# VULNERABILITY, IRREPLACEABILITY AND RESERVE SELECTION FOR THE ELEPHANT-IMPACTED FLORA OF THE ADDO ELEPHANT NATIONAL PARK, EASTERN CAPE, SOUTH AFRICA.

THESIS
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# Abstract

The Addo Elephant National Park (AENP) is the only existing national park situated in succulent thicket. This unique veld type is endemic to the Eastern Cape, and forms an important centre of endemism for small succulents and geophytes which comprise the subdominant component of the vegetation. It is regarded as the most threatened vegetation type in the Eastern Cape, as much of it has been severely degraded by farming activities and its rate of regeneration is very low. Thus the AENP represents an important sanctuary for certain species. However, large herbivores, particularly elephants, pose a further threat to the vegetation, and areas from which elephants have been excluded in the park (botanical reserves) have been shown to be more species-rich than the surrounding vegetation. Most elephant-impact studies have focussed on the large shrub component of the vegetation, and only preliminary studies have been done in AENP to date. As the elephant population continues to grow, there is pressure to utilise the botanical reserves to increase the amount of available grazing. It is thus important that the botanical reserve system be highly effective and efficient in terms of area. Existing botanical reserves were established *ad hoc* and are therefore not necessarily optimal in this regard. An iterative reserve-selection algorithm was used to maximise plant species conservation in the most efficient area.

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# CHAPTER 1:

# GENERAL INTRODUCTION

The Addo Elephant National Park (AENP) is situated in the Eastern Cape Province of South Africa. In 1991, the park covered approximately 8000 ha, of which more than 90% is succulent thicket (Moolman and Cowling, 1994). Since then the park has been considerably enlarged and amalgamated with the former Zuurberg National Park, 18% (or 6593 ha) of which is valley bushveld (succulent thicket) (Novellie, 1991). Future reference to the AENP implies the study area only, unless otherwise stated. Although the park was originally proclaimed to protect the last remaining elephants, *Loxodonta africana*, of the Cape region, the first conservation objective of the park is to 'preserve intact a viable example of valley bushveld' (Novellie, 1991). However, as the succulent thicket of the Eastern Cape has been progressively degraded, it has become increasingly apparent that protection of its flora should be one of the main functions of the AENP. It is essential to find the most efficient means of protecting the flora of the park, while maintaining the maximum amount of grazing for elephant. This chapter introduces the thesis by placing the flora and vegetation of the study site in a broader regional context. It identifies the gaps which the thesis has aimed to fill, and presents these as tractable research questions.

Before proceeding, some geographical concepts of the Eastern Cape need to be clarified. The Eastern Cape Province of South Africa only formally came into being during the mid-1990's as part of a provincial restructuring exercise throughout the whole country. It comprises parts of what were included in the former Cape Province and the 'self-governing territories' of Ciskei and Transkei. Prior to this, the term 'Eastern Cape' had been widely used for various parts of the province, but not in any consistent way. The region referred to as the Eastern Cape in this work is defined by the new provincial boundaries (see Figure 1.1), and corresponds to the area used by Low and Rebelo (1996).

The northern boundary to the Free State and the north-western boundary to the Northern Cape remain relatively unchanged. The Transkei is now included in the eastern section of the province (with the boundary at the Mzimkulu River), and the western boundary has been shifted to just east of Plettenberg Bay. The inclusion of these new areas has almost doubled the area of the province from 88 000 $km^2$ (Gibbs Russell and Robinson, 1981) to approximately 169 570 $km^2$ (Low and Rebelo, 1996). This accounts in part for the discrepancies in estimates of species number for the province: Gibbs Russell and Robinson (1981) estimated the flora at 3600-4000 species, while the latest estimate (Low and Rebelo, 1996) stands at 6164 species. Prior to 1996, however, authors still referred to slightly different areas, which makes comparison difficult. Lubke *et al.* (1986, 1988) referred to the region as lying between 31°S and the coast and 24°-29°E, bounded by the Mbashe River in the east. Gibbs Russell and Robinson (1981) defined the region from 32°S to the coast and 24°E to the Mbashe River. Kerley (1996) follows the latter definition. All use the Sneeuberg-Winterberg-Stormberg escarpment to denote the northern boundary. These discrepancies must be kept in mind when comparing the works of various authors – when reference is made to previous works, the Eastern Cape boundaries will follow that author's definition of the region.

## *1.1. EASTERN CAPE FLORA AND VEGETATION:*

The Eastern Cape has long been recognised as an area of botanical importance, with a flora estimated at 6164 species (Low and Rebelo, 1996). It is said that virtually all climatic and topographic variations in southern Africa are found in the Eastern Cape: the terrain is dissected by numerous small and several large rivers with little flat country, resulting in marked environmental heterogeneity over short distances. In addition, abrupt changes in soil composition interact with water availability to produce a wide range of habitats (Gibbs Russell and Robinson, 1981). This has resulted in the region's unusually high diversity of vegetation types: it encompasses 21 of Acocks' 70 veld types (Gibbs Russell and Robinson, 1981); according to White (1983), six of southern Africa's seven major

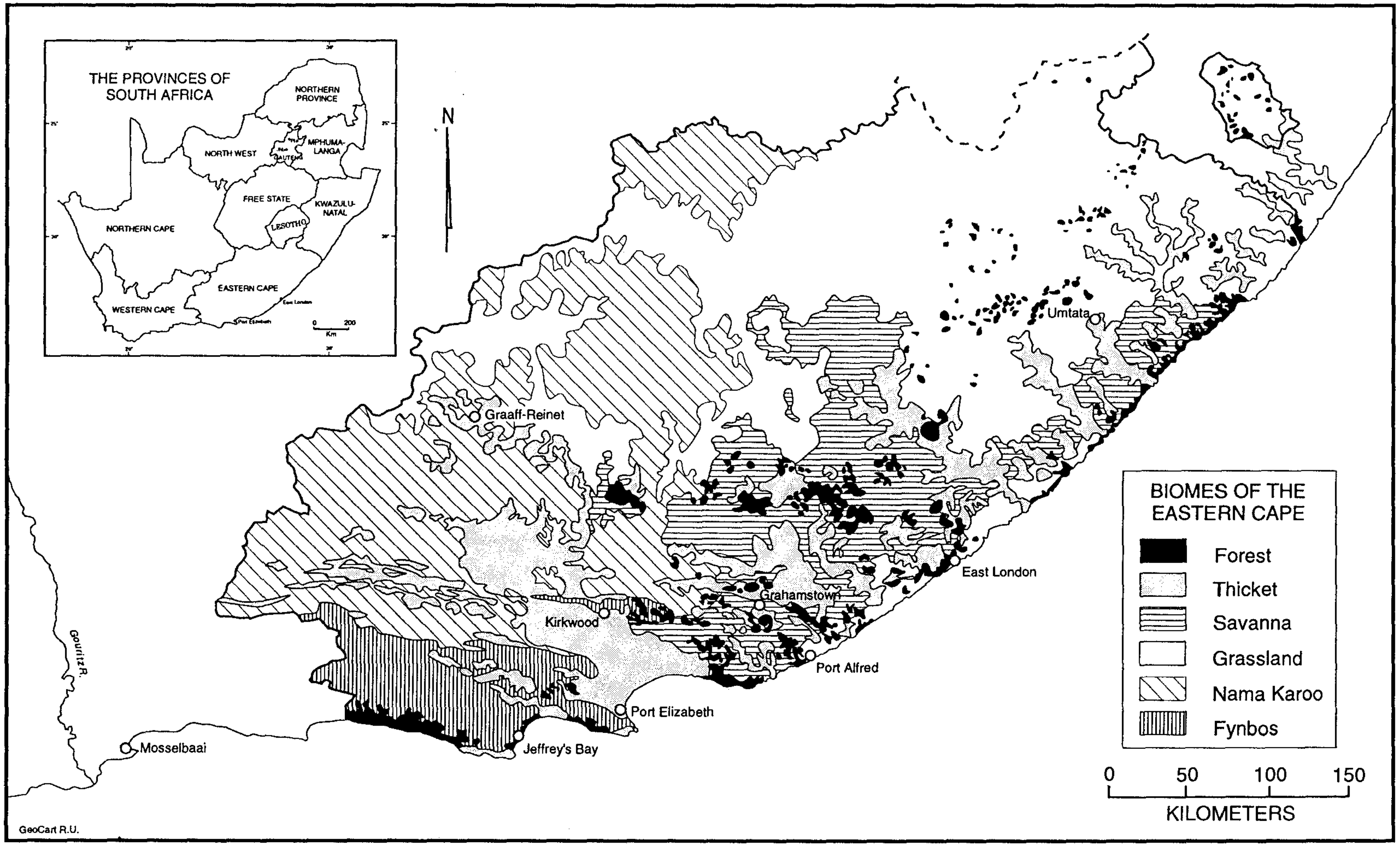


Figure 1.1. Biomes of the Eastern Cape (After Low and Rebelo, 1996).

phytochoria occur here: the Cape, Karoo-Namib and Afromontane archipelago-like regional centres of endemism, the Tongaland-Pondoland regional mosaic, the Kalahari-Highveld regional transition zone and the Afro-alpine region of extreme floristic impoverishment. These phytochoria all extend into the region from west, east and north, though none is limited to it (Cowling, 1983a; Lubke *et al.*, 1986). According to the memoir accompanying the revised vegetation map of southern Africa (Low and Rebelo, 1996), all seven of the biomes of southern Africa (Forest, Thicket, Savanna, Grassland, Nama-Karoo, Succulent Karoo and Fynbos) occur in the Eastern Cape, encompassing 28 different vegetation types (Figure 1.1). Thus, at the level of vegetation type and biome, biodiversity in the Eastern Cape is the highest in southern Africa.

This complex transition zone, or tension zone (Cowling, 1983a,b) is rich in species and communities, with all major vegetation formations represented (Lubke *et al.*, 1986). Previous studies have shown that most species in the area have their centres of distribution elsewhere, either extending west from the subtropical region, east from the Cape region, or south from the karroid hinterland, but not beyond the Eastern Cape. Those species that do extend in both directions from the region are widespread throughout southern Africa. Thus it is an area where many taxa of diverse phytochorological affinities reach their distributional limits (Gibbs Russell and Robinson, 1981).

Although the region is species-rich, it appears to have relatively low species-level endemism, estimated at 6-7% (Lubke *et al.*, 1988). Gibbs Russell and Robinson (1981) note that the diversity in the area is due to the composition of species from different phytochoria converging at the ends of their ranges, rather than as a result of *in situ* speciation. This is considered to be unusual in a region of marked fine-scale heterogeneity: one would expect fragmentation of populations and subsequent limitation of gene flow to occur, and thus promote the formation of 'species complexes'. This phenomenon is usually enhanced in semi-arid regions where climatic shifts force populations to become restricted to favourable areas (Stebbins, 1952), and marginal populations at the ends of their distributional limits are more likely to become isolated (Stebbins and Major, 1965).

One possible reason for the low *in situ* diversification in the Eastern Cape is that it is habitat generalist members of the different phytochoria that converge there, and that these lineages are not prone to diversification (Gibbs Russell and Robinson, 1981). However, although overall endemism is much lower than, for example, the Cape Floristic Region (90 000 $km^2$, 70% endemism) and the Succulent Karoo (120 000 $km^2$, 40% endemism) (Bond and Goldblatt, 1984; Hilton-Taylor, 1994), endemism within certain phytochoria in the region may be quite high: 43.5% of the Cape taxa and 28.5% of the Tongaland-Pondoland taxa are endemic to the Eastern Cape (Lubke *et al.*, 1988).

Within the Tongaland-Pondoland region, endemism appears to be highest in semi-arid vegetation types with large numbers of succulents (e.g. succulent thicket) (Cowling and Holmes, 1991), and declines rapidly with decreasing and increasing moisture as well as in overgrazed sites. Thus, endemism is not universally low in all vegetation types of the Eastern Cape: Cowling (1983a) recognised two centres of endemism in the south-eastern Cape region, one for Cape taxa and the other for karroid and subtropical taxa, with karroid succulents being extremely important in the latter group. These species may have been more widespread during drier glacial conditions and are now restricted to dry river valleys, while subtropical elements only invaded the area in the last 12 000 years, since the climatic amelioration of the Holocene (Cowling, 1983a, Cowling and Campbell, 1984). Hoffman (1989) argues that many of these taxa are in fact of subtropical origin, and that it is possible that subtropical elements have been moving into and out of the Eastern Cape river valleys since long before the last glacial maximum. Lubke *et al.* (1988) note that endemism in the region is difficult to estimate accurately as the composition of the flora is not sufficiently well known, but they suggest that succulent thicket vegetation has the highest number of endemics of all Eastern Cape vegetation types.

## *1.2. THE ALBANY HOTSPOT:*

This region in the Eastern Cape was recognised as an important phytogeographical centre by Nordenstam (1969) in his study on speciation and endemism in *Euryops*. A number of other studies have shown the area to be the focus of speciation and endemism for several groups including the genus *Euphorbia* (Croizat, 1965; Court, 1988) and the Mesembryanthema (Hartmann, 1991). This area has become recognised as area of such botanical importance that is it now referred to as the 'Albany Hotspot' (Cowling and Hilton-Taylor, 1994). The authors recognised that southern Africa's enormous biodiversity is not uniformly distributed, but concentrated in some areas, and identified eight such hotspots which contain 52.2% of southern Africa's endemics in 12.1% of its area, all of which are under threat. The Albany Hotspot stretches from Baviaanskloof and the Gamtoos River to the Kei River, bounded inland by the escarpment of the Amatole and Winterberg ranges (Phillipson, 1995) (Figure 1.2).

Cowling and Hilton-Taylor (1994) estimate the flora of the Albany Hotspot to comprise at least 2000 vascular plant species. The area is regarded as a transitional centre for many genera centred in the Maputoland-Pondoland, Cape and Karoo-Namib regions (Cowling, 1994). Succulent thicket is the dominant vegetation type in the region, covering an estimated 22 500 $km^2$, or 30-35% of the Albany Centre. The flora of succulent thicket in the region is estimated at 600 vascular plant species with a level of endemism of approximately 10% (Cowling, 1994). While there are no endemic families or genera restricted to succulent thicket, many succulent genera are centred here in terms of species numbers and endemism (Cowling, 1994). Van Jaarsveld (1987) notes that this is a region of active succulent speciation due to the diversity in local terrain combined with climatic transition between the subtropical east coast and the temperate Cape. This is evident in predominantly succulent genera such as *Gasteria*, *Haworthia*, *Bulbine*, *Crassula* and *Euphorbia*. Thirty percent of southern Africa's succulent *Euphorbia* species are represented in the Eastern Cape, of which 48% are endemic to the Eastern Cape (14% of southern Africa's species in this group) (Court, 1988). *Faucaria*, *Bergeranthus* and

*Glottiphyllum,* all Mesembryanthemaceae, are so-called neo-endemic genera of the region (van Jaarsveld, 1987).

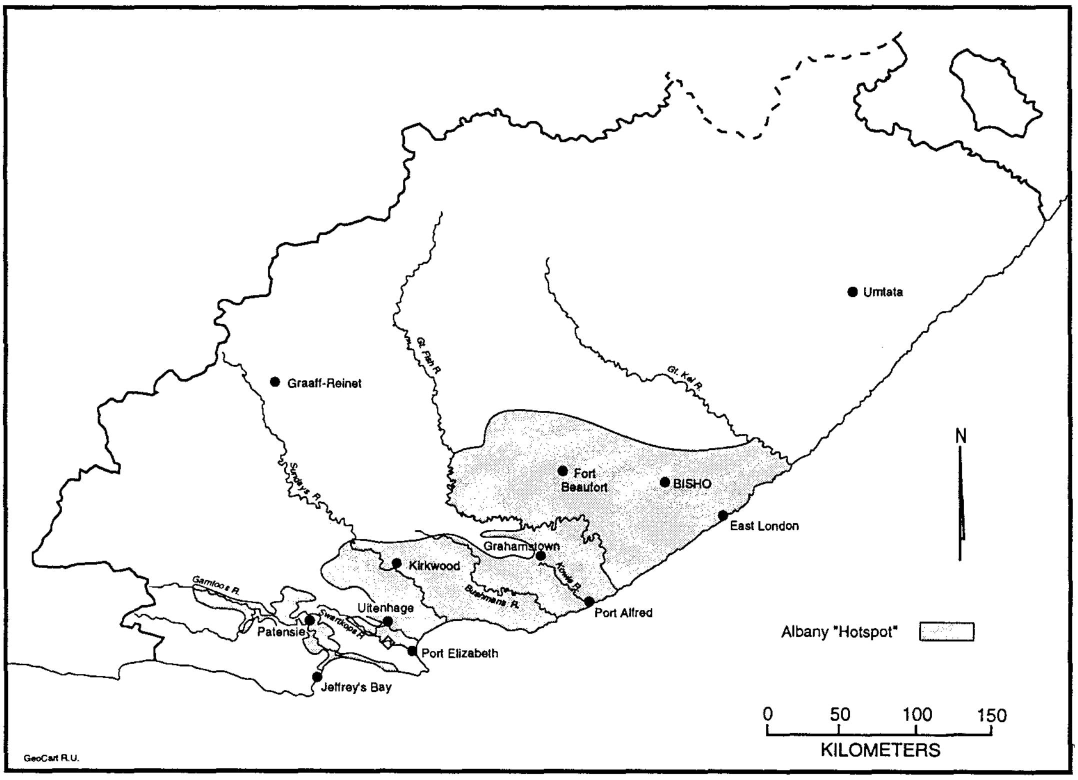


Figure 1.2. Map showing the location of the Albany Hotspot in the Eastern Cape (after Phillipson, 1995).

### *1.3. SUCCULENT THICKET IN THE EASTERN CAPE:*

Succulent thicket, which is concentrated in the Albany Hotspot, is regarded as a transitional vegetation type because its floristic components are shared with many other phytochoria (Low and Rebelo, 1996). Gibbs Russell and Robinson (1981) note that this mixing may be so intimate that species of different phytochorological affinities, including Tongaland-Pondoland, Karoo-Namib, Cape, Zambezian and Afromontane, may be found in a single stand. The canopy is generally dominated by trees and shrubs of subtropical affinity while karroid shrubs and succulents comprise the understorey (Cowling and Holmes, 1991) (Figure 1.3).

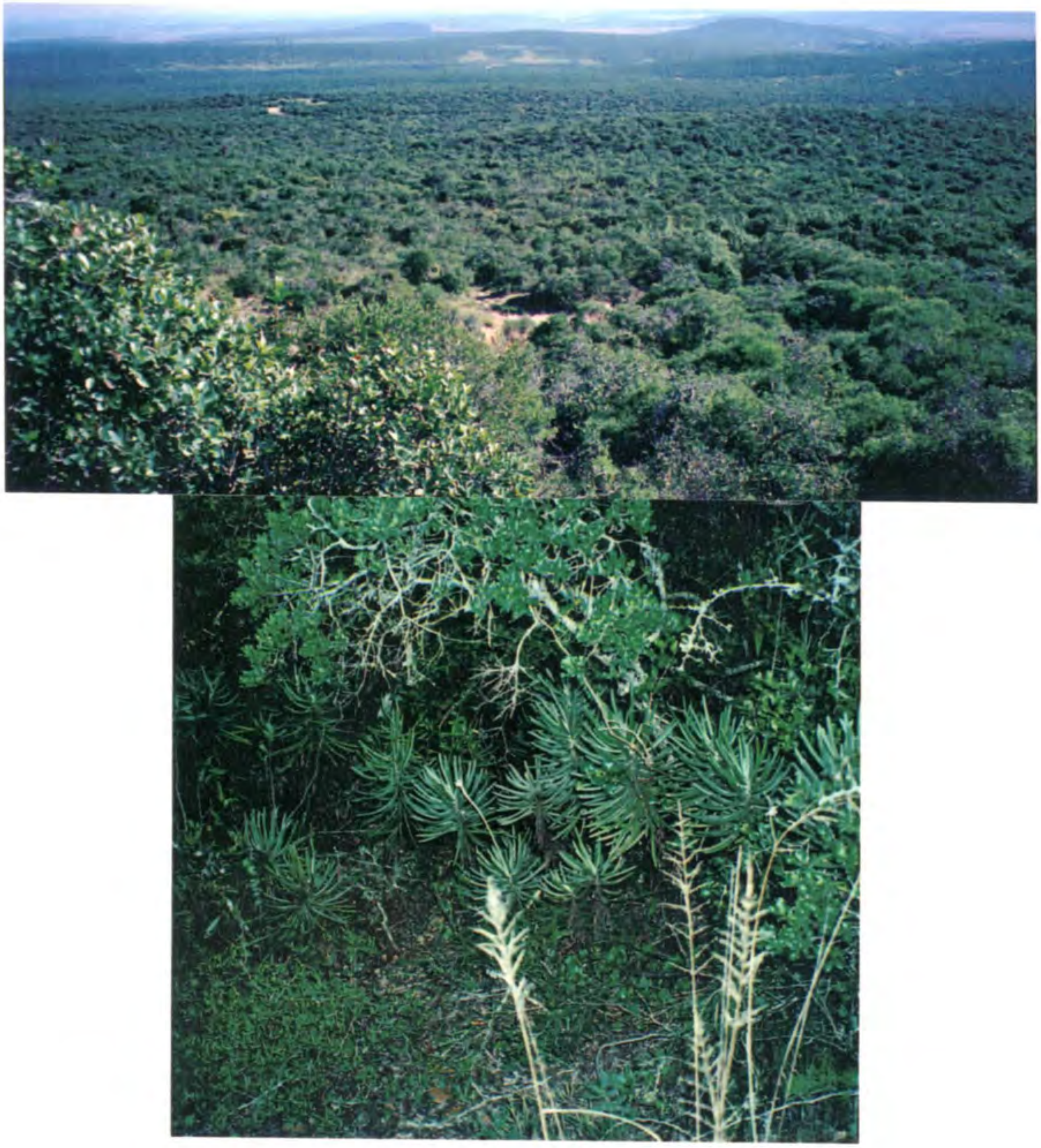

Figure 1.3. Examples of succulent thicket. Above: typical dense bushland of moderate height; below: the understorey, rich in endemic succulent species.

The functional affinities of this vegetation, which covers some 25% of the Eastern Cape (Kerley, 1996), have always been an enigma to ecologists. Acocks (1952) regarded succulent thicket to be a karroid veld type; White's (1983) view was that succulent thicket only occurs in areas where rainfall is too low to support climax forest, and classified it as transitional bushland; Rutherford and Westfall (1986) included it in the savanna biome. More recently, Low and Rebelo (1996) gave thicket vegetation biome status, regarding it neither forest nor savanna - they state that while it shares certain floristic elements with forest and savanna, it is structurally distinct. Midgley *et al.* (1997) have included succulent thicket in the forest biome, noting its functional similarities to forest, including fire resistance, reproductive biology and nutrient-cycling processes. This study follows the definition of succulent thicket as given by Low and Rebelo (1996).

Several attempts at a structural classification of this vegetation have been made. Acocks's (1952) classification has been used as the standard guide to South African vegetation for many years, but has been criticised in that his veld types were grouped according to veld utilisation potential, and thus placed structurally and floristically unrelated veld types together (Martin and Noel, 1960; Cowling, 1984; Lubke *et al.*, 1986; Everard, 1987). However, he accurately recognised six variations of succulent thicket: valley bushveld proper, north and south variations; Fish River scrub; Addo bush; Sundays River scrub and Gouritz River scrub. Lubke *et al.* (1986) described eight vegetation classes in the Eastern Cape in an attempt to combine Acocks's veld type classification into the international framework of the biome concept, and grouped six of Acocks's veld types into a single unit of succulent thicket. This was divided into four types: Dune thicket, Noorsveld, Spekboomveld and Valley Bushveld. In order to prioritise these vegetation types for conservation, Cowling (1984) and Everard (1987) divided the order subtropical transitional thicket syntaxonomically and structurally into two classes: kaffrarian succulent thicket and kaffrarian thicket, with xeric and mesic communities in each class. Low and Rebelo (1996) have divided the Thicket Biome into five vegetation types: dune thicket, valley thicket, xeric succulent thicket, mesic succulent thicket and spekboom succulent thicket.

Succulent thicket is floristically and structurally heterogeneous (Midgley *et al.*, 1997). Low and Rebelo (1996) describe it as a closed scrubland to low forest dominated by a mixture of evergreen schlerophyllous and succulent shrubs. It is dense, spiny and often impenetrable and is usually unistratal (Lubke *et al.*, 1988). In arid forms the field layer is sparse, composed mainly of succulents, dwarf shrubs and geophytes, while in more mesic forms a herbaceous layer of shade-loving grasses and forbs becomes more prominent (Everard, 1991).

Succulent thicket is ecologically restricted by several factors. It grows on moderately deep, mainly orange-red, well-drained soils (Everard, 1991) of the dry river valleys of the Eastern Cape. This vegetation rarely occurs above 800 metres above sea level. which correlates closely to rainfall totals, and these two factors appear to be the most critical in influencing the distribution of succulent thicket (Marker, 1991). Stuart-Hill (1992) gives an estimate of 225-500 mm rainfall per annum, but rainfall may be erratic due to the convergence of four rainfall regimes in the area. Totals may thus be deceptive, and are at times inflated by periodic phenomena such as 'three-day rains' (Marker, 1991).

However, the Addo Basin benefits from the moderating coastal influence, so although rainfall is low, it is reasonably predictable (Hoffman, 1989). This has been related to the high incidence of succulence in the area, which decreases sharply with the increasing aridity further north (Hoffman and Cowling, 1990). Temperature appears to have little effect on succulent thicket, except in bottomlands and inland areas where frost occurs, as many succulent species such as *Portulacaria afra* are frost-sensitive. Succulent thicket is not fire-prone (Midgley *et al.*, 1997), but is highly sensitive to over-grazing due to the slow growth rates of the main fodder plants (Moolman and Cowling, 1994), and low levels of recruitments of the dominant shrubs (Stuart-Hill and Danckwerts, 1988). Succulent thicket is thus being rapidly eliminated by poor farming practices in the Eastern Cape (Hoffman and Cowling, 1990).

## *1.4. ELEPHANT IMPACTS AND DYNAMICS OF SUCCULENT THICKET:*

The dynamics of succulent thicket are still poorly understood. It appears to be a highly stable system (Midgley, 1991), but extremely slow to regenerate after excessive disturbance (e.g. clearing, prolonged overgrazing), possibly due to a lack of seedling recruitment of dominant shrubs (La Cock, 1991). Midgley (1991) reported that most species produce ramets and very few produce genets, so that seedlings of common succulent thicket species, such as *Portulacaria afra*, *Euclea undulata*, *Sideroxylon inerme* and *Schotia afra,* were rarely observed. These species were therefore rarely present in the understorey, and the correlation between canopy and understorey dominance was found to be almost non-existent. Everard (1988) proposed that the vegetation may conform to a gap-phase system whereby fleshy fruits are dispersed by birds into disturbance patches. However, Midgley (1991) suggested that seedling establishment may only be important in the establishment of thicket initials away from the main community. La Cock (1992) has since shown that germination and seedling establishment does occur regularly, but that the microclimate provided by bushclumps is essential to this process, and that seedling establishment will not occur in open areas. A build-up of positive Aluminium ions in open areas appears to be toxic to many plants, in addition to the loss of possible nurse plants, especially *Ptaeroxylon obliquum*, in cleared areas (La Cock, 1992). Therefore, although mortality rates are very low, successional replacements are infrequent (Midgley and Cowling, 1993) and these will only occur within the modified environment of the bushclump (La Cock, 1992).

Most shrub and tree species are long-lived, and appear to reproduce mainly by ramets (except arborescent *Aloe* and *Euphorbia* species) (von Maltitz, 1991). They are thus very sensitive to 'bottom-up' browsing typical of goats which, in *Portulacaria afra*, removes the 'skirt' of hanging branches and thus prevents coppicing (Figure 1.4). The resulting umbrella-shaped plants become top-heavy and often collapse (Stuart-Hill, 1991a).

Figure 1.4. *Portulacaria afra,* showing typical umbrella shape after goat-grazing (above) (photo: G. Kerley) and with 'skirt' (below).

However, *P. afra* actually benefits from some forms of browsing. The 'top-down' browsing pattern typical of elephants encourages the production of a 'skirt' and thus ramets (Figure 1.4). It is clear that *P. afra* has adapted to cope with this disturbance (von Maltitz, 1991), and its morphology must have been influenced by elephants, which were previously common throughout the area (Stuart-Hill, 1991a). However, elephant-browsed areas support fewer species than protected areas (although more than goat-grazed areas) in the AENP and its surroundings (Stuart-Hill, 1992; Moolman and Cowling, 1994). The sub-dominant component of the vegetation is particularly susceptible to the effects of intense elephant browsing: aside from direct feeding, elephants trample many smaller plants, uproot them accidentally and open paths through the dense vegetation which allows smaller herbivores access to these plants (P. Novellie, pers. comm., 1996). Tortoises, for example, may attain biomasses as high as $>8 kg.ha^{-1}$ (leopard tortoises) and are important ground-level feeders (Mason and Weatherby, 1996).

According to the recommended carrying capacity for other reserves with similar rainfalls, such as Kruger National Park and Tsavo National Park, AENP is overstocked by 2-8 times the number of elephants above which habitat deterioration occurs (Moolman and Cowling, 1994). The vegetation appears to have reached a steady state, adequate to sustain the elephant population at the current stocking rate of 2-3 $km^{-2}$, but species richness has been sacrificed, and more species, particularly endemics, may be lost as the elephant population increases.

The park is thus faced with a dilemma, as elephants are the main generators of essential income through tourism. This is especially significant as individual parks are increasingly expected to be financially self-sufficient (Novellie *et al.*, 1996). However, there is a need to reduce stocking densities in order to fulfil the park's objectives of conserving a representative and functionally intact example of a valley bushveld ecosystem. Smaller elephant population sizes could, however, result in an unacceptable level of inbreeding (Novellie, 1991). Thus, although the park represents a potential sanctuary for many plant taxa, due to unavoidable overstocking of large herbivores, it poses its own threat to their survival.

### *1.5. CONSERVATION STATUS:*

Of the vegetation classes of the Eastern Cape, Lubke *et al.* (1986) listed subtropical transitional thicket (succulent thicket) as the most threatened, with the highest numbers of rare, indeterminate, uncertain and endemic species, and only 1.21% of the vegetation conserved. By 1991, Everard claimed that 6-10% of this area was conserved. Low and Rebelo (1996) estimate that 4.18% of the vegetation type is conserved The remainder of succulent thicket is largely used for goat grazing (Moolman and Cowling, 1994), although increasing areas are being used for wildlife ranching. Figures must thus be regarded as dynamic. The main conservation areas in the Eastern Cape that include succulent thicket are shown in Figure 1.5, and details of these reserves are given in Table 1.1.

Everard (1988) lists three major threats to the vegetation of the Eastern Cape:

1. <u>Indirect human impact</u>, including alien plants, pollution and erosion where grazing pressure is excessive;
2. <u>Natural factors</u> such as pathogens, fires and genetic factors where population sizes have been drastically reduced;
3. <u>Direct human impacts</u> include urbanisation, pastoralism and agriculture.

Commercial farming has been commonplace in the Eastern Cape since the 1770's, while subsistence livestock grazing has been taking place in the area for centuries prior to that time. Khoi-khoi nomadic pastoralists occupied the western part of the region some 1500 years ago, while Bantu-speaking agro-pastoralists moved into the eastern region around 1000 years ago. Associated with the increase in farming activities, bush has also been cleared for the construction of roads, railway lines, reservoirs and towns, and number of

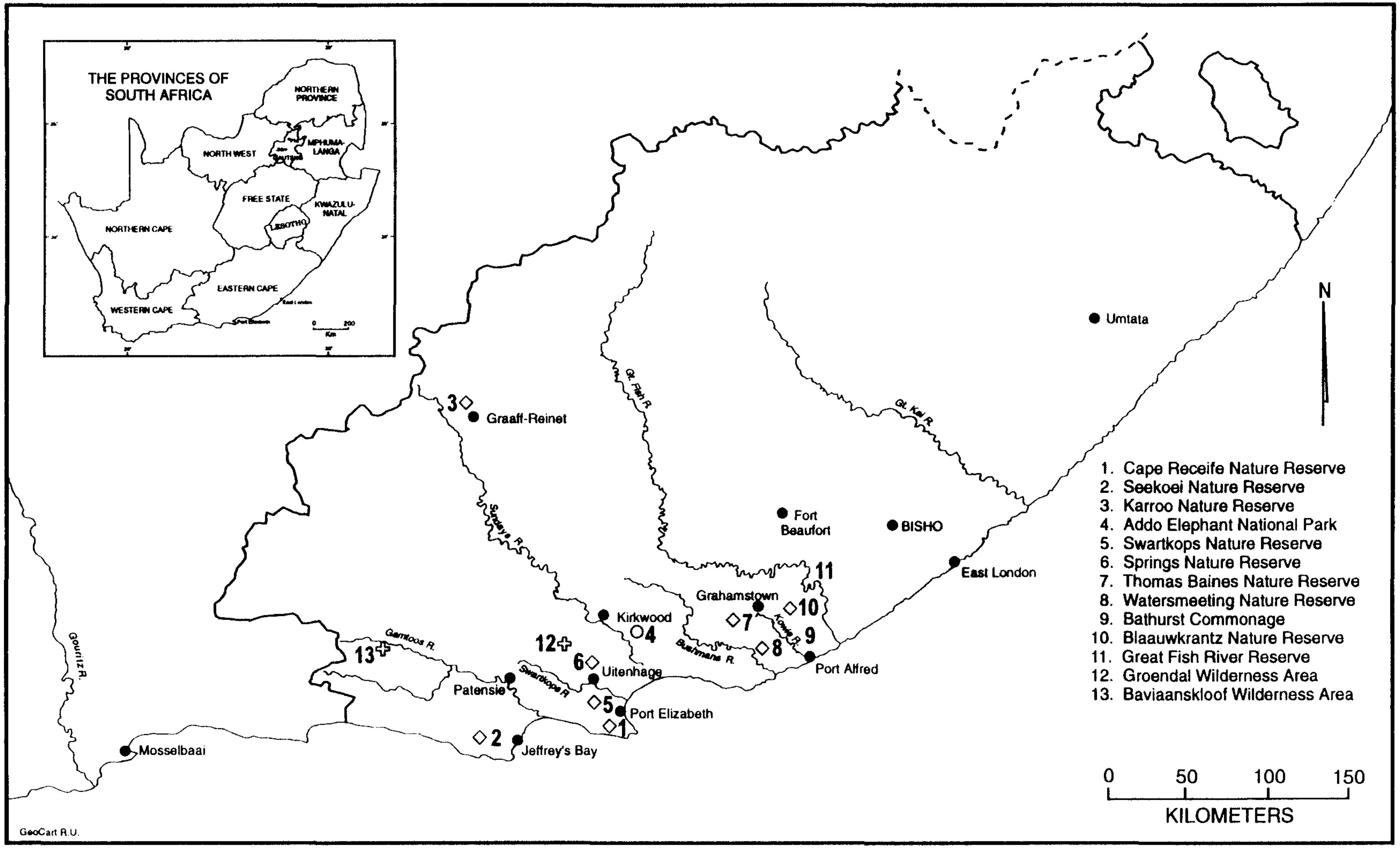


Figure 1.5. Map showing localities of main conservation areas in the thicket biome, Eastern Cape.

Table 1.1. Details of conservation areas shown in Figure 1.5 above.
AENP = Addo Elephant National Park. GVRRC = Great Fish River Reserve Complex. NR = Nature Reserve. WA = Wilderness area. CONS. AUTH. = conservation authority. NPB = National Parks Board. ECNC = Eastern Cape Nature Conservation. P.E. = Port Elizabeth. U. = Uitenhage. TLC = Transitional Local Council. * = excluded from Category 2 analysis (see Chapter 2). ** = excluded from species-area analysis (see Chapter 2).

| RESERVE | AREA ($km^2$) | DOMINANT VEGETATION | NO. OF SPECIES | CONS. AUTH. | SOURCE |
|---|---|---|---|---|---|
| AENP | 120 | Thicket | 581 | NPB | This study |
| Bathurst Commonage | 30 | Thicket | 227 | ECNC | Hobson (1993) |
| Baviaanskloof WA** | 2071 | Thicket/Fynbos | 1200 | ECNC | ECNC pers. comm. |
| Blaauwkrantz NR | 2 | Thicket | 253 | WDC | Lloyd (1987) |
| Cape Receife NR* | 3.36 | Dune thicket/Fynbos | 173 | P.E. TLC | Olivier (1983) |
| Groendal WA** | 291 | Thicket/Fynbos | 177 | ECNC | ECNC pers. comm. |
| GVRRC | 220 | Thicket | 389 | ECNC | ECNC pers. comm. |
| Karoo NR | 162 | Thicket/Nama Karoo | 336 | ECNC | Palmer (1989) |
| Seekoei NR | 1.41 | Thicket | 217 | ECNC | ECNC pers. comm. |
| Springs NR | 4.1 | Thicket | 318 | U. TLC | Olivier (1981) |
| Swartkops NR | 4.5 | Thicket | 365 | P.E. TLC | ECNC pers. comm. |
| Thomas Baines NR | 2.6 | Thicket/Grassland | 374 | ECNC | Cowling *et al.* (1997) |
| Watersmeeting NR | 42.47 | Thicket/Forest | 273 | ECNC | ECNC pers. comm. |

alien species have been introduced (Jacot-Guillarmod, 1988). Large tracts of land have been cleared for wheat and other crops in an essentially marginal agricultural area. The fine soil is susceptible to wind and water erosion if exposed (Hoffman and Everard, 1987), and some 35 tonnes of soil per hectare are estimated to be lost from cleared areas each year (Everard, 1988). The boom in the mohair industry has led to extensive overgrazing with some 92% of the thicket ecosystem utilised in this way (Moolman and Cowling, 1994). Although succulent thicket produces high quality forage, it has a low production potential, and is rapidly eliminated by grazing. Several studies have shown that overgrazing, particularly by goats, has severely affected the vegetation (Hoffman and Cowling, 1990; Stuart-Hill, 1991b; Stuart-Hill, 1992; Moolman and Cowling, 1994).

Overstocking with goats reduced the frequency of the palatable succulent shrub *Portulacaria afra* by 40%, its density by 71%, with a 91% decline in total area rooted by the plant, as well as a reducing the number of dominant shrub species per quadrat (Stuart-Hill, 1992). *Portulacaria afra* has been shown to take up to 275 days to recover from 50% defoliation (Aucamp and Tainton, 1984). Some 150 000 ha of succulent thicket in the Uitenhage district have been so badly overgrazed that recovery is considered impossible (Hoffman and Cowling, 1990; Everard, 1988) (Figure 1.6).

Figure 1.6. Fence-line contrast between grazed and ungrazed succulent thicket farmlands in the Eastern Cape. (photo: G. Kerley)

This situation also seriously threatens the endemic-rich sub-dominant component of the vegetation (Moolman and Cowling, 1994): perennial succulents are the first species to disappear and are replaced by ephemeral karroid species of Mesembryanthemaceae and Chenopodiaceae (Hoffman and Everard, 1987). The productive shrublands are thus radically altered, and the important bushclump microclimate for seedling germination is affected, reducing recruitment of dominant, palatable shrubs. The worst-case scenario following degradation is desertification: here total plant cover is reduced, dominant species are replaced by less palatable species, with a high number of annuals and an increase in soil erosion (Hoffman and Cowling, 1990; Kerley *et al.*, 1995; Kerley, 1996).

## *1.6. ADDO ELEPHANT NATIONAL PARK: PHYSICAL AND BIOLOGICAL FEATURES:*

The park is situated in the Sundays River Valley basin, some 25 km from the coast and 60 km north of Port Elizabeth (Hall-Martin and van der Walt, 1979) (Figure 1.5). The park has been considerably enlarged over the last few years by the acquisition of surrounding farmlands, and the amalgamation with the former Zuurberg National Park. The park thus consists of a variety of areas with different management histories (Figure 1.7, 1.8).

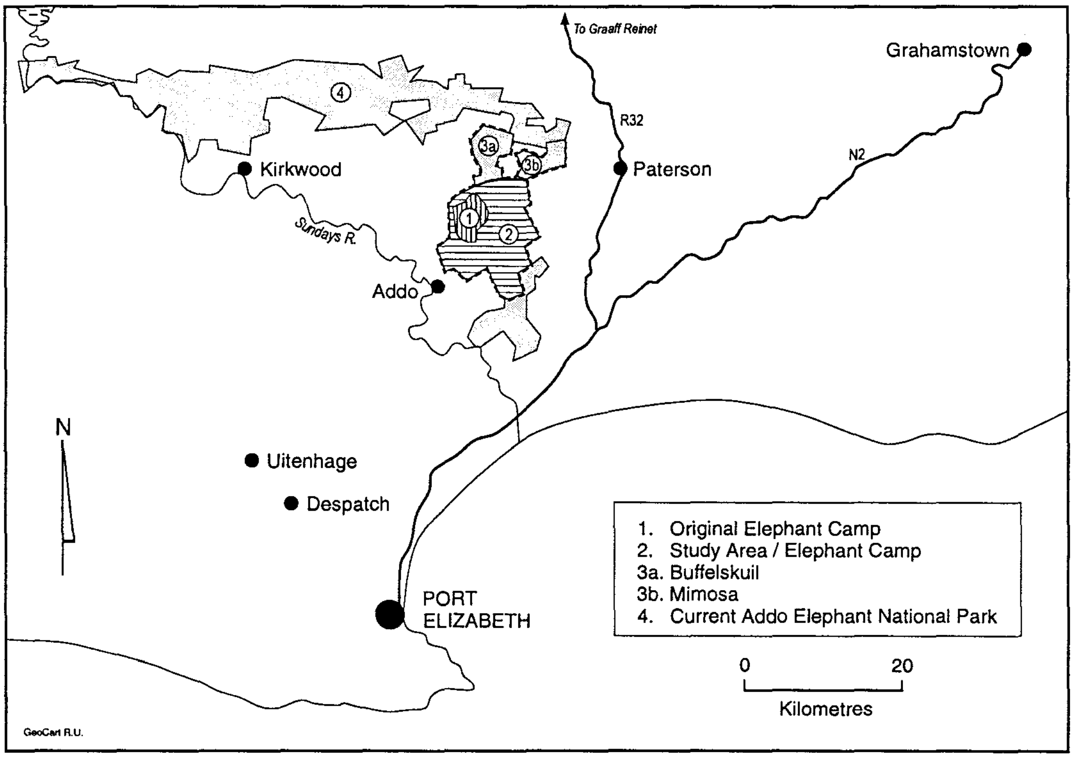


Figure 1.7. Map of entire Addo Elephant National Park, showing original and present elephant camp (see text). (after Kerley and Boshoff, 1997).

None of the newly-acquired areas have been elephant-fenced as yet, and elephants are still only present in the core area of the park. The study area is thus the elephant-grazed section of the park, and the three botanical reserves within that area, and analyses do not include those portions of the park acquired after 1991 (Figure 1.7).

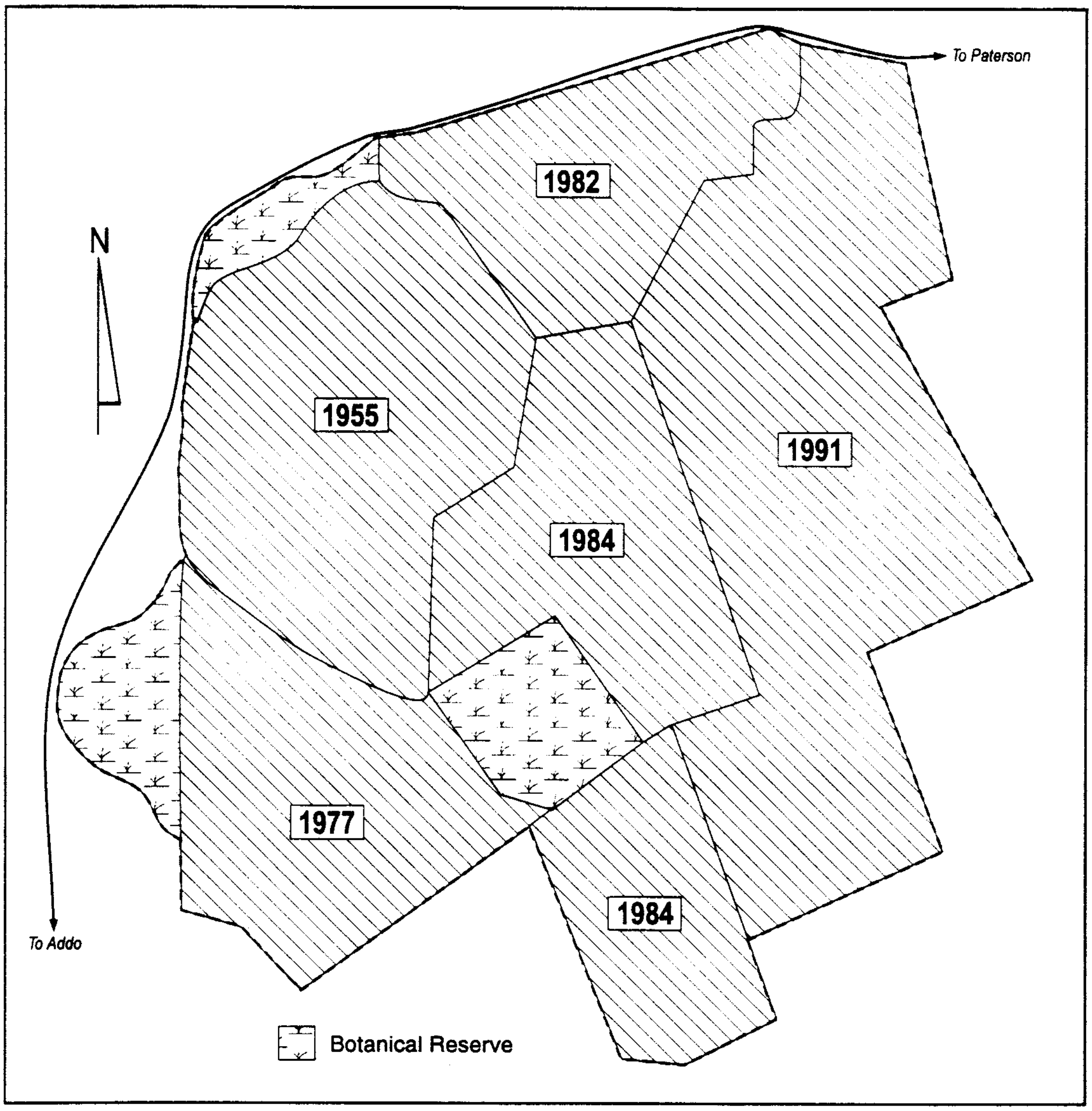


Figure 1.8. The study area (elephant camp) of the AENP, showing time of inclusion of areas into the elephant camp.

The park lies within the Addo Basin, a large valley whose floor drops as low as 50 m above sea level in places (Hoffman and Cowling, 1990). Most of the park consists of low, gently undulating hills with altitudes of 75-125 m above sea level. A limestone plateau runs along the central region of the park from north to south, with Zuurkop being the highest point in the park at 341 m above sea level. These limestones belong to the later Tertiary Alexandria Formation. The remaining rocks, which are deeply buried beneath surficial deposits, are mudstones and sandstones of the Sundays River Stage of the Cretaceous Uitenhage Group (Hoffman and Cowling, 1990). Most soils in the park are light-red clay loam derived from the sandstones and mudstones of the Sundays River Stage (Pentzhorn *et al.*, 1974). Skeletal, calcareous sandy loams overlie the Alexandria limestones (Hoffman and Cowling, 1990). Rainfall seasonality is relatively unpredictable, but trends show spring and autumn peaks and a mean annual rainfall of 436 mm (Moolman and Cowling, 1994) (Figure 1.9).

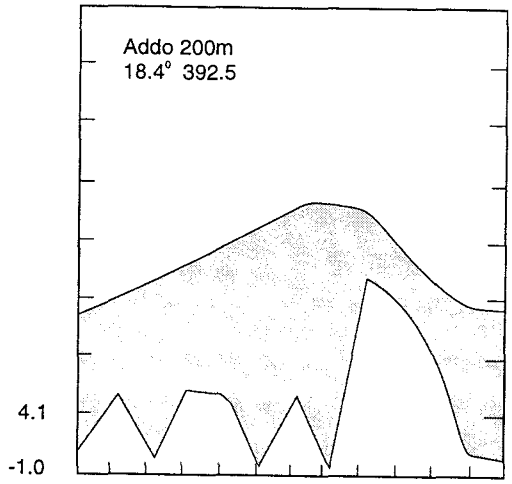


Figure 1.9. Walter-Leith climate diagram for Addo (after Midgley *et al.*, 1997).

There are no permanent streams in the park (Archibald, 1955). Temperatures vary from an average of 32°C in January to 13.5°C in July (Moolman and Cowling, 1994), with very rare frosts during the winter months (Figure 1.9).

Archibald (1955) described five vegetation communities for the AENP as it was at that time (see Figure 1.7), shown in Table 1.2 below. The relative uniformity of the vegetation of the park is apparent:

Table 1.2. Vegetation types of AENP after Archibald (1955).

| Vegetation type | Description | Area |
|---|---|---|
| Karoo-bushveld | open community of low karroid shrubs with bare ground between them | 7% |
| Mixed shrub and grassveld | mixed community of grasses and ericoid shrubs restricted to the Zuurkop plateau | 0.4% |
| Bontveld | thicket clumps in a grassland matrix | 3 - 4% |
| Coastal bush | dense thicket | 1% |
| Spekboomveld | dense to moderately dense succulent thicket | 88% |

## *1.7. ELEPHANTS AND THE ROLE OF BOTANICAL RESERVES IN AENP:*

The park was proclaimed in response to the slaughter of the last remaining Cape elephants. This project was initiated in 1919 when Major Pretorius was commissioned by the Provincial Administration to eliminate them from the area, which had become their last refuge in the province, and represented South Africa's largest elephant population at that time (Hoffman, 1993). At the beginning of this century, the Eastern Cape experienced a severe drought, and the conflict between farmers and elephants reached a peak. The elephant population in the region had reached about 150 individuals, and represented a threat to the water schemes and large agricultural developments that had taken place in the region. In 1916, discussions were initiated between the provincial authority and the local farmers, who called for the total extermination of the herd. Although there was some discussion regarding the establishment of a reserve, it was decided that extermination of the elephants would be cheaper, and Major Pretorius was hired. By the mid 1920's some 110 elephants had been shot, and only 16 individuals remained. Largely as a result of objections by Major Pretorius himself, these individuals were spared (Hoffman, 1993). The park was proclaimed in 1931, and expanded in 1935 to a total of 8000 morgan (6850 ha).

The elephants were not confined to the park, and made frequent forays to surrounding farms. Several elephants were shot by farmers, and a number of humans were killed by elephants within the park. The elephants quickly learnt to break through an electrified fence, so the warden at the time, Mr. Armstrong, designed and erected a fence made of tram lines and lift cables (Archibald, 1955). The design was so successful it is still used today. By 1954, the elephants were restricted to approximately one third of the park (Archibald, 1955). After the erection of the fence, the elephant population increased rapidly, tripling in 18 years (Pentzhorn *et al.*, 1974). The elephant camp, originally only 2270 ha, has been expanded three times since 1954: in 1977, 1982, and 1984, as the elephant population grew (Novellie, 1991) (Figure 1.8). In 1977, a monitoring program for the park was initiated to assess the impact of elephants on the vegetation; by the early 1990's, it was clear that vegetation in the elephant camp showed a significant decline in species richness and biomass, total canopy volume and height (Barratt and Hall-Martin, 1991).

In addition to its 240 elephants, the AENP supports approximately 40 black rhino, about 130 buffalo and more than 250 kudu, all in an area of 14 400 ha (W. Erlank pers. comm., 1997). Several areas in the park have been fenced off from the elephants and other large herbivores. Three such botanical reserves exist in the park (Figure 1.8). The main botanical reserve, established specifically because plant diversity was being affected by the elephants, is situated in the south central region of the park and covers 367.3 ha. The other two botanical reserves, one on the western boundary covering 415.7 ha and one on the north western boundary covering 164.8 ha, were established fortuitously as parts of the park were excluded from the elephant camp (Knight and Hall-Martin, 1995). These sites have provided essential 'witness stands' of lightly used vegetation (Novellie, 1991) and have been used in several comparative studies of the vegetation to monitor goat and elephant impact (Midgley and Joubert, 1991; Stuart-Hill, 1991b; Stuart-Hill, 1992; Moolman and Cowling, 1994).

Moolman and Cowling (1994) note that the impact of elephants on vegetation in the park has generated much research, but that this has all been concentrated on the woody component (Pentzhorn *et al.*, 1974; Stuart-Hill and Danckwerts, 1988; Stuart-Hill, 1991a,b; Barratt and Hall-Martin, 1991; Stuart-Hill, 1992), as it has elsewhere in Africa (e.g. Van Wyk and Fairall, 1969; Laws, 1970; Anderson and Walker, 1974; Ruess and Halter, 1990). These studies have focused on the architectural changes to the vegetation induced by elephant grazing, and not on the effects on biodiversity (Cumming *et al.*, 1997). Moolman and Cowling's (1994) study was one of the first to show the effects of heavy elephant grazing on plant diversity. Their results indicated that species richness was highest in the botanical reserves, which had become important refuges for a number of species in the subdominant component of the vegetation, the sector of succulent thicket vegetation that is the most critically in need of conservation. Yet there is mounting pressure to utilise the botanical reserves, either as introductory enclosure camps for black rhino, after which the reserves would have to be incorporated into the elephant camp, or to open them up simply to expand the area available to elephants. Novellie and Knight (1995) strongly caution against such actions - 14 species were identified in the botanical reserves which were not represented in any previous collections made in the park, and some species are highly localised and found in only one of the botanical reserves (Moolman and Cowling, 1994). Crassulaceae are the only group of succulents that are not adversely affected by the presence of elephants. This is probably due to the ability of many Crassulaceae to reproduce vegetatively from plant fragments, which are generated during elephant feeding as a result of their large bite size (Moolman and Cowling, 1994). Most Mesembryanthemaceae and geophytes were less affected by grazing, due to unpalatability, but succulent Asclepiadaceae, Euphorbiaceae and Liliaceae (*sensu lato*) were some of the families unfavourably influenced by the presence of elephants (Moolman and Cowling, 1994), and these families contain many Eastern Cape endemics.

Elephants also significantly reduce canopy height and volume as well as plant density, with an ultimate reduction in species richness in AENP, where stocking rates have reached as much as 3.8 elephants km$^{-2}$ (Barratt and Hall-Martin, 1991; Hall-Martin and Barratt, in press). Damage to the vegetation at these stocking rates is considerably less than in other reserves owing to the high total plant biomass, its resilience to fire and drought, and the actual stimulation of some plants by light grazing, e.g. *Portulacaria afra* (Hall-Martin and Barratt, in press). However, Hall-Martin and Barratt (in press) suggest that the AENP cannot support more than two elephants per $km^2$ in the long-term without serious loss of species richness. In an attempt to increase the carrying capacity of the park, AENP is currently undergoing major expansion. Several neighbouring farms have already been purchased (Figure 1.7). Some of these new areas may contain pristine pockets of vegetation, rich in species which are rapidly eliminated by elephants, such as arborescent *Aloe* and *Euphorbia* species. Before elephants and other large herbivores are introduced to these new areas, an assessment of the vegetation is crucial, with a view to setting aside further areas as botanical reserves. A thorough knowledge of the vegetation and communities of the park, including these new areas, is essential to optimise the botanical reserve system in the park. It is vital to utilise the minimum amount of land for maximum species preservation, ensuring that the botanical reserve system is both efficient in terms of land use and representative of all the major plant communities and species in the park.

Iterative reserve selection algorithms have been used very successfully recently to account for criteria such as representation of the full range of conservation features in an area, reserve design and land suitability (Bedward *et. al.*, 1992). Such systematic procedures overcome the *ad hoc* approach to reserve selection, which is often expensive and reduces the likelihood of representing all elements of biodiversity in a system (Pressey, 1994). This is evident in AENP, where two of the three botanical reserves were established fortuitously, rather than by planning, and are not necessarily optimally placed in the reserve. 'Irreplaceability' is another important aspect in reserve selection: sites can be scored according to their uniqueness in a region, and species can be scored according to their representation in the park and the region as a whole (Pressey *et al.*, 1994a), which is vital in the context of botanical reserve selection in AENP. Vulnerability of sites and species is another important concept, which can be combined with irreplaceability to facilitate the recognition of priority areas for conservation (Pressey *et al.*, 1996). None of the existing botanical reserves were surveyed prior to their selection, so their species composition is largely unknown. This procedure can be used to improve the efficiency of botanical reserve placement in the park, by limiting duplication of areas while ensuring representation of species, thus maximising plant species conservation in the minimum area.

## 1.8. KEY QUESTIONS:

Given the problems and conflicts between maintenance of elephant populations and maintenance of plant biodiversity in the AENP, this thesis addresses the following questions:

1. To what extent does the AENP maintain populations of rare and endemic plant species that are not conserved in other reserves in the Albany Centre that include succulent thicket? i.e. to what extent is the vegetation of the AENP irreplaceable in terms of plant diversity conservation?
2. Does this threatened component of the vegetation of the AENP fit the biological profile of plants vulnerable to elimination by elephant grazing?
3. What is the configuration of a botanical reserve system in the AENP that can most effectively and efficiently conserve the park's threatened plant biodiversity, taking both vulnerability and irreplaceability into account?

The first question is addressed by improving the species list for the park, and extracting a list of threatened species from this list. Threatened species are considered to be: (i) species endemic to the Albany Hotspot and those with formal conservation (Red Data List) status; and/or (ii) species conserved only in AENP, and not in other reserves in the region. The importance of the park as a botanical sanctuary is thus established. Profiles of plant species most threatened by grazing and loss of habitat are developed.

The second question is addressed by determining whether the frequency of rare and endemic plants in terms of biological categories is significantly different from the frequency of common and widespread species in the AENP. The biological profile of the rare and endemic component of the vegetation was then compared with the biological profile of species vulnerable to elephant grazing as identified by Moolman and Cowling (1994).

The third question is dealt with by zoning the park into management and vegetation units and sampling in each of the zones. A reserve selection algorithm is applied to the data to predict the most efficient system(s) of botanical reserves in the park, which will represent the maximum number of species conserved in the minimum possible area. Indices for vulnerability and irreplaceability of zones and species are calculated to support the results.

This thesis is structured in the following way: Chapters 2 and 3 are prepared in the format of research papers; Chapter 2 addresses questions 1 and 2, and Chapter 3 addresses question 3. There is thus a degree of repetition in the chapters. The concluding chapter integrates the results, and provides suggestions for additional research.

# CHAPTER 2:

# The flora of the Addo Elephant National Park: profiles of threatened species and their vulnerability to elephant damage.


## *SUMMARY:*

The Addo Elephant National Park was originally proclaimed to protect the last remaining elephants of the Eastern Cape, but part of the National Parks Board's mandate is to 'protect intact a viable example of valley bushveld' (succulent thicket). The park falls within the Albany Hotspot, a centre of diversity which is under threat due to agricultural practices in the region. Elephants have been shown to decrease species richness and abundance in the park, and the lower stratum of vegetation, which contains most of the region's endemic species, is the most severely impacted by grazing. A botanical reserve system exists in the park, but justification for its maintenance was required. A vascular plant species list of 581 species was first compiled, from which a list of threatened plant species was extracted. Threatened plants were divided into two categories: 1) species endemic to the Albany Hotspot, or with formal conservation (Red Data List) status (12.4% of the total flora); 2) species conserved only in AENP, and not in other predominantly succulent thicket reserves (32.2% of the total flora). The park was found to have a reasonably high species-area relationship in comparison to other reserves in the region. To establish whether the threatened component of the vegetation displayed any taxonomic or biological bias, a profile of threatened species was developed. Succulents and geophytes were over-represented as growth forms in both categories, and families such as the predominantly succulent Mesembryanthemaceae and Euphorbiaceae, and geophytic Hyacinthaceae and Asphodelaceae were over-represented. This component of the flora is most vulnerable to elephant damage, and a representative system of botanical reserves must be established in order to conserve them.


## *2.1. INTRODUCTION:*

The Addo Elephant National Park (AENP) was established in 1931, primarily to protect the last remaining elephants, *Loxodonta africana*, in the Eastern Cape. However, a major objective of the park as set out in the 'Conservation Management Plan for the AENP'

(Hall-Martin and van der Walt, 1979) has been to 'preserve intact a viable example of 'valley bushveld'', or succulent thicket, a vegetation type endemic to the Eastern Cape (Low and Rebelo, 1996). Succulent thicket has been recognised as the most threatened vegetation type of the region, harbouring the greatest number of rare and endemic plants in a system that is under extreme grazing pressure and is very poorly represented in conservation areas (Hoffman and Everard, 1987). The AENP is the only National Park located in this vegetation type. The conflict between maintaining a viable elephant population and maintaining the vegetation structure and plant diversity has become critical.

The National Parks Board authorities are faced with a dilemma: elephants are the major tourism attraction for the park but, when stocked at high densities, are highly detrimental to the vegetation (Pentzhorn *et al.*, 1974; Novellie *et al.*, 1991; Stuart-Hill, 1992; Moolman and Cowling, 1994). Despite these studies which have warned of the danger of the park being severely overgrazed, the elephant population has continued to increase. Culling has been ruled out as an option for reducing grazing pressure in the park (P. Novellie, pers. comm., 1996), and without expansion of the area accessible to elephants, structure and composition of the vegetation will continue to degrade. Novellie *et al.* (1996) argue that a stocking rate of two elephants km$^{-2}$ is sustainable for population maintenance, but will negatively impact plant diversity. It is difficult to reconcile this loss of plant species diversity with the park's main objective of ecosystem conservation.

For some time, elephants have been recognised as agents of habitat change, particularly woodland (savanna) destruction, throughout sub-Saharan Africa (Van Wyk and Fairall, 1969; Laws, 1970; Anderson and Walker, 1974; Ruess and Halter, 1990; Cumming *et al.*, 1997). The same is true for the AENP: Pentzhorn *et al.* (1974) showed that by the early 1970's, plant biomass had decreased by half and that botanical species composition had been altered since the elephants' enclosure in 1954. Novellie *et al.* (1991) demonstrated that elephants affected the grass species composition in the park. Hall-Martin and Barratt (in press) showed that 20 years of elephant impact had reduced canopy volume and height, as well as plant species richness. The parks authorities established a system of botanical reserves in the park as benchmark sites against which to compare the vegetation in the elephant-grazed areas, as well as in surrounding farmlands. Moolman and Cowling (1994) showed that species richness in these reserves was considerably higher than in both elephant- and goat-grazed areas The component of the vegetation most affected by grazing was the lower stratum consisting mostly of succulents and geophytes.

The AENP falls within the Albany Hotspot of the Eastern Cape (Figure 1.2), which has been recognised as an important centre of diversity, particularly for succulents and geophytes (Croizat, 1965; Nordenstam, 1969; Hartmann, 1991; Cowling and Hilton-Taylor, 1994). Van Jaarsveld (1987) notes that the lower stratum of the Eastern Cape thicket vegetation harbours the majority of threatened and endemic species. Moolman and Cowling (1994) argued that since elephants were most likely to impact the endemic component of succulent thicket, of which many species are poorly conserved, their overall impact on plant conservation could be substantial.

Despite Moolman and Cowling's (1994) findings, and their conclusion that the AENP should be expanded and further tracts of land should be set aside as botanical reserves, there is continued pressure to use the existing reserves for various purposes. In addition to providing extra grazing for elephants, there has been a proposal to use the main botanical reserve as a camp for the introduction of black rhinoceros, *Diceros bicornis*, into the park. The botanical reserve would serve as a core territory for the introduced rhino, and the fence would ultimately be removed, expanding the elephant area in the process. Novellie and Knight (1995) strongly cautioned against such action, and motivated instead for the expansion of the park. Since then, the park has been considerably enlarged (see Figure 1.7), but the cost of fencing remains a major problem, so threats to the botanical reserves remain. In order to enlarge the area accessible to elephants, it was proposed that the fencing round the botanical reserve in the centre of the park be used (M. Knight, pers. comm. 1997).

In order to justify the maintenance of these botanical reserves in the AENP, two important questions must be answered. Firstly, how important is the Addo flora regionally? In other words, does the flora of the reserve represent a unique sample of the Albany Hotspot flora that is not preserved in other conservation areas in the region? Secondly, are these restricted elements, as well as the endemic portion of the flora, vulnerable to elephant grazing, in terms of the profile of a vulnerable species as described by Moolman and Cowling (1994)?

## *2.2. METHODS:*

### 2.2.1. Compilation of floristic list:

The list of vascular plant species (see Appendix 5.1) for the AENP was compiled by amalgamating several sources. These included: existing checklists (Pentzhorn and Olivier, 1974; National Parks List of Species); searches on the Selmar Schönland Herbarium Database (Rhodes University) using grid references and localities; compilations from literature sources (E.E.A Archibald's personal notes; de Graaf *et al.*, 1973; Hall-Martin *et al.*, 1982; Midgley and Joubert, 1991; E. Campbell, pers. comm. 1997). Extensive collecting was also done in the park from January 1996 to June 1997. Most specimens were identified in the Selmar Schönland Herbarium, Grahamstown, with the assistance of staff. Mesembryanthemaceae were sent to Ms. P. Burgoyne (National Herbarium, Pretoria); stapeliads were sent to Dr. P. Bruyns (University of Cape Town); Prof. S. Baijnath (University of Durban-Westville) was consulted about the *Bulbine frutescens* var. ined. (Baijnath); and Dr. P. Vorster (University of Stellenbosch) was consulted about a new species of *Apodolirion*. Only species with voucher specimens or which had appeared in publications were included. Nomenclature follows Arnold and de Wet (1993).

### 2.2.2. Species-area relationships:

In order to ascertain the relative richness of the AENP flora, a least squares regression was fitted to a plot of log area versus log species number (Rosenzweig, 1995) for the AENP and ten other reserves in the Eastern Cape with succulent thicket as their dominant vegetation types (see Figure1.5). Baviaanskloof and Groendal Wilderness areas were excluded from this analysis as they contain a large proportion of fynbos species. The area and species number of these reserves is listed in Table 1.1. It should be noted that the species lists for most of these reserves include Pteridophyta and aliens. Where possible these species were removed from the analysis.

### 2.2.3. Profile of the threatened component of the flora:

Plant species may be threatened as a result of several factors. The factors considered in this study include species vulnerable to extinction by grazing either due to their limited distribution in the Eastern Cape and limited representation in conservation areas, or those with formally recognised conservation (Red Data Book) status. Two categories of threatened plants were thus established.

Category 1 (see Appendix 5.1, 5.2) includes species with conservation status cited in the Red Data List (Hilton-Taylor, 1996) and species endemic to the Albany Hotspot from Cowling (1982), Bond and Goldblatt (1984), and Hoffman and Cowling (1991). A few special cases were also made: *Bulbine inae* ined. and *Bulbine frutescens* var. ined. are only known from a few localities in the Albany Hotspot (S. Baijnath, pers. comm., 1997); *Albuca nana* was known only from the type specimen; *Ornithogalum monophyllum* was known from only one (Transvaal) specimen; *Apodolirion* sp. ined. is a new species (P. Vorster, pers. comm., 1997); *Eulophia hereroensis* (A. Hall, pers.comm., 1997) and *Pelargonium ochloleucum* (B. Marais, pers. comm., 1997) are distributed beyond the political boundaries of the Eastern Cape, but are found only in a few very small, localised populations. Some examples of Category 1 species are given in Figure 2.1.

Figure 2.1. Examples of Category 1 species. Clockwise from top left: *Freesia corymbosa*, *Lachenalia bowkeri*, *Pelargonium ochloleucum*, *Pachypodium bispinosum*. (photos: D. Weeks).

Category 2 (see Appendix 5.1) includes plant species not found in other reserves in the Albany Hotspot that include succulent thicket. Checklists were obtained from eleven reserves (Table 1.1) and cross-checked against the AENP species list to ascertain the number of species in the park which were not represented in any other reserve (Cape Receife Nature Reserve was not included in the analysis). Checklists from other reserves were often out of date, but nomenclature was updated as far as possible.

In order to establish whether the threatened component of the Addo flora is a random subset of the flora or if it exhibits any taxonomic or biological bias (Cowling and Holmes, 1992), two analyses were carried out. First, the frequency of species in the ten largest families in the AENP flora, minus the threatened component in order to ensure an independent sample, was compared to the frequency of Category 1 and Category 2 species in the same families. Only large families were used in order to avoid unacceptably low frequencies for subsequent statistical analysis. Secondly, all species were categorised according to the following growth form classes: forb, geophyte, succulent and shrub. The frequency of species within these growth form classes was compared for the threatened and non-threatened categories. The null hypothesis that representation in terms of frequencies was the same for common and threatened species, in taxonomic (i.e. family) and biological (i.e. growth form) categories, was tested using chi-squared analysis on the untransformed data.

## *2.3. RESULTS:*

### 2.3.1. Composition and size of flora:

The AENP includes 581 known vascular plant species in 289 genera and 75 families (see Appendix 5.1). Of these species, 72 (12.4%) fall into Category 1, while 168 (32.2%) fall into Category 2 (Appendix 5.1).

The species-area relationship of predominantly succulent thicket reserves in the Eastern Cape is shown in Figure 2.2. Along with three other reserves (Springs, Thomas Baines and

Swartkops Nature Reserves), the flora of AENP falls on the positive side of the regression, suggesting a high relative richness at this scale.

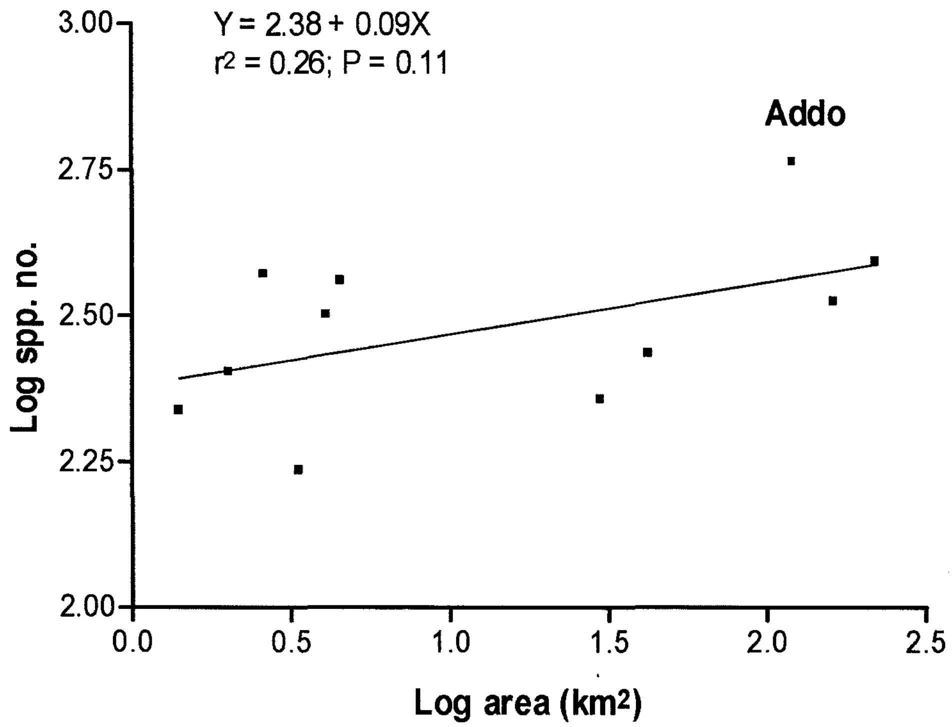


Figure 2.2. For its area, the AENP flora, together with Springs, Thomas Baines and Swartkops Nature Reserves, is relatively rich since AENP falls on the positive side of the regression.

The ten largest families and genera of the AENP flora are shown in Table 2.1 and Table 2.2 respectively. The numbers of genera and species in each of the largest families are indicated in Table 2.1 and the number of species in each of the largest genera is indicated in Table 2.2. These data are compared to the ten largest families and genera found in three other reserves in the Eastern Cape with comprehensive checklists: the Swartkops Nature Reserve, chosen for its proximity to the AENP, the Karoo Nature Reserve, and the Great Fish River Reserve Complex, chosen for their comparable size.

Table 2.1. The ten largest families in the AENP compared with those in three other Eastern Cape reserves. Values are given as percentages of the floras of each reserve, with the total percentage of the 10 families indicated. G.F.R. = Great Fish River.

| ADDO ELEPHANT NATIONAL PARK | | | KAROO NATURE RESERVE | | | SWARTKOPS NATURE RESERVE | | | G.F.R. RESERVE COMPLEX | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Family | Genera | Species | Family | Genera | Species | Family | Genera | Species | Family | Genera | Species |
| Asteraceae | 12.5 | 11.5 | Asteraceae | 15.2 | 16.8 | Asteraceae | 8.8 | 10.9 | Poaceae | 10.8 | 10.9 |
| Poaceae | 11.1 | 8.1 | Poaceae | 13.1 | 11 | Poaceae | 7.5 | 5.3 | Asteraceae | 10.8 | 9.8 |
| Mesembryanth. | 5.9 | 7.6 | Crassulaceae | 2.1 | 4.9 | Crassulaceae | 1.3 | 5 | Asphodelaceae | 6.9 | 7.1 |
| Crassulaceae | 1.4 | 5.5 | Fabaceae | 4.2 | 4.3 | Fabaceae | 5.8 | 4.7 | Crassulaceae | 1.7 | 6.8 |
| Hyacinthaceae | 3.1 | 4.5 | Scrophulariaceae | 4.2 | 4.3 | Mesembryanth. | 5.3 | 4.5 | Fabaceae | 4.7 | 5.2 |
| Fabaceae | 5.2 | 3.8 | Sterculiaceae | 0.3 | 4.3 | Asphodelaceae | 2.7 | 4.5 | Mesembryanth. | 5.2 | 4.1 |
| Geraniaceae | 1 | 3.8 | Asphodelaceae | 3.1 | 3.4 | Euphorbiaceae | 2.2 | 3.9 | Euphorbiaceae | 2.6 | 4.1 |
| Asphodelaceae | 2.4 | 3.6 | Mesembryanth. | 4.7 | 3.1 | Acanthaceae | 3.5 | 3.6 | Lamiaceae | 3.4 | 2.7 |
| Euphorbiaceae | 2.1 | 2.8 | Geraniaceae | 1 | 3.1 | Chenopodiaceae | 3.5 | 3.4 | Celastraceae | 2.2 | 2.5 |
| Asclepiadaceae | 3.8 | 2.6 | Anacardiaceae | 0.3 | 2.8 | Iridaceae | 4.4 | 3.1 | Geraniaceae | 0.9 | 2.5 |
| TOTAL | 48.5 | 53.8 | TOTAL | 48.2 | 58 | TOTAL | 45 | 48.9 | TOTAL | 49.2 | 55.7 |

Table 2.2. The largest genera in the AENP compared with those in three other Eastern Cape reserves, with the number of species in each genus indicated as a percentage of the total species number. G.F.R. = Great Fish River.

| ADDO ELEPHANT NATIONAL PARK | | KAROO NATURE RESERVE | | SWARTKOPS NATURE RESERVE | | G.F.R. RESERVE COMPLEX | |
|---|---|---|---|---|---|---|---|
| Genus | Species | Genus | Species | Genus | Species | Genus | Species |
| *Crassula* | 4.3 | *Hermannia* | 4.3 | *Crassula* | 3.1 | *Crassula* | 4.9 |
| *Pelargonium* | 3.3 | *Crassula* | 3.4 | *Euphorbia* | 2.8 | *Euphorbia* | 2.7 |
| *Senecio* | 1.7 | *Rhus* | 2.8 | *Pelargonium* | 2.2 | *Protasparagus* | 2.7 |
| *Euphorbia* | 1.5 | *Pelargonium* | 2.4 | *Protasparagus* | 2.2 | *Pelargonium* | 2.2 |
| *Rhus* | 1.5 | *Protasparagus* | 2.4 | *Senecio* | 2.2 | *Senecio* | 2.2 |
| *Bulbine* | 1.4 | *Senecio* | 2.1 | *Aloe* | 1.7 | *Cyperus* | 1.6 |
| *Albuca* | 1.4 | *Aloe* | 1.5 | *Zygophyllum* | 1.1 | *Cotyledon* | 1.4 |
| *Protasparagus* | 1.4 | *Diospyros* | 1.5 | | | *Eragrostis* | 1.4 |
| | | *Felicia* | 1.5 | | | *Maytenus* | 1.4 |
| | | *Sutera* | 1.5 | | | *Rhus* | 1.4 |

The AENP has a flora similar to all three of these reserves, with widespread families such as Asteraceae and Poaceae dominating the floras of all four reserves. However, all reserves show a high rank of predominantly succulent families such as the Crassulaceae and Mesembryanthemaceae, as well as succulent genera such as *Crassula*, *Euphorbia* and *Aloe*. Only AENP has predominantly geophytic lineages (*Albuca*, *Bulbine*) among its largest genera.

### 2.3.2. Taxonomic Profile of Threatened Species:

There were some important differences in the taxonomic profiles of the two categories of threatened species (Table 2.3). Mesembryanthemaceae were significantly over-represented among both Category 1 and 2 species, whereas Asphodelaceae and Euphorbiaceae were over-represented in Category 1 only, and Asclepiadaceae and Hyacinthaceae in Category 2 only. The well-dispersed and generally widespread species of Poaceae are significantly under-represented in both categories. Owing to the significant under-representation of Category 2 species, the AENP Crassulaceae are relatively well-conserved in other reserves in the Albany Hotspot.

Table 2.3. The percentages of Category 1 (rare and endemic) and Category 2 (conserved only in AENP) species in the ten largest families of the AENP flora. Chi-square analysis was performed on untransformed data.
ns = non-significant, * = P < 0.05, ** = P < 0.01, *** = P < 0.001

| FAMILY | TOTAL SPP # | CATEGORY 1 | | | CATEGORY 2 | | |
|---|---|---|---|---|---|---|---|
| | | % rare | % non-rare | $\chi^2$ | % conserved AENP only | % conserved elsewhere | $\chi^2$ |
| **TOTAL** | 581 | 12 | 88 | | 32 | 68 | |
| Asteraceae | 67 | 6 | 94 | $2.78^{ns}$ | 24 | 76 | $0.32^{ns}$ |
| Poaceae | 47 | 0 | 100 | 7.28* | 15 | 85 | 3.87* |
| Mesembryanth. | 44 | 27 | 73 | 9.59* | 61 | 49 | 28.15*** |
| Crassulaceae | 32 | 12 | 88 | $0^{ns}$ | 9 | 91 | 5.42* |
| Hyacinthaceae | 26 | 19 | 81 | $1.61^{ns}$ | 58 | 42 | 12.83*** |
| Fabaceae | 22 | 5 | 95 | $1.31^{ns}$ | 41 | 59 | $2.18^{ns}$ |
| Geraniaceae | 22 | 18 | 82 | $0.69^{ns}$ | 36 | 64 | $0.98^{ns}$ |
| Asphodelaceae | 21 | 30 | 70 | 5.85* | 25 | 75 | $0.05^{ns}$ |
| Euphorbiaceae | 16 | 38 | 62 | 9.46** | 6 | 94 | $3.64^{ns}$ |
| Asclepiadaceae | 15 | 6 | 94 | $0.47^{ns}$ | 52 | 48 | 5.33* |

## 2.3.3. Biological Profile of Threatened Species:

Neither Category 1 nor 2 species are random assemblages of species with regard to growth form classes. Geophytes and succulents were over-represented among Category 1 species, while shrubs and forbs are under-represented. Geophytes appear to be strongly over-represented and succulents moderately over-represented among species that are conserved only in AENP (Category 2).

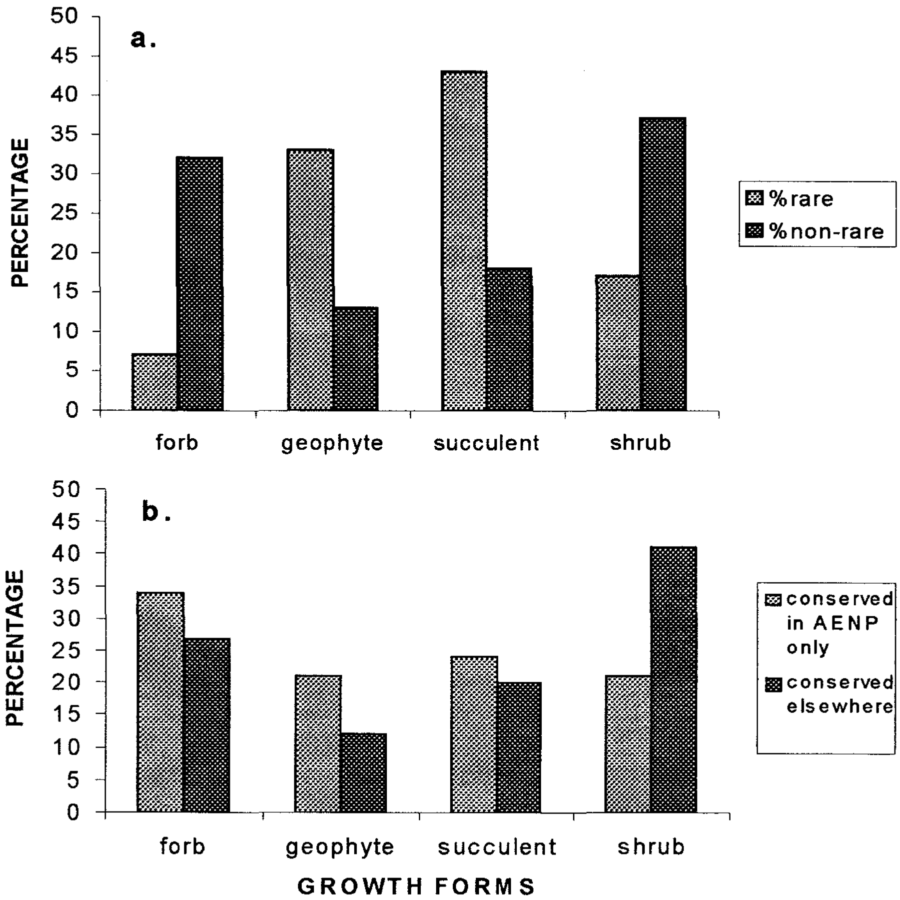


Figure 2.3. The percentage of threatened species in different growth form classes. Species belong to a) Category 1 (rare and endemic), and b) Category 2 (conserved only in AENP). Chi-square analysis performed on untransformed data. ***=P<0.001.

## *2.4. DISCUSSION:*

The flora of the AENP includes 581 vascular plant species and was found to be relatively rich in comparison to other reserves in similar vegetation in the Albany Hotspot, Eastern Cape (see Fig. 2.2). Although this is partly a function of under-collection in many areas of the Eastern Cape, and the problematic nomenclature of certain groups, particularly Mesembryanthemaceae, these results suggest that AENP, despite its apparently homogeneous environment (Pentzhorn *et al.*, 1974), protects a species-rich flora.

Like other reserves in the Albany Hotspot, AENP includes high numbers of Mesembryanthemaceae (Hartmann, 1991) and Crassulaceae (succulents), and Hyacinthaceae and Asphodelaceae (predominantly geophytes) (Table 2.1, 2.2). These components reflect links with the Cape and Succulent Karoo floras of South Africa (Goldblatt, 1978, Cowling and Hilton-Taylor, 1994).

Moreover, the park has a high number of threatened plant species, both in the category of Albany Hotspot endemics and Red Data List species (Category 1 – 12.4% of the total), as well as in the category of species not represented in other conservation areas in the Eastern Cape (Category 2 – 32.2% of the total). This suggests that the AENP has a high conservation value, or 'irreplaceability' (Pressey *et al.*, 1993) in the context of the Albany Hotspot.

Analysis of Category 1 species shows that these are not a random assemblage of species with regard to taxonomy or biology. Succulents and geophytes, mainly understorey components in succulent thicket, were over-represented among the rare and endemic (Category 1) component (Figure 2.3.a). These species are largely members of the Mesembryanthemaceae, and Euphorbiaceae (succulents) and Asphodelaceae (succulents and geophytes) and Hyacinthaceae (geophytes) (Table 2.3). Similar patterns have been found for the Albany Hotspot as a whole (Cowling and Holmes, 1991) as well as the

Succulent Karoo where low succulent shrubs and geophytes are massively over-represented among the endemic component (Cowling and Hilton-Taylor, 1994).

Species in Category 2 (those conserved only in AENP) are likely to include range-restricted and otherwise threatened species covered in Category 1, as well as relatively common and widespread species that do not, for a variety of reasons, occur in any reserve other than AENP. Geophytes, and to a lesser extent, forbs and succulents, are over-represented among this component (Figure 2.3.b). All of these growth forms occur predominantly in the understorey of succulent thicket. Mesembryanthemaceae and Hyacinthaceae are very poorly conserved in other Eastern Cape reserves. Given the importance of the Sundays River Basin as a centre of diversification for Mesembryanthemaceae (Hartmann, 1991), conserving this flora is highly significant.

This study has established that the flora of the AENP is an important botanical conservation area, both in terms of rare and range-restricted species, as well as species not found in other conservation areas in the region. Are these threatened components also vulnerable to elephant damage? In both categories, lower stratum species, especially succulents and geophytes, are over-represented. Species fitting this biological profile were identified by Moolman and Cowling (1994) as being most vulnerable to local extinction as a result of elephant impact. It is thus essential that these species be represented in a botanical reserve system in order to ensure their conservation. The location of an optimal botanical reserve system to conserve the threatened component of the AENP flora is given in Chapter 3.

## 2.5. CONCLUSION:

The Addo Elephant National Park is important in the conservation of the flora of the Eastern Cape. It contains a number of endemic succulents and geophytes not represented in other conservation areas. However, these elements of the flora are vulnerable to disturbance by elephants and other large herbivores. Thus, in order to maintain the biodiversity of succulent thicket, as set out in the management plan of the AENP, the area of botanical reserves must be maintained or increased. To make this cost effective and efficient, a representative system must be established.

# CHAPTER 3:

# Optimal botanical reserve placement in the Addo Elephant National Park.

***SUMMARY:***

The importance of botanical reserves for the conservation of threatened plants in the Addo Elephant National Park was shown in previous studies, but the efficiency and effectiveness of this reserve system is unknown. With elephant grazing at a premium in the park, it is essential that the botanical reserves be placed so that the maximum number of species is conserved in the minimum area. The park was divided into sixteen zones, on the basis of vegetation type and management history. Zones were sampled throughout the year, and the presence and abundance of threatened plants was recorded for each zone. An iterative reserve selection algorithm was applied to the data to predict which zones should be included in the botanical reserve system. Vulnerability and irreplaceability indices were developed for zones and species. To protect the threatened flora and represent all vegetation types of the park most efficiently, the recommended botanical reserve system for the park is as follows: botanical reserves 3 (including zone 11a) and 1 should be retained; zones 6b and 10 should be added; and botanical reserve 2 should be removed from the system as it is, for the most part, redundant. Zone 10 may not need to be fenced as it scores very low on the vulnerability index, but plant species composition and abundance should be monitored. Zone 6b is a unique habitat in the park, known as Karoo-Bushveld, and should be fenced. Various options are given for fencing this area. It is recommended that similar procedures be carried out those extensions to the park into which elephants are to be introduced.

## *3.1. INTRODUCTION:*

The importance of maintaining botanical reserves in the Addo Elephant National Park (AENP) was shown in a study by Moolman and Cowling (1994). They demonstrated clearly that elephant grazing at the densities experienced in the park strongly affected percentage cover and total plant species number, while the number of endemic plant species was reduced in the elephant-grazed areas relative to protected botanical reserves. Several 'indicator' species, including *Senecio pyramidatus*, *Euphorbia ledienii* and arborescent succulents, were identified – these species are rapidly eliminated in elephant-grazed areas and thus are indicators for management. It was also shown that the component most affected by the grazing regime was the sub-dominant portion of the vegetation, consisting mainly of small succulents and geophytes, many of which are endemic to the Eastern Cape. An earlier study by Stuart-Hill (1992) showed that elephant browsing did not adversely affect the large shrub and tree component of succulent thicket in AENP.

Three botanical reserves are maintained in the park, only one of which was established especially for the monitoring of the vegetation of the park. The other two, one on the western boundary and one around the rest camp/entrance area, were established fortuitously when the park was fenced. Thus, none of the reserves was planned in terms of biological criteria. They have all, however, provided essential 'witness stands' of vegetation for several studies that have assessed the impact of grazing on succulent thicket (Midgley and Joubert, 1991; Stuart-Hill, 1992; Moolman and Cowling, 1994). The botanical reserves cover a total of 997 ha, or 8.3% of the park.

Despite all the evidence presented by Moolman and Cowling (1994), there is ongoing pressure to utilise the botanical reserves for several purposes. These are:

1. To increase the grazing available to elephants and other large herbivores in the park (Novellie, pers. comm., 1996).
2. As an introduction camp for black rhinos – the reserve area would then serve as a core territory for the rhino, and the fence would be removed once the animal was established, again increasing the available grazing area (Novellie and Knight, 1995).
3. To provide elephant-proof fencing for newly acquired extensions to the park (M. Knight, pers. comm., 1997).

Although consideration is being given to establishing botanical reserves in the new sections of the park (Novellie and Knight, 1995), the condition of the vegetation in these areas is not well known, and it cannot be guaranteed that equivalent stands of vegetation will be found.

Novellie and Knight (1995) caution that in view of the fact that valley bushveld (succulent thicket) is under extreme threat, it is desirable to maintain viable populations of as many endemic plant species as possible. Goat grazing has an even more severe effect on the endemic component of the vegetation than elephant grazing, and much of the Eastern Cape is utilised for this purpose (Moolman and Cowling, 1994). A recent study (Cumming *et al.*, 1997) has shown that elephant-induced habitat change results in the loss of plant, invertebrate and vertebrate diversity. The state of the vegetation in an elephant-grazed system is thus an important indicator of the health of the system as a whole, which adds to the importance of botanical reserves as 'benchmark' sites.

There has thus far been no assessment as to whether the botanical reserves in the AENP are optimally placed in terms of habitat structure and species representation. All three reserves were selected *ad hoc*, especially the two on the boundary, and the main reserve (see Figure 1.8) was never surveyed for species composition before its establishment. A major objective of the AENP is to 'preserve intact a viable example of valley bushveld (succulent thicket)' (Novellie, 1991). With grazing at a premium in the park, it is desirable that the minimum possible land is set aside for plant species conservation. It is uncertain to what extent the current botanical reserve system represents the flora of the park, and how efficiently this is being done. In order to represent maximum diversity in the park, better planning is required. By applying the principles of reserve planning, this can be achieved. If the AENP is considered as a single system, and the botanical reserves form a reserve network within that system, then it is essential that the botanical reserves be optimally located in order to conserve plant diversity and vegetation type effectively and efficiently.

The concept of rational and effective reserve planning emerged in the 1970's, when it was recognised that a system of natural reserves surrounded by man-modified habitat resembled a system of islands (Diamond, 1975), and theories of island biogeography were applied to this planning. This approach provoked much debate as to its feasibility in biological terms (Simberloff and Abele, 1975) and well as the optimal shape and size of reserves as determined by species diversity on islands (Game, 1980). This issue developed into the SLOSS (single large or several small) debate (Pavlik, 1996). It became apparent that the approach, although backed by theory, fell down in the face of the realities of management at reserve and ecosystem levels (Lomolino, 1994; Pavlik, 1996).

More recently, focus has shifted to the optimisation of reserve systems to preserve the maximum number of species in the most efficient area (KirkPatrick, 1983; Margules and Nicholls, 1988). It was clear that the majority of reserves were established *ad hoc*, usually because the land was of little value for commercial use or for human habitation: 'the lands nobody wanted' (Pressey, 1994). This is true of the AENP, as a whole as well as its botanical reserves: the area in which the park is situated was considered the least hospitable of the region, and was thus the last to be exploited as farmland. It was into this thick and impenetrable bush that the remaining elephants were forced, where a fence was eventually erected around them (Hoffman, 1993). The lack of permanent water in the park is the kind of problem associated with this opportunistic style of reserve selection.

Pressey and Tulley (1994) describe the disadvantages of *ad hoc* reservation: firstly, environments most in need of preservation are not effectively protected; secondly, the diversity of a system is inefficiently represented in terms of features per unit area. This ultimately increases the cost of representation of a region's biodiversity (Pressey, 1994).

As iterative procedures became popular for the task of representing the full range of conservation features, be they species, communities, or land systems, additional criteria such as land suitability and efficiency emerged (Bedward *et al.*, 1992). One problem to emerge from simple iterative procedures was that a diffuse scatter of sites was selected, impractical from a management and reserve design viewpoint. In terms of land use, reserves must be drawn from least disturbed areas and the surrounding land should be compatible with the conservation goal.

Three key principles of reserve design are highlighted by Pressey *et al.* (1994a). These are efficiency, flexibility and irreplaceability:

1. Efficiency is similar to the concept of complementarity: here the smaller the number of sites required to represent all the features in an area, the higher the efficiency of the system. Iterative procedures overcome unnecessary duplication of features by adding sites to a system in a stepwise manner depending on how well they complement other sites.
2. Flexibility concerns the number of possible combinations of sites; these different scenarios can be used in negotiation with planners and other concerned parties, and the extent to which efficiency is lost to accommodate other conservation goals can be decided. This allows one to not only maximise representation, but also to consider factors such as contiguity and land suitability (Pressey *et al.*, 1994b).
3. Irreplaceability is a measure of the potential contribution of a site to a representative reserve system. This concept is considered in more depth by Pressey *et al.* (1994b) who describe it as a fundamental measure of the conservation value of a site.

Irreplaceability has a number of potential uses in reserve planning. Firstly it should be included in iterative procedures as it forms the logical basis from which sites can be selected from most to least irreplaceable. Sites that are considered to be 100% irreplaceable form fixed 'nodes' around which other sites can be grouped. Secondly, it helps to choose between sites before they are acquired, and thus contributes to a potential reservation goal. It is a relative and dynamic index of the conservation value of a site, dependent on features present in other sites, as well as the representation of other sites in the reserve system (Pressey *et al.*, 1994b).

Iterative reserve selection procedures were pioneered in Australia (KirkPatrick, 1983; Margules and Nicholls, 1988; Bedward *et al.*, 1992; Pressey and Tulley, 1994; Pressey *et al.*, 1994a,b), but important contributions have been made by South African researchers (Rebelo and Siegfried, 1992; Rebelo, 1994; Lombard *et al.*, 1995; Trinder-Smith *et al.*, 1996; Lombard *et al.*, 1997). These techniques can be effectively applied in the AENP to select the best possible sites for botanical reserve placement, taking efficiency, flexibility and irreplaceability into account. The park can be effectively divided into zones, based not only on the vegetation, but also on past management of the park. Over the years, elephants have been restricted to various areas (Figure 1.8), which means that different areas in the park have experienced different grazing regimes. In addition, the newly acquired areas in the park have been utilised in a number of ways, ranging from goat grazing to clearance for cultivation.

The objective of this study is thus to identify areas within the AENP which should be set aside as botanical reserves. These areas must be complementary and efficient in terms of species representation and vegetation types, in order to effectively conserve the flora of the park and thus fulfil its management objectives.

## *3.2. METHODS:*

### 3.2.1. DATA COLLECTION:

Mapping:

In order to divide the park into manageable zones for sampling, both vegetation type and management history were taken into account. First, the vegetation of the park as mapped by Archibald (1955) (Table 1.2) was digitized from 1:10 000 orthophotos, into a geographic information system (GIS), ArcView 3 (Environmental Systems Research Institute, Redlands, California). Second, a map of land-use history of the park was delineated from various sources of information (Archibald, 1955; Novellie, 1991; W. Erlank, pers. comm., 1996). The elephant camp has been enlarged several times, as additional land has been required. Some of this land belonged to the park, and had not been exposed to elephant grazing since their enclosure in 1954. Other areas were purchased subsequent to the proclamation of the park, and have been under a variety of farming regimes, ranging from goat grazing to bush clearing for agriculture. This map was overlaid with the digitized vegetation map to further delineate what were considered to be homogeneous zones with respect to vegetation type and management history. A total of 16 zones was thus delineated (see Figure 3.1). Explanations of their management histories are given in Table 3.1). The three botanical reserves were treated as zones (zones 1, 2 and 3). However, the main botanical reserve in the centre of the park contains two different vegetation types, and it was thus divided into 2 zones: zone 3 (thicket) and zone 11a (bontveld) (see Figure 3.1). For the purpose of the reserve-selection exercise (described below), zones 1, 2, 3 and 11a are thus referred to as the four botanical reserves.

Sampling:

Transects of 1 m wide were made in each zone from September 1996 to June 1997, in order to accommodate the seasonality of many plant species, particularly geophytes. Transect lengths were calculated in proportion to the area of each zone to ensure equal sampling intensities. Only plant species with recognised conservation status (Hilton-Taylor, 1996), restricted ranges (Bond and Goldblatt, 1984, Hoffman and Cowling, 1991), or those that were indicators of grazing pressure (Midgley and Joubert, 1991) were sampled (see Appendix 5.1 – Category 1). Hereafter, these species are referred to as 'Category 1 species'. The presence and frequency of these 76 species was recorded along each transect. Only 58 of the 76 species were encountered, so data analysis is based on these 58 species (delineated by an asterisk in Appendix 5.2). None of these 58 species were encountered in zone 13, so this zone was omitted from the analyses.

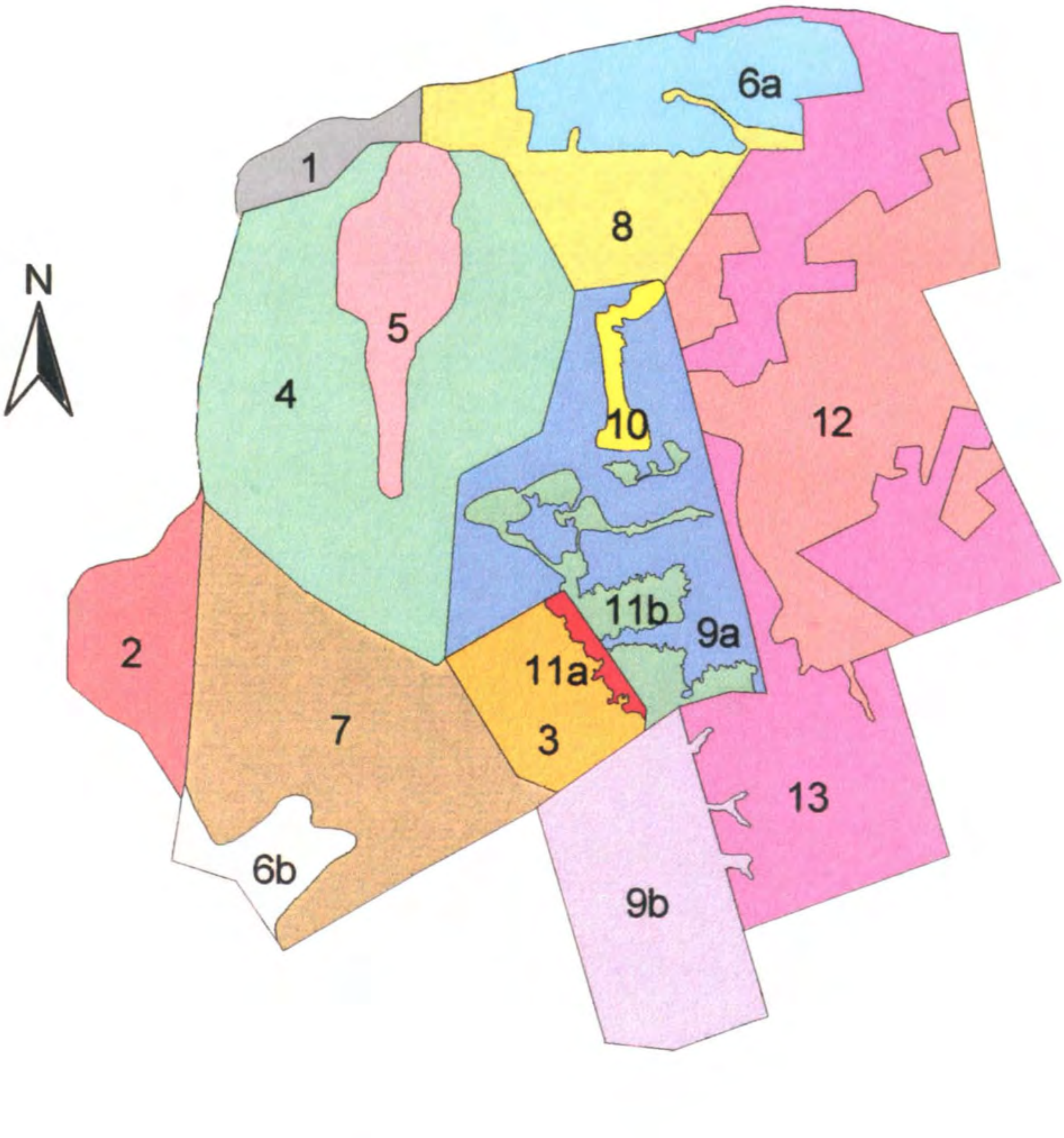


Figure 3.1. Map of study area within the Addo Elephant National Park, showing delineation of zones for sampling. Details given in Table 3.1 below.

Table 3.1. Vegetation type (after Archibald, 1955) (spekboomveld = succulent thicket) and management history of zones shown in Figure 3.1.

| ZONE | VEGETATION | MANAGEMENT HISTORY |
|---|---|---|
| 1 | Spekboomveld | Botanical reserve. Ungrazed by elephants since 1954. |
| 2 | Spekboomveld | Botanical reserve. Ungrazed by elephants since 1954. |
| 3 | Spekboomveld | Botanical reserve. Ungrazed by elephants since 1954. |
| 4 | Spekboomveld | Original elephant camp, fenced in 1954. 42 years of elephant grazing. |
| 5 | Spekboomveld | Overgrazed section of original camp, around waterholes. 42 years grazing. |
| 6a | Karoo-Bushveld | False Karoo-bushveld. 15 years exposure to elephant grazing. Bush cleared in 1950's for springbok. |
| 6b | Karoo-Bushveld | True Karoo-bushveld. 20 years of elephant grazing. |
| 7 | Spekboomveld | 20 years of elephant grazing. |
| 8 | Spekboomveld | 15 years of elephant grazing. |
| 9a | Spekboomveld | 13 years of elephant grazing. |
| 9b | Spekboomveld | 13 years of elephant grazing – previously a private farm, Marion Baree. |
| 10 | Mixed Shrub & Grassveld | Restricted to limestone plateau. 20 years of elephant grazing. |
| 11a | Bontveld | Part of main botanical reserve. Ungrazed by elephants since 1954. |
| 11b | Bontveld | 13 years exposure to elephant grazing. |
| 12 | Spekboomveld | 6 years elephant grazing. Prior management history as farmlands uncertain. |
| 13 | | Farmlands cleared for agriculture. Purchased by park in 1991. |

### 3.2.2. DATA ANALYSIS:

Effects of management history on vegetation:

The data were used to examine the effects of management history on species abundance and species richness in each zone. The abundance of each species was calculated for each zone. Abundance patterns were then determined for areas with different elephant-grazing histories, namely 0 years (bot reserves), 6-15 years, 20 years and 42 years. Species richness of zones was calculated as the number of species per hectare in each zone. This was plotted against number of years grazed, for thicket and other vegetation types. Owing to sufficient data points, a least squares regression was fitted to the data for the thicket zones.

Botanical reserve selection:

The aim of the reserve-selection exercise was to capture all 58 Category 1 species in the minimum number of zones. Zones were thus used as the selection units. Six reserve-selection analyses were completed.

The first five analyses were based on the reserve-selection algorithm developed by Rebelo and Siegfried (1992). A presence/absence matrix of Category 1 species versus zones was developed. The number of zones in which each species occurred was found. Each species was given a score based on the total number of zones in the park, divided by the number of zones in which that species occurred; for example, a species that occurred in all 15 zones scored 1, and a species that was unique to one zone scored 15. A 'rarity score' was then calculated for each zone. This score is the sum of all the species' scores in that zone. The zone with the highest rarity score was chosen as the first reserve. All the species that were present in this zone were then deleted from the matrix, and the selection exercise was repeated until all species were represented in chosen zones. Ties were solved by choosing the zone with the highest species richness per hectare, or by ignoring the two indicator species present on the list of 58 Category 1 species (*Viscum rotundifolium* and *V. obscurum*). Analysis six was based on species richness. The richest zone was chosen first, and subsequent zones were chosen in the same way on the complement of species (i.e. unconserved species).

In the first analysis, all zones were included, ignoring the presence of existing botanical reserves. In the second analysis, the four botanical reserves (zones 1, 2, 3 and 11a) were chosen as mandatory sites, and the number of zones required to conserve the complement of species was determined.

For the third analysis, only zones 1, 3, and 11a were designated as mandatory sites. There were three reasons for excluding zone 2: (i) it consistently added only two species to previous reserve-selection procedures and one of those species was an indicator species; (ii) it had the lowest species richness per hectare of all botanical reserves; (iii) the vegetation appeared to be in poorer condition than that of the other botanical reserves (personal observation). The efficiency of this reserve in contributing to the conservation goal thus needed to be examined in more detail. In addition, its exclusion from the botanical reserve system would be useful in a trade for another area that would contribute more efficiently to the reservation goal.

In the fourth analysis, zones 6b and 10 were designated as mandatory sites. These two zones consistently came up as the first two zones to be selected in each algorithm. Their combined contribution was 38 out of 58 species, and the zones needed to conserve the complementary 20 species needed to be determined.

The fifth analysis used zone 1 as the only mandatory site. Zone 1 surrounds the rest-camp/entrance area, and is thus the only fixed botanical reserve in the park. Zones needed to be ranked after considering the species composition of that zone.

Analysis six compared results using a different approach – here zones were chosen purely on the basis of total species richness, irrespective of area.

Selection of zones was based on presence data only, and did not take abundance into account. Owing to the small number of species sampled, it would have been difficult to exclude species that occurred below a certain abundance, and may not have been representative of the species richness of each zone. The biology of each species would need to be carefully examined, as some species occur naturally in very low densities, and would be prejudiced by their exclusion from the analysis.

Vulnerability and irreplaceability:

Two aspects other than presence of species are considered to be important in the reserve selection procedure. These are the concepts of 'vulnerability' and 'irreplaceability'. These concepts can be applied to both zones and species.

The vulnerability of a zone was considered to be its potential for negative impact by grazing. The vulnerability index for zones was considered to be a function of the vegetation type of the zone (as a surrogate for grazing value), the number of waterholes in the zone, and its management history Each of these categories were scored (see Table 3.2), and the sum of scores for each zone was considered to be its vulnerability index.

Table 3.2. Scoring system used for determining the vulnerability index of zones.

| **SCORE** | **3** | **2** | **1** |
|---|---|---|---|
| Vegetation* | Succulent thicket (spekboomveld) | Karoo-bushveld/Bontveld | Mixed shrub and grassveld |
| No. Waterholes | 3 | 2 | 1 |
| No. Years grazed | 0 years | 6-20 years | >20 years |

*ranked according to grazing value

The irreplaceability index for zones was determined by taking the rarity scores for each zone from the first iteration of Analysis 1, as described in the reserve-selection procedure above. These are given in Table 3.3 below.

Table 3.3. Rarity scores used for the irreplaceability index of zones. Z = zone; S = score.

| **Z** | **1** | **2** | **3** | **4** | **5** | **6a** | **6b** | **7** | **8** | **9a** | **9b** | **10** | **11a** | **11b** | **12** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S | 50.5 | 58.9 | 85.3 | 20.8 | 9.3 | 21.4 | 114.9 | 38.7 | 49.5 | 29 | 18.6 | 88 | 69 | 56.2 | 43.8 |

The vulnerability index for species was scored using the profile of a plant vulnerable to elimination by grazing as described by Moolman and Cowling (1994). This is based largely on the growth form of the plant. Succulents were scored as 4, geophytes as 3, forbs as 2 and shrubs as 1.

The irreplaceability index for species was scored using the number of reserves in which each species is currently conserved in the Albany Hotspot. Checklists were obtained from 11 reserves in or adjacent to the thicket biome (reserves listed in Table 1.1), and their floras compared with that of AENP. Baviaanskloof and Groendal Wilderness areas were included in this analysis, as they contain large numbers of thicket species. The number of other reserves that the 76 species in Category 1 occurred in was determined. The maximum number of reserves any Category 1 species occurred in was 8, so in order to rank these in descending order, they were subtracted from 9. Thus, a species occurring in eight reserves scored 1, while a species occurring in one reserve only, scored 8.

These data were used to show which zones contain the largest numbers of species with high vulnerability and irreplaceability scores (top right-hand corner of the irreplaceability/vulnerability plane). First, the 22 species falling in the four data points in the top right-hand corner of the graph were scored from 1 to 3. The total score for each zone based on these 22 species was found and plotted on a graph. Then, the combined vulnerability and irreplaceability score for each of the 58 Category 1 species was found, and plotted on a second y-axis on the same graph. This allowed zones to be ranked in a different manner: zones with high numbers on both y-axes had high numbers of threatened (Category 1) plants, including species with high vulnerability and irreplaceability scores.

By combining these concepts, species and zones were prioritized in a different way for inclusion into the park. A workable solution for inclusion of zones as botanical reserves in the park can be formulated by combining this approach with the results obtained from the reserve selection procedure.

## 3.3. RESULTS:

### 3.3.1. Effects of elephant-grazing history on vegetation:

Species abundance:

The number of individuals per hectare of Category 1 species was more evenly spread throughout the density classes for the ungrazed (botanical reserves) relative to the grazed zones (Figure 3.2). Thus, these species tend to be more abundant in ungrazed than grazed zones. This is especially evident in the zones with the longest grazing history (42 years) where most species have a very low abundance. However, after 20 years of grazing, a few species still remain abundant. It must be noted that only the shape of the graphs is relevent, as different numbers of zones fall into each category of grazing history.

Species richness:

There were sufficient data only for succulent thicket (spekboomveld) for a quantitative analysis of the relationship between richness of Category 1 species and history of elephant grazing. This shows that species richness decreases in an exponential manner with sustained grazing, and will halve approximately every 7 years (Figure 3.3). The contrast between ungrazed and grazed bontveld communities (zones 11a and 11b respectively) is clearly shown in Figure 3.4. Zone 11b shows a dramatic decline in species richness per hectare after only 12 years of grazing, while zone 11a has the highest species richness per hectare of all the zones. The difference in species richness in zones 6a and 6b (karoo-bushveld) is attributable to their different management histories. Zone 6b is in its natural state, while zone 6a was previously a thicket community that was bulldozed in the 1950's to provide grazing for springbok, and is thus not a natural community. Its species diversity may thus have been lower than that of zone 6b before exposure to elephant grazing. Zones 6b and 10 have both been exposed to elephant grazing for 20 years, and still support species-rich vegetation. This is partially due to the fact that these zones are less heavily utilised by elephants than succulent thicket zones. However, species abundance has been shown to decrease most dramatically after 20 years, so this must be taken into account.


Figure 3.2. Numbers of Category 1 species (see text) in density classes in four grazing history categories in the Addo Elephant National Park.

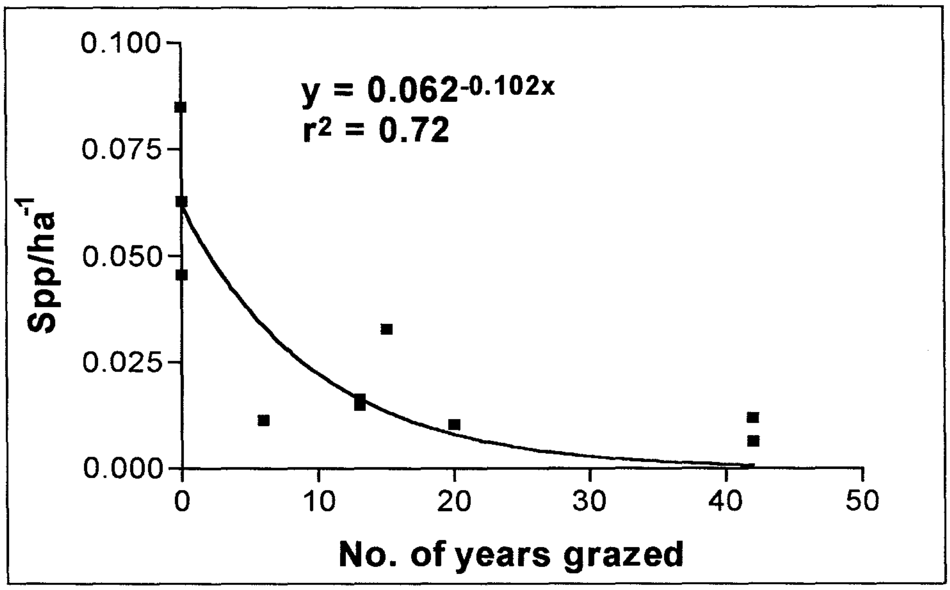


Figure 3.3. Number of species per hectare for 10 thicket communities of different grazing histories.

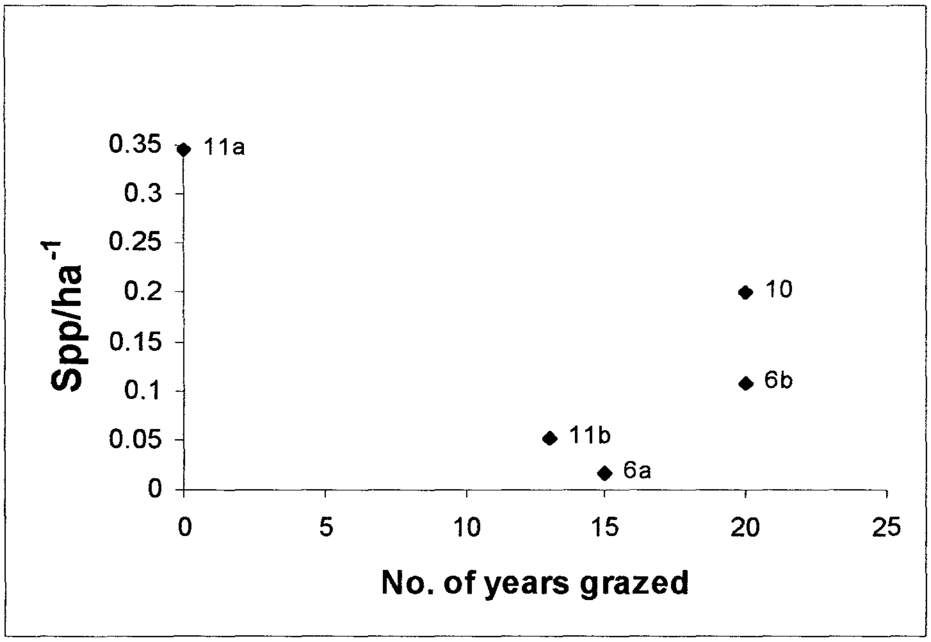


Figure 3.4. Number of species per hectare for karoo-bushveld (6a and b), mixed shrub and grassveld (10) and bontveld (11a and b) communities with different grazing histories.

### 3.3.2. Botanical Reserve Selection:

Results of the reserve selection analyses are shown in Table 3.4. In the first five reserve selection analyses, zones 6b, 10, 3, 1 and 11a were required, in that order, to represent 90% of the threatened species of the AENP. Zone 2, a botanical reserve, contributed only 2 complementary species, one of which was an indicator species, and was thus not considered essential to the botanical reserve system. Zones 3, 1, and 11a are existing botanical reserves. Zones 6b and 10 are not botanical reserves, yet account for 38 (66%) of the threatened species of the park, and should thus be included in the system of reserves. In the sixth analysis, a 'greedy' algorithm was used. Zone 3 was selected first on the basis of its species richness, followed by zones 6b, 10, 1 and 11a. Again, zone 2 contributed only 2 complementary species, one of which was an indicator species.

The remaining 4 species (7%) were each only represented in single zones (zones 7, 8, 11b, 12), and were not included in the solution. Alternative solutions for these four species will need to be found.

### 3.3.3. Vulnerability and Irreplaceability:

Zones falling in the top right quarter of the vulnerability/irreplaceability plane in Figure 3.5 are considered to be the most urgent priorities in terms of conservation action. Zone 3 is the only zone to score sufficiently highly in both categories to fall into this quarter. Zones 6b, 10 and 11a all fall in the high irreplaceability but low vulnerability quarter, as based on their vegetation type (karoo-bushveld, mixed shrub and grassveld and bontveld respectively) and lack of waterholes.

Most of the Category 1 species were located in the priority zone (upper right quarter of the plane) of the vulnerability/irreplaceability plane for species (Figure 3.6). Therefore, only species falling in the four data points with the highest scores in the uppermost right corner of the graph (ranked 1-3) were considered to have the highest conservation value. (Axes

Table 3.4. Table showing results of reserve selection analyses. Step one shows the mandatory sites included in the algorithm for each analysis, steps 2-11 show sites conserved in order by the number of complementary species each contributed to the algorithm. Z = zone; # = number of complementary species conserved; % = accumulative total of percentage of threatened species conserved.

| STEP | ANALYSIS 1 | | | ANALYSIS 2 | | | ANALYSIS 3 | | | ANALYSIS 4 | | | ANALYSIS 5 | | | ANALYSIS 6 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Z | # | % | Z | # | % | Z | # | % | Z | # | % | Z | # | % | Z | # | % |
| 1 | | 0 | 0 | 1,2,3, 11a | 41 | 71 | 1,3, 11a | 36 | 62 | 10, 6b | 38 | 66 | 1 | 14 | 24 | 3 | 23 | 40 |
| 2 | 6b | 22 | 38 | 6b | 8 | 85 | 6b | 11 | 81 | 3 | 8 | 79 | 6b | 34 | 59 | 6b | 14 | 64 |
| 3 | 10 | 16 | 66 | 10 | 5 | 93 | 10 | 5 | 90 | 1 | 3 | 84 | 10 | 45 | 78 | 10 | 9 | 79 |
| 4 | 3 | 8 | 79 | 7 | 1 | 95 | 2 | 2 | 93 | 11a | 3 | 90 | 3 | 49 | 83 | 11a | 3 | 84 |
| 5 | 1 | 3 | 84 | 8 | 1 | 97 | 7 | 1 | 95 | 2 | 2 | 93 | 11a | 52 | 90 | 1 | 3 | 90 |
| 6 | 11a | 3 | 90 | 11b | 1 | 98 | 8 | 1 | 97 | 7 | 1 | 95 | 2 | 54 | 93 | 2 | 2 | 93 |
| 7 | 2 | 2 | 93 | 12 | 1 | 100 | 11b | 1 | 98 | 8 | 1 | 97 | 7 | 1 | 95 | 7 | 1 | 95 |
| 8 | 7 | 1 | 95 | | | | 12 | 1 | 100 | 11b | 1 | 98 | 8 | 1 | 97 | 8 | 1 | 97 |
| 9 | 8 | 1 | 97 | | | | | | | 12 | 1 | 100 | 11b | 1 | 98 | 11b | 1 | 98 |
| 10 | 11b | 1 | 98 | | | | | | | | | | 12 | 1 | 100 | 12 | 1 | 100 |
| 11 | 12 | 1 | 100 | | | | | | | | | | | | | | | |
| TOTAL: | | 58 | | | 58 | | | 58 | | | 58 | | | 58 | | | 58 | |

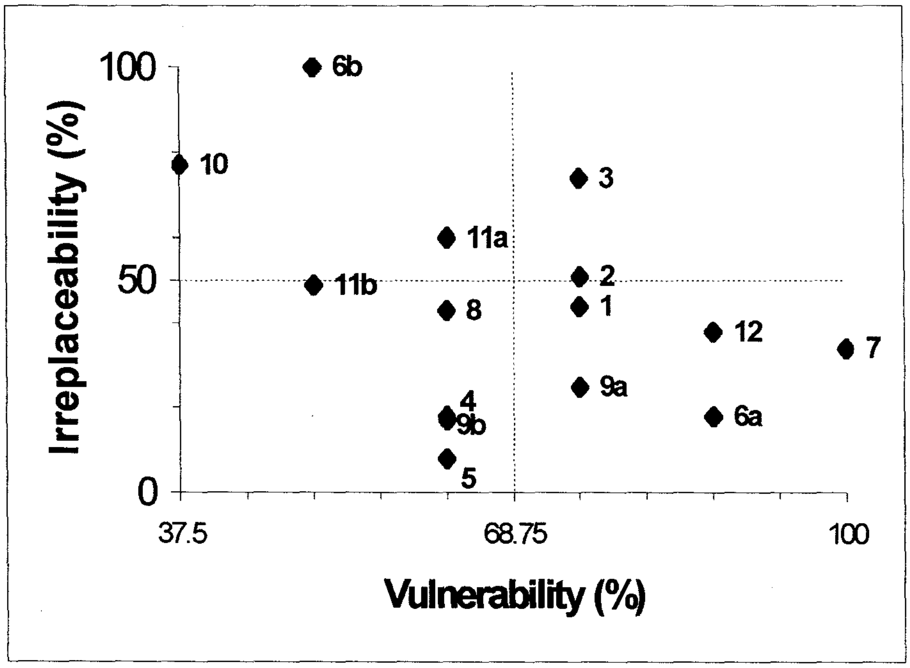


Figure 3.5. Vulnerability versus irreplaceability for zones.

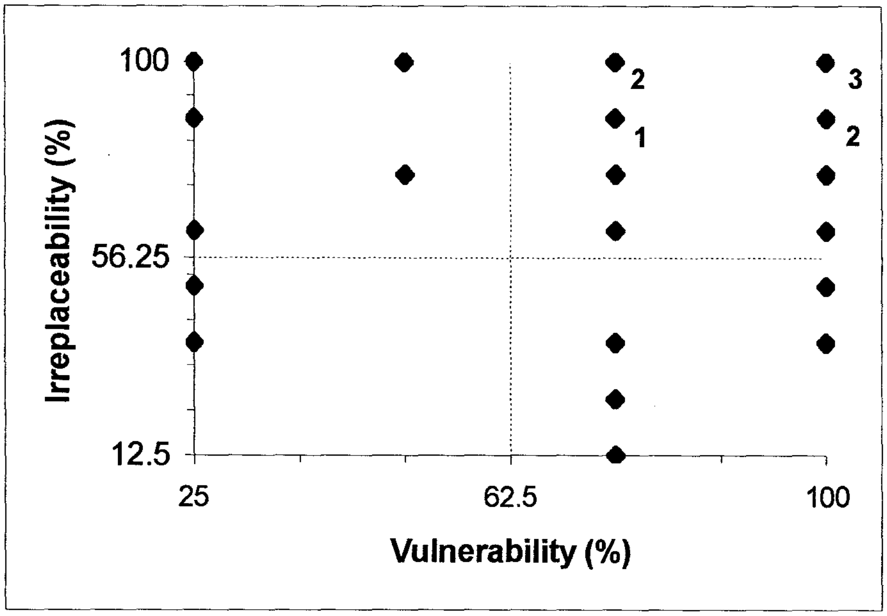


Figure 3.6. Vulnerability versus irreplaceability for each species. Species with rankings of 1, 2 and 3 (see text for explanation) are listed in Table 3.5 below.

were normalised, but actual values were used to calculate scores for these species.) Three species had a combined vulnerability and irreplaceability score of 12 (ranked 3); 16 had a combined score of 11 (ranked 2), and 3 species had a combined score of 10 (ranked 1). These species are listed in Table 3.5.

Table 3.5. Species ranked as 1, 2 and 3 in terms of the combined vulnerability/irreplaceability scores (see Figure 3.7).

| RANK 3 | RANK 2 | RANK 1 |
|---|---|---|
| *Bergeranthus longisepalus* | *Albuca nana* | *Holothrix schleteriana* |
| *Huernia brevirostris* | *Albuca schonlandii* | *Lachenalia bowkeri* |
| *Lampranthus productus var. productus* | *Apodolirion sp. ined.* | *Pelargonium dichondrifolium* |
| | *Bulbine c.f. inae* | |
| | *Bulbine frutescens var. ined.* | |
| | *Cyrtanthus loddigesianus* | |
| | *Dietes bicolor* | |
| | *Eriospermum bifidum* | |
| | *Eulophia hereroensis* | |
| | *Ornithogalum monophyllum* | |
| | *Pelargonium ochloleucum* | |
| | *Pelargonium radulifolium* | |
| | *Euphorbia inermis var. inermis* | |
| | *Faucaria felina* | |
| | *Mestoklema albanicum* | |
| | *Trichodiadema bulbosum* | |

When zones are scored on the basis of combined vulnerability/irreplaceability scores for all the Category 1 species present and for those 22 species that scored the highest in the vulnerability/irreplaceability plane (Figure 3.6), the following patterns emerge (Figure 3.7):

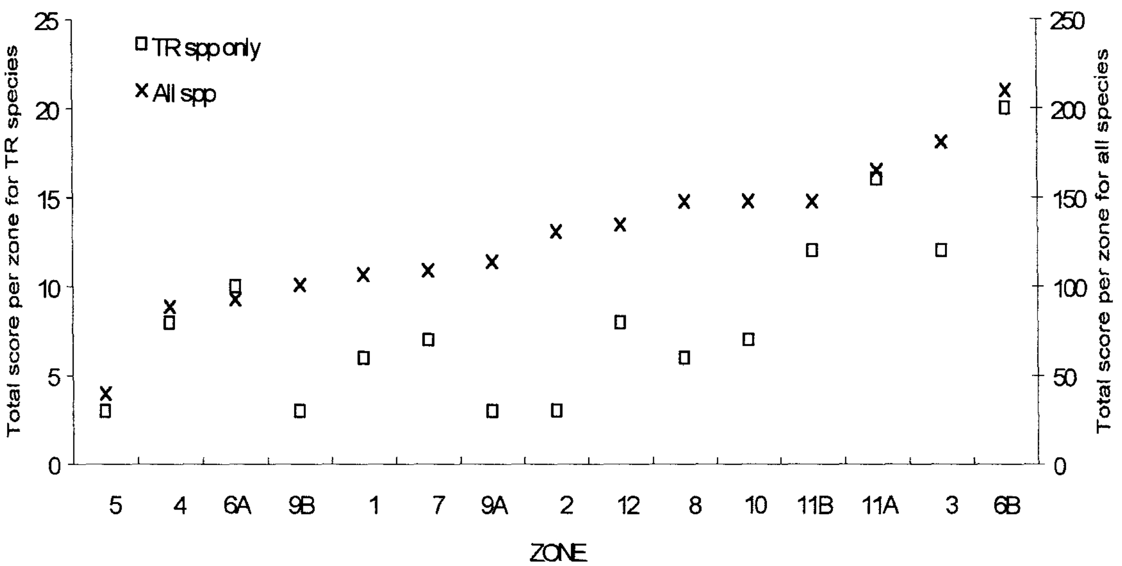


Figure 3.7. Scores for each zone based on Figure 3.6 above. Open squares denote the scores per zone for the species in the top right (TR) corner of Fig. 3.6 only, and crosses are the scores per zone for all Category 1 species.

Here, zones 6b, 3 and 11a stand out as having both the highest numbers of Category 1 species, as well as the highest numbers of priority species for conservation. Zone 10, despite its size, also has high numbers of Category 1 species, although fewer of its species fall in the high vulnerability/irreplaceability plane. Zone 2 has a relatively large number of Category 1 species, but few of these are considered to be conservation priorities. These results correspond well with the results obtained in the reserve selection analysis. Zones 6b, 10, 3 and 11a were considered priority zones for conservation. Zone 1 is a fixed botanical reserve, and although it has fewer priority species, it does contribute a complement of Category 1 species. Zone 2, an existing botanical reserve, contributes little to the reservation goal in terms of complementary species, numbers of species per hectare, or species with a high conservation priority.

## *3.4. DISCUSSION:*

### 3.4.1. Impact of grazing on species abundance and richness:

Elephants account for approximately 78% of the total herbivore biomass in the AENP, and grazing effects in the park are thus mostly attributable to them (Stuart-Hill, 1992). Both species abundance and richness were shown to be affected by elephant grazing. Abundance declined markedly only after 20 years of exposure to elephants (Figure 3.2), when larger density classes decreased, and species were less evenly spread throughout these classes. Species richness, however, declined more rapidly. Thicket communities (Figure 3.3) appeared to be more sensitive to loss of species as a result of prolonged exposure to elephant grazing than other communities (Figure 3.4), with species richness in thicket communities halving approximately every 7 years. These data provide further evidence for the inevitable loss of species as a result of elephant grazing (Moolman and Cowling, 1994; Cumming *et al.*, 1997).

### 3.4.2. Botanical reserve selection:

Traditional reserve selection procedures have focussed on the effective and efficient placement of reserves in regional contexts (KirkPatrick, 1983; Pressey *et al.*, 1994 a,b; Rebelo, 1994; Lombard *et al.*, 1995; Pressey *et al.*, 1996). The concept of identifying reserves with a reserve is a unique one, brought about by several unusual and conflicting facets of conservation in the AENP. While the conservation of the elephant population in the park is paramount, it is vital that the unique flora of the region is also adequately conserved. As elephants at high population densities clearly impact negatively on the abundance and richness of species, it is essential that botanical reserves be set aside within the park. In this way, the park becomes an ecosystem reserve, rather than a reserve solely for the conservation of one species at the expense of many others. The minimum set approach was used in this analysis to produce an effective and efficient solution to botanical reserve placement in the AENP. This new approach to reserve selection should be expanded in the context of the park, as new areas are added to it.

### 3.4.3. Implementation of the system:

The proposed botanical reserve system for the AENP is shown in Figure 3.8 below. The six different reserves selection procedures used for designing a representative botanical reserve system for the AENP all rendered similar results (Table 3.4). In all six procedures, zones 6b, 10, 3, 1, 11a and 2 were consistently required to represent 93% of the park's threatened plant species (Category 1), in that order. Zones 3, 1, 11a and 2 are existing botanical reserves. It is clear from these results that zones 6b and 10 must be incorporated into the botanical reserve system to effectively preserve 93% of threatened species of the park. The remaining four species, which each fall in a different zone (7, 8, 11b, 12), will need to be conserved in other ways, for example by surveying the existing botanical reserves again for those four species only, or by transplanting those species to suitable sites.

Efficiency of the botanical reserve system is being reduced by the inclusion of zone 2 (currently a botanical reserve). This zone is redundant as it is, for the most part, a duplication of the other thicket zones (zones 1 and 3), and contributes only two complementary species (3% of total), one of which is an indicator species, while the other falls low on the vulnerability index. It would be considerably more efficient in terms of plant species conservation to incorporate zones 6b and 10 to the botanical reserve system, and to include zone 2 in the elephant camp. Exclusion of this zone from the reserves system would still result in conservation of 90% of the Category 1 species. Zone 2 is the largest of the existing botanical reserves, covering 416 ha, which would be more efficiently managed as elephant grazing than for plant species conservation.

Both zones 6b and 10 are high on the irreplaceability index, but fall low on the vulnerability index due to their lack of waterholes and their vegetation types (karoo-

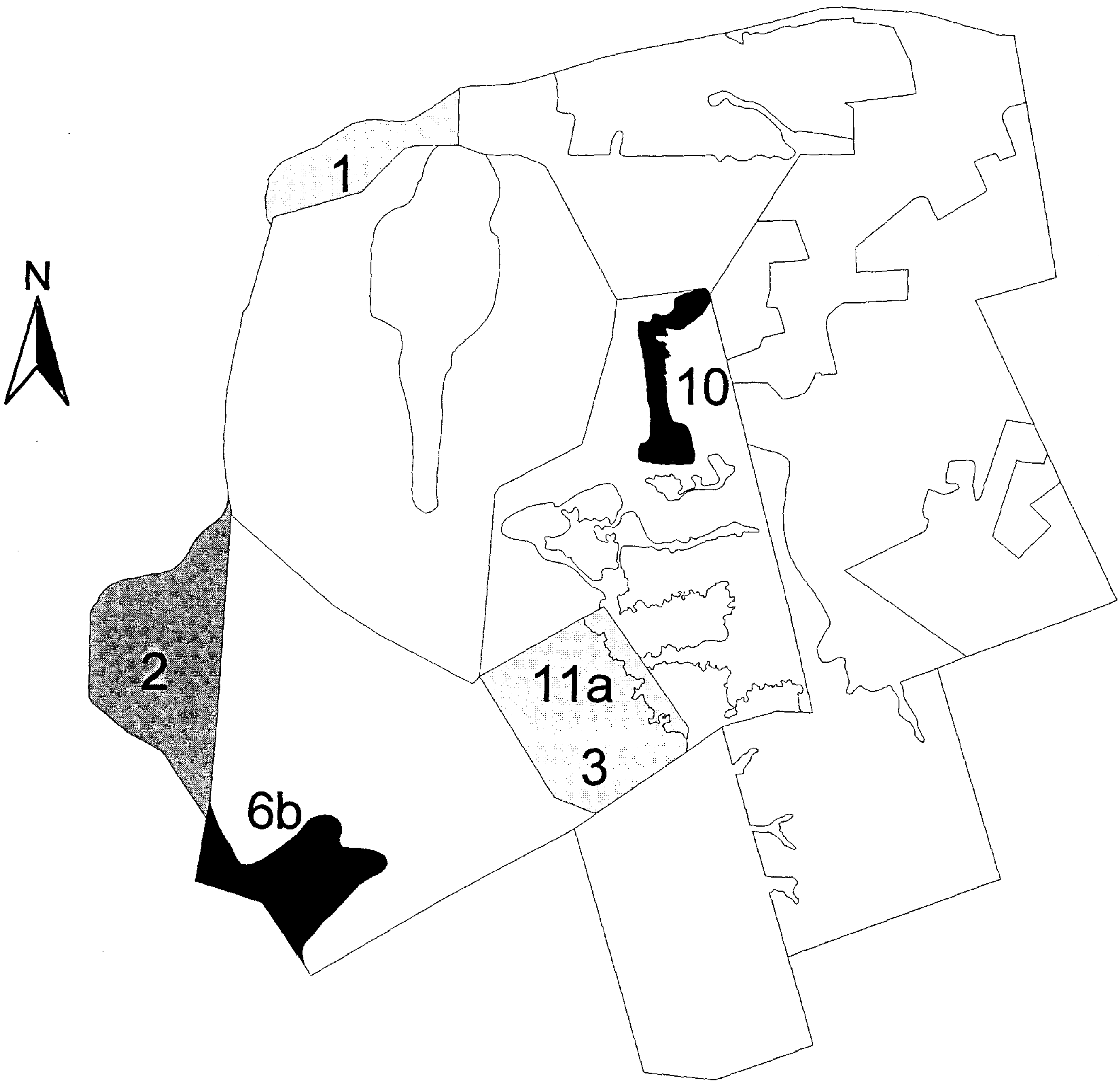


Figure 3.8. Map of proposed botanical reserve system for the AENP. Pale grey indicates zones that should be retained. Dark grey indicates zones that should be removed. Black indicates zones that should be included in the system of reserves.

bushveld and mixed shrub and grassveld, respectively) (Figure 3.5). Both have been grazed for 20 years and show little loss of species richness (Figure 3.4) in comparison to thicket zones (Figure 3.3). However, their species richness prior to elephant grazing is unknown, and in addition, species richness is shown to decline most markedly only after 20 years, so these zones may still experience loss of species richness. When incorporating zones 10 and 6b into the system of reserves, irreplaceability was thus considered to be more important than vulnerability. The impact of elephants on these communities is still uncertain, as there are no data with which to compare current species composition and abundance, and no other zones of similar vegetation but different grazing histories. Impact of elephants on bontveld (zone 11b) was, however, shown to be severe in relation to the species-rich bontveld community within the botanical reserve (zone 11a) (Figure 3.4). Therefore, it is essential that zone 11a be retained in the botanical reserve system.

Zone 10 is fairly inaccessible to elephants, being along a steep ridge, in addition to its unpalatable vegetation and lack of water. It is unlikely to be heavily grazed; it may thus be a 'natural' botanical reserve, and not need to be fenced. This would be preferable, as tourist roads pass through the zone, and elephant fencing would be unsightly and inconvenient. However, species composition and abundance must be monitored carefully over the coming years to ensure that they do not decline further. This may become a problem if the grazing pressure in the elephant camp is not reduced in the immediate future.

Zone 6b is more vulnerable in terms of potential for species loss by grazing than zone 10. There is a nearby waterhole, and the vegetation provides more suitable habitat for elephants, which do frequent the area at times. This zone supports a different suite of species, due to slight environmental differences from the rest of the park. The zone lies in a small depression – an area of salt accumulation – and is termed 'brakveld' (Archibald, 1955). Unusual species not seen elsewhere in the park that were not necessarily included on the threatened list (Category 1), as their status is as yet unknown, include a large number of geophytes such as *Ledebouria* c.f. *graminifolia* (which may be a new species), and *Fockea gracilis* (a rare but widespread species). Those on the threatened list (Category 1) that were not found elsewhere in the park include *Pelargonium ochloleucum*, *Bulbine frutescens* var. ined. Baijnath (a highly localised white-flowered variety of the species), *Euphorbia inermis* var. *inermis*, and *Mestoklema albanicum*, a species for which there is only one other record lodged at the National Herbarium, Pretoria.

Not all of zone 6b need be fenced in – this can be done in the most cost-effective way, and can actually save elephant fencing. Two fencing scenarios are shown in Figure 3.9. Costs are given in Table 3.6. The external boundary will need to be fenced with double-stranded electrical fencing, at a cost of R25 000/km, while elephant fencing is estimated to cost R100 000/km (J. Adendorf, pers. comm., 1997). Fence B is recommended, as overall costs are lower, while more area of zone 6b is conserved.

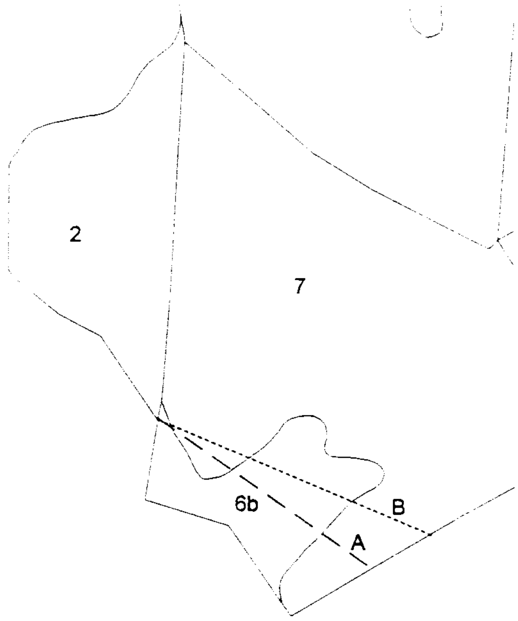


Figure 3.9. Fencing scenarios for the proposed AENP botanical reserve system.

By including zones 6b and 10 into the botanical reserve system, all vegetation types in the park, except the small portion of coastal bush, will be included in the system. Zone 1 includes a fairly large vlei as well, so that unique habitat will also be preserved. It is vital to represent all vegetation types in the reserve system to ensure the greatest representation of species. Zones 6b, 3 and 11a had the highest numbers of both Category 1 species and priority species for conservation (Figure 3.7), indicating that these zones not only have the highest numbers of threatened plant species, but also the highest number of vulnerable and irreplaceable species of those threatened plants. Zone 10 has a high number of threatened species, but fewer species with high vulnerability and irreplaceability. This confirms the reserve selection analysis, indicating that it is a priority to include zone 6b in the system, retain zones 3 and 11a and that zone 10 may not need to be fenced but should be regarded as part of the system and monitored as such.

Table 3.6. Costs of fencing zones 6b and 2.

| | Fence A | Fence B |
|---|---|---|
| Length of fence | 2682m | 3045m |
| Area of zone 6b included | 110ha | 150ha |
| Area of zone 7 lost from elephant camp | 51ha | 100ha |
| Area of zone 2 added to elephant camp | 415.7ha | 415.7ha |
| Total area added to elephant camp | 254.7ha | 165.7ha |
| Elephant fence saved around perimeter of 6b | 3854m | 4567m |
| Elephant fence saved between zones 2 and 7 | 4170m | 4170m |
| Elephant fence required to fence zones 2 and 6b | 8519m | 8882m |
| Total elephant fence required | 495m | 145m |
| Cost of elephant fencing | R 49 500 | R 14 500 |
| Cost of electric fencing | R 96 350 | R 114 175 |
| TOTAL COST | R 145 850 | R 128 675 |

Of the 76 species on the threatened list (Category 1), only 58 were encountered and included in the analysis. However, this does not discount the importance of the remaining 18 species, which may have already been eliminated from the park, or be significantly reduced. They may thus be the most threatened of all the Category 1 species, and attention should be focussed on these 18 species. Should they be located in the future, consideration must be given to their preservation.

### 3.4.4. Expanding Addo – a warning.

Two of the new sections of the park (Figure 1.7, sections 3a and b), Buffelskuil and Mimosa, were sampled as well. However, this area was found to support a different vegetation type, transitional between succulent thicket and Afromontane forest. A different suite of species was encountered, with the vegetation in the understorey consisting mostly of forbs, with few succulents or geophytes. In addition, the areas were difficult to divide into workable zones in the same manner that the rest of the area was treated, as these areas were entire farms, and thus had no variation in past management history. The region was considerably more heterogeneous than the study area, and vegetation altered with factors such as aspect and slope. A few important species were encountered here, including *Euphorbia ledienii* and *Mestoklema albanicum*, as well as large stands of arborescent *Aloe* and *Euphorbia* species. These species are likely to be heavily impacted by elephant grazing, so should elephants be introduced to these sections of the park, due consideration must be given to setting aside botanical reserves within these areas.

## *3.5. CONCLUSION:*

In order to represent the maximum number of threatened species in the AENP, all vegetation types should be represented in the botanical reserve system. Existing botanical reserves 1, 3 and 11a should be retained, but botanical reserve 2 may be incorporated into the elephant camp. Zones 6b and 10 should be added to the botanical reserve system, as these account for 66% of the threatened plant species sampled. Zone 10 may not need to be fenced as it is not vulnerable to elephant grazing, but species composition and abundance of the area must be monitored. At least a portion of zone 6b should be fenced off from elephants. Future research must focus on areas that will be included in the elephant camp, and due consideration must be given to preserving species in these areas.

# CHAPTER 4:

# GENERAL CONCLUSIONS:

It has been established that the Addo Elephant National Park is an important reserve in terms of the flora of the Eastern Cape. The flora of the park comprises at least 581 vascular plant species, of which more than 12% are endemic or have formal conservation status according to the Red Data List (Hilton-Taylor, 1996). Many of these already threatened species fit the profile of a plant vulnerable to elimination by grazing pressure (Moolman and Cowling, 1994), and must be protected in botanical reserves. The efficiency of the botanical reserve system in the park has been improved by the addition of zones 6b and 10, and the removal of zone 2. Fencing scenarios and costs have been calculated to provide National Parks management with various options for achieving the conservation goals of the AENP in the most cost-effective manner.

A major contribution of this study was to apply conservation planning principles (KirkPatrick, 1983; Pressey 1994; Pressey *et al.*, 1994a) to identify special botanical reserves within a conservation area. These techniques can now be used to plan for additional botanical reserves as the AENP expands (Kerley and Boshoff, 1997). The study provided good evidence that prolonged elephant grazing negatively affects not only the richness, but the abundance of endemic and otherwise threatened plant species.

One limitation of this study is that the park is being expanded at a huge rate (Kerley and Boshoff, 1997), and as fast as this work was being completed, it was becoming outdated. It is essential that similar issues be addressed in all new areas of the park, particularly where elephants are to be introduced. The botanical reserve system for the entire AENP should be continually revised as new areas are acquired to maintain the efficiency of the system. Methods of zoning new areas without different management histories need to be found. In addition, more attention should be given to species that are not well-represented in other reserves, particularly if these also fall into Category 1.

A second limitation of the study was the lack of previous research on the threatened plants of the Eastern Cape. One major reason for this is that the Eastern Cape has historically been included in the Cape Region, and was largely overlooked as an entity. It is essential that researchers begin to treat the Eastern Cape as a separate region, and recognise its importance as such. Data on the endemism of plant species in the Eastern Cape could then be improved, which would greatly facilitate works such as this one.

Work within the Eastern Cape also needs to be examined. With the exceptions of the Baviaanskloof Wilderness Area and the Swartkops, Great Fish River and Karoo Nature Reserves, checklists for the reserves of the Eastern Cape were generally poor. Most of these overlooked groups considered to be 'difficult' to identify, particularly geophytes and Mesembryanthemaceae, which constitute two important groups among Eastern Cape endemics. With the thicket biome unique to this region, and under constant threat, it is vital that researchers begin to focus on this component of the vegetation in more detail.

In this regard, it is also important that the National Parks Board begins to treat their succulent thicket reserve as an 'ecosystem reserve', rather than focussing on single species management approaches. The name, Addo Elephant National Park, biases the conservation objectives of the park from the outset, and perhaps this should be examined. Although it is clear that elephants and other members of the 'big five' are so-called 'flagship species' and are recognised as the main generators of income through tourism, as the park expands it will include an enormous diversity of vegetation types, possibly unparalleled elsewhere in the world (Kerley and Boshoff, 1997). This feature, above all, could be used to make the park a world-class tourist attraction. The park has a unique opportunity to represent a huge range of biodiversity, and should look towards that as a major objective.

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# APPENDIX 5.1. List of Vascular Plant Species for the Addo Elephant National Park.

C. = Category. Category 1 species are defined as having formal conservation (Red Data List) status, or being endemic to the Eastern Cape. Category 2 species are those species in the AENP not found in other reserves surveyed here. These reserves are listed as 1-11. 1 = Seekoei Nature Reserve; 2 = Springs Nature Reserve; 3 = Watersmeeting Nature Reserve; 4 = Baviaanskloof Wilderness Area; 5 = Great Fish River Reserve Complex; 6 = Groendal Wilderness Area; 7 = Thomas Baines Nature Reserve; 8 = Karoo Nature Reserve; 9 = Swartkops Nature Reserve; 10 = Blaauwkrantz Nature Reserve; 11 = Bathurst Commonage. * = species present in reserve indicated. 021 = Midgley and Joubert (1991). 050 = Hall-Martin *et al.* (1982). 051 = De Graaff *et al.* (1973).

| C. | SPECIES: | VOUCHER #: | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **APONOGETONACEAE** | | | | | | | | | | | | |
| | *Aponogeton desertorum* Zeyh. ex. Spreng. f. | CJ 216, GRA. | | | | * | | | | | | | |
| | *Aponogeton junceus* Lehm. ex Schlechtd. subsp. *junceus* | Anon. s.n., KIM. | | | | * | | | | | | | |
| | **CYPERACEAE** | | | | | | | | | | | | |
| | *Cyperus difformis* L. | CJ 218, GRA. | | | | * | | | | | | | |
| | *Cyperus rubicundus* Vahl | CJ 217, GRA. | | | | * | | | | | * | | |
| 2 | *Mariscus marlothii* (Boeck.) C.B. Cl. | LL 7755, KIM. | | | | | | | | | | | |
| 2 | *Ficinia stolonifera* Boeck. | CJ 182, GRA. | | | | | | | | | | | |
| 2 | *Ficinia truncata* (Thunb.) Schrad. | TD 2405, GRA. | | | | | | | | | | | |
| | *Schoenoplectus decipiens* (Nees.) J. Raynal | EA 5267, GRA. | | | | * | | | | | | | |
| 2 | *Schoenoplectus muricinux* (C.B. Cl.) J. Raynal | LL 7751, KIM. | | | | | | | | | | | |
| 2 | *Bulbostylis hispidula* (Vahl) R. Haines | LL 7745, KIM. | | | | | | | | | | | |
| | **COMMELINACEAE** | | | | | | | | | | | | |
| | *Commelina africana* L. | LL 7387, KIM. | * | * | * | * | | | * | | * | * | |
| | *Commelina benghalensis* L. | LL 6629, KIM. | * | | * | * | * | | | | | | |
| | *Cyanotis speciosa* (L. f.) Hassk. | CJ 077, GRA. | | | * | * | * | | | | * | | |
| | **ASPHODELACEAE I** | | | | | | | | | | | | |
| | *Bulbine abyssinica* A. Rich. | PP field obs. | | | * | * | | | * | | | | |
| | *Bulbine alooides* (L.) Willd. | PP field obs. | | | | * | | | | | | | |

| C. | SPECIES: | VOUCHER #: | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Bulbine filifolia* Bak. | CJ 168, GRA. | | | | | | | | * | | | |
| 1 | *Bulbine frutescens* (L.) Willd. | LL 6630, KIM. | | * | * | * | * | | * | * | * | | |
| 1,2 | *Bulbine frutescens* (L.) Willd. var. ined (Baijnath) | TD 2402, GRA. | | | | | | | | | | | |
| 1,2 | *Bulbine inae* Baijnath ined. | TD 2365, GRA. | | | | | | | | | | | |
| | *Bulbine latifolia* (L. f.) Roem. & Schult. | BB 5616, KIM. | * | | * | | | | | * | | | |
| | *Bulbine narcissifolia* Salm-Dyck | CJ 146, GRA. | | | | | | | * | | | | |
| 2 | *Trachyandra affinis* Kunth | TD 2363, GRA. | | | | | | | | | | | |
| 2 | *Trachyandra saltii* (Bak.) Oberm. var. *saltii* | LL 7720, KIM. | | | | | | | | | | | |
| | *Chlorophytum crispum* (Thunb.) Bak. | CJ 091, GRA. | * | * | | | | | | | | * | |
| | **ERIOSPERMACEAE** | | | | | | | | | | | | |
| 1,2 | *Eriospermum bifidum* R.A. Dyer | CJ 248, GRA. | | | | | | | | | | | |
| 2 | *Eriospermum thyrsoideum* Bak. | LL 7684A, KIM. | | | | | | | | | | | |
| | **ASPHODELACEAE II** | | | | | | | | | | | | |
| 1 | *Aloe africana* Mill. | CJ field obs. | * | | * | | | | | * | | | |
| | *Aloe ferox* Mill. | CJ field obs. | * | * | * | * | | * | * | * | * | * | |
| 1,2 | *Aloe tenuior* Haw. | AH 1927, KIM. | | | | | * | | | | | | |
| | *Gasteria bicolor* Haw. | CJ 008, GRA. | | * | | * | | | | | | | |
| | *Haworthia cooperi* Bak. | TD 2367, GRA. | | * | * | * | | | | | | | |
| 2 | *Haworthia foliosa* Haw. | TD 2360, GRA. | | | | | | | | | | | |
| | *Haworthia viscosa* (L.) Haw. | LL 6244, KIM. | | | * | | | | * | | | | |
| | **ALLIACEAE** | | | | | | | | | | | | |
| 2 | *Tulbaghia cominsii* Vosa | BB 5768, GRA. | | | | | | | | | | | |
| | **HYACINTHACEAE** | | | | | | | | | | | | |
| 2 | *Albuca altissima* Dryand. | CJ 241, GRA. | | | | | | | | | | | |
| 2 | *Albuca aurea* Jacq. | LL 6610, KIM. | | | | | | | | | | | |
| 2 | *Albuca cooperi* Bak. | EA 3838, GRA. | | | | | | | | | | | |
| 2 | *Albuca fastigiata* (L. f.) Dryand. | LL 6609, KIM. | | | | | | | | | | | |
| 2 | *Albuca glandulosa* Bak. | CJ 128, GRA. | | | | | | | | | | | |
| 1,2 | *Albuca nana* Schonl. | CJ 242, GRA. | | | | | | | | | | | |
| 1,2 | *Albuca schonlandii* Bak. | TD 2349, GRA. | | | | | | | | | | | |
| | *Albuca shawii* Bak. | CJ 157, GRA. | | | | * | | | | | | | |
| | *Urginea altissima* (L. f.) Bak. | Anon 366, KIM. | | | * | * | | | | | * | | |
| | *Drimia anomala* (Bak.) Benth. | CJ 167, GRA. | | | * | * | | | | * | | | |

| C. | SPECIES: | VOUCHER #: | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Drimia haworthioides* Bak. | TD 2395, GRA. | | | | * | | | | | * | | |
| 2 | *Drimia robusta* Bak. | LL 7687A, KIM. | | | | | | | | | | | |
| 2 | *Dipcadi cilare* (Zeyh. ex. Harv.) Bak. | CJ 165, GRA. | | | | | | | | | | | |
| | *Dicadi viride* (L.) Moench | CJ 256, GRA. | | | | * | * | | | | | | |
| | *Ornithogalum dubium* Houtt. | CJ 258, GRA. | | * | | * | | | | * | | | |
| | *Ornithogalum graminifolium* Thunb. | CJ 134, GRA. | | | * | * | | | | | | | |
| | *Ornithogalum juncifolium* Jacq. | TD 2291, GRA. | | | | * | | | | | | | |
| 1,2 | *Ornithogalum monophyllum* Bak. | CJ 142, GRA. | | | | | | | | | | | |
| 2 | *Ornithogalum ornithogaloides* (Kunth) Oberm. | EA 3752, GRA. | | | | | | | | | | | |
| 2 | *Ornithogalum tenuifolium* Delaroche | CJ 096, GRA. | | | | | | | | | | | |
| 2 | *Ornithogalum thyrsoides* Jacq. | WH s.n., GRA. | | | | | | | | | | | |
| 1,2 | *Neopatersonia uitenhagensis* Schonl. | EA 5256, GRA. | | | | | | | | | | | |
| 2 | *Ledebouria cooperi* (Hook. f.) Jessop | EA 3726, GRA. | | | | | | | | | | | |
| 2 | *Ledebouria c.f. graminifolia* (Bak.) Jessop | TD s.n.ex hort. | | | | | | | | | | | |
| 2 | *Ledebouria revoluta* (L. f.) Jessop | CJ 046, GRA. | | | | | | | | | | | |
| | *Ledebouria undulata* (Jacq.) Jessop | CJ 115, GRA. | | | | * | | | | | | | |
| 1 | *Lachenalia bowkeri* Bak. | TD 2418, GRA. | | | | | | | | * | | | |
| | *Polyxena ensifolia* (L.f.) Schonl. | CJ 031, GRA. | | | | | | * | | | | | |
| | **DRACAENACEAE** | | | | | | | | | | | | |
| 1 | *Sansevieria aethiopica* Thunb. | CJ 105, GRA. | | | | * | | | | * | | | |
| | *Sansevieria hyacinthoides* (L.) Druce | AH 5703, GRA. | | * | | | * | | * | | * | * | * |
| | **ASPARAGACEAE** | | | | | | | | | | | | |
| | *Protasparagus aethiopicus* (L.) Oberm. | AH 5745, KIM. | * | | | * | | | | | | | |
| | *Protasparagus africanus* (Lam.) Oberm. | PB 528, KIM. | | | | * | * | | | | * | | |
| 1 | *Protasparagus crassicladus* (Jessop) Oberm. | CJ 001, GRA. | | * | | * | * | | * | | | * | * |
| | *Protasparagus densiflorus* (Kunth) Oberm. | AH 5971, KIM. | | * | | * | * | | | | | * | |
| | *Protasparagus racemosus* (Willd.) Oberm. | AH 5963, KIM. | | * | | | | | | * | * | * | |
| | *Protasparagus striatus* (L. f.) Oberm. | BB 5738, KIM. | | * | | * | * | | | * | * | * | * |
| | *Protasparagus suaveolens* (Burch.) Oberm. | AH 5964, KIM. | * | * | | * | * | | | * | * | | * |
| 1 | *Protasparagus subulatus* (Thunb.) Oberm. | EC PEU. | | * | | * | * | | | * | * | * | |
| | *Myrsiphyllum asparagoides* (L.) Willd. | AH 5970, KIM. | * | | * | | * | | | | * | * | |
| | *Myrsiphyllum kraussianum* Kunth | TD 2443, GRA. | | * | | | | | | | | | |
| | *Myrsiphyllum volubile* (Thunb.) Oberm. | EC PEU. | | | | | | | | | * | | |

| C. | SPECIES: | VOUCHER #: | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
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| | **LUZURIAGACEAE** | | | | | | | | | | | | |
| | *Behnia reticulata* (Thunb.) Didr. | from 051 | | | | | | | | * | | * | |
| | **AMARYLLIDACEAE** | | | | | | | | | | | | |
| 2 | *Gemmaria gemmata* D. & U. Muller-Doblies | CJ 233, GRA. | | | | | | | | | | | |
| 1,2 | *Apodolirion* sp. ined. | TD 2380, GRA. | | | | | | | | | | | |
| | *Haemanthus albiflos* Jacq. | CJ 130, GRA. | | * | * | * | | | * | * | | | |
| | *Haemanthus coccineus* L. | BB 5764, GRA. | | | * | | | | | * | | | |
| | *Scadoxus puniceus* (L.) Friss & Nordal | CJ 137, GRA. | | | * | | | | | | | | |
| 2 | *Brunsvigia grandiflora* Lindl. | FL 981, GRA. | | | | | | | | | | | |
| 1 | *Brunsvigia gregaria* R.A. Dyer | Anon. 426, KIM. | * | | | | | | | * | | | |
| | *Ammocharis coranica* (Ker-Gawl.) Herb. | AH 914, KIM | | | | * | | | | * | | | |
| 1,2 | *Cyrtanthus helictus* Lehm. | EA field obs. | | | | | | | | | | | |
| 1,2 | *Cyrtanthus loddigesianus* (Herb.) R.A. Dyer | CJ 152, GRA. | | | | | | | | | | | |
| | **HYPOXIDACEAE** | | | | | | | | | | | | |
| | *Empodium plicatum* (Thunb.) Garside | CJ 234, GRA. | | | * | | | | | | | | |
| 2 | *Hypoxis argentea* Harv. ex Bak. var. *argentea* | LL 7726, KIM. | | | | | | | | | | | |
| 2 | *Hypoxis filiformis* Bak. | LL 6645, KIM. | | | | | | | | | | | |
| | *Hypoxis rigidula* Bak. | EA 5002, GRA. | | | | | | | | | | * | |
| | *Hypoxis stellipilis* Ker-Gawl. | EA 3843, GRA. | | | * | | | | | * | | | |
| 2 | *Spiloxene scullyi* (Bak.) Garside | AH 6698, KIM. | | | | | | | | | | | |
| 1 | *Spiloxene trifurcillata* (Nel) Fourc. | CJ 225, GRA. | * | | * | | | | | | | | |
| | **TECOPHILAEACEAE** | | | | | | | | | | | | |
| | *Cyanella lutea* L. f. | CJ 176, GRA. | | | * | * | | | | | | | |
| | **IRIDACEAE** | | | | | | | | | | | | |
| | *Moraea polyanthos* L. f. | AH 5607, KIM. | | | * | | | | | | | | |
| 2 | *Moraea stricta* Bak. | LL 6614, KIM. | | | | | | | | | | | |
| 1,2 | *Dietes bicolor* (Steud.) Sweet ex Klatt | CJ 121, GRA. | | | | | | | | | | | |
| 2 | *Dietes grandiflora* N.E. Br. | BB 5759, KIM. | | | | | | | | | | | |
| 1 | *Tritonia dubia* Eckl. ex Klatt | CJ 055, GRA. | * | * | | * | * | | | * | | | |
| | *Tritonia lineata* (Salisb.) Ker-Gawl. | EA 3858, GRA. | * | | * | | | | | * | | | |
| 1 | *Gladiolus permeabilis* Delaroche subsp. *edulis* (Burch. ex Ker) Oberm. | CJ 253, GRA. | * | | * | | | | | * | | | |
| 1 | *Freesia corymbosa* (Burm. f.) N.E. Br. | CJ 248, GRA. | * | | * | * | * | | | | | | |

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| | **ORCHIDACEAE** | | | | | | | | | | | | |
| 1 | *Holothrix schlechteriana* Schultr. ex. Kraenzl. | CJ 236, GRA. | | | * | | | | | | | | |
| | *Bonatea speciosa* (L.f.) Willd. var. *speciosa* | CJ 131, GRA. | * | | | * | | | | | * | | |
| 1,2 | *Acrolophia capensis* (Berg.) Fourc. | TD 2289, GRA. | | | | * | | | | | * | | |
| 1 | *Eulophia hereroensis* Schltr. | CJ 150, GRA. | | | | | | | | | | | |
| | *Eulophia streptopetala* Lindl. | CJ 129, GRA. | | * | | | | | | | | | |
| | **LORANTHACEAE** | | | | | | | | | | | | |
| | *Moquinella rubra* (Spreng. f.) Balle | CJ 220, GRA. | | * | | * | * | | | * | | | |
| | **VISCACEAE** | | | | | | | | | | | | |
| 1 | *Viscum crassulae* Eckl. & Zeyh. | from 021 | | * | | * | | | | | | | |
| 1 | *Viscum obscurum* Thunb. | TD 2373, GRA. | | * | | | | | | * | * | * | |
| 1 | *Viscum rotundifolium* L. f. | CJ 045, GRA. | | * | | * | * | | | | * | * | |
| | **SANTALACEAE** | | | | | | | | | | | | |
| | *Colpoon compressum* Berg. | EC PEU. | * | * | | * | | * | | | | | * |
| 2 | *Thesidium microcarpum* (A. DC.) A. DC. | EC PEU. | | | | | | | | | | | |
| | *Thesium flexuosum* A. DC. | CJ 192, GRA. | | | | * | * | * | | | | | |
| 1 | *Thesium scandens* Sond. | TD 2368, GRA. | | * | | | | | | * | * | | |
| 1,2 | *Thesium triflorum* Thunb. | AH 5732, KIM. | | | | | | | | | | | |
| | **POLYGONACEAE** | | | | | | | | | | | | |
| | *Emex australis* Steinh. | BB 5631, KIM. | | | | * | | | | * | * | | |
| 2 | *Polygonum aviculare* L. | Anon 324, KIM. | | | | | | | | | | | |
| | **CHENOPODIACEAE** | | | | | | | | | | | | |
| 2 | *Chenopodium album* L. | BP 6624, KIM. | | | | | | | | | | | |
| | *Chenopodium mucronatum* Thunb. | LL 6648, KIM. | | | | | | | | | | * | |
| 2 | *Chenopodium murale* L. | AH 5992, KIM. | | | | | | | | | | | |
| | *Atriplex nummularia* Lindl. subsp. *nummularia* | BB 5623, GRA. | | | | | | * | | | | | |
| | *Atriplex semibaccata* R. Br. | AH 5765, KIM. | | | | | * | | | | * | | |
| 2 | *Atriplex suberecta* Verdoorn | LL 6649, KIM. | | | | | | | | | | | |
| | *Atriplex vestita* var. *appendiculata* (Thunb.) Aell. | AH 1920, KIM. | | | | | | | | | * | | |
| 2 | *Salsola kali* L. | BB 5678, KIM. | | | | | | | | | | | |
| | AMARANTHACEAE | | | | | | | | | | | | |
| | *Amaranthus thunbergii* Moq. | TD GRA. | | | | | | | | | | | |
| | *Pupalia lappaceae* (L.) A. Juss. | EC PEU. | | | * | | | | | | | * | * |

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| | AIZOACEAE | | | | | | | | | | | | |
| | *Limeum aethiopicum* Burm. | AH 6672, KIM. | | | | | * | | | | | | |
| | *Limeum telephioides* E. Mey. ex Fenzl var. *telephioides* | LL s.n., KIM. | | | | | | | | | | | |
| 2 | *Psammotropha mucronata* (Thunb.) Fenzl. | TD 2388, GRA. | | | | | | | | | | | |
| | *Pharnaceum dichotomum* L. f. | LL 6325, KIM. | | | | | | | | | | * | |
| 2 | *Pharnaceum elongatum* (D.C.) Adamson | EC PEU. | | | | | | | | | | | |
| | *Galenia pubescens* (Eckl. & Zeyh.) Druce | AH 1889, KIM. | | | | | | | * | | | | |
| | *Galenia sarcophylla* Fenzl | from 051 | | | | | | | | * | | | |
| | *Galenia secunda* (L. f.) Sond. | LL 7384, KIM. | | | | | | | | | | * | |
| | *Aizoon glinoides* L. f. | PB 525, KIM. | | * | * | | * | | | | | | * |
| | *Aizoon rigidum* L. f. var. *angustifolium* Sond. | AH 1923, KIM. | * | | | | | | | * | * | | |
| 2 | *Tetragonia echinata* Ait. | EA 5264, GRA. | | | | | | | | | | | |
| | **MESEMBRYANTHEMACEAE** | | | | | | | | | | | | |
| | *Aptenia cordifolia* (L. f.) Schwant. var. *cordifolia* | CJ 244, GRA. | | * | * | * | * | | | | | * | |
| 1,2 | *Bergeranthus longisepalus* L. Bol. | CJ 038, GRA. | | | | | | | | | | | |
| 2 | *Carpobrotus deliciosus* (L. Bol.) L. Bol. | CJ 255, GRA. | | | | | | | | | | | * |
| 2 | *Delosperma acuminatum* L. Bol. | CJ 222, PRE. | | | | | | | | | | | |
| | *Delosperma* cf. *cloetae* Lavis | CJ 057, PRE. | | | | | | | | | | | |
| 1 | *Delosperma ecklonis* (Salm-Dyck) Schwant. var. *ecklonis* | CJ 013, PRE. | | * | | * | * | | * | | | | |
| 1,2 | *Delosperma* cf. *hollandii* L. Bol. | CJ 120(2) PRE. | | | | | | | | | | | |
| 2 | *Delosperma* cf. *karroicum* L. Bol. | CJ 212, PRE. | | | | | | | | | | | |
| 2 | *Delosperma litorale* (Kensit) L. Bol. | LL 6625, KIM. | | | | | | | | | | | |
| | *Delosperma prasinum* L. Bol. | CJ 040, PRE. | | * | | | | | | | | | |
| 1 | *Delosperma pruinosum* (Thunb.) J. Ingram | CJ 084, GRA. | | * | | * | * | | * | | * | | |
| 2 | *Delosperma uniflorum* L. Bol. | LL 6358, KIM. | | | | | | | | | | | |
| 2 | *Delosperma verecundum* L. Bol. | LL 7694, KIM. | | | | | | | | | | | |
| | *Disphyma* sp. | LL 6624, KIM. | | | | | | | | | | | |
| 2 | *Drosanthemum floribundum* (Haw.) Schwant. | LL 6346, KIM. | | | | | | | | | | | |
| 1,2 | *Drosanthemum fourcadei* (L. Bol.) Shwant. | EA 3744, GRA. | | | | | | | | | | | |
| 2 | *Drosanthemum hispidum* (L.) Shwant. | EA 3767, GRA | | * | | * | * | | * | | * | | |
| 1 | *Faucaria felina* (Weston) Schwant. & Jacobsen | CJ 117, GRA. | | | | | * | | | | | | |
| 1 | *Glottiphyllum longum* (Haw.) N.E. Br. var. *longum* | CJ 151, GRA. | | * | | | | | | | * | | |
| 2 | *Lampranthus coccineus* (Haw.) N.E. Br. | BP 6617, KIM. | | | | | | | | | | | |

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| 2 | *Lampranthus haworthii* (Donn) N.E. Br. | AH 5709, GRA. | | | | | | | | | | | |
| 1 | *Lampranthus productus* (Haw.) N.E.Br. var. *productus* | CJ 247, PRE. | * | | | | | | | | | | |
| 2 | *Lampranthus stayneri* (L. Bol.) N.E. Br. | CJ 014, PRE. | | | | | | | | | | | |
| 2 | *Malephora uitenhagensis* (L. Bol.) Jacobsen & Schwant. | EA 3799, GRA | | | | | | | | | | | |
| | *Mesembryanthemum aitonis* Jacq. | LL 7688, KIM. | * | | | * | | | | | | | |
| 2 | *Mesembryanthemum louiseae* L. Bol. | CJ 245, PRE. | | | | | | | | | | | |
| 1 | *Mestoklema albanicum* N.E. Br. | CJ 235, PRE. | | | | | | | | | | | |
| 2 | *Mestoklema elatum* (L. Bol.) Jacobsen & Schwant. | EA SMJ763, GRA | | | | | | | | | | | |
| 2 | *Mestoklema illepidium* N.E. Br. ex Glen | EA SMJ763, GRA | | | | | | | | | | | |
| | *Mestoklema tuberosum* (L.) N.E. Br. ex Glen | LL 6640, KIM. | | | * | | | | * | | | | |
| 1 | *Platythyra haeckeliana* (Berger) N.E. Br. | TD 2376, GRA. | * | | * | | | | | | | | |
| | *Psilocaulon granulicaule* (Haw.) Schwant. | LL 6666, KIM. | | | * | * | | | | | | | |
| 2 | *Psilocaulon liebenbergii* L. Bol. | LL 7689, KIM. | | | | | | | | | | | |
| 2 | *Psilocaulon simile* (Sond.) Schwant. | BB 6590, KIM. | | | | | | | | | | | |
| 2 | *Psilocaulon tenue* (Haw.) Schwant. | BB 6561, KIM. | | | | | | | | | | | |
| 2 | *Ruschia britteniae* L. Bol. | TD 2359, GRA. | | | | | | | | | | | |
| 2 | *Ruschia knysnana* (L. Bol.) L. Bol. | LL 6293, KIM. | | | | | | | | | | | |
| 2 | *Ruschia orientalis* L. Bol. | Anon s.n., KIM. | | | | | | | | | | | |
| 2 | *Ruschia tenella* (Haw.) Schwant | EC PEU. | | | | | | | | | | | |
| 21 | *Sphalmanthus primulinus* (L. Bol.) L. Bol. | LL 7691, KIM. | | | | | | | | | | | |
| 2 | *Sphalmanthus radicans* (L. Bol.) L. Bol. | LL 7393, KIM. | | | | | | | | | | | |
| 1 | *Trichodiadema bulbosum* (Haw.) Schwant. | BB 6524, KIM. | | | | * | | | | | | | |
| 2 | *Trichodiadema pomeridianum* L. Bol. | CJ 109, PRE. | | | | | | | | | | | |
| | **PORTULACACEAE** | | | | | | | | | | | | |
| 2 | *Talinum caffrum* (Thunb.) Eckl. & Zeyh. | TD 2396, GRA. | | | | | | | | | | | |
| | *Anacampseros arachnoides* (Harv.) Sims | CJ 213, GRA. | | | * | * | | | | | | | |
| | *Portulacaria afra* Jacq. | BB 5724, KIM. | * | * | * | * | | * | * | * | * | * | |
| | **MENISPERMACEAE** | | | | | | | | | | | | |
| | *Cissampelos capensis* L.f. | CJ 232, GRA. | | | * | | | | | | | | |
| | **PAPAVERACEAE** | | | | | | | | | | | | |
| 2 | *Argemone ochroleuca* Sweet subsp. *ochroleuca* | BB 6557, KIM. | | | | | | | | | | | |

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| | **BRASSICACEAE** | | | | | | | | | | | | |
| | *Heliophila suavissima* Burch. ex DC. | CJ 154, GRA. | | | | * | * | | | | | | |
| 2 | *Lepidium desertorum* Eckl. & Zeyh. | EA 5265, GRA. | | | | | | | | | | | |
| 2 | *Sisymbrium capense* Thunb. | LL 7734, KIM. | | | | | | | | | | | |
| 2 | *Sisymbrium thellungii* O.E. Schultz | CJ 231, GRA. | | | | | | | | | | | |
| 2 | *Raphanus raphanistrum* L. | AH 1904, KIM. | | | | | | | | | | | |
| 2 | *Rorippa fluviatilis* (E. Mey. ex Sond.) Thell. | EA 3801, GRA. | | | | | | | | | | | |
| | *Capsella bursa-pastoris* (L.) Medik. | MS, KIM. | | | | | * | | | | | | |
| | **CAPPARACEAE** | | | | | | | | | | | | |
| | *Capparis sepiaria* L. var. *citrifolia* (Lam.) Toelken | CJ 144, GRA. | * | * | * | * | * | * | | | * | * | * |
| | *Boscia oleoides* (Burch. ex DC.) Toelken | BB 6555, KIM. | | | | * | * | | | * | * | | |
| | *Cadaba aphylla* (Thunb.) Wild | PB 565, KIM. | | | | * | * | | | * | * | | |
| | *Maerua cafra* (DC.) Pax | TD 2370, GRA. | * | * | * | * | | * | | | * | * | * |
| | **CRASSULACEAE** | | | | | | | | | | | | |
| 1 | *Cotyledon campanulata* Marloth | CJ 097, GRA. | | | | * | * | | | | | | |
| | *Cotyledon orbiculata* L. | BB 5688, KIM. | * | | * | * | * | | | * | * | | |
| 1 | *Cotyledon velutina* Hook. f. | LL 6351, KIM. | | * | | * | * | | | | * | | |
| | *Kalanchoe rotundifolia* (Haw.) Haw. | BB 5782, KIM. | | * | * | * | * | | | * | * | | * |
| | *Crassula alba* Forssk. var *alba* | CJ 162, GRA. | | | * | | | | | | | | |
| 2 | *Crassula arborescens* (Mill.) Willd. | PP field obs. | | | | | | | | | | | |
| | *Crassula capitella* Thunb. subsp. *capitella* | CJ 204, GRA. | | | | * | | | | | | | |
| | *Crassula capitella* Thunb. subsp. *thyrsiflora* (Thunb.) | CJ 205, GRA. | | * | | * | | | | * | | | * |
| | *Crassula cordata* Thunb. | BP 6632, KIM. | | | | | * | | | | * | | |
| | *Crassula cotyledonis* Thunb. | CJ 49, GRA. | | | | * | * | | | | | | |
| | *Crassula cultrata* L. | BP 6628, KIM. | | * | | * | * | | | | | | |
| | *Crassula ericoides* Haw. subsp. ericoides | CJ 015, GRA. | | | | | * | * | | | | | |
| | *Crassula expansa* Dryand. | AH 5962, KIM. | | * | * | * | * | | | * | * | * | * |
| 2 | *Crassula inanis* Thunb. | CJ 030, GRA. | | | | | | | | | | | |
| 1 | *Crassula mesembryanthoides* (Haw.) Dietr. subsp. *mesembryanthoides* | CJ 023, GRA. | | * | * | | * | | | | | * | * |
| | *Crassula muscosa* L. var. *muscosa* | BB 5621, KIM. | | * | * | * | * | * | | * | * | * | * |
| | *Crassula natans* Thunb. | TD 2426, GRA. | | | | | | | | | * | | |
| | *Crassula nudicaulis* L. var. *nudicaulis* | CJ 037, GRA. | | | | * | * | | | | | | |
| | *Crassula orbicularis* L. | LL 6338, KIM. | | | | * | * | | | | * | | |

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| | *Crassula ovata* (Mill.) Druce | Anon s.n., KIM. | | * | * | * | * | | | * | * | * | * |
| | *Crassula perfoliata* L. | BB 5885, KIM. | | * | * | * | * | | | | * | * | * |
| | *Crassula perforata* Thunb. | BB 5635, KIM. | | * | * | * | * | | | | * | * | * |
| | *Crassula pubescens* Thunb.subsp. *radicans* | LL 7749, KIM. | | | | * | | | | | | | |
| | *Crassula rubricaulis* Eckl. & Zeyh. | LL 7758A, KIM. | | | | * | | | | | | | |
| 2 | *Crassula sebaeoides* (Eckl. & Zeyh.) Toelken | BB 5639, KIM. | | | | | | | | | | | |
| | *Crassula spathulata* Thunb. | BP 6636, KIM. | | * | | | * | | | | * | * | |
| | *Crassula tetragona* L. subsp. *acutifolia* (Lam.) Toelken | LL 7750, KIM. | | * | | * | * | | | | | * | |
| | *Crassula tetragona* L. subsp. *tetragona* | CJ 024, GRA. | | | | | | | * | * | * | | |
| 2 | *Crassula vaillantii* (Willd.) Roth | AH 5949, KIM. | | | | | | | | | | | |
| 1 | *Adromischus cristatus* (Haw.) Lem. var. *clavifolius* (Haw) Tolken | CJ 207, GRA. | | | | * | | | | | * | | |
| | *Adromischus maculatus* (Salm-Dyck) Lem. | LL 7702, KIM. | | | | * | | | | | * | | |
| | *Adromischus sphenophyllus* C.A. Sm. | CJ 166, GRA. | | | | * | * | | | | | | |
| | **FABACEAE** | | | | | | | | | | | | |
| | *Acacia karroo* Hayne | BB 5735, KIM. | * | * | * | * | * | | * | * | * | * | * |
| | *Schotia afra* (L.) Thunb. var. *afra* | AH 5707, KIM. | * | * | * | * | * | * | * | * | * | * | * |
| 2 | *Lotononis glabra* (Thunb.) D. Dietr. | CJ 193, GRA. | | | | | | | | | | | |
| 2 | *Lotononis umbellata* Benth. | LL 6328, KIM. | | | | | | | | | | | |
| 2 | *Lebeckia macrantha* Harv. | LL 6286, KIM. | | | | | | | | | | | |
| 1,2 | *Lebeckia psiloloba* Walp. | CJ 208, GRA. | | | | | | | | | | | |
| | *Aspalathus subtingens* Eckl. & Zeyh. | AH 5604, KIM. | | | | * | | | | | | | |
| | *Melolobium candicans* (E. Mey.) Eckl. & Zeyh. | PB 547, KIM. | | | | | | | | * | | | |
| 2 | *Medicago polymorpha* L. | BB 5614, KIM. | | | | | | | | | | | |
| 2 | *Melilotus alba* Desr. | BB 5736, KIM. | | | | | | | | | | | |
| 2 | *Melilotus indica* (L.) All. | BB 5632, KIM. | | | | | | | | | | | |
| 2 | *Indigofera angustata* E. Mey. | Anon. 6644, KIM. | | | | | | | | | | | |
| | *Indigofera heterophylla* Thunb. | CJ 125, GRA. | | | | * | * | | | * | | | |
| | *Indigofera sessilifolia* DC. | from 050 | | | | | * | | | | | * | |
| 2 | *Indigofera stricta* L. f. | EC PEU. | | | | | | | | | | | |
| 2 | *Indigofera* c.f. *zeyheri* Spreng. ex Eckl. & Zeyh. | CJ 016, GRA. | | | | | | | | | | | |
| | *Tephrosia capensis* (Jacq.) Pers. | BB 5659, KIM. | * | * | | * | * | | | | * | * | |
| | *Lessertia* sp. | PB 524, KIM. | | | | | | | | | | | |
| 2 | *Vicia sativa* L. | PB 524, KIM. | | | | | | | | | | | |

| C. | SPECIES: | VOUCHER #: | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
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| | *Rhynchosia ciliata* (Thunb.) Schinz | EA 3857, GRA. | | | | * | | | | | | | |
| | *Dipogon lignosis* (L.) Verdc. | EC PEU. | | | * | * | | | | * | | | * |
| | *Dolichos hastaeformis* E. Mey. | CJ 153, GRA. | | | | | * | | | | | | |
| | **GERANIACEAE** | | | | | | | | | | | | |
| | *Monsonia emarginata* (L. f.) L'Hérit. | CJ 189, GRA. | | * | | * | | | | | * | | |
| 2 | *Erodium malachoides* (L.) Willd. | TD 2400, GRA. | | | | | | | | | | | |
| 2 | *Erodium moschatum* (L.) L'Hérit. | BB 5633, KIM. | | | | | | | | | | | |
| 1,2 | *Pelargonium acetosum* (L.) L'Hérit. | BB 5730, GRA. | | | | | | | | | | | |
| | *Pelargonium alchemilloides* (L.) L'Hérit. | CJ 075, GRA. | | | | * | * | | | | * | | |
| | *Pelargonium aridum* R.A. Dyer | TD 2389, GRA. | | | | | * | | | * | | | |
| 2 | *Pelargonium auritum* (L.) Willd. | BB 6597, KIM. | | | | | | | | | | | |
| 1 | *Pelargonium dichondrifolium* DC. | CJ 042, GRA. | | | | * | | | | | | | |
| 2 | *Pelargonium echinatum* Curtis | AH 6699, KIM. | | | | | | | | | | | |
| | *Pelargonium grossularioides* (L.) L'Hérit. | BB 6522, GRA. | | | | * | | | | | | | |
| | *Pelargonium inquinans* (L.) L'Hérit. | LL 6667, KIM. | | * | | | * | | | | * | | |
| 2 | *Pelargonium iocastum* (Eckl. & Zeyh.) Steud. | AH 5957, KIM. | | | | | | | | | | | |
| | *Pelargonium multicaule* Jacq. | TD 2357, GRA. | | | | * | | | | | | | |
| | *Pelargonium myrrhifolium* (L.) L'Hérit. | BB 5685, KIM. | | | | * | | * | | * | | | |
| 1,2 | *Pelargonium ochloleucum* Harv. | TD 2379, GRA. | | | | | | | | | | | |
| | *Pelargonium odoratissimum* (L.) L'Hérit. | CJ 060, GRA. | * | * | | | * | | | | * | | |
| | *Pelargonium peltatum* (L.) L'Hérit. | BP 6635, KIM. | * | * | * | * | * | | | | * | * | * |
| 2 | *Pelargonium pulverulentum* Colv. ex. Sweet | EA 3719, GRA. | | | | | | | | | | | |
| 1,2 | *Pelargonium radulifolium* (Eckl. & Zeyh.) Steud. | CJ 174, GRA. | | | | | | | | | | | |
| | *Pelargonium reniforme* Curtis subsp. *velutinum* (Eckl. & Zeyh.) Dreyer | BB 5786, KIM. | | * | | * | * | | | | * | * | |
| | *Pelargonium sidoides* DC. | TD 2378, GRA. | | | | * | | | | | | | |
| | *Pelargonium zonale* (L.) L'Hérit. | BB 5687, GRA. | | | | * | | | | * | * | | |
| | **OXALIDACEAE** | | | | | | | | | | | | |
| | *Oxalis depressa* Eckl. & Zeyh. | AH 1893, KIM. | | | | * | | | | | | | |
| | *Oxalis imbricata* Eckl. & Zeyh. | PB 579, KIM. | | | | * | | | | | | | |
| 2 | *Oxalis punctata* L. f. | BB 6553, GRA. | | | | | | | | | | | |
| | *Oxalis smithiana* Eckl. & Zeyh. | CJ 221, GRA. | * | * | | * | | | | | | | |
| | *Oxalis stellata* Eckl. & Zeyh. var. *stellata* | BB 6552, GRA. | | * | | | | | | | | | |
| | *Oxalis stenorrhyncha* Salter | BB 6542, GRA. | | | | | | | | | | * | |

| C. | SPECIES: | VOUCHER #: | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
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| | **ZYGOPHYLLACEAE** | | | | | | | | | | | | |
| | *Zygophyllum debile* Cham. & Schlechtd. | CJ 171, GRA. | | | * | | * | | | | | | |
| | *Zygophyllum divaricatum* Eckl. & Zeyh. | EA 3873, GRA. | | | | | | | | * | | | |
| | *Zygophyllum gilfillani* N.E. Br. | LL 6321, KIM. | | | | | | | * | | | | |
| | *Zygophyllum morgsana* L. | CJ 170, GRA. | | | * | | | | | * | | | |
| 1,2 | *Zygophyllum uitenhagense* Sond. | AH 6678, KIM. | * | | | | | | | | | | |
| | *Tribulus terrestris* L. | AH 1936, KIM. | | | * | | | | * | | | | |
| | **RUTACEAE** | | | | | | | | | | | | |
| | *Zanthoxylum capense* (Thunb.) Harv. | BP 6601, KIM. | * | * | * | * | | | | * | * | * | |
| | *Agathosma capensis* (L.) Dümmer | EA 3864, GRA. | | | * | | | | | * | | | |
| | *Agathosma ovata* (Thunb.) Pillans | CJ 249, GRA. | | | * | | * | | | | | | |
| | **PTAEROXYLACEAE** | | | | | | | | | | | | |
| | *Ptaeroxylon obliquum* (Thunb.) Radlk. | CJ 147, GRA. | * | * | * | * | | * | | * | * | * | |
| | **POLYGALACEAE** | | | | | | | | | | | | |
| 1 | *Polygala asbestina* Burch. | CJ 145, GRA. | | | | | | | * | | | | |
| 1 | *Polygala ericaefolia* DC. | CJ 173, GRA. | * | | * | | | | | * | | | |
| 1 | *Polygala microlopha* DC. var. *microlopha* | EA 3870, GRA. | | | * | * | | | | * | | | |
| | *Polygala uncinata* E. Mey. ex Meisn. | AH 5937, KIM. | | | | * | | | | | | | |
| | *Polygala virgata* Thunb. | CJ 163, GRA. | * | | * | | * | | | * | * | | |
| | *Polygala rehmannii* Chod. | LL 7732, KIM. | | | | | * | | | | | | |
| | **EUPHORBIACEAE** | | | | | | | | | | | | |
| | *Phyllanthus verrucosus* Thunb. | BB 5841, KIM. | * | * | | * | * | | | * | * | * | |
| | *Croton rivularis* Muell. Arg. | CJ 224, GRA. | | * | | | | | | | * | * | |
| 1 | *Jatropha capensis* (L. f.) Sond. | BB 5835, KIM. | * | | * | * | * | | | | | | |
| | *Clutia affinis* Sond. | Anon s.n., KIM. | * | | * | | | | | | | | |
| | *Clutia alaternoides* L. | CJ 188, GRA. | | | * | | | | | | | | |
| | *Clutia daphnoides* Lam. | Anon 435, KIM. | * | | * | | * | | | | | | |
| | *Euphorbia burmannii* E. Mey. ex Boiss. | TD 2431, GRA. | | | | | | | | * | | | |
| 2 | *Euphorbia caterviflora* N.E. Br. | AH 5761, KIM. | | | | | | | | | | | |
| 1 | *Euphorbia clava* Jacq. | CJ 064, GRA. | * | * | * | | | | | * | * | | |
| 1 | *Euphorbia fimbriata* Scop. | CJ 118, GRA. | | | | * | | | | * | | | |
| 1 | *Euphorbia globosa* (Haw.) Sims | EC PEU. | * | | | | | | | * | | | |
| 1 | *Euphorbia inermis* Mill. var. *inermis* | CJ 246, GRA. | | | | * | | | | | | | |

| C. | SPECIES: | VOUCHER #: | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
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| 1 | *Euphorbia ledienii* Berger. | CJ 133, GRA. | | * | | | | | | | * | | |
| | *Euphorbia mauritanica* L. | LL 6345, KIM. | | * | * | * | * | * | | * | * | * | * |
| | *Euphorbia rhombifolia* Boiss. | EC PEU. | | * | | * | | | | | | | |
| | *Chamaesyce inaequilatera* (Sond.) Sojak | AH 1930, KIM. | | | | | * | | | | | | |
| | **ANACARDIACEAE** | | | | | | | | | | | | |
| | *Rhus crenata* Thunb. | CJ 250, GRA. | * | | * | | | | | | | | * |
| 2 | *Rhus incisa* L. f. var. *effusa* (Presl) R. Fernan | EC PEU. | | | | | | | | | | | |
| | *Rhus longispina* Eckl. & Zeyh. | BB 5766, KIM. | | * | * | * | * | | | * | * | * | * |
| | *Rhus lucida* L. | EC PEU. | * | * | * | * | | * | | | | | |
| | *Rhus pallens* Eckl. & Zeyh. | EC PEU. | * | | * | | | | * | | | | * |
| | *Rhus pterota* Presl | EC PEU. | * | | | | | | | | | | |
| | *Rhus refracta* Eckl. & Zeyh. | BB 5834, KIM. | | * | | | * | | | * | | * | |
| | *Rhus tomentosa* L. | JG s.n., KIM. | | | * | * | | * | | | | | * |
| | *Rhus undulata Jacq.* | AH 5951, KIM. | | | | * | | * | * | * | | * | |
| | **CELASTRACEAE** | | | | | | | | | | | | |
| 1 | *Maytenus capitata* (E. Mey. ex Sond.) Marais | AH 5952, KIM. | | * | | | * | | | * | * | | |
| | *Maytenus heterophylla* (Eckl. & Zeyh.) N.K.B. Robson | BB 5700, KIM. | * | * | * | * | * | * | * | * | | * | * |
| | *Maytenus polyacantha* (Sond.) Marais | AH 5986, KIM. | | * | | | * | * | | * | * | | |
| | *Maytenus undata* (Thunb.) Blakelock | BP 6634, KIM. | | * | * | * | * | | | | | | * |
| | *Putterlickia pyracantha* (L.) Szyszyl. | CJ 160, GRA. | * | * | * | * | * | | | | * | * | * |
| | *Pterocelastrus tricuspidatus* (Lam.) Sond. | TD 2444, GRA | * | * | * | * | * | * | * | | * | * | * |
| | *Cassine aethiopica* Thunb. | BP 6629, KIM. | * | * | * | * | | * | | | * | * | * |
| | *Cassine crocea* (Thunb.) Kuntze | CJ 251, GRA. | | * | * | | * | | | | | | * |
| | *Cassine tetragona* (L. f.) Loes. | BP 6631, KIM. | | | | | | * | | | * | * | * |
| | **SAPINDACEAE** | | | | | | | | | | | | |
| | *Pappea capensis* Eckl. & Zeyh. | MS, KIM. | * | * | * | * | * | * | | * | * | | * |
| | *Hippobromus pauciflorus* (L. f.) Radlk. | AH 5958, KIM. | * | * | * | * | * | * | * | | * | * | * |
| | **RHAMNACEAE** | | | | | | | | | | | | |
| | *Scutia myrtina* (Burm. f.) Kurz | EC PEU. | * | * | * | * | * | * | * | | * | * | * |
| | **VITACEAE** | | | | | | | | | | | | |
| | *Rhoicissus digitata* (L. f.) Gilg & Brandt | AH 5840, KIM. | * | * | * | * | * | * | | | * | * | * |
| | *Rhoicissus tridentata* (L. f.) Wild & Drum. | AH 5704, KIM. | * | * | * | * | * | | * | * | * | * | * |
| 2 | *Cyphostemma cirrhosum* (Thunb.) Descoings ex Wild & Drum. | TD 2352, GRA. | | | | | | | | | | | |

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| 2 | *Cyphostemma quinatum* (Dryand.) Descoings ex Wild & Drum. | AH 5715, GRA. | | | | | | | | | | | |
| | **TILIACEAE** | | | | | | | | | | | | |
| | *Grewia occidentalis* L. f. | BB 5694, KIM. | * | * | * | * | * | | * | * | * | * | * |
| | *Grewia robusta* Burch. | AH 5760, KIM. | | | | * | * | | | * | * | * | |
| | **MALVACEAE** | | | | | | | | | | | | |
| | *Abutilon sonneratianum* (Cav.) Sweet | AH 6677, KIM. | | * | * | * | * | | * | * | * | * | * |
| 2 | *Malva parviflora* L. | from 051 | | | | | | | | | | | |
| | *Sida ternata* L. f. | CJ 161, GRA. | | | | * | * | | | * | | | |
| | *Hibiscus pusillus* Thunb. | CJ 158, GRA. | | | | * | * | | | * | | | |
| | **STERCULIACEAE** | | | | | | | | | | | | |
| | *Hermannia althaeoides* Link | BB 6545, KIM. | | * | * | * | * | * | | | * | | * |
| | *Hermannia cuneifolia* Jacq. var. *cuneifolia* | AH 1895, KIM. | | | | | | | | * | | | |
| | *Hermannia flammea* Jacq. | LL 6317, KIM. | | | | * | | | | | * | | |
| | *Hermannia incana* Cav. | EA 3771, GRA. | | | | | | | | | | * | |
| 2 | *Hermannia multiflora* Jacq. | BB 5612, KIM. | | | | | | | | | | | |
| | *Hermannia pulverata* Andr. | TD 2438, GRA. | | | | | | | | * | | | |
| | FLACOURTIACEAE | | | | | | | | | | | | |
| 2 | *Homalium rufescens* Benth. | CJ 177, GRA. | | | | | | | | | | | |
| | *Dovyalis caffra* (Hook. f. & Harv.) Hook. f. | BB 5854, KIM. | | | * | | * | | | | | | |
| | **THYMELAEACEAE** | | | | | | | | | | | | |
| | *Passerina rubra* C.H. Wr. | BB 5656, KIM. | | | | | | | | | * | | |
| | **APIACEAE** | | | | | | | | | | | | |
| 2 | *Lichtensteinia interrupta* (Thunb.) Sond. | CJ 190, GRA. | | | | | | | | | | | |
| 2 | *Lichtensteinia kolbeana* H. Bol. | LL 7728, GRA. | | | | | | | | | | | |
| 2 | *Anginon* sp. | LL 7725, KIM. | | | | | | | | | | | |
| 2 | *Deverra burchellii* (DC.) Eckl. & Zeyh. | LL 6285, GRA. | | | | | | | | | | | |
| 2 | *Ammi majus* L. var. *glaucifolium* (L.) Godron | BB 5722, KIM. | | | | | | | | | | | |
| | *Peucedanum ferulaceum* (Thunb.) Eckl. & Zeyh. | CJ 186, GRA. | | | | | | * | | | | | |
| 1,2 | *Peucedanum zeyheri* Sond. | TD 2428, GRA. | | | | | | | | | | | |
| | **PLUMBAGINACEAE** | | | | | | | | | | | | |
| | *Plumbago auriculata* Lam. | BB 6554, KIM. | | * | * | * | * | | * | | | * | * |
| | **SAPOTACEAE** | | | | | | | | | | | | |
| | *Sideroxylon inerme* L. subsp. *inerme* | BB 5755, KIM. | * | * | * | * | * | | * | | * | * | * |

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| | **EBENACEAE** | | | | | | | | | | | | |
| | *Euclea schimperi* (A. DC.) Dandy var. *schimperi* | BP 603, KIM. | | * | * | * | | | * | | | | * |
| | *Euclea undulata* Thunb. var. *undulata* | AH 6673, KIM. | * | * | * | * | * | | * | * | * | | * |
| | *Euclea natalensis* A. DC. | CJ 252, GRA. | | | * | * | | * | | | | | * |
| | *Diospyros dichrophylla* (Gand.) De Winter | BB 5636, KIM. | * | * | * | * | * | * | * | | * | * | * |
| | *Diospyros scabrida* (Harv. ex Hiern) De Winter | CJ 249, GRA. | | * | * | * | * | * | | | | * | * |
| | *Diospyros villosa* (L.) De Winter var. *villosa* | BB 5858, KIM. | | | * | | | | | * | | | * |
| | **OLEACEAE** | | | | | | | | | | | | |
| | *Olea europaea* L. subsp. *africana* (Mill) P.S. Green | BB 5743, KIM. | * | | * | * | * | * | * | * | * | * | * |
| | *Olea exasperata* Jacq. | EC PEU. | * | | * | | | | | | * | | * |
| | *Jasminum angulare* Vahl | BB 5726, KIM. | | * | * | * | * | | | | * | * | * |
| | **SALVADORACEAE** | | | | | | | | | | | | |
| | *Azima tetracantha* Lam. | AH 5706, KIM. | * | * | * | * | * | * | * | | * | * | * |
| | **LOGANIACEAE** | | | | | | | | | | | | |
| | *Buddleja saligna* Willd. | BB 5699, KIM. | * | * | | * | * | * | | * | | | |
| | **APOCYNACEAE** | | | | | | | | | | | | |
| | *Acokanthera oppositifolia* (Lam.) Codd | JR s.n., KIM. | | * | * | * | * | * | | | | * | * |
| 2 | *Carissa haematocarpa* (Eckl.) A. DC. | CJ 005, GRA. | | * | | * | * | | | * | * | | |
| | *Carissa macrocarpa* (Eckl.) A. DC. | HB 822, KIM. | | | | | | | | | | | |
| 1 | *Pachypodium bispinosum* (L. f.) A. DC. | TD 2372, GRA. | | * | | * | * | * | | | * | | |
| | *Pachypodium succulentum* (L. f.) Sweet | TD 2375, GRA. | | * | | * | * | | | * | * | * | |
| | **ASCLEPIADACEAE** | | | | | | | | | | | | |
| | *Cynanchum gerrardii* (Harv.) Liede | TD 2429, GRA. | | * | | | | | | | * | | |
| | *Cynanchum obtusifolium* L. f. | EC PEU. | * | | | | | | | | | | |
| | *Sarcostemma viminale* (L.) R. Br. | AH 5960, KIM. | * | * | | * | * | * | | * | * | * | |
| | *Secamone filiformis* (L. f.) J.H. Ross | TD 2406, GRA. | | * | | * | | | * | | | | |
| 2 | *Brachystelma circinatum* E. Mey. | TD 2374, GRA. | | | | | | | | | | | |
| 2 | *Ceropegia africana* R. Br. | CJ 022, GRA. | | | | | | | | | | | |
| | *Ceropegia carnosa* E. Mey. | CJ 141, GRA. | | | | * | | | | | * | | |
| | *Ceropegia stapeliiformis* Haw. | Field obs. TD | | | | * | | | | | | | |
| 2 | *Duvalia caespitosa* (Mass.) Haw. | CJ 240, GRA. | | | | | | | | | | | |
| 2 | *Duvalia reclinata* (Mass.) Haw. | EA 3787, GRA. | | | | | | | | | | | |
| 1 | *Stapelia grandiflora* Mass. | CJ 237, GRA. | | * | | * | | | | | * | | |

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| 2 | *Orbea verrucosa* (Mass.) Leach. | CJ 239, GRA. | | | | | | | | | | | |
| 1,2 | *Huernia brevirostris* N.E. Br. | CJ 238, GRA. | | | | | | | | | | | |
| 2 | *Tylophora* sp. | AH 5872, KIM. | | | | | | | | | | | |
| | *Fockea edulis* (Thunb.) K. Schum. | TD 2371, GRA. | * | | | | | | | * | * | | |
| 2 | *Fockea gracilis* R.A. Dyer | TD 2381, GRA. | | | | | | | | | | | |
| | **CONVOLVULACEAE** | | | | | | | | | | | | |
| 2 | *Cuscuta campestris* Yunck. | TD 2386, GRA. | | | | | | | | | | | |
| | *Ipomoea ficifolia* Lindl. | Anon 446, KIM. | * | | | * | | | | | | | |
| 2 | *Ipomoea simplex* Thunb. | TD 2355, GRA. | | | | | | | | | | | |
| | **BORAGINACEAE** | | | | | | | | | | | | |
| | *Ehretia rigida* (Thunb.) Druce | PB 568, KIM. | * | * | * | * | * | | * | * | | * | |
| 2 | *Lappula squarrosa* (L.) Dumort. subsp. *heteracantha* (Ledeb.) Chater | BB 5657, KIM. | | | | | | | | | | | |
| | **VERBENACEAE** | | | | | | | | | | | | |
| | *Lantana rugosa* Thunb. | BB 5875, KIM. | | * | * | * | * | | * | * | * | * | |
| 2 | *Lippia javanica* (Burm. f.) Spreng. | TD 2391, GRA. | | | | | | | | | | | |
| | *Plexipus cuneifolius* (L. f.) Rafin. | CJ 172, GRA. | * | * | * | * | | | * | | * | * | |
| | **LAMIACEAE** | | | | | | | | | | | | |
| | *Leucas capensis* (Benth.) Engl. | TD 2364, GRA. | | | | * | | | | * | | | |
| | *Stachys aethiopica* L. | CJ 175, GRA. | | | * | * | | | | | * | | |
| 2 | *Salvia runcinata* L. f. | BB 5670, GRA. | | | | | | | | | | | |
| 1,2 | *Salvia scabra* L.f. | CJ 159, GRA. | | | | | | | | | | | |
| 1 | *Salvia triangularis* Thunb. | TD 2433, GRA. | * | | | * | | | | | | | |
| | *Plectranthus madagascariensis* (Pers.) Benth. | CJ field obs. | | * | * | * | | * | | * | | * | |
| | **SOLANACEAE** | | | | | | | | | | | | |
| | *Lycium cinereum* Thunb. (sens. lat.) | EA 3799, GRA. | | | * | | | | * | * | | | |
| | Lycium ferocissimum Miers | BB 5647, KIM. | | | | | | | | * | | | |
| | *Lycium schizocalyx* C.H. Wr. | CJ 051, GRA. | | | | | | | * | | | | |
| | *Solanum coccineum* Jacq. | LL 6291, KIM. | | | | * | | | * | | | | |
| | *Solanum guineense* L. | AH 5871, KIM. | | | * | | | | | | | | |
| | *Solanum tomentosum* L. | TD 2401, GRA. | | * | * | | * | | | | | * | |
| | **SCROPHULARIACEAE** | | | | | | | | | | | | |
| 2 | *Diascia cuneata* E. Mey. ex Benth. | CJ 156, GRA. | | | | | | | | | | | |
| | *Nemesia affinis* Benth. | BB 6571, KIM. | | | * | | | | | | | | |

| C. | SPECIES: | VOUCHER #: | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
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| 2 | *Nemesia cheiranthus* E. Mey. ex Benth. | BB 5741, GRA. | | | | | | | | | | | |
| | *Nemesia floribunda* Lehm. | LL 6302, KIM. | | | | | * | | | | | | |
| 2 | *Nemesia versicolor* E. Mey. ex Benth. | AH 5946, KIM. | | | | | | | | | | | |
| | *Sutera atropurpurea* (Benth.) Kuntze | CJ 135, GRA. | | | | * | | * | | | | | |
| | *Sutera campanulata* (Benth.) Kuntze | LL 6315, KIM. | * | | * | | * | | | | * | | * |
| 1 | *Sutera foliolosa* (Benth.) Hiern | AH 1891, KIM. | | | | | | * | | | | | |
| | *Sutera microphylla* (L. f.) Hiern | BB 5776, KIM. | * | | | | | | | | * | | |
| 2 | *Limosella grandiflora* Benth. | TD 2442, GRA. | | | | | | | | | | | |
| | **SELAGINACEAE** | | | | | | | | | | | | |
| | *Selago albida* Choisy | BB 5698, GRA. | | | | | | | | * | | | |
| 2 | *Selago decumbens* Thunb. | PB 559, KIM. | | | | | | | | | | | |
| 2 | *Walafrida cinerea* (L. f.) Rolfe | BB 5697, GRA. | | | | | | | | | | | |
| 1 | *Walafrida decipiens* (E. Mey.) Rolfe | Anon 441, KIM. | | * | | | | | | | | | |
| 2 | *Walafrida densiflora* (Rolfe) Rolfe | CJ 209, GRA. | | | | | | | | | | | |
| | *Walafrida geniculata* (L. f.) Rolfe | BB 5644, KIM. | | * | * | | * | * | | * | | * | * |
| 2 | *Walafrida paniculata* (Thunb.) Rolfe | AH 5953, KIM. | | | | | | | | | | | |
| | **BIGNONIACEAE** | | | | | | | | | | | | |
| | *Tecomaria capensis* (Thunb.) Spach subsp. *capensis* | BB 5696, KIM. | | * | * | * | * | * | | | | * | * |
| | *Rhigozum obovatum* Burch. | CJ 143, GRA. | | | | * | * | | | * | | | |
| | **GESNERIACEAE** | | | | | | | | | | | | |
| | *Streptocarpus meyeri* B.C. Burtt. | CJ 242, GRA. | | | | * | | | | * | | | |
| | **ACANTHACEAE** | | | | | | | | | | | | |
| | *Thunbergia capensis* Retz. | CJ 253, GRA. | | * | | | | | | | | * | * |
| | *Chaetacanthus setiger* (Pers.) Lindl. | AH 5712, GRA. | | | | * | | * | | | * | * | |
| | *Barleria irritans* Nees | CJ 203, GRA. | | | | | | | | * | * | | |
| | *Barleria obtusa* Nees | CJ 169, GRA. | | * | * | * | * | | | * | * | | * |
| | *Barleria pungens* L. f. | AH 5705, KIM. | | * | | | * | | | | | | |
| | *Blepharis capensis* (L. f.) Pers. var. *capensis* | TD 2353, GRA. | | | | * | * | | | * | * | | |
| | *Blepharis integrifolia* (L. f.) E. Mey. ex Schinz | LL 6657, KIM. | | | | | | | | | | * | |
| | *Salpinctium stenosiphon* (C.B. Cl.) T.J. Edwards | CJ 178, GRA. | | | | | | | | | | * | |
| 1 | *Peristrophe cernua* Nees | BB 5836, KIM. | | | * | | * | * | | | * | | |
| | *Hypoestes aristata* (Vahl.) Soland. ex Roem. & Schult. var. *aristata* | AH 1934, KIM. | | | | * | * | | * | | | * | |
| 2 | *Isoglossa ciliata* (Nees) Lindau | TD 2445, GRA. | | | | | | | | | | | |

| C. | SPECIES: | VOUCHER #: | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Justicia capensis* Thunb. | Anon 442, KIM. | | * | * | | | | | | | | * |
| | *Justicia cuneata* Vahl | PB 553, KIM. | | | | | | | | * | * | | |
| 2 | *Justicia orchioides* L. f. | TD 2354, GRA. | | | | | | | | | | | |
| | **PLANTAGINACEAE** | | | | | | | | | | | | |
| | *Plantago lanceolata* L. | BB 5643, KIM. | | | | | | | * | | | * | |
| | **RUBIACEAE** | | | | | | | | | | | | |
| | *Canthium spinosum* (Klotzsch) Kuntze | CJ 254, GRA. | * | | * | | | * | | | | * | |
| | *Anthospermum aethiopicum* L. | EC PEU | | | | * | | * | | | | * | * |
| | *Anthospermum galioides* Reichb | TD 2436, GRA. | | | | * | | | | | | | |
| 2 | *Nenax microphylla* (Sond.) Satter | EA 3834, GRA. | | | | | | | | | | | |
| | **DIPSACACEAE** | | | | | | | | | | | | |
| | *Scabiosa columbaria* L. | BB 5838, KIM. | * | | | * | | * | | * | | * | |
| | **CUCURBITACEAE** | | | | | | | | | | | | |
| | *Kedrostis africana* (L.) Cogn. | CJ 126, GRA. | | | * | | * | | | * | | * | * |
| 2 | *Kedrostis foetidissima* (Jacq.) Cogn. | CJ 081, GRA. | | | | | | | | | | | |
| | *Kedrostis nana* (Lam.) Cogn. var. *schlechteri* (Cogn.) A. Meeuse | BP 6004, KIM. | | * | * | * | | * | | | * | * | * |
| | *Cucumis* sp. | AH 1870, KIM. | | | | | | | | | | | |
| | *Coccinia quinqueloba* (Thunb.) Cogn. | AH 1945, KIM. | | | | * | | | | | | | |
| | **CAMPANULACEAE** | | | | | | | | | | | | |
| | *Lightfootia albens* Spreng. ex. A. DC. | LL 7731, KIM. | | | | | * | | | * | | | |
| | *Lightfootia divaricata* Buek var. *divaricata* | AH 1876, KIM. | | * | | | | * | | | | | |
| 2 | *Lightfootia nodosa* Buek | LL 7738, KIM. | | | | | | | | | | | |
| | **LOBELIACEAE** | | | | | | | | | | | | |
| 1,2 | *Cyphia heterophylla* Presl ex. Eckl. & Zeyh. | CJ 021, GRA. | | | | | | | | | | | |
| | *Cyphia linarioides* Presl. | CJ 093, GRA. | | * | | | | | | | | | |
| | *Cyphia sylvatica* Eckl. | CJ 095, GRA. | | | | * | * | | | * | | | |
| 2 | *Cyphia triphylla* Phill. | TD 2430, GRA. | | | | | | | | | | | |
| | *Cyphia undulata* Eckl. | CJ 210, GRA. | | * | | | | | | | * | | |
| 2 | *Cyphia volubilis* (Burm. f.) Willd. var. *volubilis* | AH 1881, GRA. | | | | | | | | | | | |
| | **ASTERACEAE** | | | | | | | | | | | | |
| | *Vernonia capensis* (Houtt.) Druce | TD 2393, GRA. | | * | | * | * | | | | | | |
| | *Pteronia incana* (Burm.) DC. | BB 5613, KIM. | | * | | * | * | * | | | * | | |
| | *Pteronia paniculata* Thunb. | BB 5618, KIM. | | | | | | | | | * | | |

| C. | SPECIES: | VOUCHER #: | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Amellus strigosus* (Thunb.) Less. | BB 6582, KIM. | | | | | | | | * | | | |
| | *Aster* sp. | from 051 | | | | | | | | | | | |
| | *Felicia echinata* (Thunb.) Nees | BB 6598, GRA. | * | | | | | | | | | | |
| | *Felicia fascicularis* DC. | BB 6599, KIM. | | * | | | | | | | | | |
| | *Felicia filifolia* (Vent.) Burtt Davy | BB 6600, KIM. | | * | | * | * | * | | * | * | * | |
| | *Felicia muricata* (Thunb.) Nees | CJ 020, GRA. | | | | * | * | | | * | | * | |
| | *Microglossa mespilifolia* (Less.) B.L. Robinson | AH 1905, KIM. | | * | | * | | | | | | | |
| | *Chrysocoma ciliata* L. | AH 1917, KIM. | | | | * | * | | * | * | * | * | |
| | *Brachylaena ilicifolia* (Lam.) Phill. & Schweick. | TD 2398, GRA. | | * | * | | * | * | | | * | * | * |
| 2 | *Gnaphalium gnaphalodes* (DC.) Hilliard & Burtt | AH 1982, KIM. | | | | | | | | | | | |
| | *Troglophyton capillaceum* (Thunb.) Hilliard & Burtt subsp. capillaceum | LL 6336, KIM. | | | | | | | | * | | | |
| | *Helichrysum anomalum* Less. | EC PEU. | * | | * | * | | | | | | * | * |
| 2 | *Helichrysum arenicola* M.D. Henderson | LL 7730, KIM. | | | | | | | | | | | |
| 2 | *Helichrysum dregeanum* Sond. & Harv. | PB 561, KIM. | | | | | | | | | | | |
| 2 | *Helichrysum pentzioides* Less. | BB 5622, KIM. | | | | | | | | | | | |
| | *Helichrysum rosum* (Berg.) Less. var. *rosum* | LL 7721, KIM. | | * | | | * | | | * | * | * | |
| 2 | *Helichrysum rugulosum* Less. | LL 6305, KIM. | | | | | | | | | | | |
| | *Disparago ericoides* (Berg.) Gaertn. | CJ 251, GRA. | | * | | * | | * | | | * | * | |
| | *Metalasia muricata* (L.) D. Don | PB 567, KIM. | * | * | | | | * | | | | | |
| | *Pegolettia baccaridifolia* Less. | TD 2427, GRA. | | | | | | | | * | | | |
| | *Pegolettia retrofracta* (Thunb.) Kies | EA 3868, GRA. | | | | | | | | * | | | |
| | *Verbesina encelioides* (Cav.) Benth & Hook. | BB 5779, KIM. | | | | * | * | | | | | | |
| | *Eriocephalus africanus* L. | CJ 025, GRA. | | | | * | * | * | * | * | * | * | |
| | *Cotula anthemoides* L. | LL 6316, KIM. | | * | | | | | | * | | | |
| | *Cotula heterocarpa* DC. | LL 6295, KIM. | | | | | | * | | | | * | |
| 2 | *Pentzia calcarea* Kies | AH 1919, KIM. | | | | | | | | | | | |
| 2 | *Pentzia globosa* Less. | BB 6538, KIM. | | | | | | | | | | | |
| | *Pentzia incana* (Thunb.) Kuntze | AH 1885, KIM. | | | | * | * | | | * | | | |
| 1,2 | *Hertia kraussi* (Sch. Bip.) Fourc. | EA 5261, GRA. | | | | | | | | | | | |
| | *Cineraria lobata* L'Hérit. | LL 7729, KIM. | | * | | * | * | * | | | | | |
| 1 | *Senecio angulatus* L. f. | BB 5833, KIM. | | | * | * | * | | | | * | | * |
| | *Senecio articulatus* (L.) Sch. Bip. | CJ 252, GRA. | | | | | | | | | | | |
| 2 | *Senecio chrysocoma* Meerb. | LL 7388, KIM. | | | | | | | | | | | |

| C. | SPECIES: | VOUCHER #: | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
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| | *Senecio deltoideus* Less. | AH 5873, KIM. | | | | * | * | | | | | | |
| | *Senecio inaequidens* DC. | CJ 228, GRA. | | * | | | * | | | | | * | |
| 1 | *Senecio linifolius* L. | BB 6531, KIM. | | | | * | * | | | | * | * | |
| | *Senecio macroglossus* DC. | BB 5640, KIM. | | * | * | | | | | | | | |
| | *Senecio pterophorus* DC. | LL 7724, KIM. | | | | | | | | | * | * | |
| 1 | *Senecio pyramidatus* DC. | CJ 006, GRA. | | * | | * | | * | | | * | | |
| | *Senecio radicans* (L. f.) Sch. Bip. | BB 6523, KIM. | | * | * | | * | | | * | * | * | * |
| 2 | *Senecio ruwenzoriensis* S. Moore | CJ 223, GRA. | | | | | | | | | | | |
| | *Euryops algoensis* DC. | CJ 227, GRA. | | * | | | | * | | | | | |
| | *Euryops anthemoides* B. Nord. subsp. *anthemoides* | AH 1879, KIM. | | | | | | | | * | | | |
| | *Euryops spathaceus* DC. | AH 6679, KIM. | | | | * | * | | | * | * | | |
| | *Othonna carnosa* Less. | CJ 029, GRA. | | | * | * | | | | | * | | |
| 2 | *Othonna eriocarpa* (DC.) Sch. Bip. | TD 2362, GRA. | | | | | | | | | | | |
| 2 | *Othonna obtusiloba* Harv. | TD 2361, GRA. | | | | | | | | | | | |
| | *Dimorphotheca cuneata* (Thunb. ) Less. | EA ANP2, GRA. | | | | | | | | | * | | |
| | *Osteospermum calendulaceum* L. f. | AH 6683, KIM. | | | | | | | | * | | | |
| | *Osteospermum imbricatum* L. subsp. *imbricatum* | BB 5666, KIM. | | * | | * | | * | | | | | |
| | *Ursinia nana* DC. subsp. *nana* | LL 6304, KIM. | | * | | | | | | * | | | |
| 2 | *Arctotis acaulis* L. | LL 7727, KIM. | | | | | | | | | | | |
| 2 | *Arctotis arctotoides* (L. f.) O. Hoffm. | BB 6593, KIM. | | | | | | | | | | | |
| 2 | *Arctotis discolor* (Less.) Beauv. | CJ 018, GRA. | | | | | | | | | | | |
| | *Arctotheca calendula* (L.) Levyns | LL 6314, KIM. | | | | * | | | | | | | |
| | *Gazania krebsiana* Less. subsp. *krebsiana* | LL 6298, KIM. | * | | * | | * | | | | * | * | |
| | *Gazania linearis* (Thunb.) Druce | CJ 017, GRA. | | * | | | | | | | * | | |
| | *Berkheya angustifolium* (Houtt.) Merr. | EC PEU. | | | | | * | | | | | | |
| | *Cuspidia cernua* (L. f.) B.L. Burtt subsp. *cernua* | AH 6601, KIM. | | | | | | | | * | * | | |
| 2 | *Platycarpha glomerata* (Thunb.) Less. | LL 7703, KIM. | | | | | | | | | | | |
| 2 | *Mantisalca salmantica* (L.) Briq. & Cavillier | BB 5678, KIM. | | | | | | | | | | | |
| 2 | *Cichorium intybus* L. | BB 5740, KIM. | | | | | | | | | | | |
| | *Sonchus oleraceus* L. | BB 5080, KIM. | | | | | * | | | | | | |
| 2 | *Lactuca capensis* Thunb. | LL 7719, KIM. | | | | | | | | | | | |
| | **POACEAE** | | | | | | | | | | | | |
| | *Cymbopogon plurinodis* (Stapf) Stapf ex Burtt Davy | JR s.n., KIM. | | | | | * | * | * | * | | | |

| C. | SPECIES: | VOUCHER #: | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Themeda triandra* Forssk. | LL 7715, KIM. | * | | * | * | * | | * | * | * | * | |
| | *Digitaria eriantha* Steud. | CJ 200, GRA. | * | | * | * | | | * | | * | * | |
| | *Panicum coloratum* L. var. *coloratum* | AH 6696, KIM. | | | | | | * | | | | | |
| | *Panicum deustum* Thunb. | BB 6562, KIM. | * | | * | * | | | | | * | * | |
| | *Panicum maximum* Jacq. | BB 5661, KIM. | * | | * | * | | * | * | * | * | * | |
| | *Panicum stapfianum* Fourc. | CJ 183, GRA. | | | * | | | | | | | | |
| | *Setaria sphacelata* (Schumach.) Moss var. *sphacelata* | CJ 201, GRA. | | | * | * | | | * | | * | * | |
| | *Cenchrus ciliaris* L. | AH s.n., KIM. | | | * | | | * | * | | | | |
| | *Ehrharta calycina* J.E. Sm. | LL 6681, KIM. | | | * | | * | | * | * | * | * | |
| 2 | *Ehrharta erecta* Lam. var. *erecta* | BB 6540, KIM. | | | | | | | | | | | |
| 2 | *Phalaris minor* Retz. | BB 6539, KIM. | | | | | | | | | | | |
| 2 | *Helictotrichon capense* Schweick. | BB 5683, GRA. | | | | | | | | | | | |
| | *Merxmuellera disticha* (Nees) Conert | CJ 199, GRA. | | | * | * | | | * | | | | |
| | *Karroochloa curva* (Nees) Conert & Tuerpe | LL 7718A, KIM. | | | | | | | | | * | | |
| 2 | *Pentaschistis airoides* (Nees) Stapf subsp. *jugorum* (Stapf) Linder | LL 6647, KIM. | | | | | | | | | | | |
| | *Pentaschistis angustifolia* (Nees) Stapf | LL 7717, KIM. | * | | | | | | | | | | |
| | *Pentaschistis curvifolia* (Schrad.) Stapf | WH s.n., GRA. | | | * | | | | | | | | |
| | *Pentaschistis pallida* (Thunb.) Linder | LL 7723, KIM. | * | * | | | | | | | | | |
| 2 | *Stipagrostis dregeana* Nees. | EC PEU. | | | | | | | | | | | |
| 2 | *Stipagrostis zeyheri* (Nees.) De Winter subsp. *zeyheri* | EC PEU. | | | | | | | | | | | |
| | *Aristida diffusa* subsp. *diffusa* Trin. | CJ 197, GRA. | | | * | | * | | | | | | |
| | *Stipa dregeana* Steud. var. *elongata* (Nees) Stapf | LL 6303, KIM. | | | * | * | | | * | | | | |
| | *Tragus berteronianus* Schult. | CJ 196, GRA. | | | * | * | | | * | | * | | |
| | *Tragus racemosus* (L.) All. | AH 1906, KIM. | | | | * | | | * | | | | |
| | *Sporobolus fimbriatus* (Trin.) Nees | AH 5767, KIM. | | * | * | * | | | * | | | | |
| | *Sporobolus ioclados* (Trin.) Nees. | CJ 180, GRA. | | | | * | | | | | | | |
| | *Sporobolus nitens* Stent | LL 7685, KIM. | | | | * | | | * | | | | |
| | *Eragrostis capensis* (Thunb.) Trin. | CJ 195, GRA. | * | * | * | | * | * | | | * | | |
| | *Eragrostis curvula* (Schrad.) Nees | CJ 202, GRA. | * | * | * | * | * | * | * | | * | * | |
| | *Eragrostis obtusa* Munro ex Fical. & Hiern | CJ 184, GRA. | * | | * | * | | * | * | | * | | |
| 2 | *Microchloa caffra* Nees | from 051 | | | | | | | | | | | |
| | *Cynodon dactylon* (L.) Pers. | AH 329, KIM. | * | | * | * | | | * | * | * | * | |
| | *Cynodon incompletus* Nees | AH 6668, KIM. | | | | * | | * | * | | | | |

| C. | SPECIES: | VOUCHER #: | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
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| | *Eustachys paspaloides* (Vahl) Lanza & Mattei | CJ 194, GRA. | | | * | * | | | | | | | |
| 2 | *Dactyloctenium aegyptium* (L.) Willd. | EC PEU. | | | | | | | | | | | |
| 2 | *Diplachne fusca* (L.) Beauv. ex Roem. & Schult. | EA 3757, GRA. | | | | | | | | | | | |
| | *Triraphis andropogonoides* (Steud.) Phill. | Anon s.n., KIM. | | | * | | | | | | | | |
| 2 | *Enneapogon cenchroides* (Roem. & Schult.) C.E. Hubb. | CJ 185, GRA. | | | | | | | | | | | |
| | *Enneapogon scoparius* Stapf | CJ 179, GRA. | | | * | * | | | * | | | | |
| | *Elytrophorus* sp. | KIM 9903700. | | | | | | | | | | | |
| | *Melica racemosa* Thunb. | CJ 181, GRA. | * | | | * | * | | * | | | | |
| | *Tribolium uniolae* (L. f.) Renvoize | CJ 198, GRA. | | | * | | | | | | | | |
| | *Schismus barbatus* (Loefl. ex L.) Thell. | BB 6544, KIM. | | | | * | | | | | | | |
| | *Poa* sp. | KIM 9904070. | | | | | | | | | | | |
| | *Bromus catharticus* Vahl | BB 6536, KIM. | * | | | | | | | | | | |
| | *Hordeum murinum* L. | BB 6530, KIM. | * | | | | | | | | | | |

**Collectors:**
EA – E.E.A. Archibald
PB – P.J. Barnard
HB – H. Bezuidenhout
BB – B.P. Botha
EC – E. Campbell
TD – T. Dold
JG. – J.H Grobler
AH – A.J. Hall-Martin
WH – W. Howe
CJ – C. Johnson
LL – L. Liebenberg
FL – F.R. Long
BP – B.L. Pentzhorn
PP – P.B. Phillipson
JR – J.A. Russell
MS – M. Stalmans

# Appendix 5.2: List of Category 1 (rare and endemic) plant species in Addo Elephant National Park:

indicates if species was encountered during sampling.
B&G = Bond and Goldblatt (1984). H&C = Hoffman and Cowling, 1991. RDL = Red Data List (Hilton-Taylor, 1996). ECE = Eastern Cape endemic.
Towns abbreviated as follows: P.E. = Port Elizabeth; Hum = Humnasdorp; Udale = Uniondale; Uit = Uitenhage; Oudsh = Oudshoorn; Knys = Knysna; Sw-Berg = Swartberg; Ladism. = Ladismith

| | Species | Status | Source |
|---|---|---|---|
| * | *Bulbine frutescens* (L.) Willd. | ECE | B&G |
| * | *Bulbine frutescens* (L.) Willd. var. ined. Baijnath | Rare, endemic | pers comm. S. Baijnath. |
| * | *Bulbine inae* Baijnath ined. | Rare, Endemic | pers. comm. T. Dold |
| * | *Eriospermum bifidum* R.A. Dyer | ECE (P.E.) | B&G, H&C |
| * | *Aloe africana* Mill. | ECE (Hum - P.E.) | B&G, H&C |
| | *Aloe tenuior* Haw. | ECE | B&G |
| * | *Albuca nana* Schonl. | Rare | Known only from type |
| * | *Albuca schonlandii* Bak. | Rare | pers. comm. T. Dold. |
| * | *Ornithogalum monophyllum* Bak. | Rare | one specimen, Transvaal |
| | *Neopatersonia uitenhagensis* Schonl. | ENDEMIC | RDL |
| * | *Lachenalia bowkeri* Bak. | ECE (P.E.) | B&G |
| * | *Protasparagus crassicladus* (Jessop) Oberm. | ECE | B&G, H&C |
| | *Protasparagus subulatus* (Thunb.) Oberm. | ECE (Hum - P.E.) | B&G |
| * | *Apodolirion* sp. ined. | Rare, Endemic | new species |
| | *Brunsvigia gregaria* R.A. Dyer | ECE (Udale -P.E.) | B&G, H&C |
| | *Cyrtanthus helictus* | RARE and ENDEMIC | RDL |
| * | *Cyrtanthus loddigesianus* (Herb.) R.A. Dyer | ECE (Hum/ P.E.) | B&G |
| * | *Spiloxene trifurcillata* (Nel) Fourc. | ECE (Hum - P.E.) | B&G |
| * | *Dietes bicolor* (Steud.) Sweet ex Klatt | RARE, ENDEMIC | RDL |
| * | *Tritonia dubia* Eckl. ex Klatt | ECE (Hum - P.E.) | B&G |
| | *Gladiolus permeabilis* Delaroche subsp. *edulis* (Burch. ex Ker) Oberm. | ECE (George - P.E.) | B&G |
| * | *Freesia corymbosa* (Burm. f.) N.E. Br. | ENDEMIC | RDL |
| * | *Holothrix schlecteriana* Schultr. Ex. Kraenzl. | Very localised in park | |
| * | *Acrolophia capensis* (Berg.) Fourc. | NT, ENDEMIC | RDL |

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| * | *Eulophia hereroensis* Schltr. | widespread but rare | pers comm. A. Hall |
| | *Viscum crassulae* Eckl. & Zeyh. | Indicator species. | Midgley and Joubert, 1991 |
| * | *Viscum obscurum* Thunb. | Indicator species. | Midgley and Joubert, 1991 |
| * | *Viscum rotundifolium* | Indicator species. | Midgley and Joubert, 1991 |
| * | *Thesium scandens* Sond. | ECE (Uit) | B&G |
| | *Thesium triflorum* Thunb. | ECE (Hum - P.E.) | B&G |
| * | *Bergeranthus longisepalus* L. Bol. | ECE | B&G |
| * | *Delosperma ecklonis* (Salm-Dyck) Schwant. var *ecklonis* | ECE (Hum - Uit.) | B&G |
| | *Delosperma c.f. hollandii* L. Bol. | ECE (Uit, P.E. ) | B&G |
| * | *Delosperma pruinosum* (Thunb.) J. Ingram | ECE (Hum - Uit) | B&G |
| | *Drosanthemum fourcadei* (L. Bol.) Schwant. | ECE (U-dale - Hum) | B&G |
| * | *Faucaria felina* (Weston) Schwant. & Jacobsen | ECE (Uit) | B&G |
| * | *Glottiphyllum longum* (Haw.) N.E. Br. var. *longum* | ECE (Uit - P.E.) | B&G |
| * | *Lampranthus productus* (Haw.) N.E.Br. var. *productus* | ECE (Uit - P.E.) | B&G |
| * | *Mestoklema albanicum* N.E. Br.ex. Glen | ENDEMIC, K | RDL. |
| * | *Platythyra haeckeliana* (Berger) N.E. Br. | ECE (Uit - Hum) | B&G |
| | *Sphalmanthus primulinus* (L. Bol.) L. Bol. | ECE (Hum - P.E.) | B&G |
| * | *Trichodiadema bulbosum* (Haw.) Schwant. | ECE (P.E.) | B&G |
| * | *Cotyledon campanulata* Marloth | ECE (Oudsh - P.E.) | B&G, H&C |
| * | *Cotyledon velutina* Hook. f. | ECE (Knys - P.E.) | B&G |
| * | *Crassula mesembryanthoides* (Haw.) Dietr. subsp. *mesembryanthoides* | ECE (U-dale - P.E.) | B&G, H&C |
| * | *Adromischus cristatus* (Haw.) Lem. var. *clavifolius* (Haw) Tolken | ECE (Hum) | B&G |
| * | *Lebeckia psiloloba* Walp. | ECE (Uit) | B&G |
| | *Pelargonium acetosum* (L.) L'Hérit. | ECE (Uit) | B&G |
| * | *Pelargonium dichondrifolium* DC. | ECE (Hum - P.E.) | B&G |
| * | *Pelargonium ochloleucum* Harv. | widespread but rare | pers comm. B. Marais |
| * | *Pelargonium radulifolium* (Eckl. & Zeyh.) Steud. | ECE (George - Uit) | B&G |
| * | *Zygophyllum uitenhagense* Sond. | ECE (Uit - P.E.) | B&G, H&C |
| * | *Polygala asbestina* Burch. | ECE (Oudsh - P.E.) | B&G |
| * | *Polygala ericaefolia* DC. | ECE (George - P.E.) | B&G |
| * | *Polygala microlopha* DC. var. *microlopha* | ECE (Sw-berg - Uit) | B&G |
| * | *Jatropha capensis* (L. f.) Sond. | ECE (Hum - P.E.) | B&G |
| * | *Euphorbia clava* Jacq. | ECE (Uit - P.E.) | B&G |
| * | *Euphorbia fimbriata* Scop. | ECE (Uit) | B&G |

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| * | *Euphorbia globosa* (Haw.) Sims | ECE (Uit - P.E.),<br>RARE | B&G,<br>RDL |
| * | *Euphorbia inermis* Mill. var. *inermis* | Endemic | pers. comm. G. Marx. |
| * | *Euphorbia ledienii* Berger. | ECE (Hum - P.E.),<br>RARE | B&G,<br>RDL |
| | *Maytenus capitata* (E. Mey. Ex Sond.) Marais | ECE (Uit) | B&G |
| * | *Peucedanum zeyheri* Sond. | ECE (Uit) | B&G, H&C |
| * | *Pachypodium bispinosum* (L. f.) A. DC. | ECE (Ladism - Uit) | B&G |
| * | *Stapelia grandiflora* Mass. | ECE (Uit) | B&G |
| * | *Huernia brevirostris* N.E. Br. | ECE (Hum - Uit ) | B&G |
| | *Salvia scabra* L.f. | ECE (Hum - Uit) | B&G |
| * | *Salvia triangularis* Thunb. | ECE (Hum - Uit) | B&G |
| | *Sutera foliolosa* (Benth.) Hiern | ECE (Knys - Uit) | B&G |
| | *Walafrida decipiens* (E. Mey.) Rolfe | ECE (Uit) | B&G |
| | *Peristrophe cernua* Nees | ECE (Hum - Uit) | B&G |
| * | *Cyphia heterophylla* Presl ex. Eckl. & Zeyh. | ECE (George - Hum) | B&G |
| | *Hertia krausii* (Sch. Bip.) Fourc. | ECE (U-dale - P.E.) | B&G |
| | *Senecio angulatus* L. f. | ECE (Uit) | B&G |
| * | *Senecio linifolius* L. | ECE (Hum - Uit) | B&G, H&C |
| * | *Senecio pyramidatus* DC. | ECE (Hum - P.E.) | B&G, H&C |