FLORA OF THE CAPE PENINSULA: ENDEMISM, THREATENED PLANTS AND CONSERVATION IN PERSPECTIVE

by

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PREFACE

Chapters 4 and 5 are similar to two papers recently accepted for publication in a special edition of the journal *Biodiversity and Conservation*, dealing with diverse aspects concerning the biodiversity of the Cape Peninsula. Both chapters were co-authored by fellow scientists whose contributions I would like to acknowledge:

Chapter 4 which deals with various aspects of endemic and threatened taxa was co-authored by Professors R.M. Cowling and H.P. Linder. Professor Cowling, as editor of the special issue, gave invaluable comments and made substantial changes to the structure of the manuscript. Furthermore his assistance with statistical procedures and advice on ecologically related issues is thereby acknowledged. Professor Linder as supervisor of this thesis gave invaluable guidance and advice throughout all phases of the paper.

Chapter 5 deals with conservation aspects of the biodiversity of the Peninsula. Dr A.T. Lombard dealt with the Geographic Information System (GIS) analyses and the production of the maps in this chapter. Her meticulous approach and astute interpretation and analysis of results was also essential for the completion of this paper. Dr M.D. Picker provided the distributional data concerning the endemic faunal species incorporated in the analysis.

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I am indebted to a number of academic staff at UCT without whose knowledge and assistance this study would not have been possible:-
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Thanks are extended to a number of institutions and individuals for supplying data required in this study:-
The CSIR's Division of Forest Science and Technology (Forestek) supplied many of the spatial databases used in Chapter 5. They also processed data and provided these in a user-friendly format. In this respect Dr. B. van Wilgen and David McKelly are particularly acknowledged;
The National Botanical Institute provided a PRECIS list of Peninsula specimens housed in the National Herbarium;
Dr. M.D. Picker supplied the distributional data for the endemic animal species;
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Finally I thank my late father and my mother, to whom I dedicate this thesis, for instilling an appreciation for, and a nurturing spirit towards the environment.

ABSTRACT

An updated and nomenclaturally accurate species list of the flora of the Cape Peninsula was established. The distribution of each of these species was then databased from c. 42 000 herbarium sheets housed in the three main herbaria in South Africa. The composition of the flora, taxonomic and biological aspects of endemic and threatened taxa and the conservation status of the flora and endemic fauna of the Cape Peninsula were then investigated.

A large nomenclatural and taxonomic change was detected with 25% of species having undergone name changes since the last taxonomic survey in 1950. There are more families and genera than previously recorded as a result of many taxonomic revisions. Monocotyledons, though only representing 18% of families, are well represented at the generic (25%) and specific (29.4%) level with both petaloid and non-petaloid monocotyledons being important. Pteridophytes in contrast represent 10.9 % of families and only 3% of species.

Of the 2285 species in the flora 90 are endemics and 141 are threatened. The Bykov's level of endemism at 6.1 for the Peninsula was high in global terms. Endemic and threatened taxa were found not to be a random assemblage taxonomically, with Ericaceae and Proteaceae being over-represented in terms of endemics. The aforementioned families plus Restionaceae and Orchidaceae were over-represented with respect to threatened taxa. A logistic regression analysis on the biological traits of endemic taxa showed the most likely biological profile of a Peninsula endemic to be a low, non-sprouting shrub with short-distance dispersal mechanisms. The profile of threatened taxa was found to be similar to endemic taxa. Many of these biological characteristics make these taxa vulnerable to extinction and therefore have certain management implications concerning their sustained existence. Furthermore, Peninsula endemics and threatened plants were found to be significantly over-represented in mid- to high altitude, mesic to wet habitats. However, urbanization has reduced certain lowland vegetation types thus causing over-representation of these taxa in these areas. These habitats require urgent protection.

An analysis using a Geographic Information System (GIS) showed the present reserve system inadequate in terms of protecting all plant and endemic faunal species on the Peninsula. The inclusion of all publicly owned land into the reserve system improved the conservation status dramatically, with only 13 species remaining unconserved. A third scenario is assessed whereby it is assumed that no public land is available for inclusion into a reserve system. An iterative reserve selection algorithm was then applied to allocate areas outside existing reserves to ensure each species is protected at least once. A total of 51 cells were required. All cells but for one lay in close proximity to existing reserves and could be incorporated at relatively little expense. Finally, based on a minimum cost consideration, it was suggested that all publicly owned land become incorporated into a reserve system and private reserves be created to protect the few unprotected species. It was also stressed that the current management system was inadequate and a new, single, scientifically based management plan needs to be implemented.

CONTENTS

CHAPTER 1

INTRODUCTION

1.1 Background to the Peninsula

Botanically, the Cape Peninsula must undoubtedly be one of the most fascinating places in southern Africa. The staggering diversity of the natural areas is nothing less than overwhelming. This richness of the flora has captured much attention and has been the focus of botanical exploration and study since the area was first settled by the Dutch in the seventeenth century. Indeed, some of the first Cape plants described were proteaceous species from Table Mountain (Rourke, 1980).

In identifying those areas in the world which have high species richness, high levels of endemism and which are experiencing rapid transformation due to anthropogenic activity, Myers (1988, 1990), singles out the Cape Floristic Region (Goldblatt, 1978) as being the most important "hot-spot" globally. The Cape Peninsula, at the south-western most extremity of this Region, is highlighted as an area of extreme species richness with high levels of endemism and large numbers of threatened taxa by botanical works published in the past (Bolus and Wolley-Dod, 1903; Levyns, 1923; Adamson and Salter, 1950; Roux, 1979; Hall and Ashton, 1983). The Peninsula, in Myer's terminology then, is a "hot-spot" within a "hot-spot".

The north-eastern section of the Peninsula is characterized by a rapidly expanding urban area. There are smaller developments within its boundaries displaying a similar trend, and the population of the Greater Cape Town metropolitan area is estimated to reach 6.2 million by 2020 (Anon, 1986). The natural environment is increasingly placed under threat as demands grow for further urbanization and the expansion of recreational facilities. The spread of invasive alien plants is a further major threat to the area, which, if it remains unchecked, has the potential of causing a serious reduction of floral biodiversity (Richardson *et al.*, in press). There is an urgent need for carefully constructed management plans which will ensure the maintenance of the rich biodiversity of the area, in conjunction with the needs of the people.

1.2 Aim

Despite the botanical work done on the Peninsula to date, the scientific information required for formulating management plans has hitherto been lacking. A recent move towards acquiring World Heritage Status for the Peninsula, based on its unique physiographical and botanical attributes, has been instrumental in bringing about a concerted collaborative effort to provide the scientific knowledge required to support such a motivation. Pivotal to the success of this motivation lies the quality of the data on which management will be based. The aim of this study was to provide the basic data required for scientific analysis (an accurate species list and the distributional data of each species), and to analyze aspects of the data essential to the formulation of sound management proposals.

1.3 Methods and materials

Each chapter in the thesis is very specific with respect to the questions being addressed and the analyses being done. The methods and materials used in each chapter are therefore mostly exclusive and these are discussed at the beginning of the each individual chapter. However, where the methods and materials are relevant to two or more chapters, these are dealt with in Chapter 2.

1.4 Flora

Primary to any botanical research dealing with aspects of biodiversity, is an accurate knowledge of the flora of the area being researched. Valuable work in this regard has been done in the past with Levyns's (1923) key to the genera of the Peninsula and Adamson and Salter's (1950) floral account being of particular importance. However, a result of taxonomic revisions is that 25% of species names have changed since publication of Adamson and Salter's Flora (1950). It is therefore essential that these changes be reflected. In Chapter 3 the flora is analyzed at both a higher taxonomic level (e.g. numbers of monocotyledons and dicotyledons) and at the family level where numbers of genera and species is reflected. This allowed comparisons to be made with floras of other areas within the Cape Floristic Region. The Peninsula is also briefly discussed in terms of its position with respect to phytochoria in southern Africa and certain aspects of phytogeography are addressed. The topic addressed in Chapter 3 is therefore not new, and consequently the chapter is brief, but it serves the need for presenting updated data in hard copy format.

1.5 Profile modelling of endemic taxa and their comparison to threatened taxa

When addressing the issue of biodiversity conservation, knowledge of endemic and threatened species is important since management strategies are primarily centered around the appropriate management of these taxa (Terborgh and Winter, 1983; Rebelo and Tansley, 1993). Chapter 4 deals with the analysis of taxonomic and biological aspects of endemic and threatened taxa. The biological profiles of Peninsula endemics are predicted by applying logistical modelling. This method was used to establish the odds on endemism based on three biological traits (growth form, regeneration strategy and dispersal mode), with each of the three traits being assigned to every species on the Peninsula. The use of logistic regression analyses as opposed to the conventional two-way contingency approach, as used by Cowling and Holmes (1992) and McDonald and Cowling (1995) to predict profiles for the Agulhas and southern Langeberg floras respectively, allows greater confidence levels in predicting the chances of an endemic having a particular biological profile. The latter measures the effect of a single attribute at a time, whereas logistic regression analysis investigates the possibility of simultaneous interactions between the attributes which may influence endemism. Due to logistic problems regression was not used to establish profiles for threatened species on the Peninsula. However, to facilitate a comparison between the biological profiles of threatened and endemic taxa, a two-way contingency table analysis was applied. The same biological attributes (growth form, regeneration strategy and dispersal mode), were assessed for both endemic and threatened taxa. The comparison of biological and taxonomic profiles between threatened and endemic taxa has not been done for any other local flora in the fynbos. Furthermore, the profile of Peninsula endemics was equated to profiles of endemics of other floras in the biome. The number of endemic and threatened taxa within each vegetation type (habitat) were assessed and, coupled to the biological aspects of these taxa, their vulnerability with respect to the major threats on the Peninsula were discussed.

1.6 The Peninsula and biodiversity conservation

For maximum protection of biodiversity, the strategic placement of reserves in the area of concern is imperative. Reserve selection procedures may vary greatly (Terborgh and Winter, 1983; Margules *et al.*, 1988; Cowling and Bond, 1991; Ryti, 1992; Rebelo and Tansley, 1993), with quality of data ultimately determining the selection process (Kirkpatrick, 1983; McKenzie *et al.*, 1989; Rebelo and Siegfried, 1992). In Chapter 5 three scenarios are presented under which reserve systems are considered and their implications for biodiversity conservation assessed. Scenario one considered the conservation status of plants, endemic animal species and vegetation types in the existing reserve system. Scenario two reassessed the status in the event of all publically-owned land being incorporated to existing reserves and scenario three used the iterative reserve-selection algorithm (Kirkpatrick, 1983; Rebelo and Siegfried, 1992) whereby the minimum number of areas outside current reserves are identified which would conserve each species at least once.

CHAPTER 2

MATERIALS AND METHODS

2.1 Study area

The study area lies in the extreme south-western corner of the Cape Floristic Region, South Africa (Goldblatt, 1978). The Cape Peninsula is defined as the area which lies west of 18°30' E., a line which runs between Table Bay and False Bay, from Milnerton Lagoon to Muizenberg respectively (Adamson and Salter, 1950) and covers an area of 471 km^2 (Fig. 2.1).

The topography of the area can be divided into two distinct regions; the Cape Flats on the north eastern periphery and a mountainous zone which runs from north to south along the full extent of the Peninsula. The Flats form part of a low plain which extends some 50 km to the Hottentots Holland Mountains in the east. This plain is interspersed with low sand-hills on the False Bay Coast and several permanent or seasonal shallow lakes and marshes (vleis).

The large remaining section of the Peninsula can be divided into a northern, central and southern part by distinct physical features. The Table Mountain massif, 1083m at its highest point, dominates the northern section which is demarcated at the southern end by the Hout Bay Valley. The central part runs from Constantia Nek (Vlakkenberg) in the north and ends at the Fish Hoek Gap. This central portion has the Constantiaberg (928m) as its highest peak. The southern part is separated from the central section by a prominent gap in the north-south range of mountains which runs from Fish Hoek in the east to the Noordhoek flats in the west (Fish Hoek Gap). The terrain of the southern section is more undulating and of lower elevation but for a prominent ridge which runs along the eastern periphery from Fish Hoek to Cape Point. The highest point of the area is Swartkops Peak (678m), immediately south of Simon's Town. A striking feature of the topography is the steep elevational change often encountered over short distances. The most dramatic being along the western face of Table Mountain where the

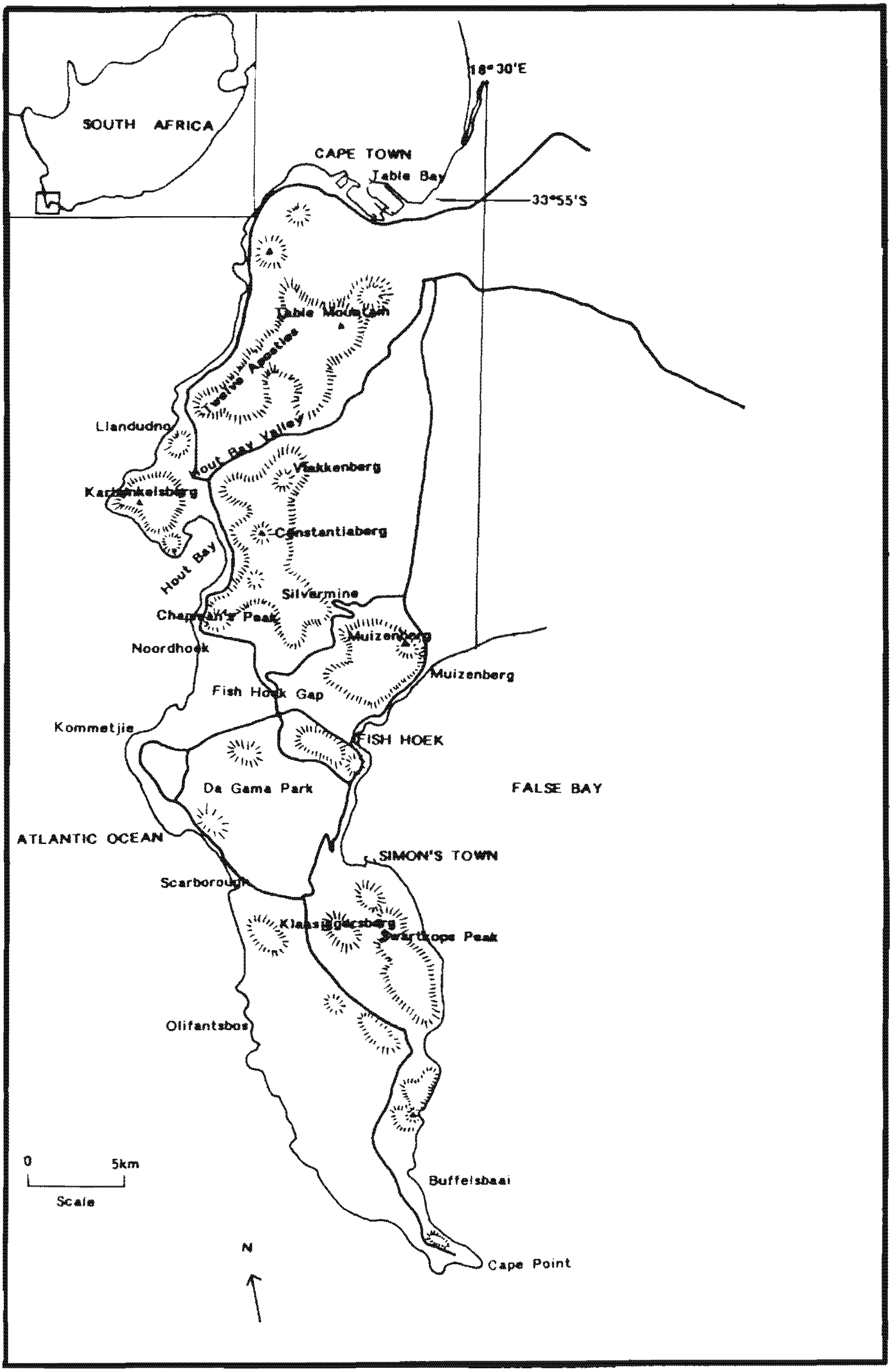

Figure 2.1. Map of the study area. Inset shows location of study area in South Africa.

altitude changes from sea level to 1000m within 2 km.

The geology consists of four main sequences of sedimentary and igneous origin. A band of Malmesbury shale, the oldest formation, runs across the northernmost sector of the Peninsula and includes Signal Hill and portions of the northern and eastern slopes of Devil's Peak under the 400m contour. Clayey, relatively nutrient rich soils are derived from this substrate (Deacon *et al.*, 1992). Intrusions of granite (Cape Granite Suite), are exposed in a mosaic across the Peninsula. Lion's Head in the north and Wynberg Hill are the most prominent. Outcrops are found along the Atlantic coast as far south as Chapman's Peak, along the lower eastern slopes of Constantiaberg and from Simon's Town to Smitswinkel Bay on the False Bay Coast. Soils of moderate nutrient status are derived from granite. The largest part of the Peninsula is comprised of the Table Mountain Group (TMS), a sandstone which produces acidic, nutrient poor substrates. In the northern and central sectors all areas above the 400m contour and most areas above 200m are of sandstone. The southern sector is almost entirely TMS, but for narrow strips of coastal sands. Late Tertiary and Quaternary Sands cover the majority of low altitude areas. This nutrient poor substrate was deposited by fluctuating sea levels during the Cainozoic era (Deacon *et al.*, 1992). A small band of limestone runs across the southern tip of the Peninsula just north of Cape Point.

The climate is strictly Mediterranean-type with hot dry summers and cool wet winters. Frontal systems introduce moisture and precipitation is mostly orographic. The average annual rainfall varies from 500mm along the Table Bay foreshore and along the western fringe of the southern Peninsula to 1600mm on the upper plateau of Table Mountain (Dent *et al.*, 1987). During summer the south-easterly winds often cause orographic cloud formation over higher altitude zones. On the Swartkops Mountains south of Simon's Town and on the Muizenberg Mountains cloud formation is above the 300m contour, whereas on Table Mountain and on Constantiaberg, clouds seldom form below 600m. Experiments conducted by Marloth (1903, 1905) showed that remarkable amounts of moisture condense on vegetation during such a south-easterly induced cloud forming event, increasing annual precipitation in such areas to more than twice that recorded in the conventional manner.

The vegetation on the Peninsula is predominantly fynbos, characterized by the ubiquitous small-leaved, sclerophyllous-type plants found across the entire biome (Taylor, 1978), of which the families Restionaceae, Proteaceae, Ericaceae, Penaeaceae, Bruniaceae, Stilbaceae and Grubbiaceae are the most distinctive (Levyns, 1964). Small patches of Afromontane forest (White, 1983) are found in moist kloofs particularly on eastern and southern mountain slopes. Elements of the Succulent Karoo Flora occur, with families such as Mesembryanthemaceae, Aizoaceae and the geophytic families Oxalidaceae and Iridaceae well represented. Fifteen vegetation types have been described (Cowling and Macdonald, in press) which closely reflect the high degree of environmental heterogeneity (Simmons and Cowling, in press).

2.2 Flora

This study used a species list based on Adamson and Salter (1950), and incorporates taxonomic change up to the end of 1994. Nomenclature follows Arnold and De Wet (1993). Figures reported in this study are taken from the above mentioned database. Families are treated *sensu stricto* (e.g. Lobeliaceae is treated separately from Campanulaceae; Mesembryanthemaceae separately from Aizoaceae and the ten families into which the Liliaceae were split by Dahlgren and Clifford (1982) are recognized). Infraspecific taxa (subspecies and variety) are included in species numbers totals.

2.3 Species distributional data

Over the past century the Peninsula has attracted much attention botanically, and is well collected by South African standards. The details of each specimen collected in each of the major South African herbaria (some 48 000 records) were databased. A one km^2 grid coinciding with the Gauss Conformal Conic projection was generated over a 1:50 000 map published by the Trigonometrical Survey of South Africa (3318CD:Cape Town and 3418AB/CD:Simon's Town). Each collection was allocated coordinates and placed in the center of a cell according to the positional details supplied on the collectors' labels. Where descriptions of a specimen's distribution indicated it to be larger than $1km^2$, the record was allocated to four adjoining cells i.e. the distribution of the species was considered extending over $4km^2$.

2.4 Endemic and threatened plant data

The list of endemic and threatened plant species was compiled from three main sources: the Flora of the Cape Peninsula (Adamson and Salter, 1950), a list of threatened plants of the Cape Peninsula (Hall and Ashton, 1983) and the South African Red Data Book for Fynbos and Karoo Biomes (Hall and Veldhuis, 1985). Where there was any discrepancy concerning the endemic status of a particular species, herbarium collections were checked for records off the Peninsula subsequent to the publication of the above mentioned references. Taxonomists specializing in the Cape flora made valuable contributions in problematic cases.

The distributional data of each endemic species was assessed. Where all records of a particular species fell within areas which have subsequently been developed, or where no collections have been made for 60 years or more, endemic species were regarded as being extinct. The same criteria were used for non-endemic threatened species which were regarded as extinct on the Cape Peninsula.

2.5 Biological aspects

The checklist of the flora of the area (T. Trinder-Smith unpublished data) was used to test whether endemics and threatened plants on the Peninsula are a random assemblage in terms of their biological attributes. All exotic species were excluded. Taxa in the tree and climber growth form categories and all pteridophytes were excluded from the database since these groups had no endemic species on the Peninsula. A subsidiary reason for their exclusion being that low species numbers in these categories would further complicate subsequent statistical modelling of the biological aspects. All the remaining species (2305 in total which includes many extinct species for which biological attributes were known) were coded for the biological attributes of growth form, post fire regeneration strategy, dispersal mode and their endemic/non-endemic status. The following categories were assigned within each of the attributes: (1) Growth forms; low shrubs (0-1m), mid-high shrubs (1-2m), tall shrubs (1-2m), graminoids, forbs, and geophytes. (2) Post fire regeneration strategies; non-sprouters and sprouters. (3) Dispersal modes; passive/unknown, wind-dispersal and ant-dispersal (myrmecochory) (Table 2.1).

The placing of species into categories with respect to their biological attributes was based on Adamson and Salter (1950), Bond and Slingsby (1983), Maddox and Carlquist, (1985), McDonald, *et al.*, (in press), inspection of herbarium sheets, consultation with specialist taxonomists, and unpublished personal observations. In instances where genera included predominantly non-myrmecochorous species and there was uncertainty as to which species were myrmechochorous, I opted for a conservative approach and classified the entire genus as being passively dispersed.

Table 2.1: Categories of the biological attributes for the 2305 species studied in the Cape Peninsula flora. Regeneration refers to post-fire regeneration.

Factor	Index	Category 1	2	3	4	5	6
Growth form (G)	i	Low Shrub	Mid-high Shrub	Tall	Graminoid Shrub	Forb	Geophyte
Regeneration (R)	j	Non-sprouter	Resprouter				
Dispersal mode (D)	k	Passive/ unknown	Wind		Ant		
Endemism (E)		Endemic	Non-endemic				

CHAPTER 3

THE COMPOSITION AND AFFINITIES OF THE PENINSULA FLORA

SUMMARY

The flora of the Peninsula was analyzed at various taxonomic levels. Monocotyledons form almost a third of the species on the Peninsula but only 18% of families. Pteridophytes in contrast are well represented at the family level, but are poorly represented at both generic and species level. Gymnosperms are poorly represented at all taxonomic levels, which is a phenomenon found throughout the Fynbos biome. At all taxonomic levels dicotyledons form approximately 70% of the flora. This equates well to other floras in the biome. The families with the highest number of genera and species are ubiquitous families found in most other biomes in southern Africa. The typically fynbos families Restionaceae and Ericaceae rank amongst the 10 most genus and species rich families on the Peninsula. Apart from the genus *Erica*, which has the highest number of species, no other typically fynbos genus ranks amongst the 10 most specious genera.

INTRODUCTION

The southern African region as delimited by Goldblatt (1978) has a flora rich in species, resulting in high species/area ratios (Gibbs Russell, 1987) and remarkable levels of endemism at both generic and specific levels. The Cape Floristic Region (Goldblatt, 1978; Bond and Goldblatt, 1984), one of five phytogeographical regions in southern Africa recognized by White (1976, 1978), is afforded Floral Kingdom status (Takhtajan, 1969; Good 1974) because of its high species richness and high levels of endemism. The Cape Peninsula at the south-western extremity of this Region is extraordinary with respect to plant species richness and numbers of endemic and threatened taxa (Adamson and Salter, 1950; Hall and Ashton, Hall and Veldhuis, 1985; Cowling and Macdonald, in press; Simmons and Cowling, in press).

Although the flora of the Peninsula is well documented (Bolus and Wolley-Dod, 1903; Levyns, 1923; Adamson and Salter, 1950), much nomenclatural and taxonomic change has occurred since 1950. The accuracy of data on the flora of an area is important since they are often used in the compilation and analysis of floras at broader scales. Goldblatt (1978), in a comprehensive study of the flora of southern Africa used figures of the flora of the Peninsula as a comparison to the floras of various regions of the world. Furthermore, the number of species in a flora and the number of endemics are used in comparisons with other floras in the biome (Cowling *et al.*, 1992); McDonald and Cowling, 1995) and used to establish phytogeographic centers (Weimarck, 1941; Oliver *et al.*, 1983).

MATERIALS AND METHODS

3.1 Study area

See Chapter 2.

3.2 Flora

See Chapter 2.

RESULTS

3.3 Flora

The flora of the Peninsula consists of 138 (158) families, 663 (759) genera and 2285 (2580) species. These numbers reflect extant taxa only and numbers in parenthesis include exotics. Of the 138 families 15 are pteridophytes, two gymnosperms and 121 angiosperms. Twenty five of the latter are monocotyledons and 96 dicotyledons; their proportions are represented in Fig. 3.1. At the generic level there are 29 pteridophytes, two

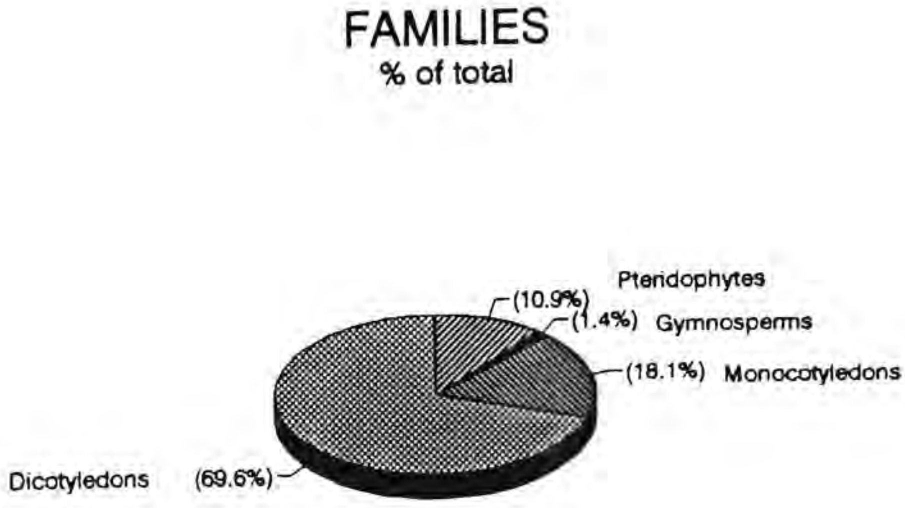

Figure 3.1. The proportional representation of families in the pteridophytes, gymnosperms, monocotyledons and dicotyledons in the Peninsula flora.

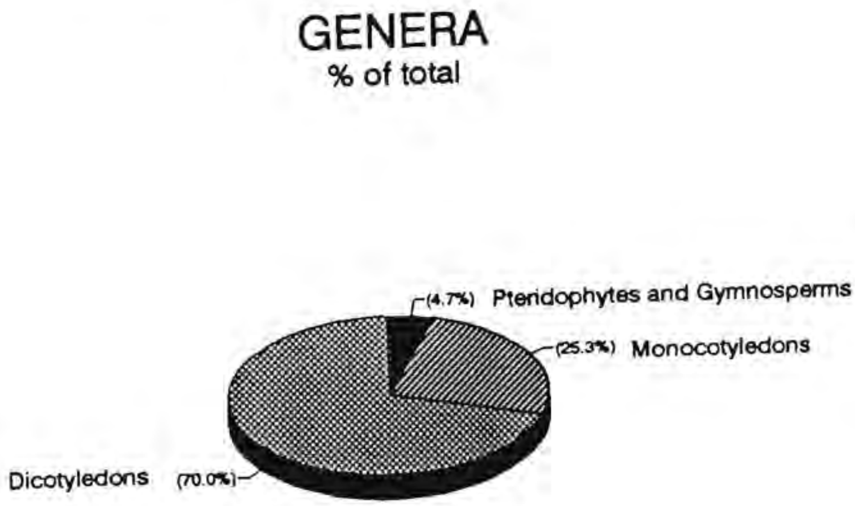

Figure 3.2. The proportional representation of genera in the pteridophytes and gymnosperms, monocotyledons and dicotyledons.

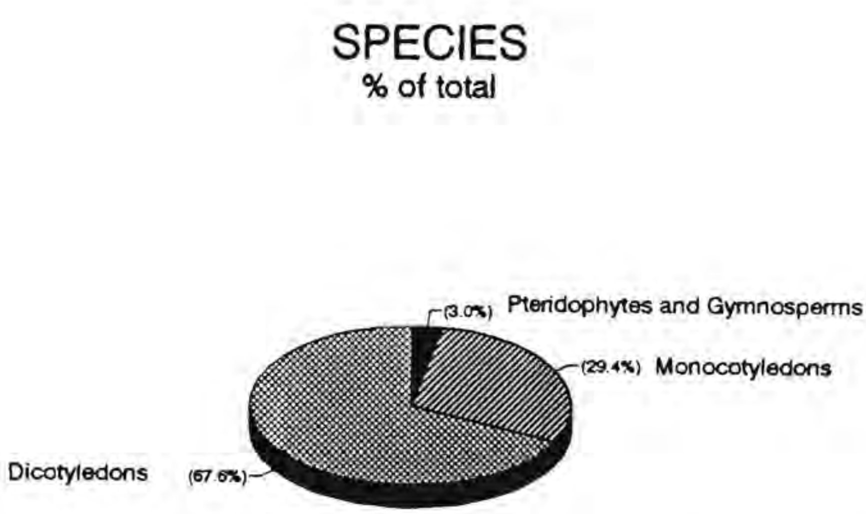

Figure 3.3. The proportional representation of species within the pteridophytes and gymnosperms, monocotyledons and dicotyledons.

Table 3.1: The families with the highest number of genera and species in the flora.

Family	No. Genera	Rank	No. Species	Rank
Asteraceae	72	1	286	1
Poaceae	46	2	141	5
Fabaceae	26	3	162	3
Iridaceae	25	4	168	2
Cyperaceae	23	5	146	4
Mesembryanthemaceae	21	6	66	9
Scrophulareaceae	20	7	59	10
Orchidaceae	19	8	118	6
Apiaceae	16	9	57	-
Restionaceae	14	10	102	8
Ericaceae	7	-	112	7

Table 3.2: The most speciose genera in the flora.

Genus	No. species	Rank
Erica	103	1
Aspalathus	55	2
Senecio	47	3
Oxalis	38	4
Ficinia	37	5
Crassula	36	6
Cliffortia	33	7
Pelargonium & *Disa*	30	8
Helichrysum, Tetraria & *Thesium*	28	9
Lampranthus	23	10

gymnosperms and 632 angiosperms of which 168 are monocotyledons and 464 dicotyledons; proportional representation is shown in Fig 3.2. The number of species in each group are 66 pteridophytes, two gymnosperms, 672 monocotyledons and 1545 dicotyledons, the proportions of which are shown in Fig. 3.3.

The Pteridophytes occupy a larger proportion of the flora at the family level than at generic or specific levels indicating a low family to genus, and family to species ratios. In contrast the monocotyledons occupy a smaller proportion of the flora at family level, yet represents a quarter of the genera and almost a third of the species on the Peninsula.

The families which rank highest in terms of number of genera and species are shown in Table 3.1. The Asteraceae have the highest number of genera (72) and species (286). Poaceae has the second highest number of genera (46) and Iridaceae is second most species rich with 168 species. The ten most species rich genera are shown in Table 3.2. *Erica* and *Aspalathus* are the most speciose with 103 and 55 species respectively. The ratio of genera/family is 4.2, species/family 14.3 and 3.5 for species/genus. The species/unit area (1km^2) ratio is 4.9. If considered that only 310 km^2 of the Peninsula is pristine vegetation once all developed and severely disturbed land is removed from calculation (the species numbers reflected are accurate for natural areas), this ratio increases to 7.4 species/km^2.

DISCUSSION

3.4 Phytochoria, phytogeography and flora

In the classification of White (1965, 1971) the Peninsula is part of the Cape phytochorion. This delimitation is based on the high levels of regional endemism at the specific level. Although recognized as being a predominantly African flora (Levyns, 1964; Adamson, 1958) studies in the past have viewed the Cape phytochorion separately from other phytochoria in Africa. Linder (1990) argues that, based on a certain degree of homogeneity at the generic level, one large Afrotemperate Region should be recognized with the delimitation of centers of endemism based on endemism at the specific level. The Cape Floristic Center with a 68% level of specific endemism (Bond and Goldblatt, 1984), being one of the recognized centers within this Region.

Weimarck (1941) recognized phytogeographical centers within the Cape Flora based on local species richness patterns and levels of endemism. In this work the Cape Peninsula is given sub-centre status within the South-western center, but in a re-appraisal by Oliver *et al.* (1983) this area was recognized as a distinct center. Oliver *et al.* (1983) attributed this mainly to the many genera which are particularly species rich (Table 3.2). The number of families with large numbers of genera and species (Table 3.1) and the many endemic species also justifies this status. The number of monocotyledonous species is high (Fig. 3.3) relative to most other floras in Africa (Gibbs Russell, 1975) and closely resembles that of the Cape Hangklip flora (Boucher, 1977), an area in close proximity to the Peninsula. Where most other floras analyzed by Gibbs Russell (1985) show Poaceae to be the most speciose monocotyledonous family, Iridaceae and Cyperaceae rank higher in the Peninsula. Orchidaceae and Restionaceae are also important families in this flora (Table 3.1). Within the monocotyledons both petaloid and non-petaloid families are therefore important.

The center of diversity for the many petaloid monocotyledonous geophytes lies to the north and north east of the Peninsula in the centers termed Northern, West Coastal and South-western by Oliver *et al.* (1983). This is true for a number of iridaceous taxa (Goldblatt, 1991) particularly *Moraea* (Goldblatt, 1986), *Watsonia* (Goldblatt, 1989), *Homeria* (Goldblatt, 1981) *Geissorhiza* (Goldblatt, 1985), for *Strumaria* and *Hessia* in the Amaryllidaceae (Snijman, 1994) and for *Satyrium* (Hall, 1982) and *Disa* (Linder, 1981) in the Orchidaceae. The Peninsula is often the most south-western range of many species within these genera whether their centers of richness lie to the north or east of this area. The large number of species in the Cyperaceae may possibly reflect the detailed and accurate systematic work of Levyns in Adamson and Salter (1950), which is unparalleled at distinguishing species in this difficult group. The Restionaceae as studied by Linder (1985) is also more species rich compared to the floras of the Agulhas Plain and Humansdorp (Cowling *et al.* 1992) and the southern Langeberg Mountains (McDonald and Cowling, 1995) and is a center for richness (Oliver *et al.*, 1983).

The dicotyledonous taxa are not unusual in terms of their levels of richness compared to other floras within the fynbos (Boucher, 1977) and other southern African biomes Gibbs Russell (1975). The ubiquitous families Asteraceae and Fabaceae, as in the floras mentioned above, are the richest at both generic and specific level (Table 3.1). Pteridophytes on the other hand are depauperate at the generic and species level.

CONCLUSION

The figures at the different taxonomic levels given for the Peninsula flora in the the past differ from those presented in this study. Of particular note are the number of families and genera which are substantially higher than the numbers reflected previously. This can be attributed to the number of taxonomic changes which have occured over the past forty five years. The correction of numbers at the different taxonomic levels is essential as the outcome of many comparative studies are reliant on the accuracy of these figures.

The monocotyledons form a large part of the flora compared to floras east of the Cape Peninsula and both petaloid and non-petaloid monocotyledons are of importance. This can be ascribed to the fact that the centre of diversity of particularly the petaloid monocotyledons lies to the north of the Peninsula with many genera and species reaching their southern-western most range extension on the Peninsula.

CHAPTER 4

MODELLING THE BIOLOGICAL AND TAXONOMIC PROFILES OF PENINSULA ENDEMICS AND THEIR COMPARISON TO THREATENED TAXA

SUMMARY

The Cape Peninsula (area: 471 km^2), situated at the south-western extremity of the Cape Floristic Region, has exceptionally high plant species richness (2285 taxa) and numbers of endemic (90) and threatened (141) taxa. This biodiversity is threatened by urban development and the spread of invasive alien plants. Peninsula endemics are concentrated in a few, predominantly species-rich, families and these correspond well with endemic-rich families in other areas of the Cape Floristic Region. A high level of similarity exists between families with threatened and families with endemic taxa. A logistic regression analysis of the biological traits of endemic and a frequency analysis of endemic taxa and threatened taxa shows that low growing, ant-dispersed shrubs are over-represented in both groups. Endemics are most likely to be non-sprouters, but threatened plants do not have a specific post-fire regeneration strategy. Threatened taxa have higher frequencies of geophytes, sprouters and wind-dispersed species compared to endemic taxa. Numbers of endemic and threatened species are not randomly distributed with regard to occurrence in vegetation types and patterns are similar for both groups. The habitat and biological profiles of both endemic and threatened taxa suggest that they are highly vulnerable to extinction as a result of increasing rates of alien plant infestation, urbanization and inappropriate fire regimes.

INTRODUCTION

Species richness of many different organisms tends to increase from temperate to tropical zones (Dobzhansky, 1950; Pianka, 1966, MacArthur, 1965; Rhode, 1992) and from high to low elevation sites (Stevens, 1992). There is a strong positive relationship for higher plants between the number of endemic species and total species richness (Cowling and Samways, in press) and consequently these latitudinal and elevational gradients are duplicated in patterns of endemic plant species richness (Gentry, 1986; Major, 1988; Stevens, 1989; Cowling and Samways, in press). An exception to this global pattern is that certain temperate zones, and in particular Mediterranean-type climate regions, are rich in both total and range-restricted (endemic) plant species (Stebbins and Major, 1965; Raven and Axelrod, 1978; Lamont *et al.,* 1977; Cody, 1986; Cowling *et al.*, 1992). The Cape Floristic Region in South Africa's Mediterranean-type climate region is remarkable in this respect (Taylor, 1978; Goldblatt, 1978; Bond, 1983; Oliver *et al.*, 1983; Myers, 1990; Cowling *et al.*, 1992; Rebelo, 1994).

Previous studies have focussed predominantly on determining patterns of endemism at global and regional scales (Major, 1988; Cowling, 1983). More recently, awareness of the looming biodiversity crisis (Myers, 1988, 1990) has brought about the need for studies of floras at a local level in order to identify areas of botanical importance. Procedures implemented in reserve selection exercises incorporate data relating to endemicity and rarity (Kirkpatrick, 1983; Terborgh, 1974; Terborgh and Winter, 1983; Rebelo, 1994). Successful management of designated reserves requires knowledge of endemic and threatened plants to ensure their preservation (Kruckeberg and Rabinowitz, 1985).

The Cape Peninsula, a botanically well documented and remarkably species-rich area (Bolus and Wolley-Dod, 1903; Adamson and Salter, 1950; Cowling and Macdonald, in press; Simmons and Cowling, in press) within the Cape Floristic Region, affords an excellent opportunity to analyze aspects of endemism and rarity in higher plants. Recent studies within the Cape Floristic Region show that local endemics have particular taxonomic and biological profiles (Cowling and Holmes, 1992; McDonald and Cowling, 1994; McDonald *et al.*, in press). Knowledge of these profiles provides information useful in formulating management strategies for conserving endemics and threatened taxa. Despite extraordinary high numbers of threatened plant taxa in the Cape Floristic Region (Hall and Veldhuis, 1985), and in particular the Cape Peninsula (Hall and Ashton, 1983), these taxa have hitherto been poorly studied. The primary aim of this chapter is to address three main issues: to establish the taxonomic and biological profiles of Peninsula endemics and compare these with those from other parts of the Cape Floristic Region; to establish taxonomic and biological profiles of Peninsula threatened taxa and compare these with those for endemic taxa; and to relate habitat and biological aspects of endemism and rarity to threats within the area.

MATERIALS AND METHODS

4.1 Study area and flora

A detailed description of the study area and the method of compiling the species list used in this chapter appear in Chapter 2.

4.2 Endemic and threatened plant data.

For the method used in acquiring the list of endemic and threatened taxa and their distributional data see Chapter 2.

Threatened Peninsula endemics were categorized according to the Mace and Stuart's (1994) Version 2.2 of the IUCN Red List Categories. Non-endemic threatened species have not been updated from the original IUCN categories (Lucas and Synge, 1978) as knowledge of their status off the Peninsula was insufficient for their categorization according to Mace and Stuart (1994).

I used Bykov's (1979 in Major, 1988), index of endemism which allows for the comparison of levels of endemism between different sized areas. The index is as follows: $I_e = E_f/E_n$ where E_f is the actual percentage of endemism for a particular area and E_n is the "normal" percentage of endemism read off a nomogram, where the ordinate is area and the abscissa percentage endemism. A value of $I_e = 1$ indicates that an area has the expected level of endemism for its size. A value >1 implies an area has higher, and a value < 1, lower than "normal" levels of endemism. The published nomogram (Bykov, 1979 in Major, 1988) does not accommodate an area as small as the Peninsula. Extrapolation of the x and y axes allowed an estimate of what the "normal" percentage of endemism for an area equal to the study site should be (approximately 0.5 %).

4.3 Taxonomic aspects

A chi-squared analysis was used to test the null hypothesis that the frequency of endemics and threatened species in a family would not deviate significantly from their frequency in the entire flora, excluding that family. Only families with more than 30 species were used in the analysis to avoid the problem of unacceptably low cell count frequencies.

4.4 Environmental data

I correlated the incidence of endemism (i.e. number of taxa) and rarity (i.e. threatened taxa) in each of the 590 grid squares with environmental data. Variables used were annual rainfall range, altitudinal range, and the number of lithological types (no adequate soil type data were available). Rainfall data were obtained from a spatial database (Dent *et al.*, 1987). Elevations were derived from the 1:50 000 maps published by the Trigonometrical Survey of South Africa. The maximum and minimum altitude in each cell was to the nearest 20m. The number of lithological types was derived from the 1:50 000 Geological Series map published by the Department of Mineral and Energy Affairs. Lithological types are derived from four basic geological formations: Table Mountain Group Sandstone (TMS), Cape Granite, Malmesbury Shale and Late Tertiary to Quaternary Sands.

Since vegetation cover integrates many abiotic factors, I also explored the environmental aspects of endemism and rarity by determining whether numbers of endemic and threatened species were more frequent in the different vegetation types of the Peninsula (Cowling and Macdonald, in press) than would be expected on the basis of the area of each type (McDonald and Cowling, 1994). The area of each vegetation type and the number of endemics and threatened plants occurring in each was determined using a Geographic Information System (GIS): ARC/INFO version 6.1.1, Environmental Systems Research Institute, Redlands, California. Chi-squared tests were used to test the hypothesis that the numbers of endemic and threatened species in each vegetation type were not significantly different from those expected on the basis of its area. In the case of unacceptably low expected cell count frequencies, similar vegetation types were collapsed into a single category.

Although data exist for historical distributions of vegetation types and localities for endemic and threatened species, only extant distributions and contemporary vegetation cover were used (i.e. excluding land transformed by urbanization and agriculture) (see Richardson *et al.*, in press).

4.5 Biological aspects

For the methods applied with respect to acquiring the list of species to which biological attributes were given and the categories into which they were placed, see Chapter 2.

Two-way contingency tables were used to analyze the frequency of endemics and non-endemics, threatened and non-threatened species in each of the categories of biological attributes into which they were classified. Chi-squared analysis was used to test for significant difference in the frequency of each biological trait within the endemic and threatened categories.

The list of species, which included all the species in the six selected growth form categories was cross-classified following the method of McDonald *et al.* (in press), whereby the enumeration of endemics and non-endemics found in the patterns of biological attributes is reflected.

Logistic regression was used to test how the probability of endemism depended upon the three variables growth-form (G), regeneration strategy

(R) and dispersal mode (D). A hierarchy of models were fitted which included these main effects and their interactions (Appendix 1), until the most parsimonious model was found (Trexler and Travis, 1993). The model was based on the model fitted by McDonald *et al.* (1995) to endemism data in the southern Langeberg Mountains of the Cape Floristic Region. The models were compared using the minimum Akaike Information Criterion (AIC) (Lenhart and Zucchini, 1986). This criterion is deviance (likelihood ratio chi-squared statistic) plus 2p where p is the number of parameters in the model. The deviance always decreases as extra parameters are added to the model, irrespective of whether or not they are statistically significant. The AIC criterion adjusts for the inclusion of extra parameters and allows comparisons to be made between models with differing numbers of parameters. The model with the minimum AIC is considered most suitable.

The use of statistical modelling in determining the biological profile of an endemic is considered advantageous above other methods (two-way contingency approach), since it tests for interactions between biological attributes as opposed to testing each attribute independently, and consequently the predictive value is enhanced. In this study the predictive value is especially reliable since the model was run for all species on the Peninsula (entire statistical "population") as opposed to a subsample (J. Juritz, pers. comm.)

RESULTS

4.6 Levels of endemism

Of the 2285 extant indigenous taxa on the Peninsula 90 (3.98 %) are endemics (Table 4.1). These species can all be regarded as extreme local endemics (confined to an area of 471km^2), of which many are restricted to only a few or single localities within the area. Of the 90 endemics, 65 are threatened. The total number of threatened plants was 141. The Bykov's index (I_e) for the flora of the Peninsula (inclusive of transformed land) was 6.1.

Table 4.1. The frequency of endemic and threatened plants in families of the Cape Peninsula flora. The chi-square (X^2) analysis tests the null hypothesis that the frequency of endemic plants and of threatened plants in a family would not be different to the frequency in the total flora. To avoid the problem of low cell count frequencies only families with more than 30 species were analysed. *** = $p<0.001$, ** = $p<0.01$, NS = not significant. All families with endemic and threatened plants are listed. Comparative data on endemics are included from other areas in the Cape Floristic Region: the Agulhas Plain (AP, 1750 spp) in the south-west, the Langeberg Mountains (LM, 1230 spp) in the south, and Humansdorp (H, 870 spp) in the south-east. A + after a figure indicates over-representation and a - under-representation.

Family	Cape Peninsula										AP	LM	H
	Non-endemic	Local endemic	Percent of total	X^2	Sig.	Non-threatened	Threatened	Percent of total	X^2	Sig.	Local endemic	Local endemic	Regional endemic
All	2195	90	3.9	-	-	2144	141	6.6	-	-	-	-	-
Apiaceae	-	-	-	-	-	56	1	1.8	1.2	NS	-	-	-
Asteraceae	283	3	1.1	5.64	**	281	5	1.7	8.5	***	2-	14-	12
Brassicaceae	36	3	7.7	0.60	NS	37	2	5.1	0.07	NS	-	-	-
Bruniaceae	8	2	20	-	-	6	4	40	-	-	-	-	-
Campanulaceae	35	1	2.8	0.00	NS	39	1	2.5	0.39	NS	1	-	-
Crassulaceae	-	-	-	-	-	-	-	-	-	-	-	-	1
Cyperaceae	143	3	2.1	0.86	NS	136	10	6.8	0.02	NS	1-	-	-
Ericaceae	77	35	31.3	155.60	***	85	27	22	49.98	***	22+	49+	11+
Eriospermaceae	-	-	-	-	-	6	2	25	-	-	-	-	-
Euphorbiaceae	-	-	-	-	-	-	-	-	-	-	-	-	4
Fabaceae	155	7	4.3	0.01	NS	149	13	3	0.6	NS	8	16	10
Geraniaceae	-	-	-	-	-	-	-	-	-	-	-	-	1
Haemodoraceae	6	1	14	-	-	-	-	-	-	-	-	-	-
Hyacinthaceae	-	-	-	-	-	39	2	4.9	0.01	NS	-	-	-
Iridaceae	161	7	3.9	0.00	NS	157	11	6.1	0.01	NS	7	5	3
Mesembryanthemaceae	61	5	7.6	1.35	NS	60	6	9.1	0.5	NS	9+	-	8+
Orchidaceae	115	3	2.6	0.27	NS	97	21	17.8	22.31	***	-	6	-
Oxalidaceae	-	-	-	-	-	38	1	2.6	0.35	NS	-	-	-
Poaceae	140	1	1.4	1.70	NS	-	-	-	-	-	-	-	2-
Polygalaceae	-	-	-	-	-	33	1	2.9	0.17	NS	7+	-	-
Proteaceae	39	8	17	16.46	***	36	11	23.4	19.7	***	11+	8	-
Restionaceae	98	4	3.9	0.00	NS	89	13	12.7	5.9	**	1-	17+	1
Rosaceae	37	1	2.6	0.00	NS	35	3	7.9	0.09	NS	-	-	-
Rutaceae	20	2	10	-	-	-	-	-	-	-	11+	11	8+
Selaginellaceae	-	-	-	-	-	0	1	100	-	-	-	-	-
Scrophulariaceae	-	-	-	-	-	57	2	3.4	0.37	NS	-	-	1
Sterculiaceae	19	2	9.5	-	-	17	3	15	-	-	-	-	-
Thymelaeaceae	35	1	2.8	0.00	NS	35	1	2.8	0.24	NS	1-	-	5+

4.7 Taxonomic aspects

The endemics are restricted to 18 (13% of total) families and 41 (6%) genera. The majority of the larger families in the flora were neither significantly over- nor under-represented in terms of the frequency of endemics. Exceptions were the Ericaceae and Proteaceae which are strongly over-represented ($P < 0.001$) and the Asteraceae which are under-represented ($P < 0.01$) (Table 4.1). Families which showed a tendency towards over- or under-representation, but did not attain statistical significance at the $P < 0.05$ level were Cyperaceae and Mesembryanthemaceae (over-representation) and Poaceae (under-representation).

The 141 extant threatened plants constitute 6% of the flora. Thirty nine species listed as threatened (Hall and Ashton, 1983) are regarded as extinct on the Peninsula according to the criteria set out above. This includes those species listed as extinct by Hall and Ashton (1983). Of these, 15 are endemics of which two (*Erica verticillata and E. turgida*) are extinct in the wild. Sixty five (72%) of the extant endemic plants are threatened, of which 70% fall in the top three most critical categories (Table 4.2).

As with the endemics, few of the larger families were significantly over- or under-represented in terms of threatened plant taxa. Only the Asteraceae were significantly under-represented ($P < 0.001$), whereas four families, Ericaceae, Orchidaceae, Proteaceae ($P < 0.001$) and Restionaceae ($P < 0.01$), were over-represented (Table 4.1). Threatened taxa were represented in 23 (17% of total) families and 63 (10%) genera.

4.8 Vegetation data and environmental correlates

Two vegetation types, coastal scree asteraceous fynbos combined with mesic oligotrophic proteoid fynbos (low elevation), and mesic mesotrophic proteoid fynbos (moderate to high elevation), occupied the largest areas and had the highest number of endemic and threatened taxa, yet were under-represented with respect to numbers of endemic and threatened taxa

Table 4.2: The number of threatened endemic plants in each of the IUCN (Version 2.2) categories on the Peninsula

Category	Number
Extinct	13
Extinct in the Wild	2
Critically endangered	15
Endangered	17
Vulnerable	13
Low Risk	15
Data Deficient	4
Not Evaluated	1
TOTAL	80

Table 4.3. The association between vegetation types and number of endemic and threatened species in each. The chi-square (X^2) analysis tests the hypothesis that the number of endemics and threatened species should not be different from the numbers expected on the basis of the area covered by each vegetation type. ** = $p<0.001$, * = $p<0.01$. Figures in parentheses represent percentages of the total.

Vegetation type	Area of veg. type (ha)	No.of endemics	Expected	X^2	Sig.	No. threatened	Expected	X^2	Sig.
Forest/Thicket	1107 (4)	11 (3)	12	0	NS	17 (4)	18	0	NS
Dune Asteraceous Fynbos	2235 (7)	29 (8)	23	1	NS	44 (9)	35	2	NS
Wet Restioid Fynbos	3151 (10)	32 (9)	33	0	NS	40 (8)	50	2	NS
Ericaceous Fynbos & Upland Restioid Fynbos	1491 (5)	38 (11)	16	32	**	46 (9)	24	22	**
Sandplain Proteoid Fynbos	2433 (8)	40 (11)	26	8	*	55 (11)	38	7	*
Coastal Scree Asteraceous Fynbos & Mesic Oligotrophic Proteoid Fynbos	9050 (29)	63 (18)	95	11	*	92 (19)	143	18	**
Mesic Mesotrophic Proteoid Fynbos	7018 (23)	49 (14)	73	8	*	79 (16)	111	9	*
Undifferentiated Cliff Community	722 (2)	17 (5)	8	12	**	21 (4)	11	.8	*
Vlei & Wetlands	495 (2)	22 (6)	5	54	**	33 (7)	8	81	**
Wet Oligotrophic Proteoid Fynbos	1030 (3)	23 (7)	11	14	**	20 (4)	16	1	NS
Wet Mesotrophic Proteoid Fynbos	1234 (4)	24 (7)	13	10	*	23 (5)	19	1	NS
Renosterveld/Grasslands	989 (3)	8 (2)	10	1	NS	18 (4)	16	0	NS

expected on the basis of their area occupied (Table 4.3). Four vegetation types were over-represented with respect to endemic and threatened species: upland restioid fynbos combined with ericaceous fynbos (wet, high elevation, nutrient poor), sandplain proteoid fynbos (drier, low elevation, moderate nutrient status), undifferentiated cliff communities (moderate to high altitude, mesic to wet) and vlei and wetlands. Wet oligotrophic proteoid fynbos (moderate altitude) and wet mesotrophic proteoid fynbos were over-represented with respect to endemic species only (Table 4.3).

4.9 Biological data

Endemic and threatened species showed distinctly non-random patterns with respect to biological attributes (Fig. 4.1). In both cases low shrubs were over-represented, and forbs and graminoids under-represented among these groups (Fig. 4.1a and 4.1d). Non-sprouters were significantly over-represented among endemics but the relative frequency of taxa in the threatened categories did not differ according to regeneration mode (Fig. 4.1b and 4.1e). Both endemic and threatened taxa were significantly over-represented with respect to ant-dispersal (Fig. 4.1c and 4.1f), while among endemics, wind-dispersed species were strongly under-represented.

Numbers of species in each pattern of the biological attributes showed passively dispersed species to be the most numerous, constituting 69% of species. Within the passively dispersed group there were more non-sprouting species and low shrubs were the most representative growth form. This combination of attributes was also associated with the largest number of endemic species (Table 4.4). Within the wind-dispersed category (22% of the flora), geophytes (sprouters) had the largest number of species and number of endemics. Only 8% of species were ant-dispersed with 40% of these being low, non-sprouting shrubs.

4.10 Model selection

The model selection procedure whereby the minimum Akaike Information Criterion (AIC) was used is shown in Appendix 1. Model 5 was adopted since it had the lowest AIC value. The percentage of variation explained by

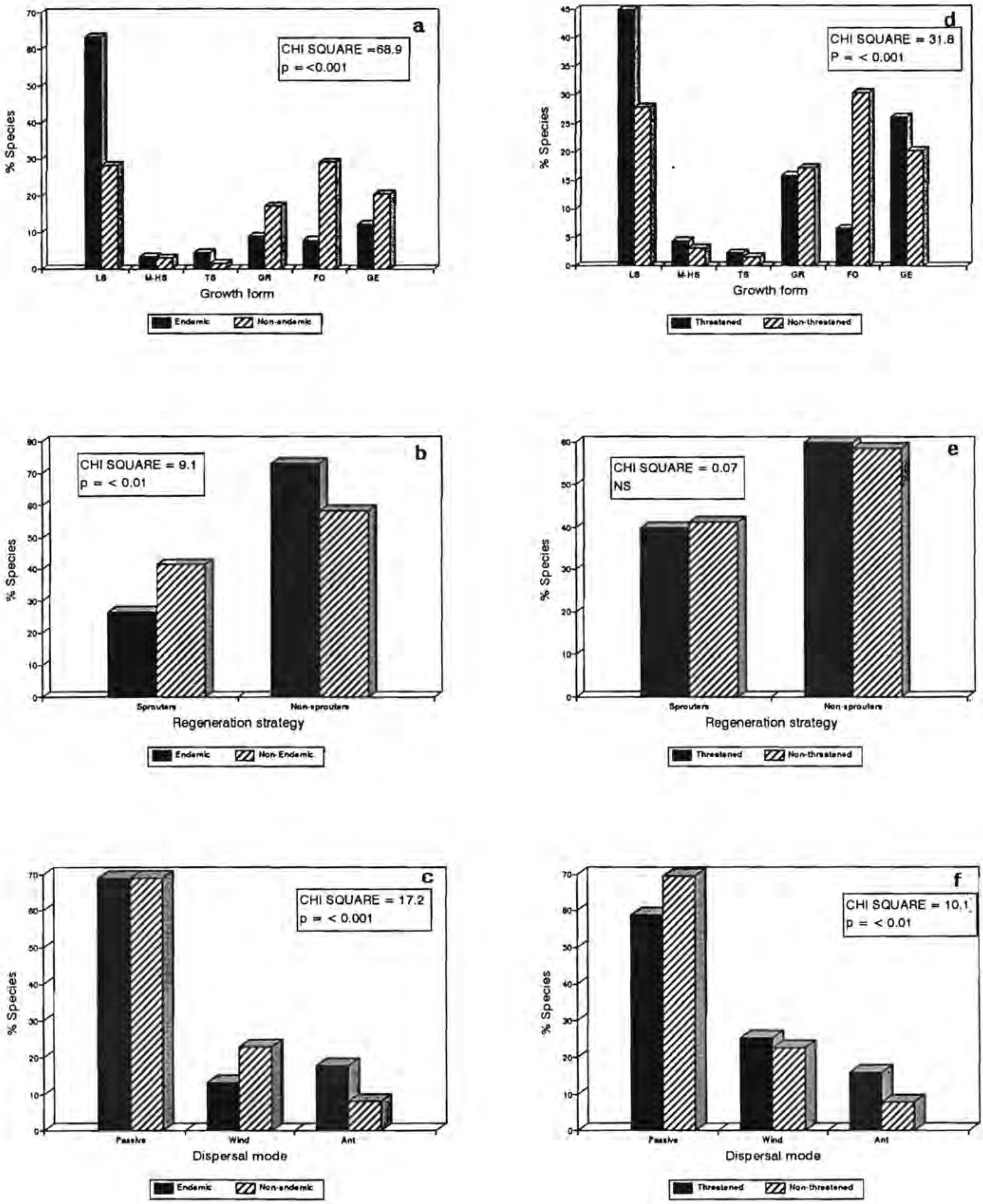

Figure 4: The percentage of endemic versus non-endemic and threatened versus non-threatened species in the six growth form classes, two regeneration strategy classes and three dispersal mode classes. (LS - low shrub, M-HS - mid-high shrub, TS - tall shrub, , GR - graminoid, FO - forb, GE - geophyte) NS - not significant.

Table 4.4: The cross-classification of the endemic plants according to the biological attributes growth form, regeneration and dispersal.

Dispersal	Regeneration	Growth Form	Endemism: Endemic	Endemism: Non	Total
Passive	Non-sprouter	Low Shrub	41	388	429
		Mid-high Shrub	3	40	43
		Tall Shrub	2	23	25
		Graminoid	3	164	167
		Forb	12	350	362
		Geophyte	*	*	*
	Sprouter	Low Shrub	0	94	94
		Mid-high Shrub	0	14	14
		Tall Shrub	0	7	7
		Graminoid	4	175	179
		Forb	1	49	50
		Geophyte	3	222	225
Wind	Non-sprouter	Low Shrub	1	87	88
		Mid-high Shrub	0	11	11
		Tall Shrub	0	1	1
		Graminoid	0	6	6
		Forb	0	119	119
		Geophyte	*	*	*
	Sprouter	Low Shrub	0	8	8
		Mid-high Shrub	*	*	*
		Tall Shrub	*	*	*
		Graminoid	1	10	11
		Forb	1	45	46
		Geophyte	14	214	228
Ant	Non-sprouter	Low Shrub	8	69	77
		Mid-high Shrub	0	5	5
		Tall Shrub	0	2	2
		Graminoid	1	5	6
		Forb	0	24	24
		Geophyte	*	*	*
	Sprouter	Low Shrub	3	33	36
		Mid-high Shrub	*	*	*
		Tall Shrub	1	1	2
		Graminoid	1	20	21
		Forb	0	4	4
		Geophyte	0	16	16

this model compared to a model that assumes that the probability of an endemic is the same for all combinations of growth form, dispersal mode and regeneration strategy is 81%. Inclusion of the dispersal mode by regeneration strategy (DR) and growth form by regeneration strategy (GR) interactions explained 68% more of the variation in the data compared to a model which assumed that growth form (G), dispersal mode (D) and regeneration strategy (R) affect endemism independently of each other.

The form of the final model was as follows:
Let π_{ijk} be the probability of an endemic in i^{th} growth form, j^{th} regeneration strategy and k^{th} dispersal mode (see Table 2.1 for these indices).
Then the logistic model is:

$$\log\left(\frac{\pi_{ijk}}{1-\pi_{ijk}}\right) = \mu + \lambda_i^G + \lambda_j^R + \lambda_k^D + \lambda_{ij}^{GR} + \lambda_{kj}^{DR}$$

for

$$i = 1,\ldots,6 \qquad j = 1,2 \qquad k = 1,2,3$$

where all lambdas with any subscript equal to 1 are zero and only the statistically significant GR and RD interaction parameters are included. The values of the lambdas are given in Appendix 2.

The model fitted the data well apart from the passive, non-sprouting graminoid categories. There appears to be no biological reason for this result.

The fitted and observed probabilities are given and the odds on endemism in the various categories are reflected in Table 4.5.

No significant growth form by dispersal mode (GD) interactions were found which implies that the effect of dispersal method is the same for all growth forms. There were also no three factor (GRD) interactions. However, there was strong evidence for dispersal mode by regeneration strategy (DR) interactions throughout the data and the model justified a cross-classification of these interactions. The odds against endemism in this two-way interaction are displayed in Table 4.6. There was some evidence for a growth form by regeneration strategy (GR) interaction but further

Table 4.5: Fitted values for the growth form, regeneration and dispersal combinations from the model and odds against a species in each category being endemic. (Non-spr.- Non-sprouter; Regen. - Regeneration Strategy)

Growth Form	Regen.	Dispersal	Pobs	Pfit	Odds*
Low Shrub	Non-spr.	Passive	0.096	0.096	9*
Low Shrub	Non-spr.	Wind	0.011	0.007	133
Low Shrub	Non-spr.	Ant	0.104	0.099	9
Low Shrub	Sprouter	Passive	0.000	0.013	78
Low Shrub	Sprouter	Wind	0.000	0.063	15
Low Shrub	Sprouter	Ant	0.083	0.054	17
Mid-high shrub	Non-spr.	Passive	0.070	0.059	16
Mid-high shrub	Non-spr.	Wind	0.000	0.004	225
Mid-high shrub	Non-spr.	Ant	0.000	0.061	15
Mid-high shrub	Sprouter	Passive	0.000	0.008	131
Tall shrub	Non-spr.	Passive	0.080	0.074	13
Tall shrub	Non-spr.	Wind	0.000	0.006	177
Tall shrub	Non-spr.	Ant	0.000	0.076	12
Tall shrub	Sprouter	Passive	0.000	0.070	13
Tall shrub	Sprouter	Ant	0.500	0.253	3
Graminoid	Non-spr.	Passive	0.018	0.023	42
Graminoid	Non-spr.	Wind	0.000	0.002	598
Graminoid	Non-spr.	Ant	0.167	0.024	41
Graminoid	Sprouter	Passive	0.022	0.019	52
Graminoid	Sprouter	Wind	0.091	0.091	10
Graminoid	Sprouter	Ant	0.048	0.079	12
Forb	Non-spr.	Passive	0.033	0.032	30
Forb	Non-spr.	Wind	0.000	0.002	423
Forb	Non-spr.	Ant	0.000	0.033	29
Forb	Sprouter	Passive	0.020	0.004	247
Forb	Sprouter	Wind	0.022	0.021	47
Forb	Sprouter	Ant	0.000	0.018	55
Geophyte	Sprouter	Passive	0.013	0.012	84
Geophyte	Sprouter	Wind	0.061	0.059	16
Geophyte	Sprouter	Ant	0.000	0.051	19

* Indicates that there are nine chances of a species being non-endemic and one of being endemic. The odds on endemism is one to nine.

investigation showed that only a few of the GR interactions were statistically different from zero. These interactions pertained to the graminoids and tall shrubs. A cross-classification of the data is presented to show the odds against endemism (Table 4.7) on the basis of these two attributes.

Inferences from the model are summarized:

1. Tall, sprouting, ant-dispersed shrubs have the lowest odds against being endemic (Table 4.4).

2. Low shrubs have low odds against being endemic if they are passively or ant-dispersed non-sprouters. The odds are virtually the same for both these dispersal modes (Table 4.4).

3. Sprouting graminoids have low odds against being endemic if they are wind or ant-dispersed (Table 4.4).

4. Ant-dispersed species generally have low odds against endemism and wind dispersed species high odds. Of the 14 combinations of biological attributes which have odds against endemism of less than 1:20, 50% are ant dispersed and 71% of the seven combinations which have high odds against endemism (>1:100) are wind dispersed (Table 4.8).

5. For all growth forms, ant-dispersed species have low odds against being endemic, irrespective of the regeneration strategy. Passively dispersed species however, have low odds against endemism only if they are non-sprouters. Wind dispersed species show the opposite trend (Table 4.6).

6. Irrespective of dispersal mode, shrubs have low odds against endemism if they are non-sprouters. Mid-high shrubs have higher odds than the other two size classes. Tall shrubs which are sprouters have the lowest odds against endemism (Table 4.7).

The model enabled us to estimate odds on endemism for GDR combinations in which no endemics were found (Table 4.4). The model indicates that the odds on endemism in some of these combinations were much smaller than others, for instance the combination of a non-sprouting, wind-dispersed

Table 4.6: A cross-classification of the data on the bases of the evidence for dispersal mode by regeneration interaction. The true odds against endemism with respect to these two attributes are displayed.

Dispersal Mode	Regeneration strategy	
	Non-sprouter	Sprouter
Passive	1:16*	1:70
Wind	1:224	1:17
Ant	1:12	1:15

* This implies that the chance of a plant with a passive dispersal mode and a non-sprouting regeneration strategy of being endemic is one out of 17.

Table 4.7: A cross-classification of the data on the basis of the evidence for growth form by regeneration interactions. The true odds against endemism with respect to these attributes are displayed.

Growth Form	Regeneration strategy	
	Non-sprouter	Sprouter
Low Shrub	1:11*	1:45
Mid-high Shrub	1:19	-
Tall Shrub	1:13	1:8
Graminoid	1:44	1:34
Forb	1:41	1:49
Geophyte	-	1:27

* This implies that the chance of a plant that is a low shrub and has a non-sprouting regeneration strategy being an endemic is one out of 12.

Table 4.8: The odds against endemism displaying those particular patterns of biological traits in Peninsula plants which have the highest likelihood of being endemic first. The likelihood of being endemic diminishes towards the bottom of the table.

Growth Form	Regeneration Strategy	Dispersal Mode	Odds
Tall Shrub	Sprouter	Ant	3*
Low Shrub	Non-sprouter	Ant	9
Low Shrub	Non-sprouter	Passive	9
Graminoid	Sprouter	Wind	10
Graminoid	Sprouter	Ant	12
Tall Shrub	Non-sprouter	Ant	12
Tall Shrub	Non-sprouter	Passive	13
Tall Shrub	Sprouter	Passive	13
Low Shrub	Sprouter	Wind	15
Mid-high Shrub	Non-sprouter	Ant	15
Geophyte	Sprouter	Wind	16
Mid-high Shrub	Non-sprouter	Passive	16
Low Shrub	Sprouter	Ant	17
Geophyte	Sprouter	Ant	19
Forb	Non-sprouter	Ant	29
Forb	Non-sprouter	Passive	30
Graminoid	Non-sprouter	Ant	41
Graminoid	Non-sprouter	Passive	42
Forb	Sprouter	Wind	47
Graminoid	Sprouter	Passive	52
Forb	Sprouter	Ant	55
Low Shrub	Sprouter	Passive	78
Geophyte	Sprouter	Passive	84
Mid-high Shrub	Sprouter	Passive	131
Low Shrub	Non-sprouter	Wind	133
Tall Shrub	Non-sprouter	Wind	177
Mid-high Shrub	Non-sprouter	Wind	225
Forb	Sprouter	Passive	247
Forb	Non-sprouter	Wind	423
Graminoid	Non-sprouter	Wind	599

* Indicates that there are three chances of a tall, sprouting, ant-dispersed shrub of being non-endemic and one of being endemic. The odds on endemism for this particular pattern of attributes is one to three.

graminoid with odds of 1 to 599 are far less likely to have endemics than non-sprouting, ant-dispersed forbs with odds of 1 to 29 (Table 4.8).

DISCUSSION

4.11 Level of endemicity

The percentage of endemism in the flora of the Peninsula at 3.98% (Table 4.9), is less than the level of between 7 to 10% in previous studies (Raven and Axelrod, 1978; Goldblatt, 1978; Cowling *et al.*, 1992; McDonald and Cowling, 1995). When compared to other areas in the Cape Floristic Region (CFR), continental areas, islands and mountains (Table 4.9), the percent endemism for the Peninsula is low. The number of Peninsula endemics (90) however, as determined in this study, is remarkable for an area of such small size. The calculated Bykov's index I_e value (6.1), exceeds those for other continental areas which include both tropical and similar Mediterranean-type climate regions (Table 4.9). These regions are known for high levels of endemism compared to other areas in the world (Cody, 1986; Gentry,1986; Cowling, *et al.*, 1992). The I_e value equates more to geographically or environmentally isolated areas such as certain oceanic islands and mountain peaks, areas which are generally known for high levels of endemism due to their isolation (Major, 1988,) (see Table 4.9). At a regional scale, the level of endemicity for the Peninsula was similar when compared to studies done in other areas in the CFR (Cowling et al., 1992; McDonald and Cowling, 1995). Humansdorp in the extreme east and Agulhas in the south (both primarily coastal flats), have slightly lower I_e values and the Langeberg mountains in the southern CFR has a higher value than the Peninsula (Table 4.9). However, if one considers that only 310km^2 of the Peninsula remains natural once all transformed land is removed, and all 90 of the endemics occur in this area, the I_e value increases to 9.1. This value, albeit an artifact of anthropogenic interference, accurately reflects the current status and is then higher than for any of the areas studied. The trend which emerges is that levels of endemism increase from east to west in the CFR and from coastal flats to areas with mountainous terrain.

Table 4.9: Levels of endemism in four areas within the Cape Floristic Region, (CFR), various continental areas, mountains and islands. (I_e - Bykov's index used to compare levels of endemism for areas of different size).

Locality	Area km^2	Local endemics	%Endemism	I_e
CFR and areas within				
Cape Floristic Region	90000	-	68	10.5
Langeberg[1]	1748	160	13.02	8.68
Humansdorp[2]	5050	109*	12.45	5.39
Agulhas[2]	1609	100	12.4	5.33
Cape Peninsula[3]	471	90	3.98	6.1
Continental areas				
Iberian Peninsula[4]	582000	-	26	1.92
Panama[6]	75000	-	15	2.5
California[4]	411000	-	30	2.7
Greece[4]	129000	-	20	2.5
Israel[4]	20000	-	6.5	1.6
Islands				
Taiwan[4]	36000	-	48	10.66
Phillipines[4]	290000	-	72.6	7.41
Cyprus[4]	93000	-	5.9	2.18
Hawaii[5]	16600	-	43	13
New Zealand[5]	268000	-	81	9
Mountains				
Pyrenees[4]	12000	-	14	4.2
Alps[4]	110000	-	31	3.9

[1] McDonald and Cowling (1995)
[2] Cowling and Holmes (1992) and Cowling *et al.*, (1992)
[3] This study
[4] Compiled by Major (1988)
[5] Compiled by Bond and Goldblatt (1984)
[6] Compiled by Gentry (1986)

* Regional endemics

A point which needs to be raised is the question of the number of 'real' endemics in any particular area studied. The southern Langeberg for instance, is fringed by poorly collected areas. Better collection of the inland mountains may well reveal species regarded as endemic to that area to occur elsewhere. Such discoveries could ultimately reduce the number of endemics listed for local floras as well as for the Cape Floristic Region in general.

4.12 Taxonomic and biological profiles of endemics

The taxonomic and biological profiles of Peninsula endemics were very similar to those from other predominantly fynbos floras from the Cape Floristic Region. As in the Peninsula flora, studies of the Agulhas Plain flora (Cowling and Holmes, 1992) and the Langeberg Mountain flora (McDonald and Cowling, 1995) showed that endemics were massively over-represented among Ericaceae. On the Peninsula Proteaceae, Mesembryanthemaceae, Rutaceae, Sterculiaceae, Brassicaceae and Bruniaceae had higher than average (6.68%, excluding Ericaceae) numbers of endemic taxa. This related well to the Agulhas and southern Langeberg floras where three of the four and three of the nine families with a higher than average number of endemics were the same as the Peninsula respectively. In the case of the Agulhas flora Proteaceae, Mesembryanthemaceae and Rutaceae were the same and Mesembryanthemaceae, Rutaceae and Bruniaceae were the Langeberg families which coincided. As was the case for the above mentioned floras, Peninsula endemics were restricted to a remarkably small proportion of higher taxa. The Langeberg has 25 (McDonald and Cowling, 1995), the Peninsula 18 (Table 4.1) and Agulhas Plain 16 families with endemics (Cowling and Holmes, 1992). There is a high level of similarity between families with endemics in these floras. Ten families with endemic species occur in all three floras. The Agulhas Plain has no family with endemic species unique to itself since the remaining six families with endemics are shared with the floras of either the Peninsula or the Langeberg. These results would suggest that certain families are more prone to endemism than others. With respect to how 'typical' these families are of 'fynbos', there is no clear distinction to be made. Approximately one half of the shared families (Ericaceae, Proteaceae, Restionaceae, Rutaceae, Polygalaceae, Bruniaceae and Thymelaeaceae) are families which distinguish fynbos (Gibbs Russell, 1987) and the majority of the remaining families have a cosmopolitan distribution (Gibbs Russell, 1985).

With respect to biological traits, the profile of an endemic on the Peninsula was similar to the Agulhas and Langeberg floras (Cowling and Holmes, 1992; McDonald and Cowling, 1995; McDonald *et al.*, in press). All three floras showed endemics were more than likely to be non-sprouting shrubs with seeds dispersed either passively or by ants (short dispersal distance). Short dispersal distance is associated with narrow endemism in Californian (Lewis, 1962), tropical (Gentry, 1986) and Australian floras (Renner, 1990). Similarly, studies in California have shown high levels of endemism in taxa with non-sprouting as a regeneration mechanism (Lewis 1962; Wells, 1969).

4.13 Comparative profiles of endemic and threatened taxa

Endemics and threatened taxa were not a random assemblage and had similar taxonomic and biological profiles. This is expected given the substantial overlap between the endemic and threatened floras. However, the families Orchidaceae and Restionaceae had higher-than-expected numbers of threatened but not endemic taxa. The former has many taxa that are pollinator-specific (Johnson, 1992; Johnson and Bond, 1993) and the latter many habitat specific taxa (Linder, 1985). Both these phenomena are conducive to various forms of rarity (Rabinowitz, *et al.*, 1986). The high level (70%) of endemics which are threatened would suggest that Peninsula endemics are part of the group of plants highly vulnerable to extinction in the area.

The biological profile of a threatened species was remarkably similar to that of an endemic, being characterized predominantly as a low shrub habit with short dispersal distance. However, the proportion of threatened and non-threatened taxa were similar in both regeneration categories, suggesting that the mode of fire survival is not a trait strongly associated with rarity.

These differences in the biological and taxonomic profiles of endemic and threatened taxa are attributed to the relatively high frequency among threatened taxa of sprouting plants with wind dispersed seeds, being largely geophytes belonging to the Orchidaceae and Iridaceae, but also graminoids in the Restionaceae and Cyperaceae.

4.14 Habitat and biology in relation to threats

Many endemic and rare species are habitat specialists (Raven, 1964; Hedberg, 1965; Papanicolaou *et al.*, 1983; Baskin and Baskin, 1988; Cowling et al., 1992; Linder *et al.*, 1993). Studies in a lowland area to the south east of the Peninsula, on the Agulhas Plain, have shown a high degree of edaphic specificity among endemics. Endemic taxa are especially over-represented relative to the areas occupied by these unusual substrata (Cowling and Holmes, 1992). In the Langeberg, a montane area in the southern Cape, endemics are significantly over-represented in high altitude, wet habitats (McDonald and Cowling, 1995). Peninsula endemics were similarly over-represented, relative to area occupied, in vegetation types associated with high altitude, wet habitats. Their over-representation in certain lowland habitats is probably an artifact of their enormous reduction as a result of urbanization (Richardson *et al.*, in press). Not surprisingly, threatened taxa show similar vegetation/habitat relationships to endemic species. The largest numbers of both groups of taxa occur in the lowland vegetation types and these also occupy the largest area. It is precisely these habitats that are most vulnerable to further transformations, through for example, alien plant invasion and urbanization, leading to serious losses in biodiversity (Richardson *et al.*, in press). It is crucial, therefore, that lowland areas identified as irreplaceable sites in terms of their biological uniqueness, are speedily incorporated into a formal reserve network.

Many Peninsula endemics and regionally threatened taxa have small populations associated with rare and unusual habitats (T. Trinder-Smith, personal observation). The destruction of such habitats is likely to result in severe population reductions or even extinction. The biological characteristics of many endemics and threatened taxa also make them vulnerable to extinction. For example, low non-sprouting shrub species are most adversely affected by alien plants invasions (Richardson and Van Wilgen, 1986; Richardson *et al.*, 1989). Ant-dispersed species are especially vulnerable to the invasive alien ant *Iridomyrmex humilis*, which ousts indigenous ant species, thereby collapsing the ant-seed mutualism essential for good post fire regeneration of myrmecochores (Bond and Slingsby, 1984, see also McDonald and Cowling, 1995). The high frequency and also, therefore, the low intensity burning regime that is now widespread on the Peninsula is particularly inimical to the regeneration of large seeded (Bond *et al.*, 1990), and slow maturing species (Van Wilgen *et al.*, 1992), a combination of traits associated with many endemic and threatened taxa. Finally, the reproductive success of the threatened pollinator-specific geophytes (Johnson, 1992; Johnson and Bond, 1992) is likely to be adversely affected by habitat transformation leading to population fragmentation (Usher, 1987).

CONCLUSION

Judging from the results of this study and the comparisons with other floras in the Cape Floristic Region, a general taxonomic and biological profile for an endemic and a threatened plant begins to emerge. However, as tempting as it may be to categorize a Peninsula endemic as a "typical" fynbos endemic, there are a number of points which need to be raised. The areas so far studied were confined to a relatively small area within the western sector of the CFR. Areas in the eastern and north-western parts need similar studies conducted since environmental conditions are known to differ substantially across the extent of the Floristic Region (Goldblatt, 1978). Rainfall progressively decreases and becomes more seasonal towards the west and north-west, a factor which influences the ecological functioning of the fynbos flora. An analysis of the Cedarberg flora in the north-west and the Baviaanskloof mountains in the east, for which checklists now exist, would be beneficial. Therefore, only once we have evaluated whether we can talk of a "typical" fynbos endemic profile can we regard the Peninsula as being "typical".

The established taxonomic and biological profiles of endemics do offer a substantially improved basis from which to approach the management of these taxa. However, thus far, approaches to the conservation of the Cape Peninsula's flora have focussed on the distribution and population sizes of threatened taxa (Hall and Ashton, 1983), threats such as alien plants and urbanization (Moll and Trinder-Smith, 1992; Richardson *et al.*, in press) and the optimal location of a reserve network. Very little attention has been given to the dynamic aspects of biodiversity conservation on the Peninsula. Clearly, initial intervention should be aimed at establishing and defending an appropriate reserve network. However, more research is required on the management requirements of the numerous endemic and rare species, including those that are not classified as threatened, on the Peninsula (see also Simmons and Cowling, in press).

CHAPTER 5

RESERVE SCENARIOS FOR THE CAPE PENINSULA: HIGH, MIDDLE AND LOW ROAD OPTIONS FOR CONSERVING THE REMAINING BIODIVERSITY

SUMMARY

The Cape Peninsula is botanically exceptionally species-rich and has high concentrations of both endemic and threatened plant species. Alien invasive trees, urban expansion and growing tourism are impacting increasingly on the landscape and biota. Three reserve scenarios were modelled, the primary objective being to maximize the conservation of biodiversity in a manner which takes both cost and efficiency into account. A comprehensive plant species database, an endemic animal species database, a vegetation type database, land-tenure and land-use data were used in this process. The resolution of all databases was 1 by 1 km cells. The first scenario investigated the effectiveness of the existing reserve system in conserving the Peninsula's biodiversity. The second assessed the benefit of adding all publicly owned land to the existing reserves. In scenario three, a reserve-selection algorithm was applied to conserve those plant species outside existing reserves at least once. Where endemic animal species, and areas with high concentrations of threatened and endemic plant species were not adequately conserved, extra cells were added for their inclusion. Finally, one cell was added to cater for one inadequately conserved vegetation type. Fifty-one cells were needed to satisfy the requirements stipulated in scenario threets
. Analyses showed that twenty-two per cent of plant species have all their records within existing reserves. Adding all public land improves the status to 43% with 97% of those having >50% of their records included in reserves. In scenario three, these figures are 32% and 87% respectively. In terms of animal species, four species are unconserved in scenario one, two in scenario two, and all species are conserved in scenario three. I conclude that scenarios two and three provide practical options for conserving the Peninsula's remaining biodiversity.

INTRODUCTION

The Cape Peninsula is situated in the extreme south-western corner of the Cape Floristic Region (CFR) (Bond and Goldblatt, 1984), and comprises a predominantly fynbos vegetation (Cowling and Macdonald, in press). The Peninsula occupies an area of 471 km^2 and is topographically and climatically complex. The Peninsula is also extremely rich in species (Simmons and Cowling, in press), endemics and threatened taxa (Hall and Ashton, 1983; Picker and Samways, in press). These attributes qualify it for exceptional conservation status locally, nationally and globally (Van Wilgen, in press). Unfortunately, the area is subject to increasing alien plant invasion, urban development and recreational demands (Richardson *et al.*, in press).

The Peninsula has enormous potential for the generation of income from recreation and tourism, particularly ecotourism. However, this demands that its use be appropriately managed (Van Wilgen, in press) and, most importantly, that a representative reserve (protected area) system be designed for the Peninsula. Such a system is currently lacking. Proclaiming a reserve system which caters for the needs of people and the effective conservation of the environment would be a major step towards achieving the long-term sustainability of the biodiversity of the Peninsula.

The Peninsula has an existing complement of four, isolated reserves. The Cape of Good Hope Reserve (GHR - 8104 ha) is the largest and encompasses the southern tip of the area. Table Mountain Nature Reserve (TMR - 3058 ha) is in the northern part and incorporates the upper reaches of Table Mountain, Lion's Head and Signal Hill. Silvermine Nature Reserve (SMR - 2166 ha) is situated in the central block of mountains which includes the Muizenberg, Steenberg and Kalk Bay Mountains. The smallest, Rondevlei Bird Sanctuary (RVBS - 208 ha), encloses a freshwater body recognized for its importance as a sanctuary for numerous migratory and non-migratory water birds.

This chapter aims to establish how effective the current reserves are in conserving the Peninsula's plants and animals and it is attempted to design a system of reserves which would conserve all those plant and endemic animal species not already conserved, in a manner which takes land suitability, cost and efficiency into account (Bedward *et al.*, 1991). Various scenarios are explored and viewed with respect to the above mentioned criteria. Particular attention is given to the inclusion of those areas where concentrations of endemic and/or threatened biota occur.

APPROACH AND METHODS

Procedures directed at the selection of reserve sites are increasingly based on sound ecological principles which take population genetics (Soulè and Simberloff, 1986; Cowling and Bond, 1991), areas of concentrated endemism or rare plant species (Terborgh and Winter, 1983; Rebelo and Tansley, 1993), focal taxa (Ryti, 1992) and/or total biological diversity into consideration (Margules *et al.*, 1988). The latter approach may include weighting for taxonomic (Williams *et al.*, 1991) or biological peculiarity (Faith, 1992; Linder and Midgley, 1994). The quality of the data often determines the process or method whereby reserves are selected (Kirkpatrick, 1983; Rapoport *et al.*, 1986; McKenzie *et al.*, 1989; Rebelo and Siegfried, 1992). Where the data are poor, the theoretical aspects of conservation (island biogeography models and metapopulation dynamics) are often relied upon when conservation decisions need to be made (Margules and Stein, 1989; Doak and Mills, 1994). In this study, I use a comprehensive plant database and an incomplete animal species database, to design a reserve system which will ensure maximum conservation of biological diversity. I use plants as the focal taxon around which reserves are designed (Margules *et al.*, 1988), considering that distributional data for other taxa are at a less refined scale or lacking in the case of many invertebrates. A conservation strategy based primarily on plant distributions, would, by associations such as herbivory, conserve many of the animal species (primarily insects) not considered in this study (Picker and Samways, in press). I also attempt to conserve as much of each of the 15 vegetation types (Fig. 5.1) as possible, hence ensuring that all habitats are adequately conserved (>33% of the area covered by each vegetation type was regarded as adequate). Cowling and Bond (1991) emphasize the importance of area size to ensure genetic viability of Cape fynbos species. The areas under discussion, particularly the larger reserves, are sufficiently large (>300-600 ha) to discount the possibility of species loss owing to habitat fragmentation. However, the use of the term 'conserve' in this chapter does not imply that viable populations of biota have been protected, but rather that species, or vegetation types, have been incorporated into reserves. There are currently insufficient data to allow population viability assessments to be completed for all species in the database.

6.1 Databases

All spatial databases for the Cape Peninsula were analysed using a Geographic Information System (GIS): ARC/INFO version 6.1.1, Environmental Systems Research Institute, Redlands, California. The data used, their sources and their scales are summarized in Table 5.1. A Gauss Conformal Conic projection was used for all data. Digital maps were generated for all species' distributions, vegetation types, land tenure and land uses.

6.2 Plant Species

A total of 2253 indigenous plant species, in 137 families, was used in the analyses. There were insufficient distributional data for an additional 32 species, which were thus omitted from the analyses. As shown in Table 5.1, plant specimens from herbarium records were coded for the 1 x 1 km grid cell, on the Cape Peninsula, in which they had been found. Table 5.2 describes the score given to each species, based on its status on the Peninsula as defined by Hall and Ashton (1983) and T. Trinder-Smith . 'Endemic' plants are found only on the Cape Peninsula, 'rare' plants have < 5 records on the Peninsula, but may occur elsewhere in the south-western Cape, and 'threatened' plants are listed in the Red Data Book (Hall and Veldhuis, 1985). All endemic species are categorized according to version 2.2 (Mace and Stuart, 1994) of the IUCN threatened plant categories, and the 'threatened' plants according to version 1 (Lucas and Synge, 1978). A total of 167 species received scores. Data were manipulated to exclude duplicate occurrences of species within Peninsula grid cells. Sums of all species' scores were then calculated for each grid cell. These data, rather than species richness, were used in the reserve-selection procedure. This plant species database, which consists of 48139 records, can be considered as relatively complete (*i.e.* all available data are included).

Table 5.1: Spatial databases used in all analyses

Database	Source	Description
Peninsula grid	T. Trinder-Smith	A grid of 590 1 x 1 km cells covering the study area
Plant species	Herbarium records extracted from the four main herbaria in South Africa*	Each specimen was coded for the appropriate Peninsula grid cell
Animal species	Literature records	Each species was coded for the appropriate Peninsula grid cell
Vegetation types	Institute for Plant Conservation (IPC), University of Cape Town	Polygons were delineated on 1:10 000 orthophotos
Alien vegetation	IPC; Forestek	Polygons of alien cover were delineated on 1:10 000 orthophotos
Land tenure	Cape Town City Council	Polygons were delineated on 1:10 000 orthophotos
Land use	Forestek	Polygons were derived from Landsat TM imagery: Landsat 5, Oct. 1992, 30 x 30 m resolution

*BOL, PRE, NBG, STE (Holmgren *et al.*, 1990)

Table 5.2: Scores assigned to plant species, depicting their status on the Cape Peninsula (based on Red Data Book or as assigned by T. Trinder-Smith)

Score	Number of Species	Status on Cape Peninsula
1	36	Threatened
2	40	Rare and threatened
3	26	Endemic
4	37	Endemic and threatened
5	28	Endemic, rare and threatened
Total	167	

6.3 Animal species

The distributions of 44 species (representing 17 families)(Table 5.3) were mapped, using distribution records from the literature. Most of these species are considered endemic to the Peninsula (a few are near endemics), thus no scoring system was used to rank species. The species richness in each Peninsula grid cell was calculated and used for the reserve-selection procedure. This species database is incomplete, in that only those species considered to be endemic to the Peninsula were included, and within this subset, only those species with distributions described in the published literature were included. The insect fauna was excluded and the composition and nature of this fauna is described by Picker and Samways (in press).

6.4 Vegetation types

A total of 15 vegetation types was mapped (Fig. 5.1). Vegetation types were delineated on 1:10 000 orthophotos (Cowling and Macdonald, in press; Table 5.1).

6.5 Alien vegetation

Data for alien vegetation included the distributions of the six major invasives, namely *Acacia cyclops* A. Cunn. ex G.Don; *A. saligna* (Labill.) Wendl., *Hakea gibbosa* (Sm.) Cav., *H. sericea* Schrad., *Pinus pinaster* Ait. and *P. radiata* D. Don. Other alien species do exist on the Peninsula, but these six species were considered to pose the greatest threat to indigenous vegetation (Moll and Trinder-Smith, 1992). Each polygon of alien vegetation was coded for the percentage alien coverage, as follows: 5-25 %, 25-50 %, 50-75 % (dense), > 75 % (very dense) (Fig. 5.2).

6.6 Land tenure

A new, composite map of land tenure (Fig. 5.3) was derived from the land-tenure and land-use databases described in Table 5.1. Existing reserves were obtained from the land-tenure database. Areas coded as urban within the land-tenure and land-use databases were classified as 'developed', as were areas

Table 5.3: Animal families, and numbers of species used in reserve selection

Family	Common name	Number of species
Acropsopilionidae	harvestmen	1
Arionidae	slugs	1
Bufonidae	frogs	1
Buthidae	scorpion	1
Chthoniidae	pseudoscorpions	1
Endodontidae	snails	2
Leptodactylidae	frogs	1
Lucanidae	stag beetles	1
Lycaenidae	butterflies	4
Paramelitidae	amphipods	8
Peripatopsidae	velvet worms	2
Pipidae	frogs	1
Rhaphidophoridae	camel crickets	1
Sironidae	harvestmen	2
Spelaeogryphidae	shrimp	1
Triaenonychidae	harvestmen	12
Trichoniscidae	isopods	4
Total		44

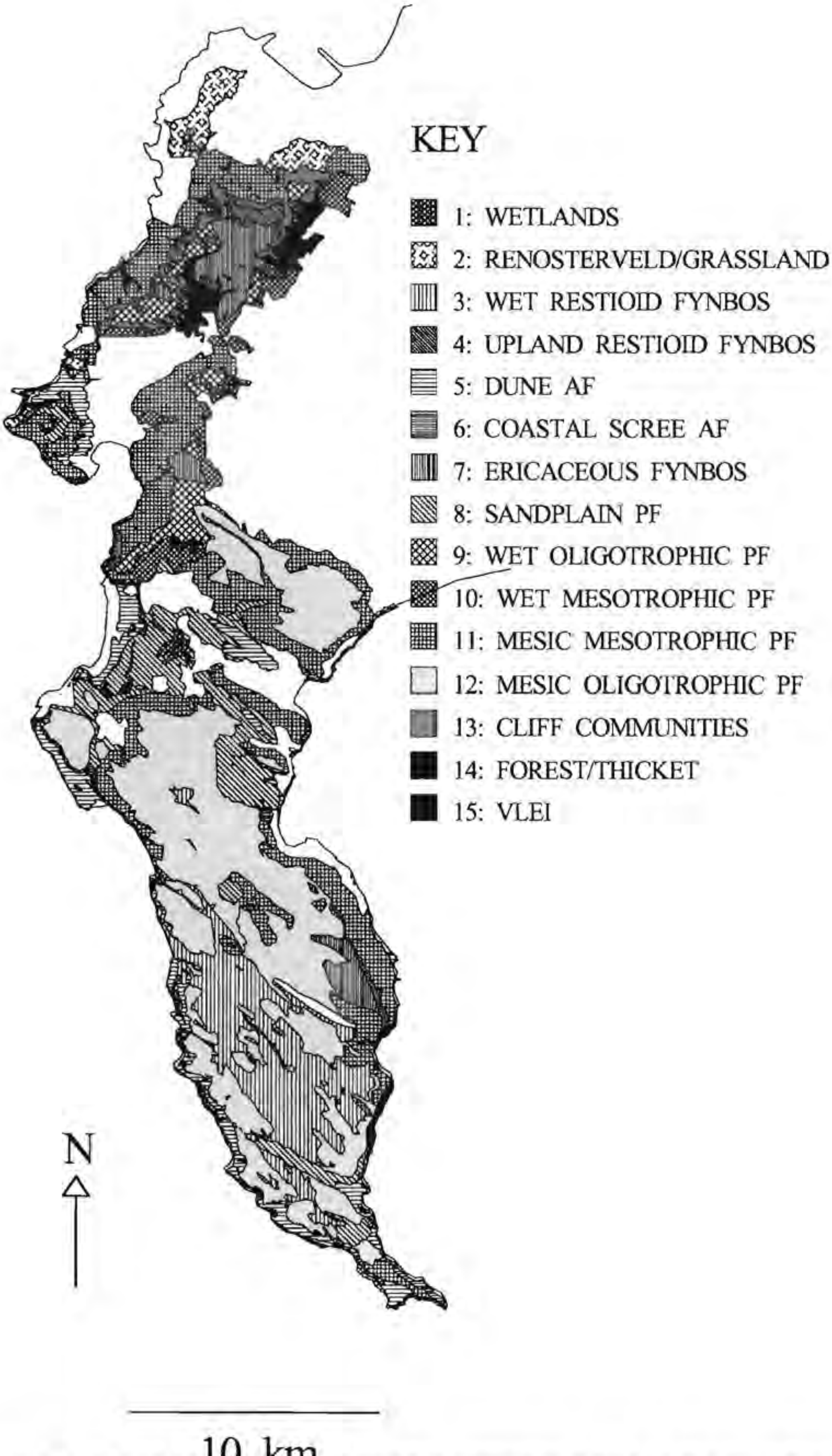

Figure 5.1 The 15 vegetation types found in undeveloped land on the Cape Peninsula. AF - Asteraceous Fynbos; PF - Proteoid Fynbos.

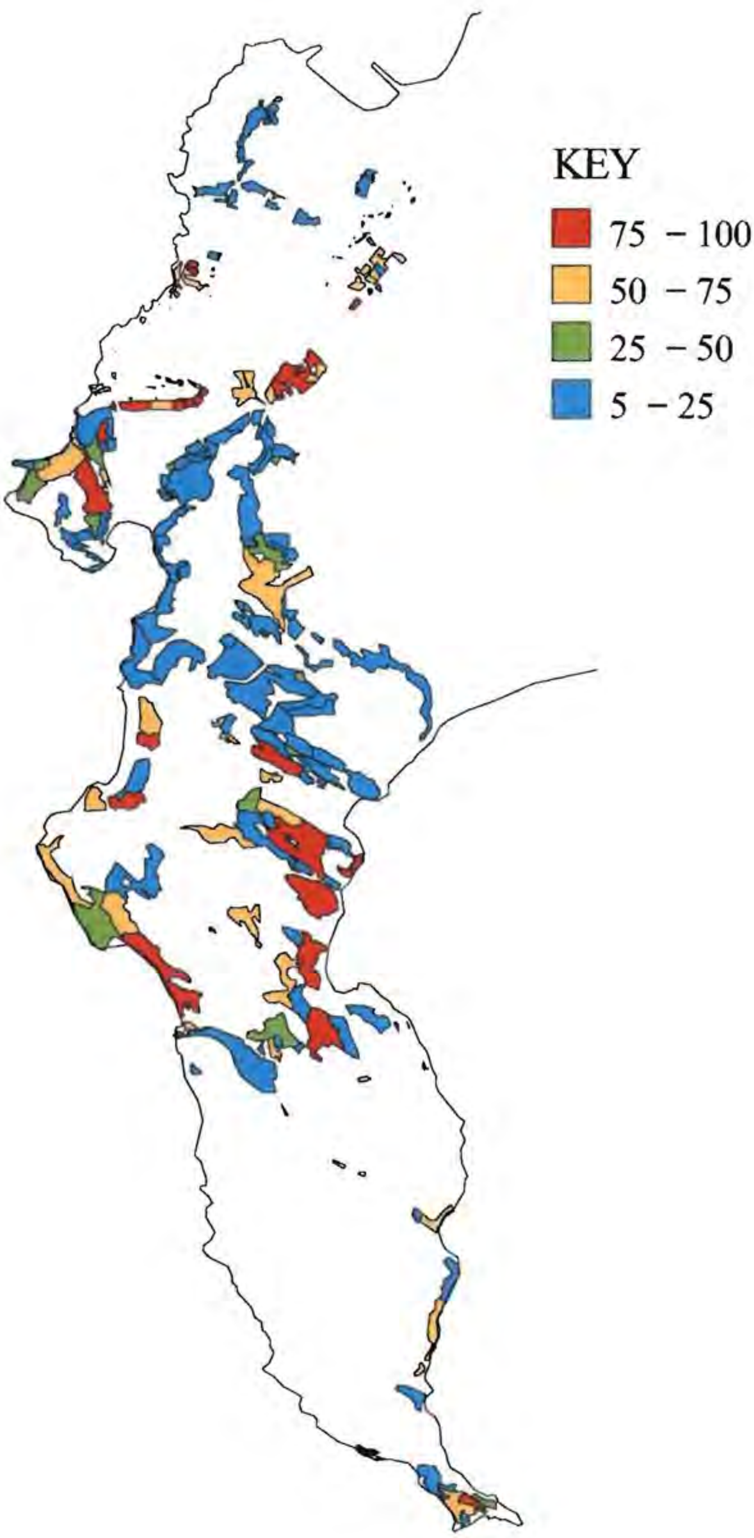

Figure 5.2. Alien vegetation on the Peninsula. Different shades denote the percentage cover of six alien species (*Acacia cyclops, A. saligna, Hakea gibbosa, H. sericea, Pinus pinaster* and *P. radiata*). Coverages of these six species are combined for the purpose of displaying percentage cover.

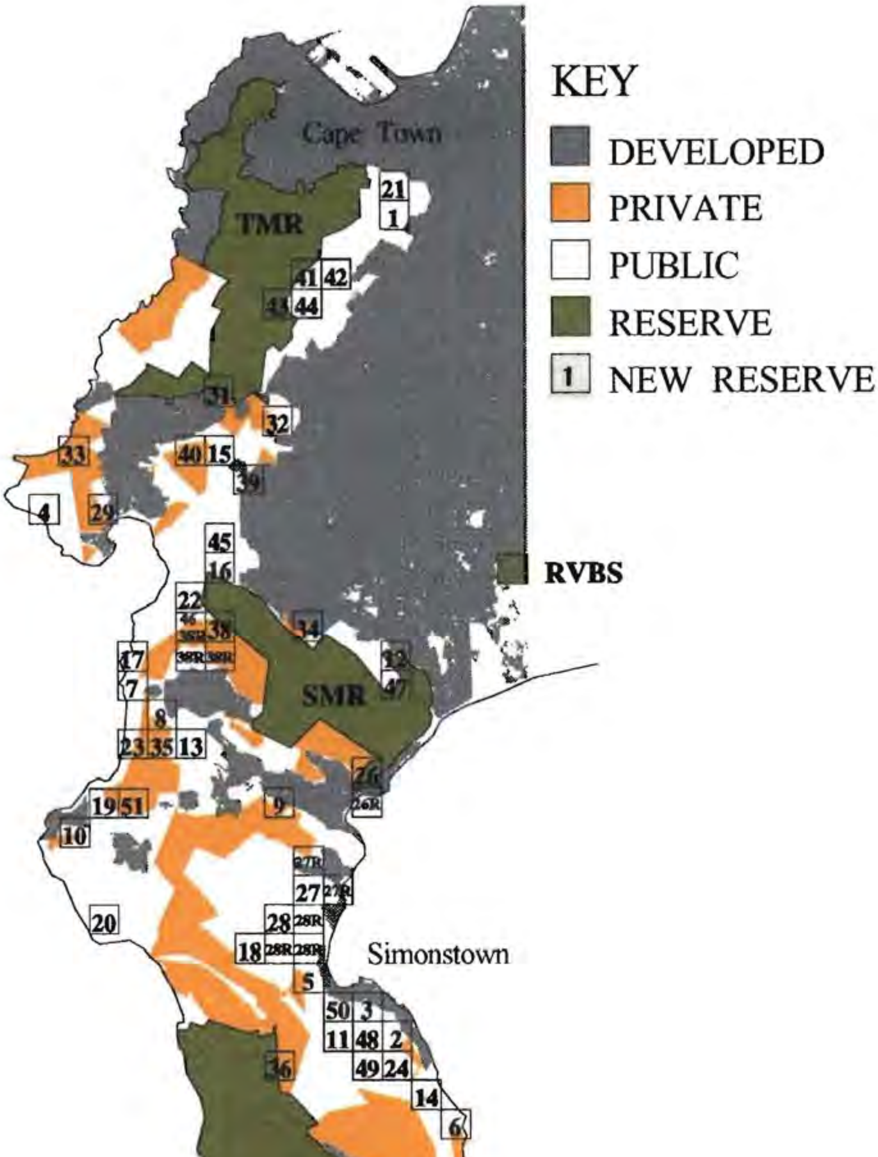

Figure 5.3. Land tenure on the Cape Peninsula, and the 51 cells selected for conservation by scenario 3 (which assumes that not all public land is available for conservation). Cells 1-38 represent all plant species at least once (1-28 fall on public land, and 29-38 fall on private land). Cells 39 and 40 protect currently unconserved animal species, cells 41-50 protect unconserved hotspots, and cell 51 protects an inadequately conserved vegetation type (vlei). Cells marked with an 'R' indicate flexibility (e.g. cell 28 can be replaced with one of three other cells). (TMR-Table Mountain Reserve, SMR-Silvermine Reserve, GHR- Cape of Good Hope Reserve, RVBS- Rondevlei Bird Sanctuary).

coded as agriculture within the land-use database. Areas coded as private within the land-use database were classified as 'private', and all remaining areas were classified as 'public'. Each cell in the Peninsula grid (see Table 5.1) was coded for the four land-tenure categories in Fig. 5.3. Reserve cells were coded for the per cent of the cell falling within the reserve (1-33 %, 33-66 %, 66-100 %). A cell was considered conserved only if > 33 % fell in an existing reserve. The same ruling applied to developed cells. Remaining cells were coded for the land-tenure category that occupied the greatest cell area. Owing to the fact that plant specimens were obtained from herbarium records, a possibility exists that certain species may no longer be extant on the Peninsula, as a result of extensive urbanization. Consequently, all developed areas were excluded from the reserve design analyses, and only undeveloped land was considered available for further conservation. Undeveloped land thus included existing reserves, or undeveloped public or private land.

6.7 Reserve scenarios

Three different reserve scenarios were modelled for the Peninsula. Scenario one (the 'low road') determined the conservation status of the plant and endemic animal species, and vegetation types, within the existing four reserves. The conservation status of plant species and vegetation types was calculated as the percentage of the known records of each plant species, and percentage of each vegetation type, that fell within existing reserves. Animal species were considered conserved if at least one record fell within a reserve. Scenario two (the 'high road') recalculated these figures in the event of all publicly owned land (as shown in Fig. 5.3) being added to existing reserves. Scenario three (the 'middle road') used an iterative reserve-selection algorithm (Rebelo and Siegfried, 1992) to identify the minimum, or close to minimum, number of grid cells that would incorporate all of the currently unconserved plant species on the Peninsula. This algorithm is similar to other heuristic reserve-selection algorithms defined by Kirkpatrick (1983) and Margules *et al.* (1988), in that it identifies a set of complementary reserves that would capture all species at least once. Cells were chosen in public land where possible, but 13 species are found in private land only, thus scenario three does include the incorporation of certain private areas into the reserve system. Additional cells were added to scenario three to incorporate (i) unconserved 'hotspots' of high scoring plant species; (ii) unconserved animal species; (iii) unconserved hotspots of animal species richness; and (iv) vegetation types not adequately conserved (*i.e.* < 33 % of vegetation type conserved).

RESULTS

Once all developed land had been excluded from analyses, 147 plant and one animal species (the harvestman *Montadaeum purcelli* Lawrence.), as well as a percentage of some vegetation types, were lost. Of the 147 lost plant species, 21 are scored species (see Table 5.2) of which three occur on Rondebosch Common and 11 occur on Kenilworth Racecourse. These two areas are small vestiges of semi-natural vegetation nested within urban areas. One species is common to both sites (see below). The Red Data Book status of two of the Rondebosch Common species is indeterminate, and one is critically rare. Two of the Kenilworth Racecourse species are endemic, of which one is extinct in the wild, and one is critically rare. Of the remaining nine species, one is critically rare, one is endangered, three are vulnerable and four are indeterminate (Hall and Veldhuis, 1985). The threatened species of indeterminate status, *Eriospermum pumilum* Salter (Eriospermaceae) occurs at both sites.

Of the remaining eight scored species that are lost, two are endemic. *Moraea aristata* (Delaroche) Aschers. & Graebn. is found in the Royal Observatory grounds, and should receive a high conservation priority. *Hermannia procumbens* Cav. occurs on Paarden Island and is currently listed as critically rare, but its status needs to be re-evaluated. The status of the remaining six species is rare and threatened, of which five are indeterminate and one is uncertain.

Fig. 5.4 depicts the area of each vegetation type, falling within undeveloped land. Mesic proteoid fynbos (types 11 and 12) makes up just over 50 % of the total undeveloped area.

The cumulative scores for plant species, per cell, are shown in Fig. 5.5. Five areas of importance were identified. These include the central and eastern portions of TMR (Reserve Peak and Skeleton Gorge), the eastern edge of SMR (in the vicinity of the Muizenberg Cave), the north-western edge of SMR (Noordhoek Peak), the area just to the south of Simonstown (northern peak of

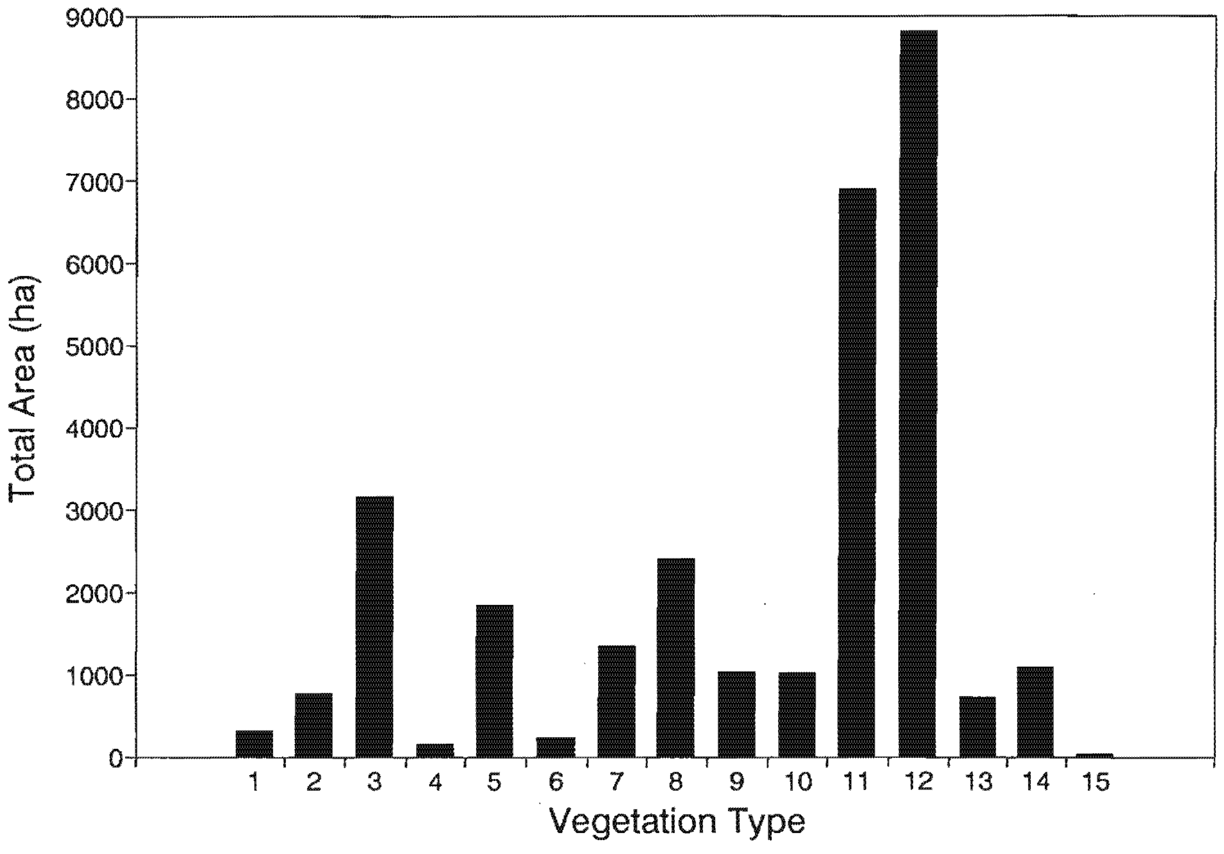

Figure 5.4. The total area of each vegetation type falling within undeveloped land. (1 - wetlands, 2 - renosterveld /grasslands, 3 - wet restioid fynbos, 4 - upland restioid fynbos, 5 - dune asteraceous fynbos, 6 - coastal scree asteraceous fynbos, 7 - ericaceous fynbos, 8 - sandplain proteoid fynbos, 9 - wet oligotrophic proteoid fynbos, 10 - wet mesotrophic proteoid fynbos, 11 - mesic mesotrophic proteoid fynbos, 12 - mesic oligotrophic proteoid fynbos, 13 - undifferentiated cliff communities, 14 - forest/thicket, 15 - vlei).

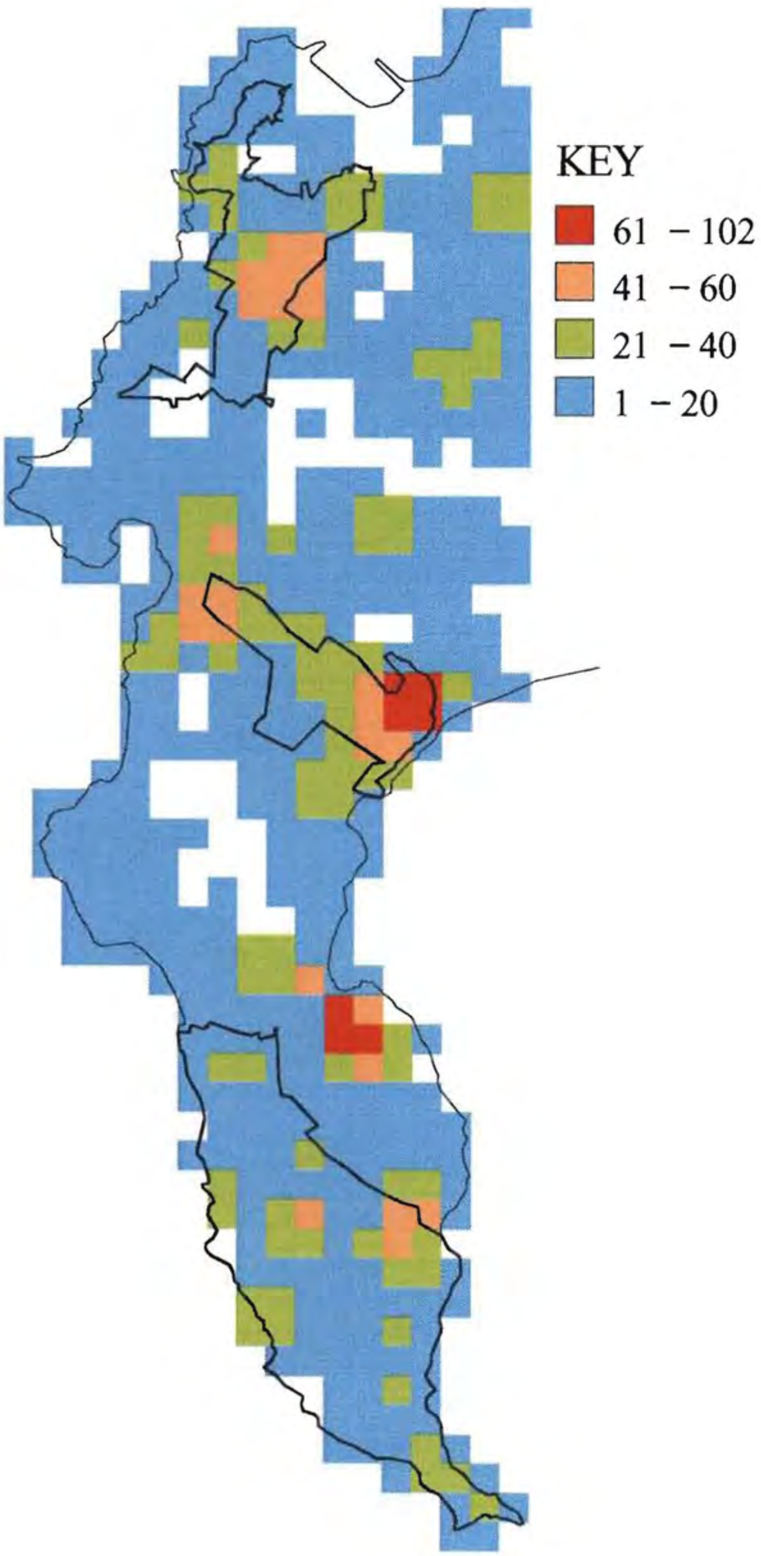

Figure 5.5. Cumulative scores for the 167 scored plant species in Table 5.2, for each 1 x 1 km cell.

Simonsberg), and the northern part of GHR (Rooihoogte). All of these areas enjoy at least partial conservation within existing reserves, with the exception of the Simonsberg area, which has no conservation status.

Endemic animal species richness per cell is shown in Fig. 5.6. Four centres of richness were identified. Again, these include the central and eastern portions of TMR, the eastern half of SMR, and the area to the south and west of Simonstown (including Red Hill). Groot Rondevlei within the GHR was the fourth area of importance. A very similar pattern was obtained using a more complete data set (Picker and Samways, in press).

Results of the three different reserve scenarios are as follows:
Scenario one: the current conservation status of the 2106 plant species found in undeveloped land is depicted in Fig. 5.7. A total of 119 species does not occur in existing reserves, and 141 species have between 1 - 30 % of their records falling within reserves. Only 1500 species have over 50 % of their records in reserves, with 458 species falling completely within reserves. In terms of the animal species, four do not fall within existing reserves: the butterfly *Aloeides egerides* (Riley, 1938)., the amphipods *Paramelita auricularia* (Barnard, 1916) and *P. pheronyx* (Stewart and Griffiths, 1916), and the snail *Trachycystis cosmia* (Pfeiffer, 1852). Fig. 5.8 shows the percentage of each vegetation type in undeveloped land that is conserved in existing reserves. Four vegetation types have < 33 % of their area conserved (types 8, 10, 11 and 15), and four types have > 50 % of their area conserved (types 2, 3, 4 and 6).

Scenario two: Fig. 5.7 shows how the conservation status of plant species on the Peninsula would change, if all undeveloped, publicly owned land on the Peninsula is added to the existing reserve system. In this case, only 13 species remain unconserved, and only eight species have between 1 - 30 % of their records falling within reserves. A total of 2034 species have over 50 % of their records conserved, and 901 species fall completely within reserves. In terms of the animal species, two still remain unconserved: *Paramelita auricularia* (Barnard, 1916) and *Trachycystis cosmia* (Pfeiffer, 1852). Fig. 5.8 shows the percentage of each vegetation type that would be conserved given this scenario. Only one vegetation type now has < 33 % of its area conserved (type 15 - vlei vegetation), and the remaining 14 have over 70 % of their area conserved.

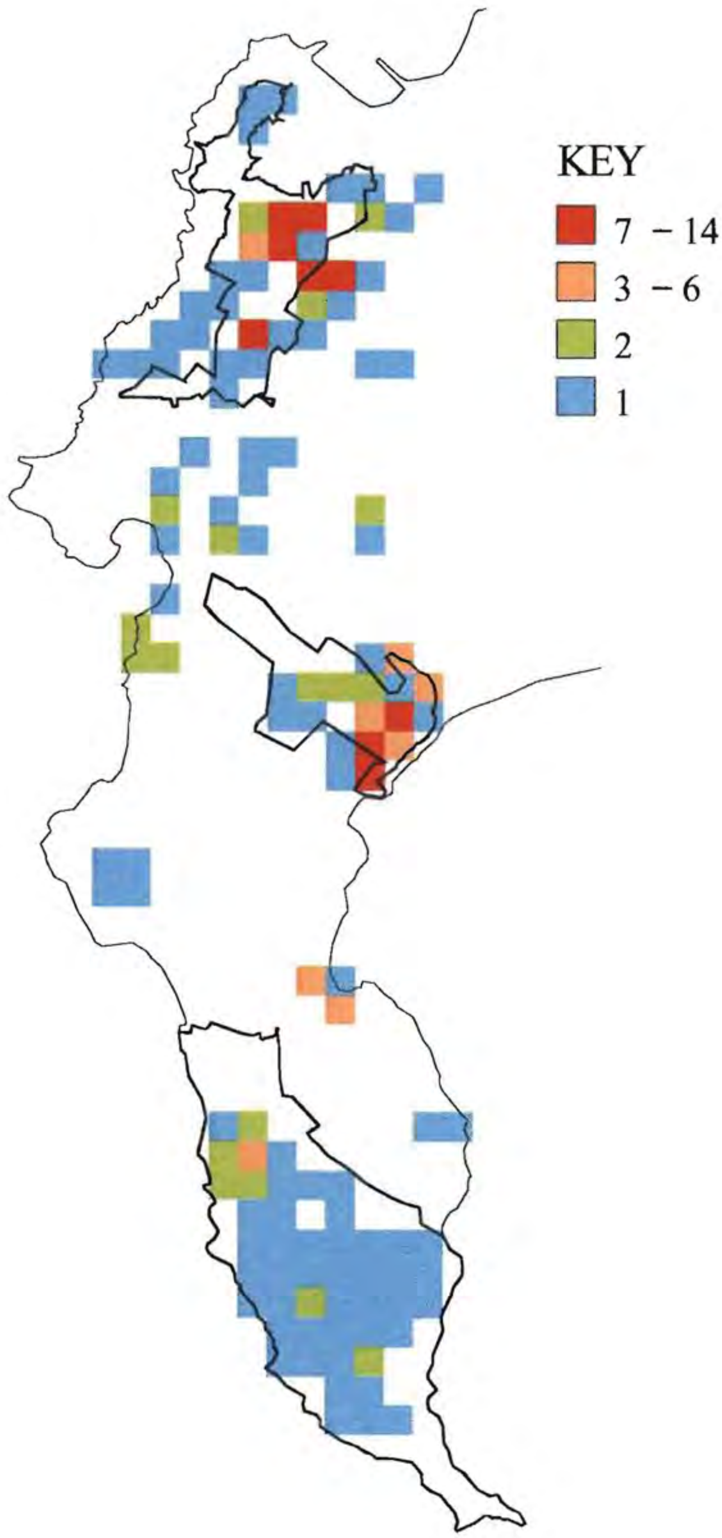

Figure 5.6. Endemic animal species richness per 1 x 1 km cell.

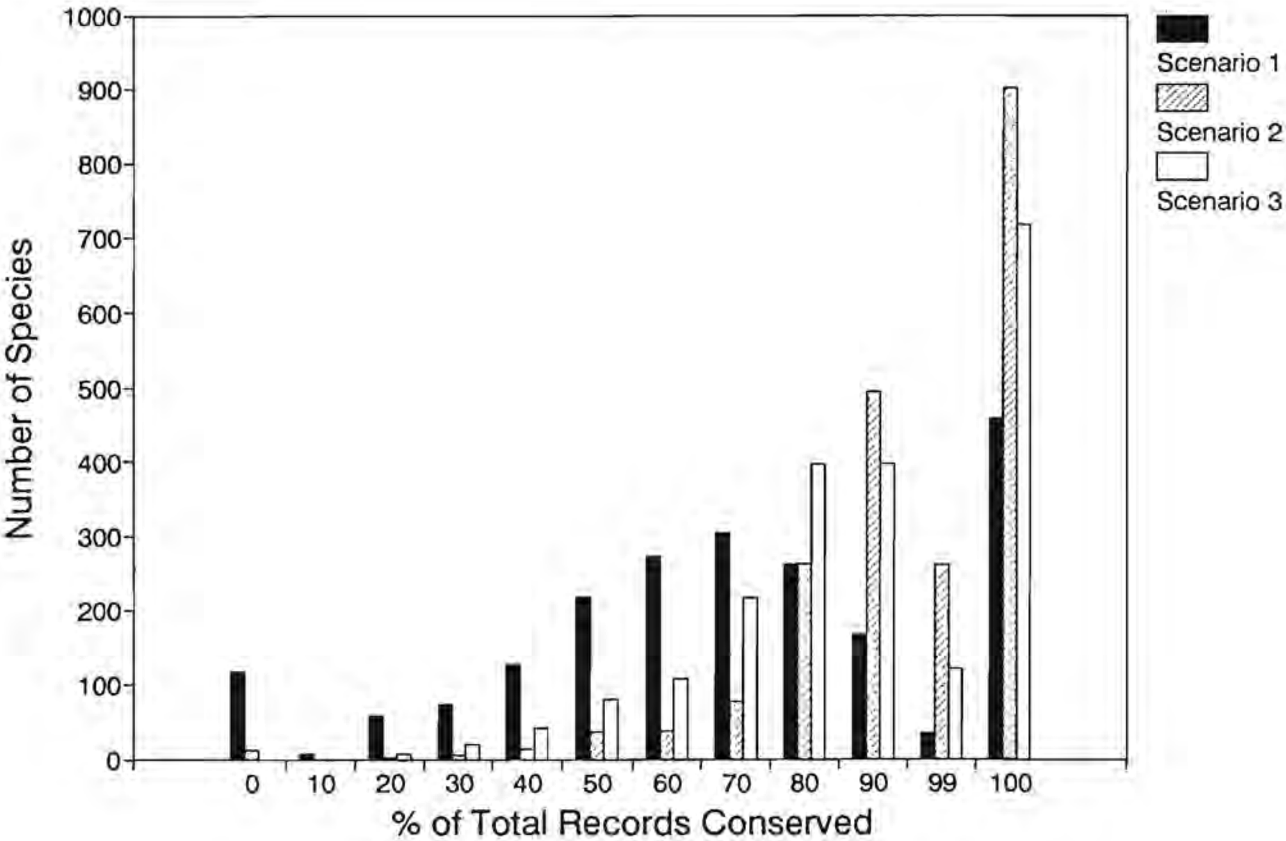

Figure 5.7. Conservation status of the 2106 plant species found in undeveloped land, given the three different reserve scenarios: scenario 1 - existing reserves only; scenario 2 - existing reserves and all public land; scenario 3 - existing reserves and iteratively selected reserves. Note: the X axis has frequency classes of 10 % each, except the first class (= 0 only), the second last class (91-99) and the last class (= 100 only).

Scenario three: given that not all publicly owned land may be available for conservation, the 51 cells shown in Fig. 5.3 should be added to existing reserves to form a new, extended Peninsula reserve system. Cells 1-28 were selected by the reserve-selection algorithm, to conserve all presently unconserved plant species found in public land. Cells 29-38, on private land, were selected to conserve the 13 remaining unconserved plant species not present in public land. In each case, a cell is selected to conserve a particular complement of species that is present within the cell. By examining the component species of all other cells within the database, one can ascertain whether any of the selected cells are 'flexible' (*i.e.* the complement of species that any one cell is selected for may also occur in one or more other cells). A flexibility analysis was thus applied to all selected cells. Within public land, three cells were flexible: cells 26, 27 and 28 had one, two and three replacement cells, respectively. Within private land, only cell 38 was flexible, with three replacement cells. These cells are depicted with an 'R' in Fig. 5.3. Each of these replacement cells was examined for its plant species score, its animal species richness, its percentage alien cover, and its proximity to developed and reserved areas. The most appropriate cell was then chosen for incorporation into the selected set of cells (these cells lack the 'R').

By definition, the selected set of cells represented all unconserved plant species in the database at least once. However, two animal species still remained unconserved (*Paramelita auricularia* (Barnard, 1916) and *Trachycystis cosmia* (Pfeiffer,1952), and cells 39 and 40 respectively were chosen to represent these species. In addition, all of the remaining unconserved cells that represented hotspots of plant scores and animal species richness were selected (cells 41-50). Hotspots were defined as cells with 41-102 cumulative plant scores, or 3-14 animal species (*i.e.* the top two class intervals in Figs. 6.5 and 6.6 respectively). Finally, the only vegetation type that was still considered inadequately conserved was the vlei vegetation (with only 17 % of its area in existing and selected reserves). Cell 51 was thus chosen to provide extra conservation for vlei vegetation, bringing its total conserved area to 69 % (Fig. 5.8). All other vegetation types had at least 43 % of their areas conserved, which was considered adequate (none of the vegetation types is endemic to the Peninsula).

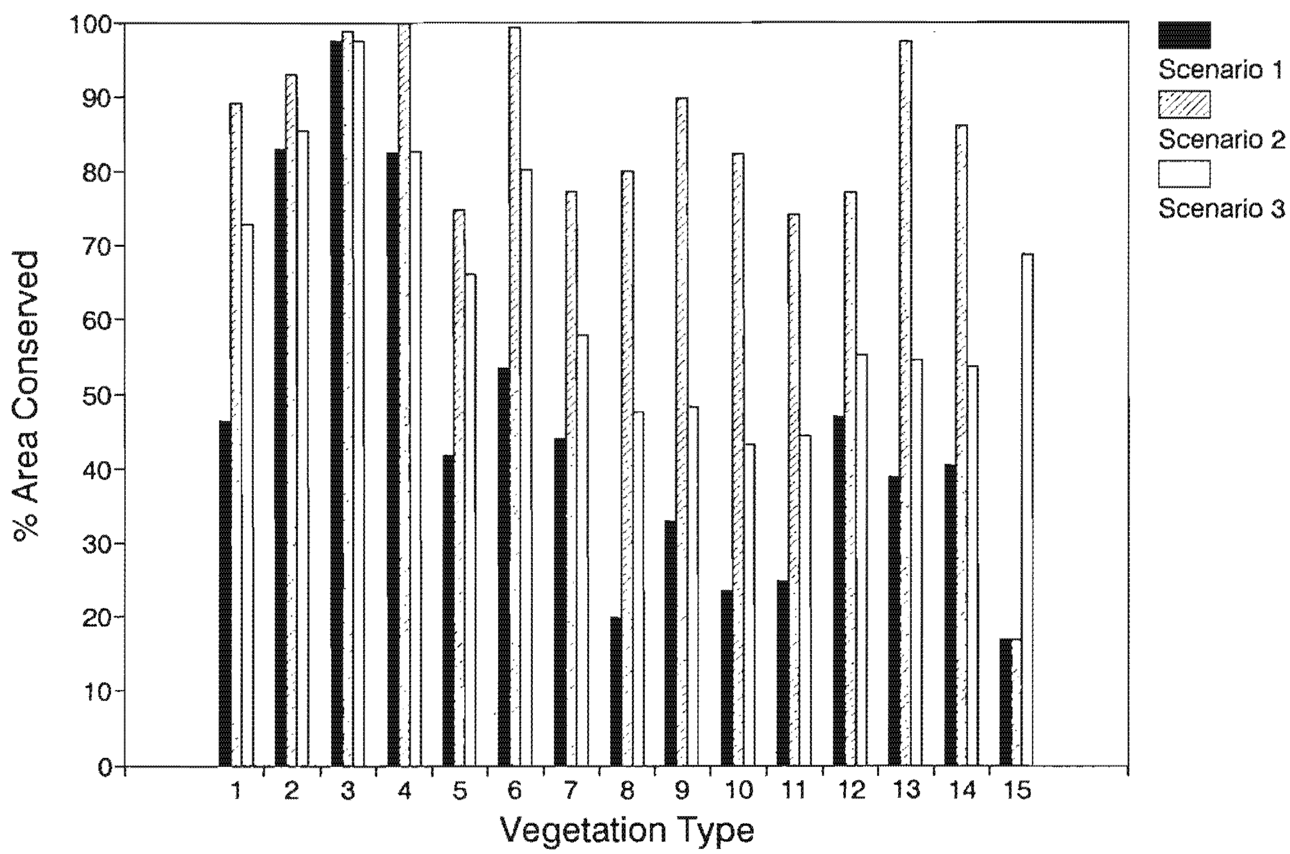

Figure 5.8. Conservation status of each vegetation type in undeveloped land, given the three different reserve scenarios: scenario 1- existing reserves only; scenario 2- existing reserves and all public land; scenario 3- existing reserves and iteratively selected reserves. (1 - wetlands, 2 - renosterveld /grasslands, 3 - wet restioid fynbos, 4 - upland restioid fynbos, 5 - dune asteraceous fynbos, 6 - coastal scree asteraceous fynbos, 7 - ericaceous fynbos, 8 - sandplain proteoid fynbos, 9 - wet oligotrophic proteoid fynbos, 10 - wet mesotrophic proteoid fynbos, 11 - mesic mesotrophic proteoid fynbos, 12 - mesic oligotrophic proteoid fynbos, 13 - undifferentiated cliff communities, 14 - forest/thicket, 15 - vlei).

All the selected cells were examined for their proximity to developed, or developing areas. All cells, except cell 19, were in appropriate areas for conservation action. Cell 19 is located at the center of a developing area, and the possibility of conserving it in the future is small. In order to replace cell 19, the cell immediately above it, and one of the cells either to its right or immediately below it, should be added to the reserve system. All selected cells were also examined for the presence of aliens, and only cells 5, 11, 27, 27R and 29 had over one third of their areas invaded by very dense (> 75 %) alien cover. Another four cells (8, 9, 19 and 33) had over one third of their areas invaded by dense (50-75 %) alien cover.

The final set of selected cells provided a conservation status for each plant species as depicted in Fig. 5.7. All species are now conserved at least once. Only 25 species have between 1 - 30 % of their records conserved, 1956 species have over 50 % of their records in reserves, and 716 species fall completely within reserves .

DISCUSSION

6.9 Scenario 1: Current reserves

The existing reserves conserve 29% of the total area of the Peninsula. These reserves achieve much in terms of conserving the plant and animal diversity of the Peninsula. The fact that such a considerable proportion of plant species is conserved stems from the fact that richness on the Peninsula is determined largely by environmental heterogeneity (high beta diversity) (Simmons and Cowling, in press). The existing reserves span steep and long environmental gradients and hence conserve many species. This is reflected in the fact that substantially different suites of vegetation types and therefore habitat types are conserved by the different reserves (Fig. 5.1). The difference is particularly evident between Table Mountain Reserve (TMR) in the north and Good Hope Reserve (GHR) in the south. Of the eight vegetation types conserved by TMR and the ten by GHR, only three are shared, these being types 11 (mesic mesotrophic proteoid fynbos), 13 (cliff communities) and 14 (forest/thicket). Four types (2 - renosterveld/grasslands, 4 - upland restioid fynbos, 7 - ericaceous fynbos and 9 - wet oligotrophic proteoid fynbos) and three types (3 - wet restioid fynbos, 5 - dune asteraceous fynbos and 15 - vlei) are conserved exclusively by TMR and GHR respectively. Furthermore, Simmons and Cowling (in press) illustrate considerable species turnover within vegetation types (high gamma diversity). The fact that Silvermine Reserve conserves seven vegetation types, all of which are shared with either Table Mountain Reserve or Good Hope Reserve, does not imply lower conservation efficiency since a high *gamma* diversity means that new species are always encountered.

The reserves also capture the majority of those areas with high concentrations of endemic and threatened plants and endemic animals (Fig. 5.5; Fig. 5.6). However, if one is to to ensure that each species is conserved at least once , additional reserves need to be incorporated to accommodate those unconserved species (Nicholls and Margules, 1993). The current reserve system also lacks connectivity (Rapoport *et al.*, 1986; Bedward *et al.*, 1992) and the three larger reserves lie in a matrix of public and private land which remains undeveloped. Corridors could be established between the reserves in mostly public land at present, but increased development may change this situation in the near future. Rondevlei Bird Sanctuary is confronted with the problem in that it is already isolated by urbanization.

6.10 Scenario 2: Adding all public land

The public land which does not fall within the current reserve system (Fig. 5.3) is owned by a number of agencies. A comprehensive study investigated the feasibility of consolidating the management of this land. The recommendation in the Draft Policy (UCT, 1994) proposed that the two agencies which currently manage the reserves be instated as managers for all publicly owned areas. Should this recommendation be adopted, it would greatly enhance the proposal that all public land be given conservation status (Van Wilgen, in press). The area conserved would practically double, with a dramatic improvement in the status of the number of species conserved (Fig. 5.7).

Such a scenario would present near optimal conservation conditions. Firstly there would be no costs incurred in terms of land acquisition. Furthermore, the majority of this land abuts upon existing reserves which makes it highly suitable for consolidation into larger conservation units (Bedward *et al.*, 1992). In the case of TMR the conserved area would increase without the length of the boundaries changing. The edge to area effect is improved substantially which may have advantages for reduced management costs. Unconserved public land abutting upon SMR and GHR is severely fragmented by tracts of private land. This is detrimental in terms of the edge effect. The borders between public and private land are convoluted and the management of these areas may be prohibitively expensive. However, large portions of private land are not suitable for development or agriculture, owing to the topography (Richardson *et al.*, in press), and thus rate highly with regard to their conservation value. In such instances a compromise could be reached between private land owners and public management agencies whereby private land owners allow their land to be managed for them, or commit themselves to manage their land according to mutually agreeable management practices (such a private reserve has been proclaimed in the Red Hill area and initiatives are underway at Karbonkelberg). The adoption of more projects of a similar nature would have enormous advantages. Virtually the entire southern part of the Peninsula between Fish Hoek (cell 26R, Fig. 5.3) and Kommetjie (cell 19, Fig.5.3) can be managed as a unit with minimum interface between conserved and unconserved zones.

Connectivity between the southern and northern zones (a break in the mountain range, the Fish Hoek Gap, creates a natural division between the northern and southern Peninsula) should be maintained via the Noordhoek Flats (cells 8-10, Fig. 5.3). This is the only portion of the Fish Hoek Gap which is mostly undeveloped. The importance of this corridor has also been emphasized in the reserve system described under scenario three below.

One major disadvantage with the current reserve system is that in no instance is there a connection between high altitude zones and the coast. Coast to crest conservation is important for both the aesthetic value it affords and also to protect a complete set of ecotonal and habitat changes which occur along such steep gradients (Simmons and Cowling, in press). There are two instances where such protection is possible: along the western fringes of TMR and SMR. In both cases the landscape is dramatic, rising from sea level to over 800m in a short distance. This scenario would also ensure the protection of sections of coastline and inter-tidal zones outside of the Good Hope Reserve, beyond which there is no coastal protection. Entire mountain streams, important for animal endemics, could also be conserved.

The unchecked spread of alien vegetation on the Peninsula is regarded as one of the major threats to the maintenance of biodiversity (Bolus and Wolley-Dod, 1903; Hall, 1961; McLachlan *et al.*, 1980; Moll and Trinder-Smith, 1992; Richardson *et al.* in press). The incorporation of public land into the current reserve system would afford better alien control, since conserved public areas appear to have better alien eradication management practices than unconserved public areas (Van Wilgen, in press). This is possibly a direct consequence of the multiple ownership of unconserved public land where each agency has its own alien eradication management policy. Often these policies are not complementary and do not merge into a unified eradication strategy (Van Wilgen, in press). This is detrimental to the area as a whole. The area to the north of GHR and south of Fish Hoek would benefit particularly from a more rigorous programme, considering that large tracts of land have an alien coverage of more than 25%.

6.11 Scenario 3: Reserve-selection algorithm

This scenario is based on the premise that all public land may not be available for reserve allocation. I used an iterative selection procedure (Rebelo and Siegfried, 1992) to prioritize those areas which need conservation to ensure that each plant species is conserved at least once. Using this method to select reserve sites on public land first (28 cells), is a cost effective approach, since only 10 additional cells are required on private land to ensure the conservation of all plants (Fig. 5.6). Clearly the advantage of using this method also lies in its efficiency (Pressey and Nicholls, 1989) at maximizing the conservation of biodiversity in the smallest possible area. In order to conserve all remaining unconserved animal species, hotspots of high scoring plant species (Fig. 5.5) and animal species richness (Fig. 5.6), as well as all vegetation types, an extra 13 cells are needed, of which only three fall mostly on private land.

The cells selected for reserves are mostly clustered (Fig. 5.3). These clustered cells can be consolidated into larger areas of conservation with the concomitant reduction in conservation costs owing to the area to edge phenomenon (Bedward *et al.*, 1992). In many cases, extending the borders of existing reserves captures many of the desired cells. Up to 25 cells on public land and 7 on private land can be incorporated in this way (Fig. 5.3). The extension of GHR in a northerly direction would be particularly successful in capturing a large number of the selected cells.

Two areas with clusters of cells are too isolated to be included by extending the boundaries of existing reserves, and would require separate conservation strategies. These are the areas Constantiaberg and Noordhoek Flats (between cells 17 and 10) and the Vlakkenberg (cells 40,15 and 39). The Constantiaberg - Noordhoek Flats area, as mentioned in the previous scenario, remains important to ensure connectivity between the northern and southern areas of the Peninsula. A number of isolated single cells (9, 20 and 32), would also require separate reserves to ensure their inclusion into a comprehensive reserve system. Proclaiming the public area cell 4 as a reserve would ensure the conservation of a portion of coastline in the northern sector of the Peninsula. The coastline in the vicinity of cell 20 has already been designated as a recreational zone and cannot be conserved in a pristine state.

The percentage area of each vegetation type conserved improves substantially compared to scenario 1 (Fig. 5.8). Those vegetation types which occupy small total areas (Fig. 5.4) in which particular improvement is evident are types 1,5,6,8, and 15 and the total area conserved within each type reaches satisfactory levels (43% of its area conserved, Fig. 5.8). Furthermore it is important that as much of the area occupied by each vegetation type be conserved as each of these types have varying numbers of both threatened and endemic plants (Richardson *et al.*, in press).

6.12 The ultimate scenario

There is a fourth scenario which could be considered, providing the most comprehensive reserve system possible. This would require all public land to be proclaimed a reserve and it would also include those cells on private land described in scenario three. Only thirteen cells on private land need to be included: cells 29-38 for unconserved plants, cell 40 for the animal *Trachycystis cosmia* (Pfeiffer, 1852) (terrestrial snail), cell 46 as part of a plant hotspot and cell 51 to provide extra conservation of vlei vegetation. The positive aspects of both scenario two and three are accommodated in such a reserve system.

6.13 The enclaves Rondebosch Common and Kenilworth Racecourse

The two areas Rondebosch Common (37 ha of commonage which is a proclaimed a national monument) and Kenilworth Racecourse (56 ha) are of the last remaining islands of sandplain proteoid fynbos in what has become a totally urbanized area. The conservation value of both these areas is high in terms of conserving 13 of the 21 scored plant species which now occur nowhere else in the Peninsula, and the above mentioned vegetation type which has a small absolute area in the Peninsula (Fig. 5.1).

CONCLUSION

Several primary areas are crucially important for conservation, the first being the eastern fringe of the Peninsula from Fish Hoek as far as the southern extremity of the Swartkops Mountain Range. This area incorporates many of the selected cells and two important hotspots. The central Peninsula contains many hotspots: Constantiaberg Peak, Noordhoek Peak, the Muizenberg Cave, Reserve Peak, Skeleton Gorge and its immediate junction with the lower plateau on Table Mountain. In addition, the Noordhoek Flats are important for conserving many plant species as well as maintaining a corridor between the northern and southern parts of the Peninsula. Finally, the Rooihoogte area in the Good Hope Reserve is of great importance. Kenilworth Racecourse and Rondebosch Common on the Cape Flats contain many rare and threatened plant species which occur nowhere else on the Peninsula. It is thus extremely important that these two areas be awarded conservation status.

The major problem confronting a successful conservation scenario is the cost of management, particularly with respect to alien plant eradication (Van Wilgen, in press). In addition, the lack of a coordinated management policy would seriously hamper conservation efforts. Many of the areas highlighted in this study as being important abut upon presently well-managed reserves and could successfully be incorporated at little cost.
The existing reserves on the Peninsula successfully conserve a substantial part of the terrestrial biota. This is serendipitous as reserves were not sited to fulfill this specific objective. The option exists to greatly strengthen the conservation status at little expense. The inclusion of undeveloped public land and strategically placed private reserves could ensure the long term survival of this

richly diverse area. An added benefit of having large tracts of pristine land conserved would be the economic benefits related to the, as yet, unexplored ecotourism potential.

CHAPTER 6

CONCLUSION

The botanical aspects of the Cape Peninsula investigated in this study serve to highlight this area as being remarkably diverse (2285 spp.) with levels of endemism and threatened plants exceptionally high both regionally and globally. Irreversible transformation threatens this flora as a result of a burgeoning population within the bounds of the Greater Cape Town metropolitan area. This study has shown 22% of threatened taxa (including threatened endemics) and 14% of endemic taxa to have become extinct in the area since the turn of the century and many of those taxa which remain (50% of endemics) fall within the most critical IUCN categories for threatened plants. Indiscriminate development and the lack of a comprehensive management strategy, particularly with respect to the control of alien plants, have been the major causes for a diminishing diversity. It has been increasingly recognised that there exists a lack of knowledge with respect to these focal taxa. In order to redress the increasing vulnerability of these taxa and the flora in general, pro-active steps are essential to put a comprehensive conservation and management plan in place.

The biological profile of endemic taxa as established by the logistic regression model, should facilitate the formulation of guidelines for the management of these taxa. The biological traits of these taxa have particular management requirements with respect to fire regimes and alien control mechanisms. The similar profiles of threatened and endemic taxa implies that these groups of taxa do not require different management strategies. This has great advantages for initiating a single management approach and for cost effectivity.

The application of the Geographic Information System indicated areas of importance with regard to threatened and endemic taxa. This was useful to prioritize areas in need of urgent conservation outside already existing reserve systems. The fact that there exists a number of options to conserve the remaining biodiversity is fortuitous. Even more fortunate is the fact that these options presently remain both viable and implementable. The onus rests upon those in the decision making positions to act wisely since irresponsible decisions now will do great injustice to the immediate community, the country and indeed the world at large.

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Appendix 1. The model selection using the minimum AIC (Akaiki Information Criterion is Deviance + 2p.) (G - Growth form, D - Dispersal mode, R - Regeneration strategy)

	Model	Deviance	df	AIC
1	Constant only	80.86	29	82.8
2	1 + Main effects of G,D,R	49.64	21	67.6
3	2 + GR interations	43.59	17	66.59
4	3 + DR interations	14.87	15	44.87
5	G,D,R + D + sig. GR only	15.57	17	41.57

Appendix 2: Maximum likelihood parameters of the model parameters

Parameter	Symbol	Estimate	s.e.	t-score
Constant	μ	-2.245	0.160	-14.04
Mid shrub	λ_2^G	-0.523	0.612	-0.85
Tall shrub	λ_3^G	-0.286	0.750	-0.38
Graminoid	λ_4^G	-1.502	0.528	-2.84
Forb	λ_5^G	-1.155	0.310	-3.72
Geophyte	λ_6^G	0.072	0.591	-0.12
Wind	λ_2^D	-2.646	0.989	-2.68
Ant	λ_3^D	0.033	0.377	0.09
Sprouter	λ_2^R	-2.109	0.578	-3.65
Tall shrub, sprouter	λ_{32}^{GR}	2.06	1.41	1.46
Graminoid, sprouter	λ_{42}^{GR}	1.895	0.819	2.31
Wind, sprouter	λ_{22}^{DR}	4.31	1.11	3.87
Ant, sprouter	λ_{32}^{DR}	1.465	0.709	2.07