CHAPTER 11

General Discussion and Conclusions

The purpose of Chapter 11 is to synthesize the key points and primary conclusions arising from the previous chapters. I have frequently written that the Witwatersrand is a '*multicultural and cosmopolitan centre for African trade and traditional practices*', and described how the emergence of the mining industry in the region shaped the characteristics of the emerging urban population. This influence extended to the emergence of employment opportunities within the formal and informal business sectors, and ultimately the emergence of the Johannesburg metropole as the biggest centre of trade and commerce in Africa. Activities related to traditional healing also emerged and expanded, and the influence of the populations' cultural diversity extended to the diversity of the species used and traded in the region (Williams *et al.* 2000, 2005, in press 1). While Zulus dominate the medicinal plant trade on the Witwatersrand, the requirements of non-Zulu consumers have also contributed to the creation of a supply chain for plants harvested in a number of South African provinces and African countries. In a subsequent study by Williams and Wong (2006) on market networks for medicinal bark in southern Africa, it was established that healers and harvesters have strong ties to customary land, i.e. communal land that is owned and managed under a system of customary tenure. Furthermore, the expatriate community of foreign nationals source many of their medicines from their country of birth. In a study conducted by the Forestry Research Institute of Malawi (FRIM) at the Mwanza border post (SW Malawi) between June and December 2004 for example, 50 Malawians were recorded to be exporting medicinal plants – 90% of whom were destined for South Africa where they were now resident (Meke and Kayambazinthu 2005).

In 'unravelling' the commercial market for medicinal plants in the Witwatersrand, the nature of the links between the stakeholders, trade, harvesting sites and species emerged. In South Africa, commercial harvesters (who are usually not traditional healers) are the principle suppliers of plants to the *muti* shops and market vendors. In 1994, only 14.5% of the plants sold by *muti* shops were actually harvested by the shop owners (Williams *et al.* 2000). Instead, shops relied on, and were supplied by, commercial gatherers going directly to the shops (36.1%) with bags of plants or by vendors in markets such as Faraday Street in Johannesburg and Warwick Street in Durban (40.2%). Some vendors in markets such as Faraday, however, are also gatherers. In 2001, 18.3% of the Faraday traders only harvested the plants they sold, 42.9% only ever bought the plants from gatherers, and 42.9% both bought and harvested the plants they sold (Williams 2003). The ratio of plant material bought and/or gathered, however, can be species-specific. In a study on the trade of *Merwilla plumbea* bulbs conducted by Williams *et al.* (2006), it was found that 79–86% of traders in the *muti* shops (in 1994) and Faraday (in 2001 and 2006) only ever bought the bulbs from gatherers, whereas 3–19% of traders only ever harvested the bulbs themselves. These statistics contrast with the tendency for ≥74% vendors in pre-commercial markets such as Malawi and Zambia to harvest all the plants they sell themselves (Williams and Wong 2006).

Results from the surveys also revealed that KwaZulu-Natal (KZN) is the largest site source for plants sold in the Witwatersrand markets (Williams 2003, 2004; Williams *et al.* 2000). In 1994, 42.1% of plants sold in *muti* shops were harvested from KZN, followed by Gauteng (15.2%) and Limpopo (7.2%). In Faraday in 2001, at least 66.2% of plants had been harvested in KZN. Neighbouring countries are, as previously indicated, a source of traditional medicines. Swaziland and Mozambique were usually the primary source for species that had become scarce in South Africa, e.g. *Warburgia salutaris* and *Siphonochilus aethiopicus*. However, a recent discussion with a shop owner has indicated that Zimbabwe, rather than Swaziland and Mozambique, has become the primary international site source of certain plant products such as *W. salutaris* bark (S. Dorasamy, *pers. comm*.).

By recording the common names ('ethnospecies') of the medicinal plants sold by the *muti* shops and Faraday vendors, inventories of the most commonly available species in commercial trade were compiled. Species identification was primarily achieved through matching the vernacular names to botanical names from previously published studies. In some cases, the species were visually identifiable, or were subsequently identified from purchased specimens. Species identification through published records is problematic, and some errors in identification are known to have occurred. However, this was considered the most expedient mechanism for 'identifying' large numbers of inventoried plants. Therefore, when using the species lists in this thesis, one must be aware of the chance of mistaken identification, and it is the responsibility of the researcher to positively identify the species if the actual identity is critical (e.g. in the case of medical research).

The lexicon of plant names, including orthographic and orthographic variations of the vernacular names, recorded from the survey of 50 *muti* shops was published in 2001 (Williams *et al.* 2001). One purpose for extensively listing the variations in the vernacular names was for using these data to help researchers with species identification. It was common for traders to shorten the orthographic common names of the plants, thus making it difficult to use published lists of species where the correct names were listed. For example, *Cephalaria humilis* is commonly known as uMpikayibone in Zulu, however other names for this species that were recorded include: pigabone, pigayiboni, dira-ga-dibone (Sotho), mpheabonwe and raadeboni.

Following experience gained from the 2001 Faraday market survey, the *muti* shop species inventories were recaptured on a database and combined with the Faraday species inventory to construct a consistent and standardised species list used in the subsequent species diversity and risk assessment analyses. The combined list of species are in Appendices A and B, and are preferred *a propos* species identification. A summary of the taxonomic prevalence of plants traded on the Witwatersrand (shop and Faraday inventories combined) is shown below.

<u>Taxonomic prevalence of plants sold by the shop and Faraday traders</u>
Number of families: 133
Number of genera: 348
Number of species: >550
Ten families with the most genera: Fabaceae (29 genera), Asteraceae (27), Euphorbiaceae (15), Rubiaceae (12), Hyacinthaceae (9), Apocynaceae (8), Rutaceae (7), Amaryllidaceae (6), Apiaceae (6), Iridaceae (6). If one combines the families that comprise Liliaceae *sensu lato*[1], then there were 24 genera in this family
Twelve families with the most species: Asteraceae (49 species), Fabaceae (43), Asphodelaceae (>30), Euphorbiaceae (26), Amaranthaceae (19), Hyacinthaceae (17), Rubiaceae (14), Orchidaceae (12), Celastraceae (10), Apocynaceae (9), Apiaceae (9), Iridaceae (9). There were 74 species in the family Liliaceae *sensu lato*.

Because it was nearly impossible to record and identify every species sold by the shops and street traders given the extensiveness of the surveys, some species were missed during the sampling procedure. Some of these species, subsequently identified, include: *Berula erecta* (Hudson) Cov. (Apiaceae); *Cotyledon orbiculata* L. (Crassulaceae); *Eulophia petersii* Rchb.f. (Orchidaceae); *Gerrardanthus macrorhizus* Harv. Ex Benth. & Hook.f. (Cucurbitaceae); *Gomphocarpus* spp. (Apocynaceae); *Heteromorpha arborescens* (Spreng.) Cham. & Schltdl. (Apiaceae); *Huernia hystrix* (Hook.f.) N.E.Br. (Apocynaceae); *Lithops lesliei* (N.E.Br.) N.E.Br. (Mesembryanthemaceae); *Lycopodiella cernua* (L.) Pic.Serm. (Lycopodiaceae); *Prionium serratum* (L.f.) Drège ex E.Mey. (Juncaceae); *Rumex* sp. (Polygonaceae); *Tarchonanthus camphoratus* L. (Asteraceae); *Tridactyle bicaudata* (Lindl.) Schltr. (Orchidaceae); and *Watsonia* sp. (Iridaceae).

With the broad objective of conducting an ethnobotanical survey of the Witwatersrand medicinal plant trade having been achieved, another objective was to explore and develop methods to quantify and analyse ethnobotanical data. There is evidence of this objective in every chapter, ranging from the stratified random sampling technique used to select survey participants to the statistical analyses of the data. However, novel methods were also employed, some of which were derived from standard techniques used in ecology.

In Chapter 3, the use of species diversity indices to analyse ethnobotanical data was first explored. The success of the preliminary investigation led to the expansion of this idea in Chapter 6, and the subsequent development of a methodology recommended for ethnobotanical surveys of plant species used and/or sold commercially. Twenty-two measures of species richness, diversity and evenness were reviewed using seven data sets, including a data set derived from the study of medicinal plants sold by vendors on the western boundary of the Kruger National Park conducted by a colleague (Dr J. Botha) (Botha 2001). The diversity measures were coupled with species accumulation curves to construct cumulative diversity curves that could be used firstly, to understand the relative diversities of the different samples, secondly appraise plant availability within the *muti* shops and street markets, and thirdly to establish the minimum number of research participants necessary for an ethnobotanical study (Williams *et al.* 2005). Ultimately, seven measures were recommended to describe the richness, diversity and heterogeneity of ethnobotanical samples.

[1] Liliaceae *sensu lato* includes the following families (from Leistner 2000): Agapanthaceae, Alliaceae, Asparagaceae, Asphodelaceae, Colchicaceae, Dracaenaceae, Eriospermaceae, Hyacinthaceae, Luzuriagaceae, and Smilacaeae.

The use of incidence-based species richness estimators, species accumulation curves and similarity measures was another novel approach taken in the quantitative appraisal of the data (Williams *et al.* in press 1). An incentive for this investigation was the availability of public-domain software called *EstimateS* (Colwell 2005). The software had been developed as a way to predict the total species richness of a study site from the richness of samples taken at the site, and was conjectured to be useful in predicting how complete ethnobotanical plant inventories actually are, i.e. how many more species would have been recorded with increased sampling effort. A conclusion from this study was that richness estimation adds value to the description of data sets (especially using *EstimateS*), and that there is merit in applying the techniques to other case studies for further scrutiny. Furthermore, the least one should do with an ethnobotanical data set is plot the sample-based species accumulation and rarefaction curves to compare the richness and density of data at similar levels of sampling effort.

Results from the richness and diversity investigations (specifically, Hill's number N_∞) also highlighted the dominance of approximately 40 and 106 ethnospecies respectively in the sample of 349 and 371 ethnospecies recorded in the Faraday market and *muti* shops respectively (Williams *et al.* 2005a). These ethnospecies were the most prevalent of the plants sold commercially in the shops and market, and the results complemented the methods applied to the measurement of the probability of certain taxa being used and/or sold (Chapter 3, Williams *et al.* 2000). Using Spearman rank correlations, chi-squared and Fisher's exact probability tests with species recorded in the *muti* shops, results indicated that ≈46% of the taxa had a higher than expected probability of being used (in relation to their proportional availability in the southern African flora and biomes). Furthermore, taxa tended to be harvested from the largest families proximate to the markets. Pharmacologically active compounds known to be present in some plant families also resulted in a significantly greater proportion of species per family being sold.

From the volume of plants estimated to be harvested annually (Chapter 9, Williams *et al.* in press 2), it was clear that commercial exploitation of medicinal plants is a major cause of unsustainable resource depletion. Furthermore, the impacts on some species are greater than for others, especially those species that are more prevalent in the markets and/or are slow growing. From the survey conducted in 1994/95 it became evident, for example, that *W. salutaris* bark harvested in South Africa was predictably thinner than bark imported from Mozambique, suggesting that there had been an erosion of the South African resource base and that bigger trees with thicker bark were less accessible to RSA harvesters. Cunningham (1993) once wrote that information on the quantities of traditional medicine harvested is sparse and of little relevance unless expressed in terms of impacts on the species concerned. In 1994, the only quantitative data available on the volumes of plant material sold were from the KZN markets, and were based on the estimated quantities of 50 kg-size bags sold annually by 54 herb traders *circa* 1987 (Cunningham 1988, 1990). Cunningham (1988) also estimated that one 50 kg-size bag of *Ocotea bullata* bark represented three 40-44 cm dbh stems ring-barked to 2 m. This paucity of data relating market information to the condition of the resource base had motivated the study to translate the volumes traded into the number of individual plants estimated to be harvested annually. The concept of 'individual equivalents' was conceived as a way to express the estimates. However, before estimates of the number of individual plants harvested could be made for trees, the relationship between bark thickness and tree size had to be established

Bark is the most popular product harvested for traditional medicine in South Africa. Harvesting is sometimes selective for particular stem size-classes and the effect of bark removal and the sustainability of harvesting practices are species-specific. Baseline autecological data that would assist conservation and trade monitoring efforts are not easily measured and rarely available. In an effort to link bark thickness records obtained from three surveys conducted on the Witwatersrand medicine markets, the relationship between bark thickness and stem diameter at breast height (dbh) was investigated for six species. 1026 bark samples were removed from 207 tree stems. The samples were weighed and measured every week for 12 weeks after being placed in a phytotron chamber to dry out. In the first paper of Chapter 7, the change in bark thickness over time was regressed with stem diameter to predict dbh from bark thickness records (Williams *et al.* in press 3). The strength of the relationship between bark thickness and diameter appeared to be strongly influenced by the macroscopic bark morphology. In species where the outer bark is periodically shed (e.g. *Acacia xanthophloea*), there was no relationship between bark thickness and dbh. In species where the outer bark tends to crack but is not shed (e.g. *W. salutaris*), dbh can be reliably predicted from bark thickness. In the second paper of Chapter 7, the harvestable mass of bark per stem size-class was determined, and regression analyses were used to describe the relationship between bark mass (wet- and oven-dried) and stem diameter (Williams *et al.* in press 4). The results provided a potential means by which the number of trees ring-barked annually could be estimated.

The method of using a 5 cm diameter hole-saw attached to a hand-held brace to remove bark was specifically developed for this study on the advice of my late father, Mr. F.T. Williams. The method differs from an approach commonly taken of removing strips of bark of varying widths and lengths using a hammer and chisel (e.g. Geldenhuys 2004). One advantage of the method applied in this thesis, is that all bark samples are *exactly* the same size and can be efficiently removed. Furthermore, each hole has a centre point and the extent of species-specific wound recovery patterns can be accurately measured later. Such a follow-up study was conducted in 2004 (results not part of this thesis). The trees at some of the original survey sites were located and the wounds were examined and remeasured to estimate the extent of wound recovery and bark regrowth. *Albizia adianthifolia* exhibited the best recovery with 100% (n=91) wound closure, whereas *Balanites maughamii* exhibited the least recovery with 14.4% ± 18.8% wound closure (mean ± SD, n=56) (Williams and Geldenhuys 2004) (Figure 1). These results will be formally written up and published from 2007.

a) 100% wound recovery for *Albizia adianthifolia*

b) 0% wound recovery for a *Balanites maughamii* scar

Figure 1: Examples of the extent of wound recovery for two species six years after the bark was removed.

Having established a methodology for estimating dbh and harvestable bark mass from bark thickness records, the results were applied to the estimation of the size and number of individual tree stems targeted by harvesters between 1995 and 2001. Scenarios for the estimated number of trees debarked were based on: 1) the prevalence of bark of a certain thickness correlated with stem diameter; 2) the mean harvestable bark volume per stem size-class; and 3) the extent of ring-barking (e.g. 10%, 50% or 100% bark removal to 2 m) (Williams *et al.* in press 5). There appears to have been a decline in the availability of thick bark harvested from larger trees between 1995 and 2001, especially for *Elaeodendron transvaalense* and *W. salutaris*. In 1995, the most prevalent bark thickness size-classes for these species was predicted to have been harvested from trees with a dbh >40 cm. By 2001, the bark sold in the markets was usually thinner and most likely harvested from trees with a dbh <20 cm. In terms of predicting the number of 'individual equivalent' trees debarked, and assuming a scenario where stems are 100% ring-barked to 2 m in the 10-19cm dbh size-classes, then the volume of *E. transvaalense* and *W. salutaris* bark sold in Faraday in 2001 would equate to 1,617 and 1,277 individual trees respectively (Williams *et al.* in press 5).

The numbers of individual bulbs harvested annually were also estimated, and this was based on the size-classes of the bulb diameters most prevalent in the markets (Williams *et al.* 2007). Results for the trade in bulbs showed there to be a significant decrease in the size of *Eucomis autumnalis* bulbs sold in the markets between 1995 and 2001 (Williams *et al.* 2007). The diameters of *Drimia* spp. bulbs, the most popular species in the Witwatersrand markets, were also decreasing, but the diameter differences were not significant by 2001. Scenarios for the number of *E. autumnalis* bulbs estimated to be sold in Faraday in 2001 ranged from 34,062 bulbs if all are 6 cm diameter to 69,490 bulbs if all are 4 cm in diameter.

Another method that can be used to estimate the number of bulbs bought annually by traders in the markets, is to establish the mean number of sales of a species per day to customers. Traders usually sell 3-4 bulbs per sale (depending on bulb size) and the annual values can be estimated accordingly. This was the approach used by Williams *et al.* (2006) to estimate the number of *M. plumbea* bulbs sold in the Faraday and Warwick markets in 2006. The number of bulbs predicted to be sold annually in Warwick was ≈1.85 million bulbs! Harvesting of selected resources is therefore clearly not sustainable at current rates, especially if wild populations are small and reproducing slowly.

It was clear from the research that the demand for traditional medicinal plants and products in South Africa has created an extensive cross-border industry involving thousands of harvesters and traders. The market values of individual taxa vary considerably. Pricing structures fluctuate between markets and over time as the cost of harvesting species varies depending on a gatherer's access to the resources and the proximity of markets to the harvesting sites. The paper in Chapter 9 presented estimated trade values for 22 selected species, described the prices paid for these resources, investigated pricing structures relative to the mass/volume sold and the factors that influence the market price for plants (Williams *et al.* in press 2). An important result from this study is that there is an inverse and disproportionate relationship between the price per kilogram (R/kg) and mass of the product sold (kg/S). The smaller the quantity sold, the higher the R/kg sale values are relative to sales of larger quantities. Hence, products such as leaves will usually have a higher R/kg sale value compared to heavier products such as bulbs and tubers. This result has important implications for conservation priority assessments where an assumption is often made that scarce species have a high price relative to the mass sold. A further conclusion from this research was that R/kg and kg/S are better used as indicators of risk/threat within groups of a specific plant part type (e.g. bark, bulbs or roots).

Having thus achieved the objectives of developing methods to quantify ethnobotanical data, assessing species diversity, relating market information to the condition of the resources in the wild (and the change in the condition over time), one of the remaining goals was to integrate the data from the previous chapters and develop a risk assessment model to determine the impact of over-exploitation on indigenous plant resources. Over-exploitation is a deterministic factor in the extinction risks to species. Risk assessments (RAs) are necessary so that species can be categorised according to their relative risks, and conservation priorities set (Frankham *et al.* 2004). There are various tools available to assess the risks and conservation status of species and/or populations. For single species assessments, Population Viability Analysis (PVA) is a form of risk assessment model traditionally used to model the combined impacts of deterministic and stochastic factors to estimate the minimum viable population size and hence predict extinction risks (Burgman *et al.* 1993; Pfab and Witkowski 2000; Frankham *et al.* 2004; O'Grady *et al.* 2004). Additionally, the IUCN Red List categories of threats to species (e.g. Critically Endangered, Endangered or Vulnerable) rank the risks of extinction according to a set of predictive criteria that inform the urgency of conservation measures if conditions that endanger a species prevail (de Grammont and Cuarón 2006; IUCN 2006).

The method developed to assess risks to commercially harvested medicinal plants incorporated aspects of multivariate statistical models traditionally used in ecological risk assessments with methods that incorporated indigenous knowledge and selected biological and ecological traits of the species being exploited. Cluster analysis and principle components analysis were used to identify groups of species that had similar profiles of relative risk, threat and vulnerability to unsustainable over-harvesting and over-utilisation by the medicinal plant trade. The species were then placed into a number of categorical risk hierarchies.

From approximately 392 ethnospecies (>550 species) sold commercially in the Witwatersrand *muti* shops and Faraday market, a short-list of 119 ethnospecies was identified as medium-high risk using eight variables. From this group, a final list of 87 species was selected for more in-depth analysis using ten variables. Four groups of species with three conservation priority profiles ('higher', 'medium' and 'lower') were ultimately identified. Species in the 'higher conservation priority' group were divided into two (Table 1): the first group based on high scores for trade variables (column A), and the second group based on high scores for biological variables (column B). Furthermore, species in column A are sold in very large quantities by a large number of traders and are regarded as the most popular by traders. Species in column B, however, have a higher level of phylogenetic distinctness and more restricted distribution; they also tend to be Red Listed and are most often regarded as scarce by the traders.

Table 1: Thirty-one higher conservation priority species identified as high risk from the assessment of >550 species sold commercially in the Witwatersrand medicinal plant markets. Species in (a) tended to have higher trade variable scores, whereas species in (b) had higher biological variable scores. * species currently classified as 'threatened' by IUCN Red Lists. For a complete list of higher conservation species, see Chapter 10, Table 19.

A	B
Drimia spp.	*Siphonochilus aethiopicus**
Acacia xanthophloea	*Cassipourea* spp.*
Elaeodendron transvaalense	*Stangeria eriopus**
Albizia adianthifolia	*Bowiea volubilis**
Rapanea melanophloeos	*Clivia* spp. *
Trichilia spp.	*Eucomis autumnalis*
Adenia gummifera	*Ocotea bullata*
Helichrysum spp.	*Warburgia salutaris*
Maytenus undata	*Gunnera perpensa*
Schotia brachypetala	*Eriospermum mackenii*
Sclerocarya birrea	*Myrothamnus flabellifolia*
Curtisia dentata	*Callilepis laureola*
Hydnora africana	*Ekebergia capensis*
Hypoxis spp.	*Schlechterina mitostemmatoides*
Merwilla plumbea	
Urginea spp.	
Dioscorea sylvatica	

The methods designed and developed throughout this thesis ultimately meet the goals of the last two study objectives, namely: to short-list priority species sold commercially in the Witwatersrand medicinal plant markets that are most vulnerable to unsustainable harvesting, and to facilitate the selection of taxa that are candidates for further research, management and protection within the ambit of conservation and sustainable utilisation programmes. Species in Table 1 would warrant consideration on South Africa's 'Orange Lists' and possibly even re-evaluation for the Red Lists. Species in Table 1a have either never been evaluated, or were data deficient according the RL criteria. Nine species in Table 1b have been evaluated – four of which were found to be 'Least concern' (*Eucomis autumnalis*, *Ocotea bullata*, *Warburgia salutaris* and *Schlechterina mitostemmatoides*). There is thus clearly a need to make medicinal plants a priority in South Africa given overwhelming evidence in this thesis of unmitigated commercial exploitation of many species.

Among the set of recommendations that have been compiled over the years relating to the conservation of medicinal plants at various international conferences is the need for more information on the medicinal plant trade, and the establishment of systems for inventorying and monitoring the status (i.e. the extinction risks) of medicinal plants (Hamilton 2004). This thesis succeeds in addressing global needs for new information. Furthermore, its primary contribution to science is that it develops and advocates new and quantitative protocols for inventorying and monitoring medicinal species (e.g. bark protocols, diversity indices and risk model), as well as analysing ethnobotanical data in a manner not previously attempted. Moreover, the volume of new information on the trade and conservation of medicinal plants at more than just a single species level is enormous.

And so, what of the future? Within my study area of the Witwatersrand at least, there is no real need to continue conducting extensive surveys of medicinal plants traded in the various sectors of the industry. By-and-large, inventories of plants traded in some of the most important medicinal plant markets in South Africa have been compiled. However, applying the risk assessment methods and other techniques to plants traded in other markets would be of value. The monitoring of selected species is also of great importance, especially if it relates to assessing the condition of the resource in the wild through data collected in the markets (e.g. *M. plumbea* survey by Williams *et al.* 2006). This also appears to be the direction taken by the South African National Biodiversity Institute in terms of their increasing focus on investigating the sustainability of harvesting priority species. These data ultimately inform strategies for commercializing and cultivating medicinal plants. However, future research, especially in conservation initiatives, should also include the participation of the invested stakeholders to avoid the *"loss of a sense of purpose"* for conserving a species amongst the local communities that use, harvest or trade the resource (Hamilton 2004). Failure to do so will intensify the risk factors currently endangering plant populations and impede the potential for successful sustainable harvesting scenarios.

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