CHAPTER 7

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

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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).

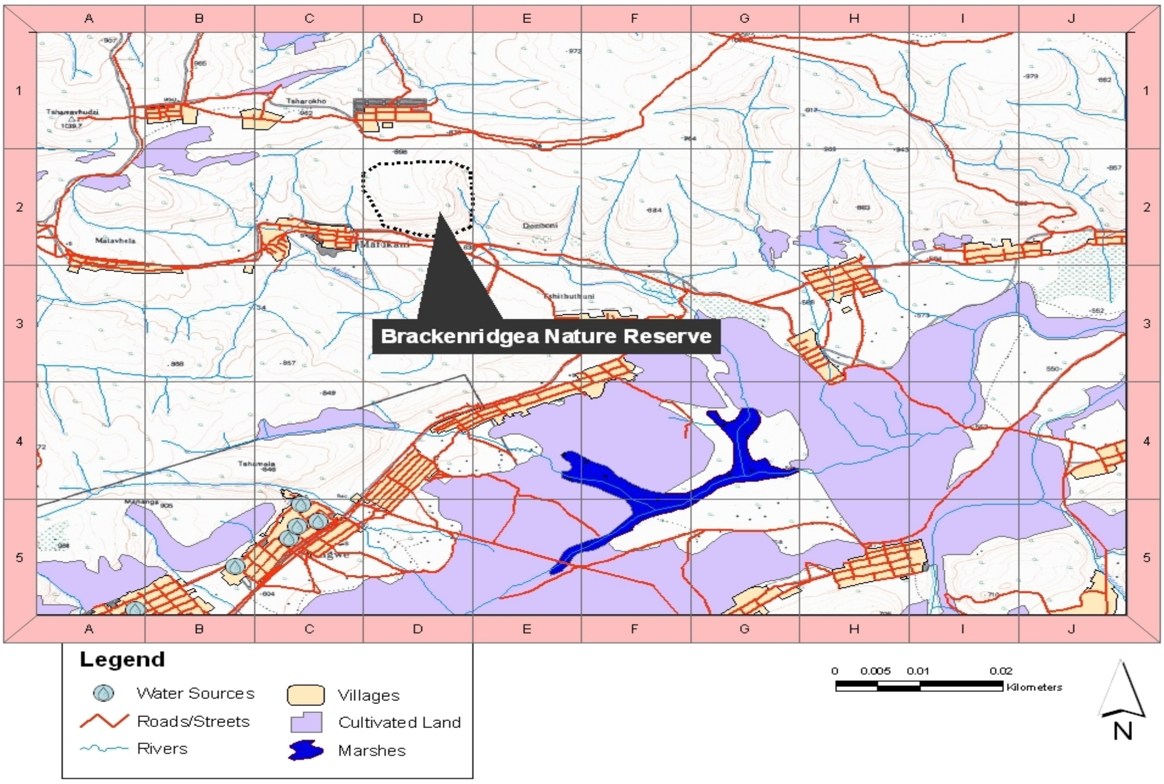

Figure 7.1: Grid map of the Thengwe region where the Brackenridgea Nature Reserve (boundary indicated by the black dotted line) is located.

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.

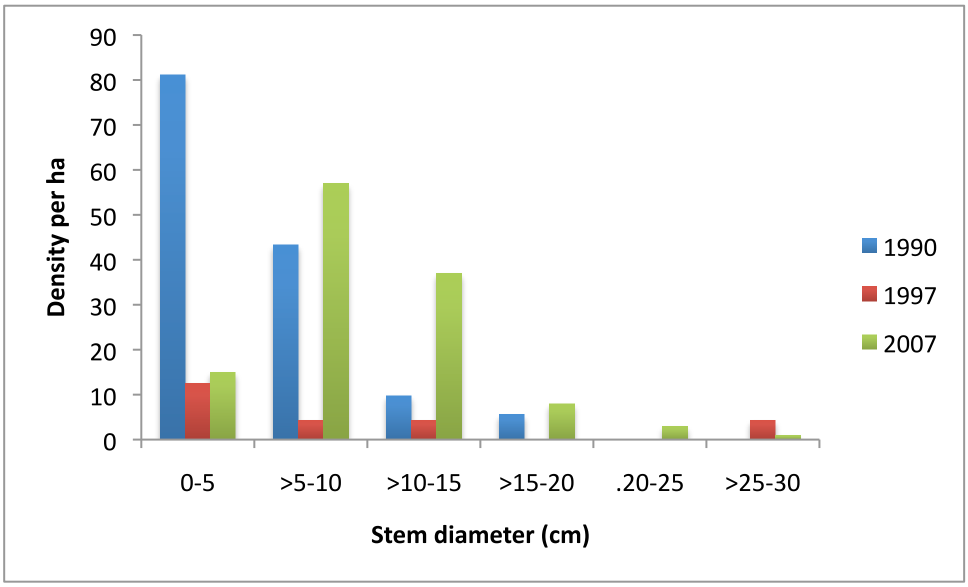

Figure 7.2: Changes in the size class distribution of *Brackenridgea zanguebarica* in the Brackenridgea Nature Reserve from 1990 to 2007 (1990 and 1997 from Todd unpublished data).

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.

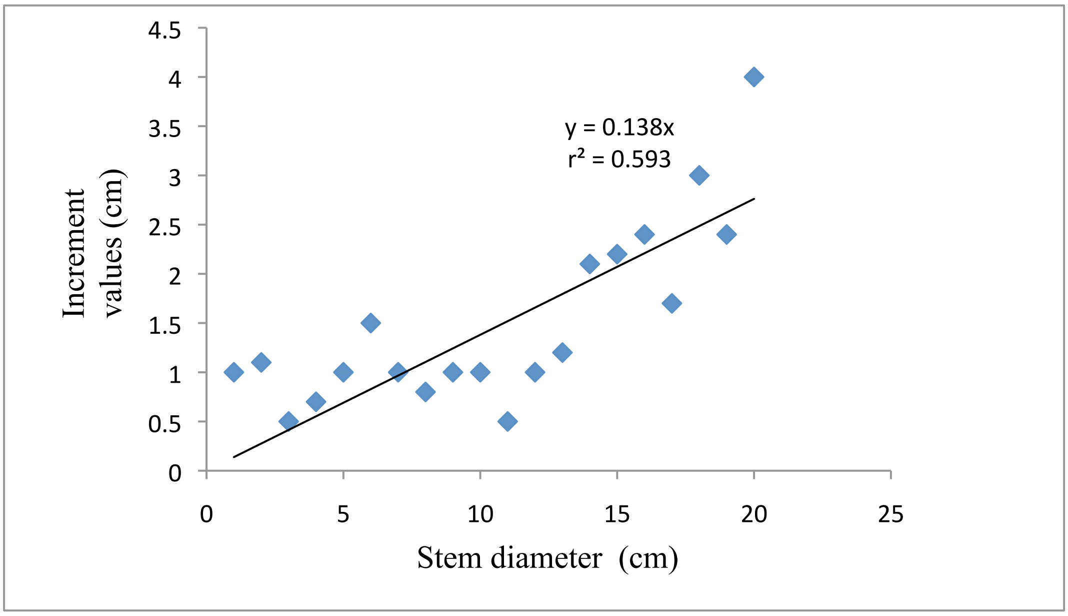

Figure 7.3: *Brackenridgea zanguebarica* annual stem circumference increment of 20 individuals as measured on the Thengwe population outside the Brackenridgea Nature Reserve, Venda region between 2004 and 2005. (Note intercept has been forced through zero).

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

	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)
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 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			
							%	ha				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

		Step 8		Step 9									Step 12			
	Cell	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			
		$1\text{-}C_i$	$A_2 = A_1/(1\text{-}C_i)$ (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

		Step 8		Step 9									Step 12			
	Cell	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)	Cultivatio n	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)								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
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) 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	0.1	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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