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Trade in commonly used medicinal bulbs: value and ecological implications

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Trade in commonly used medicinal bulbs: value and ecological implications



Vanessa Jean Brueton

A research dissertation submitted to the Faculty of Science, University of the Witwatersrand, Johannesburg in fulfilment of the degree of Master of Science

DECLARATION

Johannesburg, October 2013

I declare that this dissertation is my own, unaided work. It is being submitted for the degree of Master of Science at the University of the Witwatersrand. It has not been submitted before any degree for examination purposes in any other university.



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Date: 14 Day of October 2013

Place: Johannesburg

ABSTRACT

The relationship between human activity and the environment has created ecological, socio-economic and cultural patterns and feedback mechanisms that govern the presence, distribution and abundance of plant species assemblages. The trade in traditional medicinal plants in South Africa is estimated to be worth approximately R2.9 billion per year with 27 million consumers throughout the country. Bulbous species compose about 14% of the traded medicinal plant species in South Africa, however the majority of research at the species or generic level has concentrated on a limited number of life forms and plant parts and the ecological consequences of harvest and use of commonly used bulb species is poorly known. Ethnobotanical studies generally focus on 'ethnospecies' – i.e. the traditional name that a species may be known by. Species-specific evidence of the effects of trade and harvest is needed to provide more clarity on the implications of trade, especially since increased commercialisation of medicinal plants has often resulted in over-harvesting and, in severe cases, near extinction of valued indigenous plants. The overall aim of this study was to determine the ecological consequences, as well as some of the economic implications of harvesting important bulb species for the regional medicinal plant trade.

Traditional medicinal bulb species are susceptible to over-exploitation because they are destructively harvested in large quantities. Four perennial bulbous genera were surveyed: two within the Amaryllidaceae (*Boophone* and *Crinum*) and two in the Hyacinthaceae (*Bowiea* and *Drimia*). Some discrepancies were noted where traders and traditional healers recognised species that have been synonymised by taxonomists. In order to understand the impacts of all recognised forms, original nomenclature was used to describe different bulb forms that had been synonymised. The proposed 'functional taxonomy' does not aim to re-examine the taxonomic revisions by previous taxonomists but rather provides a way to identify forms that have no accepted species name. In this way, the impacts on harvesting of different bulb forms can be quantified. Based on this functional taxonomy, the genus name *Urginea* has been used although *Urginea* is currently synonymised under *Drimia*. However, this is only to describe the different bulb form and is not meant to replace the current taxonomic nomenclature. Surveys were conducted in two national level and two small regional level markets to determine the impacts of trade. Bulb characteristics were described and used together with taxonomic literature to produce a key to bulbous species commonly traded in the markets of South Africa. Distribution data and other important information were collected and combined to provide species-specific information. Identification based on vegetative characteristics was possible, with certain features being more useful than others for creating a key. The most useful identification characteristic was the bulb scale type in the Hyacinthaceae together with bulb shape and colour, while bulb size was least useful. For the Amaryllidaceae, bulb colour and characteristics such as tunics cannot always be used due to similarities between species. However, bulb size and shape are helpful indicators and can group species into classes of similar species. Leaf characteristics are very important and may be the only way to accurately identify some species. The adaptation of taxonomic information and previous keys into more 'vegetative' friendly keys can provide ethnoecologists with an identification tool not solely based on ethnospecies name. The ability to identify species will allow ethnoecologists to provide more comprehensive assessments on the impact of the trade.

The diameter of bulbs sold at Faraday market (Johannesburg), Warwick market (Durban) and smaller Free State markets were recorded for four genera (*Bowiea, Boophone, Crinum,* and *Drimia* – including *Urginea* forms), and the data were used in a variety of ways to determine the effects of trade. Populations of species of anthropogenic importance should show a corresponding decrease in the frequency of individuals in large size-classes and a decreased number of size-classes with time. Size-class distributions of *Drimia delagoensis* and *Bowiea volubilis* followed an inverse J-shaped curve, often indicative of a regenerating population (high frequency of small bulbs); however, in this case intense harvesting pressure has resulted in a highly skewed population structure. High rates of harvesting will ultimately result in regeneration failure because smaller bulbs are unable to reach maturity before harvest. All species studied tended towards smaller mean market bulb diameters over time. These trends suggest that without appropriate mitigation, bulb populations will be further

impacted in the future. Bulb diameters in the market were also smaller than diameter records collected from herbarium material and literature records. *Bowiea volubilis* is the most severely impacted by the medicinal plant trade, with approximately 87% of bulbs <4cm in diameter, and significantly smaller than both bulb diameters in medicinal plant markets in 2001 ($p<0.0001$) and pressed bulbs from several herbaria ($p<0.0001$). The large bulbed Amaryllidaceae species *Boophone disticha* and *Crinum* species also showed a decrease in bulb diameter between the 2001 and 2007 Faraday surveys (by 1.5cm and 2.7cm, respectively), while *Urginea epigea* (Hyacinthaceae) showed a 1.2cm decrease in mean size in 6 years.

Traditional healers, traders and harvesters can provide a wealth of information on species populations in the wild. Trader and harvester preferences may affect the impact of harvesting and trade on wild populations. Information on trader/harvester preferences and perceptions was gathered from Warwick and Free State markets. Overall, the average earnings per month per trader selling medicinal plants were low (approximately R833 in Warwick and R2,100 in Free State). Bulb species contributed 10-40% of the total earnings per trader at Warwick and 10-50% in the Free State markets. The relatively large contributions of bulb species to trader incomes emphasise the importance of popular bulb species economically and socially. The number of bulbs (equivalent in size to the mean bulb diameter) harvested annually was large and provides an order of magnitude estimate of harvesting impacts on medicinal plant species populations. The number of *Drimia elata* harvested was greatest in the Free State (between 600,000 and 1,400,000 dependent on estimation method). In Warwick, species sold in the largest quantities were *D. robusta*, *Crinum* species, *B. volubilis* and *U. epigea* (approximately 400,000 – based on actual volume). The high variability of number of bulbs harvested between traders suggests that these numbers should be treated with caution.

The number of populations required and the rate of population regeneration needed to sustain harvesting for the traditional medicine trade is extremely high; and, without mitigating factors, the increased commercialisation of the medicinal plant industry may have potentially dramatic, negative implications on popular bulb populations. Social surveys and ethnobotanical work in local markets are the first steps in understanding patterns of demand for particular plant species, and integrated with population structure and size-class distributions, it allows for an amalgamated and complex awareness of the impacts of resource harvesting. With over 30,000 species of animals and plants that are detrimentally affected by trade worldwide, market surveys are increasingly important to provide information on the extent of trade. The varied data collected in this study included: size-class distributions, temporal changes in bulb diameter, volume and number of bulbs harvested, economic value and trader perceptions. Overall, the results suggested that all species studied were negatively impacted by harvesting to various degrees. In South Africa, harvest and trade is sometimes the only form of income generation and harvest can threaten species populations. By quantifying the volume, value and the number of individuals harvested for bulb species, together with perceived scarcity and popularity and place of harvest, a better understanding of the state of the resource-base has been provided. Continued use of market surveys as monitoring tools is important, because in the current (2011) socio-economic context of South Africa, trade and harvest is likely to increase.

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GLOSSARY OF TERMS AND ACRONYMS:

Acuminate: Part tapers gradually, often in a concave manner

Apex: The end of a leaf or growing tip of a shoot

Arcuate: shaped or bent like an arc or bow

Bulb: A large bud, with swollen, modified leaves or scales attached to a small, compressed stem that bears adventitious roots and food is stored in thickened scale leaves.

Bulb scales: Thickened cataphylls or foliage leaf bases (not sheathing)

Bulb Tunics: Sheathing leaf bases

Canaliculate: longitudinally channelled or grooved, especially on leaf stalks and midribs

Cartilaginous border: the border of the leaf that has tough, slightly whitened edges like cartilage.

Cernuous: Drooping or nodding, somewhat inclined as opposed to erect

Ciliate: Marginally fringed with hairs

Clustering: A group of the same or similar elements (e.g. bulbs) gathered or occurring closely together; a bunch

Conical: Shape related to that of a cone

Conniving: Converging, coming into contact, not fused

Cylindrical: Shape related to that of a cylinder, longer than wide, not tapering inwards

CITES: The Convention on International Trade in Endangered Species of Wild Flora and Fauna

Declinate: bending downwards

Dentate: toothed with teeth directed outwards

Distichous: Arranged in two vertical rows on opposite sides of an axis (e.g. Leaves of *B. disticha*)

Ensiform: shaped like a sword

False stem: A false stem made of the sheathing bases of leaves

Flaccid: Without rigidity; lax and weak

Glaucous: Bluish white; covered or whitened with a very fine, powdery substance

Imbricate bulbs: bulb scales which are not concentric but loosely or tightly arranged like the petals of a flower (like garlic).

Inflorescence: Flowers borne on modified terminal or axillary shoots

Keel: Central ridge along the back of any organ of any plant

KZN: The abbreviation used throughout the dissertation for KwaZulu-Natal

Lanceolate: shaped like a lance head; narrow and tapering to a pointed apex

Margin: An edge of a flat structure, such as a leaf

Midrib: Central, primary or main vein of a leaf

Nodding: Drooping, usually referring to the entire inflorescence

NTFPs: Non-timber forest products

Oblong: shape having a somewhat elongated form with approximately parallel sides

Pedicels: The stalk of an individual flower in an inflorescence

Peduncle: A primary flower stalk, supporting either a cluster or a solitary flower

Perianth: The floral envelope consisting of two outermost whorls. Term usually used when these whorls are indistinguishable. The parts are then known as tepals.

Pyriform: Having the form of a pear; pear-shaped

Revolute: rolled backwards from margins or apices

Rosulate: A cluster of leaves that grows in a circular overlapping pattern

SCD: Size-class distributions

Segments: Division of perianth (i.e. 1 tepal)

Spreading: having a horizontally branching habit (general appearance)

Suberect: Ascending towards the edges

Subglobose: not quite circular or globular, slightly flattened

Subspreading: less than horizontally branching general appearance

Toothed: Having the margin shallowly divided into small, tooth-like segments

Tunicate bulbs: numerous tunics which form concentric circles around the bulb (like an onion),

Umbel: An inflorescence with several stalked flowers arising from the same level

***Umuthi*:** Herbal or Traditional medicine or plants with cultural or religious functions. These include medicines, charms, species used for divination etc.

***Umuthi* markets**: Commercial centres of trade in herbal or traditional medicines or plants with cultural or religious functions

Undulate: With a wavy surface and slightly uneven margin

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CHAPTER 1

Introduction

1. GENERAL INTRODUCTION

1.1. CONSERVATION AND RESOURCE USE

Learning how to deal with uncertainty and adapting to changing conditions brought about by global change is becoming essential in a world where humanity plays a major role in shaping biospheric processes from genetic to global scales (Olsson *et al.,* 2004). However, successful adaptive responses for ecosystem management need to be built upon an understanding of resource and ecosystem dynamics (Olsson *et al.,* 2004). The knowledge and values of local communities are now being acknowledged as valuable in terms of biodiversity conservation (Pretty and Smith, 2004). Hence, there is a need to blend the biological and social elements of conservation (Pretty and Smith, 2004). Over 30,000 species of animals and plants are thought to be detrimentally affected by trade worldwide (Abensperg-Traun, 2009), with non-sustainable harvest of resources in many countries, threatening the survival of key species (van Andel and Havinga, 2008).

Although there is a general expectation that human use of resources will invariably negatively affect biodiversity (Robinson, 1993; Redford and Richter, 1999), this is not always the reality of how communities harvest resources. Instead, there is a tendency for communities to over-harvest certain resources and then shift to another method of money-making (Robinson, 2006). The IUCN Sustainable Use Policy (Resolution 2.29, adopted in 2000) recognizes the need to understand the biological characteristics of natural resources, but focuses more attention on the socio-economic context (Robinson, 2006). Human livelihoods are inextricably linked to the conservation of natural resources and thus conservation is deemed critical for development. Natural resources are limited and thus development should meet the needs of the present without compromising the ability of future generations (WCED, 1987; Sharma and Ruud, 2003). The use of wildlife and plant species in developing countries is more of an imperative than a choice (Abensperg-Traun, 2009). However, there is growing support for the idea that human-driven impacts can induce sudden changes in ecosystems (Pardini *et al.,* 2010), and understanding the effects of human use of resources is vital.

In South Africa, development has been prioritized by the National Government's electoral mandate (Coetzer *et al.,* 2010). Landscape transformation is unavoidable with ongoing population growth and socio-economic development (Coetzer *et al.,* 2010). Conservation, therefore, has to evolve to be politically acceptable and conservation decisions cannot occur in isolation. In addition, humans alter ecological processes directly and indirectly through land use, management and policy decisions regarding natural resources (Dale *et al.,* 2005). In the United States, food production uses about 50% of the total land area, 80% of the fresh water and 17% of the fossil fuel energy used in the country. Land degradation via removal of vegetation, soil erosion, salinization and soil compaction is also severe (Dale *et al.,* 2005). The promotion of harvesting of many non-timber forest products (NTFPs) is based on the argument that conservation initiatives must be able to offer local people economic incentives in order counteract the threat of more destructive land uses such as logging and cattle ranching or land use for food production (Ticktin, 2004).

The conditions that are necessary for sustainable harvesting, however, have been widely debated (Ticktin, 2004). At the crux of the argument lies a fundamentally important question: what are the ecological consequences of the harvesting of these resources? In addition, there needs to be an understanding of the mechanisms underlying the ecological impacts of resource harvesting and an understanding of the management practices that may mitigate these impacts (Ticktin, 2004). Trade may be an important driving factor in over-exploitation of common species; however, there are fundamental gaps in our knowledge (Strandby and Olsen, 2008). Researchers need to know how market chains are structured and

how they operate as well as the drivers of demand in order to understand the full pressures of traditional medicinal harvesting (Strandby and Olsen, 2008).

The Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES) aims to regulate trans-boundary trade in species and their derivatives through a system of permits and certificates as to ensure that trade conforms to the principles of sustainability (Abensperg-Traun, 2009). However recent evidence suggests that the legal attributes of CITES have limited capacities to prevent trade and overharvest, but instead sustainable use of species is best achieved by gaining the support of local communities. In a 2008 study of *Abies guatemalensis* Redher (Guatemalan Fir), increasing legal supplies through the decrease of production costs as well as the inclusion of the local community was useful for *in-situ* management of the species (Strandby and Olsen, 2008). This once again emphasises the importance of studying ecological and social systems together (Redman *et al.,* 2004).

Common-pool resources such as forests, water resources, rangelands and medicinal plants provide a wide variety of economic benefits to communities in southern Africa. However, there is a need for adaptive local management systems that enhance the ecological knowledge of users and regulate market structures to favour long-term livelihood securities (Mutenje *et al.,* 2011). For long-term sustainable harvest to occur, an understanding of species' life-history, dispersal and requirements for survival are needed so that local communities can better manage their resources (Dzerefos *et al.,* 2009). This is especially important as land use is expanding in the unprotected areas that surround the world's protected areas (Hansen and Defries, 2007). Despite the high level of protection that fauna and flora receive in protected areas, critical ecological processes such as fire, flooding and climate regimes have been altered – leading to some native species becoming extinct in these areas (Hansen and Defries, 2007). Protected areas do not occur in isolation and all land areas need to be taken into account.

Human disturbances are varied and occur at different spatial and temporal scales as well as at different intensities, creating a network of interactions between resources and resource harvesters that shapes the natural, cultural and economic mosaic in a heterogeneous landscape (Giannecchini *et al.,* 2007). Without understanding this cultural and ecological landscape, it becomes increasingly difficult to determine methods of sustainable harvesting, especially in developing countries. Studies must take into account factors such as the political context as well as economic and ecological implications, in order to be of value (Giannecchini *et al.,* 2007).

1.2. TRADITIONAL MEDICINAL PLANT USE IN SOUTH AFRICA

Quantitative ethnobotany, (i.e. the enumeration, discovery and evaluation of plant uses by different societies) (Schultes and Von Reis, 1995) is an important form of research. Medicinal plant harvesting is not only an important activity in southern Africa, but in many areas around the world. The World Health Organisation estimated that the 2009 demand for traditional medicine was approximately US$14 million per year and was estimated to grow to US$5 trillion by 2050 (Bhowmik *et al.,* 2009). In addition, 25% of prescription drugs are based on plant derived chemicals (Sahoo *et al.,* 2010), making traditional medicinal plants and the study of their use very important. In the Himalayan area of Sikkim, for example, the number of wild collected individual plants is high – between 800,000 and 7,700,000 (data collected for six popular species from the area) (Rai *et al.,* 2000). It is therefore important to understand how different communities influence the ecosystems that they rely on for medicinal plants. Recognising the value of local knowledge and building on it to produce scientific collaborations with local communities is important for many reasons. For example, it can lead to new insights in species identification, ecological processes and rational resource management (Abraão *et al.,* 2008).

The commercial harvesting of resources to meet the growing urban demand is often an environmentally destructive activity. Non-sustainable harvest threatens both the harvested species and the people that depend on them (van Andel and Havinga, 2008). However, medicinal plants decline not only because of collection, but also due to other factors such as agricultural and/or uncontrolled burning, forest clearing, aforestation, livestock grazing, and commercial harvesting by large pharmaceutical companies (Cunningham, 1993).

Decline in commonly used species leads to an ever greater demand for increasingly dwindling resources, and may lead to the disappearance of favoured and effective species (Cunningham, 1993). The trade in traditional medicinal plants plays an important role in South African communities and in the economy of the country (Williams *et al.,* in press). Natural resources such as medicinal plants are the most accessible sources of products and income for economically marginalised people (Mutenje *et al.,* 2011), with approximately 27 million consumers and 3,000 traders of medicinal plants in South Africa (Mander *et al.,* 2007). In a study of medicinal plants in the Eastern Cape Province of South Africa, it was found that a minimum of 166 medicinal plant species were traded, providing approximately 525 tonnes of plant material valued at R27 million annually (Dold and Cocks, 2002). Ninety-three percent of the species documented were being harvested unsustainably and 34 species were prioritised for conservation management (Dold and Cocks, 2002). With 80% of medicinal plants harvested leading to the death of the individual (Mander *et al.,* 2007), medicinal plant harvesting can have enormous negative impacts.

Umuthi refers to herbal or traditional medicine or plants used for cultural or religious purposes throughout the dissertation (Williams, 1992; Williams, 2003; Williams *et al*., 2011) whilst *umuthi* markets refers to commercial centres of trade of herbal and traditional medicines or plants used for cultural or religious purposes. Medicinal plant surveys can provide numerous insights, including information on the diversity, prevalence and salience of these commonly traded medicinal plants (Mati and de Boer, 2010). While surveys can estimate the total traded species richness, some biodiversity may be overlooked and it has been argued that species entering a medicinal market represent a shortlist of far greater diversity of species used in rural areas with the total number of species used being far greater than a survey of a commercial market will ever capture (Williams *et al.,* 2005; Mati and de Boer, 2010).

Despite this, medicinal market surveys in South Africa have provided detailed information (Cunningham, 1988; Mander, 1997; Mander, 1998; Dold and Cocks, 2002; Botha *et al.,* 2004a; Williams, 2003; 2004; 2007). These broad-based surveys provide a starting point for new studies with some researchers now focussing on species that were previously not identified, for example, the root holoparasite, *Hydnora abyssinica* A.Br. (Williams *et al.,* 2011). Population studies on important species such as Baobabs (*Adansonia digitata* L.) which provides food and medicine and are under increasing pressure due to increased commercialisation have also been undertaken (Venter and Witkowski, 2010). There is also an increased focus on genetic, ecological and environmental differences of plants harvested from different localities (Street *et al.,* 2008). Plant age, seasonal variation and geographical deviation in harvest site are all contributing factors to biological activity and studies looking at these factors have also been conducted (Taylor and van Staden, 2001; Shale *et al.,* 2005; Buwa and van Staden, 2007).

Cultivation is often not a viable option for vulnerable medicinal plants as it is usually not profitable due to the low market prices paid for species and the relatively slow growth rates of the plants (Botha *et al.,* 2007). In South Africa, medicinal plant nurseries have not eased the pressure on wild resources because in most cases these outreach programmes have not met either conservation or financial objectives (Botha *et al.,* 2007). Nurseries usually fail because of marketing difficulties, e.g. a lack of markets, nurseries located far from markets, pricing difficulties, inadequate transport and limited marketing communications. In addition, nurseries have had difficulties obtaining seedlings at prices that the subsistence sector resource users can afford (Botha *et al.,* 2007). With the use of traditional medicines expected to increase in the near future, the over-exploitation of medicinal plant resources is also expected to increase (Bhowmik *et al.,* 2009).

Urbanisation does not decrease the use of traditional medicine, instead the demand for traditional medicine is high in urban areas and the supply is met by a network of commercial gatherers who sell to herb traders and traditional healers in the major cities (Williams *et al.,* 1997; 2001). Commercial harvesting is more destructive, partially because there often is a breakdown in customary harvesting practices (Williams, *et al.,* 1997), and the volumes harvested to sustain the demand are enormous. Moreover, within urbanized areas there are high rates of unemployment, as the formal business sector and the rural subsistence economy fail to provide jobs to the growing number of job seekers (Williams *et al.,* 2000). This together with the fact that traditional medicine is more affordable, accessible and acceptable than western medicine could have devastating effects on wild populations.

One challenge facing conservation efforts of medicinal plants is the need to reconcile the two previously opposing and mutually exclusive activities of conservation and natural resource utilisation (Williams, 2003). However, despite the economic context, it must be remembered that the declining supply of indigenous medicinal plants is likely to generate significant economic welfare losses in addition to a loss in income-earning opportunities (Mander, 1997; Mander, 1998; Williams, 2004). In other areas such as the Himalayas, a decline in medicinal plants resulted in a ban on the harvesting and trade of vulnerable species; however, in South Africa, legislation has failed to curb the trade in vulnerable medicinal plants (Botha *et al.,* 2004b).

A staggering 2062 plant taxa have been documented in the medicinal plant trade in South Africa, with 656 recorded in trade, many of which are destructively harvested and likely to be threatened by medicinal plant use (Williams *et al*., 2013). However, Red Data list assessments of commonly used species are not easy because medicinal species are often widespread (Raimondo *et al.,* 2009). Of the 656 traded species, 18.9% are of conservation concern with 8.5% (56) listed as threatened (Critical (C), Endangered (EN) or Vulnerable(V)), 4.6% (30) listed as Near Threatened (NT) and 5.2% (43) listed as declining (Williams *et al*., 2013). Raimondo *et al.* (2009) suggest that conservation policies that are currently used in South Africa need to be adapted, so that trade in medicinal plants is not indiscriminately banned or limited by conservation agencies. Many medicinal species play such a vital role in supporting the livelihoods of many South Africans that continued use is needed for livelihood protection (Raimondo *et al.,* 2009; Williams *et al*., 2013).

1.3. ECONOMIC IMPLICATIONS OF MEDICINAL PLANT USE

The understanding of the dependence and value of natural resources in the lives of rural communities throughout the world (Shackleton and Shackleton, 2006) has developed, in part, from the antagonistic views of development economics and conservation. Both of these views have guided and enhanced the use of natural resources as a possible approach to increasing livelihood security and poverty reduction, thus providing viable incentives for conservation and sustainable use (Shackleton and Shackleton, 2006). Attaching market values on natural resources is one means of conserving biodiversity and has become more popular in the last decade: the proponents of this philosophy encapsulate this in the catch phrase "use it or lose it" (Shackleton, 2001).

Although resource harvesting is potentially damaging, the alternative – which is converting communal lands to some other land use – is potentially even more damaging. Furthermore, if land is changed to another land use then local households will have to source these resources elsewhere (Shackleton, 2001). People in rural households whose income falls below the poverty line are often forced to seek employment in towns and cities, which then creates strong rural-urban linkages and dependencies (Williams, 2004). One of the forces driving the expansion of the medicinal plant trade is poverty in rural households. Harvesting is often a last resort activity, sometimes characterized by local capital or skills thresholds and participants are often in over-saturated markets that offer very low returns for labour (Williams, 2004).

In South Africa, the use of indigenous medicine is widespread, with value of traded material equivalent to state-subsidized health programmes (Shackleton, 2001). The annual value of this trade was ca. R2.7 billion per annum in 2007 (Mander *et al.,* 2007), and if the value of traditional medicinal resources was to be lost to over-exploitation, land transformation or state regulation, then the state would have to allocate additional resources to the state health care system. The value attached to direct provisioning is therefore, in effect, an opportunity cost that should be factored into the cost-benefit analysis of alternative land uses (Shackleton, 2001) and thus needs to be understood as part of the economic context under which resource harvesting occurs. Contributions of natural resources to a household's total livelihood income range from over 50% in some settings to less than 20% in others. Thus, understanding the factors that influence resource use can help provide information on economic as well as conservation issues (Shackleton and Shackleton, 2006).

Traditional conceptualisation of value incorporates the idea of supply and demand, with the value of resources thought to be determined by the market place (Straton, 2006). In the Mediterranean region, however, non-timber forest products (NTFPs) are a source of livelihood and sustainable development.

Studies showed that NTFPs provide annual benefits of approximately €39/ha and account for about a fourth of the total economic value of the forests studied (Croitoru, 2007). In northern Morocco, one ethnobotanical survey showed that of the 102 species studied, 13% were widely commercialised and the income derived from these plants was about US$ 1,826,900 per year and thus an important economic resource for the region (El-Hilaly *et al.,* 2003). By explicitly incorporating environmental products in household income, studies have determined that in Ethiopia, products from environmental sources represent a large component of rural livelihoods (second only to crop income) (Babulu *et al.,* 2009).

To a certain extent, however, the medicinal plant trade is driven by customer demand (Williams, 2004). However, customer demand may change and consequently opportunities become limited and these activities are likely to be abandoned if options that are more attractive become available. Although demand related plant scarcities drive up market prices, higher prices paid for certain species encourages depletion of the resource because of the potentially higher income generated (Williams, 2004). In addition to this, lower prices act as a stimulus for over-collection, as traders feel the need to over-harvest in order to obtain a reasonable income. Market conditions therefore work against the environment (Williams, 2004). The rural-urban dependency seldom favours the rural centres and it is estimated that much of the income from Faraday *umuthi* market, Johannesburg (one of the largest informal medicinal markets in South Africa), does not reach the rural areas and is instead spent in the city. This leads to increased reliance on the resources and a continuation of household poverty (Williams, 2004).

Commercialisation of resources is a growing trend in southern Africa (Shackleton and Shackleton, 2006). Resource commercialisation presents both opportunities and constraints to poorer households. In most cases, poor households tend to benefit more from the commercialisation of NTFPs; however, there is always a danger that the local elite or external agents may capture the benefits at the expense of the subsistence users or household level traders (Shackleton and Shackleton, 2006). Poorer households are often involved in more opportunistic, low skilled and low return activities, with fewer barriers to entry. Women with fewer sources of income become increasingly reliant on resource harvesting as a method of income generation, primarily because they have no means to leave their family to seek employment (Shackleton and Shackleton, 2006). Providing economic incentives in terms of income generation from natural resources may encourage forms of conservation and prevent land use changes that would further impact plant populations and communities (Alcorn, 1995).

1.4. ECOLOGICAL IMPLICATIONS OF MEDICINAL PLANT USE

One method for determining the implications of harvest and trade is to look at the market, the harvesters and the post-harvest survival of species. In one study in Suriname, of the 249 commercial species, less than half were harvested exclusively from the wild and increased commercialisation due to urbanisation did not invariably lead to declining resources (van Andel and Havinga, 2008). However, the impact of increased commercialisation on resources is dependent on a number of factors, including socio-economic factors such as: 1) demography of human populations; 2) technological change; 3) economic growth; 4) political and social institutions; 5) culture and 6) knowledge and information exchange (Redman *et al.,* 2004). There are also a number of ecological factors that are important.

Plant populations can be driven to extinction if harvesting increases to chase an ever-diminishing yield (Begon *et al.,* 1986). However, the impacts of harvesting depend on factors such as plant part removed, the level of harvesting and the efficiency of the gatherers (Williams, *et al.,* 2007a). For bulbous plants or smaller herbs and shrubs where the roots or bulbs are entirely removed, often little sign remains of their former presence in a locality (Cunningham, 1988; Williams *et al.,* in press) and field observations are usually under-estimates. There is a relationship between the species population size and volume of material available to harvest (Wild and Mutebi, 1996). This relationship is modified by a number of factors, including species ecology and life history, as well as the growth and reproductive capacity and how this capacity responds to harvesting. Moreover, for any one species the range of harvestable quantities will vary with location, season and plant part harvested. This range can be considered the margin of vulnerability (Wild and Mutebi, 1996).

Very few (if any) habitats are still pristine. The structure and composition of habitats is altered by a number of abiotic and biotic factors, of which humans are a key factor. Whether or not local, national or

international markets for any particular natural resource will exacerbate or detract from impacts is difficult to predict. However, the assumption that in certain 'natural' areas composition, structure and function is untouched by humans and therefore the idea that we must seek to limit its use is erroneous. Disturbances like harvesting for the medicinal trade often have the effect of altering or determining the plant population structure. However, the effect of a single disturbance depends on the intensity, frequency, duration, timing and nature of the disturbance as well as the characteristics of the species being disturbed (Botha *et al.,* 2004a). Therefore, the relative impacts of each and every resource that is harvested needs to be considered (Shackleton, 2001).

Ecological sustainability may be assessed by directly measuring the rate of extraction and comparing it to the rate of natural replacement (Botha *et al.,* 2004b). This may prove to be time consuming and expensive for species with high longevities. Demographic studies are a cost effective means of providing useful data on the impact of harvesting and other disturbances, contributing to the development of effective management strategies as well as providing quantitative data to ascertain whether further in-depth research or monitoring is required (Botha *et al.,* 2004b). Size-class distributions allow identification of poorly represented life history stages and also the stages that are affected by variations in harvesting intensity (Williams *et al.,* in press). Changes in population structure may also indicate declining recruitment (Botha *et al.,* 2004a). However, there are only a few studies in southern Africa that record assessments of harvesting impacts based on size-class distributions and plant population sizes.

Medicinal plants are used in a multitude of ways, and this suggests that medicinal plants should be evaluated on a case specific basis (Dzerefos and Witkowski, 2001); studies at such a scale give a more composite understanding of harvesting and resource use in general. It is also important to appreciate the scale of cultivation required to replace harvested stocks as well as to understand the extent of damage to wild populations (Williams, 2004). While data on the estimated mass of plants harvested annually informs the magnitude of resource depletion, these data would be of more use if they were translated into the number of individual plants harvested annually (Williams, 2004). In addition, it is still important to consider the impacts of harvesting on populations as well as landscape levels (Cunningham, 2001).

The paucity of information on plant population sizes makes it difficult to judge the annual rate of decline for a species based on off-take for the medicinal trade (Williams *et al.,* 2007a). To deal with such issues, Williams *et al.* (2007a) devised the notion of "*individual equivalents*" – a concept whereby volume traded (in terms of number of sacks of medicinal bulbs) is equated to an actual number of bulbs harvested, equivalent to a certain size. The concept of individual equivalents can provide a nuanced understanding of resource depletion as it determines an estimate of the *number* of bulbs harvested and traded. The individual equivalent method provides a starting point for quantifying the annual extent of resource depletion (Williams *et al.,* 2007a).

2. RATIONALE

Medicinal "*umuthi*" markets are important centres for the sale of medicinal plants in urban areas. The diversity of species on sale is a product of the medley of ethnic groups using traditional medicines from southern Africa and the customary botanical knowledge of the resource users (Williams *et al.,* 2005). Examining traditional medicinal markets as centres for the trade in traditional medicinal plants is useful in that they provide varied and layered information, e.g. the extent, volume and value of trade in certain common species. This information, taken into context, can provide valuable insight into the impacts and effects of medicinal plant use on wild populations (Cunningham, 1988; Williams, 2003; Williams and Wong, 2006; Williams *et al*., 2013.).

Management and harvesting practices may have positive or negative effects on certain populations. Therefore, understanding these practices is essential. The effect is mitigated by factors such as intensity and frequency of harvest and therefore studies that quantify such practices may be useful in determining the full ecological consequences of harvest (Ticktin, 2004). Ethnobotanical information is paramount in providing an understanding of harvesting impacts of commonly used species; however, studies rarely combine ethnobotanical data with population assessments (Ticktin, 2004). In addition, ecological studies seldom use ethnobotanical information and studies that combine both provide a more integrated and

complete assessment of anthropogenic impacts on plant populations. The social survey method is the first step in understanding patterns of demand for a particular species (Cunningham, 2001).

Economic alternatives are central aspects for managing many human inhabited ecosystems (Begossi *et al.,* 2002). The collection of many NTFPs can be destructive and understanding the relationship between the ecological impacts of harvest and the economic contribution of harvested species therefore, becomes crucial; however, collection of NTFPs can stimulate management schemes that provide both ecological and economic benefits for both the ecosystem and the communities that rely on them (Begossi *et al.,* 2002). It is widely accepted that natural resources contribute to many livelihoods, however there are relatively few case studies from southern Africa that attempt to determine the value of resources and their contributions to household livelihood (Shackleton and Shackleton, 2006). In many ways, the harvest and trade of natural resources, including medicinal plants falls within a 'hidden economy' that fails to become uncovered (IIED, 1997). Studies that determine the value of the trade of certain valuable species help uncover this hidden economy, which can then later indirectly assist the creation of management systems that protect the populations of commonly used species (Campbell and Luckert, 2002).

Although there is enormous variation in plant species harvested, as well as variation in the studies (worldwide) that look at harvesting impacts on these species, the majority of research at the species or generic level has concentrated on a limited number of life forms and plant parts. It is because of this that the ecological consequences of bulbs (in the broad sense), bark, roots, gum and resin extraction is poorly known (Ticktin, 2004), and studies on the specific impacts of harvesting on these plant parts are vitally important. Relatively few studies have been conducted on underground storage organs (bulbs, corms and tubers), however developing sustainable harvest rates for a large group of plant species of great importance for food or medicine is a high priority as bulb species are commonly used but are generally destructively harvested (Cunningham, 2001). A bulb is a large bud, with swollen, modified leaves or scales attached to a small, compressed stem that bears adventitious roots and food is stored in thickened scale leaves (Galil, 1980)

The removal of whole plants, roots and bulbs for medicinal purposes totalled 57% of the total plant material traded on the Witwatersrand ca. 1994/95 (Williams *et al.,* 2000) and bulbs made up 14% of the R2.7 billion trade in South Africa ca. 2007 (Mander *et al.,* 2007). Although not explicitly stated, this refers to bulbs *senso stricto,* as corms and tubers were dealt with separately (Williams, 2003; Mander *et al*., 2007). Harvesting these plant parts may signify the loss of an individual plant, which will then negatively impact an entire population. Previous studies have found that many bulb species are used medicinally (Williams, 2007). This together with the fact that the harvesting of bulbs is often destructive and there is a dearth of information on the impacts of trade on bulb species sold for medicine, makes the study of commonly used bulbs of paramount importance.

Various bulb 'ethnospecies' (different species known by the same traditional name) (Hanazaki *et al.,* 2000) may be impacted differently due to distinct use patterns, volumes harvested, popularity and population responses to harvesting and therefore the study of the economic and ecological implications of their trade is essential. There have been no previous studies of the demand and trade, together with population structure dynamics undertaken for the medicinal bulb species selected for this study. In this dissertation, all species studied are bulbs *senso stricto*. Understanding the effects of the trade in important medicinal species is the first step to uncovering methods to mitigate and prevent negative ecological impacts in the future.

3. AIMS AND OBJECTIVES

The overall aim of this study was to determine ecological consequences, as well as some of the economic implications of harvesting important bulb species for the regional medicinal plant trade. This was achieved by acquiring an understanding of the numbers and size-class distributions of harvested and traded bulb populations in the key medicinal markets of South Africa. In market situations, species identification is based on the plant part on sale or the traditional name (Hanazaki *et al.,* 2000), In order for the most detailed information possible to be collected at a species level, a species identification key based on vegetative parts was created. In addition, the volume, value and extent of trade were quantified.

Adding qualitative indigenous knowledge about the scarcity and harvesting risk to populations allowed for an integrated assessment of the economic and ecological consequences associated with the trade of key species.

There were three main aims, which are dealt with in separate chapters. Each main aim has a number of objectives that are listed below.

Chapter 2: An identification key for medicinal market assessments of commonly traded Hyacinthaceae and Amaryllidaceae bulb species

The main aim of the initial part of the study was to determine the number of species occurring within the ethnospecies groupings studied. Ethnospecies groupings included species from two genera of the Amaryllidaceae and two from the Hyacinthaceae. Bulb characteristics were described and used together with taxonomic literature to produce a key to bulbous species from four genera sold in the traditional medicine markets of eastern South Africa. Taxonomic information and previous keys (from the literature) were also adapted to allow for easier identification of commonly used medicinal species. Distribution data and other important information are also presented.

Objectives:

1. To produce an identification key to some commonly used medicinal bulbs from the Hyacinthaceae and Amaryllidaceae
2. To provide species summaries that include a variety of information that can be used in further studies
3. To use herbarium resources to determine pertinent information, e.g. flowering and fruiting season and geographic range.

Chapter 3: Size structure of commonly traded bulbs in South African traditional medicine markets: ecological implications

The aim of this part of the study was to establish the ecological consequences of the harvesting and trade of commonly used bulb species in medicinal plant markets in eastern parts of South Africa using size-class distributions (SCD). Additional factors that also result in variability in bulb size, such as drying over time, different sources of supply and season of collection were also investigated in order to better understand the ecological implications.

Objectives:

1. To record bulb diameters from South African markets to determine bulb size-class distributions for all species studied
2. To compare bulb size-class distributions between markets to determine market-linked differences between bulb diameters
3. To compare bulb size-class distributions with data collected in 1995 and 2001 to ascertain the effects of harvesting over time
4. To compare bulb size-class structure between bulbs collected from markets and those collected and pressed as herbarium voucher specimens
5. To use herbarium data to determine the relationship between bulb diameters and the reproductive status of wild populations
6. To determine the effects of seasonality on bulb diameters traded in South African medicinal plant markets
7. To determine the relationship between mass and diameter for bulb species studied
8. To determine the effect of drying on bulb diameter and mass.

Chapter 4: Volume, economic value and trader perceptions of the trade in commonly traded bulb species in Warwick market, KwaZulu-Natal and smaller Free State markets, South Africa

The main aim of this part of the study was to establish the ecological consequences of the harvest and trade of commonly used bulb species by quantifying the volume and value of trade in commonly used bulbous species in Warwick market, Durban, and smaller informal markets in the Free State. The number of 'individual equivalents' of the commonly traded bulb species and trader perceptions were also determined.

Objectives:

1. To quantify the volume of trade of each bulbous species in both the Warwick (KwaZulu-Natal) and smaller markets in the Free State
2. To determine the number of individual equivalents of each species to better understand the effects of trade on harvested populations
3. To quantify the economic value of the trade of commonly used bulbous species in Warwick and smaller markets in the Free State and the proportion that each species contributes to the total income
4. To determine the relationship between mass and value (R/kg) for commonly used medicinal bulbs in both Warwick and smaller markets in the Free State.
5. To determine trader demographics and perceptions of the harvest of trade of commonly used bulbous species.
6. To establish the ecological implications of harvest and trade by combining trader information of habitat and general trader perceptions, geographical distribution of commonly used species, and the volume, value and number of individual equivalents.

4. MEDICINAL MARKET STUDIES IN SOUTH AFRICA

Cunningham (1988) was one of the first South African scientists to use traditional medicinal markets to understand the effects of the harvest and trade of medicinal plants. His work in Warwick *umuthi* market was reported in '*An investigation of the herbal medicine trade in Natal/KwaZulu',* and provided much of the common methods used today in medicinal market surveys. Mander *et al.* (1998) continued to work on the effects of trade in KwaZulu-Natal and later Mpumalanga while Botha *et al.* (2000; 2004) also studied trade in Mpumalanga. In the Eastern Cape region, Dold and Cocks (2002) made inroads on the effects of trade in medicinal plants in the area. Williams *et al.* (1992,1997; 2000; 2007, 2011) has provided the most comprehensive studies of medicinal plants in the Gauteng area. This dissertation has relied heavily on the published reports and papers by these authors as they have all contributed to the current knowledge base of the effects of medicinal plant use on wild populations. While working closely with V.L. Williams, this study was planned to continue the work on bulbs, originally collected for Williams' PhD thesis (Williams, 2007). As such, a brief account of Williams' studies which have been used in this dissertation are provided below.

In 1992, Williams commenced a study of *umuthi* shops in the Witwatersrand region, this study continued in 1994 and focused on the more formal sector traders operating from shops from around the Witwatersrand area because the informal market was small and developing (Williams 1992; 2007). Data collected from this study was used in Williams Honours Dissertation and later PhD Thesis. Results indicated that Faraday *umuthi* market represented approximately 31% of the *umuthi* shop suppliers at that time. Although a brief investigation of Faraday umuthi market did occur in 1995 (Williams, 2003), the increasing number of species threatened justified a more comprehensive study of the market. In 2001, Williams commenced with the Faraday *umuthi* market study which was originally published as a report for the Gauteng Directorate of Nature Conservation (Williams, 2003) although data was used in later papers (e.g. Williams *et al.,* 2007). Data collected for this dissertation occurred in 2007 and was compared to *umuthi* **shop** 1995 and *umuthi* **market** 1995 and 2001 data collected by Williams *et al.* (1997, 2000, 2001; 2007). Results from the 1995 *umuthi* market survey are called Faraday 1995 while results from 2001 Faraday *umuthi* market survey are called Faraday 2001. Data collected from *umuthi* shops is called *umuthi* shops 1995.

5. ETHICS CLEARANCE

Ethics clearance was obtained from the University of the Witwatersrand for all surveys (Ethics clearance number: H071116). In all cases, participation was voluntary and verbal consent was obtained once details of the study had been fully explained.

6. DISSERTATION STRUCTURE

There are five chapters in this dissertation. A synthesis of literature, the rationale for the study and the aims and objectives for the study are presented in Chapter 1. Chapter 2 presents an identification key and a detailed summary of the species encountered during the study, while Chapter 3 focuses on size-class distribution of commonly used bulb species. Change in diameter over time, differences between diameters in different markets, differences between market diameters and diameters reported in the literature, information of area of harvest together with the effects of drying on bulb diameter and mass are also reported on in Chapter 3. Data collected from trader interviews were used to determine trader perceptions, economic implications, volume of trade and estimations of the number of bulbs harvested a year in Chapter 4, and the ecological impact of trade was discussed. An overall discussion and recommendations are provided in Chapter 5. This discussion focuses primarily on the ecological implications of the market data collected.

Chapters 2, 3 and 4 all present results for this study and have been written separately for intended submission to peer-reviewed journals. Although none of these chapters have been submitted at this point, it was felt that presenting the data as free-standing chapters would allow for detailed discussion of the main results. This format, however, has led to some repetition, especially concerning the description of species and markets. The references have been provided at the end of each chapter to make them easily accessible. Appendixes are provided at the end of the dissertation. Wherever possible, there has been an attempt to keep repetition to a minimum. Some information from Chapter 2 was used in a recent analysis of the geographical range and identification of *Drimia cooperi* published in *Bothalia* (Crouch *et al.,* 2010). The publication is provided in Appendix 1.

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CHAPTER 2

An identification key for medicinal market assessments of commonly traded Hyacinthaceae and Amaryllidaceae bulb species

ABSTRACT:

Studies on the trade and harvest of medicinal species provide important information on the effects and implications of resource use. Many ethnobotanical studies, however, focus on 'ethnospecies' (more than one species known by one traditional name or more than one species known by the same traditional name) because of the absence of reproductive material available in market settings for species level identification. Although necessary in broad scale studies, the use of ethnospecies nomenclature can be problematic and more clarity on the species-specific effects of trade and harvest is needed. Although bulbs make up a large proportion of the plant material traded in South Africa, there have only been a few studies on the effects of trade on bulbous species. The identification to species level of sterile bulb material purchased in the markets can be difficult because of the paucity of data on vegetative features that can be used for identification. Furthermore, taxonomic uncertainties concerning some commonly used species also makes identification difficult. Various species may have different distributions, population structures and may respond differently to harvesting. Ethnospecies from two genera of the Amaryllidaceae (*Boophone* and *Crinum*) and two from the Hyacinthaceae (*Bowiea* and *Drimia*) were studied. Some discrepancies were noted where traders and traditional healers recognised species that have been synonymised by taxonomists. In order to understand the impacts of all recognised forms, original nomenclature was used to describe different bulb forms that had been synonymised. The proposed 'functional taxonomy' does not aim to re-examine the taxonomic revisions by previous taxonomists but rather provides a way to identify forms that have no accepted species name. In this way, the impacts on harvesting of different bulb forms can be quantified. Bulb characteristics were also described and used together with taxonomic literature to produce a key to bulbous species commonly traded in the markets of South Africa. Distribution data and other important information were collected and combined to provide species-specific information. Identification based on vegetative characteristics was possible, with certain features being more useful than others for creating a key. The most useful identification characteristic was the bulb scale type in the Hyacinthaceae together with bulb shape and colour, while bulb size was least useful. For the Amaryllidaceae, bulb colour and characteristics such as tunics cannot always be used due to similarities between species. However, bulb size and shape are helpful indicators and can group species into classes of similar species. Leaf characteristics are very important and may be the only way to accurately identify some species. The adaptation of taxonomic information and previous keys into more 'vegetative' friendly keys can provide ethnoecologists with an identification tool not solely based on ethnospecies name. The ability to identify species will allow ethnoecologists to provide more comprehensive assessments on the impact of the trade.

Keywords: Amaryllidaceae; Bulbs; Ethnospecies; Hyacinthaceae; Key; South Africa; Species Identification; Traditional Medicine; Vegetative Parts

1. INTRODUCTION

1.1. IMPORTANCE OF SPECIES-SPECIFIC IDENTIFICATION IN MEDICINAL MARKET SURVEYS

It is widely accepted that any study of plants that aims to draw on scientific literature and/or place new information into the public domain must use botanical names (the Latin genus and species name) (Nesbitt *et al.,* 2010). By using the botanical name, one enables movement of data across languages, scientific disciplines and electronic retrieval systems. However, in some disciplines, plants may present challenges in identification and naming. Firstly, the species may look very similar to other more well known species; secondly, ethnoecologists in market situations may not be trained botanists and thirdly, the plant part available in the market setting may not facilitate easy identification. However, medicinal market studies can provide detailed information and in order to be accessible to other disciplines, identification and correct nomenclature is of the utmost importance.

Large surveys of medicinal plant markets in South Africa have provided much information on the volume and effects of trade of numerous species (Cunningham, 1988; Mander, 1997; Dold and Cocks, 2002; Botha *et al.,* 2004; Williams, 2003). In broad scale studies, identification to species level at the market is often difficult due to the lack of reproductive material available. Ethnobotanists and ethnoecologists, therefore, have to collect material for identification purposes, which can be onerous. The concept of 'ethnospecies' is sometimes used as a proxy whereby identification is based on traditional or folk name (Reyes-Garcia *et al.,* 2006). This can be problematic as in most cases, two or more species will be known by the same ethnospecies name, which can lead to confusion; in addition, one species may be known by more than one traditional name (Hanazaki *et al.,* 2000; Reyes-Garcia *et al.,* 2006).

Species making up an ethnospecies grouping may vary greatly in their geographical distribution, population density, growth rate and population biology (Cunningham, 1988). For example, the Zulu ethnospecies name for *Clivia* species is *uMayime* and applies to *Clivia caulescens* R.A. Dyer, *C. gardenia* Hook., *C. miniata* (Lindl.) Bosse, and *C. nobilis* Lindl. These species have different distributions and may respond differently to harvesting (Williams, 2007). The study of differing volumes, economic value and trader perceptions of individual species is, therefore, very important. In order to make these data available to other researchers, naming each species of the ethnospecies correctly is also extremely important.

The use of traditional or common names is no substitute for botanical identification (Nesbitt *et al.,* 2010). For example, the book, *The Traditional Food Plants of Kenya* (Maundu *et al.,* 1999), gives approximately 3800 common names, of which 10% are used for two or more species, and 2% for species in different genera (Nesbitt *et al*., 2010). Although ethnospecies-based research is invaluable, information of the species-specific effects of trade is still required and thus correct use of botanical nomenclature is necessary. Providing ethnoecologists with tools that allow them to identify medicinal plants and obtain detailed information on the taxonomy together with ethnobotanical information can be very useful.

1.2. FUNCTIONAL TAXONOMY

The characteristics of vegetative plant parts can provide a wealth of information that can be used by taxonomists to better understand the systematics of different taxa. Although bulb characteristics in some taxa can be variable (Jessop 1977), they can provide very important features for identification. For example, the recognition of the tribe Amaryllideae (formally Crinae) as a natural group within the Amaryllidaceae, was first advanced by Traub (1957). One of the key characteristics of the group is the fibres that appear when bulb tunics are torn and pulled apart (Meerow and Snijman, 2001). Other morphological features used for identification and cladistic analysis includes the type of bulb tunics (fibrous or brittle) as well as information on leaves (Meerow and Snijman, 2001). However, important to note is that in an ethnobotanical context, the characteristics used by traditional healers and collectors to differentiate between species are of the utmost importance and these characteristics may differ from those used by taxonomists.

For the most part, it appears that traditional healers and medicinal harvesters do not use the same characteristics as taxonomists. Distinction based on detailed study of fine-scale features is not always practical for traditional harvesters. Firstly, these features are not always available (as harvesting may take place in winter months where reproductive plant parts are not available). More importantly, there is an intrinsic difference in objectives of classification. Traditional medicinal harvesters and healers classify species based on their needs and species are often lumped together if they have similar medicinal uses, thus, fine scale identification is not necessary. Taxonomy is a field of science (and major component of systematics) that encompasses description, identification, nomenclature, and classification (Simpson, 2010). Identification means recognition of material as the same as or different to another known entity; nomenclature involves attributing a name to the material and classification involves the proper placement of the material within the taxonomic system (Sivarajan, 1991). One of the main aims of taxonomy is to provide a classification system based on the natural relationships between taxa. Modern taxonomy is entrusted with the task of 'detection of evolution at work' and provides information on evolutionary phenomena that allows one to reconstruct phylogeny and make important conceptual contributions to biology (Sivarajan, 1991). This can have implications for the evolutionary history of the species and thus accuracy is a key objective. Characteristics used for identification by taxonomists and traditional healers and harvesters, therefore, may differ.

To deal with this, ethnobotanists and ethnoecologists often use the concept of ethnospecies where more than one species can be known by one traditional name or sometimes more than one name refers to varieties of a single recognised species. It is interesting to note that rather than 'lumping' some species together under the same traditional name, traditional healers and harvesters have sometimes separated one species into different traditional names, based on factors such as the area it has been collected from and bulb characteristics. This, however, can lead to some confusion since there may be no accepted species name to refer to these forms. However, if various forms of the same species are identified as different by traditional healers and harvesters, then they may be subject to dissimilar harvesting pressure and may react differently to harvesting. Thus from an ethnoecology view it is vital to study the size structure, volume and value of each form in order to understand the impacts of trade.

The difference between identification by taxonomists and that by traditional harvesters and healers is highlighted in the following example. Jessop (1977) synonymised *Urginea epigea* R.A. Dyer. under *Drimia altissima* (L.f.) Ker Gawl. Although, he made mention of the epigeal form of the species which was known as *U. epigea* in the past, he attributed this differences in the bulb structure between *D. altissima* and the epigeal form to environmental factors as it was not possible to link the difference in bulbs to morphological characteristics or geographical distribution (Jessop, 1977). The one form of *D. altissima* (*U. epigea*) is epigeal (i.e. found 'above ground' and partly exposed), while *D. altissima* is hypogeal (bulbs occurring below ground) (Jackson, 1900). The epigeal form has gregarious bulbs with loose scales; while the *D. altissima* form is less prone to clustering and has tight white scales (Obermeyer, 1980). Traders in Warwick (Durban) and Faraday (Johannesburg) markets will typically call the epigeal type '*umHlabelo*' and the *D. altissima* form '*umMahlokoloza*' or 'white *skenama*', although some overlap can occur (V.J. Brueton, pers. obs.). These forms also occur in various quantities in assorted markets and the question arises, how do ethnoecologists quantify the disparate trade if the traditional healers and harvesters recognise more than one type within a delineated species? In this dissertation, various forms are defined by visibly contrasting bulbs that are known by different traditional names but are classified as one species and the notion of 'functional taxonomy' was used to better understand the impacts of harvesting on these contrasting forms.

The concept of 'functional taxonomy' in this dissertation is based on the idea that the impacts of medicinal plant harvesting on different forms of a species need to be understood and thus different forms need to be 'named' to facilitate discussion. In this case, original nomenclature was used to describe forms that had been synonymised. This only occurred in the genus, *Drimia* (accepted in the broad sense as discussed by Jessop (1977)). Species with different bulb forms included *D. altissima* (L.f.) Ker Gawl.; *D. elata* Jacq.; and *D. delagoensis* (Baker) Jessop. These forms were described using their original species names in *Urginea*, although the genus *Urginea* has been synonymised with *Drimia*. Table 1 provides information on ethnospecies' current names together with 'functional' nomenclature used in this study. It is important to note that the functional taxonomy described here does not attempt to replace the currently accepted identification of the species. Its purpose is to provide a means to discuss disparate trade (and associated impacts) on various bulb forms that are recognized as different in medicinal market settings.

In Chinese Medicine Material (CMM), a focus on quality and efficacy of medicinal material has resulted in the need for a simple, accurate and convenient method to facilitate farmers, pharmacists and the public in identifying and evaluating CMMs (Zhao *et al*., 2011). The use of macroscopic identification methods has been proposed and involves examining the gross morphological features of CMMs by observing, touching, smelling, tasting, and/or testing with water or fire. Although, this method does not necessarily link with taxonomic nomenclature it provides an example of differing methods of identification for different purposes. Using all available tools at the market, including information of the ethnospecies name, area of collection and even how the material is packaged or sold, can provide evidence that will aid identification. In this study, species summaries aim to aid identification by providing information on how the species is sold in the market, prices, how common it is together with information on its distribution and traditional name.

1.3. BULB DEFINITIONS

Bulbs seem to have evolved along several lines of evolution (Dahlgren *et al.,* 1985). Studies on the core Liliales (including *Calochortus, Fritillaria, Lilium* and *Tulina*) show evidence of concerted convergence and phylogenetic niche conservatism, with invasion of open, seasonal habitats accompanied by showy flowers and wind-dispersed seeds (Patterson and Givnish, 2002). There is no reason to regard bulb morphology or even the presence of bulbs as being static (Dahlgren *et al.,* 1985). Moreover, any characteristic that provides useful information is important for identification (Stace, 1989).

Bulbs, however, can vary according to soil conditions and differences in the looseness of the bulb scales may be related to the extent of water-logging of the soil (Jessop, 1977). It was for this reason that qualitative differences in bulbs used in some taxonomic literature were not included by Jessop (1977) in his taxonomic description of *Drimia*. It is, nevertheless, very important to understand the structure of a bulb and how that may differ between families. A bulb is defined as a short, often plate like stem bearing a number of thick, fleshy leaves or leaf bases that store water and nutrients (Dahlgren *et al.,* 1985). In the Hyacinthaceae, Speta (1998a) defines bulbs as formed by thickened cataphylls and/or foliage leaf bases. The scales in adult bulbs are basally vaginate, imbricate or more or less connate. Bulbs in the Amaryllidaceae to the contrary are tunicate with numerous sheathing leaf bases or tunics formed in a concentric circle (Meerow and Snijman, 1998).

Further, the outer bulb scales may be membranous or fleshy with adventitious roots (often contractile) developing from the basal part of the stem or stem plate (Bell and Bryan, 2008). Bulbs occur in most taxa of the Hyacinthaceae, Alliaceae and Amaryllidaceae and in the Liliaceae *sensu* Dahlgren, Calochortaceae and a few genera of the Iridaceae. There are two types of bulbs: tunicate bulbs and imbricate/non-tunicate bulbs. A tunicate bulb has numerous tunics which form concentric circles around the bulb (like an onion), while an imbricate bulb, has bulb scales which are not concentric but loosely or tightly arranged like the petals of a flower (like garlic). The bulb scales can overlap each other either to a small degree or to a large degree (Sadhu, 1989).

The removal of whole plants, roots and bulbs for medicinal purposes accounted for 57% of the total plant material traded in the Witwatersrand *umuthi* shops ca. 1994/1995 (Williams *et al.,* 2000) and bulbs contributed approximately 14% of traded medicinal plants in 2007 (Mander *et al.,* 2007). Species from the Amaryllidaceae and Hyacinthaceae compose a high proportion of the bulbous species on sale in the medicinal plant markets (Cunningham, 1988; Williams *et al.,* 2001). The identification of sterile bulbous material (i.e. without flowers) purchased from the markets is often difficult due to the paucity of literature on vegetative features that can assist with identifying plants to species level (Rejmanek and Brewer, 2001), the lack of diagnostic features on the bulbous material (Arroyo and Cutler, 1984; Jessop, 1977) and taxonomic uncertainty with some of the traded bulb species (Fangan and Nordal, 1993; Jessop, 1975; Jessop, 1977; Manning and Goldblatt, 2003; Meerow *et al.,*1999; Stedje, 2001; Pfosser and Speta, 1999).

Two genera in the Amaryllidaceae and two in the Hyacinthaceae family were chosen for this study (Table 1). All of the species studied had bulbs. Previous studies suggest that many ‘ethnospecies’ within these genera fall in the medium or higher conservation priority lists and are therefore at risk due to factors such as habitat specificity, endemism or plant part used (Williams, 2007). However, the species-specific effects

of the harvest and trade of most bulbs for medicinal purposes are not known. In addition, bulb characteristics within these ethnospecies groups differ marginally or to a large degree and the construction of an identification key for these bulbs will improve species identification in medicinal market assessments. It is important to note that *Urginea* has been synonymised under *Drimia*. Although the genus name *Urginea* has been used, this is only to describe the different bulb form and is not meant to replace the current taxonomic nomenclature.

Table 1: Ethnospecies, taxonomic and functional nomenclature of species studied (note in some cases functional and official nomenclature do not differ) (Source: [1] Cunningham, 1988; [2] Hutchings *et al.,* 1996; [3] Mander, 1997; [4] Diederichs, 2001; [5] Williams *et al.,* 2001; [6] Germishuizen and Meyer, 2003; [7] Williams, 2007; [8] V.J. Brueton, pers. obs). *Note: ethnospecies names that are underlined were most often used by traders.* Names highlighted in grey are no longer accepted but have been used in this dissertation to describe different bulb forms.

Family [6]	Genus	Nomenclature		Ethnospecies nomenclature	Conservation priority [7]
		Functional	Current Botanical		
Amaryllidaceae	*Boophone*	*B. disticha* (L.f.) Herb.		*iNcotho, Incoto, Ngoto; Ngubozohlonya, incotho, incwadi (Zulu)* [1, 2, 5]	Medium
	Crinum	*C. acaule* Baker; *C. bulbispermum* (Burm.f.) Milne-Redh. and Schweick.; *C. buphanoides* Welw. ex Baker; *C. campanulatum* Herb.; *C. graminicola* I.Verd.; *C. lineare* L.f.; *C. lugardiae* N.E. Br.; *C. macowanii* Baker; *C. moorei* Hook.f.; *C. paludosum* I.Verd.; *C. stuhlmannii* Baker		*Mduze, Umduze, umNduze, umDuzi (Zulu)* [1 2 5]	
Hyacinthaceae	*Bowiea*	*B. volubilis* Harv. ex. Hook. f.		*iGibisila, iguleni, ugibisisila (Zulu)* [1, 2, 3, 5]	High
	Drimia	*D. altissima* (L.f) Ker Gawl.		*isiKlenama, Mahlokoloza, sekanama, skanama, uMahlogolosi, umHlabelo, White skenama* [1, 5]	
		D. cooperi (Baker) Baker		*uMahlogolosi* [8]	
		D. delagoensis (Baker) Jessop		*isiKlenama, ndongwana-zimbomvana, indongana-zibomvana, umqumba; sekanama, skanama, unDongananzibomvana, (Zulu)* [1, 2, 3,5]	
		D. elata Jacq.			
		D. robusta Baker	*D. elata* Jacq.		
		D. sanguinea (Schinz.) Jessop			
		U. epigea R.A. Dyer *U. lydenburgensis* R.A. Dyer	*D. altissima* (L.f.) Ker Gawl. *D. delagoensis* (Baker) Jessop	*umHlabelo, umahlokolozi, umgulube, inguduza, isiKlenama, uMahlogolosi* [4, 5, 8]	

The creation of identification keys for bulbs is not common and the use of these keys may require more training as the terminology for some vegetative characters can be vast and unfamiliar to people who are not taxonomists (Rejmanek and Brewer, 2001). Species or genus level identification of medicinal plants based on vegetative characters may only be feasible for families where the species have been well described and for plant groups in which the taxonomy is well understood (Rejmanek and Brewer, 2001). However, although the taxonomy of some species within the Hyacinthaceae and Amaryllidaceae may be debated, a key to medicinal bulbous species (which are sold in the markets) based on vegetative characters is useful in terms of understanding impacts of trade at species level.

The overall aim of this study was to produce a key to commonly used bulb species in traditional medicinal markets in eastern South Africa. Bulbous characteristics and taxonomic literature were used to describe five genera from the Hyacinthaceae and Amaryllidaceae. Distribution data and other important information are also presented, and the number of different types of species occurring within ethnospecies groupings was determined.

Objectives:

1. To construct an identification key to some commonly used medicinal bulbs from the Hyacinthaceae and Amaryllidaceae
2. To provide species summaries that include a variety of information that can be used in further studies

3. To use herbarium data to determine flowering and fruiting season and geographic range of commonly used medicinal bulbs.

2. METHODS

2.1. STUDY SITE DESCRIPTIONS

Two national level and three regional markets were visited in four provinces in South Africa (Map 1). Warwick is the largest traditional medicine market in southern Africa and is located at Warwick Junction in Durban, KwaZulu-Natal (Chazan 2005). The Faraday market is second in size and is located in central Johannesburg, Gauteng (Williams *et al.,* 2005). In Nelspruit, Mpumalanga (Botha *et al.,* 2004), and Bloemfontein and Phutaditjhaba, Free State, (P. Zietsman, pers. comm.) there are no dedicated full time herbal medicine markets. In the latter, operators trade on pavements while in Nelspruit traders are found at pension pay-out points as well as on pavements (Mander, 1997; Botha *et al.,* 2004).



Map 1: Map of South Africa showing regional and national level traditional markets visited between April 2007 and March 2008

The ethnicity and gender of the traders are different in the five markets (Table 2). Detailed demographics for Nelspruit markets are not available; however the majority of traders in 1997 were men (Botha *et al.,* 2004). The area is known to be culturally diverse and traders are likely to be Tsonga, Pedi or Swazi (Mander, 1997; Botha *et al.,* 2004). Use patterns in the different parts of the country may vary (V.L. Williams, pers. comm.), and may be related to differing distributions of species making up an ethnospecies (Map 1).

Table 2: Differences in ethnicity, age, gender and healer status of traders in Faraday, Warwick and selected Free State markets, South Africa (Sources: [1]Williams *et al.,* 2006; [2]Williams, 2003; [3]Williams and Wong, 2006; [4]V.J. Brueton, pers. obs.).

	Faraday, 2001 [1, 2] (N=26) (%)	Faraday, 2006 [1] (N=30) (%)	Warwick, 2006 [1, 3] (N=46) (%)	Warwick, 2008 [1] (N=31) (%)	Free State, 2008 [4] (N=14) (%)
Ethnicity					
Xhosa			7	16	
Zulu	96	100	89	84	9
Sotho					82
Swazi	4		2		9
Mozambican			2		
Age profile					
<25 years	17				
26-30 years	17	27	3	26	
31-40 years	34	30	27	42	27
41-50 years	15	40	37	13	9
51-60 years	10	3	13	10	55
>60 years	6		20	10	9

	Faraday, 2001 [1, 2] (N=26) (%)	Faraday, 2006 [1] (N=30) (%)	Warwick, 2006 [1, 3] (N=46) (%)	Warwick, 2008 [1] (N=31) (%)	Free State, 2008 [4] (N=14) (%)
Gender					
Male	57	28	43	13	45
Female	43	72	57	87	55
Healer Status					
Not healer	54	97	d.n.a	90	27
Traditional Healer	46	3%	d.n.a	10	73

2.2. BULB SAMPLES

Medicinal plant markets in four provinces were visited between April 2007 and March 2008 and, where possible, at least ten samples of each species were purchased. All bulb samples were labelled and diameter and mass was determined using a pair of electronic digital callipers (0-150mm, accurate to 0.01mm) and a *BEL engineering* balance (accurate to 0.01g) respectively. All bulbs were photographed with a Fugifilm 5500 digital camera with a 55mm lens. Bulbs were then placed into one of two growing treatments to aid in later identification: (1) bulbs planted in the greenhouse, or (2) planted in an outside garden (Table 3). Bulb characteristics were noted and photographs were taken.

Table 3: Description of the soil used, light exposure and watering regime for the two bulb growing treatments.

Treatment number	Treatment description	Soil mixture	Exposure	Watering
1	Greenhouse	1:1 potting soil and coarse grained sand	Full sun	1 x week
2	Outside garden	1:1 Garden soil and perlite	Partial sun	1 x week

Bulb specimens were planted between July 2007 and April 2008 and left to grow until leaf or reproductive material was available. The time taken for bulbs to produce leaves or become reproductive differed. Specimens remained planted for a minimum of 2 months and maximum of 18 months so that all specimens had the necessary time to produce material that could be used for identification. During this period, the bulbs were observed once a week and any new growth was noted and photographed. Reproductive parts together with bulbous material pressed and voucher specimens were lodged at the C.E. Moss Herbarium (J) at the University of the Witwatersrand.

The species names, collector's names, dates of collection and herbarium accession numbers for the voucher specimens collected are provided in Table 4 below.

Table 4: Collection details for Voucher Specimens

Family	Genus	Species Names	Collectors Names	Herbarium Accession numbers	Date of Collection
Amaryllidaceae	*Boophone*	*Boophone disticha*	V Brueton 22	-	7 Nov 2008
	Crinum	*Crinum bulbispermum*	V Brueton, V Williams, N Crouch 23	095894	7 Nov 2008
		C. buphanoides	V Brueton, V Williams, N Crouch 3	095886	7 Nov 2008
		C. delagoense	V Brueton, V Williams, N Crouch 15	095892	7 Nov 2008
Hyacinthaceae	*Bowiea*	*Bowiea volubilis*	V Brueton 27	095905	7 Nov 2008
	Drimia	*Drimia. elata*	V Brueton 18	-	7 Nov 2008
		D. robusta	V Brueton 9	-	7 Nov 2008
		D. sanguinea	V Brueton, V Williams, N Crouch 5	095888	7 Nov 2008
		Urginea delagoense	V Brueton 14	-	7 Nov 2008
		D. altissima (U. epigea form)	V Brueton, V Williams, N Crouch 1	095884	7 Nov 2008

2.3. HABITAT PREFERENCE AND DISTRIBUTIONS

Data on habitat, flowering and fruiting season, distribution, species descriptions and bulb dimensions were obtained from thirteen herbaria from around Gauteng, Mpumalanga, Limpopo, KwaZulu-Natal, Eastern Cape and the Free State, between March and September 2008 (Table 5). Pressed bulb material was used to differentiate between ethnospecies', 'forms' and synonymised species, and original nomenclature was used for species that had been recently sunk into broader new delimitations. Data were sometimes sent electronically by herbaria, and hence pressed herbarium specimens were not always directly accessed. The current identification of the pressed herbarium sample was then used.

Table 5: Herbarium name and location

Herbarium Abbreviations	Herbarium Name	Herbarium Location
BNRHS	Herbarium, Buffelskloof Nature Reserve	Buffelskloof Nature Reserve, Mpumalanga
CPF	Donald Killick Herbarium	KZN Nature Conservation Service, Pietermaritzburg, KwaZulu-Natal
GLOW	Herbarium, Lowveld Botanical Garden	Lowveld Botanical Garden, Nelspruit, Mpumalanga
GRA	Selmar Schonland Herbarium	Albany Museum, Grahamstown, Eastern Cape
J	C.E. Moss Herbarium	University of the Witwatersrand, Johannesburg, Gauteng
KEI	Herbarium, Walter Sisulu University	Walter Sisulu University, Umtata, Eastern Cape
KNP	Skukuza Herbarium	Skukuza, Kruger National Park, Mpumalanga
LYD	Herbarium, Mpumalanga Parks Board	Mpumalanga Tourism and Parks Agency (MPTA), Lydenburg, Mpumalanga
NH	KwaZulu-Natal Herbarium, SANBI	SANBI, Durban, KwaZulu-Natal
NMB	Herbarium, National Museum	National Museum, Bloemfontein, Free State
PRE	National Herbarium	SANBI, Pretoria, Gauteng
PRU	H.G.W.J Schweickerdt Herbarium	University of Pretoria, Pretoria, Gauteng
ZPB	Herbarium Zoutpansbergensis	Louis Trichardt, Limpopo

2.4. KEY TO SPECIES

Data collected on internal and external macroscopic bulb characters, traditional names and species appearance in the market was used to create a key to the bulb species studied. However, in some species, bulb characteristics can only assist with identification to a certain level. Taxonomic revisions that include details on both leaf and reproductive part characters were then utilised in order to assist with these identifications so that in all cases, species and 'form' (different forms of bulbs but currently synonymised species) identifications were possible. Various keys were reviewed in order to obtain the best possible format (von Breitenbach, 1967; Bruce, 1979; Low, 1983; Beyers, 2001). In order to support the use of the key, a glossary of terms is provided in Chapter 1. Stearn (1980) was consulted to obtain the correct botanical terminology. In addition, for simplicity and clarity, the simplest possible descriptions and terms are used and data such as the traditional name and market occurrence are used to describe species. Bulb photos are included in Plates 1 and 2.

2.5. SPECIES OVERVIEW

Internal and external macroscopic descriptions, geographical distribution, flowering season and market descriptions of all the species encountered in the medicinal markets are summarised to aid species-level assessments. Due to taxonomic uncertainty, infraspecific taxa (including subspecies) will be provided although not all subspecies have been noted in the markets. Data was collected from published literature, herbarium specimen sheets and markets. Statistica 6 was used for data analysis (Statsoft, 1984-2002). Although bulbs are not often pressed, a wealth of information can be obtained from herbarium specimens (Hildreth *et al.,* 2007). Synonyms are taken from Germishuizen and Meyer (2003) as well as The Plant List Database which combines multiple checklist datasets from the Royal Botanic Gardens, Kew and Missouri Botanical Garden (www.theplantlist.org) and medicinal uses of all species encountered are provided in the Appendix 1.

3. A BULB IDENTIFICATION KEY AND SPECIES DESCRIPTIONS

3.1. KEY TO BULB IDENTIFICATION

Key 1: Dichotomous key to the families of commonly traded bulb species in South African medicinal plant markets

a.)	Bulb tunics absent or when present do not produce extensible threads or fibres when pulled apart, membranous	Hyacinthaceae – Key 2
b.)	Bulb tunics with extensible fibres or threads present when the tunics are broken and pulled apart, bulb tunics fibrous.	Amaryllidaceae – Key 3 and Key 4

Key 2: Dichotomous key to some of the commonly traded bulb species of the Hyacinthaceae in South African medicinal plant markets

1.)	Bulb tunics present	*B. volubilis pg. 38*
	Bulb tunics absent	2.
2.)	Bulb scales tightly imbricate, difficult to pull apart, bulbs not often clustering or if clustering with only two daughter bulbs	3.
	Bulb scales loosely imbricate, easy to pull apart, bulbs often clustering with more than two daughter bulbs	4.
3.)	Bulb scales red to pink, or	*5.*
	Bulb scales cream	*D. altissima pg.43*
4.)	Bulb scales thick and rough; basal stem long	*U. epigea pg. 44*
	Bulb scales fleshy and smooth; basal stem absent	*D. delagoensis pg. 48*
5.)	Bulb, red to red green and fleshy	*6.*
	Bulb, peach to pink and compact	*D. cooperi pg.49*
6.)	Bulb ovoid	*D. robusta pg.46*
	Bulb pyriform	*7.*
7.)	Bulb scales about half the length of the bulb, encircling the bulb	*U. lydenburgensis pg. 49*
	Bulb scales as long as the bulb	*8.*
8.)	Bulb neck narrow, widest diameter of the bulb is about 5cm	*D. elata pg. 46*
	Bulb neck broad, widest diameter of bulb up to 10 cm	*D. sanguinea pg.40*

Key 3: Dichotomous key to some of the commonly traded bulb species of the Amaryllidaceae in South African medicinal plant markets

1.)	Bulb globose to subglobose; neck varying in length	2.
	Bulb ovoid, without distinct neck region	*Boophone disticha* pg. 51
2.)	Leaf tips exit bulb in concentric circles, except in *Crinum buphanoides*	Key 4. (*Crinum* species)
	Leaf tips exit bulb in two opposite rows	*Brunsvigia* species



5cm

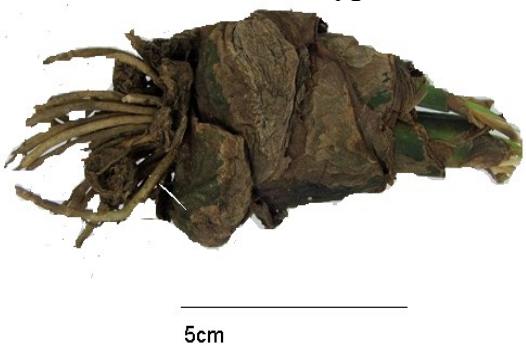
Bowiea volubilis pg. 38



Drimia elata pg. 46



Drimia robusta pg.46



Drimia delagoensis pg. 48



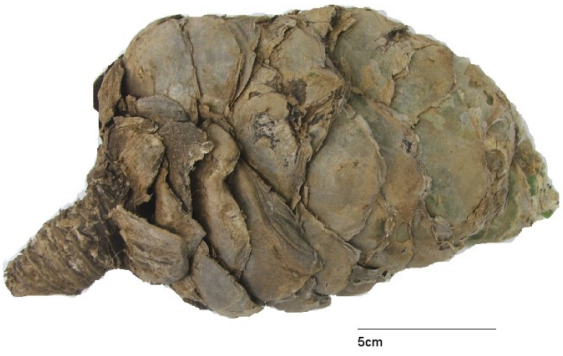
Urginea lydenburgensis pg. 49



Drimia cooperi pg. 49



Drimia sanguinea pg. 40



Urginea epigea pg. 44



Drimia altissima pg. 43

Plate 1: *Bowiea*, *Drimia*, and *Urginea* bulbs (page numbers of species descriptions are also included)

3.2. *CRINUM* BULB DIAGNOSTIC CHARACTERS

Similarities between species make vegetative identification difficult within the genus *Crinum*. Bulb neck characters, however, are helpful diagnostic characters within the *Crinum* species traded in the market and can be used to group species into clusters (Table 6). Traders and harvesters do not discriminate between *Crinum* spp. and instead the species occurring in the markets are a product of opportunistic harvesting of populations that occur in close proximity to settlements. Therefore, all *Crinum* spp. can potentially occur in market settings and the cluster of species in Table 6 does not only focus on known medicinal *Crinum* species. In addition, the ethnospecies name '*uMduze*' refers to both *Crinum* and *Brunsvigia*. However, only five species of *Crinum* were positively identified from market samples, so Key 4 only includes these species.

Table 6: Clusters of species within the genus *Crinum*, based on bulb characters (Adapted from Verdoon, 1973).

Group 1	Group 2	Group 3	Group 4
Small bulbs (up to 10cm in diameter), narrowed into relatively long neck (4–14cm long)	Bulb varying in size (up to 15cm in diameter), narrowed gradually towards apex (not produced into a distinct neck)	Bulbs varying in size (up to 25cm in diameter), subglobose, narrowing into a long neck	Bulbs large (up to 22cm in diameter) and globose, abruptly narrowing into a thick neck of varying length
C. campanulatum *C. acaule* *C. lineare* *C. lugardiae* *C. minimum*	*C. variabile* *C. bulbispermum*	*C. paludosum* *C. moorei* *C. macowanii*	*C. buphanoides* *C. crassicaule* *C. graminicola* *C. stuhlmannii*

Key 4: Key to species of Crinum encountered in markets based on leaf and bulb characters (Adapted from Verdoorn, 1973)

1.)	Leaves distichous	*Crinum buphanoides* pg. 53
	Leaves rosulate	2.
2.)	False stem present, formed by leaves sheathing at base	3.
	False stem absent	4.
3.)	Leaf margins cartilaginous; leaves flaccid and arcuate; new leaves with tip in centre, without obvious parallel venation	*Crinum bulbispermum* pg. 58
	Leaf margins non cartilaginous and smooth; leaf, ensiform, with obvious parallel venation	*Crinum moorei* pg. 55
4.)	Leaf margins cartilaginous; leaves canaliculate and slightly to strongly undulate	*Crinum macowanii* pg. 59
	Leaf margins ciliate; leaves broad and spreading, not undulate	*Crinum stuhlmannii* subsp. *delagoense* pg. 56



Boophone disticha pg. 51



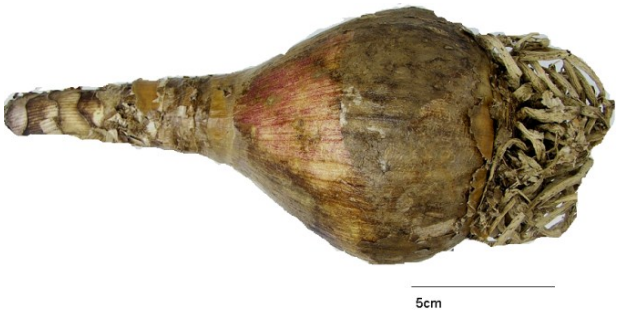
Crinum buphanoides pg. 53



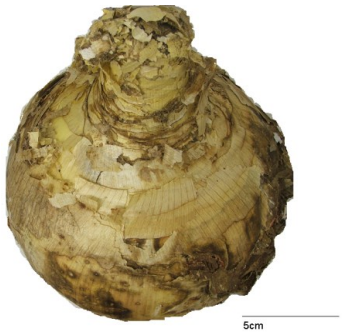
Crinum bulbispermum pg. 58



Crinum moorei pg. 55



Crinum macowanii pg. 50



Crinum stuhlmannii subsp. *delagoense* pg.56

Plate 2: *Boophone* and *Crinum* bulbs (page numbers of species descriptions are also included)

3.3. SPECIES SUMMARIES: HYACINTHACEAE

3.3.1. *Bowiea volubilis* Harv. ex Hook. f. subsp. *volubilis*

Bowiea volubilis Harv. ex Hook.f. is a member of the Hyacinthaceae (Hooker; 1867). It is closely related to the *Urginea, Drimia, Rhadamanthus, Litanthus, Thuranthos, Urgineopsis* and *Schizobasis* genera (Jessop, 1975) and is defined by long lived flowers, free tepals, persistent perianth and twining, much branched and fleshy inflorescence (Manning and Goldblatt, 2003). Both *Bowiea* and *Schizobasis* differ from any other South African members of the Hyacinthaceae in that they lack foliage leaves in the mature plant and have a branched aerial stem (Jessop, 1975).

Synonym
Bowiea kilimandscharica Mildbr
Red list status
VU A2ad

Vernacular names:
Zulu: *Gibisile, uGibisila* (Williams *et al.,* 2001) *uguleni, ugibisisila* (Hutchings *et al.,* 1996) *iGibisila* (Botha *et al.,* 2004)

Macroscopic description

External:

The species is recognizable by its fleshy, green, much branched and climbing peduncles that can reach 0.5–2m in length. The mature plant does not have leaves and instead photosynthesis takes place in the inflorescence (Jessop, 1975). Bracts are spurred and the pedicels are solitary and up to 100mm long. Flowers are white, green or yellowish green, with fleshy, spreading or reflexed, mostly free, narrowly lanceolate perianth segments (Jessop, 1975).

Bulb: internal and external

Bulbs can reach up to 15cm in diameter (Jessop, 1975); however, in South African markets they are generally very small (ca. 2cm in diameter). Bulbs are subglobose or depressed globose with fleshy cream to sometimes green bulb tunics (Speta, 1998). Often the outer edge of the bulb tunic is truncated, forming terraces around the bulb. There is no bulb neck, however, occasionally the base plate is slightly projected out of the base of the bulb. The non-contractile roots are attached to this plate. Internally, bulbs have an 'onion' like appearance and are usually cream with patches of green. The dirty cream coloured base plate is small and extends less than one third into the bulb.

Occurrence at medicinal markets

Bulbs were commonly traded in the KZN (Cunningham, 1988) and Faraday (Williams, *et al.,* 2001) markets; however, in Warwick in 2008 there were only a few traders selling this species. The bulbs are infrequently traded in the Free State markets and have been recorded in Bushbuckridge area, Mpumalanga (Mander, 1997). No bulbs were observed in Nelspruit. Small bulbs are commonly traded in 'onion' sachets with approximately 50 bulbs per sachet at Faraday. Occasionally large bulbs are traded; however, these are not in sachets and instead are found drying on sacks in front of stalls.

Geographical distribution and flowering and fruiting season

Bowiea volubilis flowers all year round, however the highest flowering frequency occurs in the hot summer months (December, January and February) (Figure 1). Fruiting occurs over the same period, although at lower frequencies. No inflorescences have been observed in the market so flowering time may not be useful in market settings alone. However, market samples flower prolifically if planted soon after purchase (independent of planting time); therefore, the ability to flower year round can aid identification of market specimens.

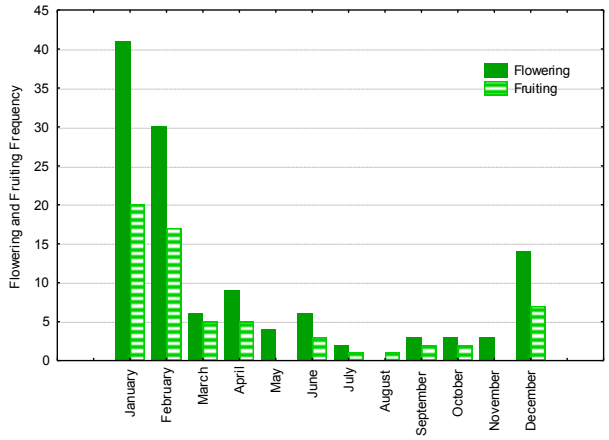
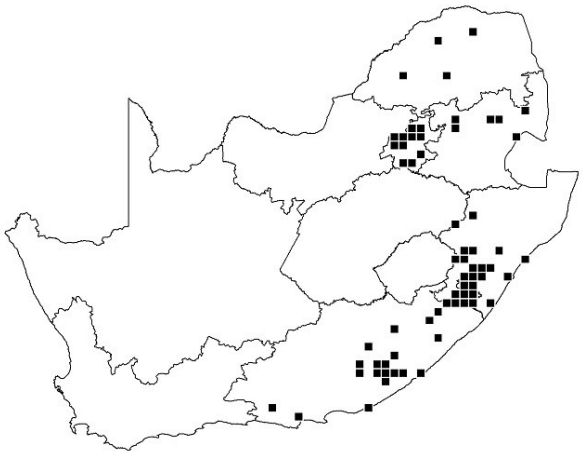


Figure 1: Flowering and fruiting frequency (number) recorded from herbarium collections for *Bowiea volubilis*



Map 2: Distribution data for *Bowiea volubilis* in South Africa (note that only the distribution within South Africa was mapped)

The species has a relatively large distribution (Map 2); however, the concentration of localities around the highly populated KZN and Gauteng regions may have negative impacts for this species. The species is known to be locally extinct in some areas of KZN already (Cunningham, 1988).

3.3.2. The *Drimia* Jacq ex Willd. / *Urginea* Steinh. Complex

The genus, *Drimia* belongs to the Hyacinthaceae family, which currently comprises ca. 1,000 species distributed roughly into 70 genera (Speta 1998a, 1998b). Jacquin recognised the genus *Drimia* and placed four species within it based on the presence of conspicuously reflexed perianth segments (Jessop, 1977);

however, the name was only validated in 1799 (Willdenow, 1799; Jessop, 1977). In 1808, problems were encountered in separating species with spreading perianth segments from those with reflexed perianth segments when Thunberg transferred *Anthericum* (with spreading segments) to *Drimia* (reflexed perianth segments) (Jessop, 1977), this later led to the creation of *Urginea* Steinh., which was used for species with spreading perianth segments and included species from Europe and South Africa (Jessop, 1977). Baker (1897) placed 22 species within *Drimia* Jacq. and 27 species within *Urginea* Steinh. (13 and 25 respectively, which he had described himself) (Jessop, 1977).

More recent work, however, has not found justification for such splitting with Jessop (1977) reducing *Urginea* to synonymy under *Drimia*. The principal differences between the genera: the degree of fusion of the perianth; the tendency for the stamens to be connivent in *Drimia* and the reflexed perianth in *Drimia* showed considerable overlap. Stedje (1987; 1996; 1998) and Manning and Goldblatt (2003) have also taken this conservative approach and the broad circumscription of the genus, *Drimia* seems to be favoured.
In this broad sense, *Drimia* is well defined by a short-lived flowers with the tepals approximately united at the base. Each flower lasts a single day or less and the perianth is caducous, abscising at the base to wither as a cap on the developing capsule. *Drimia* in this sense is a sister clade to *Bowiea*, the remaining genus in the subfamily, Urgineoideae (Manning and Goldblatt, 2003). The broad delineation of *Drimia* is acceptable, however species descriptions within the genera have often not taken into account bulb morphology and formation and in order to discriminate between bulb forms, original nomenclature has been used (often within the genus *Urginea*).

3.3.3. *Drimia sanguinea* (Schinz) Jessop

Drimia sanguinea is well accepted and recognised by its linear-lanceolate leaves, cylindric raceme (approximately 17cm long) with numerous white (with brown keel) flowers and a globose, scaly wine red bulb (Dyer, 1942b; Jessop, 1977)

Synonyms
Sekanama burkei (Baker) Speta*; Sekanama sanguinea* (Schinz) Speta*; Urginea burkei* Baker*; Urginea rautanenii* Baker*; Urginea sanguinea* Schinz

Vernacular names:
isiKlenama, *uMahlogolosi* (Zulu); *sekanama*, *skanama* (Sotho) (Diederichs, 2001; Williams *et al.,* 2001)

Red list status
NT A2d

Macroscopic description

External:

D. sanguinea is a bulbous herb with hysteranthous leaves which are ca. 25cm long and 1cm broad, and linear-lanceolate in shape (Dyer, 1977). Numerous white flowers are borne on a cylindrical raceme. The perianth is ca. 1cm long, oblong-lanceolate and white with a brown dorsal stripe or keel (Dyer, 1942b). Additionally the stamens are white and the anthers yellow (Dyer, 1977).

Bulb: internal and external

Bulbs are between 4–9cm long and ca. 7cm in diameter (Philips, 1924; Jessop, 1977). The average diameter in the market is between 7 and 8cm (V.J. Brueton, pers. obs.). The bulb has tightly imbricated bulb scales which are distinctly wine red and when cut are ‘fleshy’. There is a distinct but thick neck and a woody base plate, often with fleshy roots attached. Bulbs can cause great irritation and a burning sensation when rubbed on skin. Internally, bulbs are wine red; however, the innermost and new bulb scales are cream and gradually become darker with age.

Occurrence at medicinal markets

Bulbs are very common in Faraday, occasional in some of the Free State informal stalls and infrequent in Warwick. No bulbs were seen in Nelspruit; however, bulbs have been recorded in the Bushbuckridge area (Mander, 1997). In Faraday (where common), the bulbs are found in large stacks and approximately 4–5 bulbs are purchased at one time. In Warwick and the Free State markets, however, ca. 1–2 bulbs are sold at a time and the volume on sale is small.

Geographical distribution and flowering and fruiting season

The flowering season of *D. sanguinea* appears to be narrow, occurring mainly between September and November (Figure 2). This species is known to be highly poisonous and prolific (Bullock, 1952). Due to the fact that the species is relatively common, collection intensity may be decreased as collectors were able to identify the species and no further specimens were required.

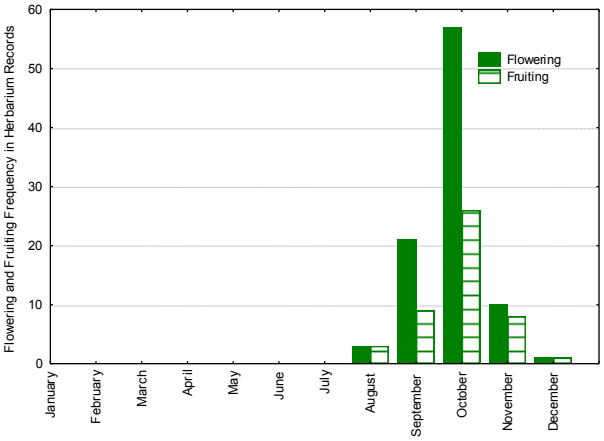
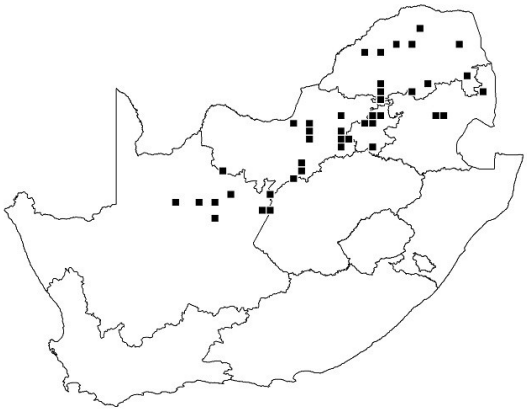


Figure 2: Flowering and fruiting frequency (number of records) recorded from Herbarium collections for *Drimia sanguinea*



Map 3: Distribution data for *Drimia sanguinea*

The species is distributed across the northern reaches of the country and is quite common in the Gauteng region (Map 3). This distribution likely contributes to the high volume of bulbs found at Faraday market, Johannesburg.

3.3.4. *Drimia altissima* (L.f.) Ker Gawl. and *Urginea epigea* R.A. Dyer

The current accepted nomenclature for both the epigeal and hypogeal bulb form is *Drimia altissima (L.f)* Ker Gawl. In order to ensure the relevant taxonomic information is provided, all synonyms and vernacular names related to the current accepted name is provided below. Separate sections are then provided for the hypogeal type (*D. altissima)* and the epigeal form, (*Urginea epigea*).

Synonyms

Drimia barteri Baker; *Drimia paolii* Chiov.; *Drimia uitenhagensis* Eckl.; *Idothea altissima* (L.f.) Kuntze; *Idothea barteri* (Baker) Kuntze; *Ornithogalum altissimum* L.f.; *Ornithogalum giganteum* Jacq.; *Scilla micrantha* A.Rich.; *Urginavia altissima* (L.f.) Speta; *Urginavia epigea* (R.A.Dyer) Speta; *Urginavia micrantha* (A.Rich.) Speta; *Urginea altissima* (L.f.) Baker; *Urginea brevipes* Baker; *Urginea epigea* R.A.Dyer; *Urginea micrantha* (A.Rich.) Solms*

Vernacular names:

isiKlenama, *Mahlokoloza*, *sekanama*, *skanama*, *uMahlogolosi*, *umHlabelo*, White *skenama* Lukhovo (Swati), *UmHlabelo*, umahlokolozi, umgulube, inguduza, *isiKlenama*, *uMahlogolosi* (Zulu)
(Cunningham, 1988; Williams *et al.,* 2001;)

Red list status

LC-Declining

*Please note that all known synonyms from The Plant List (www.theplantlist.org) are provided even in the case where the synonym it is referring to the epigeal form.

At the species level, there is much taxonomic confusion between *Drimia altissima* (L.f.) Ker Gawl. and the species described by Dyer as *Urginea epigea* R.A. Dyer, as some consider *U. epigea* (reduced to synonymy under *D. altissima*) to be a separate species (Dyer, 1947; Obermeyer, 1980; Koorbanally *et al.,* 2005a). Initially, it was separated from *Drimia altissima* [then *Urginea altissima* (L.f) Baker)] by Dyer (1947) based on its less dense inflorescence and epigeal, large and fleshy bulbs. When Jessop (1977) synonymised *Urginea* under *Drimia*, special mention was made of *D. altissima* and the epigeal form of the species which was known as *Urginea epigea* in the past: specifically, differences in the bulb structure between *D. altissima* and the epigeal form were attributed to environmental factors as it was not possible to link the difference in bulbs to morphological characteristics or geographical distribution (Jessop, 1977).

Factors suggested as contributing to the misunderstanding regarding *D. altissima* and the epigeal form, *U. epigea* include, the absence of leaves at flowering time and the difficulty in preserving large bulbs in herbarium records (Dyer, 1947). *Urginea epigea* inhabits semi-arid, rocky grasslands in a number of southern African countries, particularly along the eastern coast, which differs from the widespread hypogeal *D. altissima* (Koorbanally *et al.,* 2004). In addition, traders, harvesters and traditional healers recognise the differences between taxa (V.J. Brueton, pers. obs.). Recent phytochemical studies have discovered the presence of Bufatetraenolide (a novel bufadienolide, possessing a 3,5-conjugated diene system) (Koorbanally *et al.,* 2004) as well as sesquiterpenes, which have only been isolated in *Urginea epigea* and not in *D. altissima* (Koorbanally *et al.,* 2005a).

In this study, *D. altissima* (hypogeal form) refers only to the species with hypogeal bulbs with tightly imbricated scales that are whitish cream to light brown. In addition, the species is thought to have shorter pedicels and a very dense inflorescence, while *U. epigea* (epigeal form) has a less dense inflorescence and epigeal, large and loosely imbricate bulb scales and will be treated separately.

Geographical distribution and flowering and fruiting season

Flowering season in *D. altissima* and *U. epigea* follows a similar pattern, with the highest flowering frequency in herbarium records occurring in summer (Figure 3). *D. altissima* has the highest flowering frequency between October and January while *U. epigea* flowers slightly earlier: from September to December. In addition, it appears that *D. altissima* has a broader flowering season and may flower in winter months (July) while no flowering was recorded in winter for *U. epigea*. The same pattern is noted in regards to fruiting season (Figure 3).

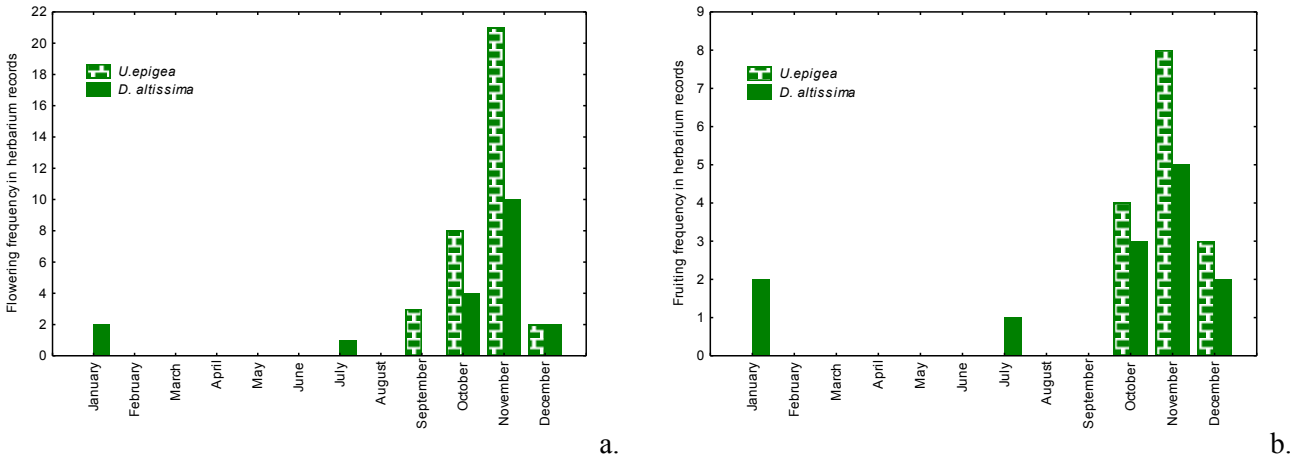


Figure 3: Differences in a.) flowering and b.) fruiting frequency (number of records) between *Drimia altissima* and *Urginea epigea* in herbarium records



a ***b***

Map 4: Distribution data for a.) *Drimia altissima* and b.) *Urginea epigea*

The distribution of the functional species (Map 4a and b) differs with *D. altissima* being more widespread in the northern parts of the country and along the Eastern Cape. In contrast, *U. epigea* is mainly found along the border with Mozambique and is less widespread. Some overlap does occur.

3.3.4.1. *Drimia altissima (L.f)* Ker Gawl. (hypogeal form)

Synonyms
Urginea altissima (L.f.) Baker
Red list status
LC-Declining

Vernacular names:
isiKlenama, *Mahlokoloza*, *sekanama*, *skanama*, *uMahlogolosi*, *umHlabelo*, White *skenama* (Cunningham, 1988; Williams *et al.,* 2001;)

Macroscopic description

External:

D. altissima is a bulbous herb with hysteranthous leaves that are glabrous, lanceolate and approximately 30–45cm long and 5cm broad (Baker, 1897). The species has a stout peduncle and a cylindrical raceme that is moderately dense. In terms of the reproductive parts, the species does not differ greatly from *U. epigea* other than in its very dense inflorescence and generally smaller pedicels. As with *U. epigea*, the perianth is white or cream with a green dorsal stripe and reflexed petals (Dyer, 1977). The stamens are white with yellow anthers, the ovary is green and the stigma and style both white (Dyer, 1947). Between 100 and 300 flowers are spirally arranged and spurred bracts are present.

Bulb: internal and external

The bulb is large, ovoid and hypogeal. The light brown to cream outer scales are membranous and cover more tightly packed inner fleshy scales that are cream coloured (Baker, 1897; Jessop, 1977). In South African markets, the average bulb diameter is ca. 9cm. The bulb scales differ from *U. epigea* in that they are thinner and very tough. They also often cause irritation as small hair-like 'splinters' attach to the skin when the bulb is handled. The species is not prone to clustering; and, like *U. epigea*, the bulb does not have a distinct neck region but rather slowly tapers towards an apex. Additionally, the bulb is very difficult to cut open as it is denser than *U. epigea*. Internally, the species is cream to slightly peach coloured and has a darker base plate that can take up to one half of the length of the bulb. The bulb scales also appear to have numerous thread-like fibres. The species does have a projecting base plate, where fleshy roots attach, however it does not have the long protruding stem like base plate of *U. epigea.*

Occurrence at medicinal markets

The species is common in Faraday but occasional in the Warwick market (where *U. epigea* is common). The species was not encountered in the Free State or Nelspruit markets, although it has been recorded in the Bushbuckridge area (Mander, 1997). However, whether the species referred to as *U. altissima* in Mander (1997) is referring to *U. epigea* or *D. altissima* is not known. Approximately 2–3 bulbs are sold at a time in Faraday, whereas in Warwick only one bulb is sold at a time.

3.3.4.2. *Urginea epigea* R.A. Dyer (epigeal form)

Synonyms
Note: This name is not the currently accepted name and this form is currently synonymised under *D. altissima*. In this case, it is used to describe the epigeal form of *D. altissima*).

Vernacular names:
Lukhovo (Swati), *UmHlabelo*, umahlokolozi, umgulube, inguduza, *isiKlenama*, *uMahlogolosi* (Zulu) (Diederichs, 2001; Williams *et al.,* 2001; Koorbanally *et al.,* 2004)

Red list status
LC

Macroscopic description

External:

The leaves of this bulbous herb are hysteranthous, linear-lanceolate and ca. 15–30cm long and 2–3cm broad (Dyer, 1947). Spurred bracts occur on approximately two thirds of the terete, erect, one metre tall scape. The perianth lobes are white with a narrow green keel and the petals are reflexed, while the stamens are white with yellow anthers. The ovary is green and the stigma and style both white (Dyer, 1947). In addition, the pedicels are ca. 15mm long (generally longer than in *D. altissima*) (Jessop, 1977).

Bulb: internal and external

The bulb is epigeal with bulbs presented mainly above ground (Koorbanally *et al.,* 2004). The average bulb diameter is ca. 10–15cm (Dyer, 1947); however, in South African markets the average diameter is ca. 8–9cm. They are often formed into groups of two to four bulbs composed of thick and fleshy scales that are ca. 5–7cm broad and about 1cm long (Dyer, 1947). In cross section, the bulb appears star shaped or pentagonal. There is no distinct neck but rather the bulb gradually converges towards the apex. The bulb has a long projecting stem extending from the basal plate that withers quickly when dry. Internally, the bulb scales are thick and fleshy but appear somewhat dry. The base plate is small (less than one quarter of the entire length) although it does extend outwards. The tips of the cream scales are green.

Occurrence at medicinal markets

The bulbs are common in both Faraday and Warwick markets, and are occasional in Free State markets. In the present study, no bulbs were observed in Nelspruit; however, Mander (1997) recorded *U. altissima* in Bushbuckridge. Whether the bulbs observed in Bushbuckridge were the epigeal form (*U. epigea*) or hypogeal form (*D. altissima*) or both is unknown. However, the bulb is known to occur throughout the Kruger National Park (Map 4b), and hence may be traded in the area. Approximately 2–3 bulbs are sold at a time in Faraday, between 1–2 bulbs at Warwick and only one bulb in the Free State.

3.3.5. *Drimia elata* Jacq. and *Drimia robusta sensu* Baker form (robust form of *D. elata*)

The current accepted nomenclature for both the robust and smaller bulb form is *Drimia elata Jacq.* In order to ensure the relevant taxonomic information is provided, all synonyms and vernacular names related to the current accepted name are provided below. Separate sections are then provided for the robust type (*D. robusta)* and the slender form, (*D. elata*).

Synonyms
Drimia alta R.A.Dyer; *Drimia altissima* Hook.f. [Illegitimate]; *Drimia burchellii* Baker; *Drimia ciliaris* Jacq. ex Willd.;*Drimia concolor* Baker;*Drimia elgonica* Bullock; *Drimia purpurascens* J.Jacq.;*Drimia rigidifolia* Baker; *Drimia robusta* Baker; *Drimia rudatisii* Schltr.; *Drimia villosa* Lindl.; *Drimia zombensis* Baker; *Hyacinthus ciliaris* (Jacq. ex Willd.) Poir.; *Hyacinthus elatus* (Jacq.) Poir.; *Idothea burchellii* (Baker) Kuntze; *Idothea ciliaris* (Jacq. ex Willd.) Kunth; *Idothea concolor* (Baker) Kuntze;*Idothea elata* (Jacq.) Kunth; *Idothea purpurascens* (J.Jacq.) Kunth; *Idothea rigidifolia* (Baker) Kuntze; *Idothea robusta* (Baker) Kuntze; *Idothea villosa* (Lindl.) Kunth; *Idothearia ciliaris* (Jacq. ex Willd.) C.Presl; *Idothearia elata* (Jacq.) C.Presl; *Idothearia purpurascens* (J.Jacq.) C.Presl; *Idothearia villosa* (Lindl.) C.Presl; *Strepsiphyla villosa* (Lindl.) Raf.*

Vernacular names:
IsiKlenama, *ndongwana-zimbomvana, indongana-zibomvana, umqumba, unDongananzibomvana,* (Zulu) *sekanama*, *skanama* (Sotho) (Cunningham, 1988; Hutchings *et al.,* 1996; Mander, 1997; Williams *et al.,* 2001)

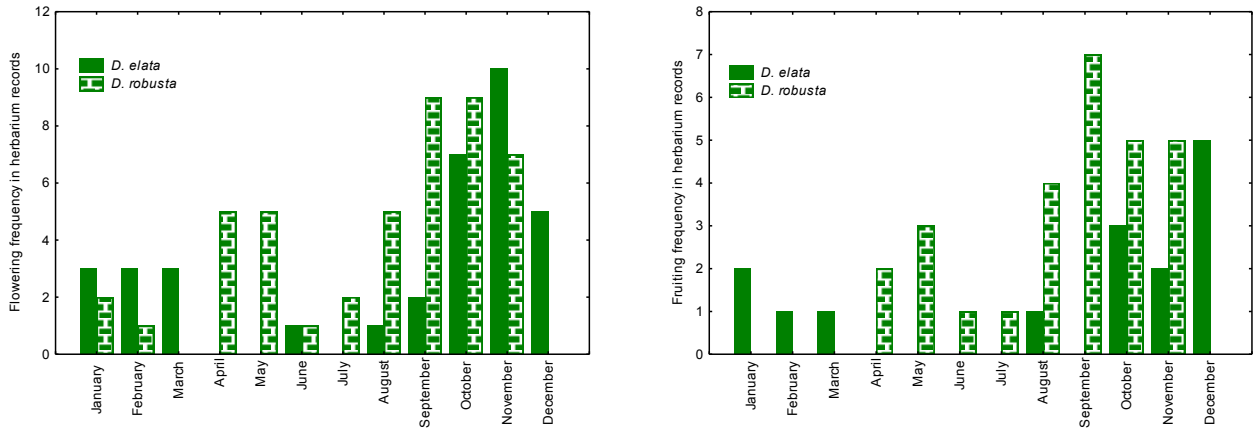
Red list status
DDT

*Please note that all known synonyms from The Plant List (www.theplantlist.org) are provided even in the case where the synonym it is referring to the robust form.

Jessop's concept of *D. elata* included a wide range of forms (some of which had been given separate species status by various authors) (Jessop, 1977). The reason for the inclusion of these 'forms' is principally the lack of identifiable herbarium specimens (although leaves occur on many) (Jessop, 1977). The inclusion of *D. robusta* is problematic (especially in terms of ethnobotanical studies) because of its narrow distribution and popularity in the KwaZulu-Natal herbal medicine trade.
In this study, *D. robusta* will include *D. alta* R.A. Dyer, and will be treated separately from *D. elata* so that differing effects of trade can be determined. *Drimia elata* is a widespread species and recognisable by its small, dark pink to red fleshy bulb with distinctive but thin neck, while *D. robusta* is very robust and has a distinctive bulb.

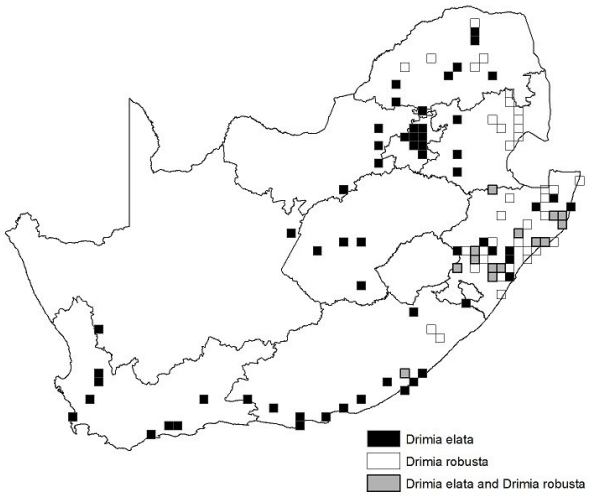
In terms of reproductive material, *D. robusta* does not differ largely from *D. elata*. This similarity may indicate that *D. robusta* is a robust form *D. elata* rather than a separate species. More study is necessary to understand all the subtleties and implications. Despite this confusion, the more restricted distribution of the robust form or species and its popularity in KZN makes it very important to understand the effects of trade on this taxon.

Geographical distribution and flowering and fruiting season
Flowering season differs between *D. elata* and *D. robusta. D. elata* flowers primarily in the summer months (September to March), with occasional winter flowering specimens collected (June and August). *D. robusta* appears to have a longer flowering season that occurs between January and November (Figure 4). The same pattern is observed in the fruiting frequency in herbarium records for *D. robusta* (Figure 4).



a. b.

Figure 4: Differences in a.) flowering and b.) fruiting frequency (number of records) between *D. elata* and *D. robusta* in herbarium records



Map 5: Distribution data for a.) *D. elata*, b.) *D. robust*a and c.) *D. elata* and *D. robusta*

There were a large number of herbarium samples with no bulb material that may have been either *D. elata* or *D. robusta;* however, distribution data for the distinct types suggests that *D. elata* is more widespread occurring in Limpopo, Gauteng, along the Eastern and Western Cape coast line, KZN and occasionally in Gauteng (Map 5). In comparison, *D. robusta* is concentrated in KZN and along the Mozambique border.

3.3.5.1. *Drimia elata* Jacq (slender form)

Synonyms
Drimia alta R.A. Dyer
Drimia ciliaris Jacq. ex Willd.
Red list status
DDT

Vernacular names:
IsiKlenama, *ndongwana-zimbomvana, indongana-zibomvana, umqumba, unDongananzibomvana,* (Zulu) *sekanama*, *skanama* (Sotho) (Cunningham, 1988; Hutchings *et al.,* 1996; Mander, 1997; Williams *et al.,* 2001)

Macroscopic description

External:

Drimia elata has between five and six lanceolate, glaucescent, glabrous and sub-erect leaves, which are often produced after the flowers (Baker, 1897). The peduncle is erect and between 30–45cm long, with a moderately dense, cylindrical raceme. The perianth segments are canaliculate, reflexed and variable in colour. They range from greenish purple, white striped with brown, silvery white or pinkish with a darker or greenish brown median stripe (Baker, 1897; Jessop, 1977). The stamens are white with yellow anthers.

Bulb: internal and external

The bulb is globose and about 7cm in diameter and has fleshy bulb scales that are light red to pink as long as the bulb. The neck is thin and often the dry, membranous outer scales converge around the neck region and sometimes up the stem. Bulbs in South African markets are usually small, ca. 5.5 cm in diameter. Internally, the bulb is purple although the tips of the young, central bulb scales are white-pink or cream. The base plate is small and inconspicuous and does not seem to extend past the base of the bulb. The roots are contractile.

Occurrence at medicinal markets

Bulbs are seasonally abundant in Faraday but occasional in Warwick. They are very common in the Free State markets and have also been recorded in the Eastern Cape markets (Dold and Cocks, 2002). However, there is no record of the species in Nelspruit or Bushbuckridge (Mander, 1997). As the bulbs are small, ca. 9 bulbs are sold at a time in Faraday, and about 2 bulbs are sold at a time in the Free State. Only one trader stocked the species in Warwick, so it is difficult to know the average although in that instance, 6 bulbs were sold for R10.

3.3.5.2. *Drimia robusta* Baker (robust form)

Synonyms
Drimia altissima Hook. f.
Note: This is not the currently accepted name and this form is currently synonymised under *D. elata.* In this case, it is used to refer to the 'robust' form of *D. elata*
Red list status
DDT

Vernacular names:
IsiKlenama, *ndongwana-zimbomvana, indongana-zibomvana, umqumba, unDongananzibomvana*, (Zulu) *sekanama*, *skanama* (Sotho) (Cunningham, 1988; Hutchings *et al.,* 1996; Mander, 1997; Williams *et al.,* 2001)

Macroscopic description

External:

This bulbous herb has approximately six to eight lorate-lanceolate, fleshy leaves that occur at the time of flowering (Baker, 1897). The leaves can be between 36–120cm long and between 2–7cm broad. The peduncle is very robust and the cylindrical raceme occupies approximately half its length (Dyer, 1943). The pedicels are spreading, with lanceolate bracts and dull reddish white perianth segments that are convolute. Often there is a broad pink brown band and reflexed white margins (Dyer, 1943). The stamens are white but have pinkish purple bases and dark purple anthers.

Bulb: internal and external

The bulb is ovoid and approximately 7–10cm in diameter (Baker, 1897), however, the average diameter in South African markets is ca. 7cm. The reddish scales are densely packed and fleshy although the apices

of the scales are often dried and membranous. The scales are tightly imbricate and often form a step like pattern. There is no noticeable neck region, instead the bulb tapers slowly to the apex. In most cases, the bulb does not have a projecting base plate. The bulb sap can cause great irritation and burning when rubbed on the skin and sometimes even handling the bulb can cause irritation. Internally, the bulb scales are light to darker purple with the inner new bulb scales and the base plate often a light cream colour. The base plate is not long and extends approximately one fifth of the bulb length.

Occurrence at medicinal markets

The bulbs are very common in Warwick but only occasional in Faraday. In addition, no samples were recorded in either the Free State or Nelspruit markets and it is not known to be traded in the Eastern Cape (Dold and Cocks, 2002). Approximately 3–4 bulbs are sold at a time in Faraday whereas in Warwick, only 1–2 bulbs are sold at a time.

3.3.6. *Drimia delagoensis (*Baker) Jessop and the *Urginea lydenburgensis* R.A. Dyer form (Lydenburg form of *D. delagoensis*)

The current accepted nomenclature for both the clumping and compact bulb forms is *Drimia delagoensis* (Baker) Jessop. In order to ensure the relevant taxonomic information is provided, all synonyms and vernacular names related to the current accepted name are provided below. Separate sections are then provided for the clumping type (*D. delagoensis)* and the compact form, (*U. lydenburgensis*).

Synonyms	**Vernacular names:**
Sekanama delagoensis (Baker) Speta; *Urginea delagoensis* Baker; *Urginea lydenburgensis* R.A. Dyer*	*IsiKlenama, ndongwana-zimbomvana, indongana-zibomvana, umqumba, unDongananzibomvana*, (Zulu) *sekanama*, *skanama* (Sotho) (Cunningham, 1988; Hutchings *et al.,* 1996; Mander, 1997; Williams *et al.,* 2001)
Red list status	
LC	

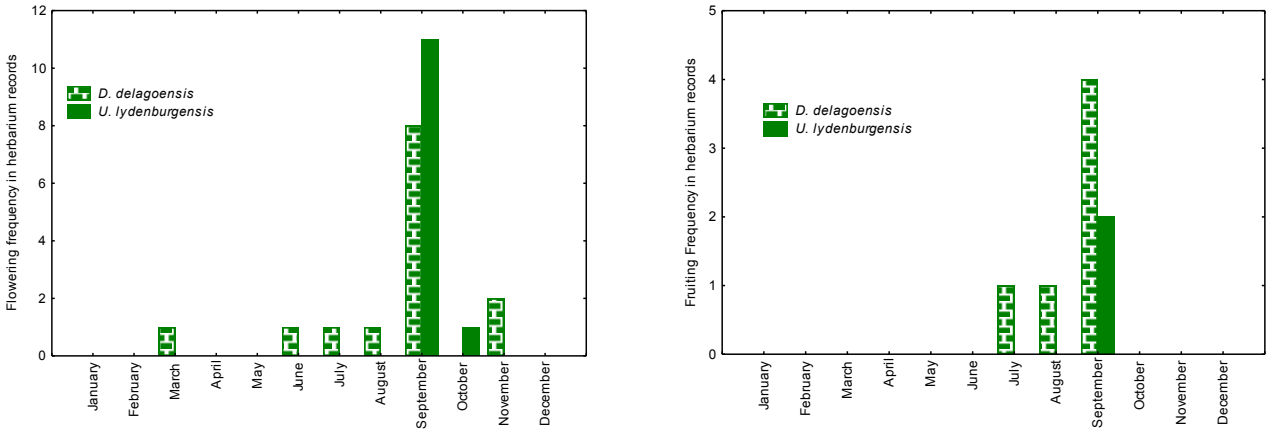
*Please note that all known synonyms from The Plant List (www.theplantlist.org) are provided even in the case where the synonym it is referring to the compact form.

Both *Drimia delagoensis* and *Urginea lydenburgensis* were originally members of the genus *Urginea* Steinh., however *Urginea* was reduced to synonymy under *Drimia* (Jessop, 1977), and the species placed as a member of the large *Drimia* group. There has been some confusion within the species group, with Dyer (1942a) feeling that *U. lydenburgensis* should be given full species status, whereas Jessop (1977) considers *U. lydenburgensis* as just a form of *D. delagoensis.*

In this dissertation, the forms have been kept separate due to their differing geographic distribution and morphological bulb characteristics. *D. delagoensis* (epigeal form) refers to the somewhat epigeal, dark olive green bulb which is prone to clumping and has loosely packed thicker outer scales. The leaves of this form are linear and deeply canaliculate (Dyer, 1942a). The compact form is referred to as *U. lydenburgensis.* This form has a pink bulb with thick, more tightly packed scales. The leaves are sub-terete and linear (Dyer, 1942a).

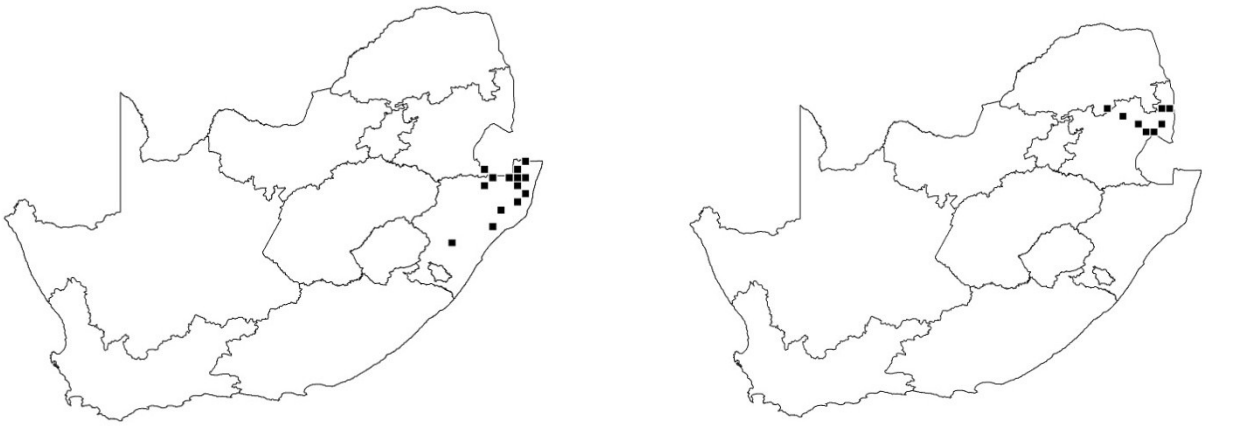
Geographical distribution and flowering and fruiting season

U. lydenburgensis is a restricted species that has only been collected in the Lydenburg area of Mpumalanga (Dyer, 1942a). *D. delagoensis* appears to have a wide flowering range as flowering occurs in both the winter and summer months (although with greater frequency in the summer months), while *U. lydenburgensis* has only been collected in September and October (Figure 5). The same pattern can be seen in the fruiting frequencies of the species (Figure 5).



a. b.

Figure 5: Differences in a.) flowering and b.) fruiting frequency (number of records) between *Drimia delagoensis* and *Urginea lydenburgensis*



a. b.

Map 6: Distribution data for a.) *Drimia delagoensis* and b.*) Urginea lydenburgensis*

The distributions of *D. delagoensis* and *U. lydenburgensis* do not overlap, with *U. lydenburgensis* being restricted to Mpumalanga and *D. delagoensis* throughout northern KZN (Map 6a and b.). However, important to note is that the distribution of either species or forms in Swaziland and Mozambique was not mapped and areas where the forms overlap may occur in these countries.

3.3.6.1. *Drimia delagoensis (*Baker) Jessop (clustering form)

Synonyms
Urginea delagoensis Baker
Red list status
LC

Vernacular names:
IsiKlenama, ndongwana-zimbomvana, indongana-zibomvana, umqumba, unDongananzibomvana, (Zulu) *sekanama*, *skanama* (Sotho) (Cunningham, 1988; Hutchings *et al.,* 1996; Mander, 1997; Williams *et al.,* 2001)

Macroscopic description

External:

The bulbous herb has approximately 5–6 synanthous, linear and glabrous leaves that are ca. 4.2mm broad (Baker, 1897). The peduncle is stiffly erect and the raceme is cylindrical and lax and has 20–50 flowers (Jessop, 1977). The perianth is light brown, creamy white, greenish white or pale mauve, with or without a darker dorsal stripe (Baker, 1897; Jessop, 1977).

Bulb: internal and external

The bulb is oblong cylindrical and very prone to cluster, often with a very gnarled exterior. The scales are very loose and green with some red washed patches. The bulb does not have a distinct neck. Bulb scales cause irritation when rubbed on skin, but outer scales are less caustic and the bulb can be handled without skin irritation. Internally, the bulb scales are purplish pink and quite dark. The average bulb diameters in South African markets are about 6.8cm.

Occurrence at medicinal markets
Bulbs are seasonally occasional in the Faraday market and occasional in the Warwick market. In both markets, only about five stalls stocked the species at one time. More bulbs were sold per sale in Faraday market (between seven and eight bulbs) while in Warwick market, only 2 bulbs on average were sold at a time.

Flowering season
Surprisingly, there are more flowering records in the winter months (June, July and August) than in some of the summer months (October, December and January) (Figure 5a).

3.3.6.2. *Urginea lydenburgensis* R.A. Dyer (Lydenburg form)

Synonyms
Note: This species name is not the accepted name and the species is currently synonymised under *D. delagoensis*. In this case it refers to the Lydenburg version of the species.
Red list status
NT B1ab(v)

Vernacular names:
masi xabana, isiKlenama (Crouch *et al.,* 2006)

Macroscopic description
External:
The species has approximately 1–2 leaves from each bulb. These leaves are about 45cm long and are between 3–5cm broad, glaucous green, sub-terete, slightly flattened along the adaxial surface and occasionally slightly grooved. The leaves are produced before the inflorescence (Dyer, 1942a). The peduncle is 30–50cm tall and 3mm thick, glaucous, sub-terete and firm, with the inflorescence approximately one third of its length. The perianth segments are whitish with a green keel and spreading from below the middle. The upper bracts are spurred, while the lower ones are much reduced (Dyer, 1942a).

Bulb: internal and external
The bulb is pyriform, up to 10cm long and 8cm in diameter (Dyer, 1942), although in Nelspruit stalls the average diameter is 6.5cm. The species is often solitary but tight clusters do occur. The external scales are pink and partly covered with a transversely ribbed membranous tip (Dyer, 1942a). The exterior is also often gnarled in appearance. Internally, the bulb is fleshy pink to green.

Occurrence at medicinal markets
Literature surveys suggest that the bulb has not been recorded in any South African medicinal markets surveys (Cunningham, 1988; Mander, 1997; Williams *et al.,* 2001; Dold and Cocks, 2002; Botha *et al.,* 2004), however bulbs have been purchased from Nelspruit for use in phytochemical analysis of the species (Crouch *et al.,* 2006). In this study, *U. lydenburgensis* was only recorded in Nelspruit, with only one trader in a group of pavement stalls stocking the species. It was not abundant and only a few individuals were on sale. On this occasion, five bulbs were purchased for R10.

3.3.7. *Drimia cooperi* (Baker) Baker

Drimia cooperi was regarded as a species restricted to the Eastern Cape (Jessop, 1977; Crouch *et al.,* 2010). However, more recent evidence suggests that it does extend northwards into KZN up to Maclear (Crouch *et al.,* 2010). It is a well defined species, although uncommon in medicinal plant markets. It was first identified in Warwick medicinal market in 2004 and the species has been observed on two more visits to Warwick medicinal market in 2008 (Crouch *et al.,* 2010) (Appendix 1).

Synonyms
Ornithogalum cooperi Baker
Red list status
VU A2ad; C2a(i)

Vernacular names:
uMahlokoloza, *uMahlogolosi* (Crouch *et al.,* 2010)

Macroscopic description
External:

Between 2–4 glabrous, sublinear, synanthous leaves occur, each leaf is 8–27cm long and ca. 1cm broad (Jessop, 1977). The elongate raceme has between 35 and 70 flowers each with a spurred bract. The perianth is greenish white and rather conspicuously striped, and is fused and spreading (Jessop, 1977). The filaments are linear and the style and ovary are approximately the same length (Baker, 1897).

Bulb: internal and external

The bulb is narrowly ovoid to globose and tapers towards a thick neck region (Baker, 1897; Jessop, 1977). The scales are compacted and firm and are light peach to salmon orange and have loosely arranged tough fibrous (although slightly succulent) scales. The scales have fine threads where the bulb scales have been shed or damaged (Jessop, 1977). When cut open, the bulb tends to lose shape and the scales are loosely arranged. Internally, bulb scales are light peach and do not appear to be very succulent.

Occurrence at medicinal markets

This species is uncommon and has only recently been recorded in Warwick (Crouch *et al.,* 2010). When the species was first encountered in the market (in 2004), only one trader was recorded with the species (*N.R. Crouch 1038* NH), however, in this study three traders were encountered with the species. On all three occasions, only a few bulbs (less than five) were on sale. The average diameter in the market is around 5cm. The species has not been encountered in any other market in South Africa (Cunningham, 1988; Mander, 1997; Williams *et al.,* 2001; Dold and Cocks, 2002; Botha *et al.,* 2004).

Geographical distribution and flowering and fruiting season

The species is very uncommon and thus information on flowering and fruiting season is difficult to obtain. From the data the species appears to flower in both summer and late winter (Figure 6). In this study, no purchased specimens flowered.

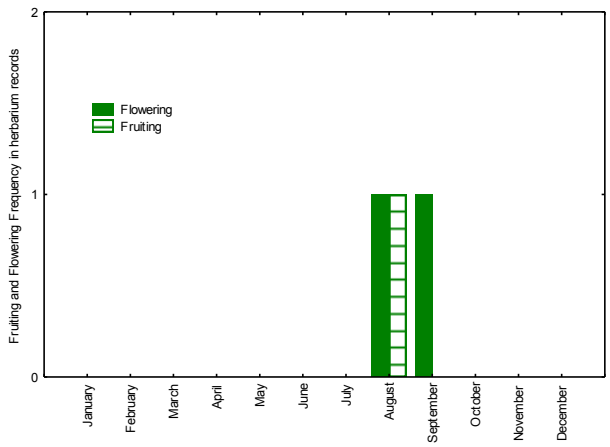
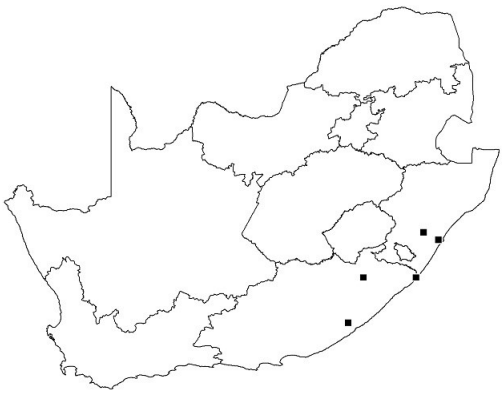


Figure 6: Flowering and fruiting frequency (number of records) from herbarium records for *Drimia cooperi*



Map 7: Distribution data for *Drimia cooperi*

The species has a very limited distribution with only five known localities in the northern parts of the Eastern Cape and the southern parts of KwaZulu-Natal (Map 7).

3.4. SPECIES SUMMARIES: AMARYLLIDACEAE

3.4.1. *Boophone disticha* (L.f.) Herb.

Boophone disticha is a member of the Amaryllidaceae and one of two species within the genus (Germishuizen and Meyer, 2003). Although there has been some variation in the spelling of *Boophone* Herb. (alternative spellings include: *Buphane*, *Boophane* and *Buphone*) (Huttleston, 1960; Archer *et al.* 2001), the species is well accepted and is recognisable by its distichous, erect leaves, tunicated torpedo shaped bulb and dense umbel of pink-purple to red flowers borne on a short, stout, somewhat compressed peduncle (Dyer, 1976).

Synonyms:
Boophone longepedicellata Pax.*;Haemanthus lemairei* De Wild.*; Haemanthus robustus* Pax; *Amaryllis disticha* L.f. *Haemanthus sinuatus* Thunb ex. Schult.f
Red data list status:
LC-Declining

Vernacular names:
iNcotho, Incoto, Ngoto
Ngubozohlonya, incotho, incwadi (Zulu) (Cunningham, 1988; Hutchings *et al.,* 1996 and Williams *et al.,* 2001), Ishwadi (Xhosa) (Dold and Cocks, 2002).

Macroscopic description
External:
Boophone disticha is a bulbous herb with two ranked, erect, ensiform and distichous leaves arranged in a fan shaped manner (Dyer, 1976; Van Wyk *et al.,* 1997). The peduncle is short, stout, solid and somewhat compressed with two deltoid bracts. The flowers occur in dense umbels and are pink to purple (Dyer, 1976). The perianth is a short subcylindric tube with equal spreading slender segments. The anthers are yellow and oblong and the style, red and curved (Baker, 1896). When the rounded inflorescence is dry, the flowerhead dehisces from the peduncle and rolls around in the wind distributing seed (Snijman and Linder, 1996).

Bulb: internal and external
Bulbs can reach 30 cm in diameter (Dyer, 1976), although in South African markets they appear smaller (c.a. 9cm in diameter). The tunicated bulbs are ovoid but can appear torpedo shaped when smaller. The outer tunics are brown and firm in texture (Baker, 1896), however these often come off when handled in the market to expose lighter, thinner and more flimsy tunics underneath. There is no bulb neck as the entire bulb tapers towards the base and apex. There is often a protruding base plate with numerous thick and fleshy roots. The bulb occurs in grassland areas and there is often evidence of burning on the upper two thirds of the bulb (van Wyk *et al.,* 1997). Internally, the bulbs are creamy white and there are numerous thin scales surrounding the torpedo-shaped base plate. When cut, the internal tunics appear to consist of numerous threads, which is characteristic of all genera within the tribe Amaryllideae of the Amaryllidaceae (Meerow and Snijman, 1998). In addition, the scales exude a creamy 'sap'. Tunics oxidize over time and become purple-brown.

Occurrence at medicinal markets:
Bulbs are common in Faraday and Warwick markets, and in smaller markets in Free State (V.J. Brueton, pers. obs.). Bulbs are also found in the Eastern Cape market (Dold and Cocks, 2002). Approximately two bulbs are usually sold at a time in both the Faraday and smaller Free State markets. In contrast, in Warwick only one bulb is sold at a time. Occasionally, bulbs are seen with leaves and/or flowers in the market.

Geographical distribution and flowering and fruiting season:
Boophone disticha does not appear to flower throughout the year (Figure 7). Instead, the early summer months (October and November) have the highest frequency of flowering (and fruiting) while April and June have no occurrences of flowering or fruiting in the herbarium records.

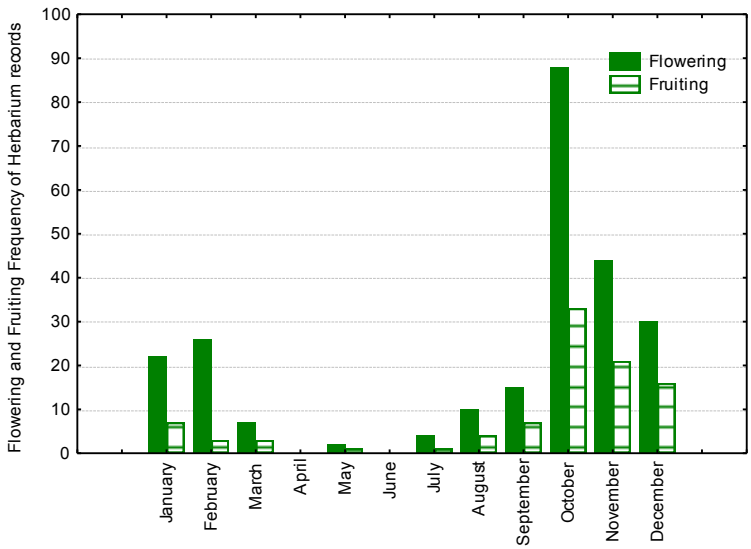
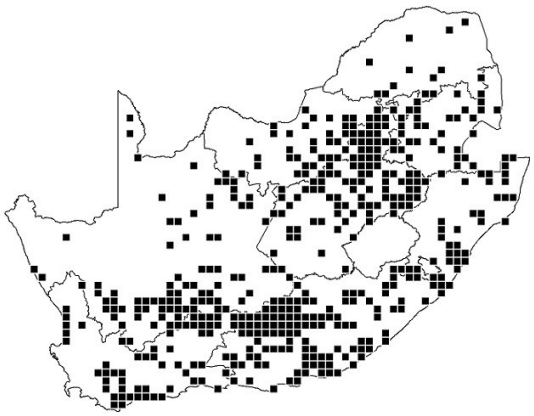


Figure 7: Flowering and fruiting frequency (number of records) recorded from herbarium records for *Boophone disticha*



Map 8: Distribution data for *Boophone disticha*

Boophone disticha has a very large distribution spanning most of South Africa (Map 8). Many localities do, however, occur close to highly populated areas. The distribution was based on PRECIS data as well as the herbarium data collected in this study. It may also include the distribution of the winter growing *B. haemanthoides*, however, a more detailed assessment of herbarium material and PRECIS data would be needed to determine this.

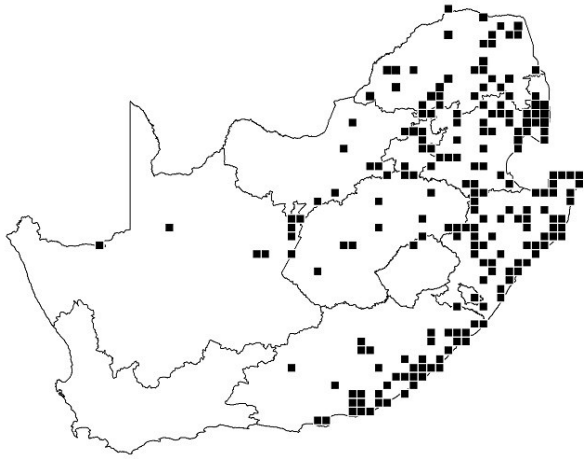
3.4.2. *Crinum* L.

The genus *Crinum* belongs to the Amaryllidaceae family, and it is estimated that there are between 60 and 70 species (Meerow *et al.,* 2003) distributed throughout the tropics and warm temperate regions of the world in Asia, Australia, Africa and America (Thi Ngoc Tram *et al.,* 2002). The seeds of the genus are well adapted for oceanic dispersal, and this is thought to have allowed its broad distribution. This genus is extremely well marked by numerous morphological synapomorphies, such as extensible fibres in the leaf tissue, bisulculate pollen with spinose exines, scapes with schlerochymatous sheaths, unitegmic or ategmic ovules and nondormant, water-rich, nonphytomelanous seeds with chlorophyllous embryos (Meerow *et al.,* 2003).

Four species are commonly recognised in South African markets, namely *C. macowanii*, *C. bulbispermum, C. moorei* and *C. stuhlmannii* (Cunningham, 1988; Williams, 2007). *Crinum foetidum* is used in Botswana and *C. paludosum* is noted for its use as cattle feed in South Africa (Fennel and van Staden, 2001). Additionally, *Crinum* species have been used for a variety of ailments in southern Africa (Fennel and van Staden, 2001). However, as *Crinum* bulb anatomy is very similar between species (Arroyo and Cutler, 1984), species identification based on bulb morphology or anatomy is difficult.

Informant interviews suggest that traders and traditional healers do not distinguish, or do not have any preference for, any species or 'form' of *Crinum* in the markets (V.J. Brueton, pers. obs.) and thus, potentially, any South African species may be sold in the markets. Species that occur within South Africa and may possibly occur in South African medicinal plant markets, include: *C. crassicaule; C. campanulatum; C. lugardiae; C. acaule; C. lineare; C. buphanoides; C. stuhlmannii; C. macowanii; C. bulbispermum; C. graminicola; C. moorei; C. minimum; C. variabile* and *C. paludosum* (Verdoorn, 1973). In this study five species were recorded using bulb and leaf characteristics. Summary information is provided for these species.

The genus *Crinum* is widely distributed throughout Limpopo, Mpumalanga, Gauteng, KZN, Free State and the Eastern Cape (Map 9).



Map 9: Distribution data for *Crinum buphanoides; C. stuhlmannii; C. macowanii; C. moorei and C. bulbispermum;*

3.4.3. *Crinum buphanoides* Welw. ex Baker

The genus *Crinum* in Africa includes about 50 species, of which about 85% have flowers that are zygomorphic (with a curved tube, declinate stamens and style and tepals connivent to a bell), while the remaining 15% possess flowers that are radially symmetrical and have arcuate stamens, a straight style and reflexed petals (Platyaster or Crinum form) (Nordal and Kwembeya, 2004). *Crinum buphanoides* is one of two species with the latter flower morphology (Verdoorn, 1973). Despite the confusion related to other species with the 'Platyaster type' morphology (Lehmiller, 1992; Nordal *et al.,* 2002; Nordal and Demissew, 2002; Nordal and Kwembeya, 2004), the species is well defined and easily recognisable due to its distichously arranged leaves and habitat preference for dry areas (Nordal and Demissew, 2002).

Synonyms
Crinum leucophyllum Baker
Red list status
LC

Vernacular names:
Mduze, *Umduze, umNduze, umDuzi*
(Zulu) (Cunningham, 1988; Hutchings *et al.,* 1996, Williams *et al.,* 2001)

Macroscopic description

External:

This species has light green, distichous leaves, which are deeply channelled (Verdoorn, 1943). The margins are ciliate with minute cartilaginous teeth and a narrow cartilaginous edge, and the lowest leaves are ca. 7–9cm broad. Each successive leaf becomes narrower, with the uppermost leaves approximately 2.5cm broad (Verdoorn, 1943; Verdoorn, 1973). The umbel is 13 to 50 flowered (Nordal and Kwembeya, 2004) and the flowers are white to pink, usually with a deep red keel. The perianth tube is long and slender with the segments spreading abruptly and recurving. The stamens are arcuate and erect and the upper parts of the filaments and style are deep rose (Verdoorn, 1973).

Bulb: internal and external

The bulb, which is covered by numerous brown papery tunics (Nordal and Kwembeya, 2004), is ca. 15cm in diameter (Verdoorn, 1943; Verdoorn, 1973) and narrowed abruptly into a neck of varying lengths. In the markets, the average diameter of bulbs identified as *C. buphanoides* was 9.3cm. Internally, the bulbs are cream coloured and produce a cream coloured, thin, watery sap when cut open, however when exposed to air the inner scales become discoloured to a darker brown purple. This discolouration increases throughout the length of the bulb, the longer the bulb scales are exposed to the air. The innermost bulb tunics are lighter in colour and the base plate is small. The base plate projects slightly out the base of the bulb and has numerous thick, contractile roots attached. As with all species within this genus, extensible fibres occur when bulb tunics are pulled apart.

Occurrence at medicinal markets

This species was only encountered in Faraday and has not been identified in previous studies (Cunningham, 1988; Mander, 1997; Williams *et al.,* 2001; Dold and Cocks, 2002). It appears to be seasonally common and was encountered in September/October 2007. At this time, many traders had numerous flowering specimens stacked on one another (enabling identification); however, the species was subsequently not observed, suggesting that its presence in the market may be occasional, occurring only when traders and harvesters come across large populations of the species in the field. On average, two bulbs were sold for R10.

Geographical distribution and flowering and fruiting season

Crinum buphanoides has the highest frequency of flowering and fruiting in the summer months (from October to February); however some flowering and fruiting specimens have been recorded in March, April and May (Figure 8).

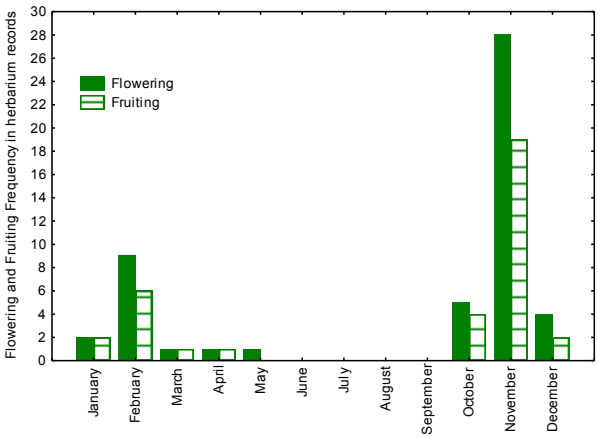
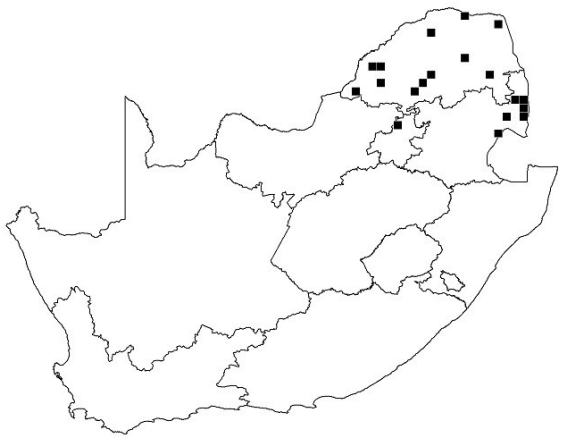


Figure 8: Flowering and fruiting frequency (number of records) recorded from herbarium collections for *Crinum buphanoides*



Map 10: Distribution data for *Crinum buphanoides*

Crinum buphanoides is distributed in the north-eastern parts of South Africa, mainly in Limpopo and Mpumalanga although it does appear to also occur in Gauteng (Map 10)

3.4.4. *Crinum moorei* Hook.f.

Crinum moorei has broad perianth segments, like many members of the Codonocrinum section of the genus *Crinum*; however in contrast to the other Codonocrinums, it has perianth segments spread from the base (Verdoorn, 1961). Although this highlights that these subgeneric delineations are not natural entities (Nordal *et al.,* 2002), the species itself is recognisable by many features that distinguish it from all other South African *Crinum species*. Definable features include a distinctly swollen midrib on the leaf, which unlike most *Crinum* species is more or less intact (Verdoorn, 1961; Verdoorn, 1973).

Initially, there was some uncertainty as the species was first described and figured from a plant from Glasnevin Gardens that had be grown from seeds collected from an unknown locality (Verdoorn, 1961). Baker (1897) recognised that plants been grown under the garden names *C. colensoi*, *C. mackenii* and *C. natalense* were all *C. moorei*, however he failed to recognise that *C. imbricatum* was also the same species (Baker, 1987; Verdoorn, 1961).

Synonyms
C. imbricatum Baker; *C. macowanii* Baker (in part); *C. schmidtii* Regel

Red list status
VU A4de

Vernacular names:
Mduze, Umduze, umNduze, umDuzi (Zulu) (Cunningham, 1988; Hutchings *et al.,* 1996, Williams *et al.,* 2001)

Macroscopic description

External:

Leaves are borne at the top of the false stem and are ensiform, narrowing to the apex and base and approximately 65cm long. The leaves have obvious parallel venation and a thickened midrib on the underside (Verdoorn, 1961; Verdoorn, 1973). The peduncle is long (ca. 70cm) and somewhat flattened, while the umbel is 8-flowered; each flower opens in succession, with sub-connivent and spreading perianth segments, so that the open flower is usually broader than deep (Verdoorn, 1961).

Bulb: internal and external

The bulb is subglobose, varying in size up to 19cm in diameter and narrowing abruptly into a long stem-like neck (Verdoorn, 1973). In some cases, this neck is bent or curved downwards. In the markets, the average diameter of bulbs identified as *C. moorei* is about 8.5cm. The tunics are cream to light brown and in many cases have pale but visible parallel venation-like stripes. Internally the bulb is cream coloured with a darker but small base plate. The bulb produces a thin creamy white sap when cut. As with all species within this genus, extensible fibres occur when bulb tunics are pulled apart.

Occurrence at medicinal markets

This species is generally recognisable in the market because of its long neck; however some individuals have a curved neck. It is recommended that all specimens are planted to confirm the species determination. The species was recorded in Faraday; however, it is not common and was only seen at the market twice during this study. In Warwick, however, the species is abundant and common. It was not encountered in the Nelspruit or Free State markets, and has not been recorded in the Eastern Cape or Mpumalanga (Mander, 1997; Dold and Cocks, 2002). The number of bulbs per sale is not dependent on the species but on the size of bulb. In both markets, the average number of bulbs was between one and three.

Geographical distribution and flowering and fruiting season

Crinum moorei has increased flowering and fruiting in the summer months (October to February) and although flowering was recorded in April, the species does not appear to flower before October (Figure 9).

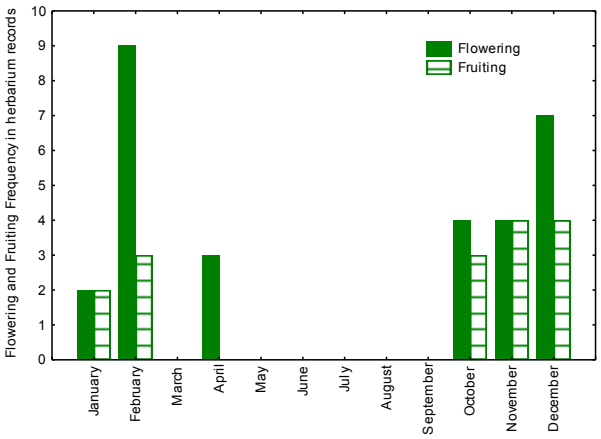
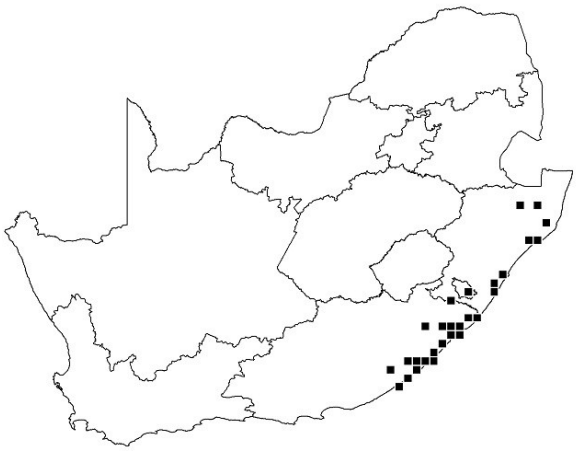


Figure 9: Flowering and fruiting frequency (number of records) recorded from herbarium collections for *Crinum moorei*



Map 11: Distribution data for *Crinum moorei*

Crinum moorei is mainly distributed along the coast of Eastern Cape and KwaZulu Natal (Map 11).

3.4.5. *Crinum stuhlmannii* Baker subsp. *delagoense* (I.Verd.) Kwembeya &Nordal

There has been some taxonomic confusion surrounding *C. stuhlmannii*, and the species now includes *C. delagoense* I.Verd. and *C. forbesii* (Lindl.) Schult. and Schult.f. In 1962, *C. delagoense* was described by Verdoorn, who felt that both *C. forbesii* and *C. forbesianum* (an illegitimate name for the species) were used incorrectly to describe two separate species. Although unsure of the true *C. forbesii,* Verdoorn felt that a new name was necessary to separately describe the Delagoa Bay plant with candy-striped flowers and long, broad, trailing leaves (Verdoorn, 1962). *C. delagoense* and *C. forbesii*, however, have now been synonomised and are known collectively as *C. stuhlmannii*.

However, recent studies have shown that there are two closely related species, one occurring in the north (found in Kenya and Tanzania), *C. stuhlmannii* Baker (1898), and one occurring in the south, *C. delagoense* I. Verd. (1962) (Zimudzi *et al*., 2006). The two are only separated on the basis of the width of the perianth segments and their geographical distribution. The two forms are closely related but vicariant taxa and were recognised by Zimudzi *et al.* (2006) as subspecies. Due to the distribution, only *C. stuhlmannii* subsp. *delagoense* (I.Verd.) Kwembeya & Nordal is thought to occur in the medicinal markets of South Africa. As such, all references to *C. stuhlmannii* in the dissertation refer to this subspecies.

Synonyms
C. delagoense I. Verd.
*C. forbesii (*Lindl.) Schult. emend. Herb. *sensu* Lehmiller
C. forbesianum Herbert
Red list status
LC-Declining

Vernacular names:
Mduze, Umduze, umNduze, umDuzi (Zulu) (Cunningham, 1988; Hutchings *et al.,* 1996; Williams *et al.,* 2001)

Macroscopic description

External:

C. stuhlmannii has long leaves, spreading at the ground level, which can be up to 15cm broad, with a narrow cartilaginous border which is distinctly ciliate (Verdoorn, 1962; Verdoorn, 1973). The peduncle is arcuate and about 40–50cm long and about 3cm broad. The umbel is 10 to 30 flowered, and the perianth of each flower is white with a distinct broad, deep rose or purplish red dorsal keel, conniving into a funnel shape, with only the apical third recurved. The stamens are declinate and the filaments are white or sufficed with rose (Verdoorn, 1962; Verdoorn, 1973).

Bulb: internal and external

The bulb is large and globose, 6–22cm in diameter with many brown tunics. The outer dry tunics often flake off to reveal reddish brown, thicker tunics that are quite brittle. The neck abruptly narrows into a short or long neck (Verdoorn, 1962). In the market, the bulbs are ca. 13cm in diameter. Internally, the bulbs are dirty cream and emit a thick sticky sap when cut open. The base plate is darker than the surrounding bulb scales but is small and does not project a great deal out of the base of the bulb. As with all species within this genus, extensible fibres occur when bulb tunics are pulled apart.

Occurrence at medicinal markets

This species appears to be relatively common throughout the year in Faraday, and is more occasional in Warwick. However, traders do not stock single species of *Crinum* but rather have a variety of species, which makes the abundance of the species in the market difficult to ascertain. As the bulbs of *C. stuhlmannii* are generally large, the number of bulbs sold per sale is usually low (usually 1–2 bulbs).

Geographical distribution and flowering and fruiting season

Flowering and fruiting season of *C. stuhlmannii* occurs primarily in the summer months between September and February) with some flowering occurring in the winter months (March and August). The same pattern is seen with the frequency of fruiting; however, some fruiting is recorded in the middle of winter (June), which suggests flowering does occur throughout the winter months (Figure 10).

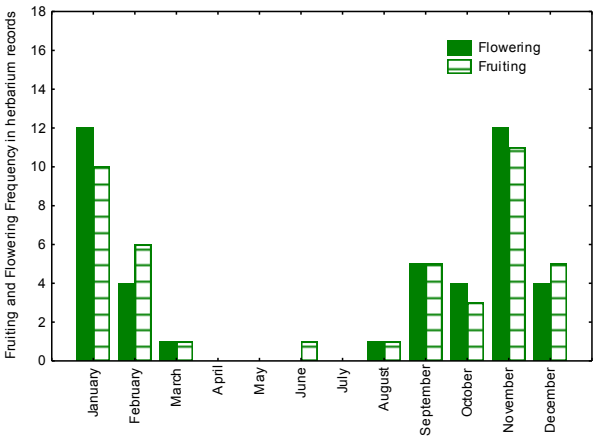


Figure 10: Flowering and Fruiting Frequency (number of records) recorded from Herbarium collections for *Crinum stuhlmannii* subsp. *delagoense*



Map 12: Distribution data for *Crinum stuhlmannii* subsp. *delagoense*

Crinum stuhlmannii subsp. *delagoense* occurs along the northern part of the KZN coast and along the Mozambique border. Some populations are found in Mpumalanga and Limpopo (Map 12).

3.4.5. *Crinum bulbispermum* (Burm.f.) Milne-Redh. and Schweick.

In the past there was some uncertainty surrounding the taxonomy of *C. bulbispermum*. It was first described as *Amaryllis bulbispermum* Burm. and then as *C. longifolium* which had been used indiscriminately to describe many species within southern Africa with long-tubed perianths (Baker, 1896; Verdoorn, 1953). However, Milne-Redhead and Schweickerdt simplified the matter in their revision of the genus *Ammocharis* (1939). They suggested that the correct name for the species was the new combination, *C. bulbispermum*, based on *A. bulbispermum* Burm. (Verdoorn, 1953). The species is easily distinguishable by its long perianth tube and segments connivent to a bell. Other defining features include a bulb that narrows gradually towards the apex, and leaves that form a stem-like column and reduce in width from the outer 9cm broad to inner thin 3mm broad leaves (Verdoorn, 1953; 1973).

Synonyms:
No synonyms

Red list status
LC-Declining

Vernacular names:
Mduze, Umduze, umNduze, umDuzi
(Zulu) (Cunningham, 1988; Hutchings *et al.,* 1996, Williams *et al.,* 2001)

Macroscopic description

External:

C. bulbispermum has glaucous green leaves, the outermost sometimes deep purple at the base. The sheathing bases of the leaves form a stem-like column of about 30cm and the tips of the leaves are truncate and have a narrow cartilaginous border (Verdoorn, 1953; 1973). The peduncle is 50–90cm long and has an umbel with between 6 to 16 flowers. The perianth has a long cylindrical tube up to 11cm long with segments conniving into a narrow funnel with the apices sub-spreading or slightly recurved (Verdoorn, 1973). The perianth is white with a dark red keel or entirely suffusedwith red, the stamens declinate, white or suffused with pink and the style deep pink in the upper portion with a light brown stigma (Verdoorn, 1973).

Bulb: internal and external

The bulbs of the species are quite distinctive as there is no neck region but rather the bulb narrows gradually towards the apex. The tunics are light brown to darker brown. The apex of the tunics is often suffused with pomegranate purple. Internally, the bulb is cream coloured with a darker cream base plate. The bulb scales produce a creamy, watery sap. As with all species within this genus, extensible fibres occur when bulb tunics are pulled apart.

Occurrence at medicinal markets

This species was not commonly seen during the present study although it was recorded in both Faraday and Warwick markets in the past (Cunningham, 1988; Williams *et al.,* 2001).

Geographical distribution and flowering and fruiting season

Flowering and fruiting frequency of *C. bulbispermum* is greatest between October and December with limited occurrences recorded in late summer (January to March). No flowering was recorded in the winter months (Figure 11).

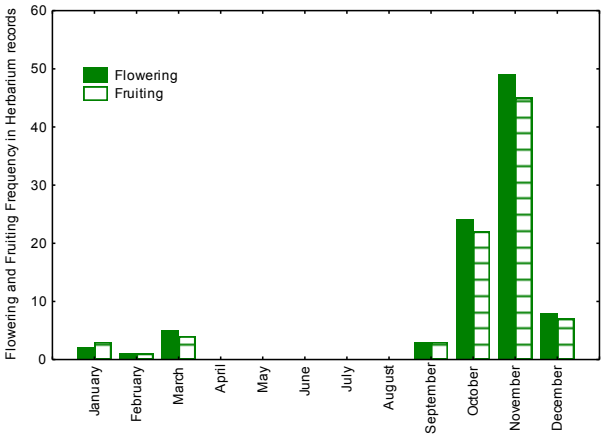
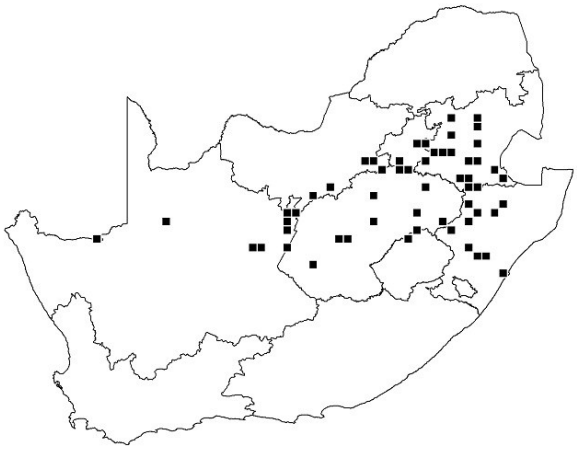


Figure 11: Flowering and Fruiting Frequency (number of records) recorded from herbarium collections for *Crinum bulbispermum*



Map 13: Distribution data for *Crinum bulbispermum*

Crinum bulbispermum occurs from the Northern Cape through the Free State into Gauteng, Mpumalanga and KZN (Map 13).

3.4.6. *Crinum macowanii* Baker

Crinum macowanii was originally described by Baker (1878) and now comprises of *C. gouwsii* and *C. macowanii* subsp. *confusum* (Verdoorn, 1973). There is some taxonomic confusion as any species with black anthers is placed in the species (N.R. Crouch, pers. comm.) and thus studies on the taxonomy of this species are needed.

Synonyms:
C. gouwsii Traub.*; C. macowanii* Baker *subsp. confusum* I. Verd.

Red list status
LC-Declining

Vernacular names:
Mduze, *Umduze, umNduze, umDuzi*
(Zulu) (Cunningham, 1988; Hutchings *et al.,* 1996, Williams *et al.,* 2001)

Macroscopic description

External:

The leaves of this species are variable: green or glaucous, spreading at the ground level or arcuate from a small stem-like base. However in general, they are deeply canaliculate and slightly to very strongly undulate (Verdoorn, 1973). They are about 80cm long or longer and have a narrow cartilaginous margin and can be fairly to densely ciliate. The peduncle can be between 19–90cm long and bearing an umbel

with between 8 to 25 flowers. The perianth can be a long or short tube, the segments conniving in a wide trumpet, with the apical portions recurved. The segments are white with a distinct rose coloured keel (sometimes rosy with carmine keel). The stamens are declinate; filaments are white and anthers black.

Bulb: internal and external

The bulb is variable in size but can be very large (6–25cm in diameter), and fairly abruptly narrows into a short or long neck. As with all species within this genus, extensible fibres occur when bulb tunics are pulled apart.

Occurrence at medicinal markets

The species was recorded in both Faraday and Warwick markets in previous studies (Cunningham, 1988; Williams *et al.,* 2001); however, during the present study, very few individuals of *C. macowanii* were collected in the market. The species does not have many defining bulb characteristics and is not distinguishable from other *Crinum* species in the markets.

Geographical distribution and flowering and fruiting season

Crinum macowanii flowers throughout the year: with the highest flowering and fruiting frequency occurring between October and January (Figure 12).

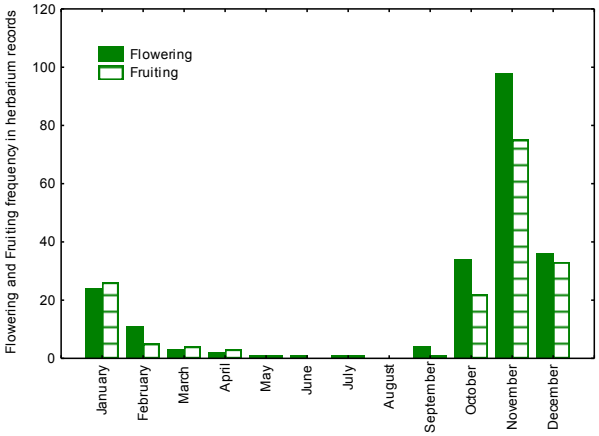
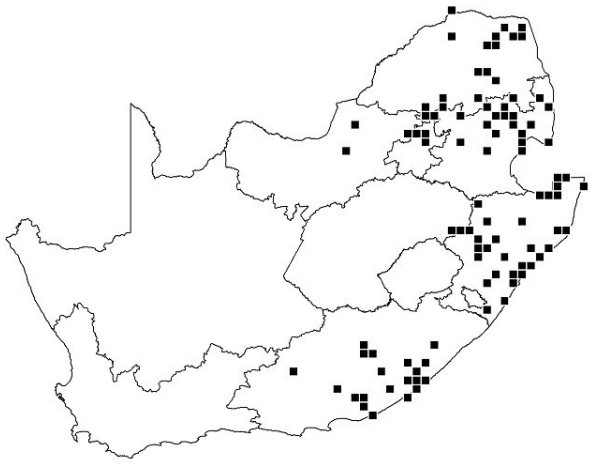


Figure 12: Flowering and Fruiting Frequency (number of records) recorded from Herbarium collections of *Crinum macowanii*

Crinum macowanii occurs along the eastern coast and border of South Africa from the Eastern Cape to Limpopo. It is the most widely distributed *Crinum* species (Map 14).



Map 14: Distribution data for *Crinum macowanii*

4. DISCUSSION AND CONCLUSION

Can bulb characteristics facilitate species-specific identification in a medicinal market setting? Evidence from this study suggests that bulb material does provide useful characteristics that can be used for identification within the Hyacinthaceae and to a lesser extent in the Amaryllidaceae. In the Hyacinthaceae, bulb scale characters together with bulb shape and colour were the most useful for the compilation of an identification key. Extensible fibres when bulb tunics are torn are a feature currently used in the identification of species within the Amaryllidaceae (Meerow and Snijman, 1998). These fibres were useful in this study for the identification to family level. However due to the similarities in tunic colour and shape of bulbs in the Amaryllidaceae, identification to species level was not possible based solely on bulb characteristics.

One striking result of this study was that traders recognise three different bulb forms that are currently synonymised in the taxonomic literature. Although taxonomists sometimes use bulb characteristics in their revisions of species, these characters are often thought to be too variable (Jessop, 1977) or too uniform (Arroyo and Cutler, 1984). Traders, traditional healers and harvesters may place emphasis on differing information and if bulb forms are recognised as distinct, then the impacts of harvesting on these forms may be diverse. Even at a larger scale, the species making up an ethnospecies may have different distribution ranges, population structure and density, growth rates and population biology (Cunningham, 1988; Williams, 2007). In this study, the concept of 'functional taxonomy' was used to describe the use of original nomenclature to describe different bulb forms. Ecology in general, has become a more predictive functional science and the value of creating trait-based functional groups which allow for a mechanistic understanding of ecosystems is well established (Pendry *et al.,* 2007). Rather than focusing on the species *per se* this approach attempts to understand the full inter-relationship (function) of a species within the landscape of the market as well as the impact of harvesting of these forms on populations. For this reason, *U. epigea, U. lydenburgensis* and *D. robusta* were used to describe bulb forms recognized by traditional healers, harvesters and traders, although these names are not recognized in the most recent taxonomic revisions.

The trade in medicinal plant species is a significant cause of resource depletion of commonly used medicinal plants (Williams, 2004; Williams *et al.,* 2007). The impact of harvesting, trade and use of medicinal plants is partly dependent on the plant part removed and the level of harvesting effort (Williams *et al.,* 2007). However, many medicinal plant surveys and studies conducted at medicinal markets have been on a large scale (Cunningham, 1988; Mander, 1997; Williams *et al.,* 2001) and have therefore focused primarily on ethnospecies groupings, although some studies have been species specific (Dold and Cocks, 2002).
In this study, eight ethnospecies (excluding variations of spellings of the same ethnospecies name) were recorded, including: *iGibisila*, *iNcotho*, *isiKlenama*, *uMahlokoloza*, *skenama*, *White skenama*, *umHlabelo* and *inDongana-zimbomvana*. Using vegetative characteristics together with leaf and reproductive characters, nearly doubles the number of species that were distinguished (Table 1). This has implications for past estimates of the number of species traded in South Africa. Mander *et al.* (2007) estimated that 771 plant species are traded in the country, with bulbs comprising 14% of trade. The overall number of plant species traded may increase (even if only slightly) if 'functional' species are treated separately.

Character states used in taxonomic studies can either be qualitative or quantitative. As the character is assumed to be discrete (i.e. the state is either present or absent), taxonomic differentiation can occur (Stevens, 1991). However, in most cases, character states are usually found to be continuous, which can lead to confusion (Steven, 1991). Bulb character states were qualitatively described and the type of leaf base (scale or tunic) was the most definitive character between the species in the Amaryllidaceae and Hyacinthaceae. Although bulb colour was highly continuous, it can be a very useful trait as it is highly noticeable and can be used to discriminate between groups of species, for example: red/red-green species belong to the ethnospecies grouping of *skenama*, *isiKlenama* or *inDongana-zimbomvana*. Bulb shape and bulb scale type can then be used to further differentiate between species.

In the Hyacinthaceae, bulb scale type is a discrete, qualitative trait. Bulb scales are imbricate — where thickened leaves overlap each other in a spiral fashion round the main axis - and the level to which these

bulb scales overlap, the looseness or tightness and the 'fleshiness' of the bulb scales can be used to differentiate between species. In addition, the shape of the overall bulb together with the presence or absence of a neck region, are also useful traits. Bulb size is the least useful character as it is dependent to a certain extent on plant age and growth rate. In the case of *D. robusta* and *D. elata*, size may not be a useful diagnostic characteristic as larger *D. elata* and smaller *D. robusta* may occur (although not common).

Bulbs of the Amaryllidaceae are tunicated, where numerous tunics form concentric circles around the main axis. These tunics can differ slightly in colour and also in how fibrous or brittle they may be however, for the main part, they cannot be used to differentiate between species. Bulb size and bulb shape can be useful indicators. Specific characteristics such as whether leaf bases leave the neck region in an opposite or rosulate manner or overall shape can provide identification at the genus level. However, as seen with the possible *Crinum* species traded in medicinal markets, a number of species may share size and shape characteristics (Table 5). These characters are still useful as they provide a method of narrowing the possible species into a smaller 'group' or class. Leaf characteristics are highly important in the identification of *Crinum* species and in many cases; growing medicinal bulbs in greenhouse conditions may be the only way to determine accurate species identification.

The adaptation of taxonomic information and previous keys (e.g. the adaptation of Verdoorn, 1973) into more 'vegetative' friendly keys provides ethnoecologists with a tool for easier identification, not solely based on ethnospecies name, and these sources of information are seldom used. In addition, other information gathered on flowering and seeding periods may provide some information, however for species such as *Crinum* species, where there is similarity in flowers and bulbs, flowering and fruiting season is likely to be the same and thus may not be the best tool. From the use of bulb size and shape and later on leaf characteristics, *C. moorei, C. buphanoides, C. bulbispermum, C.stuhlmannii* and *C. macowanii* were identified as species that are commonly traded.

Species descriptions adapted from herbarium records, literature and personal observations can provide a useful compendium of valuable resources for identification, including taxonomic descriptions of reproductive and leaf characteristics (to enable easy identification if growing them is necessary) as well as internal and external macroscopic descriptions which are not always found in the original species information. In addition, understanding how the bulbs are sold in the market (e.g. *B. volubilis* is commonly sold in 'onion sachets' in Faraday market and is known as *iGibisila*), can aid species identification.

Herbarium voucher records can provide species specific information on flowering and fruiting time; however this information did not provide any characteristics that could be used to differentiate between functional types. The data can, however, help researchers assess when planted market material may flower. Distribution data based on Quarter-Degree Squares (QDS) collected from herbaria around South Africa provided some interesting data for determining functional types. The distributions of *D. altissima* and *U. epigea* did overlap, but *U. epigea* appears to have a narrower distribution. This narrower distribution may affect population response to harvesting as impacted populations may have increased harvesting intensity (Map 4a and b). *Drimia elata* and *D. robusta* showed some overlap in their occurrence, however due to similarities in dried bulb material and reproductive plant characteristics, this may not be separate species but rather *D. robusta* (which commonly occurs in the KZN region) may be a more robust type of *D. elata* (Map 5). *Drimia delagoensis* and *U. lydenburgensis,* in terms of bulb morphology, appear to be separate species. Distribution maps (within South Africa) show that there is no overlap and *U. lydenburgensis* appears to occur solely in Mpumalanga (Map 6). Any harvest may negatively affect this species.

Recent Red Data assessments (Raimondo *et al.,* 2009) acknowledged that many medicinal plants are destructively harvested and traded in high volumes. Of the species investigated, three were assessed as Vulnerable by the 2009 Red Data Assessments. These included *B. volubilis* – VU A2ad; *D. cooperi* – VU A2ad, C2 a (i); *C. moorei* – VU A4de). *B. volubilis* and *D. cooperi* have both suffered a 30% decline over the past 30 years (Raimondo *et al.,* 2009b and Williams and Crouch, 2008) while C. moorei has declined by at least 20% over the past 70 years (or two generations). This species is also impacted by predation by the amaryllis caterpillar (Williams *et al.,* 2009m).

Drimia sanguinea and *U. lydenburgensis* were assessed as Near Threatened (NT A2d and NT B1ab (v), respectively) (Williams *et al.,* 2009j and Williams *et al.*, 2009k). *D. sanguinea* has had a population decline of 20-25% in the last three generations (60 years) due to the harvest for the medicinal plant trade while *U. lydenburgensis* has an extent of occurrence (EOO) of approximately 15 800km^2. Subpopulations are severely fragmented, and this species may become threatened in the future if further harvesting leads to significant declines in population size.

Five species were assessed as Least Concern-Declining, namely *D. altissima, B. disticha, C. stuhlmannii, C. bulbispermum* and *C. Macowanii*. Although declines have been noted, these species are widespread and declines are not expected to exceed 10%. Only *U. epigea* and *C. buphanoides* were assessed as Least Concern. *Drimia elata* and *D. robusta* were assessed as Data Deficient because of the taxonomic uncertainty between the two species (Raimondo *et al.,* 2009 a and b; SANBI, 2009; Williams *et al.,* 2009a-l). Identification to species level is therefore needed to provide adequate information on the species specific effects of trade.

Plant populations can be driven to extinction if harvesting increases to chase an ever-diminishing yield (Begon *et al.,* 1986). Medicinal plants are used in a multitude of ways; this suggests that medicinal plants should be evaluated on a case specific basis (Dzerefos & Witkowski, 2001); however this can only be achieved if specifies-specific identification of commonly used species is possible. This study is one of the only studies to use sterile vegetative characteristics for identification of commonly used medicinal species in South African medicinal markets. Vegetative characteristics can aid identification and allow for a more detailed assessment of the implications of trade (Chapter 3 and Chapter 4). This is necessary in South Africa where there are approximately 27 million users of traditional medicine (Mander *et al.,* 2007).

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CHAPTER 3
Size structure of commonly traded bulbs in South African traditional medicine markets: Ecological implications

ABSTRACT

Successful adaptive responses for ecosystem management need to be built on an understanding of resource use and ecosystem dynamics of natural resources. Bulb species used for traditional medicine are susceptible to over-exploitation because they are often destructively harvested in large quantities. Four perennial bulbous genera were surveyed: two in the Amaryllidaceae (*Boophone* and *Crinum*) and two in the Hyacinthaceae (*Bowiea* and *Drimia*). Functional taxonomy was used to describe bulb forms which are recognized as distinct by traditional healers but have been synonmysed by taxonomists. Based on this, information is also provided on *Urginea*, although the genus is currently synonmysed under *Drimia*. Surveys were conducted in two national and two small regional markets to determine bulb diameters and size structure. Bulb diameters recorded in 2007 were compared to records from Witwatersrand plant market surveys from 1995 and 2001 and voucher specimens from South African herbaria. Results indicate that *Bowiea volubilis* is the most severely impacted by the medicinal plant trade. Approximately 87% of all *B. volubilis* bulbs were <4cm in diameter, and were significantly smaller than diameters recorded in *umuthi* markets in 2001 ($p<0.0001$) and pressed bulb material in several herbaria ($p<0.0001$). Large bulbed Amaryllidaceae species, *Boophone disticha* and *Crinum* species showed a decrease in bulb diameter between the 2001 and 2007 Faraday surveys (by 1.5cm and 2.7cm, respectively), while *Urginea epigea* (Hyacinthaceae) showed a 1.2cm decrease in size in 6 years. Given the general preferences of harvesters for larger individuals, populations of species of anthropogenic importance should show a corresponding decrease in the frequency of individuals in large size-classes and a decreased number of size-classes. Size-class distributions of *Drimia delagoensis* and *B. volubilis* follow an inverse J-shaped curve (i.e. high frequency of small bulbs) – usually indicative of a regenerating population; however, in this case related to a lack of mature individuals. High rates of extraction of larger, reproductive individuals will result in population regeneration failure as smaller bulbs are unlikely to reach maturity before they are harvested. All species studied tended towards smaller market bulb diameters over time. These trends suggest that without appropriate mitigation, bulb populations will be further impacted in the future.

Keywords: Amaryllidaceae; bulb; geophyte; Hyacinthaceae; impacts of harvesting; medicinal plant trade; size-class distribution

1. INTRODUCTION

Learning how to deal with uncertainty and adapting to changing conditions brought about by global change is becoming essential in a world where humanity plays a major role in shaping biospheric processes from genetic to global scales (Olsson *et al.,* 2004). One such important factor is traditional medicinal plant use and resource harvesting. Urbanisation does not preclude the use of traditional medicine, instead the demand for traditional medicine is high in urban areas and the supply is met by a network of commercial gatherers who sell to herb traders and traditional healers in the major cities (Williams *et al.,* 2000). Commercial gathering of medicinal plant resources for trade can be a cause of major decline in populations of popular resources (Cunningham, 1993; Williams *et al.,* 2007a). It is estimated that 27 million people are users of indigenous medicine in South Africa (Thring and Weitz, 2006; Mander *et al.,* 2007), and if the harvesting effort increases with deteriorating population yields, harvesting of medicinal plant resources can have adverse effects on harvested ecological plant communities (Begon *et al.,* 1986; Cunningham, 1996; Williams *et al.,* 2007a).

Successful adaptive responses for ecosystem management need to be built upon an understanding of resource use and ecosystem dynamics of natural resources (Olsson *et al.,* 2004). Populations of popular medicinal plant species are not only affected by harvesting for the medicinal plant trade, but also by disturbances related to agricultural burning, forest clearing, afforestation of grasslands and livestock grazing (Cunningham, 1993; Botha *et al.,* 2004c), the impact of which is dependent on other aspects such as intensity, severity, duration and frequency as well as the nature of species affected (Botha *et al.,* 2004c). The effects of these disturbances and that of medicinal plant harvesting are often difficult to assess in certain species. The ecological impacts of bulbs (in the broad sense), bark, roots, gum and resin harvesting is generally poorly known (Ticktin, 2004). In South Africa, however, the harvesting of whole plants, roots and bulbs (*senso stricto*) is an important part of the medicinal plant trade and totals approximately 57% of the total plant material traded in the Witwatersrand, with about 55 species of bulbs and corms traded in the KwaZulu-Natal (KZN) markets (Cunningham, 1988; Williams *et al.,* 2007a).

Ecological sustainability may be assessed by directly measuring the rate of extraction and comparing it to the rate of natural replacement (Botha *et al.,* 2004b). For bulbous species, however, the impacts of harvesting are especially difficult to determine in the field as the whole plant is harvested and little sign remains at the harvested site. Medicinal uses and the related ethnopharmacology of commonly used bulb species has been studied in southern Africa (e.g. McCartan and van Staden, 1999; Cogne *et al.,* 2001; Elgorashi and van Staden, 2001; Elgorashi *et al.,* 2001; Pohl *et al.,* 2001; Elgorashi *et al.,* 2003; Koorbanally *et al.,* 2004; Koorbanally *et al.,* 2005a.; Koorbanally *et al.,* 2005b; Kulkarni *et al.,* 2005). However, few resource use studies have been conducted on bulbous species, although they are destructively harvested and are often long lived species (taking a long time to reach reproductive maturity), which makes them highly susceptible to over-exploitation (Cunningham, 1988; Cunningham, 2001, Williams *et al.,* 2007a). Studies on the estimated volume of plants purchased by traders provide information on resource use and depletion; however, there is a need to determine the impacts of such use on the populations of commonly used bulbous species (Williams *et al.,* 2007a). Changes in population structure often occur before major shifts in species composition or even species loss (Botha *et al.,* 2004c). In addition, size-class distributions allow identification of poorly represented life history stages and also the stages that are affected by variations in harvesting intensity (Williams *et al.,* in press). Changes in population structure may also indicate declining recruitment (Botha *et al.,* 2004a).

Bulbous species in medicinal plant markets are often stored for long periods of time, which then affects the mass and diameter of the bulbs and the size-class distribution (Williams *et al.,* 2007a). The effects of drying on bark samples of popularly used tree species has been investigated (Williams *et al.,* in press), however these impacts need to be assessed for bulbous species. A bulb is defined as a short plate-like stem often bearing a number of thick, fleshy leaves or leaf bases (Dahlgren *et al.,* 1985). Food and water is stored in these thickened scales (Cunningham, 2001), and thus the mass and diameter of bulbous species would be expected to be highly influenced by drying in market conditions.

The trade in South African markets is also not fixed, with surveys at South African markets showing that species composition at different markets is different (see Cunningham, 1988; Mander, 1997; Dold and

Cocks, 2002; Williams, 2003; and Botha *et al.,* 2004). Although the trade is centred on the large wholesale markets in Gauteng and KZN, trading occurs in small trading hubs in the Free State, Eastern Cape and Mpumalanga (Cunningham, 1988; Mander, 1988; Williams, 2003; Dold and Cocks, 2002; Botha *et al.,* 2001). One study suggested that visiting herbalists create international trade networks between South Africa and Mozambique together with smaller networks between South Africa, Zambia, Malawi and Botswana (Williams and Wong, 2006). In order to determine the full species-specific effects of trade on wild populations, countrywide surveys are required (Williams and Wong, 2006)

The overall aim of this study was to establish the ecological consequences of the harvesting and trade of commonly used bulb species in medicinal plant markets in eastern parts of South Africa. The size-class distributions of commonly used bulbs were determined. Additional factors that also result in variability in bulb size, such as drying over time, different sources of supply and season of collection were also investigated in order to better understand the ecological implications. The specific objectives are as follows:

1. To record bulb diameters from South African markets to determine bulb size-class distributions for all species studied
2. To compare bulb size-class distribution between markets to determine market-linked differences between bulb diameters
3. To compare bulb size-class distributions with data collected in 1995 and 2001 to ascertain the effects of harvesting over time
4. To compare bulb size-class distributions between bulbs collected from markets and those collected and pressed as herbarium voucher specimens
5. To use herbarium data to determine the relationship between bulb diameters and the reproductive status of wild populations
6. To determine the effects of seasonality on bulb diameters traded in South African medicinal plant markets
7. To determine the relationship between mass and diameter for bulb species studied
8. To determine the effect of drying on bulb diameter and mass

2. METHODS

2.1. SPECIES INVESTIGATED

Four perennial bulbous genera were surveyed in four South African traditional medicine markets: two genera within the Amaryllidaceae (*Boophone* and *Crinum*) and two in the Hyacinthaceae (*Bowiea* and *Drimia*). Functional taxonomy was used to describe bulb forms which are recognized as distinct by traditional healers but have been synonmysed by taxonomists. Based on this information is also provided on *Urginea*, although the genus is currently synonmysed under *Drimia*. Previous research has largely been based on 'ethnospecies' where the identification is based on traditional or folk name (Reyes-Garcia *et al.,* 2006) (see Chapter 2 for details on ethnospecies, species names and traditional names). Species studied included *Bowiea volubilis*, *Boophone disticha*, *Drimia altissima*, *D. delagoensis*, *D. elata*, *D. robusta*, *D. sanguinea, Urginea epigea* and *U. lydenburgensis*. *Crinum* species are also common in the medicinal markets of South Africa, however species are difficult to identify based on bulb characteristics and data was collected on the group as a whole. Data collected suggests that *C. buphanoides, C. macowanii, C. moorei* and *C. stuhlmannii* are commonly traded. *Brunsvigia* species are known by the same common name as *Crinum* species namely *uMduze*. While it is possible to distinguish between *Crinum* species and *Brunsvigia* species (Chapter 2), and *Brunsvigia* species have previously been recorded in the markets, no *Brunsvigia* species material was collected during this study.

Bulbous plants are geophytic, perennial herbs with underground storage organs that have renewal buds (buds that initiate growth the next growing season which are located below the ground) (Galil, 1980). In this study, only bulbs *senso stricto* have been studied. One of the typical characteristics of many bulbs is vegetative reproduction by means of bulblets formed in the axils of leaves or scales, the number of which can range from numerous to few or absent altogether (Galil, 1980). In this study, vegetative reproduction of the species studied ranged from no bulblet formation (*B. volubilis; B. disticha*) to few bulblets and

occasional clumping (*D. sanguinea; D. altissima; U. lydenburgenis*); bulblet formation with no clumping (*Crinum* species) and clumping species (*U. epigea* and *D. delagoensis*). 'Clumping' or 'clustering' individuals refer to numerous daughter bulbs clustered in a radial manner around the parent bulb.

2.2. MARKET DESCRIPTIONS

Two national level and two regional markets were visited in four provinces around South Africa in order to assess diameter and mass of bulbous species on sale. Faraday and Warwick medicinal markets are the two largest herbal medicinal markets in southern Africa (Chazan, 2005, Williams *et al.,* 2005) while markets in Phutaditjhaba and Bloemfontein (Free State) and Nelspruit (Mpumalanga) are small and informal (Chapter 2 contains details on each market).

2.3. MARKET SURVEYS

Market surveys were conducted between April 2007 and March 2008 in the Faraday, Warwick, Free State and Nelspruit markets. Surveys were stratified random (based on market and position of the stall within the market) and samples of bulbous species were purchased from traders in each market. In small informal markets such as Nelspruit and Free State, only a few traders were encountered, many of whom did not stock all the species under investigation, and surveys took place over a maximum of two days. In the Warwick market, surveys took place over three days, while in Faraday, surveys occurred over numerous visits between April and November 2007. Where possible, at least ten samples of each species were purchased. Vernacular name and information on the source of the species were also recorded when possible. Bulb mass and diameter (measured across the widest point along the horizontal axis) were measured in the laboratory. Clustering individuals (numerous daughter bulblets, clustered in a radial manner around the parent bulb) were counted as one large individual and overall diameter and mass were measured. Bulb diameters were used to determine bulb size-class distributions for species in all markets. In addition, data from past market surveys conducted in the Witwatersrad *umuthi* shops in 1995, Faraday *umuthi* market 1995 and Faraday *umuthi* market in 2001 (Williams *et al.,* 2007a) was compared against data collected from the market in 2007.

2.4 HERBARIUM RECORD SAMPLES

Bulb specimens from seven herbaria in Gauteng and Mpumalanga were examined (Chapter 2). Because of difficulties in pressing and preserving sections through bulbs, herbarium specimens are primarily composed of flowering material only. When the herbarium vouchers examined included actual pressed and dried bulb material, then bulb diameter was measured across the widest point along the horizontal axis and compared to bulb diameters from markets surveyed in 2007/2008. Herbarium records provided information on the size and reproductive status of wild populations in the past.

2.5. SEASONAL CHANGES IN BULB MASS AND DIAMETER

Williams *et al*. (2007a) suggested that there are a greater proportion of smaller bulbs present in the markets in winter compared to summer because of the tendency of traders to sell the larger bulbs first. Hence, the mean size of bulbs would be smaller in winter. The ability to replace stock in winter is limited by bulb dormancy, hence bulbs in the market tended to be larger and heavier at the beginning of spring/summer when freshly harvested stocks were obtained (Williams *et al.,* 2007a). Winter market stocks are also composed of predominantly dry bulb material. To determine the effects of drying on bulb sizes-classes, bulbs purchased from the Faraday market in winter (July 2007), spring (September 2007) and summer (October –November 2007) were compared.

2.6. DETERMINING THE EFFECT OF DRYING ON BULB MASS AND DIAMETER

Bulb samples purchased from medicinal markets around the country were planted in the greenhouse at the University of the Witwatersrand, Johannesburg, in a 1:1 potting soil to coarse grained sand. Plants were placed in full sun, were watered once a week and were left for a minimum of three months in order to reach 'wet' (maximum water content) mass and diameter. Bulbs were assumed to be at wet mass and

diameter when both leaves and roots were produced. When plants reached a wet mass, they were dug up, cleaned and photographed. Bulb diameter and mass was measured and then bulbs were placed in a controlled environment Phytotron chamber in the University of the Witwatersrand at market conditions (day T°= 20 °C; night T°= 16 °C; day RH =59%, night RH= 66%; length of day = 12 hours – conditions that mimic mean night and day conditions in Johannesburg) (Williams *et al.,* 2007b). Bulb mass and diameter was recorded once a week for a further of 12 weeks. Thereafter, the bulbs were oven dried at 65°C until the mass stabilised and remained constant. Bulbs were oven-dried for four weeks since it took approximately three weeks for the mass to stabilise in the ovens. Oven-dry mass and diameter were then determined.

2.7. STATISTICAL ANALYSIS

Bulb mass and diameter were log-transformed to approximate normality. Size-class distributions from different markets were compared by means of Kolmogorov-Smirnov two sample tests. One Way ANOVAs and t-tests were used to determine differences in mean bulb mass and diameter between markets, surveys, herbarium data and seasonal samples, and Fishers LSD was used as a post-hoc test. Regression analyses were used to describe the relationship between bulb mass and diameter. In order to determine the effects of drying on bulb mass and diameter, the relationship between wet bulb diameter (maximum water content) and drying bulb diameter over 14 (weekly) time intervals was determined by means of regression analyses. STATISTCA 6 and Excel 2003 were used for all data analyses and in all cases the null hypothesis was rejected at $p<0.05$.

3. RESULTS

Not all species were present at each market (Table 1). Faraday had the greatest number of species, followed by the Free State and Nelspruit markets. Overall, *Crinum* species were the most common species and occurred at each market. Interestingly, species from the genus, *Drimia/Urginea* was present at each market.

Table 1:Presence (✓) and absence (✗) of bulbs in four South African medicinal plant markets between 2007 and 2008.

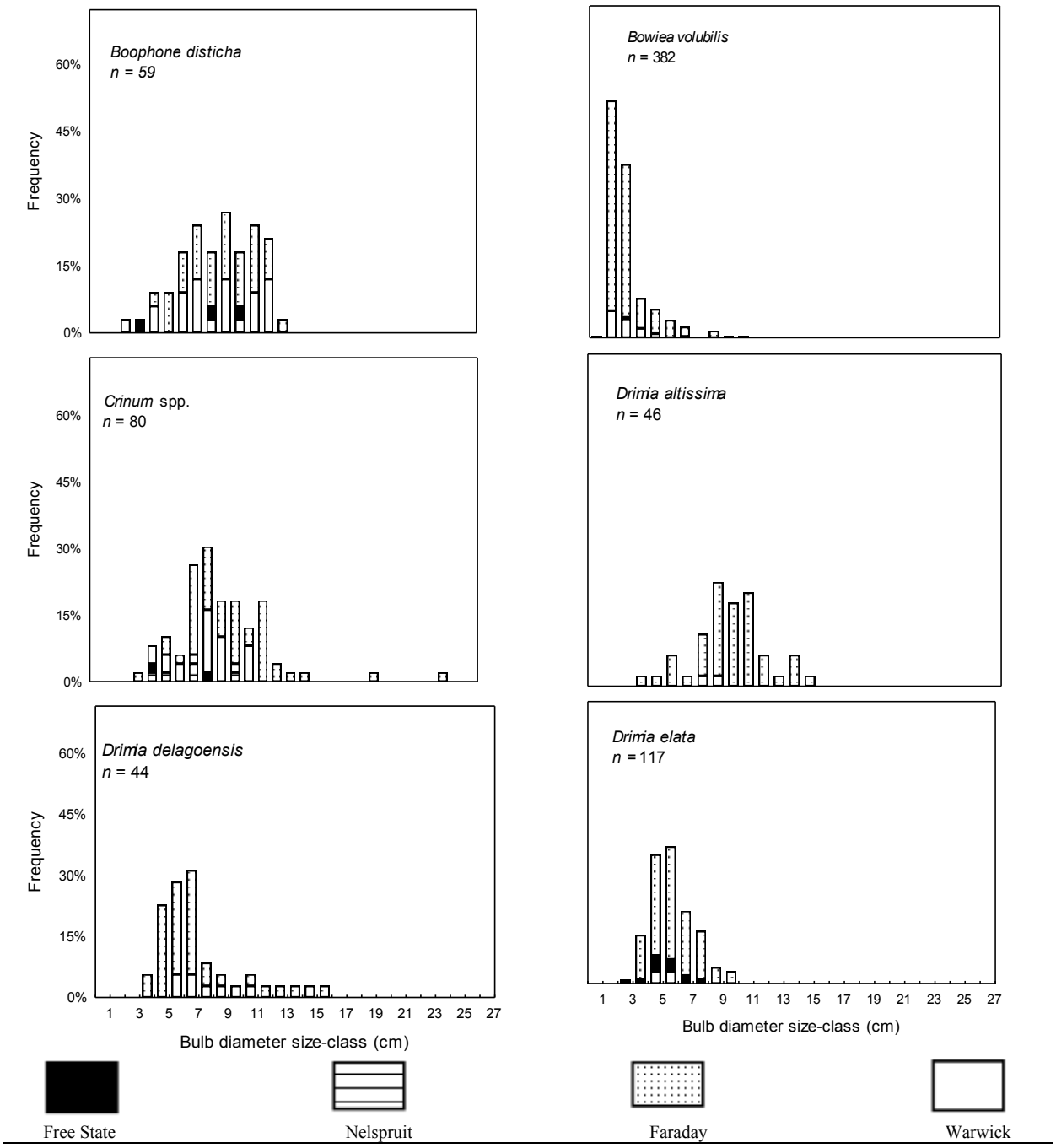
	Faraday market	Free State market	Nelspruit Market	Warwick market
Boophone disticha	✓	✓	✗	✓
Bowiea volubilis	✓	✓	✗	✓
Crinum buphanoides	✓	✗	✗	✗
Crinum macowanii	✓	✗	✗	✗
Crinum moorei	✓	✗	✗	✓
Crinum stuhlmannii	✓	✗	✗	✗
Unidentified *Crinum* species	✓	✓	✓	✓
Drimia altissima	✓	✗	✗	✓
Drimia delagoensis	✓	✗	✗	✓
Drimia elata	✓	✓	✗	✓
Drimia robusta	✓	✗	✗	✓
Drimia sanguinea	✓	✓	✗	✓
Urginea epigea	✓	✓	✗	✓
Urginea lydenburgensis	✗	✗	✓	✗

3.1. BULB SIZE-CLASS DISTRIBUTIONS IN MEDICINAL MARKETS

Bulb diameter distributions did not differ significantly from a normal distribution for all species in all markets except for *B. volubilis* from Faraday, which instead had a reverse-J shaped distribution (K-S $d_{333}= 0.1087$; $p<0.001$) (Figure 1). Bulb diameter distributions did not differ significantly between markets for *B. disticha, B. volubilis, Crinum* species*, D. altissima, D. delagoensis, D. elata, D. robusta,* and *D. sanguinea* ($p>0.10$ in all cases). Size-class distributions of *U. epigea* differed significantly between Faraday and Warwick (K-S $d_{62}= 0.128$; $p<0.01$), with a greater number larger size-classes present at Faraday than at Warwick (Figure 1). There was no difference between the latter two and the Free State markets ($p>0.10$).

3.1.1. Size-class distributions

There were four major patterns in size-class distributions recorded for bulbs collected in 2007 and 2008. *Boophone disticha, Crinum* species, *D. altissima* and *D. sanguinea* had distributions that were skewed to the right with lower frequencies of smaller bulbs present in the markets (Figure 1) and a declining frequency of very large bulbs, especially for *Crinum* species. The second pattern was characterised by a relatively normal distribution, but with very low numbers of small bulbs (Figure 1) (e.g. *D. elata* and *U. epigea*). *Drimia robusta* had a bell-shaped distribution; however, medium sized bulbs were less frequent in the market. The fourth pattern follows the classic inverse-J shaped curve, which is very pronounced in *B. volubilis* and to a lesser extent in *D. delagoensis* (Figure 1). No clear pattern was observed for *U. lydenburgensis* due to the small sample size.



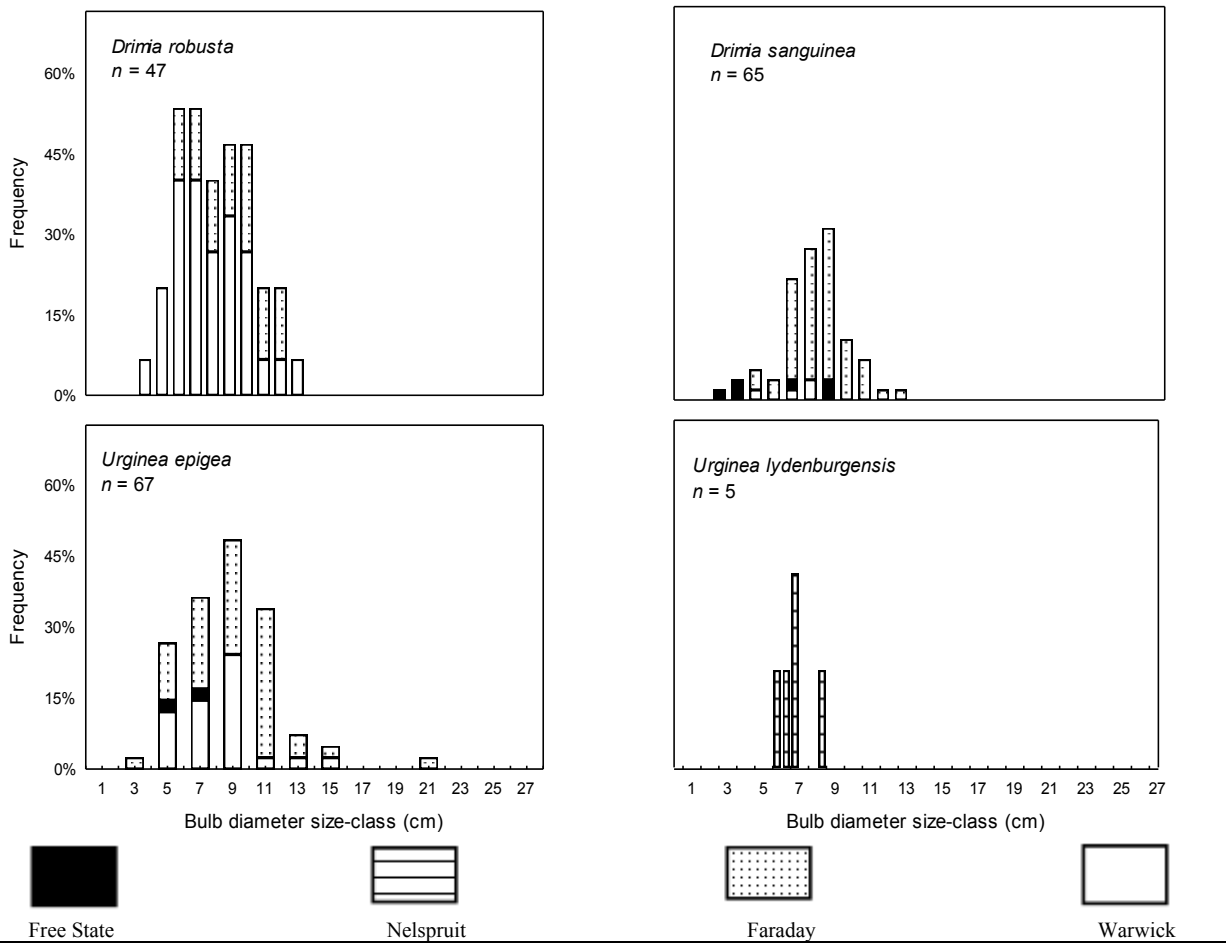


Figure 1: Bulb diameter size-class distributions in Faraday, Warwick and smaller Free State and Nelspruit markets between 2007 and 2008 for Boophone disticha, Bowiea volubilis, Crinum species, Drimia altissima, Drimia delagoensis, Drimia elata, Drimia robusta, Drimia sanguinea, Urginea epigea and Urginea lydenburgensis**.**

3.2. SOURCES OF SUPPLY OF BULBOUS SPECIES

3.2.1 Overall sources of supply in medicinal markets in 2007 and 2008

A large percentage of traders had bulbs that were collected in KZN (Table 2). The remainder of the sources of supply was species-specific, and were most diverse for *D. sanguinea. Boophone disticha* and *U. epigea* had four sources of supply (Table 2). *Bowiea volubilis, D. altissima* and *D. elata* bulbs tended to come from only three provinces including KZN, while *Crinum* species and *D. robusta* were only collected in one province other than KZN. *Urginea lydenburgensis* was only collected in Mpumalanga while *D. delagoensis* was only collected in KZN (Table 2).

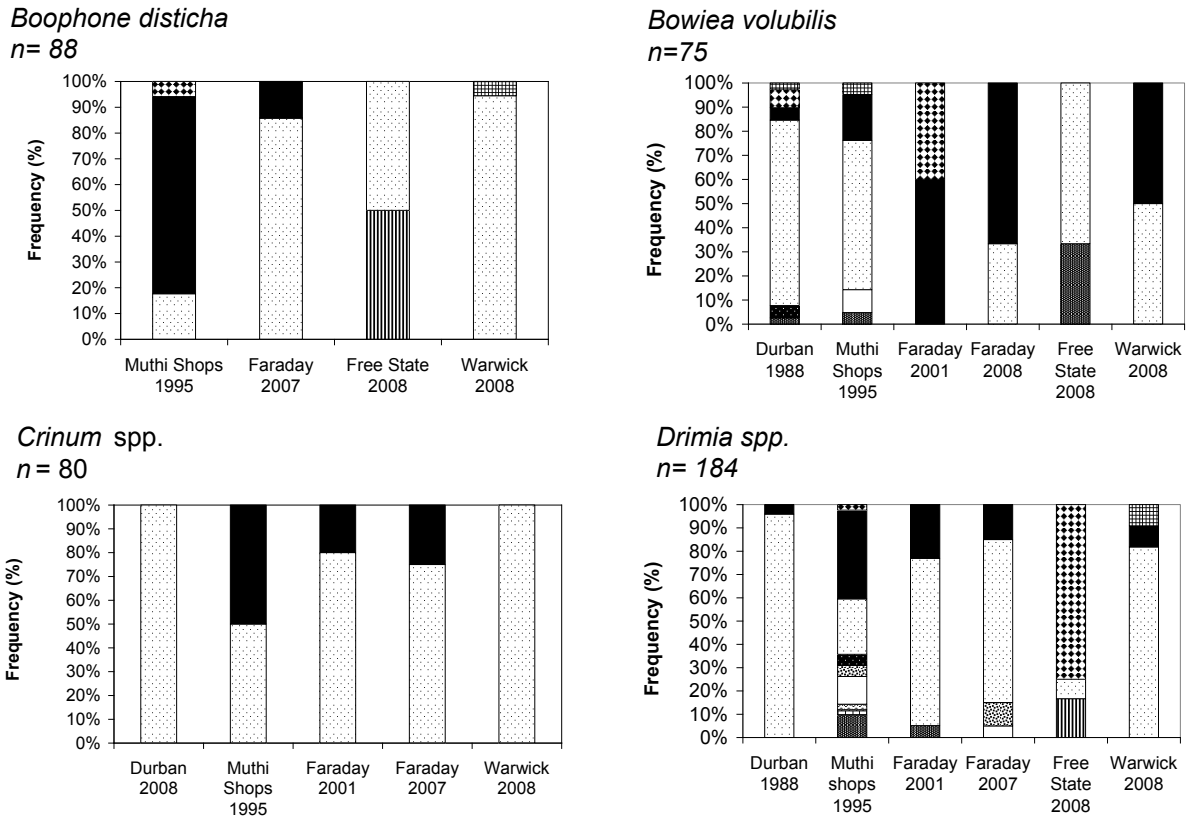
Table 2: Overall percentage sources of supply (South African Provinces and neighbouring countries) of bulbs in Faraday, Free State and Warwick markets collected between 2007 and 2008. Percentages based on number of traders (n) that responded across all markets.

	GP	KZN	EC	MP	FS	NW	Swaziland	Lesotho
Boophone disticha (n=27)	4%	89%	4%	-	-	-	-	4%
Bowiea volubilis (n=10)	40%	50%	-	-	-	-	10%	-
Crinum species(n=25)	12%	88%	-	-	-	-	-	-
Drimia altissima (n=5)	33%	50%	17%	-	-	-	-	-
Drimia delagoensis (n=6)	-	100%	-	-	-	-	-	-
Drimia elata (n=12)	-	59%	-	-	33%	-	-	8%
Drimia robusta (n=19)	-	94%	-	6%	-	-	-	-
Drimia sanguinea (n=18)	22%	32%	-	6%	28%	6%	-	6%
Urginea epigea (n=21)	-	80%	5%	10%	-	-	5%	-
Urginea lydenburgensis (n=1)	-	-	-	100%	-	-	-	-

3.2.2. Comparisons of sources of supply over time

In 2007/2008, traders, harvesters and traditional healers were reticent about divulging the whereabouts of harvested species, resulting in the numbers of traders interviewed for previous surveys being larger. The primary source of supply for bulbs sold in the Durban (1988), Witwatersrand *umuthi* shop (1995), Faraday (2001), Faraday (2007) and Warwick (2008) surveys was KZN (Figure 2). *Crinum* species howed the least variable source of supply over time. *Bowiea volubilis* showed the greatest change over time in the Durban markets, with the 1988 survey showing a wide variety of sources (Eastern Cape, Free State, Gauteng, Limpopo and Swaziland), while in 2008 the bulbs were either collected in KZN or Gauteng (and very rarely seen in the market). In Gauteng, the same pattern is seen: with more diverse sources in 1995 compared to 2001 and 2007, however in all three samples; the main source was Gauteng (Figure 2).

Drimia species (Figure 2) had very similar sources between 1988 and 2008 in Durban. In Gauteng, the 1995 survey had the most diverse sources; however this may be because *umuthi* shops have access to various methods of obtaining bulbous species. The 2001 and 2007 Faraday surveys had similar sources (mainly KZN and Gauteng), although the 2007 sample is more diverse (Figure 2). Sources of supply were the most diverse for *U. epigea* in the 1995 *umuthi* shop survey. The 2007 Faraday survey was more diverse than the 2001 survey, with a number of bulbs coming from Mpumalanga and not just KZN. For *Boophone disticha* in the 1995 *umuthi* shop survey, sources were more diverse than the 2007 Faraday survey (Figure 2), with a larger percentage of bulbs being collected in KZN in Faraday in 2007 than 1995. General trends indicate that for most species the sources of supply in the markets are becoming more diverse over time. This suggests that the harvesters are increasingly compelled to search further afield over time to meet the growing demand. It may also indicate that local or previous sources of supply have become depleted.



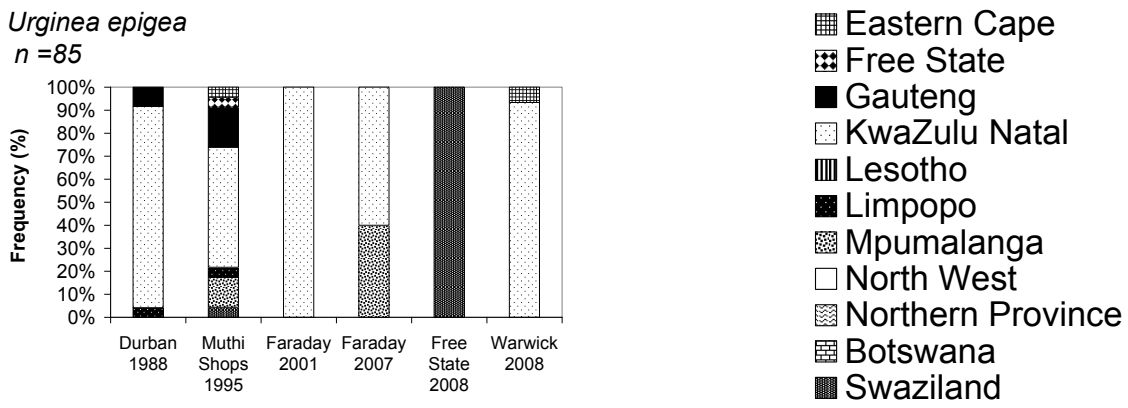
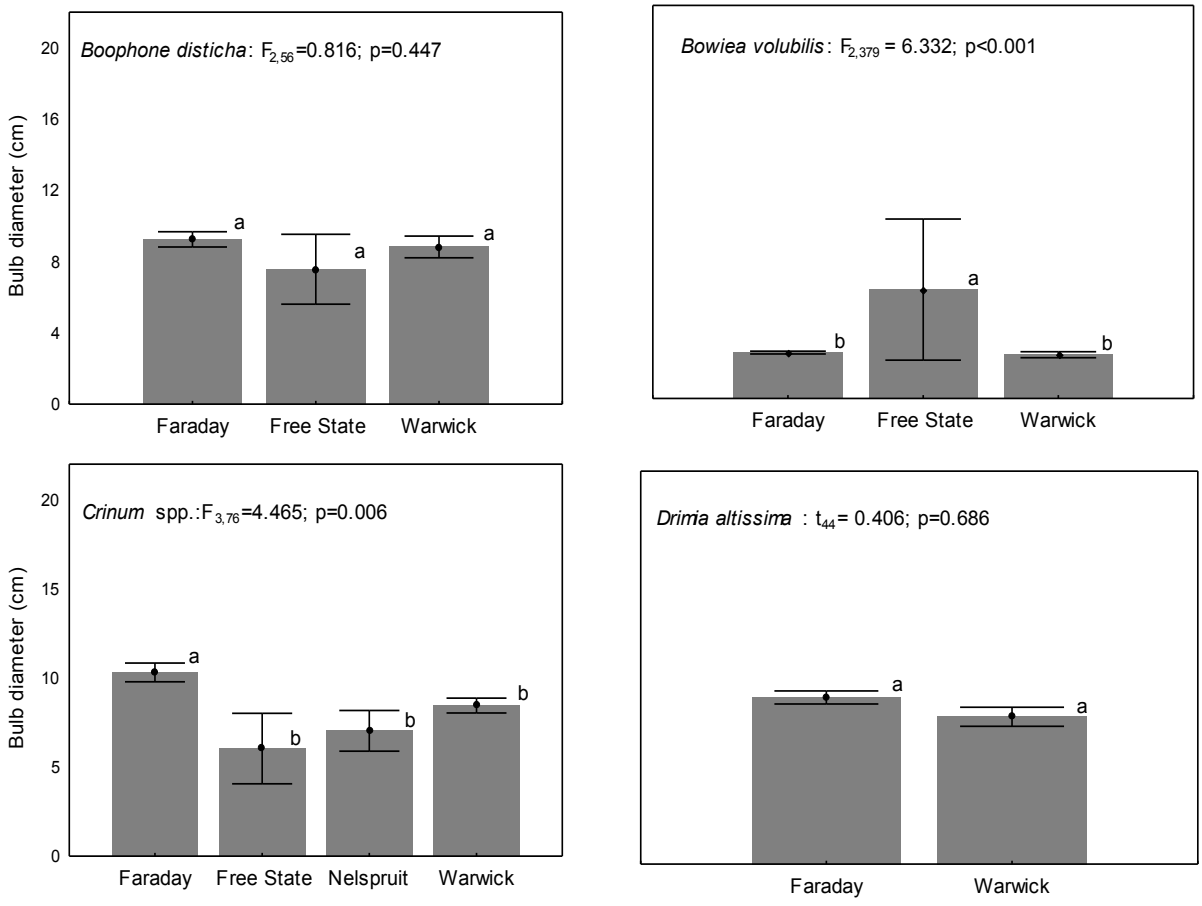


Figure 2: Percentage sources of supply of bulbous species in Durban (surveyed in 1988), Witwatersrand u*muthi* shops (1995), Faraday (2001 and 2007), Free State (2008) and Warwick (2008) markets. Percentages based on number of traders (n) that responded in each market.

3.3. MEAN DIAMETER OF BULBOUS SPECIES IN FOUR MARKETS

There were significant differences in bulb diameter between markets for *B. volubilis*, *Crinum* species, and *D. sanguinea* (p=0.002; p=0.006 and p< 0.001, respectively) (Figure 3). Bulbs tended to be largest in Faraday and smallest in Free State for both *Crinum* species and *D. sanguinea* (Figure 3). *Bowiea volubilis* bulbs were significantly larger in the Free State market compared to Faraday and Warwick (Figure 3). Bulb diameters did not differ between markets for *B. disticha*, *D. altissima*, *D. delagoensis*, *D. elata*, *D. robusta* and *U. epigea.* In general, the diameters of bulbs sold in Faraday tended to be slightly larger than those at the Warwick or Free State markets (Figure 3).



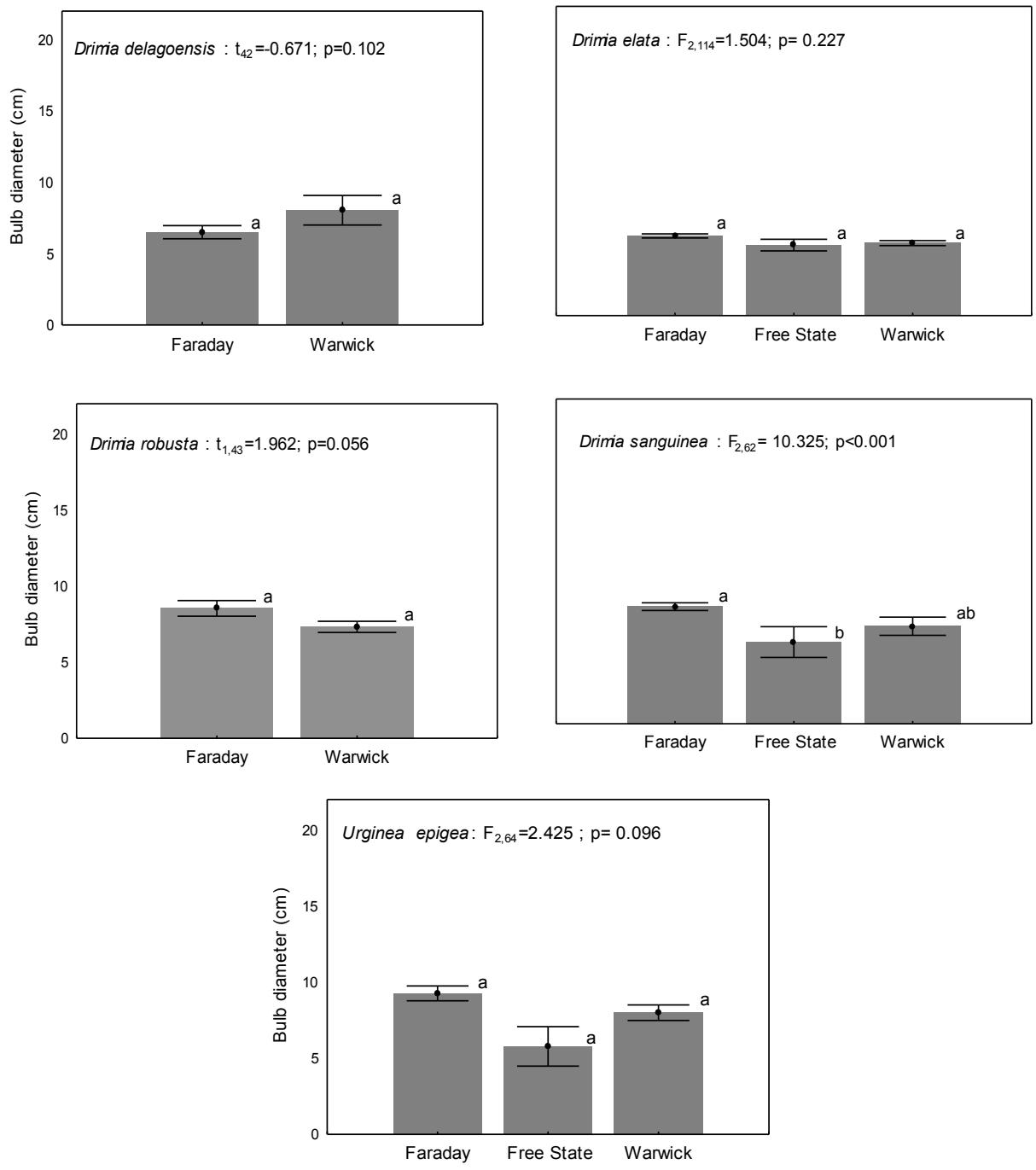
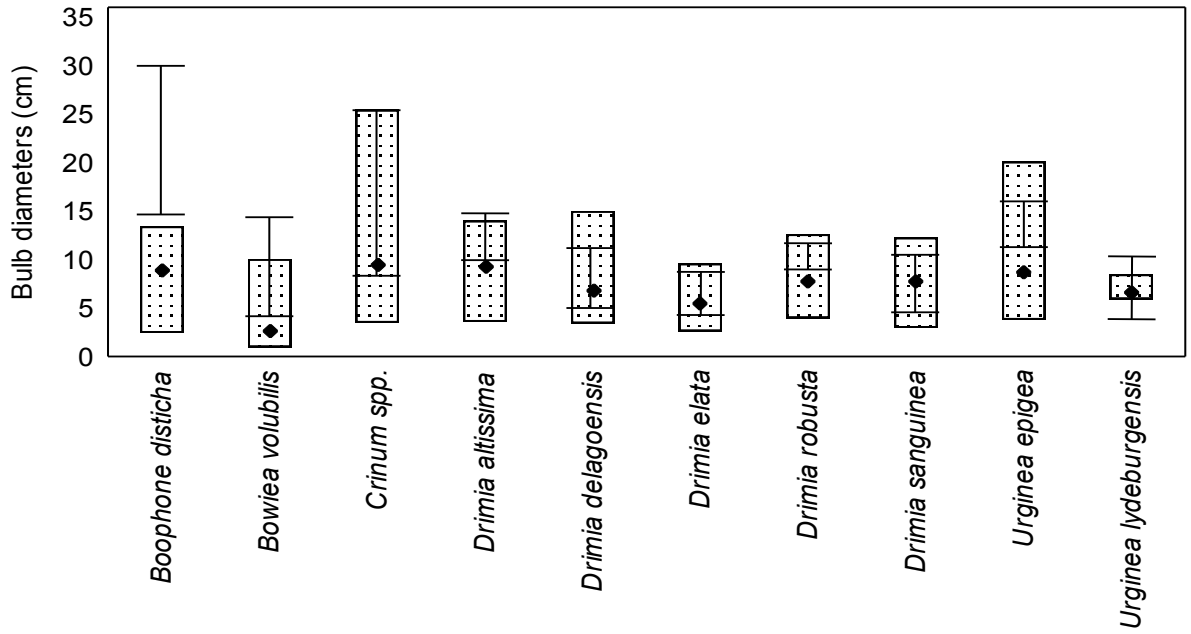


Figure 3: Mean (± SE) bulb diameters for nine bulb species sold at Faraday, Warwick, Free State and Nelspruit markets between 2007 and 2008. Results of One-Way ANOVAs and t-tests included. Means with different letters are significantly different (Fishers LSD, p<0.05).

3.3. EFFECTS OF HARVESTING ON BULB DIAMETERS

3.4.1. Reported bulb diameters in literature

Bulb diameter ranges and means collected from taxonomic descriptions of species in the literature did not provide enough replication for statistical analysis. The diameter ranges reported in the literature were relatively narrow in comparison to the bulb diameter ranges recorded in South African markets between 2007 and 2008 (Figure 4).



Fig

Figure 4: Market bulb diameters (mean ± range) of nine species and the Crinum species (collectively) from four markets between 2007 and 2008 (black diamond = mean, range = stippled rectangles). Diameter ranges reported in the literature are represented by the error bars (derived from Baker, 1896; Dyer, 1942; Dyer, 1947; Verdoorn, 1943; Verdoorn, 1973; Jessop, 1977).

The mean diameter of bulbs reported in the literature tended to be greater than those observed in the market (Table 3). The relative difference (%) between diameters reported in the literature and those recorded in the markets showed that *B. volubilis* in the markets is approximately 67% smaller than what was reported in the past (Table 3). The large-bulbed *B. disticha* and *Crinum* species are more than 30% smaller than previously reported (40% and 37.3% respectively). The smallest relative difference in bulb diameter was observed in *D. delagoensis* (2.9%). In contrast, *D. sanguinea* bulbs were slightly larger in the markets compared to records in the literature (Table 3), and there was virtually no difference in sizes for *D. delagoensis* and *D. elata.*

Table 3: Comparisons between 2007 market and histotical literature bulb diameters (Baker, 1896; Dyer, 1942; Dyer, 1947; Verdoorn, 1943; Verdoorn, 1973; Jessop, 1977)

Species	Diameter			
	Market (mean± SE) (cm) (a)	Literature (mean)(cm) (b)	Difference (cm) (a-b=c)	Relative difference (%) (c/b)*100
Boophone disticha	8.9±0.3	15.0	-6.1	-40.7
Bowiea volubilis	2.6±0.07	8.0	-5.4	-67.5
Crinum species	9.4±0.4	15.0	-5.6	-37.3
Drimia altissima	9.3±0.4	12.5	-3.2	-25.6
Drimia delagoensis	6.8±0.4	7.0	-0.2	-2.9
Drimia elata	5.6±0.13	6.0	-0.4	-6.7
Drimia robusta	7.7±0.3	9.0	-1.3	-14.4
Drimia sanguinea	7.8±0.2	7.0	0.8	11.4
Urginea epigea	8.7±0.4	12.5	-3.8	-30.4
Urginea lydenburgensis	6.7±0.5	10.0	-3.3	-33.0

3.4.2. Change in bulb diameters over time

Overall, there was a general decline in bulb diameter over time for all species. *Bowiea volubilis* bulbs were significantly smaller (by approximately 4cm) in 2007 than in 2001 in Faraday ($p<0.0001$) (Figure

6). *Drimia* species (*D. altissima, D. elata, D. robusta* and *D. sanguinea*) bulb diameters were significantly smaller in Faraday than in the *umuthi* shops in 1995 ($p<0.0001$). Within the *Drimia* species group there are large-bulbed (*D. altissima, D. robusta*), medium-bulbed (*D. sanguinea*) and small-bulbed species (*D. elata*), and the proportions of each species varied between markets (Table 4; Figure 5). Bulb diameters were not significantly different between studies for *B. disticha* and *U. epigea* (Figure 6).

Table 4: Percentage composition of four Drimia species in Faraday market in the 2001 and 2007 surveys and 2007 purchased bulb samples.

	Drimia altissima	*Drimia elata*	*Drimia robusta*	*Drimia sanguinea*
Percentage of sample: 2007 (%)	14	31	10	45
Estimated % in Faraday: 2007	25	10	5	60
Estimated % in Faraday: 1995-2001 §		≈40		≈60

§ Williams *et al.,* 2007a: exact proportions not known because the genus was grouped due to taxonomic uncertainties

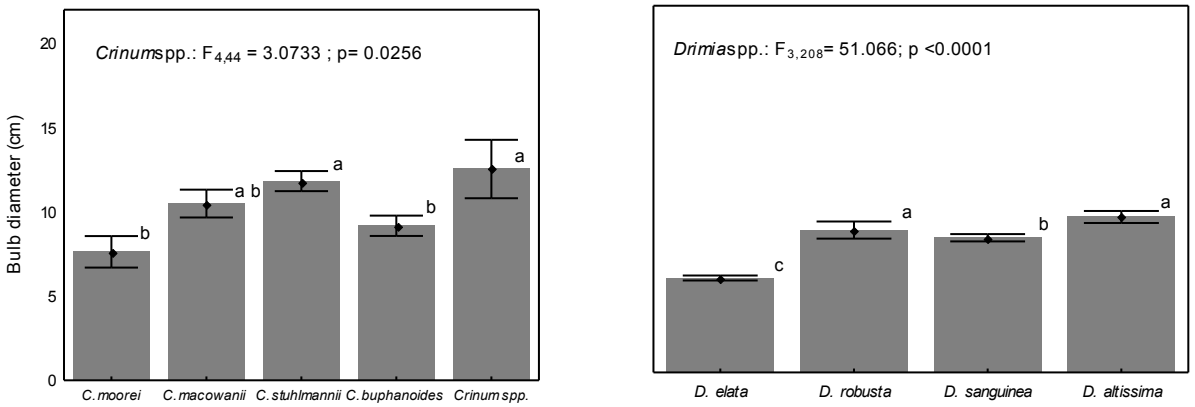


Figure 5: Mean (±SE) bulb diameters in Faraday market (2007) for species within the *Crinum* and *Drimia* species grouping. Results of One-Way ANOVAs are included. Means with different letters are significantly different (Fishers LSD: $p<0.05$).

There was a slight decrease in *Crinum* species bulb diameters between 2001 and 2007 in Faraday (Figure 6); however, the effects of grouping species may act to obscure effects of trade. Within the *Crinum* species and *Drimia* species complex, mean bulb diameters differed between species (Figure 5). Traded *Crinum* species included the smaller bulbs of *C. moorei* and *C. buphanoides,* the large bulbed *C. stuhlmannii,* and an unidentified species. The proportion of each species occurring in the market at any one time may be different (Table 5), and this would affect the mean overall bulb diameter recorded during a survey (Figure 6). For example, in 2001 there may have been a larger proportion of large bulbed *Crinum* species such as *C. stuhlmannii* and *C. macowanii* recorded which would hence mask the measurable impact of harvesting and trade over time.

Table 5: *Crinum* species composition in Faraday, Free State, Nelspruit and Warwick market in 2007/2008.

Species	*Crinum buphanoides*	*Crinum macowanii*	*Crinum moorei*	*Crinum stuhlmannii*	Unidentified *Crinum* species
Faraday (%)	40.8	12.2	10.2	14.3	22.4
Free State (%)	0	0	0	0	100
Nelspruit (%)	0	0	0	0	100
Warwick (%)	0	0	70.8	0	29.2

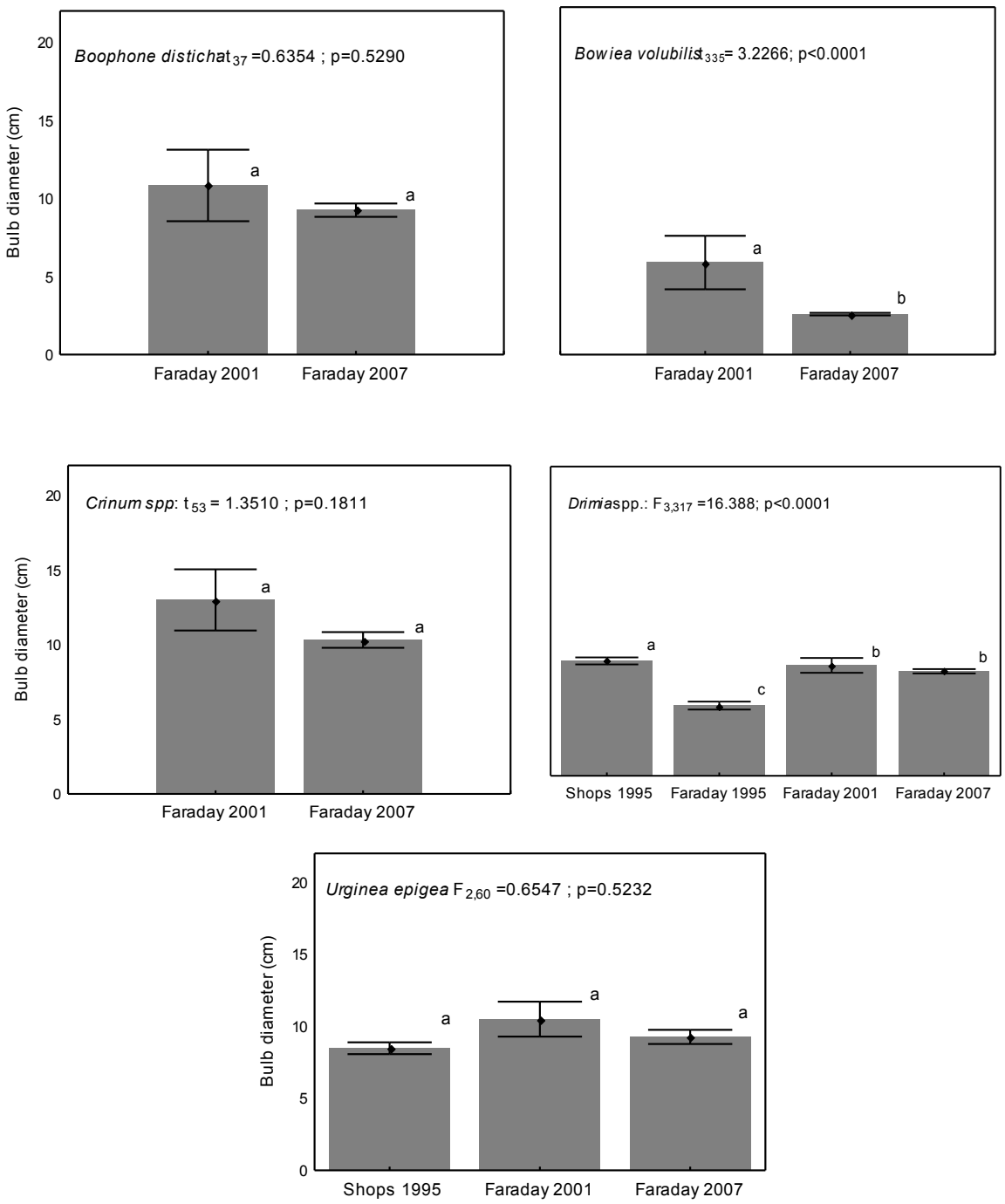


Figure 6: Mean (±95% CI) bulb diameters for species sold in Faraday market (1995, 2001 and 2007) and Witwatersrand *umuthi* shops (1995). Results of One-Way ANOVAs included. Means with different letters are significantly different (Fishers LSD: p<0.05).

3.4.2 Comparisons with herbarium record diameters

Herbarium voucher specimens provide another important source of historical bulb size. However, unlike means and ranges reported in the literature (Figure 4; Table 3), bulb drying is a noticeable factor when comparing diameters. In general, herbarium voucher specimens and market bulb diameters were similar, although market diameters were often slightly smaller (Figure 7). *Bowiea volubilis* was the only species where bulbs from the market were significantly smaller than bulb specimens in herbaria (2.4cm smaller, $p < 0.0001$) (Figure 7).

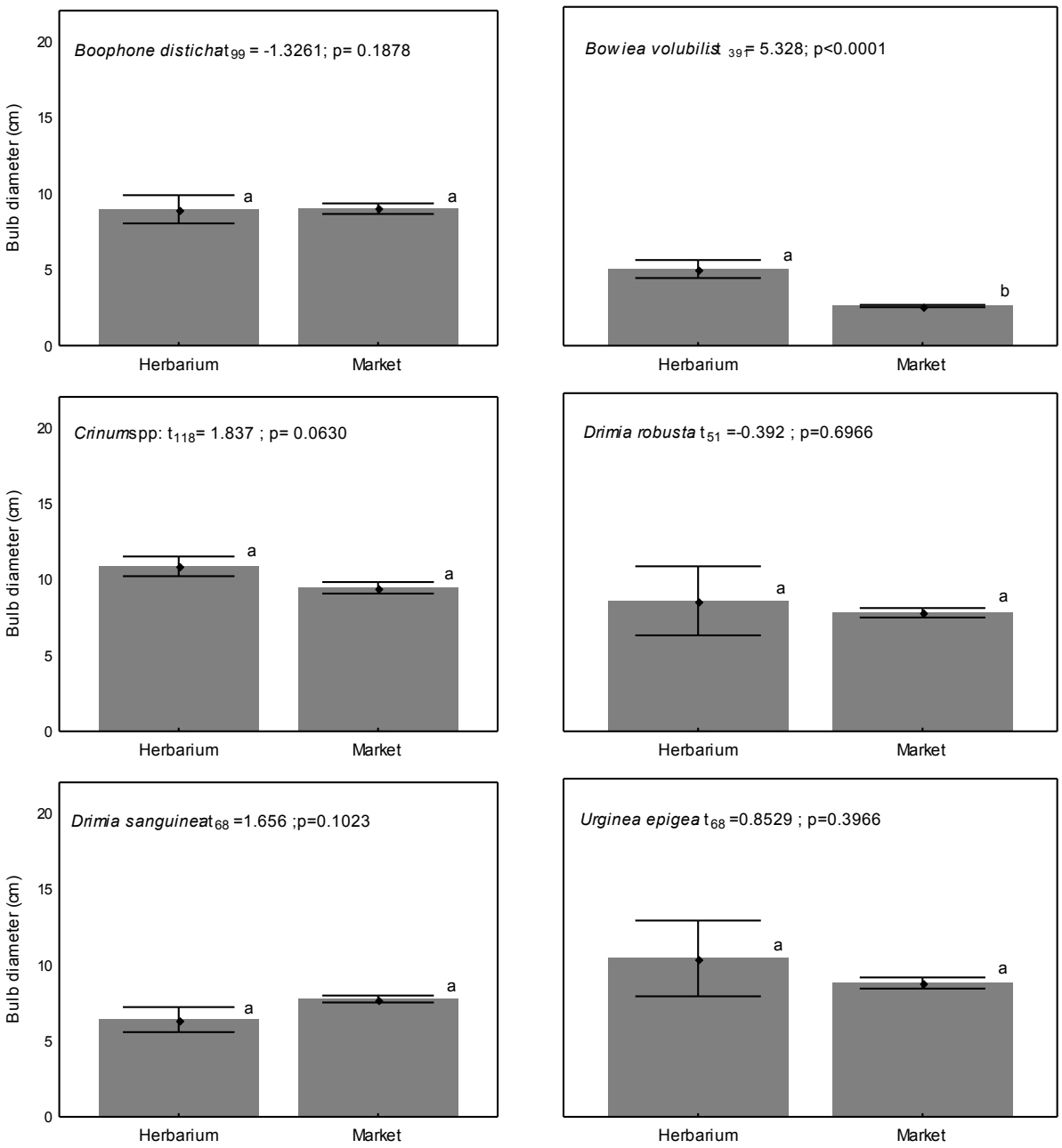


Figure 7: Mean (± SE) bulb diameters for species in medicinal markets and bulb diameters measured from herbarium vouchers. Results of two sample t-tests are included. Means with different letters are significantly different (P<0.05).

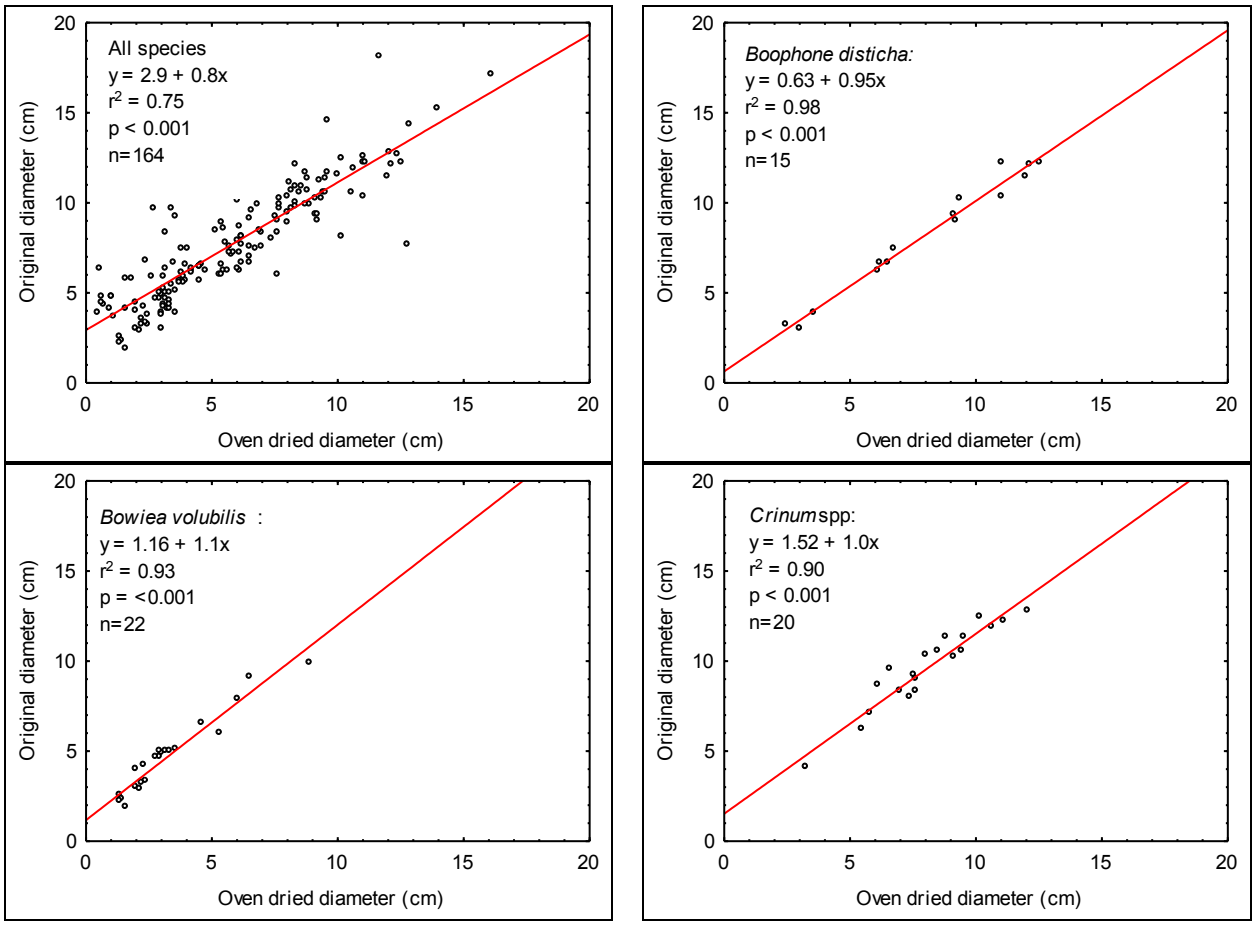
3.5. BULB DIAMETER AND REPRODUCTIVE STATUS OF PRESSED HERBARIUM SPECIMENS

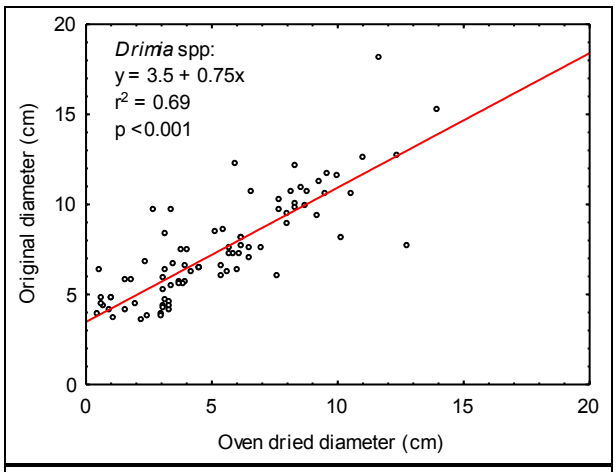
Bulb material is not often pressed and dried because of the difficulty associated with this (N.R. Crouch, pers. comm.). There were a large number of herbarium specimens without associated bulb material (Table 6). In order to relate the diameter of pressed bulb material to the market diameter of recently harvested bulbs (and hence the diameter that the herbarium specimens might have been when collected), the relationship between wet and oven dry diameters was determined. The regression between oven-dried diameter and original diameter showed a relatively strong linear regression with the r^2-value of 0.75 when all bulb species were combined species (Figure 8).

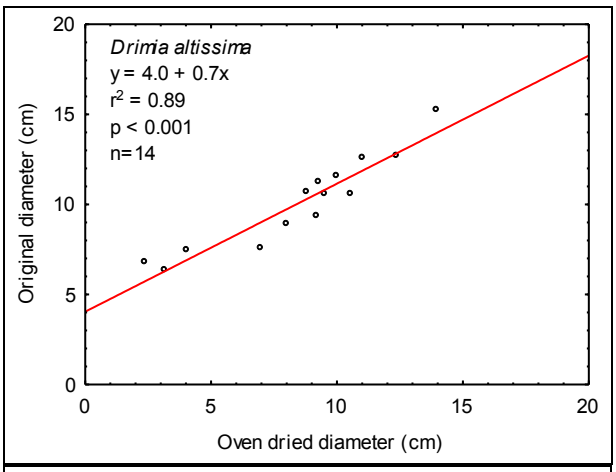
Table 6: The percentage of herbarium specimens with bulbous material, mean (±SE) bulb diameter, minimum flowering diameter, and temporal range of collected herbarium specimens.

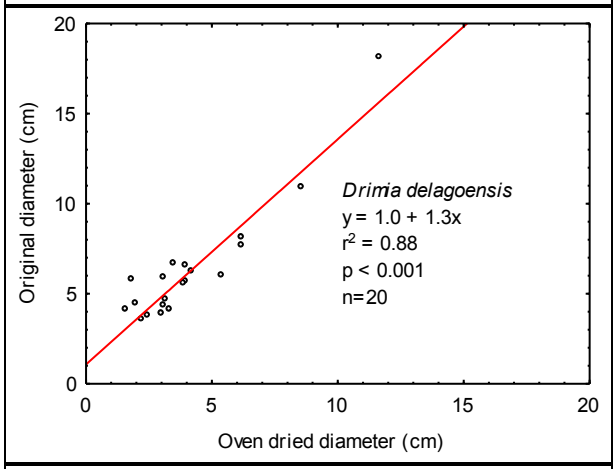
Species	Sample size (N)	% herbarium specimens with bulb material	Mean (±SE) bulb diameter (cm)	Minimum flowering diameter (cm)	Temporal range (calendar years)
Boophone disticha	34	11.6	9.4 ± 0.9	3.6	1892-2002
Bowiea volubilis	5	4.7	5.0 ± 0.6	2.3	1926-1998
Crinum species	23	7.3	10.9 ± 0.6	4.4	1912-1984
Drimia robusta	3	6.8	8.5 ± 2.2	2.8	1959-1979
Drimia sanguinea	5	6.2	6.4 ± 0.8	4.5	1957-1995
Urginea epigea	2	6.5	10.3 ± 2.5	7.7	1952-1987

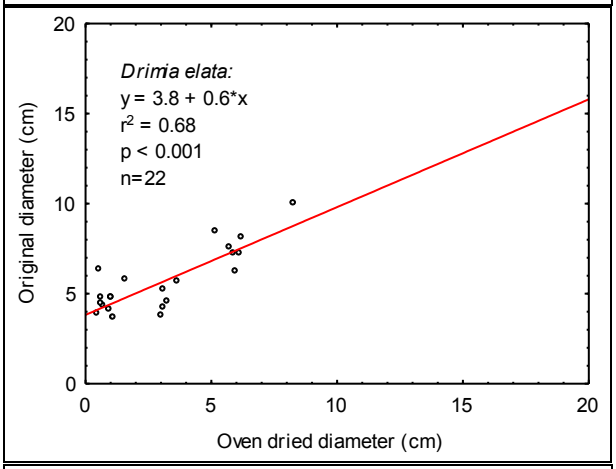
However, when linear regressions were conducted for different bulb species, different patterns emerged. Large-bulbed Amaryllidaceae species had strong linear regressions (*B. disticha* – r^2=0.98; p<0.001; *Crinum* species – r^2=0.90; p<0.001) and the difference between oven dried diameter and original (wet) diameter was not very large (Figure 8). *Bowiea volubilis* also had a very high r^2-value (0.93), as did *D. altissima* and *D. delagoensis* (0.89 and 0.88; respectively) (p<0.001 in all cases). *Drimia elata, D. robusta* and *U. epigea* had relatively weak linear regressions (0.68; 0.40 and 0.63, respectively; p<0.001). However, *D sanguinea* and *U. lydenburgensis* had the no correlation between oven-dried diameter and original diameter with r^2-values of 0.07 and 0.29, respectively and p>0.05 in both cases (Figure 8). For the latter, it most likely related to small sample size (n=3), however with *D. sanguinea*, the dried bulb often breaks apart which would therefore lead to very small oven dried bulb diameters.

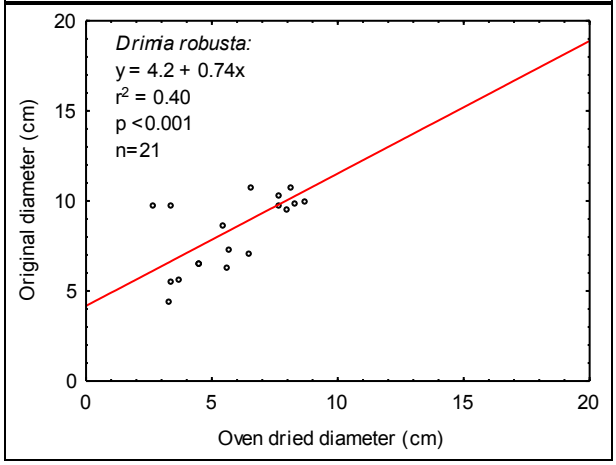


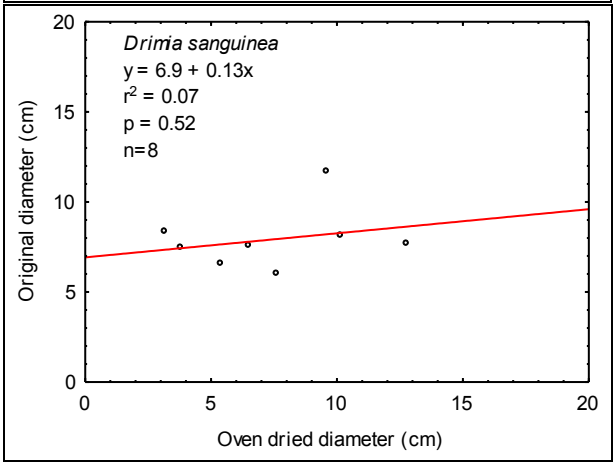

Drimia spp:
y = 3.5 + 0.75x
r² = 0.69
p <0.001
Original diameter (cm)
Oven dried diameter (cm)


Drimia altissima
y = 4.0 + 0.7x
r² = 0.89
p < 0.001
n=14
Original diameter (cm)
Oven dried diameter (cm)


Drimia delagoensis
y = 1.0 + 1.3x
r² = 0.88
p < 0.001
n=20
Original diameter (cm)
Oven dried diameter (cm)


Drimia elata:
y = 3.8 + 0.6*x
r² = 0.68
p < 0.001
n=22
Original diameter (cm)
Oven dried diameter (cm)


Drimia robusta:
y = 4.2 + 0.74x
r² = 0.40
p <0.001
n=21
Original diameter (cm)
Oven dried diameter (cm)


Drimia sanguinea
y = 6.9 + 0.13x
r² = 0.07
p = 0.52
n=8
Original diameter (cm)
Oven dried diameter (cm)

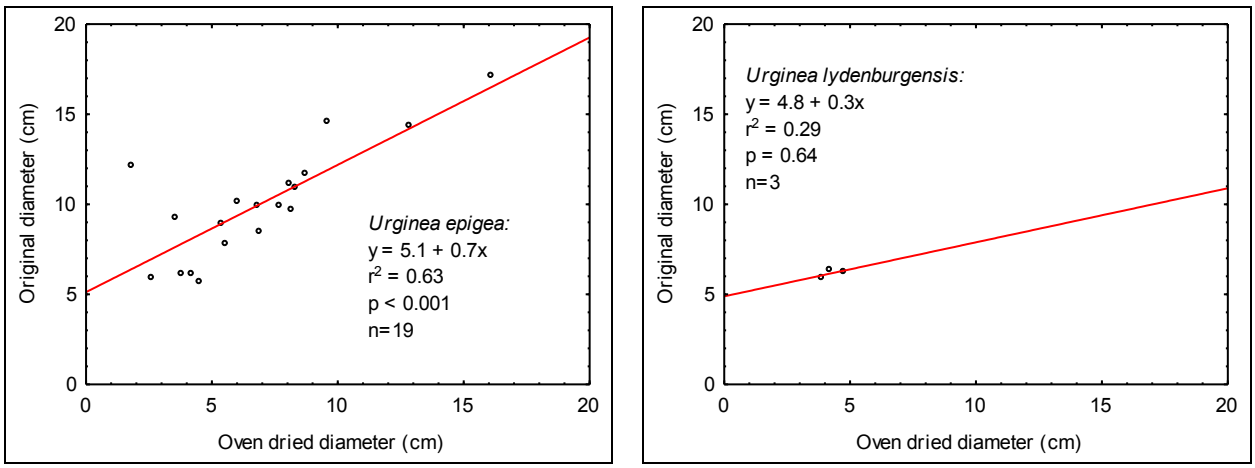


Figure 8: Regression relationships between oven-dried (dry) bulb diameter (cm) and original diameter (cm) for all species combined, six bulbous species, the genus, *Crinum* and the genus, *Drimia* collected in Faraday and Nelspruit markets in 2007 and Warwick and Free State markets in 2008.

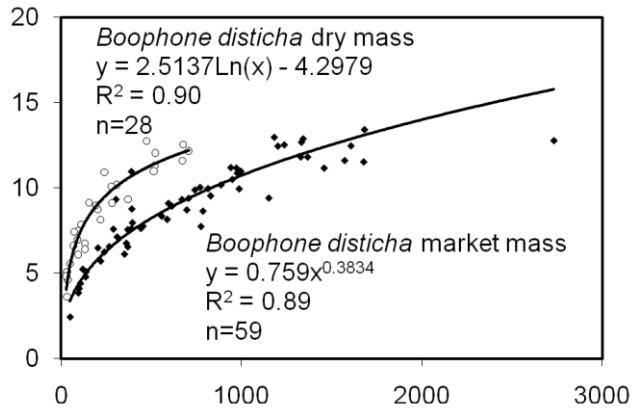
Using the species-specific regression between oven-dried and original diameter (Figure 8), there was a large increase in herbarium bulb diameter for *B. volubilis* (33.2%) and for *D. robusta* (23.4%) (Table 7). *Drimia sanguinea* also had a large increase in herbarium diameter (20.8%), however, the regression relationship for the species was very low (r^2=0.07; Figure 8). Using the combined *Drimia* species regression, the increase in herbarium diameter for *D. sanguinea* was even higher (40.6%) (Table 7). Large-bulbed species showed the smallest increase in estimated original herbarium diameter (1.6% and 13.9%) for *B. disticha* and *Crinum* spp, respectively). These are both Amaryllidaceae species with numerous tunics that do not separate when cut. Estimated minimum flowering size was sizably greater for *D. robusta* (124%), *B. volubilis* (60.4%), *U. epigea* (36.2%) and *Crinum* species (34.5%) (Table 7). The smallest increase was once again for *B. disticha* (12.5%).

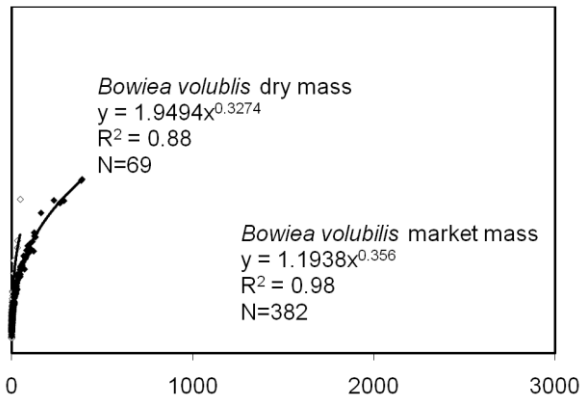
Table 7: Estimated original bulb diameter for herbarium material and percentage change from herbarium diameter and estimated diameter for six species using regression equations from Figure 8.

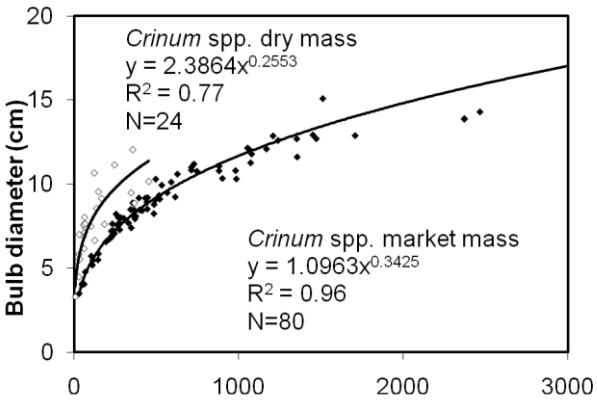
Species	Regression equation	Mean herbarium diameter (cm) (a)	Estimated original bulb diameter (cm) (b)	% Difference (b-a/a)*100	Min flowering diameter (cm) (c)	Estimated original minimum flowering size (cm) (d)	% Difference (d-c/c)*100
Boophone disticha	y=0.63+0.95x	9.4	9.6	1.7	3.6	4.1	12.5
Bowiea volubilis	y=1.16+1.1x	5.0	6.7	33.2	2.3	3.7	60.4
Crinum species	y=1.52+1.0x	10.9	12.4	13.9	4.4	5.9	34.5
Drimia robusta	y=4.2+0.74x	8.5	10.5	23.4	2.8	6.3	124.0
Drimia sanguinea (species-specific regression)	y=6.9+0.13x	6.4	7.7	20.8	4.5	7.5	66.3
Drimia sanguinea (*Drimia* species regression)	y=3.5+0.75x	6.4	9	40.6	4.5	6.8	52.7
Urginea epigea	y=5.1+0.7x	10.3	12.3	19.5	7.7	10.5	36.2

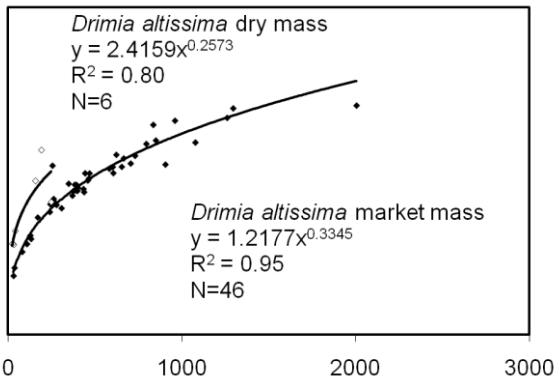
3.6. THE RELATIONSHIP BETWEEN BULB DIAMETER AND MASS

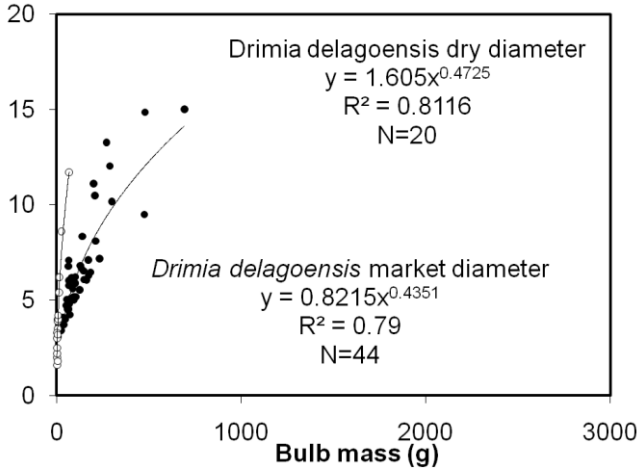
The strongest regression between market bulb mass (g) and diameter (cm) for eight species was a power curve (Figure 9). The relationship was strongest for the smallest bulbs (*B. volubilis*: $r^2 = 0.98$) followed by the largest bulbs (*Crinum* species: $r^2 = 0.96$). The weakest power curve regressions were for the strongly clustering species, *D. delagoensis* and *U. epigea* ($r^2 = 0.80$ and $r^2 = 0.75$ respectively). *D. robusta* had a strong logarithmic relationship between bulb mass and diameter ($r^2 = 0.98$), while *U. lydenburgensis* had a relatively strong linear relationship ($r^2 = 0.81$). Overall, bulb mass increased with bulb diameter (Figure 9).

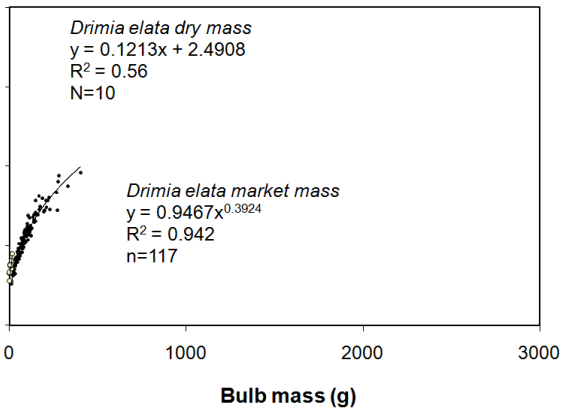

Boophone disticha dry mass
y = 2.5137Ln(x) - 4.2979
R² = 0.90
n=28
Boophone disticha market mass
y = 0.759x^0.3834
R² = 0.89
n=59

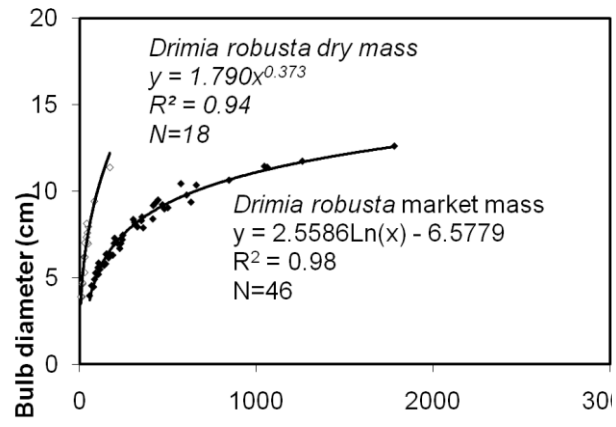

Bowiea volublis dry mass
y = 1.9494x^0.3274
R² = 0.88
N=69
Bowiea volubilis market mass
y = 1.1938x^0.356
R² = 0.98
N=382

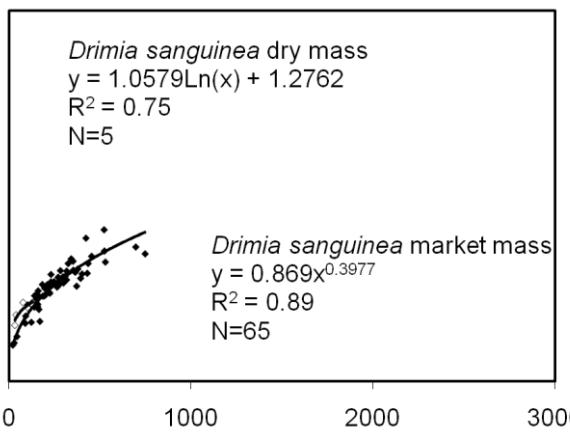

Bulb diameter (cm)
Crinum spp. dry mass
y = 2.3864x^0.2553
R² = 0.77
N=24
Crinum spp. market mass
y = 1.0963x^0.3425
R² = 0.96
N=80


Drimia altissima dry mass
y = 2.4159x^0.2573
R² = 0.80
N=6
Drimia altissima market mass
y = 1.2177x^0.3345
R² = 0.95
N=46


Drimia delagoensis dry diameter
y = 1.605x^0.4725
R² = 0.8116
N=20
Drimia delagoensis market diameter
y = 0.8215x^0.4351
R² = 0.79
N=44
Bulb mass (g)


Drimia elata dry mass
y = 0.1213x + 2.4908
R² = 0.56
N=10
Drimia elata market mass
y = 0.9467x^0.3924
R² = 0.942
n=117
Bulb mass (g)


Bulb diameter (cm)
Drimia robusta dry mass
y = 1.790x^0.373
R² = 0.94
N=18
Drimia robusta market mass
y = 2.5586Ln(x) - 6.5779
R² = 0.98
N=46


Drimia sanguinea dry mass
y = 1.0579Ln(x) + 1.2762
R² = 0.75
N=5
Drimia sanguinea market mass
y = 0.869x^0.3977
R² = 0.89
N=65

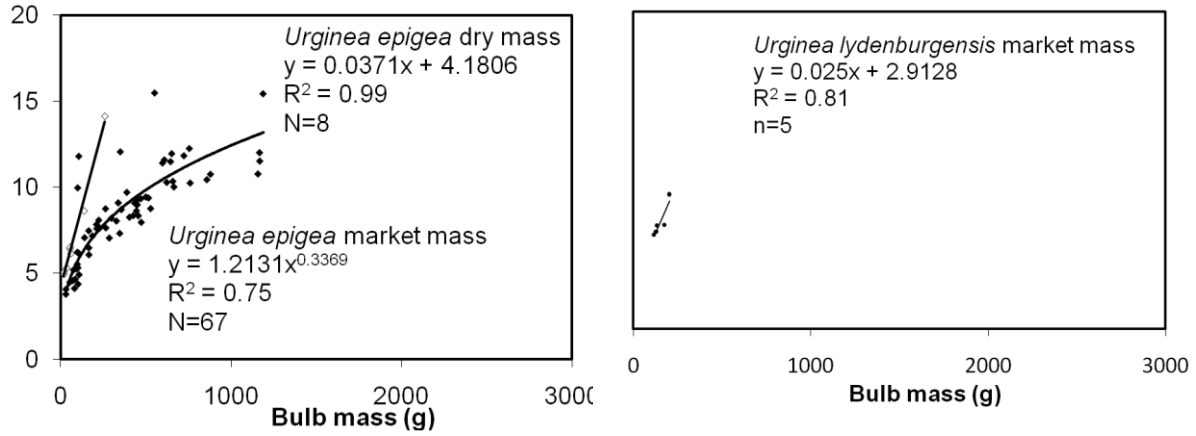


Figure 9: Regression relationships between market (filled symbols) and oven-dry (open symbols) bulb mass (g) and diameter (cm) for bulbs collected in Faraday and Nelspruit markets in 2007 and Warwick and Free State markets in 2008.

Differences in bulb mass between the markets were more pronounced than differences in bulb diameter (Figure 9; Table 8). Mass can be influenced the length of time a bulb is in storage, and results suggest that, compared to bulb diameters, bulb mass is likely to decline more over the same measured time period. The mass of *B. volubilis*, *D. delagoensis, D. sanguinea* and *U. epigea* were all significantly different between markets ($p<0.001$; $p=0.005$; $p<0.001$ and $p=0.022$ respectively) (Table 8).

Table 8: Comparisons of mean (±SE) mass of individual bulbs purchased from Faraday, Free State, Nelspruit and Warwick markets in 2007/2008. For each species, different letters indicate significant differences between markets, and significant p-values in bold (p< 0.05).

Species	Mean (±SE) individual bulb mass (g)				*t*- value/ F-value	*P* value
	Faraday	Free State	Nelspruit	Warwick		
Boophone disticha	688 ± 74 [a]	532 ± 247 [a]	-	847 ± 137 [a]	$F_{2,56} = 0.377$	0.688
Bowiea volubilis	17.4 ± 2 [a]	219 ± 170 [b]	-	12.2 ± 3 [a]	$F_{2, 379} = 6.668$	**0.001**
Crinum species	884 ± 131 [a]	172 ± 112 [b]	292± 123[b]	485 ± 69 [ab]	F = 3.937	**0.011**
Drimia altissima	553 ± 58 [a]	-	-	353 ± 46 [a]	$t_{44} = 0.175$	0.862
Drimia. delagoensis	123 ± 20 [a]	-	-	242 ± 50 [b]	$t_{42} = -2.971$	**0.005**
Drimia elata	106 ± 7 [a]	88.7± 22[a]	-	75.4 ± 7 [a]	$F_{2,114} = 1.526$	0.222
Drimia robusta	474 ± 90 [a]	-	-	326 ± 60 [a]	$t_{45} = 1.853$	0.070
Drimia sanguinea	289 ± 20 [a]	123 ± 44 [b]	-	190 ± 18 [a]	$F_{2,62} = 12.181$	**0.001**
Urginea epigea	493 ± 53 [a]	99.5± 43 [b]	-	284 ± 33 [b]	$F_{2, 64} = 4.023$	**0.022**
Urginea lydenburgensis	-	-	152 ± 16	-	-	-

3.7. SEASONAL CHANGES IN BULB MASS AND DIAMETER

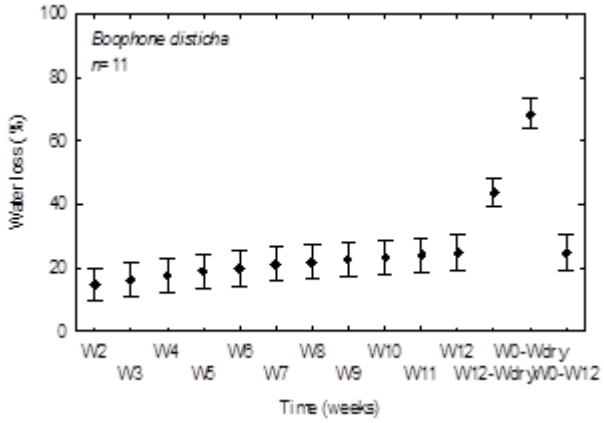
In Faraday, seasonal differences in bulb mass and diameter appears to be species-specific and significant differences in bulb diameter were recorded for *B. volubilis* ($p< 0.001$), *D. delagoensis* ($p=0.009$), *D. robusta* ($p= 0.043$) and *U. epigea* ($p< 0.001$). There were also significant differences in bulb mass for the same species ($p <0.001$; $p= 0.026$; $p= 0.019$ and $p<0.001$ respectively) (Table 9). Bulbs purchased in September 2007 were usually smaller than bulbs purchased in October/December 2007 and July/August 2007.

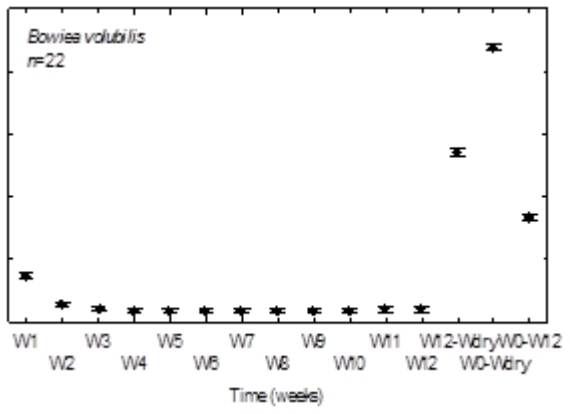
Table 9: Seasonal differences between mean (±SE) bulb mass (g) and diameter (cm) for species collected at Faraday market between July and December 2007. Means with different letters are significantly different (p<0.05) and significant p- values are highlighted.

Species		July-August 2007	September 2007	October-December 2007	F-value / *t*-value	*p* value
Boophone disticha	Diameter (cm)	-	9.1± 0.6[a]	9.6± 0.5 [a]	t_{31} = 0.829	0.413
	Mass (g)	-	689.8± 96.2[a]	684.3± 109.4[a]	t_{31} = 0.577	0.567
Bowiea volubilis	Diameter (cm)	5.2± 0.2[a]	2.2± 0.1[b]	5.9± 0.4[a]	$F_{2, 327}$ =141.1	**<0.001**
	Mass (g)	69.4± 6.6[a]	7.9± 1.0[b]	108.7± 24.3 [a]	$F_{2, 327}$ =154.7	**<0.001**
Crinum species	Diameter (cm)	11.1± 1.8 [a]	-	10.2± 0.6[a]	t_{47} = -0.613	0.543
	Mass (g)	1142.9± 513.9[a]	-	837.7± 132.2[a]	t_{47} = -0.403	0.688
Drimia altissima	Diameter (cm)	12.2± 0.6[a]	9.4± 0.4 [a]	8.8± 0.7[a]	$F_{2, 41}$ =1.656	0.203
	Mass (g)	815.0± 20.0[a]	530.9± 80.9 [a]	464.3± 80.6 [a]	$F_{2, 41}$ =1.121	0.335
Drimia delagoensis	Diameter (cm)	-	4.9± 0.3[a]	7.3± 0.6 [b]	t_{34} = 2.761	**0.009**
	Mass (g)	-	70.4± 8.1 [a]	148.4± 27.6[b]	t_{34} = 2.326	**0.026**
Drimia elata	Diameter (cm)	4.38± 0.3 [a]	5.9± 0.8 [a]	5.7± 0.2 [a]	$F_{2,96}$ =2.381	0.097
	Mass (g)	46.1± 8.4 [a]	116.1± 30.0[a b]	110.1± 7.5 [a]	$F_{2,96}$ =3.997	**0.022**
Drimia robusta	Diameter (cm)	10.9± 0.7 [a]	8.1± 0.5[b]	-	t_{15}= -2.246	**0.043**
	Mass (g)	978.3± 184.9 [a]	382.6± 92.2 [b]	-	t_{15}= -2.656	**0.019**
Urginea epigea	Diameter (cm)	10.1±1.4[a]	6.0± 0.7[b]	10.3± 0.5[a]	$F_{2,38}$ =23.942	**<0.001**
	Mass (g)	857.5± 312.5 [a]	159.9± 58.4[b]	578.5± 55.2[a]	$F_{2,38}$ =21.428	**<0.001**

3.8. THE EFFECT OF DRYING ON BULBS

There is a remarkable consistency in the mean water loss (% of total original mass). For all species, the highest percentage water loss occurred between week 12 and oven dried mass (Figure 10). The percentage water loss over 12 weeks was approximately 40% for all species.





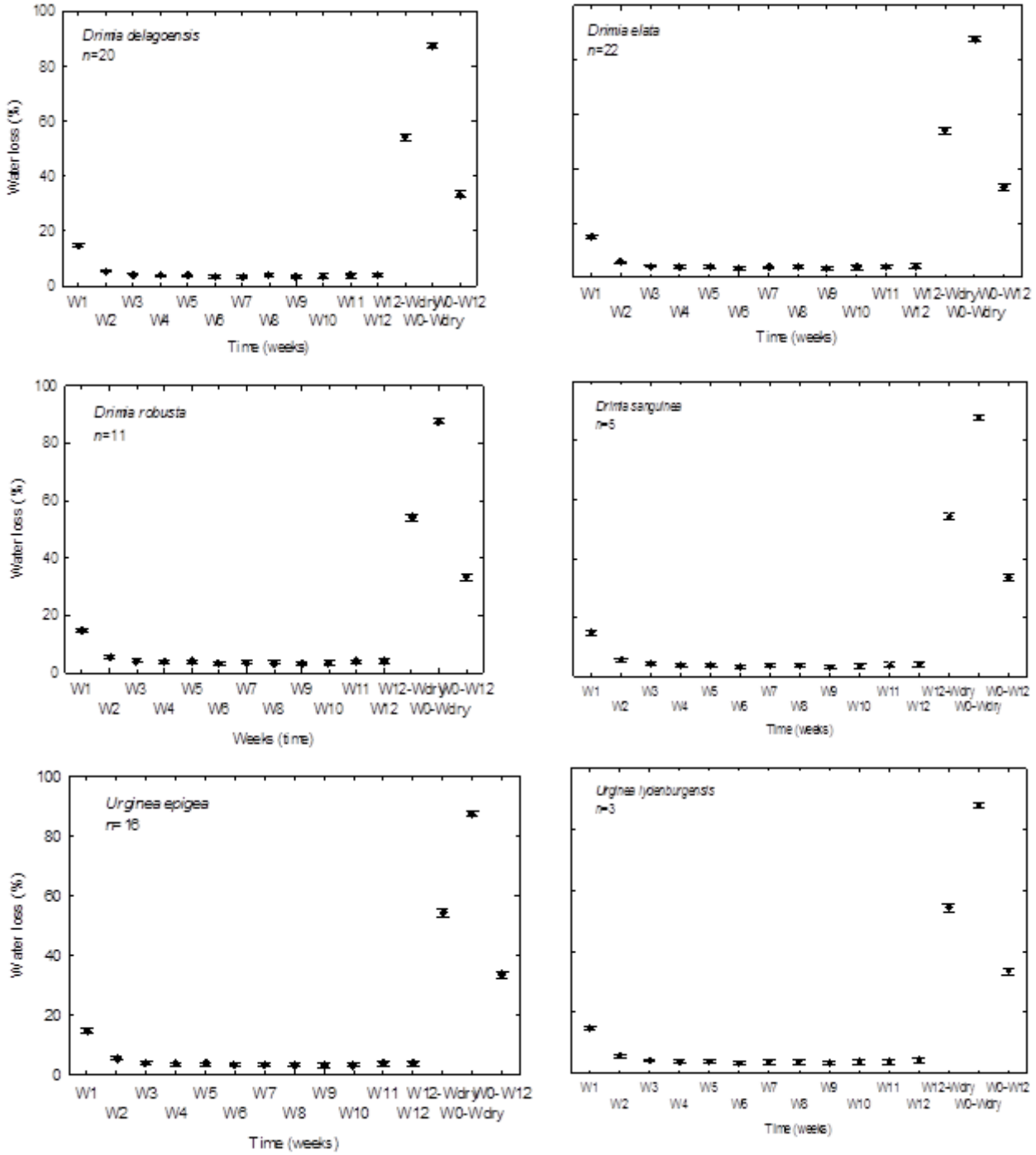


Figure 10: Mean (±SE) water loss per time period (as a percentage of the original "wet diameter" over time). Where W0= original mass; W1= $W1_{mass}$-$W0_{mass}$; W2= $W2_{mass}$-$W1_{mass}$; W3= $W3_{mass}$-$W2_{mass}$; W4= $W4_{mass}$-$W4_{mass}$; W5= $W5_{mass}$-$W4_{mass}$; W6= $W6_{mass}$-$W5_{mass}$; W7= $W7_{mass}$-$W6_{mass}$; W8= $W8_{mass}$-$W7_{mass}$; W9= $W9_{mass}$-$W8_{mass}$; W10= $W10_{mass}$-$W9_{mass}$; W11= $W11_{mass}$-$W10_{mass}$; W12= $W12_{mass}$-$W11_{mass}$; Wdry = mass after being oven dried. W0-Wdry is the total water loss per time period (i.e. after being oven dried).

Percentage decrease in diameter over time was much less apparent than change in mass (Table 10). The greatest weekly decrease was during week 1, but weekly decreases in general were low, with a maximum of 12.5%/week for *U. epigea*. Soft fleshy bulbs in the Hyacinthaceae decreased to a greater extent. Harder, more compact bulbs (e.g. *D. altissima*, *D. sanguinea*) decreased in diameter to a lesser extent (4.3% and 3.1%/week, respectively). The relationship between original 'wet' diameter and drying diameter for weeks one to twelve, showed a similar trend in all species. R^2 values were greatest in the first week and decreased with time. The relationships between wet and dry diameters had the lowest r^2 values (Table 11). Sample size was an important factor and r^2 values were lower for species with fewer samples.

Table 10: Weekly percentage decrease in bulb diameter (mean +SE); the overall difference in wet and oven dried bulb diameter (W0-W13); wet and week 12 diameter (W0-W12) and diameter decrease between week 12 and oven dried diameter (W12-W13) (Vernier callipers had a precision of 0.01mm).

	Boophone disticha n=16	***Bowiea volubilis n=23***	***Crinum* species *n=20***	***Drimia altissima n=14***	***Drimia delagoensis n=21***	***Drimia elata n = 22***	***Drimia robusta n=21***	***Drimia sanguinea n= 8***	***Urginea epigea n=20***	***Urginea lydenburgensis n=3***
W0-W1	0.3± 0.06	8.5±0.9	3.2±0.6	4.3±1.01	8.3±0.9	6±1.2	13.1±1.3	3.1±0.6	12.5±1.1	6.5±1.6
W1-W2	0.1±0.06	3.3±0.5	1.4±0.8	1.3±0.69	2.5±0.6	2±0.4	4.4±0.4	1.3±0.5	4.4±0.4	1.5±0.4
W2-W3	0.2±0.06	2.6±0.5	2.1±0.4	0.81±0.29	2.2±0.4	2±0.5	3.3±0.3	1.3±0.6	2.8±0.3	2.1±0.9
W3-W4	0.1±0.06	1.9±0.4	1.7±0.4	0.68±0.22	1.8±0.4	1±0.4	2.4±0.3	2±1	2.1±0.4	2.1±1
W4-W5	0.2±0.06	1.4±0.3	1.9±0.4	0.48±0.15	2.8±1.4	2±0.3	1.5±0.5	1.3±0.5	1.6±0.3	3.4±1
W5-W6	0.1±0.06	1.8±0.4	1.1±0.3	0.54±0.2	1.3±0.4	2±0.4	1.9±0.2	2.2±0.9	1.3±0.2	1.6±0.6
W6-W7	0.1±0.06	1.8±0.5	0.9±0.2	0.53±0.15	1.2±0.2	2±0.3	1.4±0.1	0.9±0.6	1.1±0.1	1.8±1.2
W7-W8	0.04±0.06	1.9±0.5	1.1±0.3	0.52±0.19	1.6±0.3	2±0.3	1.8±0.2	0.8±0.3	1.4±0.2	1.1±0.8
W8-W9	0.03±0.07	1.7±0.5	0.7±0.1	0.56±0.13	1.6±0.3	2±0.3	1.8±0.4	0.7±0.3	1.3±0.2	4.8±2.2
W9-W10	0.04±0.07	1.4±0.3	0.5±0.1	7.9±7.3	1.6±0.3	2±0.3	1±0.2	1±0.6	0.7±0.1	2.8±0.3
W10-W11	0.1±0.06	1.3±0.3	0.6±0.1	-6.7±7.3	1.7±0.4	1±0.3	1.5±0.2	1.9±0.8	0.8±0.1	1.8±0.5
W11-W12	0.1±0.06	0.9±0.2	1.2±0.3	1.01±0.22	3.8±0.6	2±0.3	5.1±3.9	0.4±0.7	0.4±0.6	1±0.8
W12-W13	0.38±0.06	32.8±2.2	16.4±1.6	7.4±4.7	9.4±3.5	26±6.1	58.8±4.1	-10.3±15.1	63.7±2.3	4.5±3.2
W0-W13	1.4±0.06	28.5±2	16.2±1.3	92.6±4.7	34.6±3.4	50±6.4	93.2±1	5.1±14.9	91±1.1	30.9±3.5
W0-W12	1.4±0.06	2.8±0.20	1.7±0.13	11.2±1.1	25.2±2.3	0.23±1.8	34.3±3.9	15.4±2.1	27.3±1.8	26.4±1

Table 11: Regression equations and R2 values for linear regressions between original bulb diameter (x) and bulb diameters (y) at W1 to W13 (dry diameter).

	***Boophone disticha* n=16**	***Bowiea volubilis* n=23**	***Crinum* species n=20**	***Drimia altissima* n=14**	***Drimia delagoensis* n=21**	***Drimia elata* n=22**	***Drimia robusta* n= 21**	***Drimia sanguinea* n=8**	***Urginea epigea* n=20**	***Urginea lydenburgensis* n= 3**
W1	y= -0.02+0.15x r^2=0.99	y = -0.41+0.10x r^2=0.99	y = -0.06+0.97x r^2=0.98	y = -0.25+0.98x r^2=0.98	y= -3.3+0.98x r^2=0.99	y = -0.20+0.98x r^2=0.98	y =-7.71+1.0x r^2= 0.99	y =- 0.93+0.98x r^2 = 0.99	y = 1.7+ 0.93x r^2 = 0.99	y = 43.4 + 0.23x r^2 = 0.96
W2	y=-0.04+0.10x r^2=0.99	y = -0.50+0.10x r^2=0.99	y = -0.16+0.97x r^2=0.99	y= -0.17+0.96x r^2=0.97	y= -4.62+0.98x r^2=0.99	y= -0.30+0.97x r^2=0.97	y = -8.20+1.0x r^2= 0.99	y = -1.10+0.97x r^2 = 0.99	y = -0.10+0.93x r^2 = 0.98	y = -17.7+1.30x r^2 = 0.84
W3	y=0.06+0.11x r^2=0.09	y = -0.28+0.09x r^2=0.99	y = 0.11+0.92x r^2=0.98	y= -0.12+0.95x r^2=0.97	y= -4.96+0.97x r^2=0.99	y = -0.49+0.99x r^2=0.97	y = -8.22+1.0x r^2 = 0.988	y =- 2.51+0.98x r^2 = 0.99	y = -1.00+0.92x r^2 = 0.98	y = -43.4+1.71x r^2 = 0.78
W4	y= -0.06+0.10x r^2=0.99	y = -0.36+0.09x r^2=0.99	y = 0.03+0.91x r^2=0.97	y = -0.22+0.95x r^2=0.97	y= -5.06+0.96x r^2=0.99	y = -0.49+0.98x r^2=0.97	y = -8.13+1.0x r^2 = 0.99	y =- 4.53+0.98x r^2 = 0.99	y = -1.51+0.91x r^2 = 0.97	y = -16.4+1.23x r^2 = 0.19
W5	y= -0.07+0.10x r^2=0.98	y = -0.43+0.09x r^2=0.98	y = -0.21+0.92x r^2=0.95	y = -0.30+0.96x r^2=0.97	y= -6.83+0.97x r^2=0.99	y = -0.54+0.97x r^2=0.96	y = -8.64+0.99x r^2=0.99	y =-5.12+0.98x r^2 = 0.98	y = - 1.92+0.91x r^2 = 0.97	y = -57.1+1.90x r^2 = 0.20
W6	y=-0.08+0.10x r^2=0.98	y = -0.48+0.09x r^2=0.98	y = -0.32+0.92x r^2=0.94	y = -0.29+0.95x r^2=0.97	y= -7.62+0.97x r^2=0.99	y= -0.61+0.96x r^2=0.96	y =- 8.43+0.99x r^2= 0.98	y = -8.90+1.0x r^2 = 0.96	y = -0.74+0.89x r^2 = 0.96	y = -19.7+1.23x r^2 = 0.07
W7	y=-0.09+0.10x r^2=0.98	y = -0.52+0.09x r^2=0.97	y = -0.22+0.90x r^2=0.94	y = 7.9-0.24x r^2=0.02	y= -7.50+0.95x r^2=0.98	y = -0.68+0.96x r^2=0.95	y = -7.81+0.97x r^2=0.97	y = -15.2+1.10x r^2 = 0.96	y = -0.70+0.89x r^2 = 0.96	y = -107.8+2.75x r^2 = 0.20
W8	y=-0.09+0.10x r^2=0.97	y = -0.61+0.09x r^2=0.97	y = -0.34+0.90x r^2=0.94	y = -0.53+0.97x r^2=0.96	y= -8.12+0.96x r^2=0.98	y = -0.76+0.96x r^2=0.95	y = -10.0+0.99x r^2= 0.97	y =- 11.9+1.0x r^2 = 0.95	y = -0.98+0.89x r^2 = 0.96	y = -118.6+2.93x r^2 = 0.33
W9	y= -0.06+0.99x r^2=0.99	y = -0.69+0.09x r^2=0.97	y = -0.31+0.89x r^2=0.93	y = -0.46+0.95x r^2=0.96	y= -8.67+0.95x r^2=0.98	y = -0.71+0.94x r^2=0.93	y = -17.3+1.0x r^2=0.94	y = -4.20+0.89x r^2 = 0.90	y = - 0.87+0.87x r^2 = 0.95	y = -46.3+1.63x r^2 = 0.83
W10	y= -0.08+0.10x r^2=0.98	y = -0.75+0.09x r^2=0.97	y = -0.43+0.88x r^2=0.93	y = -0.62+0.90x r^2=0.43	y= -9.55+0.96x r^2=0.98	y = -0.72+0.93x r^2=0.93	y = -9.44+0.9x r^2 = 0.96	y = -12.3+1.00x r^2 = 0.95	y = -1.73+0.88x r^2 = 0.95	y = -16.6+1.09x r^2 = 0.70
W11	y=-0.09+0.10x r^2=0.98	y = -0.76+0.09x r^2=0.97	y = -0.31+0.90x r^2=0.92	y = -0.59+0.96x r^2=0.96	y= -9.44+0.94x r^2=0.98	y = -0.77+0.93x r^2=0.93	y =-10.73+0.99x r^2= 0.96	y = -15.8+1.00x r^2 = 0.96	y = -2.51+0.89x r^2 = 0.95	y = 22.2+0.41x r^2 = 0.14
W12	y=-0.11+0.10x r^2=0.97	y = -0.76+0.09x r^2=0.96	y = -0.06+0.84x r^2=0.92	y = -0.76+0.97x r^2=0.96	y= -10.9+0.94x r^2=0.98	y = -0.62+0.89x r^2=0.92	y = -14.61+1.0x r^2=0.94	y = -13.9+1.0x r^2 = 0.96	y = -3.22+0.88x r^2 = 0.95	y =- 32.8+1.35x r^2 = 0.45
W13	y=-0.05+0.10x r^2=0.98	y = -0.79+0.08x r^2=0.93	y = -0.50+0.90x r^2=0.9	y = -7.3+1.79x r^2=0.49	y= -7.95+0.24x r^2=0.48	y = 2.67-0.25x r^2=0.10	y =1.81+0.81x r^2=0.14	y = 32.8+0.52x r^2 = 0.07	y = - 42.9+ 1.2x r^2 = 0.50	y = -113.8+2.72x r^2 = 0.13

4. DISCUSSION

4.1. BULB SIZE STRUCTURE

The ecological consequences of the harvest and trade of medicinal bulbs depend on numerous factors. The dynamics of natural populations are dependent on environmental features and external pressures that differ in both time and space (Gervais and Regan, 2007). Variations in the attributes of individuals within the population create internal structures that can be defined among ages, sizes, developmental stages and reproductive status (Menzie *et al.,* 2007). In addition, species respond differently to disturbances based on their position on the continuum between r-selected and k-selected life history strategies (Botha *et al.,* 2004a). Commercial harvesting of commonly used medicinal plant populations can have negative effects on the harvested ecological plant communities (Begon, *et al.,* 1986), especially on geophyte life forms which tend towards k-selected strategies with slow development and long life spans (Solomon *et al.,* 2002). Changes in population structure often occur before major shifts in species composition or even species loss (Botha *et al.,* 2004 a and b). In addition, size-class distributions allow identification of poorly

represented life history stages and the stages that are affected by variations in harvesting intensity (Williams *et al.,* 2011). They may also indicate declining recruitment (Botha *et al.,* 2004a).
Overall, bulb size-class distributions was similar between geographically separate markets – suggesting that either populations are harvested in similar ways or that market networks around South Africa distribute bulbs from the same (or broadly overlapping) populations to different geographically distinct markets. KZN and Gauteng have the largest populations of people (ca. 10.3 million and 10.4 million respectively) and relatively low percentages of national land area (only 7.6% and 1.4%) (Statistics South Africa, 2007). Increased medicinal plant harvesting can have large negative impacts if common species are mainly harvested from these areas. A large percentage of bulbs in Faraday and Warwick were harvested from KZN, indicating that plant populations within KZN are particularly negatively impacted (Table 2).

There were four main size-class distributions patterns noted in bulbs purchased from the markets. In all cases, size-class distributions (SCD) showed that the number of large bulbs was either sporadic or few. The evidence suggests that *B. volubilis* is particularly impacted; it was the only species with a SCD that differed from a normal distribution and followed instead an inverse J-shaped curve, normally indicative of a recruiting population (Wilson and Witkowski, 2003). However, in market situations, the low numbers of large bulbs available result in over-collection of small individuals. This can lead to a regeneration bottleneck as small bulbs are unable to properly contribute to population regeneration before they are harvested (Figure 1). Populations of species of anthropogenic importance are often characterised by a reduction in frequencies in larger size-classes as well as a decreased number of size-classes and regeneration bottlenecks (Rao *et al.,* 1990). *Bowiea volubilis* size-class distributions were characterised by a small number of size-classes and very few large individuals (Figure 1). Approximately 87% of all *B. volubilis* bulbs were <4cm in diameter and only 0.2% were >10cm in diameter. Taxonomic studies indicate that the species can reach 15cm in diameter (Jessop, 1975), and the lack of any individuals greater than 12cm highlights the impact harvest has probably had on the population. *Drimia delagoensis* also followed an inverse J-shaped curve but to a lesser degree than *B. volubilis*. This species is only collected in KZN.

Urginea lydenburgensis is a clustering species and similar in many ways to clonal plants. The population dynamics of clonal plants is dominated by the birth and death of vegetatively reproduced parts, whereas the recruitment of new seedlings may be sporadic (Clark-Tapia *et al.,* 2005). If individual life history strategies allocate resources to vegetative growth, then the loss of larger individuals may have even greater significance to populations as seedling recruitment may not be high (Clark-Tapia *et al.,* 2005). Bulbs of this species are also somewhat exposed above ground, which increases the chance of successful harvesting events during dormant periods. Dormant periods are usually periods where bulbous species have increased survival (Lesica and Crone, 2007), as without flower or leaf growth the underground bulb is generally more difficult to find and thus more protected from harvesting. However, with exposed bulbs the dormant periods would not afford this species any increased protection from harvesting. Another clustering species, *U. epigea*, also has exposed bulbs (Koorbanally *et al.,* 2004) and may be exposed to the same intensified harvesting. In addition, clonal plants are known to have longer life spans than species with little or no clonal growth (Bender *et al.,* 2000). Clustering bulbs do reproduce through the production of seeds, and more information on the patterns of growth and reproduction are needed for both *U. epigea* and *U. lydenburgensis* in order to understand the impacts of harvesting better.

Inadequate information on the life history of the various species studied complicates management and conservation scenarios and efforts because it is difficult to set conservation priorities and define sustainable harvest levels. Excessive extraction is likely to impact on population dynamics of the plants being exploited, leading to changes in community structure and organization (Ndangalasi *et al.,* 2007). The impacts of use and the understanding of these implications for conservation and protection is underpinned by floristic composition, the magnitude or intensity of harvest and the modes and seasons of harvesting (Ndangalasi *et al.,* 2007). This detailed information is not known for most bulbous species, especially those that have been synonymised. Detailed studies on life history types and effects are important for medicinal bulbous species.

Large bulb species such as *B. disticha* and *Crinum* species, as well as *D. altissima, D. elata, D. robusta*, *D. sanguinea and U. epigea,* have SCD similar to normal curves – i.e. low frequencies of bulbs in small

and large size-classes, and high frequencies of medium to large bulbs (Figure 1). However, although harvesting does not appear to be impacting SCD of these species to a large degree, the bulb size-classes with the highest frequency in the market, are also those most likely to be within the reproductive phase of the species when in the wild (Begon *et al.,* 1986). In addition, very small bulbs (<2cm) are not currently being harvested, and this indicates that unless necessary, harvesters will not remove them as they decrease harvesting efficiency and do not provide great enough income opportunities (Cunningham, 1988). The current decreased occurence of large bulbs in the markets suggests that there are a smaller proportion of large bulbs present in the populations targeted by harvesters. This decrease in number of very large bulbs in sub populations may have negative implications for reproduction of these species.

4.2. BULB DIAMETERS IN SOUTH AFRICAN MEDICINAL PLANT MARKETS

Bulb diameter is a very important indicator of population health. Studies of the commonly used medicinal bulbs *Merwilla plumbea* (Lindl.) Speta and *Urginea maritima* L. Baker suggest that bulb size and age is highly correlated (Williams *et al.,* 2007b; Al-Tardeh *et al.,* 2008). In *Ornithogalum saundersiae* Baker, medium and large bulbs had significantly longer and thicker scapes and a greater number of florets on the inflorescence (Kariuki and Kako, 1999). In addition, larger individuals tend to produce large quantities of seed (Cunningham, 2001). Underground storage organs represent energy and material reserves for geophyte species, this energy reserve allows for growth pulses triggered by the onset of rain (Ruiters, 1995). There is some evidence that larger bulbs are more likely to reproduce vegetatively (Kariuki and Kako, 1999). This has important implications for species such as *U. epigea* and *U. lydenburgensis* that both cluster to a great extent. Moreover, in most cases individuals must reach a certain size before they can reproduce (Wilson and Witkowski, 2003).

Overall, diameters of commonly sold medicinal bulbs were smaller than those reported in the literature (Table 3) with the exception of *D. sanguinea* bulbs, which were slightly larger than the mean reported diameters. The relative decrease from reported literature diameters in *B. volubilis* was especially large (67.5%). Bulb diameters for nearly all species were smaller in the market than collected herbarium specimen diameters, with a significant difference noted for *B. volubilis*. Once again, the only species that did not follow the trend was *D. sanguinea* (Figure 7). Dried herbarium specimens are smaller than the original harvested diameter because of this, here is a need to know the relationship between dry diameter and original diameter. Estimated specimen bulb diameters were between 1.7% and 40.6% greater than original living bulb diameters. The overall decrease in bulb diameters when compared to literature and herbarium data suggests that harvesting is eroding the resource base of some species. This has serious implications, since age and size at maturation and related lifetime fecundity are important life history traits that are poorly understood in many species (Ernande *et al.,* 2004).

Both reproduction and vegetative survival are crucial in the maintenance of plant populations (Phillips *et al.,* 2011). There are a number of environmental factors such as temperature, precipation, photoperiod, and the availability of pollinators can strongly affect reproductive characteristics. In addition, perennial species (such as bulbous plants) must persist vegetatively between reproductive periods (Phillips *et al.,* 2011). Studies between plant size and age in *Cynoglossum officinale* L. showed that the age plays little to no role in determining the threshold for flowering when size is accounted for (De Jong, *et al.,* 1998). Size, however, is not the only factor that determines flowering. In the genus, *Allium*, there are three distinct stage classes throughout the vegetative life span (Phillips *et al.,* 2011). Individual survival in the seedling stage is low. Seedlings which survive this stage enter the juvenile stage which lasts between 1-6 years interspersed by yearly dormant periods. The last stage begins when juveniles reach a threshold bulb size in which the reproductive phase is initiated (Phillips *et al.,* 2011). Increasingly small bulb diameters effectively 'freeze' harvested populations in the seedling or juvenile stage because larger individuals are harvested.

Harvesting can also influence the genetic composition of exploited populations by selectively removing individuals that have certain characteristics: this may result in rapid life-history evolution. The consequences of harvesting at this level are not known (Ernande *et al.,* 2004). Bulbous plants are also mainly found in grassland and savanna habitats and are well adapted to fire (Cunningham, 1988). Large individuals are the deepest rooted and most fire resilient – the decrease in the number of large bulbs could also affect the impact of fire on sub populations (Beadle, 1940; Cunningham, 1988).

Boophone disticha bulbs can reach 30 cm in diameter (Dyer, 1976), however the mean diameter currently in the markets are only 9.0 ± 0.5cm (mean ±SE) (Figure 6). Overall, 62.7% of all bulbs measured were <10cm diameter. The absence of large bulbs in the market suggests that there is an attrition of the resource supply due to harvesting (Rao *et al.,* 1990). *Boophone disticha* is known to take between six and seven years to produce seeds (Dzerefos and Witkowski, 2001), which has severe implications for harvested populations as the time taken for new recruits to become reproductively active is greater than the time between harvests. The species is mainly distributed in the grassland biome, and 26% of this biome is degraded by human land uses (Reyers *et al.,* 2001). Urbanisation in the biome and the associated impacts such as habitat loss due to construction of residential, industrial or other developments as well as harvesting has influenced the composition of vegetation (Grobler *et al.,* 2006). This together with the time taken to reach maturity, the visibility of the bulbs during dormancy and the associated ease of harvest are likely to have many negative implications for harvested populations.

Overall, bulb diameter of *Crinum* species is in the lower ranges of what is reported in the literature (Figure 4). Identification of *Crinum* species is often difficult due to the paucity of literature available on the identification of species based on vegetative characteristics (Rejmanek and Brewer, 2001) and the lack of identifying characters of some bulbous material (Arroyo and Cutler, 1984). Species-specific effects for the commonly traded *Crinum* species would elucidate the matter further as some species may be more threatened than others. *Crinum moorei*, for exmple, is an uncommon species that occurs in approximately 28 QDS (V.L. Williams, pers. comm.). Interestingly, bulbs of *C. moorei* can reach up to 19cm in diameter, while *C. buphanoides* reaches 15cm and *C. stuhlmannii* and *C. macowanii* reach 22cm and 25cm in diameter respectively (Verdoorn, 1943; 1962; 1973). Although *C. moorei* can be relatively large, the mean bulb diameter of identified bulbs was approximately 7.6cm (Figure 5). Similarly, mean bulb diameters of identified *C. buphanoides, C. macowanii* and *C. stuhlmannii* bulbs were lower than expected (only 9.6cm, 10.4cm and 11.8cm respectively) (Figure 5). This suggests that trade may negatively impact all known harvested species of *Crinum*. In addition, due to the difficulty in the identification of *Crinum* species, other lesser known *Crinum* species as well as species belonging to similar genera may be impacted. Studies on identification of all species sold under the ethnospecies name of '*uMduze*' are urgently needed.

Drimia sanguinea is the most common bulb species in the Faraday market and makes up 60% of the *Drimia* species on sale in the market (Table 5). Taxonomic studies suggest that bulbs are approximately 7cm in diameter (Philips, 1924; Jessop, 1977). Despite the species popularity, populations do not currently appear to be negatively impacted by harvesting. However, records show that the species was actively eradicated from many localities where hundreds of thousands of individuals were destroyed to prevent cattle poisoning (Stent and Curson, 1929). *Drimia sanguinea* also has the most widespread sources of supply (Figure 2) with bulbs being collected from five provinces of South Africa. The estimated land cover of these five provinces within South Africa is 437,291 km^2 and harvesting over such a large area may allow some mitigation of impacts (Low and Rebelo, 1996). The bulb is also known to be found deep within the soil (up to 30cm below the surface), thus dormant periods may protect individuals from harvesting.

4.3. GEOGRAPHICAL DIFFERENCES IN BULB DIAMETER

The average diameter of bulbs in the different markets can also provide important information. Although bulbs may be harvested from populations with similar population structures, bulb diameters may differ. Bulb diameters (±SE) in general were largest in Faraday compared to Warwick and the smaller Free State markets. Noticeably, *B. volubilis* showed signs of severe impacts; however, these impacts were more visible in Faraday and Warwick than in Free State markets (2.6 ± 0.1cm and 2.5 ± 0.2cm respectively, in comparison to 6.1 ± 3.9cm). *Bowiea volubilis* was scarce in Warwick and was only stocked by four traders (1.3% of the total traders present), two of whom had purchased bulbs from Gauteng and the other two from other KZN markets. The resource stock in many areas within KZN has been depleted for approximately 20 years; Richmond and Greytown areas supplied the Durban and Pietermaritzburg markets in the late 1960s and 1970s; however by 1988 the stocks here were exhausted and no longer supplied the larger markets (Cunningham, 1988).

Harvesters of *B. volubilis* cited KZN and Gauteng (50% and 40% of traders interviewed, respectively) and to a lesser extent Swaziland as the areas of collection (Table 2). The percentage land area of these provinces (in relation to the country as a whole) is low (7.6% and 1.4% respectively) (Statistics South Africa, 2007). Increased harvesting of populations near highly urbanized areas can magnify the negative impacts of harvest.

Free State bulb populations do not appear to have been impacted as severely by harvesting of larger bulbs (up to 10cm in diameter), although more bulb samples need to be assessed. Bulbs collected in KZN and Swaziland supply the Free State markets (Figure 2), and larger bulbs may have been transported into South Africa from Swaziland. If populations outside the country are under less threat, then population size-classes and bulb diameters may be greater outside of South Africa; however, as *B. volubilis* is a popular bulbous species there is a large probability that opportunistic harvesting and trade from the area may impact populations outside South Africa.

Studies on two Hyacinthaceae species, *Lachenalia* c.v. Ronina (Du Toit *et al.,* 2002) and *Ornithogalum longibracteatum* Jacq. (Kulkarni *et al.,* 2005), suggest that bulbs develop slower at lower temperatures (10°C), and faster at medium (15°C – 25°C) than high temperatures (>30°C). The grassland biome makes up about 76% of Lesotho's land area with mean annual temperatures of about 14.7°C and approximately 40 frost days (Mucina and Rutherford, 2006). Bulbs collected from these cooler areas may be naturally smaller as the time taken to develop may be longer in these lower temperatures. These cooler temperatures could explain the smaller *B. disticha* bulbs present in the Free State markets that are harvested within the province.

Studies have also shown that bigger bulbs often occur in drier areas, especially in sporadic rainfall areas (Procheş *et al.,* 2005). Bulbous storage organs provide a supply of water and it is likely that in areas of sporadic rainfall, bulbs may allocate resources into bulb growth so that growth and reproduction are possible in times of low rainfall. The more reliable the rainfall, the smaller the bulbs, in addition extinction rates are often lower (Procheş *et al.,* 2005). This once again emphasises the need for studies that take into account the ecology as well as harvest and trade. Effects of rainfall on bulb growth are species-specific and the relationship between rainfall and bulb size his may not be the case with all the species in this study.

Urginea lydenburgensis has a narrow distribution and only occurs in Mpumalanga, the Lebombo mountains of Swaziland and possibly in some locations in Mozambique (V.L. Williams, pers. comm.). It has also only been recorded in Mpumalanga markets (Crouch *et al.,* 2006). All bulbs collected were harvested in Mpumalanga (Table 2), parts of which are highly degraded due to loss of land cover and deforestation (Mucina and Rutherford, 2006). Similarly, *D. delagoensis* is also only harvested from one province, KZN (Table 2), and is occasional in both Faraday and Warwick markets. The small harvesting areas of both the species could have negative consequences in the future. *Drimia delagoensis* was not present at Faraday in 2001 (V.L. Williams, pers. comm., 2008) and is now present there occasionally; both size-class distributions and bulb size suggest sub-populations of this species are being impacted. Data also suggests that harvesting impacts are not only related to the popularity of the species and the volumes of bulbs being harvested, but also the area of distribution.

4.4. TEMPORAL CHANGES IN BULB DIAMETER

Mean bulb diameters of *B. volubilis* were significantly smaller in the 2007 survey when compared to those in 2001 (Figure 4). In less than a decade, mean bulb diameter has decreased by about 3cm. Cunningham's (1988) study in KZN showed that the majority of herbalists felt the species was scarce. Records also suggest that in the 20-30 years before Cunningham's study, bulb diameters decreased from between 5-10cm to 2-4cm (Cunningham, 1988). Trader interviews indicate that the species is now locally extinct in most populations in the area of occurrence in KZN. The species was listed as Vulnerable in KZN in 1999 due to over-exploitation for the medicinal plant trade (Raimondo *et al.*, 2009), and was classified as Vulnerable in South Africa according to the IUCN Red List Criteria (Raimondo *et al.,* 2009). Without other mitigation, populations in the rest of South Africa are likely to be impacted in a similar way.

Boophone disticha also showed a slight decrease (1.5cm) in mean bulb diameter between 2001 and 2007 in Faraday 2007 (Figure 4). This is mainly due to the absence of very large bulbs in the market, which suggests that harvested populations are being exploited (Cunningham, 1988). *Crinum* species also appear to be affected by trade and harvest for the medicinal plant trade. Bulb diameters decreased by 2.7cm in 6 years. As *Crinum* species are notoriously difficult to identify based on bulb characteristics (excluding the flowers), species-specific effects of trade over time cannot be determined. In addition, *Crinum* species are also threatened by horticultural collection by plant enthusiasts (Fennel and van Staden, 2001).

There is a tendency for communities to over-harvest certain resources and then shift to another method of money-making (Robinson, 2006). However, for renewable resources to be regenerated after a period of exploitation, the target resource must not occur with alternatives (i.e. species used for the same purpose) that continue to support the harvesting (Walters, 1986; Cunningham, 1988). Traders and traditional healers do not have any species preferences within the *Crinum* genus (Z.A. Khumalo, 2008, pers. comm.); however, *C. moorei* is the most vulnerable to over-exploitation due to a limited distribution in the hub of medicinal plant use activity in KZN. More widely distributed species, such as *C. macowanii* and *C. bulbispermum* (Verdoorn, 1973) therefore act to fuel the exploitation of *C. moorei,* as there is no potential for decreased use with decreased bulb stocks. One reason for this is that even with decreased availability of *C. moorei*, harvesters do not need switch to an alternative to *Crinum* species, therefore when they come across a *C. moorei* population there is the same level of harvesting intensity.

Taxonomic uncertainties surrounding the *Drimia/Urginea* complex has acted to obscure species-specific effects of medicinal plant harvesting. In addition, large market inventories often have to focus on ethnospecies groupings (Williams *et al.,* 2007a). Species-specific effects over time thus cannot be determined for separate *Drimia* species. Bulb diameters decreased from 2001 and 2007, however 1995 bulb diameters were larger. There are two major issues pertaining to this. Firstly, bulbous species in medicinal plant markets are often stored for long periods of time, which then affects the mass and diameter of the bulbs and the size-class distributions (Williams *et al.,* 2007a). The 1995 Faraday survey was conducted in the winter months and if bulbs were stored from collection in summer, bulb diameters could be expected to be lower. Secondly, proportions of *Drimia* species within the ethnospecies grouping are not static but can be expected to change based on availability. Different proportions of different sized bulbs at different times may obscure the effects of trade on individual species.

4.5. HERBARIUM DATA AND REPRODUCTIVE STATUS

In recent years, herbarium specimens have been used in a variety of ways (Savolainen *et al.,* 1995). One application that has been overlooked is the use of bulb material to ascertain the size of reproductively active individuals. Herbarium specimens usually have flowers, hence if pressed bulb material is available it can provide information on the relationship between bulb size and flowering. Although bulb material is rarely pressed important information on minimum flowering size can be determined. The importance of determining the relationship between original (wet) and dry (oven-dried) diameter is emphasised when looking at herbarium specimen bulb diameters. Minimum flowering diameter was relatively small (between 2.3 and 4.5cm) for all species except *U. epigea* (Table 7). However, once drying is taken into account there is an increase in minimum flowering size for all species (between 12.1 and 124%). In the genus *Allium*, the non-reproductive, juvenile stage can last up to 6 years interspersed by yearly dormant periods (Phillips *et al.,* 2011). If bulbs are harvested before they are reproductively active, the impact of harvest on the population will be intensified by population regeneration failure.

Bowiea volubilis is severely impacted, and based on estimated herbarium minimum flowering size bulbs only flower from approximately 3.6cm (Table 7). Bulbs in the market were approximately 2cm in diameter (Figure 4), suggesting that bulbs may be harvested in their juvenile stage before they can contribute to population regeneration. Other factors may also influence reproductive status of *B. volubilis*; studies suggest that loss of seed viability is rapid and progeny numbers are often low, making population regeneration at this point, unlikely (Symmonds *et al.,* 1997). In addition, vegetative propagation methods for *B. volubilis* provide extremely slow rates of multiplication (Hannweg, *et al.,* 1996).

Regression relationships between original (wet) and dry (oven-dried) diameters were generally strong (r^2= 0.98 to r^2=0.62; $p < 0.001$; Figure 8). The exception to this was *D. robusta* (r^2= 0.40), *D. sanguinea* (r^2=

0.07) and *U. lydenburgensis* (r^2= 0.29). Original bulb diameter estimates based on herbarium bulb diameter (which are dried) provide some information on the effect of drying on bulb diameters of herbarium specimens (Table 7). Estimated original diameters were much larger than herbarium bulb diameters for smaller bulbs. Although it may appear that *B. disticha* had a small flowering size (3.6cm), original diameter estimates are approximately 12.5% greater than actual measured diameter (4.1cm). This larger minimum flowering diameter is supported by the fact that the species is known to have a long delay before reproductive maturity is reached with plants only producing seeds and flowers six to seven years after germination (Dzerefos and Witkowski, 2001). Bulbs in the market are approximately 8.9cm in diameter suggesting that reproductive bulbs are being harvested. This has negative implications as the removal of reproductively active individuals, decreases the potential population growth of the species. It is, however, important to note that *Boophone disticha* bulbs are usually twice as long as they are wide so the diameter at the widest point may not be the best indicator of bulb age or reproductive status. Instead, small bulbs may allocate more resources to length rather than diameter and therefore length may be a more appropriate estimate of bulb age (and reproductive status). Studies of resource allocation and the relationship between age and bulb diameter and length are therefore much needed.

4.6. THE EFFECT OF DRYING

Using market bulb diameter sizes and population structure to understand the ecological implications of harvest and trade can be very useful, however, there are certain factors that need to be taken into account. One factor is the effect of drying on bulb diameters. Often it is difficult to ascertain the average length of time bulbs are stored in the markets, which makes the effects of drying difficult to discern. Bulb characteristics such as type of bulb scales and size influence the effect of drying. Regression relationships are usually stronger for species with thick, fleshy bulb scales (Williams *et al.,* 2007a). In this study, overall, the regression analyses generally showed strong relationships between bulb diameter and mass (Figure 10). Size and type of bulb scales did not appear to influence the relationship, with regressions strongest for both small bulbs with thick, fleshy bulb scales (*B. volubilis*: r^2=0.98) and large bulbs with numerous thin, papery tunics (*Crinum* species: r^2=0.96), from both the Hyacinthaceae and Amaryllidaceae.

The weakest regression relationships were for the clustering species, which are similar to clonal species. Clonal species are known to allocate resources into vegetative reproduction (Clark-Tapia *et al.,* 2005). Studies on resource allocation and growth patterns are needed, however it appears that for *D. delagoensis* and *U. epigea*, as age increases so does the number of clustering bulbs. In this way, although both mass and diameter increase with age, the diameter will increase to a larger degree because spaces between clustering individual bulbs increase the diameter more than it does the mass.

There are greater differences in bulb mass between markets than differences in bulb diameter (Table 8 and 9). Drying may act to amplify differences between markets as mass is expected to be more sensitive to the effects of drying than bulb diameter. For example, *D. delagoensis* occurs primarily in KZN (Pooley, 1998) and all traders cited the province as the sources of supply (Table 2). Individuals that occur in the Faraday market have been transported from KZN and, although bulb diameters are also lower in the market, bulb mass is significantly lower than that in Warwick, suggesting that drying affects the mass of the bulbs to a greater extent than diameter.

Another factor related to the effect of drying is that of seasonal studies. Williams *et al.* (2007a) suggested that the significantly smaller bulb diameters in 1995 compared to 2001 were likely related to the season of data collection (winter). Data from Faraday market suggests that although diameters may differ between seasons (as for *B. volubilis, D. delagoensis, D. robusta* and *U. epigea*), the differences did not follow a set pattern with smaller bulbs occurring in summer for some species and large bulbs in winter for others (Table 9). Recent informant interviews with a *umuthi* shop owner suggests that in Faraday, traders will often visit a specific area and then harvest whatever they come across (S. Dorasamy, 2008. pers. comm.). In this way, sub-populations that are more accessible may be exploited quickly while others have yet to be affected. Species that are harvested from populations that are further away from the market will be need to be transported to the market which means they may be more dry. Thus, the seasonal effects of harvest may not be related to season but rather to distance from harvest site, time since last purchase and species-specific responses to drying.

Bulb size-class distribution in the market is affected by drying of bulbs from the time of harvest to trade and sale. Understanding the effects of drying on bulb size is paramount (Williams *et al.,* 2007a). Drying may act to obscure differences between species, markets, expected diameters and changes over time. In a controlled experiment with temperature and humidity mimicking average Johannesburg conditions, nearly all species lost approximately 40% of their original mass in 12 weeks. Another 40% was lost from the end of week 12 to oven dried mass and dried bulbs were often brittle. In contrast, the decrease in bulb diameter over 12 weeks was much smaller (<1cm, ca. 7%). Although the percentage decrease in bulb diameter was much less than the percentage decrease in mass, a change of 1cm was still noted. This decrease does have implications for size-class distributions and bulb sizes of market bulbs, since the amount of drying and the time since harvest was unknown. Importantly, it also has implications for herbaria diameters. Since voucher specimens have all been dried, all bulbs have shrunk from their original size.

5. CONCLUSIONS AND RECOMMENDATIONS

Bulb size distributions suggest that the harvest and trade of commonly used medicinal bulbs is affecting both large- and small- species, mainly through the eradication of large bulbed individuals that are reproductively active. Species may be impacted differently depending on their popularity, region of harvest and bulb features. Market bulb diameters were less than those recorded in the taxonomic literature. The size of the collection area appears to act as a buffer to negative impacts, however what is of most concern is the relative decrease in size of bulbs in the markets, which suggests that harvested populations are under serious threat. In addition, geographically separate markets have similar bulb structures and diameters, suggesting that bulbs are harvested from similar areas and transported along trade networks to different markets. Bulbs are mainly harvested from KZN and Gauteng, which have large human populations. The severe impacts seen in species such as *B. volubilis, B. disticha, Crinum* speciesand *U. epigea* may be contained within sub-populations of these provinces. Despite this, these severe impacts imply that trade and harvesting will continue to have negative ecological impacts on populations of commonly used bulb species. It is recommended that studies on these species are continued in the future in order to determine species-specific temporal differences.

In conclusion, the results of this study show that size-class distributions of all bulb species were impacted with a decreased number of large bulbs and in extreme cases (*B. volubilis* and *D. delagoensis*) an inverse J-shaped curve, suggesting that only very small bulbs are available for harvest. However, not all sub-populations are likely to be impacted with the majority of bulbs being collected in KZN and Gauteng. Populations in these provinces are likely to be more severely impacted than elsewhere. Another factor that needs to be considered when using market data is the effect of drying. Drying experiments suggest that bulb mass decreases over time to a greater extent than bulb diameter. Most bulbous species diameters were smaller than diameters reported in the literature. In addition, temporal studies in Faraday market also suggest that bulb diameters in markets are smaller than in the past. Taxonomic uncertainties in the *Drimia/Urginea* complex and *Crinum* species need to be addressed. In addition, population dynamics between harvested areas and non harvested areas are needed for all species in order to better understand life history strategies and the impact of harvesting. Market surveys can thus provide detailed information on the ecological impacts of trade.

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CHAPTER 4
Volume and economic value of commonly traded medicinal bulbs in Warwick (KwaZulu-Natal) and smaller Free State markets, South Africa

ABSTRACT:

Increased commercialisation of medicinal plants has often resulted in over-harvesting and in severe cases, near extinction of valued indigenous plants. Traditional healers, traders and harvesters can provide a wealth of information on species populations in the wild, and their preferences may have an impact on the harvesting and trade on wild populations. Information on trader/harvester preferences and perceptions was gathered in the Warwick market (Durban) and smaller Free State markets. Results suggest that harvesters and traders prefer larger bulbs, which can thus negatively affect population regeneration. Overall, the average earnings per month per trader selling medicinal plants were low (approximately R1,000 in Warwick and R2,000 in smaller Free State markets). However, with rising unemployment rates, contributions to total earnings by small entrepreneurial practices, such as medicinal plant harvesting and trading, have become an important source of income. Bulb species contribute approximately 10% to 50% of the total earnings per trader at Warwick, and between 10% and 70% per trader in the smaller Free State markets. Relatively large contributions emphasise the economic and social importance of popular bulb species. The general popularity of these species has implications for the volume of bulbs purchased and hence the number of bulbs harvested annually. Market-specific estimates of the number of bulbs on sale are high for species such as *Bowiea volubilis*, *Drimia elata* and *Urginea epigea.* The number of populations and the rate of population regeneration required to sustain such harvest is extremely large, and without mitigating factors the increased commercialisation of the medicinal plant industry may have potentially dramatic, negative implications on popular bulb populations.

Keywords: Amaryllidaceae; Bulb; Economic Value; Geophyte; Hyacinthaceae; Individual equivalents; Medicinal Plant trade; South Africa; Volume

1. INTRODUCTION

The interaction between human disturbances at different intensities and spatial and temporal scales gives rise to a network of interactions between resource and resource harvester, and hence shapes a diversified natural, cultural and economic mosaic within a heterogeneous landscape (Giannecchini *et al.,* 2007). Without understanding this cultural and ecological landscape, it becomes increasingly difficult to determine methods of sustainable harvesting, especially in developing countries. Throughout the world communities use a range of NTFPs that contribute to livelihoods in three main ways: 1) direct household provisioning, 2) income generation, and 3) as a safety net for consumption (Paumgarten and Shackleton, 2009). Both direct household provisioning and income generation include medicinal species as well as species that have cultural or spiritual value. Studies on natural plant resources must take into account factors such as the plant type, volume, economic and intrinsic value as well as other disturbances in order to understand the effects of trade of commonly used species. Several factors have lead to the increased commercialisation of medicinal plants, which in many cases has resulted in over-harvesting, and in severe cases near extinction, of valued indigenous plants (Williams *et al.,* 2000). Volume is an indicator of the potential risks to the continued survival of commonly used species that are commonly harvested (Williams *et al.,* in press; 2011). As the demand for traditional medicine grows, large quantities of medicinal plant material are harvested annually. Mander *et al.* (2007) estimated that 20,000 tonnes of plant material is traded annually in South Africa, with approximately 86% of harvesting resulting in the death of the entire plant. With ca. 63,000 plant harvesters collecting medicinal plants in South Africa (Mander *et al.,* 2007), it is imperative that the volume of commonly traded material is determined.

Bulb diameters and the number of traders selling each species (Chapter 3) affect estimates of the volume of bulbs sold. Despite the importance of quantifying trade volumes, it can be difficult to extrapolate this information to understand the inherent sustainability of the bulb trade as well as the extent of resource depletion in terms of number of bulbs harvested. The paucity of information on plant population sizes also makes it difficult to judge the annual rate of decline for a species based on off-take for the medicinal trade (Williams *et al.,* 2007a). To deal with such issues, Williams *et al.* (2007a) devised the notion of "*individual equivalents*" – a concept whereby volume (in terms of number of 50kg-sized sacks) traded is equated to the number of bulbs (of a specified size) harvested annually so to better determine the effect of harvesting on the resource base. The concept can, therefore, provide a nuanced understanding of resource depletion as it determines an estimate of the *number* of bulbs harvested and traded *and* takes into account the bulb size-classes present in the markets. The individual equivalent method provides a starting point for quantifying the annual extent of resource depletion (Williams *et al.,* 2007a).

In South Africa, the use of indigenous medicine is widespread with value of traded material equivalent to state-subsidized health programmes (Shackleton, 2001). It was estimated that the trade of medicinal plants contributes at least R2.9 billion to the South African economy with approximately 27 million consumers in the country (Mander *et al.,* 2007). In addition, 2062 medicial plants have been recorded in South Africa, with 656 species recorded in trade (Williams *et al*., 2013). To a certain extent, however, the medicinal plant trade is driven by customer demand (Williams, 2004). Customer demand may change and consequently opportunities become limited and these activities are likely to be abandoned if more attractive options become available. Despite this, demand-related plant scarcities drive up market prices, and higher prices paid for certain species encourages depletion of the resource because of the potentially higher income generated (Williams, 2004). In addition to this, lower prices act as a stimulus for over-collection as traders feel the need to over-harvest in order to obtain a reasonable income. Market conditions therefore work against the environment (Williams, 2004). People in rural households whose income falls below the poverty line are often forced to seek employment in towns and cities, which then creates strong rural-urban linkages and dependencies. This rural-urban dependency seldom favours the rural centres, and it is estimated that much of the income from Faraday *umuthi* market (in Johannesburg) (the second largest informal medicinal market in South Africa) does not reach the rural areas and is instead spent in the city (Williams, 2004). This leads to increased reliance on the resources and a continuation of household poverty.

Harvesting practices may alter the response of populations to harvesting and are thus an important factor to consider (Ticktin, 2004). The knowledge and perceptions of resource users provides valuable insight

into the scarcity of medicinal plant resources (Cunningham, 1988). Such knowledge is particularly useful as it has been gathered over many years of harvesting, buying and selling materials (Cunningham, 1988), and includes information on perceptions of scarcity, value and trade of specific plants, traditional importance and areas of collection. The IUCN Sustainable Use Policy (Resolution 2.29, adopted in 2000) recognized the need to understand the biological characteristics of natural resources, but focused more attention on the need to understand the socio-economic context, including: positive economic incentives, negative sanctions, governance structures, land tenure, access rights, regulatory systems, traditional knowledge and customary law. The challenge of conservation biology is to more effectively incorporate socio-economic considerations into the analysis of conservation problems, so as to place ethnobotanical data into a more relevant and accessible context (Robinson, 2006). However, this can only been done if trader perceptions are taken into account.

Factors that influence the effects of harvesting are often based on socio-economic information. For example, the intensity of harvesting depends on resource abundance, accessibility, and market demand. This intensity often decreases with increasing distance from human settlements, transport routes and decreased accessibility of harvesting sites (Botha *et al.,* 2004a). In addition, commercial harvesting by harvesters from different areas appears to cause more ecological damage, thus understanding the demographic structure of harvesters, traders and traditional healers in a market can provide important information (Botha *et al.,* 2004b). The overall aim of this study was to establish the ecological consequences of the harvest and trade of commonly used bulb species by quantifying the volume and value of trade of these species in Warwick, Durban and smaller informal markets in the Free State. The number of bulbs harvested and trader perceptions was also determined.

Specific objectives include:

1. To quantify the volume of trade of selected bulbous species in both Warwick (KZN) and smaller markets in the Free State.
2. To determine the number of harvested bulbs equivalent in size to the mean diameter (individual equivalents) of each species.
3. To quantify the economic value of the trade of commonly used bulbous species in Warwick and smaller markets in the Free State, and the proportion that each species contributes to the average total income per trader.
4. To determine the relationship between mass and value (R/kg) in both Warwick and smaller markets in the Free State.
5. To determine trader demographics and perceptions of the harvest of trade of commonly used bulbous species in Warwick and smaller markets in the Free State.
6. To establish the ecological implications of harvest and trade by combining trader information of habitat and general trader perceptions, geographical distribution of commonly used species, and the volume, value and number of individual equivalents.

2. METHODS

2.1 SPECIES INVESTIGATED

Geophytes are plants that possess underground resting buds attached to storage organs (Galil, 1980; Mwafongo *et al.,* 2010). In this study only bulbous geophytes were considered. A bulb is defined as a short, often plate like stem bearing a number of thick, fleshy leaves or leaf bases (bulb scales) that store water and nutrients (Dahlgren *et al.,* 1985). Functional taxonomy was used to describe bulb forms which are recognized as distinct by traditional healers but have been synonmysed by taxonomists. Based on this information is also provided on *Urginea*, although the genus is currently synonmysed under *Drimia*. Species were selected based on their popularity and abundance in Gauteng markets, with all species ranked as medium to high priority conservation status (Williams, 2007; Chapter 2). Species studied included: *Bowiea volubilis, Boophone disticha*, *Drimia altissima, D. delagoensis, D. elata*, *D. robusta, D. sanguinea*, *Urginea epigea* and *U. lydenburgensis*. *Crinum* species are also common in the medicinal markets of South Africa, however the species are difficult to identify based on bulb characteristics and data was therefore collected on the group as a whole (including *C. buphanoides, C. bulbispermum, C. macowanii, C. moorei* and *C. stuhlmannii*). More detail on each species is provided in Chapter 2.

2.2. MARKET DESCRIPTIONS

Surveys took place in Warwick market (Durban) and two small informal, regional markets in Bloemfontein and Phutaditjhaba, Free State. Due to the informal nature of the trade in Free State and the small size, data from both Bloemfontein and Phutaditjhaba were combined. A small number of traders were sampled in Nelspruit. A more in depth description of the markets is provided in Chapter 2. Although data on size-class distributions was collected at Faraday market, interviews with traders were not possible because traders there did not want to participate in the survey.

2.3. MARKET SURVEYS

A three-day survey of Warwick and two-day survey of the smaller Free State markets was conducted in January and March 2008 respectively. Members of the scientific community who had trust-based relationships with traders were contacted, and in KwaZulu-Natal (KZN) the Chairwoman of Warwick (Z.A. Khumalo) facilitated the survey process. A Zulu speaking interpreter who had worked in Warwick before was also used to interpret in KZN. In the informal Free State stalls, members of the Free State Department of Department of Economic Development, Tourism and Environmental Affairs (FS-DETEA) and National Museum in Bloemfontein (who have a very good relationship with traders) facilitated surveys by taking us to known areas of trade (as there is no dedicated full time market).

The survey questionnaire was designed after an extensive literature review and was semi-quantitative. General sections included: trader information (demographics), species on sale at the stall, market name and date of survey. More detailed information was collected by estimating the volume of each species and the diameter of the bulbs. Respondents were asked if they purchased or harvested their plant material. Each respondent was also asked a number of questions relating to number of sales, frequency of harvest/purchase, preferences and perceptions of scarcity and popularity (Appendix 3).

Traders and traditional healers that sold one or more of the species in question were asked to participate in the study. Before taking part, a brief explanation of the study was given to each potential respondent, and emphasis was placed on two factors: 1) that their participation was voluntary, and 2) respondents would remain anonymous. Informed consent was obtained in all cases (Ethics clearance number: H071116). In addition, to prevent confusion about species with the same traditional name, a picture guide was used (Appendix 4). The number of traders interviewed for each species in each market differed since not all traders stocked all species. Also, not all traders were willing to answer each question; hence, sample sizes for a specific question may also differ. Overall, 31 traders in Warwick and 12 traders in the smaller Free State markets were interviewed. Data was collected for each functional species (Chapter 2) in each market and for the 'ethnospecies' group '*uMduze*' (*Crinum* species) and occasionally other Amaryllidaceae species such as *Brunsvigia* species.

2.3.1. Trader perception and harvesting practices:

To obtain a qualitative understanding of trade in the species under investigation, the respondents were asked about perceived scarcity and popularity of each species. Traders that harvested their own plant material were asked a number of additional questions relating to harvesting practices, for example: seasonal timing of the harvest, timing of the harvest in the plant life cycle, frequency of the harvest, size of individuals harvested, harvest intensity.

2.3.2. Value, volume, number of bulbs sold and harvested:

In order to calculate the value, volume and number of bulbs harvested, data was collected for a number of variables. Tables 1, 2, 3 and 4 give the list of variables and equations used in the calculations.

2.3.2.1. Value

The overall number of sales for all medicinal plants and for individual bulb species is different depending on the day of the week and month. Respondents were asked to estimate the number of sales made on 'quiet' and 'busy' days (Variables A and B – all plant species; Variables C and D – individual species).

Traders then provided information on busy periods, which was then used to determine the average number of quiet and busy days per annum (Variable E and F, respectively). The total number of selling days/annum was also determined (Variable I). The total number of medicinal plant sales (per trader/annum) (Variable J) together with the fixed cost price for sales at Warwick and Free State markets (R5) was used to determine the economic value of all medicinal plant sales at each market (Variable K). The mean economic value and standard error was then determined. Although, price is usually fixed at R5 per sale, this does occasionally change. Samples of each species were purchased and the average value per sale was determined (Variable G). Variable G was used to determine the economic value of sales for each species (*Species A*) per trader/annum (Variable M) (Table 1).

This data was used to determine the percentage contribution of each species to the overall earnings of traders per market (Variable N) and the Rand per kilogram (R/kg) of each species (Variable O). Although traders in Faraday market could not be interviewed, data on the number of bulbs per sale, the cost per sale and the R/kg were collected and compared to both Warwick and Free State markets (Table 1).

Table 1: Variables and equations used to determine economic values per trader and market

Variable	Symbol	Equation
Number of medicinal plant sales† per day on quiet days	A	
Number of medicinal plant sales† per day on busy days	B	
Number of sales of *Species A* per day on quiet days	C	
Number of sales of *Species A* per day on busy days	D	
Number of quiet days/annum	E	
Number of busy days/annum	F	
Average value per sale of *Species A*	G	
Mass of *Species A* bulbs per sale	H	
Total number of selling days/annum	I	=E+F
Total number of medicinal plant sales† per trader/annum	J	=(A*E)+(B*F)
Economic value of medicinal plant sales† per trader/annum	K	=J*R5.00
Number of sales §of *Species A* per trader/annum	L	=(C*E)+(D*F)
Economic value of *Species A* sales per trader/ annum	M	=L*G
% contribution of *Species A* to overall earnings/trader/annum	N	=(M/K)*100
Rand per kilogram *Species A* (R/kg)	O	=G/H

† all species; R5 sales

2.3.2.2. Volume

Data collected from the markets was used together with laboratory data to determine the volume traded. Estimation of bulb volume in the laboratory will be described in Section 2.4. The total volume of selected bulb species visible at each trader's stall was estimated (Variable P). Previous studies have used the number of 50 kg-sized bags purchased as a proxy for the plant volume harvested/traded (Cunningham, 1988, Williams *et al.,* 2007a). In my study, smaller plastic shopping bags (called 'checkers') were used as proxy for volume in addition to the 50 kg-size bags. Visible volume was estimated as number of 'checkers' of each species at each stall. The volume of the checkers was then determined (in the laboratory, using volumetric equations-section 2.4), so that estimates of volume based on the number of 'checkers bags' could be equated to the number of 50kg-size bags, or fraction thereof. Traders were also asked to determine how often they purchased the visible volume (the volume that was visible at the stall, estimated as a number of 50kg-sized bags or 'checkers' packets) and this was converted to purchases per month (Variable Q). Volume purchased per annum was determined (Variable R) (Mean and standard error were calculated) and used to determine the total volume per market per annum (Variable U) (Table 2).

Table 2: Variables and equations used to determine volume

Variable	Symbol	Equation
Volume of *Species A* visible at each stall	P	
Number of times visible volume (P) of *Species A* was purchased per trader/market/month	Q	
Volume of *Species A* purchased per trader/market/annum	R	=P*Q*12
Proportion of total traders/market selling *Species A*	S	
Total number of traders at the market	T	
Total volume of *Species A* per market/annum	U	=R*S*T

2.3.2.3. Number of bulbs sold to consumers

The number of bulbs sold to consumers per annum per market was determined (Variable W). To do this, information on the number of sales of *Species A* (Variable L), number of bulbs per sale (Variable V), proportion of traders selling *Species A* (Variable S) and total number of traders at each market (Variable T) (Table 3) was collected.

Table 3: Variables and equations used to determine the number of bulbs sold to consumers per market and trader

Variable	Symbol	Equation
Number of sales of *Species A* per day on quiet days	C	
Number of sales of *Species A* per day on busy days	D	
Number of quiet days/annum	E	
Number of busy days/annum	F	
Number of sales of *Species A* per trader/market/annum	L	=(C*E)+(D*F)
Proportion of total traders/market selling *Species A*	S	
Total number of traders at the market‡	T	
Number of *Species A* bulbs per sale§	V	
Total number of *Species A* bulbs sold per annum per market	W	=L*V*S*T

‡ 150 and 300 traders in Free State and Warwick markets respectively

2.3.2.4. Estimating the number of bulbs harvested

"Individual equivalents" is a method devised by Williams *et al.*(2007a) to equate the volume traded to an actual number of bulbs harvested, equivalent to a certain size (in this case, mean bulb diameter). Market information collected from traders at Warwick and Free State were used together with data collected during bulb volume laboratory experiments (Section 2.4.) to estimate the number of bulbs harvested (Variable β). Firstly, the total volume of *Species A* purchased by traders/market/annum (Variable U) was calculated and then divided by the mean volume of a *Species A* bulb of a specified size (Variable Z). For example, if the mean volume of a 7cm diameter *B. disticha* bulb was 0.5 litres, then the total number of bulbs calculated to be harvested would be equivalent in size to the 7cm bulb. Estimation of bulb volume and the number of bulbs /sack/ or /bag was based on two assumptions. First it was assumed that when bulbs were packed in a sack or bag, there would be a certain amount of space between each bulb due to their shape. Second it was assumed that estimates that did not take into account bulb shape would result in an over-estimate of numbers (and hence upper-limit) for the total volume and hence the number of bulbs per bag.

Counts of traders were used as an indication of the number of traders for Warwick (300 traders). In the Free State, only two towns were visited and only 12 traders were interviewed. A large percentage of traders in each town were interviewed (information provided by National Conservation officials). It was therefore estimated that approximately 10 traders would be found in at least 15 towns in the province. The overall trader estimate for the Free State was 150. More information on the number of traders in each town and city is needed and this estimation was based heavily on the assumption that due to the informal nature of the trade, that only a small number of traders would occur in some towns or cities.

Table 4: Variables and equations used to determine number of bulbs harvested annually per market.

Variable	Symbol	Equation
Volume of *Species A* visible at each stall	P	
Number of times visible volume of *Species A* was purchased per trader/month	Q	
Volume of *Species A* purchased per trader/annum	R	=P*Q*12
Proportion of total traders selling *Species A*	S	
Total number of traders at the market λ	T	
Total volume of *Species A* per annum	U	=R*S*T
Volume of 50kg-sized sack	X	
Number of sacks traded/annum	Y	=U/X
Average bulb volume (for mean bulb diameter)φ	Z	
Number of bulbs/annum (equivalent in size to mean diameter)	β	=U/Z

φ Calculated from laboratory experiments; λ 150 traders for Free State and 300 traders for Warwick market

2.4. ESTIMATION OF BULB VOLUME:

Estimations of individual bulb volume took place in the laboratory at the University of the Witwatersrand. This data was then used together with market data to determine the total number of bulbs harvested per market/annum (Table 4; Variable β). A random samples of bulbs was purchased at the market were oven-dried so that turgidity of bulbs (related to water-loss and time since harvest) did not bias the results. Three methods were used to determine bulb volume. Two of these methods provided 'actual' volume, while the third provided estimation based on calculations.

The methods are:

- Volume estimate 1: The volume of water displaced when a bulb was placed in a beaker of water. Bulb volume was then related to the diameter of the bulbs measured. This volume estimate was the closest approximation to the 'true' volume of each bulb. In this way, the 'actual' volume of the mean bulb diameter present at the market (Variable Z) was determined so that the total number of bulbs harvested could be determined (Variable β). However, this method over-estimates the total volume traded since it does not take into account spaces between the bulbs when they are packed in a bag.
- Volume estimate 2: The diameter of bulbs purchased in the market was determined. Volumetric equations for (a) cube-, (b) cylinder-, (c) cone- and (d) sphere-shapes were used to calculate volume based on bulb diameter measurements. Sphere and cylinder volume calculations would over-estimate total volume occupied within a bag, since based on the volumetric equation, there would be no spaces between the bulbs when packed in a bag

2.5. STATISTICAL ANALYSES

STATISTCA 6 and Excel 2003 were used for all data analyses and in all cases the null hypothesis was rejected at $p<0.05$. One-Way ANOVAs and T-tests were used to determine differences between total sales per day/annum between markets and differences between Rand per kilogram for both species and markets. Linear regressions were used to determine the relationship between bulb diameter and volume and for the relationship between actual volume (based on water displacement) and calculated bulb volume (using volumetric equations). One-Way ANOVAs were also used to determine the difference between volume and number of bulbs harvested between species, markets and methods.

3. RESULTS

3.1. TRADER PERCEPTIONS AND HARVESTING PRACTICES:

3.1.1. Trader Demographics

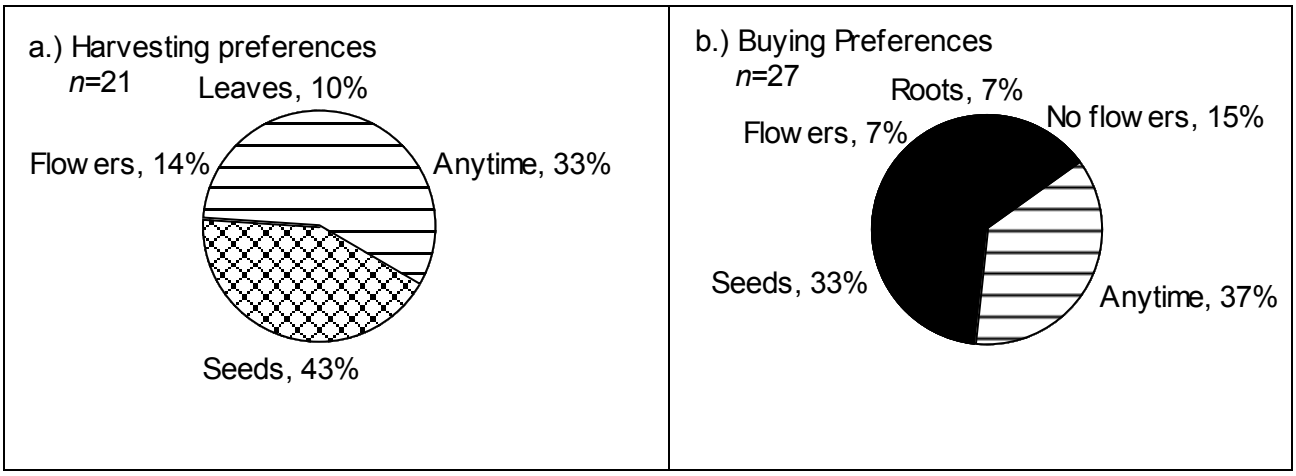
The demographics of the respondents (traders, harvesters and/or healers) selling bulbs in Warwick and the Free State were mostly different in terms of ethnicity, age profile, gender and healer status (Table 5). Respondents in the Free State tended to be older, Sotho-speaking traditional healers. Respondents in Warwick, however, were primarily younger, Zulu-speaking, female traders that were not traditional healers. In both markets, 'home' for the traders tended to be in the same province that they worked in.

Table 5: Trader demographics in the Warwick market and combined smaller informal Free State markets.

Variables		Warwick Market, 2008: *n*=31 (%)	Free State informal markets, 2008: *n*=12 (%)
Trader home province country	Eastern Cape	13	0
	Free State	0	82
	KwaZulu-Natal	87	0
	Lesotho	0	9
	Swaziland	0	9
Ethnicity	Xhosa	16	0
	Zulu	84	9
	Sotho	0	82
	Swazi	0	9
Age profile	<25 years	0	0
	26-30 years	26	0
	31-40 years	42	27
	41-50 years	13	9
	51-60 years	10	55
	>60 years	10	9
Gender	Male	13	45
	Female	87	55
Healer Statis	Not healer	90	27
	Traditional Healer	10	73

3.1.2 Trader harvesting practices

In terms of seasonality and related reproductive status, most harvesters (43%) preferred to harvest bulbous plants that were seeding and 14% when the bulbs were flowering, hence 57% of harvesters favoured reproductive bulbs (Figure 1a). Slightly fewer traders (40%) preferred purchasing reproductive bulbs (7% with flowers, and 33% with seeds) (Figure 1b). Thirty three percent and 37% of harvesters and traders, respectively had no preference for when the bulbs were harvested. (Figures 1a & 1b). In terms of size, harvesters tended to prefer to remove large bulbs (41%) (Figure 1c) and 41% of buyers preferred to purchase batches of bulbs of mixed sizes (i.e. small, medium and large bulbs) (Figure 1d).



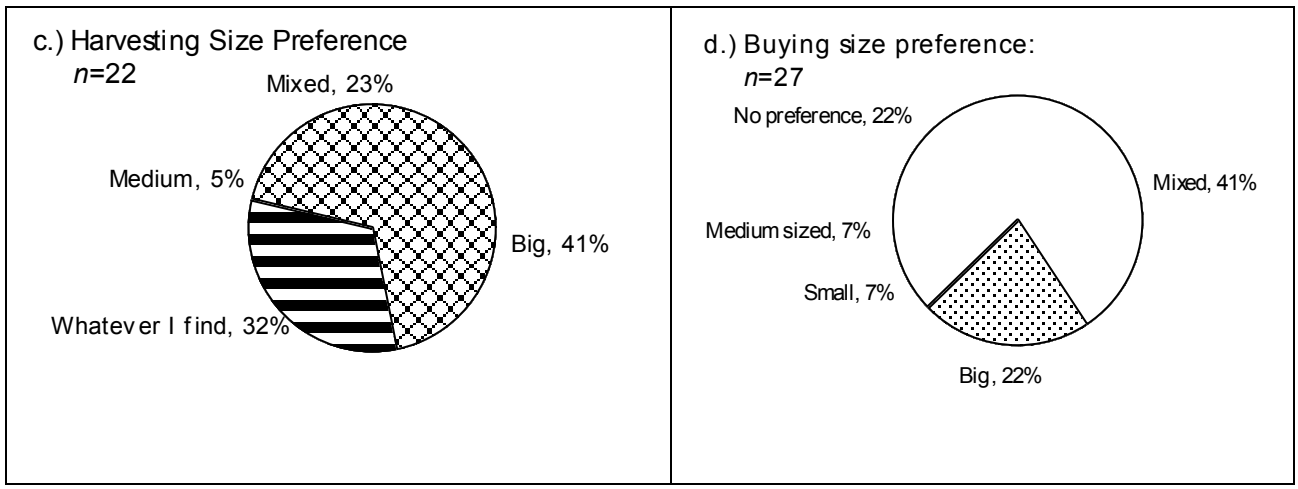
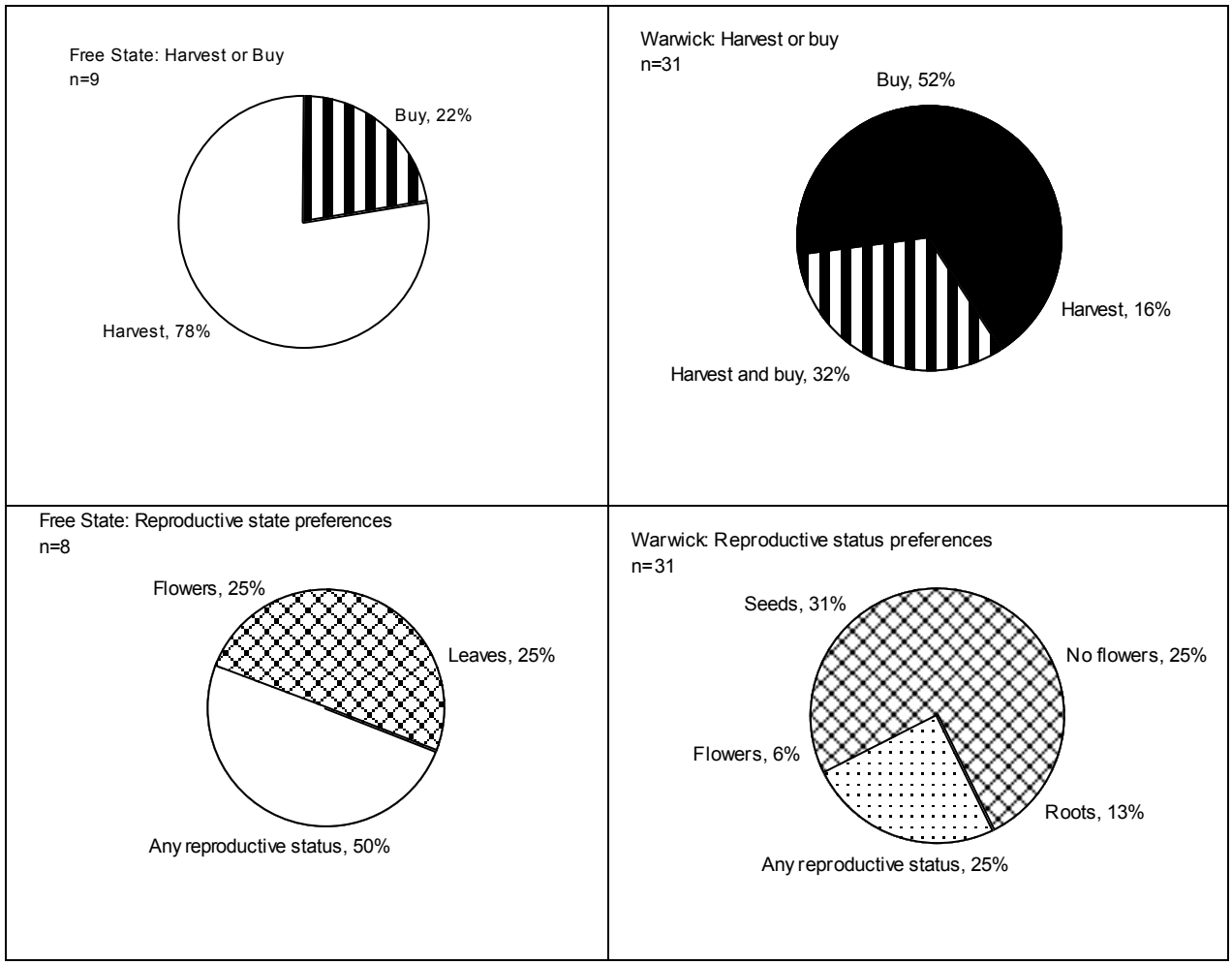


Figure 1: Preferences of traders (including harvesters) for bulbous species for both Warwick and smaller Free State markets combined. Note: Harvesting preferences (a. and b.) presents information on reproductive status at harvest with 'anytime' referring to no specific reproductive status preference, while c and d refer to bulb size preference.

In the Free State, the majority of respondents harvested their own stock and had no preference in regards to reproductive status (50%) or size (67%) (Figure 2). In Warwick, however, the majority of respondents either bought their stock (52%) or harvested and bought their stock (32%) (Figure 2). Traders at Warwick preferred bulbs that were harvested while seeding (31%) and liked either mixed or big bulbs (40% and 37% respectively) (Figure 2).



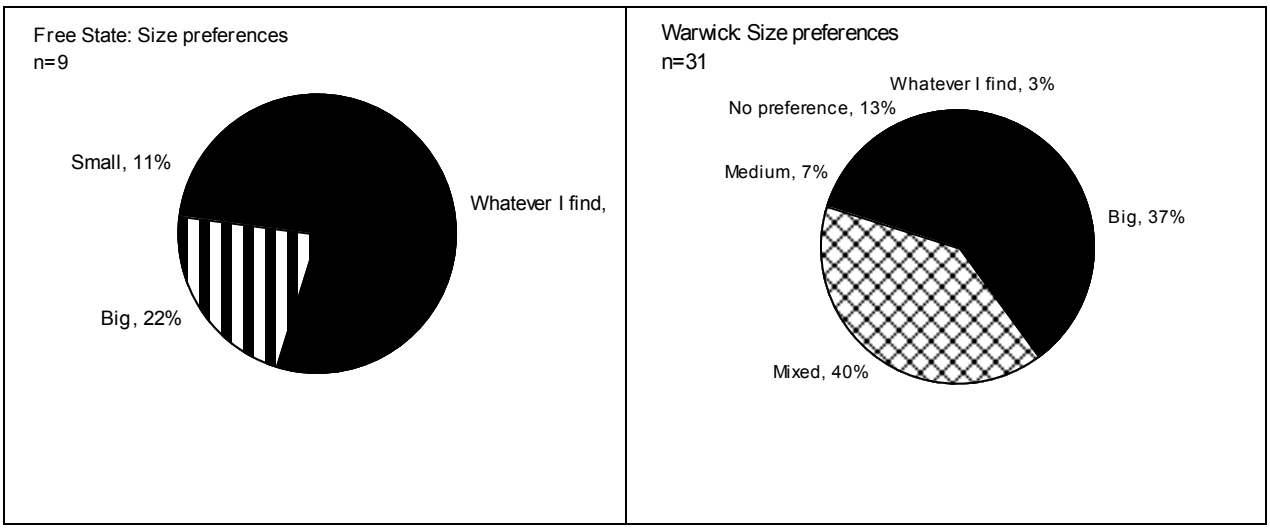


Figure 2: Differences in preferences between Warwick and Free State market

Questions about trader practices and perceptions were asked in such a way that two possible outcomes could be chosen, for example: "popular" or "not popular". In general, sample sizes in Free State were small due to fewer traders in the region. *Drimia altissima* and *D. delagoensis* were not recorded in the Free State, and the species were not common in Warwick.

Table 6: Trader practices and perceptions of commonly traded bulb species traded in Warwick (n= 31 traders) and smaller markets in the Free State (n= 12 traders). Not all traders stocked all species or were willing to answer each question. Blank cells indicate the question was not answered.

	Trader Perceptions and Practices (% of traders)							
	Bulbs difficult to locate		**All of site harvested**		**All sizes at site harvested**		**Popular**	
	Warwick	Free State	Warwick	Free State	Warwick	Free State	Warwick	Free State
Boophone disticha	75% n=8	50% n=2	11% n=19	0% n=2	25% n=8	0% n=2	32% n=19	50% n=2
	Both Markets: 70%		Both Markets: 10%		Both Markets: 20%		Both Markets: 33%	
Bowiea volubilis	100% n=1	100% n=1	0% n=1	100% n=2	100% n=1	-	0% n=1	50% n=2
	Both Markets: 100%		Both Markets: 67%		Both Markets: 100%		Both Markets: 33%	
Crinum species	40% n=5	100% n=2	0% n=16	0% n=2	0% n=5	0% n=1	38% n=16	50% n=2
	Both Markets: 57%		Both Markets: 0%		Both Markets: 0%		Both Markets: 39%	
Drimia altissima	-	-	0% n=2	-	-	-	0% n=2	-
Drimia delagoensis	0% n=3	-	0% n=3	-	0% n=3	-	67% n=3	-
Drimia elata	0% n=1	43% n=7	0% n=1	14% n=7	0% n=1	0% n=4	100% n=1	100% n=6
	Both Markets: 38%		Both Markets: 12%		Both Markets: 0%		Both Markets: 100%	
Drimia robusta	71% n=7	-	11% n=18	-	33% n=6	-	75% n=16	-
Drimia sanguinea	100% n=1	29% n=7	0% n=2	29% n=7	0% n=1	0% n=3	50% n=2	100% n=6
	Both Markets: 38%		Both Markets: 22%		Both Markets: 0%		Both Markets: 88%	
Urginea epigea	86% n=7	100% n=1	6% n=16	0% n=2	14% n=7	0% n=1	32% n=16	100% n=1
	Both Markets: 88%		Both Markets: 6%		Both Markets: 12%		Both Markets: 35%	

In general, trader perceptions and practices differed in Warwick and the Free State. For example, 100% of traders interviewed in Free State and 40% of traders in Warwick felt *Crinum* species was difficult to find. In both markets, *B. volubilis* was perceived to be the most difficult to locate and bulbs of all sizes were harvested when located (Table 6). *Drimia elata* was the most popular species. For *Crinum* species, *D. elata* and *D. robusta*, there was a preference for larger bulbs with a tendency to leave small bulbs behind).

3.2. VALUE OF TRADE

Total number of medicinal plant sales per trader/market/annum (based on number of R5 sales per annum) was calculated for both Free State and Warwick (Variable J). Free State had a greater number of sales per day and greater total earnings than Warwick markets for all species combined ($p< 0.05$). On average, traders at Warwick earned approximately R11,000 per year from sales from all medicinal plants while at Free State, respondents earned approximately R25,000 per year (Figure 3).

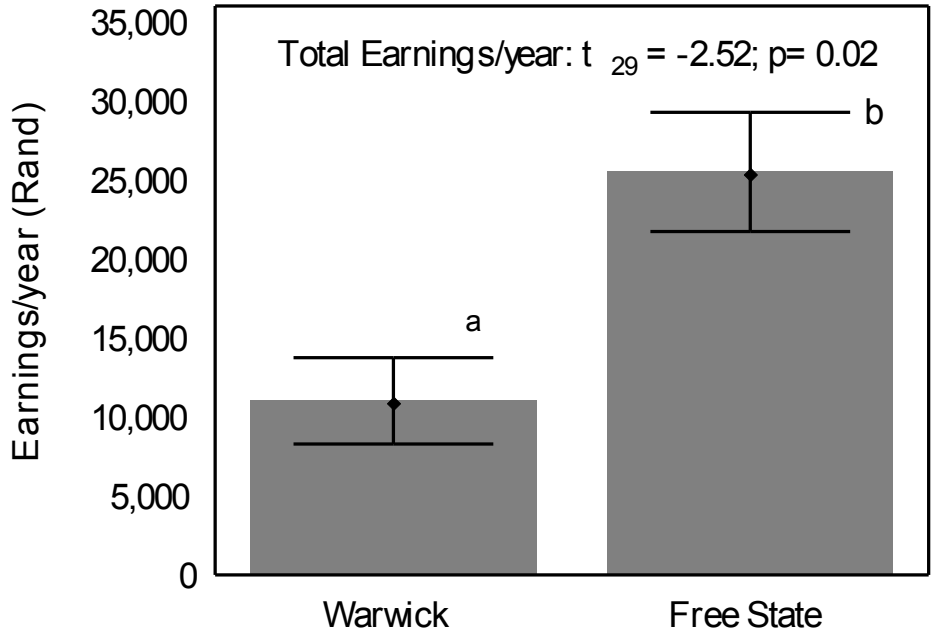


Figure 3: Total earnings per trader per annum (all medicinal plant species on sale included) (mean ± SE) for Warwick market, Durban (n= 24) and smaller Free State markets (n=7). Results of a t-test are included and means with different letters are significantly different ($p<0.05$).

In general, bulb species in the Free State contributed between 10% and 50% (Figure 4a) to the total earnings from medicinal plant sales which was very similar to contributions by bulb species at Warwick (in general between 10% and 40%) (Figure 4b). *Boophone disticha, B. volubilis, Crinum* species and *U. epigea* had the lowest contributions to overall earnings at Free State (between 10-15%). *Bowiea volubilis,* a species of conservation concern, contributed approximately 40% of the total trader earnings per year in Warwick, however commonly available species such as *D. delagoensis* and *D. robusta* also contributed around 30-40% (Figure 4b). *Drimia sanguinea* was only sold by one trader at Warwick, while *B. volubilis* and *U. epigea* were only sold by one trader in Free State. This small sample has implications for the accuracy of the mean values and in both markets as standard error was large.

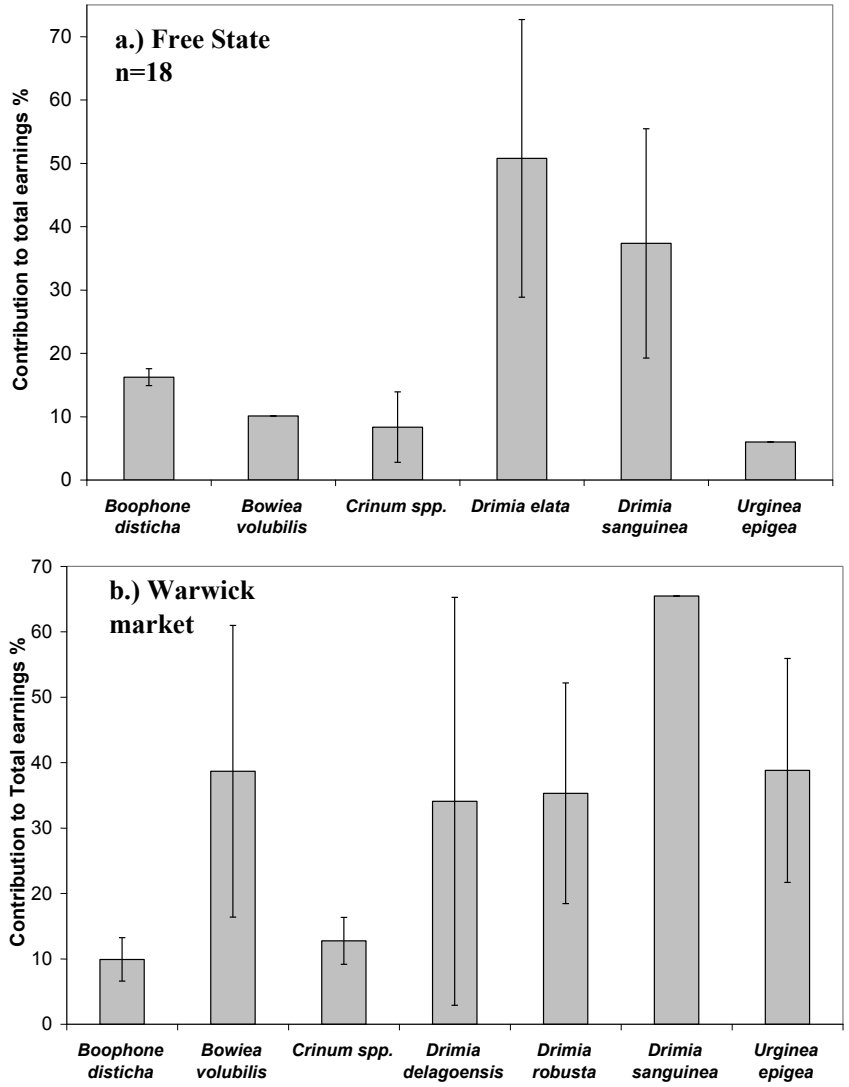


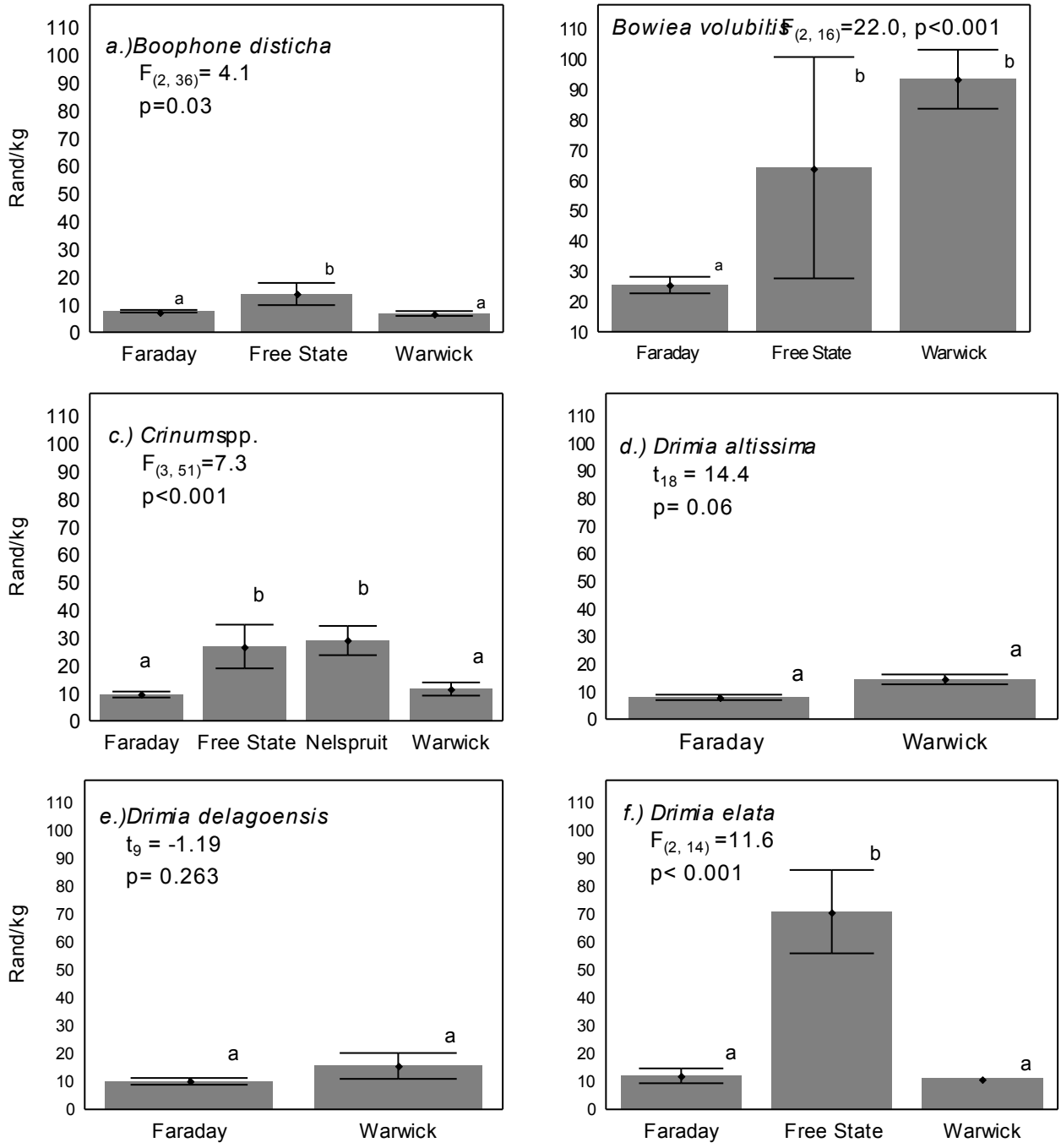
Figure 4: Percentage contribution to total earnings per bulb species per year (mean ± SE) in a.) Free State and b.) Warwick market. Data for eight and six species were collected in Warwick and Free State markets respectively.

The relative standard deviation (CV) provides a comparison of the variation between markets and species (Table 7). Relative variance was high for all species except *B. disticha* (12%), while relative variance in Warwick was even higher for all species (82%-135%), suggesting that traders in medicinal markets differ in a) the earnings made per species and b) the total earnings for all medicinal plants (Figure 4a and b; Table 7).

Table 7: Total earnings per trader/market per year and standard deviation and relative standard deviation (CV).

	Total earnings (R/year)		Standard Deviation (R/year)		CV= (Std dev/mean)*100 (%)	
	Free State	Warwick	Free State	Warwick	Free State	Warwick
Boophone disticha	4140; n=2	1234; n=9	481	1241	12	101
Bowiea volubilis	2580; n=1	4820; n=2	-	3932	-	82
Crinum species	2128; n=2	1589; n=7	2006	1183i	94	74
Drimia delagoensis	-	4248; n=2	-	5498	-	129
Drimia elata	12950; n=5	-	12499	-	97	-
Drimia robusta	-	4401; n=8	-	5948	-	135
Drimia sanguine	9527; n=7	8160; n=1	12218	-	128	-
Urginea epigea	1530; n=1	4836; n=8	-	6033	-	125

In all markets there is a fixed price per sale (R10 in Faraday; R5 in Free State and Warwick) so changes in Rand per kilogram are related to the volume purchased per sale. *Bowiea volubilis* had a large R/kg proportion in all markets (R25/kg; R65/kg; R95/kg in Faraday, Free State and Warwick respectively), suggesting that smaller volumes are being sold for the same price. This coincides with size-class information that bulbs are becoming smaller (Chapter 3) (Figure 5b). *Drimia elata, D. sanguinea* and *U. epigea* had a higher R/kg ratio at Free State than the other markets ($p<0.001$) (Figure 5f, h, i). For the majority of species, R/kg was not significantly different between markets (*B. disticha, D. altissima, D. delagoensis* and *D. robusta*) (Figure 5a, d, e, g). These species, had, for the most part an average of R10/kg. *Crinum* species in Free State and Nelspruit had a higher R/kg (R30/kg) (Figure 5c).



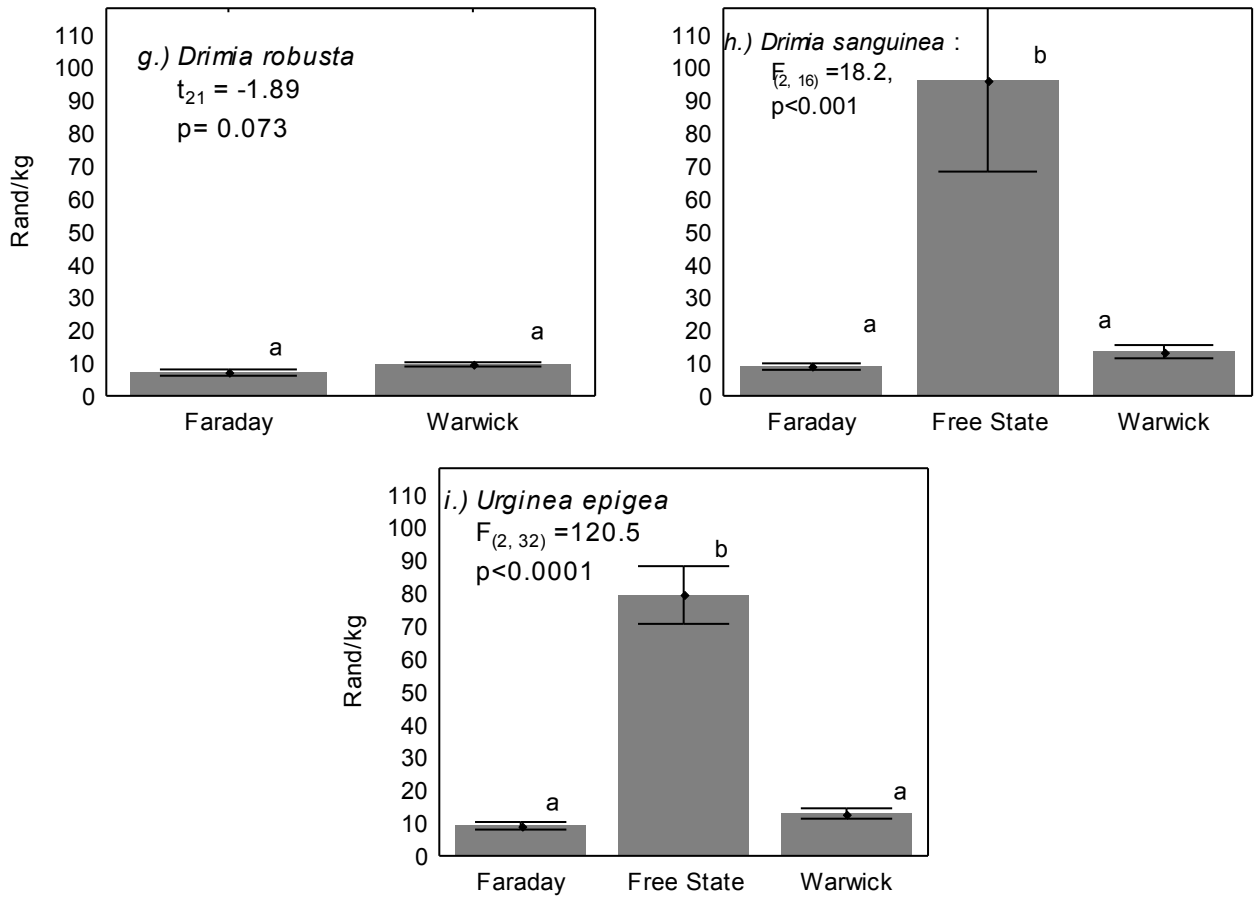


Figure 5a-i: R/kg (mean ± SE) for nine bulb species sold at Faraday market, Johannesburg, Warwick market, Durban, and where possible: smaller Free State and Nelspruit stalls. Results of One Way ANOVA and t-tests are included and means with different letters are significantly different ($p<0.05$).

The overall regression relationship between mass and sale value (R/kg) for all species and markets showed that the smaller the quantity sold per sale (mass), the greater the sale value (R/kg) relative to the sale of larger quantities (Figure 6a and b). Figure 6a highlights the high sale value of *B. volubilis* while Figure 6b shows that smaller quantities are sold for the same price at Free State market and larger volumes are sold for sale at Faraday.

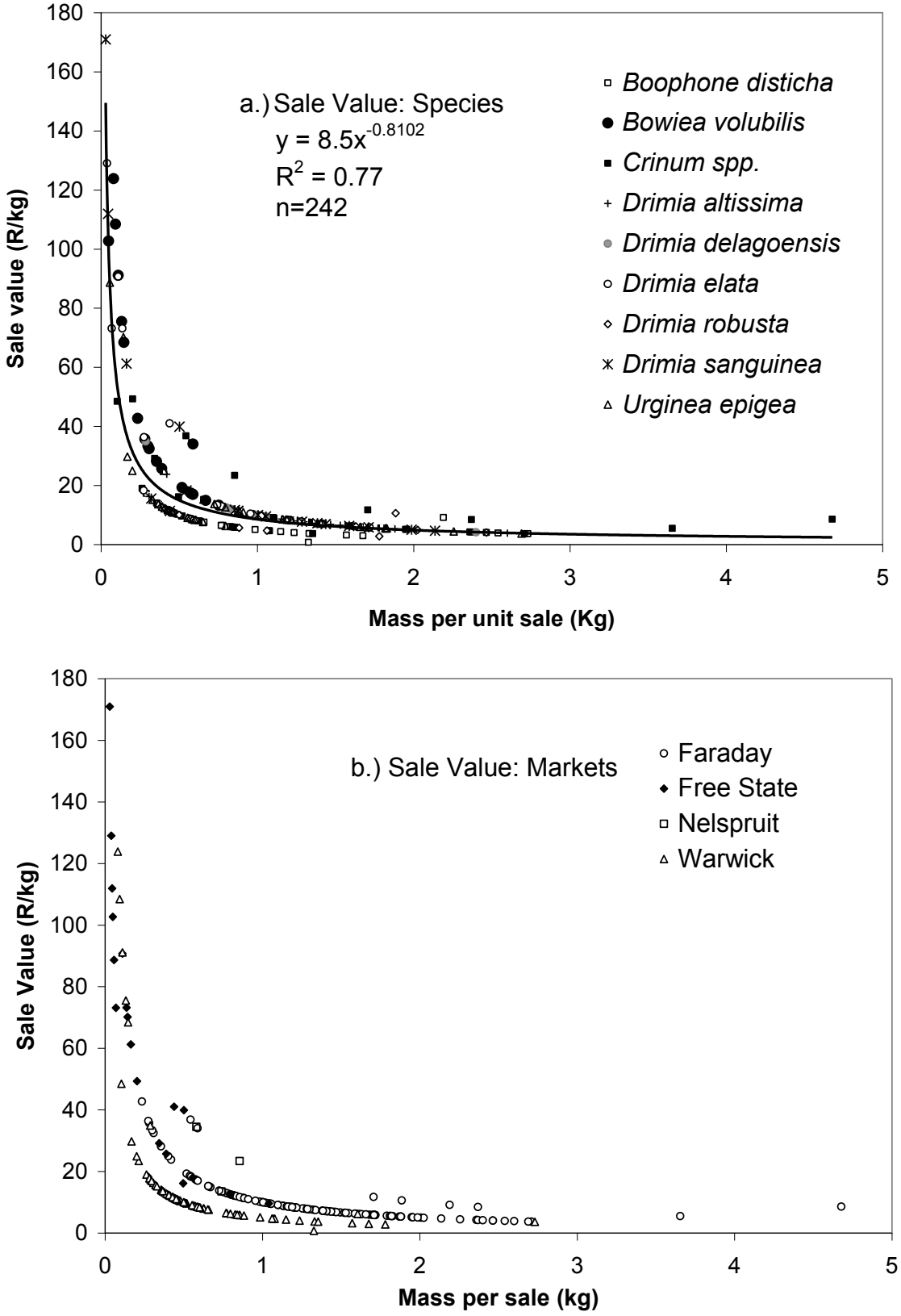


Figure 6 a and b: Regression analysis between mass (kg) and sale value (R/kg) showing trends for a) different species and b) different markets. The regression equation provided is for all species/markets

Overall, there was a significant difference in the R/kg between species (Species: $F_{(10, 231)} = 7.7$; $p < 0.001$), with the main differences occurring between *B. volubilis* (which had a larger R/kg overall) and all species except *D. cooperi* and *U. lydenburgensis. Drimia elata* and *D. sanguinea* also had relatively large R/kg values (Figure 7a). In terms of differences between markets, Free State bulbs had the highest

R/kg and differed significantly from all markets (Markets: $F_{(3,\ 228)}$ =48.1, p< 0.001). Faraday and Warwick markets differed from each other but not from Nelspruit, which had a larger R/kg (Figure 7b).

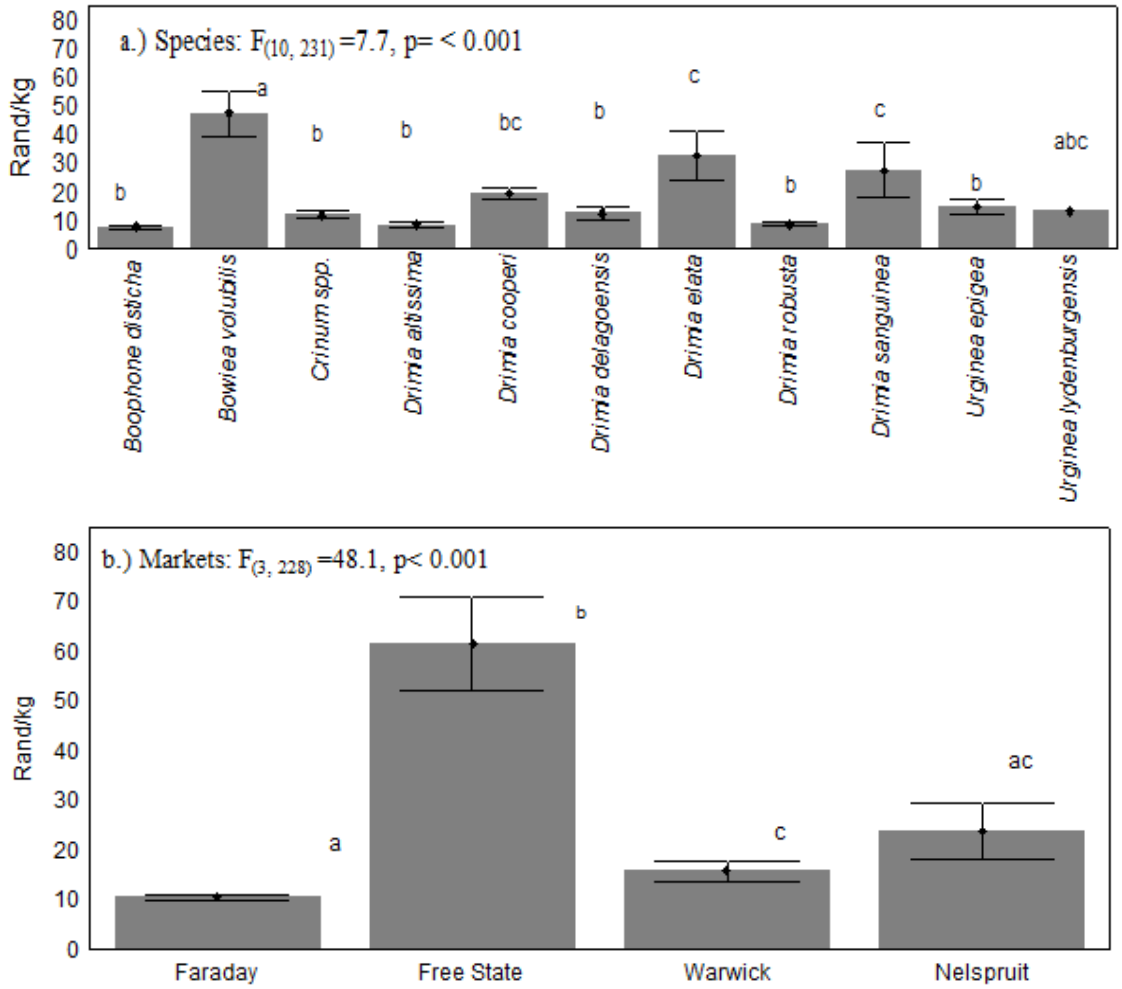
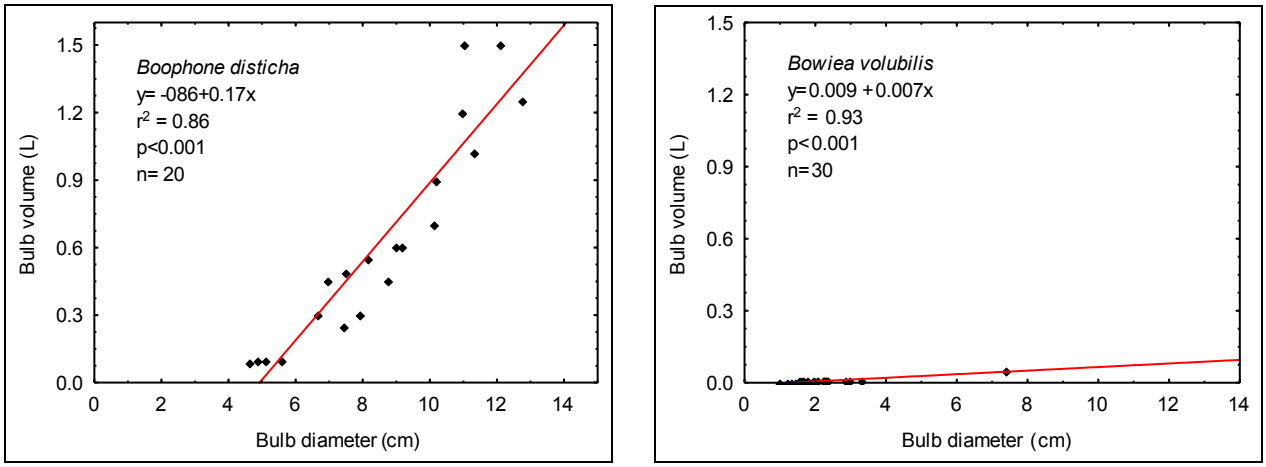


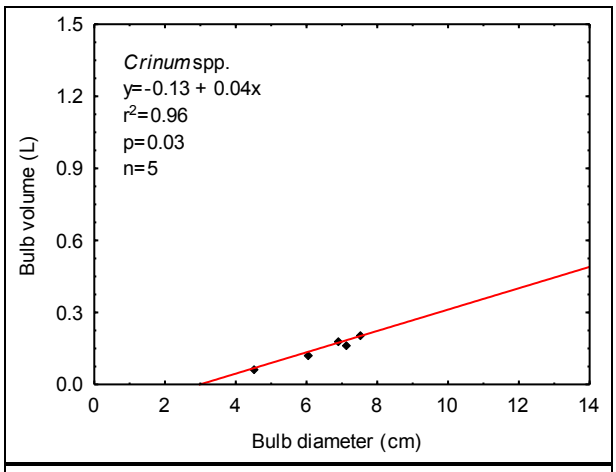
Figure 7a and b: Difference in R/kg between eleven bulb species and between markets (Faraday, Free State, Warwick and Nelspruit). Results of One Way ANOVA and Fisher LSD Post-Hoc tests are included and means with different letters are significantly different

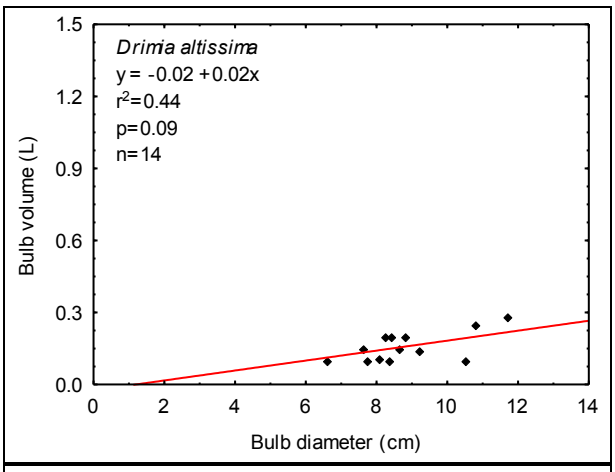
3.3. VOLUME OF TRADE

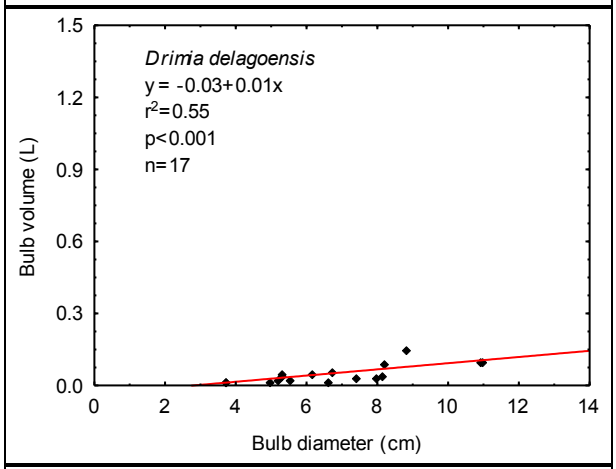
3.3.1. Estimation of bulb volume

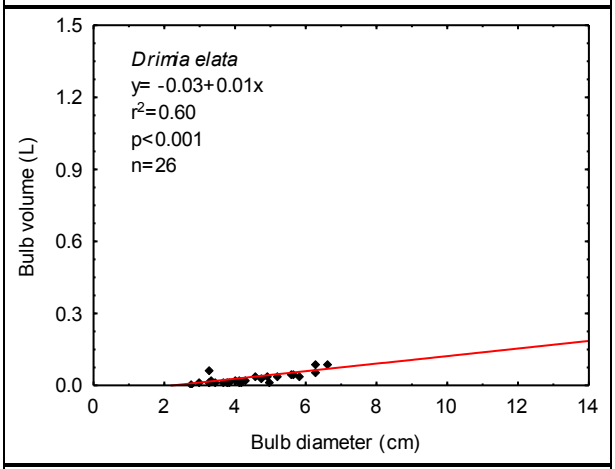
Figure 8 provides the Linear regressions between bulb diameter (x) and 'actual' bulb volume (water displacement) (y).

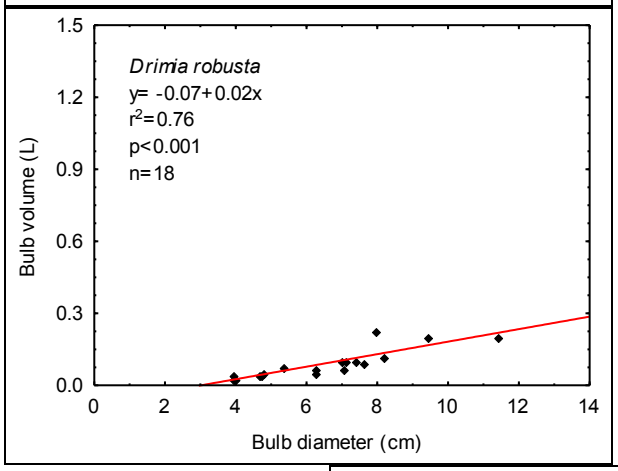


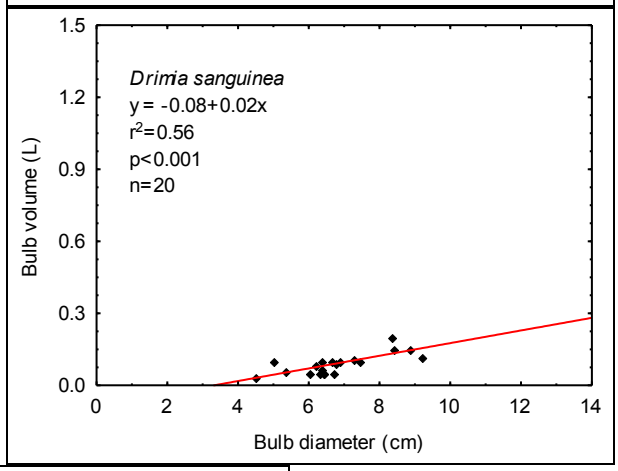

Crinum spp.
y=-0.13 + 0.04x
r²=0.96
p=0.03
n=5
Bulb volume (L)
Bulb diameter (cm)


Drimia altissima
y = -0.02 +0.02x
r²=0.44
p=0.09
n=14
Bulb volume (L)
Bulb diameter (cm)


Drimia delagoensis
y = -0.03+0.01x
r²=0.55
p<0.001
n=17
Bulb volume (L)
Bulb diameter (cm)


Drimia elata
y= -0.03+0.01x
r²=0.60
p<0.001
n=26
Bulb volume (L)
Bulb diameter (cm)


Drimia robusta
y= -0.07+0.02x
r²=0.76
p<0.001
n=18
Bulb volume (L)
Bulb diameter (cm)


Drimia sanguinea
y = -0.08+0.02x
r²=0.56
p<0.001
n=20
Bulb volume (L)
Bulb diameter (cm)

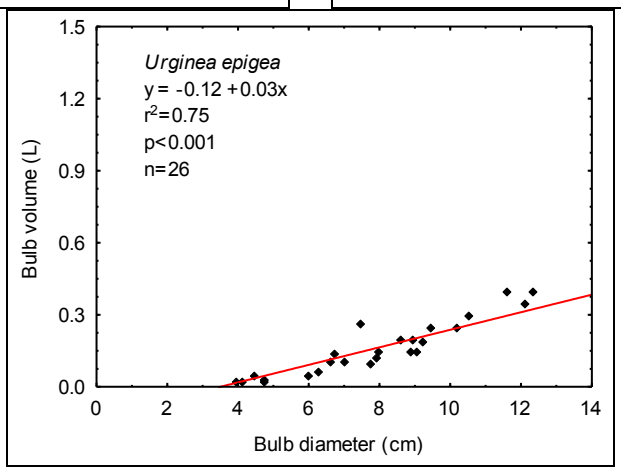
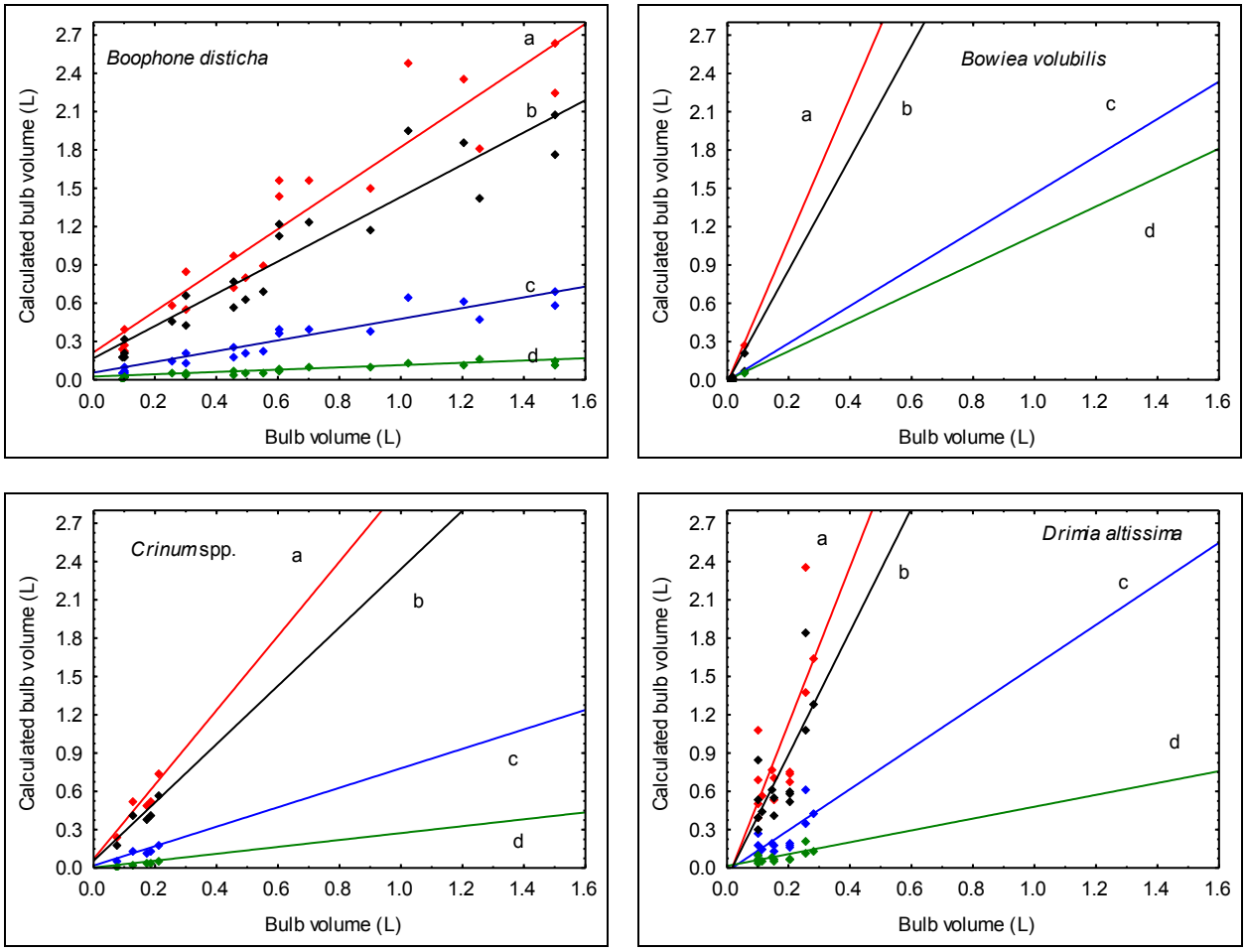

Urginea epigea
y = -0.12 +0.03x
r²=0.75
p<0.001
n=26
Bulb volume (L)
Bulb diameter (cm)

Figure 8: Linear regressions between bulb diameter (x) and bulb volume (y) for nine species from the Hyacinthaceae and Amaryllidaceae. Regression equations, p-values and r^2 values are included.

Linear regressions were strongest for *Crinum* species (r^2=0.96), *B. volubilis* (r^2=0.93), B. *disticha* (r^2=0.86), *D. robusta* (r^2=0.76) and *U. epigea* (r^2=0.75). In the most part, these bulbs were all large, (except *B. volubilis*), but included thick Hyacinthaceae bulbs and Amaryllidaceae with thin papery bulb scales (Figure 8). Small to medium-sized *Drimia* bulbs did not have very strong regression relationships (between r^2=0.55 to r^2=0.60). *Drimia altissima* is a medium sized bulb but with compacted scales, and the regression relationship was weakest for this species (r^2=0.44) (Figure 8). *Boophone disticha* had the steepest relationship while *B. volubilis* had the least steep relationship between bulb diameter and actual volume.

Linear regression relationships between calculated bulb volume (using volumetric equations) and actual bulb volume (y) showed great variability depending on the volumetric equation used (Figure 9). Volume calculated using the cube volumetric equations was greatest for all species. The smallest estimate of bulb volume was using the sphere volumetric equation – as this did not take into account the neck region of the species.



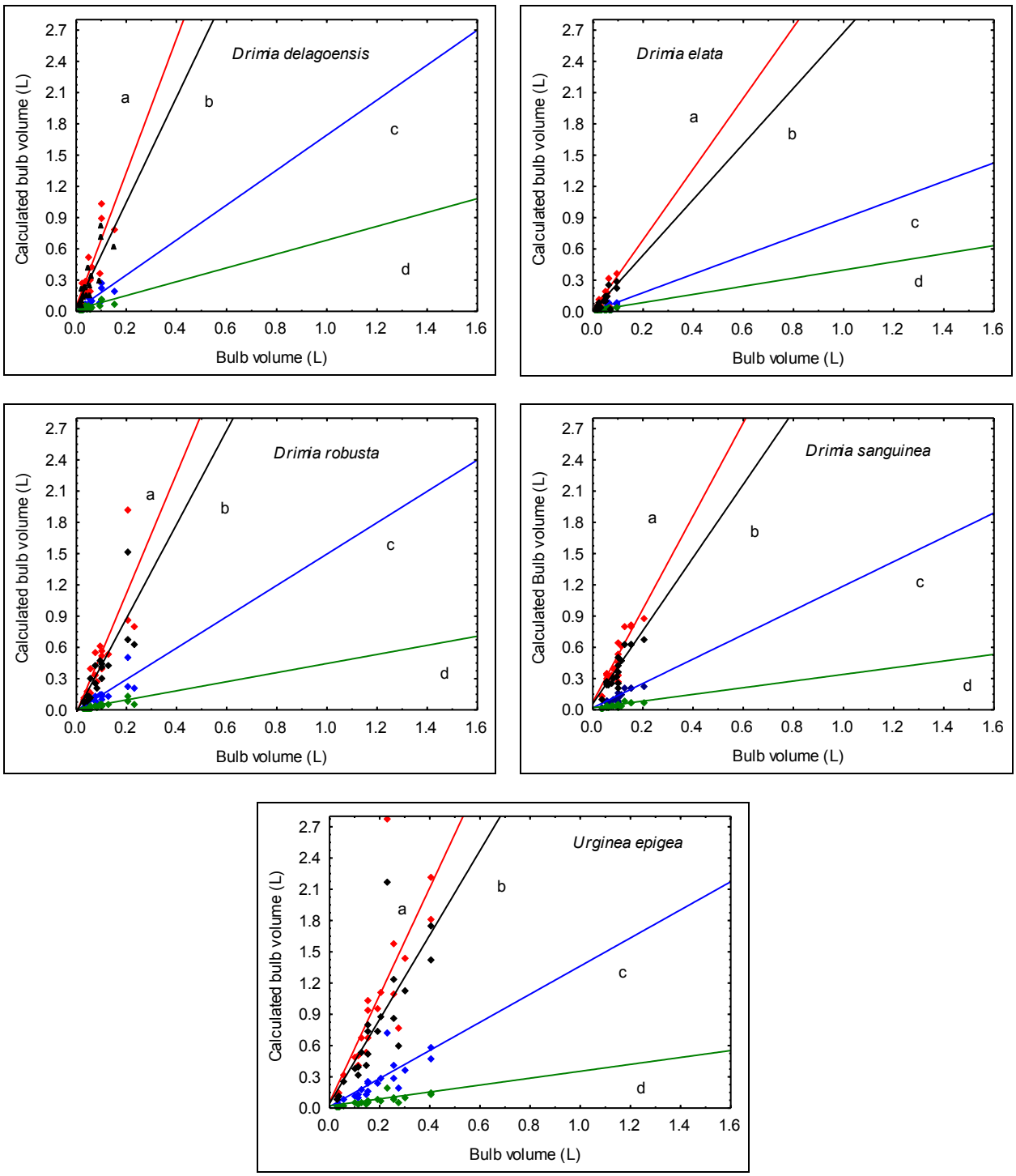


Figure 9: Linear regressions between actual bulb volume (x) and volume determined using volumetric equations (y) for nine species from the Hyacinthaceae and Amaryllidaceae. Trend lines include a.) Cube; b.) cylinder; c.) cone; d.) sphere. Regression equations, p-values and r^2-values are provided in the table below.

For all species, volume estimated using the cube equation was greatest (Figure 9; Table 8), however depending on the shape of bulb, some estimations were closer to the actual volume (calculated from water displacement) than others. *Boophone disticha* is torpedo shaped and the cylinder and cone estimations were most similar to the actual volume (Table 9). For *B. volubilis*, the best estimations were cone and sphere, most likely due to the subglobose nature of the bulb, similarly, *D. elata* showed the same pattern and for *D. delagoensis* sphere volume estimations was also closest to actual volume. *Crinum* species *D. sanguinea* and *D. robusta* actual volume was most similar to volume estimated by cone (Table 8). For the majority of species, actual volume was relatively similar to the sphere estimation that did not take into account packing of the shape of the bulb. Number of bulbs harvested per annum

was calculated using the 'actual' volume (to provide an upper limit) and cube volume (to provide an estimate which takes into account space between bulbs into account)

Table 8: Linear regression equations, p-values, r^2-values and estimates of individual bulb volume for nine species from the Hyacinthaceae and Amaryllidaceae. Significant p-values are highlighted

	Calculated Bulb volume (l)			
	Cube (a)	**Cylinder (b)**	**Cone (c.)**	**Sphere (d)**
Boophone disticha	y=0.21+1.6x	y=0.16+1.26x	y=0.05+0.42x	y=0.02+0.08x
x=0.6l	r^2=0.89	r^2=0.89	r^2=0.89	r^2=0.89
	p<0.001	**p<0.001**	**p<0.001**	**p<0.001**
	n=20	n=20	n=20	n=20
	y=1.2	y=0.9	y=0.3	y=0.07
Bowiea volubilis	y= -0.02+5.5x	y=-0.01+4.39x	y= -0.005+1.46x	y= -0.001+1.13x
x=0.02l	r^2=0.94	r^2=0.94	r^2=0.97	r^2=0.94
	p<0.001	**p<0.001**	**p<0.001**	**p<0.001**
	n=30	n=30	n=30	n=30
	y=0.09	y=0.08	y=0.02	y=0.02
Crinum species	y=0.07+2.91x	y=0.05+2.28x	y=0.01+0.76x	y=0.003+0.27x
x=0.2l	r^2=0.81	r^2=0.81	r^2=0.81	r^2=0.97
	p=0.03	p=0.03	p=0.03	**p=0.002**
	n=5	n=5	n=5	n=5
	y=0.7	y=0.5	y=0.2	y=0.05
Drimia altissima	y=0.10+6.14x	y=-0.07+4.82x	y=-0.02+1.60x	y=0.01+0.46x
x=0.1l	r^2=0.52	r^2=0.52	r^2=0.52	r^2=0.42
	p=0.003	**p=0.003**	**p=0.003**	p=0.01
	n=14	n=14	n=14	n=14
	y=0.9	y=0.6	y=0.2	y=0.08
Drimia delagoensis	y=0.04+6.41x	y=0.03+5.01x	y=0.01+1.67x	y=0.01+0.66x
x=0.04l	r^2=0.70	r^2=0.70	r^2=0.70	r^2=0.55
	p<0.001	**p<0.001**	**p<0.001**	**p<0.001**
	n=17	n=17	n=17	n=17
	y=0.3	y=0.2	y=0.08	y=0.04
Drimia elata	y=0.008+3.39x	y=0.006+2.66x	y=0.002+0.88x	y=0.007+0.39x
x=0.02l	r^2=0.82	r^2=0.82	r^2=0.82	r^2=0.80
	p<0.001	**p<0.001**	**p<0.001**	**p<0.001**
	n=26	n=26	n=26	n=26
	y=0.09	y=0.07	y=0.02	y=0.02
Drimia robusta	y=-0.03+5.74x	y=-0.02+4.51x	y=-0.008+1.50x	y=0.008+0.43x
x=0.09l	r^2=0.81	r^2=0.81	r^2=0.81	r^2=0.86
	p<0.001	**p<0.001**	**p<0.001**	**p<0.001**
	n=18	n=18	n=18	n=18
	y=0.5	y=0.4	y=0.1	y=0.04
Drimia sanguinea	y=0.07+4.46x	y=0.05+3.51x	y=0.01+1.16x	y=0.02+0.32x
x=0.05l	r^2=0.88	r^2=0.88	r^2=0.88	r^2=0.76
	p<0.001	**p<0.001**	**p<0.001**	**p<0.001**
	n=20	n=20	n=20	n=20
	y=0.3	y=0.2	y=0.07	y=0.04
Urginea epigea	y=0.05+5.15x	y=0.04+4.04x	y=0.01+1.34x	y=0.02+0.03x
x=0.1l	r^2=0.80	r^2=0.80	r^2=0.80	r^2=0.76
	p<0.001	**p<0.001**	**p<0.001**	**p<0.001**
	n=26	n=26	n=26	n=26
	y=0.6	y=0.5	y=0.2	y=0.02

3.3.1 Volume of bulbs harvested per annum

The mean estimated volume per trader per annum (for both markets) did not differ significantly between species (p=0.82) and was between 350 litres (l) and 850l. Large standard error suggests that the volume harvested varied to a large degree between traders (Figure 10). Overall, *D. sanguinea* was estimated to be harvested in the largest quantities per annum (850l).relative to other species. There was a significant difference in mean volume/year (litres) between markets with Free State traders harvesting a significantly greater volume of all species (t_{91}=3.31; p=0.001) (Table 10).

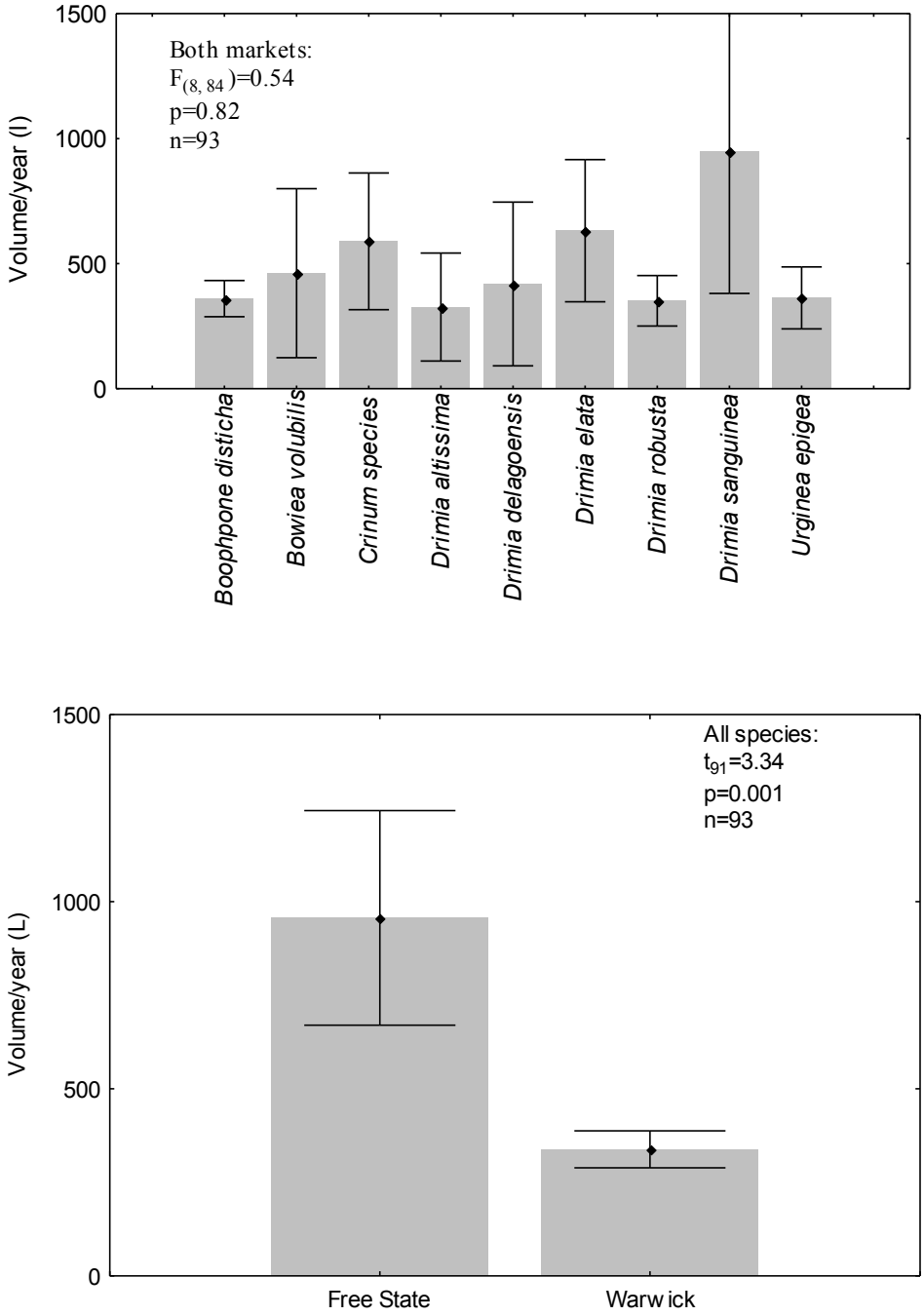


Figure 10: Differences in mean (±SE) estimated volume/year (litres) between a.) nine species and b.) Free State and Warwick market. Results of One-way ANOVA and T-tests are provided.

Species-specific mean volume/annum (litres) did not differ significantly for *B. disticha, B. volubilis, D. elata, D. sanguinea* and *U. epigea* ($p>0.05$), although in general, a greater volume/annum was harvested in Free State for all species (Figure 11). Traders in Free State markets harvested a significant greater volume/annum when compared to traders in Warwick ($t14=-2.48$; $p<0.001$) (Figure 11).

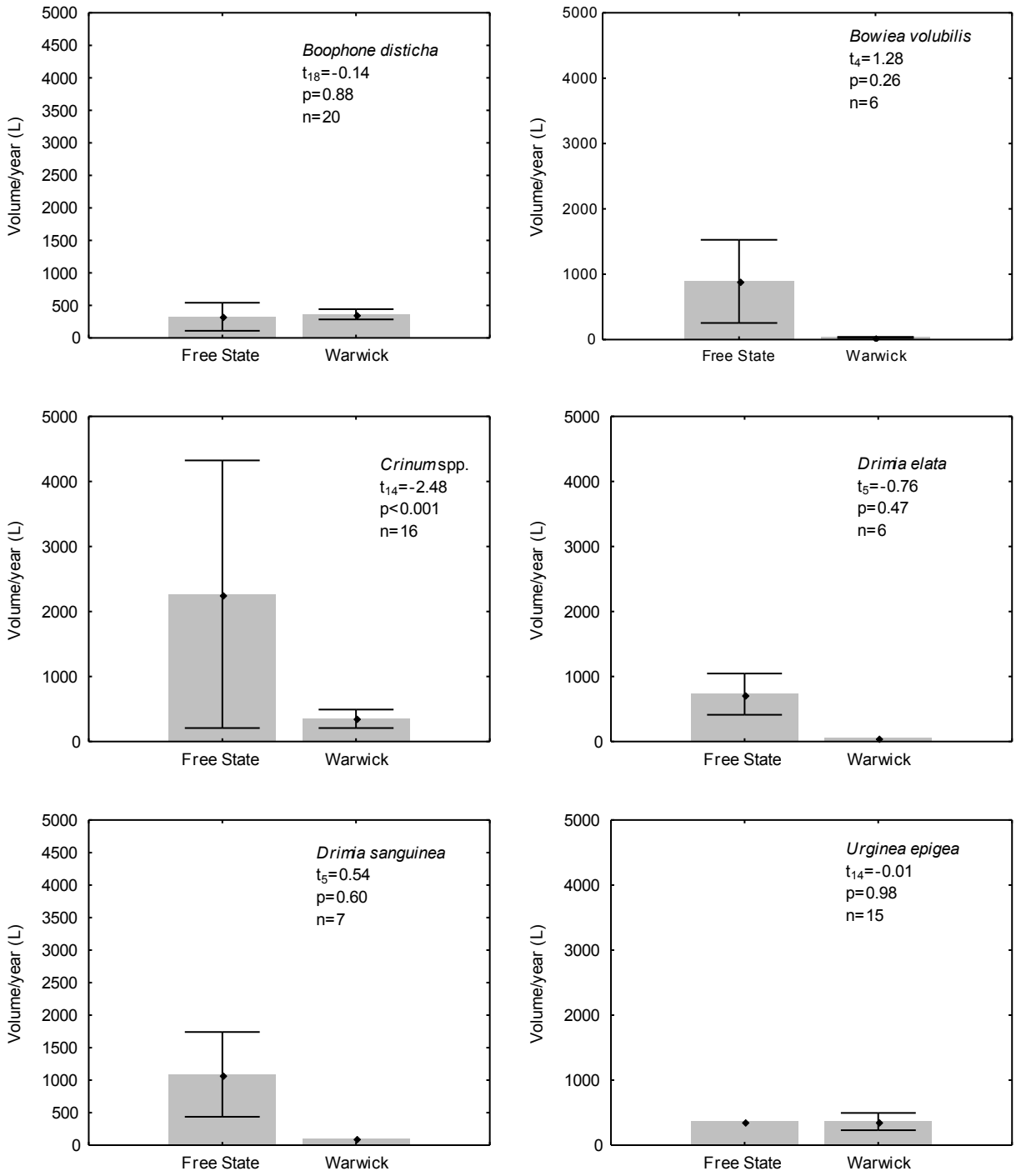


Figure 11: Comparisons in estimated mean (±SE) volume/year (litres) purchased by traders in Free State and Warwick market for nine species. Results of T-tests are provided.

3.4. ESTIMATED NUMBER OF BULBS PER TRADER/ ANNUM

3.3.1. Number of bulbs sold per annum

The estimates of number of bulbs sold to consumers per annum were generally much less than number of bulbs harvested (Table 9; Figure 13). *Drimia elata* and *D. sanguinea* were the most commonly sold species in the Free State while *D. robusta* and *U. epigea* were the most common in Warwick market.

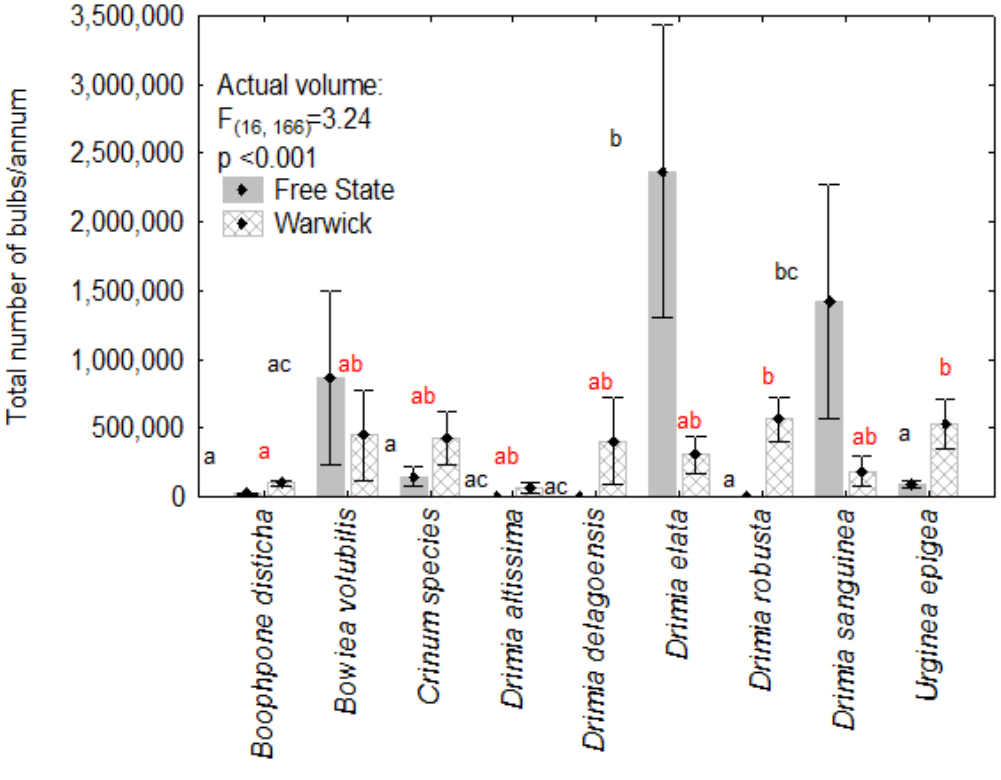
Table 9: Estimates of number of bulbs traded equivalent in size to the mean diameter (based on the mean number of bulbs per sale, the mean number of sales per trader per annum, the proportion of traders selling each species and number of traders per market (Free State: 150; Warwick: 300). Estimates were only determined for markets where the number of sales per day could be calculated).

Species	Markets	Individual equivalents
Boophone disticha	Free State	54,338±4,462
	Warwick	50,422±16,898
Bowiea volubilis	Free State	12,900
	Warwick	57,218±33,001
Crinum species	Free State	14,250±9,500
	Warwick	43,372±12205
Drimia delagoensis	Free State	-
	Warwick	36,542±10,757
Drimia elata	Free State	219,900±94,916
	Warwick	-
Drimia robusta	Free State	-
	Warwick	160,126±56,301
Drimia sanguinea	Free State	107,180±51,951
	Warwick	21,058
Urginea epigea	Free State	5,100
	Warwick	149,768±66,055

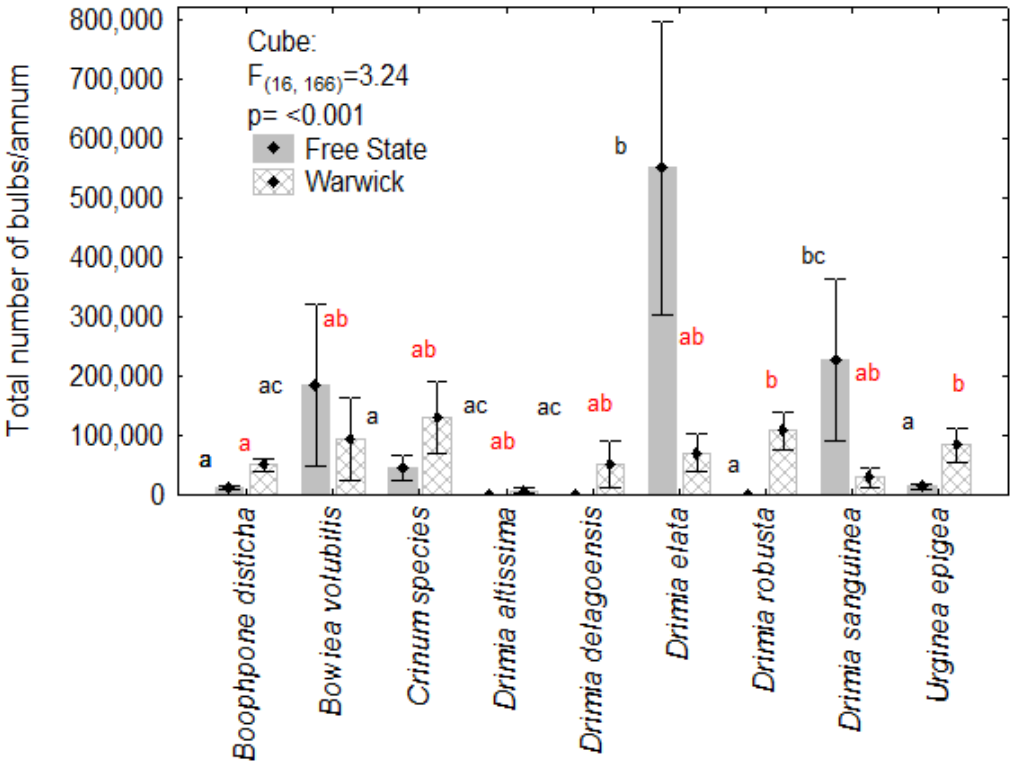
3.4.2 Number of bulbs harvested per annum

Based on the results of the regression analysis (Figures 8 and 9 and Table 8), the number of bulbs purchased by traders for sale in the medicinal plant markets of Free State and Warwick was estimated (Figure 12 a and b). Actual volume was thought to be an under-estimate of individual bulb volume for a number of reasons, 1) actual volume based on water displacement did not take into account packing of bulbs within a sack, 2) oven-dried bulbs were used in all measurements and air pockets between dried bulb scales allowed water to fill up spaces between bulb scales (decreasing the overall determined volume). Actual volume thus provides an upper limit for the number of bulbs harvested. Volume modelled on cube equations took into account the presence of the neck region of the bulb and was thus more realistic.

Overall for both methods, the estimated number of B. *volubilis, D. elata* and *D. sanguinea* harvested annually was greater in the Free State (Figure 12 a and b). *Boophone disticha, Crinum* species*, D. altissima, D. elata, D. robusta* and *U. epigea* were harvested in greater numbers in Warwick. Both methods followed the same trends and the Free State, *D. elata* was significantly different to all species than *D. sanguinea*. In Warwick, *B. disticha* was significantly different to *D. robusta* and *U. epigea* (Fishers LSD: $p < 0.05$) (Figure 12 a and b). The greatest number of bulbs harvested was for *D. elata* in the Free State (between 550,000 and 2,500,000 bulbs depending on the method used to calculate volume) (Figure 12 a and b). *Drimia sanguinea* and *B. volubilis* in the Free State were also harvested in large quantities. *Crinum* species, *B. volubilis* and *U. epigea* were harvested in large numbers in Warwick (between 100,000 and 500,000 bulbs annually) (Figure 12 a and b).



a.)



b.)

Figure 12 a and b: Total number of bulbs harvested annually (Mean ± SE) equivalent in size to the mean bulb diameter at Warwick and Free State markets. Results of One-Way ANOVAs are provided. Results of Fisher LSD tests are provided ($p<0.05$) with different letters denoting significant differences between species (black= Free State; red= Warwick).

The total number of bulbs harvested annually for all species was significantly less when calculated using the bulbs/bag volume regression than the cube equation (Figure 13). The estimations of total number of bulbs harvested were highly variable (Figure 12 a and b; 13) and should be taken as an order of magnitude rather than an exact figure.

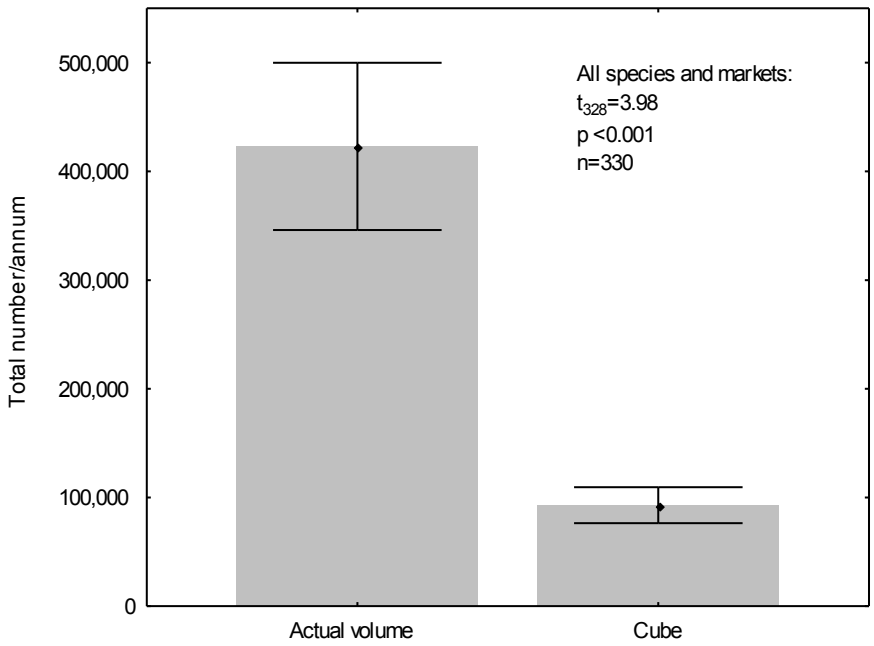


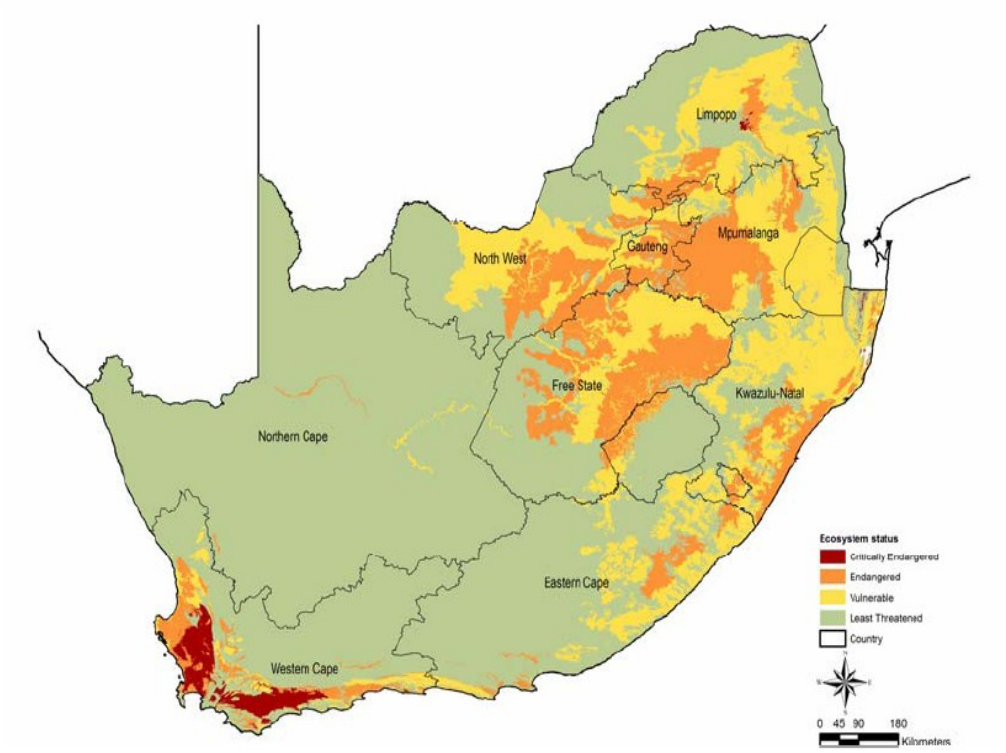
Figure13. Difference in total number of bulbs harvested based on actual volume and cubic volume of a bulb for all species and markets combined (Results of T-test is provided).

4. DISCUSSION

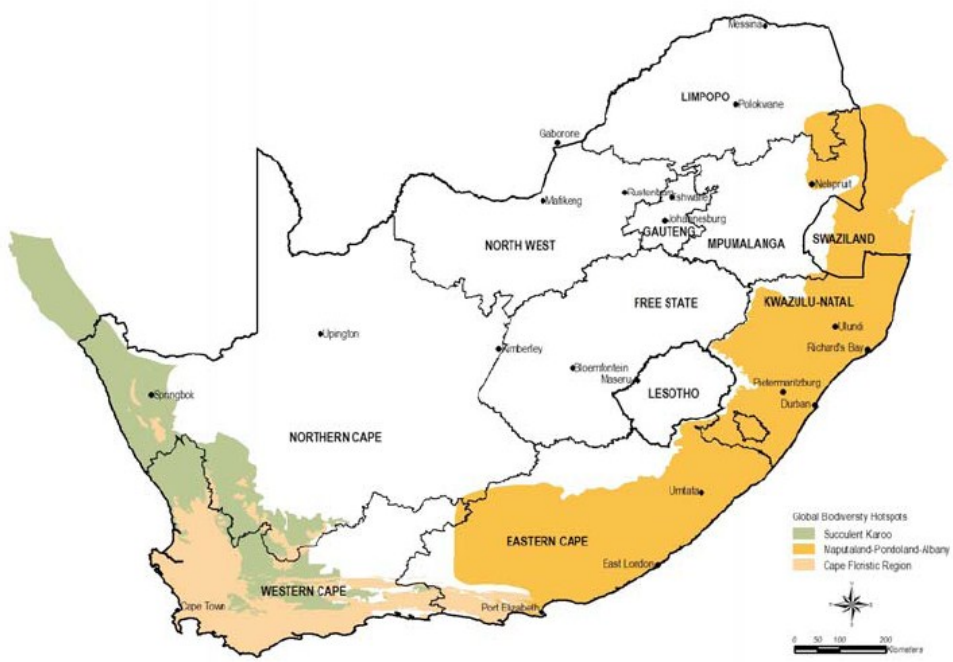
The understanding of the dependence and value of natural resources in the lives of rural communities throughout the world (Shackleton & Shackleton, 2006) has developed, in part, from the antagonistic views of development economics and conservation. Both of these views have guided and enhanced the use of natural resources as a possible approach to increasing livelihood security and poverty reduction, thus providing viable incentives for conservation and sustainable use (Shackleton & Shackleton, 2006). Attaching market values on natural resources is one means of conserving biodiversity and useful wild resources, and has become more popular in the last decade with the proponents of this philosophy encapsulating this in the catch phrase "use it or lose it" (Shackleton, 2001). Although resource harvesting is potentially damaging, the alternative – which is converting communal lands to some other land use – is potentially even more damaging. Furthermore, if land is changed to another land use then local households will have to source these resources elsewhere (Shackleton, 2001). Traditional medicine is a widely practiced part of South African cultures and beliefs (Chinsamy *et al.,* 2011), and as such determining the impact of traditional medicinal plant use is vital.

4.1. ECOLOGICAL IMPLICATIONS OF HARVESTING LOCATION

Data collected from markets about the sources of supply (Chapter 3) of bulbous species suggested that for almost all species, the majority of the individuals in the market had been collected from KZN and Gauteng. Both these areas have been given 'Endangered' or 'Vulnerable' ecosystem status (Map 1) (King *et al.,* 2005). In addition, KZN falls within the Maputuland-Pondoland-Albany global biodiversity hotspot region (Map 2) (King *et al.,* 2005). The effect of harvest and trade of popular bulbous species will not only be on the harvested populations, but also on the ecosystems and the habitats from where the species have been harvested. The sensitive nature of ecosystems in KZN makes the harvest of medicinal bulbs detrimental at a landscape level. Size-class studies of medicinal bulb species commonly traded (Chapter 3) show that in many cases, populations have already been affected. To have a better understanding, however, there is a great need to understand both the economic underpinnings together with the ecological implications of trade and harvest.



Map 1. Ecosystem status of terrestrial ecosystems (Source: Driver *et al.,* 2005; King *et al.,* 2005)



Map 2. Biomes and Biodiversity hotspots of South Africa (Source: Low and Rebelo, 1996; Mittermeier *et al*. 2005; King *et al.,* 2005)

4.2 EFFECTS OF TRADER AND HARVESTER PREFERENCES

One important factor influencing the effect of harvest and trade of medicinal bulbs is the preference of traders and harvesters for large-bulbed individuals. In Warwick market, there was a greater preference for large bulbs (Figures 1 & 2). There are a number of reasons for this, firstly in terms of harvesting effort, the bigger the bulb, the greater the price (in relation to volume obtained for a single harvesting

event). It would appear, therefore, that there is an incentive to harvest larger bulbs. Competition between traders may also be a motivator. With a greater number of harvesters, selling to a large number of traders, harvesting efficiency must be high: the more bulbs harvested from a location in a single harvesting trip, the greater the stock available for sale. Harvesters cannot afford to harvest only what they need in one trip as this leaves available resources open for other harvesters. The number of harvesters and the popularity and scarcity of the species all drive harvesters to harvest greater numbers of bigger bulbs (Williams *et al.,* 2001)

An implication of the preference for larger bulbs is that of age and related reproductive status. With *B. disticha,* flowering and production of seeds only occurs approximately 6-7 years after germination (Dzerefos & Witkowski, 2001). Harvesters in general appear to prefer bulbs that are either flowering or with seeds (Figure 1, Figure 2). Larger bulbs are more likely to flower or seed, which makes them more visible to harvesters. However there is no data support that the reproductive status preference is related to size preferences. Future studies are needed to determine the effects of such preferences and to determine the reasons flowering plants are preferred. In addition, buyers appear to prefer bulbs with flowers or seeds (Figure 1, Figure 2). Targeting reproductively active, large bulbed individuals can have enormous ecological implications. For example, mean bulb diameter decreased between 2001 and 2007 for *B. disticha* (Chapter 3), mainly due to the absence of very large bulbs in the market. This decrease in diameters suggests harvested populations are being exploited (Cunningham, 1988), which has worrying implications. *Boophone disticha* primarily occurs in open grasslands (Van Wyk *et al.,* 1997), which have experienced high amounts of transformation and have high levels of degradation (Reyers *et al.,* 2001). Medicinal plant harvesting, targeting large individuals who are better able to deal with fire disturbances and likely to produce more seeds (Beadle, 1940; Cunningham, 1988), is likely to accelerate land degradation disturbances on the species.

Trader practices and perceptions (Table 6) provided information on destructive practices. Overall, in both markets, respondents felt that *B. volubilis* was difficult to locate, and that when found all sized bulbs were harvested (Table 6). Species that are difficult to find or negatively impacted by harvesting often become more in demand, with an increase in R/kg, which acts as a further stimulus for over harvesting (Williams *et al.,* 2007a). Harvesters feel the need to harvest all sized bulbs at a site so as to maximise their income. However, this practice has very many negative implications.

4.3. ECONOMIC VALUE OF COMMONLY USED BULB SPECIES

Commercialisation of resources is a growing trend in southern Africa (Shackleton & Shackleton, 2006). This commercialisation changes volumes, trader preferences and even the demographics of the population involved in the harvest and trade in medicinal plants. In Free State, where there is no large centre of trade but instead numerous smaller stalls in different towns and cities, the majority of traders interviewed were traditional healers over the age of 50. Interestingly, the male to female ratio was similar in the Free State whereas in Warwick 90% of the traders were not traditional healers, 87% were female and the majority were between 20-40 years in age (Table 5). Women with fewer sources of income become increasingly reliant on resource harvesting as a method of income generation. One of the reasons for this reliance is primarily because they have no means to leave their family to seek employment (Shackleton & Shackleton, 2006). In addition, poorer households are often involved in more opportunistic, low skill and low return activities, with fewer barriers to entry (Williams, 2003).

Poverty and opportunistic activities like medicinal plant harvesting are some of the forces driving the expansion of the medicinal plant trade. Harvesting is often a last resort activity, sometimes characterized by local capital or skills thresholds and participants are often in over-saturated markets that offer very low returns for labour (Williams, 2003). People in rural households whose income falls below the poverty line are often forced to seek employment in towns and cities, which then creates strong rural-urban linkages and dependencies (Williams, 2003). Urbanisation is a dominant demographic trend and major cause of global transformation with more than half of the planet's population, now living in cities (Pickett *et al.,* 2011). However, the increase in urbanised areas does not decrease the volume of medicinal plants traded; instead, the demand in South Africa is met by a network of harvesters, traders and traditional healers (Williams *et al.,* 2001).

Differentiation in the medicinal plant trade is occurring and large numbers of harvesters come from rural areas to sell harvested species to traders and then return home. In KZN, for all bulb species, the majority of traders did not harvest their own stock but bought the goods instead (Figure 2). The same is not true for the smaller, less commercialised, Free State stalls where for most species traders harvested their own stock (Figure 2). The difference in trader practices and demographics between the highly commercialised Warwick market and smaller Free State stalls is also mirrored in the species traded and the percentage of income generated from the sales of medicinal bulbous species.

The stipulated minimum wage in South African rural areas in 2007 was R713 per month with the minimum living requirement or poverty line, approximately R1,290 per month (per family of four) (Shackleton and Shackleton, 2006). In addition, estimates suggest that in 2005 approximately 70% of South Africans working in the informal sector earned less than R1,000 a month (Chazan, 2005). Although the financial gains from harvesting may not be immense, the overall economic value of this 'hidden economy' (Cunningham, 1988) was approximately R2.9 billion with 20,000 tonnes consumed ca. 2007 (Mander *et al.,* 2007). Surprisingly, in the more commercialised Warwick market total earnings per year for all medicinal species (determined by asking traders the total number of sales a day) was significantly lower than in the small Free State stalls: approximately R12,000/year versus approximately R25,000/year (Figure 3). This would suggest that traders in Warwick earn about R833 per month, lower than the 2005 average (Chazan, 2005) but greater than the stipulated minimum wage in the rural areas. More importantly, based solely on trade of medicinal plant species, traders at Warwick fall below the 'poverty line' which has implications for the economic importance of medicinal plant trading in South Africa.

Free State traders earn approximately R2,018/month creating an increased dependence on medicinal plant harvesting in the area. Harvesting provides an income greater than the 2005 estimated average of R1,000/month (Chazan, 2005) for the informal sector and more than double the average income in rural areas estimated by Shackleton *et al.* (2007). Seventy three percent of all Free State respondents are traditional healers (Table 5), which is likely to influence the earning potential between markets. Traditional healers are able to charge more for smaller volumes because of their knowledge and skills. The increased commercialisation at Warwick has resulted in a decrease in traditional healers and an increase of the number of unskilled traders. These traders are unable to charge the same price per volume.

There are a number of assumptions when dealing with the valuation of harvest and trade. One very basic but important assumption is that interviewed respondents have provided true estimates. Warwick market has been studied numerous times and has been raided by conservation officials in recent years. The large number of traders leads to competition and prices and number of sales per day may have been lowered for two reasons. Firstly, traders may not have trusted that the information given would not negatively impact them and secondly, traders may not wish for the number of sales to be known by other traders as this may invoke envy. In contrast, this is the first study in Free State markets and the National Museum and regional conservation agencies have a very good relationship with the traders in the area (P. Zietsman, *pers. comm*.). Traders and harvesters may have been more open and honest as they were not worried about the negative effects of the information. Assuming that the valuation per market was accurate, the most likely reason for this contrast in earnings per year is the large number of unskilled traders in the commercialised environment of Warwick. When supply (number of traders selling similar species) is greater than demand, prices are likely to decrease.

Each bulb species will contribute to the overall earnings of the traders (Figures 4a and b), however the magnitude of this contribution depends on a number of factors. Factors include the level of commercialisation of markets, surroundings ecosystems and their dominant life forms and different uses and medicinal beliefs of the people in the area. Zulu beliefs and uses dominate in the South African *umuthi* markets (Williams *et al.,* 2001). Studies by V.L Williams in the Faraday market, Gauteng, in 2001 showed that 97% of the traders in the market were migrants to the area from KZN (Williams *et al.,* 2001; Williams, 2004, Williams *et al.,* 2007a) bringing with them Zulu medicinal culture and medicine. However, commonly on Fridays and month ends, Sotho speaking women arrived in the market with plants harvested from western Gauteng, Free State and Lesotho (Williams, 2003). These harvesters had different species on sale. The species on sale are related to the demographics of the traders in a market.

Pricing structures and contributions of species fluctuate between markets and over time as the cost of the plants per unit mass increases or varies according to the gatherers' access to resources and the proximity of the markets to harvesting sites (William *et al.,* 2007b). In KZN, medicinal plants are harvested in great numbers from areas such as Ulundi, Empangeni, Eshowe, Mtubatuba and Nongoma and the informal trade is growing constantly due to expanding populations and increasing modernisation of society (Matsiliza and Barker, 2001; Ndawonde, 2006).

Williams (2004) hypothesised that the medicinal plant trade is driven to a large extent by customer demand: however this demand may change, limiting opportunities and sometimes leading to a change in harvesting activities. Despite this Williams' (2004) noted demand related plant scarcities drive up market prices, leading to an increase in harvesting of scarce species because of the potentially higher income generated. One important tenet of ecological valuation of resources is that scarcity will be reflected in market prices. However, many practitioners of ecological economics distrust market prices (Loomis, 2000). Some feel that in order for prices to correctly reflect scarcity there is a need for knowledge of future demand, stock and technology of extraction. Although market prices do have certain assumptions attached they do provide an order of magnitude of the relative 'worth' of a species. As medicinal plant populations decrease, constructive resource management and conservation strategies based in knowledge of medicinal plant use are needed (Okigbo *et al.,* 2008). Valuation can be useful to decision makers at a national and local level (Olsen, 2005).

Scarcity and availability of the resource over time (including seasonal availability), consumer demand and the plant part traded have a large impact on the market price of a species (Williams *et al.,* 2007b). In the Free State, bulbous species assessed in this study contributed between 10-50% of the total earnings of the traders and traditional healers (Figure 4a). Bulbous species in this study also contributed greatly to overall earnings in Warwick market (Figure 4b). In Free State, the common bulbous species sold in the area, *D. elata* contributed the most to overall earnings while in Warwick, *D. sanguinea* appeared to contribute the most (Figure 4b). This figure needs to be approached with caution, however, as *D. sanguinea* was only sold by one trader at Warwick. The high estimated monthly earnings contribution by *D. sanguinea* in Warwick could be based on a high price paid for a 'scarce' species in the market.

Bowiea volubilis was also not common in either market but appears to be the most negatively impacted in regards to population size structure of market bulbs (Chapter 3). Notably, trader interviews suggested that this species was particularly scarce, with traders in Warwick market having to buy their stock from Faraday (Chapter 3) and stock in Free State often coming from Lesotho. R/kg values are often used as an indicator of value and risk to over-exploitation with assumption being that taxa with high R/kg values are more valuable and face greater potential threats (Williams *et al.,* 2007b). With *B. volubilis*, there were very high R/kg results, approximately R65/kg in Free State and R95/kg in Warwick market (Figure 5b) – this is especially high in Warwick where average R/kg is approximately R20/kg (Figure 7b). This high R/Kg value has some important ecological implications. With high monetary returns, traders will continue to harvest the species in order to supplement their income. This suggests that the difficulty to locate the species will not deter harvesters leaving the already impacted population highly vulnerable to over harvesting. Diameters in the market already showed an extreme inverse J-shaped relationship indicative of a population with large numbers of small bulbs with no bulbs greater than 10cm in diameter (Chapter 3).

In 1988, sources indicated to A.B. Cunningham that *B. volubilis* was locally extinct in the KZN area (Cunningham, 1988). Size-class data together with economic value and historical information suggests that *B. volubilis* is highly threatened and more local extinctions may occur. Data from Faraday market on R/kg shows that in this area, the species is more easily found with R/kg approximately R25/kg (Figure 5b). However, with average bulb diameters equal to approximately 1cm (Chapter 3), the scarcity of the species is expected to increase; increased scarcity leads to an increase in contributions to total earnings, and a higher R/kg value can be expected if trends in the Free State and Warwick market are followed.

Sale value (R/kg) varies between markets and over time (Williams *et al.,* 2007b). Variation in sale value depends on a number of factors including harvesters' access to resources; scarcity, popularity, consumer demand and plant part traded (Williams *et al.,* 2007b). There are a number of assumptions when dealing with R/kg. Firstly, when comparing R/kg values it is assumed that all species will be at the same stage of

drying. This is not always the case. In a study of bark moisture content, species with the highest R/kg were also species that lost the most moisture after harvesting (Williams *et al.,* 2007b). Thus, R/kg can also be affected by characteristics intrinsic to the morphology of the plant part on sale (Williams *et al.,* 2007b); because of this, R/kg relationships should only be compared for the same life forms and plant part on sale. Moisture content can also be important even when comparing the same life form types: in this case, percentage water loss over a 12 week period was approximately 30% for all species and thus the impact of drying over time in the market is not likely to affect comparisons between species (Chapter 3).

The high R/kg value of *B. volubilis* (Figure 7a), is most likely related to decreased size of bulbs occurring in the market (Chapter 3) rather than intrinsic differences between species. Despite this, it is still essential to take water loss into account, especially in the large, moisture rich bulbous species. Bulbs that are not so popular and are only purchased/harvested by traders at random intervals may have a lower R/kg value. Using oven-dried mass to determine R/kg may decrease differences due to intrinsic moisture content

In addition, R/kg proportions, however do tend to create a bias towards lighter and less dense plant parts like *B. volubilis*. When looking at large dense bulbs, R/kg values may not highlight the effects of trading. In both Warwick and Free State more than half the traders suggested that the large bulbed *B. disticha* was difficult to locate (Table 6). Size-class distributions of the species suggested that there was a negative impact with a lower number of large bulbs occurring over time (Chapter 3). However, the species contributed approximately 10% to overall trader earnings in Warwick and had a low R/kg value (Figures 4b and 5a). Williams *et al.* (2007) found that in Faraday, R/kg was inversely proportional to the mass of the products sold. The same trends were found in both Free State and Warwick market (Figure 6a) with large bulbed species having a greater mass and lower R/kg values relative to small-bulbed species. Small markets such as Free State appear to sell a smaller volume per sale (Figure 6b). At Warwick, the relationship is similar to Faraday, although R/kg values are lower for the same mass per sale (Figure 6b)

4.4. NUMBER OF BULBS HARVESTED

The number of bulbs sold to consumers per annum can provide valuable information on the popularity of each species as well as the implications of trade. In all cases, estimates of number of bulbs sold to consumers were less than the annual volume harvested which is likely related to a certain amount of wastage of harvested bulbs (Table 9, Figure 12 a and b). *Drimia elata* and *D. sanguinea* were sold in the greatest quantities in the Free State while *D. robusta* and *U. epigea* were sold in the greatest numbers in Warwick (Table 9). For these four species, more than 100,000 bulbs per annum were sold. This estimate is based on the number of bulbs per sale and the estimated number of sales per annum and for species commonly traded may provide a more reliable estimate of the number of bulbs (equivalent to mean bulb diameter).

Medicinal plants are used in a multitude of ways; this suggests that medicinal plants should be evaluated on a case specific basis (Dzerefos & Witkowski, 2001). It is also important to appreciate the scale of cultivation required to replace harvested stocks as well as to understand the extent of damage to wild populations, as this allows an understanding of the impacts of harvesting (at both an individual and population scale) (Williams, 2003). Bulb volume estimations can be very important in determining the order of magnitude of the trade. Intrinsic morphological characteristics are extremely important when looking at new, time efficient methods of estimating bulb volume. *B. disticha* and *Crinum* species appeared to have a similar relationship between bulb diameter and volume in that bulbs around 5cm in diameter were less than 0.2 litre in volume. In contrast, *D. altissima* bulbs from the Hyacinthaceae had a smaller volume at larger bulb diameters (Figure 8). This suggests that diameter size is not the only factor influencing volume. Both Amaryllidaceae species have numerous ‘tunics’ (Chapter 2) which are relatively dry and although increase the diameter do not influence the water content to a large extent. In contrast, Hyacinthaceae species have water rich bulbs. When dried, the bulb leaf bases become thin and brittle and there is a certain amount of space between each leaf bases. This then influences the relationship between diameter and volume. In all cases, oven-dried bulbs were used in volume calculations making their drying characteristics important.

Despite these intrinsic differences, regression relationships between actual volume (based on water displaced) and estimations of volume (based on volumetric equations) (Figure 9, Table 8) were similar in numerous ways. Firstly, the smallest estimates of volume were based on sphere equation and the largest estimates of volume were based on the cube equations. Actual volume as determined using water displacement and was the smallest estimate of volume for all species (Figures 8). In this case, volume of actual volme and volume based on cube equations were used to determine number of bulbs harvested. Actual volume therefore provides an upper-limit of the number of bulbs harvested as space between bulbs is not taken into account. Water displacement has been used to determine the true volume of hardwood logs (Martin, 1984); in agricultural products (Wang and Nguang, 2008) and to determine the accuracy of volume estimations (Breiman *et al.,* 1982). The regression analyses between bulb diameter and actual volume was strong for species such as *B.volubilis, B. disticha, Crinum* species *D. robusta* and *U. epigea* (between r^2=0.96 and r^2=0.75) (Figure 8) suggesting that in the future, bulb diameter can be determined in the market and bulb volume will be closely related. Regression analyses between cube estimation of bulb volume based on water displacement volume (Figure 9) also had relatively high r^2 values ($r^2 > 0.70$ for all species other than *D. altissima*) (Table 8). Once again this has important implications for use in market situations as species-specific estimates based can be determined.

The concept of individual equivalents (Williams *et al.,* 2007a) allows for a more composite understanding of harvesting and resource use in general. While data on the estimated mass of plants harvested annually informs the magnitude of resource depletion, these data would be of more use if they were translated into the number of individual plants harvested annually (Williams, 2004). By estimating overall volume at the stall and overall volume sold by traders and dividing this by the average volume of a species for the mean bulb diameter on sale, an estimation of the number of bulbs sold was determined. There was a significant difference between the two estimates of the number of bulbs harvested (Figure 13) with estimates based on actual bag much larger than estimates based on cube volume. The actual volume was very large for most species (up 2,500,000 for *D. elata*) which most likely represents an over-estimate and upper limit for the number of bulbs harvested per year for sale in traditional medicinal markets.

Importantly, although these estimations can highlight intense harvesting pressure, the numbers present more of an order of magnitude than the 'true value'. The number of bulbs harvested at Free State was greater than that at Warwick for *B. volubilis*, *D. elata*, *D. sanguinea* (Figure 12 a and b). Although the standard error of the mean was great, these estimates do provide some important information on the status of the resource base. Conservation assessments such at the Red Data list of medicinal plants often have to use extrapolations of existing data to infer impacts (von Staden *et al.,* 2009). Inferences on the extent of resource use (related to the estimated number of individuals harvested) can provide important information for conservation assessments and managers of threatened species populations.

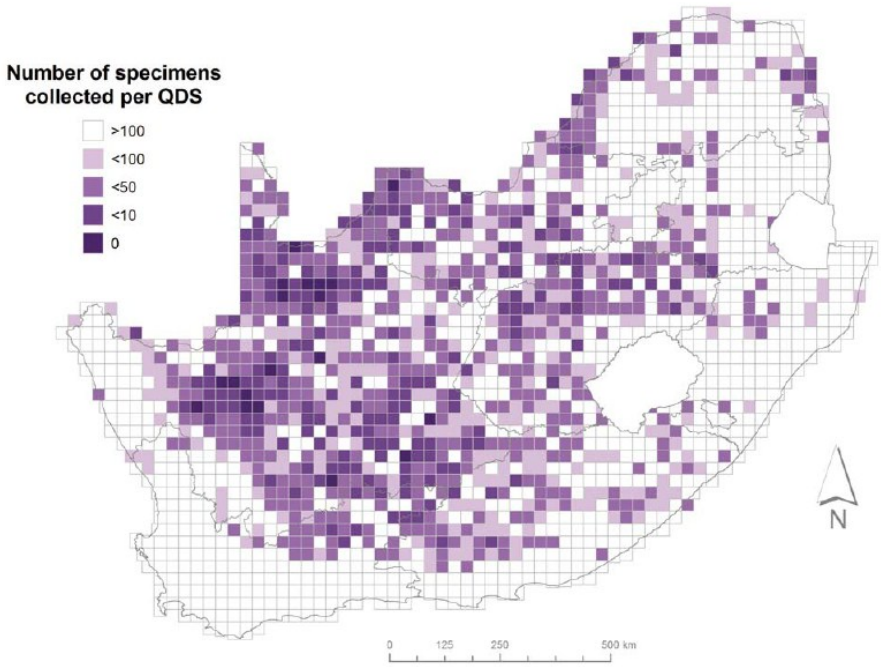
Drimia elata is not particularly popular in Warwick or Faraday, the two largest medicinal plant markets in South Africa and due to taxonomic uncertainty with *D. robusta* was listed as Data Deficient in the recent Red data list (Williams *et al.,* 2009a). At that time, the magnitude of trade in the Free State had not been quantified and data such as these provide important information for decision makers and conservation managers. This data also emphasises the need for countrywide surveys. The composition of the traders in Warwick and Free State are different as are their preferences (Table 5, Figure 1 & 2), and without countrywide samples, some species may be overlooked. One of the major priorities listed by the recent Red Data list book was an urgent focus on taxonomic monographs on all species listed as DDT (Driver *et al.,* 2009). It was estimated in 2009, that between 20-30% of plant taxa in South Africa have never been revised or have not had revisions since 1945 (Driver *et al.,* 2009). Old taxonomic revisions do not have the information required for conservation assessments.

At Warwick, *D. robusta* (currently synonymous with *D. elata*) was harvested in large numbers (c.a. 500,000 based on actual volume and 100 000 bulbs/year based on cube equations) (Figure 12 a and b). This species is very popular in Warwick although it does not appear in Free State markets (and only occasionally in Faraday markets). The R/kg value of *D. robusta* was relatively low (R10/kg) (Figure 5g), however it was cited as popular by the majority of traders (75% at Warwick) and difficult to locate (71% at Warwick) (Table 7). In this case, one source of data does not provide all the relevant information regarding the implications of trade and harvest. Although, this species is popular, used in great numbers

and difficult to locate in the wild, this has not translated in a higher R/kg value. Numerous sources of information are needed in order to properly determine the impacts of trade.

Crinum species were harvested in the greatest numbers (based on cube equations) in Warwick market (c.a. 500,000 bulbs/year based on actual volume or 120 000 bulbs based on cube equations) (Figure 12 a and b). Seventy percent of *Crinum* species at Warwick market was identified at *C. moorei* (Table 4; Chapter 3). *Crinum moorei* was classified as VU A4de in the latest Red Data book (Williams *et al.,* 2009m) mainly due to its limited distribution in KZN and intense harvesting for the *umuthi* trade. The large number of *Crinum* species bulbs harvested for sale in Warwick has negative implications for the already vulnerable *C. moorei*.

Not surprisingly, a large number of individual equivalents were calculated for *B. volubilis* (Figure 12 a and b). With market size-class distributions showing that the greatest numbers of individuals were between 1cm and 2cm in diameter (Chapter 3), the risk of harvest and trade is extremely high. In addition, unlike *D. elata* and *D. robusta*, *B. volubilis* is popular in both markets and difficult to obtain. It is especially important to consider the impacts of harvesting on population as well as landscape levels (Cunningham, 2001). The majority of known localities occur in KZN although the species was already thought to be locally extinct in many areas in the province in 1988 (Cunningham, 1988). In addition, localities occur in biodiversity hotspot areas and areas that are thought to vulnerable or endangered (Maps 1 and 2.). The remaining localities are centred around Gauteng which is highly impacted by human expansion and habitat encroachment. This distribution centred around large cities (for all species) may be due to collection effort.



Map 3: Number of herbarium specimens per QDS (Quarter Degree Square = ±676.6km^2) (From Raimondo and Von Staden, 2009).

The number of specimens collected in certain areas of South Africa is very low (Map 3) and is largely due to collection effort. Areas near roads, towns and cities are more likely to be visited by taxonomists and in areas such as the Kruger National Park, decades of study have provided large numbers of specimens. This disparity between certain areas can affect our knowledge of species distribution and range and distribution maps provided in this study (although based on numerous herbaria data) is most likely an underestimation of the true range of these species. In the same way, harvesters are most likely to overharvest and impact populations in areas close to roads, towns and cities. However, the paucity of data on plant population sizes makes it difficult to judge the annual rate of decline for a species based on off-take for the medicinal trade (Williams *et al.,* 2007b). By estimating the number of individuals and

comparing this to the number of known localities, it becomes easier to understand the order of magnitude of the trade and the ecological implications. Species with smaller distributions are more likely to be at risk. *Boophone disticha* has a very large distribution (Chapter 2) while *B. volubilis* has a comparatively small distribution. Although, *B. disticha* is traded in large numbers and is very popular, traders feel that it is not as difficult to find as *B. volubilis*. Population sizes of harvested species also provide much information regarding the regeneration ability of harvested species

At Warwick market, *D. sanguinea* is not very common and only two stalls had a small number of the bulb. Sales estimates suggest that despite this, *D. sanguinea* is actually more common in Warwick than it may appear. This also could be related to the high level of commercialism in the market: *D. sanguinea* is extremely popular at Faraday market and traders in Warwick know it as the 'Johannesburg type' of *inDogana-zimbovana,* a name given to popular species, *D. robusta* in Warwick. Traders who come down from Johannesburg with collected material to sell will be able to sell the species as it is not unknown despite the fact that it is usually collected in Gauteng (Chapter 3) and according to herbarium data is only known from localities in Mpumalanga, Limpopo, Gauteng and the North West (Chapter 2). Despite its popularity in Faraday (where interviews could not occur) and its sale in both Free State and Warwick market, *D. sanguinea* is known from only 44 known QDS points localities and although numerous populations may occur with one locality, it has a much narrower distribution than *D. elata* (74 known QDS) or *B. disticha* (168 QDS) (Chapter 2). In addition, records show that *D. sanguinea* was actively eradicated from many localities where hundreds of thousands of individuals were destroyed to prevent cattle poisoning (Stent and Curson, 1929).

In South Africa, the use of indigenous medicine is widespread, with value of traded material equivalent to state-subsidized health programmes (Shackleton, 2001). More than 1,000 species of medicinal plants are traded in southern Africa. The annual value of this trade is approximately R2 billion/year c.a. 2007 (Mander *et al.,* 2007). Contributions of natural resources to a household's total livelihood income range from over 50% in some settings to less than 20% in others. Thus, understanding the factors that influence resource use can help provide information on economic as well as conservation issues (Shackleton & Shackleton, 2006). Plant populations can be driven to extinction if harvesting increases to chase an ever-diminishing yield (Begon *et al.,* 1986). However the impacts of harvesting depends on factors such as plant part removed; the level of harvesting and the efficiency of the gatherers (Williams, 2004). For bulbous plants or smaller herbs and shrubs where the roots are entirely removed, often little sign remains of their former presence in a locality and field observations are usually under-estimates. There is a relationship between the species population size and volume of material available to harvest (Wild & Mutebi, 1996). This relationship is modified by a number of factors including species ecology and life history, as well as the growth and reproductive capacity and how this capacity responds to harvesting. Moreover, for any one species the range of harvestable quantities will vary with location, season and plant part harvested. This range can be considered the margin of vulnerability (Wild & Mutebi, 1996).

Looking at both economic value and ecological implications of trade and harvest can provide an overall indication of the importance and value of species to household income, which can be a driving factor of harvesting intensity. In both markets studied, all species contributed between 10% and 50% of total earnings. Bulb species contributed more in the less commercialised markets in the grassland regions of the Free State. With increasing populations and poverty, there may be a move towards a more commercialised state in the smaller Free State markets which would have damaging consequences on common species such *B. disticha, Crinum* species, *Bowiea volubilis* and *Drimia elata*. In the more commercialised Warwick market- the largest medicinal plant market in southern Africa- bulbs also contribute a large amount to total earnings. Although these are estimates, they do provide an order of magnitude in regards to trade and harvesting impacts. Number of bulbs purchased by consumers showed that popular species are sold in large quantities, while estimates of number of bulbs harvested show the magnitude of trade of commonly used resources. Using other information, such as R/kg, size-class structure and changes in bulb diameter (Chapter 3) and localities (Chapter 2) can provide these estimates with more value as they can indicate the number of bulbs of a certain size that are needed in each locality just to provide enough bulbs at the current harvesting rate. What is clear, however, is that harvest and trade has ecological implications for all species. The extent of these implications relates to intrinsic morphological and population characteristics, popularity and extent of harvest. Using size-class

distributions together with in-depth information on species characteristics can provide new methods of understanding the ecological implications of trade.

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CHAPTER 5
Discussion and Recommendations

1. GENERAL DISCUSSION

The relationship between human activity and the environment has created ecological, socio-economic and cultural patterns and feedback mechanisms that govern the presence, distribution and abundance of species assemblages (Farina, 2000). The trade in traditional medicinal plants in South Africa was estimated to be worth approximately R2.9 billion per year with 27 million consumers throughout the country ca. 2007 (Mander *et al.,* 2007). Bulbous species composed about 14% of the traded medicinal plant species in South Africa (Mander *et al.,* 2007), however the majority of research at the individual or population level has concentrated on a limited number of life forms and plant parts and the ecological consequences of harvest and use of commonly used bulb species is poorly known (Ticktin, 2004).

Landscape transformation is unavoidable with ongoing human population growth and socio-economic development. In addition, socio-economic development has been prioritized by the South African National Government's electoral mandate until 2014 (Coetzer *et al.,* 2010). Conservation, therefore, has to evolve to be politically acceptable and conservation decisions cannot occur in isolation any longer (Coetzer *et al.,* 2010). Apart from land use change and increased CO_2 emissions leading to global climate change, human populations impact on natural resources by using them for food, firewood and as grazing for livestock. In addition, plant species play an important role in the provision of essential services such as water and air purification, prevention of soil erosion, regulation of climate, pollination of crops, etc. (Raimondo *et al.,* 2009b). The loss of any species can, therefore, diminish the quality of our lives and our basic economic security. There has been a growing awareness of the importance of species diversity, however many species are declining to critically low levels (Raimondo *et al.,* 2009b). Conservation targets, including those set by the Convention of Biological Diversity's for 2010 have been set to try and diminish the extinction crisis. However, without an understanding and documentation of anthropogenic effects, no real decision making and conservation can take place and impacts of anthropogenic use of species can go unchecked and in some cases lead to local extirpations or even extinction (Raimondo *et al.,* 2009b).

Traditional medicinal markets can be used as a source of information for determining the impacts of plant harvesting by combining a multitude of information varying from economic returns (earnings, R/kg) to perceptions (popularity, scarcity) or volume of plant species traded (Williams *et al.,* 2001, Williams *et al.,* in press). These data can be thought of as indicators of negative effects of ecological impact (Figure 1). The most direct ecological consequences of medicinal plant harvesting are changes in the survival rates, growth and reproduction of harvested populations (Gaoue and Ticktin, 2007). However, the use of plants as resources (e.g. for medicinal purposes) can lead to local extirpations, and 80% of all plants harvested for the medicinal plant trade are estimated to lead to the death of the individual plant (Mander *et al.,* 2007).

In order to understand the totality of ecological impacts, there is a need for studies that integrate large and varied amounts of data about species of concern. All species have specific external and internal factors that influence their population dynamics. External factors are not related to medicinal market harvesting, however, they can have either a negative or positive impact on harvested populations and thus also need to be taken into account. These external factors can include, but are not limited to, herbivory, the effect of exotic invader species, climate change and fire regimes. Internal population factors can be thought of as factors that are implicit to each species and can include time to maturity, distribution and the threat level to the biome in which the species is most likely to occur (Figure 1) (Gaoue and Ticktin, 2007; Strandby and Olsen, 2008).

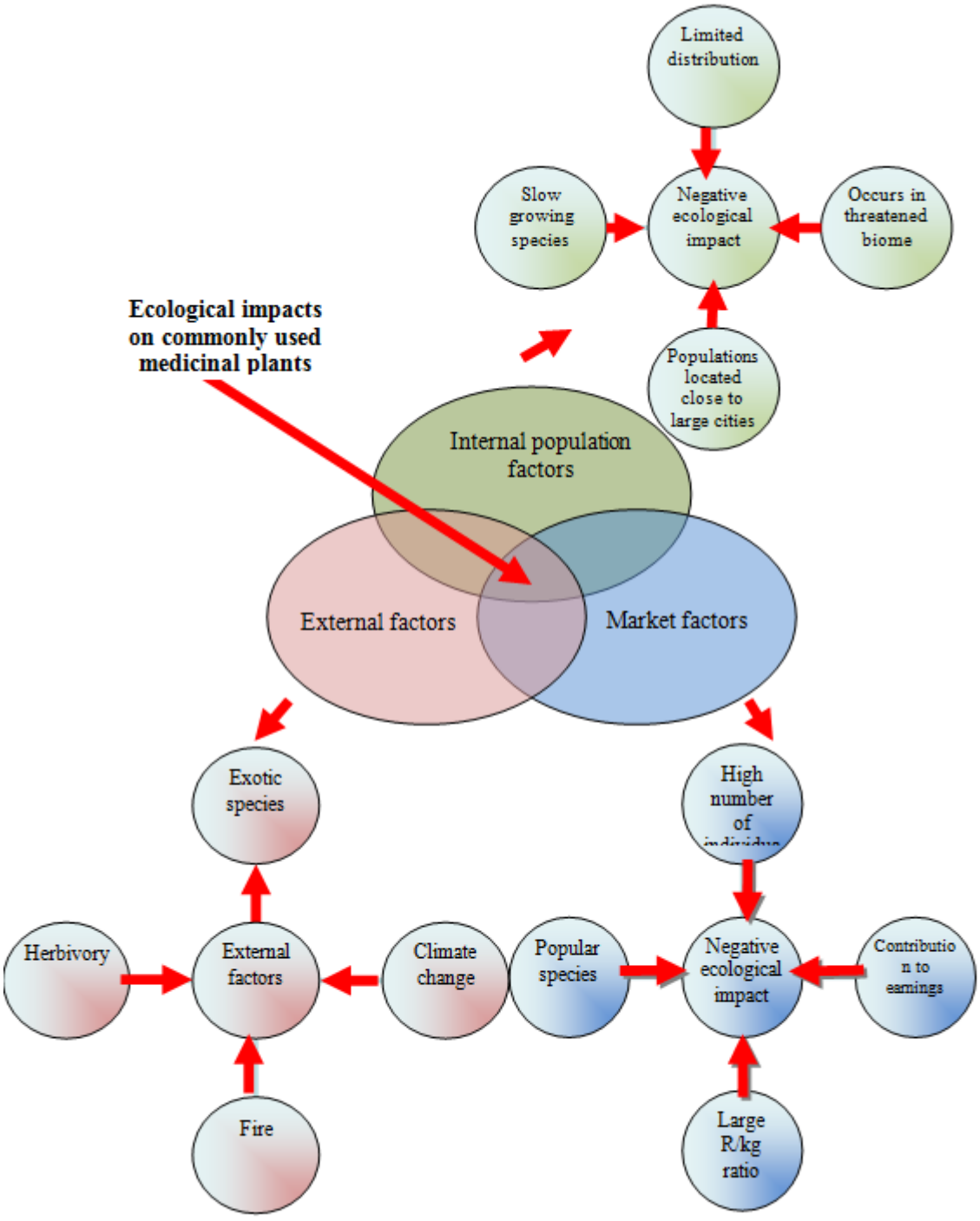


Figure 1: Integrated external, internal and market factors affecting commonly used medicinal species.

The main aim of this study was to determine the ecological consequences, together with some economic implications, of the harvest and trade in commonly used medicinal species. Chapter 2 provided the means to identify many of the species. Most medicinal market studies are based on inventories of ethnospecies (i.e. the traditional name a species may be known by) (Hanazaki *et al.,* 2000). Different traditional medicinal resources may vary in population structure, density and react differently to harvesting (Cunningham, 1993). Studies based on identification to species level allows for a greater understanding of ecological impacts of trade. Chapter 3 focused on size-class distributions, while Chapter 4 provided

estimations of the volume, economic value as well as the number of individual equivalents. This final chapter focuses on creating a synthesized and integrated discourse on all data collected, focusing on the indicators of ecological impact, together with internal and external population factors that can have an effect on the consequences of harvest and trade for medicinal purposes.

1.1. THE IMPORTANCE OF IDENTIFICATION TO SPECIES LEVEL

Medicinal plant surveys in South Africa have provided a wealth of information on the extent and impacts of trade and harvest of commonly used species (Williams *et al.,* 2007, Mander *et al.,* 2007, Cunningham, 1988; Botha *et al.* 2004a and Dold and Cocks, 2002). Species making up an ethnospecies grouping may vary greatly in their geographical distribution, population density, growth rate and population biology (Cunningham 1988). In this study, eight ethnospecies (excluding variations of spellings of the same ethnospecies name) were recorded, including: *iGibisila, iNcotho, isiKlenama, uMahlokoloza*, *skenama*, White *skenama*, *umHlabelo* and *inDongana-zimbomvana*. Using vegetative characteristics together with leaf and reproductive characters nearly doubles the number of species were identified (Chapter 2, Table 1).

Vegetative plant part identification is possible for species of the Hyacinthaceae and to a certain extent, the Amaryllidaceae. Without species-specific identification, traditional medicinal plant surveys cannot provide the detailed information needed for conservation planning and decision making. However, identification to species level is difficult, making this study one of the only medicinal plant surveys that attempts to provide a key to species level identification based on bulbous material. In the survey of some commonly traded geophytes (Williams *et al.,* 2007), there was a concerted effort to identify species belonging to the ethnospecies *skenama*; (*Drimia* species), however, due to taxonomic uncertainty and the difficulty to identify vegetative parts, some species were misidentified (*D. sanguinea* was identified as *D. elata*) (Williams *et al.,* 2007). The paper on *D. cooperi* showed that the distribution of the species was wider than previously thought (Crouch *et al.,* 2010). The previous taxonomic revision of the species had misidentified a number of specimens and this underestimated the extent of the known distribution. These examples highlight the need for vegetative identification.

One of the main factors influencing the effectiveness of medicinal plant surveys is clear taxonomic information allowing for easy identification of species. In medicinal market settings, reproductive plant parts such as flowers are very rare and most material is sterile. Identification based on vegetative characteristics is thus very important. Taxonomic differentiation of bulbous species, however, does not usually take into account distinctions in bulb colour, size, bulb scale type, shape or factors such as stinging sap or splinters (see Jessop, 1977). Identification without description of vegetative parts can lead to confusion with certain species of the Hyacinthaceae and Amaryllidaceae having very similar reproductive part characteristics, for example, *D. elata* and *D. robusta*. This taxonomic uncertainty can lead to issues surrounding the protection of the species. *Drimia elata* and *D. robusta* were both listed as Data Deficient in the recent Red Data list because of a lack of information on the taxonomic differences between the species (Raimondo *et al.,* 2009b; Williams *et al*., 2009h).

1.2. SYNTHESIS OF FINDINGS

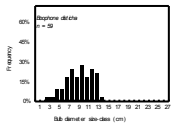
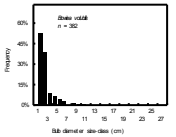
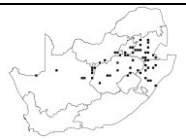
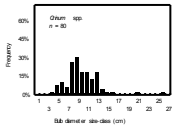
One of the key objectives of market surveys is to monitor the effects of trade and harvesting. Table 1 shows some of the key results tabulated together with Red Data List assessments for the species investigated. For the most part, the threats to species inferred by the results of this study are congruent with the Red List assessments. For example, all indicators in this study suggest that *B. volubilis* is negatively impacted by trade. The species was assessed as Vulnerable in the recent Red Data List assessment (Raimondo *et al.,* 2009a), and there has been a ≥30% decline in the population nationally over the past 30 years. With the species locally extinct in many areas of KZN and still traded in high volumes, this assessment is duly justified. *Crinum moorei* was also assessed Vulnerable due to its decline in the past and the anticipated decline in the future as a result of harvesting for the medicinal plant trade (Williams *et al.,* 2009m). *Crinum* species as a whole are popular and traded in large numbers. *Crinum moorei* is the most prevalent species in the KZN markets; in addition, it commonly occurs in human degraded habitat in KZN and is affected by the Amaryllis caterpillar (*Brithys crini*) (Nichols, 2005; Williams *et al.,* 2009m).

Urginea lydenburgensis has a very restricted distribution in Mpumalanga and any decline will have lasting impacts. The species was assessed as Near Threatened based on its restricted range, however some population decline has occurred but the extent and time frame are not known (Williams *et al.,* 2009k). *Drimia sanguinea* was also assessed as Near Threatened (Williams *et al.,* 2009j), however it has a relatively large distribution. The number of bulbs equivalent to the mean market diameter traded is approximately 900,000 in both markets combined. The species is very common in Faraday market and although no estimates could be calculated, the number of bulbs needed to sustain the trade is large. In addition, records show that the species was actively eradicated from many localities where hundreds of thousands of individuals were destroyed to prevent cattle poisoning (Stent and Curson, 1929).

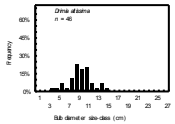
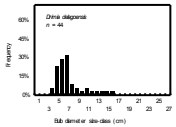
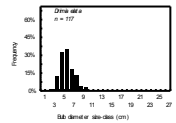
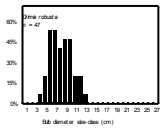
Urginea epigea was assessed as Least Concern (Williams *et al.,* 2009l); however, this study has evidence that the population is already declining. Bulb diameters reported in the literature are 30% larger than market diameters. This may be due to drying out of bulbs in the market place however this figure also suggests that harvesters no longer have access to the large bulbs they did in the past. With approximately 183,000 bulbs harvested every year for trade in Warwick market, population regeneration is likely to be affected. This species does occur in the Kruger National Park, which provides a buffer from harvesting. However, the species contributes a large percentage to total earnings and has a high R/kg ratio, which suggests that harvesting pressure will not decrease. The size-class distributions and number of individuals estimated to be harvested annually indicates that the South African population is already declining; hence, the results suggest that the species should be reassessed as Least Concern-Declining.

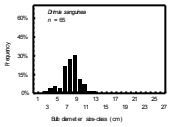
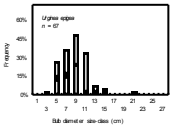
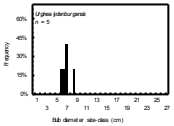
Drimia delagoensis has a relatively small geographic range and has an inverse J-shaped size-class distribution which indicates the population has been negatively impacted by harvest and trade. Of more concern is that the species did not appear in Faraday in 2001 (Williams *et al.,* 2007g) and it is now seasonally common. Thus, changes in population structure would have occurred over a small period of time given evidence of harvesting for the *umuthi* trade. The results suggest that this species should possibly be reassessed as Declining or Near Threatened as “rapid population decline in relation to life history of the taxon, in the past, present or projected into the future” (Raimondo *et al.,* 2009b) has occurred and a decline of at least 20% can be inferred.

Table 1: Synopsis of indicators of ecological impacts on commonly used medicinal plants.

Species	2009 IUCN Red List status	Indicators								
		Distribution[1]	**Market size-class distributions[2]**	**Place of harvest[3]**	**% decrease in bulb diameter reported in literature vs. markets[4]**	**Significant change in bulb diameter between 2001 – 2007 (✓=yes; ✖=no)[5]**	**Contribution to overall trader earnings[6]**	**Maximum estimated no. of individual equivalents x 1000 (calculated based on the volumes of bulbs traded at Warwick and Free State Market Combined).[7]**	**R/kg[8]**	**Minimum flowering diameter (cm)[9]**
Boophone disticha	LC-dec			78% - KZN 11%- GP 11% - Lesotho	40%	✖	Free State - ± 30% Warwick – ± 8%	±100	±8R/kg	3.6cm
Bowiea volubilis	VU A2ad			50% - KZN 40%- GP 10% -Swaziland	67%	✓	Free State - ± 45% Warwick – ± 12%	±700	±45R/kg	2.3cm
Crinum bulbispermum	LC-dec			88%- KZN 12% - GP	33%	✖	Free State - ± 30% Warwick – ± 8%	±300	±12R/kg	4.4cm
Crinum buphanoides	LC									

[1] Species distributions provided in Chapter 2
[2] Size class distributions provided in Chapter 3; Figure 1
[3] Place of Harvest is provided in more detail in Chapter 3; Figure 2
[4] More detail on percentage decrease is provided in Chapter 3; Figure 7
[5] More detail on the differences between bulb diameter between 2001 and 2007 are provided in Chapter 3; Figure 6.
[6] Contributions to overall trader earnings is provided in Chapter 4; Table 4.
[7] Volume is provided in Chapter 4; Figure 10a. The figure provided in the table above is calculated by adding together the total annual volume traded per species for Free State and Warwick and dividing by the average volume of one bulb (volume based on the mean diameter).
[8] R/Kg is provided in Chapter 4; Table 7
[9] Minimum flowering diameter is provided in Chapter 3; Table 6.

Species	2009 IUCN Red List status	Indicators								
		Distribution[1]	Market size-class distributions[2]	Place of harvest[3]	% decrease in bulb diameter reported in literature vs. markets[4]	Significant change in bulb diameter between 2001 – 2007 (✓=yes; ✖=no)[5]	Contribution to overall trader earnings[6]	Maximum estimated no. of individual equivalents x 1000 (calculated based on the volumes of bulbs traded at Warwick and Free State Market Combined).[7]	R/kg[8]	Minimum flowering diameter (cm)[9]
Crinum macowanii	LC-dec									
Crinum moorei	VU A4de									
Crinum stuhlmannii	LC-dec									
140Drimia altissima	LC-dec			50% - KZN 33% - GP 17% - EC	26%		No Data	±100	±10R/kg	No data
Drimia delagoensis	LC			100% - KZN	2.6%		Warwick – ± 12%	±450	±15R/kg	No data
Drimia elata	DDT			59% - KZN 33% - FS 8% - Lesotho	7.1%	✓	Free State - ± 15%	±1400	±35R/kg	No data
Drimia robusta	DDT	See map for *D. elata*		94% - KZN 6% - MP	14.4%		Warwick – ± 5%	±600	±10R/kg	2.8cm

Species	2009 IUCN Red List status	Indicators								
		Distribution[1]	**Market size-class distributions[2]**	**Place of harvest[3]**	**% decrease in bulb diameter reported in literature vs. markets[4]**	**Significant change in bulb diameter between 2001 – 2007 (✓=yes; ✖=no)[5]**	**Contribution to overall trader earnings[6]**	**Maximum estimated no. of individual equivalents x 1000 (calculated based on the volumes of bulbs traded at Warwick and Free State Market Combined).[7]**	**R/kg[8]**	**Minimum flowering diameter (cm)[9]**
Drimia sanguinea	NT A2d			32% - KZN 28% - FS 22% - GP 6% - NW 6% MP 6% - Lesotho	-11.4%		Free State - ± 18% Warwick – ± 18%	±900	±30R/kg	4.5cm
Urginea epigea	LC			80% - KZN 10%- MP 5% - EC 5% - Swaziland	30.4%	✖	Free State - ± 45% Warwick – ± 5%	±400	±15R/kg	7.7cm
Urginea lydenburgensis	NT B1ab (v)			100%- MP	33.0%	No data	No data	No data	±12R/kg	No data

The review of data collected in this study (Table 1) shows the resolution of detailed information traditional medicinal market surveys can provide if species-specific data is collected. It also outlines the difficulty of market surveys when identification to a species level is not possible (e.g. *Crinum* species) and highlights the areas where more information is needed. Data is available for both *B. disticha* and *B. volubilis* due to easily identifiable vegetative parts and the common occurrence of these species in medicinal plant markets of the eastern part of South Africa.

Comparisons with the recent Red Data List suggest that market data and the Red Data assessments are very similar; this is partly because preliminary data from this study was incorporated into the Red List assessments. Medicinal plant species usually have large distributions, which makes them difficult to assess in terms of the restricted range criteria (Raimondo *et al.,* 2009b). By specifically using medicinal plant surveys to infer decline in populations, assessments that are more detailed were possible. Only two commonly used medicinal species from this study are thought to be more impacted than the 2009 Red Data assessments suggests.

1.3. SPECIES DISTRIBUTION AND ECOLOGICAL IMPACTS

Distribution maps based on quarter-degree square (QDS) collected from several herbaria in South Africa provide an overall impression of both the extent of the distribution throughout the country, and the number of locations at which species occur. In general, if a species is widespread and occurs in multiple locations it is less likely to become nationally extinct, however there is ample evidence of common species becoming extinct (Gaston, 2008). Studies in the past have often focused on rare plants, as they are disproportionately vulnerable to extinction events because of the small numbers of individuals (Gaston, 2008). There is a need for national herbaria to create a bridge between local botanists and conservation, as distribution data of plant species is often based on herbarium specimens (Schatz, 2009). However, distributions based in QDS data from herbaria are affected by collection effort. Areas in the Northern and Eastern Cape have a much lower number of specimens collected per QDS than other areas (Raimondo and Von Staden, 2009). The high density of QDS points around cities in Gauteng and KwaZulu Natal is most likely related to the ease of access to species in the areas. Populations in these areas are also more likely to be impacted by harvesting, however other populations which have not been collected most likely occur in less dense areas.

Urbanisation is a dominant demographic trend with estimates suggesting that in the next 25 years, all population growth will occur with in urban areas (Pickett *et al.,* 2011).It is therefore imperative to study the relationship between conservation and urbanisation (Pickett *et al.,* 2011). In Cape Town, South Africa, the concentration of biodiversity within the city poses a challenge for conservation (Rebelo *et al.,* 2011). Threats for species around urban areas include (but are not limited to), plant collection and resource use, alien invasive species, air pollution, sewage pollution and loss of habitat integrity (Rebelo *et al.,* 2011). Although most likely related to collection effort, the co-occurrence of high numbers of QDS locations with areas of high human density (e.g. around large metropolitan areas such as Johannesburg) makes the populations occurring within these localities at higher risk of over-exploitation than species occurring in areas of low human density.

Other factors that also need to be considered include land use change, protected areas and the effects of climate change. For example, *B. disticha* is widely distributed in all provinces of South Africa. However, known populations are clustered around large cities in Gauteng, Free State, Eastern Cape and KwaZulu-Natal. These populations near cities are likely to be negatively impacted due to their proximity to human populations and ease of access for harvesters. Another concern is that the species occurs mainly in the grassland biome, which is severely threatened and has very few protected areas (Reyers *et al.,* 2001; Grobler *et al.,* 2006). Species which don't occur in protected areas do not have the buffers that protected areas provide. The number of specimens collected in certain areas of South Africa is low (Raimondo and Von Staden, 2009), and is largely due to collection effort. Areas near road, towns and cities are more likely to be visited by taxonomists. This disparity between certain areas can affect our knowledge of species distribution and range and distribution maps provided in this study (although based on numerous herbaria data) is most likely an underestimation of the true range of these species. In the same way, harvesters are most likely to overharvest and have an impact on populations in areas closer to roads, towns and cities.

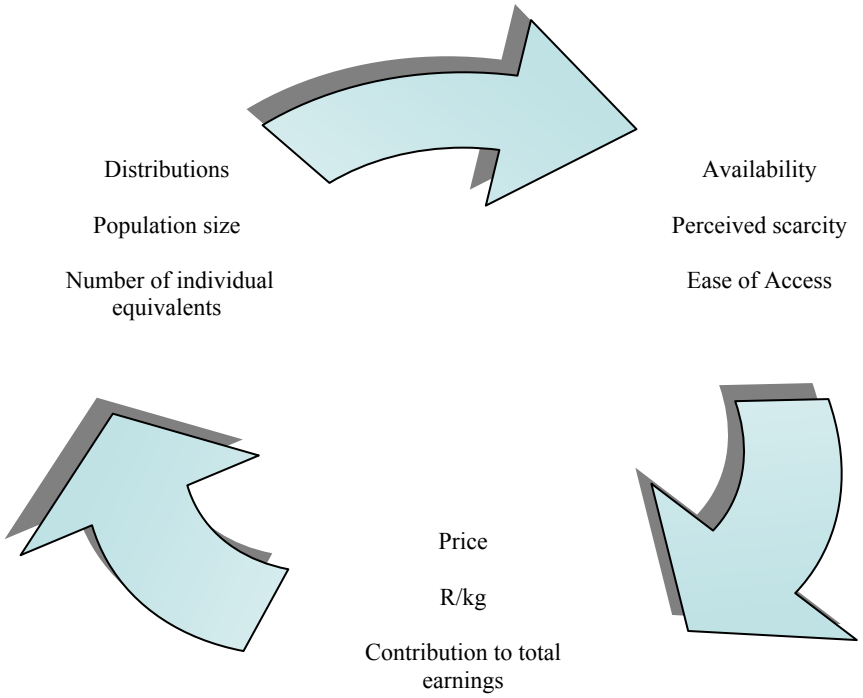


Figure 2: Conceptual diagram of the inter-relationships between population, trade and economic factors.

Effective conservation plans require accurate estimates of species distributions, such information can allow conservationists to predict how a species' distribution will respond to landscape alteration and environmental (climate) change (Hernandez *et al.,* 2006). Population size is influenced by the extent of a species' distribution. The size of the population influences the size of the resource base and hence the number of bulbs that can be harvested before the population starts to decline. Therefore, species with more restricted distributions are at greater risk of over-harvesting (Figure 2). Species that are readily available, easy to access and not perceived to be scarce usually have lower R/kg values and make smaller contributions to the overall earnings of the traders. *Urginea lydenburgensis* has a very restricted distribution (Table 1) with only a few localities known in Mpumalanga, hence increased and sustained harvesting efforts will negatively affect the species.

Another factor linked to the geographic range of the species is the possible harvesting sites available. Although the majority of the traders said that bulbs were collected in KZN (Table 1), the size of the bulbs can be related to the source. Studies on two Hyacinthaceae species, *Lachenalia* c.v. Ronina (Du Toit *et al.,* 2002) and *Ornithogalum longibracteatum* Baker (Kulkarni *et al.,* 2005) suggest that bulbs develop slower at lower temperatures (10°C), and faster at medium (15°C -25°C) than high temperatures (>30°C). The grassland biome makes up about 76% of Lesotho's land area with mean annual temperatures of about 14.7°C and approximately 40 frost days (Mucina and Rutherford, 2006). Bulbs collected from these cooler areas may be naturally smaller as the time taken to develop may be longer at these lower temperatures. These cooler temperatures could explain the smaller *B. disticha* bulbs occurring in the Free State markets as some specimens in the markets are likely to be collected from Lesotho which is cooler than South Africa.

Studies have also shown that often bigger bulbs occur in drier areas because sporadic rainfall makes the nutrient and water storage function of a bulb vital (Procheş *et al.,* 2005). In more reliable rainfall areas, bulbs are smaller and there are often decreased extinction rates. Bulb species can contribute more energy to reproduction and less to nutrient storage as resources are less sporadic in reliable rainfall areas (Procheş *et al.,* 2005). The ecology, impact of climate and intrinsic features of each species needs to be combined with market data in order to properly understand the impacts of harvest and trade. In KZN, summer rainfall is relatively predictable and reliable (Jury, 1998). Reliable rainfall would suggest that

bulbs are smaller and less likely to become locally extinct. However, in the context of South African harvesting patterns, KZN has the largest medicinal plant market in southern Africa and also has a large human population which suggests that these bulbs are most at risk.

1.4. ECOLOGICAL IMPLICATIONS OF CHANGING SIZE STRUCTURE

Resource-use scientists use size-class distributions to understand the effects of multiple uses on populations (Botha *et al.,* 2004; Wilson and Witkowski, 2003; Williams *et al.,* 2007; Helm *et al.,* 2009). Traditional healers and harvesters, however, do not take decreased bulb diameters into account if the species is still readily available, (although, they will notice a decrease in size) (Mr. Mvubu, pers. comm.). The size-class distributions of *B. volubilis* follows an inverse J-shaped curve, which is often interpreted as describing healthy and potentially growing populations (Wilson and Witkowski, 2003). This, however, may not hold true for longer-lived individuals where species can sustain population levels with low or episodic recruitment (Venter and Witkowski, 2010). In this case, the highly skewed size structure of *B. volubilis* is related to the low numbers of large bulbs available for harvest.

Demographic trends are often better described by life stages than size-class distributions (Williams *et al.,* 2006). In addition, size-class distributions allow identification of poorly represented life history stages and also the stages that are affected by variations in harvesting intensity (Williams *et al.,* 2011). Studies on the genus *Allium* suggest there are three pertinent life stages: seedlings, juveniles and reproductive adults. The juvenile stage often lasts between 6-7 years and is interspersed with dormant periods (Phillips *et al.,* 2011). If commonly used bulbs are harvested during this dormant period then individuals are unable to contribute to the population before they are harvested. Studies of the commonly used medicinal bulbs *Merwilla plumbea* (Lindl.) Speta and *Urginea maritima* L. Baker suggest that bulb size and age is highly correlated (Williams *et al.,* 2006; Williams *et al.,* 2007b; Al-Tardeh *et al.,* 2008). Due to the lack of data on the relationship between bulb age and diameter however, it was not possible to estimate the age range of the bulbs encountered in this study during the market surveys. However, a small sample of bulbs collected in this study suggests that specimens of *B. volubilis* that are about 2cm in diameter are approximately 5 years in age. If individuals take approximately 5 years to reach 2 cm in diameter, the time taken for the resource base to regenerate is large, even for small bulbed species. It is not known how long *B. volubilis* populations will be able to withstand the intense harvesting for medicinal use.

Boophone disticha is known to take between six and seven years to produce seeds (Dzerefos and Witkowski, 2001), which has severe implications as larger bulbs are targeted by harvesters for the traditional medicinal plant trade. If the time taken for an individual to reach maturity is greater than the time populations have to recover between harvests to recover, then the viability of the population is at risk and a population crash is possible. Inadequate information on the ecological productivity, growth forms, life history and conservation of the various species involved complicates management and conservation scenarios and efforts, making it difficult to set conservation priorities and define sustainable harvest levels (Ndangalasi *et al.,* 2007). This detailed information is not known for most bulbous species, especially those that have been synonymised. Detailed studies on life history types and effects are important for medicinal bulbous species.

Size-class distributions remain one of the most robust indicators of ecological impacts (Venter and Witkowski, 2010). Although market size-class distributions is based on samples purchased from traders from different markets and originating different harvesting locations, it provides an overall estimate of the availability of sizes available to harvesters. Harvesters prefer to harvest big bulbs (Cunningham, 1988) as they provide maximum return on harvesting effort, however they will harvest small bulbs if necessary. Size-class distributions suggest that there is a larger frequency of smaller bulbs in the markets (Table 1). Another indicator that highlights this increase in small bulbs is difference in diameter cited in taxonomic descriptions and the market. Data suggests that bulbs in the market are smaller than cited taxonomic references. Percentage reduction in bulb diameters varied between 2.6% to 67% for all surveyed bulb species except *D. sanguinea.* Size-class distributions provide some of the detail needed, however population studies are needed to truly understand the effects of harvest on popular species.

Information on diameter size cited in taxonomic descriptions of the species was collected (Chapter 3). However, these descriptions did not explicitly state the number of samples investigated. The diameter of

bulbs cited in taxonomic literature is not thought to be affected by drying as diameter was likely measured before a voucher specimen was prepared. However, collectors may be biased towards medium to small sized bulbs as these are likely to be flowering and also easier to collect. Very large specimens have more roots and are more difficult to remove, which may suggest that diameters cited in taxonomic literature may be slightly smaller than expected (which also infers that there's been a bigger decrease in bulb size than the results suggest). Drying is a factor that needs to be considered when using dried bulbs from herbarium specimens to infer past bulb diameters. Estimated herbarium bulb diameter increased by between 1.6% and 40%, once drying had been taken into account.

In *Ornithogalum saundersiae*, medium and large bulbs had significantly longer and thicker scapes and a greater number of florets on the inflorescence (Kariuki and Kako, 1999). In addition, larger individuals tend to produce large quantities of seed (Cunningham, 2001). These factors make medium and large bulbs highly important for population regeneration. Size-class distributions for commonly used species showed that the majority of bulbs were either between 5-7cm or 7-9cm in diameter (Figure 2; Chapter 3), and this has many implications for the reproductive health of the plant populations. Market indicators such as size-class distributions need to be related to both internal and external population factors in order for the real implications of trade to be understood (Figure 1). The bulb size-classes with the highest frequency are those most likely to be within the reproductive phase of the life-history of the species (Begon *et al.,* 1986). Removing individuals that are most likely reproductively active can create an increased negative impact since the removal of the individual not only decreases the size of the population, but also reduces the future viability of the population.

Urginea lydenburgensis and *U. epigea* are both clustering species and are similar in many ways to clonal plants. The population dynamics of clonal plants is dominated by the birth and death of vegetative reproduced parts, whereas the recruitment of new seedlings may be sporadic (Clark-Tapia *et al.,* 2005). Underground storage organs represent energy and material reserves for geophyte species; this energy reserve allows for growth pulses triggered by the onset of rain (Ruiters, 1995). These growth stages alternate with periods of prolonged dormancy, which has been found to increase fitness because dormant plants were more likely to flower the following year and less likely to die while dormant (Lesica and Crone, 2007). Since larger bulbs are more likely to contain more nutrients and water, they provide a large amount of energy to an individual plant, especially in nutrient impoverished soils. They are also more likely to survive adverse conditions in a prolonged dormant state. Furthermore, there is some evidence that larger bulbs are more likely to reproduce vegetatively (Kariuki and Kako, 1999). If individual life history strategies allocate resources to vegetative growth, then the loss of larger individuals may have even greater significance to populations as seedling recruitment may not be high.

Another factor to be considered is fire. Fire directly induces environmental changes through the alteration of temperature, oxygen concentrations in the soil, increases in resource availability and reduced plant competition. In fire prone environments, it is also a selective force that shapes the evolution of plant reproductive traits such as resprouting ability and germination (Diadema *et al.,* 2007). Within the Cape Floristic region, geophytes are common and studies have shown that persistence of geophyte species is often through the longevity of their seeds and the use of storage organs, that often reduce local extinctions (Garcia and Zamora, 2003; Diadema *et al.,* 2007). Geophyte abundance is also often linked to their adaptation to fire and the dormancy period corresponding to the fire season (Le Maitre and Midgley, 1992). In addition, bulbous and tuberous geophytes are more prone to rarity and extinction than rhizomatous geophytes (Diadema *et al.,* 2007). Although individuals from all life-history stages are needed for a healthy and growing population, large-bulbed individuals are also an important source of new individuals in the population. Their size and depth beneath the soil makes it more likely to survive incidences of fire. The number of fires per square kilometre per year is relatively high in the north-eastern parts of South Africa (Archibald *et al.,* 2010), where many of the species studied occur. The decrease in numbers of bigger bulbs has implications for bulb populations, as these populations may be less able to deal with fire disturbances.

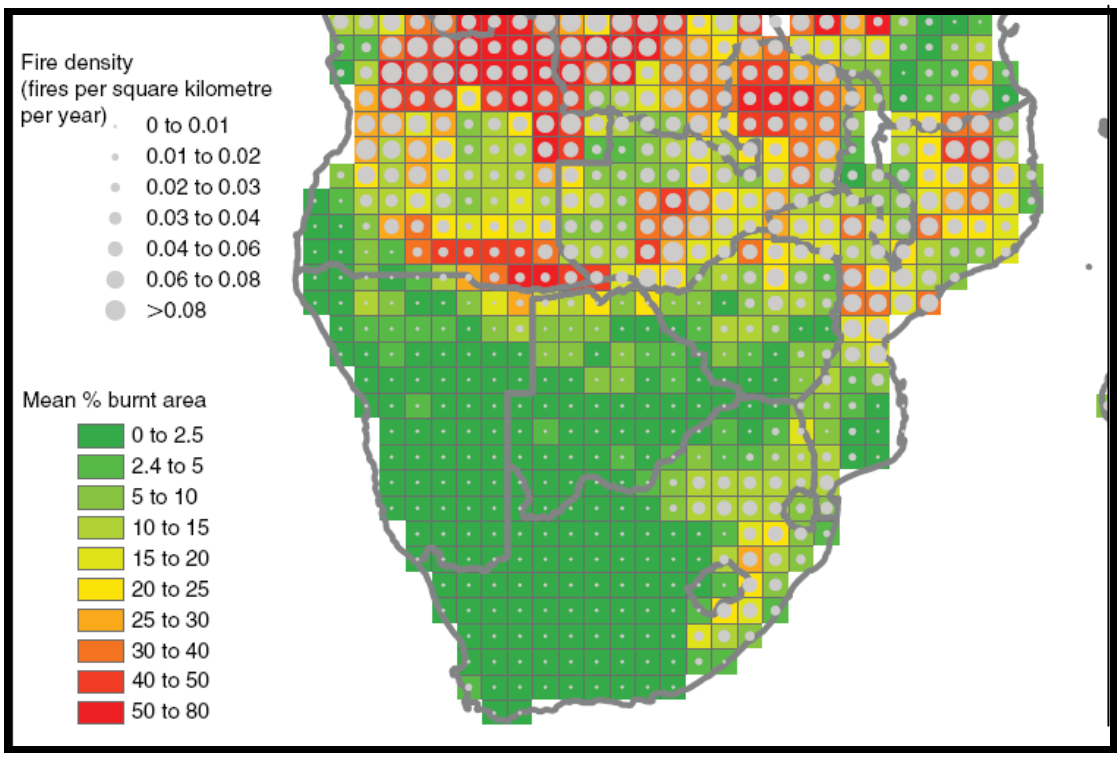


Figure 3: Maximum density of fires per square kilometre plotted over the mean % burnt area for southern Africa (from Archibald *et al.,* 2010)

Another external influencing factor on bulb populations is invasive species. Invasive species can cause numerous environmental issues including competition for resources, alteration of ecosystem properties such as nutrient cycling and hydrology and increased disturbances (Reichard *et al.,* 2005). Members of the Amaryllidaceae are susceptible to disease and pests (Dodds, 1991). The exotic invader, the South American Amaryllis moth caterpillar causes significant damage on species like *C. moorei,* which is one of the reasons that this species was assessed as Vulnerable on the 2009 Red Data List (Raimondo *et al.,* 2009m). Harvesting for medicinal purposes is not the only factor influencing bulb populations, however negative effects of medicinal harvesting, exotic invader pests and fire can combine to cause significant negative effects on populations.

1.5. ECONOMIC VALUE AND INCENTIVE FOR HARVESTING

Markets have been recognised as places that reflect regional trade and culture, and have been used to study the commercialisation and utilisation of natural products (Mati and de Boer, 2010). One of the core theoretical tenants of economics is the theory of value and the allocation of resources to competing uses. Ecological resources, however, are complicated as they are complex in nature and have considerable non-market value (Straton, 2006). The modern neoclassical idea of value includes the combination of supply and demand, and value is thought to be determined by the market place (Staton, 2006). Despite this, economists often feel that price has historically failed to critically reflect the state and quality of ecological resources (Georgescu-Roegen, 1975; Straton, 2006). In many low and middle-income countries, more than three-quarters of health care is provided in the 'non state sector' (Cross and MacGregor, 2010), in South Africa, the traditional medicinal trade represents about 5.6% of the national health budget (Mander *et al.,* 2007).

Understanding the economic value of trade can provide an indicator of the incentive for harvest and sale of specific species in the medicinal plant trade (Robinson, 2006). Although these values do not take into account the non-market value of the species, they do provide an indication of what traders and consumers feel a species is 'worth', which is related to the ease of access, availability, perceptions of scarcity and popularity of the species. Williams (2004) suggested that market conditions work against the environment. This premise is supported by data collected in this study, where trader perceptions led to high R/kg ratios and high contributions to overall earnings. However, the regression relationship between

R/kg and mass showed that bigger bulbs, in general did have smaller R/kg compared to small bulbs. This is supported by Williams *et al.,* (2007b). Both factors suggest that traders would put more effort to obtain the high value species, despite the difficulty to locate them as raised prices provide an incentive to harvest (Williams, 2003). Increased incentive leads to increased harvesting intensity and would allow for continued negative impacts on size-class distributions and the population as a whole.

Urbanisation does not preclude the use of traditional medicine and the demand in large cities is met by a large network of commercial gatherers (Williams *et al.,* 1997); however, most of the income derived from large medicinal markets does not reach rural areas (Williams, 2004). Despite this, numerous studies have shown that use of natural resources in rural communities is very important: approximately 35% of total income in Zimbabwe (Cavendish, 1999), 30% of household income in rural Malawi (Fisher 2004) and 39% in Western Ethiopia originated from environmental products (Getachew Mamo *et al.,* 2007; Babulu *et al.,* 2009). This dependence on natural resources drives the commercialisation of trade.

Traders are known to be slightly reticent about revealing the economic value of their trade as often they are sceptical of researchers, afraid of government interference and concerned that they may be taxed (Mati and de Boer, 2010). In my study, traders at Faraday refused to take part in the interview stage of the study. In Warwick, the chairwoman of the market (Z.A. Khumalo) facilitated the interviews; however, some traders were not comfortable answering questions relating to economic value. In the smaller Free State markets, a good relationship between conservation officials and traders allowed for very open discussions. It is in the context of differing perceptions of conservation agencies, scientists and medicinal studies that data on economic value must be evaluated. In all cases, the contribution to earnings (by bulbs species) was greater in the Free State markets than in Warwick market. In addition, overall trader earnings were greater in the Free State.

The overall economic value of the 'hidden economy' of the medicinal resources trade is immense, (Cunningham, 1988) and in c.2007 was worth approximately R2.9 billion, with 20,000 tonnes consumed per year (Mander *et al.,* 2007). Approximately 70% of South Africans working in the informal sector earn less than R1,000 a month (Chazan, 2005). In 2004, a review of the value of direct-use value of natural resources from several studies was R3853 per household per year (Shackleton and Shackleton, 2004). This 'environmental income' can contribute up to 40% of the total household income and because common resources are inexpensive or free, these direct-use values constitute a savings for the household (Hunter *et al.,* 2008). Surprisingly, in the more commercialised Warwick market total earnings per year per trader (for all plant parts) was significantly lower than in the small Free State stalls: approximately R12,000/year versus approximately R25,000/year respectively (Figure 2). This suggests that traders in Warwick earn about R833 per month, lower than the average calculated by Chazan (2005). In contrast, Free State traders on average earn approximately R2,018 per month (Chapter 4). This higher monthly income may be related to an increased number of traditional healers at Free State market.

Harvesting is most often a last resort activity for women with limited opportunities for earning a living, hence they can become increasingly reliant on resource harvesting for as means of income generation (Williams, 2004). In addition, poorer households are often involved in more opportunistic, low skilled and low return activities, with fewer barriers to entry (Shackleton and Shackleton, 2006) and thus the income generated by the traditional medicinal trade is increasingly important. The 2007 stipulated minimum wage in rural areas in South Africa is R713 per month and the minimum living requirement or poverty line is approximately R1,290 per month (per family of four) (Shackleton *et al.,* 2007). Earnings from trading medicinal plants in both Warwick and Free State markets is greater than the minimum wage in rural areas, which can act as an incentive for harvest and trade.

Scarcity does indeed increase the price of medicinal species (Williams, 2003; 2004); however, popularity can also act as a price stimulant. *Bowiea volubilis* was the scarcest species in this study; in both Warwick and Free State markets, it had the highest R45/kg value as well as the highest contribution to total earnings (Table 1). *Drimia sanguinea* was very popular in Faraday market, however the R/kg value was relatively low (Chapter 4). It was not very common in Free State or Warwick yet it had a high R/kg value overall (R30/kg) and the highest contribution to total earnings in Warwick market (18%). In contrast, *B. disticha* was common in both markets but had a low R/kg value. In all these cases, it is not necessarily the overall scarcity of the species but the scarcity at the specific market that increases value.

1.6. VOLUME AND NUMBER OF BULBS HARVESTED

Plant populations can be driven to extinction if there is an increase in harvesting and an ever-diminishing yield (Begon *et al.,* 1986). However, the impacts of harvesting depend on factors such as plant part removed, the level of harvesting and the efficiency of the gatherers (Williams, 2004). The quantity of individuals removed is also an important factor. Mass (often expressed as tonnes) is typically used to describe the amounts of an individual species traded, however, mass is not an easy 'visible' method of estimation, and volume is a better method of estimation as it is more visually accommodating (Williams *et al.,* 2007a). One of the benefits of the use of volume as an estimation tool for bulbs is that it allows the calculation of the number of individual harvested. In my study, the number of individuals harvested was expressed in terms of the number of 'individual equivalents' i.e. the number of individuals of a certain size harvested (Chapter 4). The paucity of data on plant population sizes makes it difficult to judge the annual rate of decline for a species based on off-take for the medicinal trade (Williams *et al.,* 2007b). By estimating the number of individuals and comparing this to the number of known localities, it becomes easier to understand the order of magnitude of the trade and the ecological implications (Williams *et al.,* 2007b)

Medicinal plants are used in a multitude of ways; this suggests that medicinal plants should be evaluated on a case specific basis (Dzerefos & Witkowski, 2001). It is also important to appreciate the scale of cultivation required to replace harvested stocks as well as to understand the extent of damage to wild populations, as this allows an understanding of the impacts of harvesting (at both an individual and population scale) (Williams, 2003). Bulb volume estimations can be very important in determining the order of magnitude of the trade. Intrinsic morphological characteristics are extremely important when looking at new, time efficient methods of estimating bulb volume.

Crinum species and *D. altissima* (from the Amaryllidaceae and Hyacinthaceae, respectively) appeared to have a similar relationship between bulb diameter and volume in that bulbs around 8cm in diameter were less than 0.3l in volume. In contrast, *B. disticha* bulbs from the Amaryllidaceae had a larger volume at similar bulb diameters (approximately 0.5l) (Figure 8: Chapter 4). Regression relationships between actual volume (based on water displaced) and estimations of volume (based on volumetric equations) (Figure 9, Table 8) were similar in numerous ways. Firstly, the smallest estimates of volume were based on sphere equation and the largest estimates of volume were based on the cube equations. Actual volume was the smallest estimate of volume (Figure 8 & 9; Table 8; Chapter 4). In this case, actual volume and volume of a cube were used to determine number of bulbs harvested. Water displacement has been used to determine the true volume of hardwood logs (Martin, 1984); in agricultural products (Wang and Nguang, 2008) and to determine the accuracy of volume estimations (Breiman *et al.,* 1982), it was also the smallest volume estimate and therefore provided an upper limit for the number of bulbs harvested. Importantly, the regression between actual volume and diameter for each species were relatively strong (Figure 9; Chapter 4), suggesting that in the future, bulb diameter can be determined in the market and bulb volume will be closely related. Regression analyses between cube estimation of bulb volume based on water displacement volume (Figure 9; Chapter 4) also had relatively high r^2 values ($r^2 > 0.70$ for all species other than *D. altissima*) (Table 8; Chapter 4). Once again this has important implications for use in market situations as species-specific estimates based can be determined.

The ability of researchers to estimate volume from stalls quickly is important and will allow for better understanding in seasonal changes in trade, differences between species and/or markets, as well change in traded volumes over time. Continued studies are vital for decision making as all species in this study except *C. buphanoides; D. delagoensis* and *U. epigea* are rated as declining (Raimondo *et al.,* 2009). Accurate monitoring is therefore essential as populations are already negatively impacted. Volume, in turn can be used to determine the number of bulbs harvested for trade in medicinal plant markets. There are different methods to estimate the number of individuals harvested in the Himalayan area of Sikkim, the number of wild collected plants is high – between 800,000 and 7,700,000 and was estimated using a kilogram of harvested individuals. The number of each species required to reach a kilogram was then estimated (Rai *et al.,* 2000). In the method used in this study, individual equivalents differed greatly by species and also in terms of the equation/method used to determine bulb volume. The greatest number of individual equivalents was determined using the actual volume (calculated using water displacement).

Cube equations did take into account the neck region of the bulb but not packing. Both estimates can create a wealth of information on the implications of continued trade.

The greatest number of bulbs traded per annum for *D. elata* - approximately 2,500,000 bulbs/annum in Free State and 500,000 bulbs/annum in Warwick (based on actual volume). *Bowiea volubilis* and *D. sanguinea* were also traded in large numbers in Free State, while approximately 500,000 bulbs/annum of *D. robusta, Crinum* species, *B. volubilis*, and *U. epigea* were traded in Warwick (Figure 12 a and b; Chapter 4). Overall, the average bulbs/annum for both markets was greatest for *D. elata, D. sanguinea* and *B. volubilis* (1,400,000; 900,000 and 700,000 bulbs/annum). Every year more than 400,000 tons of medicinal and aromatic plants from approximately 3,000 species are traded internationally (Taylor, 2008). With such a growth in demand, medicinal use threatens natural resources. The new International Standard for Sustainable Wild Collection of Medicinal and Aromatic Plants (ISSC-MAP) is intended to balance the needs of livelihoods and the plants' long term survival and involves stakeholders along the supply chain- from wild plant harvesters to sellers- in a process for determining how to sustainably harvest and trade (Taylor, 2008). A central tenet for such a standard is the ability to monitor trade and the effects of harvest on commonly used medicinal plants. Volume and number of individual equivalents provides a basis for understanding the size of trade in relation to the resources base.

2. FUTURE AREAS OF RESEARCH

With medicinal plant surveys becoming more necessary there is the opportunity for comparison for monitoring purposes. Without ongoing focus on the effects of trade on commonly used medicinal bulbs, there may be local extirpations (as with *B. volubilis* is some areas of KZN). Some important studies that need to be conducted in the future include:

- A more in-depth study on the impacts of the traditional medicinal trade on *Crinum* species As *Crinum* species were only identified after being purchased in the market, detailed data is not available for individual species. *Crinum moorei* was assessed as Vulnerable in the recent Red Data List, and detailed market information is needed for the individual species that are very prevalent in the Warwick market.

- Detailed information on the trade of commonly used medicinal bulbs could not be collected in Faraday market. Studies at the market are needed, especially on species that are very common (e.g. *D. sanguinea*).

- Detailed taxonomic studies on *D. altissima* and *U. epigea; D. elata* and *D. robusta*; and,*D. delagoensis* and *U. lydenburgensis* in order to determine whether vegetative differences are due to intra-species variability or if differences are significant at a species level.

- Temporal studies for species of concern to monitor changes in the volume, value, number of individual equivalents and size-class distributions. This is especially important for species such as *B. volubilis*, and *D. sanguinea* that are listed as Vulnerable and Near Threatened respectively.

- Population assessments of all species to determine size-class distributions, growth rates and mortality rates as well as the impact of fire, herbivory and exotic invader species on population dynamics.

- Studies on the relationship between age and diameter so that life-history stages can be determined. If necessary, individuals could be cultivated so as to determine their age. Methods to determine this relationship should be assessed.

- A detailed study of *U. lydenburgensis* is needed in the smaller markets of Nelspruit.

- *Crinum* species are often used in the horticultural industry – the impact of this on wild populations is needed.

- Modelling based on population assessments would provide useful and perceptive data that could be used to estimate yields, develop population matrix models and provide survivorship curves between growth classes.

- A more in depth province wide survey of medicinal markets in Free State is needed to determine the full scale of resource use in the area.

- The impact of wastage was not taken into account in the surveys undertaken as part of this dissertation. Market studies that focus on the impacts of wastage on individual equivalent estimates would be useful.

3. CONCLUSION

Social surveys and ethnobotanical work in local markets are the first steps in understanding patterns of demand for particular plant species, integrated with population structure and size-class distributions, it allows for an amalgamated and complex awareness of the impacts of resource harvesting. With over 30,000 species of animals and plants that are detrimentally affected by trade worldwide (Abensperg-Traun, 2009), market surveys are increasingly important to provide information on extent of trade. Sustainable use of natural resources can be defined as a level of harvest that does not impair the ability of a population to replace itself (Mutenje *et al.,* 2011), however there is a need to take into account the potential variation in harvesting strategies and their drivers (Ticktin, 2004). Poverty, low incomes and immediate survival often drives local people to overharvest at the expense of sustainability (Strandby and Olsen, 2008). Legal methods of control, however appear to have limited capabilities and instead sustainable use of species may be best achieved by gaining the support of affected communities (Abensperg-Traun, 2009).

Main themes emerging from this study include:

- Most commonly used bulbs from the Hyacinthaceae and Amaryllidaceae can be identified to species level using bulb or leaf characteristics. With the help of vegetative identification keys, more detailed information will become available for decision makers and conservationists.

- Size-class distributions of all bulb species were affected by traditional medicinal harvesting, with a decreased number of large bulbs and in extreme cases (*B. volubilis* and *D. delagoensis*) an inverse J-shaped curve suggesting that only very small bulbs are available for harvest.

- Bulbs are mainly collected in KZN and Gauteng. Populations in other parts of the country may not be as badly impacted, but country-wide population assessments are needed.

- Distribution data on geographic range of species can provide important information that can be used with market data to determine the sustainability of harvest.

- Market data collected from surveys can provide detailed information on ecological impacts if factors such as drying, geographic range and species identification are taken into consideration.

- Most bulbous species diameters were smaller than diameters reported in the literature, and temporal studies in Faraday market suggest that bulb diameters in the market are smaller than in the past. This suggests that populations are being negatively impacted

- Trade in different markets is different and different quantities and types of species are common in different markets. In order to determine the country-wide effects of trade, surveys in more than one market are needed.

- Economic value acts as an incentive for harvest of scarce species.

- Volume of bulbs traded can be estimated in a number of ways, these estimations provide an order of magnitude of the quantity of traded material. Importantly, this data can also be converted into the number of bulbs harvested per annum which together with the number of known localities, can provide an estimate of the size and number of populations needed to sustain the current trade in medicinal bulb species.

The Red Data list assessment found that of the 656 traded species, 18.9% are of conservation concern with 8.5% (56) listed as threatened (Critical (C), Endangered (EN) or Vulnerable(V)), 4.6% (30) listed as Near Threatened (NT) and 5.2% (43) listed as declining (Williams *et al*., 2013). The significant income contribution to livelihoods suggests that not all species should be limited in the same way. In South Africa, comprehensive studies on medicinal plant trade at Faraday (Williams, 2007) and at Warwick (Cunningham, 1988), provide the structure of the market to a certain extent. These studies also provide detail about the diversity of plant species traded in South Africa (together with studies by Dold and Cocks, 2002; Botha *et al.,* 2004; Mander *et al.,* 2007). More detailed studies on smaller cohorts of species (i.e. commonly traded medicinal bulbous species) can provide high resolution data for decision making and conservation planning such as Red Data List assessments. By quantifying the volume, value and number of individual equivalents for bulb species together with perceived scarcity and popularity and place of harvest, a better idea of the state of resource-base can be ascertained. Continued use of market surveys as monitoring tools is important.

This study found that many of the species studied were negatively impacted by harvest to a certain degree. All species contribute to the limited earnings traders make in medicinal markets which makes them economically important to the community. The prevention of trade through trade laws does not stop trade, but instead forces it underground. In addition, the use of cultivation is not a viable option with most bulb species being slow growing. Community owned nurseries are also not often successful due to a variety of reasons (Botha *et al.,* 2007). Convincing communities that sustainable harvest is necessary may be the best method (Abensperg-Traun, 2009), however due to the failure of the South African economy to provide jobs (Williams, 2004), harvesting and trade is sometimes the only form of income generation. Assessments such as the Red Data list Assessment (Raimondo *et al.,* 2009) highlight species that are most affected and important as a monitoring tool. However, in the socio-economic context of South Africa, trade and harvest of medicinal bulbs is likely to increase.

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APPENDIX 1

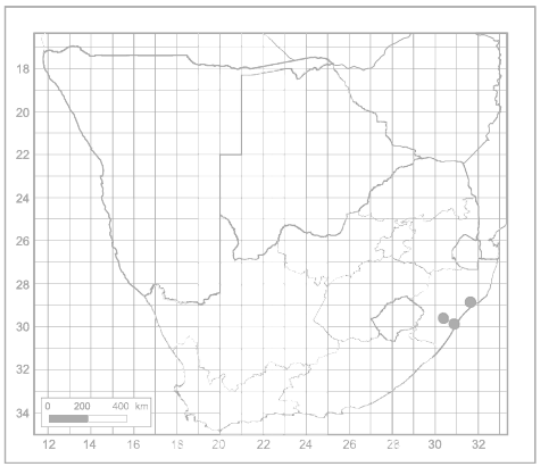


FIGURE 18.—Distribution in *FSA* region of *Diplazium esculentum*, ●.

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HYACINTHACEAE

DRIMIA COOPERI IN KWAZULU-NATAL, AND THE ETHNOMEDICINAL TRADE

Drimia cooperi (Baker) Baker is currently regarded as being restricted to the Eastern Cape Province (Jessop 1977; Manning & Goldblatt 2006). Within this province, Jessop (1977) recorded it from only the Stutterheim and Butterworth Districts, but more recent collections (*Bester 1529* NH) extend its known range northwards to Maclear (Figure 19).

Following the appearance of bulbs of an unknown member of the Hyacinthaceae in late 2004 in the Warwick Triangle medicinal market in Durban, plants purchased were grown on to flowering and subsequently identified as *D. cooperi*. This collection of market-traded material (*N.R. Crouch 1038* NH) was sold under the isZulu name *umahlokoloza*, and noted by the trader to have been harvested in the Eastern Cape, although further details on the locality were not forthcoming. The bulbs of this species are distinguished from other Hyacinthaceae in trade on the basis of a combination of characters: their medium size (± 50 mm diameter), flesh-pink to salmon-orange colour, and loosely arranged scales (Figure 20A). The bulb scales are not thickly succulent and brittle, but rather of a tough fibrous yet semi-succulent nature. Among other Hyacinthaceae in trade in KwaZulu-Natal, the fibrous character of the bulb best approximates that of *Drimia altissima* (L.f.) Ker Gawl., although the tough scales are tightly packed in this latter species. Notably, the vernacular name *umahlokoloza* is also applied in Durban to *D. altissima* (*N.R. Crouch 792* NH). We have since observed *D. cooperi* in the Warwick Triangle market on two further occasions during infrequent visits, suggesting that this taxon is more numerous and possibly more widely distributed than indicated by herbarium vouchers. Its Red List assessment, based

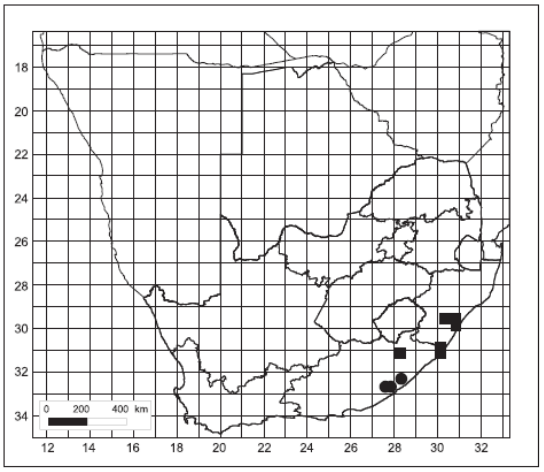


FIGURE 19.—Known distribution of *Drimia cooperi*, according to Jessop (1977), ●, with additional localities, ■, following a re-assessment of herbarium materials.

on 2001 IUCN Red List criteria, is currently VU A2ad; C2a(i) (Williams & Crouch 2009). The rationale for this Vulnerable assessment is that the species is estimated to have experienced a decline of more than 30 % during the last 30 years, attributed to land transformation and medicinal plant harvesting. The extant subpopulations are fragmented and suspected to occur in fewer than 10 locations. Furthermore, the population size is estimated to be less than 10 000 mature individuals, and the number of mature individuals that have been recorded in a subpopulation is less than 100 (Williams & Crouch 2009).

In flower, *Drimia cooperi* produces inflorescences up to 600 mm tall, with flowers presented on pedicels no longer than 4 mm (Figure 20B). The perianths are shorter than 6 mm long. Plants bear 2–4 sublinear leaves, each up to 270 mm long and 13 mm broad. The species was considered by Jessop (1977) to occupy rather an isolated position in the genus, although its shows similarities in floral characteristics to *D. anomala* (Baker) Baker, another species with its primary distribution in the Eastern Cape, though typically in more arid situations. *Drimia anomala* is separated by its rigid, terete leaves, which are usually produced singly each season (Dyer 1951) and its shorter bracts up to 1 mm long, and longer pedicels, up to 13 mm (Jessop 1977). Although *D. delagoensis* (Baker) Jessop is keyed out by Jessop alongside *D. cooperi*, their distribution ranges do not overlap. *D. delagoensis* possesses predominantly epigeal bulbs of an olive-green and silvery brown colour, the scales of which are somewhat more succulent, and brittle rather than fibrous. The leaves are narrower too, thicker, and strongly channelled on the dorsal surface.

Subsequent examination of herbarium specimens at NH has revealed a flowering voucher (*W.J. Lawson 584* NH) documenting the presence of *Drimia cooperi* in KwaZulu-Natal for more than half a century. Jessop, in revising *Drimia* and allied genera, evidently did not utilize NH collections and accordingly missed the significant collection by Lawson. Further NH accessions misidentified as *Urginea kniphofioides* Baker are here assigned to *D. cooperi*. Subsequent to Lawson's gathering, an imperfect collection was made (*E.J. Moll 1869* PRE) during August 1965 on the fringes of what was then the Oribi aerodrome in Pietermaritzburg. As only plants in bud were found and collected by Moll, this would account for reticence on the part of Jessop to identify this specimen as *D. cooperi*, thereby reflecting a significant range extension for the species.

A recent field trip (October 2008) to Pietermaritzburg surrounds to revisit the perimeter of Oribi Airport has revealed that this species is still to be found in grassland bordering the cordoned off area. The species is also extant within the Hesketh Conservation Area adjacent to the old Roy Hesketh racetrack in Hayfields, a 65 hectare site of grassland and savanna that since 1995 has been afforded some protection by the local municipality. At both sites, plants grow in shallow clay soils overlying Lower Ecca Shale in vegetation corresponding to Ngongoni Veld (Svs 4) (Rutherford *et al*. 2006). The hypogeal bulbs develop a 20–30 mm long neck that protrudes above the soil surface. Residual fibrous leaf bases persist to provide the bulb apex with protection from flames, and necks were observed to be intact following veld fires that occurred approximately one month prior to the site visits. Although flowering was observed on these occasions, the extent to which fire stimulates this process is presently unknown. The linear leaves of *D. cooperi* are partly synanthous, with a single inflorescence produced per bulb, and within a single subpopulation at Oribi in Pietermaritzburg, two floral colour forms are evident: tepal segments are either cream-coloured with green central stripes, or salmon-brown with brown stripes. Geophytes associated with *D. cooperi* at Oribi include *Cyrtanthus breviflorus* and *C. contractus* (Amaryllidaceae), *Ledebouria ovatifolia*, *Albuca virens*, and *Schizocarphus nervosus* (Hyacinthaceae). At the Hesketh site, *Albuca* sp. cf. *pachychlamys* Baker grows alongside *D. cooperi*. Small bulb clumps of up to six plants occur, indicating limited vegetative reproductive capacity.

Additional records from the Umtamvuna Nature Reserve in southern KwaZulu-Natal document the occurrence of *Drimia cooperi* in the intervening part of its range (Figure 19), and show that it occurs within at least this formally protected area.

Our investigation has revealed that plants growing in Pietermaritzburg, and those reputedly harvested in the Eastern Cape, differ in several respects from the ones described by Jessop (1977). Whereas Jessop (1977) described the bulb scales as more or less firmly arranged, we observed the scales to be loosely attached (Figure 20A), although we do not dismiss the possibility that this is turgor-related. Such is their looseness that *Drimia cooperi* bulbs readily disintegrate if cut tangentially in the course of preparing herbarium specimens. This phenomenon would account for the scale-depleted bulb specimen (*H.G. Flanagan 1302* PRE), essentially the central core, that seemingly informed Jessop of bulb shape and dimensions. Given the difficulty of pressing these organs, most sheets of this species lack well-preserved bulbs. The largest field bulb measured 80 × 75 mm (excl. neck), as opposed to the length range of 25–50 mm recorded earlier (Jessop 1977). Such non-representative herbarium bulb vouchers and associated artifactual information (Baker 1897) were earlier noted by

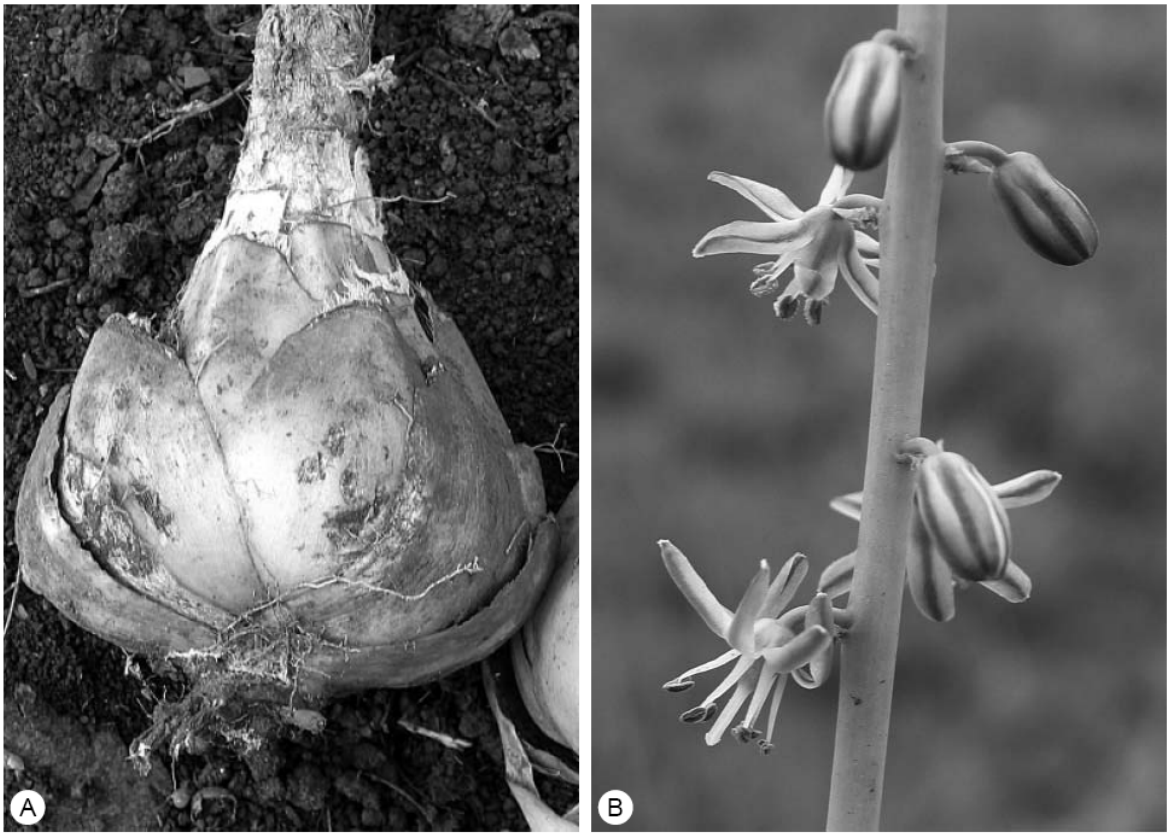


FIGURE 20.—*Drimia cooperi, N.R. Crouch 1180* (NH): A, bulb; B, median portion of inflorescence. Photographs: N.R. Crouch.

Dyer (1942) for *D. delagoensis*. As indicated above, the scales of *D. cooperi* were uniformly dark salmon-orange or flesh-coloured, rather than 'more or less white' as indicated by Jessop—a likely artifact of the preservation process. Perianth segments in the field were observed to spread, as anticipated by Jessop (1977), with margins distinctly rolled under (Figure 20B). The stability of this margin character has not been ascertained. Consideration of the holotype of *Urginea echinostachya* Baker has revealed this to be conspecific with *D. cooperi* rather than with *D. macrocentra* (Baker) Jessop as concluded by Jessop (1977). The type of *Urginea echinostachya* is of a plant with a peduncle substantially less stout at the base (± 4.5 mm diameter) than that of *D. macrocentra* (± 25 mm diameter). The raceme of the *U. echinostachya* type is less dense and the flowers have shorter perianths.

Drimia cooperi *(Baker) Baker* in Flora capensis 6: 443 (1897). *Ornithogalum cooperi* Baker: 284 (1873). Type: Cape [Eastern Cape], 'ad oram orientalis', *Barber s.n.* (TCD, lecto., designated by Jessop: 287 (1977); –K, photo.!).

Urginea echinostachya Baker (1897), syn. nov. Type: Natal [KwaZulu-Natal], Inanda, *J.M. Wood 276* (K, holo.!; NH, iso.!).

Additional specimens examined

KWAZULU-NATAL.—2930 (Pietermaritzburg): Oribi, Pietermaritzburg, (–CB), 25-09-1957, *W.J. Lawson 584* (NH); Oribi aerodrome, Pietermaritzburg, grassland, 730 m, (–CB), 17-08-1965, *E.J. Moll 1869* (PRE); Hesketh Conservation Area, top of Hayfields, Pietermaritzburg. To west of old Hesketh racing track, 700 m, S 29° 36' 59.68", E 30° 25' 30.73", (–CB), 12-10-2008, *N.R. Crouch 1179* (NH); grassland adjacent to Oribi Airport alongside railway line near Oribi Village, Pietermaritzburg, 710 m, S 29° 38' 36.64", E 30° 24' 7.57", (–CB), 12-10-2008, *N.R. Crouch 1180* (NH); Inanda, (–DB), October, *J.M. Wood 276* (NH); New Germany, mountain ridge, along M19, ± 700 m from Otto Volek Drive towards Blair Atholl, 300 m, (–DD), 17-09-1998, *Y. Singh 402* (NH). 3030 (Port Shepstone): Umtamvuna Forestry Reserve, grassveld, (–CC), 22-09-1966, *R.G. Strey 6967* (NH). 3130 (Port Edward): Umtamvuna Nature Reserve, Pont Outpost, grassland, (–AA), 11-09-1983, *A. Abbott 1313* (NH), 300 m, (–AA), 01-09-1994, *A. Abbott 6268* (NH, PRE); Umtamvuna Nature Reserve, Clearwater, grassland, 240 m, (–AA), 14-08-1985, *A. Abbott 2704* (NH). Without locality: purchased at Warwick Triangle medicinal plant market, Durban, 01-12-2004, *N.R. Crouch 1038* (NH); 23-01-2008, *V.J. Brueton 33* (J).

EASTERN CAPE.—3128 (Umtata): Maclear, Farm Sunny Slopes, 1 300 m, S 31° 6' 54", E 28° 24' 29", (–AB), 06-11-93, *S.P. Bester 1529* (NH). 3227 (Stutterheim): near Komgha, grassy hills, 605 m, (–DB), December 1892, *H.G. Flanagan 1302* (PRE).

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APPENDIX 2

MEDICINAL USES AND PHYSIOLOGICAL EFFECTS

Species	Medicinal uses	Physiological effects
Boophone disticha	The dry outer scales of the bulb are used as an outer dressing after circumcision and are also applied to boils and septic wounds (van Wyk *et al.,* 1997). Bulb decoctions are administered by mouth or as enemas to adults suffering from headaches, sharp chest pains and persistent bladder pains (Hutchings *et al.,* 1996). In addition, bulbs are taken as narcotics by the Sotho and Xhosa (Watt and Breyer-Brandwijk, 1962) and can be used as a sedative or for divination purposes as large doses elicit visual hallucinations (van Wyk *et al.,* 1997). The bulb was also used as arrow poisons by the San and Khoi (Hutchings *et al.,* 1996).	Bulbs are reported to have caused both acute and fatal poisonings in human beings (Hutchings *et al.,* 1996). Symptoms include unsteady gait, dryness of mouth, thirst, nausea, vomiting, giddiness and impaired vision. In addition, the scent of the flowers and inhalation of pollen can sometimes cause headaches, sore eyes and drowsiness (Batten and Bokelmann, 1966).
Bowiea volubilis	Bulbs are used in potions taken by men as love charm emetics (Gerstner, 1939). Bulbs are also taken as infusions during pregnancy to facilitate delivery and to procure abortions (Gerstner, 1941). In addition, hot infusions of outer bulb scales are used to treat dropsy (Watt and Breyer-Brandwijk, 1962), and lotions are made to treat sore eyes, skin diseases and for protection during travelling (Hutchings *et al.,* 1996). Decoctions of bulb scales are taken for bladder pain associated with venereal disease and are used as purgatives by the Xhosa (Hutchings *et al.,* 1996).	All parts of the plants are toxic and both human and animal deaths have been recorded, and this is usually attributed to cardiac failure (Watt and Breyer-Brandwijk, 1962). Additionally, bulb sap can cause severe itching and dried can irritate damp skin (Gerstner, 1941), and bulbs are reported to cause haemolysis, vomiting and purging.
Crinum bulbispermum	This species is used in a multitude of ways by the Zulu: roasted bulbs are applied to aching joints, rheumatism, varicose veins and backache. They are also used as poultices for septic sores and abscesses (Hutchings *et al.,* 1996). Leaves are used to bind dressings and flowers are bound over swollen joints to reduce swellings, while chopped leaf decoctions are taken as treatment for rheumatic fever. Unspecified parts are also used in mixed infusions called *unembe* and are taken during pregnancy to ensure an easy delivery (Gerstner, 1941; Hutchings *et al.,* 1996). Additionally, the Sotho use the species as treatment for colds, to stimulate breast milk and as protective charms, and the Tswana use bulbs to treat rheumatism, aching joints, septic sores and bladder infections (Watt and Breyer-Brandwijk, 1962; Hutchings *et al.,* 1996).	Numerous alkaloids have been isolated from the species together with steroidal and flavonoidal constituents (Hutchings *et al.,* 1996). Extracts of the bulbs are slightly effective in the treatment of malaria (Watt and Breyer-Brandwijk, 1962). Studies also suggest the extracts of the leaves sedative and antioxidant activities (Ratnasooriya *et al.,* 2005). The alkaloid constituents isolated in the species appear to have antitumour, hypotensive and analgesic effects (van Wyk *et al.,* 2002).
Crinum buphanoides	As this species is not often recorded in market surveys, species-specific medicinal uses are not known. However, *Crinum* species are used in a variety of ways. The Zulu use roasted bulbs for relief of aching joints, rheumatism, varicose veins and backache; in addition, poultices are applied on septic sores and abscesses (Roberts, 1990; Hutchings *et al.,* 1996). Decoctions of	*C. buphanoides* has not been tested and thus its chemical constituents have not been isolated. However, various alkaloids have been isolated in *C. bulbispermum* (El-moghazi and Ali, 1976; Elgorashi *et al.,* 2003), *C. moorei* (Elgorashi *et al.,* 2001; Elgorashi *et al.,* 2003), *C. lugardiae*

Species	Medicinal uses	Physiological effects
	bulbs are also taken for swelling of the body, urinary tract problems and as blood purifiers, while chopped leaves decoctions are taken for rheumatic fever. The Sotho plant the species as a protective charm (Jacot and Guillarmod, 1971).	(Elgorashi and van Staden, 2001) and *C. macowanii* (Elgorashi *et al.,* 2003), and therefore it is likely that *C. buphanoides* has similar alkaloid constituents. Various effects have been ascribed to such alkaloids including anti-tumour, hypotensive and analgesic activity (van Wyk *et al.,* 2002).
Crinum macowannii	Bulbs are used in decoctions to treat swellings of the body and urinary tract infections (Hutchings *et al.,* 1996). The species is also used in the treatment of scrofula, micturition, blood cleansing and rheumatic fever as well as skin problems such as sores, boils and acne (van Wyk *et al.,* 2002).	Numerous Amaryllidaceae alkaloids have been isolated in *C. macowanii* including alkaloids such as lycorine, crinine, powelline, crinamine, crimamidine and cherylline (Elgorashi *et al.,* 2002). Lycorine has been found to have many biological effects, including antitumour, hypotensive and analgesic properties (van Wyk *et al.,* 2002). The species has also been found to be highly active against flaviviruses yellow fever and Japanese encephalitis (Hutchings *et al.,* 1996).
Crinum moorei	Bulb decoctions of this species are taken by the Zulu for swelling of the body and urinary tract problems and unspecified parts are used medicinally for cattle (Hutchings *et al.,* 1996).	Thirteen alkaloids have been isolated from *C. moorei*; these include bulbispermine and mooreine (Elgorashi *et al.,* 2001), lycorine, cheryrilline, crinamidine, crinidine, dihydocrinidinr and powelline (Watt and Breyer-Brandwijk, 1962). These compounds are thought to have various effects, including anti-tumour, hypotensive and analgesic activity (van Wyk *et al.,* 2002).
Crinum stuhlmannii	Bulb decoctions of the species (like *C. moorei*) are used for swelling of the body and urinary tract problems. Additionally, unspecified parts are used medicinally for cattle (Hutchings *et al.,* 1996). Water extracts are also thought to cure cancer (Nair *et al.,* 1998).	Novel alkaloids such as delagoensine and delagoenine have been isolated in the species together with alkaloids that are widely distributed in the genus (Lycorine). Lycorine, in particular has many biological and pharmacological activities (antitumour, hypotensive and analgesic activity) (Nair *et al.,* 1998; van Wyk *et al.,* 2002).
Drimia altissima	*D. altissima* is known to be used as poultices for rheumatic swellings and gouty limbs as well as to treat bronchitis, asthma, hoarseness and influenza (Hutchings, 1997). Additionally, it is used to treat gastro-intestinal ailments (McCartan and van Staden, 1999).	This species is also toxic to stock, with symptoms resembling those of *Drimia sanguinea* (Watt and Breyer-Brandwijk, 1932). Irritation when rubbed on skin is also noted and is due to the presence of calcium oxalate, which is grouped into bundles known as raphides and are ca. 200–300 μm long (Cogne *et al.,* 2001). The species exhibits digitalis-like action and possesses a caustic sap (Pohl *et al.,* 2001).

Species	Medicinal uses	Physiological effects
		Bufadienolides have also been isolated from the species (Pohl *et al.,* 2001).
Drimia cooperi	The species is known as *uMahlokoloza* in the Warwick market where it has been collected (interestingly, this is the same as *D. altissima* and *U. epigea*) and is most likely to have similar medicinal uses. *D. altissima* is known as to be used as poultices for rheumatic swellings and gouty limbs as well as to treat bronchitis, asthma, hoarseness and influenza (Hutchings, 1997). Additionally, it is used to treat gastro-intestinal ailments (McCartan and Van Staden, 1999).	No irritation was noted when handling the species but inner bulb scales may have a caustic sap. The presence of caustic sap indicates the presence of bufadienolides and symptoms of poisoning would be similar to those seen in 'Slangkop' poisoning.
Drimia delagoensis	The bulbs of this species are used in *intelezi* mixtures (as a protective charm) and are also used to protect animal skins against dogs (when they are being dried) (Hutchings *et al.,* 1996). Decoctions of bulbs are also taken orally for the treatment of broken bones (Koorbanally *et al.,* 2005b).	Sap from the bulb irritates the skin and causes severe itchiness (Hutchings *et al.,* 1996) and its use as a dog deterrent highlights its distasteful qualities. However, livestock feeding experiments indicate that *D. delagoensis* is non toxic and biochemical analysis isolated a homoisoflavanone rather than a bufadienolide (which is common on other species within the Drimia genus). This is the only species within the genus *Drimia* that has had a homoisoflavanone isolated (Koorbonally *et al.,* 2005b).
Drimia elata	The bulb is used to treat high blood pressure (McCartan and van Staden, 1999). In addition, bulb scales are rubbed on the chest for stabbing pains and are used in protective charm mixes known as *intelezi* (Hutchings *et al.,* 1996). The leaves are said to be a diuretic, emetic and expectorant and are used to clean the bladder and treat diseases of the uterus (Watt and Breyer-Brandwijk, 1962; van Wyk *et al.,* 2002).	The bulb scales and leaves produce a stinging effect when rubbed on the skin and the rash can persist for up to 24hours, with the stinging effect of the leaves being greater than that of the bulb scales (Hutchings *et al.,* 1996). The pharmacology of *D. elata* seems to be unknown but its similarity with *D. robusta* and *D. sanguinea* suggest the presence of both calcium oxalate crystals and bufadienolide compounds (van Wyk *et al.,* 2002). Symptoms of poisoning would be similar to that of Slangkop poisoning and the species may implicated in cases of stock poisoning. These symptoms include: frequent urination, diarrhoea, muscular tremors, increased respiratory rate and later weak and slow heart rate (Marx *et al.,* 2005).
Drimia robusta	*D. robusta* is heavily utilised medicinal bulb and is used as an expectorant, emetic and enema to treat feverish colds (McCartan and Van Staden, 1999). Bulbs are also used in protective charm mixtures called *intelezi* and to treat diseases of the uterus and to promote the healing of broken bones (Pohl *et al.,* 2001).	The plant is thought to be toxic to stock (Hutchings, 1997). Symptoms include dyspnoea, quickening and then slowing of the pulse and general muscular paresis. The bulbs cause irritation when handled due to crystalline needles of calcium

Species	Medicinal uses	Physiological effects
		oxalate (van Wyk *et al.,* 2002). In addition, the species has been found to contain bufadienolides (Pohl *et al.,* 2001).
Drimia sanguinea	The species is commonly used as an expectorant, emetic, heart tonic, diuretic and for wound healing and is a very important traditional medicine (van Wyk *et al.,* 2002). In addition, it has been used as an abortifacient, treatment for venereal diseases, abdominal pain, backache and hypertension (Marx *et al.,* 2005). It is very poisonous (Dyer, 1977) and is a major cause of accidental deaths by people using traditional medicine. The species also causes major stock losses (Dyer, 1977).	The main toxin is cardiac glycoside (bufadienolide) which produces gastrointestinal symptoms, including nausea and vomiting (van Wyk *et al.,* 2002). The cardiac glycoside binds to extra cellular binding sites on cell membranes, especially of conducting tissues such as nerve fibres, cardiac-, skeletal- and smooth muscles (Marx *et al.,* 2005). In stock animals, the symptoms of what is known as 'Slangkop poisoning' have been recorded and consist of frequent urination, diarrhoea, muscular tremors, increased respiratory rate and later weak and slow heart rate (Marx *et al.,* 2005).
Urginea epigea	The bulbs are used as soap and for the treatment of backache in Swaziland (Koorbanally *et al.,* 2004) and in Sekhukhuneland; the smoke of smouldering bulbs is inhaled to relieve headaches (Dyer, 1947). It is also a treatment for colds (McCartan and van Staden, 1999).	The bulb sap of *U. epigea* usually induces a mild skin irritation when rubbed on the skin. This species has not been implicated in any stock poisoning, however the presence of bufadienolides suggest that these may occur (Koorbanally *et al.,* 2004). The physiological effects of such poisoning would be similar to 'Slangkop' poisoning of *D. sanguinea* and would most likely include symptoms of frequent urination, diarrhoea, muscular tremors, increased respiratory rate and later weak and slow heart rate (Marx *et al.,* 2005).
Urginea lydenburgensis	The bulb is used internally for the treatment of asthma and itching of the skin and can be used in conjunction with *D altissima* and *U. epigea*, respectively to relieve asthma and blood impurities. Swazi traditional healers use the species to alleviate body pains (possibly rheumatism) (Crouch *et al.,* 2006).	Phytochemical analysis has indicated the presence of novel bufadienolides (Crouch *et al.,* 2006). The species has been indicated in cases of stock poisoning and toxicology tests have shown that the species is highly toxic (van der Walt and Steyn, 1939). Symptoms of poisoning include apathy and severe diarrhoea (consistent with cardiotoxicosis) (Crouch *et al.,* 2006).

APPENDIX 3

SURVEY QUESTIONNAIRE

Questionnaire number		Interviewer	
Date of interview		Location	

Trader information: Look at the trader and write down whether they are male or female and estimate how old they look. Ask them where home is and if they are a traditional healer or not.

Gender		Ethnicity	
Healer? (Y/N)		Where is 'home'?	
Visual estimation of age			

Species information:

1.) Look at all the species present at the stall. Estimate the % of the total volume, i.e. 10% of total	Ncotho	Gibisila	*Mduze*	*uMahlokoloza*	*UmHlabelo*	*skenama/ inDongana-zimbomvana*	
				D. altissima	*U. epigea*	*D. delagoensis*	
				D. cooperi		*D. elata*	
						D. robusta	
						D. sanguinea	
						other	

2.) Look at all the species present at the stall. Estimate the total volume present by imagining the numbers of checkers would be filled. (i.e. ¼ checkers)	Ncotho	Gibisila	*Mduze*	*uMahlokoloza*	*UmHlabelo*	*skenama/ inDongana-zimbomvana*	
				D. altissima	*U. epigea*	*D. delagoensis*	
				D. cooperi		*D. elata*	
						D. robusta	
						D. sanguinea	
						other	

For *Mduze*:
Look at the bulbs on sale and see if you can see a difference in the bulbs on sale using the photos below. Then estimate the % of each bulb type present.

Picture						Other
Species	*C. stuhlmannii*	*C. moorei*	*C. buphanoides*	*C. bulbispermum*	*C. macowanii*	
3.) % of total						
4.) Where from?						
5.) Proportion of *Brunsvigia* species						

For each species, look at a few of the most common sized bulbs and use the diameter figure to estimate the mean bulb size at the stall. Work out the % of each size at the stall

6.) Estimate the % of bulbs of each size present	<20mm	*B. disticha*	*Crinum spp*	*D. delagoensis*	*D. elata*	*D. robusta*	*D. sanguinea*	*U. epigea*	Other
	21-40mm								
	41-60mm								
	61-80mm								
	81-100mm								
	101-120mm								
	121-140mm								
	141-160mm								
	161-180mm								
	181-200mm								
For *B. volubilis*: number of sachets on sale:									

7). Do you buy this species you/your family harvest it? (x or ✓)		
Buy:	Sometimes both	Self harvest:

8. Who do you **buy** it from, and where do they come from? What province?		And/ OR	9. Where do **you harvest** it from? (private, farms, nature reserves, communal land) Near what town, region, province?
B. disticha			
B. volubilis			
Crinum spp			
D. altissima			
D. delagoensis			
D. elata			
D. robusta			
D. sanguinea			
U. epigea			
Other:			

10. Look at the bulbs. Estimate how many 'checkers' are filled. Then ask the trader how often he buys the amount		Price/ volume	And/ OR	11. Look at the bulbs. Estimate how many 'checkers' are filled. Then ask the trader how often he harvests that amount
B. disticha				
B. volubilis				
Crinum spp				
D. altissima				
D. delagoensis				
D. elata				
D. robusta				
D. sanguinea				
U. epigea				
Other:				

12.) In the summer when you have a choice do you prefer to buy bulbs that have been harvested at a specific time?			13.) Do you prefer to harvest bulbs when it has?	
Yes, harvested when flowering			Flowers	
Yes, harvested with seeds			Seeds	
No, any time			Any time	

14.) Do you prefer to buy bulbs that are a specific size? Or do you buy whatever the harvesters have?			15.) Do you prefer to buy bulbs that are a specific size? Or do you harvest whatever the harvesters have?	
Yes, I like big bulbs			Yes, I like big bulbs	
Yes, I like small bulbs			Yes, I like small bulbs	
No, whatever I get given			No, whatever I get given	

16. How much does 1 bag cost?			17. How much do you usually dig out?	
			Proportion of 50kg sized bag:	
Proportion of 50kg sized bag filled for that price:				

18) How difficult is it to find this bulb?			
	Very difficult	Not so difficult	Very easy
B. disticha			
B. volubilis			
Crinum spp			
D. altissima			
D. delagoensis			
D. elata			
D. robusta			
D. sanguinea			
U. epigea			
Other:			

19) When you and harvest this bulb, do you harvest everything?			
	Yes/No	If you don't take about everything what do you take and what do you leave behind?	
B. disticha			
B. volubilis			
Crinum spp			
D. altissima			
D. delagoensis			
D. elata			
D. robusta			
D. sanguinea			
U. epigea			
Other:			

20) When you find this bulb in the wild how close together are the bulbs (close together or spread out)	Close/Scattered	21.) When you find this bulb is it in rocky area or flat areas?
B. disticha		
B. volubilis		
Crinum spp		
D. altissima		
D. delagoensis		
D. elata		
D. robusta		
D. sanguinea		
U. epigea		
Other:		

22) Do many people like to buy and use this plant?

	Lots of people buy it	Only a few	Other?
B. disticha			
B. volubilis			
Crinum spp			
D. altissima			
D. delagoensis			
D. elata			
D. robusta			
D. sanguinea			
U. epigea			
Other:			

23) How many bulb sales do you make in a day/week/month?		
	When it's quiet?	When it's busy?
B. disticha		
B. volubilis		
Crinum spp		
D. altissima		
D. delagoensis		
D. elata		
D. robusta		
D. sanguinea		
U. epigea		
Other:		

24.) How many total sales do you make a day?										
Free State	**<2**	**2-4**	**4-6**	**6-8**	**8-10**	**10-12**	**12-14**	**14-16**	**16-18**	**>18**
Warwick	**<4**	**4-8**	**8-12**	**12-16**	**16-20**	**20-24**	**24-28**	**28-32**	**32-36**	**>36**

25.) How many customers do you see a day on quiet days?	
26.) How many customers do you see on busy days?	
27.) How many quiet days do you have a month/week?	
28.) How many busy days do you have a month/week?	

APPENDIX 4

BULB PHOTOS SHOWN DURING MARKET SURVEYS

Species	Photo
Boophone disticha	
Bowiea volubilis	
Drimia altissima	
Drimia elata	
Drimia lydenburgensis (Nelspruit)	
Drimia robusta	

Species	Photo
	
Drimia sanguinea	
Drimia delagoensis	
Urginea epigea	