The impacts of harvesting circumcision amaryllids from the Eastern Cape Province, South Africa

BY

NOMATILE NOMBEWU

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SUPERVISOR: PROF E.E. CAMPBELL

DECLARATION

I declare that this thesis "The impacts of harvesting circumcision amaryllis from the Eastern Cape Province, South Africa" has not been submitted previously for a degree at this or any other university, and that it is my own work and all reference material that I have used has been acknowledged.

…….. ……

Nomatile Nombewu January 2014

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ABSTRACT

This quantitative study seeks to determine the impacts of harvesting three plant species traditionally used for wound healing during circumcision. Three localities where these plant species occur have been identified. The population size for each species was determined and an assessment of the extent of harvesting was determined through repeated assessment of marked plants. A significant harvest of these species resulted in the unsustainable use of our natural resources. Out of 25 *Boophone disticha* plants marked, only one plant was remaining after two circumcision seasons. The *Brunsvigia grandiflora* and *Scadoxus multiflorus* populations monitored disappeared completely, with no single marked plant found after two circumcision seasons.

Growth rates of wild populations of *Boophone disticha* and cultivated *Brunsvigia grandiflora* and *Scadoxus multiflorus* plants were determined. The seedling bulbs of *Brunsvigia grandiflora* grew significantly more slowly at less than 0.6 cm per year, while *Scadoxus multiflorus* grew faster at over 1 cm per year.

A model for population dynamics of the three plant species was designed which showed that the plants are being harvested before they even flower.

It is therefore recommended in this study that a conservation plan for these plant species must be done to save the little that is left in the wild before they become critically endangered.

CHAPTER 1

INTRODUCTION

Species of the family Amaryllidaceae are found all over the world and are comparatively well developed in South Africa, where you can find at least 250 species (Procheş *et al*., 2005).

In Africa medicinal plants are found in abundance, and these are used in the traditional treatment of various diseases like sinusitis, stomach ache, coughs, diabetes, venereal diseases, pneumonia and many more (Hutchings *et al*., 1996). In Africa the family Amaryllidaceae consists of 300 species with 30 genera and these genera are divided into three tribes which are Amaryllideae, Cyrtantheae and Haemantheae (Meerow & Snijman, 2001). African traditional medicine is considered to be the oldest medicinal system as is evidenced by cultural activities reported from the Cradle of Humankind (Van Vuuren, 2008).

In South Africa plants are widely used by all sections of the population either directly as folk remedies, in different indigenous systems of medicine or indirectly in the pharmaceutical preparations of modern medicines. Plants used in traditional medicine may be an important source of novel biologically active compounds (Masoko *et al*., 2007). South Africa boasts a unique and diverse botanical heritage that comprises over 30 000 plant species of which some 3 000 species are used for therapeutic purposes (Van Wyk *et al*., 1997). In South Africa there is a dual healthcare system whereby one is based on traditional medicine and the other based on Western medical practices (Stafford, 2008). Even though Western medicine is freely available in the 21st century and may be fully accessible, many communities in South Africa still depend on, and often prefer traditional medicine or '*muthi*' as an important component of primary health care (Williams *et al*., 2013). It has been estimated that 72% of black South Africans subscribe to traditional health care systems which involve the consumption of medicinal plants. This dependence on traditional medicine is also found in urban areas. More than 70 000 tonnes of plant material is estimated to be consumed for medicinal uses in South Africa each year (Mander *et al*., 2007). South Africa's increasing population has led to an increase in the demand and consumption of traditional botanical remedies during the latter part of the twentieth century.

Harvesting of wild populations of plants for medicine is becoming a major concern and it often occurs under non-sustainable conditions. It is estimated that as much as 85% of harvested medicinal plant parts are non-renewable sources such as bulbs, bark and rhizomes (Fennell *et al*., 2004).The trade in traditional medicines forms part of a multi-million rand 'hidden economy' in southern Africa stimulated by high population growth, rapid urbanization, unemployment and the high cultural value of traditional medicines (Dold & Cocks, 2002). The tribe Amaryllideae is distributed primarily in South Africa but a few of its genera extend outside this region (Nair *et al*., 2012).

Demand generates a species-specific trade network that can extend across national boundaries. Consequently, the trade in traditional medicines is now greater than any time in the past and is certainly the most complex resource management issue facing conservation agencies, healthcare professionals and resource users in South Africa today. The use and trade of plants for medicine is therefore no longer confined to traditional healers but has entered both the informal and formal entrepreneurial sectors of the South African economy, resulting in an increase in number of herbal gatherers and traders. Demand for plant-derived medicines has created a trade in indigenous plants in South Africa currently estimated to be worth approximately R270 million a year. More than 700 plant species are known to be actively traded for medicinal purposes throughout the country and intensive harvesting of wild material is acknowledged as a serious threat to biodiversity in the region. Increasing harvesting pressures on traditional supply areas are linked to a growing shortage in supply of popular medicinal plant species. Several plant species have been so greatly exploited that they are seldom found in unprotected areas. The harvesting and trade of plant (and animal) material from the wild populations for medicinal purposes has been, and remains, controversial, particularly with regard to biodiversity conversation (Mander, 1998).

The use of medicinal plant species in such a way that they will remain in a healthy state and be available for use by subsequent generations is at the centre of this study. The use of a species becomes non-sustainable when they are harvested at a level that cannot be compensated for by the capacity of the population for increase through reproduction. If harvesters for example, consistently remove individuals from the population at a rate that becomes greater than they

can be replaced, even when the population can achieve its maximum rate of growth, the population will crash. This overexploitation of natural resources leads to direct destruction of habitats (Pullin, 2002).The short term financial gains in selling these non-renewable plants and their parts appear to be more compelling to the harvester than the thought of the long term ecological impact and the availability of scarce plants for use by future generations. This attitude has led to some plant species having become scarce, endangered and even extinct.

It would appear that the only remedy to this predicament is the small scale farming and production of medicinal plant species. However, medicinal plants cultivated and harvested artificially according to Western methods are often not acceptable to many conservative traditional healers, who claim that the plants become less effective and they tend to lose their potency if not harvested from the wild (Fennell *et al*., 2004). A decrease in the availability of many plant species, along with an increase in the demand for, and price of these plants has left the majority of traditional healers with no alternative but to accept that agricultural cultivation is the only sustainable long term solution (Fennell *et al*., 2004). The use of plants for the treatment of various ailments has several advantages. Plant-derived medicines are generally better tolerated by patients and have fewer side effects. If harvested correctly, medicinal plants are a sustainable natural source of medicine and the cultivation and processing of these plants does not lead to the inevitable air pollution associated with the industrial processes used to produce many Western drugs. Cultivation and selling of medicinal plants could also provide needy families with a small income. With the development of drug resistance in many diseases, plant-derived medicines are expected to become more important (Vermani & Garg, 2002).

Knowledge of medicinal plants was passed on from one generation to the next and has recently received attention in herbal journals (Balumas & Kinghorn, 2005). This knowledge is important and applicable to our times for various reasons. Firstly, it promotes the discovery of new alternatives to drugs currently being used. Secondly, it is important from a conservation point of view; if overexploitation of a medicinal plant species should occur; restrictive measures can and should be taken to ensure survival and sustainability of the species. From a cultural point of view, important knowledge regarding the traditional use of plants is lost as it is not being

passed on from one generation to the next anymore. Thus it is important that this knowledge be documented to ensure that it is at the disposal of future generations (Thring & Weitz, 2006).

According to Van Wyk *et al*. (2005), selective harvesting is important and an experienced "inyanga" will generally seek the guidance of an ancestral spirit before embarking on a collecting trip. The healer, through dreams, or during prayers, will be advised which particular plants to collect for a particular patient, and where these plants may be found.

The healer supplements this supernatural advice with his/her own knowledge, training and experience. Factors that may be taken into account include a particular favoured locality, the correct season of collection, the best aspect on a mountain slope, type of soil and its moisture content, and time of the day. These factors are known by the healers to influence the potency of their medicinal plants, and are well understood by scientists to have a significant influence on the chemistry of plants. Certain potentially toxic plants, for example *Boophone disticha* (L.f.) Herb. (Van Wyk *et al*., 2005) are sometimes collected from a single locality only so that the healer can anticipate the desired therapeutic effect. The conservation measures include traditions and taboos associated with the collection of plants. These can be interpreted as a means of preventing the over-harvesting of plant material. *Alepideaamatymbica* Eckl. & Zeyh., for example, is generally only collected in winter, thereby reserving the plants for the season when coughs, colds, influenza and bronchitis are most prevalent. This tradition also ensures that plants are left in the field to set seed in the summer months. In Gazankulu, a Shangaan taboo dictates that if the remaining root system of *Elephantorrhiza elephantina* (Burch.) Skeelsis not covered after a portion has been removed, the patient treated with it will not get better. Bark that is used for treating kidney diseases are sometimes only harvested from the eastern and western sides of the tree, traditionally symbolizing the kidneys, thereby preventing ring-barking. In addition to the wise and sustainable use of the natural resource, cultivation on farms becomes necessary when new phytomedicines are developed. Some rare and valuable medicinal plants are already being cultivated to reduce pressure on the wild populations. Examples include buchu or *Agathosma betulina* (P.J.Bergius) Pillans, the pepper-bark or *Warbugia salutaris* (Bertol.f.) Chiov; and wild ginger or *Siphonochilus aethiopicus* (Schweinf.) B.L.Burtt. Van Wyk *et al*. (2005) suggested that while some plants or parts of plants can only be

used in a fresh state, many can be dried and stored. Plant material may be dried in the sun or shade, or may be cut into slices and left to dry. Once dry, the plant material may be stored as is, or may be reduced to powder. Dry plant material is stored in paper bags, newspaper, glass jars or tin cans. With modern phytomedicines, care is taken to ensure that the active ingredients remain stable and that the packing materials do not degenerate and contaminate the medicine. Since it is unacceptable for the plant material to be left exposed to the sun, wind, dust, and potential contact with strangers, associations representing traditional healers are actively advocating the introduction of proper warehousing facilities for herbal remedies marketed in the cities.

The Eastern Cape Province, home to 15.5% (6.3 million) of South Africa's total population (40.6 million in 1996), incorporates two of the former 'homelands' of the apartheid period (i.e. Ciskei and Transkei), where many aspects of traditional culture are still part of everyday life. Of the Eastern Cape population, 86% is African, 37% is urbanized, 49% is unemployed (with 31% of those employed earning less than R500 a month), and 41% of the households live in traditional dwellings (Victor & Dold, 2003). The people of the Eastern Cape tend to be more traditional and rural, but also significantly poorer and less developed, than those in other parts of South Africa. A large proportion of the province's population is reliant to some extent on natural resources for direct subsistence use or indirectly, for generating income. A rapidly growing population coupled with increasing poverty and urbanization has a compound impact on the province's resource base (Dold & Cocks, 2002).

AIM

This study aimed to assess the impacts of harvesting three circumcision amaryllids from the Eastern Cape Province in South Africa: *Boophone disticha*, *Brunsvigia grandiflora*Lindl.and *Scadoxus multiflorus* (Martyn) Raf. subsp. *katharinae* (Baker) Friis& Nordal.

OBJECTIVES

This assessment was planned to fulfill the following objectives:

1. Monitoring plant populations of *Boophone disticha*, *Brunsvigia grandiflora* and *Scadoxus multiflorus* to assess the impacts of harvesting.

2. Assessing the growth rate of *B. disticha*, *B. grandiflora* and *S. multiflorus* to estimate the age of plants in the field.

CHAPTER 2

LITERATURE REVIEW

In this chapter, main subgroups of phytochemicals as the biological active compounds in medicinal plants are presented. A brief overview of *Boophone disticha, Brunsvigia grandiflora* and *Scadoxus multiflorus* is given, including botanical classifications and vernacular names, morphology and geographical distributions. A brief summary of the known major phytochemical constituents of each of these species is also given, as well as the ethnopharmacological application of these plants by various cultures, and previous scientific research conducted on the efficacy of these plants in treating the conditions for which they are used.

According to Manning (2009) amaryllids are bulbous or rhizomatous perennials with slimy sap. The leaves are basal, spirally arranged or more usually in two ranks. They are often strap-like or slender to broad and usually they have no midrib, sometimes spreading on the ground and rarely hairy. The inflorescence is an umbel and is borne on a leafless scape, sometimes one flowered or rarely subterranean and in the bud stage they are enclosed by two or more large papery or leafy bracts. The flowers of the amaryllids have various colours, they are often red, pink or yellow and they are star or funnel shaped with six tepals that are separated or joined at the base into a tube. There are six stamens, but may rarely be more. Stamens arise at the top of the tube and are either all of similar length, or may have one of two lengths. They spread or are arching downward. The ovary is inferior; the style is slender and straight or arching downward. The fruit may be dry or fleshy when mature.

Amaryllids, as with many geophytes, have a dormant period when the above ground parts die back in response to seasonally stressful conditions (Raunkiaer, 1934). Plant dormancy is a type of phenotypic plasticity whereby an individual plant is able to change its phenotype to minimize the exposure of plant to stressful conditions caused by seasonal variations. Plant dormancy is also a form of stress relief because dormant plants do not grow or reproduce when they are in such a state (Hoffman & Parsons, 1993).

An underground storage organ bears a perennating bud for regrowth of the plant. This is possible because of the nutrients that are conserved in the underground storage organ and deposited in the growing seasons (Vaughton& Ramsey, 2001).

2.1 ***Boophone disticha***

2.1.1 Botanical classification, vernacular names and status

The botanical classification of *B. disticha* is as follows:

Kingdom: Plantae
Division: Magnoliophyta
Class: Liliopsida
Order: Asparagales
Family: Amaryllidaceae
Species: *Boophone disticha* (L.f.) Herb.

The genus *Boophone* is one of the most interesting genera in family Amaryllidaceae. The name has been spelled in four different ways: *Boophane*, *Buphane*, *Boophone* and *Buphone*. *Boophone disticha* has also been known as *Buphane toxicaria*, *Haemanthus toxicarius*, *Amaryllis disticha* and *Boophone toxicarius* (Huttleston, 1960).

Vernacular names: bushman poison bulb, fan-leaved boophone, sore-eye flower, tumblehead [English]; gifbol, perdespook, seerooglelie [Afrikaans]; muwandwe [Shona]; kxutsana-ya-naha, leshoma, lesoma, motlatsisa [Southern Sotho, Tswana]; incumbe, siphahluka [Swati] incwadi [Xhosa]; incotho, ibhade [Zulu] (Manning, 1998 & Pooley, 2005).

Conservation status

The Red List status of this plant shows that the plant is declining in the wild, which means that is abundance is declining but has not yet reached a threshold of concern (Raimondo *et al*., 2009 & Kraaij, 2011). According to the information that was collected by a group of ethnobotanists on which to base the status assessment, the population decline through harvesting for the informal trade includes: observed losses of individuals, the extent of such decline in the distribution range, relative abundance, quantities of plant material traded, the type of

harvesting, life cycle characteristics like the reproductive capabilities and growth rate of a plant (Williams, 2003).

2.1.2 Medicinal uses

Boophone disticha is perhaps the most important and interesting of all southern African poisonous plants. It is extremely toxic and has been the cause of several human fatalities resulting from murder, suicide or accidental poisoning by traditional medicine (Nielsen *et al*., 2004). Its bulbs have been reported to cause acute and fatal poisoning in humans (Botha *et al*., 2005). It is one of the most prominent arrow poisons used in southern Africa and of considerable ethnobotanical interest as a hallucinogen and in traditional medicine (Watt &Breyer-Brandwijk, 1962). The Khoi/San people use the poison obtained from the bulb for their arrows (Neergaard *et al*., 2009). *Boophone disticha* has been used in traditional medicine for centuries. Medicinally the plant is used in the treatment of pain in wounds. The dry outer scales of the bulb are used as an outer dressing after circumcision and are also applied to boils or septic wounds (often mixed with water, milk or oil) to alleviate pain and to draw out the pus. Weak decoctions of the bulb scales are administered by mouth or as an enema for various complaints such as headaches, abdominal pain, weakness and eye conditions (Neergaard, 2009). Very weak decoctions of the bulb scales are used as an effective sedative. These bulb scales are used to sedate violent, psychotic patients and bulb infusions are reported to be used for the treatment of mental illness (Adewusi, 2012). Internal use is dangerous and should be avoided (Van Wyk *et al*., 1997). Higher doses induce visual hallucinations, which are sometimes used for divination and even higher doses can be fatal (Manning, 1998). Decoctions and fresh scales from the bulbs are also used by the Zulu people orally or either as enemas to treat hysterical adolescent females (Gordon, 1947). The bulbs are also used to treat varicose ulcers, cancer and also for the relief of urticarial rashes (Botha *et al*., 2005).

2.1.3 Morphological description

Boophone disticha is a distinctive plant that has a large bulb growing partly above the ground, from which the symmetrically arranged leaves emerge after flowering. The bulb is easily recognized by the thick layers of papery scales surrounding the fleshy inner part and these are partly exposed above the surface of the ground. The rounded umbel has numerous pink flowers (Plate 1). When dry, the inflorescence rolls about in the wind, distributing the seeds (Van Wyk *et al*., 1997).The Xhosa also use the name "*ishwadi*" a respect word for "*incwadi*" (book or paper) which refers to the bulb scales that are arranged like pages in a book.

Plate 1: The rounded umbel of *Boophone disticha.*

2.1.4 Geographical distribution

Boophone disticha is widely distributed in southern Africa and further north into tropical Africa, occurring mainly in grassland and bushveld (Van Wyk, 2000). The plant can be found as far north as Sudan (Nair, 2012).It is widely distributed in a range of habitats, from the winter

rainfall region in the south, through the dry Karoo to the moist summer rainfall grassland regions and it occurs from sea level to fairly high altitudes in mountainous regions (Van Wyk & Nigel, 2000).

2.1.5 Major chemical constituents

Amaryllidaceae alkaloids are known mainly for their extreme toxicity, but also show narcotic, hypotensive, vasodilatory and analgesic activity (Stafford *et al*., 2008). The analgesic effect of buphanidrine is at a level of 6.2 mg/kg in mice and the lethal dose of 8.9 mg/kg makes it much too toxic for therapeutic use. A number of biologically active alkaloids have been isolated from the bulbs. Several alkaloids have been characterized and reported. These include crinine, buphanidrine, buphanisine, buphanamine, lycorine, powelline, distichanidrine and 3-O-methylcrinamidine (Figure 1). A range of Amaryllidaceae alkaloids have earlier been tested in a binding assay for affinity to the serotonin transporter for the screening of plants that are used for anxiety and depression (Nielsen *et al*., 2004). Several of these tested compounds showed high to moderate affinity for the transporter (Sandager *et al*., 2005). In another study buphanidrine and buphanamine have been reported to have affinity to serotonin transporter. This affinity was attributed to the presence of a 1, 3-dioxole moiety (Neergaard *et al*., 2009).

In a screening of plants that are used to treat depression-like disorders, ethanolic extracts of leaves and bulbs of *Boophone disticha* has shown affinity to serotonin transporter both *in vitro* and *in vivo.* The alkaloids that have been isolated from the ethanolic extract are shown in the diagram below (Stafford *et al.*, 2013). One of the alkaloids above, which is distichamine is structurally unique to possess both vinylic methoxyl and α, β-unsaturated ketone C-ring functionalities (Nair *et al.,* 2012).

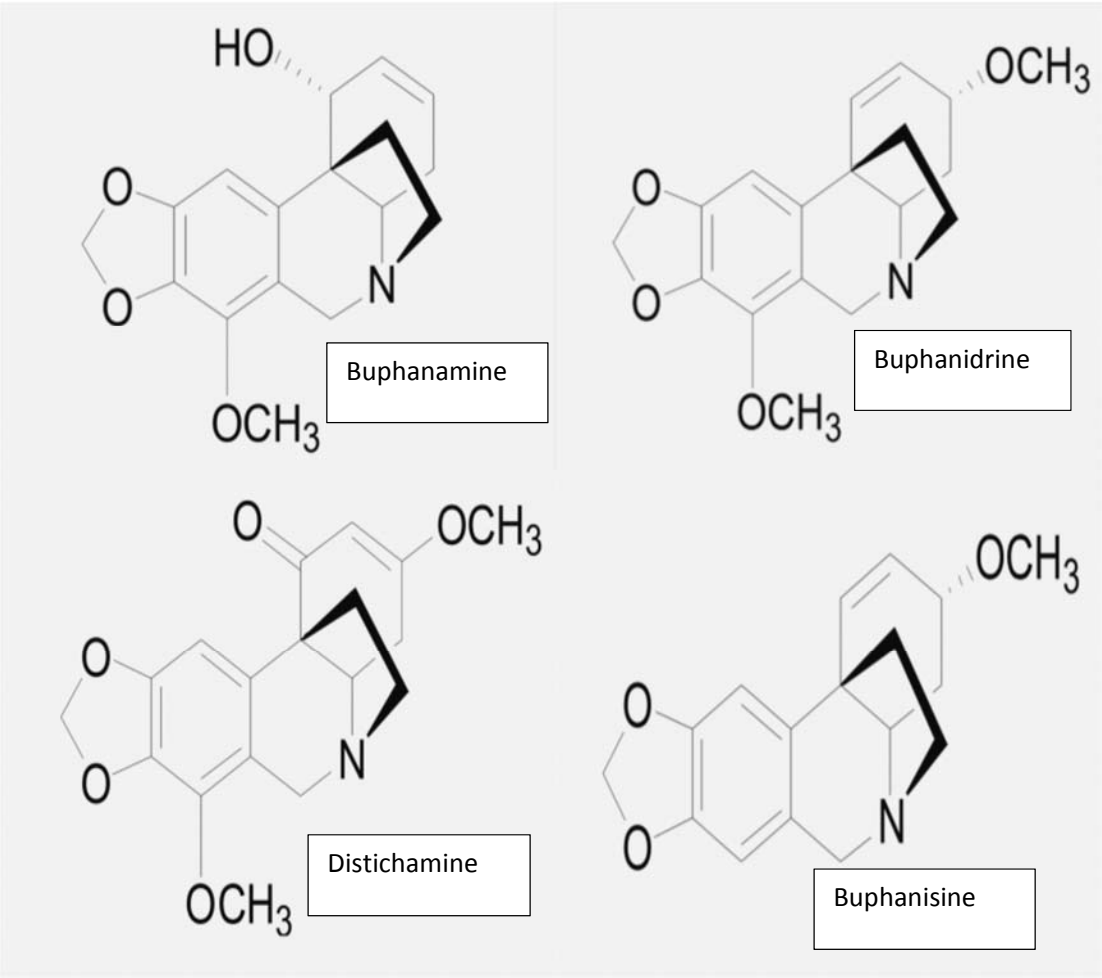

Figure 1: Structures of some of the major alkaloids extracted from the bulb of *Boophone disticha* (Gadaga, 2012).

2.2 ***Brunsvigia grandiflora***

2.2.1 Botanical classification, vernacular names and status

The botanical classification of *B. grandiflora* is as follows:

Kingdom: Plantae
Division: Magnoliophyta
Class: Liliopsida
Order: Asparagales
Family: Amaryllidaceae
Species: *Brunsvigia grandiflora* Lindl.

Vernacular names: giant candelabra flower, candelabra lily [English]; kandelaarblom [Afrikaans]; isichwe [Xhosa]; umqhele–wenkunzi [Zulu] (Watt &Breyer-Brandwijk, 1962).

Conservation status

The Red List status of this plant species shows that the plant is Least Concern – LC (Raimondo *et al*., 2009). According to the quantitative thresholds that are used to assess the probabilities of extinction there are five broad criteria (A to E) and if a species does not meet any of the criteria it is then classified as LC and may be additionally flagged as being of conservation concern either as Rare, Critically Rare or Declining (Williams *et al*., 2013).

2.2.2 Medicinal uses

Medicinally, bulb decoctions are used for coughs and colds and administered as enemas for renal and liver complaints. The outer skin of the bulb of *B. grandiflora* is used as a circumcision wound dressing by the Xhosa and reported to promote very rapid healing (Hutchings *et al*., 1996). Plate 2 shows how the herbs are used after circumcision.

Plate 2: The herbs used after circumcision. Left hand "swadi" *B. disticha* stops bleeding. Right hand "isichwe" *B. grandiflora* is used as an antiseptic (http://www.bulbsociety.org/Gallery).

2.2.3 Morphological description

Brunsvigia grandiflora is characterized by large bulbs which sometimes protrude above the ground (Van Wyk, 2000). Each bulb bears 10 to 15 leaves that are erect or soft and bending. The leaves are flat with wavy margins. They usually emerge around the same time as the flower stalk and they can tolerate a light frost, but it is recommended to protect the plant from freezing temperatures. It is summer-growing (Manning 2009).

The spreading inflorescence has about 30 to 60 flowers that are about 50-70 mm long and are light to dark pink in colour. In the wild *B. grandiflora* bears flowers in January to March (Pooley, 2005).

2.2.4 Geographical distribution

Brunsvigia is a South African genus of Amaryllidaceae that grows in semi-arid regions. *Brunsvigia grandiflora* comes from eastern South Africa, primarily from the grassland biome (Manning, 1998).

2.3 *Scadoxus multiflorus* subsp.*katharinae*

Scadoxus species are deciduous or evergreen, rhizomatous or partially bulbous perennials. The leaves are petiolate with a thin-textured, oval to lance-shaped blade with a prominent midrib. The flowers are in a compact head surrounded by several large, green or brown bracts which are narrowly funnel or salver-shaped. The flowers are erect or spreading on very short pedicels and they are orange to red, the stamens are erect or spreading and separate. The fruit is a red berry (Manning, 2009).

2.3.1 Botanical classification and vernacular names

The botanical classification of *S. multiflorus* is as follows:

Kingdom: Plantae
Division: Magnoliophyta
Class: Liliopsida
Order: Asparagales
Family: Amaryllidaceae
Species: *Scadoxus multiflorus* (Martyn) Raf.subsp. *katharinae* (Baker) Friis & Nordal

Vernacular names: catherine wheel, blood flower [English]; bloedblom [Afrikaans]; idunjana, ubukhoswane [Zulu], inkupulwane (Watt & Breyer-Brandwijk, 1962; Pooley, 2005; Dold & Cocks, 1999).

Conservation status

According to Raimondo *et al*., 2009, the Red Data List status of this plant species shows that the plant is also Least Concern – LC.

2.3.2 Medicinal uses

Scadoxus multiflorus is used medicinally in many parts of Africa for wound therapy, colds, asthma and other ailments (Van Wyk *et al*., 1997). It is used by the Zulus to make love charms and emetics. The plant is reported to be very poisonous. The leaves are reported to be cyanogenic (Hutchings *et al*., 1996)

2.3.3 Morphological description

Scadoxus multiflorus is a bulbous geophyte that is between 30 and 100 cm tall, the flowering stem speckled with purple (Plate 3). The leaves are arranged in fours to fives, the bases forming a false stem, the blades are pale green and broad and the surface is wavy. The pinkish to red flowers are many and occur in a dense terminal cluster. They are borne on fairly long stalks, forming a rounded umbel about 20 cm in diameter. Flowering occurs mainly in April and May (Van Wyk *et al*., 1997). The pinkish or red flowers of *S. multiflorus* are adapted to attract insects and this is characteristic of all amaryllids. Their large clusters of funnel-shaped flowers secrete energy-rich nectar at the base of the floral tube where it is accessible only to the siphon-like mouthparts of butterflies (Manning, 1998).

The subspecies of *Scadoxus multiflorus* found in the Eastern Cape is *S. multiflorus* subsp. *katharinae* which flowers in January-March with deep pinkish red flowers while subsp. *multiflorus* flowers in October-December with pink flowers and red stamens (Pooley, 2005).

Plate 3: Young plants of *Scadoxus multiflorus* with red-speckled stems and wavy leaves.

2.3.4 Geographical distribution

Scadoxus multiflorus subsp. *katharinae is* found in coastal and inland forests from East London to southern Mpumalanga (Van Wyk, 2000).

2.3.5 Major chemical constituents

Scadoxus species contain isoquinoline alkaloids, the so-called Amaryllidaceae alkaloids (Van Wyk *et al*., 2005). Haemanthamine and haemanthidine have been isolated from *S. multiflorus* (Figure 2) and are named after another genus of Amaryllidaceae, *Haemanthus* that also

contains them. The genus *Scadoxus* contains alkaloid-rich, strongly toxic plants. Two species, *Scadoxus multiflorus* and *Scadoxus cinnabarinus* are known to be used in Cameroon, Gabon, Angola and the Central African Republic in conjunction with a number of other plants, as an arrow poison. In Guinea and northern Nigeria the bulbs are used to make a fishing poison. The bulb is also used to treat dropsy, scabies and poorly healing wounds. These alkaloids are highly toxic and their indiscriminate use is potentially lethal. They are known to be lethal to stock, mainly goats and sheep grazing on them when other plants are scarce, and the leaves appear to have exactly the same toxic effects as the bulb (Van Wyk *et al*., 2005).

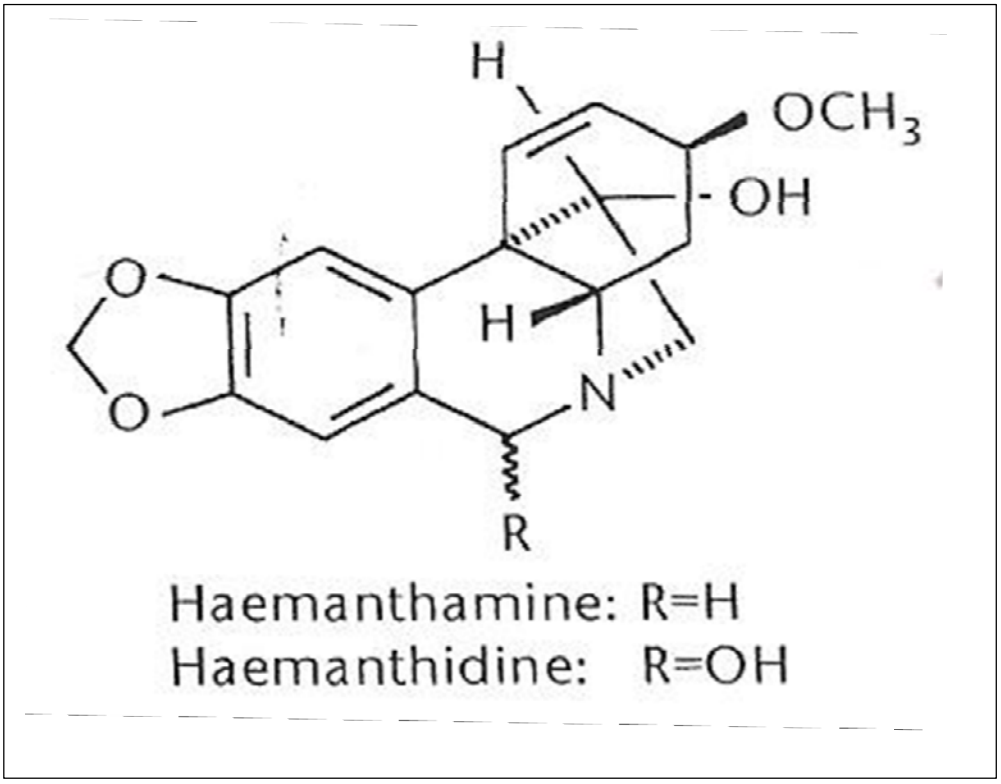

Figure 2: Structures of haemanthamine and haemanthidine (Van Wyk *et al*., 2005).

CHAPTER 3

MATERIALS AND METHODS

This chapter presents the materials and methods used in propagation of *Brunsvigia grandiflora* and *Scadoxus multiflorus* to compare the growth rate of geophytes that are grown under controlled environment conditions with those that are in the wild. It also deals with the assessment of the growth rate of *Boophone disticha* in protected areas compared to the ones in the study area identified. The materials and methods used in the assessment of harvesting *B. disticha, B. grandiflora* and *S. multiflorus* are also presented.

Geophytes are those plants that have underground resting buds attached to the storage organs such as rhizomes, bulbs, tubers or corms. Even though some geophyte species are evergreen, most of them survive periods of environmental stress such as winter cold or summer drought by dying back to these underground storage organs (Dafni *et al*., 1981). When environmental conditions become favourable they resprout new foliage in the next or following growing season (Elser *et al*., 1999).

3.1 Germination and Growth

Germination is a process that involves the imbibition of water and mobilization of nutrient reserves and is accompanied by increased respiration (Fenner, 1985). It is considered to be taking place when an active embryo grows; resulting in the rupture of seed coat and emergence of a young plant. According to this definition of germination, it is presumed that the seed has been in a state of rest after it developed, and during this period of rest, the seed is inactive and the metabolic rate is low. It remains in this state until environmental conditions trigger the resumption of the active growth (Bewley, 1997).

Seeds of *B. grandiflora* and *S. multiflorus* obtained from Kirstenbosch Botanical Gardens, Cape Town were germinated in February 2010 in the glasshouse of the Department of Botany at the Nelson Mandela Metropolitan University (South Campus).

3.1.1 Germination of *S. multiflorus*

The seeds were sown in single species seed trays filled with potting soil and once they germinated the soil was watered once a week or less if the soil remained moist. Once the seedlings were large enough to handle they were carefully uprooted for transplantation (Plate 4). After the seedlings were uprooted they were washed carefully with distilled water to remove the soil.

Plate 4: **Uprooting seedlings of *Scadoxus multiflorus*.**

3.1.2 Germination of *B. grandiflora*

The procedure of uprooting the seedlings of *B. grandiflora* was in the same manner as that for *S. multiflorus*. The seeds were germinated in seed trays and after germination they were uprooted for transplantation (Plate 5).

Plate 5: Uprooting seedlings of *Brunsvigia grandiflora.*

After the seedlings of *B. grandiflora* and *S. multiflorus* were washed they were weighed and the seedling height was measured from above the bulb to the leaf tip. After weighing and measuring, the seedlings were transplanted singly into 15 cm diameter pots (Plate 6, August 2010). The seedlings of *B. grandiflora* and *S. multiflorus* had small bulbs with long, white roots that require careful handling so as not to break them during transplanting. The seedlings were

planted by carefully filling the pots with soil (Plate 7) and gently pressing the bulbs into the soil so as to remove air spaces in the soil and to prevent the development of fungus at the base of the bulb.

The transplanted seedlings were watered well after planting and watered once a week thereafter. Plants were kept in the glasshouse for a period of three years. Observation of the growth was done by measuring the plant height annually.

Plate 6: Transplanted seedlings of *Scadoxus multiflorus*.

Plate 7: Transplanted seedlings of *Brunsvigia grandiflora*.

The Nature Reserve at the Nelson Mandela Metropolitan University (south campus) was used to assess the growth rate of *B. disticha* in a protected area where there was no disturbance to the plants. This was done by marking 30 plants in August 2010 and measuring their bulbs (Plate 8). Measurements were again recorded in October 2011 and August 2013.

Plate 8: Measuring of *Boophone disticha* in the NMMU nature reserve.

3.2 Impact of harvesting

Three study areas were identified based on locality information obtained from PRECIS at the South African National Biodiversity Institute. The locality chosen for each of the species was as follows (Figure 3):

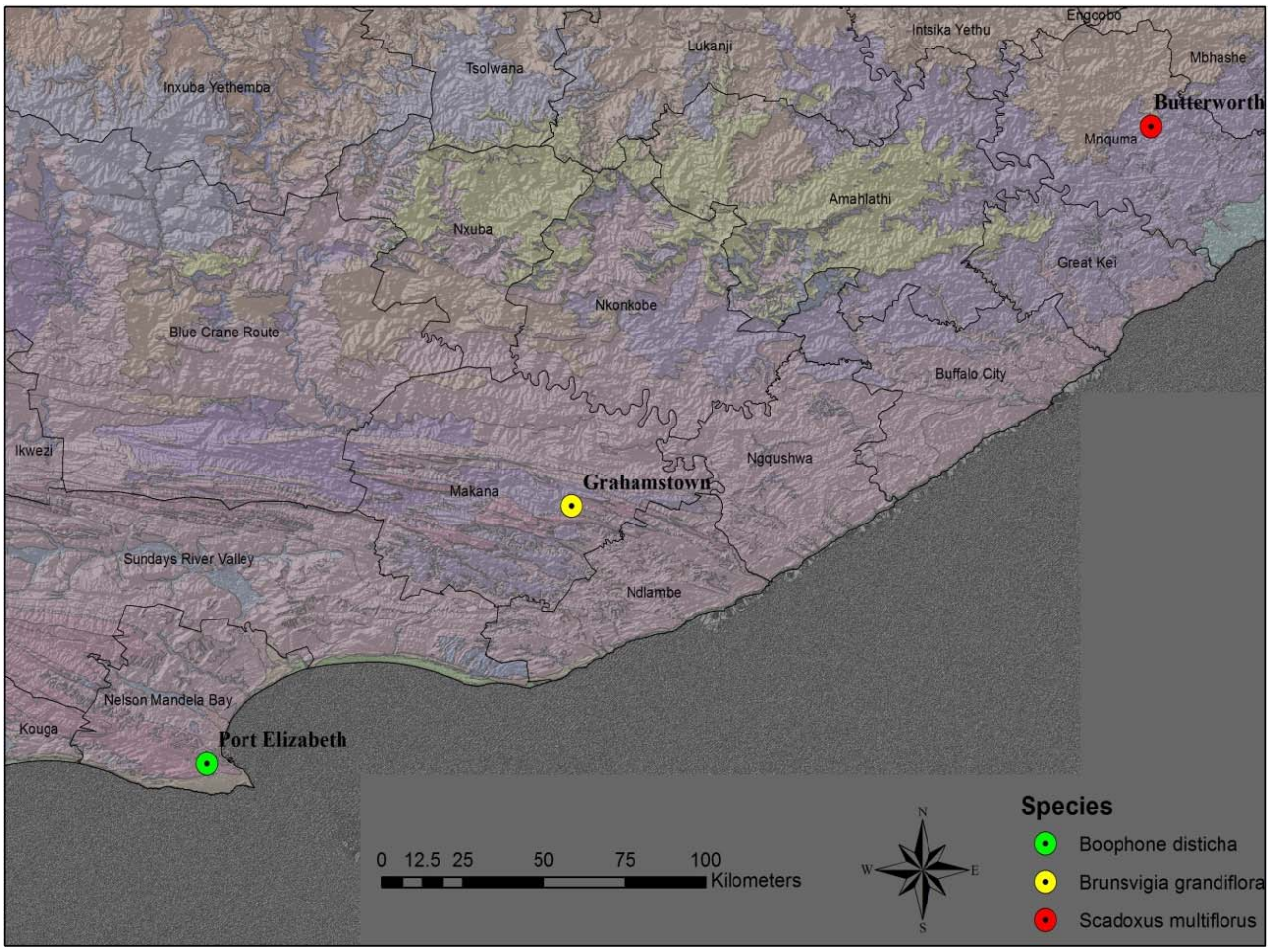

Figure 3: The localities of the three study sites selected for the assessment of harvesting.

- The *Boophone disticha* localities were in a public open space in the Baakens Valley of Port Elizabeth (Figure 4)

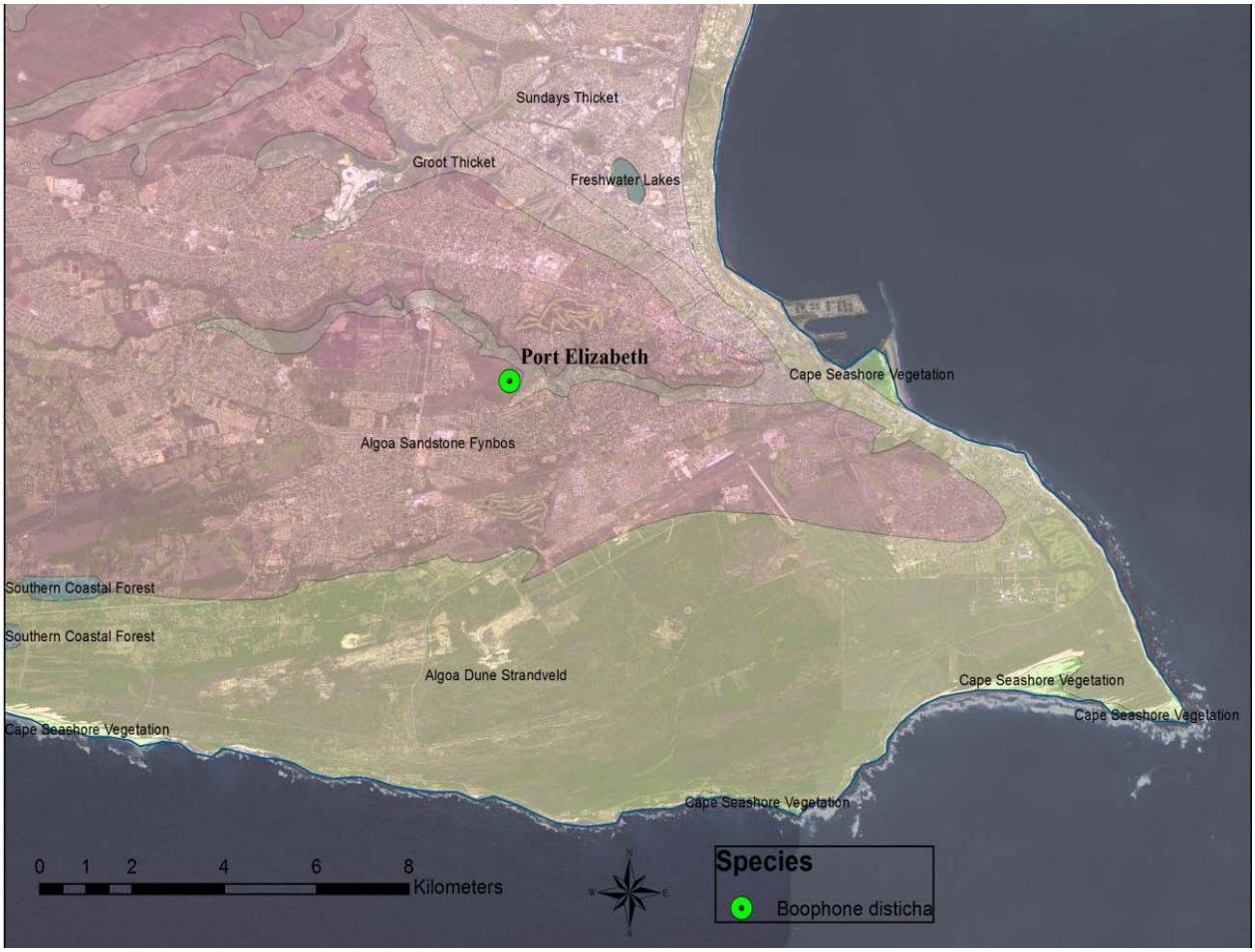

Figure 4: The site for monitoring harvesting of *Boophone disticha* in the Baakens River Valley, Port Elizabeth.

The study site that was chosen to assess the growth rate of *Boophone disticha* was in the Nelson Mandela Metropolitan University Nature Reserve (Figure 5) and this site was chosen on the basis that it is a protected and undisturbed site as it falls inside the University's Nature Reserve. The Baakens Valley site had Algoa Sandstone Fynbos and is dry and rocky with patches of shrubs. The NMMU Nature Reserve site had St Francis Dune Thicket and Fynbos mosaic vegetation (Algoa Dune Strandveld) and is well drained with patches of near-surface calcrete.

Figure 5: The study site where growth rates of *Boophone disticha* were measured in the Nelson Mandela Metropolitan University Nature Reserve, Port Elizabeth.

- *Brunsvigia grandiflora* was sampled near Grahamstown next to the N2 road to Port Elizabeth (Figure 6). The study site was a slope of a ridge where the population was found scattered in grassland vegetation of Bhisho Thornveld.

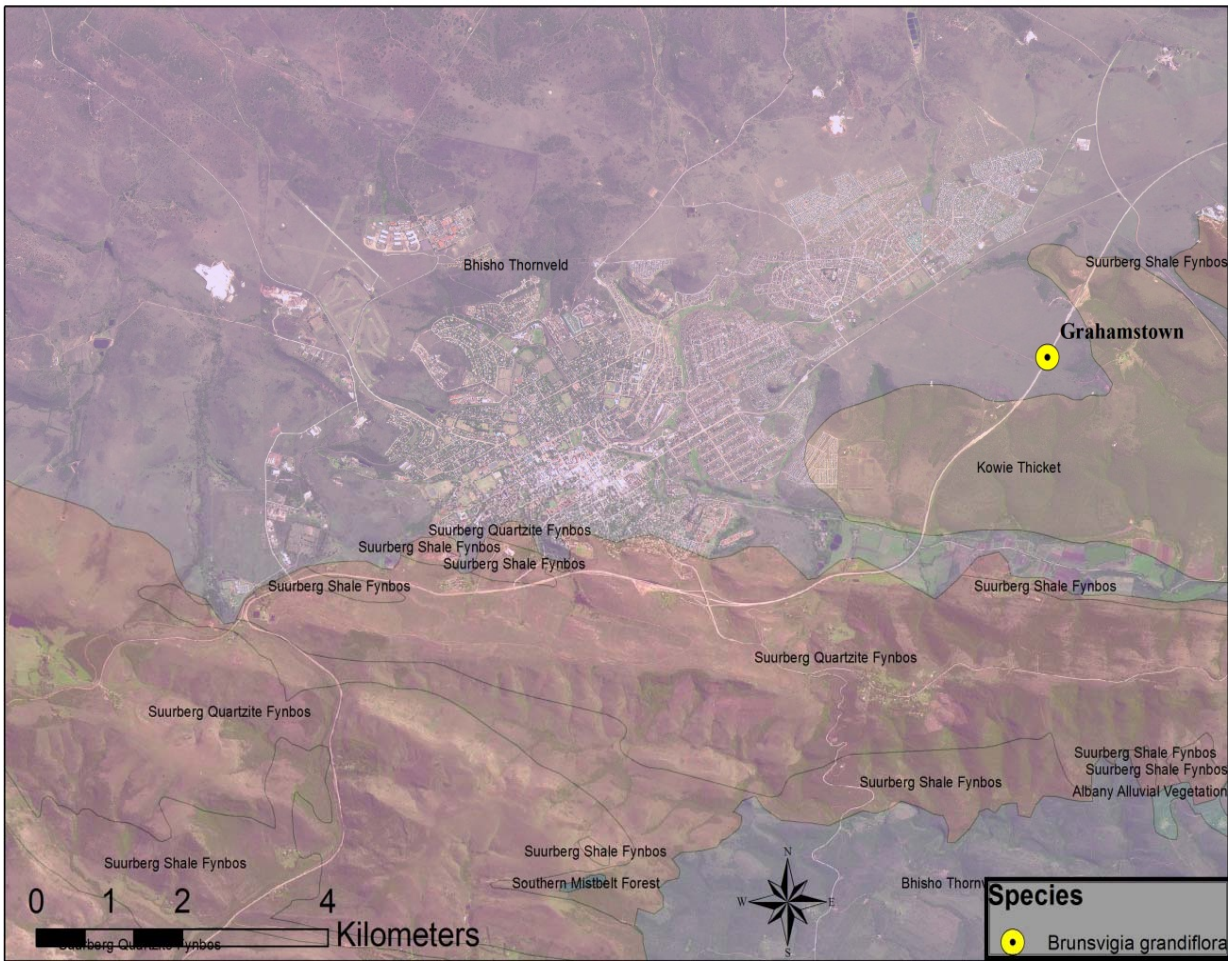

Figure 6: The study site for monitoring harvesting of *Brunsvigia grandiflora* near Grahamstown.

- *Scadoxus multiflorus* subsp. *katharinae* was sampled near Butterworth on the N2 road towards Idutywa (Figure 7).

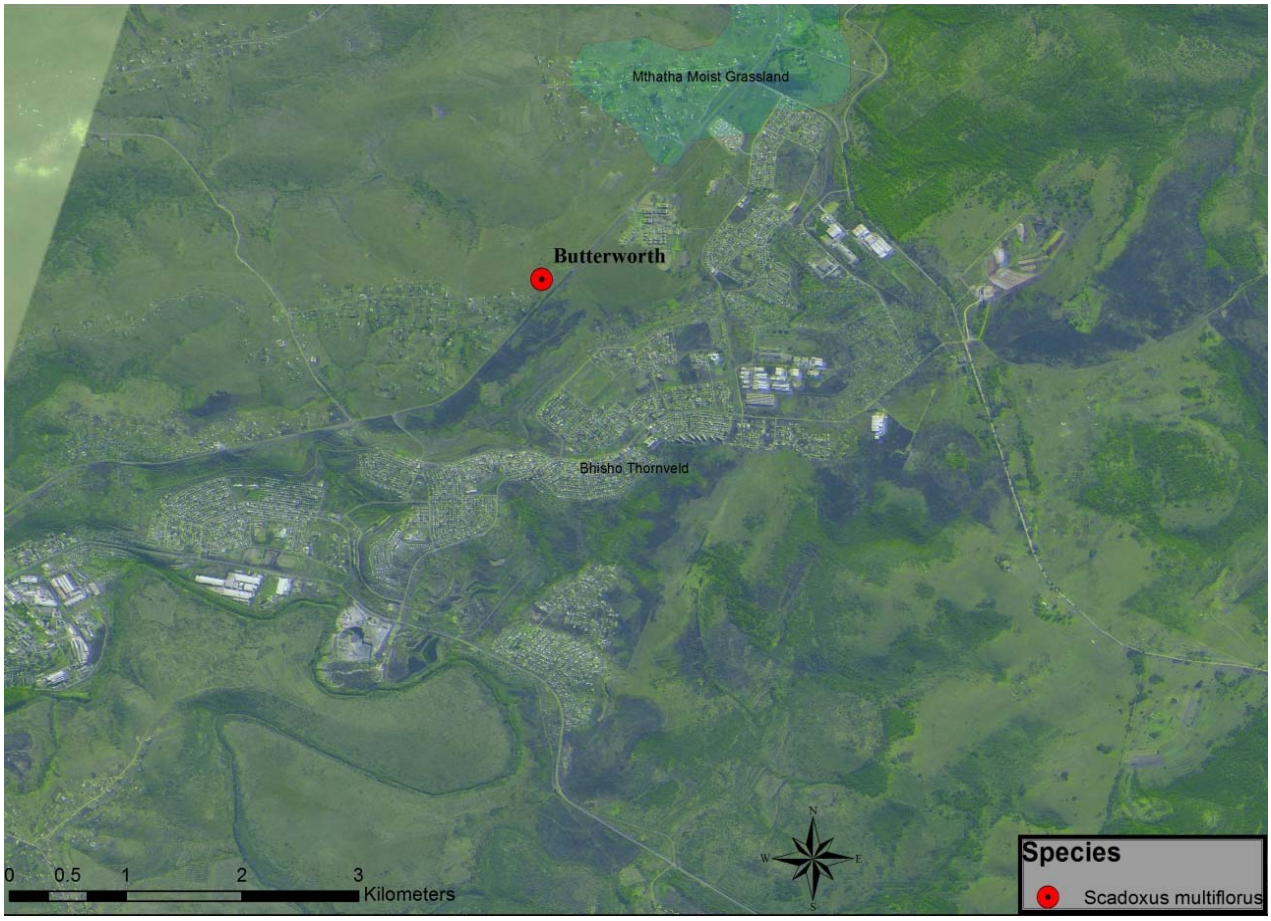

Figure 7: The study site for monitoring harvesting of *Scadoxus multiflorus* near Butterworth.

At the *B. disticha* study site 25 plants were marked for monitoring (Plate 9). A small wooden stick was used to mark each plant that was counted and each stick had a number written on it with a permanent marker. The sticks were buried in the soil in such a way that only a small part of it was left above-ground so as to minimise the visibility of the sticks to the harvesters (Plate 10).

Plate 9: Pegs used to mark plants of *Boophone disticha* for subsequent surveys.

Plate 10: Pegs used to mark plants of *Scadoxus multiflorus* for subsequent surveys.

The *B. grandiflora* and *S. multiflorus* plants were marked in February 2011 and in May 2011 respectively. A total of 20 plants of *B. grandiflora* were marked, 11 of them with flowers and 9 were about to flower at that time. Similarly 22 plants of *S. multiflorus* were marked, 9 of them with flowers and 13 were about to flower at that time.

The initial measurement of *B. disticha* was done in August 2010 and the diameters of the bulbs of the marked plants were measured at that time. Bulb diameters were measured again in 2011 at which time another small sample of 10 plants was measured. The extent of harvesting *B. disticha* at the Baakens Valley was also measured at this time. During 2013, another set of *B. disticha* plants were measured.

CHAPTER 4

RESULTS

4.1 Growth rates

In the Baakens Valley the population of *Boophone disticha* had bulb diameters of the marked plants between 1 and 8 centimetres in August 2010 (Appendix 1).This measurement of bulb diameters was going to be used to determine the growth rate of the plants by remeasuring them at the end of the growing season. However, only one plant could be found to measure at the time of returning (see section 4.3) and it had grown from 3 cm to 4.5 cm (Appendix 1).

The *Boophone disticha* plants measured in the NMMU nature reserve, however, increased in diameter by an average of just over 0.8 cm per year (Figure 8).The seedling bulbs of *Brunsvigia grandiflora* grew significantly more slowly at less than 0.6 cm per year (measured over 3 years of growth, $t = 3.248$, $d.f = 16$, $p = 0.005$; (Figure 8) while *Scadoxus multiflorus* grew faster at over 1 cm per year (measured over 3 years of growth, $t = 0.839$, $d.f = 15$, $p = 0.209$; Figure 9). The t-test here was done using the data analysis extension of MS excel and assuming unequal variances and the bulb sizes measured are presented in Appendix 2.

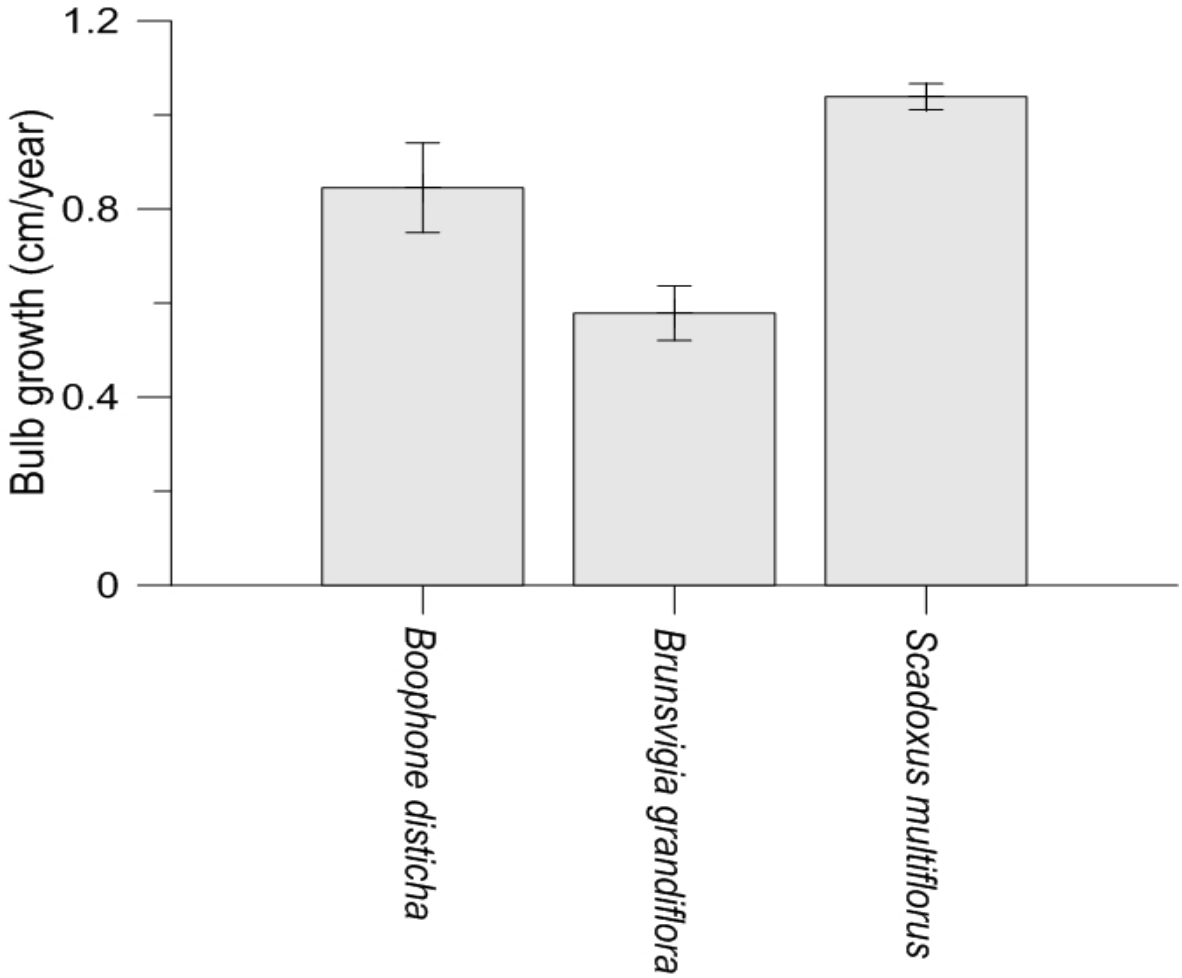

Figure 8: Growth rate of *B. disticha*, *B. grandiflora* and *S. multiflorus* measured as increase in bulb diameter per year (*B. disticha* was measured in the wild in the NMMU Nature Reserve as their bulbs protrude from the ground. The other two species were grown from seed to determine growth rate as their bulbs are not visible above the ground and cannot be measured in the field). Vertical bars represent ± 1 S.E.

For *B. grandiflora* and *S. multiflorus* the growth rates could also be expressed as increase in mass (Figure 9; Appendix 3). Using mass, the pattern was different because *B. grandiflora* bulbs are narrow and tall (Plate 11) while *S. multiflorus* bulbs are flat and wide (Plate 10). The growth rates using mass are also significantly different (t = 3.369; d.f. = 9; p = 0.004).

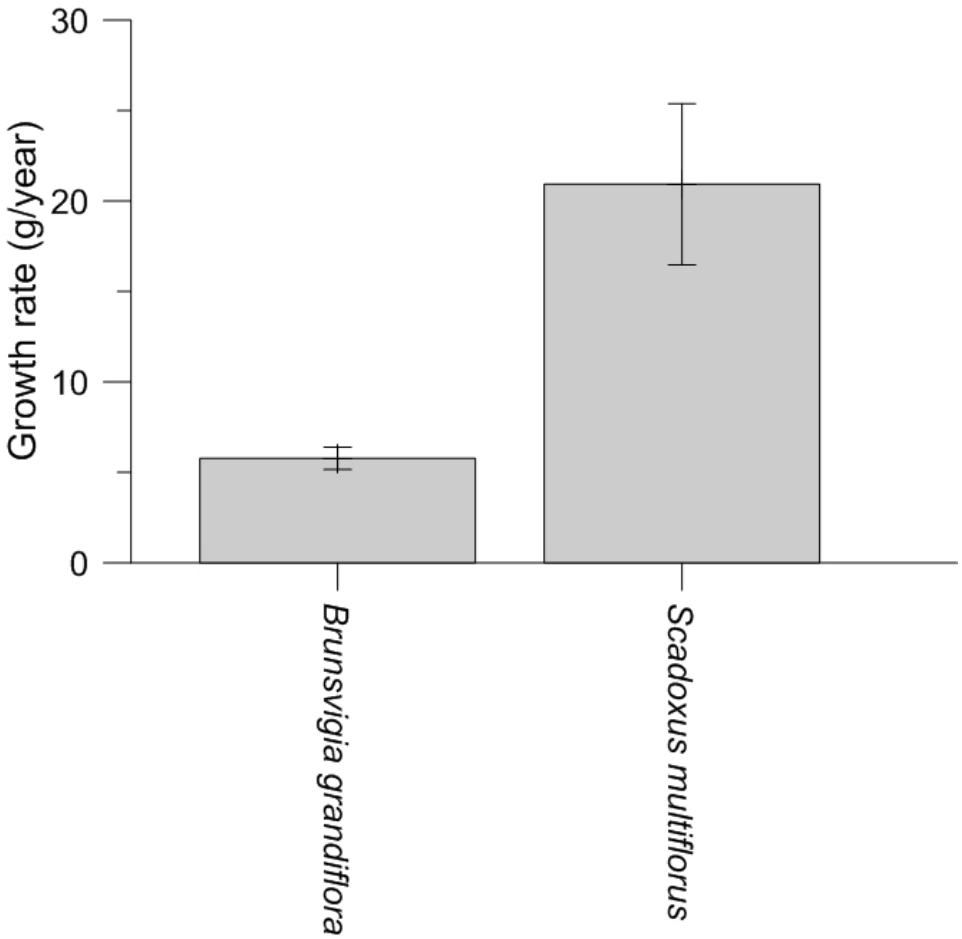

Figure 9: Growth rate of *B. grandiflora* and *S. multiflorus* measured as increase in bulb mass per year. Vertical bars represent ± 1 S.E.

Both *B. grandiflora* and *S. multiflorus* have the adaptation whereby the leaves die back to the ground and the plant become dormant until the next growing season. Even the seedlings showed this adaptation because the measurement of the height of the plants showed an annual decrease in height (Figure 10). Most of the growth effort is in producing the underground perennating organs (Appendix 4 & 6). *Scadoxus multiflorus*, with its larger bulb (Figure 10) had a significantly greater reduction in plant height (t = 2.185; d.f. = 14; p = 0.023).

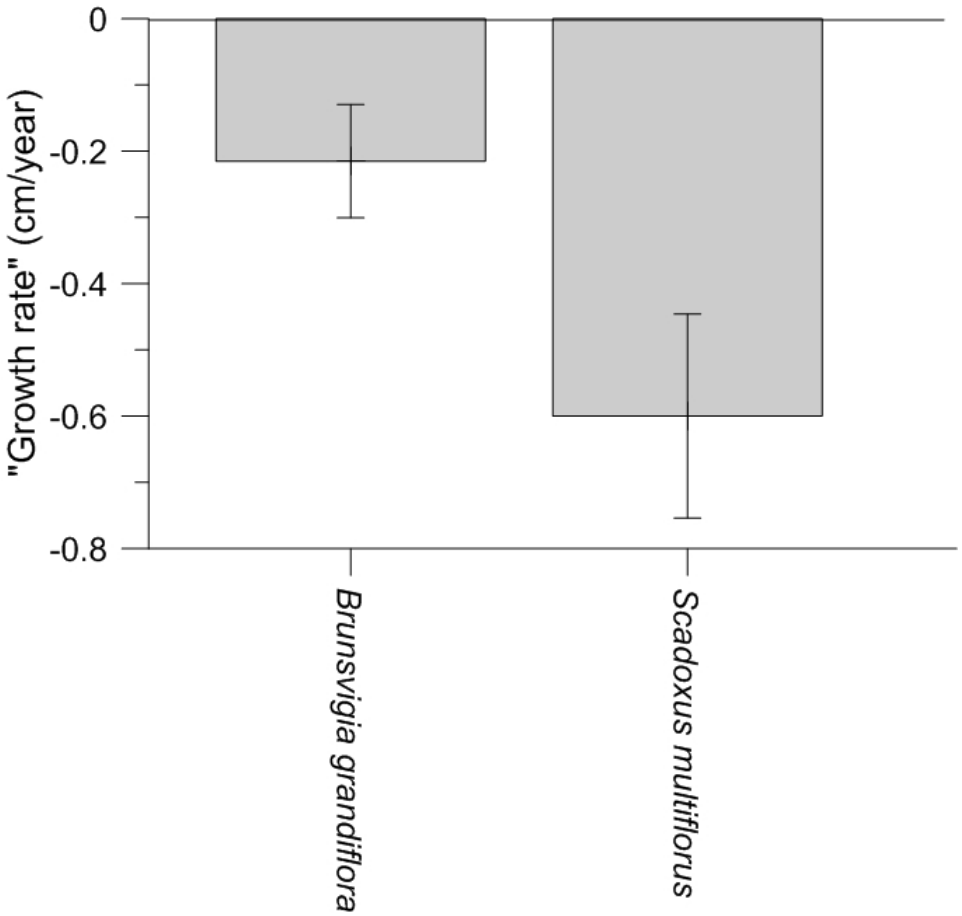

Figure 10: "Growth rate" of *B. grandiflora* and *S. multiflorus* measured as "increase" in plant height per year. Vertical bars represent ± 1 S.E.

4.2 Vulnerable stages

Small bulbs are unlikely to be harvested for use as the will not provide sufficient material for use in treatment. Vulnerable stages in the life cycle of the plant are evident when plotting plant sizes in a population (Figure 11). These vulnerable stages are juvenile stages and the larger bulbs. Applying this assumption, it is evident that the targeted sizes of the bulbs are those of at least 6 cm.

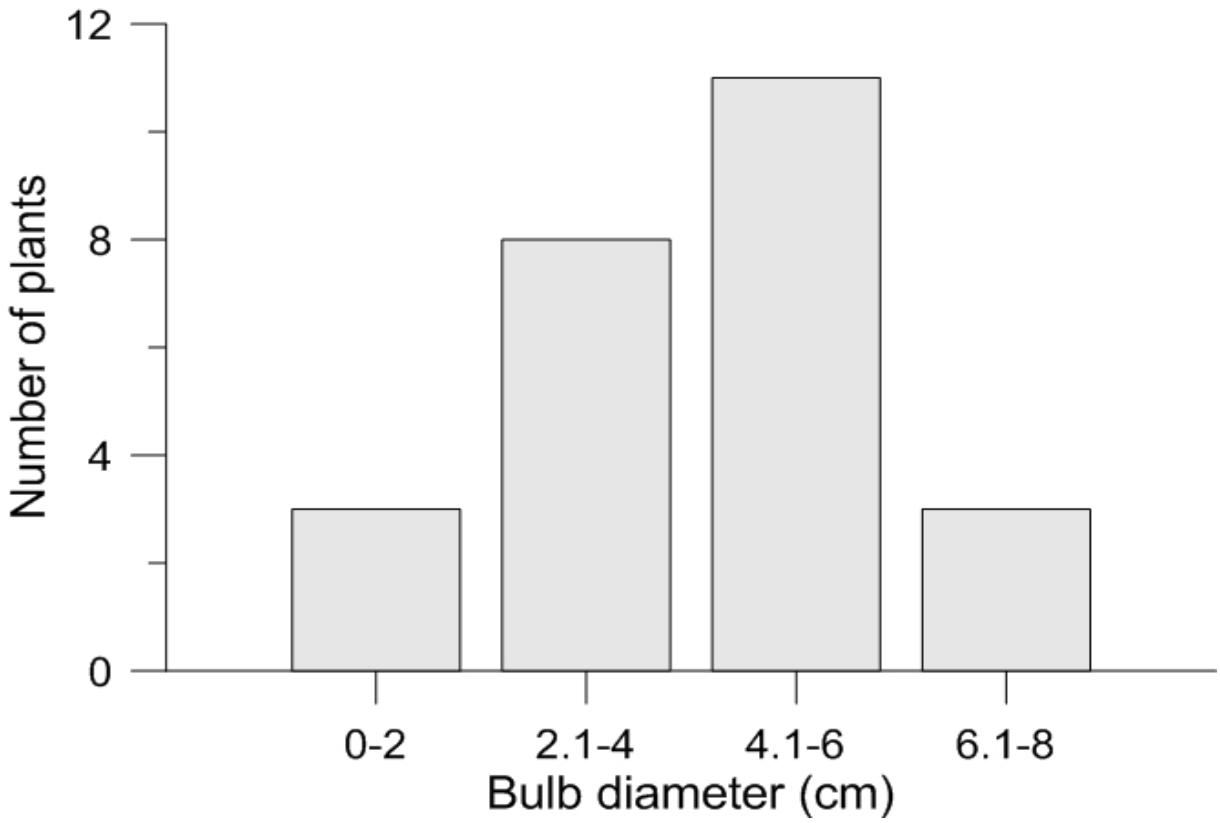

Figure 11: The bulb size classes in the wild population of *Boophone disticha*.

4.2.1 Juvenile stages

A total of 50 seeds for both *Brunsvigia grandiflora* and *Scadoxus multiflorus* were germinated. Of these 90% of *Brunsvigia grandiflora* germinated, 72% of seedlings able to grow to pre-transplanting age and 62% of the seedlings survived the transplanting process (Figure 12). *Scadoxus multiflorus* fared better with 92% of seeds germinating, however, only 58% of the seedlings grew to pre-transplanting age and 52% of survived the transplanting (Figure12).

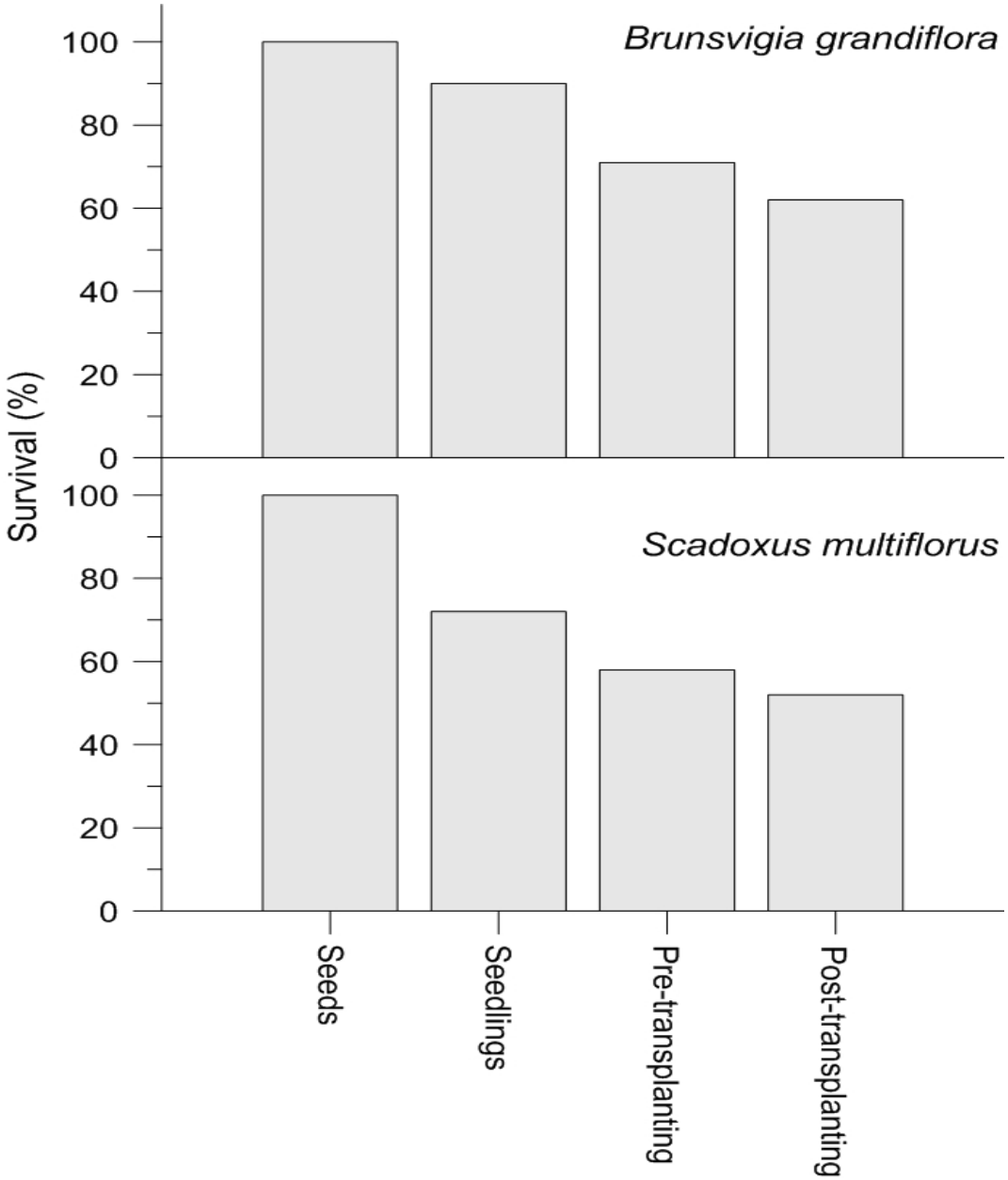

Figure 12: Graph showing the percentage survival of *Brunsvigia grandiflora* and *Scadoxus multiflorus* seedlings.

4.2.2 Harvested stages

Using increase in bulb diameter of the plants that were measured at the Nelson Mandela Metropolitan University Nature Reserve, plants will take 7 years for the *Boophone disticha* bulbs to become 6 cm in diameters and of harvestable age.

Also using bulb growth rates, it is estimated that *Brunsvigia grandiflora* takes 11 years to become 6 cm in diameter and of harvestable age.

Scadoxus multiflorus plants take 6 years to grow to be large enough to be targeted for harvesting.

Plate 11: Inflorescence and bulb of *Boophone disticha* (A) and immature bulbs of *Brunsvigia grandiflora* (B) & *Scadoxus multiflorus* (C).

4.2.3 Model of population dynamics

A model of population dynamics for the three species in this study is designed here. This model is based on bulb diameters growth rates of *Boophone disticha* measured at the Nelson Mandela

Metropolitan University Nature Reserve and using the bulb diameters of eight *Brunsvigia grandiflora* and six *Scadoxus multiflorus* seedlings that survived up to the end of the study period. To base the model on seedling bulb growth, the 12 smallest bulbs from the *Boophone disticha* growing in the NMMU Nature reserve (four 5 cm and eight 5.5 cm diameter bulbs) were used to calculate comparable average growth rates for this species giving a diameter increase of 0.99 cm per year for these young individuals (cf. Figure 9 for the growth rate for all bulb sizes).

The following parameters were used to model population dynamics in wild populations (Figure 13):

Boophone disticha:

- Bulb diameters increase by 0.99 cm per year (small individuals in the NMMU nature reserve, Appendix 2)
- Plants take 15 years to reach a flowering age (Pooley, 2005)
- Bulbs appear to be harvested when they reach 6 cm diameter (Baakens Valley population, Figure 11)

Brunsvigia grandiflora:

- Bulb diameters increase by 0.58 cm per year (seedling data, Figure 9)
- Plants take 15 years to reach a flowering age (as for *Boophone disticha*)
- Bulbs appear to be harvested when they reach 6 cm diameter(as for *Boophone disticha*)

Scadoxus multiflorus:

- Bulb diameters increase by 0.89 cm per year(seedling data, Figure 9)
- Plants take 15 years to reach a flowering age (as for *Boophone disticha*)
- Bulbs appear to be harvested when they reach 6 cm diameter (as for *Boophone disticha*)

From the quantitative data above a model illustrates the severity of the threat to the three plant species in this study (Figure 13). It is evident from the measurements taken during this study (Appendices) that the biggest bulb NMMU was 15 cm (or 16 years old) while the biggest bulb in the Baakens Valley population was 8 cm (only 8 years old) at the start of the study. This shows that the bulbs in the harvested population cannot reach flowering size.

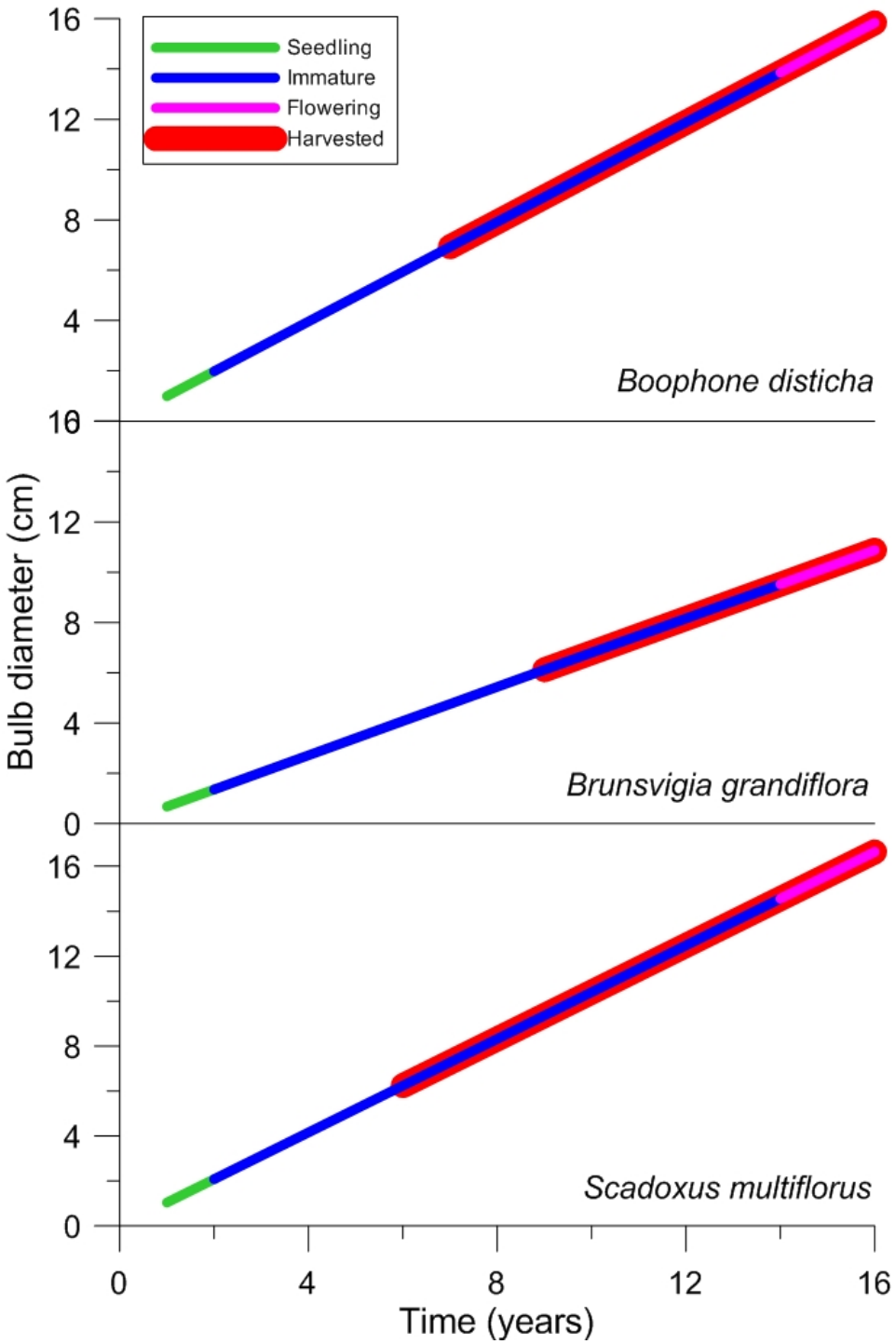

Figure 13: A model of population dynamics for *Boophone disticha, Brunsvigia grandiflora* and *Scadoxus multiflorus* plants in unharvested conditions (narrow lines). Plants are harvestable at age indicated in the wide red lines, illustrating the severity of the threat to these species.

4.3 Harvesting impacts

Considering the modelled threat to these three species, a wild population of each of the species was located and monitored over two circumcision seasons to determine whether the severity of the threats were realistic.

4.3.1 ***Boophone disticha***

Assessment of the impact of harvesting *B. disticha* covered two circumcision periods (December 2010 and June 2011). By October 2011, in the study area where the plants were marked, only one plant could be found. Some ten other plants were found, but these were not the marked individuals, and their bulbs were small compared to those that were counted and marked previously, indicating that they could be seedlings.

These smaller individuals were inspected again in 2013 and found to have not flowered yet. Measured plants that had flowered could be identified by the scar where the umbel detached from the plant. Even though these plants do not flower every year (Van Wyk et al., 2005), the small bulbs indicated that the plants were still in their juvenile stage.

4.3.2 ***Brunsvigia grandiflora***

Assessment of the effect of harvesting on *B. grandiflora* was conducted in January 2012, after two circumcision periods (June 2011 and December 2011). In the study area where the plants were marked, none of them could be found. This was also their flowering season so it was unlikely that the plants could not be found because they were in their dormant phase. The situation was particularly alarming in that not even a single plant could be found at the locality.

4.3.3 ***Scadoxus multiflorus* subsp. *katharinae***

Assessment of harvesting *S. multiflorus* was conducted in January 2012, after two circumcision periods (June 2011 and December 2011). The marked plants in the study area could not be found. There were a few plants of the same species at the study site, but they were not the ones that were marked as they were far smaller than those initially marked. Based on seed germination and also seedling survival results of the study it will be of vital importance to have a clear plan to save these plant species in the wild. According to their morphological

descriptions these three plants produce between 30 and 60 flowers in spreading inflorescences and this gives the plants to possibly bear as many fruits (Plate 12).

Plate 12: Fruits (A) and germinating seeds (B) of *Scadoxus multiflorus.*

The fruits photographed in Plate 11 are the fruits of *Scadoxus multiflorus* collected at from the study site to observe their flowering and fruit production as well as germination.

It is clear that the bulbs cannot replace themselves because it appears that most of the reproductive bulbs are being harvested during each circumcision period. In as much as the growth rates of *Brunsvigia grandiflora* and *Scadoxus multiflorus* is slow, these three species can still be cultivated so as to take pressure off the populations in the wild. It can would be useful if people cultivate these plants in their gardens as they bear attractive flowers. This will be reasonably simple as there is good success withseed germination and a reasonable number of seedlings survive in cultivation.

CHAPTER 5

DISCUSSION AND CONCLUSION

People in the Eastern Cape rely on plants for many reasons. According to Victor &Dold (2003) the Eastern Cape Province, covering approximately 170 500 km^2, is home to 15.5% (6.4 million) of South Africa's total population (48.8 million in 2001). Some 49% of the province's population is unemployed compared to the national figure of 25%; 39% of those employed earn less than R500 a month compared to 25% nationally. The people of the Eastern Cape are more rural and significantly poorer than those in other parts of South Africa; a large proportion of them rely to some degree on natural resources for direct subsistence or indirect as a form of income generation.

Extinctions in South Africa are proceeding at an increasing rate, highlighting the urgent need for nature conservation in its broadest sense. Overharvesting of many medicinal plants has placed many species at risk of extinction. Commercial exploitation has also sometimes led to traditional medicines becoming unavailable to the indigenous people that have relied on them for centuries or millennia (Roberson, 2008).

Now the fundamental questions for conserving biodiversity are: what have we got, where does it occur and how much is left? The knowledge and understanding of the biodiversity in South Africa is, in many respects, still inadequate to completely answer these questions and therefore to guarantee proper conservation support. Further scientific research is needed where we accurately document the country's biodiversity and improve the possibilities for its optimal conservation.

At the end of the day it is not knowledge, though, that will save the South African biodiversity treasure trove, but it is action. Based on the objectives of the study, it can therefore be recommended that, there is a need to balance human demands with the importance of conserving the natural environment. While we continue to exploit our natural resources such as land, forests, water, fauna and flora; if these are in limited supply that would lead to them being exhausted and degraded, rendering a stunted economic growth. Therefore educating our

communities could lead to sustainable development. If we can reach out and educate those people using these resources about the importance of sustainable use of our natural resources and also about the importance of protecting their immediate environments, they may feel a sense of responsibility to their environment and in return, these communities will benefit from the availability of these resources in the near future rather than becoming endangered in the wild because of their exploitation. Sustainable use of resources can be achieved through education and an improved awareness of the value of our natural environment to present and future generations.

According to the results it is clear that the harvest volume of these plant species in the wild is very high during each circumcision period. It shows that plants are heavily harvested in the wild during each circumcision period. It is also evident that plants are harvested long before they even flower and this trend is putting a lot of pressure in the life cycle of these plants as they need to flower so as to complete their life cycles and for them to reproduce. The harvest frequency of the population of these plant species shows that they are collected in large amounts and in their immature stages. The trends of harvest are increasing and this suggests an appropriate precautionary approach.

The model of population dynamics is going to assist in predicting the dynamics of plant populations before and after harvesting and also to predict the change in extinction probability as a result of harvesting. The model will also help in identifying important data to collect so as to accurately predict the population dynamics of the three plant species under study by knowing where the gaps are in the existing knowledge and it will serve as an indicative measure as to where additional information would improve confidence in applying monitoring protocols.

Considering the findings of this study it is evident that there is not enough “effective education”; people will only care about things that they can associate with, therefore a challenge goes to the conservation agencies like the national parks and nature reserves to educate the communities about the sustainable use of our natural resources. Whether the information generated by the scientists is used wisely and effectively depends on the capacity of the country’s conservation agencies to deliver and have clear conservation plans to prevent

further decline of our biodiversity. It is therefore of reality that we cannot only depend on the seed storage, which is the most effective and widely-practiced means of *ex situ* (outside the natural environment) conservation of plant generic resources because some seed material is hard to store and require expensive biotechnological processes to maintain (Chambers & Macmahon, 1994).

To address the issues of conservation of these three species, it is therefore important to develop a conservation plan that can be implemented to save these species in the wild. To look at this, one needs to understand the pathways that seeds follow after they have left the parent plant, the states in which they reside, and also some biotic and abiotic factors that influence them (Chambers & Macmahon, 1994).

There has been an evolution of a broad-scale conservation planning and efforts to make the process more systematic, scientifically defensible, and rigorous are underway. These efforts include the establishment of conceptual frameworks for planning and to also set the standards and the criteria to guide and evaluate individual conservation plans. However conservation biologists recognize that each case study in many ways is unique and must be therefore treated as such. However, there are also commonalities among cases that need a degree of standardization of planning methodology (Noss *et al*., 2002). The plant species under the present study show a huge decline due to overharvesting; I would therefore suggest that an underlying principles and concepts of reserving these plants should be considered. An assessment of which species are threatened allows resources for species conservation to be prioritized. Here I present guidelines for future scientific work by developing a protocol for the application of conservation planning. There is a need for us to re-commit ourselves to conservation of our remaining species so that we minimize these declines. Implementing sustainable use through conservation planning and also cultivation measures are the only solution to control the decline of medicinal plants through overharvesting (Noss *et al*., 2002).

Basic steps for conservation planning:

1. Identify areas for conservation

For the past decades attempts to identify new reserves using a number of systematic, large-scale conservation planning have been receiving an increased attention (Noss *et al*., 2002).

Considering different types of conceptual models that are in use, the model to be used in the plan must be chosen. Practitioners, local scientists and conservationists must be awarded opportunity to provide valuable and often undocumented information on conservation elements, threats and feasibility of the site protection. Involvement of the experts through workshops can help to improve the effectiveness of conservation plans and also to identify the areas for conservation. The input and advice generated through these review processes (workshops) can be used to fine-tune the boundaries of the conservation areas as well as improve conservation plans (Jones *et al*., 2006). According to Margules & Pressey (2000) the most convenient methods for the selection of conservation areas involve algorithms that use explicit rules for selecting a reserve.

After carrying out the assessment of the impacts of harvesting the three plant species in this study I think it is necessary to declare the study sites as conservation areas because this is where these plants occurred naturally. Depending as to when the conservation plan will be implemented maybe these plant populations in the study areas will be able to rise again and replace those that have been wiped away when the implementation of the plan takes place. On the other hand looking at their growth rate during the whole study period it might take a very long time to replace the ones that have been heavily harvested and in that case the plants can be planted back in the conservation areas by making use of their seeds.

According to the Red List of South African Plants the Species of Conservation Concern (SCCs) are defined as those taxa that are important for South Africa's conservation decision making-process and this include those that are Extinct in the Wild, Critically Endangered, Endangered, Vulnerable, Data Deficient (due to insufficient information), Near Threatened, Critically Rare, Rare, and Declining (Raimondo *et al*., 2009). *Boophone disticha* is therefore SCCs because it is

listed as Declining and *Brunsvigia grandiflora* and *Scadoxus multiflorus* are listed as Least Concern (Raimondo *et al*., 2009). The Baakens River Valley is an area of significant conservation importance in the Nelson Mandela Bay Municipality. In the study conducted by Grobler (2012) there are plants that are listed as Critically Endangered, Endangered, Vulnerable, Near Threatened and Declining that are found in this area and *Boophone disticha* is among those that are listed as declining.

2. Identify stakeholders

Identification of stakeholders play a very important role for conservation plans to be successful and prospects for successful implementation are enhanced if all the relevant agents participate in the planning process from the beginning. Stakeholders are people, groups or institutions, who are likely to be affected by the proposed project and they can also affect the outcome of the project. Public participation meetings of different stakeholders in the whole process play vital role so as to introduce a wide range of ideas. There must also be outreach programs to acquire public support and also to ensure the success of the plan. If the members of the public are not satisfied or they are not well educated through these outreach programs then the success of the plan is unlikely. The outreach program must provide on-going education that must not end with the signing of the implementation agreement; it must continue to avoid future legal challenges that might arise and also to promote the sustainability of the plan and to reinforce why it is important to use our natural resources in a sustainable manner. These outreach programs should include designing printed materials and community information meetings. The community meetings can be held in the form of open days whereby there are informal meetings at a public location just to allow the public to ask questions and express their views directly to the project staff.

The stakeholders play an important role in implementing and monitoring a conservation plan (stages 8 and 9 below). Then the question is who is a legitimate stakeholder? This question must be addressed before any plan is developed, so as to achieve the conservation goals (Sarkar &Illoldi-Rangel, 2010). The stakeholders may include government officials from the local conservation authorities, biological and other experts, elected representatives from local and

indigenous communities (in the case of the present study these may include traditional healers and also traditional leaders as they are the custodians of the circumcision practice in the Eastern Cape province), non-governmental organizations (NGOs). The stakeholders will inherit the plan and therefore they will develop a sense of ownership of the process (Sarkar &Illoldi-Rangel, 2010 and Pierce *et al*., 2005). In the public participation meetings working with local and indigenous communities to learn and also to respect their rights, tradition and cultures is very important. Stakeholders will provide valuable information regarding the needs and they will be able to recognize the hidden items that might not be so obvious in the planning stage. They will encourage each other with a sense of ownership in the project to conserve the plant species. After identifying the stakeholders there must be an establishment of a stakeholder's forum so as to make sure that the cultural values of the custodians of the circumcision practice are not being compromised.

3. Compile data on process

The findings of the present study must be used together with the vegetation map from the South African National Biodiversity Institute (SANBI) to collect data of the three plants that were assessed. A vegetation map is a convenient and effective way of mapping habitats. The SANBI vegetation map is the result of a collaborative project involving many experts. The vegetation map is the most complete and up to date information on the vegetation types of South Africa (Rouget *et al*., 2004). Vegetation map will also assist on making informed decision as to which area/s must be identified for conservation of the three plant species in the present study. The information on vegetation map will form a baseline to provincial authorities on the population size, distribution and structure across the species range and will assist provincial authorities to make such informed decisions.

4. Set goals and targets

There must be quantitative conservation targets; for example, number of species, vegetation types, and so on, and these targets must be explicit so as to evaluate efficiency of conservation

planning during the process, starting from conservation assessment to monitoring (Knight *et al*., 2006).

The results of the present study show the unsustainable use of all the three plant species under the study, therefore the goals of the conservation plan has to ensure the long-term conservation of the study areas, restoration and sustainable use of the plants. Each stakeholder must be having a clear insight of the role to play to ensure the long-term conservation and sustainable use of the species.

5. Review existing conservation areas

In order to do a conservation assessment, one needs to know how much of various biodiversity features is already protected. This must be done using a map of protected areas. One can get information from South African National Parks (SANParks), Department of Environmental Affairs and Tourism, South African National Biodiversity Institute (SANBI) and also from provincial conservation organizations. The existing conservation system in the Baakens River Valley is only the Settlers Park local nature reserve and is covered by an area approximately 75 ha (Grobler, 2012).

6. Prioritize areas for conservation

After establishing the new conservation areas, they must be prioritized so that the specified goals and targets are met when these areas are eventually included in existing protected areas in the region concerned (Sarkar &Illoldi-Rangel, 2010). It has been suggested that site prioritization should be based on two measures and these are (i) irreplaceability which is described as a measure of site importance and (ii) vulnerability which is described as the site's susceptibility to threats and is meant to indicate the urgency of protection of the site: a highly vulnerable site must be given priority to be protected (Arponen, 2009). Due to the decline in plant populations of the plant species under the present study it is therefore a need to consider their conservation a priority. If these plants are continuing being under the Least Concern

category they will soon go to the endangered category if there are no measures in place to control their decline.

7. Assess irreplaceability and site vulnerability

Several dynamic, sequential selection algorithms have been developed to address the issue of scheduling which areas should be protected urgently. As a matter of fact, in reality funds allocated for conservation are rarely available all at once but rather as smaller amounts but over a longer period of time, therefore site vulnerability is the one that guides, informs and contributes towards achieving the conservation goals (Arponen, 2009). To identify priority core areas for conservation campaigns one needs to rank each core area in terms of its irreplaceability and vulnerability. The concept of irreplaceability provides a measure of the relative contribution different core areas make to reach overall conservation goals, while a measure of vulnerability reveals the degree of current and future to individual core areas and helps determine which cores are in urgent need for immediate protection (Jones *et al*., 2006).

In the present study there is a high degree of vulnerability due to overharvesting of the plant species in all the three study areas.

8. Implement conservation plan

After all the above steps have been followed then the conservation plan needs to be implemented. Conservation plans may be incompletely implemented or they may be implemented part by part over a period of years. These possibilities may even change the nature of the whole plan however to overcome these challenges one needs to have an appropriate set of stakeholders from the beginning (Sarkar &Illoldi-Rangel, 2010).

9. Create a monitoring program

It is ideally that all implemented conservation plans should include a monitoring program. The aim of a monitoring program is to make a follow up on change in species abundances,

population quality of the species, or whatever happens that would be the most suitable indicators of success relevant to the aims of the program. The information collected during monitoring should help to influence future decisions so that conservation actions that are effective are favored and those that are ineffective are changed (Arponen, 2009). After implementing the conservation plan then monitoring must be done to determine the numbers of individuals in populations, either by counts again or by sampling in plots for a statistical estimate of total numbers of plants at the conservation site. A repeated monitoring over several years will be done to show trends in population size over time and to measure the conservation success of the conservation plan. There must be an oversight committee that will conduct field visits to sites, provide expertise on plant species and evaluate plants on the risk groups, life-history of plants and their growth rate.

Below are specific guidelines and recommendations for drawing up a functional and scientifically defensible monitoring program. However, according to Atkinson *et al*., 2004 there is no one best approach for managing and monitoring any system, but following these steps will yield a monitoring program that fulfills the requirements of a conservation plan:

Stepwise approach to creating a monitoring program (Atkinson *et al*., 2004)

Step 1

Identify the goals and objectives of the conservation plan

One needs to identify and state clearly the conservation goals and objectives so as to evaluate the success of any conservation program. These goals and objectives should be easily understandable by all stakeholders. Once the goals and objectives are clear and specific then that makes the design and implementation of the monitoring program easier, whereas goals and objectives that are vague consume staff time as they will have to interpret the initial intention of the plan.

Step 2

Identify the scope of the monitoring program

Here in this step the scope and boundaries of the intentions of the monitoring are identified so as to evaluate and identify any requirements, obligations and opportunities that need to be accommodated in the program's design.

Step 3

Compile information relevant to monitoring program design

There must be compilation of information for developing conceptual model (step 5 below) and this information must be compiled by monitoring program designers. The information on existing monitoring programs and existing data on species must be collected.

Step 4

Strategically divide the system and prioritize for monitoring program development

A clear strategy and setting priorities in designing an effective monitoring program plays a very important role in identifying the most important system element to monitor and the critical uncertainties to address.

Step 5

Develop simple management-oriented conceptual models

Monitoring program design is significantly improved by the use of conceptual models, it is therefore important that one needs to develop the models. There are many different types of conceptual models that are in use (Atkinson *et al*., 2004).

In the case of the present study a lot of information is known that is needed when developing a conceptual model for example scientific and common names, taxonomic or identification issues this may include life expectancy (annual, biennial, or perennial) in this case the plant species are perennials and also the threats that cause the decline in the populations. The best time for monitoring is when the plants are most visible or easily identified.

Step 6

Identify monitoring recommendations and critical uncertainties

After the draft of conceptual models, the monitoring program can select which characteristics of the system to monitor, determine the specific monitoring objectives and appropriate monitoring variables for each characteristic and identify critical uncertainties that require targeted study.

Step 7

Determine strategy for implementing monitoring

Developing a strategy for implementing monitoring is very important because once the monitoring variables and critical uncertainties have been identified; they should be prioritized and organized into a work plan that includes anticipated monitoring and adaptive management tasks and timelines.

Step 8

Develop data quality assurance, data management, analysis, and reporting strategies

Information gathered during monitoring must be analyzed correctly, archived well, reported in a timely manner and must also be communicated well and appropriately. According to National Park Service Inventory and Monitoring Program it is recommended that at least 30 percent of monitoring funds must go to data management and reporting. This maximizes the usefulness of the data, making it available for any queries by managers and scientists addressing new issues and research questions while also providing information for the long-term monitoring program. The data collected must be analyzed based on the goals and monitoring objectives.

Step 9

Complete the adaptive management loop by ensuring effective feedback to decision-making

A good decision support systems that will feedback information efficiently into decision-makers requires both initial planning and adjustment over time. This decision support system serves the entire conservation program.

There must be an oversight committee that will assist in conducting field visits to the conservation sites, provide expertise on plant species and monitor and also evaluate or assess the plants time and again based on the risk categories. For the success of the conservation plan the oversight committee must always keep in mind the goals of the conservation plan.

Unfortunately, systematic conservation planning also has some limitations. There are five major limitations: (1) systematic conservation planning software is difficult to use, (2) systematic conservation planning requires extensive biodiversity distribution data, (3) setting targets for representing conservation features is not possible, (4) the advantages of systematic conservation planning do not outweigh the costs and lastly (5) systematic conservation plans identify unsuitable areas (Smith *et al*., 2006). It is therefore very important to look at how these limitations relate to the three study areas.

In the event that these limitations become the barriers to implementation of the conservation plan discussed above, it would be advisable to cultivate these plants for commercial purposes to sell to the harvesters or to plant them back into the wild at times outside of the circumcision season. This could be done using the protocol below:

(a) Sow 10-20 seeds into a pot containing moist potting soil.

(b) Cover the trays with cling wrap and put them in a refrigerator for 2-4 days to simulate vernalisation

(c) Place the covered pots in a warm environment with light.

(d) Remove cling wrap after the first leaves appear

(e) Water when necessary.

(f) Transplant seedlings into individual pots after one growing season.

(g) Plants should be grown in pots until they are 3 cm in diameter (no longer sensitive juveniles) at which time they can be planted into the soil at the study site with their potting soil attached.

(h) Plants should be planted into the wild at the start of the growing season, when any damage due to transplanting will be rapidly repaired by the growing plant.

More than 50% of the uprooted seedlings for both *Brunsvigia grandiflora* and *Scadoxus multiflorus* survived in the glasshouse three months after transplanting. The seedling survival declined after transplanting and this could be explained by many possibilities for example the interaction between the seeds and the microsites and also the fact that in general burial of seeds in a cool dry soil may promote the longevity of the seed, while burial in a cool moist soil may result in natural stratification and increased seed germination and in a warm humid area burial may increase the rate of seed decomposition and the probability of attack by pathogens of the seedlings.

Generally, it does not matter how careful you have been during transplanting the seedlings, the transplanted seedlings will experience some transplanting shock. This reaction is caused by the damage of the roots during the uprooting.

Even though the thickest roots are nearest to the bulb but the most important roots and those that actually do most of the work are those located farthest away from the bulb. These tiny roots are covered by even tinier hairs to absorb most of the water from the soil. During transplanting therefore, these tiny roots are destroyed and they are destroyed either by being cut or by drying out through exposure to air during the process of transplanting them. The result of the loss of the feeder roots is that the plant fails to draw the amount of moisture it requires for growth. This phenomenon (transplanting shock) will result in other seedlings being not able to survive the transplanting.

Plant dormancy is a form of phenotypic plasticity that minimizes exposures to seasonally stressful conditions. Phenotypic plasticity is the ability of an individual plant to alter its phenotype in response to changes in environmental conditions and is widely regarded as a mechanism to cope with heterogeneous environments. Plasticity can be selectively advantageous in habitats that encounter predictable environmental change. Long-lived plants occurring in seasonal environments must adapt to the conditions posed by both favourable and unfavourable seasons. The life cycle of most geophytes includes dormant periods during which time the above ground parts of the plant die back in response to seasonally stressful conditions. Regrowth occurs by means of the perennating bud that is borne on an under-ground storage organ such as a tuber, a bulb or a corm. The storage organ conserves nutrients between

seasons and allows rapid growth of leaves under favourable conditions (Vaughton & Ramsey, 2001). The growth rates of the seedlings in the glasshouse was rather slow during the duration of the study but this was not surprising because according to Vaughton & Ramsey (2001) seedlings of many geophytes should be allowed to remain in their single pots for two years, and at the beginning of their third season, the first flowers can be expected, under ideal conditions. This gives a room for predicting that at the time of concluding with the results of the assessment the plants that were in the glasshouse were not yet of flowering size as it was still early for them to flower according to what Vaughton & Ramsey (2001) are saying about the flowering of many geophytes. As for the findings in the study sites it is up to no doubts that the plant species are under threat in the wild. According to the latest status of the three plant species *Boophone disticha* is listed as declining in the wild, and *Scadoxus multiflorus* & *Brunsvigia grandiflora* are only listed as Least Concern (Raimondo *et al*., 2009). If the factors that are causing the decline continue operating these plants will soon be in the endangered category according to the IUCN Red Data categories.

Recommendations and future research

The aim of this study was to assess the impacts of harvesting three circumcision amaryllids in the Eastern Cape Province in South Africa, however in the study it has been found that the plants are being harvested and their growth rate is slow for them to recover from the pressure of harvesting. This warrants a chance for future research to collect large amounts of data to be able to make meaningful and accurate quantitative predictions of species concerned population dynamics. Population modelling can be performed with little quantitative data but it can be continually improved by collecting more data. As the new data become available to update predictions that could particularly be useful to improve and develop models for species that are repeatedly harvested.

Research work on the systematic conservation assessment and planning for the three plants species under study will also help to conserve the small populations that are still available in the wild.

The study period was too short to fully assess the growth rates of geophytes as their growth rates are slow, future research study to assess the growth rates is needed and to also test and evaluated the designed population modelling for population dynamics of the plants. The model needs to be evaluated qualitatively by checking its behaviour and its ability to simulate expected phenomena and also evaluate it quantitatively by comparing the model outputs to real data.

Appendix 1: Bulb diameters of *Boophone disticha* in the Baakens Valley.

	Bulb diameter (cm)	
Plant no	**August 2010**	**October 2011**
1	1.5	-
2	1.5	-
3	5.5	-
4	5.5	-
5	5.5	-
6	5.5	-
7	5.5	-
8	5.5	-
9	3.0	-
10	3.0	-
11	3.0	-
12	3.0	4.5
13	3.0	-
14	3.0	-
15	3.0	-
16	3.0	-
17	6.0	-
18	6.0	-
19	5.0	-
20	5.0	-
21	5.0	-
22	8.0	-
23	8.0	-
24	8.0	-
25	1.0	-

Appendix 2: Bulb diameters of *Boophone disticha* in the NMMU Nature Reserve.

	Bulb diameter (cm)		
Plant No	**August 2010**	**October 2011**	**August 2013**
1	7	10	10.5
2	7.0	9.5	10
3	7.0	10.5	10.5
4	5.5	7.5	8.5
5	5.5	6.5	7
6	5.5	8.0	8.5
7	5.5	6.0	-
8	5.5	5.5	-
9	5.5	10	11
10	5.5	6.5	7.5
11	5.5	5.5	-
12	6.0	9.0	10.5
13	6.0	8.5	9.5
14	6.0	7.5	8
15	6.0	8.0	8.5
16	8.0	10	10.5
17	8.0	9.5	10.5
18	8.0	8.5	9.5
19	8.0	9.0	9.5
20	8.0	10	10.5
21	8.0	9.5	11
22	8.0	8.0	9.5
23	8.0	8.5	9
24	5.0	6.5	7.5
25	5.0	7.0	8.5
26	5.0	6.0	-
27	5.0	6.5	7
28	12	12.5	13
29	12	14	14.5
30	12	14	15

Appendix 3 : Seedling mass (g) of *Brunsvigia grandiflora*.

Seedling No	August 2010	2013
1	1.63	-
2	3.49	35.3
3	2.48	26.2
4	1.39	-
5	1.86	-
6	1.10	-
7	2.19	21.6
8	2.75	-
9	2.40	-
10	3.38	26.6
11	1.22	-
12	2.38	21.4
13	2.11	-
14	2.34	20.5
15	1.31	-
16	2.95	-
17	1.20	7.4
18	1.39	-
19	2.97	16.5
20	2.73	-
21	3.10	-
22	3.56	20.6
23	3.02	-
24	2.55	19.3
25	2.71	-
26	1.87	-
27	1.56	11.5
28	3.33	-
29	2.95	13.1
30	2.76	-
31	1.54	-
32	1.16	-
33	2.25	-
34	2.68	18.8
35	1.90	-
36	1.69	-

Appendix 4: Seedling height (cm) of *Brunsvigia grandiflora*.

Seedling No	August 2010	October 2011	August 2013
1	7.5	7	-
2	12.5	10.5	10
3	8	7.8	8
4	7	7	-
5	6.5	6	-
6	4.5	-	-
7	6.9	7	6
8	6.8	5	-
9	5.1	3.5	-
10	7.5	8	7.5
11	5.3	-	-
12	6.8	7	6.5
13	5.3	3	-
14	5.4	6	5
15	6.2	5	-
16	5.6	4.5	-
17	5.3	5	4.5
18	4.6	3.5	-
19	10.5	9	8.5
20	11	8	-
21	11.5	-	-
22	13.5	14	13
23	12.5	8.5	-
24	11.5	11.5	11
25	10.5	7.5	-
26	9.5	6.5	-
27	9	9.5	9
28	13	11.5	-
29	6.5	7	7.5
30	6	-	-
31	7	6.5	-
32	6.5	6	-
33	7.5	8	-
34	10.5	11	9
35	8.5	8	-
36	7.5	-	-

Appendix 5: Seedling mass (g) of *Scadoxus multiflorus*.

Seedling No	August 2010	August 2013
1	11.35	-
2	13.12	68.5
3	19.30	-
4	6.89	29.1
5	14.80	-
6	14.06	-
7	7.47	-
8	16.13	67.2
9	8.39	-
10	24.83	92.5
11	16.47	-
12	12.58	-
13	15.20	-
14	19.98	60.7
15	7.94	26.2
16	12.48	65.3
17	2.40	-
18	2.49	-
19	33.48	202.7
20	6.20	-
21	4.38	-
22	6.72	-
23	16.53	-
24	20.64	98.7
25	18.07	-
26	13.16	-
27	3.98	-
28	0.93	-
29	21.28	93.8

Appendix 6: Seedling height (cm) of *Scadoxus multiflorus*.

Seedling No	August 2010	October 2011	August 2013
1	5.3	5.5	-
2	6.8	7	5.8
3	8.5	8	-
4	8.5	4	3.7
5	5.6	6	-
6	6.3	6.5	-
7	5.2	5.9	-
8	6.3	6.6	5.2
9	3.7	4.6	-
10	8.1	8.9	6.8
11	6.6	6.2	-
12	6.5	6	-
13	5.8	-	-
14	6.3	5.8	4.2
15	3.9	3.4	3.2
16	6.1	6.5	5.8
17	2.8	-	-
18	2.7	2.5	-
19	9.1	8.6	8.2
20	6.5	6.2	-
21	3.3	3.1	-
22	5.3	5.6	-
23	6.1	5.7	-
24	8.2	7.8	6.3
25	7.9	7.3	-
26	5.9	5.8	-
27	3.1	2.8	-
28	2.1	-	-
29	8.1	7.8	4.2

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