CHAPTER 3

The Commercial Market for Medicinal Plants and Plant Parts

UNRAVELING THE COMMERCIAL MARKET FOR MEDICINAL PLANTS AND PLANT PARTS ON THE WITWATERSRAND, SOUTH AFRICA[1]

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Williams, Vivienne L., Kevin Balkwill, and Edward T. F. Witkowski *(Department of Animal, Plant and Environmental Sciences, University of the Witwatersrand, Private Bag 3, WITS 2050, Gauteng, South Africa).* UNRAVELING THE COMMERCIAL MARKET FOR MEDICINAL PLANTS AND PLANT PARTS ON THE WITWATERSRAND, SOUTH AFRICA. *Economic Botany 54(3):310–327, 2000. To unravel the market for commercial medicinal plants on the Witwatersrand in South Africa, a semiquantitative approach was taken. A stratified random sample of 50 herb-traders was surveyed, and an inventory of all plants and parts sold was compiled. Research participants were questioned on the scarcity and popularity of the plants traded, as well as suppliers and origins. The rarefaction method established that the sample size was adequate. The diversity of the sample was determined using ecological indices of diversity, and found to be comparatively high. In addition, Spearman rank correlations, chi-squared and Fisher's exact probability tests were used to assess the probability of certain taxa being used. At least 46% of the taxa traded showed a higher than expected probability of being utilized, and taxa tended to be harvested from the largest families proximate to the markets. About 511 species are traded in the region, and there is a low dominance in the use of species. Ethnic and floristic diversity are influential in deciding the trading patterns that have emerged.*

DÉCOUVRIR LE MARCHÉ DES PLANTES MÉDICINALES ET DES PARTIES DE PLANTES DANS LA RÉGION DU WITWATERSRAND, EN AFRIQUE DU SUD. *Pour découvrir le marché commercial des plantes médicinales et des parties de plantes, nous avons utilisé une approche semiquantitative. Un échantillon pris au hasard, de 50 commerces basé sur une connaissance corporative de ce monde spécifique, et un inventaire de toutes les variétes de plantes offertes à la vente dans ces échopes a été effectuée. Les participants, furent questionnés sur la rareté et la popularité des plantes à l'étalage, ainsi que sur l'origine et les fournisseurs de ces mêmes plantes. La méthode basée sur la raréfaction indiqua que la taille de l'échantillonage était adéquat. La diversité des échantillons fut déterminé en utilisant les indices écologiques, de diversité et se révéla, en comparaison, important. De plus, la corrélation linéaire de Spearman, le test* χ^2*, et les tests de probabilité éxacte de Fisher furent utilisés pout évaluer la probabilité de certaine taxa utilisée. Au moins 46% de la taxa vendue, montre une probabilité supérieure à la moyenne d'être utilisée, et la taxa tend a être récoltée parmi les familles de plantes situées dans la vicinité des lieux de vente. 511 espéces sont à la vente dans la région, et il n'y a pas de dominance particulière sur certaines especes. La présence de plusieurs groupes ethniques et la diversité végétale influence les habitudes commerciales qui constituent la base de l'étude.*

Key Words: ethnobotany; medicinal plants; survey; trade; diversity; biome; harvesting; South Africa.

The trend towards increased commercialization of medicinal plants in South Africa has resulted in overharvesting and, in some cases, near-extinction of some valued indigenous plant species. Several factors have stimulated the rise, including: a rapidly growing and urbanizing Black population, an estimated 80% of whom consult traditional healers (Cunningham 1988); the affordability, accessibility, and acceptability of traditional medicine over western medicine; and a high rate of unemployment and low level of formal education, especially in rural areas. Together, the factors have resulted in the commercial exploitation of economically valuable plants by commercial gatherers to obtain an income (Cunningham 1988). The unemployment rate is high, in part, because job opportunities in

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the formal business sector and in the rural subsistence economy have failed to keep pace with the growing number of new job-seekers (Huntley, Siegfried, and Sunter 1989).

The harvesting of medicinal plants was formerly the domain of trained traditional medical practitioners, renowned for their skills as herbalists and diviners (Cunningham 1991a). Strict customary conservation practices were respected, which regulated plant collection times and quantities. With the advent of urbanization and the consequent commercialization of traditional health care, however, the demand for medicinal herbs has increased. As a result, harvesting has become the domain of untrained, and often indifferent, commercial gatherers with no other income sources. Harvesting and the provision of medicinal plants to meet the urban demand has thus become an environmentally destructive activity.

There is an ecological context within which people interact with plants that goes beyond the query of ''What is the name of this plant and what is it used for?'' (Peters 1996). Some studies in South Africa have focused on recording the customary knowledge and uses of indigenous plants by various communities (e.g., Hutchings 1989, Hutchings and van Staden 1994), while ignoring their economic significance, the extent of commercial harvesting, and the potential impact harvesting has on regional species diversity. There are exceptions, for example, Cunningham (1988), Mander (1997), and Mander, Quinn, and Mander (1997). A question that should be asked is: ''What are the long-term impacts of the actions of the people who use the local flora?'' (Peters 1996).

In February 1994, an investigation was launched to examine the commercial market for medicinal plants in the medicinal markets of the Witwatersrand, South Africa. Included in the objectives of the study was the development of methods to quantify the regional herbal medicine trade. The herb-traders on the Witwatersrand have been quantitatively and qualitatively characterized (Williams, Balkwill, and Witkowski 1997). This paper identifies the species being traded in the region, the plant parts harvested, the suppliers of the plants, and the sources of supply. In addition, the following questions were asked: 1) was sampling adequate; 2) what is the diversity of the sample and is species use equitable; and 3) do certain taxa have a higher than expected probability of being utilized?

Regional Setting

The Witwatersrand is an extensively urbanized complex running along an east-west axis of approximately 100 $\times$ 40 km from Nigel to Randfontein in the province of Gauteng, South Africa (Fig. 1). Urban growth in the area is largely centered around the city of Johannesburg, which is also at the center of an emerging north-south industrial axis (Dauskardt 1994). Traders in traditional medicine in the region can be differentiated into two sectors, namely formal businesses and informal markets. The formal sector is represented by herb-traders, including traditional healers, trading from fixed licensed premises called *umuthi* shops. At the time of the survey in 1994, there were approximately 166 shops. The informal sector, is represented by transient commercial gatherers, hawkers, and traditional healers who sell medicinal plants from the pavements and open markets. There are estimated to be more than 100 gatherers, 75% of which are women from the rural areas of southern Africa.

Methods

Selecting Research Participants

The investigation focused on surveying the formal sector. Therefore research participants were chosen from the 166 *umuthi* shops. Concentrating on the formal sector permitted repeated visits to the research participants. Observations could be subsequently cross-checked if necessary—a difficult task with the transient commercial gatherers. In order for the sample not to be biased in favor of any one sociogeographic group, a stratified random sample of 50 research participants was selected. The participants were proportionately representative of the geographical distribution, ethnicity, and gender of the herb-traders on the Witwatersrand at the time of the survey (Williams, Balkwill, and Witkowski 1997).

Prior to the commencement of the investigation and the final selection of the research participants, it was important to establish a position of credibility and trust with the herb-traders. The objectives, methods, and foreseeable implications and consequences of the research were explained to potential participants. The proposed survey did not anticipate compromising the in-

Fig. 1. Location of the study area, the Witwatersrand, in the province of Gauteng, South Africa.

tellectual property rights of the participants, hence no arrangement for equitable compensation for information was negotiated. After the completion of the survey, however, gifts of information, plants, and elephant dung (requested by the herb-traders) were given in gratitude for the participants' cooperation.

Semiquantitative Survey

Between July and December 1994, a semiquantitative survey of 50 *umuthi* shops was conducted. A complete checklist of all plants and their parts was compiled for each shop. Plant names were recorded in the vernacular. Thereafter, the research participants were asked to nominate plants perceived as being popular and scarce. Questions relating to the suppliers of the plants (e.g., commercial gatherer or wholesaler) and their sources, i.e., the region from which they were harvested (if known), were also asked. Plant use was not directly relevant to the study, hence no participant was asked for the use of any plant on the checklist—an issue that was brought to their attention before the study commenced.

Synthesis

Species Identification

The scientific names for the plants recorded in each *umuthi* shop were determined using the extensive and reliable literature that exists for southern African plant names in Latin and the vernacular. A set of voucher specimens was purchased from one of the *umuthi* shops, and is presently being incorporated into the traditional medicine collection at the Adler Museum of the History of Medicine, University of the Witwatersrand in Johannesburg. The external appearance and features of the plant parts sold under the same name in different shops were consistent throughout the survey, and matched the vouchers in the reference collection at the Adler Museum, except where otherwise indicated. Thus, the scientific names allocated to the plants are, for the most part, reliable. The method of species identification is detailed in Williams, Balkwill, and Witkowski (in press).

Database

Following species identification, the data were entered into a relational database designed in the program DATAEASE by modifying the herbarium management system of the C. E. Moss Herbarium. The botanical names of most species encountered in the study had been entered previously in that system. The data capture format was modified specifically for the entry of the survey records, and the data were entered under the following fields for each species recorded in an *umuthi* shop: a) genus and species number (Genspec No., following Arnold and de Wet (1993)); b) genus and species; c) common names; d) language of the common name; e) traders' opinion of scarcity; f) supplier code; g) source code; h) plant part; i) plant use (if volunteered by the herb-trader); j) additional information (e.g., price, description of the plant, or plant popularity); and k) trader information and code. Herb-traders were given codes denoting the region and order in which they were surveyed, for instance JB30 for Johannesburg Shop 30. The number of records entered for the fifty herb-traders totaled 6285—an average of 126 species per *umuthi* shop.

Following data capture, a complete list of all plant families, genera, and species found to be traded could be extracted from the database. In addition, the number of records of each taxon could be established to determine the most frequently or rarely recorded species. The number of records or citations per taxon were used to quantitatively establish the adequacy of the sample size and diversity of the sample using ecological indices of species diversity.

Adequacy of the Sample Size

In ecological situations where sample sizes (n) differ, rarefaction may be used to allow comparisons of species numbers between communities (Ludwig and Reynolds 1988). Rarefying a sample computes the expected number of species [$E(S_n)$] at different sample sizes, i.e., $E(S_n)$ at n = 50, 100, or 1000, etc. Rarefaction helps to determine how many species [$E(S_n)$] are likely to have been recorded (Krebs 1989) if the sample had consisted of n individuals (citations of species). Therefore, rarefaction may be used to evaluate sampling effort (Begossi 1996). When more individuals are added to the sample and $E(S_n)$ does not increase, then sampling effort is said to be sufficient (Begossi 1996).

Sampling effort can be shown graphically on a rarefaction curve. The expected number of species [$E(S_n)$] is plotted on the y-axis, and the number of citations per species (n) on the x-axis. A leveling off of the curve indicates that increasingly fewer new species are expected to be added to the sample as more *umuthi* shops are sampled. The BASIC program RAREFRAC.BAS (Ludwig and Reynolds 1988), was used to compute $E(S_n)$ at different sample sizes.

Assessing Species Diversity

Three questions were asked: 1) what is the species richness of the sample; 2) what is the diversity of the species sold in Witwatersrand *umuthi* shops; and 3) is there dominance in the use of a few species? Diversity measures take into account two factors: taxon richness (i.e., the total number of taxa, S) and evenness (or "equitability," i.e., how equally abundant the taxa are in the sample). An index of species diversity (also called an index of heterogeneity) incorporates both richness and evenness in a single value and calculates the probability that two species drawn at random from a sample belong to the same species. If the probability is high, then the diversity of the sample is low. The seven ecological measures of species diversity used here are: 1) species richness (S or N0); 2) Simpson's index of heterogeneity (λ); 3) the Shannon-Wiener index (*H*prime); 4) Hill's diversity numbers N1, N2, and $N\propto$; and 5) evenness measure *J*prime. The Shannon-Wiener index is the more widely known diversity measure, and is based on information theory. Hill's diversity numbers give a measure of the "effective number of species present in a sample" (Ludwig and Reynolds 1988). N0 is the number of all species in the sample, N1 is the number of abundant species in the sample, N2 is the number of very abundant species, and $N\propto$ is the number of most abundant species. The indices of richness, heterogeneity, and evenness were computed using the BASIC program SPDIVERS.BAS (Ludwig and Reynolds 1988).

Assessing the Utilization of Species

Exploring causation of species utilization raises the following questions: 1) are taxa concentrated in particular families and biomes, and 2) do certain taxa have a higher than expected probability of being used medicinally? Question one was answered using Spearman's rank correlation coefficients (r_s) (Siegal 1956). The correlations tested the null hypothesis that the ranks of families from the survey were not statistically different from the ranks of corresponding families in the southern African flora and biomes. The families found to be traded medicinally were correlated with: 1) 119 corresponding families of southern African angiosperms, gymnosperms, and pteridophytes, ranked by number of species and infraspecific taxa (Gibbs Russell 1985) (Appendix); and 2) corresponding families represented by more than 1% of the total number of taxa in any one of the six southern African biomes (Gibbs Russell 1987). The biomes analyzed were: Grassland, Savanna, Desert, Nama-Karoo, Succulent Karoo, and Fynbos (Rutherford and Westfall 1986). The flora of the Forest biome and a new biome described as ''before Thicket'' in Low and Rebelo (1996) were not included in the floristic analysis because data were not available in Gibbs Russell (1987).

Question two was answered using Chi-squared (χ^2) 2×2 contingency tables and Fisher's exact probability test. The following null hypothesis was tested: the frequency of species used medicinally per family would not be statistically different from the frequency of occurrence of species in corresponding families in the southern African flora—i.e., that species use is proportional to what is available. The alternative hypothesis was that most families would show a significant difference in the observed frequency. Therefore species use would not be proportional to availability, and could be due instead to the size and the geographical availability of families in the southern African flora and biomes, and/or the presence of desirable pharmacologically active chemicals in different plant families. Chi-square tests were performed on all the families. Where a minimum expected cell frequency of <5 was obtained, Fisher's exact probability test was executed instead.

RESULTS

ADEQUACY OF SAMPLE SIZE

The rarefaction curve for the sample of 511 species and 6285 citations (Fig. 2) indicates that sampling effort was sufficient. This is evidenced by the leveling off of the rarefaction curve to a rate of one new species for every 100 species recorded, or, approximately 1.3 new species for every additional *umuthi* shop surveyed. One would not expect the curve to level off completely, as this would infer that either all plants considered to be medicinally useful have been sampled, or that every taxon sold on the Witwatersrand had been sampled.

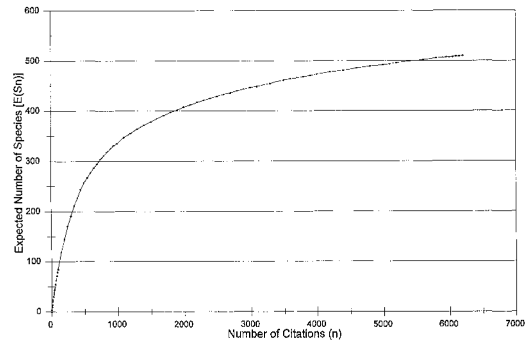

Fig. 2. Rarefaction curve for the sample of Witwatersrand *umuthi* shops, based on number of citations per species. The curve shows the expected number of species [E(Sn)] as a function of n = number of citations/records of all species traded in 50 *umuthi* shops.

SPECIES PRESENT IN THE MARKET

Five hundred and eleven species, representing 328 genera and 119 families (Appendix), were identified and recorded for sale in 50 Witwatersrand *umuthi* shops. A further 70 specimens from the sample remain unidentified. The largest families in trade, by number of genera, are: Fabaceae (28), Liliaceae *sensu lato* (23), Compositae (20), Euphorbiaceae (14), and Rubiaceae (13). Five families contain about 33% of the species and infraspecific taxa traded, namely: Liliaceae *s.l.* (57), Fabaceae (38), Compositae (34), Euphorbiaceae (28) and Amaryllidaceae (15). A study of the taxa traded commercially in South Africa reported similar trends (Mander, Quinn, and Mander 1997). The number of species in the 50 shops surveyed is shown in Fig. 3. The average number of species per shop is 126 ± 65.9 (SD).

Species Commonly Traded

Table 1 lists the most frequently occurring species in the *umuthi* shops surveyed. No species was present in more than 42 of the 50 shops. *Drimia* spp. (bulbs) had the highest recorded frequency of occurrence (82%). Of the

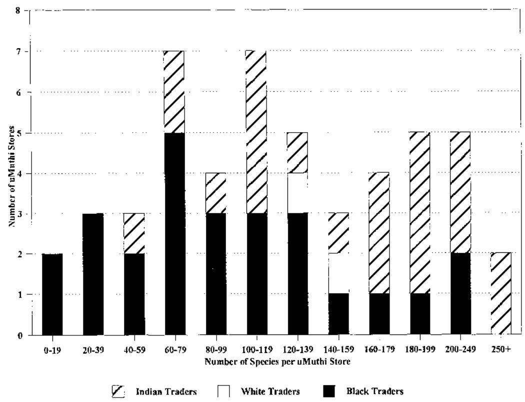

Fig. 3. The number of species identified in the 50 *umuthi* shops surveyed, according to the race-group of the herb-trader. The mean number of species per shop is 126 ± 65.9 (SD). The minimum and maximum number of species recorded in a shop was 10 and 294 respectively.

511 species inventoried, 78 (15.3%) were recorded once in a shop (Fig. 4), and 61 species (11.9%) were recorded twice. By contrast, 36 species (7.0%) occurred in more than 33 of the shops surveyed.

Popular Species

Herb-traders derive a regular income from those species perceived to be "popular"—i.e., in demand, frequently purchased by consumers, and regularly restocked by the traders. Table 2 lists the species most commonly nominated as popular and in demand. These plants have been described as the so called bread-and-butter commodities of the herb trade.

Scarce Species

Table 3 lists species most commonly nominated by ≤10% of the research participants as "scarce," i.e., becoming increasingly unavailable and usually expensive. *Drimia elata* is presently considered only seasonally scarce, whereas *Bowiea volubilis* is a vulnerable species that has become locally extinct in some regions of KwaZulu-Natal (McKean 1993). Of the trees, *Ocotea bullata* is considered the most scarce and is threatened not only by excessive ring-barking and the high price it demands in the *umuthi* trade, but also by forest destruction and the furniture industry (McKean 1993). The populations of *Warburgia salutaris* are few and critically small. *Siphonochilus aethiopicus* was unanimously viewed as the scarcest plant in trade—an opinion verified by the known distribution of the species in South Africa. The species is extinct in the wild in KwaZulu-Natal, except where it appears to be cultivated around homesteads (Mander, Quinn, and Mander 1995).

TRADE IN PLANT PARTS

The plant parts most traded on the Witwatersrand are roots (38.4%), followed by bark (25.6%), leaves/stems (13.5%), and bulbs (10.8%) (Table 4). Combined, the removal of whole plants, roots, and bulbs is 57.3%, compared to 17.1% for aerial parts other than bark. Therefore, the harvesting of almost two-thirds of the species for the Witwatersrand medicinal plant trade will almost always result in plant mortality. These results are similar to those reported by Cunningham (1988) for a survey of the trade in medicinal plants in Durban.

SUPPLIERS

The major suppliers of plants to the Witwatersrand are the commercial gatherers in the informal, open air markets (Table 5). Combined, the Faraday Street market in Johannesburg and the markets of Durban in KwaZulu-Natal account for 40.2% of the trade. Deliveries by gatherers directly to *umuthi* shops account for 36.1% of the supply. The importance of gatherers as suppliers depends on the distance of the *umuthi* shop to the nearest open market—the closer to the open-markets the herb-traders are, the less they rely on door-to-door deliveries by gatherers.

SOURCES OF SUPPLY

Species traded on the Witwatersrand are mainly harvested from the province of KwaZulu-Natal (42.1%) (Table 6) followed by Gauteng (15.2%), the Northern Province (7.2%), Swaziland (6.3%), and Mpumalanga (3.2%). The percentages were calculated as the mean percentage of the species kept by herb-traders said to be harvested from the various regions.

Some regions for which percentage contribution to the source profile is unexpectedly low (e.g., Eastern Cape), may be accounted for in the 21.1% of unknown sources. In addition, some participants were uncertain of the origin of the plants purchased at the Faraday Street and Durban markets, but cited KwaZulu-Natal as a probable source. A re-analysis of the data from

TABLE 1. SPECIES MOST COMMONLY AVAILABLE IN AT LEAST TWO-THIRDS OF THE *UMUTHI* SHOPS ON THE WITWATERSRAND (N = 50 *UMUTHI* SHOPS).

Species	Family	Common name	Plant part	% Traders with species
Drimia spp.[a]	Liliaceae	Skanama	bulb	82
Eucomis autumnalis (Mill.) Chitt.	Liliaceae	uMathunga	bulb	78
Scilla natalensis Planch.	Liliaceae	inGuduza	bulb	78
Elaeodendron transvaalensis (Burtt Davy) R.H. Archer[b]	Celastraceae	iNgwavuma	bark	74
Rapanea melanophloeos (L.) Mez	Myrsinaceae	uMaphipha	bark	74
Acacia xanthophloea Benth.	Mimosoideae	umKhanyakude	bark	70
Clivia spp.[c]	Amaranthaceae	uMayime	bulb	70
Helichrysum spp.[d]	Compositae	iMphepho	leaves/stem	70
Knowltonia bracteata Harv. ex Zahlbr.	Ranunculaceae	umVuthuza	whole plant	70
Thesium pallidum A. DC.	Santalaceae	uMahesaka, red	root	70
Adenia gummifera (Harv.) Harms	Passifloraceae	imPindamshaye	stem	68
Alepidea amatymbica Eckl. & Zeyh.	Umbelliferae	iKhatazo	root	68
several species[e]		uBangalala	root	68
Albizia adianthifolia (Schumach.) W.F. Wight	Mimosoideae	umGadankawu	bark	66
Hypoxis spp.[f]	Hypoxidaceae	iLabatheka	bulb	66
Ocotea bullata (Burch.) E. Mey.	Lauraceae	uNukani	bark	66

[a] Generally *Drimia elata* Jacq. or *D. robusta* Bak.; sometimes *Urginea altissima* (L.f.) Bak., *U. delagoensis* Bak., *U. macrocentra* Bak. and *U. sanguinea* Schinz.
[b] Formerly *Cassine transvaalensis* (Archer and van Wyk 1998).
[c] *Clivia miniata* (Lindl.) Regel and *C. nobilis Lindl.*
[d] *Helichrysum cymosum* (L.) D. Don, *H. decorum* DC., *H. epaposum* Bolus, *H. gymnocomum* DC., *H. natalitium* DC., *H. nudifolium* (L.) Less and *H. odoratissimum* (L.) Sweet.
[e] Identification uncertain, but one of several species is used, including: *Corchorus asplenifolius* Burch., *Eriosema salignum* E. Mey., *Gymnosporia buxifolia* (L.) Szyszyl., *Hippocratea longipetiolata* Oliv., *Rhynchosia* sp., *Salacia krausii* (Harv.) Harv. (M. Mander. pers. com.) and *Tragia meyeriana* Müll. Arg.
[f] Including *Hypoxis colchicifolia* Bak.

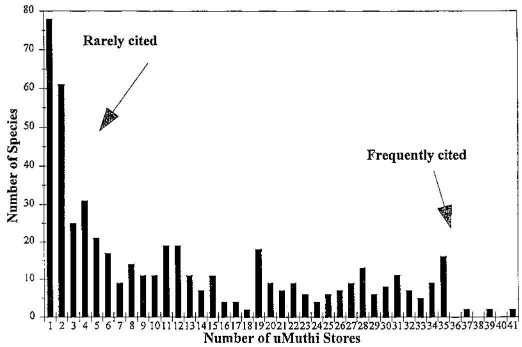

Fig. 4. Relative frequencies of the 511 species recorded for sale in 50 *umuthi* shops on the Witwatersrand. There were 78 species recorded in only one *umuthi* shop, 61 species recorded in two shops, 25 species recorded in three shops, etc.

the Durban and Faraday Street markets revealed that an additional 15.2% of plants could have been harvested from areas other than KwaZulu-Natal, as originally cited. Therefore the origins of 36.3% of the plants are potentially unknown.

Apart from the sale of nonindigenous species grown and harvested in southern Africa, e.g., *Cinnamomum camphora*, species imported from India are present in the market. Asian herb-traders usually import the plants as substitutes for scarce indigenous species or as new medicines. The plants are redistributed through wholesalers and other herb-traders until they reach the Witwatersrand markets. There are approximately 11 imported species on the market at present, including: *jikantambo* (a seed capsule), *mlomomnandi* and *dumaphanzi* (both roots). The scientific names for these species are not known.

Species Richness, Heterogeneity, and Evenness

The richness, heterogeneity, and evenness of species sold on the Witwatersrand are comparatively high (Table 7). The Shannon index (*J*prime = 0.932) suggests that there is a relatively high evenness in the distribution of species in the sample, i.e., that there is a low dominance. Simpson's index (λ) for the Witwatersrand confirmed that the diversity of the sample was high. The probability of two records drawn at random belonging to the same species is low ($\lambda = 3.44 \times 10^{-3}$). Hill's diversity numbers for the effective number of species in the sample corroborate *J*prime. Of the 511 species inventoried, the number of abundant species (N1) in the sample is 335; the number of very abundant species (N2) is 291.

Utilization of Species

The rank correlation between the plant families used medicinally on the Witwatersrand and the southern African flora is significant ($P < 0.001$; $r_s = 0.652$) (Table 8). The results suggest that taxa harvested and used medicinally are associated with the largest southern African floral families. Rank correlations with families in six

Table 2. Species most commonly nominated as 'popular' and in demand.

Species	Common name	Plant part	% Trader opinion of popularity
Eucomis autumnalis (Mill.) Chitt.	uMathunga	bulb	16
Helichrysum spp.[a]	iMphepho	leaves/stem	14
Drimia spp.[b]	Skanama	bulb	14
Scilla natalensis Planch.	inGuduza	bulb	14
Dianthus mooiensis F.N. Williams[c]	Tjanibeswe	whole plant	12
Warburgia salutaris (Bertol. f.) Choiv.	isiBhaha	bark	8
Peucedanum magalismontanum Sond[d]	iBheka	whole plant	8
Elaeodendron transvaalensis (Burtt Davy) R.H. Archer[e]	iNgwavuma	bark	6
Gunnera perpensa L.	uGopho	root	6
Rapanea melanophloeos (L.) Mez.	uMaphipha	bark	6

[a] *Helichrysum cymosum* (L.) D. Don, *H. decorum* DC., *H. epaposum* Bolus, *H. gymnocomum* DC., *H. natalitium* DC., *H. nudifolium* (L.) Less and *H. odoratissimum* (L.) Sweet.

[b] Generally *Drimia elata* Jacq. or *D. robusta* Bak.; sometimes *Urginea altissima* (L.f.) Bak., *U. delagoensis* Bak., *U. macrocentra* Bak. and *U. sanguinea* Schinz.

[c] In KwaZulu/Natal the species *Dianthus zeyheri* Sond. is used and is called iNingizimu.

[d] In KwaZulu/Natal the species *Scabiosa columbaria* L. is used as iBheka.

[e] Formerly *Cassine transvaalensis* (Archer and van Wyk 1998).

TABLE 3. SPECIES NOMINATED AS SCARCE BY 10% OR MORE OF THE RESEARCH PARTICIPANTS.

Species	Common name	Plant part	% Trader opinion of scarcity
Siphonochilus aethiopicus (Schweinf.) B.L. Burtt	isiPhepetho	root	66
Eucomis autumnalis (Mill.) Chitt.	uMathunga	bulb	36
Bowiea volubilis Harv. ex Hook. f.	iGibisile	bulb	26
Drimia spp.[a]	Skanama	bulb	24
Ocotea bullata (Burch.) E. Mey.	uNukani	bark	24
Synaptolepis kirkii Oliv.	uVuma, white	root	22
Brackenridgea zanguebarica Oliv.	mutavhasindi	root	20
Stangeria eriopus (Kuntze) Baill.	imFingo	tuber	18
Cinnamomum camphora (L.) J. Presl[b]	uRoselina	bark	14
unconfirmed species[c]	bangalala	root	14
Warburgia salutaris (Bertol. f.) Choiv.	isiBhaha	bark	12
unconfirmed species	uSilephe	root	12
Scilla natalensis Planch.	inGuduza	bulb	12
Alepidea amatymbica Eckl. & Zeyh.	iKhatazo	root	10
Pappea capensis Eckl. & Zeyh.	uVuma, red	root	10

[a] Generally *Drimia elata* Jacq. or *D. robusta* Bak.; sometimes *Urginea altissima* (L.f.) Bak., *U. delagoensis* Bak., *U. macrocentra* Bak. and *U. sanguinea* Schinz.

[b] Exotic.

[c] Identification uncertain, but one of several species is used, including: *Corchorus asplenifolius* Burch., *Eriosema salignum* E. Mey., *Gymnosporia buxifolia* (L.) Szyszyl., *Hippocratea longipetiolata* Oliv., *Rhynchosia* sp., *Salacia krausii* (Harv.) Harv. (M. Mander, pers. com.) and *Tragia meyeriana*.

[f] Including *Hypoxis colchicifolia* Bak.

southern African biomes indicate that taxa used medicinally on the Witwatersrand have more in common with the Savanna (P = 0.048, r_s = 0.45) (Table 8) than the other biomes. The results suggest a tendency for species to be harvested from the biomes proximate to the markets (Fig. 6) and from taxa common in biomes in the regions from which the commercial gatherers harvest (Table 6) and with which they are familiar.

Seventy-two (61%) of the plant families investigated exhibited significant differences in the observed proportion of species used per family when compared to the southern African flora. Species utilization, therefore, is not proportional to availability for these families. Only 46 families (39%) showed no significant differences in their observed frequencies. Species utilization, therefore, is hypothesized to be proportional to their availability. The families can be subdivided into four groups depending on the statistical significance of the χ^2 and Fisher's exact probability tests (Fig. 5, Tables 9, 10). The rank of the families in the proximate biomes of the Savanna and Grassland are included in the comparison be-

TABLE 4. THE NUMBER AND PERCENTAGE OF PLANTS FOR WHICH PARTICULAR PLANT PARTS ARE TRADED.

Plant part	Number of plants	Percentage of plants
Roots (incl. ligno-tubers)	227	39.3
Bark	148	25.6
Leaves and stems	78	13.5
Bulbs	61	10.6
Whole plant	43	7.5
Fruit	12	2.1
Seeds	6	1.0
Flowers	3	0.5

TABLE 5. SUPPLIERS OF MEDICINAL PLANTS TO THE WITWATERSRAND HERB-TRADERS.

Suppliers	% Supplying the trade*
Commercial gatherers delivering directly to shops	36.1
Faraday Street market gatherers	31.2
Herb-traders gathering own plants	14.5
Durban market gatherers	9.0
Wholesalers	4.5
Farmers	2.9
Mai Mai Bazaar	0.2
Unknown	1.6

* Calculated from the total number of citations (n = 6285).

TABLE 6. REGIONAL SOURCES OF PLANTS HARVESTED FOR THE TRADE, BASED ON THE MEAN PERCENTAGE OF SPECIES HARVESTED PER REGION PER HERB-TRADER.

Province or country	Percentage
KwaZulu/Natal	42.1
Gauteng	15.2
Northern Province	7.2
Swaziland	6.3
Mpumalanga	3.2
North West	2.0
Lesotho	0.8
Free State	0.7
Eastern Cape	0.6
India	0.4
Botswana	0.3
Western Cape	0.05
Northern Cape	0.03
Mozambique	0.02
Unknown	21.1

TABLE 8. RESULTS OF THE SPEARMAN RANK CORRELATION (r_s) BETWEEN: 1) 119 FAMILIES USED MEDICINALLY AND CORRESPONDING FAMILIES OF SOUTHERN AFRICAN FLORA; AND 2) FAMILIES OF MEDICINAL FLORA AND FAMILIES THAT REPRESENT MORE THAN 1% OF THE TOTAL NUMBER OF TAXA IN A PARTICULAR BIOME.

Level of correlation	Correlation coefficient (r_s)	*P*	n
Southern Africa	0.652	<0.001	119
Savanna	0.447	0.048	20
Grassland	0.373	0.104	20
Succulent Karoo	0.359	0.139	18
Fynbos	0.349	0.119	21
Nama-Karoo	0.317	0.121	22
Desert	0.085	0.697	22

cause they can partially explain under- and over-utilization of certain taxa.

Group I families (Table 9) showed no significant differences in the observed frequency of occurrence of species per family. Therefore, the number of species used is proportional to the number of species available. Most of the families, especially the Fabaceae, showed similarly high rankings in the sample and the Savanna and Grassland biomes. Group II families (Table 9) exhibited significant differences in their observed frequencies, however the proportion of species utilized per family was either higher than expected (e.g., Euphorbiaceae and Liliaceae *s.l.*) or lower than expected (e.g., Poaceae and Mesembryanthemaceae). The rank of most of the families in Savanna and Grassland was relatively high, except for Mesembryanthemaceae, which is represented by few species in the Savanna biome (Gibbs Russell 1987).

Group III families (Table 10) demonstrate significant differences in their observed frequencies and there are proportionately more species utilized per family than expected. In addition, the families are either not ranked in the Savanna and Grassland (i.e., the families are represented by less than 1% of the total number of taxa in the biome) or, they are ranked very low, e.g., Anacardiaceae. Group IV families (Table 10) exhibit significant differences in their observed frequencies of occurrence and the number of species used are proportional to their availability. The families are either not ranked or they are absent from the Savanna and Grassland.

TABLE 7. COMPARISONS OF SPECIES RICHNESS, HETEROGENEITY AND EVENNESS FOR THE WITWATERSRAND, AND SELECTED STUDIES[1]

Index/measure	Witwatersrand n = 50 herb-traders 6285 citations	Tonga n = 50 informants 2037 citations	Mexico n = 106 informants 2727 citations	Peru n = 29 informants 1383 citations
Species Richness				
# Species (S or N)	511	105	335	472
Indices of Heterogeneity				
Shannon-Wiener (H′)[2]	5.81	4.49	5.16	5.95
Evenness Index				
Shannon (J′)	0.93	0.97	0.89	0.97

[1] Source: Begossi (1996).
[2] Log_e.

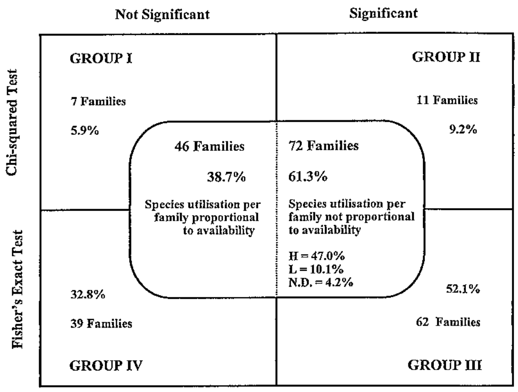

Fig. 5. The 119 families used medicinally on the Witwatersrand can be divided into 4 groups, depending on whether there is a statistically significant under- or over-utilisation or not, and on the statistical test used. H = proportionately more species used per family; L = proportionately fewer species used per family; N.D. = not determined.

DISCUSSION

ADEQUACY OF SAMPLING

The sampling strategy chosen for the survey and the stratified random sample of 50 herb-traders selected, constituted an adequate and representative sample of the herb-traders on the Witwatersrand at the time of the survey. The results obtained from the rarefaction method indicate that the results of the survey are not an artifact of a small and inadequate sample size or unrepresentative research participants.

The inventory interview process was appropriate for establishing the suppliers of the plants in stock and the sources of supply. However, it was not entirely suitable for eliciting an adequate response from participants on the perceived scarcity and popularity of the plants traded. For the most part, the participants' opinions were based on plants in the shop during the interview. Therefore, potentially scarce species that were not in stock were overlooked. Thus the results in Tables 2 and 3 underestimate the per-

TABLE 9. COMPARISON[1] OF THE OBSERVED FREQUENCIES OF SPECIES IN SELECTED FAMILIES OF THE SURVEY DATA WITH SOUTHERN AFRICAN FLORA—GROUPS I AND II. THE RANK OF THE FAMILIES IN THE SAVANNA, GRASSLAND AND SAMPLE ARE INCLUDED IN THE COMPARISON.

			No. of species in family		Family rank		
Family	χ^2	P	Survey (n = 495[2] spp.)	S. Africa (n = 22,604 spp.)	Savanna[3]	Grassland[4]	Survey[5]
GROUP I							
Fabaceae	0.019	NS	38	1802	2	3	2
Lamiaceae	0.002	NS	5	257	11	9	14
Orchidaceae	<0.001	NS	10	480	14	8	9
Rutaceae	0.005	NS	6	306	NR	NR	13
GROUP II							
Asclepiadaceae	3.167	* L	11	892	9	7	8
Campanulaceae	3.310	* L	1	273	NR	NR	18
Compositae	5.875	* L	34	2417	3	1	3
Euphorbiaceae	19.881	*** H	28	526	8	12	4
Iridaceae	8.397	*** L	8	1024	17	10	11
Liliaceae *sensu lato*	33.834	*** H	57	1142	5	4	1
Mesembryanthemaceae	51.371	*** L	3	2684	NR	13	16
Poaceae	9.703	** L	6	955	1	2	13
Proteaceae	2.947	* L	3	392	NR	NR	16
Rubiaceae	12.287	*** H	14	236	4	11	7
Scrophulariaceae	6.315	* L	3	568	10	6	16

[1] The χ^2 test was applicable to all the families listed in the table because expected cell frequencies were >5.
[2] = Total no. spp. was 511, but the angiosperms were analysed separately from the gymnosperms and pteridophytes (total no. of species = 16).
[3] Highest rank given for a family = 21.
[4] Highest rank given for a family = 23.
[5] Highest rank given for a family = 18.
χ^2 = chi-square, NS = not significant, * = $P < 0.05$, ** = $P < 0.01$, *** = $P < 0.001$, NR = no rank available for the family, H = proportionately more species used per family than expected, L = proportionately fewer species used per family than expected.

TABLE 10. SELECTED[1] COMPARISON OF FREQUENCIES OF SPECIES IN FAMILIES OF THE SURVEY DATA AND SOUTHERN AFRICAN FLORA—GROUP III FAMILIES. THE RANK OF THE FAMILIES IN THE SAVANNA, GRASSLAND AND SAMPLE ARE INCLUDED IN THE COMPARISON.

Family	Fishers exact probability	No. of species in family: Survey (n = 495 spp.[2])	No. of species in family: S. Africa (n = 22,604 spp.)	Family rank: Savanna[3]	Family rank: Grassland[4]	Family rank: Survey[5]
GROUP III						
Amaryllidaceae	***H	15	205	NR	16	5
Anacardiaceae	***H	5	120	20	20	14
Apiaceae	***H	9	221	NR	18	10
Apocynaceae	***H	9	41	NR	NR	10
Capparaceae	***H	5	63	NR	NR	14
Carophyllaceae	***H	6	66	NR	NR	13
Celastraceae	***H	13	59	NR	NR	7
Combretaceae	***H	7	49	NR	NR	12
Ebenaceae	***H	7	51	NR	NR	12
Flacourtiaceae	***H	6	26	NR	NR	13
Lauraceae	***H	5	13	NR	NR	14
Loganiaceae	***H	6	24	NR	NR	13
Meliaceae	***H	5	17	NR	NR	14
Polygalaceae	***H	9	210	NR	NR	10
Rhamnaceae	***H	5	203	NR	NR	14
Rutaceae	***H	6	306	NR	NR	13
Sapotaceae	***H	6	14	NR	NR	13
Solanaceae	***H	7	98	NR	22	12
Thymelaeaceae	**H	5	199	NR	NR	14

[1] The χ^2 test was not applicable to the families listed in this table because expected cell frequencies were <5, therefore Fishers exact probability test was used. Only families with >5 spp. were included in the table.
[2] = Total no. spp. was 495, but the angiosperms were analysed separately from the gymnosperms and pteridophytes (total no. of species = 16).
[3] Highest rank given for a family = 21.
[4] Highest rank given for a family = 23.
[5] Highest rank given for a family = 18.
NR = no rank available for the family, ** = $P < 0.01$, *** = $P < 0.001$, H = proportionately more species used per family than expected.

centage of traders that would regard species as being scarce or popular. On average, each trader only mentioned five scarce or popular species and because there is a large number of species in trade, it is a good indication of potential popularity even if only 16% of the herb-traders nominated a particular species as being popular. Ideally, a checklist of all plants cited as scarce and popular should be returned to all participants to more decisively establish the trends in trader opinion.

SPECIES PRESENT IN THE MARKET

A starting point for unraveling and understanding the commercial market for medicinal plants on the Witwatersrand is knowing what species are traded commercially. Many more species are used than have been identified in this study. However, knowing what taxa are sold, the extent to which they are traded, and the perceived scarcity and popularity of these plants are starting points for conservation action and evaluating potentially threatened species. In addition, the number of species traded can be an indicator of the size of the regional market and the diversity of the supply and demand. On the Witwatersrand, the diversity of demand is largely a result of the ethnic diversity of the traditional healers, consumers, and commercial gatherers.

In addition to reflecting the ethnic diversity of the consumers near a market, the demand, popularity, and presence of species can reflect regional differences in the health needs of users and the distribution of the plants. Historical ethnic differences in utilization are evident on the Witwatersrand. *Brackenridgea zanguebarica* bark, for example, is better known to the Venda people of the Northern Province than to Zulus from KwaZulu-Natal (KZN). *Dianthus mooiensis,* widespread in the Gauteng grasslands and popular in the Witwatersrand markets, is largely unknown in the KZN markets. A related species, *Dianthus zeyheri*, is used instead.

The number of species traded can reflect regional market variations. Cunningham's (1988) survey, for example, indicated that more than 400 species are sold commercially in the urban markets of KZN. Hutchings (1996), however, identified 1032 species used by Zulus in KZN. Therefore, not all species used have commercial value. A survey by Mander, Quinn, and Mander (1997) indicated that about 550 species are likely to be traded in South Africa—a further 200 species are infrequently traded, if at all. On the Witwatersrand, approximately 78 of the 511 species identified are likely to be commercially less important because they were recorded in only one *umuthi* shop, and the national commercial trade is unlikely to be extensive for these species. Speculative harvesting by commercial gatherers may be a reason for their appearance in the market.

Despite the response of research participants to the perceived scarcity and popularity of the plants in trade, species in Tables 2 and 3 can be seen as ''indicator'' species. The knowledge of resource users provides valuable insight into the scarcity of medicinal plants (Cunningham 1988). This qualitative knowledge has been gained from years of harvesting, buying, and selling plants, and can be tested against current knowledge of population size and rarity (Cunningham 1988). There is a realistic concern that plants in Table 3 are indicators of species that are currently scarce and threatened (e.g., *Warburgia salutaris*), or will become scarce and threatened in the future (e.g., *Helichrysum* spp.). Continued removal of large quantities of these plants to supply the herb-trader's demands might not be sustainable.

Trade in Plant Parts

There is a clear relationship between the plant part being harvested, the impact on the plant, and the degree of disturbance to the population (Cunningham 1988). The removal of whole plants, bulbs, roots, and bark has a more immediate and damaging effect than the harvesting of leaves and fruit (Cunningham 1988). Harvesting roots or whole plants usually results in plant mortality. If the entire root is removed before the plant has gone to seed, it effectively ends the possibility of future growth and regeneration of that individual (Sheldon, Balick, and Laird 1997). The damage caused by partial removal of the roots drastically reduces water uptake and increases the susceptibility to fungal diseases, which can lead to mortality. Bark collection is not always detrimental to trees, but ring-barking potentially inhibits long-term growth and/or reproductive fitness. Depending on the resilience of a species to persistent and extensive bark-removal, mortality is possible. The harvesting of aerial parts does not always result in mortality because leaves and fruit are considered renewable (Sheldon, Balick, and Laird 1997). In general, harvesting may cause mortality, inhibit growth, and extend the time taken to reach critical life stages, or have no discernible adverse consequences. Plant productivity and sustainable utilization are contingent on the severity of harvesting practices.

Suppliers and Sources

The demand for traditional medicines in urban areas has led to the development of a substantial network of rural commercial gatherers, herb-traders, traditional healers, and consumers. Plants harvested from wild populations in rural and urban areas are transported nationally and from abroad into the city for resale and consumption. Prior to the establishment of the Faraday Street market circa 1992, commercial gatherers sold plants directly to *umuthi* shops. Faraday subsequently expanded from about 10 to 100+ gatherers and this has significantly changed the supplier profile. Most noticeable has been the decline in the number of gatherers delivering directly to *umuthi* shops and a corresponding increase in the number of traders having to travel to the markets. One result has been to increase the herb-traders' costs.

A small percentage of research participants, mostly traditional healers, harvest some of the plants they sell. What they don't gather themselves, they purchase from the commercial gatherers. A few Asian traders surveyed regularly drove to the traditional medicine markets in Durban in KZN (about 570 kilometers away) to buy plants. They thought Durban markets had a better range and larger volume of plants available and were less dangerous to visit.

The cultural diversity of the Witwatersrand's consumers, traditional healers, commercial gatherers, and traders is partly responsible for the localities that plants are harvested from. People living in the metropolis have ethnic ties to cer-

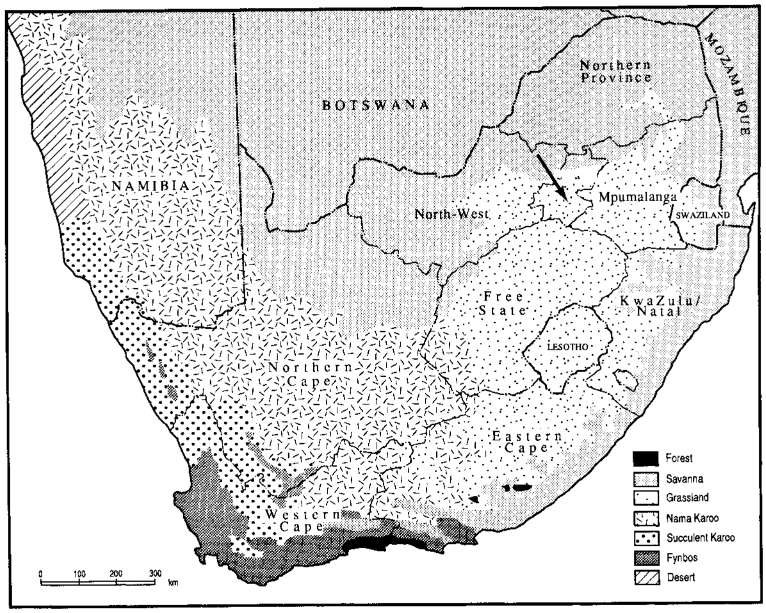

Fig. 6. Distribution of southern African biomes. Adapted from Rutherford and Westfall (1994), Low and Rebelo (1997). Study area marked with an arrow (see Fig. 6.).

tain provinces in South Africa, e.g., Zulus to KZN. Therefore, the demand created by ethnic diversity stimulates commercial harvesting from localities with medicinal plants known to the resource user. Despite the prevalence of other ethnic groups in the Witwatersrand (e.g., Sotho et al.), Zulu traditional medicines harvested in KZN predominate in the market.

Species Diversity

The large floristic diversity of plants traded commercially on the Witwatersrand is probably due to 1) the richness and diversity of the southern African flora; 2) the regional ethnic diversity; and 3) the wide geographical area from which the plants are harvested (Table 9). The high equitability, or low dominance, in the use of species may be ascribed to: 1) the high richness of the taxa traded and 2) the number of species used medicinally, compared to the number with commercial value. In KZN, about 40% of the taxa used are traded commercially. A market has, therefore, developed over time for a suite of plants with commercial value. On the Witwatersrand, an estimated 335 species (N1–66% of the sample) constitute a large core group of plants that are traded regularly.

A study of the diversity of species utilization in South America and Asia (Begossi 1996), showed that utilization diversity in Tonga, for example, was low—despite an adequate sample size (Table 8). The evenness of use for Tonga was higher than for the current study. Peru, by contrast, demonstrated high levels of richness, heterogeneity, and evenness (472; 5.95; and 0.97 respectively) despite a small sample size. Mexico, on the other hand, showed lower values for the diversity of species use and a higher dominance (*J*prime = 0.89). High diversity of plant use in Mexico and Peru was ascribed to high diversity of the vegetation in the study sites (Begossi 1996). In Tonga low diversity was probably a representation of the island nation's low floristic diversity.

Probability of Species Utilization

There is a positive association between plants sold commercially and the size and distribution of southern African floral families. Larger families occurring in biomes proximate to the market and the geographical sources of supply have a greater probability of being harvested.

Taxa in the Savanna have a greater probability of being utilized for several reasons. First, the biome is the largest in southern Africa south of 22°S, occupying about 46% of the total area

(Low and Rebelo 1996) (Fig. 6). Second, taxa harvested in the Savanna account for about 48% of the cited sources. And third, it appears that resource users, commercial gatherers, and their antecedents historically inhabited the biome—hence the disproportionate use of species even today. Parts of woody plants (e.g., roots and bark), not geophytes and grasses common to Grassland, predominate in the market, thus the plant parts most commonly harvested (Table 4) corroborate evidence that Savanna is highly traded.

Taxa in Grassland have a lower than expected probability of being utilized considering the study area is at its geographic center (Low and Rebelo 1996). Taxa harvested in Grassland account for about 31% of the cited sources. However, the biome shares 60% of its taxa with Savanna (Gibbs Russell 1987) and only covers about 17% of southern Africa. Therefore, although Savanna appears to be the most utilized biome, it is not necessarily the most threatened by commercial harvesting. Urbanization is a major influence on the loss of natural areas (Low and Rebelo 1996). Gauteng grasslands are especially threatened by extensive urban development, industrialization, mining and, to a lesser extent, agriculture (Bredenkamp and van Rooyen 1996).

The use of and demand for traditional medicines can be species specific and alternatives are not easily provided due to the characteristics of the plant material, their symbolism, and the form in which they are taken (Cunningham 1991b). African people have depended for ages on their natural environment for their health and survival (Mabogo 1990). This dependence has developed from centuries of experimentation with the flora available to them. The lack of scientific proof of the efficacy of (some of) the medicines does not necessarily mean that the medicines used are not valuable (Mabogo 1990).

Thirty-nine percent of the taxa sold commercially (Groups I and IV) exhibit no significant differences between their observed and expected frequencies. Utilization, therefore, is likely to be proportional to their availability in the southern African flora and biomes, and random—i.e., the taxa have an equal chance of being harvested.

Evidence suggests that 46% of the taxa traded commercially have a higher than expected probability of being utilized (Group III and some Group II). There thus appears to be specific factors determining the utilization, selection, harvesting, and commercial value of species in these families by the traditional health care profession, the commercial gatherers, and the market. Pharmacologically active chemical compounds present in Group II and III families may partially explain utilization (especially in Group II where the families are smaller and geographical distribution is not as extensive as some Group III families). Overutilization of some Group II families is possibly the result of large family size and their prevalence in Savanna and Grassland. Families that are underutilized may have limited representation in the vegetation types proximate to the major harvesting sources (e.g., Mesembryanthemaceae) or they may be chemically inert. Poaceae, for example, is ranked 1 and 2 in Savanna and Grassland respectively, yet only six species are traded. The family may be under-represented because its high availability has eroded its commercial value.

CONCLUSION

Knowing what species are traded commercially is the foundation for identifying threatened taxa and comparing regional and national medicinal markets. Furthermore, understanding the dynamics of the trade and factors influencing supply and demand are steps towards identifying solutions and survey methods for setting priorities and goals for sustainable development.

In unraveling the commercial market for medicinal plants on the Witwatersrand, a trend emerges. The trend is that ethnic and floristic diversity are influential in deciding the sources and suppliers of plants and the high diversity and equitability of species that are traded. In addition, the diversity and geographic distribution of southern African taxa are partly responsible for at least 46% of the families traded having higher than expected probabilities of being utilized.

Finally, in this survey of the Witwatersrand medicinal plant market, quantitative methods and techniques rarely attempted by ethnobotanists were used to collect and analyze data. In the process, the results were statistically validated, and new questions relating to the pattern of plant utilization and trade were answered with more confidence.

Acknowledgments

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APPENDIX. MEDICINAL PLANT FAMILIES OF THE UMUTHI SHOPS. LIST OF THE 119 PLANT FAMILIES RECORDED FOR SALE IN 50 *UMUTHI* SHOPS ON THE WITWATERSRAND, SOUTH AFRICA BETWEEN JULY AND DECEMBER 1994. FIVE HUNDRED AND ELEVEN SPECIES REPRESENTING 326 GENERA WERE RECORDED.

Family	Number of genera	Number of species and infra-specific taxa
ANGIOSPERMS		
Acanthaceae	2	2
Aizoaceae	2	2
Amaranthaceae	3	3
Amaryllidaceae	6	15
Anacardiaceae	5	5
Annonaceae	2	3
Apocynaceae	5	9
Aquifoliaceae	1	1
Araceae	2	2
Araliaceae	1	1
Asclepiadaceae	7	11
Balanitaceae	1	1
Balanophoraceae	1	1
Basellaceae	1	1
Begoniaceae	1	2
Bignoniaceae	1	1
Boraginaceae	2	2
Brassicaceae	1	1
Burseraceae	1	3
Buxaceae	1	2
Cactaceae	1	1
Campanulaceae	1	1
Canellaceae	1	1
Capparaceae	3	5
Carophyllaceae	2	6
Celastraceae	9	13
Chenopodiaceae	1	2
Chrysobalanaceae	1	1
Combretaceae	2	7
Commelinaceae	1	1
Compositae/Asteraceae	20	34
Convolvulaceae	3	4
Cornaceae	1	1
Crassulaceae	1	2
Cucurbitaceae	1	1
Cunoniaceae	1	1
Dioscoreaceae	1	3
Dipsacaceae	2	2
Ebenaceae	2	7
Euphorbiaceae	14	28
Flacourtiaceae	5	6
Geraniaceae	2	2
Graminae	2	6
Greyiaceae	1	1

APPENDIX. CONTINUED.

Family	Number of genera	Number of species and infra-specific taxa
Haloragaceae	1	1
Guttiferae	2	3
Hydnoraceae	1	1
Hypoxidaceae	1	4
Icacinaceae	1	1
Iridaceae	6	8
Labiatae/Lamiaceae	4	5
Lauraceae	3	5
Lecythidaceae	1	1
Leguminosae-Caesalpinioideae	7	7
Leguminosae-Mimosoideae	5	11
Leguminosae-Papilionoideae	16	20
Liliaceae sensu lato	23	57
Loganiaceae	3	6
Loranthaceae	1	1
Malpighiaceae	1	2
Malvaceae	2	3
Martyniaceae	1	1
Meliaceae	3	5
Melianthaceae	1	4
Mennispermaceae	1	1
Mesembryanthemaceae	3	3
Moraceae	1	1
Myricaceae	1	1
Myrothamnaceae	1	1
Myrsinaceae	3	3
Myrtaceae	2	2
Nymphaceae	1	2
Ochnaceae	2	3
Olacaceae	1	2
Oleaceae	1	1
Oliniaceae	1	2
Orchidaceae	7	10
Passifloraceae	2	2
Pedaliaceae	1	1
Periplocaceae	2	2
Phytolaccaceae	1	2
Pittosporaceae	1	1
Plumbaginaceae	1	1
Polygalaceae	2	9
Polygonaceae	1	2
Portulacaceae	2	2
Proteaceae	2	3
Ptaeroxylaceae	1	1
Ranunculaceae	3	4
Rhamnaceae	5	5
Rhizophoraceae	1	2
Rosaceae	2	3
Rubiaceae	13	14
Rutaceae	5	6
Santalaceae	2	2

APPENDIX. CONTINUED.

Family	Number of genera	Number of species and infra-specific taxa
Sapindaceae	4	4
Sapotaceae	3	6
Scrophulariaceae	3	3
Solanaceae	3	7
Sterculiaceae	2	2
Thymelaeaceae	2	5
Tiliaceae	2	3
Typhaceae	1	1
Ulmaceae	2	2
Umbelliferae/Apiaceae	5	9
Verbenaceae	3	4
Viscaceae	1	1
Vitaceae	1	2
Zingiberaceae	1	1
Zygophyllaceae	1	1
Total	313	495
GYMNOSPERMS		
Cupressaceae	2	2
Pinaceae	1	1
Podocarpaceae	1	1
Stangeriaceae	1	1
Zamiaceae	1	1
Total	6	6
PERIDOPHYTA		
Adiantiaceae	2	4
Aspidaceae	1	2
Cyathaceae	1	1
Equisetaceae	1	1
Lycopodiaceae	1	1
Polypodiaceae	1	1
Total	7	10