VAN STADEN, J. 2000b.Plant part substitution – a way to conserve endangered medicinal plants? *Journal of Ethnopharmacology* **71: 281–292.**

APPENDIX A

Table 1: The woody plant species in Venda compiled from PRECIS and Hahn (undated). Bark use as reported in the literature* has been indicated by x

Botanical names	Common names (English (E), Venda (V)	Family	Reported bark use
Acalypha glabrata	Copperleaves (E), Mulambila (V)	Euphorbiaceae	
Acokanthera oppositifolia	Bushman's poison (E), Mutsilili (V)	Apocynaceae	*
Acokanthera rotundata	Round-leaved Poison-bush (E)	Apocynaceae	
Adansonia digitata	Boabab (E), Muvhuyu (V)	Malvaceae	*
Adenia spinosa	Elephant's foot (E), Tshivhuyudumbu (V)	Passifloraceae	*
Adenium multiflorum	Impala lily (E)	Apocynaceae	
Adenopodia spicata	Spiny splinter-bean (E)	Fabaceae	
Aeschynomene nodulosa	False teeth bush (E), Muvumbaredzi (V)	Fabaceae	
Afzelia quanzensis	Pod-mahogany (E), Mutokota (V)	Fabaceae	*
Albizia adianthifolia	Flat-crown (E), Muelela (V)	Fabaceae	*
Albizia amara	Bitter albiza (E), Muvhola (V)	Fabaceae	
Albizia anthelmintica	Wormbark falsethorn (E), Muime (V)	Fabaceae	*
Albizia brevifolia	Mountain falsethorn (E), Mutsilari (V)	Fabaceae	
Albizia forbesii	Broad-pod false-thorn (E), Mupfumbadzi (V)	Fabaceae	
Albizia harveyi	Sickle-leaved Albizia (E), Muvhola (V)	Fabaceae	
Albizia tanganyicensis	Paperbark albizia (E), Mulelu (V)	Fabaceae	*
Albizia versicolor	Largeleaf false-thorn (E), Mutamba-pfunda (V)	Fabaceae	*
Alchornea laxiflora	Lowveld bead-string (E)	Euphorbiaceae	
Allophylus decipiens	Cape Bramble (E)	Sapindaceae	
Allophylus melanocarpus	Black false-currant (E), Sudzungwane (V)	Sapindaceae	
Allophylus transvaalensis	Black Bastard Currant (E)	Sapindaceae	
Aloe angelica	Tshikhopha (V)	Asphodelaceae	-
Aloe arborescens	Japan aloe (E), Tshikhopha (V)	Asphodelaceae	-
Aloe excelsa	Tshikhopha (V)	Asphodelaceae	-
Aloe littoralis	Tshikhopha (V)	Asphodelaceae	-
Aloe marlothii	Binamutsho (V)	Asphodelaceae	-
Andrachne ovalis	False Lightning Bush (E)	Euphorbiaceae	
Androstachys johnsonii	Lebombo ironwood (E), Musimbiri (V)	Picrodendraceae	
Annona senegalensis	Muembe (V)	Annonaceae	*
Anthocleista grandiflora	Forest fever-tree (E), Mueneene (V)	Gentianaceae	*
Antidesma venosum	Tasselberry (E), Mupalakhwali (v)	Phyllanthaceae	
Aphloia theiformis	Mountain peach (E)	Flacourtiaceae	
Apodytes dimidiata	Birds-eye (E), Tshiphopha-madi (V)	Icacinaceae	*
Artabotrys brachypetalus	Mudzidzi (V)	Annonaceae	
Artabotrys monteiroae	Munnamutswu (V)	Annonaceae	
Azanza garckeana	Azanza (E), Mutogwe (V)	Malvaceae	
Azima tetracantha	Murunda (V)	Salvadoraceae	
Balanites maughamii	Torchwood (E), Mudulu (V)	Balanitaceae	*
Balanites pedicellaris	Danzwa-nombe (V)	Balanitaceae	

Botanical names	Common names (English (E), Venda (V)	Family	Reported bark use
Bauhinia galpinii	Pride of De Kaap (E), Mutswiriri (V)	Fabaceae	
Bauhinia tomentosa	Yellow Bauhinia	Fabaceae	*
Berchemia discolor	Brown-ivory (E), Munie (V)	Rhamnaceae	*
Berchemia zeyheri	Red-ivory (E), Munieniane (V)	Rhamnaceae	*
Bersama tysoniana	White Ash Forest (E), Sando (V)	Melianthaceae	*
Bersama lucens	Glossy bersama (E)	Melianthaceae	*
Bolusanthus speciosus	Tree-wisteria (E), Mukambana (V)	Fabaceae	*
Boscia albitrunca	Shepherd tree (E), Muthobi (V)	Capparaceae	*
Boscia foetida	Stink shepherd tree (E), Tshithobi (v)	Capparaceae	
Brachylaena discolor	Coast silver-oak (E), Mufhata (v)	Asteraceae	
Brachylaena huillensis	Silver oak (E), Mutonzhe (V)	Asteraceae	
Brachylaena transvaalensis	Forest silve oak (E), Mufhata (V)	Asteraceae	
Brachystegia spiciformis	Bean-pod tree (E)	Fabaceae	*
Brackenridgea zanguebarica	Yellow peeling plane (E), Mutavhatsindi (V)	Ochnaceae	*
Breonadia salicina	Matumi (E)	Rubiaceae	*
Bridelia cathartica	Blue sweetberry (E)	Phyllanthaceae	
Bridelia micrantha	Coast gold- leaf (E), Munzere (V)	Phyllanthaceae	*
Bridelia mollis	Velvet Sweetberry (E), Mukumba-kumbane (V)	Phyllanthaceae	
Buddleja saligna	False Olive (E)	Buddlejaceae	
Buddleja salviifolia	Sagewood (E), Mudiatholana (V)	Buddlejaceae	
Burkea africana	Wild seringa (E), Mufhulu (v)	Fabaceae	*
Cadaba aphylla	Desert broom (E), Tshikuni (V)	Capparaceae	
Cadaba natalensis	Natal Worm Bush (E)	Capparaceae	
Cadaba termitaria	Grey-leaved Wormbush (E)	Capparaceae	
Calodendrum capense	Cape-chestnut (E), Muvhaha (V)	Rutaceae	
Calpurnia aurea	Wild laburnum (E), Muhalika (V)	Fabaceae	
Canthium ciliatum	Hairy Turkey-berry (E), Mulume-khoda (V)	Rubiaceae	
Canthium inerme	Turkeyberry (E), Muvhibvela-shadani (V)	Rubiaceae	
Canthium mundianum	Rock alder (E), Mutomboti (V)	Rubiaceae	
Canthium setiflorum	Rough-leaved Turkey-berry (E)	Rubiaceae	
Capparis fascicularis	Weeping caper creeper (E)	Capparaceae	
Capparis sepiaria	Hedge caper-bush (E),Gwambadzi (V)	Capparaceae	
Capparis tomentosa	Wooly caper-bush (E), Muobadali (v)	Capparaceae	*
Carissa bispinosa	Forest num-num (E), Mutungulu (V)	Apocynaceae	
Carissa edulis	Simple-spined num-num (E), Mutungulu (V)	Apocynaceae	
Carissa tetramera	Sand num-num (E)	Apocynaceae	
Cassia abbreviata	Long-tail cassia (E), Muvhonela-thangu (V)	Fabaceae	*
Cassine peragua	Spoonwood (E)	Celastraceae	
Cassipourea malosana	Pillarwood (E)	Rhizophoraceae	*
Catha edulis	Bushman's tea (E), Luthadzi (V)	Celastraceae	*
Catophractes alexandri	Trumpet-thorn (E)	Boraginaceae	*
Catunaregam spinosa	Common Emetic Nut (E)	Rubiaceae	
Celtis africana	Whitestinkwood (E), Mumvumvu (V)	Celtidaceae	
Cephalanthus natalensis	Strawberry bush (E)	Rubiaceae	
Chaetacme aristata	Thorny elm (E)	Celtidaceae	*
Chionanthus battiscombei	-	Oleaceae	
Choristylis rhamnoides	Mukuda-khombe (V)	Escalloniaceae	

Botanical names	Common names (English (E), Venda (V)	Family	Reported bark use
Clausena anisata var. anisata	Horsewood (E)	Rutaceae	
Clerodendrum glabrum	Smooth tinderwood (E)	Lamiaceae	
Cliffortia strobilifera	Tree euphorbia (E)	Rosaceae	
Cnestis polyphylla	Itch pod (E)	Connaraceae	
Coddia rudis	Small Bone-apple (E)	Rubiaceae	
Colophospermum mopane	Mopane (E), Mupani (V)	Fabaceae	*
Combretum apiculatum	Red bushwillow (E), Musingidzi (V)	Combretaceae	
Combretum collinum	Weeping bushwillow (E), Muvuvha (V)	Combretaceae	
Combretum erythrophyllum	River bushwillow (E), Muvuvhu (V)	Combretaceae	*
Combretum hereroense	Russet bushwillow (E), Mugavhi (V)	Combretaceae	
Combretum imberbe	Leadwood (E), Mudzwiri (V)	Combretaceae	*
Combretum kraussii	Forest bushwillow (E), Muvuvhu-thavha (V)	Combretaceae	
Combretum microphyllum	Flame creeper (E), Mukopokopo (V)	Combretaceae	
Combretum moggii	Rock Bush Willow (E), Muvuvha-thavha (V)	Combretaceae	
Combretum molle	Velvet bushwillow (E), Mugwiti (V)	Combretaceae	*
Combretum mossambicense	Knobbly creeper (E), Gopo-gopo (V)	Combretaceae	
Combretum vendae	Venda Bushwillow (E)	Combretaceae	
Combretum zeyheri	Largefruit bushwillow (E), Mufhatela-thundu (V)	Combretaceae	*
Commiphora africana	Poison-grub corkwood (E)	Burseraceae	
Commiphora angolensis	Sand corkwood (E)	Burseraceae	
Commiphora edulis	Rough-leaved corkwood (E),Mubobobo (V)	Burseraceae	
Commiphora glandulosa	Tall firethorn corkwood (E)	Burseraceae	
Commiphora marlothii	Paperbark corkwood (E), Mukarakara (V)	Burseraceae	*
Commiphora mollis	Velvetleaf corkwood (E), Muukhuthu (v)	Burseraceae	
Commiphora neglecta	Sweet Root Corkwood (E),Mundalindali (V)	Burseraceae	
Commiphora pyracanthoides	Common corkwood (E), Mutalu (V)	Burseraceae	*
Commiphora schimperi	Glossy-leaved corkwood (E), Tshiuvhu (V)	Burseraceae	
Commiphora tenuipetiolata	Satin-bark corkwood (E), Mutahadzi (V)	Burseraceae	
Commiphora viminea	Zebrabark corkwood (E)	Burseraceae	*
Coptosperma rhodesiacum	-	Rubiaceae	
Coptosperma supra-axillare	Narrow-leaved butterspoon (E)	Rubiaceae	
Coptosperma zygoon	-	Rubiaceae	
Cordia africana	Mufhafha (V)	Boraginaceae	
Cordia caffra	Septee tree (E), Mududa (V)	Boraginaceae	
Cordia grandicalyx	Mutogwa (V)	Boraginaceae	
Cordia ovalis	Sandpaper saucer-berry (E), Munganingani (V)	Boraginaceae	
Cordia sinensis	Grey-leaved saucer berry (E)	Boraginaceae	*
Crossopteryx febrifuga	Common crown-berry (E),Mukhobigwa (V)	Rubiaceae	
Crotalaria capensis	Cape rattle-pod (E), Musumbudza-nduhu (V)	Fabaceae	
Croton gratissimus	Lavender feverberry (E), Mufhorola (V)	Euphorbiaceae	*
Croton megalobotrys	Large feverberry (E), Muruthu (V)	Euphorbiaceae	*
Croton menyharthii	Rough-leaved feverberry (E)	Euphorbiaceae	
Croton pseudopulchellus	Small lavender feverberry (E)	Euphorbiaceae	
Croton sylvaticus	Forest feverberry (E), Mulathoho (V)	Euphorbiaceae	*
Cryptocarya transvaalensis	Wild Quince (E)	Lauraceae	*
Curtisia dentata	Assegai (E), Musangwe (V)	Cornaceae	*
Cussonia natalensis	Rock cabbagetree (E)	Araliaceae	
Cussonia spicata	Cabbage tree (E), Musenzhe (V)	Araliaceae	*

Botanical names	Common names (English (E), Venda (V)	Family	Reported bark use
Cyathea capensis	Forest Tree Fern (E)	Cyatheaceae	-
Cyathea dregei	Tree fern (E)	Cyatheaceae	-
Dalbergia armata	Thorny rope (E)	Fabaceae	
Dalbergia melanoxylon	Zebrawood (E), Muuluri (V)	Fabaceae	*
Dalbergia nitidula	Glossy flat-bean (E)	Fabaceae	*
Deinbollia xanthocarpa	Northern soap-berry (E)	Sapindaceae	
Dichrostachys cinerea	Sickle bush (E), Murenzhe (V)	Fabaceae	*
Diospyros dichrophylla	Poison star-apple (E), Tshithala (V)	Ebenaceae	
Diospyros lycioides	Bluebush (E), Muthala (V)	Ebenaceae	
Diospyros mespiliformis	Jackalberry (E), Musuma (V)	Ebenaceae	*
Diospyros villosa	Hairy Star Apple (E)	Ebenaceae	
Diospyros whyteana	Bladdernut (E), Munyavhili (V)	Ebenaceae	*
Diplorhynchus condylocarpon	Hornpod (E), Muthowa, Musunzi (V)	Apocynaceae	
Dodonaea angustifolia	Sand Olive (E)	Sapindaceae	
Dombeya burgessiae	Pink wild pear (E), Mufulwi (V)	Malvaceae	
Dombeya rotundifolia	Wild pear (E), Tshiluvhari (V)	Malvaceae	*
Dovyalis caffra	Kei-apple (E), Mutunu (V)	Salicaceae	
Dovyalis lucida	Glossy Kei-apple (E), Munwevha (V)	Salicaceae	
Dovyalis zeyheri	Apricot Kei-apple (E), Mutunu (V)	Salicaceae	
Dracaena aletriformis	Dragon dracaena (E)	Dracaenaceae	
Drypetes gerrardii	Forest ironplum (E), Mutongola (V)	Putranjivaceae	
Ehretia amoena	Sandpaper puzzle-bush (E), Shombe (V)	Boraginaceae	
Ehretia obtusifolia	Glandular puzzle-bush (E)	Boraginaceae	
Ehretia rigida	Puzzlebush (E), Mutepe (V)	Boraginaceae	
Ekebergia capensis	Cape ash (E), Mutobvuma (V)	Meliaceae	*
Ekebergia pterophylla	Rock Cape-ash (E)	Meliaceae	
Elaeodendron croceum	Common saffron (E)	Celastraceae	*
Elaeodendron transvaalense	Transvaal saffron (E), Mulumanamana (V)	Celastraceae	*
Elephanthorrhiza goetzei	Narrow-pod elephant root (E)	Fabaceae	
Elephantorrhiza burkei	Elephant root (E)	Fabaceae	
Elephantorrhiza elephantina	Eland's bean (E)	Fabaceae	*
Encephalartos transvenosus	Modjadji cycad (E), Tshifhanga (V)	Zamiaceae	
Englerophytum magalismontanum	Stemfruit (E), Munombelo (V)	Sapotaceae	
Ensete ventricosum	Wild-banana (E), Mulolo (V)	Musaceae	
Entandrophragma caudatum	Mountain mahogany (E), Munzhounzhou (V)	Meliaceae	
Erica simii	-	Ericaceae	
Erythrina humeana	Dwarf coral tree (E), Tshivhale (V)	Fabaceae	
Erythrina latissima	Broadleaf coraltree (E), Muvhale (V)	Fabaceae	*
Erythrina lysistemon	Common coral tree (E), Muvhale (V)	Fabaceae	*
Erythrococca menyharthii	Northern red-berry (E)	Euphorbiaceae	
Erythroxylum emarginatum	African coca-tree (E), Nyathonge (V)	Erythroxylaceae	
Euclea crispa	Blue guarri (E)	Ebenaceae	
Euclea divinorum	Magic guarri (E), Mutangule (V)	Ebenaceae	
Euclea linearis	-	Ebenaceae	
Euclea natalensis	Hairy guarri (E)	Ebenaceae	*
Euclea schimperi	Bush guarri (E)	Ebenaceae	*
Euclea undulata	Common guarri (E)	Ebenaceae	*
Eugenia natalitia	Forest myrtle (E), Tshitawatawane (V)	Myrtaceae	

Botanical names	Common names (English (E), Venda (V)	Family	Reported bark use
Eugenia woodii	Hairy myrtle (E), Tshitawatawane (V)	Myrtaceae	
Euphorbia confinalis	Lebombo euphorbia (E), Tshikone-ngala (V)	Euphorbiaceae	
Euphorbia cooperi	Transvaal candelabratree (E), Mukonde-ngala (V)	Euphorbiaceae	
Euphorbia espinosa	-	Euphorbiaceae	
Euphorbia guerichiana	Paper-bark euphorbia (E)	Euphorbiaceae	
Euphorbia ingens	Naboom (E), Mukonde (V)	Euphorbiaceae	*
Euphorbia tirucalli	Hedge euphorbia (E), Mutungu (V)	Euphorbiaceae	
Euphorbia zoutpansbergenss	Mukonde-ngala (V)	Euphorbiaceae	
Faidherbia albida	Anatree (E)	Fabaceae	*
Faurea galpinii	Forest Boekenhout (E), Mutango (V)	Proteaceae	
Faurea rochetiana	Broad-leaf Boekenhout (E)	Proteaceae	
Faurea saligna	Boekenhout (E), Mutango (V)	Proteaceae	
Ficus abutilifolia	Largeleaf rock fig (E)	Moraceae	
Ficus capreifolia	Muhuyu-lukumbe (V)	Moraceae	
Ficus craterostoma	Forest fig (E)	Moraceae	
Ficus glumosa	Hairy rock-fig (E)	Moraceae	
Ficus ingens	Redleaf fig (E), Tshikululu (V)	Moraceae	*
Ficus natalensis	Coast strangler fig (E), Muumo (V)	Moraceae	
Ficus salicifolia	Wonderboom fig (E), Muungulawe (V)	Moraceae	
Ficus sansibarica	Knob fig (E)	Moraceae	*
Ficus stuhlmannii	Lowveld fig (E)	Moraceae	
Ficus sur	Broomcluster fig (V), Muhuyu (V)	Moraceae	*
Ficus sycomorus	Sycomore fig (E), Tshikululu (V)	Moraceae	*
Ficus tettensis	Small-leaved rock fig (E), Tshikululu (V)	Moraceae	
Ficus thonningii	Comonn wild-fig (E), Muumo (V)	Moraceae	*
Flacourtia indica	Governers-plum (E)	Flacourtiaceae	
Flueggea virosa	Whiteberry bush (E), Mutangauma (V)	Euphorbiaceae	
Garcinia livingstonei	African mangosteen (E), Muphiphi (V)	Clusiaceae	
Gardenia resiniflua	Gummy gardenia (E)	Rubiaceae	
Gardenia ternifolia	Yellow gardenia (E)	Rubiaceae	
Gardenia volkensii	Bushveld gardenia (E)	Rubiaceae	*
Grewia bicolor	White raisin (E), Murabva (V)	Malvaceae	
Grewia caffra	Climbing raisin (E)	Malvaceae	
Grewia flava	Velvet raisin (E), Muredwa (V)	Malvaceae	
Grewia flavescens	Sandpaper raisin (E), Mupharasheni (V)	Malvaceae	
Grewia gracillima	-	Malvaceae	
Grewia hexamita	Giant raisin (E), Mukukunu (V)	Malvaceae	
Grewia inaequilatera	False silver raisin (E)	Malvaceae	
Grewia microthyrsa	Sand raisin (E)	Malvaceae	
Grewia monticola	Silver raisin (E)	Malvaceae	
Grewia occidentalis	Crossberry (E), Mulembu (V)	Malvaceae	*
Grewia retinervis	False sandpaper raisin (E)	Malvaceae	
Grewia subspathulata	False grey raisin (E)	Malvaceae	
Grewia sulcata	Stellar raisin (E)	Malvaceae	
Grewia tenax		Malvaceae	
Grewia villosa	Mallow raisin (E), Tshirabva (V)	Malvaceae	
Greyia radlkoferi	Woolly bottlebrush (E)	Greyiaceae	
Guibourtia conjugata	Small False Mopane (E)	Fabaceae	

Botanical names	Common names (English (E), Venda (V)	Family	Reported bark use
Gymnosporia buxifolia	Spikethorn (E)	Celastraceae	*
Gymnosporia maranguensis	Tropical spikethorn (E)	Celastraceae	
Gymnosporia mossambicensis	Black forest spikethorn (E)	Celastraceae	
Gymnosporia putterlickioides	Forest false spikethorn (E)	Celastraceae	
Gymnosporia senegalensis	Red spikethorn (E)	Celastraceae	
Gymnosporia tenuispina	Bell spikethorn (E)	Celastraceae	
Gyrocarpus americanus	Propeller tree (E)	Hernandiaceae	*
Halleria lucida	Tree-fuchsia (E)	Scrophulariaceae	
Heinsia crinita	Bush apple (E)	Rubiaceae	
Heteromorpha arborescens	Parsley tree (E), Muthathavhanna (V)	Apiaceae	*
Heteropyxis natalensis	Lavendertree (E), Mudedede (V)	Heteropyxidaceae	*
Holarrhena pubescens	Fever pod (E)	Apocynaceae	*
Homalium dentatum	Brown-ironwood (E)	Salicaceae	
Hymenocardia ulmoides	Small red-heart (E), Tshikonwa (V)	Phyllanthaceae	
Hyperacanthus amoenus	Thorny gardenia (E)	Rubiaceae	
Hypericum revolutum	Curry bush (E), Mudyanongo (V)	Hypericaceae	
Hyphaene petersiana	Norther lala-palm (E), Mulala (V)	Arecaceae	
Ilex mitis	Cape holly (E), Mutanzwa-khamelo (V)	Aquifoliaceae	*
Indigofera lyalli	Venda Indigo (E)	Fabaceae	
Karomia speciosa	Wild parasol flower (E)	Lamiaceae	
Keetia gueinzii	Climbing Turkey-berry (E)	Rubiaceae	
Kigelia africana	Sausage tree (E), Muvevha (V)	Bignoniaceae	*
Kiggelaria africana	Wild-peach (E)	Achariaceae	
Kirkia acuminata	Common kirkia (E), Mubvumela (V)	Kirkiaceae	
Kirkia wilmsii	Mountain-seringa (E)	Kirkiaceae	
Lagynias dryadum	Woodland pendent-medlar (E)	Rubiaceae	
Lannea discolor	Live-long (E), Muvhumbu (V)	Anacardiaceae	*
Lannea schweinfurthii	False marula (E), Mulivhadza (V)	Anacardiaceae	*
Lauridea tetragona	Climbing saffron (E)	Celastraceae	
Leucosidea sericea	Oldwood (E)	Rosaceae	
Mackaya bella	Forest bell-bush (E)	Acanthaceae	
Maclura africana	African Osage-orange (E)	Moraceae	
Maerua angolensis	Bead-bean (E)	Capparaceae	*
Maerua cafra	Bush-cherry (E)	Capparaceae	*
Maerua parvifolia	Small-leaf bush-cherry (E)	Capparaceae	
Maerua rosmarinoides	Needle-leaf bush-cherry (E)	Capparaceae	
Maesa lanceolata	False-assegai (E), Mutibamela (v)	Maesaceae	
Manilkara mochisia	Lowveld milkberry (E)	Sapotaceae	
Margaritaria discoidea	Peacock-berry (E)	Phyllanthaceae	*
Markhamia zanzibarica	Bell bean tree (E)	Bignoniaceae	
Maytenus acuminata	Silk-bark (E), Tshinembane (V)	Celastraceae	
Maytenus peduncularis	Cape blackwood (E), Mukwatule (V)	Celastraceae	
Maytenus undata	Koko tree (E), Tshiphandwa (V)	Celastraceae	
Memecylon natalense	Small-leaf rose-apple (E)	Melastomataceae	
Micrococca capensis	False bead-string (E), Mulambilana (V)	Euphorbiaceae	
Milletia stuhlmannii	Panga-panga (E), Muangaila (V)	Fabaceae	
Mimusops zeyheri	Common redmilkwood (E), Mumbubulu (V)	Sapotaceae	
Monodora junodii	Green apple (E), Nyagokwane (V)	Annonaceae	

Botanical names	Common names (English (E), Venda (V)	Family	Reported bark use
Morella pilulifera	Broadleaf waxberry (E)	Myricaceae	
Mundulea sericea	Corkbush (E), Mukundandou (V)	Fabaceae	*
Myrsine africana	Cape myrtle (E)	Myrsinaceae	
Mystroxylon aethiopicum	Kooboo-berry (E)	Celastraceae	*
Nuxia congesta	Wild-elder (E)	Buddlejaceae	
Nuxia floribunda	Forest elder (E), Mulanotshi (V)	Buddlejaceae	
Nuxia oppositifolia	Water elder (E)	Buddlejaceae	
Obetia tenax	Mountain nettle (E)	Urticaceae	
Ochna arborea	Murambo (V)	Ochnaceae	
Ochna holstii	Red-ironwood ochna (E), Tshipfure (V)	Ochnaceae	*
Ochna inermis	Stunted plane (E)	Ochnaceae	
Ochna natalitia	Natal plane (E)	Ochnaceae	
Ochna pulchra	Peeling-bark ochna (E), Tshithothonya (V)	Ochnaceae	
Ocotea kenyensis	False stinkwood (E)	Lauraceae	*
Olax dissitiflora	Small false-sourplum (E), Munie-dombo (V)	Olacaceae	
Olea capensis	Ironwood (E)	Oleaceae	
Olea europaea subsp. africana	African olive (E)	Oleaceae	*
Olea woodiana	Forest olive (E)	Oleaceae	
Olinia emarginata	Mountain hardpear (E)	Oliniaceae	
Olinia rochetiana	Mulondwane (V)	Oliniaceae	
Oncoba spinosa subsp. spinosa	Snuff-box tree (E)	Salicaceae	
Oricia transvaalensis	Twin-berry Tree (E)	Rutaceae	
Ormocarpum trichocarpum	Caterpillar bush (E), Muthari (V)	Fabaceae	*
Osyris lanceolata	Rock tannin-bush (E), Mupeta (V)	Santalaceae	
Oxyanthus speciosus	Wild-loquat (E)	Rubiaceae	
Ozoroa albicans	-	Anacardiaceae	
Ozoroa engleri	White resin tree (E), Mudumbula (V)	Anacardiaceae	*
Ozoroa paniculosa	Common resintree (E), Tshinungumafhi (V)	Anacardiaceae	
Pachystigma bowkeri	Forest crowned-medlar (E)	Rubiaceae	
Pachystigma triflorum	Waterberg medlar (E)	Rubiaceae	
Pappea capensis	Jacket-plum (E), Tshikavhavhe (V)	Sapindaceae	
Parinari curatellifolia	Mabola-plum (E), Muvhula (V)	Chrysobalanaceae	*
Passerina montana	Mountain gonna (E)	Thymelaeaceae	
Pavetta eylesii	Flaky-bark bride's-bush (E)	Rubiaceae	
Pavetta gardeniifolia	Stink-leaf brides-bush (E)	Rubiaceae	
Pavetta inandensis	Forest brides-bush (E)	Rubiaceae	
Pavetta lanceolata	Weeping brides-bush (E)	Rubiaceae	
Pavetta schumanniana	Poison brides-bush (E), Tshituku (V)	Rubiaceae	
Pavetta trichardtensis	-	Rubiaceae	
Peddiea africana	Poison olive (E)	Thymelaeaceae	
Peltophorum africanum	African-wattle (E), Musese (V)	Fabaceae	*
Philenoptera violacea	Appleleaf (E), Mufhanda (V)	Fabaceae	*
Phoenix reclinata	Wild datepalm (E), Mutshevho (V)	Arecaceae	
Phyllanthus pinnatus	Mopane potato bush (E)	Phyllanthaceae	
Phyllanthus reticulatus	Potato bush (E), Mutangauma-vhadzimu (V)	Phyllanthaceae	
Piliostigma thonningii	Camelfoot (E), Mukolokote (V)	Fabaceae	*
Piper capensis	Golden shrimp plant (E), Mukara (V)	Piperaceae	*
Pittosporum viridiflorum	Cheesewood (E)	Pittosporaceae	*

Botanical names	Common names (English (E), Venda (V)	Family	Reported bark use
Plectroniella armata	False Turkey-berry (E)	Rubiaceae	
Pleurostylia capensis	Coffee-pear (E), Murumelela (V)	Celastraceae	*
Podocarpus falcatus	Outeniqua yellowwood (E), Mufhanza (V)	Podocarpaceae	
Podocarpus latifolius	Broadleaf yellowwood (E), Muhovho-hovho (V)	Podocarpaceae	*
Portulacaria afra	Porkbush (E), Tshilepetwe (V)	Portulacaceae	
Pouzolzia mixta	Soap-nettle (E), Muthanzwa (V)	Urticaceae	*
Protea caffra	Common sugarbush (E), Tshidzungu (V)	Proteaceae	*
Protea gaguedi	White sugarbush (E), Tshididiri (V)	Proteaceae	
Protea rhodantha	Common sugarbush (E)	Proteaceae	
Protea roupelliae	Silver sugarbush (E), Tshididiri (V)	Proteaceae	*
Protorhus longifolia	Red-beech (E)	Anacardiaceae	
Prunus africana	Red stinkwood (E)	Rosaceae	*
Pseudolachnostylis maprouneifolia	Kuduberry (E), Mutondowa (V)	Phyllanthaceae	*
Psoralea pinnata	Broad-leaf fountain-bush (E)	Fabaceae	
Psychotria capensis	Black bird-berry (E), Tshinangana (V)	Rubiaceae	
Psychotria zombamontana	Red bird-berry (E)	Rubiaceae	
Psydrax livida	Green tree (E)	Rubiaceae	
Psydrax locuples	Sand quar (E)	Rubiaceae	
Psydrax obovata	Quar (E)	Rubiaceae	
Ptaeroxylon obliquum	Sneezewood (E), Munari (V)	Ptaeroxylaceae	*
Pteleopsis myrtifolia	Stink-bushwillow (E)	Combretaceae	
Pterocarpus angolensis	Kiaat, Bloodwood (E), Mutondo (V)	Fabaceae	*
Pterocarpus rotundifolius	Roundleaf bloodwood (E), Mukwatamba (V)	Fabaceae	
Pterocelastrus echinatus	White candlewood (E)	Celastraceae	
Pterocelastrus rostratus	Red candlewood (E)	Celastraceae	*
Pterolobium stellatum	Red-wing (E)	Fabaceae	
Pyrostria hystrix	Porcupine bush (E)	Rubiaceae	
Rapanea melanophloeos	Cape-beech (E)	Myrsinaceae	*
Rauvolfia caffra	Quinine tree (E), Munadzi (V)	Apocynaceae	*
Rawsonia lucida	Forest peach (E)	Flacourtiaceae	
Rhamnus prinoides	Dogwood (E)	Rhamnaceae	*
Rhigozum zambesiacum	Mopane pomegranate (E)	Bignoniaceae	
Rhoicissus digitata	Five-finger grape (E)	Vitaceae	
Rhoicissus revoilii	Forest grape (E), Tshikundwi-mai (V)	Vitaceae	
Rhoicissus rhomboidea	Glossy forest grape (E), Tshikundwi-mai (V)	Vitaceae	
Rhoicissus tomentosa	Common forest grape (E)	Vitaceae	
Rhoicissus tridentata	Bushmans grape (E), Murumbula-mbudzana (V)	Vitaceae	
Rhynchosia clivorum	Escarpment shaggy-bush (E)	Fabaceae	
Rinorea angustifolia	White violet-bush (E)	Violaceae	
Robsonodendron eucleiforme	False silky-bark (E)	Celastraceae	
Rothmannia capensis	False-gardenia (E), Murathamapfene (V)	Rubiaceae	
Rothmannia fischeri	Bushveld false-gardenia (E)	Rubiaceae	
Rothmannia globosa	September bells (E)	Rubiaceae	
Salix mucronata subsp. woodii	Wild willow (E), Munengeledzi (V)	Salicaceae	*
Salvadora australis	Narrowleaf mustardtree (E)	Salvadoraceae	
Schefflera umbellifera	False-cabbagetree (E)	Araliaceae	*
Schotia brachypetala	Weeping schotia (E), Mulubi (V)	Fabaceae	*
Schrebera alata	Wild-jasmine (E)	Oleaceae	

Botanical names	Common names (English (E), Venda (V)	Family	Reported bark use
Sclerocarya birrea	Marola (E), Mufula (V)	Anacardiaceae	*
Sclerochiton harveyanus	Blue lips (E)	Acanthaceae	
Scolopia zeyheri	Thorn pear (E)	Flacourtiaceae	
Scutia myrtina	Cat-thorn (E)	Rhamnaceae	
Searsia chirindensis	Red-currant (E), Muvhadelaphanga (V)	Anacardiaceae	*
Searsia gueinzii	Thorny karee (E), Mushakaladza (V)	Anacardiaceae	
Searsia lancea	Karee (E), Mushakaladza (V)	Anacardiaceae	
Searsia leptodictya	Mountain karee (E), Mushakaladza (V)	Anacardiaceae	*
Searsia lucida	Glossy currant (E)	Anacardiaceae	
Searsia pentheri	Crow-berry (E), Mutasiri (V)	Anacardiaceae	
Searsia pyroides	Common wild-currant (E), Mutasiri (V)	Anacardiaceae	
Searsia rehmanniana	Blunt-leaf crow-berry (E), Tshitasiri (V)	Anacardiaceae	
Searsia tomentosa	Bicolour currant (E), Tshidzimba-vhalisa (V)	Anacardiaceae	
Searsia transvaalensis	Escarpment currant (E), Mutshaku-tshaku (V)	Anacardiaceae	
Searsia tumulicola	Hard-leaf currant (E)	Anacardiaceae	
Securidaca longepedunculata	Violet tree (E), Mupesu (V)	Polygalaceae	*
Senegalia ataxacantha	Flame thorn (E), Muluwa (V)	Fabaceae	
Senegalia burkei	Black monkey thorn (E)	Fabaceae	*
Senegalia caffra	Common hookthorn (E), Muvunda-mbado (V)	Fabaceae	*
Senegalia davyi	Corky thorn (E), Muunga (V)	Fabaceae	
Senegalia erioloba	Camel thorn (E), Musivhitha (V)	Fabaceae	*
Senegalia erubescens	Blue thorn (E), Mulondo (V)	Fabaceae	
Senegalia gerrardii	Greyhair thorn (E), Muunga (V)	Fabaceae	*
Senegalia grandicornuta	Horned thorn (E)	Fabaceae	
Senegalia karroo	Sweet thorn (E), Muunga (V)	Fabaceae	*
Senegalia mellifera	Black thorn (E)	Fabaceae	
Senegalia nebrownii	Water thorn (E)	Fabaceae	
Senegalia nigrescens	Knob thorn (E), Munanga (V)	Fabaceae	
Senegalia nilotica	Scented pod (E)	Fabaceae	*
Senegalia permixta	Hairy senegalia (E)	Fabaceae	
Senegalia polyacantha	White thorn (E), Tshikwalo (V)	Fabaceae	
Senegalia rehmanniana	Silky thorn (E), Musivhitha (V)	Fabaceae	
Senegalia robusta	Robust thorn (E), Muvumba-ngwena (V)	Fabaceae	*
Senegalia schweinfurthii	Muombaluwa (V)	Fabaceae	
Senegalia senegal var. *leiorhachis*	Three-hook thorn (E), Muunga-thuda (V)	Fabaceae	
Senegalia senegal var. *rostrata*	Three-hook thorn (E), Muunga-thuda (V)	Fabaceae	*
Senegalia sieberiana	Paperbark thorn (E)	Fabaceae	*
Senegalia tortilis	Umbrella thorn (E), Musu (V)	Fabaceae	*
Senegalia welwitschii	Delagoa thorn (E), Munangania (V)	Fabaceae	
Senegalia xanthophloea	Fever tree (E), Muunga-ngwena (V)	Fabaceae	*
Senna petersiana	Monkey pod (E), Munembenembe (V)	Fabaceae	*
Sericanthe andongensis	Venda coffee (E)	Rubiaceae	
Sesamothamnus lugardii	Sesamebush (E)	Pedaliaceae	
Sesbania sesban	Egyptian pea (E)	Fabaceae	
Sideroxylon inerme	Whitemilkwood (E)	Sapotaceae	*
Solanum aculeastrum	Bitter-apple (E)	Solanaceae	
Solanum giganteum	Giant bitter-apple (E)	Solanaceae	
Spirostachys africana	Tamboti (E), Muonze (V)	Euphorbiaceae	*

Botanical names	Common names (English (E), Venda (V)	Family	Reported bark use
Steganotaenia araliacea	Carrot-tree (E)	Apiaceae	*
Sterculia rogersii	Star-chetsnut (E), Mukakate (V)	Malvaceae	
Strophanthus speciosus	Forest poison-rope (E)	Apocynaceae	
Strychnos decussata	Cape-teak (E)	Strychnaceae	*
Strychnos henningsii	Red bitterberry (E)	Strychnaceae	*
Strychnos madagascariensis	Black monkey-orange (E), Mukwakwa (V)	Strychnaceae	*
Strychnos mitis	Yellow bitterberry (E)	Strychnaceae	
Strychnos potatorum	Black bitterberry (E)	Strychnaceae	
Strychnos pungens	Spineleaf monkey-orange (E), Muramba (V)	Strychnaceae	*
Strychnos spinosa	Green monkey-orange (E)	Strychnaceae	*
Strychnos usambarensis	Blue bitterberry (E)	Strychnaceae	*
Suregada africana	Common canary-berry (E)	Euphorbiaceae	
Suregada procera	Forest canary-berry (E), Tshitongola (V)	Euphorbiaceae	
Synadenium cupulare	Dead-mans tree (E), Muswoswo (V)	Euphorbiaceae	*
Syzygium cordatum	Water berry (E), Mutu (V)	Myrtaceae	*
Syzygium gerrardii	Forest water-berry (E), Mutawi (V)	Myrtaceae	*
Syzygium guineense	Woodland waterpear (E), Mutumadi (V)	Myrtaceae	*
Syzygium legatii	Mountain umdoni (E)	Myrtaceae	
Tabernaemontana elegans	Toadtree (E), Muhatu (V)	Apocynaceae	
Tarchonanthus camphoratus	Wild camphor bush (E), Mutwari (V)	Asteraceae	
Tarchonanthus trilobus	Three-lobed camphor bush (E), Mutwari (V)	Asteraceae	
Tarenna supra-axillaris	Narrow-leaf butterspoon (E)	Rubiaceae	
Tarenna zygoon	-	Rubiaceae	
Teclea natalensis	Natal cherry-orange (E)	Rutaceae	
Tecomaria capensis	Wild honeysuckle (E)	Bignoniaceae	*
Terminalia prunioides	Purplefruit clusterleaf (E)	Combretaceae	*
Terminalia sericea	Silver cluster-leaf (E), Mususu (V)	Combretaceae	*
Tetradenia riparia	Ginger bush (E)	Lamiaceae	
Thilachium africanum	Cucumber-bush (E)	Capparaceae	
Tinnea rhodesiana	-	Lamiaceae	
Toddalia asiatica	Climbing orange (E)	Rutaceae	
Toddaliopsis bremekampii	Mutswolotswondo (V)	Rutaceae	
Trema orientalis	Pigeonwood (E), Mukurukuru (V)	Celtidaceae	
Tricalysia capensis var. *capensis*	Cape-coffee (E)	Rubiaceae	
Tricalysia junodii	Fluffy-flower jackal-coffee (E)	Rubiaceae	
Tricalysia lanceolata	Jackal-coffee (E)	Rubiaceae	
Trichilia dregeana	Forest natal-mahogany (E), Mutuhu (V)	Meliaceae	*
Trichilia emetica	Natal mahogany (E), Mutshikili (V)	Meliaceae	*
Trichocladus grandiflorus	Splendid underbush (E)	Hamamelidaceae	
Trilepisium madagascariense	Venda fig (E)	Moraceae	
Trimeria grandifolia	Wild mulberry (E)	Salicaceae	
Turraea nilotica	Lowveld honeysuckle-tree (E), Tshigombo (V)	Meliaceae	
Turraea obtusifolia	Small honey-suckle tree (E)	Meliaceae	*
Uvaria gracilipes	Small-leaved cluster-pear (E)	Annonaceae	
Vangueria cyanescens	Smooth wild-medlar (E)	Rubiaceae	
Vangueria infausta	Wild-medlar (E), Muzwilu (V)	Rubiaceae	
Vangueria soutpansbergensis	-	Rubiaceae	
Vepris lanceolata	White-ironwood (E), Muhondwa (V)	Rutaceae	

Botanical names	Common names (English (E), Venda (V)	Family	Reported bark use
Vepris reflexa	Bushveld white-ironwood (E)	Rutaceae	
Vernonia amygdalia	Bitter leaf (E)	Asteraceae	
Vernonia colorata	Lowveld tree vernonia (E)	Asteraceae	
Vernonia myriantha	Silver vernonia (E)	Asteraceae	
Vitex ferruginea	Plum fingerleaf (E)	Lamiaceae	
Vitex patula	Golden finger-leaf (E)	Lamiaceae	
Vitex pooara	Smelly-berry fingerleaf (E)	Lamiaceae	
Vitex rehmannii	Pipe-stem finger-leaf (E)	Lamiaceae	
Warburgia salutaris	Pepper-bark tree (E), Mulanga (V)	Cannellaceae	*
Widdringtonia nodiflora	Mountain-cypres (E)	Cupressaceae	
Wrightia natalensis	Saddlepod (E), Musunzi (V)	Apocynaceae	*
Xanthocercis zambesiaca	Nyalatree (E), Mutshato (V)	Fabaceae	
Xeroderris stuhlmannii	Wingpod (E)	Fabaceae	
Ximenia americana	Muthanzwa (V)	Olacaceae	*
Ximenia caffra	Sourplum (E), Mutshili (V)	Olacaceae	*
Xylopia parviflora	Muvhula-vhusiku (V)	Annonaceae	
Xymalos monospora	Tshipengo (V)	Monimiaceae	*
Zanthoxylum capense	Small knobwood (E), Munungunungwane (V)	Rutaceae	*
Zanthoxylum davyi	Forest knobwood (E), Munungu (V)	Rutaceae	*
Zanthoxylum humile	Hairy knobwood (E), Munungwane (V)	Rutaceae	
Zanthoxylum leprieurii	Sand knobwood (E), Munungu (V)	Rutaceae	
Zanthoxylum thorncroftii	Small knobwood (E)	Rutaceae	
Ziziphus mucronata	Buffalo thorn (E), Mukhalu (V)	Rhamnaceae	*
Ziziphus rivularis	False buffalo-thorn (E), Mulalantsa (V)	Rhamnaceae	
Zoutpansbergia caerulea	-	Asteraceae	

* Watt and Breyer-Brandwijk 1962, Palgrave 1988, Mabogo 1990, Van Wyk *et al.* 1997, Venter and Venter 1996, Tshisikhawe 2002, Schmidt *et al.* 2002, Van Wyk 2008, Van Wyk *et al.* 2008, Van Wyk and Van Wyk 2009, Mannheimer and Curtis 2009, Boon 2010.

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APPENDIX B

Derivation of the vulnerability scores for the species where a score of 1, 0 or -1 was given based on expert knowledge.

Species	Score																			
	No & size of populations	Widespread distribution	Generalist status	Temporal niche dependent	Extreme fluctuations	Post disturbance regeneration	Vigorous growth	Competitive ability	Time to reproduction	Reproductive life-span	Reliable seed production	No of seeds	Seed longevity	Dispersal ability	Fire response	Grazing, drought resistance	Coppicing ability	Pathogen susceptibility	Mutualist dependent	Degree of bark harvest
Senegalia karroo	1	1	-1	1	1	1	-1	1	1	1	1	1	1	1	1	1	1	-1	1	1
Senegalia tortilis subsp. *heteracantha*	1	1	-1	1	1	-1	-1	1	1	1	1	1	1	1	1	1	1	-1	1	1
Adansonia digitata	1	1	-1	1	1	-1	-1	-1	-1	-1	1	1	-1	1	-1	-1	-1	-1	1	-1
Adenia spinosa	-1	-1	-1	1	-1	-1	-1	-1	-1	-1	1	1	-1	-1	-1	-1	-1	-1	-1	1
Afzelia quanzensis	-1	1	-1	1	1	1	1	1	-1	1	1	1	1	1	-1	1	1	-1	1	1
Albizia adianthifolia	-1	-1	-1	1	-1	-1	1	1	-1	1	1	1	1	1	-1	-1	-1	-1	-1	1
Albizia versicolor	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1	1	-1	-1	-1	-1	-1	-1	1
Annona senegalensis	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Berchemia discolor	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Bolusanthus speciosus	-1	-1	-1	1	1	-1	1	1	-1	1	1	1	1	1	-1	-1	-1	1	1	-1
Brackenridgea zanguebarica	-1	-1	-1	1	-1	-1	-1	-1	1	1	-1	1	1	-1	-1	-1	-1	-1	1	-1
Burkea africana	1	1	-1	1	1	1	1	1	-1	1	1	1	1	1	1	1	1	1	1	1
Combretum molle	1	1	1	1	1	1	1	1	-1	1	1	1	1	1	-1	1	1	1	1	1
Commiphora marlothii	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Commiphora merkeri	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Croton gratissimus var. *gratissimus*	1	-1	-1	1	1	-1	1	1	-1	1	1	1	1	-1	-1	1	-1	-1	-1	1
Croton megalobotrys	-1	-1	-1	-1	-1	-1	1	1	-1	1	1	1	-1	-1	-1	-1	-1	-1	-1	1
Cussonia spicata	1	1	1	1	1	-1	1	1	1	1	1	1	1	1	-1	-1	1	1	1	-1
Dalbergia melanoxylon	1	-1	-1	1	1	1	1	1	-1	1	1	1	1	1	1	1	1	1	1	1

Dichrostachys cinerea subsp. *africana*	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Diospyros mespiliformis	-1	-1	1	1	1	1	1	-1	-1	1	1	1	1	1	1	1	1	1	1	1
Dombeya rotundifolia var. *rotundifolia*	1	1	1	1	1	1	1	1	-1	-1	1	1	1	1	-1	1	1	1	1	1
Ekebergia capensis	1	-1	-1	1	1	-1	1	1	-1	1	1	1	1	1	1	1	1	1	1	1
Elaeodendron transvaalense	1	-1	-1	1	1	1	1	1	-1	1	1	1	-1	1	1	1	1	1	1	-1
Elephantorrhiza elephantina	-1	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Erythrina lysistemon	1	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Euphorbia ingens	1	1	1	1	1	1	1	1	1	1	1	1	1	-1	1	1	-1	-1	1	1
Faidherbia albida	-1	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Ficus ingens	1	1	1	1	1	-1	1	-1	-1	1	1	1	1	1	1	1	1	-1	1	1
Ficus sansibarica subsp. *sansibarica*	-1	1	1	1	1	-1	1	1	-1	1	1	1	1	1	1	1	1	-1	1	1
Maerua angolensis subsp. *angolensis*	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Maerua caffra	1	1	1	1	1	1	1	1	1	1	-1	1	1	1	1	1	1	1	1	1
Mundulea sericea	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1	1	1	1	1	1
Ozoroa engleri	1	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Parinari curatellifolia	1	-1	1	1	1	1	1	1	-1	1	1	1	1	1	1	1	1	1	1	1
Peltophorum africanum	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
Piliostigma thonningii	1	-1	1	1	1	1	1	1	-1	1	1	1	1	1	1	1	1	1	1	1
Pleurostylia capensis	-1	1	1	1	1	1	-1	1	1	1	1	1	1	1	1	1	1	1	1	1
Podocarpus latifolius	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pseudolachnostylis maprouneifolia	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pterocarpus angolensis	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
Rapanea melanophloeos	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Rauvolfia caffra	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Schotia brachypetala	1	1	1	1	1	1	1	1	-1	1	1	1	1	1	1	1	1	1	1	1
Sclerocarya birrea subsp. *caffra*	1	1	1	1	1	1	1	1	-1	1	1	1	1	1	1	1	1	1	1	-1
Searsia leptodictya	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Securidaca longepedunculata	-1	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Spirostachys africana	1	1	1	1	1	1	1	1	1	-1	1	1	1	1	1	1	1	1	1	1
Strychnos madagascariensis	1	1	1	1	1	1	-1	1	-1	1	1	1	1	1	1	1	1	1	1	1
Synadenium cupulare	1	1	-1	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Syzygium cordatum	1	1	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Syzygium guineense	1	1	-1	1	1	1	1	1	1	1	1	1	1	1	1	-1	1	1	1	1
Terminalia sericea	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Trichilia dregeana	-1	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Trichilia emetica subsp. *emetica*	-1	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Warburgia salutaris	-1	-1	1	1	1	1	1	1	-1	-1	-1	-1	-1	-1	-1	-1	1	-1	1	-1
Wrightia natalensis	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1	1	1	1	1	1
Zanthoxylum davyi	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

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