Phytogeography, endemism and diversity of the fynbos of the southern Langeberg

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'I look to the mountains; where will my help come from?

My help comes from the Lord, who made heaven and earth.'

Psalm 121: 1–2.

'... lofty mountains are most worthy of deep study. For everywhere you turn, they present to every sense a multitude of objects to excite and delight the mind. They offer problems to our intellect; they amaze our souls. They remind us of the infinite variety of creation, and offer an unequaled field for the observation of the processes of nature.'

Josias Simler (1574)

De alpibus commentarius

The southern Langeberg looking westwards from 12 O'Clock Peak (Crown Peak, 1428 m). The highest peak visible is Leeurivierberg (1628.5 m).

Preface

Why study fynbos? This question has no doubt been asked many times. In a personal sense it may be appropriate to briefly trace how I came to study fynbos and how I have become closely involved with the flora and vegetation of one of the major mountain ranges in the fynbos biome.

My interest in fynbos vegetation developed when, as an undergraduate student at the University of Natal University, Pietermaritzburg, I read papers and articles on the rich and varied flora of the Cape. Prior to this time I had not ever visited this part of South Africa so was otherwise unfamiliar with fynbos vegetation. This early interest was stimulated further during my Botany Honours course when I investigated the growth and propagation of *Protea neriifolia* using tissue culture. Later, faced with the decision of following a career in plant propagation or plant ecology, I opted for the latter. My particular goal was then to study aspects of the ecology of Cape fynbos, and more specifically the fynbos of the mountains.

In mid-1980 a position was advertised for a research assistant at the Botanical Research Unit, Stellenbosch (part of the former Botanical Research Institute), to become part of a mountain vegetation survey team. My application was successful and I became part of the team whose object was to survey 'Mountain Fynbos' according to a programme entitled "Botanical survey of the Mountain Fynbos vegetation of South Africa' first drafted in 1965. The programme was to have been 'an Acocks-type survey of all the Mountain Fynbos in south Africa, with special reference to the Capensis area'. As trained staff and resources became more limited and priorities changed in the early to mid-1970's the early plans were amended a number of times. At this time the structural-functional classification of fynbos in the mountains by Prof Bruce Campbell was underway and the focus of the parallel floristically-based 'semi-detailed phytosociological surveys' was aimed at two areas designated as the 'Western Mountain Fynbos' and the 'Southern Mountain Fynbos' (details from an memorandum: H.C. Taylor, February 1980).

In 1978 the Fynbos Biome Project was constituted as a loose alliance of researchers in the fynbos (Kruger 1978). One of the special sites earmarked for study was Swartboschkloof at Jonkershoek near Stellenbosch. After my appointment to the staff of the Botanical Research Unit, Stellenbosch at the beginning of 1981 my first project was a survey of the vegetation of Swartboschkloof, under the leadership of Mr Hugh Taylor. Within a few months I took over this project, completed it and wrote a thesis entitled 'The vegetation of Swartboschkloof, Jonkershoek, Cape, South Africa' for a Master of Science degree at the University of Cape Town in 1983. Jonkershoek falls within the 'Western Mountain Fynbos' zone and since Hugh Taylor was aiming at future work on the Cedarberg, in the western zone, I chose to move my focus eastwards to the 'Southern Mountain Fynbos'.

The flora and vegetation of the Langeberg were inadequately known and from personal correspondence with the Directorate of Forestry, Department of Environment Affairs, which at that time (1984) was responsible for the management of the mountain catchments of the Langeberg, I ascertained that a survey of the vegetation of this mountain range had a high priority. There was a definite need for a comprehensive study of the flora and vegetation of the Langeberg and this became the primary motivation for selecting this mountain range for study.

The first general objective of the study of the vegetation of the Langeberg was to sample and describe the plant communities. An early proposal was to subdivide the Langeberg range into sections and sample each of these using a north-south transect that would straddle the mountain. Four transects were initially proposed but this was later reduced to three. The fourth transect was to have been in the section of the Langeberg, referred to as the north-west Langeberg, between Montagu-Ashton and Worcester. However, since this part of the Langeberg is bioclimatically quite different from the southern Langeberg (that part of the range from Montagu-Ashton eastwards to the Gouritz River), a survey of the vegetation of the north-west Langeberg was not carried out. I concentrated my efforts on the southern Langeberg.

In studies of the fynbos, as with many other vegetation types, descriptive studies of vegetation based on the floristic composition of the respective communities are of great importance. However, there has been a tendency for these to be seen as an end in themselves. This is a short-sighted view because these studies are rich sources of data that can be used for a variety of other purposes. The data are usually rigorously collected in plots of pre-determined size and the plant species encountered are arduously identified either in the field or in the herbarium. This demands that such data be used for more that just simply describing the assemblages of plants found in a study area; a necessity that is underscored by the high financial and physical cost of acquiring data, particularly in the mountains. Therefore, the second general aim of my study of the vegetation of the southern Langeberg was to extend the use the phytosociological data to investigate the phytogeographic and ecological patterns apparent in the fynbos communities. The idea was to use this data to answer questions that would give insights into the environmental determinants of the distribution of the plant communities as well as the determinants, both environmental and biological, of endemism and diversity.

In this study a fair measure off success has been achieved in using phytosociological data for the purposes described. However, as rich as they are, these data do not necessarily offer all that is required for more detailed analyses. It has been necessary to obtain additional data from other sources such as herbaria and published taxonomic accounts as well as climate databases and models, to augment the data set. Some limitations of the present data set, for example the location of sample plots, have prevented optimal use of the data in the study of beta diversity for instance. This has highlighted the need for more careful phytosociological sampling procedures that would accommodate more suitable location of plots for other additional analyses.

The accumulation and analysis of vegetation data from the southern Langeberg has been a time-consuming, demanding and expensive task but at the same time extremely challenging and enriching. Despite many trials it has been a great privilege to work in this wonderful environment and explore its mysteries. Unfortunately, the cost of extensive surveys such as the one on which this study is based will in future be prohibitive, so this type of work will probably not be done on a large scale. This is all the more reason why it has been imperative to capitalize on the available data and use them as meaningfully as possible. Not only have theoretical questions required answers, but more importantly an attempt has been made to address practical questions aimed at conserving the fynbos as a national and global resource.

It is my hope that the work presented in this thesis – which is the culmination of a number of years of intimate contact with the southern Langeberg and its flora – will contribute in some way to the understanding and wise use of the fynbos in general and more specifically to the conservation of the fynbos of the southern Langeberg.

Acknowledgements

During the course of this project many people assisted in numerous ways, both large and small. Each of these people has made a contribution, not only to the final product but also to me personally. To all of them, although they may not be named, I am deeply indebted.

My family has made a great sacrifice in accepting long weeks of absence of a husband and father while I was away from home on field trips. These were difficult times and I am grateful for their patience. In the later 'writing-up' stages of the project and production of this thesis my family has been equally supportive and understanding. To Anne, Ross, Bryony and Claire I owe my sincere appreciation for their love, care and long-suffering. I also appreciate the 'long-range' support of my parents, Colin and Jess McDonald and my parents-in law, Bill and Barbara Elliott.

Many colleagues willingly offered their friendship, expertise and help. I owe special thanks to the present and past members of the Stellenbosch Herbarium (formerly the Botanical Research Unit, Stellenbosch), especially Jo Beyers, Anna Fellingham, Madelaine Morley, Ted Oliver, Hugh Taylor, and Peter Zeier. More recently my colleagues at the National Botanical Institute, Kirstenbosch, have been very encouraging and accommodating and to all of them but particularly John Donaldson, Craig Hilton-Taylor, Guy Midgley, Fiona Powrie, John Rourke, Gill Scott and Lynda Smith, my grateful thanks. I would also like to thank Prof June Juritz of the Department of Statistical Sciences, University of Cape Town for so kindly sharing her expertise in statistical modelling with me.

The Department of Environment Affairs and later Cape Nature Conservation gave me permission to work in the mountain catchments in the Langeberg. I acknowledge this with gratitude and thank Christo Marais, Chris Martens, Theo van der Merwe and Piet van Zyl for much logistic and other support. The provision of a forest guard, namely Charlie Ruiters, to assist me in the field is also much appreciated. To Charlie Ruiters personally, I owe a great deal. Without his help this work would not have been possible. He was a good companion in fine weather and foul and his sound knowledge of the Langeberg was a great asset in many situations. The kindness of the Oosthuizen family of Bergfontein (Albertinia District) in giving me free accommodation while working in their area is also much appreciated.

My supervisors, Richard Cowling and Charlie Boucher have not only given freely of their expert knowledge of the fynbos and analysis of vegetation data but have guided and often encouraged me when I was despondent and confused. I am extremely grateful to them both and trust that this thesis does justice to the time and effort they have invested in supervising me.

The work reported in this dissertation was done as part of a project on Cape mountain ecosystems established by the former Botanical Research Institute and more recently supported by its successor the National Botanical Institute. This support is gratefully acknowledged. The Chief Director, Prof Brian Huntley and the Deputy Director: Research, Dr Mike Rutherford, of the National Botanical Institute have been very indulgent in allowing me to continue and make the most of the Langeberg project. My thanks to them for allowing me the opportunity to pursue work on Cape mountain ecosystems.

ABSTRACT

Phytogeography, endemism and diversity of the fynbos of the southern Langeberg.

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The thesis presents a multi-faceted investigation of aspects of phytogeography, endemism and species diversity in the rich fynbos flora of the southern Langeberg, Cape, South Africa. The basis was a survey of the fynbos vegetation of the southern Langeberg carried out following the Braun-Blanquet or Zürich-Montpellier approach. Forty-six plant communities were described which were ultimately synthesized into 14 'community groups'.

The core of the study consisted of three parts: (1) A multivariate analysis of vegetation-environment relationships where questions concerning the distribution of fynbos communities and environmental controls were addressed. It was found that mean annual precipitation was the most important abiotic variable, apart from fir determining distribution of fynbos communities. A model was developed whereby distribution of floristically determined 'community groups' could be predicted from combinations of environmental variables. (2) The southern Langeberg is rich in endemic species and patterns of endemism were investigated using (a) two-way contingency table analysis and (b) generalised linear modelling. From the contingency table approach it was found that endemism is not randomly distributed taxonomically, in terms of biological attributes of species and with respect to the montane habitats where they occur. The majority of endemic species are restricted to 6.7% of the plant families represented and were significantly over-represented in high-altitude wet habitats. The use of generalised linear modelling was a new approach and extension of the contingency table method. It allowed numerical estimation of the probability that a species with a given set of attributes would be endemic. Seven inferences were made from the model but most importantly, an ant-dispersed, non-sprouting low shrub has the largest probability of being endemic. (3) Species diversity in the southern Langeberg flora was analysed firstly in terms of species richness (α diversity) and rarity and secondly with respect to turnover on ecological gradients (β diversity) and geographical gradients (γ diversity). The patterns of species diversity observed are related more to high turnover of sparsely distributed (rare) species on ecological and geographical gradients than to levels of α diversity.

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General Introduction

Mountains have inspired and challenged humankind from the beginnings of time. They have provided many resources, both spiritual and material but they have also often been obstacles to progress and human development. The inspiration has mostly come from imposing mountain peaks and dramatic montane landscapes while the challenges have arisen from how the highest peaks can be climbed and 'conquered' or how the many and varied resources offered by mountains can be harnessed and used. But whatever the inspiration or the challenge, mountains and humans have been intimately involved for millennia on every continent on the globe.

In Africa, the mountains of the south have played a major role in the history of the subcontinent not only in terms of human history but more profoundly in the evolution of biodiversity. A chain of mountain ranges with diverse topography, geology and biological resources forms a ring-like barrier between the moist, low-lying coastal regions and the dry, high-lying inland regions. This mountain barrier is the meeting point of many abiotic and biotic systems which have and will continue to influence the existence and evolution of biological organisms on both sides of the barrier and on the mountains themselves. An understanding of these mountains and the processes which take place on them is thus essential for their conservation, both for the resources they harbour which can be used by humans and, perhaps more importantly, for the intrinsic worth of their biotic and abiotic systems.

The vegetation of the Cape Fold Mountains of the Western Cape and Eastern Cape provinces in South Africa is dominated by species-rich sclerophyllous fynbos shrublands with enclaves of Afromontane forest forming a much smaller part. The fynbos of the Cape mountains makes a large contribution to the unique flora of the Cape Floral Kingdom, the smallest but richest per unit area of the six floral kingdoms of the world. These fire-prone shrublands have evolved in response to the interacting factors of a harsh climate, varied topography, nutrient-poor soils and the stochastic disturbance effects of fire and are renowned for their diversity of composition.

When compared with the vegetation of the human-impacted lowlands the vegetation of the Cape mountains is relatively well-preserved. However, that is not reason for complacency. There are numerous threats to the integrity of Cape mountain ecosystems such as invasive alien plants and animals, injudicious use of fire and fragmentation of mountain catchments through dam-building, construction of roads and inappropriate agricultural practices. However, although careful attention needs to be directed at the removal or at least control of these threats, many areas in the Cape mountains are still relatively unaffected. Valuable opportunities therefore exist for study of these ecosystems which may ultimately become besieged as development extends from the lowlands into the mountains.

Current growth of the human population in the Western and Eastern Cape is extremely rapid and in the future heavy demands are bound to be placed on the water resources of Cape mountain catchments. Additional demands on other resources such as wildflowers and plants collected for traditional and herbal medicines are predicted to add to the pressures experienced by these montane ecosystems. Careful monitoring of activities in the mountains will therefore be necessary to minimize the negative impacts of increased use.

Historically mountain catchment land-use decisions have often been uninformed, subjective, uncoordinated and controversial. This has led to many conflicts which have ultimately had a negative effect on the management of mountain land. This cannot continue because future pressures on the mountains and lack of foresight in the management of mountain catchments will be very detrimental to their well-being. This emphasizes the importance of management being based on informed decisions. But what is necessary for more informed decisions? The basic requirement for improved management and conservation of mountain catchments is sound information about their functioning. This has been a great challenge to ecologists working in the CFR and more particularly in the Fynbos Biome. Central to this challenge has been the unravelling of the intriguing and complex processes at work in the unique fynbos flora both at the organism and ecosystem levels. It is insights into these processes through goal-directed research which have already positively influenced management practices and fostered conservation. There is a pressing need for this to continue.

Rationale

The rationale for the study presented in this dissertation is embodied in the ethic of conservation of the fynbos as outlined above; not only for its value to human society but also for its own worth as a 'jewel of creation'. The study was aimed at making a contribution to the understanding and conservation of fynbos vegetation at large by focussing at the local level on part of the Langeberg mountains. There were many mountain areas that could have been selected for study, but apart from the appeal of the southern Langeberg to me personally, the choice of studying this mountain range was determined by a number of factors. Firstly, no major study of the flora and vegetation of the southern Langeberg had been done previously and a need for this was identified by the former Directorate of Forestry, Department of Environment Affairs. Secondly, the linear shape of the southern Langeberg offered a system where west–east and south–north

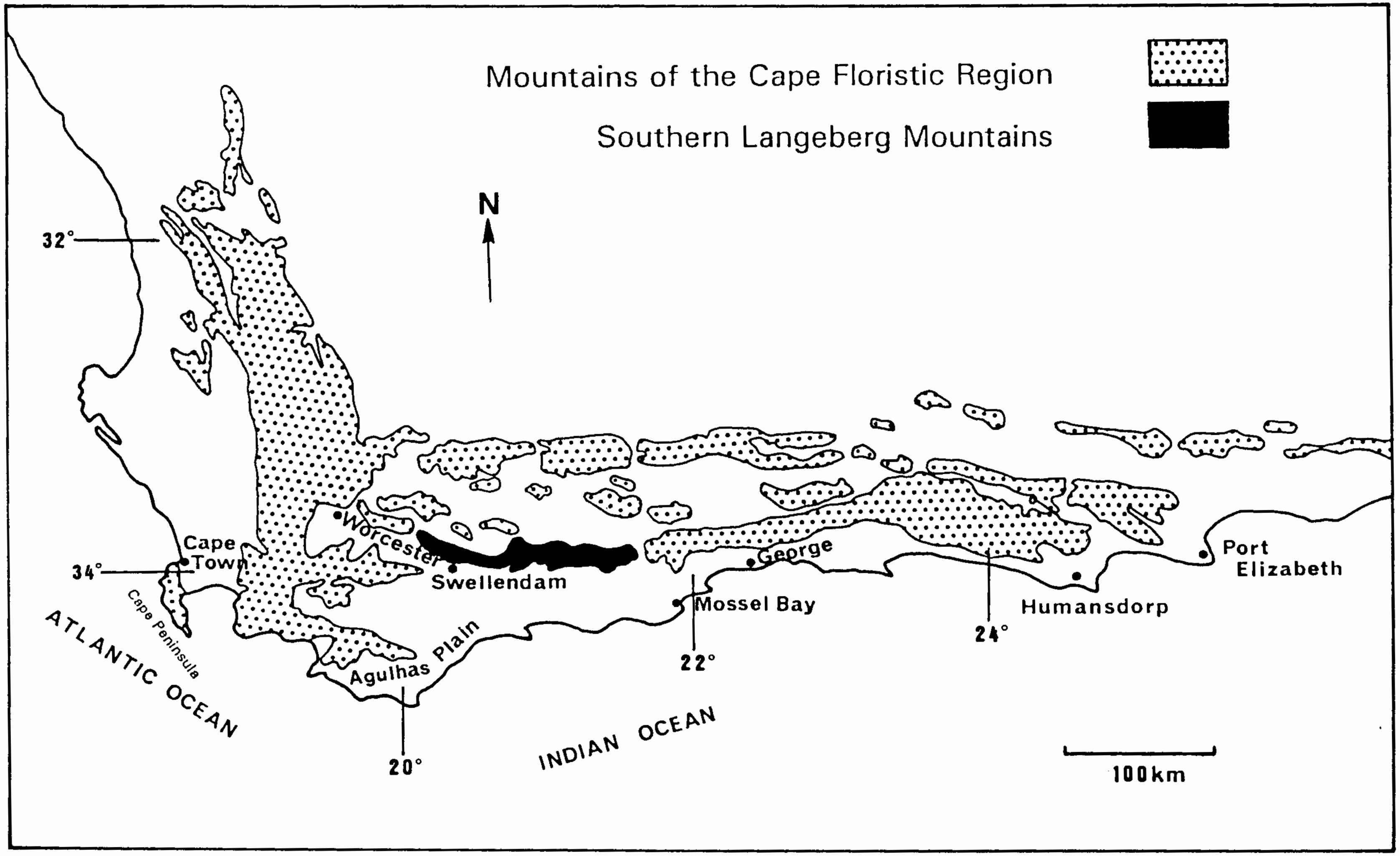

Figure 1. The position of the southern Langeberg in relation to the other mountains of the Cape Floristic Region.

climatic and other gradients could be investigated. Thirdly, the southern Langeberg is not badly infested with invasive alien plants and large areas are well-managed under the jurisdiction of Cape Nature Conservation. The southern Langeberg is also intermediate between the western and eastern mountains of the fynbos biome (Figure 1) and was determined as a centre of plant endemism by Weimarck (1941) (Figures 2 and 3). The north-western section of the Langeberg was not included in the detailed study of the vegetation because it is bioclimatically different to the southern Langeberg. However, for a general perspective, some details of the physiography, climate, geology and soils of the north-west Langeberg are given below in the section on study area.

Initially the study was aimed at surveying and describing the vegetation communities of the southern Langeberg and inventorying the flora. For this three sample transects were selected at intervals along the southern Langeberg, in the Marloth Nature Reserve (33° 58' S, 20° 28' E) at Swellendam, in the Boosmansbos Wilderness Area (33° 57' S, 20° 53' E) near Heidelberg and at Bergfontein (33° 58' S, 21° 33' E) near Albertinia. Three criteria were used for selecting the transects, (i) representativeness of the vegetation of that part of the Langeberg, (ii) maturity of the vegetation i.e. > 6 years post-fire age and (iii) accessibility of the area. Mid-way through the survey of the Bergfontein transect, an extensive fire occurred, necessitating samples to be taken in the Rooiwaterspruit-Phesantefontein area west of Garcia's Pass. The third transect was therefore a 'composite transect' of samples from different areas (see Appendix C for details).

Necessary as phytosociological surveys are, they have often been seen as an end in themselves. During the course of the vegetation survey of the southern Langeberg, given in Appendices A–C, a number of phytogeographical questions arose. I soon realized that much more could be made of a database such as the one being developed than simply

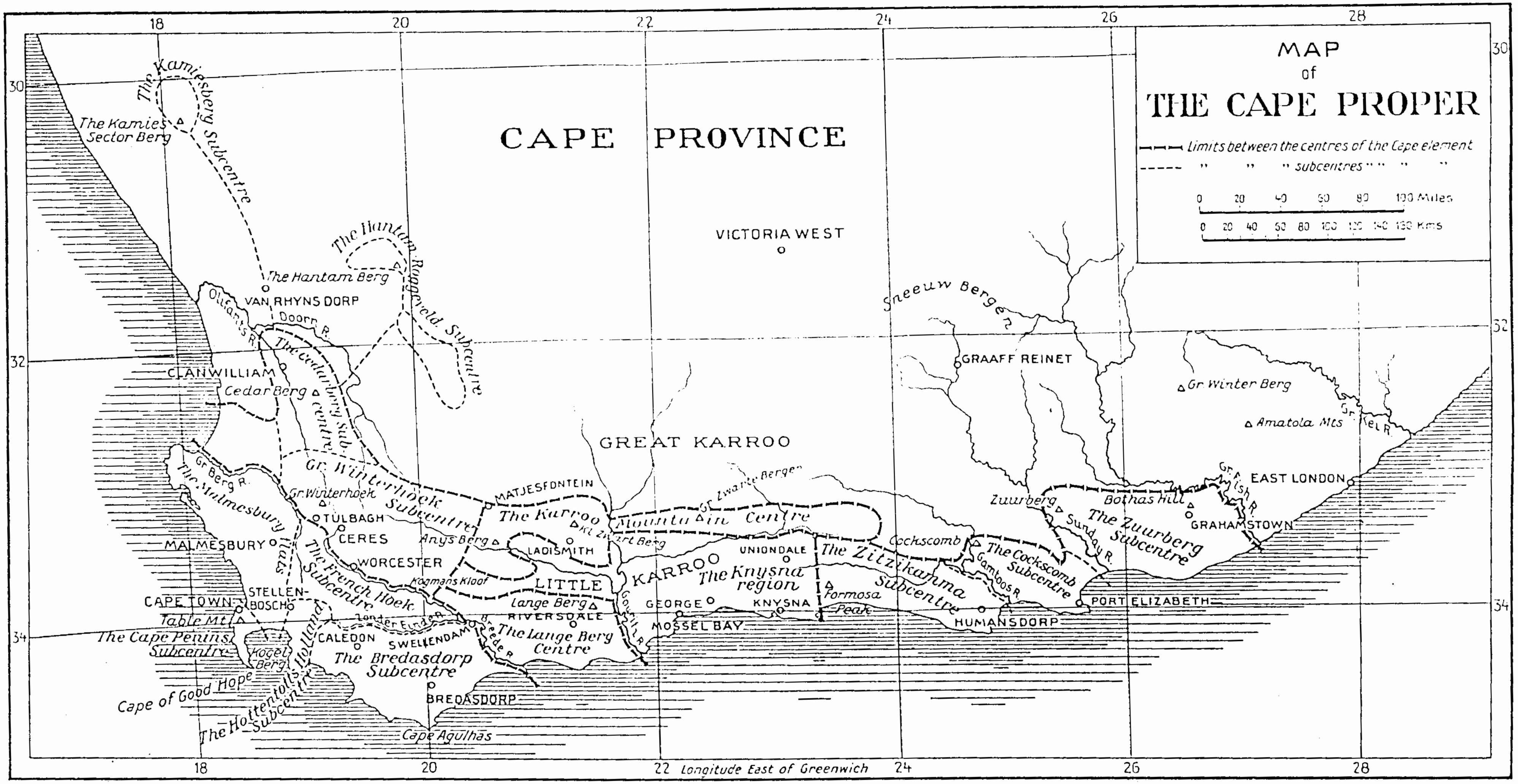

Figure 2. Weimarck's (1941) original map of the centres and sub-centres of endemism in the 'Cape Province'.

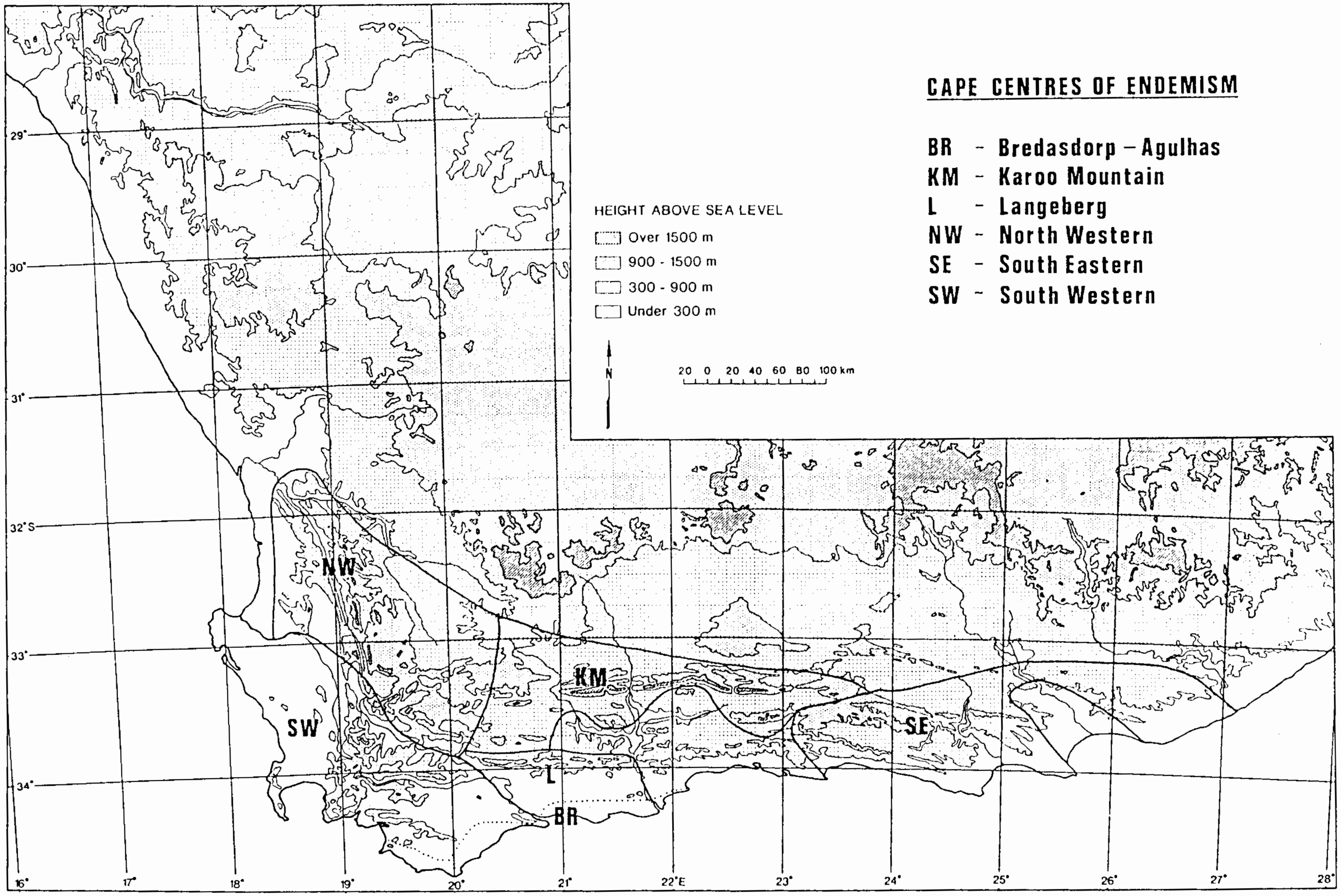

Figure 3. The Cape centres of endemism as currently recognized, after Cowling *et al.* (1992).

leaving it at the level of description of plant communities inhabiting a montane landscape. A second phase was thus initiated, based on the data collected during the survey and description of the southern Langeberg plant communities, to investigate further questions. The three papers given in Appendices A, B and C serve therefore only as background material for the information of and convenient reference for the reader of the thesis. The second phase of the study which constitutes an extension from the background phytosociological work and which has drawn on data from other additional sources, forms the body of this dissertation. It should be emphasized that this was carried out subsequent to the phytosociological classification and consists of three parts:

Part 1 details the initial in-depth look at the vegetation-environment gradients on the southern Langeberg. The objective was to formulate an empirical model of the distribution of plant communities on the southern Langeberg as a broad framework for examining other aspects of the flora. Multivariate ordination techniques were used to analyse the relationships between the vegetation and the abiotic environmental variables to establish whether those variables adequately explained the distribution of fynbos communities or whether stochastic phenomena had an overriding effect. To augment the value of the empirical model, particularly for fynbos managers, the floristic classification of the southern Langeberg fynbos was also critically compared with the structural classification of fynbos developed by Campbell (1985) to determine the level of compatibility between the two systems.

Weimarck's (1941) conclusions concerning the Langeberg Endemic Centre were based on relatively few data, so the phytosociological survey and classification and gradient analysis I had performed also offered a platform for a more intensive investigation of

Langeberg endemism, species diversity and rarity. The investigation of endemism in the flora of the southern Langeberg constitutes Part 2 of the thesis.

The flora of the southern Langeberg is rich in endemics and despite a lack of plant collections from many parts of the mountain range, a reasonably comprehensive database of plant species with their biological attributes was established. The database was based on the approximately 1000 collections I made as well as other collections from the southern Langeberg housed in the three Cape herbaria namely the Compton (NBG), Bolus (BOL) and Stellenbosch (STE) herbaria. Additional information was obtained mainly from 'Plants of the Cape Flora' (Bond & Goldblatt 1984) as well as from other literature sources. A number of specialist taxonomists were also consulted concerning undocumented species.

The main question asked about southern Langeberg endemics is whether they are randomly distributed both spatially and in terms of their biological attributes. This question was investigated in two closely linked ways. The first was to determine the levels of endemism, the spatial distribution of endemics, their taxonomic homo- or heterogeneity and their tendency or otherwise to have particular biological attributes (Part 2.1). The second was to model the biological aspects of endemism using logistic regression analysis to determine the simultaneous effects and interactions of the biological attributes of the southern Langeberg flora on the occurrence of endemism (Part 2.2).

The explanation of species diversity and rarity have both intrigued and frustrated biologists throughout the world, mainly related to problems of scale (Cowling *et al.* 1989), and the fynbos of the Cape is no exception. Species richness is a relatively easily interpreted concept although reasons for its patterns are often not clear. In contrast the concepts of β- and γ-diversity are 'slippery' and are not easily interpreted in practice. The latter two aspects of species diversity have therefore not been adequately addressed in the fynbos and scope still exists for studies in this field. Using the available phytosociological data, species diversity and rarity in the species-rich vegetation of the southern Langeberg were examined. A measure of success was achieved in explaining the observed patterns but there were some shortcomings in the data which point to the requirement of more rigorous sampling for this type of study. The results of this section of the study are reported in Part 3 of the thesis. Part 3.1 describes the first attempt to model species richness in fynbos vegetation with abiotic explanatory variables using generalised linear modelling, Beta diversity is described on altitudinal gradients and gamma diversity in six different habitat types along geographical gradients on the southern Langeberg.

General

The thesis consists of a series of five papers, some of which have been published and some of which are still to be submitted for publication. There is consequently a degree of unavoidable overlap and repetition between these papers, particularly in the introductory sections. However, this repetition serves to reinforce the central theme of the study. Where my supervisors or other people have been involved in guiding my work, their names are given as co-authors of the respective chapters (papers).

Study Area

Physiography

The fynbos biome *sensu* Rutherford & Westfall (1986) is characterized by mountainous topography with intervening low-lying intermontane valleys. Coastal forelands lie between the mountains and the coast to the west and south. The mountains are collectively termed the Cape Fold Mountains (Deacon *et al.* 1992), consisting of sub-parallel folded ranges. Those in the west strike more-or-less northwest-southeast and those in the south strike from west to east (de Villiers 1944; King 1963, in Taylor 1978). The syntaxis of the zone is in the Caledon area (Wellington 1955; Kruger 1979; Lambrechts 1979; Söhnge 1934, 1983).

The Langeberg is one of the west-east trending mountain ranges with northward verging folds, in the eastern zone of the Cape Fold Mountains. It extends from the Worcester-Nuy area (33° 37' S, 19° 41' E) in the north-west to the Gouritz River in the east (33° 57' S, 21° 40' E), forming an almost unbroken orographic line for 240 km. It is traversed by only three passes through narrow kloofs (ravines), at Kogmanskloof, Tradouw Pass and Garcia's Pass. The Langeberg is narrow and linear, being approximately 13 km wide at its widest point in the Boosmansbos Wilderness Area. Twenty-four peaks along the Langeberg exceed 1300m (4264') in altitude above sea level, the highest of which, Misty Point or Goedgeloof Peak (1710m, 5610') is found near Swellendam in the central part of the range.

To the south of the Langeberg lies the southern Cape coastal foreland (Cape Agulhas to Mossel Bay), to the west, the Breede River valley and the Worcester-Robertson Karoo and to the north the Little Karoo. To the east lie the Outeniqua and Tsitsikamma mountains, the eastward extension of the Langeberg.

From Swellendam eastwards the Langeberg lies just north of the 34° S parallel whereas from Swellendam westwards it curves towards Worcester in a north-westerly direction, lying behind the Riviersonderend Mountains. In the former part it is regarded as a coastal range but the north-western section approaches the condition of the inland ranges (*sensu* Campbell 1983). The north-western zone of the Langeberg lying in the rainshadow of the Riviersonderend Mountains results in the south-west-facing slopes being much drier than the south-facing slopes of the range further to the east, which are strongly influenced by the inflowing moist air from the sea. The north slopes of the Langeberg are dry along the entire length of the range.

The southern Langeberg is therefore defined in this study as the mountain catchments from Kogmanskloof (33° 48'S, 20° 6'E) to the Gouritz River which forms a bioclimatic unit more mesic and separate from the more xeric north-western part.

Geology

The Cape mountains consist of Cape Supergroup rocks (Table Mountain, Witteberg and Bokkeveld Groups) which were laid down as sediments in the Cape basin between the late Ordovician to Carboniferous (450–300 Myr ago). Deposition of these sediments terminated when the centre of deposition moved northwards to the Karoo basin during a period of uplift (Deacon *et al.* 1992). The Cape Fold Mountains formed during the Cape orogeny when the rocks of the Cape Supergroup were folded in a single phase, multiple event orogeny of Permian (278 Myr) to late Triassic (215 Myr) age (De Villiers 1944; Hälbich *et al.* 1983). The mountains were then eroded and provided material for deposition in the Karoo basin, a process which ended in the Jurassic (208–145 Myr) prior to the break-up of Gondwanaland (Deacon *et al.* 1992). The Langeberg consists mainly of sediments of the Table Mountain Group (Cape Supergroup) of which there are five formations. In addition there are outcrops of Cape Granite as well as Bokkeveld Group and pre-Cape Malmesbury Group sediments. The core of orogenic folding in the Langeberg is at Tradouw Pass where the massive folding has resulted in what le Roux (1974) describes as the Langeberg mega-structure.

Table Mountain Group

(i) Peninsula Formation

The Peninsula Formation consists of thick sediments of coarse-grained orthoquartzites. The rock has a characteristic whitish-grey appearance and occasionally contains pebbles of vein quartz (Rust 1967; Truswell 1970; Theron 1983; S.A.C.S. 1980). In the Langeberg this formation is well represented on the south and southwestern sides. The Peninsula Formation sediments are more or less equivalent in thickness to those of the Nardouw Sub-group from Worcester through to just east of 21° E longitude. East of this location, the Peninsula Formation becomes less evident as the Gouritz River is approached.

(ii) Cedarberg Formation

The Cedarberg Formation (also known as the Cedarberg Shale band) is made up of argillaceous mudstones and fine-grained sandstones (Truswell 1970; Theron 1983; S.A.C.S. 1980). Since the Pakhuis Formation is not found in the Langeberg, the Cedarberg Formation lies directly between the Peninsula Formation and the Nardouw Subgroup. The Cedarberg Shale band is less resistant to erosion than the quartzitic sediments and consequently gives rise to valleys with braided streams between the quartzitic formations. The Cedarberg shale is not sub-horizontal as in the Cedarberg mountains but is upturned owing to folding and faulting of the Langeberg. For the same reason, the altitude of exposure of the Cedarberg Formation varies considerably from the western to the eastern end of the Langeberg.

(iii) Nardouw Subgroup

The Nardouw Subgroup consists of three formations. These are the Rietvlei, Skurweberg and Goudini sandstone formations. The Langeberg is not situated far enough east (i.e. beyond 22° E) for the formations of the Nardouw Subgroup to be regarded as the Baviaanskloof, Kouga and Tchando sandstone formations as in the south eastern Cape (Theron 1983 & S.A.C.S. 1980). The three formations reflect changes in the sedimentary deposition processes. The basal zone is the Goudini Formation which consists of fine-grained sandstone beds alternating with purple siltstones. The overlying Skurweberg Formation is characterized by large-scale cross-bedding and consists of medium- to coarse-grained quartz arenites with pebble lag deposits. Above this are quartz arenites and mudstones deposited in a shallow near-shore environment which constitute the Rietvlei Formation (Theron 1983).

The Nardouw Subgroup sediments generally lie on the northern side of the Langeberg except in the Heidelberg district where these sediments also appear on the lower south slopes.

Cape Granite

In the Langeberg foothills north-west of Robertson in the Willemnelsrivier area and in the Bruintjiesrivier, batholiths of intrusive Cape granite are found. The granitic magma intruded during the orogenic events which gave rise to the Langeberg (Söhnge 1934; De Villiers 1944; de Bruyn *et al.* 1974).

Malmesbury Group

Malmesbury Group sediments, although mainly a feature of the lowlands west of the Langeberg, are found up to an altitude of 900m on the Langeberg southwest slopes near Robertson. These Malmesbury shales extend eastwards in a narrow band on the southern footslopes of the mountain to just beyond Swellendam (de Bruyn *et al.* 1974).

Geology of the surrounding lowlands

In the intermontane valleys, both north and south of the Langeberg, shales of the Bokkeveld Group are encountered. Enon Formation conglomerates are also found in the south and western foothills of the Langeberg around Heidelberg and Riversdale, Swellendam, Worcester and Robertson (Theron 1983; Schloms *et al.* 1983).

Silcretes (duricrusts) which are remnants of Tertiary erosion surfaces are widely distributed in the western and southern Cape. Flanking the Langeberg on the north and south sides silcretes are found capping mesas of varying size; overlying either Bokkeveld shales or Enon conglomerates (Lenz 1957; Schloms *et al.* 1983; Schloms & Ellis 1984; see also Partridge & Maud 1987).

Soils of the Langeberg

The pedology of the Fynbos Biome has been reviewed by Kruger (1979) and Lambrechts (1979, 1983). Campbell (1983), however, challenged some of the existing 'myths' concerning soils of Cape mountain environments. He differed from previous workers in three respects. Firstly, he contended that the soils are much deeper than usually assumed; secondly that podzolization is generally rare and has been over-emphasized and thirdly that soil colour, usually taken to be greyish, is not so, and is often red or yellow-brown. Kruger (1979) and Lambrechts (1979), however, clearly indicate that podzolization is a feature of the humid, southern regions of the Fynbos Biome and not of the drier inland ranges. Campbell (1983) also shows a west-east gradient of increase in fine-grained soil particles and an increasing clay-fraction to the east.

The TMG sandstones of the Langeberg from Worcester to Kogmanskloof are typically acid, sandy, skeletal and oligotrophic. Soils derived from Cedarberg shale are finer textured, clayey and richer in nutrients. On the south slopes, particularly around Robertson, where Malmesbury shale occurs, slightly acid, loamy topsoils on clayey, red and yellow blocky-structured subsoils occur on convex slopes. On concave slopes, at positions lower in the soil catena, textural differentiation, structural development and poorer internal drainage increase (Lambrechts 1989).

Climate

In general the climate of the Fynbos Biome is of the mediterranean type, with hot, dry summers and cold wet winters. This pattern is most marked in the west, where the seasons are most clearly different, but becomes less distinct towards the all-year-round rainfall zone of the southern Cape. There is also a gradient of increasing aridity from the coast inland, with obvious rainshadows on the inland slopes of the mountains (Fuggle & Ashton 1978; Schulze & McGee 1978; Campbell 1983).

According to the Köppen system the climate of the Fynbos Biome is Cs, Cf and BS (Schulze & McGee 1978; van Wilgen 1984). However, the north-south and west-east subcontinental climatic gradients superimposed on the mountainous topography result in a complex pattern of climatic zones in the western and southern Cape (Fuggle & Ashton 1979; Fuggle 1981). The climate ranges from typically Mediterranean in the west to humid, temperate in the east and from subarid to perhumid from north to south (Kruger 1979). The Langeberg ranges from being within the typical Mediterranean zone of the extreme western Cape (north west part of the range) to the all-year-round rainfall zone of the south eastern Cape. Although the Langeberg is not a high mountain range, its linear continuity presents a distinct barrier for influence of coastal climate on the Little Karoo interior. The climate of the Langeberg is thus best described by the Cfa and Cfb categories of Köppen's classification (Schulze & McGee 1978).

Wind

The southern Langeberg lies subparallel to the southern Cape coast and thus prevailing winds which blow along the coastline (Schulze 1965) strongly influence the climate of the Langeberg. Winds originate from the seasonal shift in position of the South Atlantic subtropical anticyclone and from air circulation associated with the passage of east-moving low-pressure cyclones. Coastal lows or 'leader fronts' also affect wind patterns.

In summer, winds influencing the southern Langeberg prevail mainly from the southeast (anticyclonic) and from the southwest (cyclonic). This strongly influences rainfall (see below). In winter, with the northward movement of the anticyclonic high-pressure cell, low-pressure cyclones exert more influence and winds prevail from the northwest and southwest. Hot, desiccating Föhn-like berg winds also occur in the winter between anticyclonic and cyclonic circulations that develop as a cold front approaches (Heydoorn & Tinley 1980). These berg winds greatly enhance the risk of wild fires in the dry winter months by elevating the air temperature (van Wilgen 1984).

Precipitation

The southern Langeberg is situated in the transition zone between the winter rainfall area of the south western Cape and the year-round rainfall area of the southern Cape. The north western Langeberg (Worcester–Robertson area) receives rain mainly in autumn and winter whereas the southern Langeberg, from Swellendam to the Gouritz River, can receive rain at almost any time. An analysis of percentage winter rainfall at weather stations along the Langeberg indicated that Robertson in the north-west experiences between 10 and 15 % more winter rainfall on average than localities further east (Table 1).

Precipitation on the southern Langeberg is associated with the passage of cold fronts along the southern Cape coast. Rain may occur from unstable pre-frontal and frontal conditions but is most often associated with post-frontal events. The South Atlantic anticyclone usually ridges in behind the eastward-moving cold fronts and strong anticyclonic air movement over the warm Agulhas current results in onshore advection of cool moist air

(Cowling 1984; Preston-Whyte & Tyson 1988). This moist air strikes the southern Cape mountains and orographic rain occurs, mainly on the south aspects. Coastal lows along the southern Cape coast seldom produce any precipitation more than mist or drizzle. Rain on the north slopes of the southern Langeberg results from cold fronts and cut-off lows (Preston-Whyte & Tyson 1988; van Heerden & Hurry 1987). The latter occur when a low pressure cell is ‘cut off’ in the interior, usually the southern Karoo region, resulting in heavy rain in otherwise rainshadow areas. Snow may occur at high altitudes two or three times a year in late winter and spring.

Table 1. Distribution of winter rainfall at stations along the length of the Langeberg (average over 10 year period).

Station	**Grid reference**		**Total annual precipitation (mm) (A) ***	**Winter precipitation (mm) (W) ***	**(W/A) x 100**
	S	E			
Robertson (S)	33° 50’	19° 54’	280.7	100.8	35.9
Montagu (N)	33° 48’	20° 08’	353.5	109	30.8
Marloth Nature Reserve (S)	34° 02’	20° 26’	874.2	184	21.0
Swellendam (S)	34° 02’	20° 27	700.6	181.7	25.9
Weltevrede (N)	33° 56’	20° 37’	358.4	118.5	33.0
Dundonald (S)	34° 00’	20°45’	600.9	152.2	25.3
Strawberry Hill (S)	33° 59’	20° 50’	1020.1	223.6	21.9
Karringmelks-rivier	34° 08’	20° 46’	426.8	124.9	29.3
Klein Doornrivier (N)	33° 51’	20° 57’	163.9	34.4	20.9
Riversdale (S)	34° 05’	21° 16’	462.2	123.9	26.8
Waboomsrivier (N)	33° 56’	21° 35’	490.8	118.4	24.1

The seasonal distribution of rainfall on the south slopes of the southern Langeberg is bimodal with peaks in October (spring) and April (autumn). On the north side of the range the rainfall is bimodal at Weltevrede with peaks in May and August; further east at Klein Doornrivier rainfall only peaks in April and at Waboomsrivier rainfall is erratic but shows bimodal peaks in April and October (Figure 4).

Total annual precipitation on the lower north slopes of the Langeberg (280–400 mm) is approximately 200 mm less than that received on the lower south slopes (600–800 mm) (Soil and Irrigation Research Institute, SIRI, 1986). At 1000 m a.s.l. on the south slopes the annual rainfall is estimated as slightly in excess of 1000 mm whereas at the same altitude on the north slopes, annual rainfall is estimated at 700–800 mm. The high peaks receive an estimated mean annual rainfall of 1200–1400 mm (Dent *et al.* 1987). High altitude mist significantly augments rainfall but estimates of the amounts are generally poor and not documented except for some early studies by Marloth (1903, 1905) on Table Mountain, which were criticized by Stewart (1903), and more recent studies by Nagel (1956) and Kerfoot (1968).

Temperature

No data are available for temperatures at high elevations of the southern Langeberg. This is a serious drawback in the interpretation of the climate of the range. The climate diagrams for Weltevrede and Swellendam (Figure 4), however, show the mean annual temperatures experienced on the lower north and lower south slopes of the Langeberg respectively. Table 2 gives mean daily maximum and minimum temperatures for five weather stations close to the Langeberg. This allows for comparison of the temperatures on the equatorial north-facing slopes and the polar south-facing slopes.

On the south side of the Langeberg at Swellendam and Riversdale the highest mean daily maximum recorded is in January (29.4°C and 28.2°C) and the lowest mean daily minimum in July (6.6°C and 5.6°C). In contrast the highest mean daily maximum at Weltevrede is in February (30.0°C) and at Montagu in January (30.2°C) with mean winter minima at these stations being 2.9°C and 3.9°C respectively. The mean monthly maxima are slightly higher on the north slopes (Weltevrede) in summer, autumn and spring, with similar maximum temperatures experienced in winter at Swellendam and Weltevrede. On the other hand, Weltevrede experiences lower minimum temperatures than Swellendam throughout the year. This is attributed to the maritime influence on the south slopes and higher heat loss due to reflected radiation on the north slopes.

Table 2. Mean daily maximum and minimum temperatures (°C) at five weather stations close to the Langeberg (Means for 10 year period; data supplied by Agrometeorology, Soil and Irrigation Research Institute, Elsenburg).

	Month											
Locality	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Swellendam												
T max	29.4	29.1	27.3	24.6	21.9	19.1	18.5	19.8	21.4	23.0	25.6	27.7
T min	15.8	16.0	14.7	12.3	9.7	7.3	6.6	7.3	9.1	10.7	12.9	14.5
Riversdale												
T max	28.2	28.0	26.7	24.5	22.3	19.5	18.9	19.9	21.5	22.8	24.9	26.8
T min	16.0	16.3	14.8	12.2	9.2	6.4	5.6	6.4	8.7	10.8	13.2	15.0
Weltevrede												
T max	29.9	30.0	28.0	25.0	22.2	18.8	18.4	19.7	22.1	23.9	26.6	28.6
T min	13.3	13.5	11.7	9.2	6.4	3.6	2.9	4.0	6.0	8.1	10.5	12.2
Montagu												
T max	30.2	29.7	28.1	25.3	21.9	19.2	18.9	19.9	22.1	24.7	26.9	29.0
T min	15.9	15.8	13.6	11.0	7.7	5.2	3.9	5.5	8.1	11.0	13.2	14.7
Robertson												
T max	30.7	30.2	28.1	25.1	22.4	19.4	18.7	20.1	22.4	24.8	27.6	29.5
T min	15.7	15.9	14.2	11.4	8.4	5.4	5.2	6.0	8.3	10.3	12.9	14.6

If an environmental lapse rate of 0.6°C per 100 m is taken (Cowling 1984), then a decrease in temperature of approximately 9.45°C on south-facing slopes above Swellendam and 7.8°C on north-facing slopes above Weltevrede at an altitude of 1700 m a.s.l. is predicted.

Insolation and Evaporation

Solar radiation has been invoked as one of the prime driving forces of ecosystems since it provides the energy necessary for ecosystem functioning (Morris 1981; Schulze 1975 a & b; Schulze & McGee 1978; Swift 1976).

Incoming radiation may be measured directly or derived from sunshine duration. Mountainous terrain, however, presents a variety of slopes and aspects with attendant marked effect on insolation and the vegetation. Direct measurement of radiation such as that carried out by Morris (1981) is therefore often not practical. However, methods are available where incoming radiation on sloping terrain may be estimated (Schulze 1975b; Schulze & Lambson 1986, Swift 1976).

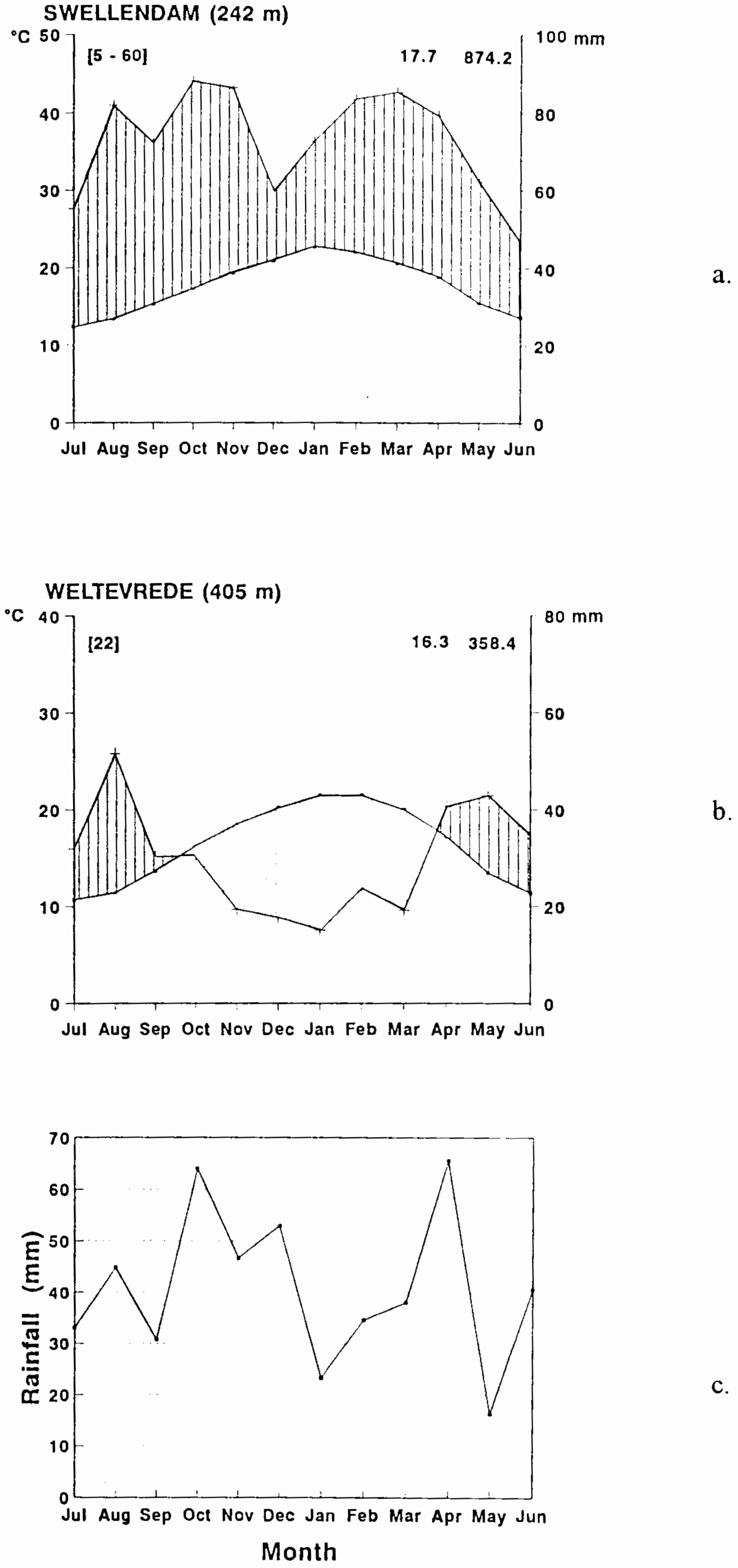

Figure 4. Walter-Lieth climate diagrams for **a.** Swellendam, on the south side of the Langeberg and **b.** Weltevrede on the dry northern side of the range. **c.** Distribution of annual rainfall at Waboomsrivier (33° 55' S, 21° 35' E) on the north side of the southern Langeberg flanking the Little Karoo.

With the orientation of the southern Langeberg being more or less parallel to the 34° S latitude, it was expected that there would be a marked difference in insolation between the south- and north-facing slopes. In addition it would be predicted that seasonal differences in radiation flux densities between summer and winter would be great. No data have been published on sunshine duration for the Langeberg.

Bond (1981) used Swift's (1976) algorithm to calculate potential radiation for a range of slopes and aspects for the latitude 33° 30'S which is roughly equivalent to the latitude for the southern Langeberg. He found that potential radiation is relatively similar on all aspects and slopes in summer, with marked differences between north and south aspects, particularly steep slopes, in winter.

In this study the RADSLOPE model (Schulze & Lambson 1986) was used to calculate estimates of radiant flux densities. The results (not reported here but included in the multivariate analyses of Chapter 1.1) agreed generally with those expected from previous studies (Schulze 1975b; Bond 1981; Cowling 1984) where there is little variation in incoming radiation from site to site in summer. The low azimuth of the sun in winter, however, results in the high contrast between the well-irradiated steep north slopes and the much less irradiated steep south slopes.

Evaporation is strongly linked to aspect, topography and consequent potential radiation. In addition precipitation plays an important role. The evaporation on given slopes may also be estimated using the RADSLOPE model based on the Penman Equation; this procedure was carried out concurrently with the calculation of radiant flux densities and the results also used in multivariate analyses (Chapter 1.1).

Vegetation

In the past the fynbos has been variously classified as Macchia, Coastal Macchia and False Macchia (Acocks 1953), Mountain Fynbos, Arid Fynbos and Coastal Fynbos (Taylor 1978) and Mountain Fynbos, Grassy Fynbos and Lowland Fynbos (Moll *et al.* 1984). For reasons of structural similarity between lowland and montane fynbos and arguments that the fynbos of adjacent mountains can be more different than that of adjacent mountains and lowlands, these distinctions have been largely dismissed (Cowling *et al.* 1988; Cowling & Holmes 1992). However, for geographical reasons I make a distinction between the fynbos of the mountains and fynbos of the lowlands in this dissertation which does not imply any particular classification of fynbos.

Fynbos (Kruger 1979) and Afromontane Forest (White 1978; McKenzie 1978; Geldenhuys 1983) are the two main vegetation types found on the Langeberg. On the southern Langeberg proteoid vegetation generally occurs on slopes at low to mid altitudes on somewhat heavier soils and where rainfall is lower, whereas ericaceous fynbos dominates the upper wet south-facing slopes at high altitude on highly leached, sandy soils. On the extreme north slopes asteraceous fynbos dominates (see Campbell 1985). The flora of the Langeberg range forms a link between the floras of the mountains of the south-western and north-western Cape with the Outeniqua and Tsitsikamma mountains of the southern Cape. This is particularly important when considering the pool of species from which local floras are drawn. Detailed descriptions of the communities encountered in this study are given in Appendices A–C.

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Langeberg Landscapes

Plate 1. The southern mesic to wet slopes of the southern Langeberg in the Boosmansbos Wilderness Area (Transect C)

Plate 2. View southwards from Grootberg (Lemoenshoek Peak, 1627.5 m) over the Boosmansbos valley, with Hôringberg Peak (1487.5 m) at the extreme left and Noukrans Peak (1443 m) in the centre.

Plate 3. Intermontane valley running eastwards along the Cedarberg Formation shaleband from Stinkhoutbos to the 'nek' between Phesanteberg (1323 m, visible in picture) and Korenteberg (1322 m, not visible, to the right). Note the folds in the Nardouw Subgroup sandstone strata.

Plate 4. Northern slopes of the southern Langeberg consisting of Nardouw Subgroup sandstone at Muurivier near Barrydale.

Plate 5. **a.** *Berzelia intermedia–Erica melanthera* Shrublands, dominated *by E. melanthera*, with *Leucadendron eucalyptifolium* in the foreground. **b.** *Hypodiscus aristatus–L. eucalyptifolium* Shrublands. **c.** *Berzelia intermedia–Erica blenna* Shrublands. Boosmansbos Wilderness Area, Transect C.

Plate 6. View eastwards from summit of 12 O'Clock Peak. Note restioid fynbos in the foreground and wet ericaceous fynbos on the south-facing slopes of the ridge in the middle distance.

Plate 7. *Erica hispidula–Spatalla nubicola* Shrublands on the south-facing slopes of Repeater Kop ridge at 1460 m (Plot 95). Boosmansbos Wilderness Area,.Transect C.

Plate 8. **a.** *Restio inconspicuus–Anthochortus crinalis* Shrublands with *Erica regerminans* in full bloom, Platbosrivierkloof, Boosmansbos Wilderness Area (Transect C). **b.** *Hypodiscus aristatus–Restio strictus* Shrublands at 1420 m in the Marloth Nature Reserve (Plot 166, Transect W). **c.** *Passerina obtusifolia–Leucospermum calligerum* Shrublands (dry asteraceous fynbos) on the lower north slopes of the Boosmansbos Wildereness area, above Witbooisrivier (Plot 166, Transect C).

Part 1. Vegetation-environment relationships on the southern Langeberg.

> *'Whatever may be the equation for men and land, it is improbable that we as yet know all its terms.'*
>
> Aldo Leopold
>
> *A Sand County Almanac*

1.1

Vegetation-environment relationships on a species -rich coastal mountain range in the Fynbos Biome (South Africa).[2]

D.J. McDonald, R.M. Cowling and C. Boucher

Abstract

The species-rich fynbos of the southern Langeberg Mountains, South Africa was studied along three transects (a) to evaluate the compatibility of a previously established floristic classification of the southern Langeberg vegetation with a fynbos biome-wide structural classification of mountain vegetation, (b) to describe the environmental gradients to which the vegetation responds and (c) to investigate the relationship between the vegetation and the abiotic environmental variables which determine the pattern of distribution of the fynbos communities on the southern Langeberg.

Principal Components Analysis (PCA) was used to determine correlations between environmental variables independent of vegetation data. Similarities between the 46 communities (determined by floristics) from the three transects were determined using cluster analysis and grouped into 14 higher level units. Detrended Correspondence Analysis (DCA) was then used for indirect gradient analysis after which Canonical

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[2] Submitted to *Vegetatio* for publication

Correspondence Analysis (CCA) was used in a direct gradient analysis of the vegetation with the environmental variables.

Compatibility between the floristic and structural classification of the vegetation was analysed. The PCA principal gradient was defined as one from sites with high rock cover, shallow soils and north aspects to those with low rock cover, deeper soils and south aspects. The second gradient is most strongly positively correlated with percentage organic carbon and most strongly negatively correlated with soil clay content. In contrast to the PCA, the DCA showed that the principal gradient is a precipitation gradient, with the response of the vegetation dominated by the change from wet to dry conditions and from low to high winter incoming radiation. The CCA showed that the variation in the mountain habitats to which the vegetation responds can be predicted from a combination of a few environmental variables. The principal gradient was one of change from high to low mean annual precipitation with an opposite change in winter incoming radiation. The second gradient was described by percentage surface rock cover and soil clay content. A simple model using the environmental factors selected in the CCA was proposed for predicting the distribution of floristically determined community groups in the fynbos vegetation of the Langeberg and the southern Cape coastal mountains in general.

Keywords: Classification, Fynbos, Gradient analysis, Vegetation-environment relationships.

Nomenclature: Arnold & de Wet (1993).

Introduction

Land-use planning and management of mountain catchments in the Cape mountains is often based on personal experience and subjective decisions of managers and not on the documented distribution and dynamics of biological resources (Richardson *et al.* 1992; van Wilgen *et al.* 1992). For effective management there is a need for making more informed and less subjective decisions (van Wilgen *et al.* 1992; van Wilgen *et al.* 1994). Part of the basic information required comes from vegetation surveys of mountain catchments and the definition of ecological units and the prediction of their occurrence in the landscape. However, for vegetation classifications to be used in management decisions, classification systems should be readily interpretable and extrapolatable by managers. In order to achieve this, there is a need for predictive models of vegetation-environment relationships (Keith & Sanders 1990), i.e. where managers are able to classify vegetation types on the basis of simple environmental variables.

Recognizing the needs of managers, a central question in phytogeographical and ecological studies of the species-rich, fire-prone Cape fynbos vegetation has been whether the observed species-based pattern can be explained by environmental influences or whether stochastic events have an overriding effect (Bond 1981; Campbell 1983, 1986a & b; Cowling 1984; Cowling & Campbell 1983; Richards *et al.* in press). It has been argued that much of the floristic variation in these species-rich landscapes is associated with stochastic phenomena such as fire and other historical effects (Taylor 1985; Cowling 1987). However, Cowling & Holmes (1992) concluded that strong relationships are found between present-day ecological factors and the distribution of communities defined in terms of structure, noting that changes in fynbos vegetation structure along environmental gradients can now be predicted with fair accuracy. They contrasted this with floristic patterns in fynbos which have been studied less and are not as well understood.

Investigations of the relationship between observed floristic patterns in the vegetation of the Cape mountains and environmental gradients have mostly employed a syntaxonomic approach (Boucher 1978; Cowling 1984; Kruger 1974; McDonald 1993a, b, c (see Appendices A, B, C)) or indirect gradient analysis using procedures such as Principal Components Analysis (PCA) (Bond 1981; Campbell 1983, 1986a) or Detrended Correspondence Analysis (DCA) (van Wilgen & Kruger 1985; McDonald 1987). Direct gradient analysis has been used to a limited extent in fynbos of the mountains (Cowling & Campbell 1983) and it has been shown that there is predictable structure in lowland vegetation, related to various environmental factors (Richards *et al.* in press).

Campbell (1985, 1986a & b) developed a system whereby fynbos could be classified according to 'structural characters' and 'higher-level taxonomic groups'. He sought to avoid the problems of high beta and gamma diversity and aimed to find a unifying classification applicable to fynbos communities over a wide range of montane habitats. However, although a typology for the vegetation of the mountains (predominantly fynbos) was derived, and an arguably more ecologically interpretable classification established, in the process much valuable information held at the floristic level was ignored (Campbell 1985).

Opportunity therefore existed for comparing Campbell's (1985, 1986b) structural classification with floristic classifications of fynbos of the Cape mountains. By using the floristic classification of the vegetation of the southern Langeberg established prior to the present study (McDonald 1993a, b, c (see Appendices A, B, C)) it was possible to examine vegetation-environment relationships on the southern Langeberg Mountains and to evaluate Campbell's (1985, 1986b) structural classification system. The emphasis in this study was on vegetation-environment relationships and not on the classification – either structural or floristic – of the vegetation.

Both indirect (PCA, DCA) and direct gradient analysis (CCA) were used to quantify the relationships between the fynbos communities of the southern Langeberg (based primarily on floristic definition), and their environment. This has partly filled the need for studies of vegetation-environment relationships and for investigation of floristic patterns in the fynbos (Campbell 1983; Cowling & Holmes 1992). Key questions in the investigation were:

1. Can the observed floristic patterns of the southern Langeberg fynbos be accommodated within Campbell's (1985, 1986b) structural classification?
2. What are the major environmental gradients determining the observed patterns of plant community distribution in the fynbos vegetation of the southern Langeberg?
3. Is the distribution of plant communities adequately explained by the environmental variables considered or are stochastic phenomena more important in determining species distributions?
4. Through the development of a model of vegetation-environment relationships for the southern Langeberg, can these relationships be extrapolated to the other coastal mountain ranges in the southern Cape?

Study Area

The southern Langeberg (1748 km²) is a southern Cape coastal mountain range (Figure 1.1.1) vegetated with species-rich (>1200 species) sclerophyllous fynbos. The flora has a high level of local endemism (160 species or 13.02% of the total flora) (McDonald & Cowling 1995 (see Chapter 2.1)).

Since the southern Langeberg lies in the transitional zone between winter and year-round rainfall regions it experiences a bimodal rainfall pattern with peaks in late summer to autumn and late winter to spring. In general annual rainfall ranges from 500-600 mm on the lower south slopes, to 1200-1400 mm on the mountain peaks and 200-300 mm on the dry lower north slopes. The range from mean winter minimum to mean summer maximum temperatures is from 6.6°C to 29.4°C on south slopes and 2.9°C to 30.0°C on north slopes. Soils are generally infertile, leached sandstone soils with more fertile soils being formed from Cedarberg Formation and Malmesbury Group shales (Table 1.1.1).

Geographically the southern Langeberg is approximately centrally situated on Campbell's (1983) soil texture-fertility gradient which extends along the west-east axis of the Cape Fold Mountains from the western Cape to the eastern Cape. The southern Langeberg also clearly displays the local wet to dry moisture gradient from south to north, typical of a south coastal mountain, and lies at the mesic end of the fynbos biome-wide moisture gradient.

The fynbos of the southern Langeberg was sampled on three transects situated at intervals along the mountain range, straddling it from south to north (Figure 1.1.1). Located in the districts of Heidelberg (Boosmansbos Wilderness Area, referred to as the Central Transect - C), Swellendam (Marloth Nature Reserve, referred to as the West Transect - W) and Riversdale-Albertinia (referred to as the East Transect - E), the transects sample the range in vegetation communities encountered on this part of the Langeberg Mountains. Details of the study area, transects and 46 fynbos communities identified are described in the General Introduction and by McDonald (1993a, b, c (see Appendices A, B, C)).

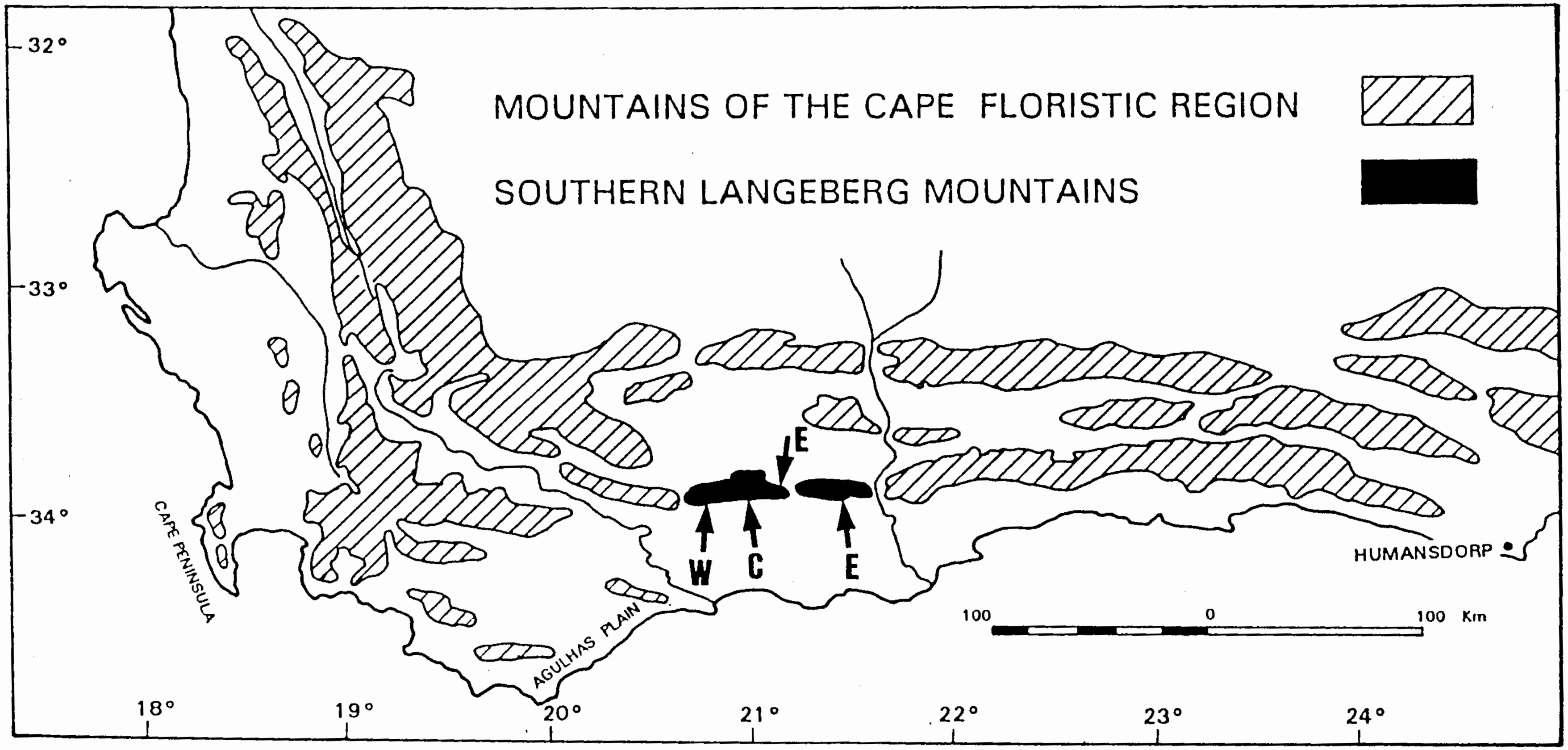


Figure 1.1.1 The southern Langeberg mountains in relation to other mountains of the Cape Floristic Region. The approximate locations of the three transects are shown: W – West Transect; C – Central Transect; E – East transect (a ‘composite transect’ from two different localities).

Methods

Data collection

Of the 299 plots sampled in the fynbos of the southern Langeberg (McDonald 1993a, b, c (Appendices A, B, C)), a 'complete set' of environmental variables (Table 1.1.1) was recorded for only 167 plots; 31 from Transect C, 75 from Transect W and 61 from Transect E.

Table 1.1.1. The 'complete set' of environmental variables. Non-soil variables were recorded in all relevés. The soil variables were recorded in a subset of 167 samples.

Variable abbreviation	**Description**
Non-soil abiotic variables	
Altit	Elevation above sea level
Aspect	Corrected aspect (degrees) (see text)
Slope	Inclination of slope (degrees)
%Rock	Estimate of percentage rock cover in plot
MAP	Mean annual precipitation (mm)
Penins	Peninsula Formation (sandstone)
Cedarbe	Cedarberg Formation (shale)
Nardouw	Nardouw Sub-group (3 sandstone formations)
Malmesb	Malmesbury Group (shale)
SGRFD	Summer global radiant flux density (MJ/m^2)
WGRFD	Winter global radiant flux density (MJ/m^2)
SPE	Summer potential evapotranspiration (mm)
WPE	Winter potential evapotranspiration (mm)
Soil variables	
Soildep	Depth of A-horizon of soil
pH	pH of A-horizon of soil
P ppm	Concentration of phosphorus in A-horizon
%Carbon	Percentage organic carbon in A-horizon of soil
%Nitro	Percentage nitrogen in A-horizon of soil
%Clay	Percentage clay in A-horizon of soil
%Silt	Percentage silt in A-horizon of soil
%Sand	Percentage sand in A-horizon of soil
CEC me%	Cation exchange capacity of soil
Na me%	Concentration of sodium ions in soils
K me%	Concentration of potassium ions in soil
Ca me%	Concentration of calcium ions in soil
Mg me%	Concentration of magnesium ions in soil
S value	The sum of exchangeable Ca, Mg, Na and K

(i) Topography

Slope inclination, aspect and elevation are the major topographic descriptors of any site. The slope and aspect of each site were measured in degrees, with aspect corrected for magnetic deviation. Aspect was then transformed into a linear form following the method of Wikum & Wali (1974; see also Shackleton *et al.* 1991) from 1° (north) to 180° (south). Aspects from 180° to 360° (north) were assigned the same value as those from 180° to 1°, which have approximately the same amount of incoming radiation. This procedure circumvents the problem of azimuth not being meaningfully interpreted in correlation and regression analysis. On the southern Langeberg which runs linearly west-east, east-facing slopes receive approximately the same amount of incoming radiation as west-facing slopes.

(ii) Climate

The RADSLOPE model (Schulze 1975; Schulze & Lambson 1986) was used to obtain incoming radiation and potential evaporation indices. Altitude data, necessary for the model, were obtained by overlaying a uniform grid over 1: 50 000 topographic maps of each of the transects. Elevation above sea level was recorded at the grid intersects for 1500 points (Transect C), 1300 points (Transect W) and 1538 points (Transect E). These data were analysed using the spatial analysis model, ACRU (Pike & Schulze 1991), to generate 'horizon' and 'geometry' data which, together with rainfall and temperature data from the weather stations nearest to the transects, were used in the RADSLOPE model.

Mean annual precipitation (MAP) was obtained for a 1'x1' grid for the respective transects from the Computing Centre for Water Research, Pietermaritzburg (see Dent *et al.* 1987). These data are coarse compared with the distribution of sample plots but are the best available.

(iii) Soils

The soils of the study area are generally shallow and soil samples were collected from the A-horizon only, the depth of which varied from a few centimetres to 0.3 m. No soil samples were taken from the shallow lithosolic Mispah Form soils of the *Passerina obtusifolia–Leucospermum calligerum* and *Cannomois parviflora–P. obtusifolia* 'Typicum' Shrublands on Transect C and the *Protea lorifolia–L. calligerum* Shrublands on Transect E (see Appendix A). These communities occur on rocky substrata where soil development is poor; what 'soil' is present is mainly coarse gravel which proved unsuitable for standard soil analyses. Soil analysis methods and variables assessed are given in Table 1.1.2.

Table 1.1.2. Soil variables assessed for 167 sample plots and the analysis methods used.

Soil variable	**Analysis method**
Soil depth (A-horizon)	Metal spike driven into soil or from soil pits
pH	pH of a 1:1 soil:0.01 mol/l $CaCl_2$ solution
P	Bray No. 2
Na	}
K	} 1 mol/l NH acetate leachate
Ca	}
Mg	}
CEC	0.5 mol/l $CuSO_4$ leachate
S value	Sum of exchangeable cations
Carbon (oxidizable)	Modified Walkley-Black method
Total nitrogen	Kjeldahl
Clay	}
Silt	} Pipette method
Sand	}

Data analysis

Vegetation data

To summarize patterns in the fynbos of the southern Langeberg, each of the 299 relevés sampled in the vegetation survey (McDonald (1993a, b, c (Appendices A, B, C) was assigned, where possible, to a structural 'type' in Campbell's (1985, 1986b) classification. These data were then analysed to determine the proportional contribution of each different structural type to each community. The aim was to see whether the floristic communities could be grouped into higher-level structural units e.g. subseries (see Cowling *et al.* 1988) or whether the variation in structural types within each floristic community was too great for this to be possible. The aim was not to establish an independent structural classification of the vegetation of the southern Langeberg.

To simplify ordination of the whole vegetation data set (299 relevés) a reduction procedure was followed resulting in 46 communities on the sample transects representing the whole vegetation data set. These 46 communities from the three sample transects were later grouped into higher-level floristic units. Firstly each community was reduced to a 'synoptic community unit' by amalgamating the representative relevés, paying careful attention to relative abundances of species. Then, using cluster analysis (unweighted pair group method employing the Jaccard Coefficient (Kovach 1993)), the 46 'synoptic community units' were clustered into 14 higher-level floristic units. Finally, to examine the gradients, the higher order vegetation units were superimposed on the ordination diagrams using the computer program CANODRAW 3.0 (Smilauer 1992).

Choice of analytical methods

Since the floristic gradients in the southern Langeberg are long (> 3 SD), it was assumed that the response of species to the underlying structure of the Langeberg environmental data would be non-linear. Therefore, analytical methods based on Gaussian models as opposed to linear models were used (Prentice 1977; ter Braak 1987a, b; Brown et al. 1993; Saetersdal & Birks 1993). Correlations between environmental variables were analysed independently of the vegetation data using PCA. PCA covariance biplots were constructed (ter Braak 1987a). The variables were standardized to zero mean and unit variance prior to analysis. The following step was to use DCA (indirect ordination) (Hill 1979) to investigate compositional gradients in the vegetation data. In this case only vegetation data was used. This was followed by CCA to determine the direct relationships between the vegetation data and explanatory environmental variables (Borcard et al. 1992; Jean & Bouchard 1993). The use of DCA and CCA sequentially enables one to judge how much of the variation in the species data can be attributed to the environmental data (ter Braak 1986; Franklin & Merlin 1992). CANOCO version 3.12 (ter Braak 1990a, b) was used for all ordination analyses.

DCA was applied to two data sets: (i) The 46 fynbos communities (full species lists were compiled from all plots in the respective communities) identified by McDonald (1993a, b, c (Appendices A, B, C)), and (ii) the 167 plots for which the 'complete set' of environmental variables was available. In the second case, correlation analysis of the explanatory (environmental) variables was carried out twice, once including and once excluding the soil chemical variables, since soil chemical variables were available for only these 167 of the 299 relevés.

For the CCA's (also done on data from 167 relevés) the default option was used in the majority of cases after all the environmental variables were log transformed. After initial CCA analyses of the 'complete set' of environmental variables (CCA 1) and the 'reduced set' (where soil chemical variables were excluded) (CCA 2), forward selection of all the explanatory variables was used to determine a 'minimum set' (ter Braak 1990b) (Table 1.1.3). Soil chemical variables were then removed and the same procedure followed, to assess the importance of the inclusion of soil chemical variables in the environmental data set. The Monte Carlo permutation test (ter Braak 1990a & b) was used to test for significance of the canonical correlations.

The use of canonical coefficients in determining the significance of environmental variables is undesirable because they can be unstable. Intra-set correlations (i.e. the inter-set correlations divided by R (the species-environment correlation of the axis) from the CCA's were therefore used to assess the importance of the environmental variables (ter Braak 1986, 1987; Franklin & Merlin 1992; Brown *et al.* 1993).

Results

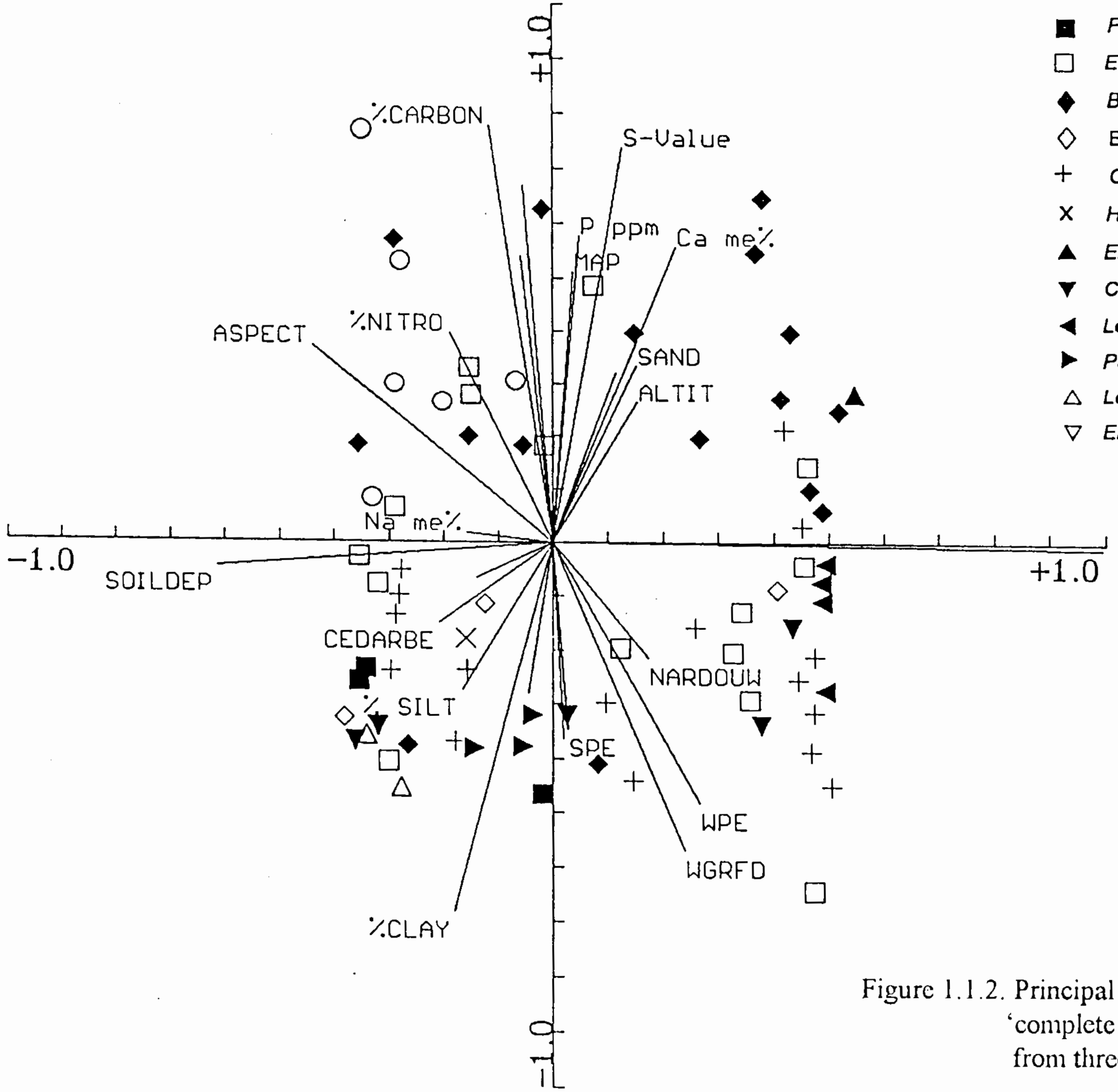
Classification of vegetation data according to structure

The structural classification of the relevés was poorly related to the floristic communities (McDonald 1993a, b, c (Appendices A, B, C)) at type and subseries levels; 59% of the floristic communities contained more than one structural subseries. In addition, once the communities were grouped into broader floristic community groups (see below), the structural equivalency became even less clear. The structural types and subseries (Campbell 1985) found in each of the 46 communities recognized by McDonald (1993a, b, c (Appendices A, B, C)) are given in Appendix 1.1.1. Of these communities, 18 had direct structural type equivalents; 23 communities contained more than one structural subseries and four communities were equivalent to a single subseries but each of these subseries had two types represented. One community, the *Erica versicolor–Agathosma ovata* Shrublands, could not be classified according to the structural classification. On

Transect E of the Langeberg vegetation survey (McDonald 1993c (Appendix C)), 72% of the plots were in immature vegetation (6-7 years old). In communities 32-39 (see Appendix 1.1.1) it was difficult to assign the relevés (particularly for stands where tall proteoids would ultimately dominate) to structural types in Campbell's (1985) system, which requires that the vegetation should be mature (> 10 years old).

None of the floristic communities were found to contain the structural subseries Mesotrophic Proteoid Fynbos as was indicated by McDonald (1993b (Appendix B)). This is contrary to what was expected in some cases e.g. proteoid communities on low-altitude shale soils, but the understorey was not grassy enough for samples to qualify for inclusion in structural types within Mesotrophic Proteoid Fynbos. Talus Asteraceous Fynbos or Waboomveld (Taylor 1978) was only sampled in one area, at Bergfontein (McDonald 1993c (Appendix C)). On the southern Langeberg it is widely but patchily distributed on fine-textured clay-rich soils at sites with low rainfall.

The cluster analysis resulted in the 46 floristic communities being combined into 14 higher-level, broad-scale units or community groups. Communities 28, 30, 40, 41 and 44 remained ungrouped with any other. The community groups are shown by symbols in Figure 1.1.3 (DCA) and the names of the groups with the communities they contain are given in Appendix 1.1.2. Of the 14 community groups, only groups A, J, M and N are equivalent to structural subseries (Campbell 1985).



Key to community 'groups'

- ○ *Protea grandiceps*– *Erica transparens* Group (1, 2, 17, 31)
- ■ *Protea grandiceps*– *Helichrysum oxyphyllum* Group (3, 4)
- □ *Ehrharta rupestris* subsp. *dodii* – *Platycaulos major* Group (5, 6, 7, 8, 9)
- ◆ *Blechnum tabulare* – *Erica atropurpurea* Group (14, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 29)
- ◇ *Erica pubigera* – *Protea piscina* Group (15, 16)
- + *Centella lanata* – *Indigofera alopecuroides* Group (32, 33, 34, 35, 36, 37, 38, 39)
- × *Hypodiscus aristatus* – *Erica multumbellifera* Group (28)
- ▲ *Erica versicolor* – *Agathosma ovata* Group (41)
- ▼ *Centella glabrata* – *Pelargonium ovale* Group (10, 11)
- ◀ *Leucadendron eucalyptifolium* – *Hypodiscus argenteus* Group (30)
- ▶ *Paranomus spathulatus* – *Osteospermum junceum* Group (42, 43, 45)
- △ *Leucadendron eucalyptifolium* – *Elegia filacea* Group (44)
- ▽ *Erica hispidula* – *Protea nitida* Group (40)

Figure 1.1.2. Principal components analysis (PCA) biplot of the 'complete set' of environmental variables and 167 plots from three sample transects on the southern Langeberg .

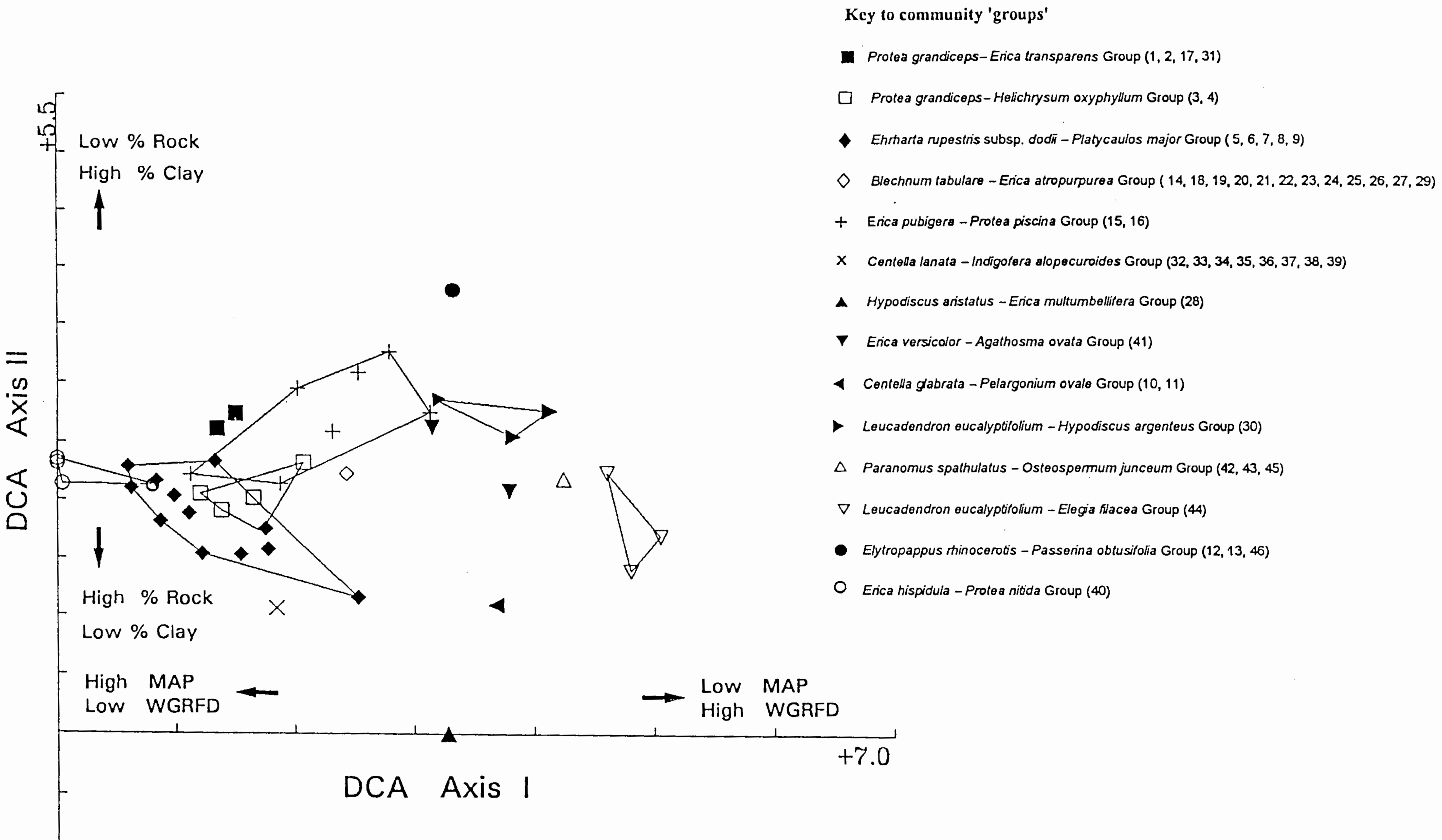


Figure 1.1.3. Detrended correspondence analysis (DCA) scatter diagram of 46 floristic communities of the southern Langeberg recognized by McDonald (1993a, b, c. See Appendices A, B, C), classified according to the 14 community 'groups' determined by cluster analysis (see Appendix 1.1.2) and showing the principal gradients on axes I and II.

(i) Environmental gradients

Principal components analysis (PCA) of the environmental variables

The results of the PCA of the environmental variables for 167 plots showed that Axis 1 (which explained 40% of the variance when soil chemical variables were present and 61.9 % when they were absent), showed the strongest positive correlation with percentage rock cover (%Rock) and the strongest negative correlation with aspect and soil depth (Figure 1.1.2). The gradient defined is one from sites with high %Rock, shallow soils and north aspects to those with low %Rock, deeper soils and south aspects. Axis 2, when soil chemical variables are present, accounts for 17.1% of the variance and is most positively correlated with percentage organic carbon (%Carbon) and most negatively with percentage clay (%Clay) (Figure 1.1.2). In contrast, when soil chemical and texture variables are absent, Axis 2 accounts for 13.1% of the variance and is most strongly correlated with winter global radiant flux density (WGRFD) and most negatively with aspect (not illustrated). This indicates that soil chemical and texture variables positively contribute to explaining the variance accounted for by the second principal component. The gradient defined is one from sites with high %Carbon and low %Clay to those with the opposite conditions. Axis 3 accounts for 9% of the variance when soil chemical variables are present and 6.2% when they are absent, indicating once again that soil chemical variables are important. This weak gradient is a soil-texture gradient, from sites with soils of high %Clay and low %Sand to sites with high %Sand and low clay content.

(ii) Vegetation-environment gradients

The results of the vegetation-environment ordinations are presented as follows: unconstrained site ordinations (DCA's) with (DCA 1; n = 167 relevés) and without (DCA 2; n = 299 relevés) soil chemical variables and constrained site ordinations with (CCA 1; n = 167 relevés) and without (CCA 2; n = 299 relevés) soil chemical variables (Table

1.1.3). DCA_{CO} is the DCA of the 46 southern Langeberg fynbos communities (Table 1.1.3; Figure 1.1.3). Values in square brackets [r] are regression coefficients for DCA and intra-set correlations for CCA, for the respective explanatory variables.

(a) Unconstrained site ordination (DCA)

Eigenvalues, site-environment correlations and percentage variance explained for three axes for DCA's with and without soil chemical variables are given in Table 1.1.3. The two analyses, with and without soil chemical variables, gave the same eigenvalues but lower site-environment correlations and higher percentage of variance explained when soil variables were excluded. The lengths of the gradients represented by Axes 1 & 2 in both analyses was > 5 SD, indicating a complete turnover in species composition along these gradients. A well-defined gradient in MAP [r^2= -0.70] was found on Axis 1, reflected in the species composition from wet to dry sites in the study area (DCA's 1 & 2). This axis was also correlated with a gradient in pH [r^2= 0.47] from sites with low pH to those with relatively high pH (DCA 1) and from low to high winter global radiant flux density (WGRFD) [r^2= 0.50] (DCA 2).

Axis 2 was positively correlated with %Clay [r^2= 0.49] and negatively with MAP [r^2= -0.58], indicating a gradient from sites with clay-rich soils and low MAP to those with sandy soils and high MAP (DCA 1). DCA 2 showed a similar negative correlation of Axis 2 with MAP [r^2= -0.64] but was positively correlated with Cedarberg Formation shale [r^2= 0.49]. This agreed with the gradient defined from DCA 1 since shale soils are clay-rich.

Axis 3 was positively correlated with Nardouw Subgroup sandstone in both analyses (DCA 1:[r^2= 0.69]; DCA 2: [r^2= 0.77]) and similarly negatively correlated with Peninsula Formation sandstone (DCA 1: [r^2= -0.53]; DCA 2: [r^2= -0.59]). This defined the distinction between sites located on the two different types of sandstone found in the study area.

Figure 1.1.3 summarizes the results of DCA 1 and DCA 2 as an ordination of the communities (DCA_{CO}). It shows the distinction between the communities in the *Erica melanthera* Shrublands, and those in both the *Willdenowia glomerata* Shrublands and *Erica hispidula–Protea nitida* Shrublands of the southern Langeberg. The *E. melanthera* Shrublands (which include community groups A–J) are found at the wetter end of the primary gradient with only one community classified in this major group occurring beyond 3.0 SD on Axis 1 of the ordination (Figure 1.1.3). The *W. glomerata* Shrublands (which include community groups K–M) are found at the driest extreme of the gradient. The distinction between shrublands on different soils was found on Axis 2 which represented the second gradient, where percentage of clay in the soil was important. Mesic to wet sites with a relatively high percentage of clay support the *Centella lanata–Indigofera alopecuroides* Group whereas sites which are similarly placed on the MAP gradient but which have less clay in the soil support the *Blechnum tabulare–Erica atropurpurea* Group. The eigenvalues in Table 1.1.3 for the first DCA axis were relatively high, indicating that Axis 1 captured the greater proportion of the variation in species composition among communities. The species-environment correlation was also high, showing that the species data were strongly related to the measured environmental variables.

(b) Constrained site ordination (CCA)

The eigenvalues of the CCA axes were somewhat lower than for the DCA axes (Table 1.1.3), indicating that important explanatory site variables were not measured and included in the analysis or some of the variation was not explained by environmental variables. However, the expected species-environment correlations were higher for the

CCA axes, except for the analysis where soil variables were absent and the remaining variables forward selected (Table 1.1.3).

Table 1.1.3. Results of DCA and CCA in terms of the magnitude, community- and species-environment correlations of axes 1 – 3.

	Axes												
Analysis	λ_1	λ_2	λ_3	r_1	r_2	r_3	$p(\lambda_1)$	$\%_1$	$\%_2$	$\%_3$	$G.L._1$	$G.L._2$	G.L.
DCA $_{CO}$	0.645	0.348	0.248	-	-	-	-	9.7	5.3	3.7	5.049	3.800	2.25
DCA 1	0.664	0.455	0.363	0.892	0.810	0.766	-	12.7	5.0	0	5.997	5.201	3.76
DCA 2	0.664	0.455	0.363	0.844	0.717	0.705	-	18.9	6.3	0	5.997	5.201	3.76
CCA 1	0.560	0.340	0.326	0.935	0.909	0.893	0.01	13.4	8.1	7.9	-	-	-
CCA 2	0.520	0.322	0.283	0.915	0.897	0.869	0.01	20.2	12.6	11.0	-	-	-
CCA 1 f.s.	0.538	0.312	0.300	0.922	0.891	0.883	0.01	20.7	12.0	11.6	-	-	-
CCA 2 f.s.	0.499	0.308	0.271	0.897	0.892	0.863	0.01	25.6	15.9	13.9	-	-	-

-	- Results not relevant
λ	- Axis eigenvalue
r	- Community-environment correlation for DCA & species-environment correlation for CCA
$p(\lambda_1)$	- Level of significance of first canonical axis
%	- Percentage of variance explained
co	- 46 fynbos communities
1	- Environmental variables including soil chemical variables
2	- Environmental variables excluding soil chemical variables
f.s.	- CANOCO option: forward selection of variables
G.L.	- Gradient length

The CCA of the 'complete data set' resulted in strong community-environment correlations on the first three canonical axes (Table 1.1.3). A test for significance with an unrestricted Monte Carlo permutation test (99 permutations; ter Braak, 1990b) found the F-ratios for the Axis 1 eigenvalue and the trace statistic to be significant ($p < 0.01$). Collinearity was exhibited by the nominal variable Malmesbury Group, so it was omitted from the analysis. Axis 1 was most positively correlated with MAP [$r = 0.74$] and most negatively with winter global radiant flux density (WGRFD) [$r = -0.5$]. Axis 2 was most positively correlated with soil depth [$r = 0.42$] and most negatively with %Rock [$r = -0.57$]. Axis 3 was most positively correlated with Nardouw Subgroup sandstone [$r = 0.79$] and most negatively with Peninsula Formation sandstone [$r = -0.63$]. These results were similar to those for Axes 1 & 3 of the DCA but differed for Axis 2.

In the absence of soil chemical variables, Axis 1 was most negatively correlated with MAP [r = -0.77] and most positively with WGRFD [r = 0.54]. Both Axis 2 and Axis 3 were most positively correlated with Peninsula Formation sandstone and most negatively with Nardouw Subgroup sandstone. In this case the results for all three axes were similar to those for the DCA.

The results of the CCA's with forward selection of variables are given in Table 1.1.4, both for the 'complete set' of environmental variables and for the 'reduced set', where soil chemical variables were excluded. Because the eigenvalue for Axis 1 dropped below an arbitrary 0.5 when the 'reduced set' was forward-selected and since the PCA indicated the important contribution of soil chemical variables, it was argued that soil chemical variables should have been included in the final CCA analysis. Further interpretation is therefore based on the CCA of this 'complete set'. Figure 1.1.4 is the biplot of 167 sites and the 12 best explanatory environmental variables obtained by forward selection. Axis 1 represented the same MAP and WGRFD gradients as above. Percentage organic carbon (%Carbon) in the soil was also strongly positively correlated with Axis 1 (Figure 1.1.4). Large amounts of organic carbon accumulate and form acid 'peats' at high elevation on the steep south-facing slopes where incoming radiation is low, particularly in winter (WGRFD). In contrast, warm, dry conditions prevail on north-facing slopes which receive relatively high incoming radiation throughout the year. Percentage organic carbon is low because organic material decomposes more rapidly than on the cooler, less exposed south slopes, and does not accumulate (Bond 1981). Axis 2 represents a gradient of %Rock, associated with geology. Sites on Peninsula Formation and Nardouw Subgroup sandstones have high %Rock compared with sites located on Cedarberg Formation shale where %Rock is low. Axis 3 shows the distinction between Nardouw Subgroup and Peninsula Formation sandstone but where soil chemical variables are absent, MAP is most strongly positively correlated with this axis and Nardouw Subgroup most negatively correlated. Nardouw Subgroup sandstone occurs where MAP is lowest. This is related to the stratigraphy of the Langeberg (McDonald 1993a (Appendix A)); Nardouw Subgroup sandstones are generally found on the north (dry) side of the mountain range.

Table 1.1.4. Intra-set correlations between CCA axes and the vegetation of the southern Langeberg. The environmental variables are those selected as the 'minimum set' of explanatory variables from (a) the 'complete set' of environmental variables and (b) environmental variables excluding soil chemical variables. Canonical coefficients in bold type are for those variables most positively and most negatively correlated with the respective axes.

(a)

		Axes	
Variable	**1**	**2**	**3**
Slope	0.3308	0.3470	-0.0072
% Rock	-0.3212	**-0.6223**	-0.1204
MAP	**0.7719**	-0.4292	-0.1558
% Carbon	0.7428	-0.0663	-0.4032
% Nitrogen	0.4509	0.2520	0.2026
% Clay	-0.4420	0.2257	0.0807
Na me%	-0.1248	0.3698	0.2534
SGRFD	-0.0116	-0.2673	0.2907
WGRFD	**-0.5171**	-0.3557	0.3925
Peninsula [1]	0.1597	0.1847	**-0.6590**
Cedarberg [1]	-0.1078	**0.3878**	-0.1887
Nardouw [1]	-0.0703	-0.3170	**0.8589**

(b)

Slope	-0.3503	0.3072	-0.2152
% Rock	0.3538	-0.4671	0.4469
MAP	**-0.7972**	-0.2944	**0.4877**
SGRFD	0.0105	-0.3783	-0.0983
WGRFD	**0.5433**	**-0.5006**	-0.2069
Peninsula [1]	-0.1456	**0.5058**	0.4681
Cedarberg [1]	0.0990	0.4279	-0.0354
Nardouw [1]	0.0548	-0.7204	**-0.6120**

MAP - Mean annual precipitation
SGRFD - Summer global radiant flux density
WGRFD - Winter global radiant flux density
[1] Geological formation

In all the CCA's, Axis 1 represented a strong precipitation gradient and a gradient in WGRFD. The distribution of plant species, and hence communities on the southern

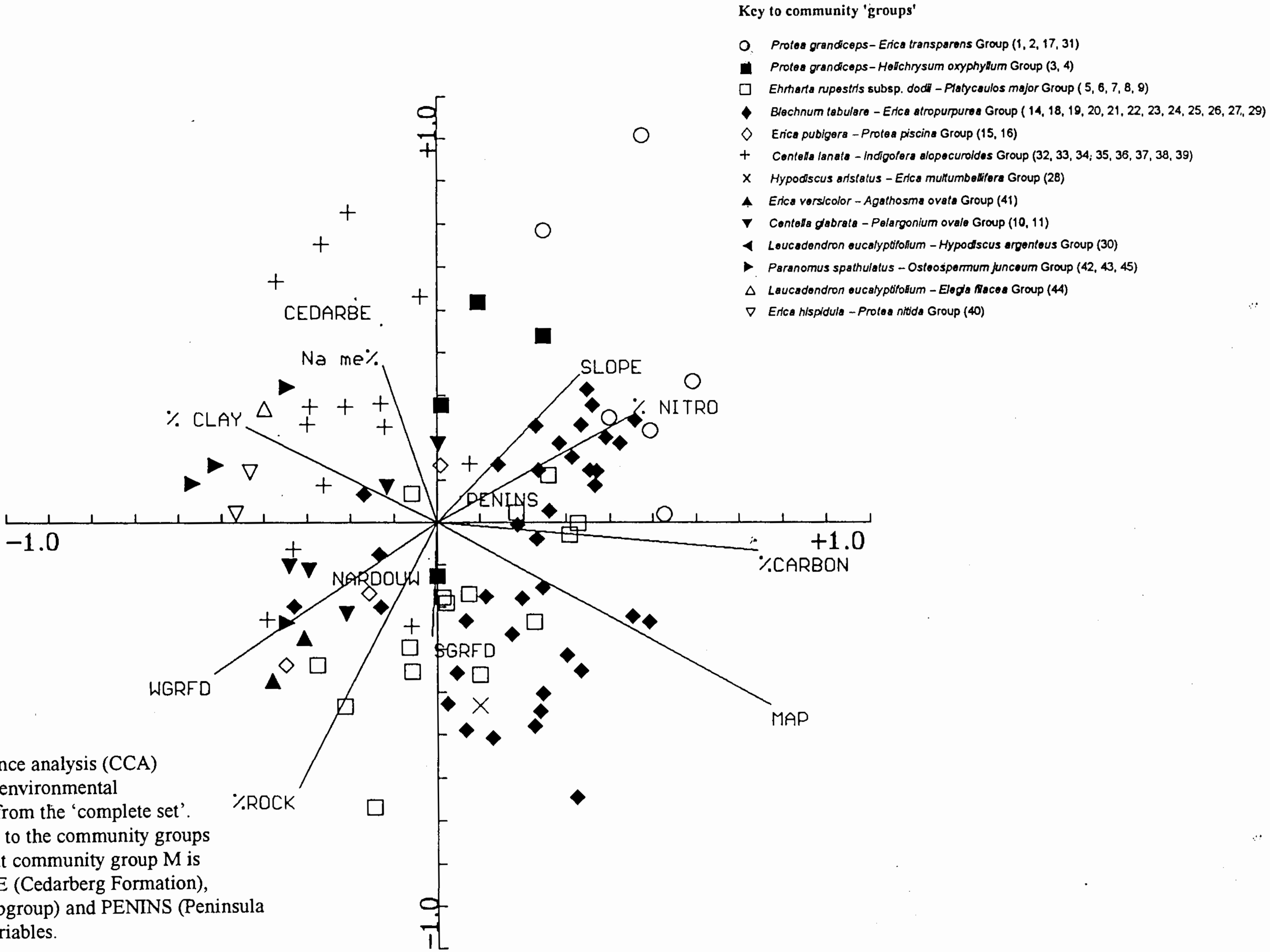


Figure 1.1.4. Canonical correspondence analysis (CCA) biplot of 167 plots with 12 environmental variables forward selected from the 'complete set'. The site classes correspond to the community groups listed in Appendix 1.1.2 but community group M is not represented. CEDARBE (Cedarberg Formation), NARDOUW (Nardouw Subgroup) and PENINS (Peninsula Formation) are nominal variables.

Langeberg is most strongly influenced by these two factors. Of the soil chemical variables measured, %Carbon is the most important.

The only other soil chemical variables selected were %Nitrogen and Na me%. Generally, nitrogen is positively correlated with organic carbon but no collinearity was found here. %Nitrogen was positively correlated with fynbos communities on wet sites (community groups 1, 2 & 4) and negatively correlated with fynbos occurring on mesic to dry sites (community groups 3, 5, 8 & 10) (Axis 1), and Na me% was positively correlated with the *Centella lanata–Indigofera alopecuroides* Group (F) but negatively correlated with the *Blechnum tabulare–Erica atropurpurea* Group (D) on Axis 2 (Figure 1.1.4).

Discussion

Vegetation classifications as a basis for interpreting vegetation-environment relationships

For the development of a typology for Cape fynbos a number of approaches have been adopted, all aimed at a suitable definition of fynbos, but often resulting in disagreement and controversy (Campbell 1985, 1986b; Cowling & Holmes 1992). In one of the first studies to apply the Braun-Blanquet phytosociological methodology in Cape fynbos, Werger *et al.* (1972) commented on the disparity between physiognomic structure and floristic composition of fynbos communities. Hopkins & Griffin (1984) reviewed the relationships between physiognomy and floristics in similarly species-rich kwongan vegetation of south western Australia and concluded that a similar situation exists in this vegetation. The lack of congruency in all cases was ascribed to disturbance by fire, which can dramatically alter the structure of vegetation but affect its floristics relatively little, as well as to high gamma diversity where environmentally similar sites may have structurally identical communities but with different species composition. Campbell (1986b) reviewed the use of structural approaches in classifying Cape fynbos and argued in favour of this type of approach as being more practical, cost-effective and ecologically meaningful than a floristic approach. He stated clearly (Campbell 1986b), however, that his structural classification was formulated from samples in mature (10-25 year old) fynbos vegetation, which does limit the application of his system in the fire-prone fynbos. Linder *et al.* (1993) observed that although some agreement is found between structural and floristic classifications, much of the subtle information linked to species may be lost in structural classifications. They added that despite this, Campbell's (1985) system does provide a broad framework for interpreting variation in the fynbos of Cape mountain ecosystems.

In this study it was firstly necessary to see whether any compatibility existed between the structural classification devised by Campbell (1985) and the floristic classification erected for the fynbos of the southern Langeberg by McDonald (1993a, b, c (Appendices A, B, C)), and secondly whether either or both classifications could be used for interpretation of vegetation-environment relationships.

The fynbos of the southern Langeberg consists of a fine-scale mosaic of (often small) communities which have been recognized and classified floristically (McDonald 1993a, b, c (Appendices A, B, C)). To be of value for management, these communities have had to be grouped into larger units. In addition, to interpret the patterns evident in the fynbos of the southern Langeberg Mountains it was necessary to develop a framework which would allow for broad-scale units but not mask the floristic complexities of the vegetation. Campbell's (1985) structural classification of mountain fynbos and the floristically-based study of the fynbos of the southern Langeberg (McDonald 1993a, b, c (Appendices A, B, C)) provided an opportunity for rigorous comparison of the two classification methods, while also providing a platform for interpreting vegetation-environment relationships.

At the level of 'type' or 'community' i.e. the basic units in the two classifications, we found that each classification provided information of a different but complementary nature.

However, at this level, neither was suitable for interpreting vegetation-environment relationships because the scale was too small (see Bond 1981). In addition, the lack of congruency between 'communities' and 'types' meant that a structural classification could not be simply used at a higher level e.g. subseries, to summarize patterns in the fynbos of the southern Langeberg. The observations of Werger *et al.* (1972), Hopkins & Griffin (1984) and McDonald (1988) that floristically determined communities are not necessarily structurally uniform are borne out here. The strong congruency between structural and floristic units found in a study of the plant communities of the Riversdale Plain (Rebelo *et al.* 1991) can be attributed to the broad scale and low intensity of sampling, emphasized by the purposeful selection of plots in mature vegetation according to Campbell's (1985) pre-requisites. The fewer the samples in a floristic unit, the less the structural variation within that unit and the more straight-forward the classification. Therefore, where broad vegetation units are sampled extensively, Campbell's structural system may be appropriate whereas if the aim is to determine fine-scale relationships, intensive, floristically based sampling is necessary. Nevertheless, because the floristic classification of the southern Langeberg vegetation was hierarchical, the communities could be grouped into mappable broad-scale units (groups). The added advantage of the floristic approach is that young vegetation (<10 years old) can be sampled and classified. Thus despite the extremely time-consuming data gathering and analysis in floristic studies (Bond 1981; Hopkins & Griffin 1984; Cowling & Holmes 1992) compared with the economy of time and effort in structural surveys, floristic studies provide detailed information from fine to broad scale. By interpolation it is possible to construct a structural classification from floristic relevés but the reverse is not possible. In addition, floristic studies provide data for analysis of patterns of endemism and species diversity in the sampled flora; data which are not found in structural surveys and which are important for appropriate management of fynbos rich in species and endemics (McDonald & Cowling 1995(see Chapter 2.1).

We concluded that the two classification systems should be viewed as complementary and not antagonistic, and we support the view of Campbell (1986b) that ecologically useful information is offered by the structural classification, and phytogeographical information e.g. on patterns of diversity and endemism, is provided by the floristic classification. However, because of the wide variation in structural types found within the floristic communities in this study, we have emphasized the floristic approach for interpreting vegetation-environment relationships.

Vegetation-environment relationships

When vegetation data were excluded, the rockiness-soil depth/aspect gradient described by our PCA's agreed with that for the principal 'within single transect' gradient described by Campbell (1983) and in general with the aspect/rockiness gradients described for the Outeniqua and Swartberg Mountains by Bond (1981). The gradients described by the second and third principal components in this study were also similar to those described by Bond (1981) and Campbell (1983), where %Carbon, %Clay and %Sand (soil texture) were important explanatory variables. The minor importance of MAP and altitude as explanatory variables in our PCA's is explained in terms of the strong correlation between these factors, aspect and %Carbon. Therefore, apart from some local variations on the southern Langeberg, our PCA's provided little additional information to that given by Bond (1981) and Campbell (1983; 1986a) for environmental gradients on the southern Cape mountains.

A broad-scale rainfall gradient exists from the moist south side of the southern Langeberg to the dry north side (Campbell 1983), a gradient recognized by McDonald (1993a, b, c (Appendices A, B, C)) in the sampling of the vegetation. When the vegetation data were analysed independently of environmental variables (DCA), a different emphasis was obtained when compared with the PCA results as to which abiotic factors are most important. The results of the DCA's supported the recognition of the broad-scale rainfall gradient as one of the major environmental gradients determining the observed plant community distribution patterns. MAP and WGRFD were determined as the most important explanatory variables on the primary gradient, with soil variables and geology controlling the distribution of species on lower order gradients. High percentage clay in the soil is correlated with low rockiness, high soil nutrient status, high pH, relatively deep soils and poor drainage. Soils with these qualities tend to support proteoid dominated communities (Campbell 1986a) and then, depending on the moisture availability, aspect and altitude, distinction can be made between the different communities.

Canonical Correspondence Analysis (CCA), where species and environmental variables are constrained by each other, was used to resolve the differences of the indirect ordination methods of PCA and DCA. It also permitted the quantification of species- and community-environment relationships. This approach which has not previously been used in Cape Mountain Fynbos ecosystems addressed the need identified by Campbell (1983) and Cowling & Holmes (1992) for this type of study.

The CCA's have shown that less than half (c. 44%) of the site variation in the vegetation can be predicted from a combination of a limited number of abiotic environmental factors. The results also supported the conclusion from the DCA, that MAP is important on the primary gradient, by showing that the 46 communities recognized by McDonald (1993a, b c (Appendices A, B, C)) are strongly influenced by precipitation despite rainfall apparently being a poor predictor of moisture availability (Bond 1983). We concluded that the primary gradient is complex in that it does not simply follow a geographical trend from south to north. It also extends from the high altitude, cool, wet sites where wet fynbos is found, southwards to the low-altitude dry sites where mesic fynbos occurs, and northwards to the low-altitude arid sites where dry fynbos is found.

Solar radiation exerts an important influence in determining the differences between plant communities because it influences a range of factors relevant to plant growth. Interpreted in terms of heat loading, it has been used as the main predictor of microclimate variation in the Grampian Mountains of Australia (Enright *et al.* 1994). The effect of incoming radiation is most marked at mid-latitudes in mid-winter (Granger 1975; Schulze 1975a & b; Schulze & McGee 1978; Bond 1981) and particularly on mountain slopes as opposed to level surfaces (Price 1981). In the southern hemisphere, incoming radiation is similar on all slopes and aspects in summer but steep south-facing slopes intercept the least, and steep north-facing slopes the most incoming radiation in winter due to the low azimuth of the sun (Schulze & McGee 1978; Bond 1981; Hopkins & Griffin 1984). The negative correlation of winter incoming radiation (WGRFD) with the primary gradient on the southern Langeberg demonstrates this phenomenon and the effects are evident in the distribution of the plant communities. In general fynbos communities grouped in the *Protea grandiceps–Erica transparens* Group are found where lowest levels of winter incoming radiation occur. The communities in the groups I-M (see Appendix 1.1.2) are found on highly exposed slopes where the highest levels occur. The effect is enhanced by orographic cloud which occurs mainly on mid- to upper south slopes and very little on high north-facing aspects; this phenomenon is most pronounced in the hot, dry summer because it inhibits high evapotranspiration rates and the wet fynbos on the ridge crests experiences little or no summer drought (Bond 1981; Campbell 1986b).

At a broad scale, the distribution of fynbos communities on the southern Langeberg and their relationship to the abiotic environment agrees with the patterns described for southern coastal mountains (Campbell 1986a; Bond 1981; Cowling & Holmes (1992). At a fine scale, the differences between floristically determined plant communities and structural subseries are the result of species responses to local habitat conditions of soil and climate, the independent effects of which cannot be teased out without experimentation (Campbell 1983; 1986a). The boundaries and composition of these communities are also affected by disturbance events such as fires, where some species may be favoured and others adversely affected by stochastically variable fire regimes, to the extent of local extinction (Cowling 1987; Cowling & Gxaba 1990; Esler & Cowling 1990). However, where a severe summer wildfire occurred in the southern Langeberg, in the Boosmansbos Wilderness Area, the geographical location and species composition of the communities were observed three years after the fire to be very similar to the pre-fire state and identifiable according to the floristic classification. What had changed were the relative densities of overstorey proteoid shrubs in proteoid dominated communities and the persistence of early succession fire ephemerals such as *Ursinia trifida* (Thunb.) N.E. Br. (Asteraceae) on cool south slopes. The latter species would probably diminish in abundance as other shrubs became more prominent. Interpretation of the effects of fire are therefore scale-dependent with the greatest effect seen at the 'community' or 'type' level in the classification hierarchy and the least effect seen at the level of broad landscape units.

The role of soil nutrients in determining fynbos plant community distribution and species richness have been well documented for the Cape mountains as well as the lowlands (Campbell 1983, 1986a; Cowling 1990; Richards *et al.* in press). On the southern Langeberg, of the nutrients essential for plant growth, only %Nitrogen was selected in the CCA 'minimum set' of explanatory variables. It was positively correlated with the gradients described and is strongly positively correlated with %Carbon and negatively correlated with pH. Phosphorus was positively correlated with the primary gradient but not extracted as an important factor. These results agree with those of Kruger (1974) for soils of a mountain catchment in Groenlandberg, south-western Cape. They also support the general model for the function of soil nutrients in determining patterns of fynbos community distribution on the southern Cape mountains, developed by Bond (1981) and Campbell (1983; 1986a). Campbell (1983) criticized the past tendency of ignoring soils in phytosociological studies, particularly the lack of quantitative statements about rock cover. The inclusion of soil analyses in the survey of the southern Langeberg vegetation has facilitated the interpretation of the floristic communities and made the classification more generalizable to areas beyond those sampled.

Over wide landscapes, environmental gradients are considered to have greater influence on the distribution of plant communities than disturbances such as fire. This is evident from the agreement between the studies quoted on southern Cape mountains. A general

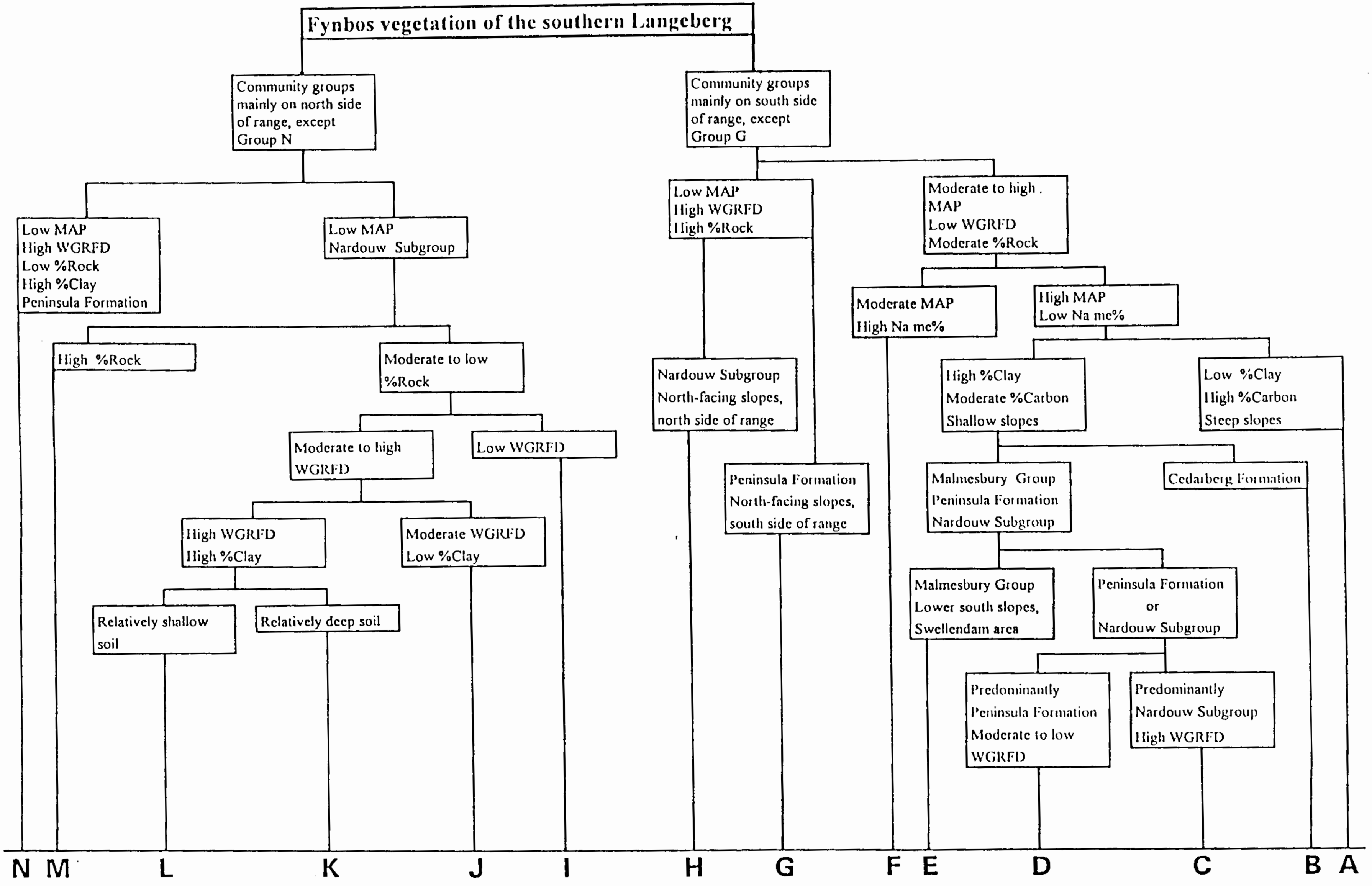


Figure 1.1.5. Dendrogram showing the relationships between environmental variables and the 14 higher-order community groups (Appendix 1.1.2) in the fynbos vegetation of the southern Langeberg.

statement of vegetation-environment relationships for the southern Langeberg mountains is therefore possible and a model can be proposed. The model which is similar to but somewhat simpler than Campbell's (1983; 1986a) model for southern Cape coastal mountains is given as a dendrogram key in Figure 1.1.5. No other suitable data are presently available to test the model, however, as these data become available in the future this will be possible.

Conclusions

The relationship between the species-rich flora of the southern Langeberg and the environment in which it occurs poses difficulties when interpretation is limited to a fine-scale analysis of floristic communities or structural types. However, when grouped into higher-level categories, the major environmental gradients determining the distribution of the fynbos communities of the southern Langeberg are more easily understood. These communities are then also more easily placed in a regional or biome-wide context.

Less than 50% of the variance in the vegetation data was accounted for by the abiotic variables measured. Future research should focus on what variables should be measured in direct gradient analyses to account for the remaining variance or alternatively other explanations should be sought. The proposed model of vegetation-environment relationships should be evaluated in other parts of the southern Langeberg in order to refine it and test its applicability for use by managers of mountain catchments.

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Appendix 1.1.1. Southern Langeberg plant communities from McDonald (1993a, b & c), with structural 'subseries' from Campbell's (1985) classification which are represented in the floristic units. The subseries are abbreviated: Ad - Dry Asteraceous Fynbos; At - Talus Asteraceous Fynbos; Ra - Azonal Restioid Fynbos; Em - Mesic Ericaceous Fynbos; Ew - Wet Ericaceous Fynbos; Pd - Dry Proteoid Fynbos; Pm - Mesic Proteoid Fynbos; Pw - Wet Proteoid Fynbos. Where only one structural type is found in the subseries, the type name precedes the subseries code e.g. Ruitersberg Ew. Where only one subseries is found but which contains more than one type, the number of types is given in parentheses.

Floristic Community	**Structural subseries**
1. *Erica hispidula–Spatalla nubicola* Shrublands	Ruitersberg Ew
2. *Restio inconspicuus–Anthochortus crinalis* Shrublands	Ew; Em; Ra
3. *Restio inconspicuus–Protea grandiceps* Shrublands	Em; Ra
4. *Restio inconspicuus–Protea aurea* subsp. *aurea* Shrublands	Outeniqua Pw
5. *Hypodiscus aristatus–Leucadendron eucalyptifolium* Shrublands	Pm (2)
6. *Berzelia intermedia–Erica melanthera* Shrublands	Landdros Em
7. *Berzelia intermedia–Erica blenna* var. *blenna* Shrublands	Ew; Em
8. *Hypodiscus aristatus–Erica versicolor* Shrublands	Em (2)
9. *Restio inconspicuus–Hypodiscus aristatus* Shrublands	Em; Rm
10. *Leucadendron eucalyptifolium–Protea lorifolia* Shrublands	Pm; Pd
11. *Leucadendron eucalyptifolium–Staberoha cernua* Shrublands	Thomas Pd
12. *Passerina obtusifolia–Leucospermum calligerum* Shrublands	Sebrafontein Ad
13. *Cannomois parviflora–Passerina obtusifolia* Shrublands 'Typicum'	Sebrafontein Ad
14. *Widdringtonia nodiflora–Rhodocoma fruticosa* Shrublands	Ew; Em
15. *Leucadendron eucalyptifolium–Hippia pilosa* Shrublands	Em; Pm
16. *Leucadendron eucalyptifolium–Erica vestita* Shrublands	Robinson Pm
17. *Erica hispidula–Brunia alopecuroides* Shrublands	Ruitersberg Ew
18. *Erica hispidula–Berzelia intermedia* Shrublands	Ew; Em; Ra
19. *Berzelia intermedia–Erica conferta* Shrublands	Ew; Em
20. *Berzelia intermedia–Grubbia rosmarinifolia* Shrublands	Keurbos Ew
21. *Berzelia intermedia–Cliffortia grandifolia* Shrublands	Ew; Em

22. *Erica hispidula–Pentaschistis malouinensis* Shrublands	Ew; Em; Ra
23. *Pentaschistis malouinensis–Tetraria bromoides* Shrublands	Em; Pw; Ra
24. *Erica hispidula–Hypodiscus aristatus* Shrublands	Landdros Em
25. *Hypodiscus aristatus–Phylica pinea* Shrublands	Em (2)
26. *Hypodiscus aristatus–Erica versicolor* Shrublands	Em; Rm
27. *Hypodiscus aristatus–Restio strictus* Shrublands	Em; Ra; Rm
28. *Hypodiscus aristatus–Erica multumbellifera* Shrublands	Tafelberg Em
29. *Leucadendron eucalyptifolium–Erica melanthera* Shrublands	Pm (2)
30. *Leucadendron eucalyptifolium–Hypodiscus argenteus* Shrublands	Pm; Rm
31. *Erica hispidula–Brunia alopecuroides* Shrublands	Ruitersberg Ew
32. *Restio inconspicuus–Chondropetalum mucronatum* Shrublands	Ew; Pm; Rm; Ra
33. *Restio inconspicuus–Selago serrata* Shrublands	Ew; Pm; Rm; Ra
34. *Restio inconspicuus–Erica melanthera* Shrublands	Ew; Em; Pm; Rm
35. *Tetraria bromoides–Berzelia galpinii* Shrublands	Ew; Pm; Rm
36. *Ischyrolepis hystrix–Phylica rubra* Shrublands	Outeniqua Pw
37. *Ischyrolepis hystrix–Phylica pinea* Shrublands	Pw; Pm
38. *Tetraria bromoides–Hypodiscus striatus* Shrublands	Pm; Rm
39. *Tetraria bromoides–Protea coronata* Shrublands	Pm; Em
40. *Erica hispidula–Protea nitida* Shrublands	Rooiberg At
41. *Erica versicolor–Agathosma ovata* Shrublands	Unclassified
42. *Protea neriifolia–Merxmuellera decora* Shrublands	Pm; Rm; Rd
43. *Protea neriifolia–Erica articularis* Shrublands	Kouga Rm
44. *Leucadendron eucalyptifolium–Elegia filacea* Shrublands	Thomas Pd
45. *Protea lorifolia–Ficinia lacineata* Shrublands	ThomasPd
46. *Protea lorifolia–Leucospermum calligerum* Shrublands	Sebrafontein Ad

Appendix 1.1.2. Community 'groups' of the southern Langeberg, with the community numbers given in parentheses (see Appendix 1.1.1). Groups G, H, J, L & N are represented by single communities.

A *Protea grandiceps–Erica transparens* Group (1, 2, 17, 31)

B *Protea grandiceps–Helichrysum oxyphyllum* Group (3, 4)

C *Ehrharta rupestris* subsp. *dodii* – *Platycaulos major* Group (5, 6, 7, 8, 9)

D *Blechnum tabulare* – *Erica atropurpurea* Group (14, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 29)

E *Erica pubigera* – *Protea piscina* Group (15, 16)

F *Centella lanata* – *Indigofera alopecuroides* Group (32, 33, 34, 35, 36, 37, 38, 39)

G *Hypodiscus aristatus* – *Erica multumbellifera* Group (28)

H *Erica versicolor* – *Agathosma ovata* Group (41)

I *Centella glabrata* – *Pelargonium ovale* Group (10, 11)

J *Leucadendron eucalyptifolium* – *Hypodiscus argenteus* Group (30)

K *Paranomus spathulatus* – *Osteospermum junceum* Group (42, 43, 45)

L *Leucadendron eucalyptifolium* – *Elegia filacea* Group (44)

M *Elytropappus rhinocerotis* – *Passerina obtusifolia* Group (12, 13, 46)

N *Erica hispidula* – *Protea nitida* Group (40)

Part 2. Endemism in the fynbos flora of the southern Langeberg.

' The study and precise interpretation of the endemism of a territory constitute the supreme criterion, indispensable for arriving at any conclusions regarding the origin and age of its plant population. It enables us better to understand the past and the transformations that have taken place. It also provides us with a means of evaluating the extent of these transformations, the approximate epoch when they occurred, and the effects which they produced on the development of the flora and the vegetation. '

J. Braun-Blanquet (1923)

Plate 9. **a.** *Protea aurea* subsp. *aurea (Proteaceae),* a seed-regenerating tall shrub which prefers clay-rich soils, particularly of the Cedarberg Formation shaleband. b. Skeleton of adult *P. aurea* killed by fire with masses of offspring surrounding the parent, three years after the fire. c. The first record of *Paranomus spathulatus* (Proteaceae) resprouting from a rootstock after being burnt. d. *Erica transparens* (Ericaceae), one of the few southern Langeberg ericas found to resprout after fire.

Plate 10. **a**. *Erica blenna* var. *blenna* and **b**. *Erica chlorosepala,* endemic ericas of the southern Langeberg. *E. chlorosepala* occurs in the vicinity of Misty Point (Transect W) and is rare. **c.** *Thamnochortus amoena* (Restionaceae) an endemic restio found on the lower dry north slopes of the southern Langeberg at Muurrivier (type locality). **d**. *Herschelianthe schlechteriana* (Orchidaceae) an rare endemic ground orchid also found on the lower dry north slopes of the southern Langeberg.

a.

b.

c.

d.

Plate 11. **a**. *Spatalla nubicola* (Proteaceae), endemic to the high altitude peaks and ridges of the Boosmansbos Wilderness Area (Transect C). **b**. *Geissoloma marginatum* an enigmatic species in the monotypic family Geissolomataceae endemic to the southern Langeberg. **c**. *Penaea dahlgrenii* (Penaeaceae) one of three species in the family Penaeaceae endemic to the southern Langeberg. **d.** *Leucospermum mundii* (Proteaceae), one of three species of *Leucospermum* endemic to the southern Langeberg.

2.1

Towards a profile of an endemic mountain fynbos flora: implications for conservation. [1]

D.J. McDonald & R.M. Cowling

Abstract

Patterns of endemism in the fynbos flora of the southern Langeberg mountains, Cape Province, South Africa, are discussed. The majority of endemic species are restricted to 6.7% of the plant families represented, with 48 (30% of total) endemic species in the genus *Erica* (Ericaceae) alone. The greater proportion of endemics are found in mesic to wet habitats. Endemics are significantly over-represented in high-altitude wet habitats where almost twice the number of endemics occur than expected on the basis of area occupied by these habitats. This has important implications for conservation because the mesic and wet habitats are the most susceptible to invasion by alien plants and are most favoured by wildflower harvesters. Local endemics in mountain fynbos are most likely to be low, non-sprouting shrubs with short-distance seed dispersal. Endemics are consequently vulnerable to frequent and unseasonal fires. Injudicious use of fire and/or frequent wildfires could increase the chances of extinction of these species.

Keywords: Cape Floristic Region, conservation, endemism fynbos, Langeberg mountains.

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[1] Published in *Biological Conservation* 72: 1–12.

Introduction

High costs in terms of money and manpower determine that many conservation decisions have to be based on limited data from often very large areas (Margules & Stein, 1989; Kunin & Gaston, 1993). This applies to mountain environments in the Cape Floristic Region (CFR) where the chances of extensive biological surveys in the future are slim. Investigation of patterns in endemic floras, like research on rare species (Kunin & Gaston, 1993), provides one option for obtaining data for more informed, rational, conservation management decisions (van Wilgen, Bond & Richardson, 1992). For example, species with narrow distribution ranges (i.e. endemic to relatively small areas) are used to define centres of endemism or core areas for the delimitation of reserves (Terborgh & Winter, 1983; Gentry, 1986; Rebelo & Siegfried, 1990; Saetersdal, Line & Birks, 1993). It is therefore important to know whether or not an endemic flora constitutes a random assemblage with respect to taxonomy, habitat preference and biological attributes (Kruckeberg & Rabinowitz, 1985; Major, 1988). If not, then the peculiar characteristics of the endemic flora should be considered when formulating management policies for their maintenance in nature reserves.

The CFR has extraordinarily high levels of endemism (Goldblatt, 1978; Cowling, Holmes & Rebelo, 1992). This is mostly associated with fynbos, a fire-prone, sclerophyllous shrubland (Muir, 1929; Kruger, 1979). Studies in lowland floras of the Cape Floristic Region (Cowling & Holmes, 1992; Cowling *et al.*, 1992) have shown (1) that certain families have proportionally more endemics than others; (2) that endemics are not random assemblages with respect to biological attributes i.e. they are most likely to be dwarf to low non-sprouting shrubs with ant-dispersed, soil-stored seed and/or microsymbiont-mediated nutrient uptake; and (3) most endemics are edaphic specialists.

The mountains of the CFR are topographically and climatically complex and this study focuses specifically on a montane fynbos flora. The main aim is to identify correlates of endemism useful for conservation. The role of habitat is investigated (are endemics more abundant than expected by chance in particular habitats?) and the growth form, regeneration strategy and seed dispersal correlates of endemism analysed. The last mentioned three factors are important for developing policies and guide-lines for the fire-management of fynbos, the most important tool available to managers for maintaining biodiversity in this extraordinarily species-rich region (van Wilgen *et al.*, 1992).

Study Area

The southern Langeberg (see Figures 1 and 1.1.1) is one of the west-east trending mountain ranges, in the eastern zone of the Cape Fold Belt. Although gradients are impressively steep, altitudes are moderate; the highest peaks reach around 1700 m. The Langeberg consists mainly of orthoquartzites and shales of the Table Mountain Group (Figure 2.1.1). By global standards, soils in the Langeberg are extremely nutrient poor (Groves *et al.*, 1983).

The study area lies in the non-seasonal rainfall zone of the CFR. Rainfall is associated with circumpolar westerly fronts (highest frequency in winter) and post-frontal conditions associated with advection of cool moist air over the warm Indian Ocean (highest frequency in spring and autumn). Topography and aspect exert a strong influence on climate. The north slopes (rain-shadow) of the southern Langeberg receive between 200 and 400 mm per annum (Figure 2.1.1); the lower south slopes receive 600-800 mm *per annum* and those at higher altitude (1000 m) between 700 and 800 mm *per annum*. The high peaks (> 1200 m) receive an estimated mean annual precipitation of 1200-1400 mm (Dent, Lynch & Schulze 1987), much of which is accounted for by high-altitude mist.

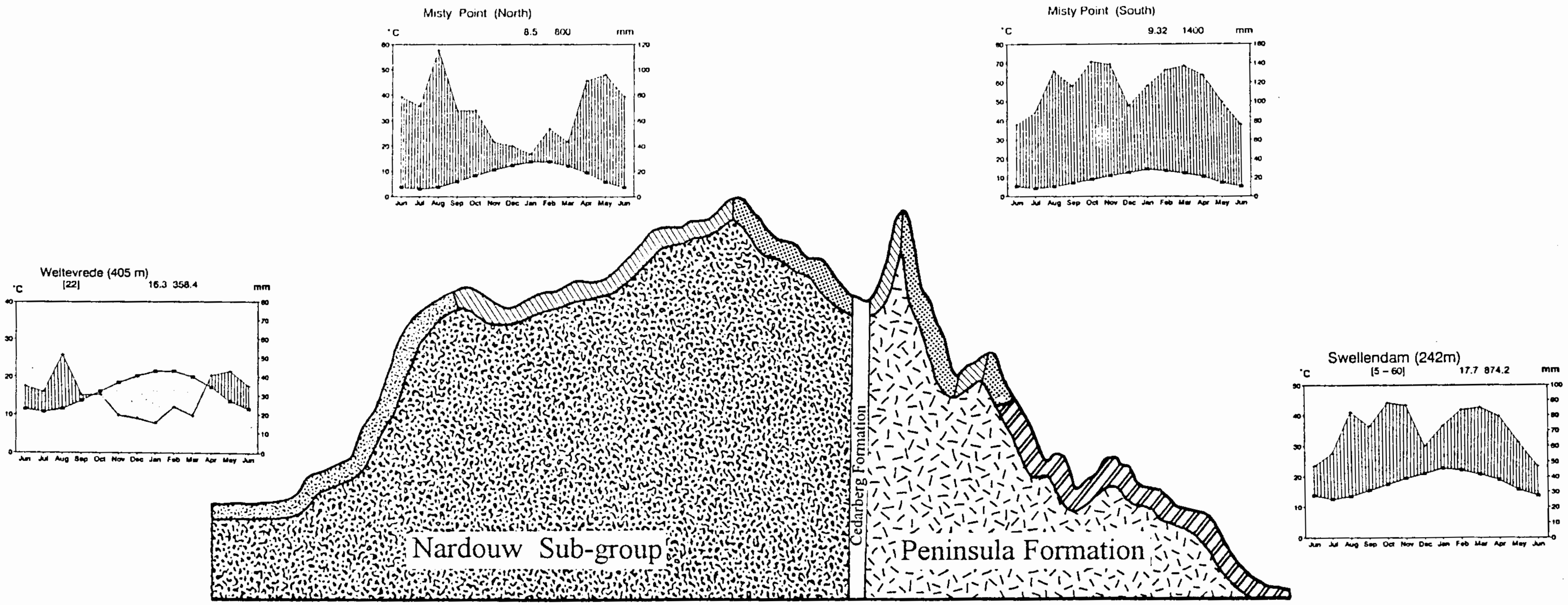

Figure 2.1.1. Schematic cross-section through the southern Langeberg showing the relief, geology and four broad habitats recognized: MSS -- mesic south-facing slopes ▨, HAW -- high-altitude wet south-facing slopes ▦ HAD high-altitude dry north-facing slopes ▧ AR -- arid lower north-facing slopes ░

The southern Langeberg lies at mid-latitudes, resulting in a distinct difference in insolation between the south- and north-facing slopes, particularly in winter. Temperatures are generally mild. On the south slopes, highest mean daily maximum temperature occurs in January (29.4°C) and lowest mean daily minimum occurs in July (6.6°C) (Figure 2.1.1). Highest mean daily maximum on the lower north slopes is in February (30.0°C) with a winter minimum of 2.9°C. With an environmental lapse rate of 0.6°C per 100 m (Cowling, 1984) a decrease in temperature of approximately 9.45°C on south-facing slopes and 7.8°C on north-facing slopes at an altitude of 1700 m a.s.l. is expected.

The predominant fynbos vegetation on the southern Langeberg is typical of the coastal mountains of the southern Cape both in structure and levels of species richness (Bond, 1981; Campbell, 1985). This is managed primarily for water production and nature conservation (van Wilgen *et al.*, 1992). Until recently mountain catchments were burnt as 'block burns' on a 15-20 year rotation; the catchments were burnt in late summer and autumn to promote regeneration of the fynbos and prevent extensive wildfires (van Wilgen *et al.*, 1992). The current approach is implementation of 'adaptive interference fire management', a flexible system which ranges from an almost natural burning regime with some interference to a more rigid controlled compartment burning system (Seydack, 1992).

Methods

Data collection

A check-list of the flora of the southern Langeberg comprising 1228 species and subspecific taxa was compiled from two main sources: the catalogue of plant species of the Cape Floristic Region (Bond & Goldblatt, 1984) and the plant collections and identifications from 304 plots sampled by the first author during phytosociological studies of the southern Langeberg (McDonald, 1993a, b, c (Appendices A, B, C). Additional unpublished information was obtained on undescribed endemic taxa from taxonomists specializing in the systematics of the Cape flora. Endemics refer to species confined to the southern Langeberg mountains (see Figure 1.1.1; Appendix 2.1.1), which are part of the Langeberg Endemic Centre as originally delimited by Weimarck (1941). Data on the growth form, regeneration strategy, dispersal mode and preferred habitat for each species were obtained from a variety of sources including taxonomic revisions, herbarium specimens, collecting registers and field notes. Seven growth-form categories were recognized: forbs (FO), geophytes (G), graminoids (HG), low shrubs, ≤1.0 m (LSH), mid-high shrubs, 1.0-2.0 m (MSH), tall shrubs, >2 m (TSH) and trees (T). In the analysis of growth-form associated with endemism, ferns (28 species), vines, lianes and epiphytes (19 species) were excluded because of low numbers in the flora. Four dispersal modes were recognized: wind (W), vertebrate (V), ant (A), and passive/unknown (P). Seeds dispersed by ballistic means are not moved long distances from the parent plants. Thus depending on whether or not the seeds had elaiosomes for secondary dispersal by ants, the plant species were assigned to ant-dispersed or passive/unknown dispersal categories. Regeneration strategies were reduced to two; whether plants resprout or not after fire. The categories used are consistent with those used by Cowling *et al.* (1992).

Taxonomic aspects of endemism

To determine whether Langeberg endemics are a taxonomically heterogeneous group or whether certain taxa have a higher than expected probability of being endemic, local endemism in the plant families of the southern Langeberg flora was analysed using contingency tables. Chi-square analysis was used to test the hypothesis that the frequency of endemics in a 'test family' would not be significantly different from the frequency for the remaining flora (independent sample). Nine families were considered (out of a total of 104) where the expected frequency of endemics in the chi-square analysis was ≥5 (Table 2.1.1).

Habitat aspects

Four broad habitat categories, based on climate and topographic position were recognized (see Study Area): (i) Mesic South Slopes (MSS), 500-900 m a.s.l., (ii) High-altitude Wet Slopes (HAW), 901-1710 m a.s.l. on south-facing aspects, (iii) High-altitude Dry Slopes (HAD), 901-1710 m a.s.l. on north-facing slopes and (iv) Arid Slopes (AR), 500-900 m a.s.l. on north-facing slopes adjoining the Little Karoo (Figure 2.1.1). These habitat categories were determined as the simplest set particularly since data for many of the species were obtained from sources such as herbarium material and checklists and not only from relevés sampled on the southern Langeberg. There is consequently no correspondence between the four community groups of level two described in the model of vegetation-environment relationships presented in Figure 1.1.5). A larger set of habitats would have presented difficulty in that too many habitats would affect cell frequencies by reducing the counts in each cell. This simple classification is also appropriate for planners and managers who would ultimately use this information for broad-scale planning purposes.

A crude estimate of area of the four different habitats was obtained by measuring the areas delimited on 1: 50 000 topographic maps, using a LI-COR optical area measuring apparatus (LI-COR Inc., Lincoln, Nebraska, USA). The error in determining surface area on sloping, mountainous terrain using this method is within acceptable limits (H. Rüther pers. comm.). Although the habitat 'zones' were treated as distinctly separate, it should be stressed that the boundaries were not sharp and could overlap. For the purposes of categorical analysis, each species was placed in only one habitat category, where it was most common, although it could occur in more than one.

Given the areas of the broad habitats measured as proportional to the total study area, the number of endemics expected for each area was calculated as a proportion of the total number of endemics. The expected frequency was then compared with the observed frequency of endemics by chi-squared test.

A quantitative index of endemicity (I_e) was calculated for the southern Langeberg, for comparison with other areas in the CFR. Bykov's index of endemicity is $I_e = E_f / E_n$, where E_f is the factual percentage endemism (i.e. 13.02% for the southern Langeberg) and E_n is the normal percentage endemism read from the nomogram, a log-log plot of area against percentage endemism (Figure 5.1 in Major, 1988) derived from Bykov's data (Bykov, 1979 in Major, 1988). A value of $I_e = 1$ indicates that an area has the normal expected degree of endemicity whereas areas with $I_e > 1$ have higher than normal endemicity and areas with $I_e < 1$ have lower than normal endemicity (Major, 1988).

Biological aspects

Biological aspects (growth form, regeneration strategy, dispersal mode) of endemism were also analysed using simple two-way contingency tables of endemic category by biological trait. Chi-square analysis was used to test for significant difference in the frequency of each trait with respect to endemic category.

Results

Levels of endemism

From the species-area relationships for the CFR (Cowling *et al.* (1992), the predicted number of species for the Langeberg would be 2542 species if the mountain range was located in the south-west and 1080 species if located in the south-east. It lies in a more-or-less intermediate position, so the number of species recorded (1228) is about what could be expected. Of the 1228 species and subspecies recorded for the southern Langeberg, 160

(13.02%) are endemic. This is much higher than the 1.5% obtained from the endemicity nomogram given by Major (1988). The Bykov index of endemicity (I_e) for the southern Langeberg flora is 8.68, which also indicates a much higher degree of endemicity than would be expected for the area (Table 2.1.1). Bykov indices for other areas in the CFR are given for comparison (Table 2.1.1).

The total flora of the southern Langeberg is spread over 366 genera and 104 families of which one family, the monotypic Geissolomataceae is endemic (Dahlgren & van Wyk, 1988) and one monotypic genus, *Langebergia* (Asteraceae) is endemic (Anderberg, 1991). Twenty-five families (24.03%) have at least one endemic species (Table 2.1.2; Appendix 2.1.1) and nine families (8.65%) each have five or more. These nine families account for 132 endemics (82.5% of the total). *Erica* has 48 endemic species, the highest number in any one genus.

Table 2.1.1 Levels of endemism in four areas of the CFR with the Bykov index of endemicity (I_e) for comparison.

Locality	Area (km²)	Local endemics	% endemism	I_e
Cape Peninsula[a]	471	182	8.06	16.2
Langeberg	1748	160	13.02	8.68
Humansdorp[a]	5050	109[b]	12.4	5.39
Agulhas[a]	1609	100	7.47	5.33

[a] Data from Cowling & Holmes (1992); Cowling *et al* (1992).

[b] Regional endemics

Taxonomic aspects

The Ericaceae and Restionaceae are the only families in the southern Langeberg flora in which endemics were significantly over-represented relative to the remaining flora in an independent sample. Levels of endemism in the Fabaceae, Iridaceae, Orchidaceae and Proteaceae reflected those of the entire southern Langeberg flora (independent sample) whereas the numbers of endemics were significantly low in the Asteraceae, Cyperaceae and Poaceae (Table 2.1.2).

Habitat aspects

Species richness in the southern Langeberg reflects the proportions of each habitat to the total study area ($\chi^2 = 41.76$, $p < 0.001$). The mesic south slopes occupy the largest area and have the highest number of species followed by the arid, high-altitude wet and high-altitude dry habitats. The high altitude wet habitats are prominent in having the highest concentration of endemic species while only ranking third in species richness. Much lower numbers of endemic species (ca. half as many) were recorded for the high-altitude dry and arid north slope habitats combined (Table 2.1.3).

Endemics were not distributed in the same proportion as non-endemics in each of the four habitat categories (Table 2.1.4). Almost twice the number of endemics were found at high-altitude wet sites than was expected for the area of this habitat type. Almost three times the number of endemic ericas and five times the number of orchids occur in high-altitude wet habitats than expected. On mesic south-facing slopes and high-altitude dry slopes, the number of endemics did not differ significantly from the expected number. Only endemic orchids were significantly fewer than expected on mesic south-facing slopes. On arid north slopes, however, endemics were under-represented by more than a third, with Ericaceae being most markedly affected (Table 2.1.4).

Table 2.1.2. The frequencies of endemism in families of the southern Langeberg flora. The chi-square (χ^2) analysis tests the null hypothesis that the frequency of endemics in a family would not be different from the frequency in the total flora excluding that family. Families where expected χ^2 cell frequencies ≥ 5 lacking endemics were included only. NS, not significant, *** = $p < 0.001$, ** = $p < 0.01$, * = $p < 0.05$. –, no statistical analysis since χ^2 cell frequencies ≤ 5.

	Southern Langeberg flora				
Family	Non-endemic	Local endemic	%[a]	χ^2	Significance
Geissolomataceae	0	1	(100.0)	–	–
Penaeaceae	3	3	(50.0)	–	–
Ericaceae	79	49	(38.3)	77.94	***
Bruniaceae	11	6	(35.3)	–	–
Mesembryanthemaceae	4	2	(33.3)	–	–
Stilbaceae	2	1	(33.3)	–	–
Rutaceae	25	11	(30.5)	–	–
Boraginaceae	3	1	(25.0)	–	–
Restionaceae	61	17	(21.9)	4.85	*
Lobeliaceae	15	4	(21.0)	–	–
Proteaceae	44	8	(15.4)	0.09	NS
Gentianaceae	6	1	(14.3)	–	–
Rosaceae	18	3	(14.3)	–	–
Orchidaceae	48	6	(13.6)	0.05	NS
Polygalaceae	14	2	(12.5)	–	–
Rhamnaceae	15	2	(11.8)	–	–
Campanulaceae	19	2	(10.5)	–	–
Scrophulariaceae	9	1	(10.0)	–	–
Thymelaeaceae	19	2	(9.5)	–	–
Iridaceae	49	5	(9.3)	0.40	NS
Asteraceae	155	14	(8.3)	3.42	*
Rubiaceae	14	1	(6.7)	–	–
Fabaceae	77	16	(6.5)	1.17	NS
Santalaceae	17	1	(5.5)	–	–
Liliaceae	27	1	(3.7)	–	–
Cyperaceae	57	0	(0)	7.79	**
Poaceae	42	0	(0)	5.38	*
Other families	235	0	(19.1)	–	–
Total	1068	160	(13.0)		

[a] Percentage of total number of species

Table 2.1.3. Area, total number of species and number of observed and expected endemic species in four habitats in the southern Langeberg. NS, not significant, *** = p< 0.001, p< 0.05.

Habitat	Area (ha)	% Study Area	Total species	Endemics			χ^2	Significance
				Observed	%[a]	Expected		
Mesic south slopes	76 115	43.5	674	67	(42)	70	0.10	NS
High-altitude wet slopes	29 380	16.8	211	51	(32)	27	21.64	***
High-altitude dry slopes	21 230	12.1	113	15	(9.4)	19	0.98	NS
Arid north slopes	48 132	27.5	230	27	(17)	44	6.57	*
Total	174 857	100	1228	160	(100)	160	_	

[a] Percentage of total endemics

Table 2.1.4. Occurrence of southern Langeberg endemics belonging to large families (see Table 2.1.2) in relation to major habitat classes. Families where expected χ^2 cell frequencies were low were included for completeness of the analysis. MSS, Mesic south slopes; HAW, High-altitude wet slopes; HAD, High-altitude dry slopes; AR, Arid north slopes. Chi-square goodness-of-fit tests the hypothesis that endemics are distributed in the same proportion as the habitat areas. NS, not significant, *** = p<0.001.

	Habitats									
	MSS		HAW		HAD		AR			
	Number of endemics									
Family	Obs.	Exp.	Obs.	Exp.	Obs.	Exp.	Obs.	Exp.	χ^2	Significance
Asteraceae	8	6	3	2	0	2	3	4	3.416	NS
Ericaceae	22	21	20	8	5	6	2	14	28.500	***
Fabaceae	4	7	5	3	0	2	7	4	6.869	NS
Iridaceae	3	2	2	1	0	1	0	1	3.500	NS
Orchidaceae	0	3	5	1	0	0	1	2	19.500	***
Proteaceae	1	4	2	1	1	1	4	2	5.250	NS
Restionaceae	4	7	5	3	4	2	4	5	4.819	NS

INSERT FIGURE 2.1.2

Biological aspects

Endemics were not a random assemblage with regard to biological attributes (Figure 2.1.2). In the growth form classes, low shrubs were over-represented as endemics. Endemism in mid-high shrubs does not differ significantly from expected frequencies and is in equal proportions to non-endemism in this class. All other growth forms were under-represented as endemics (Figure 2.1.2a).

Endemics were significantly over-represented as non-sprouters (Figure 2.1.2b) and over-represented as passive/unknown and ant-dispersed species but under-represented as wind and vertebrate-dispersed species (Figure 2.1.2c).

Discussion

Overall levels of endemism

From the Bykov index of endemicity (I_e) and the nomogram derived from Bykov's data (Major, 1988), it is clear that by global standards, the southern Langeberg has a high level of endemism (13.02%) for the relatively small area (174 857 ha) occupied. Compared with other areas in the CFR (Table 2.1.1), the southern Langeberg has an index of endemicity about one-third higher than the lowland areas (Agulhas Plain and Humansdorp) but only a little over half the endemicity of the Cape Peninsula. Any one index of endemism is likely to have shortcomings but the Bykov index displays well the contrast between endemism in the montane fynbos of the Langeberg and that of the Agulhas Plain, and between both these areas and the Cape Peninsula.

Taxonomic aspects of southern Langeberg endemism

Endemics are generally concentrated in a limited number of taxa and are not a random assemblage taxonomically (Major, 1988). This is true for other floras in the CFR namely the Agulhas Plain, Cape Peninsula and Humansdorp region where certain taxa such as the Ericaceae have a higher than average level of endemism (Cowling *et al.*, 1992). A similar pattern is observed on the southern Langeberg where the majority of endemics are restricted to seven families. The significant over-representation of endemic Ericaceae was expected to be higher than other areas because large tracts of ericaceous fynbos cover the mesic south-facing slopes of the southern coastal mountains (Campbell 1985). However, over-representation of endemic Restionaceae on the southern Langeberg was surprising. With respect to the Restionaceae the flora of the southern Langeberg differs distinctly from floras of the Agulhas Plain, Humansdorp region and Cape Peninsula (Cowling *et al.*, 1992).

The high speciation of the genus Erica in the CFR is well documented and the dominance of this genus in the fynbos is well known (Bond 1989). However, little is known about the phylogenetics of Erica and no cladograms exist. It was therefore not possible to include possible phylogenetic factors for Erica that may have influenced the results of the analysis. Nonetheless Erica does have a disproportionate influence in determining the biological profile of an endemic. However, the biological profile was consistent across a number of unrelated lineages e.g. Asteraceae and Proteaceae (see also Cowling & Holmes 1992). The aim of the paper was also not to investigate evolutionary determinants of endemism but more specifically to show how endemism can be used to strengthen arguments for the conservation of the flora of the southern Langeberg.

Habitat aspects

Many of the southern Langeberg endemic species are confined to one or a few local populations, for example in the genus *Coleonema* (Williams, 1981) and other Rutaceae, or located on isolated mountain peaks e.g. *Erica* species (E.G.H. Oliver pers. comm.). High-altitude wet and mesic south-facing habitats together harbour 74% of the southern

Langeberg endemic flora which indicates that in this flora endemism is more strongly associated with cooler, moister habitats than with drier, hotter slopes.

Although species richness is highly correlated with habitat area, levels of endemism do not reflect this pattern. Species richness and endemism are not coupled and endemism is clearly not explained by the size of a given habitat on the southern Langeberg.

Biological aspects

The southern Langeberg endemics show similar biological attributes to those of the Agulhas Plain and Humansdorp floras (Cowling & Holmes, 1992; Cowling *et al.*, 1992). They are mainly non-sprouting, low shrubs with short-distance seed dispersal; seed is either passively dispersed or dispersed by ants. This reinforces the conclusion that endemism is associated with these biological traits in particular. This may in turn be associated with speciation (Cowling & Holmes, 1992; Cowling *et al.*, 1992) but can also be conducive to local extinction when these species are subject to catastrophic events such as too frequent fires (van Wilgen, Everson & Trollope, 1990). The role of biological attributes in the determination of endemism were pursued in a separate paper (Part 2.2).

Conservation of southern Langeberg endemism

Management objectives in the mountain catchments of the southern Langeberg are no different from those in other Cape mountain catchment areas. The prime goals are production of potable water and nature conservation, with fire hazard reduction, wildflower harvesting, recreation and grazing of lesser importance. In turn, the main aims of nature conservation are the maintenance of biotic diversity and fostering ecosystem processes (Seydack, 1992; van Wilgen *et al.*, 1994).

The concentration of endemics on the mesic south-facing slopes and in the high-altitude wet habitats of the southern Langeberg indicates that these habitats deserve careful attention. Much of the high-altitude zone is located in declared nature reserves or on protected state land and is thus well-protected. However, with many endemics isolated on mountain peaks and the disproportionately high frequency of endemics in the high-altitude wet habitats, those parts of the high-altitude zone that are not well-protected should be identified and if possible be given a higher conservation status.

Fire plays a pivotal role in fynbos ecosystems by governing the life-cycles of fynbos plants. For this and other reasons e.g. cost-effectiveness, burning is the most practical management option. Consequently the ecology of fire in fynbos has received much attention (van Wilgen *et al.*, 1992). However, a number of aspects of the effects of fire on the natural biota of fynbos still require investigation.

Much research has been directed at the response of shrubby Proteaceae to fire (van Wilgen *et al.* 1992) resulting in management policies which have inevitably favoured this plant family. The shortcomings of the approach that 'what is good for one is good for all' and that biotic diversity is bound to diminish under a fixed fire regime are recognized, but no satisfactory alternatives have been offered (van Wilgen *et al.*, 1994).

Some consideration has been given to rare and endangered taxa in management policies (van Wilgen *et al.*, 1994), but endemics need not be rare (Gentry, 1986) or endangered. Where do fynbos endemic species fit in? Evaluation of the effects of fire on all fynbos species would be an impossible task (van Wilgen *et al.*, 1994) but evaluation of the effects on endemics, for example those of the southern Langeberg, need not be so onerous and could provide useful insights into ecosystem processes. Many endemics have short-distance dispersal and require specific habitats with the chances of dispersal and survival beyond these limited ranges being low. Endemic species are also not confined to one plant family and their biological attributes are not uniform. With more detailed information on their distribution, biological attributes, preferred habitats and their response to fire, management policies can be tailored where necessary to maintain endemic species. This would augment the holistic approach to catchment management (in the case of the southern Langeberg, 'adaptive interference fire management') in the move away from the 'single-family-dominated' management policies which have been implemented until now (Seydack, 1992; van Wilgen *et al.*, 1994). Indications are that more attention should be directed to the low, passively dispersed, non-sprouting shrubs in the Ericaceae, at least on the southern Langeberg where there is a significant over-representation of endemics in this family. 'Adaptive interference fire management' holds most promise for sound management for species diversity on the southern Langeberg. From what is currently known about the biological attributes of Langeberg endemics, this type of management should promote their survival.

At present, invasion by alien plant species in the southern Langeberg is relatively limited (personal observation). However, the Langeberg mountain range is potentially invasible by *Pinus* species from commercial timber plantations, *Hakea* species and exotic *Acacia* species from disturbed agricultural lands along the foothills. The mesic south-facing slopes (and to a lesser extent the high-altitude wet habitats) where most endemic species occur, are the most vulnerable to invasion by alien plants because of their mesic nature and the large source of seed of exotic species in adjacent afforested and agricultural land (Richardson, Macdonald, Holmes & Cowling, 1992; Richardson & Cowling, 1992). Low non-sprouting shrub endemic species would be most adversely affected by alien infestation due to canopy closure effects (Richardson & van Wilgen, 1986; Richardson, Macdonald & Forsyth, 1989).

The threat of invading alien invertebrates, such as the Argentine ant (*Iridomyrmex humilis*), ousting indigenous ant species which disperse the seed of myrmecochorous southern Langeberg species including endemics in the families Penaeaceae, Proteaceae and Rutaceae (Appendix 2.1.1), must not be underestimated (de Kock *et al.*, 1992; Bond & Slingsby, 1983; 1984a & b). Recreational hiking and other tourist activities on the southern Langeberg are increasing as more hiking trails and camp-sites are developed (C.

Martens pers. comm.). This greater human usage of mountain areas increases the chances of dispersal of Argentine ants into these ecosystems (Bond & Slingsby 1984a), which in turn could increase their negative impact on the local biota.

The wildflower trade concentrates mainly on floral material from three plant families in the fynbos, the Asteraceae, Ericaceae and Proteaceae (Davis, 1984; Greyling & Davis, 1989). In the flora of the Langeberg these families together contain 44% of the endemics. Flower harvesting is becoming increasingly widespread on the Langeberg, particularly on the more accessible lower south slopes where the highest number of endemic species occur. The danger exists that indiscriminate flower picking could affect populations of endemic species (van Wilgen & Lamb, 1986; van Wilgen *et al.*, 1992). This need not be only from removal of flowering material but could also result from mechanical damage due to trampling or from the spread of detrimental pathogens (von Broembsen, 1979; von Broembsen & Kruger, 1985).

The high number of endemics on the mesic to wet south-facing slopes of the southern Langeberg, coupled with the possible negative impacts of alien plant (and animal) invasions, uncontrolled flower picking and inappropriate fire regimes, indicate that it is towards these habitats that monitoring should be directed to prevent the loss of endemic species.

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Appendix 2.1.1. Endemic species occurring on the southern Langeberg mountains, Cape Province, arranged alphabetically according to family. Growth form (GF) - G = geophyte, FO = forb, HG = graminoid, LSH = low shrub, MSH = mid-high shrub, TSH = tall shrub. Regeneration strategy (RS) - NS = non-sprouter, S = sprouter Dispersal mode (DM) - A = Ant, P = passive/unknown, W = wind. Habitat (HAB) - MSS = mesic south-facing slopes, HAW = high-altitude wet slopes, HAD = high-altitude dry slopes, AR = arid north-facing slopes.

Endemic species	**GF**	**RS**	**DM**	**HAB**
Asteraceae				
Arctotis virgata Jacq.	FO	NS	W	AR
Athanasia inopinata (Hutch.) Källersjö	LSH	NS	P	MSS
Felicia comptonii Grau	LSH	NS	W	AR
Gymnostephium fruticosum DC.	LSH	NS	P	HAW
Helichrysum plebium DC.	LSH	NS	W	MSS
Heterolepis sp. nov. (D.J. McDonald 2091)	LSH	NS	W	AR
Hippia integrifolia Less.	LSH	NS	P	HAW
Osteospermum pyrifolium Norl.	FO	NS	P	MSS
Langebergia canescens (DC.) Anderb.	LSH	NS	W	HAW
Pteronia beckioides DC.	LSH	NS	W	MSS
Senecio aquifoliaceous DC.	FO	NS	W	MSS
Senecio incisus Thunb.	LSH	NS	W	MSS
Senecio muirii L.Bolus	LSH	NS	W	MSS
Ursinia hispida (DC.) N.E.Br.	FO	NS	W	MSS
Boraginaceae				
Lobostemon muirii Levyns	LSH	S	P	AR
Bruniaceae				
Berzelia galpinii Pillans	MSH	S	P	MSS
Mniothamnea bullata Schltr.	LSH	S	P	MSS
Mniothamnea callunoides (Oliv.) Nied.	LSH	S	P	MSS
Raspalia barnardii Pillans	LSH	NS	P	MSS
Raspalia schlechteri Dummer	LSH	NS	P	MSS
Thamnea gracilis Oliv.	LSH	NS	P	MSS

Campanulaceae				
Prismatocarpus lasiophyllus Adamson	FO	NS	P	HAD
Wahlenbergia fruticosa Brehmer	LSH	NS	P	MSS
Ericaceae				
Erica albescens Klotzsch ex Benth.	LSH	NS	P	MSS
Erica amicorum E.G.H. Oliv.	LSH	NS	P	MSS
Erica ardens Andrews	LSH	NS	P	HAW
Erica atropurpurea Dulfer	LSH	NS	P	HAW
Erica barrydalensis L.Bolus	TSH	NS	P	AR
Erica blenna Salisb.	MSH	NS	P	MSS
Erica caterviflora Salisb.	TSH	NS	P	MSS
Erica chartacea Guthrie & Bolus	LSH	NS	P	MSS
Erica chlorosepala Benth.	LSH	NS	P	HAD
Erica comata Guthrie & Bolus	LSH	NS	P	HAW
Erica crassisepala Benth.	LSH	NS	P	HAW
Erica dysantha Benth.	LSH	NS	P	HAW
Erica gigantea Klotzsch ex Benth.	MSH	NS	P	MSS
Erica granulatifolia H.A.Baker	LSH	NS	P	HAW
Erica grata Guthrie & Bolus	LSH	NS	P	MSS
Erica heliophila Guthrie & Bolus	LSH	NS	P	MSS
Erica heterophylla Guthrie & Bolus	LSH	NS	P	MSS
Erica inclusa H.L.Wendl. ex Benth.	LSH	NS	P	MSS
Erica ixanthera Benth.	LSH	NS	P	MSS
Erica langebergensis H.A.Baker	LSH	NS	P	HAD
Erica macrophylla Klotzsch	LSH	NS	P	HAW
Erica macilenta Guthrie & Bolus	MSH	NS	P	MSS
Erica nematophylla Guthrie & Bolus	LSH	NS	P	MSS
Erica ocellata Guthrie & Bolus	LSH	NS	P	HAW
Erica oophylla Benth.	LSH	NS	P	HAW
Erica omninoglabra H.A.Baker	LSH	NS	P	HAW
Erica oxyandra Guthrie & Bolus	LSH	NS	P	HAW
Erica papyracea Guthrie & Bolus	MSH	NS	P	HAW
Erica podophylla Benth.	LSH	NS	P	HAW
Erica pubigera Salisb.	LSH	NS	P	MSS

Ericaceae (contd...)				
Erica rhodantha Guthrie & Bolus	LSH	NS	P	AR
Erica rudolfii Bolus	LSH	NS	P	HAD
Erica tradouwensis Compton	LSH	NS	P	MSS
Erica walkeria Andrews	LSH	NS	P	MSS
Erica winteri H.A.Baker	LSH	NS	P	MSS
Erica sp. nov. (D.J. McDonald 1129)				
Erica sp. nov. 'amica-amicorum'	LSH	NS	P	HAD
Erica sp. nov. (D.J. McDonald 1549)	LSH	NS	P	HAW
Erica sp. nov. (D.J. McDonald 1862)	LSH	NS	P	HAW
Erica sp. nov. (C. Boucher 1588)	LSH	NS	P	MSS
Erica sp. nov. (E. Esterhuysen 35152)	LSH	NS	P	HAW
Erica sp. nov. (E. Esterhuysen 35157)	LSH	NS	P	HAW
Erica sp. nov. near *albescens* (E. Esterhuysen 24481)	LSH	NS	P	HAW
Erica sp. nov. near *amicorum/oligantha* (E. Esterhuysen 18247)	LSH	NS	P	MSS
Erica sp. nov. near *corifolia* (E. Esterhuysen 29111)	LSH	NS	P	HAD
Erica sp. nov. near *obconica/mucronata* (E. Esterhuysen 32915)	LSH	NS	P	HAW
Erica sp. nov. (A. Schumann 780)	LSH	NS	P	HAW
Erica sp. nov. 'white flowers' (E. Esterhuysen 24480)	LSH	NS	P	HAW
Scyphogyne tenuis (Benth.) E.G.H.Oliv.	LSH	NS	P	MSS
Fabaceae				
Amphithalea axillaris Granby	LSH	NS	P	HAW
Aspalathus acanthes Eckl. & Zeyh.	MSH	NS	P	AR
Aspalathus hypnoides R.Dahlgren	LSH	NS	P	MSS
Aspalathus longifolia Benth.	MSH	NS	P	AR
Aspalathus verbasciformis R.Dahlgren	MSH	NS	P	AR
Aspalathus vulpina Garab.ex R.Dahlgren	LSH	NS	P	AR
Coelidium bullatum Benth.	LSH	NS	P	HAW
Coelidium cymbifolium C.A.Sm.	LSH	NS	P	AR
Indigofera langebergensis L.Bolus	LSH	S	P	MSS
Lebeckia leptophylla Benth.	LSH	NS	P	HAW

Fabaceae continued...				
Otholobium bowieanum (Harv.) C.H.Stirt.	LSH	S	P	AR
Otholobium saxosum C.H.Stirt.	LSH	NS	P	MSS
Priestleya teres (Thunb.) DC.	LSH	NS	P	MSS
Psoralea filifolia Thunb.	TSH	S	P	AR
Psoralea nubicola C.H.Stirt. ined.	MSH	NS	P	HAW
Rafnia fastigiata Eckl. & Zeyh.	LSH	S	P	HAW
Geissolomataceae				
Geissoloma marginatum (L.) Juss.	MSH	S	P	MSS
Gentianaceae				
Sebaea laxa N.E.Br.	FP	NS	P	MSS
Iridaceae				
Bobartia macrospatha Baker subsp. *anceps* (Baker) Strid	G	S	P	MSS
Bobartia parva J.B. Gillett	G	S	P	HAW
Freesia sparrmannii (Thunb.) N.E.Br.	G	S	W	MSS
Ixia stohriae L.Bolus	G	S	W	MSS
Nivenia fruticosa (L.f.) Baker	LSH	S	P	HAW
Liliaceae				
Rhadamanthus albiflorus B.Nord.	G	S	P	MSS
Lobeliaceae				
Laurentia longitubus E.Wimm.	FO	NS	P	MSS
Lobelia dasyphylla E.Wimm.	FO	NS	P	MSS
Lobelia hypsibata E.Wimm.	FO	NS	P	MSS
Lobelia muscoides Cham.	FO	NS	P	HAW
Mesembryanthemaceae				
Drosanthemum croceum L.Bolus	FO	NS	P	AR
Mesembryanthemaceae (contd...)				
Machairophyllum cookii (L.Bolus) Schwantes	FO	NS	P	AR

Orchidaceae				
Disa cardinalis H.P.Linder	G	NS	P	HAW
Orchidaceae continued ...				
Disa gladioliflora Lindl. subsp. *capricornis* (Rchb. f.) H.P.Linder	G	S	W	HAW
Disa subtenuicornis H.P.Linder	G	S	W	HAW
Disa tripetaloides (L.f.) N.E.Br. subsp. *aurata* (Bolus) H.P.Linder	G	S	P	HAW
Herschelianthe schlechteriana (Bolus) N.C. Anthony	G	S	W	AR
Pachites appressa Lindl.	G	S	W	HAW
Penaeaceae				
Penaea dahlgrenii Rourke	MSH	NS	A	HAW
Stylapterus dubius (Stephens) R.Dahlgren	MSH	NS	P	HAW
Stylapterus ericifolius (Juss.) R.Dahlgren	MSH	NS	P	MSS
Polygalaceae				
Muraltia langebergensis Levyns	LSH	NS	A	HAW
Polygala langebergensis Levyns	LSH	NS	A	HAD
Proteaceae				
Leucadendron radiatum E.Phillips & Hutch.	MSH	NS	W	HAW
Leucadendron tradouwense I.Williams	MSH	NS	P	MSS
Leucospermum erubescens Rourke	TSH	NS	A	AR
Leucospermum mundii Meisn.	LSH	NS	A	HAD
Leucospermum saxatile (Salisb. ex Knight) Rourke	LSH	NS	A	AR
Paranomus spathulatus (Thunb.) Kuntze	MSH	S	A	AR
Serruria balanocephala Rourke	LSH	NS	A	AR
Spatalla nubicola Rourke	LSH	NS	A	HAW
Restionaceae				
Calopsis monostylis (Pillans) H.P.Linder	HG	S	P	HAW
Calopsis muirii (Pillans) H.P.Linder	HG	S	P	AR
Ceratocaryum fistulosum Mast.	HG	S	P	MSS
Hypodiscus montanus Esterh.	HG	S	A	HAD

Restionaceae continued...				
Ischyrolepis affinis Esterh.	HG	S	P	HAW
Platycaulos acutus Esterh.	HG	S	P	HAD
Restio arcuatus Mast.	HG	S	P	MSS
Restio decipiens (N.E.Br.) H.P.Linder	HG	S	P	HAW
Restio fragilis Esterh.	HG	S	P	HAW
Restio implicatus Esterh.	HG	S	P	MSS
Restio peculiaris Esterh.	GF	S	P	HAD
Restio perseverans Esterh.	HG	S	P	HAD
Restio secundus (Pillans) H.P.Linder	HG	S	P	HAW
Thamnochortus amoena H.P.Linder	HG	S	P	AR
Thamnochortus ellipticus Pillans	HG	S	P	AR
Thamnochortus karooica H.P.Linder	HG	S	P	AR
Rhamnaceae				
Phylica longimontana Pillans	LSH	NS	P	MSS
Phylica recurvifolia Eckl. & Zeyh.	LSH	NS	P	MSS
Rosaceae				
Cliffortia alata N.E.Br.	LSH	NS	W	AR
Cliffortia densa Weim.	LSH	NS	P	HAW
Cliffortia incana Weim.	LSH	NS	P	MSS
Cliffortia lanceolata Weim.	LSH	NS	P	HAW
Rubiaceae				
Carpacoce gigantea Puff	LSH	NS	P	MSS
Rutaceae				
Acmadenia burchellii Dummer	LSH	NS	A	HAW
Acmadenia latifolia I.Williams	LSH	NS	A	HAD
Acmadenia nivenii Sond.	LSH	NS	A	AR
Agathosma linifolia (Roem. & Schult.) Licht. ex Bartl. & H.L.Wendl.	LSH	NS	A	MSS
Agathosma robusta Eckl. & Zeyh.	LSH	NS	A	MSS
Agathosma umbonata Pillans	LSH	NS	A	HAW
Agathosma sp. nov. aff. *ciliaris* (P.A. Bean 526)	LSH	NS	A	HAD

Rutaceae continued...				
Agathosma sp. nov. Sect. Alares (I. Williams 2616)	LSH	NS	A	HAD
Coleonema pulchrum Hook.	MSH	NS	A	MSS
Empleurum fragrans P.E.Glover	LSH	NS	A	HAW
Euchaetis avisylvana I.Williams	LSH	NS	A	MSS
Santalaceae				
Thesium glaucescens A.W.Hill	LSH	NS	P	MSS
Scrophulariaceae				
Sutera subnuda (N.E.Br.) Hiern.	LSH	NS	P	AR
Stilbaceae				
Stilbe phylicoides A.DC.	LSH	NS	P	MSS
Thymelaeaceae				
Lachnaea ericoides Meisn.	LSH	S	P	MSS
Lachnaea sp. nov. (D.J. McDonald 1963)	LSH	S	P	MSS

2.2

Modelling the biological aspects of local endemism in South African fynbos.[3]

D.J. McDonald, J.M. Juritz, R.M. Cowling and W.J. Knottenbelt

Abstract

The biological attributes, dispersal mode, growth form and regeneration strategy were determined for the endemic and non-endemic flora of the southern Langeberg, Cape Province, South Africa. Logistic regression analysis was used to assess the simultaneous effects and interactions between these biological attributes on the occurrence of endemism. The model allowed numerical estimation of the probability that a species with a given set of attributes would be endemic. This approach extends a contingency table analysis of the data, which merely indicated the association between the individual biological traits and endemism. Furthermore, the logistic model allows scope for the analysis of the influence of biological traits in determining endemism in other floras, and also tentative prediction of the probability of endemism in species with combinations of biological traits not yet observed in the flora of the southern Langeberg.

***Keywords*:** Cape, fynbos, endemism, dispersal, growth form, regeneration, logistic regression analysis, model, mountain

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Introduction

The Cape Floristic Region (CFR) ranks as having one of the highest levels of local plant species endemism in the world (Goldblatt, 1978; Gentry, 1986; Cowling, Holmes & Rebelo 1992; McDonald & Cowling 1995 (see Chapter 2.1)). Levels of endemism, however, differ markedly in different floras within the CFR. Comparison of levels of local endemism in the floras of the Agulhas Plain (lowland), Cape Peninsula (montane and lowland) and the southern Langeberg (montane) shows that for the respective surface areas covered, the Cape Peninsula has the highest level of local endemism, followed by the southern Langeberg and then the Agulhas Plain (Cowling *et al.* 1992; McDonald & Cowling 1995 (see Chapter 2.1)). Are these endemics merely a set of randomly distributed, unrelated cases or are unifying processes responsible for their presence (Major 1988; Kruckeberg & Rabinowitz, 1985)?

In their study of the lowland floras of the Agulhas Plain and Humansdorp region (see Figures 1 and 1.1.1), Cowling & Holmes (1992) used two-dimensional contingency tables to demonstrate that endemics were not randomly distributed either taxonomically or biologically. Other studies in the CFR have used the same approach to show similar patterns (Cowling, Holmes & Rebelo 1992; McDonald & Cowling 1995 (see Chapter 2.1)). The contingency table method highlighted the important role of certain biological traits in determining endemism (Cowling & Holmes 1992; McDonald & Cowling 1995 (see Chapter 2.1)). However, the drawback of this approach is that each contingency table only measures the effect of a single biological attribute on endemism. The joint effect of a number of attributes and their possible interactions on endemism cannot be detected. Logistic regression analysis (Hosmer & Lemeshow, 1989; Trexler & Travis, 1993) allows us to assess the simultaneous effect of a number of biological attributes on the occurrence of endemism.

Our aim in this study was to overcome the limitations of the contingency table approach by using logistic regression analysis to examine the biological determinants of endemism. Logistic regression examines the functional relationship between a binomial dependent variable (in this case endemism or non-endemism) and a number of explanatory variables which are the biological traits in our case. More specifically, our aim was to model how interaction of biological attributes of species influence endemism in a montane flora (the flora of the southern Langeberg mountain range) and to predict what the chances are of an endemic occurring given a particular biological profile.

The predictive capability of a suitable model is central to an understanding of how biological traits of species interact to influence endemism and in turn how they are associated with speciation (neoendemics) and persistence (palaeoendemics). This has important implications for management and conservation (McDonald & Cowling 1995 (Chapter 2.1)) and the location of reserves (Rebelo & Siegfried 1990; Rebelo & Tansley 1993; Willis *et al.* in press).

Study Area

The area studied was the southern Langeberg mountain range in the southern Cape, extending from Kogmanskloof (Montagu) in the west to the Gouritz River in the east (Figure 2.2.1). This section of the Langeberg forms part of the Langeberg Endemic Centre as defined by Weimarck (1941) and more narrowly defined by McDonald & Cowling (1995 (Chapter 2.1)). The mountain range is long and narrow, with steep environmental gradients from the polar (south-facing) slopes, influenced by the moist south coastal climate, to the dry north-facing slopes adjacent to the arid Little Karoo. The southern Langeberg is in the transitional zone between the predominantly winter-rainfall climate of the south-western Cape and the non-seasonal rainfall zone of the southern and south-eastern Cape. The soils are generally highly leached, acid and nutrient-poor. The dominant vegetation is fynbos, an evergreen, sclerophyllous, fire-prone, shrubby vegetation rich in species. 1228 species and subspecific taxa (henceforth referred to as species) have been recorded for the southern Langeberg for the southern Langeberg, 160 (13.02%) of which are endemic (McDonald unpublished data; McDonald & Cowling 1995 (see Chapter 2.1)). Less than 1% of the study area is occupied by Afromontane forest which is confined to moist kloofs (ravines) on the south side of the range; no endemic species are found in this vegetation type.

Methods

Data collection

The study was based on a phytosociological survey of the vegetation of the southern Langeberg (McDonald 1993 a, b, c (Appendices A, B, C) and on a descriptive catalogue of the Cape flora (Bond & Goldblatt 1984). Data on the biological attributes together with an endemic/non-endemic classification for each species was added to the list of 1228 species (McDonald, unpublished data; McDonald & Cowling, 1995 (Chapter 2.1)). The species list was then reduced to 1104 by removing all trees, ferns, lianes, climbers and epiphytes and vertebrate-dispersed species, because there were no endemics in these growth form and dispersal categories. The growth forms, post-fire regeneration strategies and dispersal modes recognized and included in the modelling procedure were as follows, 1. Growth forms: low shrubs (0–1 m), mid-high shrubs (1–2 m), tall shrubs (> 2 m), graminoids, forbs and geophytes; 2. Post-fire regeneration strategies: non-sprouters and sprouters; 3. Dispersal modes: passive/unknown dispersal, wind-dispersal and ant-dispersal.

The 1104 species remaining after refinement of the species list were cross-classified according to their growth-form, G; regeneration strategy, R; dispersal mode, D, and whether or not they were endemic, E. The levels of each classification are given in

Table 2.2.1. The endemism classification can be regarded as a response to the three factors G, R and D. The cross-classification is given in Table 2.2.2.

Table 2.2.1. Levels of each biological attribute classification for 1104 species in the southern Langeberg flora. Regeneration refers to post-fire regeneration.

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

In the data set no species were observed in seven combinations of the attributes G, R and D, neither among the endemics nor the non-endemics. These combinations of attributes represent either very rare combinations in this vegetation, which consequently did not appear in the data, or else biologically unlikely cases. These seven combinations were omitted from the subsequent modelling process.

Modelling methods

The logistic regression analysis procedure of fitting a hierarchy of models until the most parsimonious one was found was followed (Trexler & Travis 1993). The biological attributes growth form, regeneration strategy and dispersal mode can be regarded as factors that may explain the occurrence of endemism. Let n_{ijk} be the number of species with growth form in category *i*, regeneration strategy *j* and dispersal mode *k*, and let r_{ijk} be the number of these which are endemic. Let π_{ijk} be the probability that a species with these attributes is endemic. It is assumed that r_{ijk} has a binomial distribution with

Insert Table 2.2.2

parameters n_{ijk} and π_{ijk}. Logistic regression (Hosmer & Lemeshow 1989) was used to investigate how π_{ijk} depends upon G, R and D and their interactions. The statistical computer package GENSTAT (Payne *et al.* 1987) was used for the calculations.

Results

Model selection

Initially the significance of the main effects of G, R and D, and their interactions was assessed by fitting their marginal effects and partial effects. The marginal effect measures the significance of a factor when it is used as the only main effect in the model and the partial effect measures its significance after all other main effects have been fitted. The marginal and partial effects of the interactions were assessed by adding them, as described above, to a model that contained all the main effects. Their significance was tested using likelihood chi-squared statistics, or equivalently, the deviances (Table 2.2.3).

The main effects of growth form and dispersal mode were highly significant on both the marginal and partial effects. There was a significant growth form by regeneration interaction. There is some evidence of a much smaller regeneration by dispersal interaction, but this does not attain statistical significance at the 5% level on either the partial or marginal effects. Since a satisfactory model was found using growth form and regeneration combinations and a main effect of dispersal, the interaction between regeneration and dispersal was not investigated further.

The configuration of empty cells referred to above led to very unstable estimates of the interactions, so to investigate the regeneration by growth form interaction, new variables *GRij* were defined, taking on the value 1 if growth form *i* and regeneration strategy *j* was represented in the data, and zero otherwise. These variables replaced the main effects and interactions of G and R. For further details on this procedure see Hosmer & Lemeshow (1989). These variables together with the dispersal factor led to a model which fitted the data well, and produced stable estimates of the effects of growth form and regeneration strategy on endemism.

The Model

Let π_{ijk} be the probability that a species with growth form in category *i*, regeneration method *j* and dispersal mode *k* is endemic. The logistic regression model selected assumes that

$$\log\left(\frac{\pi_{ijk}}{1-\tau_{ijk}}\right) = \mu + \beta_{ij}^{GR} + \alpha_k^D,$$

where the parameters are μ, a general mean; β_{ij}^{GR} the effect of growth from *i* and regeneration strategy *j*; and α_k^D the effect of dispersal mode with $\alpha_1^D = 0$. The odds on endemism for a species with attributes *ijk* can be factored as

$$\frac{\pi_{ijk}}{1-\tau_{ijk}} = \exp^{\mu} \times \exp^{\beta_{ij}^{GR}} \times \exp^{\alpha_k^D},$$

where exp = 2.71828 and is the base of natural logs.

The probability of endemism is given by

$$\pi_{ijk} = \frac{\exp(\mu + \beta_{ij}^{GR} + \alpha_k^D)}{1 + \exp(\mu + \beta_{ij}^{GR} + \alpha_k^D)},$$

The maximum likelihood estimates of the parameters are given in Table 2.2.4. The model fitted well, with a chi-squared goodness-of-fit statistic of 9.949 with 17 degrees of freedom, p > 0.090. Two cells had large standardized residuals; for passively dispersed sprouting low shrubs, the model predicted seven endemics, but ten were observed and for ant-dispersed sprouting low shrubs the model predicted two endemics, but none were observed. However, the observed numbers are within the confidence intervals for the predicted numbers. The fitted values are given in Table 2.2.5.

Table 2.2.3. The significance of the main effects and the interactions of the growth form, regeneration and dispersal mode in the model selection.

Factor	d.f.	Main effects			
		Marginal effect		Partial effect	
		Deviance	p-value	Deviance	p-value
Growth form (G)	5	31.62	< 0.001	18.79	0.002
Regeneration (R)	1	6.82	< 0.001	1.65	0.199
Dispersal (D)	2	23.00	< 0.001	13.65	0.001
Interaction	**d.f.**	**Interactions**			
		Marginal effect		Partial effect	
		Deviance	p-value	Deviance	p-value
GR	5	17.50	0.004	14.40	0.013
GD	9	2.65	0.997	2.00	0.991
RD	2	5.75	0.057	5.17	0.075

Table 2.2.4. Maximum likelihood estimates of the model parameters.

Parameter	Symbol	Estimate	S.E.	z-Score
Constant	μ	–3.698	0.712	–5.19
Low shrub, non-sprouter	β_{11}^{GR}	2.554	0.724	3.53
Low shrub, sprouter	β_{12}^{GR}	1.551	0.791	1.96
Mid high shrub, non-sprouter	β_{21}^{GR}	2.056	0.772	2.66
Mid high shrub, sprouter	β_{22}^{GR}	1.884	0.948	1.99
Tall shrub, non-sprouter	β_{31}^{GR}	1.625	0.894	1.82
Tall shrub, sprouter	β_{32}^{GR}	1.92	1.29	1.48
Graminoid, non-sprouter		0		
Graminoid, sprouter	β_{42}^{GR}	1.880	0.757	2.48
Forb, non-sprouter	β_{51}^{GR}	1.444	0.781	1.85
Forb, sprouter		0		
Geophyte, non-sprouter		0		
Geophyte, sprouter	β_{62}^{GR}	1.757	0.811	2.17
Passive or uknown dispersal	α_1	0		
Wind dispersal	α_2	–0.842	0.290	–2.90
Ant dispersal	α_3	0.545	0.284	1.92

Table 2.2.5. Fitted values for the dispersal, regenerationa and growth form combinations from the model. R, endemic species; T, non-endemic species; N, number of species with given combination; POBS, observed proportion of endemic species; PFIT, estimated proportion of endemic species from the model; PLOW, lower limit of 95% confidence interval for the true proportion; PUP, upper limit of 95% confidence interval for the true proportion.

Dispersal	Regeneration	Growth form	R	T	N	POBS	PFIT	PLOW	PUP
Passive	Non-sprouter	Low shrub	64	214	278	0.230	0.242	0.197	0.292
Passive	Non-sprouter	Mid shrub	11	53	4	0.172	0.162	0.098	0.258
Passive	Non-sprouter	Tall shrub	3	3	26	0.115	0.112	0.042	0.265
Passive	Non-sprouter	Graminoid	2	72	74	0.027	0.024	0.006	0.091
Passive	Non-sprouter	Forb	8	83	91	0.088	0.095	0.053	0.164
Passive	Non-sprouter	Geophyte	*	*					
Passive	Sprouter	Low shrub	10	57	67	0.149	0.105	0.056	0.186
Passive	Sprouter	Mid shrub	2	13	5	0.133	0.140	0.046	0.357
Passive	Sprouter	Tall shrub	1	5	6	0.167	0.144	0.020	0.581
Passive	Sprouter	Graminoid	17	100	117	0.145	0.140	0.089	0.211
Passive	Sprouter	Forb	0	7	7	0.000	0.024	0.006	0.091
Passive	Sprouter	Geophyte	3	26	9	0.103	0.126	0.062	0.236
Wind	Non-sprouter	Low shrub	8	53	61	0.131	0.121	0.072	0.195
Wind	Non-sprouter	Mid shrub	1	20	1	0.048	0.077	0.038	0.151
Wind	Non-sprouter	Tall shrub	0	4	4	0.000	0.051	0.016	0.149
Wind	Non-sprouter	Graminoid	*	*					
Wind	Non-sprouter	Forb	3	48	51	0.059	0.043	0.021	0.088
Wind	Non-sprouter	Geophyte	0	1	1	0.000	0.011	0.002	0.046
Wind	Sprouter	Low shrub	0	10	10	0.000	0.048	0.021	0.106
Wind	Sprouter	Mid shrub	0	7	7	0.000	0.066	0.019	0.206
Wind	Sprouter	Tall shrub	0	2	2	0.000	0.068	0.008	0.387
Wind	Sprouter	Graminoid	0	2	2	0.000	0.065	0.032	0.129
Wind	Sprouter	Forb	0	3	3	0.000	0.011	0.002	0.046
Wind	Sprouter	Geophyte	6	86	92	0.065	0.058	0.029	0.113
Ant	Non-sprouter	Low shrub	16	22	38	0.421	0.354	0.243	0.485
Ant	Non-sprouter	Mid shrub	2	6	8	0.250	0.250	0.136	0.414
Ant	Non-sprouter	Tall shrub	1	4	5	0.200	0.178	0.065	0.403
Ant	Non-sprouter	Graminoid	*	*					
Ant	Non-sprouter	Forb	0	1	1	0.000	0.153	0.073	0.293
Ant	Non-sprouter	Geophyte	*	*					
Ant	Sprouter	Low shrub	0	15	15	0.000	0.168	0.084	0.306
Ant	Sprouter	Mid shrub	1	1	2	0.500	0.219	0.070	0.511
Ant	Sprouter	Tall shrub	*	*					
Ant	Sprouter	Graminoid	1	6	7	0.143	0.219	0.120	0.364
Ant	Sprouter	Forb	*	*					
Ant	Sprouter	Geophyte	*	*					

Seven inferences are made from the model. They are as follows:

(1) For all growth forms and both regeneration strategies, the odds on endemism in ant-dispersed species was 1.72 times that of a passively dispersed species (approximate 95% confidence interval for the odds is from 0.99 to 3.01).

(2) For all growth forms and both regeneration strategies, the odds on endemism in wind-dispersed species was only 0.43 that of passively dispersed species (approximate 95% confidence interval for the odds is from 0.24 to 0.76).

(3) For all growth forms and both regeneration strategies, the odds on endemism in an ant-dispersed species is 4 times that of a wind dispersed species (approximate 95% confidence interval for the odds is from 1.7 to 9.2).

(4) Ant-dispersed non-sprouting low shrubs have the largest probability of being endemic (35%) with 95% confidence interval from 24% to 49%. The next most probable is an ant-dispersed non-sprouting mid-high shrub with a probability of 25%, with the 95% confidence interval from 14% to 41%.

(5) The non-sprouting low shrubs had the largest probabilities of being endemic in all dispersal modes, with probabilities of 35% for ant-dispersal, 24% for passive dispersal and 12% for wind dispersal. The next most probable were the non-sprouting mid-high shrubs, with probabilities of 25%, 16% and 7% respectively.

(6) The probabilities for endemism in an ant-dispersed species ranged from 35% for non-sprouting low shrubs, down to 15% for a non-sprouting forb. This is in direct contrast to the wind-dispersed species where the probabilities ranged from the 12% quoted above for non-sprouting low shrubs, down to 1% for a sprouting forb or non-sprouting geophyte.

(7) In the passive/unknown dispersed species the probabilities range from 24% for the non-sprouting low shrubs followed by 16% for the non-sprouting mid-high shrubs down to 2% for non-sprouting forbs.

Discussion

Dispersal mode, acting independently from growth form and post fire regeneration strategy, is the most important factor determining endemism in the flora of the Langeberg. The chances of a species being endemic are greatly increased by short-distance dispersal (dispersal by ants or passive/unknown dispersal) with ant-dispersed species having the greatest chance of being endemic. Positive correlation of short-distance dispersal with local endemism is also found elsewhere in the Cape fynbos (Linder, 1985; Slingsby & Bond, 1985; Cowling *et al.*, 1992) and in the neotropics (Gentry, 1988). In contrast, species dispersed by wind (long-distance dispersal) are much less likely to be endemic since propagules cross population, topographic and geographic boundaries more easily (Linder, 1985; Bond, 1988). The model supports the view that generally short-distance seed dispersal enhances speciation rates in fynbos due to short gene dispersal distances and the ease with which populations can become geographically isolated (Linder, 1985, Slingsby Bond, 1985; Cowling *et al.* 1992).

The model shows that interaction between growth form and post-fire regeneration strategy plays a subordinate role in determining endemism. The importance of regeneration strategy should not, however, be underestimated. In fynbos, fire acts most severely as a disruptive force on non-sprouting species by fragmenting and isolating populations and determining distinctly separate generations (Bond, Yeaton & Stock, 1991; Cowling & Holmes 1992), particularly if species are edaphically restricted to small habitats (Cowling *et al.*, 1992). The greater proportion of the endemic fynbos species are therefore non-sprouting shrubs (McDonald & Cowling, 1995 (Chapter 2.1). Similar patterns occur in the Californian chaparral where speciation and local endemism are found in the shrub genera Arctostaphylos and Ceanothus which are non-sprouters (Wells, 1969). In contrast, sprouting species are viewed as being more resilient in fire-prone environments with different fire regimes which permits their distribution and persistence over wide geographical ranges and in a diverse array of habitats (le Maitre & Midgley, 1992). Population fragmentation in sprouters is diminished, resulting in reduced lineage turnover which leads to resistance to extinction but depressed rates of speciation (Cowling et al., 1992). A good example of this is the monotypic southern Langeberg palaeoendemic, *Geissoloma marginatum* (L.) Juss. (Geissolomataceae) (Dahlgren & Rao, 1969).

Prior to the development of this model it was only possible to speculate about the interactive effect of regeneration strategy with other biological attributes in influencing endemism (Cowling & Holmes 1992; Cowling *et al.*, 1992). With the model approach it is possible to directly examine these interactions and their influence on endemism. This is a significant advance on the previously used contingency table method and offers great advantages to future research in this field.

Extrapolating from the model for combinations not found in the data set shows its predictive capability. Of the seven combinations examined, five are biologically improbable. However, ant-dispersed tall shrubs could occur, in which case they have a 22.5% chance of being endemic and ant-dispersed, sprouting geophytes could occur with a 20.3% chance of being endemic. It is therefore interesting to ask why these combinations have not been found in the Langeberg fynbos flora and why there is a preponderance of endemism in the ant-dispersed, non-sprouting low- to mid-high shrub categories?

As with all models, there are some important limitations. The first is that it is difficult to apply to a large flora, where the biological traits such as seed dispersal and regeneration strategy are poorly known. The Cape flora with >8000 species presents such problems (Linder 1985). Secondly, in the modelling procedure, potentially important biological attributes such as seed storage (for example, soil-stored or canopy-stored seed), microsymbiont-mediated effects and pollination have been excluded. These could have some bearing on endemism, particularly pollination which is instrumental in the movement of genetic material across population boundaries (Linder 1985), but since the model explains most of the variance in the data, little variance remains to be explained by additional biological attributes.

There is considerable scope for further testing of the model in other Cape montane floras as well as in the fynbos of the lowlands. The importance of dispersal mode in determining endemism focuses on the need for detailed data on dispersal mode for the Cape fynbos flora. Our 'passive/unknown' dispersal class which acts as a 'catch-all' for many species, requires refinement. With improved data on dispersal and if possible on other biological attributes not included, the model presented could be refined and greater predictive ability achieved.

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Part 3. Patterns of plant species diversity at different spatial scales on the southern Langeberg.

'Diversity and rarity are synonyms for "everything" in ecology. If ecologists can explain and predict the patterns of diversity and rarity in communities, it means that they have understood the distribution and abundance patterns of their component species. Hence the diversity-rarity problem is one of the fundamental issues in biology.'

Michael Soulé (1986)

3.1

Modelling local plant species richness in the fynbos of the southern Langeberg, Cape, South Africa.

D.J. McDonald, J.M. Juritz and R.M. Cowling

Abstract

Alpha diversity consisting of species richness and evenness of the fynbos communities of the southern Langeberg, South Africa was investigated. The levels of species richness at the 50 m² scale are similar to levels in fynbos from other parts of the fynbos biome. At the local scale, species richness was higher in communities on the dry northern slopes than in communities on the cool, moist southern slopes.

Generalised linear models (using GLIM) were fitted to species richness data from three sample transects on the southern Langeberg. Models could only be successfully fitted to data from two of the transects where 31.6% and 51.1% of the variation in the data could be explained. Use of the models in predicting species richness from combinations of explanatory environmental variables on hypothetical gradients showed that distribution of species was erratic and no clear patterns of species richness in the landscapes were apparent. This is probably a result of the narrow range in species richness and the effects of stochastic phenomena such as fire.

Keywords: Alpha diversity, Cape Floristic Region, fynbos, Langeberg mountains, species richness, evenness

Nomenclature: Arnold & de Wet (1993).

Introduction

Floral and faunal species diversity have been extensively studied at the global scale but most of the investigations have aimed at explaining the patterns of species richness observed on latitudinal gradients from the temperate zone to the tropics (see Rohde 1992 for review and references) and from low to high elevations (Stevens 1992). From these studies attempts have been made to develop universal theories to explain species richness. However, despite a measure of success in developing a general species-energy theory (Wright 1983; Currie & Paquin 1987; Currie 1991; Latham & Ricklefs 1993; Wylie & Currie 1993, Hoffman *et al.* 1994), no general theory exists which is consistently supported by data from plant or animal communities from different parts of the world (Cowling 1983; Pianka 1989).

Explanations for variation in local species richness within regions have been considered far less than global-scale patterns (Austin 1991). However where studies have been done, local scale patterns of plant species diversity have been explained in terms of limiting factors such as resource availability, disturbance and habitat heterogeneity as well as ecological processes, biogeography and history (Bond 1983, Auerbach & Shmida 1987, Cowling *et al.* 1992, Ricklefs & Schluter 1993, Tilman & Pacala 1993, Ojeda *et al.* 1995).

The Cape Floristic Region (CFR) of South Africa, displays one of the highest levels of species richness and levels of endemism for any temperate or tropical continental region (Goldblatt 1978; Linder 1985; Gentry 1986; Cowling *et al.* 1989; Cowling *et al.* 1992; Cowling & Holmes 1992a, b). It is recognized as the richest of the world's 'hot-spots' of plant diversity (Cowling & Hilton-Taylor 1994; Myers 1990; Platnick 1992) but it has only been in the last decade or so that serious attempts have been made to analyse species diversity and advance models to explain the overwhelming richness of the CFR (Bond 1983; Cowling 1990). Various studies have been carried out at the local level to examine species diversity (Kruger & Taylor 1979, Campbell & van der Meulen 1980, Bond 1983, Cowling 1983, Cowling & Campbell 1984, Simmons & Cowling submitted) and although comparisons of aspects of these studies is possible, Bond (1983) issued a word of caution. He noted that problems of scale and the inclusion or exclusion of certain growth forms such as annuals or geophytes present discrepancies when comparing studies carried out by different investigators. Schluter and Ricklefs (1993) echoed this by saying, '... differences in sampling methods may introduce statistical and ecological bias into comparisons of diversity among different localities'. Even so, most studies in the fynbos have contributed to the present general view that in the CFR at the local scale (1–1000 m^2) there is no difference in mean species richness between the winter rainfall southwest and the non-seasonal rainfall south to southeast, despite an almost two-fold lower regional richness of landscapes in the latter area (Cowling 1983; Cowling 1990; Cowling *et al.* 1992). However, many questions remain concerning the influence of the complex interaction of abiotic factors with historical processes and present-day stochastic disturbances on patterns of species diversity at the local scale in the Cape fynbos. Some correlative studies have been carried out to relate species richness to abiotic factors (Bond 1981; Cowling 1983) and contemporary environmental heterogeneity and historical factors have been invoked to explain patterns of regional species richness in the Cape fynbos flora (Cowling & Holmes 1992b; Linder 1991, Oliver *et al.* 1983), however no previous efforts have been made to rigorously model these relationships. This study represents the first attempt to do this.

We therefore asked three questions:

1. How does species richness of the southern Langeberg compare with that of other areas of the fynbos biome?
2. Is species richness related to biomass or community type (series)?
3. To what extent can species richness in the southern Langeberg be explained by one or many abiotic environmental variables or their interactions?

Study Area

The southern Langeberg mountains (see Figures 1 and 1.1.1) cover an area of about 1748 km² and are situated at approximately 34°S latitude, parallel to the southern Cape coast. They form a major part of the west-east trending Cape Fold Mountains (Deacon *et al.* 1992). Geologically the southern Langeberg is mainly orthoquartzitic sandstone of the Peninsula Formation and Nardouw Subgroup which give rise to sandy infertile soils, and Cedarberg Formation and Malmesbury Group shales which weather to form clay-rich, more fertile soils. The Langeberg mountain chain lies in the transitional zone between the mainly winter rainfall region of the western Cape and the year-round rainfall region of the southern Cape. The south-facing slopes are influenced by the onshore flow of air from the south coast and are generally cool and moist. Annual rainfall on the lower south slopes ranges from 500-600 mm whereas the peaks receive 1200-1400 mm. In contrast, the north-facing slopes which are adjacent to the arid Little Karoo are in a rainshadow and receive 200-300 mm yr^{-1}. They also experience high radiation loads and are consequently hot and dry. On the south slopes temperatures range from 6.6°C (mean winter minimum) to 29.4°C (mean summer maximum) and on the north slopes, from 2.9°C to 30.0°C. Further details of the physiography of the southern Langeberg are given in McDonald (1993a, b, c (Appendices A, B, C)) and McDonald *et al.* (submitted (Chapter 1.1)).

Methods

Data collection

Floristic data were collected from 299 plots in the sclerophyllous fynbos shrublands on three transects straddling the southern Langeberg (McDonald 1993 a, b, c (Appendices A, B, C)). The transects were located in the districts of Heidelberg (Boosmansbos Wilderness Area, the Central Transect – C), Swellendam (Marloth Nature Reserve, the West Transect – W) and Riversdale-Albertinia (East Transect – E) (see Figures 1 and 1.1.1). Forty-six fynbos shrubland communities were described from data collected on the three transects (McDonald 1993a, b, c (Appendices A, B, C), see Table 3.1.2. and Appendix 1.1.1.

The sample plots were rectangular plots of 5 x 10 m (50 m^2). Each plot was sampled only once and only permanently recognizable species were recorded i.e. any ‘ephemeral’ geophytes and annuals found were noted but not used in the analyses. A border zone of 1.5 m from the perimeter of each marked plot was searched for any additional species. A tally of all species recorded in each plot was taken as the species richness. The plots were originally sampled for phytosociological purposes (McDonald 1993a, b & c) where additional species found on the periphery of a plot can often clarify its classification. However, in most cases very few additional species were found in the peripheral zone.

Species richness data were also obtained from studies of plant communities where 50 m^2 plots were used for sampling in other montane areas in the fynbos biome. These data were compared with local richness of the southern Langeberg communities. The areas and studies were: Cape Hangklip (Boucher 1978), Cedarberg (Taylor in press), Kleinrivier Mountains, Hermanus (de Lange 1992), Outeniqua Mountains, Ruitersbos (Bond 1981) and Swartberg Mountains (Bond 1981).

Data analysis

(a) Alpha diversity

Alpha diversity contains two components, species richness (S) which is simply the number of species at a site or within a uniform habitat and species evenness which reflects the relative abundance of each species within a community (Cody 1986; Cowling 1983 and Magurran 1988). Both these aspects of alpha diversity were investigated.

Species richness for each of the 46 communities mentioned above was calculated as the mean species richness of the number of 5 x 10 m samples (n) representing a given community. The Shannon-Wiener index (H') and Simpson's index (D), which incorporate both species richness and evenness were also calculated for the 46 communities using the BIODIV 4.1 (Baev & Penev 1993) computer package. Despite criticism of the use of the Shannon-Wiener index (Magurran 1988), it has been used here for the sake of comparison with other studies in Cape fynbos.

(b) Modelling species richness using environmental variables

Multiple Poisson regression models were fitted using GLIM (Payne 1986) to determine the relationship between species richness (SPPR) in 5 x 10 m plot samples, as the response variable, and the abiotic environmental variables of mean annual precipitation (MAP), altitude (ALTI), aspect (ASPE), slope (SLOP), percentage rock cover (ROCK) and geological formation (GEOL) as the explanatory variables. Percentage rock cover was treated as a continuous variable and all the other explanatory variables were classified into categories. The factors and their levels are given in Table 3.1.1. Separate models were fitted for each of the three sample transects. The reason for this was the difference in age of the vegetation on the different transects which affects not only the structure but also the floristic composition of the fynbos communities.

Modelling methods

Since the response variable, species richness (SPPR), is count data, the Poisson error and log link (Crawley 1993) were used in the regression modelling procedure (Vincent 1981, Margules *et al.* 1987). Vincent and Haworth (1983) showed that a different interpretation from species richness data was possible by using a generalised linear model based on Poisson errors compared with that obtained from fitting a complex nonlinear model assuming normality of the error structure (Nicholls 1991).

Initially we fitted a model with all the main effects and all the two- and three-factor interactions. This showed that there was overdispersion in the counts so allowance was made for possible additional Poisson variation. We estimated σ^2, the overdispersion parameter, from this model by using the generalised Pearson Chi-squared statistic divided by its degrees of freedom. If μ is the true mean number of species for a given combination of ASPE, SLOP, MAP, ROCK, ALTI and GEOL and y was assumed to be the number of species counted, then we assumed that

$$E(y) = \mu$$
$$\mathrm{Var}(y) = \sigma^2\mu$$

and that the value of μ depended upon some or all of the above variables.

The significance of the main effects and interactions were then tested using F-tests, which accounted for any overdispersion (Crawley 1993).

After the initial model fitting and using the scale factor to accommodate for overdispersion, we fitted the null model and then each explanatory variable individually to determine its marginal effect. This was followed by fitting all the main effects and the sequential removal of each explanatory variable individually to determine the partial effects. The partial effects were the effect of each variable on the counts, after the effects of all other variables had been accounted for. The standardized residuals and leverage were examined to determine the goodness-of-fit of the model.

(c) Relationship of species richness with biomass and community 'series'

Twenty-four communities of the 46 described by McDonald (1993a, b, c (Appendices A, B, C)) were selected to obtain an estimate of biomass. They were selected on the basis of at least one community from each of the 14 community 'groups' described by McDonald et al. (submitted (Chapter 1.1)) plus 10 random additional selections. The estimates of biomass were obtained by calculating the product of the mean percentage cover and height of each species in each community, plotting these values and then by integrating the area under the species abundance curve. We used GLIM (Payne 1986) to analyse the relationship between mean species richness (MSPR) and the index of biomass (BIOM) of the communities, once again using the Poisson error and log link (Crawley 1993). To determine whether species richness was related to the type of community, the communities were classified into five broad fynbos series (after Campbell 1985): Series Ef (1) – ericaceous fynbos; Series Pf (2) – proteoid fynbos; Series Ref (3) restioid fynbos; Series Af (4)– asteraceous fynbos; Series Ruf (5) – rupicolous fynbos (not in Campbell's classification). Rupicolous or 'rock-loving' fynbos consists of only one community, the *Erica versicolor–Agathosma ovata* Shrubland which was only found in the Bergfontein area (McDonald 1993 c (Appendix C)). 'Series' was included as a factor with five levels in the modelling process.

Table 3.1.1. Variables, their levels and variable classes used for model fitting.

Variable	Level	Class
ALTI	1	200–400 m
	2	401–600 m
	3	601–800 m
	4	801–1000 m
	5	1001–1200 m
	6	1201–1400 m
	7	1401–1600 m
	8	1601–1710 m
ASPE	1	North: 316°–360° and 0°–45°
	2	East: 46°–135°
	3	South: 136°–225°
	4	West: 226°–315°
SLOP	1	0–10°
	2	11–20°
	3	21–30°
	4	31–40°
	5	41–45°
MAP	1	200–400 mm
	2	401–600 mm
	3	601–800 mm
	4	801–1000 mm
	5	1001–1200 mm
	6	1201–1400 mm
	7	1401–1600 mm
GEOL	1	Peninsula Formation sandstone
	2	Nardouw Subgroup sandstone
	3	Cedarberg Formation and Malmesbury Group shales

Results

(a) Species richness

Species richness and evenness of the communities found in the study area are given in Table 3.1.2. Only two communities had a mean species richness of less than 20 species, with more than 50% of the communities (25) having between 20 and 29 species (Classes 5 & 6, Figure 3.1.1 D). Less than a third of the communities (13) had a mean of between 30 and 39 species and six communities had a mean of 40 or more species and all of these occurred on Transect E (Table 3.1.2). When compared with mean species richness of fynbos communities of other fynbos biome mountains (in classes of five species, see Figure 3.1.1) using the Sorensen coefficient of similarity (S_s), it was found that the pattern of distribution of mean richness of the southern Langeberg (Figure 3.1.1D) was most similar ($S_s = 0.9333$) to that of the Cape Hangklip area in the south-west (Boucher 1978) (Figure 3.1.1B) and least similar ($S_s = 0.6667$) to that of the more arid Swartberg Mountains (Figure 3.1.1F) (Bond 1981) which lie inland and to the east of the Langeberg. Mean species richness of the southern Langeberg is equally similar to hat of the south-western coastal Kleinrivier Mountains (Figure 3.1.1C) (de Lange 1992) and the Outeniqua Mountains (Figure 3.1.1E) (Bond 1981) which lie immediately to the east of the Langeberg ($S_s = 0.7273$). Comparison of mean species richness of the southern Langeberg with species richness of the Cedarberg (Taylor in press) shows a 75% similarity ($S_s = 0.7500$).

In the communities sampled on the southern Langeberg, highest species richness and evenness (given by H' in Table 3.1.2) was found in the *Protea lorifolia–Ficinia lacineata* Shrublands on Transect E. Other closely related proteoid communities, the *Protea neriifolia–Merxmuellera decora* Shrublands, the *Leucadendron* *eucalyptifolium–Elegia filacea* Shrublands and the *Protea lorifolia–Ficinia lacineata* Shrublands and the asteraceous fynbos *Erica hispidula–Protea nitida* Shrublands also had high species richness and evenness (Table 3.1.2). The lowest mean species richness was found in the *Hypodiscus aristatus–Erica multumbellifera* Shrublands (ericaceous fynbos, Transect W) which had the second lowest evenness but lowest mean dominance value ($D = 0.90$). The lowest evenness was found in the *Leucadendron eucalyptifolium–Hypodiscus argentea* Shrublands (proteoid fynbos, Transect W) which had a mean species richness of 27.6 and a high dominance value ($D = 0.98$).

(b) Modelling species richness using environmental variables

Tables 3.1.3, 3.1.7 and 3.1.12 are analysis of deviance (ANODEV) tables for the initial multiple regression models for Transects W, C and E respectively. The models with their levels of significance are given in each case. For Transects W and C only the main effects were significant; the two-and three-factor interactions were not significant. For Transect E, however, neither the main effects nor the interactions were significant. Tables 3.1.4, 3.1.8 and 3.1.13 show the marginal effects of each explanatory variable fitted independently to the data from the respective transects. For Transects W and C, only the marginal effect of ROCK was not significant, whereas on Transect E, the marginal effects of SLOP, ROCK and GEOL were not significant. Tables 3.1.5, 3.1.9 and 3.1.14 show the partial effects of each explanatory variable when removed individually from the main effects model. In this case, for Transect W, the partial effects of ASPE and GEOL were not significant. For Transect C, only the partial effect of GEOL was not significant but for Transect E, only the partial effect of ASPE was significant. The analysis of deviance of the two-factor interactions for Transect C is given in Table 3.1.10 and the maximum likelihood estimates of the model parameters for Transects W and C and E are given in

Tables 3.1.6 and 3.1.11. Since the null model was fitted for Transect E, the maximum likelihood estimate was 3.569, the standard error was 0.02434 and the z-Score was 146.631; the scale factor $\sigma^2 = 2.04$ with 60 degrees of freedom.

The models of the response of species richness on the respective transects are summarized in Table 3.1.15. The scale factors of 1.485 for Transect W and 2.04 for Transect E indicate overdispersion in these data sets meaning that one or more potentially explanatory environmental factors were not considered. In the case of Transect E, the most parsimonious model is taken to be the overall mean (see Crawley 1993). The scale factor of Transect C $\cong 1$ (0.97), therefore overdispersion is not present and species richness is adequately explained by a Poisson model. On Transect C, the two-factor interactions of SLOP x ROCK and MAP x ROCK were significant. Comparison of the squared standardized residuals from a model containing only the significant main effects with those from a model containing the interactions, SLOP x ROCK and MAP x ROCK indicated that Plot 90 – a plot with high rainfall (960 mm, MAP(4)) and no rock cover (ROCK = 0%) – made a large contribution to the MAP x ROCK interaction, and it would appear that a MAP x ROCK interaction is not generally present in the data.

The variation accounted for by the model was estimated by the percentage drop in the scaled deviance between the adopted model and the model containing only the mean. Thus, the model for Transect W accounted for 31.6% of the variation in species richness (SPPR) and with Transect C, 51.1% of the variation was explained. Because only the null model could be fitted to the data for Transect E, the model had no explanatory power.

Table 3.1.2. Alpha diversity in 50 m² plots in the fynbos shrubland communities in the study area, expressed as species richness (S) and evenness (H' = Shannon-Wiener index, D = Simpson's index). Series code follows the broad classification of communities given in the text: Ef = ericaceous fynbos; Pf = proteoid fynbos; Ref = restioid fynbos; Af = Asteraceous fynbos; Ruf = rupicolous fynbos. N = number of plots in each community, n = the total of species recorded in combined samples from each community, X = mean, SD = standard deviation.

Fynbos shrubland community	Transect	Series				S			H'			D	
		code	N	n	X	SD	Range	X	SD	Range	X	SD	Range
Widdringtonia nodiflora–Rhodocoma fruticosa	W	Ef	2	37	28.00	3.00	25 – 31	1.30	0.04	1.26 – 1.34	0.97	0.004	0.97 – 0.98
Erica hispidula–Brunia alopecuroides	W	Ef	4	38	22.50	0.87	21 – 23	1.12	0.04	1.05 – 1.16	0.93	0.008	0.92 – 0.95
Erica hispidula–Berzelia intermedia	W	Ef	5	54	19.20	8.61	8 – 29	1.04	0.20	0.78 – 1.29	0.92	0.04	0.85 – 0.97
Berzelia intermedia–Erica conferta	W	Ef	5	65	35.40	10.01	22 – 48	1.36	0.13	1.19 – 1.50	0.97	0.01	0.96 – 0.99
Berzelia intermedia–Grubbia rosmarinifolia	W	Ef	8	67	21.00	4.97	14 – 30	1.11	0.08	0.96 – 1.22	0.94	0.02	0.91 – 0.96
Berzelia intermedia–Cliffortia grandifolia	W	Ef	7	66	28.29	3.57	24 – 34	1.24	0.07	1.12 – 1.34	0.95	0.02	0.93 – 0.97
Erica hispidula–Pentaschistis malouinensis	W	Ef	5	64	21.20	7.19	11 – 28	1.15	0.15	0.88 – 1.33	0.95	0.03	0.90 – 0.98
Pentaschistis malouinensis–Tetraria bromoides	W	Ef	4	53	23.25	0.83	22 – 24	1.20	0.08	1.06 – 1.26	0.96	0.02	0.93 – 0.97
Erica hispidula–Hypodiscus aristatus	W	Ef	3	58	32.00	4.90	26 – 38	1.34	0.05	1.28 – 1.40	0.97	0.002	0.97 – 0.98
Hypodiscus aristatus–Phylica pinea	W	Ef	5	61	26.80	4.71	20 – 33	1.30	0.11	1.16 – 1.45	0.98	0.02	0.95 – 0.99
Hypodiscus aristatus–Erica versicolor	W	Ef	8	61	30.50	4.06	26 – 36	1.34	0.05	1.28 – 1.43	0.99	0.007	0.98 – 1.00
Hypodiscus aristatus–Restio strictus	W	Ef	6	67	27.83	5.30	19 – 36	1.28	0.09	1.13 – 1.42	0.97	0.01	0.95 – 0.98
Hypodiscus aristatus–Erica multumbellifera	W	Ef	2	18	14.50	0.50	14 – 15	0.78	0.10	0.68 – 0.88	0.90	0.005	0.89 – 0.90
L. eucalyptifolium–Erica melanthera	W	Ef	4	51	23.25	4.15	19 – 30	1.18	0.12	1.04 – 1.36	0.96	0.02	0.93 – 0.99
Erica hispidula–Spatalla nubicola	C	Ef	8	59	22.75	3.07	19 – 29	1.12	0.09	0.95 – 1.23	0.94	0.02	0.89 – 0.97
Restio inconspicuus–Anthochortus crinalis	C	Ef	17	107	25.18	6.64	10 – 36	1.22	0.15	0.78 – 1.41	0.95	0.03	0.85 – 0.98
Hypodiscus aristatus–Leucadendron eucalyptifolium	C	Ef	5	86	32.00	10.29	17 – 44	1.29	0.16	1.04 – 1.47	0.96	0.02	0.92 – 0.98
Berzelia intermedia–Erica melanthera	C	Ef	8	62	28.87	4.25	23 – 38	1.27	0.06	1.20 – 1.40	0.96	0.01	0.95 – 0.99
Berzelia intermedia–Erica blenna var. blenna	C	Ef	13	84	25.77	6.83	14 – 40	1.19	0.13	0.93 – 1.37	0.95	0.02	0.89 – 0.98
Hypodiscus aristatus–Erica versicolor	C	Ef	12	87	24.08	4.64	15 – 32	1.21	0.08	1.05 – 1.35	0.97	0.02	0.94 – 1.00
Restio inconspicuus–Hypodiscus aristatus	C	Ef	9	68	21.67	4.69	14 – 30	1.19	0.10	1.06 – 1.37	0.97	0.02	0.94 – 1.00
Erica hispidula–Brunia alopecuroides	E	Ef	4	40	22.50	3.42	19 – 28	1.07	0.11	0.89 – 1.15	0.93	0.03	0.87 – 0.95
Restio inconspicuus–Erica melanthera	E	Ef	12	82	28.58	6.13	21 – 40	1.23	0.12	1.06 – 1.45	0.96	0.02	0.93 – 0.99
Tetraria bromoides–Berzelia galpinii	E	Ef	10	114	34.40	8.94	19 – 50	1.31	0.15	1.02 – 1.53	0.97	0.02	0.91 – 0.99
Leucadendron eucalyptifolium–Hippia pilosa	W	Pf	5	56	27.00	3.63	20 – 30	1.21	0.08	1.07 – 1.28	0.96	0.02	0.93 – 0.97
Leucadendron eucalyptifolium–Erica vestita	W	Pf	5	63	30.60	6.25	21 – 39	1.26	0.13	1.00 – 1.36	0.96	0.03	0.91 – 0.98
L. eucalyptifolium–Hypodiscus argenteus	W	Pf	5	55	27.60	4.08	21 – 32	0.32	0.08	1.22 – 1.44	0.98	0.005	0.98 – 0.99
Restio inconspicuus–Protea grandiceps	C	Pf	4	55	28.50	1.80	26 – 31	1.26	0.04	1.19 – 1.31	0.97	0.01	0.95 – 0.98
Restio inconspicuus–Protea aurea subsp. *aurea*	C	Pf	6	69	28.33	4.98	22 – 36	1.29	0.08	1.16 – 1.38	0.97	0.01	0.95 – 0.98
Leucadendron eucalyptifolium–Protea lorifolia	C	Pf	16	116	32.19	5.38	22 – 41	1.35	0.06	1.22 – 1.48	0.99	0.01	0.97 – 1.00
Leucadendron eucalyptifolium–Staberoha cernua	C	Pf	8	90	33.13	3.22	27 – 37	1.37	0.05	1.28 – 1.46	0.98	0.006	0.97 – 0.99
Ischyrolepis hystrix–Phylica rubra	E	Pf	4	45	24.75	6.18	17 – 33	1.18	0.13	1.13 – 1.35	0.95	0.02	0.93 – 0.98
Ischyrolepis hystrix–Phylica pinea	E	Pf	6	84	35.67	5.53	28 – 45	1.37	0.09	1.23 – 1.48	0.96	0.01	0.96 – 0.99
Tetraria bromoides–Protea coronata	E	Pf	6	78	38.50	3.30	33 – 43	1.40	0.07	1.27 – 1.49	0.98	0.11	0.96 – 0.99

Table 3.1.2 continued...

Fynbos shrubland community	Transect	Series			S			H'			D		
		code	N	n	X	SD	Range	X	SD	Range	X	SD	Range
Protea neriifolia–Merxmuellera decora	E	Pf	5	83	40.60	6.83	33 – 53	1.44	0.04	1.39 – 1.50	0.99	0.005	0.98 – 0.99
Leucadendron eucalyptifolium–Elegia filacea	E	Pf	2	46	35.50	1.50	34 – 37	1.11	0.21	0.89 – 1.32	0.97	0.001	0.97 – 0.98
Protea lorifolia–Ficinia lacineata	E	Pf	4	61	44.75	2.38	42 – 48	1.49	0.03	1.45 – 1.52	0.99	0.002	0.98 – 0.99
Restio inconspicuus–Selago serrata	E	Ref	10	106	41.00	4.05	35 – 49	1.43	0.06	1.33 – 1.51	0.99	0.009	0.98 – 1.01
Tetraria bromoides–Hypodiscus striatus	E	Ref	11	98	37.27	5.15	29 – 43	1.41	0.08	1.29 – 1.53	0.98	0.006	0.97 – 0.99
Protea neriifolia–Erica articularis	E	Ref	4	71	44.25	3.56	39 – 49	1.43	0.06	1.35 – 1.53	0.99	0.004	0.98 – 0.99
Restio inconspicuus–Chondropetalum mucronatum	E	Ref	7	78	32.57	11.45	10 – 45	1.30	0.20	0.84 – 1.50	0.96	0.04	0.87 – 0.98
Passerina obtusifolia–Leucospermum calligerum	C	Af	9	76	29.00	4.64	19 – 35	1.33	0.09	1.66 – 1.47	0.99	0.01	0.96 – 1.01
Cannomois parviflora–Passerina obtusifolia	C	Af	4	51	25.50	5.89	19 – 35	1.24	0.13	1.06 – 1.44	0.98	0.02	0.96 – 1.01
Erica hispidula–Protea nitida	E	Af	4	77	42.25	4.32	37 – 49	1.42	0.06	1.35 – 1.52	0.98	0.007	0.96 – 0.99
Protea lorifolia–Leucospermum calligerum	E	Af	4	74	40.00	3.16	36 – 44	1.44	0.07	1.34 – 1.53	0.99	0.009	0.98 – 1.00
Erica versicolor–Agathosma ovata	E	Ruf	4	45	28.75	1.48	27 – 31	1.32	0.02	1.30 – 1.34	0.99	0.002	0.98 – 0.99

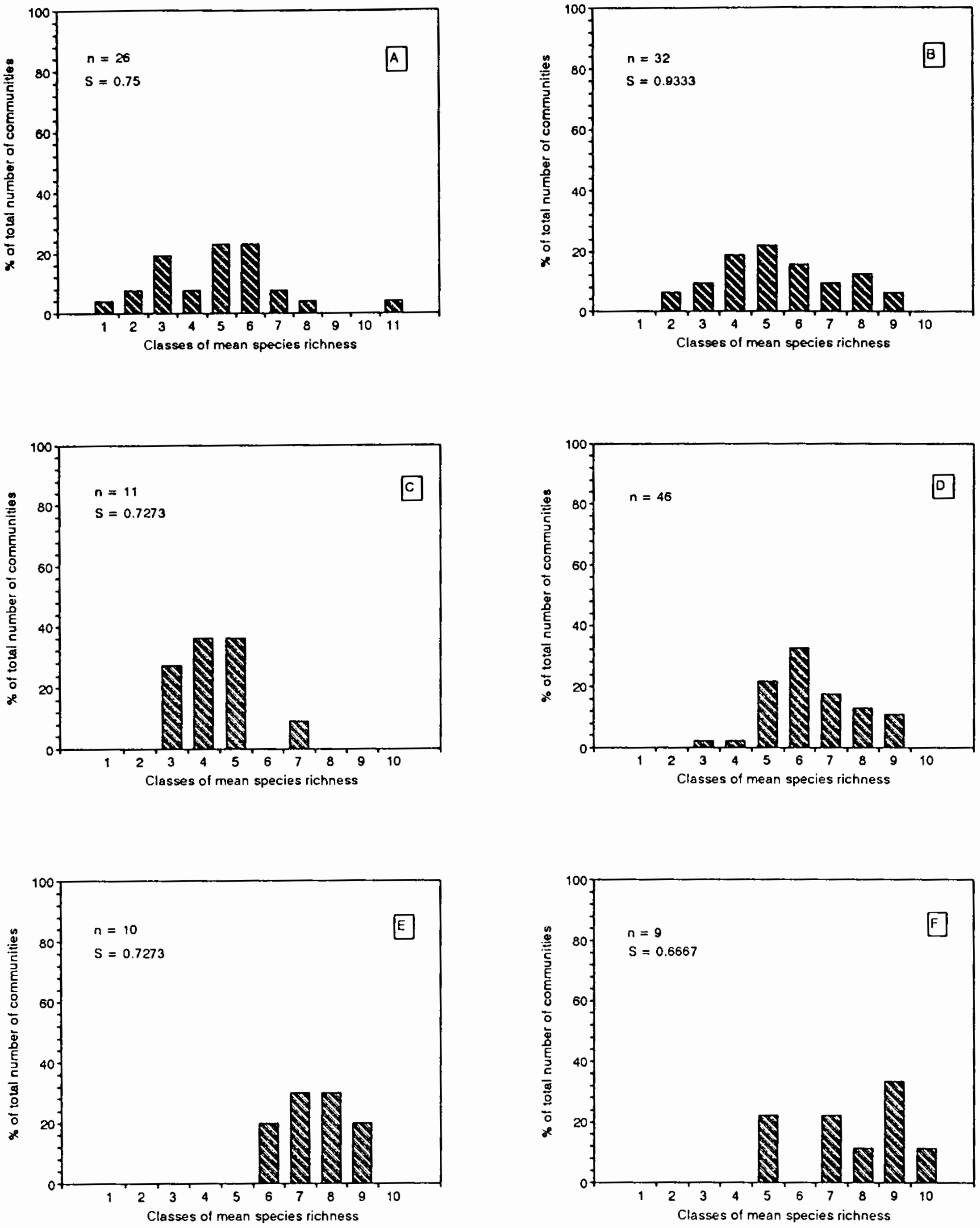

Figure 3.1.1. Distribution of mean species richness in communities (in classes of five species) described from surveys of vegetation in mountains of the Fynbos Biome. A. Cedarberg (Taylor in press); B. Cape Hangklip (Boucher 1978) C. Kleinrivier Mountains (de Lange 1992); D. Langeberg (McDonald 1993 a,b,c); E. Outeniqua Mountains and F. Swartberg (Bond 1981). n = number of communities. Classes of species richness are: 1 = 1-5 spp; 2 = 6-10 spp; 3 = 11-15 spp; 4 = 16-20 spp; 5 = 21-25 spp; 6 = 26-30 spp; 7 = 31-35 spp; 8 = 36-40 spp; 9 = 41-45 spp; 10 = 46-50 spp. n = Total number of communities. S = Sorensen coefficient of similarity to D.

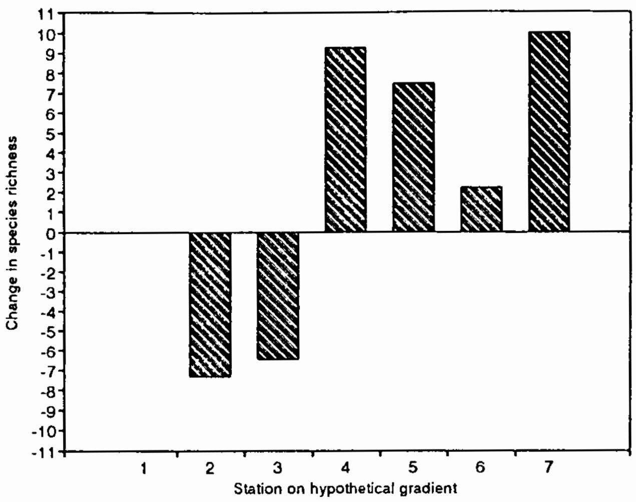

Figure 3.1.2. Change in species richness for hypothetical gradient on Transect W, from model. Combinations of explanatory variables at successive stations are: 1 = SLOP(1), MAP(1), ALTI(1) (Baseline); 2 = SLOP(3), MAP(3), ALYI(2); 3 = SLOP(3), MAP(3), ALTI(3); 4 = SLOP(3), MAP(4), ALTI(5); 5 = SLOP(3), MAP(5), ALTI(6); 6 = SLOP(3), MAP(5), ALTI(6); 7 = SLOP(4), MAP(5), ALTI(7).

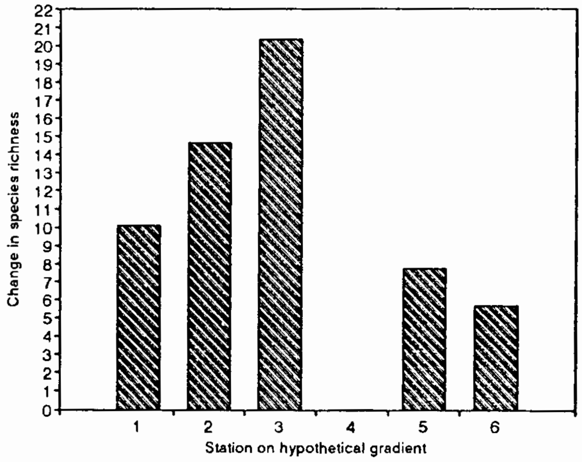

Figure 3.1.3. Change in species richness from baseline estimate for hypothetical gradient on south slopes of Transect C, from model. Combinations of explanatory variables at successive stations are: 1 = ASPE(3), SLOP(1), MAP(1), ROCK = 50%; 2 = ASPE(3), SLOP(2), MAP(2), ROCK = 50%; 3 = ASPE(3), SLOP(3), MAP(4), ROCK = 50%; 4 = ASPE(3), SLOP(3), MAP(4), ROCK = 50%; 5 = ASPE(3), SLOP(3), MAP(5), ROCK = 50%; 6 = ASPE(3), SLOP(3), MAP(6), ROCK = 50%.

Table 3.1.3. ANODEV table for the initial model of the response of species richness to environmental variables on Transect W. No scale factor was included. NS, not significant, * = $p < 0.05$.

Model	Deviance	d.f.	Effect	d.f.	Mean deviance	F	Significance
μ	164.63	82					
All main effects	100.98	64	63.5	18	3.54	2.38	*
+ Two-factor interactions	65.080	45	35.9	19	1.89	1.27	NS
+ Three-factor interactions	63.18	42	1.891	3	0.63	0.42	NS

Table 3.1.4. The marginal effects of the explanatory variables on Transect W. The scale factor σ^2 was included. NS, not significant, * = $p < 0.05$.

Variable	Deviance	d.f.	Marginal Effect	Change in deviance	d.f.	F	Significance
μ	110.86						
ASPE	106.01	79	ASPE	4.852	3	1.617	*
SLOP	99.62	79	SLOP	11.235	3	3.745	*
MAP	97.983	79	MAP	12.88	3	4.293	*
ROCK	108.37	81	ROCK	2.487	1	2.487	NS
GEOL	104.22	80	GEOL	6.636	2	3.318	*
ALTI	97.872	76	ALTI	12.99	6	2.165	*
All Main effects	67.999	64	Main effects	42.86	18		*
Scale factor $\sigma^2 = 1.485$		d.f. = 42					

Table 3.1.5. The partial effects of the explanatory variables on Transect W. The scale factor σ^2 was included. NS, not significant, * = $p < 0.05$.

Model	Deviance	d.f.	Change in deviance	d.f.	F	Significance
Main effects	67.999	64				
Main-ASPE	67.706	67	1.706	3	0.568	NS
Main-SLOP	73.543	67	5.543	3	1.847	*
Main-MAP	73.854	67	5.855	3	1.951	*
Main-ROCK	73.339	65	5.340	1	5.340	*
Main-GEOL	70.548	66	2.548	2	1.274	NS
Main-ALTI	79.143	70	11.14	6	1.856	*
Scale factor $\sigma^2 = 1.485$		d.f. = 42				

Table 3.1.6. Maximum likelihood estimates of the model parameters for Transect W.

Parameter	Estimate	Standard error	z-Score
1	3.283	0.1552	21.1533
SLOP (2)	-0.05625	0.08275	-0.6797
SLOP (3)	0.1299	0.08370	1.5519
SLOP (4)	0.1620	0.09751	1.6613
MAP (3)	-0.2413	0.1133	-2.1297
MAP (4)	0.1395	0.1236	1.1286
MAP (5)	0.08866	0.08185	1.0832
ALTI (2)	-0.2110	0.1513	-1.3945
ALTI (3)	-0.1678	0.1358	-1.2356
ALTI (4)	-0.2059	0.1338	-1.5388
ALTI (5)	0.02737	0.1596	0.1714
ALTI (6)	-0.1379	0.1461	-0.9438
ALTI (7)	0.06677	0.1816	0.3676

Scale factor $\sigma^2 = 1.485$ d.f. = 42

Table 3.1.7. ANODEV table for the initial model of the response of species richness to environmental variables on Transect C. No scale factor was included. NS, not significant, ** = $p < 0.01$.

Model	Deviance	d.f.	Effect	d.f.	Mean deviance	F	Significance
μ	192.4	118					
All main effects	107.71	96	84.7	22	3.85	3.97	**
+ Two-factor interactions	69.25	68	38.46	28	1.37	1.41	NS
+ Three-factor interactions	65.774	66	3.481	2	1.74	1.79	NS

Table 3.1.8. The marginal effects of the explanatory variables on Transect C. The scale factor σ^2 was included. NS, not significant, * = $p < 0.05$.

Variable	Deviance	d.f.	Marginal Effect	Change in deviance	d.f.	F	Significance
μ	198.35	118					
ASPE	181.69	115	ASPE	16.66	3	5.553	*
SLOP	184.06	114	SLOP	14.29	3	4.763	*
MAP	155.77	113	MAP	42.59	3	14.196	*
ROCK	198.34	117	ROCK	0.01355	1	0.01355	NS
GEOL	187.95	118	GEOL	10.4	2	5.2	*
ALTI	173.09	111	ALTI	25.27	6	4.21	*
All Main effects	111.05	96	Main effects	87.31	22	3.96	*

Scale factor $\sigma^2 = 0.97$ d.f. = 66

Table 3.1.9. The partial effects of the explanatory variables on Transect C. The scale factor σ^2 was included. NS, not significant, * = $p < 0.05$.

Model	**Deviance**	**d.f.**	**Change in deviance**	**d.f.**	**F**	**Significance**
Main effects	111.05	96				
Main-ASPE	134.72	99	23.67	3	7.89	*
Main-SLOP	120.36	100	9.318	4	2.329	*
Main-MAP	123.37	101	12.32	5	2.464	*
Main-ROCK	116.58	97	5.531	1	5.531	*
Main-GEOL	113.90	98	2.857	2	0.967	NS
Main-ALTI	128.05	103	17.01	7	2.43	*

Scale factor σ^2 = 0.97 d.f. = 66

Table 3.1.10. ANODEV table of the two-factor interactions between explanatory variables on Transect C. The scale factor σ^2 was included. NS, not significant, * = $p < 0.05$.

Model	**Deviance**	**d.f.**	**Change in deviance**	**d.f.**	**F**	**Significance**
All Main Effects	111.05	96	87.31	22	3.968	*
ASPE.SLOP	96.157	87	14.89	9	1.65	NS
ASPE.MAP	98.060	85	12.99	11	1.18	NS
ASPE.ROCK	108.12	93	2.926	3	0.98	NS
ASPE.GEOL	98.883	91	12.16	5	2.43	NS
ASPE.ALTI	88.763	80	22.28	16	1.39	NS
SLOP.MAP	93.445	87	17.6	9	1.96	NS
SLOP.ROCK	101.90	93	9.148	3	3.05	*
SLOP.GEOL	109.87	92	1.174	4	0.29	NS
SLOP.ALTI	93.164	83	17.88	13	1.38	NS
MAP.ROCK	96.379	91	14.67	5	2.93	*
MAP.GEOL	109.05	94	1.996	2	1.0	NS
MAP.ALTI	97.012	97	14.03	9	1.56	NS
ROCK.GEOL	108.74	94	2.301	2	1.15	NS
ROCK.ALTI	104.58	90	6.467	6	1.08	NS
GEOL.ALTI	104.09	90	6.960	6	1.16	NS

Scale factor σ^2 = 0.97 d.f. = 66

Table 3.1.11. Maximum likelihood estimates of the model parameters for Transect C.

Parameter	**Estimate**	**Standard error**	**z-Score**
1	2.911	0.1277	22.7956
ASPE (2)	0.2199	0.06486	3.3903
ASPE (3)	0.2438	0.05627	4.3326
ASPE (4)	0.2820	0.06955	4.0546
SLOP (2)	0.09062	0.07195	1.2594
SLOP (3)	0.1906	0.08832	2.1580
SLOP (4)	0.1617	0.1233	1.3114
SLOP (5)	0.4643	0.2270	2.0453
MAP (2)	0.3004	0.1296	2.3179
MAP (3)	0.3598	0.1194	3.0134
MAP (4)	-0.3839	0.1578	-2.4328
MAP (5)	-0.03488	0.09380	-0.3718
MAP (6)	-0.1167	0.1205	-0.9684
ROCK	0.003903	0.002445	1.5963
SLOP (2).ROCK	-0.005390	0.001586	-3.3984
SLOP (3).ROCK	-0.004803	0.001634	-2.9394
SLOP (4).ROCK	-0.002621	0.002684	-0.9765
MAP (2).ROCK	-0.001836	0.002273	-0.8077
MAP (3).ROCK	0.0007479	0.002620	0.2854
MAP (4).ROCK	0.008265	0.002645	3.1247
MAP (5).ROCK	0.003515	0.002230	1.5762
MAP (6).ROCK	0.005159	0.005936	0.8691

Scale factor $\sigma^2 = 0.97$ d.f. = 66

Table 3.1.12. ANODEV table for the initial model of the response of species richness to environmental variables on Transect E. No scale factor was included. NS, not significant.

Model	**Deviance**	**d.f.**	**Effect**	**d.f.**	**Mean deviance**	**F**	**Significance**
μ	210.54	96					
All main effects	160.7	79	49.84	17	2.93	1.44	NS
+ Two-factor interactions	126.89	63	33.81	16	2.11	1.03	NS
+ Three-factor interactions	122.68	60	4.21	3	1.40	0.69	NS

Table 3.1.13. The marginal effects of the explanatory variables on Transect E. The scale factor σ^2 was included. NS, not significant, * = $p < 0.05$.

Variable	Deviance	d.f.	Marginal Effect	Change in deviance	d.f.	F	Significance
μ	103.21	96					
ASPE	97.567	93	ASPE	5.641	3	1.88	*
SLOP	101.55	92	SLOP	1.662	4	0.415	NS
MAP	89.826	93	MAP	13.38	3	4.46	*
ROCK	100.93	95	ROCK	2.278	1	2.278	NS
GEOL	101.15	94	GEOL	2.059	2	1.029	NS
ALTI	88.174	91	ALTI	15.03	5	3.006	*
All Main effects	78.776	79	Main effects	24.43	18	1.357	S

Scale factor $\sigma^2 = 2.04$ d.f. = 60

Table 3.1.14. The partial effects of the explanatory variables on Transect E. The scale factor σ^2 was included. NS, not significant, * = $p < 0.05$.

Model	Deviance	d.f.	Change in deviance	d.f.	F	Significance
Main effects	78.776	79				
Main- ASPE	80.842	82	2.066	3	0.688	NS
Main-SLOP	81.841	83	3.065	4	0.766	*
Main-MAP	79.389	81	0.6130	2	0.3065	NS
Main-ROCK	78.798	80	0.02215	1	0.02215	NS
Main-GEOL	80.965	81	2.189	2	1.094	NS
Main-ALTI	81.074	83	2.298	4	0.574	NS

Scale factor $\sigma^2 = 2.04$ d.f. = 60

Table 3.1.15. Summary table of the response of species richness to environmental variables on three transects on the southern Langeberg.

Transect	Variables on which species richness depends	Variables on which species richness does not depend
West (W)	ALTI, SLOP, MAP	GEOL, ASPE, ROCK
Central (C)	SLOP, MAP, ROCK, ASPE, SLOP.ROCK, MAP.ROCK	ALTI, GEOL
East (E)	None	All

Application of the models

The models for each transect can be used to predict the number of species in relation to variation in the explanatory variables. The baseline coefficients, parameter coefficients and multiplicative factors for the change in species richness due to changes in the explanatory variables for Transects W and C are given in Tables 3.1.16 and 3.1.17. For Transect E, because the null model with no explanatory power was fitted, the baseline coefficient was 3.569 and the expected count of 35.48 was constant over the whole transect.

Table 3.1.16. Parameter estimates and multiplicative factors for model use, Transect W.

Baseline*: Coefficient = 3.283, Mean count = 26.66

Parameter	Estimate	Multiplicative factor
SLOP (2)	-0.05625	0.945
SLOP (3)	0.1299	1.139
SLOP (4)	0.1620	1.176
MAP (3)	-0.2413	0.786
MAP (4)	0.1395	1.150
MAP (5)	0.08866	1.093
ALTI (2)	-0.2110	0.810
ALTI (3)	-0.1678	0.846
ALTI (4)	-0.2059	0.814
ALTI (5)	0.02737	1.028
ALTI (6)	-0.1379	0.871
ALTI (7)	0.06677	1.069

* Baseline: MAP(1) = 200–400 mm, SLOP(1) = 0–10°, ALTI(1) = 200–400 m

Examples of model usage, Transect W:

1. If we consider a plot with SLOP(3), MAP(3) and ALTI(1), the multiplicative factors for these are 1.139, 0.79 and 1 respectively. So the expected count of species is:

   26.66 x 1.139 x 0.79 = 23.99

   Therefore the expected species count would decrease by 2.67 from the baseline. In other words, if the gradient of the slope increased by 10–20° from the baseline, mean annual precipitation increased from 200–400 mm from the baseline, and altitude remained at the baseline level of 200–400 m, then species richness would decrease by three species.

2. If we consider a plot with SLOP(4), MAP(3) and ALTI(3) then the mean count is given by:

   26.66 x 1.176 x 0.786 x 0.846 = 20.84

   The expected species richness would therefore decrease by 5.82 from the baseline i.e. with a steep slope of 31–40°, mean annual rainfall between 601–800 mm and altitude 601–800 m.

Examples of model usage, Transect C:

1. If we consider a plot with ASPE(2), SLOP(3) and MAP(5) and suppose that ROCK is 0%, the multiplicative factors for these are 1.246, 1.210 and 0.966 respectively, so the expected count of species is:

   18.38 x 1.246 x 1.21 x 0.966 = 26.77

   Therefore the expected species count would increase by 8.39 species from the baseline. Alternatively we can estimate the count directly using the coefficients for ASPE(2), SLOP(3) and MAP(5), which are 0.2199, 0.1906 and -0.03488 respectively. So the mean count is estimated as: exp[2.911 + 0.2199 + 0.1906 - 0.03488] = 26.75

2. If we consider a plot with ASPE(1), SLOP(1) and MAP(1) and suppose that ROCK increases to 50%, the mean count of species is estimated as:

   exp[2.911 + (50 x 0.003903)] = 22.33

   Therefore the expected count would increase by 3.95 from the baseline.

Table 3.1.17. Parameter estimates and multiplicative factors for model use, Transect C.

Baseline* : Coefficient = 2.911, Mean count = 18.38

Parameter	**Estimate**	**Multiplicative factor**
ASPE (2)	0.2199	1.246
ASPE (3)	0.2438	1.276
ASPE (4)	0.2820	1.326
SLOP (2)	0.09062	1.095
SLOP (3)	0.1906	1.210
SLOP (4)	0.1617	1.176
SLOP (5)	0.4643	1.591
MAP (2)	0.3004	1.350
MAP (3)	0.3598	1.433
MAP (4)	-0.3839	0.681
MAP (5)	-0.03488	0.966
MAP (6)	-0.1167	0.890
ROCK	0.003903	1.004
SLOP (2).ROCK	-0.005390	0.995
SLOP (3).ROCK	-0.004803	0.995
SLOP (4).ROCK	-0.002621	0.997
MAP (2).ROCK	-0.001836	0.998
MAP (3).ROCK	0.0007479	1.000
MAP (4).ROCK	0.008265	1.008
MAP (5).ROCK	0.003515	1.003
MAP (6).ROCK	0.005159	1.005

* Baseline: ASPE(1) = 0–45°, MAP(1) = 200–400 mm, SLOP(1) = 0–10°

Changes in species richness from the mean counts (baseline estimates) along hypothetical gradients on Transects W and C are given in Figures 3.1.2 and 3.1.3 respectively. For Transect W, the slope class was maintained constant except for station 7 where it was increased, with a successive increase in mean annual precipitation and altitude. Species richness changes were erratic, with a depression of the species count below the baseline at stations 2 and 3 and variable increases above the baseline at stations 4–7. On the south slopes (ASPE (3)) of Transect C, rock cover was kept constant at 50% and slope constant at 21–30°. Mean annual precipitation was increased successively. The change in species richness from the baseline was positive at all stations, with a successive increase from stations 1–3, a dramatic drop at station 4, a moderate increase at station 5 followed by a small decrease at station 6.

The highest species richness (38.54) predicted by the model for Transect W is given by the combination of steep slopes of 31–40° (SLOP(4)), mean annual precipitation of 800–1000 mm (MAP(4)) and altitudes of 1401–1600 m (ALTI(7)). The lowest species richness for the same transect is 16.04, given by the combination of moderate slopes (SLOP(2), 11–20°), mean annual precipitation of 601–800 mm (MAP(3)) and altitude of 401–600 m (ALTI(2)) (see Table 3.1.16). For Transect C, the respective model predicted the highest species richness(81.54) from the combination of westerly aspects (ASPE(4), 226–315°), steep slopes (SLOP(5), 41–45°) and a mean annual rainfall (MAP(4), 801–1000 mm) by rock cover (ROCK, set at 90%) interaction. The MAP(4) x ROCK interaction plays a significant role in determining species richness; as rock cover increases, the species richness increases. The lowest species richness for Transect C (17.07) was predicted by a combination of easterly aspects (ASPE(2), 46–135°), moderate slopes (SLOP(2), 11–20°). In this case rock cover (ROCK) was set at 0%, therefore the parameter of interaction between mean annual rainfall and rock cover (MAP(4) x ROCK) was zero (Table 3.1.17). The models for the two transects predicted similar low richness values whereas highest richness predicted for Transect C was more than twice that for Transect W. As explanatory variables slope and mean annual precipitation were common to both models, however, for Transect W altitude was significant and for Transect C, aspect and percentage rock cover were significant. No predictions of high or low species richness could be made for Transect E.

(c) Relationship of species richness with biomass and community type

The regression between biomass and species richness explained only 0.45% of the variance, indicating a very poor relationship between these variables. In contrast, the Poisson regression of species richness against community series (using GLIM) explained much of the variance ($r^2 = 0.4334$, $p < 0.001$). On average the restioid fynbos was most species-rich followed by asteraceous fynbos and proteoid fynbos. Rupicolous fynbos was only encountered once and is found in a mesic, rocky habitat but nevertheless had a higher species richness than the average for ericaceous fynbos, the commonest series, which had the lowest species richness overall. These results indicate that fynbos communities in dry habitats have the highest species richness whereas communities in mesic and particularly wet habitats have lowest species richness. Mean species richness values for the 'series' were, Ef: 25.81 (n = 24), Pf: 32.85 (n = 13), Ref: 38.77 (n = 4), Af: 34.19 (n = 4), Ruf: 28.75 (n = 1) (Figure 3.1.5).

No two-factor interactions between biomass and community series were significant.

Discussion

Distribution of species richness of the southern Langeberg showed no marked differences at the 50 m^2 plot scale and at the community scale when compared with levels at similar scales from studies in other parts of the fynbos biome (Boucher 1978; Bond 1981; de Lange 1992; Taylor in press). The majority of communities of the southern Langeberg have moderate levels of alpha richness as shown in the normal distribution of the frequency analysis of species richness in plot samples (Figure 3.1.4). Moderate species richness levels are found on the moist south-facing slopes whereas levels of species richness and evenness are highest in communities on the dry northern slopes. High species diversity on the southern Langeberg is therefore not interpreted as being related to alpha richness but rather to other components of diversity, namely beta and gamma diversity (McDonald & Cowling unpublished (Chapter 3.2)).

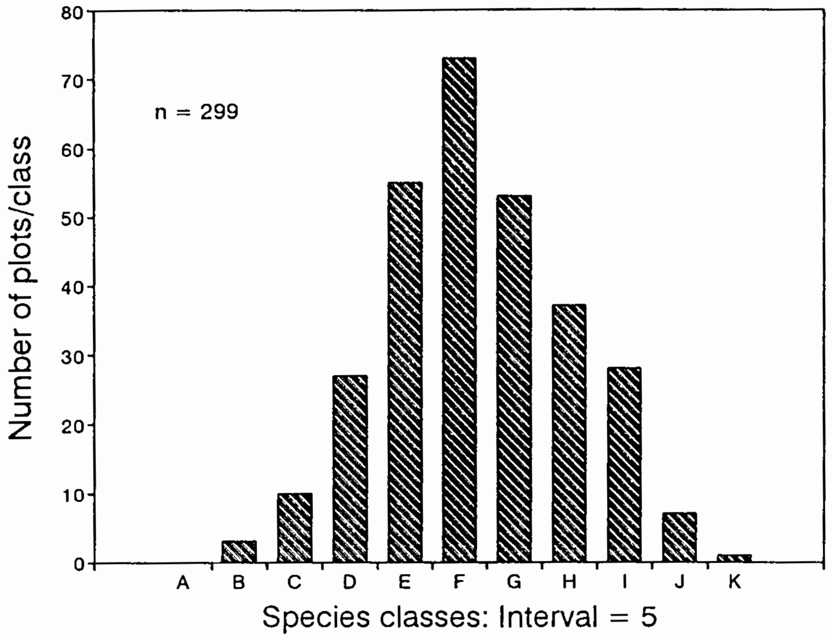

Figure 3.1.4. Frequency of number of sample plots in class intervals of five species. n = Total number of plots.

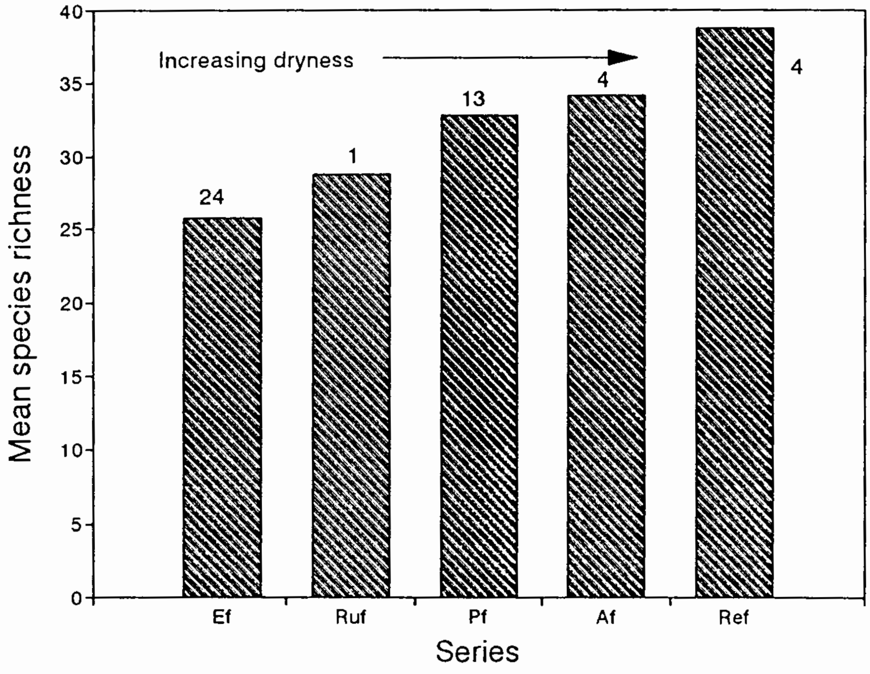

Figure 3.1.5. Mean species richness of communities grouped in series. Numbers above bars denote the numbers of communities in the series. Increasing dryness of habitat is indicated.

Studies of alpha diversity in the fynbos biome in relation to non-edaphic abiotic factors have shown no significant relationships (Cowling *et al.* 1989, Cowling *et al.* 1992) whereas both Bond (1983) and Cowling (1983) found a negative correlation between species richness and soil fertility. The use of generalised linear models in this study to examine the relationship of species richness to six abiotic explanatory variables in data from the three southern Langeberg sample transects gave variable results from which no general conclusion could be derived. The models fitted to the data from Transects W, C and E accounted for 31.6%, 51.4% and 0% of the variance in the data respectively. A large part of the variation in species richness must therefore be explained by other abiotic factors not included in the modelling procedures, by species interaction effects, by historical or biogeographic factors or by stochastic factors such as periodic fires. No soil fertility factor was included in the modelling process. Three geological categories were regarded as sufficient since they are distinct enough to reflect differences in soil nutrient status (Deacon et al. 1992). For example, geological categories (formations and subgroups of the Table Mountain Group) emerged as good predictors of soil nutrient status in the PCA of environmental data from the transects (Fig. 1.1.2). This may merit further investigation but it should be noted that even with the six variables considered, the modelling process became complicated.

The models gave clearer insights into abiotic controls on species diversity particularly where there were significant interactions between the explanatory variables. On Transects W and C, slope and mean annual precipitation were consistently important in contributing to the determination of species richness. This result agrees broadly with the conclusion that MAP is the principal abiotic factor determining community distribution on the southern Langeberg (McDonald *et al.* submitted (Chapter 1.1)). On Transect C, rock cover and its interaction with slope and mean annual precipitation was significant in that for small changes in rock cover, there were significant changes in species richness. This was interpreted as indicating the fragmentary effect of rock in the landscape, where depending on the rock cover fewer or more niches are created.

In the absence of a model for species richness on Transect E it was not possible to relate the highest observed species richness of the *Protea lorifolia–Ficinia lacineata* Shrublands (proteoid) and the *Protea neriifolia–Erica articularis* Shrublands (restioid fynbos) to values predicted from a model. For Transect W the highest observed mean species richness (X = 35.40), found in the *Berzelia intermedia–Erica conferta* Shrublands was very similar to the highest value predicted by the model, although this community occurs at lower altitude and mean annual precipitation than was predicted. The lowest observed species richness (X = 14.50) which was found in the *Hypodiscus aristatus–Erica multumbellifera* Shrublands (ericaceous fynbos) was also similar to but slightly lower than the predicted lowest richness of 16.04. The two samples representing this uncommon community (McDonald 1993b (Appendix B)) were located at distinctly different altitudes and mean annual rainfall although both had shallow (6°) slopes. Comparison with model predictions were therefore not conclusive.

The highest observed mean species richness (X = 33.13) on Transect C in the *Leucadendron eucalyptifolium–Staberoha cernua* Shrublands (proteoid fynbos) was much lower than the high richness value of 81.54 predicted by the model. Two possible explanations for this are: (1) that a site or sites with the combination of variables resulting in a high mean species richness as predicted, were not sampled and (2) the variability of percentage rock cover – which can range from 0–90% in plots representing a single community – interacting with mean annual precipitation, significantly influenced predictions made by the model. The second explanation is less likely, however, because it was found that only Plot 90 (in the *Restio inconspicuus–Anthochortus crinalis* Shrublands; ericaceous fynbos) which plot had the lowest species richness (10 species) of all plots on the transect contributed to the MAP x ROCK interaction, an interaction otherwise seldom found in the data. The observed lowest mean species richness (X = 21.67) found in the *Restio inconspicuus–Hypodiscus aristatus* Shrublands (ericaceous fynbos) on Transect C was higher than the predicted low value of 17.07 but if this is compared with the lowest species richness from a single plot (10 species of Plot 90) it is 1.7 times higher. The same explanation concerning the MAP x ROCK interaction as discussed above may be applied to this case.

There is no clear reason why a model could not be fitted to explain species richness on Transect E. It may be due to the nature of the transect. Firstly, the transect was a 'composite transect' from two different areas (see McDonald 1993 c for details (Appendix c)). Most of the southern slope samples were located in the Bergfontein area in 7 year old (relatively young) fynbos whereas most of the northern slope samples were located in old vegetation in the Phesantefontein area. This may be the most important reason but the second possibility was the distance between the two parts of the transect where the response of species to abiotic factors may have been quite different (see differences between models for transects W and C) which led to poor model fitting.

Application of the respective models to hypothetical gradients showed erratic patterns of distribution of species richness. There was no consistent increase or decrease along altitudinal gradients when the other variables in the models were kept constant or only changed slightly e.g. increasing slope at high altitude. Therefore although models could be fitted to the data and predictions made for sites with different combinations of explanatory variables, alpha diversity was haphazard on the landscape, at least at the 50 m^2 plot scale.

Is species richness related to biomass or community series? In the data set of 24 communities from the southern Langeberg no significant relationship between biomass and species richness was found. This contrasts with Bond's (1983) conclusion that point diversity (1 m^2) is correlated with biomass but agrees with the general conclusion of Gough *et al.* (1994) who found in a study of 36 marsh communities that biomass was not an adequate predictor of species richness. In the data from the southern Langeberg there was no indication that overall richness declines with increasing density and cover of the overstorey as reported in a number of studies in the CFR (Campbell & van der Meulen 1980, Bond 1983, Cowling & Gxaba 1990, Esler & Cowling 1990). This result is surprising and a rigorous test of the southern Langeberg data covering all 46 of the communities sampled would be necessary to substantiate this conclusion. Problems of scale also enter into play here and the results may reflect the complex controls on species richness resulting from point diversity and internal beta diversity (Whittaker 1977, Bond 1983).

The significant relationship between species richness and series indicates that the type of community that is sampled is important. Thus, even though at the scale of a single mountain range the differences between the communities sampled are important, it may not be appropriate to measure alpha richness using a uniform plot size in different communities. This also offers some support for interspecific interactions such as competition between species in fynbos communities being among the determinants of species richness (Shmida & Ellner 1984; Shmida & Wilson 1985; Auerbach & Shmida 1987).

The influence of fire must also be considered here. Fire as a stochastic disturbance factor serves to alter fire-prone fynbos communities in a number of ways depending on frequency and intensity. In general frequent fires favour resprouting species which can survive but they limit the existence of slow maturing seed regenerating species because the are killed and make no contribution to the seed banks. Recruitment of seed regenerating species from soil-stored seed banks is also greater following hot fires than mild fires (Bond *et al.* 1990; Cowling *et al.* 1992). The current view is also that variable fire regimes maintain coexistence between fynbos species by preventing long-term single-species dominance (Cowling 1987; Cowling *et al.* 1992). The generalizable effects of fire are thus seen to strongly influence if not override the effects of abiotic explanatory variables in determining species richness in fynbos landscapes. This makes a large part of the variation in species richness unpredictable. The erratic predictions from the species richness models and the observed haphazard patterns of species richness found in the fynbos shrublands of the southern Langeberg support these generalizations.

Conclusions

The fynbos communities of the southern Langeberg are not notably richer or poorer in species than fynbos communities in other parts of the fynbos biome. There are also no clear patterns or trends in the distribution of species richness in the montane landscapes of the southern Langeberg except that the proteoid and restioid communities of the northern drier slopes tend to be somewhat richer than the ericaceous communities on the cool, moist southern slopes.

This study is the first where species richness in the fynbos has been modelled using generalised linear models. Although models could be successfully fitted to the data of only two of the three sample transects, those models fitted offered new insights into the influence of abiotic explanatory variables on species richness, particularly where interactions between the variables were concerned. It is doubtful whether introduction of other abiotic explanatory variables such as soil fertility would account for much more variation in the species richness data. The high variation in the species richness data on the southern Langeberg points more to the stochastic effects of fire, rather than other abiotic factors, being most influential in determining patterns of species richness.

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3.2

Plant species rarity and turnover along altitudinal and geographical gradients on the southern Langeberg, Cape, South Africa.

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Abstract

Plant species turnover on altitudinal and geographical gradients as well as rarity in the fynbos vegetation of the southern Langeberg mountains, Cape, South Africa are discussed. Rank/abundance curves of the fynbos communities fit a log-normal model. The communities are dominated by a few widespread generalist species and have large numbers of sparsely occurring species. Seventy-one per cent of the species recorded occur in ten plots or fewer. This 'rarity' contributes to the high beta diversity on the altitudinal gradients examined. Gamma diversity between ecologically similar sites on the three sample transects is also high and is attributed to speciation in isolated habitats resulting from topographic heterogeneity of the landscapes.

Keywords: beta diversity, Cape Floristic Region, fynbos, gamma diversity, Langeberg mountains, rank/abundance

Nomenclature: Arnold & de Wet (1993).

Introduction

The flora of the Cape Floristic Region (CFR) is well known for its species richness and high degree of endemism at family, genus and species levels (Goldblatt 1978; Cowling *et al.* 1989; Cowling *et al.* 1992; Cowling & Holmes 1992a, b; McDonald & Cowling 1995 (Chapter 2.1)). Most studies have been conducted to determine the abiotic factors and components of diversity that would explain this extraordinary richness and have focused mainly on species richness at the local scale (Bond 1983; McDonald *et al.* submitted (Chapter 1.1)). few have investigated the contribution of the beta and gamma components to the overall patterns of diversity in the Cape (Kruger & Taylor 1979; Campbell & van der Meulen 1980; Cowling and Campbell 1984; Cowling 1990; Simmons & Cowling submitted). The complex ecological gradients of the southern Langeberg (McDonald *et al.* submitted (Chapter 1.1)) with the attendant rich flora and high level of local endemism (McDonald & Cowling 1995 (Chapter 2.1)) offered an ideal opportunity for analysing beta and gamma diversity which complements a previous analysis of alpha diversity of the same study area (McDonald *et al.* unpublished (Chapter 3.1)).

The abundance of some species and the scarcity or rarity of others have prompted many studies of different biota throughout the world [for example birds (Schoener 1987), invertebrates (Thomas & Mallorie 1985; Disney 1986) and plants (Grubb 1986; Rabinowitz *et al.* 1986; Rebelo 1992a, b)]. These studies have mostly had the conservation or preservation of species in view and in that sense, rarity is equated with the existence of the taxa in question being threatened in some way (Lucas & Synge 1981; Usher 1986; Magurran 1988; Rebelo 1992a, b; Rebelo & Tansley 1993; Simmons & Cowling submitted; Trinder-Smith *et al.* submitted). Rabinowitz (1981) described seven forms of rarity based on geographic distribution, habitat specificity and local population size. Schoener (1987) introduced additional concepts, namely suffusive and diffusive rarity and occurrence and abundance rarity. In this paper we focus on the last concept, 'abundance rarity' which Schoener (1987) defined as 'the relative or absolute abundance of the species averaged over all censuses from some locality'. On the southern Langeberg, species abundances were assessed in relation to the total flora sampled and to the communities in which the species occurred, with the objective of establishing what contribution rarity makes to species richness in the flora.

Analysis of patterns of species abundance and turnover have been aimed primarily at describing the observed patterns of rarity and beta and gamma diversity on the southern Langeberg but suggestions have also been made as to what may account for these patterns. Where possible these have then been related to the fynbos biome as a whole.

The following questions were considered:

1. What species abundance models best describe species richness and equitability in the fynbos shrublands of the southern Langeberg?
2. What are the patterns of alpha, beta and gamma diversity in the southern Langeberg flora and how can they be explained?
3. Which components of diversity contribute most to explaining the richness of the southern Langeberg flora?

The term 'species diversity' is used here as a general term including all components of diversity, namely alpha, beta and gamma diversity (Cody 1975, 1983; Whittaker 1972). Alpha diversity is the within-habitat or intra-community diversity of a homogeneous stand of a community (Cowling 1983; Whittaker 1960, 1972) and is not considered any further here. Beta diversity is the turnover of species along habitat or environmental gradients (Wilson & Shmida 1984) and gamma diversity, as used here, is identical to Whittaker's (1972) delta diversity and is the turnover of species between similar habitats along geographical gradients (Cody 1975, 1983; Cowling 1990).

The data used in the analyses are from a phytosociological survey of the southern Langeberg (McDonald 1993 a, b, c (Appendices A, B, C)), from an unpublished checklist of the southern Langeberg flora (Appendix D) and from a gradient analysis of the relationship between the fynbos vegetation and the environment of the southern Langeberg (McDonald *et al.* submitted (Chapter 1.1)).

Study Area

The Cape Fold Mountains consist of a north-south-trending belt of megafolds and monoclines in the west, parallel to the west coast, and a west-east-trending belt of northward verging folds parallel to the south coast. They have their syntaxis in the Caledon area (Söhnge 1983; Deacon *et al.* 1992). The southern Langeberg mountains (see Figures 1 and 1.1.1) where this study was carried out form part of the west-east trending belt and are situated at approximately 34°S latitude. The mountain catchments in the study area cover about 1748 km². The southern Langeberg consists largely of rocks of the Table Mountain Group of the Cape Supergroup. These rocks are mainly orthoquartzitic sandstone of the Peninsula Formation and Nardouw Subgroup which give rise to sandy oligotrophic soils, and shales of the Cedarberg Formation and Malmesbury Group which weather to form clayey, nutrient-richer substrates.

Rainfall along the southern Langeberg is bimodal with peaks in autumn and late winter to early spring. This results from the position of the mountain range in the transitional zone between the mainly winter rainfall region of the western Cape and the year-round rainfall region of the southern Cape. The onshore flow of air from the south coast influences the south-facing slopes which are generally cool and moist. The north-facing slopes which are adjacent to the arid Little Karoo are in a rainshadow and much drier. They receive 200-300 mm of rainfall annually which is less than the lower south slopes ranges which receive from 500-600 mm. Annual rainfall on the peaks is 1200-1400 mm. The north slopes also have high summer and winter radiation loads which contributes to their aridity. Temperatures on the south slopes range from 6.6°C (mean winter minimum) to 29.4°C (mean summer maximum) and on the north slopes, from 2.9°C to 30.0°C. Further details of the physiography of the southern Langeberg are given in McDonald (1993a, b, c (Appendices A, B, C)) and McDonald *et al.* (submitted (Chapter 1.1)).

Methods

Data collection

Floristic data were collected from 299 plots in the sclerophyllous fynbos shrublands on three transects straddling the southern Langeberg (McDonald 1993 a, b, c (Appendices A, B, C)). The transects were located in the districts of Heidelberg (Boosmansbos Wilderness Area, the Central Transect – C), Swellendam (Marloth Nature Reserve, the West Transect – W) and Riversdale-Albertinia (East Transect – E) (see Figure 1.1.1). Forty-six fynbos shrubland communities were described from data collected on the three transects (McDonald 1993a, b, c (Appendices A, B, C)). These communities were subsequently synthesized into 14 community 'groups' (McDonald *et al.* submitted (Chapter 1.1)).

The sample plots were rectangular quadrats of 5 x 10 m (50 m²). Each plot was sampled only once and only permanently recognizable species were recorded i.e. any 'ephemeral' geophytes and annuals found were noted but not used in the analyses. The abundance of each species was recorded using the Braun-Blanquet cover-abundance scale, the midpoint of which, given as percentage cover, is as follows: 5 = 87.5%; 4 = 62.5%; 3 = 37.5%; 2 = 15.0%; 1 = 2.5% + = 0.1%. The value R (rare) is usually ignored (Mueller-Dombois & Ellenberg 1974; Werger 1974). However, for the purposes of these analyses R = 0.01%. A border zone of 1.5 m from the perimeter of each marked plot was searched for any additional species which, if found, were assigned the percentage cover of 0.1% even if they were very rare. The percentage cover values given above were used for rank/abundance plots whereas for analyses of beta and gamma diversity the data were treated as presence/absence data.

Data analysis

(a) Species abundance models

A sub-sample of 24 communities of the 46 described by McDonald (1993a, b, c (Appendices A, B, C)) were selected to examine species abundance models. The sub-sample consisted of at least one community from each of the 14 'community groups' mentioned above (see McDonald *et al.* submitted (Chapter 1.1)) plus 10 additional random samples. The percentage cover values (see above) were summed for each species in each of the 24 communities across all representative relevés and the mean obtained for each species. The mean values were plotted as semi-log rank/abundance plots (Magurran

1988) also know as dominance-diversity curves (Whittaker 1972, 1975; Bond 1983; Wilson 1991; Watkins & Wilson 1994) to determine the type (or types) of model which best describes the diversity-abundance patterns of the southern Langeberg fynbos communities.

(b) Beta diversity

The relevés used to assess beta diversity were sampled primarily for a phytosociological survey and were therefore not located at regular intervals along the principal ecological gradients, as would be optimally required for the analyses of beta diversity patterns. However, since these were the only data available, beta diversity analyses were carried out as follows:

Single 5 x 10 m plots samples (relevés) were selected in consecutive 100 m altitude classes, as close to the mid-point of the class as possible (a) on the south side of the mountain range, with south aspect and (b) on the north side of the range with north aspect. This was carried out for Transects W and C only because plot location on Transect E was not suitable at all for beta diversity analyses. The result was therefore four separate analyses. Care was taken to ensure that all plots selected were on sandstone-derived soils. The elevation gradient was proxy for gradients in mean annual precipitation (MAP), soil moisture and temperature (McDonald *et al.* submitted (Chapter 1.1)).

Independence of alpha diversity and additivity are two important criteria necessary for 'good' performance of beta diversity measures for presence-absence data. The other two criteria are conformity with an intuitive notion of community turnover and independence from excessive sampling (Wilson & Shmida 1984). The widely used Wilson-Shmida Index (β_T) (Magurran 1988; Cowling *et al.* 1989; Cowling 1990; Cowling *et al.* 1992; Simmons & Cowling submitted), which is a modification of Cody's (1975, 1983 1986) measure of the rate of species loss and gain along a gradient and gives the number of community changes along a gradient, adequately fulfills the above criteria (Wilson & Shmida 1984, Magurran 1988). It was therefore selected for use here. Beta turnover, β_T , is defined as,

$$\beta_T = [g(H) + l(H)]/ 2\alpha$$

where on a habitat gradient H, $g(H)$ is the number of species gained, $l(H)$ is the number of species lost and α is the mean sample richness, a component of Whittaker's (1960) β-diversity measure. Since β_T satisfies the notion of community turnover, it equates with the value obtained when there are exactly β complete community changes or β+1 distinct communities along a habitat gradient. Thus if $\beta = 0$ there is no turnover between two adjacent sample stations whereas if $\beta = 1$, turnover is complete (Wilson & Shmida 1984; Shmida & Wilson 1985; Magurran 1988; Cowling *et al.* 1989). Turnover between successive plots and of the entire transect, for each of the six gradients, was calculated using BIODIV 4.1 (Baev & Penev 1993).

(c) Gamma Diversity

Gamma diversity is a measure of species turnover within similar habitats, along geographic gradients (Cody 1975, 1983, 1986; Cowling 1990). The same equation as used for beta diversity analyses was applied here except that the spatial scale is different and the sites compared were ecologically equivalent. The combination of ecological conditions for sites on the three transects is given in Table 3.2.1. Six habitats were recognized. For each habitat a species list was compiled from two plots with similar species composition, altitude and aspect. All plots selected were located on sandstone-derived soils.

Species turnover between equivalent sites was calculated westwards from Transects W, through C to E. Since there were no suitable plots from habitat 4 on Transect E and habitat 6 on Transect W, species turnover for these habitats was limited to data from these two stations only.

Table 3.2.1. Six habitats selected for analysis of gamma diversity on the southern Langeberg.

Habitat No.	Position on range	Altitude (m)		Aspect	Moisture regime
1	South side	> 1200	(High)	South	Wet
2	South side	600–800	(Mid)	South	Mesic
3	South side	< 600	(Low)	South	Mesic to dry
4	North side	> 1100	(High)	North	Mesic to dry
5	North side	600–750	(Mid)	North	Dry
6	North side	< 600	(Low)	North	Arid

Results

(a) Species abundance models

A high proportion of the species (71%) occurred in ten plots or less (Figure 3.2.1). The next class, occurrences in 11-20 plots, contained less than one-fifth of the number of species of the first class and only a few species e.g. *Erica hispidula* were found in 180 relevés or more. The frequency analysis of number of plots per class of five species showed a normal distribution (Figure 3.2.2). Classes with small and large numbers of species at the extremes contained few plots and the class with moderate numbers of species contained most plots. However, when the number of species in each class was

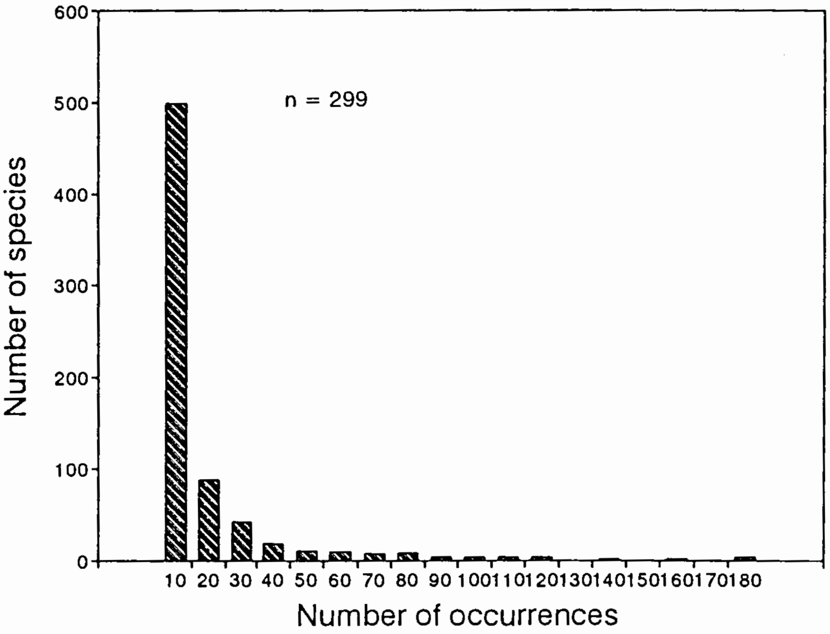


Figure 3.2.1. The frequency distribution of number of species with number of sample occurrences on the southern Langeberg. n = total number of plots.

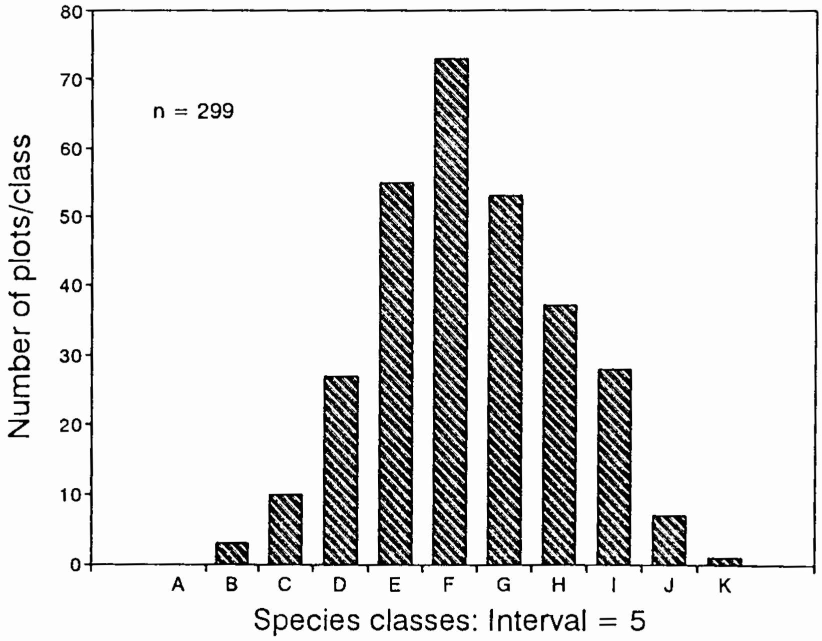


Figure 3.2.2. Frequency of number of sample plots in class intervals of five species. n = Total number of plots.

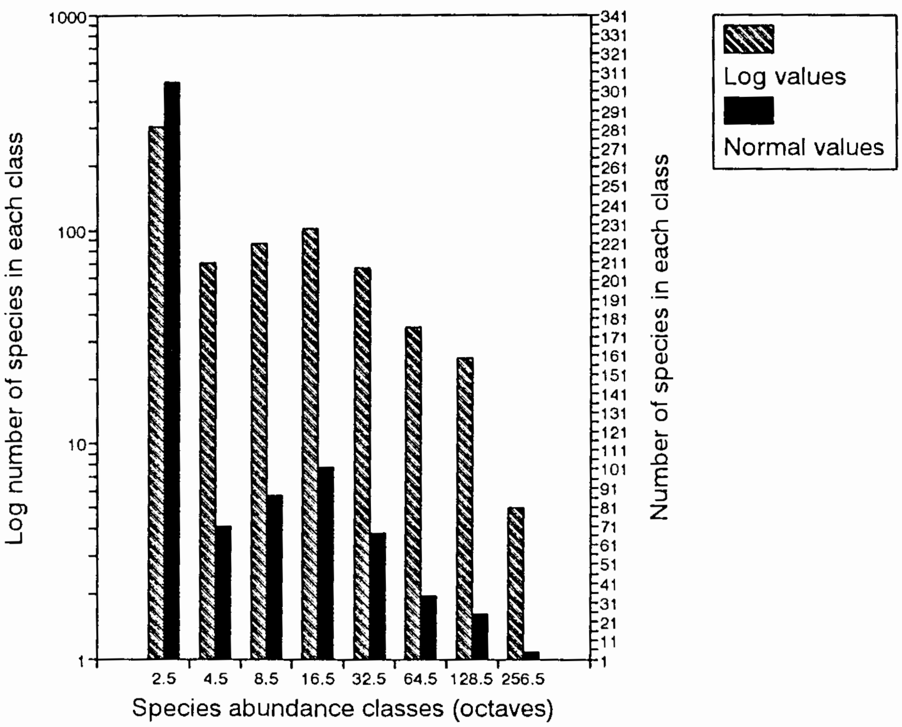


Figure 3.2.3. Frequency distribution of species abundances in octave classes.

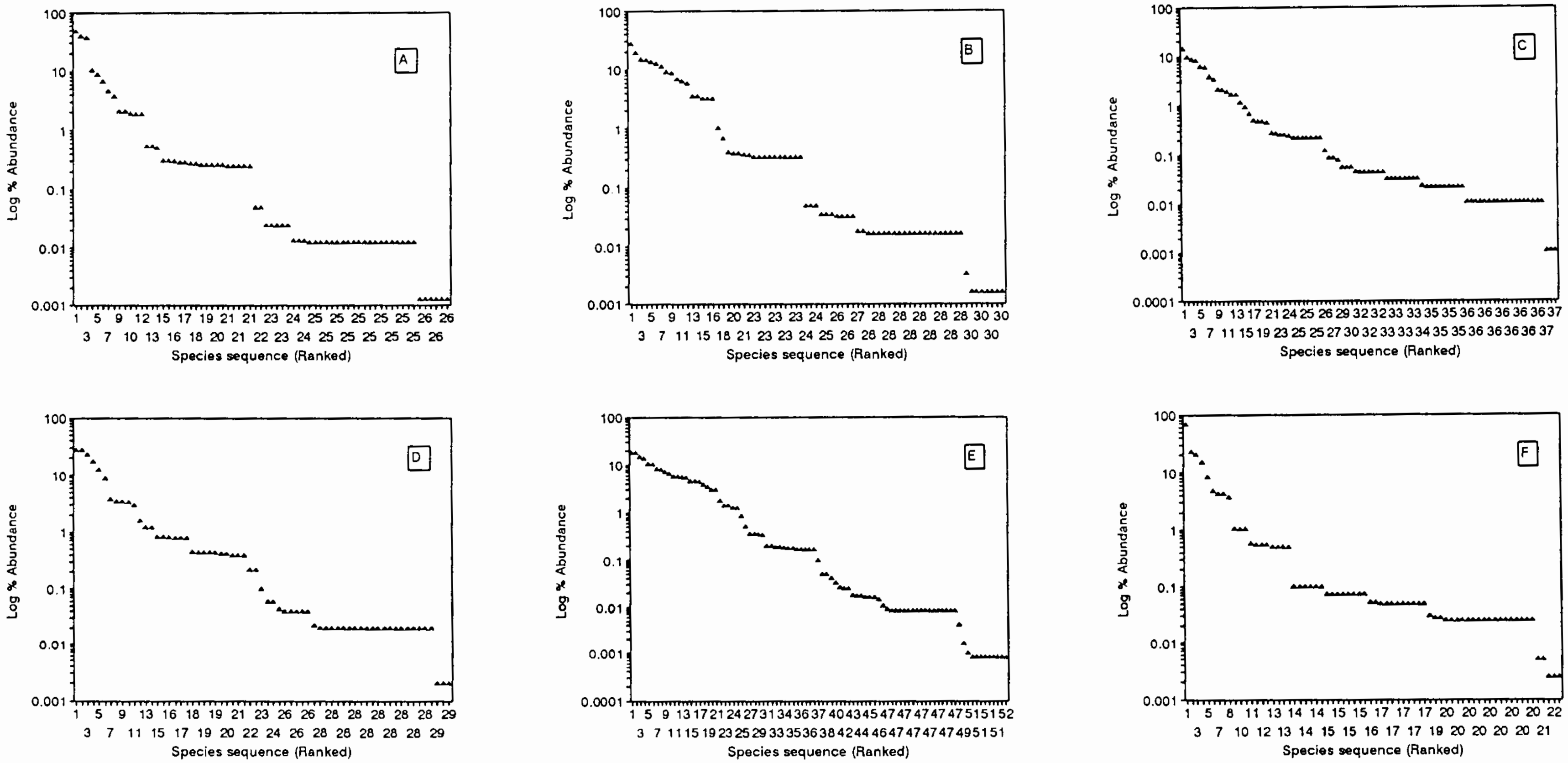


Figure 3.2.4. Rank/abundance plots of six selected communities on the southern Langeberg (from McDonald 1993a, b, c).
A. Erica hispidula-Spatalla nubicola Shrublands. B. Restio inconspicuus-Protea aurea Shrublands.
C. Passerina obtusifolia-Leucospermum calligerum Shrublands. D. Leucadendron eucalyptifolium-Erica vestita Shrublands.
E. Restio inconspicuus-Erica melanthera Shrublands. F. Erica hispidula-Protea nitida Shrublands.

plotted against species abundance in octave classes, a skewed relationship was found which was accentuated by log-transforming the number of species in each class (Figure 3.2.3).

Rank/abundance plots of the 24 fynbos communities examined (out of a total of 46) displayed a log-normal distribution of species with one or a few dominant species and a stepped distribution through species with moderate abundance to (in most cases) many species with low abundance (Figure 3.2.4).

(b) Beta diversity

Turnover between adjacent sites on all the transects was variable but generally high. The overall species turnover on the south slopes of Transects W and C was 6.4795 (over 1100m altitude range) and 8.6081 (over 1200 m altitude range) respectively. This indicates between seven and nine distinct communities on these slopes (Figure 3.2.5 A & C). On the north slopes, the overall species turnover for Transects W and C was 4.7512 and 3.8442 respectively for an altitudinal range of 700 m in both cases, denoting from four to five distinct communities on these slopes (Figure 3.2.5 B & D).

(c) Gamma diversity

Generally gamma diversity was high on the southern Langeberg. On the mesic to wet south slopes gamma diversity ranged from 0.53 to 0.76 between equivalent habitats and on the mesic to dry north slopes, where it was highest, gamma diversity ranged from 0.76 to 0.89. Gamma diversity was also higher from the central to east transect than from the west to central transect (Figure 3.2.6).

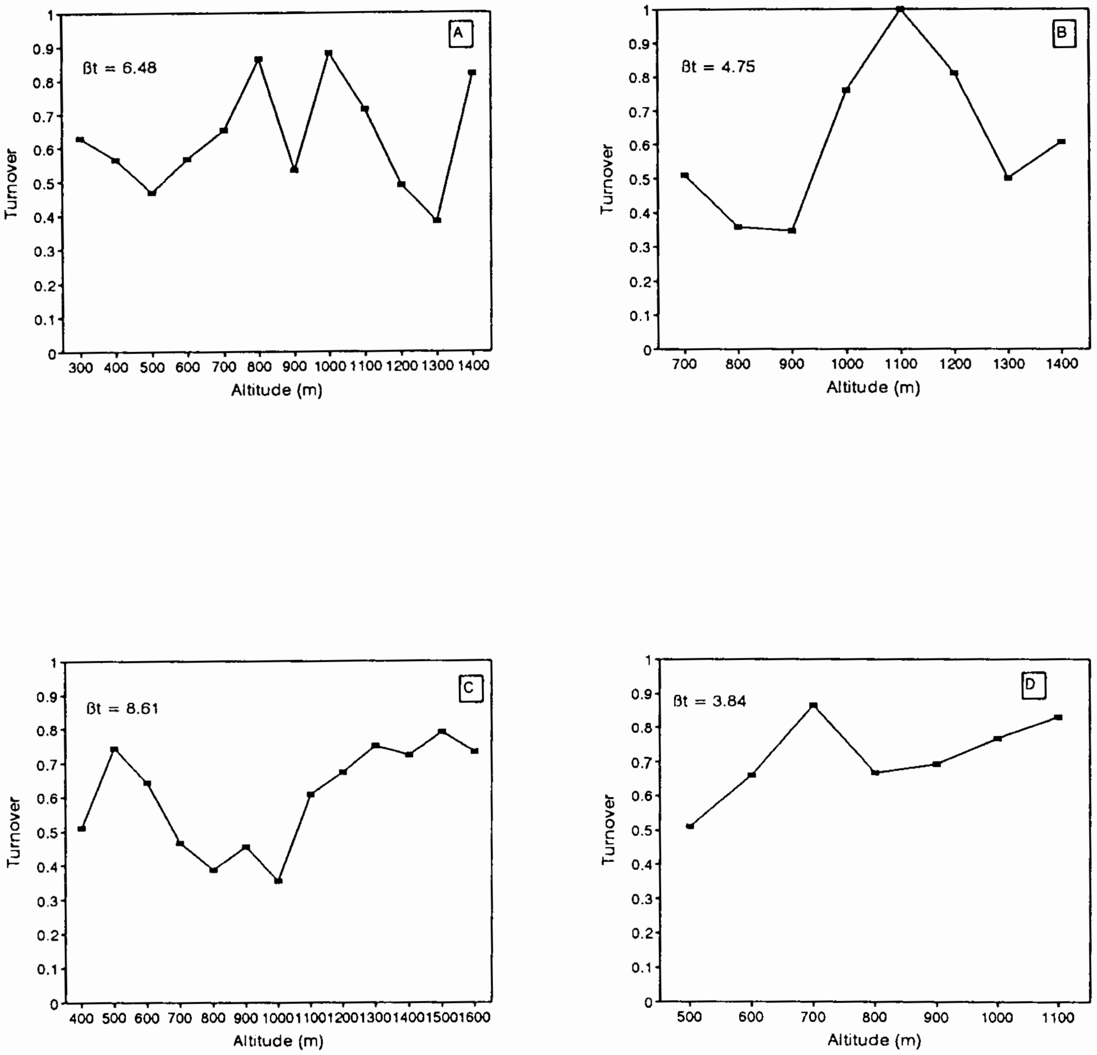
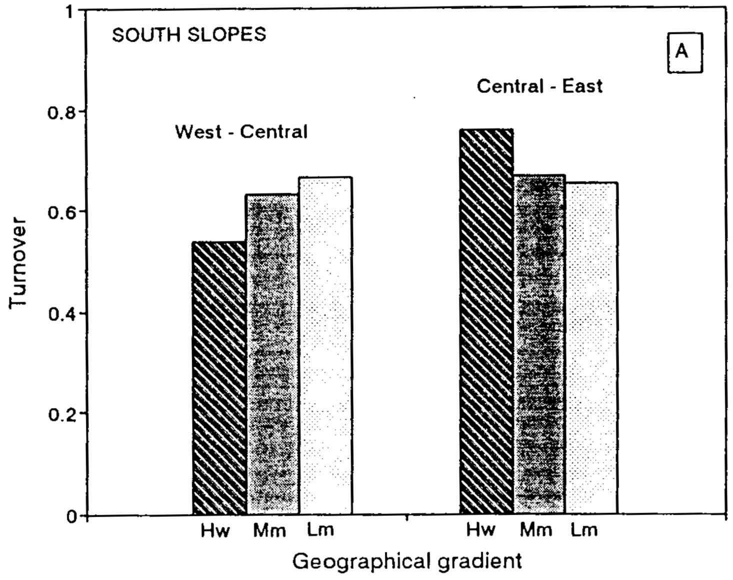


Figure 3.2.5. Beta diversity for adjacent stations along altitude gradients on two transects on the southern Langeberg. ßt = beta turnover for the whole gradient. A. Transect W, south slopes. B. Transect W, north slopes. C. Transect C, south slopes. D. Transect C, north slopes.



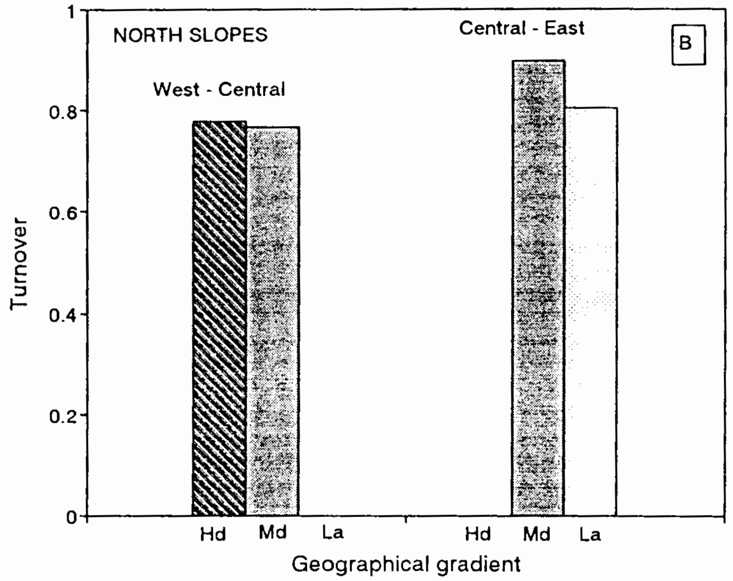


Figure 3.2.6. Gamma diversity (Wilson-Shmida index, ßt) for six habitat type across three transects on the southern Langeberg on the south slopes (A) and north slopes (B). Hw = high-altitude wet habitats, Mm = mid-altitude mesic habitats, Lm = low-altitude mesic habitats, Hd = high-altitude dry habitats, Md = mid-altitude dry habitats La = low altitude arid habitats.

Discussion

Species abundance

Not many studies have closely examined the relationship of species richness and abundance in fynbos and the ecological importance of commonness and scarcity of species is often overlooked, with equal weight given to all taxa (Schluter & Ricklefs 1993). Bond (1983) plotted dominance-diversity curves for woody communities in the southern Cape and concluded that most fynbos communities show a log-normal curve, with the exception of tall fynbos on 'islands' surrounded by indigenous forests (which had a geometric series) and waboomveld (*Protea nitida* community), (which approached MacArthur's (1957) 'broken stick' model). Observations on the southern Langeberg show that the diversity of the flora lies in the occurrence of large numbers of species with low abundance which are sparsely distributed and seldom encountered, a quality that Grubb (1986) ascribes to 'extremely species-rich' communities. Relatively few species on the southern Langeberg are widespread generalists. All the communities examined displayed log-normal distributions of species abundance, with a few dominants, moderate numbers of intermediate species and a long 'tail' of rare species. These observations agree with those of Bond (1983) except in the case of waboomveld. There is no evidence that waboomveld or the *Erica hispidula–Protea nitida* Shrubland (McDonald 1993 c (Appendix C)) approaches a 'broken stick' model but rather that this community follows a log-normal distribution similar to other fynbos communities (see Figure 3.2.4F). No clear conclusions can be drawn from the rank/abundance plots except that the 'eye ball' fit of the general log-normal model suggests that the communities are especially species-rich (Wilson 1991) or that the communities are individualistic in community structure, depending on the characteristics of the member species (Watkins & Wilson 1994). However, the responses are not necessarily significantly different from other possible curve types, therefore further investigation of dominance/diversity and spatial rank consistency models in fynbos is necessary, particularly with respect to the formal fitting of rank/abundance curves (Magurran 1988; Watkins & Wilson 1994).

Simmons & Cowling (submitted) assessed rarity of species on the Cape Peninsula by plotting the frequency distribution of species in their plots and found that 54% of the species occurred in ten plots or fewer out of a total of 836 plots. A similar pattern is evident for the southern Langeberg; 71% of the species occurred in ten plots or less of a total of 299 plots. A general principle can therefore be suggested that in montane fynbos at least, the majority of species are sparsely distributed with relatively few generalists which have wide distribution ranges. Topographic heterogeneity and stochastic influences may account for the restricted distribution of species but Grubb (1986) observed that, '...sparsity and patchiness have important roles in the maintenance of species richness because they insure that in the most species-rich communities most species are not encountering and affecting each other most of the time. At the mechanistic level emphasis is placed on the importance of the spatial dynamics of the pattern and on the limited dispersability of most plants'.

The skewed species abundance distribution in the southern Langeberg data is unusual and clearly quite different from the 'humpbacked' distributions described by Preston (1948) and May (1975). Raunkiaer's Law of Frequency (Colinvaux 1973), predicts a large number of species in the class of lowest abundance with a reversed 'J' distribution formed by the remainder of the classes. However, the distribution of species abundance in the southern Langeberg data may be described as a 'skewed-h' with highest abundances in the first octave class and the next highest in the fourth octave on the 'hump' of the 'H'. Only a few species occur in the eighth octave. These representations of the data show that species abundances in the fynbos communities of the southern Langeberg do not follow Raunkiaer's Law of Frequency. The pattern rather supports the conclusion that fynbos communities are composed of a large number of sparsely distributed (rare) species and relatively few widespread generalists. This rarity contributes significantly to beta and gamma diversity (see below).

Beta diversity

Early studies of beta diversity in fynbos vegetation raised a number of hypotheses. Firstly in a study in the south western Cape, Campbell & van der Meulen (1980) suggested that beta diversity is related more to altitudinal gradients than to disturbances such as fire (ecological effects). Later Cowling & Campbell (1984) reported relatively lower beta diversity on a fynbos ceonocline in the mountains of the south-eastern Cape, compared with beta diversity on a non-fynbos coenocline. From their study they predicted that higher beta diversity would be recorded in the fynbos of the mountains of the southern and south western Cape, for which they invoked a historical explanation of climate change since the last glacial age. It is now widely recognized (Ricklefs & Schluter 1993; Schluter & Ricklefs 1993; Cowling 1990) that both ecological factors at the regional and local scales and historical events have influenced patterns of beta diversity. Ricklefs and Schluter (1993) emphasize the necessity to look beyond the view of local determinism by realizing that 'ecology, evolution, geography, and history are different facets of a single set of processes and the patterns they generate'.

Few studies of beta diversity in the mountains of the fynbos biome have been carried out so there is little base for comparison. However, with seven to nine distinct communities encountered in a little over 1500 m change in altitude on the cool, moist south slopes and about half that number of communities on the dry north slopes over 800 m change in elevation, beta diversity of the southern Langeberg fynbos is considered to be high. In a recent study of beta diversity on the Cape Peninsula Simmons & Cowling (submitted) discussed the high turnover on the gradients they sampled. Turnover in the fynbos of the southern Langeberg was of the same magnitude as that of the Cape Peninsula fynbos.

Although the sites selected for analysis of beta diversity on the southern Langeberg were all on sandstone-derived soils, the relative fertility of the sites was not considered. In addition no recognition was given to the energy levels at the sites or the mean annual precipitation (see Hoffman *et al.* 1994). Samples were also not ideally situated along the habitat gradients. Comparison of beta diversity of the southern Langeberg with that on the lowlands of the Agulhas Plain (Cowling 1990) is not strictly appropriate but does assist in understanding edaphic gradients. On the Agulhas Plain the high levels of species turnover were attributed to edaphic specialization which was not only found between fynbos on deep acid sands and that on calcareous sand over limestone, but also between fynbos communities on colluvial acid sands derived from different substrata (Cowling 1990). Such edaphic gradients are not as apparent in the mountains but some instances of high turnover do exist e.g. from infertile sandstone-derived soils to more nutrient-rich shale soils (D.J. McDonald unpublished data). However, because of the variable geographic position elevation of the Cedarberg Formation shale as well as the other sandstone formations in the southern Langeberg, edaphic effects on the flora are confounded by climatic effects. So with the basis of beta diversity in the southern Langeberg having been established only on elevation gradients (which also reflect gradients in rainfall) in this study, there is scope for further analyses on other gradients which should also pay particular attention to sample location and ecological factors such as soil fertility at the sample sites.

Gamma diversity

Gamma diversity, which is taken as the same as Whittaker's (1977) delta diversity, is the diversity within a community at ecologically equivalent but geographically remote sites. This type of diversity is generally seen to be controlled by historical processes of speciation, extinction and migration of taxa in similar habitats on geographical gradients (Kruger & Taylor 1979; Shmida & Wilson 1985, Cody 1986, Cowling *et al.* 1992). The linear nature of the southern Langeberg means that this range has similar habitats at intervals along its length offering a close to ideal system for evaluating the turnover between sites in these habitats, where the influence of a beta component in sampling is minimized. The most 'replicable' habitats were in the wet ericaceous fynbos at high altitude on south facing slopes, particularly because the high peaks and ridges which are topographically isolated could be sampled as discrete units.

Gamma diversity on the southern Langeberg was predictably high and exceeds the value of 0.803 recorded on the Cape Peninsula by Simmons & Cowling (submitted) and the values of 0.628 for dune asteraceous fynbos and 0.667 for ericaceous fynbos on the Agulhas Plain (Cowling 1990). The patterns and processes contributing to high gamma diversity on the southern Langeberg are similar to those found on the Cape Peninsula. The high levels of local endemism (13.02%) in the Langeberg flora (McDonald & Cowling 1995 (Chapter 2.1)) may contribute substantially to the gamma diversity. The tendency of the endemics to be highly localized e.g. restricted to high altitude communities on single peaks but in ecologically similar conditions would enhance gamma diversity. Many of the endemics are dispersed only short distances (McDonald & Cowling 1995 (Chapter 2.1); McDonald *et al.* in press (Chapter 2.2)) and with explosive *in situ* speciation of taxa such as the genus *Erica* gamma diversity is expected to be high.

Conclusions

Fynbos communities of the southern Langeberg follow a log-normal pattern of ranked abundance with a few dominant species and many species with low occurrence. Many species are sparsely distributed and it is these species which make a large contribution to the high beta diversity. On all the gradients examined it was found that even though alpha diversity is moderate, there is rapid replacement of species on the ecological gradients. The general patterns of regional species diversity described by Cowling *et al.* (1992), where high species turnover on ecological gradients combined with very high turnover along geographic gradients result in high regional species richness, are therefore supported by observations of patterns of diversity in the southern Langeberg fynbos.

More rigorous goal-directed sampling for beta and gamma diversity on the southern Langeberg may yield patterns not apparent in this study, however, the patterns found here showed unequivocally that beta and gamma diversity are high.

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General Conclusions

The eminent ecologist Robert MacArthur recognized that understanding pattern in natural systems is of central importance in many aspects of ecology. He elevated the search and explanation of pattern to a science itself in his statement, 'To do science is to search for repeated patterns...' (MacArthur 1972). The thread that binds the separate parts of this study together has been the search for pattern in its variety of forms in the flora and vegetation of the southern Langeberg, Cape, South Africa. This pattern was evident firstly in the physiognomic distribution of plant communities in the mountain landscapes. Then as those communities were analysed, further patterns were found in the flora making up the communities. The communities or assemblages of plant species were not random but species occurred in recognizable associations and explanations were sought for why this was so. Patterns of plant species diversity were then examined to find explanations for the observed richness and variety in the flora and at a lower level, the patterns and determinants of local endemism were explored.

In general a correlative approach was adopted where variation in attributes and composition of the flora and vegetation was explained by reference to associated environmental variation. Plants occupy space in the landscape, but that occupation is not random. Assemblages of plant species occur together in repeated patterns, which are influenced by abiotic factors, stochastic disturbance events and the evolutionary history of the flora. The explanations advanced here for the observed pattern and the predictions that have been made have shortcomings but despite these imperfections, they provide additional insights into the fynbos communities of the southern Langeberg mountain range where previously information was limited.

Three levels of investigation were employed in this study. Firstly, the broad descriptive level. The fynbos communities of three sample transects were described, as were their relationships with each other and with other communities described by others workers for different parts of the fynbos biome. These descriptions (Appendices A, B & C) not only formed the basis for investigation of the vegetation–relationships of the southern Langeberg but also provided scope for a critical evaluation of Campbell's (1985) structural classification of the vegetation of the Cape mountains (Part 1). Secondly, at a more specific level (Part 3), patterns of plant species diversity and rarity were investigated. Species diversity itself can be analysed at different scales and here diversity in the southern Langeberg flora at the alpha and seldom considered beta and gamma levels was investigated. The third level of investigation was even more detailed (Part 2) where endemism as a specific aspect of the flora (Appendix D) of the southern Langeberg was studied.

Conclusions from Part 1

From the evaluation of Campbell's (1985) structural classification of the fynbos of the Cape mountains it was concluded that there is not necessarily a one-to-one correspondence between structural 'types' and floristic communities. Within a structural type there can be a high degree of floristic variation. Complementarity between structural and floristic classification systems was emphasized but the advantage of a floristic study is that it is possible to construct a structural classification from species data. Floristic surveys such as those described in Appendices A, B and C, also provide the data for analysis of endemism and species diversity, two important aspects of ecological biogeography. These data are not found in structural surveys.

The use of multivariate analyses to explain the distribution of fynbos communities on environmental gradients showed that less than half of the site variation in the vegetation can be predicted by a limited number of environmental factors. The gradients are complex but mean annual precipitation (MAP) and winter incoming radiation (WGRFD) were found to be the most important explanatory variables on the primary gradient. Soil variables and geology play a subsidiary, but nevertheless important role, in determining community distribution. These conclusions are not unusual or novel but rather support the patterns described by Campbell (1986) and Bond (1981) for the southern Cape coastal mountains. But what of the remaining variance in the data?

Fire is a dominant element of disturbance in fynbos shrublands (Cowling 1987) and as such its strong influence in re-arranging assemblages of different species and populations of the same species must be recognized. Because of the strong stochastic impact of fire on fynbos communities much of the variance in the data will not be explained by other abiotic factors.

However, despite the influence of fire on fynbos shrublands and the possible argument that the type of multivariate analysis employed here was simply an anachronistic application of methods with little further value, in an area with complex gradients such as the southern Langeberg, such an analysis formed a framework for other aspects of the study of the vegetation. It was therefore of fundamental importance. It provided the means for the proposal of a general model of the vegetation–relationships of the southern Langeberg, the aim of which was to simplify the use of the floristic classification for management of fynbos in the mountain catchments. This model requires testing, however, at which stage it may be rejected or refined and improved. Whatever its fate it will hopefully either add to the existing set of management tools for managers of fynbos in the mountains of the southern Cape or stimulate the development of alternative models.

Conclusions from Part 2

What are the biological determinants of endemism, how are endemics distributed in the landscape and what are the taxonomic patterns of endemism? These questions were central to the detailed investigation of endemism. From this study it was determined that the endemic plant species of the southern Langeberg are not randomly distributed either spatially in the landscape or taxonomically through plant genera or families in the flora. They are also not biologically diffuse, possessing common sets of biological traits.

Levels of endemism on the southern Langeberg are high by global as well as regional standards, with 13.02% of the flora being endemic. The endemics are found mainly in seven plant families, Asteraceae, Ericaceae, Fabaceae, Iridaceae, Orchidaceae, Proteaceae and Restionaceae, with approximately one-third of all the southern Langeberg endemics found in the genus *Erica* (Ericaceae). Analysis of the habitat preferences of these endemics showed that the majority of the endemics were found on the cool, moist, south-facing slopes and no relationship was detected between levels of endemism and extent of the habitat e.g. on the high altitude wet slopes (16.8% of the study area), 51 endemics were found whereas on the arid north slopes (27% of the study area) 27 endemics were found. Biologically, the endemics of the southern Langeberg show strong similarities to those of the Agulhas Plain and Humansdorp floras (Cowling & Holmes, 1992; Cowling *et al.*, 1992). They are mostly non-sprouting, low shrubs with short-distance seed dispersal; seed is either passively dispersed or ant-dispersed.

Modelling a 'typical' endemic using the biological traits of seed dispersal, growth form and post-fire regeneration strategy as explanatory variables in a logistic regression analysis was extremely challenging. It led to the conclusion that dispersal mode, acting independently from the latter two traits is the most important factor determining endemism in the flora of the southern Langeberg. Species with short-distance dispersal are most likely to be endemic, with ant-dispersed species having the greatest chance of being endemic. The final model supports the general view that speciation rate is enhanced by short-distance dispersal due to the consequent short gene dispersal distances and the ease of geographical population isolation. Interaction between growth form and post-fire regeneration strategy are less important in determining endemism, however, fire acts to fragment and isolate populations of non-sprouting species resulting in the greater proportion of endemic species being non-sprouting shrubs. Resprouters resist the effects of fire which in turn resists extinction but depresses speciation and the chances of a species being endemic.

Apart from some limitations to the model such as it being difficult to apply to a large flora and that other potentially important biologically traits were excluded, this is a significant advance on the previously used two-way contingency table method. This is the first time such an approach has been used and it offers considerable scope for testing in other floras in the fynbos biome, both in the mountains and the lowlands.

Conclusions from Part 3

The use of generalised linear modelling to explain species richness by a suite of abiotic variables gave erratic results. Models differed between sample transects and it was not possible to reach a single general conclusion on the abiotic control of species richness on the southern Langeberg except that proteoid and restioid communities on the dry northern slopes are richer than the ericaceous communities on the wet southern slopes. Once again the effects of fire together with a narrow range in species richness most likely account for the inconclusive results of modelling. Modelling species richness in relation to biomass gave a negative result whereas there was a significant relationship with the type of community ('series'), which indicates that attention should be paid to the type of community as well as sample scale when sampling fynbos communities.

Levels of beta and gamma diversity are high in the southern Langeberg and there is a strong link between these and the high levels of endemism recorded (see Part 2). There are many rare or sparsely distributed species. Most communities display log-normal rank/abundance distributions of species with a few dominants and a 'tail' of many rare species. Many of the rare species are habitat specialists that make a strong contribution to turnover on ecological gradients. In addition there are many ecologically equivalent species which contribute to the high diversity on geographical gradients

General

As stated in the introduction, this study was originally aimed at surveying and documenting the plant communities of the southern Langeberg. It has grown into much more and yet the data collected still holds information that has not been assessed or analysed. It is the nature of phytosociological studies to be a 'repository' of ecological information, the ecologists' equivalent of the taxonomists' herbarium. The richness of the data permits many aspects of the vegetation and flora to be explored and the patterns to be revealed and explained. But these patterns are and will always be part of the fabric of the whole. The overall aim has been to contribute to the insight needed for more appropriate management of the fynbos with its remarkable biodiversity. Contributions that have been made by this study to this objective are:

- A classification of the southern Langeberg flora and vegetation that is mappable at the 1: 50 000 scale has been developed
- A method has been formulated whereby biomass can be estimated from community composition; this is of value for obtaining biomass classes for fuel management.
- Endemic species on the southern Langeberg have been characterized in terms of their taxonomy, biological attributes and habitat preferences. This has important implications for management since endemics can be used as indicators of the stability or lack of stability in mountain ecosystems.
- Species richness on the southern Langeberg is relatively uniform and probably determined by stochastic factors beyond the control of managers.
- The presence of many rare species presents a problem for managers and the results here support the move away from 'single-family-dominated' management policies to 'adaptive interference fire management' on the southern Langeberg.
- The high beta and gamma diversity in the flora of the southern Langeberg indicate that to adequately conserve the flora, reserves should cover altitudinal gradients at regular intervals along the range.

As much as the remarks above conclude this study they also allow scope for further analyses of the vegetation data from the southern Langeberg. A kaleidoscope of patterns remain to be unravelled; an exciting challenge to respond to and an opportunity to make a contribution to the all-important preoccupation of conserving the wealth of plant diversity in the Cape Floral Kingdom.

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'When we reach the mountain summits, we leave behind us all the things that weigh heavily on our body and our spirit. We leave behind all sense of weakness and depression; we feel a new freedom, a great exhilaration, an exaltation of the body, no less than of the spirit.'

Jan Christiaan Smuts

Appendix A

Bothalia 23,1: 129–151 (1993)

The vegetation of the southern Langeberg, Cape Province. 1. The plant communities of the Boosmansbos Wilderness Area

D. J. MCDONALD*

Keywords: classification, forest, fynbos, Langeberg, phytosociology

ABSTRACT

An analysis of the fynbos shrublands and forests of the Boosmansbos Wilderness Area, southern Langeberg, Cape Province, South Africa, is presented. Data were collected at 119 sites in mature fynbos vegetation (>10 years old) and at five sites in patches of Afromontane Forest. Emphasis was placed on the fynbos shrublands and sample sites were subjectively located along a transect from south to north across the Langeberg range in the study area. This south to north orientation follows a complex gradient of changes in aspect, slope, geology, soil form and climate. Data were initially analysed using TWINSPAN and the resulting classification refined using Braun-Blanquet procedures. One forest subassociation and 12 fynbos communities were identified and described. A proposed hierarchical classification of the fynbos communities is presented.

UITTREKSEL

'n Analise van die fynbos en woude van die Boosmansbos Wildernisgebied, suidelike Langeberge, Kaapprovinsie, Suid-Afrika, word aangebied. Data is van 119 monsterpersele in volwasse fynbosplantegroei (> 10 jaar oud) en vyf monsterpersele in Afro-montane woude versamel. Klem is op die fynbosstruikveld gelê en monsterpersele is subjektief langs 'n transek van suid na noord oor die Langeberge in die studiegebied uitgelê. Die suid tot noord oriëntasie volg 'n komplekse gradiënt van veranderings in aspek, helling, geologie, grondform en klimaat. Data is aanvanklik d.m.v TWINSPAN ontleed en die resultaat met behulp van Braun-Blanquet-prosedures verfyn. Een woudsubassosiasie en 12 fynbosgemeenskappe is geïdentifiseer en beskryf. 'n Hiërargiese klassifikasie van die fynbosgemeenskappe word voorgestel.

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INTRODUCTION

The position of the Langeberg on the west-east axis of the Cape Fold Belt places it between the mountains of the southwestern Cape and those of the southern Cape (Figure 1). It therefore forms an important highland phytogeographical link between the montane floras of these respective regions.

The southern Langeberg is defined as the Langeberg Range between Kogmanskloof and the Gouritz River. The description and classification of the plant communities of the Boosmansbos Wilderness Area presented in this paper form part of a broad-scale phytosociological study of the southern Langeberg.

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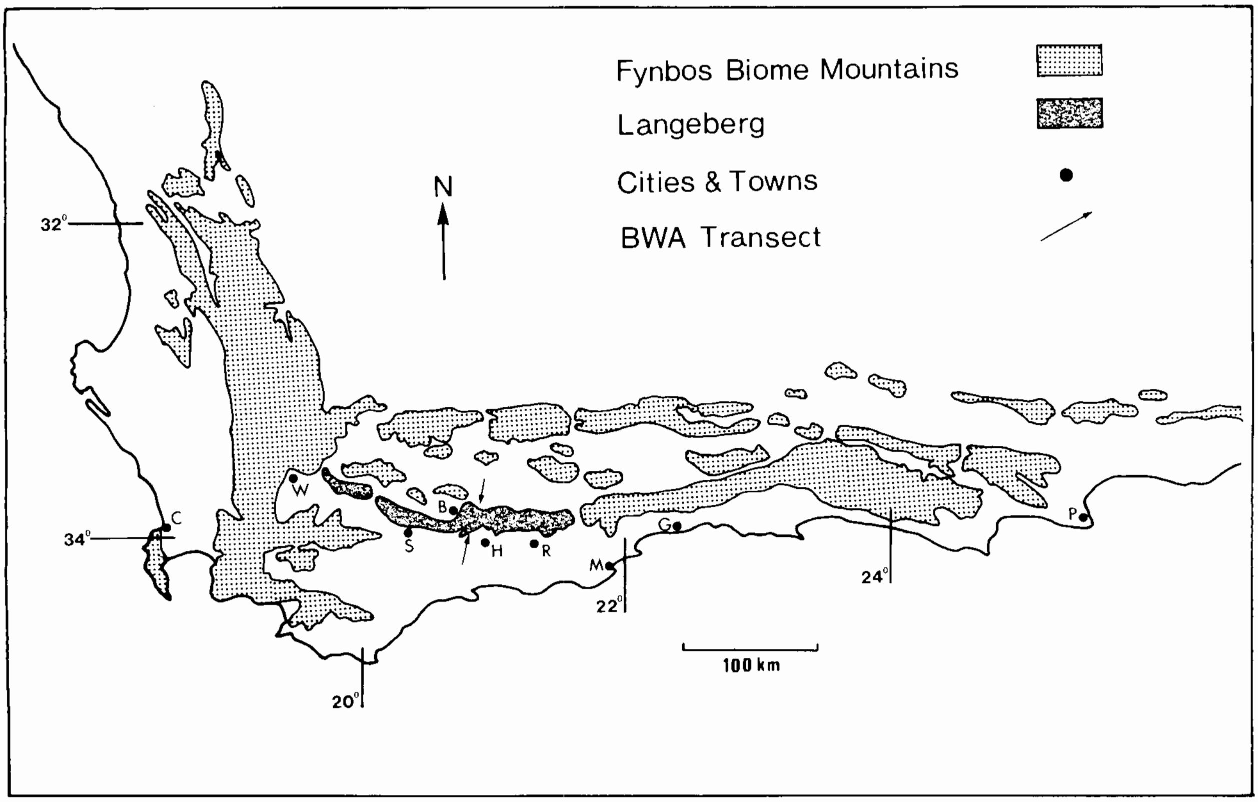

FIGURE 1.—Map of the mountains of the Fynbos Biome showing the position of the Langeberg and the location of the Boosmansbos Wilderness Area (BWA): B, Barrydale; C, Cape Town; G, George; H, Heidelberg; M, Mossel Bay; P, Port Elizabeth; R, Riversdale; S, Swellendam and W, Worcester.

Separate papers cover the description and classification of the vegetation of two other similar transects at Swellendam and Bergfontein (near the Gouritz River) (McDonald 1993a & b).

STUDY AREA

Location

The Boosmansbos Wilderness Area (BWA) near Heidelberg, Cape Province, is more or less centrally situated in the southern Langeberg and extends across its widest part (13 km). The area forms part of the Grootvadersbosch State Forest and was proclaimed a wilderness area in 1978. The mountain catchments are managed for conservation, limited-access recreational hiking and production of potable water. The Duivenhoks River has its origins in these catchments.

The BWA is approximately 14 200 ha in extent. It is bounded on the south side by agricultural land, on the north side by a private nature reserve and on the west and east sides by privately owned mountain land.

An access road, the Barend Koen Road, traverses the area from the lower south slopes, adjoining the farm Goedehoop, to Helderfontein at 1 150 m. The road is used for management and forms part of the hiking trail network in the area. During this study the road and paths gave ready access to the area for sampling purposes.

The transect was arbitrarily delimited through the centre of the BWA, straddling the Barend Koen Road on the south slopes and the path to Witbooisrivier on the north slopes. It does not follow a straight line over the mountain range but was positioned to cover as much topographical variation and plant community variation as possible. The transect area was approximately 3 000 ha.

Physiography

The southern plateau-like footslopes of the Langeberg in the BWA are deeply incised by the Duivenhoks River. At higher elevations, fault valleys such as Vaalrivierkloof, Bobbejaankloof, Platbosrivierkloof and Saagkuilkloof, which feed the Duivenhoks River, are encountered. Saagkuilkloof and Platbosrivierkloof fall within the delimited transect and have north- and south-facing slopes. North of Platbosrivierkloof is Repeater Kop, a high west-east ridge lying approximately between Vaalrivierkloof and Helderfontein. Behind (north of) Repeater Kop is the Helderfontein Valley and north of that a high ridge runs westwards from Grootberg. The Moeras River and Helderfontein Stream start at the watershed behind Repeater Kop. Moeras River drains northwestwards towards Barrydale. Grootberg is the highest peak (1 627 m) in BWA and directly below it is the deep Boosmansbos Valley. The stream from Helderfontein runs through this valley, through a gorge below Noukrans Peak (1 443 m) and Horingberg (1 487 m) to join the Duivenhoks River outside the wilderness area.

North of Grootberg is a series of sandstone ridges with interspersed shallow valleys. There is one main, relatively broad valley with a shallow gradient eastwards towards Brandrivier. North of the valley is Deception Ridge, so named because of its deceptive height. The north slopes of Deception Ridge are steep and rocky, giving way lower down to mesa-like plateaux of gravels and sandstone conglomerate (see below).

Geology

The Langeberg is one of the west-east trending mountain ranges with northward-verging folds, in the eastern zone of the Cape Fold Belt. It consists mainly of sediments of the Table Mountain Group (Cape Supergroup) and in part, of pre-Cape Malmesbury Group sediments. The range was formed during the Cape orogeny when the rocks of the Cape Supergroup were folded in a single phase, multiple event orogeny of Permian to Late Triassic age (De Villiers 1944; Hälbich *et al.* 1983). The core of folding in the Langeberg is at Tradouw Pass where the massive folding has resulted in what Le Roux (1974) describes as the Langeberg megastructure.

A transect over the Langeberg at any given locality has its own peculiar local geology owing to folding, faulting and consequent positioning of strata and fault valleys. Only one detailed geological study of a section of the Langeberg exists (Le Roux 1974, 1983). Fortuitously this coincides in part with the area proclaimed as BWA and with the vegetation sampling transect chosen for this study.

Five formations of the Table Mountain Group are found in the study area. The Peninsula Formation sandstone makes up the southern slopes from about 400–1 600 m a.s.l. At 1 150 m the Cedarberg Formation is represented by a relatively thin band of shale in the vicinity of Helderfontein. It is deeply incised and eroded at the headwaters of the Moeras and Duivenhoks Rivers.

North of the Cedarberg Formation are the sandstone sediments of the Nardouw Subgroup comprising the Goudini, Rietvlei and Skurweberg Formations. For the purposes of this study, the Nardouw Subgroup is equated with the Peninsula and Cedarberg formations since the finer distinctions are of secondary importance. Nardouw Subgroup sandstone is also found on the south side of the mountain between Tradouws Pass and Grootvadersbosch Forest Station, Ertjiesvleiberg and in a narrow band eastwards from below Horingberg to beyond Palmyra (Le Roux 1974, 1983). However, Nardouw sandstones were not encountered on the south side of the range on the vegetation transect as designated in BWA.

Above Witbooisrivier, on the north side of the transect, high terrace gravels are found (Lenz 1957; Le Roux 1974). These gravels are cemented by a siliceous matrix, forming resistant silcrete caps or duricrusts (Schloms *et al.* 1983) and are remnants of the African Erosion Surface (Partridge & Maud 1987).

Gravels of the Enon Formation are found at the southern extremity of the vegetation transect. Le Roux (1974) described the Enon sediments as 'weakly consolidated gravels and mudstones in alternating strata ... composed of vein quartz, quartzite (derived from the Table Mountain Group), greenish sandstones and shales (apparently from the Bokkeveld Group), as well as conglomerates older than the Enon Formation.'

Soils

The soils of BWA agree with the general pattern described by Campbell (1983) for southern Cape coastal mountains and the classification follows the system of the Soil Classification Working Group (SCWG 1991). The soil forms encountered, their positions in the landscape and their relationship to the geological formations are outlined below.

Oakleaf Form

Soils of this form have an orthic A-horizon over a diagnostic neocutanic B-horizon. The detailed definition of a 'neocutanic' horizon is given by SCWG (1991); briefly it is a horizon derived from recent sediments and other unconsolidated materials. It shows little colour differentiation and weak structural development.

At low altitude (350 m), at the southern extremity of the BWA vegetation transect, Oakleaf Form soils are encountered. These soils result from the weathering of Enon Formation sediments (see above). At one site (Relevé 59) on the Cedarberg Formation shale at Helderfontein, the soil was identified as Oakleaf Form. This soil has formed by weathering of shale in a moist situation as opposed to the formation of a Clovelly Form soil (described below) under slightly drier conditions.

Cartref and Houwhoek Forms

Cartref and Houwhoek Form soils are found from low (425 m) to high (1 600 m) elevations on south-facing slopes, mainly on parent rock of the Peninsula Formation. The form encountered at any position in the landscape is dependent on the land facet (convexity or concavity), its steepness and consequent drainage. The Houwhoek Form soils display weak ferrihumic character in the B-horizon and are very close to the more common Cartref Form soils with lithocutanic B-horizons, showing no podzolization.

Champagne Form

Champagne Form soils are found at sites where drainage is impeded and where deep accumulation of organic matter has occurred. This soil form is typically found at 'seeps' where Restionaceae form dense, matted peat-like deposits. On some of the high peaks (e.g. Grootberg, 1 627 m) and ridges (Repeater Kop, 1 506 m) Champagne Form soils are found on south aspects, on steep slopes. The slopes have a mean gradient of 30° and organic material has accumulated to an average depth of 700 mm. Podzolization may occur in the parent rock beneath, but this would presumably have little influence on the vegetation which is rooted in the humus.

Mispah Form

At sites where bedrock is close to the surface and where soil development is poor (due to a combination of excessive drainage, high insolation, low organic matter accumulation), Mispah Form soils with shallow orthic A-horizons over hardrock are found. This form is found on the high-altitude north-facing slopes of Repeater Kop ridge, Grootberg and on the terraced gravel-conglomerates above Witbooisrivier.

Glenrosa Form

Soils of the Glenrosa Form are also found on the north aspect of the ridges and peaks of BWA but on the middle to lower slopes. Here the form is diagnosed by presence of Orthic A and Lithocutanic B-horizons. This form typically occurs on the well-drained terraced ridges of the Nardouw Subgroup strata north of Grootberg.

Clovelly Form

Clovelly Form soils are found at three different localities in BWA. These soils with a Yellow-Brown Apedal B diagnostic horizon below an Orthic A-horizon have mainly but not exclusively resulted from accumulation of transported material. The exception is on the Cedarberg Formation shaleband near Helderfontein where the *in situ* shale, with its fine-grained matrix has weathered to Clovelly Form soils.

The south-facing slope of the ridge west of Grootberg is a debris slope of Nardouw Subgroup sandstone. These slopes which lie above the contact with the Cedarberg Formation and which are moderately well-drained, exhibit Clovelly Form soils (Relevé 64).

In the eastward-trending intermontane valley north of Grootberg, deposits of material eroded from Nardouw Subgroup sandstones have given rise to well-developed Clovelly Form soils. These soils are well drained and in one pit examined (Relevé 130) pieces of reworked ferricrete were found at 700 mm depth. On Deception Ridge (northmost ridge on the transect), the south-facing terraced slopes have a mixture of Clovelly and Glenrosa Forms depending on the presence or absence of apedal and lithocutanic B-horizons respectively.

Climate

Local climate of the Boosmansbos Wilderness Area is poorly documented. A rainfall recording station is situated at Grootvadersbosch Forest Station (Strawberry Hill), however, this inadequately reflects rainfall as it occurs and changes in the montane environment along the BWA transect. The limited data available at best reflect low-altitude conditions on the south slopes. Fuggle (1981) warns of the dangers of interpolation between climatic stations. However, since no climate measurements were made during this study, limited available data from Weather Bureau records (Strawberry Hill 025/599) and Fuggle (1981) are used to obtain at least seasonal trends in climate. Mean annual precipitation estimates were obtained from isohyet maps prepared by Dent *et al.* (1987).

Wind

In summer the prevailing winds from the southeast and southwest influence the Boosmansbos Wilderness Area the most. The onshore, moisture-laden southeast winds are trapped by the Langeberg and orographic rain occurs. During the winter the winds blow primarily from the northwest and southwest also bringing rain following cold fronts. Berg winds occur in winter heralding the approach of cold fronts (Fuggle & Ashton 1979; Fuggle 1981; Heydorn & Tinley 1980; Tyson 1964, 1969).

Temperature

Temperature data for the study area are non-existent. This situation is commonly found since few weather stations are situated in the Cape mountains (Bond 1981; Fuggle & Ashton 1979; Fuggle 1981). Temperatures in mountain areas vary considerably from place to place; therefore it is only possible to make generalized statements about the effect of latitude and altitude on temperature (Fuggle 1981.)

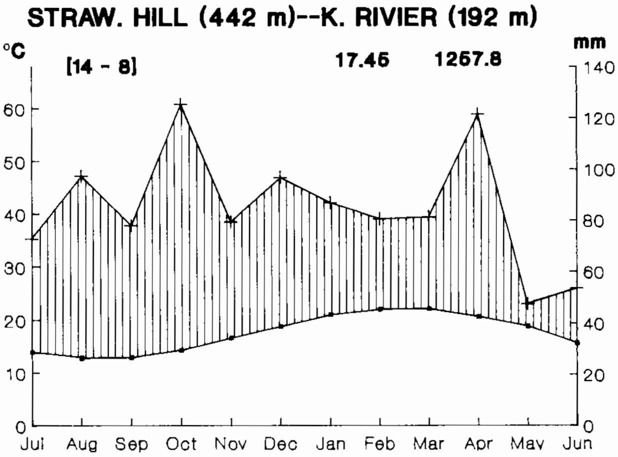

FIGURE 2.— Walter-Lieth climate diagram representing the climate on the southern slopes of the Boosmansbos Wilderness Area. Rainfall data from Strawberry Hill (Grootvadersbosch Forest Station) and temperature data from the nearest station at Karringmelksrivier, near Heidelberg.

The nearest reliable temperature data are from Karringmelksrivier (192 m a.s.l.) near Heidelberg, well away from the BWA. However, these data are used to give general trends in seasonal temperature variation. In Figure 2 they are combined with rainfall data from Strawberry Hill to give an approximation of the climate of the southern slopes of the BWA.

Precipitation

Precipitation in the BWA occurs mostly as rain. However, fog or mist from low stratus cloud plays a considerable, but unmeasured, role in contributing to total precipitation. Snowfalls occur in September, October and occasionally November.

As for other climatic parameters, rainfall is not measured on a regular basis in the study area. It is clear from observation that topography and aspect significantly affect rainfall distribution. Interpolated data from Dent *et al.* (1987) show that the lower south slopes of the study area receive approximately 600 mm mean annual precipitation. With an increase in altitude this value increases to almost 1 300 mm on the high peaks. The largest part of the study area receives 1 000 mm precipitation on average each year. With a decrease in altitude on the north slopes, bordering the Little Karoo, a steep gradient exists, with the lower slopes receiving less than 300 mm mean annual precipitation (nearby Barrydale receives 276 mm p.a.; Fuggle 1981).

The seasonal distribution of rainfall on the south aspects of the study area are reflected in the data from Strawberry Hill weather station, and on the lower north slopes by data from Klein Doornrivier, Figure 3. No month is without rain but most rain falls in spring and autumn. Rainfall results from post-frontal anticyclonic (onshore) air movement over the subcontinent from August to November. In the autumn months of March, April and May rainfall results from the progression of cold fronts along the

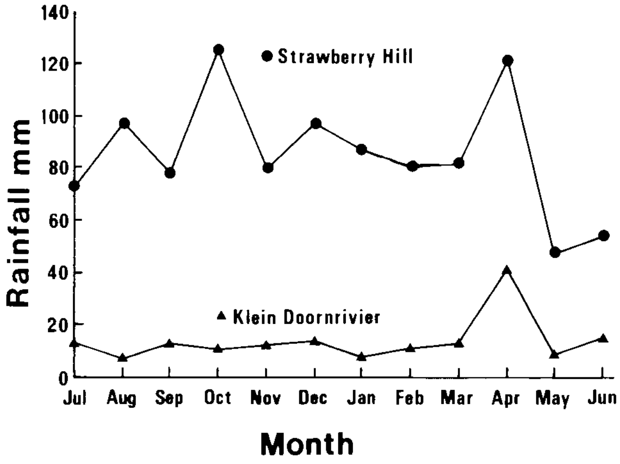

FIGURE 3.—Mean monthly rainfall at Strawberry Hill (1978–1990) and Klein Doornrivier (1982–1990) located at the lower south and north extremes of the Boosmansbos sample transect respectively. Rainfall peaks occur in spring (October) and autumn (April) at Strawberry Hill and in autumn at Klein Doornrivier.

southern coast. Occasional cut-off lows occur which may result in extensive rains (Van Heerden & Hurry 1987), affecting rainfall over the Langeberg as well.

Solar radiation

No measured data are available for incoming solar radiation on the slopes of the Langeberg. However, estimates of incoming radiation will be obtained from the RADSLOPE model (Schulze & Lambson, unpublished) and presented in a later paper (McDonald, unpublished).

Bond (1981) calculated potential radiation for a range of slopes and aspects for 33° 30′ south latitude using Swift's (1976) algorithm. Incoming radiation in summer was shown to be similar on all slopes and aspects, whereas in winter steep north slopes receive the highest and steep south slopes the lowest radiation. This is true for the Langeberg, and since the range lies between 33° 30′ and 34° South, Bond's results could safely be extrapolated here. Similar to the Outeniqua Mountains and the Swartberg, the Langeberg is also often capped with cloud, further limiting incoming radiation, particularly on the high-elevation south slopes.

METHODS

Methods employed in sampling the vegetation of Boosmansbos Wilderness Area follow those of McDonald (1983, 1988) where rectangular plots of 5 × 10 (50 m^2) were used to sample fynbos shrublands; 5 × 10 m plots are commonly used in surveys of fynbos (e.g. Boucher 1978; Bond 1981; Campbell 1985; Boucher 1987). The long axis of each plot was oriented parallel with the contour, with the plot being subdivided into 10 equal-sized subplots to facilitate data recording.

In Afromontane forests circular plots with a radius of 11.3 m ($\approx$400 m^2) were used to collect both floristic and structural data (Geldenhuys *et al.* 1988; Knight 1989).

Only permanently recognizable species were recorded. Geophytes such as *Bobartia* spp. were recorded and included in the analyses. In general 'ephemeral' geophytes and annuals encountered were noted but not used in the analyses. The Braun-Blanquet (BB) cover-abundance scale was applied as shown in Tables 1 & 2. The midpoint of the BB values given as percentage cover is as follows: 5 = 87.5%; 4 = 62.5%; 3 = 37.5%; 2 = 15.0%; 1 = 2.5%; + = 0.1%; R = value ignored (Mueller-Dombois & Ellenberg 1974; Werger 1974). A border zone of 1.5 m from the perimeter of each plot was searched for any species not found in the marked plot. Species occurring outside the plot are represented by 'O' in the phytosociological tables. Structural data were collected where the strata and their respective cover (BB scale) were recorded at each sample site. The structural characters of stems (e.g. woody, herbaceous) and leaves (e.g. simple, cupressoid, sclerophyllous, leptophyllous) were also evaluated using the BB scale.

TWINSPAN (Hill 1979) was used for initial analysis of the floristic data. The classification was then refined further by sorting the phytosociological tables with the aid of PCTables (Boucher unpublished).

Boosmansbos Wilderness Area is the only area of the Langeberg for which 1:20 000 colour aerial photography is available (Job 824). It was therefore possible to stratify the study area, identify major land type/vegetation units and predetermine general location of plot positions in these units prior to fieldwork. Precise positions of sample plots were subjectively determined with plots placed in stands of mature fynbos (>10 years old).

Floristic composition of communities was compared using diagnostic or character species of each community as the main criteria. Those communities that were not immediately obviously equivalent were subjectively judged on the basis of character species, taxonomic relatedness or morphological similarity e.g. *Berzelia lanuginosa* found in the southwestern Cape versus *B. intermedia* found on the Langeberg, in similar habitats. These relationships do not reflect strict 'synonymy' but serve as a guide for future synthesis of communities found in fynbos vegetation.

VEGETATION

Boosmansbos Wilderness Area is named after the well-preserved Afromontane Forest patch in the deep ravine below Grootberg Peak. There are a number of other smaller patches of forest below Repeater Kop as well. These forest patches represent one vegetation type of limited extent in the study area. Shrubby fynbos covers the greater proportion of BWA and is described in greater detail.

Muir (1929) recognised three major categories of fynbos in the Langeberg: 1, The Succession of Bare Rock Surfaces and Cliffs; 2, The Sclerophyllous Vegetation of the Langeberg; and 3, The Langeberg Forest and Mountain Streams. In the present study emphasis is placed on the Sclerophyllous Vegetation which Muir subdivided into (a) Heath, (b) Macchia (c) (Vegetation of …) Upper Southern Slopes and Summit and (d) (Vegetation of …) Northern Slopes and Base.

The fynbos communities are described in the order of the proposed classification. Each community is given a species-binomial name which has no syntaxonomic hierarchical rank (McDonald 1988). The communities are placed in context in the Fynbos Biome (see Rutherford & Westfall 1986) by attempting to relate them to communities described by other workers; based on both floristic and structural similarities. The structural formation of each

Table 1. A phytosociological table of the Erica hispidula Shrubland Communities south of Grootberg, Boosmansbos Wilderness Area, Langeberg

	Community
	1
	1.1 · 1.2
	1.2.1 · 1.2.2 · 1.2.3 · 1.2.4
	1.2.4.1 · 1.2.4.2 · 1.2.4.3 · 1.2.4.2
	1.2.4.2.1 · 1.2.4.2.2
	A B C D E F G H I
Relevé number	* 1* 1* * * * * * * 1
	*66778992*23333366778889992*6678*855556* 1688* 1111*111122222777* 123337889*223366792
	*59089563*11346701470360120*2311*867894*13847*36890126*458905678356*457720599254*392867234
Altitude (m)	.11111111.11111111 11111111.1111.111111. 1 1. . . 111111 1.111111111
	.24412406.01211044610132451.2212.312112.33233.56643444.578877665566.586812100133.011022135
	.89691660.58231633187341585.9384.021751.98193.13253278.160510474077.187511999581.995485804
	.64362066.29842739286612448.5402.389389.61963.84575728.828361012006.841329270188.758200935
Aspect (°)	.12122122.11123222222222211 1.1111.21 222.32 23.22121222.212111 11321.33 33 3 . 12
	.81842921.92402621061135498.6492.258521.09152.76705098.090288887103.3325362 9951.1511 1411
	.80030055.05055055050250000.5005.000000.00050.05000000.500500500005.000500050355.050050557
Differential species of Erica hispidula--Spatalla nubicola Shrublands (1.1)	
Spatalla nubicola Rourke	.12 203 2. . . . .
Helichrysum capense Hilliard	.1++R R+0. . . . .
Species common to Communities 1.1 & 1.2.1	
Anthochortus crinalis (Mast.) Linder	.33312345.2 + 114 + 1351 . . . .
Erica conferta Andr.	.1++++ +.+ + ++ + +RR2 2.0 . . . . . .
Platycaulos anceps (Mast.) Linder	.4354532 .1 + 253 3 . . . . . . + .
Brunia alopecuroides Thunb.	.4 43424 . 3 0 1. . . . . . .
Leucadendron spissifolium (Salisb. ex Knight)	.+10 +1 . 11 2. .0 . . . . .
Hippia integrifolia Less.	.1 + 2+. + + + 1. . + ...
Erica cordata Andr.	. 0+ 3.2 02 1 3. . . . . . .
Erica regerminans L.	. 3 21 . 2 2 . . . . . + . .
Hermas capitata L.f.	.+R . R . . . .
Erica granulatifolia H.A. Baker	. 1. 0 0. . . . . . .
Erica dianthifolia Salisb.	.0 . 0 + ... + . .
Differential species of Restio inconspicuus--Protea grandiceps Shrublands (1.2.2)	
Protea grandiceps Tratt.	. . + + .2300.1 . . . . .
Differential species of Restio inconspicuus--Protea aurea Shrublands (1.2.3)	
Protea aurea (Burm. f.) Rourke subsp. aurea	. . . .333231. 1. . . .

Table 1. Cont. ...

Relevé number	65	69	70	78	89	95	96	123	21	31	33	34	36	37	60	61	74	77	80	83	86	90	91	92	120	62	63	71	81	88	56	57	58	59	64	1	13	68	84	87	3	6	8	9	10	11	12	16	14	15	18	19	20	25	26	27	28	73	75	76	4	5	7	17	22	30	35	39	79	82	85	94	23	29	32	38	66	67	72	93	124
Species common to Communities (1.2.2 & 1.2.3)																																																																																			
Cliffortia atrata Weim.																													+		2	1	0	1																																															
Senecio lineatus DC.																												+		2	+	1	1	1	+																																														
Restio stokoei Pillans																												+		3			1	1																																															
Stoebe plumosa (L.) Thunb.																										+	1	+			1	1	+	+	1		0																																													
Anemone tenuifolia (L.f) DC.																										+		+		+			+	+																																															
Hippia pilosa (Berg.) Druce																											+	R	R		+	+			R																																														
Helichrysum oxyphyllum DC.																										+		+		+	R				+																																														
Psoralea monophylla (L.) C.H. Stirton																								+		+	+								1																																														
Species common to Communities 1.1, 1.2.1, 1.2.2, 1.2.3																																																																																			
Cliffortia ferruginea L.f	+					R										+						1	3				+	+	+																																																+							
Restio fragilis Esterhuysen		1												+	+						R			1			+	+																																																							
Psoralea aphylla L.																		+								+									+																																																	
Senecio erubescens Ait.								R															+							R																																																						
Kniphofia uvaria (L.) Oken												+		+						+										+			+	+																																																	
Aristea racemosa Bak.					R																										+																										+																									
Species common to Communities 1.2.2, 1.2.3 & 1.2.4.1																																																																																		
Leucadendron eucalyptifolium Buek ex Meisn.																															+	2			4	5	+	5	4	4																																														
Tetraria bromoides (Lam.) Pfeiffer																										2	2	2	1		3	3			1	1	2																																															
Anthospermum galioides Reichenb. f. subsp. reflexi..																												+	+	1	+	+	+			+	+			+																																+											
Hypodiscus albo-aristatus (Nees) Mast.																										1	1	3	2	+	3	3	0		2	1	+			+													+						0																								
Helichrysum cymosum (L.) D. Don subsp. cymosum																														0		1	3	2		R																																																		
Helichrysum spiralepis Hilliard & Burtt																										+			+							R														R																																				
Differential species of Berzelia intermedia--Erica melanthera Shrublands (1.2.4.2.1)																																																																																		
Pentaschistis sp. (unidentified 3/5)																																									1	+	+	+	+	+	1	+																																					
Lobelia coronopifolia L.																																									+		R		R	+	R																																						
Species common to Communities 1.2.4.1 & 1.2.4.2.1																																																																																		
Argyrolobium filiforme Eckl. & Zeyh.																																					R				R		R				R	R																																					
Scyphogyne muscosa (Ait.) Steud.																																				+	+				+				1	1																																						
Tetraria pillansii Levyns																																				+					2					+	+	+																																					
Species common to Communities 1.2.1, 1.2.4.2.1 & 1.2.4.2.2																																																																																		
Berzelia intermedia Schlechtd.																	+																										0	+	2	+			1	+		+	1	R	4	5	+	5	4	5																					
Erica blenna Salisb.																		+	+																								+	+						+	2	0	1	1		+	+		+	1			0																		
Erica triceps Link																																										+	3					+	+		0																																
Differential species of Hypodiscus aristatus--Erica versicolor Shrublands (1.2.4.3)																																																																																		
Erica versicolor Wendl.																								+												0	0					0																				1	5	1	2	1		4	+	4	3	3	3									
Centella virgata (L.f.) Drude var. virgata																																																													2		1	+		+					1										
Tetraria involucrata C.B. Cl.																																																																		+			3	2											

Table 1. Cont. ...

Relevé number	* 1* 1* * * * * * * 1 *66778992*23333366778889992*6678*855556* 1688* 1111*111122222777* 123337889*223366792 *59089563*11346701470360120*2311*867894*13847*36890126*458905678356*457720599254*392867234
Species common to Communities 1.2.4, 1.2.4.1, 1.2.4.2.1, 1.2.4.2.2, 1.2.4.3	
Hypodiscus aristatus (Thunb.) Krauss	. . . . + 121. 1+1+2 2.+0+ + 212 . +212 1 331.311031413
Metalasia muricata (L.) D. Don	. . . . R+ 2.1++ +0++. 0 +00 .+ 11 . 2 1
Psoralea pinnata L.	. . . . ++ . .0 11211 11.12 12 .+ 0
Ficinia trichodes (Schrad.) Benth. & Hook. f.	. . . . + .+ +++ . 0 .+30 .
Laurophyllus capensis Thunb.	.0 . + . . + . . +01 + .+ 0 .
Aristea major Andrews	. . . . 0 . +1+ . .1 + .
Diospyros glabra (L.) de Winter	. . . .R .+ . .++ R.
Lanaria lanata (L.) Dur. & Schinz	. . . . 2 . 1 +. . + .
Lightfootia tenella Lodd.	. . . . R .+ . .R R .
Stoebe saxatilis Levyns	. . . . 0 . . . . 1 0
Tetraria ustulata (L.) C.B. Cl.	. . . . 22+
Hypodiscus argenteus (Thunb.) Mast.	. . . . 1+ . . . 2 .
Indigofera langebergensis L. Bol.	. . . . + + . . . 1 .
Species common to Communities 1.2.1, 1.2.2, 1.2.3, 1.2.4, 1.2.4.1, 1.2.4.2.1, 1.2.4.2.2, 1.2.4.3	
Restio inconspicuus Esterhuysen	. +21+31+ 1112 1 .1++1. 11+ .2++11.2++11+++.+1+ 1111112 .12111242421+. 113 +112
Tetraria cuspidata (Rottb.) C.B. Cl.	. +232+12 1++ + .2 11.+11+2 .++1+1.31+21221.22+4 21++ .22 +21221+ +.1+1111113
Ehrharta dura Nees ex Trin.	. +1222141 +234 .2121.1 411.1 +.+ + . +++ + + . + +12 +2 +.+3122 +2
Erica melanthera L.	. 0+ 32 1 . 0. 32 .1+ 1+.52+55453.30 0+11+111+.3 31 ++3 1 .+ 1+ 2
Bobartia macrospatha Bak. subsp. macrospatha	. 0 1 ++++ 11 .R+ . + 0 .2+ .+11+ 1+. +++++++ 1+.1+1 + +++ +. +1+ + +
Merxmuellera rufa (Nees) Conert	. ++ .11++.322 2 .12 ++.10+1 1+.+ + +11+ .+1++ +++ . +
Tetraria brevicaulis C.B. Cl.	. 0 ++ 0++ ++++ . . . . 1++ + +. 1+ ++1 + +.R1+++ 1 + 1. ++ +
Widdringtonia nodiflora (L.) Powrie	. + 2 R 1 13+ 2. 1 .20111 . +. .0+2+22+++ 11. 01 . R
Ursinia trifida (Thunb.) N.E. Br.	. ++ 0 + + . R. . R .+++R + +. 0+ R .+ 0+01 + +.+1+ + +
Tetraria fasciata (Rottb.) C.B. Cl.	. 2 3 . + . .32 +1. 1 4. 2 + .2 +22 2 + .3+ + 3 2+
Cyclopia sessiliflora Eckl. & Zeyh.	. 1 1 1 11 .10+ .1+ ++.++ . . 01 1+ R+ . + . 1 1
Drosera aliceae Hamet	.0 R RO+ + R+R . R . . . R++0 .R 0 + R + . + .0 +R
Edmondia sesamoides (L.) Hilliard	. 0 + + .+ . . .++++ +++.R++ + + + .R + + . +0
Schizaea pectinata (L.) Sw.	. . RR+. R R.++ .+ 00 . R+ .+ + 1 . R
Corymbium glabrum L. var. glabrum	. + + + . . . 2 . +R +++ . . + . 1R +
Erica bracteolaris Lam.	. + + + + + 0 . . . . +++ . R . .
Tetraria compressa Turrill	. + +1 +. .+ 1 . ++ . 1 + . 1 21 11 1+. .
Gnidia oppositifolia L.	. + + ++ + +. . . . . R + . .
Pteridium aquilinum (L.) Kuhn	. 1 . . . . +1 . 0 12. .
Gleichenia polypodioides (L.) J.E. Sm.	. + 1. .+ . . . +. 0 + +.
Struthiola eckloniana Meisn.	. . +. + . . + . . + .
Tetraria burmanii (Schrad.) C.B. Cl.	. . +. +. .4+ 3. . .
Ficinia filiformis (Lam.) Schrad.	. 1 . . .R .+ + + . R .++ R.
Stoebe cinerea (L.) Thunb.	. + . 1.1 . +. . R . +0 . + +
Indigofera sarmentosa L.	. R R . . .++ R . . ++ .+ R +.
Helichrysum felinum (Thunb.) Less.	. + . . + . 0. + . R+ ++ . 0 . +
Amphithalea axillaris R. Granby	. + +++ . . . . 0 . 0 0 . .
Chondropetalum mucronatum (Nees) Pillans	. 5 0 . . . . . . 1 0. 0 +
Pentameris macrocalycina (Steud.) Schweickerdt	. 3 3 .+ . . . . . 1 +.+
Platycaulos acutus Esterhuysen	. . . . + . ++
Osteospermum corymbosum L.	. 0. . . + . . . +. ++
Merxmuellera stricta (Schrad.) Conert	. . . . 1. . . +1 . 41
Staberoha cernua (L.f.) Dur. & Schinz	. . . . + . 3 + . . + . +
Erica cubica L.	. 1 . . . . . 0 + . . 1
Elegia asperiflora (Nees) Kunth	. 3 . . . . . . + 1 . +
Pentaschistis malouinensis (Steud.) Clayton	. 1 . . . . . . + + . 1
Ficinia monticola Kunth	. + ... + . +

Table 1. Cont. ...

Relevé number	* 1* 1* * * * * * * 1 *66778992*2333336677888999 2*6678*855556* 1688* 1111*111122222777* 123337889*22336679 2 *59089563*11346701470360120*2311*867894*13847*36890126*458905678356*457720599254*39286723 4
Widespread species common to all Communities	
Erica hispidula L.	. ++ ++.5+23120 04441 1+ .4413.1 + +5.1++43.223313 1.355444345352.412 2+2312 +.1+131 1
Elegia juncea L.	.1+++ +++.1+++11+1 112+ 22 .+++2.1121+2.++2 +. 11 ++0.12+ 1+ +2 21.1+++0 + + 1.11+ 121++
Chrysithrix capensis L.	.+2 +1 .++++++++1 +22 . + . + +. +.1++ +++.11++ 1+ +1 .1++ ++11++ +.++111 + +
Pentaschistis colorata (Steud.) Stapf	.2+++ R++.21 43312 + 1 +1 . 1 1.+ + 3.+ 23 . + 2+ +. 2+ ++1 + .++ +1 22+0 0. 222 111
Tetraria flexuosa (Thunb.) C.B. Cl.	. 1 + .1+++++ 131 1 . 414. . 3 4. 41+++1 .2 +1 1 10.5+4+2++1 1 1. 11+ 13
Thamnochortus cinereus Linder	.0 0.+ 11 +1+ ++ + +1 .++++. + +.+1 +.++111 1+. ++ 1 . ++ 0+01. 1+ + +
Clutia alaternoides L.	. . +1++1++ ++++ . +11. ++211.1+1 +. + + ++. ++ + . R 1+ . 1++11++1
Ehrharta setacea Nees ex Trin. subsp. scabra	++0+. + 1 + . . . 1 .3+12 10+.32+++11+ 1+ .23++1 + 1.11 +1+11
Blaeria coccinea Klotzsch	.++113+22. 124++ +2+ 1123++.+1+ . +++1+. + . + . 01 +. 2 . 2 +41++
Protea cynaroides (L.) L.	. 20 + .1 +1 ++ 1+ + +++.0 +.0 + . + . . 1 1 11 0 . 00 .+ 0 +
Epischoenus cf. adnatus Levyns	. ++1 + . 12 212 + +. . . . + . 4 2+. .
Othonna quinquedentata Thunb.	.++1+ 1 . 1+ + 1 +. .+ + . . . + + . .
Blechnum tabulare (Thunb.) Kuhn	.1 . 0+ 3. . . . . 1++ + + 1. . R
Thesium carinatum A. DC.	.+ + 1 . + +++ . . . . ++
Penaea cneorum Meerb. subsp. ruscifolia Dahlg.	. 1 . + . . 1 .+ 1 .1212220 .42+2+3 +1 1. R2 1 + .3 1 3
Tetraria thermalis (L.) C.B. Cl.	. 1 . + ... + . 1+ . 1+ 1 + .
Hermas ciliata L.f.	. R .+ +++ + ... R R . .
Syncarpha eximia (L.) B. Nord.	.0 0 . + ... R . R . +
Indigofera concava Harv.	.+ + . + ... ++ + . .
Lobelia pubescens Dryand ex. Ait.var. rotundifolia	. R .R + + ... R . .
Senecio ilicifolius (L.) Thunb.	.0 . + + . .0 . . . 0 . .
Myrica kraussiana Buching ex Meisn.	. + . + 1. . . + . . + . .

community is given following the system for the Fynbos Biome proposed by Campbell *et al.* (1981).

Riparian communities were not sampled because they form narrow ribbons along streams, and are restricted to the streambanks. Typical dominants found in the non-forest riparian communities are: *Brachylaena neriifolia, Cunonia capensis, Elegia capensis, Empleurum unicapsulare, Laurophyllus capensis, Rapanea melanophloeos, Todea barbara* and *Virgilia oroboides.*

Afromontane Forest

The forest patches in the BWA are typical Afromontane Forest. They are found in deep secluded gorges which are cool and moist. These forests are floristically all of one type, based on tree species composition. The Boosmansbos Forest tends to be much wetter than the other patches sampled, shown by the high cover-abundance of *Cyathea capensis* which favours such conditions. An apparently drier-phase forest patch (Relevé 122) is characterized by *Plectranthus fruticosus.* However, this observation is at variance with that of Muir (1929) who presented an early general account of the 'Langeberg Forest' at Riversdale. He maintained that *P. fruticosus* is strongly moisture demanding. McKenzie (1978) gives detailed descriptions of the Boosmansbos forests which he classified as the *Cunonia capensis – Platylophus trifoliatus* Subassociation. A number of 'variations' were distinguished within the Subassociation according to relative wetness and dryness. No additional information was recorded or change in the classification proposed based on the five 400 m^2 plots sampled in the present study. Structurally the forests are classified as Wet High Forest (w-HF) following Geldenhuys (1983). The canopy height varies from 20–30 m and the species recorded, with synoptic Braun-Blanquet values in parentheses, are as follows:

Trees: *Cunonia capensis* (5), *Halleria lucida* (4), *Hartogiella schinoides* (2), *Ilex mitis* (2), *Kiggelaria africana* (1), *Maytenus acuminata* (3), *Ocotea bullata* (4), *Olinia ventosa* (1), *Platylophus trifoliatus* (4), *Podocarpus latifolius* (2), *Pterocelastrus rostratus* (5), *Rapanea melanophloeos* (5), *Virgilia oroboides* (3).

Shrubs: *Diospyros whyteana* (1), *Plectranthus fruticosus* (1).

Ferns: *Asplenium adiantum-nigrum* (2), *Blechnum giganteum* (5), *B. punctulatum* (2), *B. tabulare* (2), *Cyathea capensis* (5), *Hymenophyllum tunbridgense* (2), *Rumohra adiantiformis* (1), *Todea barbara* (2).

Climbers: *Myrsiphyllum scandens* (3).

Herbs: *Epischoenus adnatus* (2), *Galium undulatum* (1), *Osmitopsis osmitoides* (1), *Peperomia retusa* var. *retusa* (1), *Schoenoxiphium lanceum* (5).

Epiphytes: *Elaphoglossum angustatum* (3), *Microsorium ensiforme* (4).

Geophytes: *Oxalis purpurea* (4).

Fynbos

The cool south slopes of the southern Langeberg are covered with physiognomically uniform plant communities over large areas. The slopes are moist and may be likened to an extensive seepage zone. Apart from Muir's (1929) classification the vegetation has been variously referred to as: Wet Sclerophyll Bush (Adamson 1938); Hygrophilous Macchia or Fynbos (Phillips 1931; Taylor 1978); False Macchia (Veld Type 70) by Acocks (1988); Wet Mountain Fynbos (Moll *et al.* 1984) and Wet Ericaceous Fynbos (Campbell 1985). The apparent uniformity is deceptive, however, with close examination showing that the vegetation can be subdivided on species composition into the eight shrubland communities described under 'A' below.

TABLE 2.—A phytosociological table of the *Cannomois parviflora* Shrubland Communities north of Grootberg, Boosmansbos Wilderness Area, Langeberg

	Community 2: 2.1 (2.1.1 (J), 2.1.2 (K)); 2.2 (2.2.1 (L), 2.2.2 (M))
Releve No.	* 111111* 11111* 111111*
	*24455559990000 11*44400111*044000011*4455
	*4792345789012334*12845012*234678956*5601
Altitude (m)	.11111111111111 1.11111 1. .
	.0001013000001190.10010990.577477655.5579
	.5993932679662073.38959880.904822999.9991
	.8771786050001606.42117550.417577744.4424
Aspect (°)	.1 1 1111 2 1.111 1111. 31 1 3,2
	.439343470921 097.99988997.8331 4121.2 33
	.0000000550052505.05550550.550570000.0000
Differential species of Leucadendron eucalyptifolium--Protea lorifolia Shrublands (2.1.1)	
Protea lorifolia (Salisb. ex Knight) Fourc.	2 1+00+++ 1 1 . .
Metalasia pungens D. Don	1R++++ +++ . .
Lightfootia tenella Lodd.	+ + + + + + . .
Agathosma cerefolium (Vent.) Bartl. & Wendl.	1 121+ + . .
Stoebe aethiopica L.	+ +0 + R . .
Indigofera pappei Fourc.	+ ++ 1 . .
Stoebe saxatilis Levyns	+ 0+ . .
Erica versicolor Wendl.	++ + . .
Ursinia nudicaulis (Thunb.) N.E. Br.	R ++ . .
Differential species of Leucadendron eucalyptifolium--Staberoha cernua Shrublands (2.1.2)	
Staberoha cernua (L.f.) Dur. & Schinz	. +2 +1+ 1 .
Helichrysum rotundifolium (Thunb.) Less	. R ++R+ .
Cyphia zeyheriana Presl ex Eckl. & Zeyh.	. RR ++ .
Lachnaea penicillata Meisn.	. ++ 0 .
Erica cerinthoides L.	. ++ + .
Species common to Communities 2.1.1 & 2.1.2	
Leucadendron eucalyptifolium Buek ex Meisn.	412 14133330+2 2.3230 222 .
Tetraria bromoides (Lam.) Pfeiffer	1 1 21122+1 2.1+122221 .
Corymbium glabrum L. var. glabrum	+++++++++++++++.++++++++ .
Restio inconspicuus Esterhuysen	+++ ++ +++111+. ++ 12+ .
Protea repens (L.) L.	10+ 201 02143122. 1 1 2 .
Protea eximia (Salisb. ex Knight) Fourc.	1 11 2 2 .32334331 .
Protea neriifolia R. Br.	2 + 0+ + 10 .3 1 112 .
Haplocarpha lanata Less.	0 R +R+R + +. + 0 ++ .
Merxmuellera rufa (Nees) Conert	+ + +++++ + . + +1+1+ .
Aristea racemosa Bak.	+ + +++++++.+ + +++ .
Senecio pinifolius (L.) Lam.	R +++ ++++. + +++ .
Cliffortia pulchella L.f.	1 + + ++ 1++ 1 . 1 .
Phaenocoma prolifera (L.) D. Don	0 +00 +0 +. + .
Elytropappus glandulosus Less.	++ 1 + .R +++ + .
Clutia alaternoides L.	+ + + + .+++ + 0 .
Mastersiella purpurea (Pillans) Linder	+ 1 +. 1+2++ .
Pelargonium ovale L'Hérit. subsp. ovale	+ ++1 .R ++ .
Erica vestita Thunb.	+ + 0.R1 + + .
Tetraria fasciata (Rottb.) C.B. Cl.	1 1 1.03 21 .
Muraltia ciliaris DC.	1+ R+ ++ . + .
Elegia galpinii N.E. Br.	12 1 2 . ++ .
Clutia ericoides Thunb. var. tenuis Sond.	+ ++ 0 . 1 1 .
Tetraria flexuosa (Thunb.) C.B. Cl.	2+.1 2 3 .
Hypodiscus aristatus (Thunb.) Krauss	0 2 .2 2 + .
Hypodiscus albo-aristatus (Nees) Mast.	+ .+++ 1 .
Athrixia heterophylla (Thunb.) Less. subsp. heterop.	R . RR R+ .
Chrysithrix capensis L.	0+ + . + .
cf. Gerbera crocea (L.) Kuntze	R.+ + + .
Petalacte epaleata Hilliard & Burtt	+ + . + + .
Brunia nodiflora L.	0+ . + 1 .
Helichrysum felinum (Thunb.) Less.	R . + 0 .
Differential species of Passerina obtusifolia--Leucospermum calligerum Shrublands (2.2.1)	
Leucospermum calligerum (Salisb. ex Knight) Rourke	. . 1112 32 2
Muraltia heisteria (L.) DC.	. . +++++++0
Serruria balanocephala Rourke ined.	. . 1 20 31
Lobostemon decorus Levyns	. . +0 0 +
Thesium subnudum Sond.	. . + +0
Elytropappus cyathiformis DC.	. . 0 ++
Paranomus spathulatus (Thunb.) O. Kuntze	. . 1 21
Thamnochortus karooica Linder	. . 3 3
Releve No.	*0000000000111111*00011111*000111111*0000
	*24455559990000 11*44400111*044000011*4455
	*4792345789012334*12845012*234678956*5601
Species common to Communities 2.1.1, 2.1.2 & 2.2.1	
Thoracosperma galpinii N.E. Br.	1 2 +214+ 2+ 2. + +1+22.1 3 +2+ +
Elegia filacea Mast.	2 2 3 3+ 312.21+10 12. 1
Restio filiformis Poir.	+ + + + 1+1 1 +.+ +++ +0. 1
Ischyrolepis capensis (L.) Linder	+ R +++ + . ++ +. 1+ ++
Phylica mairei Pillans	+ 1 +2 0 . . +++++
Stoebe microphylla DC.	0 + + +. .+ ++ ++
Diosma hirsuta L.	+ +++ . + . ++
Pentaschistis colorata (Steud.) Stapf	+111 1 1+ . 0+ + . +
Ficinia lacineata T. Arnold	+ + + ++ + +. . 1
Tetraria brachyphylla Levyns	+++.+++ + . +
Struthiola ciliata (L.) Lam.	+ R + ++. ++. +
Anomalanthus sp. McDonald 1012	+ + 2 . .4+ 1 2
Willdenowia bolusii Pillans	+ + .21 . 2
Ficinia cf. pinguior C.B. Cl.	++ . + ++. +
Thamnochortus cinereus Linder	+ . + 1+ .+
Polygala refracta DC.	R +0 . 0 . +
Thesidium fragile Sond.	R . . + ++
Hypodiscus argenteus (Thunb.) Mast.	1 . . ++ 2
Senecio paniculatus Berg.	+ . . + +
Species common to Communities 2.2.1 & 2.2.2	
Passerina obtusifolia Thoday	. . 42+21+ 3+.+32
Crassula atropurpurea (Haw.) Dietr. var. atropurpu..	.
++ ++ 1 . +++
Hermannia odorata Ait.	. . + 0++ + . +1+
Diosma prama Williams	. . 1++1 + 0 .+ +
Adromischus triflorus (L.f.) Berger	. . + ++ 0 . R 0
Eriocephalus brevifolius (DC.) M. Muller	. . ++ + +.00
Lobelia coronopifolia L.	. . ++++ . ++
Agathosma ovata (Thunb.) Pillans	. . + +1 . +1+
Phylica axillaris Lam. subsp. microphylla Pillans	. . ++ .+ 11
Machairophyllum cookii (L. Bol.) Schwantes	. . +0 + . 10
Struthiola argentea Lehm.	. . +0 . ++
Crassula muscosa L.	. . + 0 . + +
Aspalathus hirta E. Mey. subsp. hirta	. . 01 . +
Ehrharta ramosa (Thunb.) Thunb.	. . + R+ . 0
Aspalathus acanthes Eckl. & Zeyh.	. . + ++ . 0
Species common to Communities 2.1.1, 2.2.1 & 2.2.2	
Relhania calycina (L.f.) L'Hérit. subsp. apiculata	1 1 ++ +++ + +++11++ .+0++
Hypodiscus striatus (Kunth) Mast.	11+ ++ +211+ 2+2 1.+221
Ficinia filiformis (Lam.) Schrad.	+ R+ + + +++ .RR++
Felicia filifolia (Vent.) Burtt Davy subsp. bodkinii	+ 2+ + +++.+2+
Pentaschistis eriostoma (Nees) Stapf	3 111+1 ++ . 13
Cymbopogon marginatus (Steud.) Stapf ex Burtt Davy	1 + + + + . +R+
Ficinia nigrescens (Schrad.) Raynal	+ + ++ + .+ +
Lightfootia rigida Adamson	+ ++ + 1. +
Elytropappus gnaphaloides (L.) Levyns	+ + +0 .+
Euclea polyandra (L.f.) E. Mey. ex Hiern	+ 0 . +
Pelargonium fruticosum (Cav.) Willd.	+ . ++
Widespread species common to all Communities	
Syncarpha paniculata (L.) B. Nord.	+++++++110+++0 +. + +.R +0 ++ .+
Willdenowia glomerata (Thunb.) Linder	01+ 1++++1+++. ++ ++. + 21 .1 +
Anthospermum spathulatum Sprengel subsp. spathulatum	+ + + + +++++. + .R++0+ +++. ++
Cannomois parviflora (Thunb.) Pillans	11+ + +11+1. 1 211. 12 +1.+ 2
Tetraria cuspidata (Rottb.) C.B. Cl.	+1++1 + +++ 1 .+ + 1 . 1 11 +.+ +
Rhodocoma fruticosa (Thunb.) Linder	2 + .++ .111++11+ .+ 1+
Metalasia densa (Lam.) Karis	+ ++ . R 0 +.++1+221 +. +
Elegia juncea L.	54+ + .1++100 . .3 +
Zygophyllum fulvum L.	+ + ++ 0 +. +. ++ + . 0
Tetraria ustulata (L.) C.B. Cl.	211 2 1 . 2 2. 1.+
Leucadendron salignum Berg.	2 1 2 . 2 . 1 .2

In the intermontane valley between Grootberg and Deception Ridge (north of Grootberg) the vegetation has a high cover of tall proteoid shrubs and fits the category of Mesic Mountain Fynbos (Moll *et al.* 1984) or Dry Proteoid Fynbos (Campbell 1985). On the north slopes of Deception Ridge above Witbooisrivier the vegetation resembles that of the inland ranges and is classified as Dry Mountain Fynbos (Moll *et al.* 1984) or Dry Asteraceous Fynbos (Campbell 1985).

The most striking feature of the fynbos of the BWA is the clear division between the vegetation of the southern and northern sides of the mountain. *Erica hispidula*, a common dominant on the south slopes, is almost completely absent on the north slopes. Although a number of other species transgress the south-north boundary, for example *Leucadendron eucalyptifolium*, it is clear that a definite floristic distinction can be made between the shrublands on the south and north sides of the mountain. This distinction is reflected in the treatment of the data from the respective areas in separate syntaxonomic tables (Tables 1 & 2), where a hierarchical arrangement of communities is also presented.

Using the default options, TWINSPAN clearly separated the mesic to dry shrublands north of Grootberg from the largely mesic to wet shrublands of the catchments south of Grootberg at Level 1. This is reflected in the treatment of the relevés in two separate phytosociological tables (Tables 1 & 2). Relevés 41 and 48, however, were included in Table 2, contrary to the TWINSPAN classification.

In the mesic to wet *Erica hispidula* Shrublands, TWINSPAN separates those relevés (except relevés 31, 33, 34, 36 & 37) which correspond with the *Erica hispidula–Spatalla nubicola* and the *Restio inconspicuus–Anthochortus crinalis* Shrublands in the BB classification from the remaining relevés which constitute the *Erica hispidula–Restio inconspicuus* Shrublands, at Level 2. Correlations between the two classifications from TWINSPAN levels 3–6 are not good but show general similarities. Nine communities are identified using the BB classification method, whereas TWINSPAN separates the relevés into 15 groups.

In the mesic to dry shrublands the distinction between the *Cannomois parviflora–Leucadendron eucalyptifolium* Shrublands and the *C. parviflora–Passerina obtusifolia* Shrublands (see below and Table 2) correlates directly with the separation indicated by the TWINSPAN classification at Level 2. Correlation at lower levels (3–6) is not good. The BB classification results in four communities being identified, with further subdivision into 13 groups, as indicated by TWINSPAN, considered to be too fine.

1. *Erica hispidula* Shrublands

Typical of the shrublands of the moist south-facing slopes of the southern Langeberg is the ubiquitous shrub *Erica hispidula*. This species is characteristic of much of the mesic to wet ericaceous fynbos of the mountains of the southwestern and southern Cape (Boucher 1978; Kruger 1979; Bond 1981; McDonald 1988), and is therefore used as a descriptor for these shrublands.

In BWA *E. hispidula* is widespread and links the south-slope shrublands floristically across physiognomic boundaries, with *Restio inconspicuus* playing a subordinate role. *R. inconspicuus* is absent only from the *Erica hispidula–Spatalla nubicola* Community, a feature attributed to the dense, waterlogged, humic substrate. *R. inconspicuus* in turn, however, links all the communities falling under the *Erica hispidula–Restio inconspicuus* Shrublands in the classification. These shrublands are equivalent to the Heathland, Mixed Sclerophyllous Scrub and Broad-sclerophyllous Scrub communities of Kruger (1979).

1.1 *Erica hispidula–Spatalla nubicola* Shrublands (A)

Differential species: *Spatalla nubicola, Helichrysum capense.*

Dominant species: *Anthochortus crinalis, Brunia alopecuroides, Platycaulos anceps.*

Structural formation: Closed Restioland with Mid-high Mid-dense Shrubland Overstorey.

Relationships: *Brunia alopecuroides–Restio bifidus* Community (Kruger 1974); Subcommunity E2 of the *Erica–Penaea* Community (Glyphis *et al.* 1978); *Restio–Hypolaena* Subcommunity (H & I) (Laidler *et al.* 1978); Ericoid-Restioid Zone Fynbos (Taylor 1978); Low Narrow-sclerophyllous Heathland (Kruger 1979); *Simocheilus carneus–Restio anceps* Community (Bond 1981); Wet Mountain Fynbos (Moll *et al.* 1984); Ruitersberg Wet Ericaceous Fynbos (Campbell 1985); *Erica hispidula–Brunia alopecuroides* Shrublands (McDonald 1993a).

This community (Figure 4) is found on the steep, cool, moist southerly slopes of the BWA, mostly at altitudes above 1 200 m. The community is found in the 'mist zone' where low stratus cloud commonly occurs around the high ridges and peaks. Annual precipitation is estimated at 1 200 mm and insolation is generally low. There is a consequent accumulation of organic material. Champagne Form soils with a strongly acid organic horizon (pH 2.9 in 0.01 mol/l $CaCl_2$) as deep as 700 mm in some cases, form the substrate of this community.

These shrublands were sampled mainly on the south side of the ridge of Repeater Kop (Relevés 65, 69, 70, 78, 95 & 96), on Grootberg Summit (Relevé 123) and on the southwest side of the high ridge between Grootberg and Horingberg (Relevé 89).

Spatalla nubicola (Proteaceae) is endemic to this community whereas *Helichrysum capense*, the second differential species has a wider distribution, being found at other localities in the Langeberg. Presence of at least one of these species is necessary to determine this community. The dominant species *Brunia alopecuroides* gives these shrublands their characteristic 'brunioid' appearance. The *B. alopecuroides* shrubs seldom exceed 1.2 m in height and their closed canopy provides dense shade for the understorey restioid and ericoid elements. *Anthochortus crinalis* and *Platycaulos anceps* (Restionaceae) dominate the dense understorey stratum. Grasses are conspicuously lacking and are only represented by *Ehrharta setacea* subsp. *scabra*, a rare endemic in the fynbos biome (Gibbs Russell *et al.* 1990), in some stands.

A population of the rare *Spatalla colorata* was found in this community on the summit of Repeater Kop in close proximity to an undescribed endemic *Erica* species. These species apparently favour moist, high-altitude habitats with highly leached soils.

1.2 *Erica hispidula–Restio inconspicuus* Shrublands

This community comprises all the shrublands apart from the *Erica hispidula–Spatalla nubicola* Shrublands. *Restio inconspicuus* and several prominent species, namely

FIGURE 4.—*Erica hispidula–Spatalla nubicola* Shrublands on high altitude, steep south-facing slopes. Note the shrubby endemic *S. nubicola* next to the range rod.

Tetraria cuspidata, Ehrharta dura, Erica melanthera and others (see Table 1) are not found in the latter community. The soils on which the *Erica hispidula–Restio inconspicuus* Shrublands occur are generally either more freely drained, with less accumulation of organic material, or are derived from non-sandstone substrates.

1.2.1 *Restio inconspicuus–Anthochortus crinalis* Shrublands (B)

Differential species: none.

Dominant species: *Anthochortus crinalis, Erica hispidula, Ehrharta dura* and *Platycaulos anceps.*

Structural formation: Closed Graminoid Shrubland. Relationships: *Brunia alopecuroides–Restio bifidus* Community (Kruger (1974); Subcommunity E2 of the *Erica–Penaea* Community (Glyphis *et al.* 1978); *Restio–Hypolaena* Subcommunity (H & I) (Laidler *et al.* 1978); Ericoid-Restioid Zone Fynbos (Taylor 1978); Low Narrow-sclerophyllous Heathland (Kruger 1979); *Simocheilus carneus–Restio anceps* Community (Bond 1981); Wet Mountain Fynbos (Moll *et al.* 1984); Ruitersberg Wet Ericaceous Fynbos (Campbell 1985); *Erica hispidula–Brunia alopecuroides* Shrublands (McDonald 1993a).

This community (Figure 5) has no differential species but shares many species with the *Erica hispidula–Spatalla nubicola* Shrublands (see Table 1); is characterized by absence of *Spatalla nubicola* and *Helichrysum capense*; and is found at altitudes higher than 1 000 m on east-, southeast-, south- and southwest-facing slopes. Sample quadrats were located at five general localities; on the upper south-facing slopes above Saagkuilkloof (Relevés 21 & 74), on the lower south- and southwest-facing slopes of Repeater Kop above Platbosrivierkloof (Relevés 34, 36, 37, 77, 80, 83, 120), on the south-facing slopes of the ridge west of Grootberg Peak (Relevés 60, 61 & 86), on the slopes southeast of Grootberg Peak overlooking Boosmansbos (Relevés 90 & 91) and on the east-facing slopes overlooking Boosmansbos (Relevés 31 & 33).

FIGURE 5.—*Restio inconspicuus–Anthochortus crinalis* Shrublands at altitudes above 1 000 m on southerly slopes.

Rainfall is between 1 000 and 1 200 mm annually, depending on altitude and aspect and the *Restio inconspicuus–Anthochortus crinalis* Shrublands are found mainly on highly leached Cartref Form soils (see SCWG 1991; Campbell 1983). Two samples (Relevé 90 & 91) were located on Champagne Form soils and show strong floristic affinity with the *Erica hispidula–Spatalla nubicola* Shrublands. However, these stands lack the differential species of the latter community.

Shrubs and graminoids are co-dominant, with the shrubs not exceeding 1 m. *Widdringtonia nodiflora* is present in some stands and is emergent up to 2 m. *Erica hispidula* and *Ehrharta dura* dominate with *Anthochortus crinalis* and *Platycaulos anceps* less conspicuous, forming part of the graminoid component.

A number of relevés (31, 36 & 92) do not have any of the differential species of the *Restio inconspicuus–Anthochortus crinalis* Community. They are regarded as samples from depauperate stands and are included here on the basis of dominant species and geographical position on the sample transect and in the landscape.

1.2.2 *Restio inconspicuus–Protea grandiceps* Shrubland (C)

Differential species: *Protea grandiceps.*

Dominant species: *Erica hispidula, Tetraria flexuosa, Tetraria bromoides.*

Structural formation: Closed Graminoid Shrubland.

Relationships: *Tetraria bromoides–Erica plukenetii* Community (Kruger 1974); *Protea–Tetraria* Dry Short Fynbos (Boucher 1978); Wet Mountain Fynbos (Moll *et al.* 1984); Boesmansbos Azonal Restioid Fynbos (Campbell 1985); *Pentaschistis malouinensis–Tetraria bromoides* Shrubland (McDonald 1993a).

This community (Figure 6) is localized on the south-facing lower to mid-slopes of the ridge west of Grootberg, overlooking the Helderfontein Valley, at 1 180–1 295 m altitude. This locality lies more or less on the contact between the Cedarberg Formation and the Nardouw Subgroup. The soils are mainly Cartref Form, where sandstone is the parent rock (Relevés 62, 63 & 71) and Clovelly Form, where shale is the parent rock (Relevé 81).

Mean annual precipitation at this locality is 1 000–1 100 mm and the soils are well drained but slightly more nutrient-rich than soils derived from Peninsula Formation sandstone (G.N. Schafer pers. comm.). The poleward aspect permits lower insolation, and *P. grandiceps* apparently favours the cooler slopes and richer soils.

This community is structurally similar to those of most other parts of the high-altitude slopes. *E. hispidula* dominates the shrub component with *P. grandiceps* having notable cover-abundance in only two of the four plots sampled (Relevés 62 & 63). Sedges such as *Tetraria flexuosa* and *Tetraria bromoides* dominate the herbaceous component. Close affinity exists between the *Restio inconspicuus–Protea grandiceps* Shrubland and the *Restio inconspicuus–Protea aurea* Shrubland, with these two communities sharing species not common to other communities (see Table 1).

1.2.3 *Restio inconspicuus–Protea aurea* subsp. *aurea* Shrublands (D)

Differential species: *Protea aurea* subsp. *aurea.*

Dominant species: *Protea aurea* subsp. *aurea.*

Structural formation: Mid-high to Tall Proteoid Shrubland with a Closed Graminoid Shrubland Understorey.

Relationships: *Tetraria bromoides–Erica plukenetii* Community (Kruger 1974); *Protea–Tetraria* Dry Short Fynbos (Boucher 1978); *Protea aurea–Pteridium aquilinum* Community (Bond 1981); Wet Mountain Fynbos (Moll *et al.* 1984); Boesmansbos Azonal Restioid Fynbos (Campbell (1985); *Pentaschistis malouinensis–Tetraria bromoides* Shrubland (McDonald 1993a).

In BWA this community (Figure 7) occurs at altitudes above 1 100 m on the Cedarberg shaleband, near Helderfontein. The shales of the Cedarberg Formation weather to produce fine-grained, clay-rich yellow-brown Clovelly Form soils, and *Protea aurea* is found almost exclusively on these soils. This correlation is found throughout the

FIGURE 6. — *Restio inconspicuus–Protea grandiceps* Shrubland localized on the south-facing slopes west of Grootberg.

FIGURE 7.—*Restio inconspicuus–Protea aurea* subsp. *aurea* Shrublands found on the Cedarberg Formation shale near Helderfontein.

Langeberg, regardless of the altitude at which the shaleband is exposed. *P. aurea* can therefore be used as a marker indicating the exposure of the Cedarberg Formation in the highly folded strata of the Langeberg.

Sample plots were located between Helderfontein and Boosmansbos (Relevés 56, 57, 58 & 59) on northeast-, southeast- and southwest-facing slopes. Two plots (Relevés 64 & 88) were also located on the lower south- and southwest-facing slopes of the ridge west of Grootberg, above the watershed between the Helderfontein and Moeras River Valleys. Relevé 88 represents a transitional situation between Communities 2.2 and 2.3 but since *P. aurea* has a relatively high BB value (3), and since the soil is Clovelly Form, it is included in the *Restio inconspicuus–Protea aurea* Shrublands.

1.2.4 *Restio inconspicuus–Hypodiscus aristatus* Shrublands 'Typicum' (I)

Differential species: none.

Dominant species: *H. aristatus, R. inconspicuus, Ehrharta dura.*

Structural formation: Closed Graminoid Shrubland.

Relationships: *Tetraria thermalis–Hypodiscus aristatus* Community (Kruger 1974); Mixed ericoid and restioid fynbos of the xeric slopes (Boucher 1978); *Leptocarpus membranaceus–Hypodiscus aristatus* Community (McKenzie *et al.* 1977); Subcommunities B & C of the *Erica–Penaea* Community (Glyphis *et al.* 1978); *Tetraria thermalis* Bergpalmietveld (Taylor 1978); Low ericoid open-heath or open graminoid-heath (Kruger 1979); *Erica viridescens–Hypodiscus aristatus* Community (Bond 1981); Mesic Mountain Fynbos (Moll *et al.* 1984); Nuweberg Mesic Ericaceous Fynbos (Campbell 1985); *Erica hispidula–Hypodiscus aristatus* Shrublands (McDonald 1993a).

The relevés grouped here (23, 29, 32, 38, 66, 67, 72, 93, 124) represent the 'typicum' of the *Restio inconspicuus–Hypodiscus aristatus* Shrublands (Figure 8). This 'typicum' or 'background community' has no floristic elements which allow subdivision into lower-ranking communities; as such it is regarded as depauperate.

These shrublands occur on shallow (0.1–0.15 m), well-drained and highly leached Cartref and Houwhoek Form soils at altitudes from 1 000–1 500 m. Parent rock is mainly Peninsula Formation sandstone with Nardouw Subgroup sandstone found in plots 92 and 124. Aspect is generally north- and northwest-facing, with two exceptions, plots 29 and 30 which face south and southeast. Surface rock cover ranges between five and 75 %; boulders were found in all plots and exposed bedrock in more than 50 %. Although rainfall probably exceeds 1 000 mm per annum, high insolation coupled with good drainage is most likely the reason for the depauperate nature and low stature of the community.

Shrubs such as *Erica hispidula* and *Penaea cneorum* subsp. *ruscifolia* are emergent up to 1.2 m but grasses (*Ehrharta dura, Pentaschistis colorata*), restios (*Hypodiscus aristatus, Restio inconspicuus*) and sedges (*Tetraria* spp.) dominate the low stratum (<0.5 m). Although strongly similar structurally and in species composition to the *Restio inconspicuus–Anthochortus crinalis* Shrublands, the *Restio inconspicuus–Hypodiscus aristatus* Shrublands have *Hypodiscus aristatus* dominant, whereas it is absent from the former community. Apparently north versus south aspects and relative wetness-dryness account for the change in species dominance and consequent distinction between these two communities.

1.2.4.1 *Hypodiscus aristatus–Leucadendron eucalyptifolium* Shrublands (E)

Differential species: none.

Dominant species: *Leucadendron eucalyptifolium.*

Structural formation: Mid-high to Tall, Mid-dense to Closed Proteoid Shrublands.

Relationships: *Berzelia–Leucadendron* Moist Tall Fynbos (Boucher 1978); Mixed Sclerophyllous Scrub (Kruger 1979); *Protea neriifolia–Leucadendron eucalyptifolium–Erica triceps* Community (Bond 1981); Mesic Mountain

FIGURE 8.—*Restio inconspicuus–Hypodiscus aristatus* Shrublands found on shallow, well-drained, highly leached sandstone soils at altitudes from 1 000–1 500 m.

Fynbos (Moll *et al.* 1984); Robinson Mesic Proteoid Fynbos (Campbell 1985).

Leucadendron eucalyptifolium is a tall proteoid shrub ubiquitous on the Langeberg. It is found at localities on south and north sides of the range. In the BWA, *L. eucalyptifolium* occurs in the Mesic Proteoid Fynbos north of Grootberg as well as at the southern end of the sample transect, on the shaleband at Helderfontein and at the head of the Moeras River Valley. Where *L. eucalyptifolium* occurs with *Protea aurea* it is found on Clovelly Form soils but in the community described here (Figure 9) the soils are either of Oakleaf or Cartref Forms.

L. eucalyptifolium shrubs up to 2.5 m high dominate the community and it is the only species found in all relevés. Relevés 1 and 13 show marked floristic affinities with the *Restio inconspicuus–Protea aurea* Shrublands, whereas the remaining three relevés do not. This is attributed to the nature of this community to transgress soil types.

Plots 1, 13 and 84 were situated in localized stands of the *Hypodiscus aristatus–Leucadendron eucalyptifolium* Shrublands on Oakleaf Form soils derived from conglomerates of the Enon Formation, detailed above. The soils are loamy with pH 4.3 (in 0.01 mol/l $CaCl_2$) in the A-horizon increasing to pH 5.3 in the B-horizon. Aspect is west to southwest at altitudes of just less than 400 m. Mean annual precipitation at these sites is estimated at 800–900 mm.

In contrast, plots 68 and 87 were located in extensive stands of the community at altitudes 1 200–1 340 m on slopes with a northwesterly aspect. Parent rock is Peninsula Formation sandstone with Cartref Form soils. These soils are somewhat more leached and acid (pH 3.2 in 0.01 mol/l $CaCl_2$) in the A- and E-horizons than the loamy

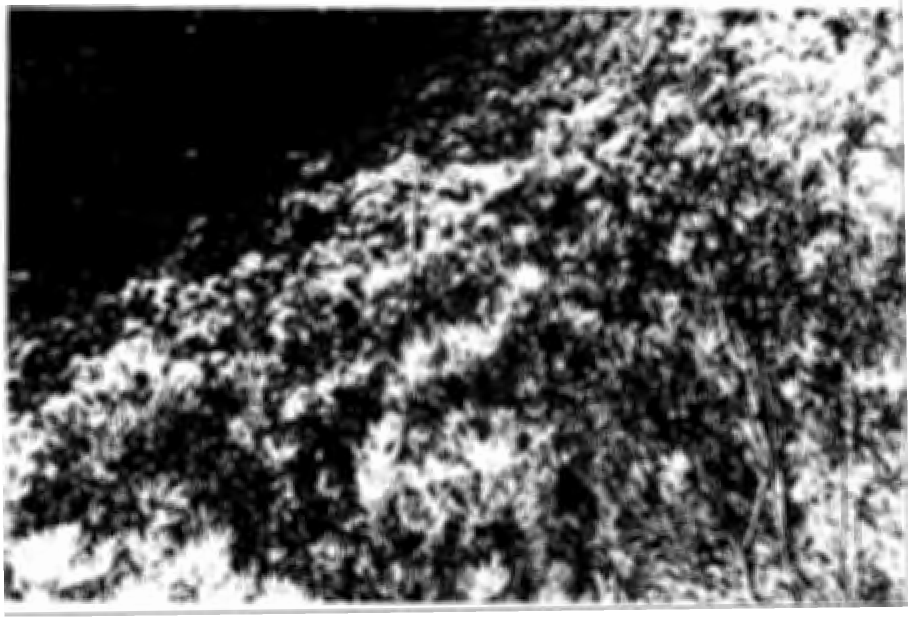

FIGURE 9.—*Hypodiscus aristatus–Leucadendron eucalyptifolium* Shrublands on a northwest-facing slope on sandstone soil west of Helderfontein.

FIGURE 10.—A dense stand of the *Berzelia intermedia–Erica melanthera* Shrublands on the lower south slopes of BWA.

Oakleaf Form soils. Mean annual precipitation is estimated at 1 000 mm.

1.2.4.2 *Hypodiscus aristatus–Berzelia intermedia* Shrublands

The *Hypodiscus aristatus–Berzelia intermedia* Shrublands comprise two communities, the *Berzelia intermedia–Erica melanthera* Shrublands and the *Berzelia intermedia–Erica blenna* Shrublands. These shrublands occur at altitudes not higher than 875 m (330–860 m) on the south slopes of the BWA, and give these slopes their characteristic ericoid-brunioid (fine-leaved) appearance. The parent rock is Peninsula Formation sandstone throughout. *Berzelia intermedia* is conspicuously present throughout these shrublands.

1.2.4.2.1 *Berzelia intermedia–Erica melanthera* Shrublands (F)

Differential species: *Lobelia coronopifolia, Pentaschistis* sp.

Dominant species: *Erica hispidula, Erica melanthera, Hypodiscus aristatus, Penaea cneorum* subsp. *ruscifolia, Tetraria cuspidata.*

Structural formation: structure of this community varies between a Low Closed Ericoid Shrubland and a Closed Graminoid Shrubland depending on the density and cover of the shrub component.

Relationships: Fynbos of the ericoid–restioid zone (Taylor 1978); Low Ericoid Heathland (Kruger 1979); *Erica arachnoidea–Pentameris dregeana* Community (Outeniqua Mountains) and the *Erica petraea–Erica nervata* and *Protea punctata–Erica melanthera, E. andraei* Communities (Swartberg) (Bond 1981); Mesic Ericaceous Fynbos (Moll *et al.*); Landdros Mesic Ericaceous Fynbos (Campbell 1985).

The dominant species, *Erica melanthera* is characteristic of this community (Figure 10). Dense stands of this erica are visible from a long distance, flowering on the lower slopes of the Langeberg in spring (Muir 1929; McDonald pers. obs.). Since the *Hypodiscus aristatus–Erica melanthera* Shrublands are poorly defined by inconspicuous differential species and because *Erica melanthera* is easily identified, it was chosen for the naming of this community. *Erica hispidula* is less dominant than *Erica melanthera* but is nevertheless well represented, as is *Penaea cneorum* subsp. *ruscifolia.* The dominant graminoids are *Hypodiscus aristatus* (Restionaceae), *Tetraria cuspidata* (Cyperaceae) and *Ehrharta setaceae* subsp. *scabra* (Poaceae). Together with other restios, sedges and grasses such as *Pentaschistis* spp. they constitute the co-dominant graminoid component.

The altitude at which these shrublands are found ranges from 330–625 m with a mean of 490 m. The soils are shallow (100–150 mm), acid (pH 3.2 in 0.01 mol/l $CaCl_2$, A-horizon) Cartref Form throughout the community. Mean annual precipitation is estimated at 900–1 000 mm. Typically these shrublands occur on gentle slopes with a mean gradient of 10° (5°–21°) with extremely variable amounts of exposed rock (0–75% cover).

1.2.4.2.2 *Berzelia intermedia–Erica blenna* var. *blenna* Shrublands (G)

Differential species: none.

Dominant species: *Berzelia intermedia, Erica blenna* var. *blenna, Erica hispidula, Psoralea pinnata, Widdringtonia nodiflora.*

Structural formation: the community is classified as a Low to Mid-high Closed Shrubland with a Mid-dense to Closed Graminoid Understorey.

Relationships: *Berzelia lanuginosa–Osmitopsis asteriscoides* Community (Werger *et al.*1972): *Erica–Osmitopsis* Seepage Fynbos and *Chondropetalum–Berzelia* Upper Hygric Fynbos (Boucher 1978); Hygrophilous Fynbos (Taylor 1978); Variation I of the *Restio–Hypolaena* Subcommunity (Laidler *et al.* 1978); Mixed Sclerophyllous Scrub (Kruger 1979); *Berzelia–Osmitopsis* Seepage Fynbos on permanent seeps (Taylor 1984); Wet Mountain Fynbos (Moll *et al.* 1984); Keurbos Wet Ericaceous Fynbos (Campbell 1985); *Berzelia lanuginosa–Merxmuellera cincta* Tall Closed Shrubland (McDonald 1988); *Erica hispidula–Berzelia intermedia* Shrublands (McDonald 1993a).

As noted above, *Berzelia intermedia* is characteristic of the *Hypodiscus aristatus–Berzelia intermedia* Shrublands (1.2.4.2). It is most dominant in the *Berzelia intermedia–Erica blenna* Shrublands (Figure 11). *Erica hispidula* also attains its highest degree of dominance in this community. *Erica melanthera* is present but much less evident than in the *Berzelia intermedia–Erica melanthera* Shrublands. *Widdringtonia nodiflora* is a conspicuous emergent shrub (up to 4 m) in most stands, whereas it is almost totally absent from the latter community. *E. blenna* var. *blenna* is endemic to the Langeberg and is restricted to the Swellendam–Heidelberg part of the range. It is used in the name of the *Berzelia intermedia–Erica blenna* Shrublands because it has its strongest expression here and the community is otherwise poorly defined. *Psoralea pinnata* is also found commonly here but it has a wider tolerance, occurring in other communities as well (Table 1). Two other species of particular note which occur in this community are the rare Langeberg endemics *Linconia alopecuroides* L. (Bruniaceae) and *Carpacoce gigantea* Puff (Rubiaceae).

This community is also found on highly leached, low pH, shallow (< 300 mm) soils of Cartref and Houwhoek Forms. Rock cover is mostly 2% or less except in plots 18 (10%) and 76 (25%). The slopes where these shrublands are located vary in aspect from east- to south-facing; one sample plot (73) was located on a west-north-west-facing slope. The mean gradient of the slopes is 19° (10°–33°). Altitudinal range of the community is from 500–850 m with a mean of 670 m. The *Berzelia intermedia–Erica blenna* Shrublands thus occupy the zone of higher, steeper slopes than the *Berzelia intermedia–Erica melanthera* Shrublands but occur below the zone occupied by the *Restio inconspicuus–Anthochortus crinalis* Shrublands (1.2.1) and *Restio inconspicuus–Hypodiscus aristatus* Shrublands (1.2.4). Mean annual precipitation is estimated at 1 000–1 100 mm.

Structurally the *Berzelia intermedia–Erica blenna* Shrublands are variable. In general the upper shrub stratum does not exceed 1.5 m in height. The exceptions are where *Berzelia intermedia* is dominant and reaches 2.5–3.0 m in height with a high projected canopy cover (Relevés 26 & 76) or where *Widdringtonia nodiflora* reaches 3–4 m and exceeds 10% projected canopy cover (Relevés 20 & 25).

1.2.4.3 *Hypodiscus aristatus–Erica versicolor* Shrublands (H)

Differential species: *Erica versicolor, Centella virgata* and *Tetraria involucrata*.

Dominant species: *Erica versicolor, Erica hispidula, Erica melanthera, Hypodiscus aristatus* and *Tetraria flexuosa*.

Structural formation: Closed Graminoid Shrubland or a Closed Herbland with a Mid-high Mid-dense Ericoid Shrubland Overstorey.

Relationships: Mesic Mountain Fynbos (Moll *et al.* 1984); *Hypodiscus aristatus–Erica versicolor* Shrublands (McDonald 1993a).

This community (Figure 12) is typically found on rocky sandstone outcrops on northwest-, north- and northeast-facing slopes, but on the south side of the range (i.e. south of Grootberg).

Soil development on the rocky outcrops where the *Hypodiscus aristatus–Erica versicolor* Community is found is poor, consisting of accumulations of sand and organic material in shallow (100 mm deep) pockets amongst the rocks. These lithosols are therefore regarded as poorly developed Mispah Form soils.

Erica versicolor has the habit of favouring almost any well-drained rocky situation and the *Hypodiscus aristatus–Erica versicolor* Shrubland Community is usually interspersed amongst other more uniformly distributed communities, forming a mosaic with the latter from low to high altitudes (400–1 200 m). The community is characterized as much by presence of *Erica versicolor* as by marked absence of a number of widely distributed species, e.g. *Cyclopia sessiliflora, Drosera aliceae, Tetraria compressa* and *Gnidia oppositifolia*, which prefer habitats where the soils are deeper and less readily drained.

The stature of *Erica versicolor* ranges from low (< 1 m) to mid-high (1–2 m) and therefore the structural form

FIGURE 11.—*Berzelia intermedia–Erica blenna* Shrublands which occur on highly leached acid sandstone soils at altitudes from 1 000–1 100 m mainly on wet south-facing slopes.

FIGURE 12.—*Hypodiscus aristatus–Erica versicolor* Shrublands found on rocky sandstone outcrops on the south side of the Langeberg in BWA.

of the *Hypodiscus aristatus–Erica versicolor* Community varies between the two forms stated above.

2. *Cannomois parviflora* Shrublands

Species with distribution common to all plant communities and with high cover-abundance are not a feature of the vegetation on the north slopes of the Langeberg in the Boosmansbos Wilderness Area. Broad-scale characterization of the plant communities occurring in this area is therefore not simple. *Cannomois parviflora* has been chosen as the 'base' species equivalent to *Erica hispidula* on the south slopes, since it is readily identifiable and found in all the communities in question (Table 2). Campbell (1985) notes that *Cannomois parviflora* (his *Elegia parviflora*) is common as a dominant in Mesic Restioid Fynbos and is also a feature of Dry Restioid Fynbos and Dry Proteoid Fynbos. This supports the use of this species in the nomenclature of the shrublands described here.

The *Cannomois parviflora* Shrublands are found on soils derived exclusively from sandstone of the Nardouw Subgroup. The communities described may or may not reflect the respective geological formations within the Nardouw Subgroup but distinctions in geological formation were not recorded and correlations between plant communities and geological formations are therefore not possible here. Four communities are identified and described, two as subdivisions of the *Cannomois parviflora–Leucadendron eucalyptifolium* Shrublands and two as subdivisions of the *Cannomois parviflora–Passerina obtusifolia* Shrublands.

2.1 *Cannomois parviflora–Leucadendron eucalyptifolium* Shrublands

Northeast of Grootberg is a shallow intermontane valley forming part of the catchment of Brandrivier. There are also a number of east-trending rocky ridges, the highest of which is named Deception Ridge in this study. Altitude diminishes eastwards towards Brandrivier. The valley has a mesic to dry climate compared with the wet south slopes and the arid north slopes adjacent to the Little Karoo. The soils are mainly accumulations of well-drained sand resulting in Clovelly Form soils. The ridges have a somewhat more xeric climate with shallow well-drained lithosols usually of Glenrosa Form.

This community is found in the above-mentioned intermontane valley and on the ridges but not on the arid north-facing slopes of Deception Ridge. They are locally extensive and are divided into two communities, the *Leucadendron eucalyptifolium–Protea lorifolia* Shrublands and the *Leucadendron eucalyptifolium–Staberoha cernua* Shrublands which are characterized by high cover-abundance of *Leucadendron eucalyptifolium*, *Protea repens* and *Tetraria bromoides*. The presence of *Leucadendron eucalyptifolium* indicates a close relationship between these shrublands and the *Hypodiscus aristatus–Leucadendron eucalyptifolium* Shrublands (1.2.4.1) described above. Their overall species composition and habitat differ, however, and they are therefore treated as separate communities. The tall shrub *Protea eximia* occurs sporadically throughout the *Cannomois parviflora–Leucadendron eucalyptifolium* Shrublands and as a dominant in the *Leucadendron eucalyptifolium–Staberoha cernua* Shrublands described below.

The *Leucadendron eucalyptifolium–Protea lorifolia* Shrublands are found on the rocky ridges north of Grootberg, forming a mosaic with the *Leucadendron eucalyptifolium–Staberoha cernua* Shrublands which occur in bottomland situations. Physiognomically the former community differs very little from the latter. Both have a Mid-dense to Closed Graminoid stratum with Mid-high to Tall, Open to Mid-dense to Proteoid Shrub Overstorey. It is therefore difficult to distinguish these communities on the basis of structure.

2.1.1 *Leucadendron eucalyptifolium–Protea lorifolia* Shrublands (J)

Differential species: *Agathosma cerefolium, Erica versicolor, Indigofera pappei, Lightfootia tenella, Metalasia gnaphalodes, Protea lorifolia, Stoebe aethiopica, Stoebe saxatilis, Ursinia nudicaulis.*

FIGURE 13.—*Leucadendron eucalyptifolium–Protea lorifolia* Shrublands found on the ridges north of Grootberg, showing the proteoid shrub overstorey with *P. lorifolia* in the left foreground.

Dominant species: *L. eucalyptifolium, Elegia filacea, Protea repens, Tetraria bromoides, Thoracosperma galpinii.*

Structural formation: Mid-dense to Closed Graminoid Shrubland with a Mid-high to Tall, Open to Mid-dense Proteoid Shrubland Overstorey.

Relationships: Proteoid Zone Fynbos (Taylor 1978); Broad-sclerophyllous Scrub or Open-scrub (Kruger 1979); *Elegia galpinii–Metalasia pulcherrima* Community (Outeniqua Mountains) and *Protea repens–Protea lorifolia–Hypodiscus striatus* Community (Swartberg) (Bond (1981); Mesic Mountain Fynbos (Moll *et al.* 1984); Thomas Dry Proteoid Fynbos (Campbell 1985).

This community (Figure 13) is found on the ridges north of Grootberg. It is best expressed on Deception Ridge where there are terraces of shallow sandy loam Clovelly Form soil (Relevés 24, 52, 53, 55, 97, 98, 99, 100) and more poorly expressed where Glenrosa Form soils occur (Relevés 47, 49, 102, 113).

Mean annual precipitation is estimated at 600–700 mm. The general aspect is northeasterly but varies at local sites from north through east to south. Although most sites are well exposed and in many respects equivalent, local site aspect apparently plays some role in determining the distribution of the community. This is currently being investigated (McDonald, unpublished).

This community is structurally variable. The lowest stratum is always dominant, with sedges, restios and ericoid shrubs in more or less equal proportions. The upper stratum consists mainly of proteoid shrubs. The broad-leafed *P. lorifolia* is particularly characteristic and apart from some transgression into the *Leucadendron eucalyptifolium–Staberoha cernua* Shrubland (see Table 2), the dominant *Protea repens* could be viewed as characteristic of this community as well.

The presence of *Erica versicolor* in the *Leucadendron eucalyptifolium–Protea lorifolia* Shrublands indicates some affinity between this community and the *Hypodiscus aristatus–Erica versicolor* Shrublands described above. However, *E. versicolor* tends to be a ubiquist on rocky outcrops if the moisture régime is high enough and the limited presence of the species in this community is thought to indicate the limit of its range on the south-north gradient. *Erica barrydalensis* H. Bol., a rare endemic species, with similar rocky habitat preferences to *E. versicolor*, was recorded on Deception Ridge (McDonald & Oliver 1987) and may replace *E. versicolor* since it apparently tolerates xeric conditions more readily.

2.1.2 *Leucadendron eucalyptifolium–Staberoha cernua* Shrublands (K)

Differential species: *Cyphia zeyheriana, Erica cerinthoides, Helichrysum rotundifolium, Lachnaea penicillata, Staberoha cernua.*

Dominant species: *Leucadendron eucalyptifolium, Protea eximia, Tetraria bromoides, Elegia filacea.*

Structural formation: Mid-dense to Closed Graminoid Shrubland with a Mid-high to Tall, Open to Mid-dense Proteoid Shrubland Overstorey.

Relationships: as for 2.1.1 above.

The differential species of this community (Figure 14) are not well-represented. It could be argued therefore that distinction between the *Leucadendron eucalyptifolium–Protea lorifolia* Shrublands and the *Leucadendron eucalyptifolium–Staberoha cernua* Shrublands is tenuous. However, the proteoid stratum of the latter community is dominated by *Protea eximia* and *Leucadendron eucalyptifolium* with *Protea repens* almost absent. In the *Leucadendron eucalyptifolium–Protea lorifolia* Shrublands, the opposite is true with *P. eximia* poorly represented and *L. eucalyptifolium* and *Protea repens* codominant. Absence of a number of species such as *Anomalanthus* sp., *Ficinia lacineata, Hypodiscus argenteus, Hypodiscus striatus, Phylica mairei, Relhania calycina* subsp. *apiculata* and *Stoebe microphylla* from the *Leucadendron eucalyptifolium–Staberoha cernua* Shrubland reinforces the distinction as well (see Table 2).

Structurally the *Leucadendron eucalyptifolium–Staberoha cernua* Shrublands are similar to the *Leucadendron eucalyptifolium–Protea lorifolia* Shrublands. The lower stratum is marginally more graminoid and the upper proteoid stratum more uniformly mid-dense. Other distinctions are negligible.

The *Leucadendron eucalyptifolium–Staberoha cernua* Shrublands are found mainly in bottomland situations with south- and southeast-facing aspects. One sample (Relevé 48) was on a 30° slope but mostly the community occurs

FIGURE 14.—*Leucadendron eucalyptifolium–Staberoha cernua* Shrublands in bottomland situations. Note the dense graminoid understorey with *Protea eximia* dominant in the proteoid shrub stratum.

where there is little or no relief apart from a shallow gradient eastwards towards Brandrivier. The soils have resulted from accumulation of sand and are all distinctly yellow and of the Clovelly Form. A typical pH 4.6 increasing to pH 4.8 (in 0.01 mol/l $CaCl_2$) was measured for samples from the A- and B-horizons respectively of soil at Relevé 105.

2.2. *Cannomois parviflora–Passerina obtusifolia* Shrublands

This community is found on the exposed north-facing slopes of Deception Ridge below an altitude of 1 000 m and on the mesa-like sandstone plateaux above the contact with the Bokkeveld Formation shales of the Little Karoo. This is the most arid aspect of the transect, with high incoming radiation and rainfall ranging between 300–600 mm p.a. Two communities are described, the first being the *Cannomois parviflora–Passerina obtusifolia* 'Typicum' and the second the *Passerina obtusifolia– Leucospermum calligerum* Shrublands.

Passerina obtusifolia is a widespread species found on sandstone soils on the dry aspects of the mountains from Clanwilliam Division in the west to Grahamstown in the east (Thoday 1924). Occurrence of this species on the lower north slopes of the Langeberg clearly places the *Cannomois parviflora–Passerina obtusifolia* Shrublands within the context of Dry Mountain Fynbos (Moll *et al.* 1984).

The species shared between the two communities show definite affinities with Karroid vegetation; succulents in the genera *Adromischus, Crassula, Machairophyllum* and *Ruschia* indicate the transition from fynbos to Succulent Karoo. The endemic *Leucospermum erubescens* is found in these shrublands but was not encountered in any of the sample plots. Its distribution appears to be erratic on the north slopes of the Langeberg from Witbooisrivier to Garcia's Pass.

2.2.1 *Passerina obtusifolia–Leucospermum calligerum* Shrublands (L)

Differential species: *Elytropappus cyathiformis, Leucospermum calligerum, Lobostemon decorus, Muraltia heisteria, Paranomus spathulatus, Serruria balanocephala, Thamnochortus karooica, Thesium subnudum.*

Dominant species: *Leucospermum calligerum, Metalasia densa, Passerina obtusifolia, Pentaschistis eriostoma, Serruria balanocephala.*

Structural formation: Mid-high Mid-dense Graminoid Shrublands.

Relationships: Arid Fynbos (Taylor 1978); Arid Fynbos (Kruger 1979); *Phyllica axillaris–Felicia filifolia* Community (Outeniqua Mountains) and *Passerina obtusifolia–Felicia filifolia–Pentaschistis eriostoma* Community (Swartberg) (Bond 1981); Dry Mountain Fynbos (Moll *et al.* 1984); Sebrafontein Dry Asteraceous Fynbos (Campbell 1985).

This community (Figure 15) is found on the lower north-facing slopes above Witbooisrivier at altitudes from 485–745 m. The habitat is not much different from that of the *Cannomois parviflora–Passerina obtusifolia* 'Typicum' except that the mean gradient of the sample sites is 8° (6°–22°). With this difference in mean gradient, changes in drainage and other subtle factors may account for the development of this community.

Leucospermum calligerum is a widely distributed proteoid species on the arid aspect of the fynbos of the northwestern and western mountains (Lokenberg and Gifberg) and on the dry north slopes of the Langeberg to the Gouritz River in the east (Rourke 1972). It therefore links this community with the widely distributed Arid Fynbos (*sensu* Taylor 1978; Kruger 1979), Dry Mountain Fynbos (Moll *et al.* 1984) or Dry Asteraceous Fynbos (Campbell 1985). At a local scale, however, endemic species such as *Paranomus spathulatus* and *Serruria balanocephala* Rourke ined., characterize the Dry Mountain Fynbos of the north slopes of the Langeberg; a more refined definition of this community may be possible with more extensive sampling.

2.2.2 *Cannomois parviflora–Passerina obtusifolia* Shrublands 'Typicum' (M)

Differential species: none.

Dominant species: *Hypodiscus striatus, Passerina obtusifolia, Pentaschistis eriostoma.*

Structural formation: Open Graminoid Shrubland with ericoid shrubs emergent to 2 m.

Relationships: As for 2.2.1 above and *Leucadendron eucalyptifolium–Hypodiscus argenteus* Shrubland (McDonald 1993a) in part.

Four relevés, 45, 46, 50 & 51, represent this community. The first two sample plots were located on the lower north slopes above Klein Witbooisrivier at 594 m a.s.l. The soils are of Mispah Form reflecting poor soil development. Relevés 50 & 51 are at 792 and 914 m a.s.l. respectively on the rocky north-facing slopes of Deception Ridge. The soils at these sites are classified as Glenrosa Form. The mean gradient of the sites is 24° and rock cover is not less than 95% at any of the sites.

All the species in the *Cannomois parviflora–Passerina obtusifolia* Shrublands are shared with other communities. The xeric conditions at the above sites limit the survival of many plant species and the community consequently lacks species requiring more favourable conditions.

DISCUSSION AND CONCLUSIONS

Much debate has surrounded the classification of the fynbos vegetation of the Cape Floristic Region. Various methods have been used in attempts to classify the floristically complex vegetation into ecologically meaningful yet 'practical' units interpretable by scientist and manager alike.

Two approaches to the classification of the fynbos of mountain ecosystems in the Cape have been used since the early 1970's: (i) the floristic approach and (ii) the structural approach. The floristic approach has been based mainly on the methodology of the Zürich-Montpellier school of phytosociology (Mueller-Dombois & Ellenberg 1974; Werger 1974). However, one of the problems facing phytosociologists in the fynbos of the Cape mountains is the great diversity of habitats and attendant high diversity of plant taxa (Werger *et al.* 1972). Floristic techniques have demanded high skills in identifying plants in the field, for example according to Bond (1981), 'high species turnover along geographic gradients places high demands on the ecologist's ability in field taxonomy for limited returns in ecological understanding. ... This reduces the generality and usefulness of a formal phytosociological approach to parochial studies in small areas.' Campbell (1986a & b) affirmed Bond's statement and severely criticised floristic techniques. However, despite this major area of difficulty the mosaic of small, localized studies that have been done have been useful in generating an overall picture of at least the broad fynbos communities present in the Cape mountains.

On the Langeberg, Muir's (1929) early descriptions, Taylor's (1955) documentation of Grootvadersbosch Forest, McKenzie's (1978) study of the forests and Campbell's (1983, 1985, 1986a) structural classification were the only studies of the vegetation prior to the present study. Campbell (loc. cit.) placed 21 samples in BWA on his 'Langeberg Transect' which he classified into six subseries (i) Azonal and (ii) Mesic Restioid Fynbos, (iii) Mesic and (iv) Wet Ericaceous Fynbos and (v) Mesic and (vi) Dry Proteoid Fynbos; 12 types were described. However, although Campbell's (1985) classification provides a comprehensive typology of Cape mountain vegetation (Cowling & Holmes 1992) it lacks floristic information found in phytosociological studies, which Bond *et al.* (1992) and Cowling *et al.* (1992) found appropriate for testing ecological and phytogeographical hypotheses. The application of the Braun-Blanquet method in this study was time-consuming but ultimately yielded an acceptable classification of the fynbos plant communities of the BWA. The classification is ecologically meaningful and easily interpretable if the user is familiar with the character species which form only a small proportion of the diverse

FIGURE 15.—*Passerina obtusifolia–Leucospermum calligerum* Shrublands on the dry lower north-facing slopes at Witbooisrivier, bordering the Little Karoo.

flora. The floristic data assembled in this study also provide a basis not only for description and hierarchical classication of fynbos plant communities but also for biogeographical studies.

The fynbos of mountain catchments of the southern Langeberg accords with Taylor's (1978) broad zonation classification of Cape mountain vegetation. In BWA, however, complex environmental gradients exist from the mesic lower south slopes through a number of fault valleys to wet high-altitude slopes and exposed peaks and ridges and then to the mesic to dry shallow valleys and ridges and very dry, exposed north slopes. This has profound local effects on the distribution of vegetation associations.

Correlation between environment and plant communities enhances the descriptive and predictive value of any phytosociological classification (Campbell 1983; McDonald 1987; Deall *et al.* 1989). Such correlations have necessarily been superficially described in this paper. Therefore, attempts to explain the gradients underlying the distribution of the communities described here will be presented in a later paper (McDonald, unpublished) where data from two additional sample transects will be available.

In attempting to show relationships between the communities described in this paper and those described by other workers in Mountain Fynbos, difficulty was experienced in equating one community with another. This is due to high geographic turnover (gamma diversity) of species in roughly similar montane habitats (Cowling & Holmes 1992). The relationships of communities shown in this paper are open to modification as greater understanding of the composition and functioning of communities is gained. As the synthesis of fynbos proceeds, the recognition of regional associations of limited extent or geographical races of an association may have to be recognized (Werger *et al.* 1972; Cowling & Holmes 1992) to overcome the problems of equivalence between communities. For instance this may ultimately result in the recognition of southwestern Cape, southern Cape and southeastern Cape zones of the Fynbos Biome.

The vegetation of the BWA was almost completely burned in a summer wildfire in February 1988, subsequent to the sampling of relevés reported on here. After three years (April 1991), apart from the predominance of 'fire-ephemerals' such as *Ursinia trifida* which dominate over large parts of the south slopes, the communities of BWA as described here are identifiable. As succession proceeds it is predicted that the robustness of the floristic classification will become even more evident as the fire ephemerals disappear and the perennial shrublands reach their mature expression.

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The vegetation of the southern Langeberg, Cape Province. 2. The plant communities of the Marloth Nature Reserve

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Keywords: classification, forest, fynbos, Langeberg, phytosociology

ABSTRACT

The Marloth Nature Reserve, encompassing the mountain catchments of the southern Langeberg immediately above Swellendam, Cape Province, South Africa, is described. The vegetation of the reserve was sampled along a transect representing the variation in plant communities over the range from the lower south to the lower north slopes. Eighty-three sample sites were subjectively located in mature stands of fynbos vegetation (>10 years old). The relevé data were initially classified using TWINSPAN and then refined by Braun-Blanquet (BB) phytosociological procedures. The Afromontane Forest patches which occur mainly on the lower south slopes were not sampled but are briefly discussed. The fynbos plant communities are described, based on tables, and a hierarchical classification is proposed.

UITTREKSEL

Die Marloth Natuurreservaat wat die bergopvanggebiede van die suidelike Langeberge bokant Swellendam, Kaapprovinsie, Suid-Afrika, insluit, word beskryf. Die plantegroei van die reservaat is versamel langs 'n transek wat die variasie in plantgemeenskappe oor die bergreeks vanaf die onderste suidelike tot die onderste noordelike hange verteenwoordig. Drie-en-tagtig monsterpersele is subjektief in volwasse fynbos (>10 jaar oud) uitgelê. Die relevé-data is aanvanklik deur middel van TWINSPAN geklassifiseer en toe deur Braun-Blanquet (BB) fitososiologiese prosedures verfyn. Die Afro-montane woudgemeenskappe wat hoofsaaklik op die onderste suidelike hange voorkom, is nie gemonster nie maar word kortliks bespreek. Die fynbosplantgemeenskappe word kortliks beskryf, gebaseer op tabelle, en 'n hiërargiese klassifikasie word voorgestel.

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INTRODUCTION

This paper is the second in a series describing the plant communities of the southern Langeberg, Cape Province. The fynbos plant communities occurring in the Marloth Nature Reserve (Swellendam State Forest) are described and classified. The Afromontane Forest patches found in the study area were not sampled but are briefly discussed based on the studies of McKenzie (1978).

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STUDY AREA

Location

The Marloth Nature Reserve (MNR) is situated in the mountain catchments of the southern Langeberg above the town of Swellendam (Figure 1). In 1928 a deputation of Swellendam residents petitioned the Minister of Lands and Forestry, General Kemp, to set aside a part of the mountain behind Swellendam as a nature reserve. The well-respected chemist and botanist Dr Rudolf Marloth proposed approximately 190 ha on the lower slopes of the Langeberg behind Swellendam, as a suitable area. This area which included the forest patches of Koloniesbos and Duiwelsbos, was proclaimed as a nature reserve and named in honour of Dr Marloth (Lückhoff 1981).

More recently, in accordance with the policy of the former Directorate of Forestry and Environmental Conservation to extend reserves for more effective management, the MNR was enlarged to more than 11 000 ha in June 1981. At the same time the Swellendam Hiking Trail was opened for recreational hiking in the MNR (Lückhoff 1981). Similar to the Boosmansbos Wilderness Area, the MNR is bounded on the north and south sides largely by agricultural lands and on the west and east sides by privately owned mountain land.

The sample transect selected in the MNR extended from the lower south slopes at the foot of 12 O'Clock Peak to the 'Plaat' or plateau and from there up the south-facing slopes of 12 O'Clock Peak. The transect was then 'broken' and continued from 10 O'Clock Peak down the north-facing slopes into Boskloof Valley and up the opposite south-facing slope to the summit of Hermitage Ridge. From this point samples were taken, roughly following the route of the Swellendam Hiking Trail to Goedgeloof Hut on the extreme lower north slopes of the range. This route gave ready access to the area. Although the transect covered a narrow belt and consequent relatively small area compared with the whole MNR, it allowed for sampling of the variety of fynbos plant communities present (Figure 2).

Physiography

The south slopes of the Langeberg above Swellendam are steep and rise rapidly to the famous 'Clock Peaks' (Figure 3). On the lower south slopes, however, the steepness is broken by the 'Plaat' at an elevation of approximately 500 m. This plateau is the result of downfaulting of the Worcester Fault along this part of the Langeberg Range. On the north side of 10 to 12 O'Clock Peaks the slopes drop steeply into the Boskloof intermontane valley (Figure 4). Between 12 O'Clock Peak and One O'Clock Peak to the west is the deeply faulted, dissected and inaccessible Hermitage Kloof. This kloof lies below Hermitage Peak (1 154 m) and Misty Point or Goedgeloof Peak (1 710 m), the highest peak of the Langeberg. To the north of and overlooking Boskloof Valley is the rocky Hermitage Ridge, which gives way in turn to the dissected area of Zuurplaats and the open high-altitude valley of Langkuilen. North of Langkuilen is Goedgeloof Ridge which lies adjacent to the Little Karoo. West of Misty Point is Protea Valley which extends westwards over Dwariganek into the Twistniet Valley. The topography from Protea Valley westwards to Nooitgedacht River is dominated by a series of peaks; Kruispad Peak (1 365 m), Leeurivierberg (1 628 m), Middelrivierberg (1 405 m) and Klipspringerkop (1 127 m). The south slopes of these peaks are steep but uniform and not deeply

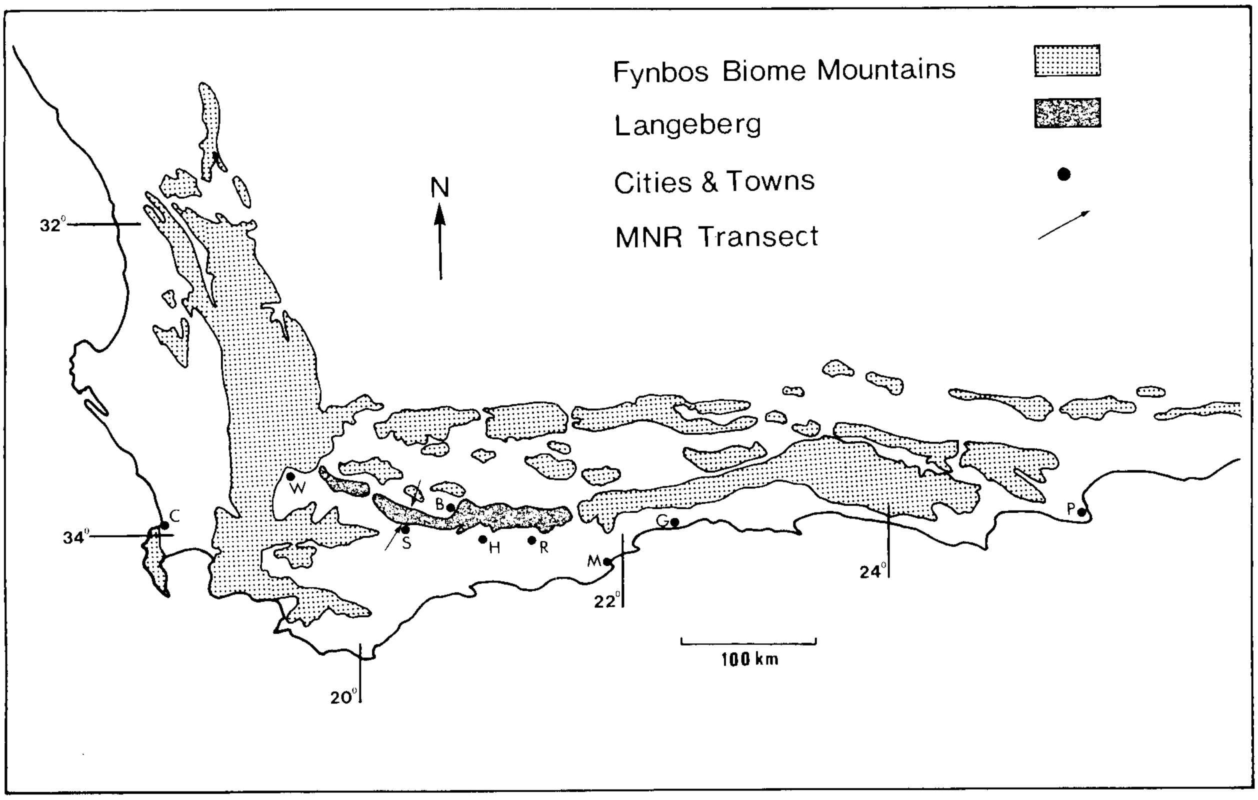

FIGURE 1.—Map of the mountains of the Fynbos Biome showing the position of the Langeberg and the location of the Marloth Nature Reserve (MNR) transect. B, Barrydale; C, Cape Town; G, George; H, Heidelberg; M, Mossel Bay; P, Port Elizabeth; R, Riversdale; S, Swellendam and W, Worcester.

FIGURE 2.—Portion of topographical map 3320CD Scheepersrus, showing part of the MNR with positions of the sample plots. (Map reproduced under Government Printer's copyright authority dated 30 October 1991).

FIGURE 3.—The steep south-facing slopes of the Langeberg above Swellendam. Photograph taken from Twelve O'Clock Peak.

dissected. In contrast, the north slopes are much more dissected and less uniform, particularly when compared with the north slopes below Misty Point.

Leeukloof, Wolfkloof, Hermitage Kloof, and Boskloof drain the mountain catchments of the area to the south and southeast. On the north slopes numerous streams such as the Rietrivier, Knapsakkraalrivier, Warmwaterrivier and Dwarigarivier have their sources at high altitude and drain the dry north-facing slopes, supplying water for agriculture on the north flank of the Langeberg.

Geology

Extending from Goudini, which lies beyond the Langeberg in the northwest, along the lower southwest side of the Langeberg, to the proximity of Sparrebosch (immediately east of Swellendam) is a 'band' of Malmesbury Group sediments. The exposure of these sediments follows the Worcester Fault and in the MNR they are found on the lower slopes of the peaks listed above, but below the 'Plaat' (i.e. below 500 m) (De Bruyn *et al.* 1974).

The main massif of the mountain in the MNR is composed of Table Mountain Group (TMG) sediments. All the high peaks on the south side of the Langeberg Range in the MNR consist of Peninsula Formation sandstone. Hermitage Peak and Misty Point, which have a more northerly position, consist of Nardouw Subgroup sandstones (South African Committee for Stratigraphy, SACS 1980). The distinction can be made by tracking the position of the intervening Cedarberg Formation shaleband. Soils derived from weathered Cedarberg Formation shale are encountered in the Boskloof Valley westwards to Hermitage Kloof. The extreme folding in Hermitage Kloof obscures the position of the shaleband, but it is once again evident in Protea Valley, at Dwariganek and into the Twistniet Valley.

A silcrete mesa extends from the base of the Langeberg below Goedgeloof Ridge northwards. The Nardouw Subgroup sandstones of the northernmost slopes thus make contact with the silcrete cap which in turn covers the Bokkeveld Group shales. The silcrete mesa forms a watershed with streams draining eastwards to the Tradouws River and westwards to the Kingna River.

Soils

The soil forms (Soil Classification Working Group 1991) occurring in MNR are summarized in Table 1, indicating their parent material, diagnostic characteristics and position in the landscape. No attempt has been made to

FIGURE 4.—Boskloof, behind the Clock Peaks, as seen from the high altitude south-facing slopes of Hermitage Ridge.

TABLE 1.—Soils of the Marloth Nature Reserve

Soil form	Parent material	Diagnostic characteristics	Position in landscape
Champagne	Organic matter	>200 mm deep, plant remains	Cool, moist, high alt. slope, S-aspect
Houwhoek	Peninsula Formation sandstones	Orthic A-horizon, E-horizon, podzol-B overlying saprolite	S-facing slopes at mid- to high altitudes, with high rainfall
Cartref	Peninsula Formation sandstones	Orthic A-horizon, E-horizon, lithocutanic B-horizon	S-facing slopes at mid- to high altitudes, with high rainfall
Clovelly	Malmesbury Group and Cedarberg Formation shales	Orthic A-horizon with yellow-brown apedal B-horizon	Below the 'Plaat' and on exposure of Cedarberg shale in Boskloof & Protea Valley
Glenrosa	Peninsula Formation & Nardouw Subgroup sandstones	Orthic A-horizon with litho-cutanic-B	Rocky, N-facing slopes with lower rainfall
Mispah	Peninsula Formation & Nardouw Subgroup sandstones	Orthic A-horizon over hard rock	Ridge crests, rock outcrops and N-aspect rocky slopes

identify all possible soil forms found in MNR, but rather to give a broad overview of major forms; particularly those encountered on the sample transect.

Climate

Climatic data for Langeberg montane environments are scant and the climate measured at the Swellendam and Weltevrede weather stations (Soil and Irrigation Research Institute, SIRI 1986), i.e. those stations closest to the MNR, does not accurately represent the montane climate. Climate diagrams for these stations, Figure 5A & B, represent the climates at the lower south and north extremes of the MNR transect.

The climate of the MNR is typical of the southern Langeberg since it falls within the transition zone between winter and year-round rainfall areas. The mean annual precipitation for the high peaks is estimated to be more than 1 400 mm (Dent *et al.* 1987). However, the climate on the south side of the range is distinctly different from that on the north side. The south slopes of the southern Langeberg experience the highest rainfall in autumn (April) and late winter to spring (August and October) with rainfall in excess of 40 mm for every month except May, the driest month. This bimodality is not evident in the rainfall pattern on the north slopes of the range which are in a rainshadow. Here a peak in rainfall occurs in autumn (April) with a dry period in May preceding a somewhat elevated winter to spring rainfall, Figure 5A. The rainfall exceeds 40 mm only in April and August. The mean summer maximum and mean winter minimum temperatures for Swellendam are 29.4°C (January) and 6.6°C (July) respectively. On the opposite side of the mountain at Weltevrede (33° 56′ S, 20° 37′ E), on the lower north slopes of the Langeberg, the equivalent temperatures are 30.0°C (February) and 2.9°C (July), Figure 5B.

The windiest months at Weltevrede are December and February and at Swellendam, May. Hot, strongly desiccating föhn-like berg winds occur mainly in May, June and July.

METHODS

During 1988, 1989 and 1990, 83 plots were sampled along a predetermined transect in the study area (Figure 2). The area was not stratified since no suitable aerial photographs were available. Consequently plots were subjectively placed in what were taken as the major landscape features and plant communities. The rectangular sample quadrats were 50 m^2, subdivided into 10 equal-sized subplots to facilitate data collection (McDonald 1988, 1993). Only permanently recognizable species were recorded. Geophytes and annuals encountered were noted but not used in the analyses. The Braun-Blanquet cover-abundance scale (Mueller-Dombois & Ellenberg 1974; Werger 1974) was applied. A border zone of 1.5 m from the perimeter of each plot was rapidly searched for any additional species not found in the marked plot.

Only the sclerophyllous fynbos was sampled since the mixed evergreen (Afromontane) forests are well documented by McKenzie (1978).

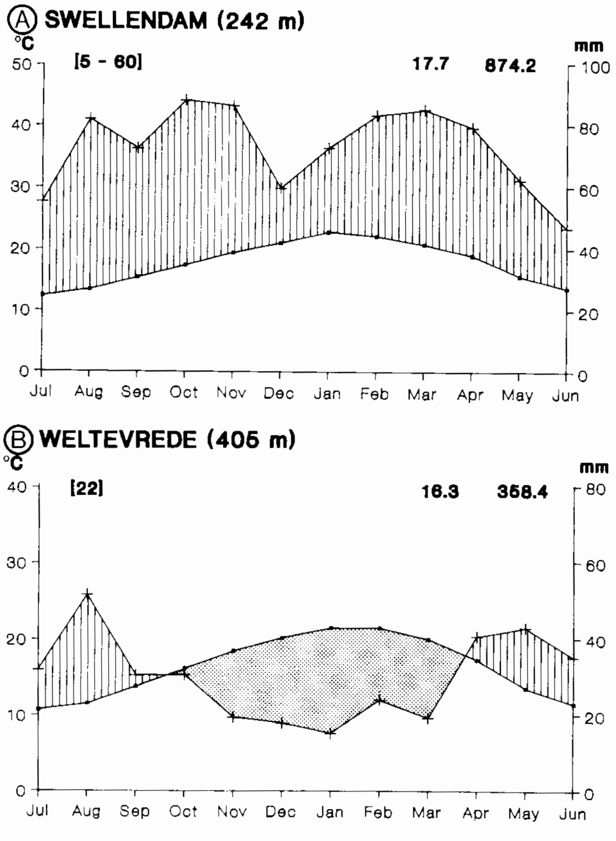

FIGURE 5.—Walter-Lieth climate diagrams for A, Swellendam and B, Weltevrede, on the northern side of the Langeberg.

Phytosociological tables were compiled by obtaining a 'first approximation' classification using TWINSPAN (Hill 1979) and then by successive refinement using Braun-Blanquet procedures with PCTables (Boucher unpublished).

Each community is described following the order in the proposed classification; the structural description follows the system advanced by Campbell *et al.* (1981). Relationships between the communities described here and communities described in other studies of mountain fynbos are given as far as possible. These relationships were determined by comparing the floristic composition of the communities of this study with the respective communities of other studies as indicated below [note that Campbell (1985) gave 'floristics' for each of his lowest level structural units].

VEGETATION

The greater part of the Marloth Nature Reserve is covered by sclerophyllous fynbos typical of the mountains of the western and southern Cape (Taylor 1978; Kruger 1979). Afromontane Forest communities in the MNR are confined to moist kloofs on the south side of the Langeberg range.

Afromontane Forest

Numerous mixed evergreen Afromontane forests (Geldenhuys 1989) are found in the MNR. These forests were exploited for hardwood timber in early colonial days, for wagon-making, furniture and general construction. The accessible forest patches are known variously as Koloniesbos, Duiwelsbos, Doktersbos and Grootbos with less accessible forests being found in Boskloof, Hermitage Kloof, Wolfkloof and Leeukloof. McKenzie (1978) described the '*Rapanea melanophloeos*–*Hartogiella schinoides*–*Podocarpus latifolius* Forest Association' as the general type found in the southwestern Cape. This association was divided into three subassociations, two of which are found in the MNR: *Cunonia capensis*–*Platylophus trifoliatus* Subassociation and *Carissa bispinosa*–*Canthium ventosum*–*Canthium mundianum*–*Pterocelastrus tricuspidatus* Subassociation. Only one of the variations of the *Cunonia capensis*–*P. trifoliatus* Subassociation, the *Cunonia capensis*–*Todea barbara* Variation was identified in MNR, whereas two variations of the second subassociation, *Buddleja saligna*–*Scolopia mundii* Variation and *Rothmannia capensis*–*Olinia ventosa*–*Canthium ventosum*–*Canthium mundianum* Variation were identified (McKenzie 1978).

The three variations of forest subassociations identified in MNR occur on a moisture gradient. The *Cunonia capensis*–*Todea barbara* Variation occurs in wet situations along streams, the *Rothmannia capensis*–*Olinia ventosa*–*Canthium ventosum*–*Canthium mundianum* Variation is found on seasonally wet to dry sites and the *Buddleja saligna*–*Scolopia mundii* Variation on relatively dry sites.

Fynbos

The complexity of the fynbos vegetation of the Marloth Nature Reserve has necessitated subdivision of the data into three parts for treatment in separate phytosociological tables (Tables 2, 3 & 4). These subdivisions represent logical separations which have facilitated definition of the fynbos shrubland communities.

The TWINSPAN analysis separated the data into 23 subdivisions. The division at Level 1 indicated the separation of the data into two groups; relevés in Tables 2 & 3 on the one hand and Table 4 on the other. TWINSPAN separated the relevés of Table 4 into two groups at Level 2 and finally into three subdivisions at Level 3; a finer classification than presented in Table 4.

At Level 2, the remaining relevés are separated into two groups; communities A–C and I–O on the one hand and communities D–H on the other. At Level 3 communities A–C (Table 2) are separated from communities I–O which are treated together with communities D–H in Table 3. At the lower levels of the TWINSPAN classification there is some agreement between this analysis and the BB-classification, however, the latter classification is favoured since it yields fewer units that are more easily interpreted and identified in the field.

1. *Cliffortia serpyllifolia* Shrublands of the lower south slopes

The shrublands of the lower south slopes of the Langeberg at Swellendam are conspicuously dominated by *Cliffortia serpyllifolia* which is hardly found higher than the edge of the 'Plaat'. The edge of the 'Plaat' represents the contact between the TMG sediments and the basement rock of the Malmesbury Group with which *C. serpyllifolia* appears to be strongly associated. A logical separation of the lower slope plant communities on Malmesbury Group sediments [Main Quartzite of the Lower Group of the Boland Formation (De Bruyn *et al.* 1974)] (Table 2) from the *Erica hispidula* shrublands (Table 3) of higher elevation on TMG sediments is therefore possible. It is important to note, however, that many of the species are common to both shrubland types.

1.1 *Cliffortia serpyllifolia*–*Widdringtonia nodiflora* Shrublands

Only one poorly defined shrubland community is included here. This community lies at the transition between the *Erica hispidula* Shrublands of the high elevation zone and the *Cliffortia serpyllifolia*–*Leucadendron eucalyptifolium* Shrublands.

1.1.1 *Widdringtonia nodiflora*–*Rhodocoma fruticosa* Shrublands (A)

Differential species: *Rhodocoma fruticosa, Tetraria brevicaulis, Ehrharta ramosa, Tetraria ustulata, Edmondia sesamoides, Ursinia nudicaulis.*

Dominant species: *Cliffortia serpyllifolia, Erica hispidula, Erica versicolor, Penaea cneorum subsp. ruscifolia.*

Structural formation: Mid-high, Mid-dense (Ericoid) Shrubland with a Mid-dense Graminoid Shrubland Understorey.

Relationships: unclear.

TABLE 2.—A phytosociological table of plant communities on the lower south slopes of the Langeberg on a transect through the Marloth Nature Reserve, Swellendam

Community	1											
	1.1							1.2				
	A		B					C				
Relevé number	131	152	129	132	133	134	135	125	126	127	128	130
Altitude (m)	580	580	310	570	515	450	390	242	242	320	320	290
Aspect (°)	40	235	170	220	215	130	210	295	295	70	290	285
Differential species of the Widdringtonia nodiflora--Rhodocoma fruticosa Shrublands (A)												
Rhodocoma fruticosa (Thunb.) Linder	1	1										
Tetraria brevicaulis C.B. Cl.	+	+										
Ehrharta ramosa (Thunb.) Thunb.	+	+										
Tetraria ustulata (L.) C.B. Cl.		3										
Edmondia sesamoides (L.) Hilliard		+										
Ursinia nudicaulis (Thunb.) N.E. Br.		+										
Differential species of the Widdringtonia nodiflora--Hippia pilosa Shrublands (B)												
Hippia pilosa (Berg.) Druce				+	+	+	+					
Athrixia heterophylla (Thunb.) Less subsp. heterop..			R		+		R					
Elegia equisetacea (Mast.) Mast.						2	1					
Osmitopsis osmitoides (Less.) Bremer				1	1							
Merxmuellera stricta (Schrad.) Conert					1		2					
Mairea hirsuta DC.					+							
Senecio cordifolius L.f.					+							
Helichrysum felinum (Thunb.) Less.					R							
Restio decipiens (N.E. Br.) Linder							+					
Restio arcuatus Mast.			+									
Lobelia neglecta Roem. & Schult.			0									
Ursinia trifida (Thunb.) N.E. Br.					+							
Restio capillaris Kunth				+								
Tetraria crassa Levyns							R					
Species common to Communities A & B												
Psoralea pinnata L.	1	1	0	0		1	1					
Widdringtonia nodiflora (L.) Powrie	+	2		0	1	1						
Elegia capensis (Burm. f.) Schelpe		1		+		1						
Ehrharta setacea Nees ex Trin. subsp. scabra (Stapf	+	+			R							
Struthiola eckloniana Meisn.	+	+	0									
Schizaea pectinata (L.) Sw.	1	+			+							
Platycaulos compressus (Rottb.) Linder		+		4								
Centella stenophylla Adamson	R					+						
Gleichenia polypodioides (L.) J.E. Sm.	+			+								
Differential species of the Leucadendron eucalyptifolium--Erica vestita Shrublands												
Erica vestita Thunb.								0	+	+	+	+
Lanaria lanata (L.) Dur. & Schinz								2	+	1	1	
Cymbopogon marginatus (Steud.) Stapf ex Burtt Davy								1		2	+	0
Berkheya sp.								R	R	+		0
Erica pubigera Salisb.									1	+	+	
Metalasia densa (Lam.) Karis								1	+	+		
Protea neriifolia R. Br.									5		0	
Cyphia zeyheriana Presl ex Eckl. & Zeyh.								0	0			
Lightfootia tenella Lodd.								+	R			
Mairea microcephala (Less.) DC.									+			
Ursinia scariosa (Ait.) Poir. subsp. scariosa								0				
Tetraria cuspidata (Rottb.) C.B. Cl.								+				
Species common to Communities B & C												
Leucadendron salignum Berg.			1		1	0	1		+	1	1	0
Leucadendron eucalyptifolium Buek ex Meisn.			1	0	0	3		3		4	2	
Restio triticeus Rottb.					1	2		+	+	1	1	1
Tetraria bromoides (Lam.) Pfeiffer			1			1	1	1	0			1
Festuca scabra Vahl			1		+		+			1	1	
Psoralea monophylla (L.) C.H. Stirton							+	1		+	+	+
Protea piscina Rourke			+				+	+	+		+	
Ehrharta dura Nees ex Trin.						+	+	1			1	1
Cassytha ciliolata Nees							+	+			+	1
Lobelia coronopifolia L.					+	0	+		R	0		
Thamnochortus cinereus Linder			1			+				1	+	
Stoebe cinerea (L.) Thunb.			+	+		+		+				
Clutia alaternoides L.			R		R	+			+			
Drosera aliceae Hamet			R						R			
Anthospermum galioides Reichb. f. subsp. reflex.			+						+	+		
Gnidia galpinii C.H. Wr.						0	0		+			
Centella lanata Compton				0	1			1				
Tetraria capillacea (Thunb.) C.B. Cl.						+			1			
Species common to Communities A, B & C												
Cliffortia serpyllifolia Cham. & Schltd.	1	2	5	2	5	2	3	1	+	0	2	2
Penaea cneorum Meerb. subsp. ruscifolia Dahlg.	2	2	1	1	+	1	1	3		1	1	1
Erica versicolor Wendl.	4	2	1	2	+	2	4	R		3	2	5
Erica hispidula L.	2	1	1	5	1	2		1	2	+	+	
Laurophyllus capensis Thunb.	+	3	+	1	+	+	1	1				+
Tetraria flexuosa (Thunb.) C.B. Cl.	2		3	1	2	2	3			2	2	4
Bobartia macrospatha Bak. subsp. macrospatha		+	0		+		1	1	+		1	+
Elegia juncea L.	+	1			+		+		0	1	+	
Berzelia intermedia (Dietr.) Schlechtd.	0	0	+	2			+		1			
Restio inconspicuus Esterhuysen		+	1	1			+			1	1	
Merxmuellera lupulina (Thunb.) Conert		+	1						1	1	1	1
Erica plukenetii L.	+	1						+	+		0	
Anthospermum spathulatum Sprengel subsp. spathulatum		+		+	+			+				
Corymbium glabrum L. var. glabrum		+				1				+	+	
Pteridium aquilinum (L.) Kuhn	+							4				+
Hypodiscus albo-aristatus (Nees) Mast.		1								1	1	
Ficinia filiformis (Lam.) Schrad.		R						2	+			
Chrysithrix capensis L.	1	+								+		
Erica melanthera L.	+									1	+	

This community is represented by only two relevés (131 & 152), found on the rocky ridge marking the edge of the ‘Plaat’, at an altitude of 580 m. Sample plot 131 was situated on the north-north-east aspect of the ridge, with a slope of 14°, and sample plot 152 was located on the south-south-west aspect of the ridge with a slope of 7°. These differences appear to have affected dominance only. The soils are lithosols and are of the Mispah and Glenrosa Forms at the two sites respectively.

The Mid-dense Graminoid Shrubland is dominant and contains all the differential species. Emergent from this stratum (< 1 m) is a Mid-high Open to Mid-dense Shrubland, with dominants as above. In relevé 152, *Laurophyllus capensis* dominates the upper stratum.

1.2 *Cliffortia serpyllifolia–Leucadendron eucalyptifolium* Shrubland

This community includes two shrubland communities both of which are found below the ‘Plaat’ in a very com-

TABLE 3.—A phytosociological table of the *Erica hispidula* Shrublands along a transect through the Marloth Nature Reserve, Langeberg, Swellendam

	Community											
	2											
	2.1	2.2						2.3				
	(D)	(E)	(F)	(G)	(H)	(J)	(I)	(L)	(M)	(N)	(K)	(O)
Relevé Number	1222	11112	11111111	1111112	11111	1111	11111	11112	11111111	111112	111	11
	7000	55550	33344566	3566660	44569	6777	77789	79990	44444788	688990	678	99
	9456	56787	67957401	8323452	08996	7456	13780	83781	12346209	627123	801	45
Altitude (m)	1111	1 11	11		1 11		11 1	111	11111111	111111	111	11
	3212	60901	77633687	7677658	60811	9988	00973	93109	34424033	422333	113	31
	2887	22846	42962008	1600399	80834	4144	43073	24081	32260200	236700	930	08
	0005	00000	00000000	0000000	00000	0580	00000	00005	00000000	050050	000	00
Aspect (°)	1221	11112	111 1211	121222	1 13	2122	12		1	112121	2	
	9149	69692	96528966	7271219	53651	3331	37062	33221	29232451	980909	162	52
	5500	35500	00074000	0450005	00053	5550	05505	50008	38507025	000500	008	07
Differential species of the Erica hispidula--Brunia alopecuroides Shrublands (D)												
Brunia alopecuroides Thunb.	5355											
Erica curviflora L.	2211		1		2							
Hippia integrifolia Less.	2 2	+										
Carpacoce spermacocea (Reichenb. f.) Sond.	011											
Mairea microcephala (Less.) DC.	2 +											
Stylapterus dubius (Steph.) Dahlg.	11											
Erica omninoglabra H.A. Bak.	2											
Species common to communities D & E												
Erica conferta Andr.	1+1+	1+1+	+							+	+	
Syncarpha eximia (L.) B. Nord.	0+0	++0 0								0		
Lobelia pubescens Dryand.ex Ait. var. rotundifolia	R	R									+	
Helichrysum capense Hilliard		+RO										
Differential species of the Berzelia intermedia--Grubbia rosmarinfolia Shrublands (F)												
Grubbia rosmarinifolia Berg. subsp. rosmarinifolia			255 25+0	00								
Erica regerminans L.	0	+	543									
Spatalla parilis Salisb. ex Knight			100 2+									
Raspalia virgata (Brongn.) Pillans			11									
Differential species of the Berzelia intermedia--Cliffortia grandifolia Shrublands (G)												
Cliffortia grandifolia Eckl. & Zeyh. var. grandifo.				3+ 2323								
Senecio hastatus L.				RR++								
Species common to communities E, F, G & H												
Restio arcuatus Mast.		++1	5 3 51	5 3554	5							
Berzelia intermedia Schlechtd.		115	4+11 52	3 ++ 0	+21							
Laurophyllus capensis Thunb.		0	+ +	1+++ 2								
Gnidia oppositifolia L.		++1	0 0 ++	+11111	+ 11							

TABLE 3.—A phytosociological table of the *Erica hispidula* Shrublands along a transect through the Marloth Nature Reserve, Langeberg, Swellendam (continued)

Relevé Number	1222 7000 9456	11112 55550 56787	11111111 33344566 67957401	1111112 3566660 8323452	11111 44569 08996	1111 6777 7456	11111 77789 13780	11112 79990 83781	11111111 4444788 12346209	111112 688990 627123	111 678 801	11 99 45
Species common to Communities E, F, G & H												
Tetraria compressa Turrill		RR+	.1 11	.0+ 111	.0 +		.	.	.	.	.	.
Calopsis membranacea (Pillans) Linder		0+2	.	. 211	.		.	.	.	.	.	.
Ursinia serrata (L.f.) Poir.		+ +	. +	. 0	.		.	.	.	.	.	.
Osmitopsis osmitoides (Less.) Brewer		+++1	. 1	.01++1+	.R 1		.	.	. +	.	.	.
Gnidia galpinii C.H. Wr.		++	.++	.R	.		.	.	.	.	.	.
Thesium carinatum A. DC.		+	. 0	.	.+		.	.	.	.	.	.
Indigofera concava Harv.		++ R	.	. + R	.+ +		.	.	.	.	.	.
Differential species of the Pentaschistis malouinensis--Tetraria bromoides Shrublands (J)												
Tetraria bromoides (Lam.) Pfeiffer		.	.	.	.	2++3		.	.	.	.	.
Protea aurea (Burm. f.) Rourke subsp. aurea		.	.	.	.	31		.	.	.	.	.
Erica pubigera Salisb.		.	.	.	.	1		.	.	.	.	.
Leucadendron salignum Berg.		.	.	.	.	1		.	.	.	.	.
Leucadendron eucalyptifolium Buek ex Meisn.		.	.	. +	. 0	3 1		.	.	.	.	.
Helichrysum pandurifolium Schrank	R	.	.	. +	.	+11		.	.	.	.	.
Species common to communities E, F, G, H & J												
Helichrysum felinum (Thunb.) Less.		0 +	. R	. 1 +++	.	.+ +		.	.	.	.+	.
Erica cubica L.			.1210 3	.	. 1 4	.02 +		.	.	.	.	.
Elegia capensis (Burm. f.) Schelpe		+11	. 1 2	.10 +	. 1	. 1		.	.	.	.	.
Hypodiscus albo-aristatus (Nees) Mast.		2	. 1	. 121	.2	.5 3		.	.	.	.	.
Erica cordata Andr.	++	1 2	.	.	.	. 4		.	.	.	.	.
Pteridium aquilinum (L.) Kuhn		+	. 00	.	.	. +		.	.	.	.	.
Differential species of the Erica hispidula--Pentaschistis malouinensis Shrublands (I)												
Pentaschistis malouinensis (Steud.) Clayton		.	.	.	.	021	. 212		.	.	.	.
Differential species of the Hypodiscus aristatus--Phylica pinea Shrublands (L)												
Phylica pinea Thunb.		.	.	. +	.	.	.	00121		.	.	.
Tetraria thermalis (L.) C.B. Cl.		.	.	.	.	.	.	11		.	.	.
Ceratocaryum decipiens (N.E. Br.) Linder		.	.	.	.	.	.	23		.	.	.
Erica atropurpurea Dulfer		.	.	.	.	.0	.	++		.	.	.
Species common to communities E, F, G, H, I, J & L												
Widdringtonia nodiflora (L.) Powrie		0+12	.+0+ 11+	.+010+12	.0 1	.0112	. 11	.+ 200		.	.	.
Blechnum tabulare (Thunb.) Kuhn	+1	R2+2	.1 0 01	.00R210	.1 +	. 1	. 1	.	1	.	.	
Bobartia macrospatha Bak. subsp. macrospatha	0	+01	.	.	.	. +	.000	.+ +		.	.	.
Epischoenus dregeanus (Boeck.) Levyns		+1	.	. +1	.1 1	. 1	.111 1	.		. 2	.	.
Ursinia scariosa (Ait.) Poir. subsp. subhirsuta			.	. 0 + +	.	.	.	. ++		.	.	.
Ehrharta ramosa (Thunb.) Thunb.			.	. +	.	. +	.	. +		.	.	.
Cassytha ciliolata Nees			.+	. +	.	.	.	. +		.	.	.
Species common to communities I, L & M												
Erica versicolor Wendl.		.	.	. 1	.	.	.+	31115	.20+ +4+3		.	.

TABLE 3.—A phytosociological table of the *Erica hispidula* Shrublands along a transect through the Marloth Nature Reserve, Langeberg, Swellendam (continued)

```
                                              Relevé Number   *1222*11112*1111111*1111112*11111*1111*11111*11112*1111111*111112*111*11
                                                              *7000*55550*33344566*3566660*44569*6777*77789*79990*4444788*688990*678*99
                                                              *9456*56787*67957401*8323452*08996*7456*13780*83781*12346209*627123*801*45

|Differential species of the Hypodiscus aristatus--Restio strictus Shrubands (N)

|Restio strictus N.E. Br.                           |     .    .      .      .     .     .     .     .          |131112|   .

|Species common to communities D--N

|Erica hispidula L.                                 |++11.435+3.3112 122.4355451.4R54 .042 .325  .12+ +.1 2211++.2+3210.514|
|Elegia juncea L.                                   |1222.12212.        +.1111+11.1 10 . 12 .11+  .12111.0111+211.1 2111.+1 |
|Anthochortus crinalis (Mast.) Linder               |5555. 2113.   1 31 . 1      . 3 32.    .   21.      .       .+  1+ .12 |
|Ehrharta setacea Nees ex Trin. subsp. scabra (Stapf| 11+.+++ +.   1+    .      +.+  1 .    .1   2.+1+ 1.1121+221.223224.1+2|
|Chrysithrix capensis L.                            | 2 1.011 2. + 111+ . ++     . 1 21. 2 +. 2132.    +.0+21     .  2232. 21|
|Platycaulos compressus (Rottb.) Linder             | 22 .     1.252222  . 2 1 1 . 21 5. 3  .422 1.+ 1  .1       + .  1++ .  1|
|Clutia alaternoides L.                             |   0.       .   +    .      +.       .++++.1++ 1. +  R. ++++ + .1+++1+. +|
|Protea cynaroides (L.) L.                          | 0+1. 0 10.11     10.01 1 0 .  10 .     .     . +   .      10 .   000. 1 |
|Pentaschistis colorata (Steud.) Stapf              |  + .  1 2. +·       .       .    .     1.12    . +21 .+1121+1 .312222.  2|
|Senecio cordifolius L.f.                           |0+1+. ++++.  R      +.+ ++++ .+ +   .  + . 1    .     .  R      .R  + +. |
|Blaeria coccinea Klotzsch                          |++21. 1 13.+++ + + .   +     .     .    . 2 12.     . 1+    + .  ++34.  |
|Petalacte canescens DC.                            | R+ . 1  1. 0  +     .       .     .    .     .     . 1       .3  ++1.+ |
|Kniphofia uvaria (L.) Oken.                        |0+ +.    +.          .       .  +  . +  .+++  .     .      +  .     .++ |
|Mairea hirsuta DC.                                 | +   . 21  .           .1 1+   .+ 10 .    . 1   .     .          .     .++ |
|Restio fragilis Esterhuysen                        | 1 +.    1.          .       .     .    . +   .     .          .     .+ |
|Leucadendron spissifolium (Salisb. ex Knight)      |1+   . 0+  .          .    2  .    + .2    .     .     . 2        .   +  .1 |
|Platycaulos anceps (Mast.) Linder                  |2  1.   1 .       21.          .    4 .    .    4 .     . +        .     .  |
|Epischoenus quadrangularis (Boeck.) C.B. Cl.       |1121.   1 .+1111++ .             .     .    .+  + .     .   1       .    +. |

|Species common to communities E--N

|Lobelia neglecta Roem. & Schult.                   |    | ++  .        .  + +++.  ++ . +++.+ +  . + +R.+ +  ++ .     . + |
|Edmondia sesamoides (L.) Hilliard                  |    |++   .   0    .        .+    .0+ +.0 0  .+     .122+2 12.22++0 .+ +|
|Tetraria brevicaulis C.B. Cl.                      |    |++1 R. +     +.   +  R.      . 1  .111 1.1++ 1.1+1+1+1+.+ +++ .1 1|
|Penaea cneorum Meerb. subsp. ruscifolia Dahlg.     |    |223  .++1+ 1 +.+222222.2 2 +. 1  .4 +  .+ + 2.0 +211++.  1    . ++|
|Centella lanata Compton                            |    |+ 1 2.1++   ++. 2+++1 .+  + .     .     .     .      0 .+   + .++ |
|Psoralea pinnata L.                                |    |+  + . 0       .+ ++1+ .1 10 .     .      .+1++ . R   2 .      . 1 |
|Erica daphniflora Salisb.                          |    | +++ .   +     .        .  + .3411. +1  .      . 1+      . 2131 .  |
|Tetraria flexuosa (Thunb.) C.B. Cl.                |    |11    .         .       .12   .   1.212+3.+  1 .       +  .1     1. 2|
|Struthiola eckloniana  Meisn.                      |    |     . +      1.  ++ +1.+     .     .+     .++1 +.       +  .      .  |
|Corymbium glabrum L. var. glabrum                  |    |++   +. R       .       .     .     .      .     .0+1+1 ++.11++++.1 1|
|Metalasia densa (Lam.) Karis                       |    |     .   R      .        .    R .    +.     .+     .112++ 2+.11++ . .  1|
|Chondropetalum mucronatum (Nees) Pillans           |    |     .+21+    4.        .     .      .    02.      .  1       .2 + R . |
|Gleichenia polypodioides (L.) J.E. Sm.             |    |++ 4 .         .+1       .     .      .     .+ +  .      10+.       .  |
|Indigofera sarmentosa L.                           |    | R+  .         .  +R  +.  +   .      .     .+  +.       +  .       .  |
|Schizaea pectinata (L.) Sw.                        |    |  +  .         .+      R.      .      .     . 1+++.       +  .      . + |
|Anemone tenuifolia (L.f.) DC.                      |    | OR  .         .+      +.      .  + .      .       .           .     .+1 |
|Bobartia parva J.B. Gillett                        |    |     .   +1    .        .      .      .     . ++   .      +   .   R .  |
|Euryops pinnatipartitus (DC.) B. Nord.             |    |  +  .         .       1.      .+   .  +  .    +.            .    +.  |
|Tetraria capillacea (Thunb.) C.B. Cl.              |    |+ 1  .         .        .      .      .     .     .    22      .     .1 |
|Ursinia scariosa (Ait.) Poir. subsp. scariosa      |    |R++  .         .        .  +   .      .     .     .            .     . + |
|Erica bracteolaris Lam.                            |    |     .         .  +     .  +   .      .  1  .     .1           .     .1 |
|Othonna quinquedentata Thunb.                      |    |   1 .         .        .      .  +0.R     .     .            .     .+ |
|Osteospermum corymbosum L.                         |    |+    .         .        .      .      .     . 0+  .      +   .       .  |
|Centella stenophylla Adamson                       |    |     .         .       2.      .      .     .1   2.+          .       .  |
|Restio triticeus Rottb.                            |    |11   . +       .        .      .      .     .     .   +        .       .  |
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TABLE 3.—A phytosociological table of the *Erica hispidula* Shrublands along a transect through the Marloth Nature Reserve, Langeberg, Swellendam (continued)

Releve Number	*1222*11112*11111111*1111112*11111*1111*11111*11112*1111111*111112*111*11 *7000*55550*33344566*3566660*44569*6777*77789*79990*44444788*688990*678*99 *9456*56787*67957401*8323452*08996*7456*13780*83781*12346209*627123*801*45
Species common to Communities E--N	
Restio decipiens (N.E. Br.) Linder	1 . . 3 . . . . . .2 .
Senecio ilicifolius (L.) Thunb.	. . R. .+ . . . . . +
Ursinia nudicaulis (Thunb.) N.E. Br.	. 0 . . . 1 .+++ . + .OR+++ + . + + .R
Cliffortia heterophylla Weim.	. . 0 . . . . 2+. + . .25
Stoebe spiralis Less.	. . . . . . + .1 1 +1. ++ . 1
Stoebe plumosa (L.) Thunb.	. 0 . . .111+. . . 1 + +. 0 .0+
Centella montana Adamson	. . . . ++ R +. +R . R
Tetraria crassa Levyns	. . . . .1 . .1 + . 1 .1
Restio capillaris Kunth	. . . .1 . . 1 . 1. .
Erica ardens Andr.	. . +.R . . + . . 1+ + . +. +
Erica imbricata L.	. . 4. .0 +0. +2 .+ .0+ . +1 +.
Differential species of the Hypodiscus aristatus--Erica multumbellifera Shrublands (0)	
Staberoha cernua (L.f.) Dur. & Schinz	 41
Erica multumbellifera Berg.	. . . . +2
Species common to communities K, L, M, N & O	
Thamnochortus cinereus Linder	. . . . . .0 +1 . 1+ 1++ .++++01.2+ .++
Hypodiscus aristatus (Thunb.) Krauss	. . . . . . 21 . 1222122. 11 .+2+.20
Cliffortia densa Weim.	. . . R. . . 2+ 1.+110 . 1 . 1.++
Erica vestita Thunb.	. . . . . . 2 2 . 1+2 1. + . +.R
Pentameris macrocalycina (Steud.) Schweickerdt	. 1. . . . . . 21 1 1 . 2 0.12 .
Stoebe cinerea (L.) Thunb.	. . . . . . + . 1. . .0+
Species common to communities E--O	
Tetraria ustulata (L.) C.B. Cl.	221+ . 1 32 1. 2211 .331 . . 20 .222++.1+ 12 + . 132 .+ +.22
Restio inconspicuus Esterhuysen	1 1. 1 1 . +0 .1 1 . 2 .21011.1+1 .11111+ +. 11121.112. 1
Tetraria cuspidata (Rottb.) C.B. Cl.	1 . + . +.1 . 3 +.11 .1++ +.+1212121.22 11+.+12.++
Erica melanthera L.	2 .02 4.1 0 .+R . . 1 .++2+ .+ + 0 . 41 . 1.35
Drosera aliceae Hamet	R + . + R. RRR .+ R .++ . R+. . . ++R.R +.++
Ursinia trifida (Thunb.) N.E. Br.	RR . . ++++ . . .+ . . +++.++++++.R +.R
Merxmuellera lupulina (Thunb.) Conert	. 11 +. . . 1 +. 2.1+ .+ 2 + . 2 21.1 1.++
Calopsis monostylis (Pillans) Linder	. 2 . . . .R 22. .1 + 1.+ + . 2. +
Ficinia filiformis (Lam.) Schrad.	. + . . .+ . + . + .1 R + 1. 1 . . +
Elegia asperiflora (Nees) Kunth	. +1 . . . . +
Tetraria compar (L.) Lestib.	. + . . 1 + ... + . . .

plex geological zone of metamorphism, at the contact between rock of the Malmesbury Group and the Table Mountain Group (see De Bruyn *et al.* 1974). These shrublands reflect the presence of soils derived from shales and other more nutrient-rich sediments.

1.2.1 *Leucadendron eucalyptifolium–Hippia pilosa* Shrublands (B)

Differential species: see Table 2.

Dominant species: *Cliffortia serpyllifolia, Erica hispidula, Erica versicolor, Penaea cneorum* subsp. *ruscifolia, Tetraria flexuosa.*

Structural formation: varies from a Low Closed Graminoid Shrubland with Mid-high Emergent Shrubs to a Mid-high to Tall Closed Shrubland with an Open to Mid-dense Graminoid Understorey.

Relationships: Enon Mesotrophic Proteoid Fynbos (Campbell 1985).

This community (Figure 6) is found at a mean altitude of 447 m (310–570 m) on the cool lower slopes below the 'Plaat'. The parent rock is Peninsula Formation sandstone and all the soils are classified as

TABLE 4.—A phytosociological table of plant communities on the extreme north slopes of the Langeberg, on a transect through the Marloth Nature Reserve, Swellendam

	Community 4								
	4.2				4.1				
	P				Q				
Relevé number	1	1	1	2	1	1	1	1	1
	4	5	5	0	8	8	8	8	9
	9	0	1	0	3	4	5	6	9
Altitude (m)	1	1							
	0	0	9	8	9	8	7	6	8
	6	6	0	0	0	0	3	8	4
	0	0	0	0	0	0	5	0	0
Aspect (°)	2	3	2	3	2	1	2	5	3
	5	0	0	2	5	0	0	5	3
Differential species of the L. eucalyptifolium--Erica melanthera Shrublands (P)									
Staberoha cernua (L.f.) Dur. & Schinz	1	1		2					
Ursinia nudicaulis (Thunb.) N.E. Br.	+	+		R					
Erica melanthera L.	2	4		0					
Penaea cneorum Meerb. subsp. ruscifolia Dahlg.	1	1		+					
Psoralea pinnata L.	+	R	+						
Erica spectabilis Klotzsch	R	R							
Struthiola eckloniana Meisn.	+	+							
Restio inconspicuus Esterhuysen	1								
Lightfootia tenella Lodd.	0								
Chrysithrix capensis L.	+								
Phylica mairei Pillans			+						
Elegia juncea L.	1								
Tetraria involucrata C.B. Cl.			0						
Tetraria capillacea (Thunb.) C.B. Cl.			1						
Phylica pinea Thunb.	1								
Thamnochortus cinereus Linder	+								
Gleichenia polypodioides (L.) J.E. Sm.	+								
Festuca scabra Vahl	1								
Aspalathus verbasciformis Dahlg.			+						
Lobelia neglecta Roem. & Schult.	0								
Erica hispidula L.	+								
Ficinia cf.paradoxa (Schrad.) Nees			+						
Tetraria brevicaulis C.B. Cl.	+								
Cliffortia pterocarpa (Harv.) Weim.	1								
Erica vestita Thunb.				1					
Restio scaberulus N.E. Br.				+					
Bobartia parva J.B. Gillett				+					
Pentaschistis acinosa Stapf				1					
Edmondia sesamoides (L.) Hilliard				0					
Differential species of the Leucadendron eucalyptifolium--Hypodiscus argenteus Shrublands (Q)									
Hypodiscus argenteus (Thunb.) Mast.	.				1	+	1	0	1
Lobelia capillifolia (Presl) A. DC.	.				+	+	+	+	+
Lanaria lanata (L.) Dur. & Schinz	.					2	1	1	2
Heteropogon contortus (L.) Roem. & Schult.	.					+	+	1	
Ehrharta ramosa (Thunb.) Thunb.	.				0		+		0
Agathosma ovata (Thunb.) Pillans	.					2	2		1
Ficinia nigrescens (Schrad.) Raynal	.					+	+		+
Willdenowia glomerata (Thunb.) Linder	.				1	+	+		
Stoebe aethiopica L.	.				0		+		+
Tetraria sp. McDonald 1848	.				+	+			
Ursinia scariosa (Ait.) Poir. subsp. scariosa	.				+	0			
Ficinia monticola Kunth	.				+		+		
Maytenus oleoides (Lam.) Loes.	.					0	+		
Corymbium glabrum L. var. glabrum	.						+		1
Leucospermum calligerum (Salisb. ex Knight) Rourke	.						2	2	
Syncarpha paniculata (L.) B. Nord.	.						+	+	
Selago sp. 183/20	.				+	+			
Prismatocarpus brevilobus A. DC.	.				+	+			
Centella glabrata L. var. glabrata	.				+				
Crassula atropurpurea (Haw.) Dietr. var. atropurpu..						+			
Felicia filifolia (Vent.) Burtt Davy subsp. bodkin..						+			
Anthospermum spathulatum Sprengel subsp.spathulatum.								1	
Lobelia coronopifolia L.	.				+				
Rhodocoma fruticosa (Thunb.) Linder	.						+		
Thoracosperma galpinii N.E. Br.	.							2	
Tetraria crassa Levyns	.						+		
Erica plukenetii L.	.							+	
Widdringtonia nodiflora (L.) Powrie	.				0				
Restio strictus N.E. Br.	.					+			
Askidiosperma paniculatum (Mast.) Linder	.							1	
Species common to Communities P & Q									
Leucadendron eucalyptifolium Buek ex Meisn.	2	3	3	4	3	3	+	+	3
Tetraria ustulata (L.) C.B. Cl.	2	2	1	3	2	2	2	2	1
Stoebe spiralis Less.	+	0	+	+	+	+	+		+
Elegia galpinii N.E. Br.	1		3	0	2	1	1		2
Restio filiformis Poir.			1	+	2	1	1	2	1
Elegia fistulosa Kunth		1			1	+	+	1	1
Restio triticeus Rottb.		1	+	1	2			1	+
Hypodiscus aristatus (Thunb.) Krauss	2	3		+	0		2		0
Anthospermum galioides Reichenb. f. subsp. reflexi.	0			1	1	1	+		+
Hypodiscus striatus (Kunth) Mast.	1	0	2		2		1	+	
Anomalanthus sp. McDonald 1012			2	2	1	2			2
Pentaschistis colorata (Steud.) Stapf				1	1	1	1		1
Tetraria cuspidata (Rottb.) C.B. Cl.	+				1	+		+	1
Tetraria thermalis (L.) C.B. Cl.	2	1			0				0
Tetraria flexuosa (Thunb.) C.B. Cl.	1	2		3	1				
Merxmuellera lupulina (Thunb.) Conert	+	+		+				1	
Ceratocaryum decipiens (N.E. Br.) Linder		0							1
Mastersiella purpurea (Pillans) Linder			1				+		
Ischyrolepis capensis (L.) Linder			+					1	
Pelargonium fruticosum (Cav.) Willd.			+		+				
Schizaea pectinata (L.) Sw.			+			+			

Glenrosa Form. Aspect of the sample sites is mainly southerly, ranging from east-south-east to south-south-west. Mean gradient is 23.4° (14°–32°, n = 5). Rock cover is low (<1%) with one exception of 25% in plot 133. Litter cover is conversely high ranging from 70–85%, with vegetation cover 100% in all samples.

This community is weakly differentiated but has strong affinity to the *Penaea cneorum–Widdringtonia nodiflora* Shrublands described below. The most striking feature is the dominance of *Cliffortia serpyllifolia*.

1.2.2 *Leucadendron eucalyptifolium–Erica vestita* Shrublands (C)

Differential species: *Erica vestita, Lanaria lanata, Cymbopogon marginatus* and others, see Table 2.

Dominant species: *Cliffortia serpyllifolia, Erica hispidula, Leucadendron eucalyptifolium, Penaea cneorum* subsp. *ruscifolia*.

Structural formation: Mid-high to Tall Sparse to Closed Proteoid Shrubland with a Low Closed Graminoid Shrubland Understorey or a Low Closed Ericoid Shrubland with a Mid-dense Graminoid Understorey.

Relationships: Enon Mesotrophic Proteoid Fynbos (Campbell 1985).

This community (Figure 7) is found on the complex zone of Malmesbury Group sediments which are exposed below the 'Plaat'. There is strong correlation between this community and the relatively nutrient rich soils of the Malmesbury Group sediments. The soils of relevés 127, 128 & 130 were 0.2–0.3 m deep and classified as Glenrosa Form, whereas those of relevés 125 and 126 exceed 1.0 m and were classified as Clovelly Form soils. The five relevés were sampled at a mean elevation of 283 m (242–320 m) with a mean gradient of 12.2° (5°–20°). Cover of exposed rock was recorded as nil except for sample plot 127 where a high value of 90% was recorded. Vegetation cover averaged 96% and litter cover 66%. Four of the five sample sites had a westerly aspect with the remaining one on a northeast-facing slope.

Erica vestita is a prominent, easily identifiable differential species in this community. It has three colour forms, two of which are found on the Langeberg. The colour form found in the *Leucadendron eucalyptifolium–Erica vestita* Shrublands below the 'Plaat' is pink, whereas in the *Erica hispidula–Hypodiscus aristatus* Shrublands (described below) the flowers are crimson red. Of further particular note in this community are *Lanaria lanata, Cymbopogon marginatus* and *Erica pubigera* which appear to favour soils with a high clay fraction.

FIGURE 6.—The *Widdringtonia nodiflora–Hippia pilosa* Shrublands on the lower south slopes of MNR below the 'Plaat', with tall *Leucadendron eucalyptifolium* in the foreground.

2. *Erica hispidula* Shrublands of the high elevation zone

The *Erica hispidula* Shrublands described in this paper are broadly equivalent to those described by McDonald (1993). *E. hispidula* is present in all but one community, the *Hypodiscus aristatus–Erica multumbellifera* Shrublands. Speculation as to the reason for this absence is given below in the description of the latter community. *Restio inconspicuus*, which assumes a distinctive yet subordinate position to *E. hispidula* in the shrublands of Boosmansbos Wilderness Area (McDonald 1993), is less prominent in MNR.

2.1 *Erica hispidula–Brunia alopecuroides* Shrublands (D)

Differential species: *Brunia alopecuroides, Carpacoce spermacocea, Erica curviflora, Erica omninoglabra, Hippia integrifolia, Mairea microcephala, Stylapterus dubius.*

Dominant species: *Anthochortus crinalis, Brunia alopecuroides.*

Structural formation: Low to Mid-high Closed Brunioid Shrubland with Closed Restioid Understorey.

Relationships: *Brunia alopecuroides–Restio bifidus* Community (Kruger 1974); *Simocheilus carneus–Restio anceps* Community (Bond 1981), Ruitersberg Wet Ericaceous Fynbos (Campbell 1985).

Similar to the *Erica hispidula–Spatalla nubicola* Shrublands of BWA (McDonald 1993), the *Erica hispidula–Brunia alopecuroides* Shrublands are found mainly on the high altitude south- to southwest-facing slopes of the peaks and ridges of the MNR, in the cool, moist 'mist zone' (Figure 8). The substratum consists of decomposed organic material, forming a deep acid peat, which is classified as Champagne Form soil.

Although the Community is found on the Clock Peaks, it was not sampled here. Most sample plots (204, 205 & 206) were located on the high-altitude south-facing slopes of Hermitage Ridge, overlooking Boskloof, with one sample (Relevé 179) situated above the south tributary of Zuurplaats Stream.

The *Erica hispidula–Brunia alopecuroides* Shrublands typically have a low to mid-high (1.0–1.5 m) closed brunioid-ericoid overstorey, dominated by *Erica curviflora* and *Brunia alopecuroides*. The understorey is dominated by *Anthochortus crinalis* with other herbaceous species playing an inconspicuous role.

FIGURE 7.—The *Leucadendron eucalyptifolium–Erica vestita* Shrublands found on the complex zone of Malmesbury Group sediments below the 'Plaat'.

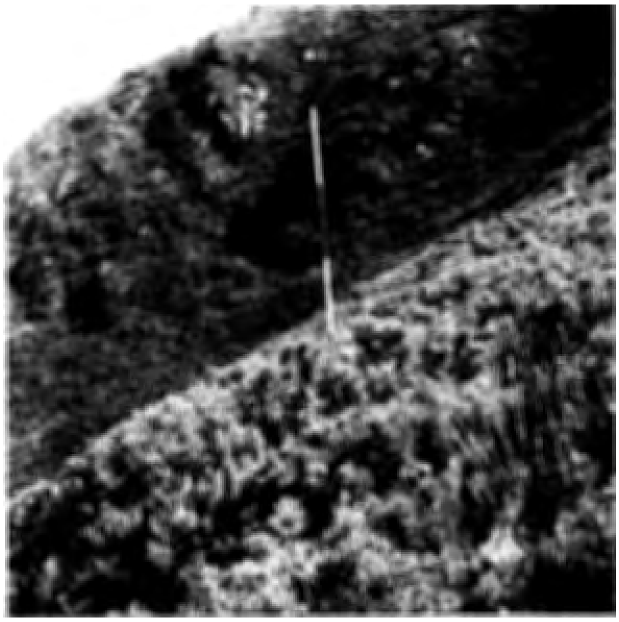

FIGURE 8.—The *Erica hispidula–Brunia alopecuroides* Shrublands found on the high altitude south slopes in the 'mist zone'.

Of particular note in this community is the presence of *Erica omninoglabra* (single occurrence in relevé 179), a rare Langeberg endemic species found sprawling amongst the matted restioid understorey, *Klattia partita* (Iridaceae), a shrubby species with non-fugaceous flowers and the endemic *Stylapterus dubius* (Penaeaceae).

2.2 *Erica hispidula–Berzelia intermedia* Shrublands

These shrublands include four communities which range from the typical form of the *Erica hispidula–Berzelia intermedia* Shrublands (E) to the *Berzelia intermedia–Erica conferta* Shrublands on organically rich soils.

Erica hispidula–Berzelia intermedia Shrublands 'Typicum' (E)

Differential species: none.

Dominant species: *Erica hispidula, Tetraria ustulata.*

Structural formation: Low Closed Ericoid Shrubland with sparse Mid-high Emergent Shrubs.

Relationships: Keurbos Wet Ericaceous Fynbos (Campbell 1985).

The *Erica hispidula–Berzelia intermedia* Shrublands (Figure 9) have no differential species but have many species in common with communities F, G and H. These shrublands may therefore be considered as the 'background' of the mosaic of communities found mainly, but not exclusively, on the south- to southeast-facing slopes of Hermitage Ridge and below the Clock Peaks. The relevés (140, 148, 159, 169) representing this community were located at elevations ranging from 600–1 200 m, with a moderate mean gradient of 22.5°. The soils are derived from Peninsula and Goudini Formation sandstone and are classified as Cartref Form. They are well drained and shallow with a mean depth of 0.15 m (0.1–0.2 m) and with a generally low average surface rock cover of 5% (2–10%). Projected vegetation canopy cover, in contrast, is high, ranging from 95–100%.

The dominant stratum of the *Erica hispidula–Berzelia intermedia* Shrublands is a Closed Graminoid Shrubland ($\leq$1.0 m) with dominance shared by the woody shrubs, *Erica hispidula* and *Penaea cneorum* subsp. *ruscifolia*, the sedges *Tetraria ustulata* and *Tetraria flexuosa* and the ubiquitous *Restio inconspicuus.*

2.2.1. *Berzelia intermedia–Erica conferta* Shrublands (F)

Differential species: *Helichrysum capense.*

Dominant species: *Anthochortus crinalis, Erica hispidula, Elegia juncea.*

Structural formation: Low Closed Ericoid Shrubland either with Sparse Mid-high Emergent Shrubs or a Tall Closed Brunioid Shrubland Overstorey.

Relationships: Ruitersberg Wet Ericaceous Fynbos (Campbell 1985); *Simocheilus carneus–Restio anceps* Community (Bond 1981); *Erica hispidula–Spatalla nubicola* Shrublands (McDonald 1993).

This community (Figure 10) is represented by five relevés (155, 156, 157, 158, 207). The only true differential species is *Helichrysum capense* since other species characterizing this community, namely *Erica conferta, Lobelia pubescens* and *Syncarpha eximia* are shared with

FIGURE 9.—The *Erica hispidula–Berzelia intermedia* Shrublands occurring mainly on the south-facing slopes of the Clock Peaks and Hermitage Ridge, forming a 'background' to the mosaic of communities.

FIGURE 10.—The *Berzelia intermedia–Erica conferta* Shrublands occurring on moist south-facing slopes below the Clock Peaks and on Hermitage Ridge.

the closely allied *Erica hispidula–Brunia alopecuroides* Shrublands. On the sample transect the community is found on the south- and southeast-facing slopes of 12 O'Clock Peak at elevations around 1 000 m, on shallow 'organic phase' Cartref Form soils. It is also found on the upper south-southwest-facing slopes of Hermitage Ridge, above Boskloof (relevé 207), where it forms part of a mosaic with the *Erica hispidula–Brunia alopecuroides* Community.

The dominant stratum of this community is a low closed ericoid layer dominated by *Erica hispidula* but with a number of other *Erica* species such as *E. cordata, E. conferta* and *E. daphniflora. Anthochortus crinalis, Elegia juncea* and *Tetraria ustulata* are the most important graminoid elements. Emergent from the low stratum in some stands is the fern *Blechnum tabulare*, with a mid-high to tall shrub stratum dominated by *Berzelia intermedia*.

2.2.2 *Berzelia intermedia–Grubbia rosmarinifolia* Shrublands (G)

Differential species: *Erica regerminans, Grubbia rosmarinifolia, Spatalla parilis, Raspalia virgata.*

Dominant species: *Erica hispidula, Grubbia rosmarinifolia, Platycaulos compressus.*

Structural formation: Mid-high to Tall Closed Shrubland with Closed Graminoid Shrubland Understorey.

Relationships: *Brunia alopecuroides–Restio bifidus* Community (Kruger 1974); *Chondropetalum–Berzelia* Upper Hygric Fynbos (Boucher 1978); Keurbos Wet Ericaceous Fynbos (Campbell 1985).

On the sample transect this community (Figure 11) is found as localized stands on the south-facing midslopes below the Clock Peaks. One sample (Relevé 147) was located at 1 320 m on the south-facing slopes of Goedgeloof Ridge, immediately west of Het Goedgeloofnek. On the mid-slopes of 12 O'Clock Peak at elevations from 600–800 m the community forms part of a mosaic with other communities in the broader *Erica hispidula–Berzelia intermedia* Shrublands.

The *Berzelia intermedia–Grubbia rosmarinifolia* Shrublands are mainly associated with local, apparently seasonally waterlogged sites. All the relevés typical of this community (136, 137, 139, 147, 154 & 160), were situated where the soils are boggy. In contrast, relevé 161 which is atypical, and where *G. rosmarinifolia* was recorded outside the plot (see Table 3), was located on a more rocky, well-drained substrate.

FIGURE 11.—The *Berzelia intermedia–Grubbia rosmarinifolia* Shrublands mainly localized on the south-facing mid-slopes of the Clock Peaks. Note the mid-high *G. rosmarinifolia* forming the overstorey.

Grubbia rosmarinifolia is strongly differential for this community. It forms a mid-high to tall, open to closed shrubland. The understorey may be subdivided into two strata in some stands. In some cases a mid-high open to closed ericoid stratum is found immediately below the tall stratum followed by a closed restioid field layer. In other stands the ericoid and restioid components combine to form a low closed field stratum.

In the samples taken, *Spatalla parilis* (Proteaceae) is restricted to the *Berzelia intermedia–Grubbia rosmarinifolia* Shrublands. *Restio arcuatus* together with *Platycaulos compressus* dominates the restioid component and *Erica regerminans* and *E. cubica* form the greater part of the ericoid component.

2.2.3 *Berzelia intermedia–Cliffortia grandifolia* Shrublands (G)

Differential species: *Cliffortia grandifolia, Senecio hastatus.*

Dominant species: *Cliffortia grandifolia, Erica hispidula, Penaea cneorum* subsp. *ruscifolia, Restio arcuatus.*

Structural formation: Low Closed Ericoid Shrubland with Closed Restioid Understorey and Mid-high to Tall Open Shrubland Overstorey.

Relationships: Keurbos Wet Ericaceous Fynbos (Campbell 1985).

The *Berzelia intermedia–Cliffortia grandifolia* Shrubland community (Figure 12) also occurs as part of the *Erica hispidula–Berzelia intermedia* Shrubland mosaic. It was sampled mainly on the southeast- to southwest-facing midslopes of 12 O'Clock Peak but occurs in patches over an extensive area on the south slopes below the Clock Peaks at elevations from around 600–700 m (above the 'Plaat'). The soils are 'organic phase' Cartref Form.

The community also occurs on the lower north- to northeast-facing slopes below the Clock Peaks, in the Boskloof Valley. These stands are represented by relevé 202 situated near Boskloof Hut at an altitude of about 900 m. Here the soils are of Glenrosa Form.

Cliffortia grandifolia is a striking species. It is a tall, sparingly branched shrub with a thin trunk, often reaching five metres in height. This species clearly characterizes the community structurally due to its stature and floristically due to its faithfulness. *Cliffortia grandifolia* forms a mid-high to tall open stratum above a low closed graminoid shrubland understorey, dominated by *Erica hispidula* and *Restio arcuatus. Penaea cneorum* subsp. *ruscifolia* also contributes significantly to the low stratum (Table 3).

2.3 *Erica hispidula–Pentaschistis malouinensis* Shrublands

Differential species: *Pentaschistis malouinensis.*

Dominant species: *Chrysithrix capensis, Erica hispidula, Tetraria flexuosa.*

Structural formation: Low to Mid-high Closed Graminoid Shrubland.

Relationships: *Simocheilus carneus–Restio anceps* Community (Bond 1981); Ruitersberg Wet Ericaceous Fynbos (Campbell 1985).

This community has no differential species, but shares *P. malouinensis* with the *Pentaschistis malouinensis–Tetraria bromoides* Shrublands and many other species with communities E–H (see Table 3). These shrublands are distinctly graminoid in character, having an abundance of restios (*Elegia, Platycaulos, Restio*), grasses (*Pentaschistis*) and sedges (*Chrysithrix, Epischoenus, Tetraria*). The shrub component is dominated by ericas.

These shrublands are found on north- and south-facing slopes overlooking Boskloof and on north-facing slopes in the Langkuilen Valley at altitudes which range from 770–1 330 m. The gradients of sites sampled ranged from almost level (3°) to moderate (29°). The shallow soils are derived from Peninsula and Goudini Formation sandstone and are classified mainly as Cartref and Mispah Forms. The soil of relevé 188, located at the almost level site, consists of organic material in excess of 0.3 m and was classified as Champagne Form. Rock cover was generally less than 10% except for relevé 172 where 80% was recorded.

The dominant stratum of the *Erica hispidula–Pentaschistis malouinensis* Shrublands is a Low Closed Graminoid Shrubland (≤ 1.0 m) with dominance shared between the woody ericoid shrubs, *Erica hispidula* and

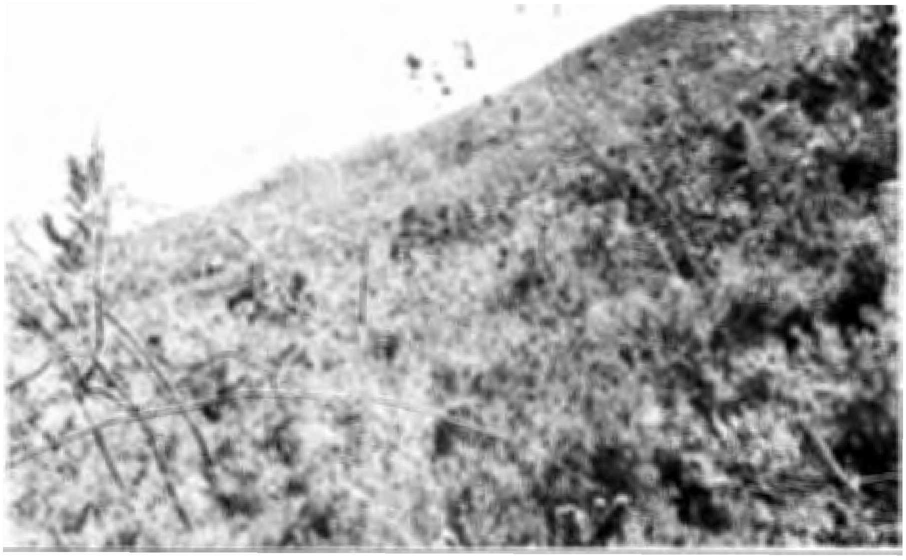

FIGURE 12.—The *Berzelia intermedia–Cliffortia grandifolia* Shrublands occurring in patches over extensive areas of the south slopes of the Clock Peaks and in Boskloof. Note the characteristic tall, slender *Cliffortia grandifolia*.

FIGURE 13.—The *Pentaschistis malouinensis–Tetraria bromoides* Shrublands found in Boskloof.

Blaeria coccinea and certain graminoids, particularly *Chrysithrix capensis* and *Tetraria flexuosa. Psoralea pinnata* and *Widdringtonia nodiflora* occur as sparse emergent shrubs up to 2 m high in some stands.

2.3.1 *Pentaschistis malouinensis–Tetraria bromoides* Shrublands (J)

Differential species: *Erica pubigera, Helichrysum pandurifolium, Leucadendron eucalyptifolium, Leucadendron salignum, Protea aurea, Tetraria bromoides.*

Dominant species: *L. eucalyptifolium, P. aurea, T. bromoides.*

Structural formation: either a Closed Graminoid Shrubland with Mid-high Open Shrubland Overstorey or a Mid-high Closed Shrubland with Tall Mid-dense Proteoid Shrubland Overstorey.

Relationships: *Tetraria bromoides–Erica plukenetii* Community (Kruger 1974); *Protea–Tetraria* Dry Short Fynbos (Boucher 1978); *Protea aurea–Pteridium aquilinum* Community (Bond 1981); Boesmansbos Azonal Restioid Fynbos (Campbell 1985); *Restio inconspicuus–Protea aurea* Shrublands (McDonald 1993).

The Cedarberg Formation shales crop out in a narrow band in a west-east direction in the Boskloof Valley. Drainage is to the east and where the shales are exposed, they support stands of the *Pentaschistis malouinensis–Tetraria bromoides* Shrublands. Three of the sample sites (Relevés 167, 175, 176) were located on shale-derived yellow-brown, Clovelly Form soils with mean pH 3.8 for the A-horizon. The fourth relevé (174) was situated on Glenrosa Form soil (pH 3.6) derived from Nardouw Subgroup sandstone. The estimated mean annual precipitation for the area where these shrublands are found is 800 mm. Elevation ranges from 840–950 m and the gradient from level (4°) to moderate (36°). Vegetation cover is usually high (mean 95%) and mean surface rock cover conversely low at 2.5%.

This community (Figure 13) is classified structurally as Low to Mid-high Closed Graminoid Shrublands with a Mid-high to Tall Open (Proteoid) Shrub Overstorey (see Campbell *et al.* 1981). Floristically these shrublands are not well defined compared with the equivalent community, the *Restio inconspicuus–Protea aurea* Shrublands found in the Boosmansbos Wilderness Area (McDonald 1993). In Boskloof, MNR, *Tetraria bromoides* is the most constant differential species with *Protea aurea* and *Leucadendron eucalyptifolium* each found in two of the four plots. *Protea aurea* was most abundant in a sheltered position on the edge of the riparian forest dominated by *Virgilia oroboides* (Relevé 175). The otherwise marked absence of stands of *P. aurea*-dominated vegetation on the Cedarberg shaleband in Boskloof suggests that this serotinous, seed regenerating species may have been adversely affected by past land use régimes (e.g too frequent or unseasonal fires). *L. eucalyptifolium* is somewhat more common but its distribution is patchy. This could indicate scattered outcropping of shale, but since this species also occurs on sandstones of the Nardouw Subgroup, no clear reason can be given for its local distribution pattern.

2.4 *Erica hispidula–Hypodiscus aristatus* Shrublands (K)

Differential species: none.

Dominant species: *Cliffortia heterophylla, Erica hispidula, Restio inconspicuus.*

Structural formation: either a Low to Mid-high, Mid-dense to Closed Shrubland or a Mid-high Closed Shrubland with a Low Mid-dense Graminoid Understorey.

Relationships: Nuweberg Mesic Ericaceous Fynbos (Campbell 1985).

This community (Figure 14) is found mainly on north- to northeast-facing slopes of the Clock Peak ridge, overlooking Boskloof, but also on the crest of 10 O'Clock Peak and on north-facing slopes above Langkuilen Valley.

FIGURE 14.—The *Erica hispidula–Hypodiscus aristatus* Shrublands found on the north- to northeast-facing slopes of the Clock Peak ridge. *Cliffortia heterophylla* dominates the overstorey in this stand.

FIGURE 15.—The *Hypodiscus aristatus–Phylica pinea* Shrublands found on the north-facing slopes of Goedgeloof Ridge and on rock outcrops in the Boskloof Valley.

Elevation of the shrublands ranges from about 1 000 m to 1 300 m on moderate slopes with a mean gradient of 27° (24°–28°). Rock cover varies from site to site over a range from 10–80%, with vegetation cover ranging from 70–95%. Estimated annual precipitation is from 800–900 mm.

The A-horizon of the soils have a mean pH 3.4. They are derived from Peninsula Formation and Goudini Formation sandstone and are classified as Cartref Form (Relevés 168 & 170) and Mispah Form (Relevé 181).

As indicated above, the community is structurally variable. The reason for presence of a mid-high closed stratum dominated by *Cliffortia heterophylla* in relevés 168 & 170 is not clear.

The *Erica hispidula–Hypodiscus aristatus* Shrubland community is the typical or 'background' community of the shrublands where *Cliffortia densa, Erica vestita, Hypodiscus aristatus, Pentameris macrocalycina, Stoebe cinerea* and *Thamnochortus cinereus* are common elements (see Table 3). It may be argued that description of the *Erica hispidula–Hypodiscus aristatus* Shrublands based on three relevés is tenuous. However, this indicates inadequate sampling, not the non-existence of the community.

2.4.1 *Hypodiscus aristatus–Phylica pinea* Shrublands (L)

Differential species: *Ceratocaryum decipiens, Phylica pinea, Tetraria thermalis.*

Dominant species: *Erica versicolor, Phylica pinea, Tetraria ustulata.*

Structural formation: Mid-high, Mid-dense Graminoid Shrubland.

Relationships: *Tetraria thermalis–Hypodiscus aristatus* Community (Kruger 1974), *Erica viridescens–Hypodiscus aristatus* Community (Bond 1981), Nuweberg Mesic Ericaceous Fynbos (Campbell 1985).

This community (Figure 15) is generally Open to Mid-dense Graminoid Shrublands with a Mid-high Open to Closed Ericoid Shrubland Overstorey (see Campbell *et al.* 1981). This community is found on the north-facing slopes of Goedgeloof Ridge and on rock outcrops in the Boskloof Valley. The rocky substrate, with a usual high percentage of boulders and exposed bedrock, results in shallow lithosols (≤ 0.20 m) classified here as Glenrosa and Mispah Forms. In Boskloof the community was sampled at 920 m (Relevés 178 & 201) whereas on Goedgeloof Ridge the mean altitude for the three sample plots (Relevés 193, 197, 198) was 1 173 m. The area sampled by the latter plots is mesic and represents a transition zone from the cooler, moister areas south of Goedgeloof Ridge to the drier lower slopes (see Table 4 and communities P & Q).

Phylica pinea is the most constant differential species in this community. Both *Tetraria thermalis* and *Ceratocaryum decipiens* have a wider distribution on the dry, north-facing slopes (see Table 4), therefore their differential value is diminished. *Erica atropurpurea* is faithful to this community but has a low cover-abundance. Dominance in the mid-high shrub stratum is held by *Erica versicolor*, which typically favours north-facing rocky outcrops (McDonald 1993). The lower stratum does not have a strikingly dominant species but *Tetraria ustulata* does stand out as having a higher cover-abundance than most.

2.4.2 *Hypodiscus aristatus–Erica versicolor* Shrublands (M)

Differential species: none.

Dominants: *Edmondia sesamoides, Ehrharta setacea* subsp. *scabra, Erica hispidula, Hypodiscus aristatus, Tetraria cuspidata.*

Structural formation: Open to Closed Graminoid Shrubland.

FIGURE 16.—The *Hypodiscus aristatus–Restio strictus* Shrublands are found at elevations from 1 200–1 400 m on exposed rocky sites with shallow soil.

Relationships: Nuweberg Mesic Ericaceous Fynbos (Campbell 1985); *Hypodiscus aristatus–Erica versicolor* Shrublands (McDonald 1993).

The habitats in which the *Hypodiscus aristatus–Erica versicolor* Shrublands and *Hypodiscus aristatus–Restio strictus* Shrublands occur are very similar. This is reflected in the structural and floristic similarity of these communities. They differ only in the respective presence and absence of *Erica versicolor* and *Restio strictus* and relative dominance of the graminoid species. The most apparent difference is that the *Hypodiscus aristatus–Erica versicolor* Shrublands are found on north-facing slopes as opposed to the south aspect of the *Hypodiscus aristatus–Restio strictus* Shrublands. This aspect difference appears to control the presence or absence of *Restio strictus* and *Erica versicolor*, therefore the difference between the communities is subtle.

Dominance of *Hypodiscus aristatus* in the graminoid component is important to note. *Rhodocoma alpina* Linder & Vlok (Restionaceae) a species endemic to this community (H.P. Linder pers. comm.) was not found in any of the relevés but was collected separately.

2.4.3 *Hypodiscus aristatus–Restio strictus* Shrublands (N)

Differential species: *Restio strictus.*

Dominants: *Chrysithrix capensis, Edmondia sesamoides, Erica hispidula, Ehrharta setacea* subsp. *scabra, Pentaschistis colorata.*

Structural formation: Closed Graminoid Shrubland.

Relationships: Nuweberg Mesic Ericaceous Fynbos (Campbell 1985).

This community (Figure 16) is found at elevations from 1 200–1 400 m. These Low Graminoid Shrublands (<1 m) vary from mid-dense to closed, depending on the locality. They may occur either on exposed rocky sites with shallow pockets of sandy soil or on sites with deeper soil and less rock exposed on the surface. The soils derived from Nardouw Subgroup sandstone vary in depth from 15–30 mm and are classified as Cartref and Mispah Forms. Aspect is mainly south- and southeast-facing, on slopes with a moderate gradient (mean 16°). The community receives an estimated mean annual precipitation of 1 000–1 200 mm, the soils are highly leached and litter accumulation is low.

This community is distinct and well differentiated by *Restio strictus.* Although ericoid shrubs are well represented, the graminoid nature of the *Hypodiscus aristatus–Restio strictus* Shrublands stands out. *Ehrharta setacea* subsp. *scabra, Pentaschistis colorata* and *Chrysithrix capensis* dominate with *Restio inconspicuus* and *Restio strictus* and various sedges playing a subordinate role. *Ursinia trifida* has low cover-abundance but is remarkably constant in the relevés and it is interesting to note the presence of *Erica daphniflora.* Notable absences are *Lobelia neglecta, Psoralea pinnata* and *Kniphofia uvaria,* but of prime importance is the absence of *Erica versicolor.* This absence distinguishes the community from the *Hypodiscus aristatus–Erica versicolor* Shrublands.

FIGURE 17.—The *Hypodiscus aristatus–Erica multumbellifera* Shrubland found on the north slopes of Goedgeloof Ridge.

2.4.4 *Hypodiscus aristatus–Erica multumbellifera* Shrublands (O)

Differential species: *Erica multumbellifera, Staberoha cernua.*

Dominant species: *Erica melanthera, Staberoha cernua, Tetraria ustulata.*

Structural formation: Closed Graminoid Shrubland.

Relationships: some affinities to the Acid Sand Flats Community (Boucher 1978).

The description of this community (Figure 17) is based on two relevés, 194 & 195. This small sample size places a question on the validity of this community concept but since it is distinctly different from all other communities described, it is retained for completeness. These shrublands show affinity to the shrublands of high elevation on shallow soils (Table 3).

The *Hypodiscus aristatus–Erica multumbellifera* Shrublands were sampled at 1 180 and 1 300 m on the north slopes of Goedgeloof Ridge. The sites were almost level with a mean gradient of 6°. The Cartref Form soils were 0.2–0.4 m deep and almost no rock was exposed on the surface. Litter was very low and vegetation cover exceeded 95%.

Relevé 194 had a more abundant graminoid component than Relevé 195, whereas *Erica melanthera* was more abundant in the latter sample. Presence of *E. melanthera* suggests impeded drainage in the soil, and a possible explanation for the existence of this community is wet soil conditions for part of the year and extremely dry soil for the remainder. This would preclude species intolerant of such conditions. A similar regime was found by Boucher (1978) in the 'Acid sand flats communities' where *Erica multumbellifera* was also found. Further sampling of the *Hypodiscus aristatus–Erica multumbellifera* Community over a wider range may provide more information about the habitat factors determining the distribution of this community.

This community is transitional between the communities of the cool, moist high elevations and those of the highly insolated, drier north-facing slopes of Goedgeloof Ridge described below. The transition is reflected in the species shared with both groups of communities.

3. *Leucadendron eucalyptifolium* Shrublands of the extreme north slopes

The two shrubland communities included in this section show strong floristic affinities to the shrublands on the lower south slopes on the sample transect. This is most likely due to the apparent equivalent nutrient status of the soils of the two extreme ends of the transect. Further investigation of these respective communities and their underlying environmental relationships is necessary before this hypothesis can be conclusively tested.

3.1 *Leucadendron eucalyptifolium–Erica melanthera* Shrublands (P)

Differential species: *Erica melanthera, Penaea cneorum* subsp. *ruscifolia, Psoralea pinnata, Staberoha cernua, Ursinia nudicaulis* (i.e. species occurring in at least three of four relevés).

Dominant species: *Leucadendron eucalyptifolium, Tetraria ustulata.*

Structural formation: Open to Closed Graminoid Shrubland with Mid-high to Tall Open Proteoid Shrubland Overstorey.

Relationships: *Protea neriifolia–Leucadendron eucalyptifolium–Erica triceps* Community (Bond 1981); Robinson Mesic Proteoid Fynbos (Campbell 1985).

This community (Figure 18) is found on the moderately steep (22°) north-facing slopes of Goedgeloof Ridge between 800–1 060 m. They are found mostly on shallow Glenrosa Form soils, but one notable exception was relevé 150 where the soil was sandy, 1.5 m deep with a bleached E-horizon and a podzolised B-horizon. This localized soil was classified as Lamotte Form, which is exceptional for this area. Surface rock cover is highly variable, ranging from 6–85% and the habitat is well drained.

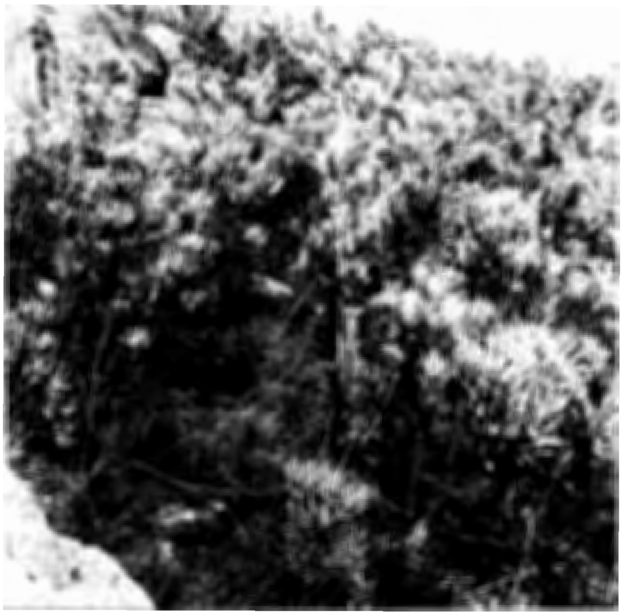

FIGURE 18.—The *Leucadendron eucalyptifolium–Erica melanthera* Shrublands are found on the moderately steep north-facing slopes of Goedgeloof Ridge.

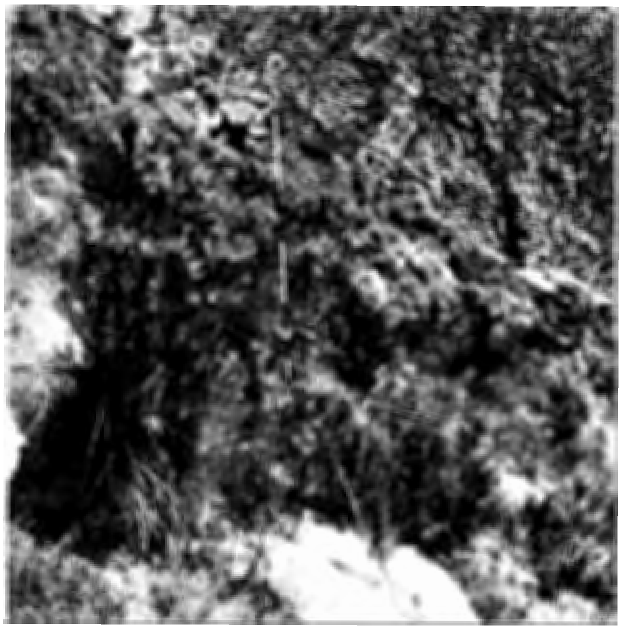

FIGURE 19.—The *Leucadendron eucalyptifolium–Hypodiscus argenteus* Shrublands found in a mosaic with the *Leucadendron eucalyptifolium–Erica melanthera* Shrublands on the moderately steep north-facing slopes of Goedgeloof Ridge.

As delimited here, the *Leucadendron eucalyptifolium–Erica melanthera* Shrubland is not floristically clearly defined. It appears that although a community definition is possible, the community represents fragments of two or perhaps more undersampled and undefined communities. They are grouped together by virtue of commonness of a few widespread 'differential' species but the 'strings' of single occurrences in Table 4 support the above conclusion. As defined, the community shows affinity to the communities of the lower south slopes and the high elevation zone described above under sections 1–3. However, high cover-abundance of *Leucadendron eucalyptifolium* and presence of *Elegia galpinii, Hypodiscus striatus* and *Anomalanthus scoparius* clearly place this community apart from those described above.

The *Leucadendron eucalyptifolium–Erica melanthera* Shrublands have two strata. The dominant stratum is an Open to Closed Graminoid Shrubland which does not exceed 1 m in height. Above this is an overstorey of *Leucadendron eucalyptifolium* (proteoid shrubs) which varies from open to mid-dense and from mid-high to tall (1– >2 m).

3.2 *Leucadendron eucalyptifolium–Hypodiscus argenteus* Shrublands (Q)

Differential species: *Heteropogon contortus, Hypodiscus argenteus, Lanaria lanata, Lobelia capillifolia* (i.e. species with four or more occurrences in five relevés).

Dominant species: *L. eucalyptifolium, Tetraria ustulata, Restio filiformis.*

Structural formation: Open to Closed Graminoid Shrubland with Mid-high Open Proteoid Shrubland Overstorey.

Relationships: in part, this community is equivalent to the *Phylica axillaris–Felicia filifolia* Community (Ruitersbos) and *Passerina obtusifolia–Felicia filifolia* Community (Swartberg) of Bond (1981) and Sebrafontein Dry Asteraceous Fynbos (Campbell 1985).

This community is found on the moderately steep north-facing slopes of Goedgeloof Ridge, in a mosaic with the *Leucadendron eucalyptifolium–Erica melanthera* Shrubland at elevations from 680–900 m. The soils, derived from Nardouw Subgroup sandstone, are classified as Glenrosa and Mispah Form. Surface rock cover exceeds 90% in all relevés representing this community but despite this there is considerable vegetation with a mean projected canopy cover of 78%. Estimated mean annual precipitation is 700–800 mm.

In the *Leucadendron eucalyptifolium–Hypodiscus argenteus* Shrublands (Figure 19), *Leucadendron eucalyptifolium* does not exceed 1.2 m and in two relevés (185 & 186), *Leucospermum calligerum* is the dominant proteoid in the overstorey. The upper stratum varies from a Mid-high Open to Tall Open Proteoid Shrubland and the lower (dominant) stratum varies from an Open to a Closed Graminoid Shrubland.

There are a number of affinities between this Community and the communities of the lower south slopes of the Langeberg above Swellendam. Equally there are numerous similarities between the *Leucadendron eucalyptifolium–Hypodiscus argenteus* Shrublands and the *Cannomois parviflora* Shrublands north of Grootberg (McDonald 1993). The *Leucadendron eucalyptifolium–Hypodiscus argenteus* Shrublands are mesic in character but may once again be represented by a group of relevés which through commonness are associated but which may truly be fragments of other communities, e.g. part of the more arid *Passerina obtusifolia–Leucospermum calligerum* Shrublands. This requires further clarification.

DISCUSSION AND CONCLUSIONS

The classification presented in this study was developed from a phytosociological perspective but with management of the fynbos shrublands of the Langeberg in mind (McDonald 1993). Some of the units defined are limited in extent, and from a management viewpoint it would not be practical to treat them separately from broader vegetation units. However, since the classification is hierarchical, similar communities are grouped together according to the level of the hierarchy. It is therefore possible for any manager of the fynbos shrublands of the Langeberg to select the appropriate level required for any particular management treatment. Those communities grouped at the same level may then be treated similarly.

Two problems have been encountered with the methods used in this study. Firstly, since no initial stratification of aerial photographs of the study area was done, some communities were undersampled. There is no satisfactory way of detecting this before analysis of the data. Both the TWINSPAN and Braun-Blanquet methods of classification have indicated communities that have been undersampled. The most obvious is the *P. malouinensis–Tetraria bromoides* Shrubland found on the Cedarberg shaleband. Another example is the *Hypodiscus aristatus–Erica multumbellifera* Shrubland for which a description is given. Ideally this community requires further sampling upon which an adequate description may be based. Fragments of communities recognized in other parts of the Langeberg are included in the *L. eucalyptifolium* Shrublands of the extreme north slopes of the transect. In the TWINSPAN analysis this was shown by relevés 185 and 186 being separated from relevés 151, 183, 184 and 199 (see also Table 4). Further sampling would clarify whether this is due to too few samples or that the communities are simply poorly represented in this part of the Langeberg. It was not possible to obtain further samples of these communities in this study because the area had been burnt soon after the initial samples were taken.

It may be argued that a community may be characterized by one or two species whose presence is a result of differential post-fire recruitment (Van Wilgen *et al.* 1992). This possibility would increase if the sample size for a given community is small, which in turn could lead to an artificial classification. However, each community is not based solely on the character species but is based on a specific combination of species for each community. These combinations should be seen as the key to identifying each community.

The complexity of the metamorphosed Malmesbury Group sediments that occur below the 'Plaat' is reflected in the vegetation occurring in this part of the MNR. Here fynbos communities characterized by constant presence of *Cliffortia serpyllifolia* are found on soils derived from quartzites and shales. The Afromontane forests also occur on the Malmesbury Group shales, but in this case in moist kloofs.

Although it has been stated that *P. aurea* may be used as a 'marker', indicating the position of the Cedarberg Formation shales in the folded strata along the length of the Langeberg (McDonald 1993), this is a misconception. A large stand of fynbos dominated by *P. aurea* is found at the base of 10 O'Clock Peak, below the 'Plaat', on Malmesbury shale-derived soil. The response of *P. aurea* is therefore to the fine-textured shale-derived soils with higher nutrient status, regardless of their lithological origin or stratigraphic position.

The vegetation of the MNR appears more complex than that of the Boosmansbos Wilderness Area (BWA) (McDonald 1993). This could be ascribed to more complex environmental gradients and a greater diversity of habitats. However, detailed analysis of environmental data is needed to substantiate such a claim.

No equivalent of the *Restio inconspicuus–Leucadendron eucalyptifolium* Shrubland which is widespread in BWA is found in the MNR. The *Restio inconspicuus–Anthochortus crinalis* Shrublands of BWA and the *Erica hispidula–Berzelia intermedia* Shrublands of MNR are essentially similar. The communities on the Cedarberg Formation shale of the two areas are similar except that the *Pentaschistis malouinensis–Tetraria bromoides* Shrubland is poorer in species. The *Cliffortia serpyllifolia* Shrublands of the lower south slopes of MNR have no equivalent in BWA. The reason for the absence of these shrublands or their equivalent in BWA is not clear but it may be due to the absence of shale-derived soils on the lower south slopes of the BWA transect.

The *Cannomois parviflora* Shrublands of BWA are represented in part by the *Leucadendron eucalyptifolium* Shrublands of the extreme north slopes of the MNR transect, but more extensive sampling and more detailed analysis is necessary to clarify the classification of these communities.

Communities identified in different studies from different mountain ranges can not be simply equated (McDonald 1993). At the landscape scale there does not appear to be much difference between the fynbos vegetation of the Marloth Nature Reserve and the Boosmansbos Wilderness Area (McDonald 1993). Apparent differences are more at the level of communities which are micro-habitat related. Closer examination is therefore required of (i) the patterns of distribution of communities on the Langeberg and (ii) the high turnover of species between communities and landscapes on the Langeberg. This is beyond the scope of the present paper but forms a principal part of further detailed analyses of the vegetation and flora of the Langeberg (McDonald unpublished).

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Appendix B

Appendix C

Bothalia 23,2: 239–263 (1993)

The vegetation of the southern Langeberg, Cape Province. 3. The plant communities of the Bergfontein, Rooiwaterspruit and Phesantefontein areas

D.J. MCDONALD*

Keywords: classification, forest, fynbos, Langeberg, phytosociology

ABSTRACT

The fynbos shrubland communities of the southeastern Langeberg, Cape Province were analysed after sampling 97 quadrats in the Bergfontein, Rooiwaterspruit (Garcia's Forest Reserve) and Phesantefontein areas. Data were initially analysed using TWINSPAN and the resulting classification refined using Braun-Blanquet (BB) procedures. One Afromontane forest community and 16 fynbos communities are recognized and described. A hierarchical classification of the fynbos communities is proposed.

UITTREKSEL

Die fynbos-struikgemeenskappe van die suidoostelike Langeberge, Kaapprovinsie, is geanaliseer. 'n Totaal van 97 monsterpersele in die Bergfontein-, Rooiwaterspruit- (Garcia Staatsbos) en Phesantefontein-gebiede is ondersoek. Data is aanvanklik deur Twinspan geanaliseer en die resultaat d.m.v. Braun-Blanquet prosedures (BB) verfyn. Een Afro-montane woudgemeenskap en 16 fynbosgemeenskappe word erken en beskryf. 'n Hiërargiese klassifikasie van die fynbosgemeenskappe word voorgestel.

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INTRODUCTION

A survey of the vegetation of the southern Langeberg was undertaken to describe the plant communities of this previously poorly documented mountain range. The descriptions of plant communities presented here are based on samples taken on the third of three sample transects

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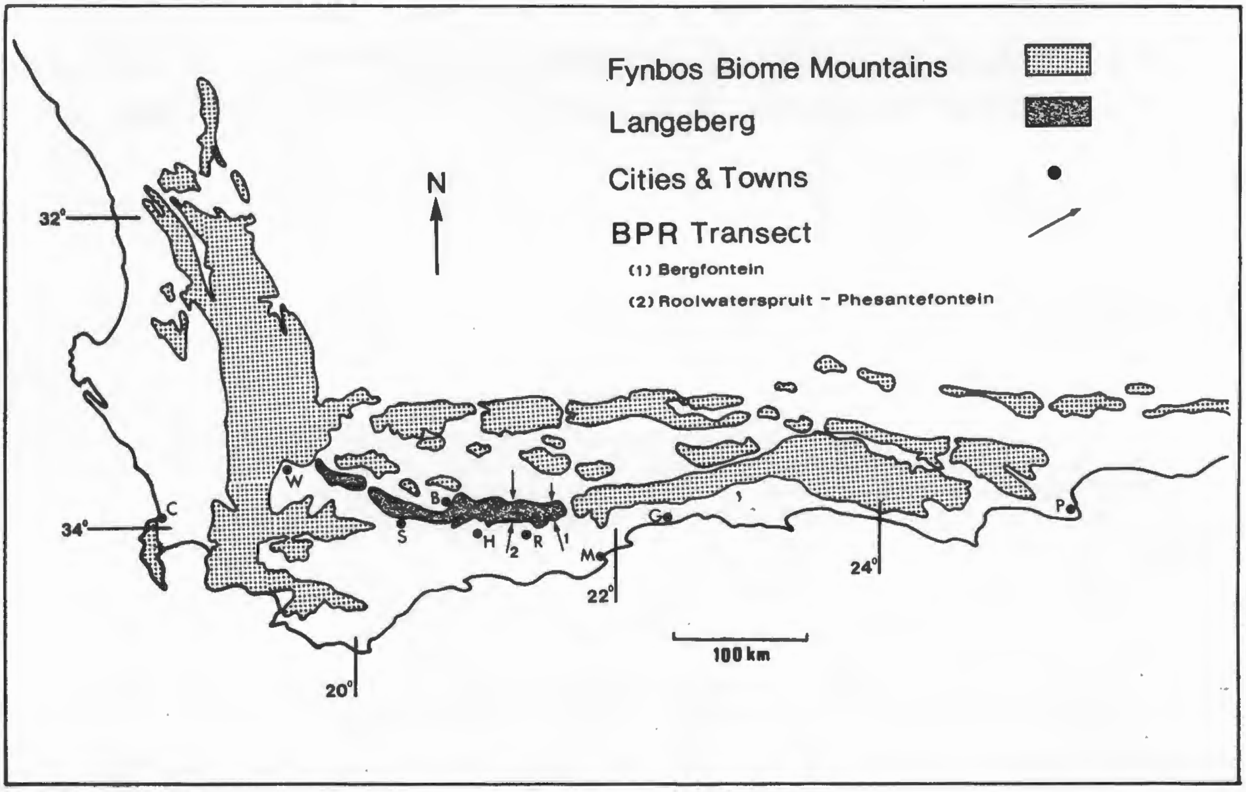

FIGURE 1.—Map of the mountains of the Fynbos Biome showing the position of the Langeberg and the location of the Bergfontein-Rooiwaterspruit-Phesantefontein areas. B, Barrydale; C, Cape Town; G, George; H, Heidelberg; M, Mossel Bay; P, Port Elizabeth; R, Riversdale; S, Swellendam and W, Worcester.

straddling the Langeberg at intervals between Swellendam and the Gouritz River. Each transect is treated separately (McDonald 1993a & b) but whereas the Marloth Nature Reserve (MNR) and Boosmansbos Wilderness Area (BWA) transects were more or less continuous from south to north, the third transect is a composite of samples from the Bergfontein area and the Rooiwaterspruit-Phesantefontein area (BRP) (Figure 1). This presented certain problems with respect to data analysis and interpretation which are discussed below.

STUDY AREA

Location

Numerous extensive wildfires have occurred on the Langeberg between Garcia's Pass and the Gouritz River in the past ten years (C. Martens pers. comm.). The fynbos vegetation on this part of the Langeberg is therefore almost all in a juvenile phase (<10 years) (Kruger 1979). Little choice was left in finding mature fynbos along a continuous transect for sampling vegetation on the third transect over the southern Langeberg. A transect which satisfied most logistic and sampling criteria was selected in the Bergfontein area, 33° 58′ S, 21° 33′ E. This area lies northeast of Riversdale, approximately midway between Garcia's Pass and the Gouritz River and is in the most easterly zone of the Langeberg. One negative feature was that the vegetation at Bergfontein was seven years old. However, despite the structural immaturity of the fynbos communities, the vegetation was in the 'maturing' successional phase (Kruger 1979) with the non-ephemeral species well established. It was therefore accepted that the floristic composition would reflect the 'mature' phase adequately and sampling could proceed.

The boundaries of the study area at Bergfontein followed the boundary between State Forest land and private agricultural land. The northern extreme of the designated transect extended onto private land where the vegetation was not disturbed by agriculture.

The Bergfontein transect followed the bridle path (Muir 1929) and sampling was largely confined to south- and southwest-facing slopes east of Witelsrivier. Four sample plots were located west of Witelsrivier opposite the western end of Koksposberg to accommodate the *Erica hispidula–Protea nitida* Shrublands not found in the remainder of the study area.

Shortly after 74 relevés had been recorded on the southern slopes of the Bergfontein transect, a wildfire destroyed all the vegetation on the transect. Therefore alternative sites with vegetation and habitat as similar as possible to the vegetation on the northern slopes and high-altitude south-facing slopes had to be found. Since no suitable sites were available east of Garcia's Pass, alternative sites were chosen west of Garcia's Pass above Rooiwaterspruit (high-altitude south-facing slopes) and above Phesantefontein (north-facing slopes) 33° 57′ S, 21° 9′ E.

At Rooiwaterspruit, which falls within the Garcia's Forest Reserve, four relevés (301–304) were recorded in vegetation on the Cedarberg Formation shaleband east of Stinkhoutbos. One plot (297) was located on the western side of the watershed between the headwaters of Rooiwaterspruit and Korinte River and three plots (298–300) were located on the steep, high-altitude south-facing slopes of the unnamed peak immediately west of Sleeping

Beauty (near trigonometric beacon 48). This latter peak is referred to as Korinteberg.

Above Phesantefontein, eight plots (286–293) were located in seven-year-old veld on the mid-altitude north-facing slopes east of Aasvoëlkrans (Garcia's Forest Reserve) and a further six (282–285, 295 & 296) in mature veld (>20 years) on the lower northern foothills of the Langeberg (Phesantefontein Farm).

Physiography and geology

Bergfontein

The south slopes of the Langeberg above Bergfontein are not as steep as the south slopes of the range further west. At the forefront of the mountain is Koksposberg, a prominent, isolated, low ridge-like hill or 'koppie'. This hill and others similar to it, to the west and east, ranging in altitude from 457–727 m and situated between the Kaffirkuils and Gouritz Rivers, are the remnants of the Peninsula Formation sandstone which is much more prominent further west. South of Koksposberg is a silcrete-capped mesa which supports fynbos. This area was excluded from the study since it fell outside the southern boundary of the transect and has been disturbed by agricultural practices. Immediately north of Koksposberg is the Cedarberg Formation shaleband which separates the Peninsula Formation sandstone from the Nardouw Subgroup sandstone. There is no deeply incised intermontane valley following the shaleband as there is in other parts of the Langeberg e.g. in BWA (McDonald 1993a). North of the shaleband is another 'koppie', of higher altitude than Koksposberg consisting of Nardouw Subgroup sandstone. Further north is Witelsberg which is a massive block of Nardouw Subgroup sandstone with steep south and north sides but with an expansive 'flat' top with shallow gradient from the west to the peak at 1 166 m at the eastern end.

Below the steep north slopes of Witelsberg is a plateau extending from west of Witelsberg to Waboomsrivier. North of the plateau is a dissected sandstone ridge which gives way to arid sandstone slopes. They in turn make contact with the Bokkeveld Group shales of the Little Karoo.

Rooiwaterspruit and Phesantefontein

In the Garcia's Forest Reserve west of Garcia's Pass, the Peninsula Formation sandstone forms massive peaks on the southern side of the mountain range. Sleeping Beauty (1 343 m) is the most prominent peak with Korinteberg (1 330 m) to the west and lower peaks further westwards towards Gysmanshoek. Behind the peaks lie two incised valleys where streams have eroded the shales of the Cedarberg Formation. North of the shaleband lies the Nardouw Subgroup sandstone with Aasvoëlkrans west of Stinkhoutbos reaching 1 341 m and another prominent peak east of Stinkhoutbos with a height of 1 330 m, referred to here as Phesanteberg.

Below the southern slopes of the mountain the Peninsula Formation sandstones make contact with silcrete-capped plateau-like mesas which in turn are dissected by numerous watercourses. The high northern slopes of Nardouw Subgroup sandstone grade at a moderate angle to the undulating foothills at Phesantefontein. The foothills consist of sandstone overburden and the remains of a once extensive silcrete-capped landscape. Remnant mesas are encountered extending well into the Little Karoo (Figure 2).

Soils

The soils of the Bergfontein and Rooiwaterspruit-Phesantefontein areas of the Langeberg are the same as those of the MNR and BWA (McDonald 1993a & b) at the level of 'form' (SCWG 1991). The climate of the three areas is similar (see below) as is the geology. Topographical variation and changes in parent material therefore account for most differences between the soils encountered on the BRP 'transect' and those of BWA and MNR. A description of the soil forms found on the southern Langeberg is given in McDonald (1993a); a summary of soil forms found on the BRP 'transect' follows:

Champagne Form soils are found at sites where there is a a deep (>200 mm) accumulation of organic material. On the BRP transect such sites are found mainly at high altitude on cool, moist south-facing slopes e.g. on Korinteberg. These soils also occur at lower elevations often in depressions where plant remains collect.

The catena of 'non-organic' soils derived from sandstone parent material in the study area include Houwhoek, Cartref, Glenrosa and Mispah Forms. Houwhoek and Cartref Form soils are closely related. The characteristics they share are an orthic A-horizon and presence of an E-horizon. They differ in that Houwhoek Form has a podzolised B-horizon overlying saprolite, whereas Cartref Form has a lithocutanic B-horizon. Glenrosa Form is similar to Cartref but lacks the eluviated E-horizon of the former. Mispah Form in turn is similar to Glenrosa Form, but here the orthic A-horizon overlies hard rock as opposed to the lithocutanic B-horizon of Glenrosa Form.

FIGURE 2.—Silcrete mesas on the north flank of the Langeberg, extending into the Little Karoo, at Phesantefontein.

Clovelly Form soils which have an orthic A-horizon over a yellow-brown apedal B-horizon are found in two situations derived from different parent materials: 1, on the Cedarberg Formation shale both at Bergfontein and at Rooiwaterspruit, behind Korinteberg; and 2, where there is accumulation of sand derived from Nardouw Subgroup sandstones, on dry north-facing slopes where leaching is limited.

Oakleaf Form soils which have limited extent in BWA (McDonald 1993a) but which were not identified in MNR occur on the lower south slopes at Bergfontein, below Koksposberg and on the west side of Witelsrivier. These soils which result from mixing of shale and sandstone have an orthic A-horizon and a reddish brown neocutanic B-horizon.

Climate

Characteristics of the climate of the BPR 'transect' are similar to those described by McDonald (1993a & b) for BWA and MNR. The southern Langeberg falls within a uniform bioclimatic zone, transitional between the winter rainfall region in the west and the year-round rainfall region in the east. The major climatic events which affect the weather of the southern Cape coast and the coastal mountains are the passage of cold fronts advancing from west to east, coastal lows and cutoff lows (Fuggle 1981; Van Heerden & Hurry 1987). A Walter-Lieth climate diagram for Riversdale (Figure 3A) gives an approximation of the climate of the lower south slopes of the Langeberg in the Riversdale-Gouritz River District.

Winds

The direction of surface winds affecting the southern Langeberg is dependent on season with summer winds blowing mainly onshore and winter winds mainly offshore. Calm periods occur approximately one-third of the time in both summer and winter (Schulze 1965).

Extreme fire-hazard conditions prevail when hot, dry berg winds occur in the southern Cape, mainly in winter (Van Wilgen 1984). They arise from air subsiding in response to pressure gradients between an established anticyclone and an advancing depression (Fuggle 1981). The fire which swept through the Bergfontein area in May 1991 occurred in such conditions.

Precipitation

Precipitation on the Langeberg is from rain, mist and snow. Snowfalls occur once or twice each winter mainly on the high peaks and ridges and do not persist. Mist is a year-round phenomenon, usually occurring at elevations from 1 000 m upwards. Rainfall occurs throughout the year with peaks in autumn (April) and spring (October). It may occur from unstable prefrontal conditions but is most often associated with postfrontal events. Eastward-moving cold fronts are usually followed by a 'ridging-in' by the South Atlantic anticyclone behind the fronts. Air movement over the warm Agulhas Current results in onshore advection of cool moist air (Cowling 1984; Preston-Whyte & Tyson 1988). Orographic rain occurs when this moist air strikes the coastal mountains.

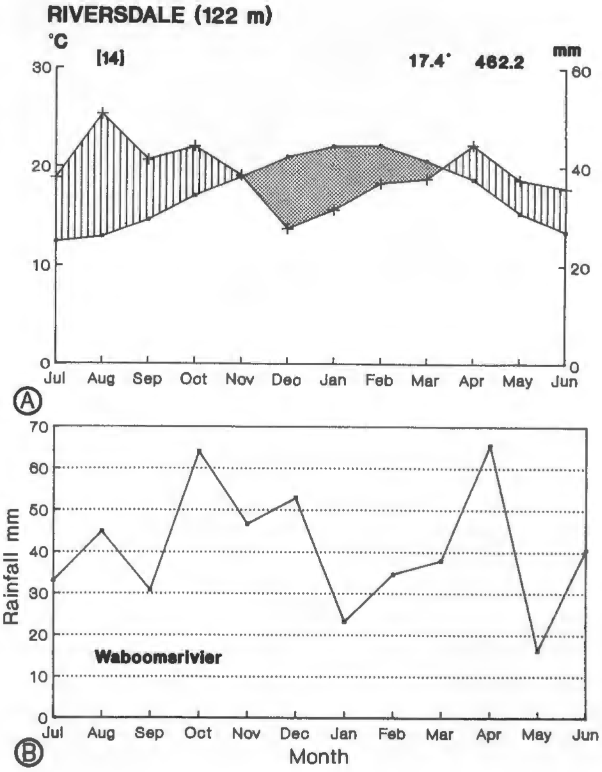

FIGURE 3.—A, climate diagram for Riversdale which approximates the climate of the lower south slopes of the Langeberg in the Riversdale-Gouritz River District; B, monthly rainfall (1984–1991) at Waboomsrivier on the north side of Witelsberg, showing peaks in April (autumn) and October (spring).

The high peaks in the MNR at Swellendam and in BWA receive an estimated 1 200–1 400 mm rainfall per annum. Proceeding eastwards, Kanetberg receives 500–600 mm, Aasvoëlkrans 600–700 mm, Korinteberg 700–800 mm and Sleeping Beauty 800–900 mm rainfall p.a. East of Garcia's Pass the peaks receive from 800–900 mm rainfall but the Bergfontein area (including Witelsberg south slopes) is much drier, receiving 600–700 mm rainfall p.a. (Dent *et al.* 1987). This gradient is opposite to that reflected in the mean annual rainfall for Heidelberg (378 mm) and Riversdale (426 mm) (Rebelo *et al.* 1991). The difference is attributed to the effect of orographic rainfall on the Langeberg; the more westerly higher altitude peaks receive more rainfall than the somewhat lower eastern part of the Langeberg close to the Gouritz River.

The north slopes of Witelsberg are in a rain shadow and are consequently much drier than the southern slopes. The mean annual precipitation for a seven-year period (1984–1990) at Waboomsrivier at the northern base of Witelsberg was 496 mm (P.E. Wadman pers. comm.); seasonal distribution of the rainfall is as shown in Figure 3B. Rooiwaterspruit and Korinteberg receive a mean annual precipitation of 700–800 mm, whereas the upper north slopes above Phesantefontein (east of Aasvoëlkrans) receive 500–600 mm and the lower north slopes 300–500 mm depending on locality (Dent *et al.* 1987).

Temperature

No temperature data are available for the study area; a situation commonplace in the Cape mountains where there are few weather stations (Bond 1981; Fuggle & Ashton 1979; Fuggle 1981). Extrapolation of temperature data from 'lowland' weather stations to montane situations has been done (Van Wilgen 1984) but this does not reflect the true montane temperature regime in most cases. The closest temperature recording station to the study area is at Riversdale. Temperatures recorded here may approximate those experienced on the lower south slopes of the Langeberg. Therefore, if the environmental lapse rate of 0.6°C/100 m (Cowling 1984) is used to predict montane temperatures, the high altitude south-facing slopes of Witelsberg at 1 150 m are predicted to have temperatures 6.26°C lower than Riversdale at 106 m.

Solar radiation

Incoming radiation may be measured directly (Morris 1981), which is cumbersome in mountainous terrain, or derived from sunshine duration. No data are published for sunshine duration on the Langeberg. Bond (1981) used Swift's (1976) algorithm to calculate potential radiation for a range of slopes and aspects for the 33° 30′ S latitude which is roughly equivalent to the latitude for the southern Langeberg. Bond (1981) found that potential radiation on the Swartberg and Outeniqua Mountains is relatively similar on all aspects and slopes in summer, with marked differences between north and south aspects, particularly on steep slopes, in winter. This holds for the Langeberg as well.

METHODS

Ninety-seven 5 × 10 m quadrats (McDonald 1983, 1988, 1993a & b; Campbell 1985; Boucher 1987) were sampled on a 'composite transect' over the Langeberg in the Bergfontein, Rooiwaterspruit and Phesantefontein areas. No stratification of the study area was undertaken since no suitable aerial photography was available. Plots were therefore subjectively placed at sites representative of major landscape features and vegetation communities.

Floristic, structural and environmental data were collected from each sample plot. Permanently recognizable species were recorded using the Braun-Blanquet cover-abundance scale (Mueller-Dombois & Ellenberg 1974; Werger 1974; Westhoff & Van der Maarel 1973). The midpoint of the BB values given as percentage cover is as follows: 5 = 87.5%; 4 = 62.5%; 3 = 37.5%; 2 = 15.0%; 1 = 2.5%; + = 0.1% ; R = value ignored. Ephemeral geophytes and annuals were noted in each relevé but were not used in analyses and descriptions of communities. A border zone of 1.5 m from the perimeter of each plot was searched for any species not found in the marked plot. Species occurring outside the plot are represented by 'O' in the phytosociological tables. Vegetation structure was measured by estimating the projected canopy cover and height of the respective strata. Environmental variables recorded include altitude, aspect, slope, geology, soil form, drainage and estimated soil depth. Mean annual rainfall was estimated from isohyet maps prepared by Dent *et al.* (1987).

Samples were taken only in fynbos shrubland communities. Stinkhoutbos in the Rooiwaterspruit area is a well-developed stand of Afromontane Forest but was not formally sampled (see below).

Two-way Indicator Species Analysis—TWINSPAN (Hill 1979a) was used to obtain an initial tabular classification of the data. This was followed by successive refinement of the phytosociological tables following the Braun-Blanquet method (Mueller-Dombois & Ellenberg 1974; Werger 1974) using the PCTables programs (Boucher pers. comm.). Detrended Correspondence Analysis—DECORANA Hill 1979b) was used to assess the relationship of the *Erica versicolor–Agathosma ovata* Shrublands to the other shrublands in the Bergfontein area (see below).

The plant communities are described in the order of the proposed hierarchical classification (see above). No syntaxonomic rank is assigned to any given community. Structural description follows the *a priori* system of Campbell *et al.* (1981).

The 'relationships' between communities described in this study and those described in other, previous studies of Mountain Fynbos were determined on the basis of floristic (mainly) and structural similarity. The similarities were determined from published descriptions and phytosociological tables. No rigid system was applied and the relationships serve merely as a guide for future synthesis of fynbos communities.

VEGETATION

The primary objective of a study such as this is to characterize the plant communities of a given area so that they may be repeatedly identified where they occur in the landscape. The early descriptions of the vegetation of the southeastern Langeberg by Muir (1929) in his treatment of the vegetation of the Riversdale area are highly informative but, apart from a broad classification, do not provide clear delineations of the fynbos communities. The fynbos vegetation sampled on the composite BPR 'transect' is classified into 16 communities: 10 at Bergfontein, two at Rooiwaterspruit and the remaining four at Phesantefontein. One Afromontane Forest community is recognized. The classification of the plant communities of the BPR transect is not complete since the scale of the study dictated that not all communities could be exhaustively sampled in the limited study area. Emphasis is on the sclerophyllous fynbos plant communities, since communities of this type make up the major part of the vegetation in the study area. Afromontane Forest communities are extremely limited in extent.

The vegetation of the south slopes of the Bergfontein area is mainly wet to mesic proteoid fynbos with a few isolated patches of trees in protected places. These trees such as *Cunonia capensis* are representative elements of Afromontane Forest. A well-developed stand of this forest type is located on an east-facing cliff of Perdeberg opposite Witelsberg. This forest is difficult to reach and fell outside the study area so it was not sampled. On the northern extreme of the Bergfontein transect, i.e. on the lower north slopes of Witelsberg, dry proteoid fynbos is encountered.

At Rooiwaterspruit, the south slopes also support wet proteoid and ericaceous fynbos with one well-developed patch of Afromontane Forest, Stinkhoutbos, in a moist kloof or ravine. The north-facing slopes above Phesantefontein have mesic proteoid to dry asteraceous fynbos communities.

During preparation of the phytosociological tables it was initially doubted whether relevés taken in mature or senescent vegetation (sensu Kruger 1979) would be satisfactorily accommodated, for reasons such as lack of differential species and overriding dominance of tall shrubs. It was interesting to note, however, that these relevés were appropriately placed in the tables and that they gave insights into the nature of the respective communities when they reach the mature and senescent phases (see 1.3.1 and 1.3.2.1 below).

Afromontane Forest

The description of Afromontane Forest is confined to the community found at Stinkhoutbos (Figure 4). No samples were taken in this forest which covers approximately 2 ha. A list of species confirms that it may be classified as the *Cunonia capensis–Platylophus trifoliatus* Subassociation (McKenzie 1978), also found in BWA (McDonald 1993a). As the colloquial name of the forest stand suggests, the stinkwood *Ocotea bullata* is common and co-dominant with *Cunonia capensis* and *Platylophus trifoliatus* in the canopy. *Virgilia oroboides* forms large trees mainly on the forest margins. *Plectranthus fruticosus* is the dominant understorey shrub.

Fynbos

1. *Erica hispidula* Shrublands

The role of *Erica hispidula* in linking the fynbos communities of the mesic to wet slopes of the southwestern and southern Cape mountains has been indicated by McDonald (1993a & b). The south slopes of the Langeberg at Bergfontein and Rooiwaterspruit are no exception. *Erica hispidula* is found in all the fynbos communities at Bergfontein except in the *Tetraria bromoides–Phylica pinea* Shrublands and with little occurrence in the wet *Erica hispidula–Brunia alopecuroides* Shrubland sampled on Korinteberg. The *Erica hispidula–Restio inconspicuus* Shrublands include the very wet high altitude shrublands on the south-facing slopes of the peaks, as well as shrublands forming part of the mosaic of communities on the mid and lower south-facing slopes of the Bergfontein area.

FIGURE 4.—Stinkhoutbos, a patch of Afromontane Forest in a secluded kloof at Rooiwaterspruit.

1.1 *Erica hispidula–Brunia alopecuroides* Shrublands

Differential species: *Brunia alopecuroides, Erica albens, E. mucronata, E. regerminans, E. transparens, Hippia integrifolia, Helichrysum capense, Indigofera concava, Lobelia pubescens* var. *rotundifolia, Restio fragilis.*

Dominant species: *Anthochortus crinalis, Brunia alopecuroides, Spatalla parilis, Platycaulos compressus.*

Structural formation: Low Closed Restioid Shrubland.

Relationships: *Brunia alopecuroides–Restio bifidus* Community (Kruger 1974); Subcommunity E2 of the *Erica–Penaea* Community (Glyphis *et al.* 1978); *Restio–Hypolaena* Subcommunity (H & I) (Laidler *et al.* (1978); Ericoid-Restioid Zone Fynbos (Taylor 1978); Low Narrow-sclerophyllous Heathland (Kruger 1979); *Simocheilus carneus–Restio anceps* Community (Bond 1981); Wet Mountain Fynbos (Moll *et al.* 1984); Ruitersberg Wet Ericaceous Fynbos (Campbell 1985); *Erica hispidula–Spatalla nubicola* Shrublands and *Restio inconspicuus–Anthochortus crinalis* Shrublands (McDonald 1993a): *Anthochortus crinalis–Erica curviflora* Shrublands (McDonald 1993b).

Owing to the fire in the Bergfontein area during this survey, sampling of the vegetation of the high altitude south-facing slopes of Witelsberg was not possible. As a substitute, four samples (297–300) were taken on similar slopes on Korinteberg. The community represented is equivalent to that found on Witelsberg prior to the fire (D.J. McDonald pers. obs.).

Moist air moving onshore from the southern Cape coast, together with mist and stratus cloud result in high orographic precipitation on the high altitude (above 1 000 m) south-facing slopes. The high precipitation, low temperature and reduced insolation result in low rates of organic matter decay and consequent accumulation of deep layers of peat-like material. This deep acid peat (pH 3.0 in 1 mol/l $CaCl_2$) with underlying Peninsula Formation sandstone, or Champagne Form soil, supports the *Erica hispidula–Brunia alopecuroides* Shrublands which are typical of these habitats (McDonald 1993a & b).

The *Erica hispidula–Brunia alopecuroides* Shrublands on Korinteberg (Figure 5) are well differentiated floristically (Table 1) with dense stands of mid-high *Brunia alopecuroides* shrubs dominating the upper stratum. *Spatalla nubicola* (Proteaceae), a narrow endemic, which is found in the equivalent shrubland community in the BWA (McDonald 1993a) is replaced by the closely allied *S. parilis* on Korinteberg. *Anthochortus crinalis* (Restionaceae), a dense mat-restio, dominates the understorey.

A specimen of *Erica dodii* was found in plot 298 on Korinteberg, which is the first record of this species on

TABLE 1.—Phytosociological table of the *Erica hispidula* Shrublands on the south slopes of the Bergfontein area, southern Langeberg

Community	1.1	1.2			1.3					1.4
	A	B	C	D	E	F	G	H	I	J
Altitude (m)	1111									
	1221	6765886	5566577666	455665445566	1154533544	8887	643343	33344344455	223443	3333
	2185	9166443	6721933544	803759746364	9922067312	7118	603129	01207135614	653536	1035
	1271	7278086	0504009122	530218078872	5534049804	6859	703844	95690894955	063594	0336
Aspect (°)	2122	1222222	1122211221	1112222221	1122222222	2222	321111	3333 3233	222211	11
	5810	7130025	9952242449	997573542875	9904811290	5296	516636	01401223843	658836	6009
	4574	0002550	0550100225	586603201583	5555000500	3000	084770	95855190805	066570	5005
Slope (°)	2433	1122321	3222212222	111211121212	21322221 1	21 2	232322	12311111222	122 11	1222
	1320	7441089	7557575466	989379922033	7927117982	2952	640021	63682949366	430966	7001
Relevé number	2223	2222222	2222222222	222222222222	2222222222	3333	222222	22222222222	222222	2222
	9990	5566777	3335555777	223334445577	1144444566	0000	233335	11122222466	111224	6666
	7890	8909346	1271267012	890890563457	2313489534	1234	734560	78902346212	456157	5678
Differential species of the Erica hispidula--Brunia alopecuroides Shrublands (1.1)										
Brunia alopecuroides Thunb.	5223									
Spatalla parilis Salisb. ex Knight	221									
Erica regerminans L.	12+									
Erica albens L.	+++									
Erica mucronata Andr.	+1R									
Erica transparens Berg.	R1									
Hippia integrifolia Less.	R++									
Helichrysum capense Hilliard	0 R									
Indigofera concava Harv.	R	+								
Lobelia pubescens Dryand ex Ait. var. rotundifolia	R +									
Restio fragilis Esterhuysen	R R									
Differential species of the Restio inconspicuus--Chondropetalum mucronatum Shrublands (1.2.1)										
Chondropetalum mucronatum (Nees) Pillans		04 1+2								
Chironia jasminoides L.		R 11+								
Species common to communities 1.1 & 1.2.1										
Platycaulos compressus (Rottb.) Linder	R233	12 2222								
Blaeria coccinea Klotzsch	1 1	32213R+		R						
Epischoenus quadrangularis (Boeck.) C.B. Cl.	++	++ 2 +3								
Anthochortus crinalis (Mast.) Linder	444	2								
Platycaulos anceps (Mast.) Linder	4	324								
Epischoenus cf. adnatus Levyns	1	+								
Erica curviflora L.	0	1								
Differential species of the Restio inconspicuus--Selago serrata Shrublands (1.2.2)										
Othonna quinquedentata Thunb.			+ 0 +0							
Selago serrata Berg.			0 0 R	+						
Syncarpha vestita (L.) B. Nord.			+1							
Species common to communities 1.2.1 & 1.2.2										
Pentameris macrocalycina (Steud.) Schweickerdt		222+15	02123222 4							
Centella lanata Compton		122222	1 +	+		R				
Syncarpha eximia (L.) B. Nord.		1+ +	0 R+ 0+		0					
Erica glomiflora Salisb. var. glomiflora		1+2+++	+ 22 2							
Berzelia burchellii Duemmer		0 5	+ 12+							
Gnidia oppositifolia L.		++1+	R		+	R				
Osteospermum corymbosum L.		0	+							
Species common to communities 1.1, 1.2.1, 1.2.2 & 1.2.3										
Pentaschistis malouinensis (Steud.) Clayton	1++	334 33	+3111+ +22	22+212+ 21			+1	+ 1		
Penaea cneorum Meerb. subsp. ovata (Eckl. & Zeyh.	111	1 ++ +	1+ ++2+1	+ +++ 0						
Chrysithrix capensis L.	++1+	1++ 1	++ R +	+ ++++ +						
Erica cordata Andr.	R233	2222	+	12						
Tetraria brevicaulis C.B. Cl.	R0	+	R1 +	+1+ +						
Senecio cordifolius L.f	R	+	+							
Centella sessilis Adamson			R++ +	R +R+ R						
Tetraria thermalis (L.) C.B. Cl.			1 +2 0	12				0		

TABLE 1.—Phytosociological table of the *Erica hispidula* Shrublands on the south slopes of the Bergfontein area, southern Langeberg (continued)

```
                                       Relevé number 2223*2222222*2222222222*222222222222*2222222222*3333*222222*22222222222*222222*2222
                                                     9990*5566777*3335555777*223334445577*1144444566*0000*233335*11122222466*111224*6666
                                                     7890*8909346*1271267012*890890563457*2313489534*1234*734560*78902346212*456157*5678

Species common to communities 1.2.1, 1.2.2, 1.2.3 & 1.3.1

Restio inconspicuus Esterhuysen                           2121+2 .+21+222+11.21111101 311.  0 + 11 1     .      .           .      .
Nevillea sp. nov.                                         122211 . +111++ 21.    21+  211.12 0+0         .      .           .      .
Berzelia galpinii Pillans                                 22 5 R .+    2   +.R23   4341 +.++2+R          .      .           .      .
Agapanthus africanus (L.) Hoffmg.                            +11 . + +      . +++ 0++    .+0     +       .      .           .      .
Edmondia sesamoides (L.) Hilliard                         R00    .+R1+RRR   .RRR11R + R0 .               .      .   +   0   .      .
Ursinia trifida (Thunb.) N.E. Br.                         +++  R .  + R 0RR+. R R R R R  .R              .R     .       +   .      .
Wahlenbergia fruticosa V. Brehm.                            +    .    R++RRR.          R .      RR       .     R.           .      .
Mairia crenata (Thunb.) Nees                                RR   . +R R   R+.      R     .+              .      .           .      .
Cullumia sp. (unidentified 237/17)                           1   .  +1      .   +1  1    .   1           .      .           .      .
Senecio purple lf. underside (lanceolate)                        .+R RR     .      RR    .  R            .      .           .      .
Bobartia macrospatha Bak. subsp. anceps Strid                    .          .       + +  .+0   +0        .      .           .      .
Erica seriphiifolia Salisb.                                      .          .            .2    ++        .      .           .      .
Lachnaea sp. nov.                                                .    ++    .            .+  0  1  +     .      .           .      .
Senecio ilicifolius (L.) Thunb.                                  .          .      0+    .  R    +       .      .           .      .

Species common to communities 1.1, 1.2.1, 1.2.2, 1.2.3 & 1.3.1

Leucadendron spissifolium (Salisb. ex Knight)        +  +.111 22 .+2+ 2 +012.   + ++     . 0 0 22        .     1.           .      .
Drosera aliceae Hamet                                 R  .R R  R . RR R+  R .RR RRR 0 RRR.    R  R       .      .           .      .
Ficinia capillifolia C.B. Cl.                        3   .   +   .          .            .         +     .      .           .      .

Differential species of the Ischyrolepis hystrix--Phylica rubra Shrublands (1.3.2.1)

Phylica rubra Willd.                                     .       .          .            .           +312       .           .      .
Cyclopia sessiliflora Eckl. & Zeyh.                  +   .       .          .            .           1R1        .           .      .
Indigofera sarmentosa L.                                 .       .          .            .   1        RRR       .           .    1 .

Differential species of the Ischyrolepis hystrix--Phylica pinea Shrublands (1.3.2.2)

Carpacoce spermacocea (Reichenb. f.) Sond. subsp.        .       .          .            .          .     0  + +            .      .
Knowltonia capensis (L.) Hutch.                          .       .          .            .          .     0   12            .    0 .
Serruria fasciflora Salisb. ex Knight                    .       .          .            .          .       ++ 0            .      .
Erica coccinea L.                                        .       .          .            .          .       ++              .      .
Pelargonium cordifolium (Cav.) Curtis                    .       .          .            .          .      +  1             .      .

Species common to communities 1.3.2.1 & 1.3.2.2

Ischyrolepis hystrix (Mast.) Linder                      .       .          .1           .   +       12 +.202121            .      .
Phylica pinea Thunb.                                     .       .          .            .0    +        +. 22+4             . 0   +.
Cannomois virgata (Rottb.) Steud.                        .       .          .            .           11 1. 5225             .      .
Erica grata Guth. & Bol.                                 .       .          .            .            111. ++21             .      .
Protea aurea (Burm. f.) Rourke subsp. aurea              .       .          .            .           43 2. 112              .      .

Species common to communities 1.2.1, 1.2.2, 1.2.3, 1.3.1, 1.3.2.1 & 1.3.2.2

Erica penicilliformis Salisb.                             +111 R .R2 2+   +1.1     + 1R 0.+1 +   +  .    .  11 +            .      .
Calopsis membranacea (Pillans) Linder                     + +    .   +11++12.        0   .  +    +  .R2  . 311              .      .
Widdringtonia nodiflora (L.) Powrie                       0002 + .   0R  1 +.       0    .    0     .21 +. +01+             .      .
Laurophyllus capensis Thunb.                                 +   .+  ++  1  .            .  1       .    . 1++10            .      .
Elegia equisetacea (Mast.) Mast.                          +      .          .            .11 2   +  .    . 1231             .      .

Differential species of the Tetraria bromoides--Hypodiscus striatus Shrublands (1.3.3)

Anomalanthus scoparius Klotzsch                          .       .     2 1  .            .          .    .+       1 1111213        .+
Hypodiscus striatus (Kunth) Mast.                        .       .          .            .   1      .    .1       12+ 321112       .
Heteropogon contortus (L.) Roem. & Schult.               .       .          .            .          .    .       ++1   11          .
Diosma tenella Williams                                  .       .                                  .    .       +++              1.
Peucedanum ferulaceum Thunb. var. ferulaceum             .       .          .            .          .    .            0            .
Polygala sp. (unidentified  222/31)                      .       .          .            .          .    .           R0+           .
Elegia galpinii N.E. Br.                                 .       .      1   .            .   +      .    .               423       .

Species common to communities 1.3.2.2 & 1.3.3

Osteospermum triquetrum L.f.                             .       .          .            .          .      +2  3.     +0 1         .
Centella virgata (L.f.) Drude var. virgata               .       .          .            .          .     +  + R. +1+ + ++         .
Otholobium sp. (1) (unidentified)                        .       .          .            .       +  .      11+  . 2                .
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TABLE 1.—Phytosociological table of the *Erica hispidula* Shrublands on the south slopes of the Bergfontein area, southern Langeberg (continued)

Relevé number	2223*2222222*2222222222*222222222222*2222222222*3333*222222*22222222222*222222*2222 9990*5566777*3335555777*223334445577*1144444566*0000*233335*11122222466*111224*6666 7890*8909346*1271267012*890890563457*2313489534*1234*734560*78902346212*456157*5678
Species common to communities 1.2.1, 1.2.2, 1.2.3, 1.3.1, 1.3.2.1, 1.3.2.2 & 1.3.3	
Merxmuellera rufa (Nees) Conert	1112 . 1 +1+ .3 R + +2 .R 2+2R 1 1. .++ .+ + +++ .
Erica triceps Link	. 3 +2 + . 333 R+ 2.1 11 R R. 1 2. . 2++ .
Hypodiscus aristatus (Thunb.) Krauss	. +1 +1112+. +1.2 + . . .1+ 1 1 .
Indigofera langebergensis L. Bol.	. + . 1+12+ R1. + . . . +R ++1 .
Acmadenia trigona Eckl. & Zeyh.	. + . . + . . + + .++ + 0++++1 .
Argyrolobium filiforme Eckl. & Zeyh.	R .RR R.ORR R . R R R . .R R . 0 .
Erica melanthera L.	. 1 + .4+0+2+ + 34. 0 . . .+ 1 + .
Tetraria fasciata (Rottb.) C.B. Cl.	. + + 12 . . 22 2 . . . 2 0 .
Syncarpha paniculata (L.) B. Nord.	.1 + + . +1 . . . . 2+ R +1 .
Pelargonium ternatum (L.f.) Jacq.	.1 . . + ...
Differential species of the Tetraria bromoides--Protea coronata Shrublands (1.3.4)	
Alepidea capensis R.A. Dyer	. . . . 0 RRR
Protea coronata Lam.	. . . . 1 +1
Erica cf. zwartbergense	. . . . ++0 2
Otholobium sp. (2) (unidentified)	. . . . 1 21
Species common to communities 1.3.3 & 1.3.4	
Tetraria pillansii Levyns	. . + ... + 21 . + 11
Tetraria capillacea (Thunb.) C.B. Cl.	. . . . . . 1 3 R.+
Species common to communities 1.3.1, 1.3.2.1, 1.3.2.2, 1.3.3 & 1.3.4	
Tetraria bromoides (Lam.) Pfeiffer	. . . 1 + 2+1111+2.+122.1++111.11 12122+ 2.+12212
Gnidia galpinii C.H. Wr.	. . . ++1+ ++ +. . +R++ .+1 + . +21+
Struthiola garciana C.H. Wright	. . . + R. . ++ .+++ +++ +R+.R
Psoralea monophylla (L.) C.H. Stirton	. . . +21 R + +. + . R+ 11. 0 .1 1
Thesium carinatum A. DC.	. . . + . . . + ++ R . 0
Clutia ericoides Thunb. var. tenuis Sond.	. . . + . . ++11 .1 . 11+
Sebaea stricta (E. Mey.) Gilg.	. . . + R . . + . . R 1
Athrixia heterophylla (Thunb.) Less subsp. heterop	. . . . RR .R . . R
Hypodiscus albo-aristatus (Nees) Mast.	. . . 2 21 . ++2. R . 2 1+ .
Aspalathus hypnoides Dahlg.	. . . + 11+. . +++ . 1 1 .
Phylica purpurea Sond. var. floccosa Pillans	. . . R . . . + ++.
Species common to communities all communities except 1.1.1, 1.1.2	
Tetraria crassa Levyns	. + + + . 2 +1 3 .1 10 22++. 1 2.2++ +. + + . + 22
Gerbera serrata (Thunb.) Druce	. + .R R . 0+ R + . . .R+++++1RR . R 0+
Berzelia intermedia Schlechtd.	. R 2 . 0 0+ . + 52 . 1 1. 24. .0 11+
Psoralea pinnata L.	. 1 + 2 . +2 .R + . 1R. ++ . + . RR+R+
Indigofera flabellata Harv.	. + .0 . + . . + .++ +R+ + 1 . 0
Stoebe alopecuroides (Lam.) Less.	. .+R + .0 R. . + .+ R .2+ +
Indigofera alopecuroides DC. var. minor	. + +++ . + . + . . 1 . 2 . + +
Tetraria fimbriolata (Nees) C.B. Cl.	. .+ + . 1 +12 1
Metalasia sp. (unidentified 219/26)	. 1 0 .+ . R . . . ++ RR . +
Species common to communities 1.2.1, 1.2.2, 1.2.3, 1.3.1, 1.3.2.1, 1.3.2.2, 1.3.3 & 1.3.4	
Thamnochortus cinereus Linder	+ + .++1101++++.1 111+ + 1+.20 + ++++. R +.+0 .1+ ++ 1+ . +
Ehrharta dura Nees ex Trin.	11 .++ ++ 1. +1 R+0 + . +++ 1+ 2. 2 R. 21 .+ 2+ R .++222
Leucadendron eucalyptifolium Buek. ex Meisn.	4 2 .+ 202+ R .2++ 2231 1.55232 1+22.3433.411211.3 401++233.55+12
Staberoha cernua (L.f.) Dur. & Schinz.	1 2 . +2 224122.2 123 +0022. 12 +1 +. . .22 221 1 .0+ 1
Tetraria flexuosa (Thunb.) C.B. Cl.	++1 . 21 +3 32. 22212+ 43.1 23125 2. . .22 2 22 . 20 2
Helichrysum felinum (Thunb.) Less	+ + 0 .11 ++R + +.+RO +1+ . 1++ . . +++ . +0 .+1+ 1R
Cullumia aculeata (Houtt.) Roesl. var. aculeata	+ . 10 . 3 12 .10 + +1++. . 1+ 1R. 10 ++ +++.
Ficinia trichodes (Schrad.) Benth. & Hook. f.	+11 .23+1 + ++1. 1+ ++1 . 2 . + . 2 + . R .
Pentaschistis colorata (Steud.) Stapf	2 2 .0+ +++ 2 . 1121 2.+ . RR . . 1 0 .43 1
Erica cubica L.	121 +. 0 .+34R+ 23 4 . R4 . . . + 1 0 0 . +
Thesium virgatum Lam.	R . R + + . R. + . . .++ 1++1+ . + +
Elegia asperiflora (Nees) Kunth	2 . R . 21 2014 1. 0 31 . . . + .
Tetraria ustulata (L.) C.B. Cl.	21 . 1 2 . . 3 . . . 2 . 1
Ehrharta ramosa (Thunb.) Thunb.	+ .+ R . R . .R . . .

TABLE 1.—Phytosociological table of the *Erica hispidula* Shrublands on the south slopes of the Bergfontein area, southern Langeberg (continued)

Relevé number	2223*2222222*2222222222*222222222222*2222222222*3333*222222*22222222222*222222*2222 9990*5566777*3335555777*223334445577*1144444566*0000*233335*11122222466*111224*6666 7890*8909346*1271267012*890890563457*2313489534*1234*734560*78902346212*456157*5678
Species common to communities 1.1, 1.2.1, 1.2.2, 1.2.3, 1.3.1, 1.3.2.1, 1.3.2.2, 1.3.3 & 1.3.4	
Stoebe plumosa (L.) Thunb.	R .+ .R 1 1 .00 1 . 2 . +. . 0 R0 . + + 1
Clutia alaternoides L.	+ . . . . .+++1.1 . .R+ ++
Elegia juncea L.	112.+ ++21 .+12++22 22.2 1 23+ ++ .122 3 11. 1+1.0 .23 +21 1 . +R+ +
Lobelia neglecta Roem. & Schult.	+ .+ 0+11R.+ + + + +.R +R+ 0.+0R+ 0+ R. +. 21R +. R R+ .+++ +
Differential species of the Erica hispidula--Protea nitida Shrublands (1.4)	
Protea nitida Mill.	. . . . 1 . 2 2222
Themeda triandra Forssk.	 5444
Forb - bristly leaves (unidentified)	. . . . ++++
Clutia laxa Eckl. ex Sond.	. . . . R+ +
Grass fine leaves bulbous base	. . . . ++0
Calopsis filiformis (Mast.) Linder	. . . . + +
Erica peltata Andr.	. . . . 11+
Tristachya leucothrix Nees	. . . . 21 1
Erica glandulosa Thunb.	. . . . 1 +
Pelargonium candicans Spreng.	. . . . R R
Protasparagus rubicundus (Berg.) Oberm.	. . . . 0 +
Rhus lucida L. forma lucida	. . . .0 . . . . +0
Eragrostis capensis (Thunb.) Trin.	 2
Species common to communities 1.3.4 & 1.4	
Diospyros glabra (L.) de Winter	. .+ . . . . . + +.+012
Anthospermum aethiopicum L.	. . . . 0 . . . 1 R+.++++
Helichrysum cymosum (L.) D. Don subsp. cymosum	. . . . +++ R. 0++
Montinia caryophyllacea Thunb.	. . . . R + 1 . + +
Crassula ericoides Harv.	. . . . + . 0RR
Rhus rosmarinifolia Vahl.	. . . . + .1+ +
Eragrostis curvula (Schrad.) Nees	. . . . 1.+ +
Pelargonium myrrhifolium (L.) L'Hérit. var. myrrhi.	. . . . + . 1
Species common to communities 1.3.3, 1.3.4 & 1.4	
Leucadendron salignum Berg.	. . . . . . +2212222 +1.++++12.3231
Selago dregei Rolfe	. . . . . . 0 ++0 . .++++
Aloe gracilis var. decumbens Reynolds	. . . . . . + + . + .++0
Species common to communities 1.3.2.2, 1.3.3, 1.3.4 & 1.4	
Phylica imberbis Berg.	. . . . . +.++++ ++ . +++ . +++
Euclea polyandra (L.f.) E. Mey ex Hiern.	. . . . . 0 0+ . +10 0+ ++. .++0+
Muraltia ciliaris DC.	. . . . . .+++ +R . R+R +.0+ R
Leucospermum cuneiforme (Burm. f.) Rourke	. . . . . R +11 . . + + .++
Scabiosa columbaria L.	. . . . . + R . .+++ R . +
Cymbopogon marginatus (Steud.) Stapf ex Burtt Davy	. . . . . 2 .+ +1.+ 2 2 .
Hermannia angularis Jacq.	. . . . . + . + .0 R .1++
Metalasia pungens D. Don	. . . . . . ++. .++ +
Senecio crenatus Thunb.	. . . . . ++ .+ . .++
Species common to communities 1.2.2, 1.2.3, 1.3.1, 1.3.2.1, 1.3.3, 1.3.4 & 1.4	
Penaea mucronata L.	. . . 0 2311+22+23. .2+11 +.21++1112+ .221121. 10+
Lanaria lanata (L.) Dur. & Schinz.	. . . 1 22. . +11+3.22212221122.+1232 .1221
Cliffortia stricta Weim.	. . . 1 ++ ++ +. . .1+ ++. 2 . R
Helichrysum nudifolium (L.) Less.	. . . R . . + . R . + . +0+
Aspalathus opaca Eckl. & Zeyh. subsp. opaca	. . . 1 ++. . .2 1 1 . 0 1 .+

TABLE 1.—Phytosociological table of the *Erica hispidula* Shrublands on the south slopes of the Bergfontein area, southern Langeberg (continued)

Relevé number	2223*2222222*2222222222*222222222222*2222222222*3333*222222*22222222222*222222*2222 9990*5566777*3335555777*223334445577*1144444566*0000*233335*11122222466*111224*6666 7890*8909346*1271267012*890890563457*2313489534*1234*734560*78902346212*456157*5678
Species common to communities 1.2.1, 1.2.2, 1.2.3, 1.3.1, 1.3.2.1, 1.3.2.2, 1.3.3, 1.3.4 & 1.4	
Tetraria cuspidata (Rottb.) C.B. Cl.	2 2 + .++11+1+1 1.+1 +2112111 . 21 11+.R . + . 11 1+2+1 +.+ 1+1 .+1++
Restio triticeus Rottb.	+ .++ + .+ 11 1 .1++1+++ 11. 11.1 ++ +.11111211+1+.22212+.2232
Ficinia filiformis (Lam.) Schrad.	R . . + + 1+ .+ . . . + 1 . + 1 .++ +
Pteridium aquilinum (L.) Kuhn	R . . .+ .1 4 . ++1 . . + +.++ +
Anthospermum galioides Reichenb. f. subsp. reflexi.	. + . 1+ .10 1 ++ +1. + +.+1 +1 .++1+1111111.+1 2R+.1+1+
Protea neriifolia R. Br.	+ . + 1R . R . + . 231.++ .221 + R23. 25 +. +
Erica versicolor Wendl.	.+ +2 2 . + 0R. + . .1 0. + +2. . +0
Lobelia coronopifolia L.	. 0 .R + ...1+ + +R+ . .++++
Ursinia hispida (DC.) N.E. Br.	. R . R . R . . .+ + . . +R
Corymbium glabrum L. var. glabrum	+ .+ 1+ 11++R.+ 222 1 . ++ . . . ++++ 11 .0 + . +
Mimetes cucullatus (L.) R. Br.	1 . 1 + . R .10 + 01 0. 1. 2+ 2. 0 . 1 0 .+11
Rhodocoma fruticosa (Thunb.) Linder	+ . 0 .++ ++. + R+ 1 ++. . .1+22+1+10 .+++ 21.++21
Psoralea azurea Stirton	++1 . 1 +. + 1+ . 1 + ...+ .R R
Senecio pinifolius (L.) Lam.	. . . + . .+ + +. 1 0+ . +++ . +0
Widespread species common to the majority of communities	
Erica hispidula L.	1 .++110R .+ 2+2 +2.++0R +R41 +.322 1++R12.1+ +. .22 2221 .232+23. ++
Bobartia macrospatha Bak. subsp. macrospatha	R .+ +R1+ .++R+ R+ ++. R+R+ . ++ +++++. R.+ +.11 ++ + .2 2+11. R+
Schizaea pectinata (L.) Sw.	R . . + R R. .++ R +RR .+RR .+ +.RR RRRRRR+. + . 0
Myrica kraussiana Buching ex Meisn.	R0 . . + . .+ . 1 +. +. .R + .++++

the Langeberg mountain range. A small population of the rare Langeberg endemic species *Empleurum fragrans* (Rutaceae) was also located close to plot 298 but not in the *Erica hispidula–Brunia alopecuroides* Shrubland; this represents a range extension of some 30 km east of its previously recorded range (Williams 1984). *Leucadendron radiatum* (Proteaceae), also a Langeberg endemic, is found on rocky promontories amongst the more uniform *Erica hispidula–Brunia alopecuroides* Shrubland.

FIGURE 5.—The *Erica hispidula–Brunia alopecuroides* Shrublands on the high altitude south-facing slopes of Korinteberg.

1.2 *Erica hispidula–Restio inconspicuus* Shrublands

This community, similar to the shrublands of the same name in BWA, comprises most of the shrublands where *Restio inconspicuus* is present. *R. inconspicuus* is not found in the *Erica hispidula–Brunia alopecuroides* Shrublands and is sparingly present in the *Tetraria bromoides–Berzelia galpinii* Shrublands (Table 2). The *Erica hispidula–Restio inconspicuus* Shrublands described here were sampled on the southern mid- to lower slopes of the Bergfontein area and are characterized by presence of *Agapanthus africanus, Berzelia galpinii, Nevillea* sp. nov. (Restionaceae) (newly discovered in the Bergfontein area) amongst other species (Table 2).

Penaea cneorum subsp. *ovata, Leucadendron spissifolium* and *Drosera aliceae*, all species which prefer moist slopes, occur in the *Erica hispidula–Brunia alopecuroides* Shrublands and the *Erica hispidula–Restio inconspicuus* Shrublands.

1.2.1 *Restio inconspicuus–Chondropetalum mucronatum* Shrublands

Differential species: *Chondropetalum mucronatum, Chironia jasminoides.*

Dominant species: *Blaeria coccinea, Platycaulos compressus, Restio inconspicuus.*

Structural formation: Closed Graminoid Shrubland.

Relationships: *Chondropetalum–Restio* Tussock Marsh (Boucher 1978); 'Slope-type' Restioid Marsh (Taylor 1978); *Erica mollis* Fynbos Community (Glyphis *et al.* 1978); *Restio–Hypolaena* Subcommunity (Laidler *et al.* 1978); Restiad Herblands (in part) (Kruger 1979); Sneeu-

TABLE 2.—A phytosociological table of the *Cullumia aculeata* var. *aculeata* Shrublands on the north slopes of Witelsberg (Bergfontein) and Phesantefontein, southern Langeberg

	Community
	3.1 3.2
	L M N O P
Altitude (m)	88776.6665.55.5555.4455 46873.3209.33.2664.7720 84866.0161.00.1015.0610
Aspect (°)	1 . .31. . 1 340 .3644.26.4234. 531 65008.2435.55.0000.5030
Slope (°)	22213.1 11. .2212. 111 66082.1924.68.8164.8944
Relevé number	22222*2222*22*2222*2222 88889*9999*99*7788*8888 67890*1234*56*8901*2345
Differential species of the Protea neriifolia--Merxmuellera decora Shrublands	
Merxmuellera decora (Nees) Conert	221 . . . R
Ischyrolepis 287/29	++ 1 . . .
Ficinia trichodes (Schrad.) Benth. & Hook. f.	+ R . . .
Differential species of the Protea neriifolia--Erica articularis Shrublands	
Ischyrolepis sieberi (Kunth) Linder	+1 . .
Euryops abrotanifolius (L.) DC.	RR . .
Aristea racemosa Bak.	RR . .
Zygophyllum fulvum L.	R + . .
Erica articularis L.	++ . .
Coelidium cymbifolium C.A. Sm.	RR . .
Cassytha ciliolata Nees	0 . .
Lobelia coronopifolia L.	R R . .
Species common to Communities 3.1.1.1 & 3.1.1.2	
Protea neriifolia R. Br.	11+21.RR+R . .
Otholobium sp. 2	+11+ .+1++ . .
Hypodiscus albo-aristatus (Nees) Mast.	1 2+ .R1 . .
Thamnochortus cinereus Linder	++++. + . .
Tetraria fasciata (Rottb.) C.B. Cl.	01 .1 . .
Phylica imberbis Berg.	1 . R . .
Tetraria pillansii Levyns	+. R . .
Phylica pinea Thunb.	1.R+ . .
Differential species of the Leucadendron eucalyptifolium--Elegia filacea Shrublands	
Elegia filacea Mast.	. 24 .
Hypodiscus laevigatus (Kunth) Linder	. 11 .
Calopsis filiformis (Mast.) Linder	. + .
Brunia laevis Thunb.	. R . .
Species common to Communities 3.1.1.2 & 3.1.2	
Centella stenophylla Adamson	RR++.+ .
Erica plukenetii L.	+ ++. 1 .
Species common to Communities 3.1.1.1, 3.1.1.2 & 3.1.2	
Leucadendron eucalyptifolium Buek. ex Meisn.	+131+.+R+0. + .
Ceratocaryum decipiens (N.E. Br.) Linder	2 1.2220.+ .
Anomalanthus scoparius Klotzsch	21.22 +.2 .
Staberoha cernua (L.f.) Dur. & Schinz.	22 .222 .1 .
Ficinia albicans Nees	R . .R .
Senecio pinifolius (L.) Lam.	++R . .RR .
Differential species of the Protea lorifolia--Ficinia lacineata Shrublands (3.2.1)	
Gnidia francisci H.Bol.	. . R+0+
Polygala refracta DC.	. . + 0R
Thesium subnudum Sond. 107/13	. . ++
Dodonaea angustifolia L.f.	. . ++++
Syncarpha milleflora (L.f.) B. Nord.	. . +R+
Cannomois parviflora (Thunb.) Pillans	. . +2
Siphocodon cf. spartioides Turcz. 47/2	. . R R
Othonna sp. 278/26	. . 1+ +
Linum gracile Planch.	. . R R+
Ficinia lacineata T. Arnold	. . +111
Relevé number	22222*2222*22*2222*2222 88889*9999*99*7788*8888 67890*1234*56*8901*2345
Species common to Communities 3.1.1.1 & 3.1.2	
Schizaea pectinata (L.) Sw.	R R . . . R
Mimetes cucullatus (L.) R. Br.	2 1+ . . .1
Anthospermum galioides Reichenb. f. subsp. reflexi	+ R . . .+1++
Rafnia capensis (L.) Druce	0 . . .1+ 1
Species common to Communities 3.1.1.2 & 3.2.1	
Erica cerinthoides L.	. +. . R+0
Phaenocoma prolifera (L.) D. Don	. + . .+ ++
Osteospermum junceum Berg.	. +. .+
Hermannia angularis Jacq.	. 0. .R
Species common to Communities 3.1.1.1, 3.1.1.2, 3.1.2 & 3.2.1	
Mastersiella purpurea (Pillans) Linder	.2+12. 0. +22
Aspalathus crassisepala R. Dahlg.	+ . +1 .0 .11++
Gerbera serrata (Thunb.) Druce	RR .RRR0.R .+ ++
Metalasia pungens D. Don	++ .++ .R .0 R
Hypodiscus argenteus (Thunb.) Mast.	22212. R . 1.11 1
Pentaschistis colorata (Steud.) Stapf	1.1+1+. R.2211
Species common to Communities 3.1.1.1, 3.1.1.2 & 3.2.1	
Struthiola garciana C.H. Wright	+0 .R RR. .++++
Thesium carinatum A. DC.	+++ . R+1. . +
Gnidia galpinii C.H. Wr.	1+++ .RR . .++1+
Thesium virgatum	+ R+. + . .R+
Euclea polyandra (L.f.) E. Mey ex Hiern.	+. . .++ +
Differential species of the Protea lorifolia--Leucospermum calligerum Shrublands (3.2.2)	
Thamnochortus karooica Linder	. . . 1 0
Lightfootia rigida Adamson	. . . ++
Machairophyllum cookii (L. Bol.) Schwantes	. . . 111+
Anthospermum spathulatum Sprengel subsp.spathulatu	. . . + ++
Metalasia massonii S. Moore	. . . + 1+
Cliffortia pulchella L.f.	. . . 0+1
Calopsis rigida (Mast.) Linder	. . . + 2
Calopsis marlothii (Pillans) Linder	. . . ++
Heterolepis sp. nov.	. . . + +
Hermannia odorata Ait	. . . +R
Passerina obtusifolia Thoday	. . . 2
Adromischus triflorus (L.f.) Berger	. . . +
Phylica purpurea Sond. var. floccosa Pillans	. . . 2+
Pentaschistis malouinensis (Steud.) Clayton	. . . +
Clutia laxa Eckl. ex Sond.	. . . +
Montinia caryophyllacea Thunb.	. . . 0
Cymbopogon marginatus (Steud.) Stapf ex Burtt Davy	. . . 1
Species common to Communities 3.2.1 & 3.2.2	
Selago dregei Rolfe	. . 0 . R
Helichrysum zwartbergense H. Bol.	. . 0 .0 0
Lobelia linearis Thunb.	. . R 0. +
Nenax acerosa Gaertn. subsp. acerosa	+ . . +1+.R
Species common to Communities 3.1.2 & 3.2.2	
Leucospermum calligerum (Salisb. ex Knight) Rourke	. +. .1211
Ficinia filiformis (Lam.) Schrad.	. RR. .++++
Stoebe microphylla DC.	. R. .1+
Acmadenia nivenii Sond.	. + . .+
Senecio paniculatus Berg.	. R . .RRR
Elytropappus rhinocerotis (L.f.) Less.	. R . . 1
Species common to Communities 3.1.2, 3.2.1 & 3.2.2	
Protea lorifolia (Salisb. ex Knight) Fourcade	. 1.+10+.1++
Lachnaea penicillata Meisn.	. 1+. + .+
Species common to Communities 3.1.1.2, 3.1.2 & 3.2.2	
Thamnochortus ellipticus Pillans	1+1+.++. . ++
Paranomus spathulatus (Thunb.) O. Kuntze	2. 1. .11 2
Protea aspera Phill.	2 1+.++. . +
Pelargonium tricolor Curt.	+.++. .R RR
Thoracosperma galpinii 97/23	03 .+ . .1+24

TABLE 2.—A phytosociological table of the *Cullumia aculeata* var. *aculeata* Shrublands on the north slopes of Witelsberg (Bergfontein) and Phesantefontein, southern Langeberg (continued)

Relevé number	22222*2222*22*2222*2222 88889*9999*99*7788*8888 67890*1234*56*8901*2345
Species common to Communities 3.1.1.1, 3.1.1.2, 3.1.2 & 3.2.2	
Restio filiformis Poir.	111 .1+21.2 . . +
Erica versicolor Wendl.	1.RR .0+. .0 R+
Species common to Communities 3.1.1.2, 3.2.1 & 3.2.2	
Willdenowia bolusii Pillans	. + . . +.2211
Syncarpha paniculata (L.) B. Nord.	R .++++. .++22.+ +
Aspalathus acanthes Eckl. & Zeyh.	. 1+. . ++1.R R
Elegia galpinii N.E. Br.	4 .+321. . 0 .213
Lightfootia fasciculata (L.f.) A. DC.	.RR +. .+++ . R
Species common to Communities 3.1.1.1, 3.1.1.2 & 3.2.1	
Osteospermum triquetrum L.f.	1+++ . 0+ . .+11+. +
Leucospermum cuneiforme (Burm. f.) Rourke	11+R . + . . 1 . +
Tetraria cuspidata (Rottb.) C.B. Cl.	+1+ .++12. .+111.+ R
Muraltia ciliaris DC.	+ . R+. .++++.+ R
Bobartia macrospatha Bak. subsp. macrospatha	R R .R . .R R.+ R
Lanaria lanata (L.) Dur. & Schinz.	12112.21+1. .++++.+ 1+
Metalasia galpinii (L.) Bol.	2. +1. .1 +. +
Tetraria crassa Levyns	11+ . + 0. . . + +
Species common to Communities 3.1.1.2, 3.1.2, 3.2.1 & 3.2.2	
Protea repens (L.) L.	R+.31.2 .011
Hypodiscus striatus (Kunth) Mast.	22.2 .1+1 .+211
Oedera imbricata Lam.	+ .R .++R+. ++R
Leucadendron salignum Berg.	122+.11.2222.1
Rhodocoma fruticosa (Thunb.) Linder	R+. R.+ + .11++
Species common to Communities 3.1.1.2 & 3.2.2	
Centella virgata (L.f.) Drude var. virgata	+. . . .0
Pelargonium fruticosum (Cav.) Willd.	+. . . .RR
Crassula atropurpurea (Haw.) Dietr. var. atropurpu	+. . . . 1
Widespread species common to all communities	
Willdenowia glomerata (Thunb.) Linder	1 ++ .+0++.RR.+++ . 0
Hypodiscus aristatus (Thunb.) Krauss	21 +. 1.1+.2111.1+
Cullumia aculeata (Houtt.) Roesl. var. aculeata	+ + +.0+++.0 .1++ .++++
Corymbium glabrum L. var. glabrum	1 +. +1 .R . +R.+ ++
Restio triticeus Rottb.	++ 11. +++.++.+1+1. +
Tetraria ustulata (L.) C.B. Cl.	2 2. 2. 2.3323.+1+1

kop Azonal Restioid Fynbos (Campbell 1985); *Restio inconspicuus–Anthochortus crinalis* Shrublands (McDonald 1993a); *Erica hispidula–Anthochortus crinalis* Shrublands (McDonald 1993b).

Chondropetalum mucronatum is widely distributed from the eastern Langeberg to Bainskloof and the Cape Peninsula in marshy places (Linder 1985). In the Cape Hangklip area Boucher (1978) records it as occurring on mountain slopes at sites with impeded drainage irrespective of aspect or altitude. This is similarly true on the Langeberg, however, at BWA and MNR (McDonald 1993a & b), stands of *C. mucronatum* are scattered and simply form part of the vegetation mosaic on south-facing wet slopes. At Bergfontein the distribution of *C. mucronatum* is not so scattered and the species differentiates a distinct community on localized seepages with a 'peaty coarse sand' substratum as it does in the Cape Hangklip mountains (Boucher 1978). *Chironia jasminoides* is also characteristic of marshy places from the southwestern Cape to the Riversdale District (Bond & Goldblatt 1984) and at Bergfontein, is almost at the eastern limit of its range.

At Bergfontein the *Restio inconspicuus–Chondropetalum mucronatum* Shrublands (Figure 6) occur within an altitudinal range from 560 m to 850 m on moderate slopes (14°–30°) with southeast- to southwest-facing aspects.

This community has an upper stratum dominated by *Chondropetalum mucronatum* (up to 1.5 m) which emerges above a low closed stratum (<0.5 m) where grasses, restios and ericas are present in more or less equal proportions. *Blaeria coccinea* (Ericaceae) is the dominant shrub with *Platycaulos compressus* and *Restio inconspicuus* (Restionaceae) and *Pentameris macrocalycina* and *Pentaschistis malouinensis* (Poaceae) comprising the major part of the graminoid component. The *Nevillea* sp. nov. recorded here is closely allied to the *N. obtusissima* recorded by Boucher (1978) in the *Chondropetalum–Restio* Tussock Marsh of the Cape Hangklip area.

1.2.2 *Restio inconspicuus–Selago serrata* Shrublands

Differential species: *Othonna quinquedentata, Selago serrata, Syncarpha vestita.*

Dominant species: *Elegia juncea, Leucadendron spissifolium, Pentameris macrocalycina, Pentaschistis malouinensis, Restio inconspicuus, Staberoha cernua.*

Structural formation: Low Open to Closed Graminoid Shrubland with sparse emergent shrubs.

Relationships: *Tetraria thermalis–Hypodiscus aristatus* Community (Kruger 1974); *Leptocarpus membranaceus (Calopsis membranacea)–Hypodiscus aristatus* Commu-

FIGURE 6.—The *Restio inconspicuus–Chondropetalum mucronatum* Shrublands on southeast- to southwest-facing slopes at Bergfontein.

nity (McKenzie *et al.* 1977); Subcommunity C of the *Penaea–Erica* Fynbos Community (Glyphis *et al.* 1978); Low Ericoid Open Heath or Open graminoid-heath (Kruger 1979); *Erica viridescens–Hypodiscus aristatus* Community (Bond 1981); Nuweberg Mesic Ericaceous Fynbos (Campbell 1985); *Hypodiscus aristatus–Berzelia intermedia* Shrublands (McDonald 1993a).

This community (Figure 7) is found on east- to southwest-facing rocky sites where surface rock was estimated at 32% on average. Slope inclination ranges from 17°–37° and the sandy Mispah Form soils (lithosols) are well drained. In general this shrubland has a single low stratum (<1 m) with *Psoralea pinnata* occasionally emergent to 2 m.

This shrubland community is poorly differentiated. It has only three character species, *Othonna quinquedentata, Selago serrata* and *Syncarpha vestita* which are poorly represented. It lacks the moisture-loving species common to communities 1.1 and 1.2.1 but has a strong graminoid component, a characteristic which it shares with the *Restio inconspicuus–Chondropetalum mucronatum* Shrubland. Apart from the dominant species, *Calopsis membranacea* and *Hypodiscus aristatus* (Restionaceae) are well represented, whereas *Berzelia galpinii* is not prominent. The low cover-abundance of *Berzelia galpinii* is ascribed to the shallow, rocky, well-drained nature of the soil.

1.2.3 *Restio inconspicuus–Erica melanthera* Shrublands

Differential species: none.

Dominant species: *Berzelia galpinii, Elegia asperiflora, Erica cubica, Pentaschistis malouinensis, Staberoha cernua, Tetraria flexuosa.*

Structural formation: Low Closed Graminoid Shrubland.

FIGURE 7.—The *Restio inconspicuus–Selago serrata* Shrublands found on rocky sites with east- to southwest-facing aspects above Bergfontein.

FIGURE 8.—The *Restio inconspicuus–Erica melanthera* Shrublands on grey shallow sandy lithosols at Bergfontein.

Relationships: as for 1.2.2 above but *Berzelia intermedia–Erica melanthera* Shrublands (McDonald 1993a) and *Leucadendron eucalyptifolium–Erica melanthera* Shrublands (McDonald 1993b).

This community (Figure 8) is found on a variety of aspects from northeast through south to southwest. The soils are grey sandy shallow lithosols, seldom exceeding 0.3 m and mostly <0.2 m deep. Amounts of exposed rock range from very low to 98% with most sample sites having 85% rock cover. Despite this, total vegetation cover is high at 94%.

The absence of differential species in this community is apparently related to the drainage régime. Species such as *Berzelia galpinii, Erica cubica* and *Elegia asperiflora* which have a strong preference for sites with impeded drainage, although occurring in other communities, play a dominant role here. *Erica melanthera* which favours shallow sandy soils is also mainly found in these shrublands, but this species is generally much less common than in the *Hypodiscus aristatus–Berzelia intermedia* Shrublands of BWA (McDonald 1993a).

The low stature of the community is ascribed to the shallowness of the soil and high percentage rock cover. It could be speculated, however, that some stands would reach mid-high to tall stature in older vegetation.

1.3 *Erica hispidula–Tetraria bromoides* Shrublands

These shrublands include five distinct communities that have *T. bromoides* as the common denominator. *T. bromoides* (Cyperaceae) is a robust leafy sedge that is known for its preference for heavier soils i.e. soils with a high clay fraction, derived from shale or sandstone (Boucher 1978; McDonald 1993a & b). Of note is the occurrence of *Penaea mucronata* in these shrublands. This species shows a distinctly different habitat preference (lower, drier slopes) to *Penaea cneorum* subsp. *ovata* which is found in communities of the *Erica hispidula–Restio inconspicuus* Shrublands on wetter, higher slopes.

1.3.1 *Tetraria bromoides–Berzelia galpinii* Shrublands

Differential species: none.

Dominant species: *Erica hispidula, Leucadendron eucalyptifolium, Penaea mucronata, Tetraria flexuosa.*

Structural formation: Low Closed Graminoid Shrubland with Mid-high Emergent Shrubs in some stands.

Relationships: *Berzelia–Leucadendron* Moist Tall Fynbos (Boucher 1978); Mixed-sclerophyllous Scrub (Kruger 1979); Mangold Wet Proteoid Fynbos (Campbell 1985).

This community (Figure 9) is found on south and southwest-facing slopes at altitudes ranging from 350–550 m. Soils are derived from sandstone of either the Peninsula Formation or Nardouw Subgroup and are generally 0.5 m deep, with soils at some sites as shallow as 0.1 m. The average slope of sampled stands is 21.3° (8°–32°). Rockiness is generally low, with an average of 12%, but with some sites having as much as 90% surface rock. Amount of litter depended on the age of the stand, with the old vegetation having an estimated 75% litter cover below the shrub canopy.

Two of the stands sampled (relevés 212 & 213) of the community were located in vegetation estimated to be 16 years or possibly older. The remainder of the samples were in six-year-old vegetation. The two mature stands gave a clear indication of how the *Tetraria bromoides–Berzelia galpinii* Shrublands would appear over a much wider area when mature. In the mature state they would be classified structurally as Tall Closed Proteoid Shrublands with a Closed Ericoid Shrubland Understorey, in contrast with the structural formation given above.

The *Tetraria bromoides–Berzelia galpinii* Shrublands are transitional between the *Erica hispidula–Restio inconspicuus* Shrublands on shallow sandy soils and the *Erica hispidula–Tetraria bromoides* Shrublands on soils with a high clay fraction derived either from shale or an admixture of sandstone and shale. Since the *Tetraria bromoides–Berzelia galpinii* Shrublands are ecotonal their floristic composition is complex, displaying elements of both the *Erica hispidula* Shrubland types given above (Table 1).

FIGURE 9.—The *Tetraria bromoides–Berzelia galpinii* Shrublands found on southerly slopes with sandy soils at altitudes from 350–550 m.

1.3.2 *Tetraria bromoides–Ischyrolepis hystrix* Shrublands

The two communities found on the Cedarberg Formation shaleband, the *Tetraria bromoides–Phylica rubra* and *Tetraria bromoides–Knowltonia capensis* Shrublands have many species in common but also a number of differences (discussed below). However, the absence of many species from these communities which are otherwise generally found in the *Erica hispidula–Tetraria bromoides* Shrublands sets these shrublands apart. These distinctions are ascribed to soil-related rather than climate-related factors.

1.3.2.1 *Ischyrolepis hystrix–Phylica rubra* Shrublands

Differential species: *Cyclopia sessiliflora, Indigofera sarmentosa, Phylica rubra.*

Dominant species: *Ischyrolepis hystrix, Leucadendron eucalyptifolium, Phylica rubra, Protea aurea, P. neriifolia, Tetraria bromoides.*

Structural formation: Tall Proteoid Shrubland with Mid-high, Mid-dense Shrub Understorey and Low Mid-dense Graminoid Field Layer.

Relationships: Broad-sclerophyllous Scrub (Kruger 1979); *Protea aurea–Pteridium aquilinum* Community (Bond 1981); Outeniqua Wet Proteoid Fynbos (Campbell 1985); *Restio inconspicuus–Protea aurea* Shrublands (McDonald 1993a); *Cliffortia serpyllifolia–Leucadendron eucalyptifolium* Shrublands and *Widdringtonia nodiflora–Tetraria bromoides* Shrublands (McDonald 1993b).

The *Ischyrolepis hystrix–Phylica rubra* Shrublands (Figure 10) were sampled on the Cedarberg Formation shaleband, east of Stinkhoutbos, behind Korinteberg. The mean altitude of the sample sites (relevés 301–304), which were located relatively close to each other in mature proteoid fynbos, is 824.5 m. Aspect ranged from southwest to west on shallow (5°) to moderate (22°) slopes. The yellow-brown sandy clay loam soils are classified as Clovelly Form, reaching a mean depth of 0.45 m. Surface rock cover is low, not exceeding 10% and the soils are moderately to well drained. Litter cover is high (60–80%) and the shrub canopy cover is closed (100%).

The age of the *Ischyrolepis hystrix–Phylica rubra* Shrublands, estimated at 15 years, could be a factor influencing the difference in species composition between this community and the closely allied but younger *Ischyrolepis hystrix–Phylica pinea* Shrublands found at Bergfontein (see below). Alternatively it may be postulated that geographical separation of the two areas where the shrublands were sampled may account for the differences between them (gamma diversity). These two shrublands may also be interpreted as variants of a broader shaleband community dominated by *Cannomois virgata, Erica grata, Ischyrolepis hystrix, Phylica pinea* and *Protea*

FIGURE 10.—The *Ischyrolepis hystrix–Phylica rubra* Shrublands found on the Cedarberg Formation shaleband east of Stinkhoutbos. Note the tall *Protea aurea* shrubs behind the figure.

aurea, since *P. aurea* and *Tetraria bromoides* dominated shaleband shrublands have been recorded in other parts of the Langeberg (McDonald 1993a & b). As much as the differential species separate the above two communities from each other, absence of numerous species, the most notable of which are *Gnidia galpinii, Lanaria lanata, Penaea mucronata* and *Struthiola garciana*, reinforce the distinction between the two shrublands (Table 2).

1.3.2.2 *Ischyrolepis hystrix–Phylica pinea* Shrublands

Differential species: *Carpacoce spermacocea, Erica coccinea, Knowltonia capensis, Pelargonium cordifolium, Serruria fasciflora.*

Dominant species: *Cannomois virgata, Ischyrolepis hystrix, Leucadendron eucalyptifolium, Phylica pinea.*

Structural formation: Tall Mid-dense to Closed Restioid/Proteoid Shrubland with Sparse Mid-high Shrub Understorey and a Low Mid-dense to Closed Graminoid Shrubland field layer.

Relationships: as for 1.3.2.1 above.

Apart from relevé 227, samples representing the *Ischyrolepis hystrix–Phylica pinea* Shrublands (Figure 11) were found at altitudes from 300–400 m on southeast- to southwest-facing slopes of the Cedarberg Formation shaleband, where it traverses the Bergfontein area. Relevé 227 was sampled on a shale lens on a moderate northwest-facing slope above Rooiwaterspruit, where the soil is a 0.3 m deep, yellow-brown loamy Clovelly Form soil. The soils at Bergfontein were not classified except that they were noted to have a grey-brown orthic A-horizon.

At Rooiwaterspruit, the vegetation in relevé 227 was dominated by *Leucadendron eucalyptifolium* in the tall (1.5–3.0 m) mid-dense canopy. Non-ericoid shrubs and graminoids combined to form a closed understorey, 1.5 m high. The community represented by relevé 227 is somewhat different to the Bergfontein Community since many of the typical shaleband-associated species are absent (Table 2). However, it is similar enough to the *Ischyrolepis hystrix–Knowltonia capensis* Shrublands and different enough from the *Ischyrolepis hystrix–Phylica rubra* Shrublands for it to be included in the former. The community at Bergfontein was dominated by the tall (1.2–5.0 m) *Cannomois virgata* in the canopy, with a mid-high, mid-dense stratum dominated by *Phylica pinea* and *Protea aurea* and a low, closed stratum dominated by restioids.

The *Ischyrolepis hystrix–Phylica pinea* Shrubland is the only community from which *Erica hispidula* is totally absent. No explanation for this can be advanced since this species occurs in similar communities in the MNR and BWA (McDonald 1993a & b). A combination of wetness and shale-derived soil may account for the absence of this species.

1.3.3 *Tetraria bromoides–Hypodiscus striatus* Shrublands

Differential species: *Anomalanthus scoparius, Diosma tenella, Heteropogon contortus, Hypodiscus striatus, Peucedanum ferulaceum, Polygala* sp.

Dominant species: *Anomalanthus scoparius, Erica hispidula, Hypodiscus striatus, Lanaria lanata, Leucadendron eucalyptifolium, L. salignum, Tetraria bromoides.*

Structural formation: Low Mid-dense to Closed Graminoid Shrubland with Mid-high to Tall, Sparse to Mid-dense Proteoid Shrubland Overstorey.

Relationships: Mixed-sclerophyllous Scrub (Kruger 1979); *Protea neriifolia–Leucadendron eucalyptifolium–Erica triceps* Community (Bond 1981); Robinson Mesic Proteoid Fynbos (Campbell 1985); *Hypodiscus aristatus–Leucadendron eucalyptifolium* Shrublands (McDonald 1993a); *Leucadendron eucalyptifolium–Erica melanthera* Shrublands (McDonald 1993b).

FIGURE 11.—The *Ischyrolepis hystrix–Phylica pinea* on the Cedarberg Formation shaleband in the Bergfontein area. Note the tall restio, *Cannomois virgata*, characteristic of this community.

These shrublands (Figure 12) were sampled on the north and northwest slopes of Koksposberg and on the west-facing mid-slopes of Witelsberg, overlooking Witelsrivier (Bergfontein area). The community occurs at altitudes from 300–550 m on sites with shallow (0.2 m) well-drained sandy loam soils, where the slopes are moderate to steep (16°–36°) and where rock cover varies from almost nil to 90%.

Presence of *Tetraria bromoides* points to soils with a higher fertility, however, soil-vegetation relationships of this community are not clear and require further investigation. The community is clearly defined and characterized by differential species (Table 1) which have a preference for stony or rocky well-drained sites. All the differential species are also species of low stature which are found in the understorey of mature stands of the *Tetraria bromoides–Hypodiscus striatus* Shrublands. *Anomalanthus scoparius* (Ericaceae) grows as a prostrate dwarf shrub covering stony soil but not over rocks (E.G.H. Oliver pers. comm.) and the erect *Hypodiscus striatus* (Restionaceae) is found as tussocks in shallow pockets of soil. *Heteropogon contortus* is a subtropical C_4 grass which Bond (1981) recorded as differential for his *Protea nitida* Community (Waboomveld) on fertile soils. At Bergfontein, *H. contortus* is faithful to the *Tetraria bromoides–Hypodiscus aristatus* Shrublands and not found at all in the *Erica hispidula–Protea nitida* Shrublands described below. *Diosma tenella* (Rutaceae) is a shrublet which Williams (1982) described as 'rather rare' but having a wide tolerance for different soil types, from shales to sandy gravels and silcrete.

From Table 1 it is seen that there are numerous species which, although not differential or dominant, are strongly represented in this community: *Acmadenia trigona, Leucadendron salignum, Lanaria lanata, Penaea mucronata, Staberoha cernua, Tetraria flexuosa* and *Rhodocoma fruticosa.*

One or two strata were found in these shrublands at the time of sampling. One stratum was found where the shrubs were co-dominant with the graminoid component up to a height of 1 m. Two strata occurred where the shrubs, mainly proteoids such as *Leucadendron eucalyptifolium* and *Protea neriifolia*, exceeded 1 m, forming a sparse to mid-dense overstorey. The immaturity of the vegetation gave a false impression of the potential structure of the community, which is predicted to become a tall closed proteoid shrubland with a low closed ericoid or restioid shrubland understorey when mature (as in relevés 261 & 262).

Relationships: Broad-sclerophyllous Scrub (Kruger 1979); Outeniqua Wet Proteoid Fynbos (Campbell 1985); Wet Proteoid Fynbos (Rebelo *et al.* 1991).

1.3.4 *Tetraria bromoides–Protea coronata* Shrublands

Differential species: *Alepidea capensis, Erica* cf. *zwartbergense, Protea coronata.*

Dominant species: *Erica hispidula, Lanaria lanata, Leucadendron eucalyptifolium, Tetraria bromoides.*

Structural formation: Mid-high Closed Proteoid Shrubland with Low Closed Graminoid Shrubland Understorey or a Low Closed Graminoid Shrubland with Sparse emergent Proteoid shrubs.

This community (Figure 13) occurs on the lower southeast-, southwest- and west-facing slopes of Koksposberg in the Bergfontein area. At plot 221 the soil is derived from Cedarberg Formation shale, whereas at the remainder of the plots (214–216 & 247) the soils are apparently derived from accumulated material at the footslopes. The soils are well-drained shallow (0.2–0.3 m) fine-textured grey-brown to dark brown sandy loams, with negligible surface rock cover.

The distribution of *Protea coronata* is strongly related to edaphic factors with this species favouring heavy soils with a high clay fraction (Rourke 1980). At Bergfontein, *Protea coronata* occurs on sandy loam soils but, contrary to Rourke's description where *Protea coronata* is said to form 'densely massed stands', the species occurs as scattered individuals. Frequent fires may have excluded *P. coronata*, a reseeding proteoid, at three of the five sample sites. Alternatively these sites may be marginally more mesic and *P. coronata*, which prefers wetter sites (Rourke 1980), may have been outcompeted by *Protea neriifolia* and *Leucadendron eucalyptifolium* (Table 2). Even though the *Tetraria bromoides–Protea coronata* Shrubland is poorly characterized by the differential species *Alepidea capensis, Erica* cf. *zwartbergense* and *P. coronata*, it is substantiated by absence of numerous species found in the *Tetraria bromoides–Hypodiscus striatus* Shrublands on the one hand and the *Tetraria bromoides–Protea nitida* Shrublands on the other. It also has many species in common with the latter community, in particular the ubiquitous 'waboomveld' species *Montinia caryophyllacea* and *Rhus rosmarinifolia. Helichrysum cymosum* is not a true differential species of the *Tetraria bromoides–Protea coronata* Community as stated by Rebelo *et al.* (1991) since this species is also well represented in the more mesic *Erica*

FIGURE 12.—The *Tetraria bromoides–Hypodiscus striatus* Shrublands on the west-facing slopes of Koksposberg with the south slopes of Witelsberg visible behind.

FIGURE 13.—The *Tetraria bromoides–Protea coronata* Shrublands on the lower slopes of Koksposberg, in the Bergfontein area.

hispidula–Protea nitida Shrublands which were not sampled or described by these authors.

Two strata were found in these shrublands. Graminoids are marginally more abundant than woody shrubs in the low stratum, which was the dominant stratum when sampled. In relevé 247, the low stratum had been disturbed by grazing animals. The upper stratum was dominated by mid-high proteoid shrubs, *Leucadendron eucalyptifolium* and *Protea neriifolia*. Following Campbell's (1985) system, the *Tetraria bromoides–Protea coronata* Shrublands would be placed in the Mesic Proteoid Subseries, however, based on floristic composition and relationships, the community is placed unequivocally in Wet Proteoid Fynbos.

Aloe gracilis Haw. var. *decumbens* Reynolds was found in this community and the *Erica hispidula–Protea nitida* Shrublands. Reynolds (1950) gives the distribution of this endemic variety of *Aloe gracilis* as from near Garcia's Pass westwards to Kleinberg at altitudes 272–364 m. Records of *A. gracilis* var. *decumbens* at Bergfontein represents a range extension for this species on the Langeberg, 30 km east of Garcia's Pass. Future searches could reveal that it may occur further east, perhaps beyond the Gouritz River.

1.4 *Erica hispidula–Protea nitida* Shrublands

Differential species: *Anthospermum aethiopicum, Calopsis filiformis, Clutia laxa, Eragrostis capensis, Erica glandulosa, E. peltata, Pelargonium candicans, Protasparagus rubicundus, Protea nitida, Themeda triandra.*

Dominant species: *Lanaria lanata, Leucadendron salignum, Protea nitida, Restio triticeus, Themeda triandra.*

Structural formation: Closed Graminoid Shrubland with Mid-high Sparse to Open Proteoid Overstorey.

Relationships: 'Waboomveld' (Taylor 1963, 1978; Taylor & Van der Meulen 1981); *Protea arborea* (*P. nitida*) Pseudo-Savannah (Taylor 1969); *Protea arborea–Rhus angustifolia* Community (Werger *et al.* 1972); *Protea–Tetraria* Dry Short Fynbos (Boucher 1978); *Restio gaudichaudianus* (*Ischyrolepis gaudichaudiana*)*–Lobostemon glaucophyllus* Community (McKenzie *et al.* 1977); *Protea arborea* (*P. nitida*) Tall Broad-sclerophyllous Shrubland or Open Shrubland with Heathland (Kruger 1979); *Protea nitida* Community (Waboomveld) [Outeniqua Mountains] & *Protea nitida–Protea repens* Community [Swartberg] (Bond 1981); *Protea nitida* Woodland ('Waboomveld') (Taylor 1984); Rooiberg Talus Asteraceous Fynbos (Campbell 1985); *Ischyrolepis gaudichaudiana–Myrsine africana* High Closed Shrubland (McDonald 1983, 1988).

Protea nitida is most often found on colluvial soils on debris or talus slopes but may also be found on fine-textured soils on lower mountain slopes (Taylor 1978; Kruger 1979; R.M. Cowling pers. comm.). These soils generally have a higher nutrient status than that of leached sandstone soils, due to colluvial mixing of soil derived from various parent materials such as sandstone, granite or shale. Fynbos with *P. nitida* as a prominent, if not dominant shrub or tree, is found throughout the Fynbos Biome and according to Taylor (1978) and Kruger (1979) characterizes a distinct formation, 'waboomveld'. The term 'waboomveld' encompasses more than one community where *P. nitida* is present, but throughout the distribution range of this species from the northwestern to the southern Cape there is a remarkably constant group of associated species including *Anthospermum aethiopicum, Ischyrolepis gaudichaudiana, Montinia caryophyllacea, Rhus rosmarinifolia* and *Themeda triandra*. Campbell (1985) explicitly stated that *P. nitida* is diagnostic and must be present for Mountain Fynbos to be classified as Talus Asteraceous Fynbos but he also indicated that *P. nitida* occurs in other communities as well.

At Bergfontein these shrublands (Figure 14) have either two or three strata. *P. nitida* forms a sparse canopy up to 2 m high. Where present the second stratum from 0.5–1.2 m is dominated by *Leucadendron salignum* and the low stratum 0.0–0.5 m by *Themeda triandra*. The community was restricted to well-drained east-facing slopes above Witelsrivier, directly opposite the west-facing slopes of Koksposberg where the closely related *Tetraria bromoides–Protea coronata* Shrublands occur. The altitude at which these shrublands are found ranges from 300–350 m with the slopes averaging 19°. Annual precipitation is estimated at 600–700 mm (Dent *et al.* 1987). The soils with pH 4.9 (n = 3) are a shallow (0.2 m) well-drained mix of sandstone debris from the Peninsula Formation sandstone and Cedarberg Formation shale. They are classified as Oakleaf Form soils. Rock cover ranges from 10–40%.

Apparently the *Erica hispidula–Protea nitida* Shrublands at Bergfontein are not burnt often, so the composition of the understorey is not attributed to regular fires or other disturbances. The grassy understorey is rather attributed to soil factors since the grasses in the community are C_4 grasses which show preference for more fertile soils (Bond 1981; Cowling 1983a & b; Linder 1989). This community qualifies for inclusion in Campbell's (1985) Rooiberg Talus Asteraceous Fynbos on the basis of presence of *Protea nitida* and 20 % grass cover. However, the lack of asteraceous 'elytropappoid' species and the high grass cover (70%) indicate closer affinities to Grassy Fynbos (*sensu* Cowling & Holmes 1992).

A stand of tall *P. nitida* with an understorey composed almost entirely of grasses was located on deep sandy soils on the plateau below the upper north slopes of Witelsberg. This community was not sampled but was observed to be quite different in structure and composition from the *Erica hispidula–Protea nitida* Shrublands. Further investigation, not possible in this study due to the fire, would be required to clarify the relationships.

2. *Erica versicolor–Agathosma ovata* Shrublands

Differential species: *Adromischus triflorus, Agathosma ovata, Centella virgata* var. *congesta, Crassula atropurpurea* var. *atropurpurea, C. muscosa, C. rupestris, Crassula* sp. (unidentified), *Erica tenuis, Ficinia elongata, Lampranthus deltoides, Lobelia pubescens* var. *pubescens, Senecio aizoides.*

Dominant species: *Agathosma ovata, Ehrharta ramosa, Erica melanthera, E. versicolor, Phylica purpurea* var. *floccosa.*

Structural formation: Sparse to Open Low Graminoid Shrubland.

Relationships: unclear.

The estimated annual precipitation for Koksposberg is 500–600 mm (Dent *et al.* 1977). However, the north-facing slopes are in a rain shadow as well as being equatorially oriented. They are therefore hot and dry and probably receive much less rainfall than the above estimate. A similar situation also exists on the upper north-facing slopes of Witelsberg. These dry, rocky slopes (Figure 15) with high incoming radiation host the *Erica versicolor–Agathosma ovata* Shrublands. The soils are lithosols (Mispah Form), are shallow and acid (pH 3.4 in 1 mol/l $CaCl_2$) and consist merely of accumulated sand and organic material in shallow depressions amongst the rocks.

FIGURE 14.—The *Erica hispidula–Protea nitida* Shrublands on the east-facing slopes, west of Bergfontein, above Witelsrivier.

FIGURE 15.—The *Erica versicolor–Agathosma ovata* Shrublands found on the rocky north slopes of Koksposberg and Witelsberg.

The parent rock of Koksposberg is Peninsula Formation sandstone and rock cover is 90% in the four relevés (208–211) representing this community. On Koksposberg the community is found at altitudes from 550–606 m on slopes varying from almost flat (7°) on the ridge to moderately steep (18°) on the north face. On Witelsberg, consisting of Nardouw Subgroup sandstone, the community is found from 788 m to 1 090 m.

Two strata are present in the *Erica versicolor–Agathosma ovata* Shrublands. The upper stratum is from 0.5–1.2 m and is dominated by the shrubby *Erica versicolor.* The lower stratum where shrubs and graminoids are co-dominant is from 0–0.5 m. Dominant species in this stratum are *Ehrharta ramosa* and *Erica melanthera.* However, the prevalence of succulent species in the genera *Adromischus, Aloe, Crassula, Lampranthus* and *Senecio* which prefer dry, rocky sites gives this community its character and sets it apart from all other communities described for the Bergfontein area (relevés not included in Table 1 or Table 2). *A. ovata* also favours a dry, rocky habitat as does *Oldenburgia paradoxa* which grows in rock crevices forming large, compact, rounded masses of short shoots.

A detrended correspondence analysis (DCA) (Hill 1979b) of the Bergfontein data showed a clear distinction between the *Erica versicolor–Agathosma ovata* Shrubland and the other shrublands. DCA Axis I represented a moisture gradient and the *Erica versicolor–Agathosma ovata* Shrublands are towards the drier end of the gradient. DCA Axis II apparently represented a soil depth/rockiness gradient, showing that the community inhabits the rockiest sites with shallowest soils in the study area.

3. *Cullumia aculeata* var. *aculeata* Shrublands

The *Cullumia aculeata* Shrublands include the non-*Erica hispidula* shrublands represented by Table 2. All these shrublands are on the northern slopes of the

Langeberg range adjacent to the Little Karoo. Most of the samples were taken in the Phesantefontein area; the exceptions are relevés 278–281 which were recorded on the north slopes of Witelsberg before the May 1991 fire.

3.1 *Cullumia aculeata–Leucadendron eucalyptifolium* Shrublands

This community is found on the mid- to upper slopes immediately east of Aasvoëlkrans. They are mesic proteoid shrublands and are separated into three distinct communities with *Leucadendron eucalyptifolium* as the common factor.

3.1.1 *Leucadendron eucalyptifolium–Protea neriifolia* Shrublands

Two communities are found in the *Leucadendron eucalyptifolium–Protea neriifolia* Shrublands. *P. neriifolia* links these shrublands, setting them apart from the *Leucadendron eucalyptifolium–Elegia filacea* Shrublands where *P. neriifolia* is absent. These shrublands have affinity to the *Tetraria bromoides–Hypodiscus striatus* Shrublands found on the southern slopes at Bergfontein with *Anomalanthus scoparius* and *Hypodiscus striatus*, differential species of the latter community, being found here as well.

3.1.1.1 *Protea neriifolia–Merxmuellera decora* Shrublands

Differential species: *Ficinia trichodes, Ischyrolepis* sp., *Merxmuellera decora.*

Dominant species: *Hypodiscus argenteus, Lanaria lanata, Merxmuellera decora.*

Structural formation: Mid-high Closed Graminoid Shrubland.

Relationships: Proteoid Zone Fynbos (Taylor 1978); Broad sclerophyllous- Scrub or Open Scrub (Kruger 1979); Sanddrift Mesic Proteoid Fynbos (Campbell 1985); affinities with *Tetraria bromoides–Hypodiscus striatus* Shrublands and *Tetraria bromoides–Protea coronata* Shrublands described above.

This community (Figure 16) is represented by five relevés (286–290) at altitudes from 630–850 m on the northeast- to northwest-facing slopes east of Aasvoëlkrans. These slopes are moderate, with shallow (0.2 m), yellow-brown sandy loam soil, classified as Glenrosa Form. The parent material of the soil is taken to be Nardouw Subgroup sandstone, but the heavy nature of the soil (relevés 286–289) suggests a high clay fraction possibly derived from a clay lens or local exposure of the Cedarberg Formation shale. This requires verification but the vegetation reflects a soil with a relatively higher nutrient status (see below). Surface rock cover is low to moderate (3–40%) except in relevé 290 which is different from the other samples. It was located on a rocky sandstone outcrop with 95% rock cover. The soil is of the Mispah Form, but the floristic composition of the relevé places it in the *Protea neriifolia–Merxmuellera decora* Shrublands.

At the time of sampling, the vegetation was seven years old. Depending on the site, the community had one or two strata, with height not exceeding 1.2 m. The shrubland was thus classified as above, a Mid-high Closed Graminoid Shrubland, but it is predicted that with time the community would mature to a Tall Closed Proteoid Shrubland with a Graminoid Understorey.

The *Protea neriifolia–Merxmuellera decora* Shrublands are poorly differentiated from the closely allied *Protea neriifolia–Erica articularis* Shrublands based on the differential species of the first community. *Merxmuellera decora* presents problems with identification in mature vegetation since it usually flowers only in the immediate post-fire phase; *Ischyrolepis* sp. (Table 2) was not identified and *Ficinia trichodes* was poorly represented. Absence of the differential species of the latter community from the *Protea neriifolia–Merxmuellera decora* Shrublands provides a sounder basis for the separation of the two communities.

3.1.1.2 *Protea neriifolia–Erica articularis* Shrublands

Differential species: *Aristea racemosa, Cassytha ciliolata, Coelidium cymbifolium, Erica articularis, Euryops abrotanifolius, Ischyrolepis sieberi, Zygophyllum fulvum.*

Dominant species: *Ceratocaryum decipiens, Elegia galpinii, Leucadendron salignum, Staberoha cernua.*

Structural formation: Low Closed Herbland or Low Mid-dense to Closed Graminoid Shrubland.

Relationships: Proteoid Zone Fynbos (Taylor 1978); Broad-sclerophyllous Scrub or Open Scrub (Kruger 1979); *Elegia galpinii–Metalasia pulcherrima* Community (Outeniqua Mountains) and *Protea repens–Protea lorifolia–Hypodiscus striatus* Community (Swartberg) (Bond 1981); Mesic Mountain Fynbos (Moll *et al.* 1984); Thomas Dry Proteoid Fynbos (Campbell 1985). *Leucadendron eucalyptifolium–Staberoha cernua* Shrublands (McDonald 1993a).

FIGURE 16.—The *Protea neriifolia–Merxmuellera decora* Shrublands found on the northeast- to northwest-facing slopes east of Aasvoëlkrans, above Phesantefontein.

This community (Figure 17) occurs on the same north-facing slopes as the *Protea neriifolia–Merxmuellera decora* Shrublands but at lower altitudes (590–630 m). The shallow (0.2–0.3 m), light grey-brown soils were classified as Glenrosa Form (relevés 291–293) and Mispah Form (relevé 294). All the relevés were situated on shallow slopes (9°–14°), between rock outcrops, where rock cover was very low except in relevé 294 where it was estimated at 20%.

The differential species of the *Protea neriifolia–Erica articularis* Shrublands are not constant throughout the community, nor do they have high cover-abundance. Of these species, *Erica articularis* and *Ischyrolepis sieberi* have highest cover-abundance whereas the remaining species are rare (Table 2). The very rare legume, *Coelidium cymbifolium*, previously known from only two collections, Muir's type collection and a collection of Middlemost (Granby 1980), was found in relevés 293 and 294 and appears to be narrowly endemic to this community. *Protea aspera*, a prostrate rhizomatous shrublet, was also recorded in this community and the *Leucadendron eucalyptifolium–Elegia filacea* Shrublands (see below and Table 2). This species is best known from Onrust to Bredasdorp but has also been recorded from an isolated population in the Langkloof, east of Garcia's Pass (Rourke 1980). Records of *Protea aspera* at Phesantefontein represent an extension of the range of the Langkloof population 5 km west of Garcia's Pass.

The *Protea neriifolia–Erica articularis* Shrublands are dominated by restios such as *Ceratocaryum decipiens, Elegia galpinii, Mastersiella purpurea, Restio filiformis, Thamnochortus ellipticus* and *Staberoha cernua*, all species preferring mesic to dry habitats. *T. ellipticus* was originally collected by Muir in the Phesantefontein area and is only known from this, the type locality (Linder 1985).

3.1.2 *Leucadendron eucalyptifolium–Elegia filacea* Shrublands

Differential species: *Calopsis filiformis, Elegia filacea, Hypodiscus laevigatus.*

Dominant species: *Elegia filacea, Protea repens.*

Structural formation: Low Closed Graminoid (Restioid/Cyperoid) Shrubland with Tall Open Proteoid Overstorey.

Relationships: as for 3.1.1.2 above and *Leucadendron eucalyptifolium–Protea lorifolia* Shrublands (McDonald 1993a).

Two relevés, 295 and 296, represent this community (Figure 18). It is found below the *Leucadendron eucalyptifolium–Erica articularis* Shrublands, and is floristically transitional between them and the *C. aculeata–Protea lorifolia* Shrublands. Both relevés were at 530 m on slopes with a shallow gradient. The soil which is 0.25–0.3 m deep is a light grey sandy loam with quartz pebbles and gravel on the surface. Rock cover is nil and the soils are classified as Glenrosa Form.

Elegia filacea is most often found on accumulated sand and the sandy nature of the soil accounts for its presence here. In this community it dominates the understorey in which grasses are absent and sedges few, mainly of the genus *Ficinia*. Low shrubs play a subordinate role in the understorey composition, but the presence of *Protea aspera*, which also favours sandy soil, should be noted. The upper (tall) stratum is composed of proteoid shrubs with *Protea repens* dominant.

FIGURE 17.—The *Protea neriifolia–Erica articularis* Shrublands on the lower north-facing slopes above Phesantefontein.

The rare, endemic *Erica rhodantha* Guth. & Bol. was found in this community. This species is apparently restricted to the fynbos shrublands of the lower north slopes of the Langeberg in the region of Garcia's Pass. Few collections of this species have been made (E.G.H. Oliver pers. comm.).

The *Leucadendron eucalyptifolium–Elegia filacea* Shrublands are the same as the *Leucadendron eucalyptifolium–Protea lorifolia* Shrublands described from BWA (McDonald 1993a), but for the purposes of this paper are treated as slightly different. The difference is based on the presence of *Calopsis filiformis, Hypodiscus laevigatus, Protea aspera and Thamnochortus ellipticus* at Phesantefontein and not at BWA.

3.2 *Cullumia aculeata–Protea lorifolia* Shrublands

This community, found at the driest extreme of the south-north climatic gradient of the Langeberg, is divided into two: the *Protea lorifolia–Ficinia laciniata* Shrublands (which fall within the *Leucadendron eucalyptifolium–Protea lorifolia* Shrublands of the BWA) and the *Protea lorifolia–Leucospermum calligerum* Shrublands (which are equivalent to the *Passerina obtusifolia–Leucospermum calligerum* Shrublands at BWA). The *Cannomois parviflora–Passerina obtusifolia* Shrublands found at BWA (McDonald 1993a) were not identified as a separate community at Phesantefontein but as part of the *Passerina obtusifolia–Leucospermum calligerum* Shrublands.

FIGURE 18.—The *Leucadendron eucalyptifolium–Elegia filacea* Shrublands.

3.2.1 *Protea lorifolia–Ficinia laciniata* Shrublands

Differential species: *Cannomois parviflora, Dodonaea angustifolia, Ficinia laciniata, Gnidia francisci, Linum gracile, Othonna* sp., *Polygala refracta, Siphocodon* cf. *spartioides, Syncarpha milleflora, Thesium subnudum.*

Dominant species: *Leucadendron salignum, Pentaschistis colorata, Hypodiscus aristatus, Tetraria ustulata.*

Structural formation: Low Mid-dense Sedgeland or Graminoid Shrubland with Mid-high Sparse Proteoid Shrubs in some stands.

Relationships: Proteoid Zone Fynbos (Taylor 1978); Broad-sclerophyllous Scrub or Open Scrub (Kruger 1979); *Elegia galpinii–Metalasia pulcherrima* Community (Outeniqua Mountains) and *Protea repens–Protea lorifolia–Hypodiscus striatus* Community (Swartberg) (Bond 1981); Mesic Mountain Fynbos (Moll *et al.* 1984); Thomas Dry Proteoid Fynbos (Campbell 1985); *Leucadendron eucalyptifolium–Protea lorifolia* Shrublands (McDonald 1993a).

This community was not found or sampled at Phesantefontein. The four relevés (278–281) representing the *Protea lorifolia–Ficinia laciniata* Shrublands were situated on the moderately steep, rocky, north-facing slopes of Witelsberg on the Bergfontein transect at altitudes from 545–730 m. The soils are shallow (0.1–0.15 m) sandy Mispah Form lithosols and surface exposure of rock was estimated to be 91% on average.

This community is well differentiated from the other shrublands represented in Table 2. This could be ascribed either to geographical separation of these relevés from the Phesantefontein area or to the habitat where this shrubland occurs not being present or not sampled at Phesantefontein. Topographically, in rockiness and in climatic regime, the north-facing slopes of Witelsberg closely resemble the north-facing slopes of Deception Ridge in BWA (McDonald 1993a). At Phesantefontein, however, moderately steep, rocky, well-drained slopes of the same type are absent. The 'habitat explanation' for the absence of this community at Phesantefontein therefore seems the most plausible.

Leucadendron salignum, Hypodiscus aristatus, Pentaschistis colorata and *Tetraria ustulata* dominate the community at this early stage of its development (6 years old), forming a low, mid-dense graminoid shrubland. As these shrublands mature it is predicted that the proteoid shrubs, *Protea lorifolia* and *Protea repens* will form a mid-high to tall, open to mid-dense overstorey.

3.2.2 *Protea lorifolia–Leucospermum calligerum* Shrublands

Differential species: *Adromischus triflorus, Anthospermum spathulatum, Calopsis rigida, C. marlothii, Cliffortia pulchella, Clutia laxa, Cymbopogon marginatus, Hermannia odorata, Heterolepis* sp. nov., *Lightfootia rigida, Machairophyllum cookii, Metalasia massonii, Montinia caryophyllacea, Passerina obtusifolia, Pentaschistis malouinensis, Phylica purpurea, Thamnochortus karooica.*

Dominant species: *Elegia galpinii, Leucospermum calligerum, Thoracosperma galpinii, Willdenowia bolusii.*

Structural formation: Low to Mid-high Mid-dense Graminoid Shrubland with Sparse emergent Proteoid Shrubs in some stands.

Relationships: Arid Fynbos (Taylor 1978; Kruger 1979); *Phylica axillaris–Felicia filifolia* Community (Outeniqua Mountains) and *Passerina obtusifolia–Felicia filifolia–Pentaschistis eriostoma* Community (Swartberg) (Bond 1981); Dry Mountain Fynbos (Moll *et al.* 1984); Sebrafontein Dry Asteraceous Fynbos (Campbell 1985); Dry Proteoid Fynbos (Rebelo *et al.* 1991); *Passerina obtusifolia–Leucospermum calligerum* Shrublands (McDonald 1993a); *Leucadendron eucalyptifolium–Hypodiscus argenteus* Shrublands in part (McDonald 1993b).

This community (Figure 19) is found on the low, arid northern foothills of Phesantefontein at altitudes from 450–520 m. The slope varies from almost level (5°) to 14° and the soils are mostly shallow (<0.1 m), well-drained, rocky (75–98%) Mispah Form soils. The exception is the Glenrosa Form soil of relevé 285 which is 0.25 m deep with an estimated surface rock cover of only 3%! Relevé 283 was situated on a rocky outcrop and was the only site where *Passerina obtusifolia* was recorded. The silcrete-capped mesas at Phesantefontein present a similar substratum and habitat to that found in relevé 283 and therefore, although these mesas were not sampled, it is predicted that they will support shrublands of the *Protea lorifolia–Leucospermum calligerum* type (Phesantefontein) or the *Cannomois parviflora–Passerina obtusifolia* type (Witbooisrivier; McDonald 1993a).

These shrublands are well defined with numerous differential species. *Heterolepis* sp. nov. (as yet undescribed), the succulent *Machairophyllum cookii* (Mesembryanthemaceae) and *Thamnochortus karooica* are endemic to this community. Species with single occurrences have been retained in Table 2 specifically for this community, for the sake of completeness. They are, however, not truly differential.

Leucospermum saxatile which is endemic to the Arid Fynbos east of Garcia's Pass (Rourke 1972) was noted in this community on the northern footslopes of Witelsberg prior to the May 1991 fire. *Serruria balanocephala* Rourke ined. found in this community at Witbooisrivier (McDonald 1993a) has not been found at Phesantefontein nor further east. *Leucospermum erubescens* recorded from Springfontein immediately west and at Garcia's Pass directly east of Phesantefontein was also not encountered at the latter locality and is apparently also not found much further east than Garcia's Pass.

Owing to the extensive fires on the Langeberg east of Garcia's Pass in the recent past, much of the vegetation on the lower northern slopes of the range is immature and thus not suitable for sampling. However, it can be confidently stated that the community named the *Passerina obtusifolia–Leucospermum calligerum* Shrublands (McDonald 1993a) and the *Protea lorifolia–Leucospermum calligerum* Shrublands (this paper) extend along the base of the Langeberg from Barrydale to the Gouritz River, fringing the Little Karoo.

DISCUSSION AND CONCLUSIONS

The hierarchical classification and description of the fynbos communities of the Bergfontein and Rooiwaterspruit-Phesantefontein areas satisfies the primary objective of the study. It also provides a framework which, together with differential species for each community, is a starting point for describing the communities over a wider area on the southeastern Langeberg. Further sampling in other areas would serve to test this classification and would most likely identify additional communities.

From the perspective of management of the fynbos of the Langeberg mountain catchments, this classification is perhaps too detailed and, as may be argued, too floristically orientated. However, it is important to be able to classify plant communities at all stages of the succession. This has raised much debate (Cowling & Holmes 1992) and it has been generally concluded that when applying structural classifications it is only possible to satisfactorily classify mature fynbos plant communities (Campbell 1985). Finding stands of mature fynbos (>10 years old) is becoming increasingly difficult (Campbell 1985; this study) so applying structural classifications becomes equally difficult. Despite the complexity of the vegetation in this study, the successful hierarchical classification of the mainly immature fynbos, and the determination of character species for communities highlights a major advantage in using the floristic classification approach. If suitably interpreted, by using the character species for different communities, the complex taxonomy of the fynbos need not be the reputed daunting obstacle for managers of fynbos vegetation (Bond 1981).

FIGURE 19.—The *Protea lorifolia–Leucospermum calligerum* Shrublands found on the flow, arid foothills of the Phesantefontein area.

In general, the communities described for the Bergfontein and Rooiwaterspruit-Phesantefontein areas are similar to those described by McDonald (1993a & b) for the Boosmansbos Wilderness Area and the Marloth Nature Reserve. Degree of difference or conversely, similarity of the fynbos communities of the southern Langeberg, which is beyond the scope of this paper, can now be assessed. A proposed synthesis is now possible which is aimed at being generally applicable in the Langeberg fynbos shrublands, and hopefully beneficial to the conservation and management of these shrublands.

Apart from the purely descriptive reference to environmental conditions pertaining to each community, little indication is given of environmental variables as the causal agents of species distribution and species composition of communities. This forms a separate aspect to the study of the Langeberg vegetation and will be reported separately (McDonald unpublished data).

The *Erica versicolor–Agathosma ovata* Shrubland found on Koksposberg does not fit well within the hierarchy of communities. This was evident in both the phytosociological tables and the ordination of the data. Many of the fynbos species found generally on the south slopes of the Bergfontein area are found in this community but the succulent differential species indicate an azonal xeric community. A clear definition of this community and its relationships to other fynbos vegetation will only be possible given additional samples. It is predicted to occur on the sandstone outliers of the Langeberg east of Garcia's Pass as described and possibly on the Aasvogelberg near Albertinia.

Garcia's Pass has historically given ready access to the Muiskraal area at its northern entrance. It has thus been an area much visited by botanists since the time of Thunberg and Masson in the late 1700's. Many collections of Langeberg north slope endemic species have Muiskraal as the type locality, notably many of Muir's collections. Many of these species are considered rare. Some of these species such as *Coelidium cymbifolium* and *Erica rhodantha* have been found in this survey at Phesantefontein which lies just west of Muiskraal. The intensity of sampling in this study has, however, been too limited to cover the area adequately. It is proposed therefore that the areas on the north slopes of the Langeberg west and east of

Garcia's Pass require thorough botanical investigation. If these areas have high numbers of endemic plant species as is indicated by this survey, these north slopes of the Langeberg deserve a higher conservation status than is currently the case.

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Errata in Bothalia 23,1: 157

The vegetation of the southern Langeberg, Cape Province. 2. The plant communities of the Marloth Nature Reserve, by D.J. McDonald.

Replace 3rd paragraph, left column with:

The climate of the MNR is typical of the southern Langeberg since it falls within the transition zone between winter and year-round rainfall areas. The mean annual rainfall for the peaks is estimated to be >1 400 mm (Dent *et al.* 1987). However, the climate on the south side of the range is distinctly different from that on the north side. The south slopes of the southern Langeberg experience the highest rainfall in late summer to autumn (March & April) and late winter to spring (August, October & November). The driest periods are early summer (December) and early winter (June), Figure 5A. A more marked bimodality is evident in the rainfall pattern on the north slopes which are in a summer rainshadow. Here peaks in rainfall occur in autumn (April & May) and late winter (August). The driest period extends from spring to late summer (October–March), Figure 5B. The mean summer maximum and mean winter minimum temperatures for Swellendam are 29.4°C (January) and 6.6°C (July) respectively. On the opposite side of the mountain at Weltevrede the equivalent temperatures are 30.0°C (February) and 2.9°C (July).

Appendix D

The montane flora of the southern Langeberg: A checklist of the flowering plants and ferns.

The systematic checklist of the flora of the southern Langeberg represents a compilation from various sources including unpublished information from a number of taxonomists currently concerned with the systematics of the Cape flora. The main sources of information were Bond & Goldblatt (1984), Geldenhuys (1992) and collections made by D.J. McDonald during the survey of the flora and vegetation of the southern Langeberg (McDonald 1993 a, b, c (Appendices A, B, C)). Each taxon in the list was checked in the three Cape herbaria, Bolus Herbarium, University of Cape Town (BOL), Compton Herbarium, National Botanical Institute, Kirstenbosch (NBG) and Stellenbosch Herbarium (STE), and where possible a collection from the southern Langeberg selected as a voucher. Stellenbosch University Herbarium (STEU) was also consulted for Geraniaceae. Voucher selection was not always possible; vouchers were not found for 131 taxa (species and subspecies).

Each record is followed by a sequence of codes and the abbreviations used are as follows:

[name, number, herbarium code] – Name of collector, collector's number, code of herbarium where the specimen is housed.

Those species endemic to the southern Langeberg are indicated as '**Endemic**'.

[X] denotes no collection selected as a voucher.

[CJG] denotes a record from the list of Geldenhuys (1992).

Growth form: DSH – dwarf shrub, Eph – epihpytic pteridophyte, F – forb, G – geophyte, H – hemicryptophyte, HE – herb, LSH – low shrub, MSH – mid-high shrub, Pa – parasite, Ph – pteridophyte, SUC – succulent plant not in any other growth from class, T – tree, TSH – tall shrub, V – vine or liane.

Post-fire regeneration strategy: NS – non-resprouter (regenerates from seed), S – resprouter.

Broad habitat type where found: AR – arid north slopes, HAD – high-altitude dry slopes, HAW – high-altitude wet slopes, MSS – mesic south slopes.

Dispersal mode: A – ant, P – passive/unknown, V – vertebrate, W – wind, WA – water.

Nomenclature : Arnold and de Wet (1993)

PTERIDOPHYTA

LYCOPODIACEAE
Lycopodium
carolinianum L. [Taylor 4772 STE] Ph NS MSS P
complanatum L. subsp. zanclophyllum (Wilce) Schelpe [McDonald 963 STE] P NS HAW P
gnidioides L.f. [McDonald 619 STE] Ph NS HAW P

OSMUNDACEAE
Todea
barbara (L.) Moore [McDonald 1590 STE] Ph S MSS P

SCHIZAEACEAE
Schizaea
pectinata (L.) Swartz [McDonald 1473 STE] Ph S HAD P

GLEICHENIACEAE
Gleichenia
polypodioides (L.) J.E. Sm. [Fellingham 448 STE] Ph S MSS P

HYMENOPHYLLACEAE
Hymenophyllum
tunbridgense (L.) J.E. Sm. [Willems 96 STE] Ph NS MSS P

CYATHEACEAE
Cyathea
capensis (L.f.) J.E. Sm. [Barker 8814 STE] Ph U MSS P

DENSTAEDTIACEAE
Histiopteris
incisa (Thunb.) J. Sm. [CJG] Ph NS MSS P
Hypolepis
sparsisora (Schrad.) Kuhn [P.J. van der Merwe s.n. STE] Ph NS MSS P
Pteridium
aquilinum (L.) Kuhn [McDonald 1592 STE] Ph S MSS P

ADIANTACEAE
Cheilanthes
viridis (Forssk.) Swartz var. viridis [CJG] Ph NS MSS P
Pellaea
calomelanos (Sw.) Link [T.J. van der Merwe 122 STE] Ph S AR P
Pteris
buchananii Bak. ex Sim [Schelpe 1028 NBG] Ph NS MSS P
dentata Forssk. [Taylor 1030] Ph NS MSS P

POLYPODIACEAE
Microsorium
ensiforme (Thunb.) Schelpe [Taylor 7777 STE] EPh NS MSS P
Pleopeltis
macrocarpa (Bory ex Willd.) Kaulf. [Taylor 3546 STE] EPh NS MSS P

ASPLENIACEAE
Asplenium
adiantum-nigrum L. [X] Ph NS MSS P
aethiopicum (Burm.) Becherer [McDonald 1587 STE] Ph NS MSS P
rutifolium (Berg.) Kuntze [Kruger 1309 STE] Ph NS MSS P
THELYPTERIDACEAE
Thelypteris
bergiana (Schlechtd.) Ching [Holland 1865 NBG] Ph NS MSS P

LOMARIOPSIDACEAE
Elaphoglossum
angustatum (Schrad.) Hieron [McDonald 1271 STE] Ph NS MSS P

ASPIDIACEAE
Dryopteris
inaequalis (Schlechtd.) Kuntze [CJG] Ph NS MSS P
Polystichum
pungens (Kaulf.) Presl [Roux 2378 NBG] Ph NS MSS P
Rumohra
adiantiformis (G. Forst.) Ching [Taylor 7593 STE] Ph NS MSS P

BLECHNACEAE
Blechnum
australe L. var. australe [Willems 92 NBG] Ph S MSS P
capense Burm. f. [CJG] Ph S MSS P
giganteum (Kaulf.) Schlechtd. [X] Ph S MSS P
punctulatum Swartz var. punctulatum [Roux 278 NBG] Ph S MSS P
tabulare (Thunb.) Kuhn [X] Ph S MSS P

GYMNOSPERMAE

CUPPRESSACEAE
Widdringtonia
nodiflora (L.) Powrie [Drÿfhout 4088 STE] TSH S MSS W

PODOCARPACEAE
Podocarpus
elongatus (Aiton) L'Her. ex Pers. [X] T NS MSS V
falcatus (Thunb.) R. Br. ex Mirb. [CJG] T NS MSS V
latifolius (Thunb.) R. Br. ex Mirb. [Taylor 339] T NS MSS V

ANGIOSPERMAE – MONOCOTYLEDONAE

POACEAE
Imperata
cylindrica (L.) Beauv. [X] HE S MSS P
Andropogon
appendiculatus Nees [Taylor 7579 STE] HE S MSS P
Cymbopogon
marginatus (Steud.) Stapf. ex Burtt Davy [McDonald 1745 STE] HE S HAD P
Hyparrhenia
hirta (L.) Stapf. [Andrag 7 STE] HE S MSS P
Heteropogon
contortus (L.) Roem. & Schult. [McDonald 1853 STE] HE S AR P
Themeda
triandra Forssk. [X] HE S MSS P
Oplismenus
hirtellus (L.) Beauv. [Mathews 1493 NBG] HE S MSS P
Melinis
nerviglumis (Franch.) Zizka [McDonald 1073 STE] HE S MSS P
Ehrharta
calycina J.E. Sm. [CJG] HE S MSS P
capensis Thunb. [Bohnen 6721 STE] HE S HAD P
dura Nees ex Trin [McDonald 1519 STE] HE S HAW P

ramosa Thunb. [McDonald 1433 STE] HE S HAW P
rupestris Nees ex Trin. subsp. dodii [Crook 2268 NBG] HE S HAW P
setacea Nees ex Trin. subsp. scabra (Stapf) Gibbs Russell [McDonald 1527 STE] HE S HAW P
Anthoxanthum
tongo (Nees) Stapf [McDonald 960 STE] HE S HAW P
Tristachya
leucothrix Nees [X] HE S MSS P
Merxmuellera
arundinacea (Berg.) Conert [McDonald 1115 STE] HE S AR P
cincta (Nees) Conert [X] HE S MSS P
decora (Nees) Conert [McDonald 1525 STE] HE S HAD P
disticha (Nees) Conert [X] HE S MSS P
rufa (Nees) Conert [X] HE S HAW P
stricta (Schrad.) Conert [McDonald 1272 STE] HE S HAD P
Pentaschistis
acinosa Stapf [McDonald 1518 STE] HE S MSS P
argentea Stapf [McDonald 1743 STE] HE S HAD P
capensis (Nees) Stapf [McDonald 1478 STE] HE S HAW P
colorata (Steud.) Stapf [McDonald 1187 STE] HE S MSS P
curvifolia (Schrad.) Stapf [McDonald 2000 STE] HE S MSS P
eriostoma (Nees) Stapf [McDonald 1006 STE] HE S AR P
involuta (Steud.) Adam. [McDonald 1520 STE] HE S HAD P
malouinensis (Steud.) Clayton [McDonald 1526 STE] HE S MSS P
rigidissima Pilg. [McDonald 1240 STE] HE S AR P
thunbergii (Kunth) Stapf [McDonald 1457 STE] HE S HAD P
viscidula (Nees) Stapf [McDonald 1465 STE] HE S AR P
Pentameris
macrocalycina (Steud.) Schweick. [McDonald 1833 STE] HE S HAW P
thuarii Beuav. [McDonald 1427 STE] HE S HAW P
Aristida
junciformis Trin. & Rupr. [Stehle 234 STE] HE S MSS P
Eragrostis
capensis (Thunb.) Trin. [Taylor 7601 STE] HE S MSS P
curvula (Schrad.) Nees [X] HE S MSS P
Tribolium
brachystachyum (Nees) Renvoize [McDonald 1233 STE] HE S HAD P
uniolae (L.f.) Renvoize [McDonald 1523 STE] HE S MSS P
Festuca
scabra Vahl [McDonald 1741 STE] HE S HAD P
Brachypodium
flexum Nees [CJG] HE S MSS P

CYPERACEAE

Ficinia
acuminata (Steud.) Nees [Haynes 1482 STE] HE NS MSS P
albicans Nees [McDonald 1420 STE] HE NS MSS P
capillifolia C.B. Cl. [X] HE NS MSS P
deusta (Berg.) Levyns [X] HE NS HAD P
distans C.B. Cl. [McDonald 1232a STE] HE NS HAD P
elongata Boeck [McDonald 2002 STE] HE NS AR P
filiformis (Lam.) Schrad. [McDonald 1872 STE] HE NS AR P
laciniata (Thunb.) Nees [McDonald 2054 STE] HE NS MSS P
levynsiae Arnold & Gordon-Gray [McDonald 1854 STE] HE NS AR P
macowanii C.B. Cl. [Forsyth 443 STE] HE NS MSS P
monticola Kunth [McDonald 973 STE] HE NS HAW P
nigrescens (Schrad.) Raynal [McDonald 1010 STE] HE NS AR P
cf. paradoxa (Schrad.) Nees [McDonald 1124 STE] HE NS HAD P
cf. pinguior C.B. Cl. [X] HE NS HAD P
quingangularis Boeck. [Esterhuysen 14440 NBG] HE NS HAW P

radiata (L.f.) Kunth [Taylor 4766 STE] HE NS MSS P
stolonifera Boeck. [Taylor 3227 STE] HE NS MSS P
sylvatica Kunth [Taylor 3224] HE NS MSS P
trichodes (Schrad.) Benth. & Hook. f. [McDonald 2003 STE] HE NS MSS P
tristachya (Rottb.) Nees [Taylor 7692 STE] HE NS MSS P
zeyheri Boeck. [Haynes 1480 STE] HE NS HAD P
Scirpus
paludicola Kunth [X] HE NS MSS P
Isolepis
digitata Schrad. [X] HE NS MSS P
fluitans (L.) R. Br. [X] HE NS MSS P
rubicunda Kunth [X] HE NS MSS P
Epischoenus
cf. adnatus Levyns [X] HE NS HAW P
dregeanus (Boeck.) Levyns [Taylor 7615 STE] HE NS HAW P
lucidus (C.B. Cl.) Levyns [McDonald 1668 STE] HE NS HAW P
quadrangularis (Boeck.) C.B. Cl. [McDonald 1430 STE] HE NS HAW P
Tetraria
bolusii C.B. Cl. [McDonald 2056 STE] HE NS MSS P
brachyphylla Levyns [X] HE NS MSS P
brevicaulis C.B. Cl. [McDonald 1895 STE] HE NS HAD P
bromoides (Lam.) Pfeiffer [McDonald 1834 STE] HE NS HAW P
burmannii (Schrad.) C.B. Cl. [McDonald 1032 STE] HE NS MSS P
capillacea (Thunb.) C.B. Cl. [McDonald 1666 STE] HE NS HAD P
compar (L.) Lestib. [Esterhuysen 17228 BOL] HE NS HAW P
compressa Turrill [McDonald 1047 STE] HE NS HAW P
crassa Levyns [McDonald 2022 STE] HE NS MSS P
cuspidata (Rottb.) C.B. Cl. [McDonald 1652 STE] HE NS MSS P
fasciata (Rottb.) C.B. Cl. [McDonald 1669 STE] HE NS HAD P
fimbriolata (Nees) C.B. Cl. [McDonald 1554 STE] HE NS HAD P
flexuosa (Thunb.) C.B. Cl. [McDonald 1076 STE] HE NS MSS P
fourcadei Turrill & Schonl. [McDonald & Morley 1120 STE] HE NS HAW P
involucrata C.B. Cl. [McDonald 1675] HE NS HAD P
microstachys (Vahl) Pfeiffer [Taylor 3233] HE NS MSS P
robusta (Kunth) C.B. Cl. [X] HE NS MSS P
secans C.B. Cl. [Esterhuysen 18504 BOL] HE NS MSS P
vaginata Schonl. & Turrill [Esterhuysen 35072 BOL] HE NS HAW P
picta C.B. Cl. [McDonald 1848 STE] HE NS AR P
pillansii Levyns [McDonald 1139 STE] HE NS HAW P
thermalis (L.) C.B. Cl. [McDonald 1157 STE] HE S HAD P
ustulata (L.) C.B. Cl. [McDonald 1117 STE] HE NS HAD P
Macrochaetium
hexandrum (Nees) Pfeiffer [McDonald 1529 STE] HE S MSS P
Chrysithrix
capensis L. [McDonald 974 STE] HE NS HAW P
Schoenoxiphium
lanceum (Thunb.) Kuekenth. [X] HE NS MSS P
lehmanii (Nees) Steud. [CJG] HE NS MSS P
Carex
aethiopica Schkuhr [P.J. van der Merwe 1386 STE] HE NS MSS P

ARACEAE
Zantedeschia
aethiopica (L.) Spreng. [X] G S MSS P
RESTIONACEAE
Staberoha
cernua (L.f.) Dur. & Schinz. [McDonald 1867 STE] H S HAD P
Ischyrolepis
affinis Esterhuysen [Esterhuysen 35 612 STE] **Endemic** H S HAW P
capensis (L.) Linder [McDonald 1106 STE] H S HAD P

curviramis (Kunth) Linder [Esterhuysen 32901 BOL] H S MSS P
gaudichaudiana (Kunth) Linder [McDonald 1851 STE] H S AR P
hystrix (Mast.) Linder [McDonald 2020 STE] H S MSS P
laniger (Kunth) Linder [X] H S HAW P
ocreata (Kunth) Linder [X] H S HAD P
sieberi (Kunth) Linder [McDonald 1119 STE] H S AR P
triflora (Rottb.) Linder [X] H S MSS P
Elegia
asperiflora (Nees) Kunth [McDonald 1667 STE] H S HAD P
caespitosa Esterhuysen [McDonald 1530 STE] H S MSS P
capensis (Burm. f.) Schelpe [Bohnen 8923 STE] H S MSS P
coleura Mast. [X] H S MSS P
equisetacea Mast. [McDonald 1419 STE] H S MSS P
filacea Mast. [McDonald 1068 STE] H NS HAD P
fistulosa Kunth [McDonald 1850 STE] H S AR P
galpinii N.E. Br. [Bohnen 9085 STE] H S AR P
juncea L. [McDonald 1116 STE] H S MSS P
neesii Mast. [X] H S MSS P
racemosa (Poir.) Pers. [Esterhuysen 30877 BOL] H S MSS P
Chondropetalum
ebracteatum (Kunth) Pillans [Esterhuysen 33 426 STE] H S HAD P
mucronatum (Nees) Pillans [McDonald 1406 STE] H S HAW P
Askidiosperma
paniculatum (Mast.) Linder [McDonald 1858 STE] H S AR P
Platycaulos
acutus Esterhuysen [McDonald 1038 STE] **Endemic** H S HAD P
anceps (Mast.) Linder [McDonald 1059 STE] H S HAW P
compressus (Rottb.) Linder [Esterhuysen 10 428 STE] H S HAW P
major (Mast.) Linder [McDonald 1054 STE] H S MSS P
Restio
arcuatus Mast. [McDonald 1612 STE] **Endemic** H S MSS P
capillaris Kunth [Burchell 7430 BOL] H S MSS P
colliculospermus Linder [Esterhuysen 33 420 BOL] H S HAW P
communis Pill. [Esterhuysen 31 792 STE] H S MSS P
decipiens (N.E. Br.) Linder [Esterhuysen 33 303 STE] **Endemic** H S HAW P
filiformis Poir. [McDonald 1063 STE] H S HAD P
fragilis Esterhuysen [Esterhuysen 33 242 STE] **Endemic** H S HAW P
implicatus Esterhuysen [McDonald 1179 STE] **Endemic** H S MSS P
inconspicuus Esterhuysen [McDonald 1042 STE] H S HAD P
peculiaris Esterhuysen [Esterhuysen 34 519 STE] **Endemic** H S HAD P
perplexus Kunth [Esterhuysen 31 772 BOL] H S HAD P
perseverans Esterhuysen [Esterhuysen 35 904 STE] **Endemic** H S HAD P
scaberulus N.E. Br. [McDonald 1278 STE] H S HAW P
secundus (Pillans) Linder [Esterhuysen 31 767 STE] **Endemic** H S HAW P
stokoei Pillans [Esterhuysen 1143 STE] H S HAW P
strictus N.E. Br. [Esterhuysen 1840 STE] H S HAW P
triticeus Rottb. [Kruger 1278 STE] H S MSS P

Calopsis
burchellii (Mast.) Linder [Bohnen 8679 STE] H S MSS P
filiformis (Mast.) Linder [X] H S MSS P
marlothii (Pillans) Linder [McDonald 2092 STE] H S AR P
membranacea (Pillans) Linder [McDonald 2062 STE] H S MSS P
monostylis (Pillans) Linder [McDonald 1665 STE] **Endemic** H S HAW P
muirii (Pillans) Linder [Kruger 1272 STE] **Endemic** H S AR P
paniculata (Rottb.) Mast. [McDonald 1426 STE] H S MSS P
rigida (Mast.) Linder [X] H S AR P
Thamnochortus
amoena Linder [McDonald 1577 STE] **Endemic** H S AR P
cinereus Linder [McDonald 1855 STE] H S HAW P

ellipticus Pillans [McDonald 2100 STE] **Endemic** H S AR P
karooica Linder [McDonald 1002 STE] **Endemic** H S AR P
Rhodocoma
alpina Linder ined. [McDonald 1860 STE] H S HAD P
fruticosa (Thunb.) Linder [McDonald 1432 STE] H S MSS P
gigantea (Kunth) Linder [McDonald 1290 STE] H S MSS P
Ceratocaryum
argenteum Nees ex Kunth [McDonald 1406a STE] H S HAD P
decipiens (N.E. Br.) Linder [McDonald 1849a STE] H S HAD P
fistulosum Mast. [X] **Endemic** H S MSS P
Cannomois
parviflora (Thunb.) Pillans [McDonald & Morley 1003 STE] H S HAD P
virgata (Rottb.) Steud. [McDonald 2035 STE] H NS HAW P
Nevillea
sp. nov. [McDonald 2045 STE] H S MSS P
Anthochortus
crinalis (Mast.) Linder [McDonald 1149 STE] H S HAW P
ecklonii Nees [McDonald 1094 STE] H S HAW P
Mastersiella
purpurea (Pillans) Linder [McDonald & Morley 1132 STE] H S HAD P
Hypodiscus
albo-aristatus (Nees) Mast. [McDonald 1856 STE] H S MSS A
argenteus (Thunb.) Mast. [McDonald 986 STE] H S MSS A
aristatus (Thunb.) Krauss [Bohnen 8432 STE] H S MSS A
laevigatus (Kunth) Linder [Muir 3181 NBG] H S AR A
montanus Esterhuysen [Esterhuysen 34 521 STE] **Endemic** H S HAD A
striatus (Kunth) Mast. [McDonald 1125 STE] H S AR A
synchroolepis (Steud.) Mast. [Esterhuysen 31 761 BOL] H S MSS A
Willdenowia
bolusii Pillans [McDonald 2102 STE] H S AR P
glomerata (Thunb.) Linder [McDonald 1849 STE] H S AR P

JUNCACEAE
Juncus
lomatophyllus Spreng. [Taylor 1044 NBG] HE NS MSS P
Prionium
serratum (L.f.) Drege ex E. Mey MSH S MSS P

COLCHICACEAE

Wurmbea
variabilis B. Nord. [McDonald 1637 STE] G S AR W

ASPHODELACEAE

Bulbine
mesembryanthemoides Haw. [X] G S MSS W
tuberosa (Mill.) Oberm. [X] G S MSS W
Chlorophytum
comosum (Thunb.) Jacq. [Taylor 3220 STE] G S MSS P
crispum (Thunb.) Bak. [Bohnen 8440 STE] G S MSS P

Caesia
contorta (L.f.) Dur. & Schinz. [McDonald 1871 STE] HE NS HAD P

Kniphofia
uvaria (L.) Oken [McDonald 1260 STE] G S HAW W
Aloe
arborescens Mill. [X] SUC S AR W
gracilis Haw. var. decumbens Reynolds [Bruyns 2844 BOL] SUC S MSS W
mitriformis Mill. [X] SUC S AR W
Haworthia
floribunda Poelln. [de Kock 318 NBG] SUC NS AR P
turgida Haw. [Bayer 2672] SUC NS AR P

ALLIACEAE
Agapanthus
africanus (L.) Hoffmg. [Viviers 1106 STE] G S MSS W

HYACINTHACEAE

Albuca
tenuifolia Bak. [McDonald 1640 STE] G S AR W
Tenicroa
exuviata (Jacq.) Speta [McDonald 1971 STE] G S MSS W
Rhadamanthus
albiflorus B. Nord. [X] **Endemic** G S MSS
Ornithogalum
dubium Houtt. [McDonald 1641 STE] G S AR W
longibracteatum Jacq. [CJG] G S MSS W
niveum Ait. [X] G S HAW W

ASPARAGACEAE

Protasparagus
aethiopicus (L.) Oberm. [Mauve & Hugo 230 STE] G S MSS V
macowanii (Bak.) Oberm. [CJG] G S MSS V
rubicundus (Berg.) Oberm. [Taylor 1036 NBG] LSH S MSS V
setaceus (Kunth) Oberm. [Taylor 331 NBG] HE S MSS V
striatus (L.f.) Oberm. [Bohnen 8442 STE] LSH S MSS V
Myrsiphyllum
asparagoides (L.) Willd. [Mauve & Hugo 250 STE] V S MSS V
declinatum (L.) Oberm. [McDonald 1999 STE] V S MSS V
scandens (Thunb.) Oberm. [Zeyher 8507b STE] V S MSS V
ramosissimum (Bak.) Oberm. [Lewis 5941 NBG] V S MSS V

HAEMODORACEAE
Dilatris
ixioides Lam. [McDonald 1099 STE] G S AR P
viscosa L.f. [McDonald 1513 STE] G S MSS P
Wachendorfia
thyrsiflora L. [Haynes 1501 STE] G S MSS P

LANARIACEAE
Lanaria
lanata (L.) Dur. & Schinz. [van Wyk 346 STE] H S MSS P

AMARYLLIDACEAE
Haemanthus
coccineus L. [X] G S MSS P
Nerine
humilis (Jacq.) Herb. [du Plessis 33 STE] G S MSS W
Cyrtanthus
ochroleucus (Herb.) Burch. ex Steud. [Oliver 8639 STE] G S MSS W
odorus Ker Gawl. [Viviers 186 STE] G S MSS W

HYPOXIACEAE
Spiloxene
flaccida (Nel) Garside [Haynes 633 STE] G S MSS P

IRIDACEAE
Moraea
angusta (Thunb.) Ker [McDonald 1988 STE] G S MSS W
gawleri Spreng. [Wurts 277 NBG] G S MSS W
inconspicua Goldbl. [McDonald 1643 STE] G S AR W
neglecta G.J. Lewis [X] G S MSS W
ramosissima (L.f.) Druce [Wurts 452 NBG] G S MSS W
tripetala (L.f.) Ker-Gawl. [Lamb 12 STE] G S MSS W
unguiculata Ker-Gawl. [Wurts 364 NBG] G S MSS W
Dietes
iridioides (L.) Sweet ex Klatt [Taylor 330 NBG] G S MSS P
Bobartia
macrospatha Bak. subsp. anceps (Bak.) Strid [McDonald 2055 STE] **Endemic** G S MSS P
macrospatha Bak. subsp. macrospatha [McDonald 1410 STE] G S MSS P
parva J.B. Gillett [McDonald 1874 STE] **Endemic** G S HAW P
Aristea
africana (L.) Hoffmg. [T.J. van der Merwe 156] G S AR P
bakeri Klatt [X] G S MSS P
confusa Goldbl. [Ruiters 44 STE] G S MSS P
ensifolia Muir [CJG] G S MSS P
major Andrews [McDonald 1048 STE] G S MSS P
monticola Goldbl. [McDonald 1445 STE] G S MSS P
racemosa Bak. var. racemosa [McDonald 1898 STE] G S HAD P
Nivenia
capitata (Klatt) Weim. [McDonald 1797 STE] LSH S HAW P
fruticosa (L.f.) Bak. [McDonald 1793 STE] **Endemic** LSH S HAW P
Tritonia
cooperi (Bak.) Klatt subsp. cooperi [McDonald 2032 STE] LSH S MSS W
Klattia
partita Bak. [McDonald 1835 STE] LSH S HAW P
Geissorhiza
aspera Goldbl. [Taylor 4228 STE] G S MSS P
burchellii Foster [Stirton & Zantovska 11276 STE] G S MSS P
foliosa Klatt [McDonald 1956a STE] G S MSS P
ovata (Burm. f.) Aschers. & Graebn. [Hugo 2707 STE] G S MSS P
parva Bak. [Wurts 389 NBG] G S MSS P
ramosa Ker-Gawl. ex Klatt. [Ruiters 42 STE] G S MSS P
Ixia
gloriosa G.J. Lewis [X] G S AR W
stohriae L.Bol. [Ruiters 19 STE] **Endemic** G S MSS W
micrandra Bak. var. micrandra [de Vos 2689 STE] G S MSS W

Babiana
fourcadei G.J. Lewis [Marsh 865 STE] G S MSS P
Gladiolus
bilineatus G.J. Lewis [Wurts 10 NBG] G S MSS W
carneus Delaroche [Taylor 4232 STE] G S MSS W
emiliae L. Bol. [Taylor 7693 STE] G S MSS W
engysiphon G.J. Lewis [X] G S MSS W
liliaceus Houtt [McDonald 1230 STE] G S MSS W
permeabilis Delaroche subsp. permeabilis [McDonald 1975 STE] G S AR W
rogersii Bak. [McDonald 975 STE] G S MSS W
Tritoniopsis
apiculata (Bol. f.) G.J. Lewis [Bohnen 8429 STE] G S MSS W
burchellii (Burm. f.) Goldbl. [X] G S AR W
caffra (Ker ex Baker) Goldbl. [Haynes 1388 STE] G S AR W
nervosa (Thunb.) Goldbl. [McDonald 1636 STE] G S AR W
ramosa (Eckl. ex Klatt) G.J. Lewis var. robusta G.J. Lewis [McDonald 1161 STE] G S HAW W
ramosa (Eckl. ex Klatt) G.J. Lewis var. unguiculata (Bak.) G.J. Lewis [Lewis 5381 NBG] G S HAW W
triticea (Burm. f.) Goldbl. [Marsh 1106 STE] G S AR W
Lapeirousia
micrantha (E. Mey. ex Klatt) Bak. [Taylor 4224 STE] G S MSS W
Watsonia
angusta Ker [Viviers 1128 STE] G S MSS W
emiliae L. Bol. [E.Ferguson: BOL 19975] G S HAW W
fourcadei J.W. Mathews & L. Bol. [McDonald 1235 STE] G S AR W
knysnana L. Bol. [McDonald 2034 STE] G S HAW W
laccata (Jacquin) Ker [Taylor 7211 STE] G S MSS W
schlechteri L. Bol. [de Kock 108 STE] G S MSS W
Freesia
sparrmannii (Thunb.) N.E. Br. [McDonald 1192 STE] **Endemic** G S MSS W

ORCHIDACEAE
Holothrix
cernua (Burm. f.) Schelpe [Thompson 3285 STE] G S MSS W
exilis Lindl. [X] G S MSS W
mundii Sond. [X] G S MSS W
parviflora (Lind.) Reichb. f. [Marsh 681 STE] G S MSS W
secunda (Thunb.) Reichb. f. [Tolken 1585 NBG] G S AR W
villosa Lindl. [Mauve & Hugo 233 STE] G S MSS W
Bartholina
etheliae H. Bol. [McDonald 1796 STE] G S HAW W
Bonatea
speciosa (L.f.) Willd. [X] G NS MSS W
Pachites
appressa Lindl. [Viviers 944 NBG] **Endemic** G S HAW W
Satyrium
acuminatum Lindl. [McDonald 1623 STE] G S MSS W
lupulinum Lindl. [McDonald 1539 STE] G S HAW W
stenopetalum Lindl. subsp. stenopetalum [Bohnen 9154] G S MSS W
Schizodium
bifidum (Thunb.) Reichb. f. [McDonald 1993 STE] G S MSS W
inflexum Lindl. [McDonald 1477 STE] G S HAW W
obliquum subsp. clavigerum (Lindl.) Linder [McDonald 918 STE] G S MSS W
Disa
atricapilla (Harv. ex Lindl.) Bol. [X] G S MSS W
cardinalis Linder [Burger 1 STE] **Endemic** HE NS HAW WA
bivalvata (L.F.) Dur. & Schinz [Thompson 640 STE] G S HAW W
cornuta (L.) Sw. [McDonald 1540 STE] G S HAW W

fasciata Lindl. [Galpin 4618] G S MSS W
ferruginea (Thunb.) Sw. [McDonald 1255 STE] G S HAW W
filicornis (L.f.) Thunb. [McDonald 1789 STE] G S HAW W
gladioliflora Lindl. subsp. capricornis (Reichb. f.) Linder [McDonald 1253 STE] **Endemic** G S HAW W
glandulosa Burch. ex Lindl. [McDonald 1887 STE] HE S HAW W
micropetala Schltr. [Esterhuysen 33 425 NBG] G S HAW W
obtusa subsp. picta (Sond.) Linder [Linder 1605 NBG] G S HAW W
sagittalis (L.f.) Swartz [McDonald 1677 STE] HE S MSS W
schizodioides Sond. [Wurts 530 NBG] G S HAW W
subtenuicornis Bol. [Linder 1708 NBG] **Endemic** G S HAW W
tenuifolia Sw. [Linder 2788 BOL] G S MSS W
tripetaloides (L.f.) N.E. Br. subsp. aurata (H. Bol.) Linder [McDonald 1886 STE] **Endemic** HE S HAW A
tripetaloides (L.f.) N.E. Br. subsp. tripetaloides [McDonald 1504 STE] HE S HAW WA
uncinata H. Bol. [McDonald 1476 STE] HE S HAW WA
vasselotii H.Bol. ex Schltr. [McDonald 1891 STE] G S HAW W
Herschelianthe
graminifolia (Spreng.) Rauschert [Wurts 558 NBG] G S HAD W
hians (L.f.) Rauschert [McDonald 1788 STE] G S HAD W
schlechteriana (H. Bol.) N.C. Anthony [McDonald 1794 STE] **Endemic** G S AR W
Monadenia
bolusiana (Schltr.) Rolfe [X] G S HAW W
bracteata (Swartz) Dur. & Schinz [McDonald 1994 STE] G S MSS W
ophrydea Lindl. [McDonald 1207 STE] G S HAW W
reticulata (Bol.) Dur. & Schinz [Barker 8838 NBG] G S MSS W
rufescens (Sw.) Lindl. [Taylor 8264 STE] G S MSS W
Disperis
capensis Sw. [McDonald 1186 STE] G S HAW W
paludosa Harv. [McDonald 1084a STE] G S HAW W
Pterygodium
acutifolium Lindl. [McDonald 1622 STE] G S MSS W
catholicum (L.) Sw. [Wurts 2188 NBG] G S MSS W
Ceratandra
atrata (L.) Dur. & Schinz [McDonald 2011 STE] G S MSS W
Corycium
carnosum (Lindl.) Rolfe [McDonald 1470 STE] G S MSS W
rubiginosum (Sond.) Rolfe [X] G S MSS W
Acrolophia
capensis (Berg.) Fourc. [McDonald 1791 STE] G S HAD W
lunata (Schltr.) Schltr. & H. Bol. [McDonald 1481 STE] G S HAW W
Polystachya
ottoniana Reichb. f. [Taylor 335 NBG] Ep NS MSS W
Eulophia
aculeata (L.f.) Spreng. subsp. aculeata [McDonald 1475 STE] G S HAD W
Angraecum
pusillum Lindl. [McDonald 1593 STE] Ep NS MSS W
sacciferum Lindl. [McDonald 1594 STE] Ep NS MSS W

ANGIOSPERMAE – DICOTYLEDONAE

PIPERACEAE
Piper
capense L.f. [P.J. van der Merwe 1390 STE] LSH NS MSS P
Peperomia
retusa (L.f.) A. Dietr. var. retusa [McDonald 1262 STE] Ep NS MSS P
tetraphylla (G. Forst.) Hook. & Arn. [van Wyk 1210 STE] Ep NS MSS P

SALICACEAE
Salix
capensis Thunb. [McDonald 914 STE] TSH NS MSS P

MYRICACEAE
Myrica
kraussiana Buching ex Meisn. [McDonald 1229 STE] DSH S HAW P
serrata Lam. [van Wyk 1210 STE] T NS MSS V

ULMACEAE
Celtis
africana Burm. f. [Taylor 7622 STE] T NS MSS V

URTICACEAE
Droguetia
burchellii N.E. Br. [CJG] F NS MSS P
thunbergii N.E. Br. [Taylor 1040 NBG] F NS MSS P

PROTEACEAE
Brabejum
stellatifolium L. [Walters 69 STE] T S MSS WA
Paranomus
dispersus Levyns [McDonald 1941 STE] LSH NS AR A
longicaulis Salisb. ex Knight [McDonald 2081 STE] MSH NS AR A
spathulatus (Thunb.) O. Kuntze [McDonald 1984 STE] **Endemic** MSH S AR A
Serruria
balanocephala Rourke [McDonald 1013 STE] **Endemic** LSH NS AR A
fasciflora Salisb. ex Knight [McDonald 1494 STE] LSH NS MSS A
Mimetes
cucullatus (L.) R. Br. [Lamb 203 STE] LSH S MSS A
splendidus Knight [McDonald 1180 STE] TSH NS HAW A
Spatalla
colorata Meisn. [McDonald 1160 STE] LSH NS HAW A
nubicola Rourke [McDonald 1057] **Endemic** LSH NS HAW A
parilis Salisb. ex Knight [McDonald 864 STE] MSH NS MSS A
Protea
aspera Phill. [McDonald 2084 STE] DSH S AR W
aurea (Burm. f.) Rourke subsp. aurea [McDonald 967 STE] TSH NS HAW P
cordata Thunb. [McDonald 1152 STE] DSH NS HAW P
coronata Lam. [McDonald 1016 STE] TSH NS MSS P
decurrens Phill. [X] LSH NS MSS P
cynaroides (L.) L. [Walters 66 STE] MSH S MSS P
eximia (Salisb. ex Knight) Fourc. [McDonald 1500 STE] TSH NS HAD P
grandiceps Tratt. [McDonald 1150a STE] MSH NS HAW P
humiflora Andr. [McDonald 2087 STE] LSH NS AR P
lorea R. Br. [Muir s.n. STE] DSH S MSS P
lorifolia (Salisb. ex Knight) Fourcade [Herre STEU 11705] MSH NS AR P
magnifica Link [Haynes 950] LSH NS HAD P
neriifolia R. Br. [McDonald 1151 STE] TSH NS HAD P
nitida Mill. [Taylor 7590 STE] TSH S MSS P
piscina Rourke [Lamb 25 STE] DSH S MSS P
repens (L.) L. [Compton & Cook 2053/23 NBG] TSH NS HAD P
scolopendrifolia (Salisb. ex Knight) Rourke [Rourke 642 NBG] DSH S MSS P
speciosa (L.) L. [Taylor 4758 STE] LSH S MSS P
Leucospermum
calligerum (Salisb. ex Knight) Rourke [McDonald 1448 STE] MSH NS AR A
cuneiforme (Burm. f.) Rourke [McDonald 1985 STE] MSH S MSS A

erubescens Rourke [McDonald 1071 STE] **Endemic** TSH NS AR A
formosum (Andr.) Sweet [McDonald 1831 STE] TSH NS MSS A
mundii Meisn. [McDonald 1248 STE] **Endemic** LSH NS HAD A
saxatile (Salisb. ex Knight) Rourke [McDonald 1771 STE] **Endemic** LSH NS AR A
winteri Rourke [McDonald 2068 STE] LSH NS HAW A
Leucadendron
album (Thunb.) Fourcade [McDonald 1162 STE] MSH NS HAD W
comosum (Thunb.) R. Br. [Bohnen 8664 STE] MSH NS HAW W
cordatum Phill. [McDonald 1876 STE] LSH NS AR P
ericifolium R.Br. [McDonald 913 STE] TSH NS AR P
eucalyptifolium Buek. ex Meisn. [McDonald 1050 STE] TSH NS MSS W
nervosum Phill & Hutch. [McDonald 1586 STE] MSH NS HAD P
radiatum Phill. & Hutch. [McDonald 1212 STE] **Endemic** MSH NS HAW W
rubrum Burm. f. [Bohnen 8652 STE] TSH NS AR W
salicifolium (Salisb.) I.J. Williams [Bohnen 8241 STE] TSH NS MSS W
salignum Berg. [McDonald 1346 STE] MSH S AR W
spissifolium (Salisb. ex Knight) Williams subsp. spissifolium [McDonald 1547 STE] LSH S HAW W
tinctum I. Williams [McDonald 1250 STE] MSH NS HAD P
tradouwense I. Williams [McDonald 911 STE] **Endemic** MSH NS MSS P
xanthoconus (O.Kuntze) K. Schum. [McDonald 1972 STE] TSH NS MSS W
Aulax
cancellata (L.) Druce [McDonald 1785 STE] MSH NS HAW W
pallasia Stapf [Bohnen 8655 STE] MSH S HAD W

SANTALACEAE
Colpoon
compressum Berg. [Burger 50 STE] MSH NS MSS P
Thesidium
fragile Sond. [X] DSH NS MSS P
microcarpum A DC. [X] DSH NS MSS P
Thesium
carinatum A. DC. [Taylor 4773 STE] LSH NS MSS P
capituliflorum Sond. [Taylor 7618 STE] DSH NS MSS P
ericaefolium A. DC. [X] DSH NS HAD P
euphorbioides L. [McDonald 2103 STE] TSH NS AR P
funale L. [Taylor 7763 STE] LSH NS MSS P
glaucescens A.W. Hill [X] **Endemic** LSH NS MSS P
glomeruliflorum Sond. [van Wyk 683 STE] LSH NS MSS P
micromeria A. DC. [X] LSH NS MSS P
nigromontanum Sond. [Taylor 3861, 7598 STE] DSH NS MSS P
paronychioides Sond. [X] DSH NS MSS P
pinifolium A. DC. [Taylor 3865 STE] TSH NS MSS P
subnudum Sond. [X] LSH NS HAD P
spicatum L. [Taylor 7599 STE] LSH NS MSS P
virgatum Lam. [Taylor 4754, 4755 STE] LSH NS AR P

GRUBBIACEAE
Grubbia
rosmarinifolia Berg. subsp. rosmarinifolia var. rosmarinifolia [McDonald 898 STE] MSH NS MSS P
tomentosa (Thunb.) Harms [Marloth 3577 STE] MSH S MSS P

POLYGONACEAE
Rumex
sagittatus Thunb. [CJG] V NS MSS P

AIZOACEAE
Galenia
africana L. [X] MSH NS AR P
Pharnaceum
ciliare Adamson [X] DSH NS AR P

MESEMBRYANTHEMACEAE
Carpobrotus
sp. edulis [X] SUC NS HAD V
Drosanthemum
croceum L. Bol. [Esterhuysen 33 307 STE] **Endemic** SUC NS AR P
Erepsia
tuberculata N.E. Br. [Esterhuysen 14 394 BOL] SUC NS AR P
Lampranthus
deltoides (L.) Glen [Levyns 695 BOL] SUC NS HAD P
Machairophyllum
cookii (L. Bol.) Schwantes [McDonald 1041 STE] **Endemic** SUC NS AR P
Ruschia
sp. [McDonald 1885 STE] SUC NS AR P

CARYOPHYLLACEAE
Dianthus
caespitosus Thunb. subsp. caespitosus [T.J. van der Merwe 280 STE] F NS AR P

RANUNCULACEAE
Anemone
tenuifolia (L.f.) DC. [McDonald 956 STE] G S HAW P
Knowltonia
anemonoides H. Rasm. subsp. tenuis H. Rasm. [McDonald 1022 STE] F S MSS P
vesicatoria (L.f.) Sims subsp. grossa H. Rasm. [Wurts 407 NBG] F S MSS P
Ranunculus
multifidus Forssk. [Marsh 1124] F S MSS P

LAURACEAE
Ocotea
bullata (Burch.) Baill. [P.J. van der Merwe 1308 STE] T S MSS V
Cryptocarya
angustifolia E. Mey. ex Meisn. [Taylor 7595 STE] T NS MSS V
Cassytha
ciliolata Nees [Wurts 472a NBG] V/Pa NS MSS V

BRASSICACEAE
Heliophila
scoparia Burch. ex DC. var.aspera (Schlechter) Marais [McDonald 1135 STE] F NS AR P
elongata (Thunb.) DC. [X] LSH NS MSS P
Cardamine
africana L. [CJG] F NS MSS P

CAPPARACEAE

Capparis
sepiaria L. var. citrifolia (Lam.) Tölken [CJG] V NS MSS P

DROSERACEAE

Drosera
aliceae Hamet [McDonald 1645 STE] HE NS MSS P
capensis L. [du Plessis 21 STE] HE NS MSS P
cistiflora L. [X] HE NS MSS P
trinervia Spreng. [Mauve & Hugo 234 STE] HE NS MSS P

RORIDULACEAE

Roridula
gorgonias Planch. [Nolte 1 STE] LSH NS MSS P

CRASSULACEAE

Crassula
atropurpurea (Harv.) Dietr. var. atropurpurea [McDonald 1008 STE] SUC NS AR P
ericoides Haw. [Hugo 1077] SUC NS MSS P
fascicularis Lam. [McDonald 1436 STE] SUC NS HAD P
lanceolata (Eckl. & Zeyh.) Endl. ex Walp. subsp. lanceolata [X] SUC NS AR P
muscosa L. [Taylor 4033 NBG] SUC NS AR P
obtusa Harv. [McDonald 1992 STE] SUC NS AR P
rubricaulis Eckl. & Zeyh. [Rourke 310 NBG] SUC NS AR P
rupestris Thunb. subsp. rupestris [du Plessis 32 STE] SUC NS AR P
Adromischus
triflorus (L.f.) Berger [Burger 88 STE] SUC NS AR P

MONTINIACEAE

Montinia
caryophyllacea Thunb. [Bohnen 8342 STE] LSH NS MSS P

PITTOSPORACEAE

Pittosporum
viridiflorum Sims [Levyns & Levyns 716 STE] T NS MSS V

CUNONIACEAE

Platylophus
trifoliatus (L.f.) D. Don [van Wyk 1219 STE] T NS MSS P
Cunonia
capensis L. [McDonald 2077 STE] T S MSS P

BRUNIACEAE

Thamnea
gracilis Oliv. [Burchell 7342 BOL] **Endemic** DSH NS MSS P
Linconia
alopecuroides L. [McDonald 1055 STE] LSH S MSS P

Raspalia
barnardii Pillans [Esterhuysen 33 405 BOL] **Endemic** LSH NS MSS P
schlechteri Duemmer [X] **Endemic** LSH NS MSS P
variabilis Pillans [T.J. van der Merwe 264 STE] MSH NS AR P
virgata (Brongn.) Pillans [McDonald 1610 STE] MSH NS MSS P

Nebelia
paleacea (Berg.) Sweet [X] LSH NS MSS P
Pseudobaeckia
cordata Nieden. [McDonald 2040 STE] MSH NS MSS P
Brunia
alopecuroides Thunb. [X] MSH NS HAW P
laevis Thunb. [T.J. van der Merwe 239] MSH NS AR P
neglecta Schltr. [McDonald 1252 STE] MSH NS HAW P
nodiflora L. [McDonald 1210 STE] MSH NS HAW P
Mniothamnea
bullata Schltr. [Esterhuysen 10 479 NBG] **Endemic** DSH S MSS P
callunoides (Oliv.) Niedenzu [McDonald & Morley 1052 STE] **Endemic** DSH S MSS P
Berzelia
burchellii Duemmer [Campbell 14 834 STE] MSH S MSS P
galpinii Pillans [Fellingham 444] **Endemic** MSH S MSS P
intermedia (Dietr.) Schlechtd. [McDonald 1507 STE] TSH S MSS P

HAMAMELIDACEAE

Trichocladus
crinitus (Thunb.) Pers. [CJG] TSH NS MSS P

ROSACEAE

Cliffortia
alata N.E. Br. [Levyns 2118 BOL] **Endemic** LSH NS AR W
atrata Weim. [X] LSH NS MSS P
burchellii Stapf [McDonald 1265 STE] MSH NS MSS P
densa Weim. [McDonald 1864 STE] **Endemic** DSH NS HAW P
dispar Weim. [Esterhuysen 10 446 BOL] LSH NS HAW P
erectisepala Weim. [Taylor 7762 STE] MSH NS MSS P
exilifolia Weim. [Esterhuysen 24 506 BOL] MSH NS HAW P
ferruginea L.f [Campbell 14833 STE] DSH NS HAW P
glauca Weim. [Kruger 1270 STE] LSH NS MSS P
gracilis Harv. [Schlechter 2203 STE] DSH NS MSS P
grandifolia Eckl. & Zeyh. var. grandifolia [McDonald 1614 STE] TSH NS MSS P
heterophylla Weim. [Taylor 4244 STE] MSH NS HAD P
lanceolata Weim. [Taylor 4244 STE] **Endemic** LSH NS HAW P
polita Weim. [Taylor 7762 STE] LSH NS MSS P
propinqua Eckl. & Zeyh. [Compton 20348 NBG] LSH NS HAD P
pulchella L.f. [McDonald 877 STE] LSH NS AR P
ruscifolia L. var. ruscifolia [van Wyk 701 STE] MSH NS MSS P
serpyllifolia Cham. & Schltd. [T.J. van der Merwe 129 STE] MSH NS MSS P
stricta Weim. [Boucher 3685 STE] MSH NS MSS P
tuberculata (Harv.) Weim. [McDonald 1893 STE] LSH NS HAW P
Rubus
pinnatus Willd. [Taylor 515 NBG] V S MSS V

FABACEAE
Virgilia
oroboides (Berg.) Salter subsp. oroboides [X] T NS MSS P
Cyclopia
aurescens Kies [X] DSH S HAW P
bowieana Harv. [McDonald 1534 STE] LSH S HAW P
intermedia E. Mey. [X] MSH S HAW P
maculata (Andr.) Kies [X] LSH S MSS P
montana Hofmeyer & Phill. var. glabra [McDonald 1408 STE] MSH S MSS P
sessiliflora Eckl. & Zeyh. [Esterhuysen 29 482 BOL] MSH S HAW P
Podalyria
amoena Eckl. & Zeyh. [McDonald 1455 STE] MSH NS AR P
cuneifolia Vent. [X] MSH NS MSS P
lanceolata Benth. [Wurts 262 NBG] MSH NS MSS P
myrtillifolia (Retz.) Willd. [McDonald 1025 STE] LSH NS MSS P
Liparia
splendens (Burm. f.) Bos & de Wit subsp. comantha (Eckl. & Zeyh.) Bos & de Wit [Haynes 663 STE] LSH NS MSS P
Priestleya
hirsuta (Thunb.) DC. [McDonald 1277 STE] TSH NS HAW P
teres (Thunb.) DC. [X] **Endemic** LSH NS MSS P
Amphithalea
axillaris Granby [McDonald 1659 STE] **Endemic** LSH NS HAW P
intermedia Eckl. & Zeyh. [Taylor 10042 STE] LSH NS MSS P
violacea (E. Mey.) Benth. [McDonald 2105 STE] DSH NS AR P
Coelidium
bullatum Benth. [X] **Endemic** DSH NS HAW P
cymbifolium C.A. Smith [McDonald 2105a STE] **Endemic** DSH NS AR P
Rafnia
capensis (L.) Druce [McDonald 2071 STE] LSH S AR P
cuneifolia Thunb. [McDonald 1243 STE] LSH S HAD P
dichotoma Eckl. & Zeyh. [McDonald 1449 STE] LSH S AR P
fastigiata Eckl. & Zeyh. [X] **Endemic** LSH S HAW P
ovata (Berg.) Schinz [McDonald 1204 STE] LSH S HAD P
racemosa Eckl. & Zeyh. [McDonald 1558 STE] LSH S HAD P
Lotononis
umbellata (L.) Benth. [X] DSH NS MSS P
varia (E. Mey.) Steud. [X] DSH NS MSS P
Lebeckia
leptophylla Benth. [X] **Endemic** LSH NS HAW P
Aspalathus
acanthes Eckl. & Zeyh. [McDonald 1773 STE] **Endemic** MSH NS AR P
angustifolia (Lam. R. Dahlgr. subsp. angustifolia [Marsh 1103 STE] LSH NS MSS P
arida E. Mey. subsp. procumbens (E. Mey.) R. Dahlgr. [X] MSH NS AR P
aspalathoides (L.) Rothm. [McDonald 1939 STE] LSH NS AR P
biflora E. Mey. subsp. biflora [McDonald 1438 STE] DSH NS MSS P
calcarata Harv. [X] LSH NS MSS P
ciliaris L. [McDonald 2036 STE] MSH NS HAW P
cliffortioides H. Bol. [McDonald 1940 STE] DSH NS AR P
crassisepala R. Dahlg. [McDonald 2072 STE] DSH NS AR P
diffusa Eckl. & Zeyh. [Stirton & Zantovska 11262 STE] DSH NS MSS P
granulata R. Dahlg. [McDonald 1066 STE] DSH NS AR P
hirta E. Mey subsp. hirta [McDonald 1069 STE] MSH NS AR P
hypnoides R. Dahlgr. [McDonald 2026a STE] **Endemic** LSH NS MSS P
inops Eckl. & Zeyh. [Taylor 10059 STE] LSH NS HAW P
longifolia Benth. [Dahlgren & Strid 2588 NBG] **Endemic** MSH NS AR P
nigra L. [McDonald 1638 STE] LSH NS AR P
opaca Eckl. & Zeyh. subsp. opaca [McDonald 2057 STE] DSH NS MSS P
pachyloba Benth. subsp. pachyloba [McDonald 1857 STE] TSH NS AR P
perforata (Thunb.) R. Dahlgr. [Schlechter 2137 NBG] LSH NS MSS P

rubens Thunb. [Compton 8587 BOL] LSH NS HAD P
securifolia Eckl. & Zeyh. subsp. securifolia [McDonald 1178 STE] LSH NS MSS P
spinosa L. subsp. glauca (Eckl. & Zeyh.) R. Dahlgr. [McDonald 1484 STE] DSH NS AR P
stenophylla Eckl. & Zeyh. subsp. garciana R. Dahlgr. [McDonald 1423 STE] DSH S MSS P
verbasciformis R. Dahlgr. [McDonald 1644 STE] **Endemic** MSH NS AR P
vulpina Garab.ex. R. Dahlgr. [Dahlgren & Strid 2582] **Endemic** LSH NS AR P
willdenowiana Benth. [McDonald 2037 STE] TSH NS HAW P

Argyrolobium
filiforme Eckl. & Zeyh. [X] F NS MSS P
Hypocalyptus
coluteoides (Lam.) R. Dahlg. [McDonald 1040 STE] TSH NS MSS P
sophoroides (Berg.) Baill. [McDonald 1454 STE] MSH NS AR P
Indigofera
alopecuroides DC. var. minor [Haynes 628 STE] DSH S MSS P
cf. declinata E. Mey. [McDonald 2013 STE] DSH S MSS P
concava Harv. [McDonald 1177 STE] DSH S MSS P
complicata Eckl. & Zeyh. [X] LSH S HAW P
filifolia Thunb. [McDonald 1802 STE] MSH S MSS P
flabellata Harv. [McDonald 1991 STE] LSH S MSS P
heterophylla Thunb. [McDonald 1965 STE] DSH NS MSS P
langebergensis L. Bol. [McDonald 1474 STE] **Endemic** DSH S MSS P
mundtiana Eckl. & Zeyh. [X] DSH S MSS P
ovata Thunb. [X] DSH S MSS P
pappei H.G. Fourcade [McDonald 1127 STE] LSH S HAD P
pentaphylla Burch. non Murr. [McDonald 1159 STE] DSH S HAW P
sarmentosa L.f. [McDonald 1803 STE] DSH S HAW P
Psoralea
aphylla L. [McDonald 1488 STE] TSH S MSS P
azurea C.H. Stirton ined. [McDonald 2042 STE] DSH S MSS P
cordata Thunb. [Barker 8949 NBG] DSH S MSS P
ensifolia (Houtt.) Merrill [T.P.Stokoe s.n. NBG] LSH S MSS P
filifolia Thunb. [Rourke 1897 NBG] **Endemic** TSH S AR P
imbricata (L.) Salter [T.P. Stokoe s.n. NBG] DSH NS MSS P
intonsa Stirton ined. [McDonald 2117 STE] MSH NS HAW P
laxa Salter [McDonald 1443 STE] DSH S MSS P
monophylla (L.) C.H. Stirton [Marsh 1164 STE] DSH S MSS P
nubicola C.H. Stirton ined. [Rourke 1760 NBG] **Endemic** MSH NS HAW P
pinnata L. [McDonald 1453 STE] TSH NS MSS P
speciosa C.H. Stirton ined. [Stirton & Zantovska 11542 NBG] LSH NS MSS P
verrucosa Willd. [X] MSH NS MSS P
Otholobium
bowieanum (Harv.) C.H. Stirton [McDonald 2131 STE] **Endemic** DSH S AR P
candicans (Eckl. & Zeyh.) C.H. Stirton [McDonald 1828 STE] LSH NS HAD P
decumbens (Ait.) C.H. Stirton [Wurts 478 NBG] DSH NS MSS P
saxosum C.H. Stirton [Bolus 11264 BOL] **Endemic** LSH NS MSS P
spicatum (L.) C.H. Stirton [Stirton & Zantovska 11279] MSH NS MSS P
striatum (Thunb.) C.H. Stirton [X] TSH NS AR P
Tephrosia
capensis (Jacq.) Pers. [McDonald 1750 STE] DSH S MSS P
Rhynchosia
chrysoscias Benth. [McDonald 1955 STE] DSH S MSS P
leucoscias Benth. ex Harv. [McDonald 1045 STE] DSH S MSS P
Dipogon
lignosus (L.) Verdc. [van Wyk 718] V NS MSS P

GERANIACEAE

Pelargonium

abrotanifolium (L.f.) Jacq. [Marloth 8618 STE] LSH NS AR W
alchemilloides (L.) L'Herit. [Marais s.n. STEU 718] F NS MSS W
candicans Spreng. [McDonald 1023 STE] DSH NS MSS W
caucalifolium Jacq. subsp. caucalifolium [McDonald 2016 STE] F NS MSS W
cf. grossularioides (L.) L'Herit. [McDonald 1818 STE] F NS MSS W
citronellum J.J.A. van der Walt [van der Walt 716 STE] MSH S AR W
cordifolium (Cav.) Curt. [McDonald 939 STE] MSH S HAW W
crispum Berg. [McDonald 910 STE] LSH S HAD W
denticulatum Jacq. [McDonald 1749 STE] MSH S AR W
fruticosum (Cav.) Willd. [McDonald 1062 STE] LSH S AR W
hermannifolium (Berg.) Jacq. [McDonald 1821 STE] LSH S HAD W
hispidum (L.f.) Willd. [McDonald 1787 STE] MSH NS HAW W
multicaule Jacq. subsp. multicaule [McDonald 1884 STE] LSH NS AR W
myrrhifolium (L.) L'Herit. [X] F NS MSS W
ovale L'Herit. subsp. ovale [Esterhuysen 26 240 NBG] DSH S HAD W
papilionaceum (L.) L' Herit. [Moffett 1074 STE] MSH NS MSS W
patulum Jacq. [McDonald 1249 STE] DSH NS HAD W
radens H. Moore [McDonald 1766 STE] LSH NS MSS W
rapaceum (L.) L'Herit. [McDonald 1747 STE] G S AR W
scabrum (L.) L' Herit. [McDonald 1937 STE] MSH S AR W
ternatum (L.f.) Jacq. [McDonald 1028 STE] LSH NS MSS W
tomentosum Jacq. [McDonald 1544 STE] DSH NS HAW W
tricolor (Andr.) Curt. [McDonald 1571 STE] DSH S AR W
triste (L.) L'Herit. [McDonald 1817 STE] G S AR W

OXALIDACEAE

Oxalis

purpurea L. [Haynes 638 STE] G S MSS P

LINACEAE

Linum

africanum L. [McDonald 1633 STE] F NS AR P
gracile Planch. [Rogers 13 702 STE] F NS MSS P
quadrifolium L. [Levyns & Levyns 700] F NS MSS P

ZYGOPHYLLACEAE

Zygophyllum

fulvum L. [McDonald 1334 STE] DSH S HAD A

RUTACEAE

Calodendrum

capense (L.f.) Thunb. [T.H. Brown s.n. NBG] T NS MSS P

Agathosma

bifida (Jacq.) Bart. & Wendl. [McDonald 1969 STE] LSH NS MSS A
blaerioides Cham. [Muir 3328 BOL] LSH NS HAW A
capensis (L.) Dummer [McDonald 2021 STE] LSH NS MSS A
cerefolium (Vent.) Bartl. & Wendl. [McDonald 1064 STE] LSH NS HAD A
crenulata (L.) Pillans [McDonald 965 STE] MSH NS MSS A
elegans Cham. Schltd. [Esterhuysen 17 223] LSH NS MSS A
linifolia (Roem. & Schult.) Bart. & Wendl. [Wurts 411 NBG] **Endemic** LSH NS MSS A
minuta Schlechtd. [McDonald 1131 STE] DSH NS AR A
odoratissima (C.V. Montin) Pillans [McDonald 1533 STE] LSH S HAW A

orbicularis (Thunb.) Bartl. & Wendl. [McDonald 1490 STE] DSH NS HAD A
ovata (Thunb.) Pillans [McDonald 2088 STE] LSH S AR A
robusta Eckl. & Zeyh. [X] **Endemic** DSH NS MSS A
serpyllacea Licht. ex Roem.& Schult. [McDonald 1349 STE] LSH S AR A
umbonata Pillans [Brett 3 STE] **Endemic** LSH NS HAW A
virgata (Lam.) Bart. & Wendl. [Bean] LSH S MSS A
sp. nov. aff. ciliaris [Bean 526 BOL] **Endemic** DSH NS HAD A
sp.nov. Sect. Alares [Williams 2616 BOL] **Endemic** DSH NS HAD A
Adenandra
fragrans (Sims) Roem. et Schultes [McDonald 900 STE] LSH NS MSS A
mundiifolia Eckl. & Zeyh. [McDonald 1241 STE] LSH NS HAD A
Coleonema
calycinum (Steud.) I.J. Williams [Taylor 10 038 STE] MSH NS MSS A
pulchrum Hook. [McDonald 1579 STE] **Endemic** MSH NS MSS A
virgatum (Schlectd.) Eckl. & Zeyh. [McDonald 867 STE] LSH NS MSS A
Acmadenia
burchellii Duemmer [Rourke 301 NBG] **Endemic** DSH NS HAW A
latifolia Williams [McDonald 2099 STE] **Endemic** LSH NS HAD A
nivenii Sond. [McDonald 2085 STE] **Endemic** LSH NS AR A
tetragona (L.f.) Bart. & Wendl. [McDonald 1976 STE] LSH NS AR A
trigona (Eckl. & Zeyh.) Druce [McDonald 1772 STE] LSH NS AR A
Diosma
hirsuta L. [McDonald 1483 STE] LSH NS AR A
prama Williams [McDonald 1635 STE] LSH NS AR A
tenella Williams [Esterhuysen 17 241 BOL] LSH NS MSS A
Euchaetis
avisylvana Williams [McDonald 1289 STE] **Endemic** LSH NS MSS A
Empleurum
fragrans P.E. Glover [McDonald 1181 STE] **Endemic** LSH NS HAW A
unicapsulare (L.f.) Skeels [McDonald 1174 STE] TSH NS MSS A
Vepris
undulata (Thunb.) Verd. & C.A. Sm. [Taylor 7621 STE] T NS MSS A

POLYGALACEAE
Polygala
affinis DC. [X] DSH S MSS A
bracteolata L. [McDonald 1422 STE] LSH S MSS A
fruticosa Berg. [McDonald 1830 STE] LSH S HAD A
langebergensis Levyns [McDonald 2098 STE] **Endemic** DSH NS HAD A
myrtifolia L. [Walgate 931 NBG] TSH NS MSS A
pappeana Eckl. & Zeyh. [McDonald 984 STE] LSH NS MSS A
refracta DC. [X] DSH S HAD A
teretifolia L.f. [McDonald 1816 STE] LSH S AR A
triquetra Presl [Levyns 644 NBG] LSH S MSS A
umbellata L. [Johnson 137 NBG] DSH S AR A
wittebergensis Compton [Bolus 11212 BOL] LSH S AR A
Muraltia
alopecuroides (L.) DC. [McDonald 1245 STE] LSH NS HAD A
ciliaris DC. [McDonald 908 STE] DSH S MSS A
heisteria (L.) DC. [McDonald 990 STE] MSH NS AR A
langebergensis Levyns [X] **Endemic** LSH NS HAW A
leptorhiza Turcz. [McDonald 1039 STE] DSH NS MSS A

EUPHORBIACEAE
Adenocline
acuta (Thunb.) Baill. [CJG] V NS MSS P

Clutia
alaternoides L. [Haynes 1386 STE] DSH S MSS P
ericoides Thunb. var. tenuis Sond. [McDonald 1146 STE] LSH NS MSS P
laxa Eckl. ex Sond. [Bond 309 NBG] LSH NS MSS P
marginata E. Meyer [X] MSH NS MSS P
polygonoides L. [T.J. van der Merwe 71 STE] DSH S MSS P
pulchella L. var pulchella [McDonald 1591 STE] MSH NS MSS P
rubricaulis Eckl. & Zeyh. ex Sond. [X] LSH NS MSS P

ANACARDIACEAE
Laurophyllus
capensis Thunb. [McDonald 1035 STE] TSH S MSS P
Rhus
chirindensis Bak. f. [Taylor 182 NBG] T S MSS V
lucida L. forma lucida [Taylor 513] MSH NS AR V
pallens Eckl. & Zeyh. forma pallens [X] MSH NS MSS V
rehmanniana Engl. var. uitenhagensis [T.P. Stokoe s.n. NBG] MSH NS MSS V
rosmarinifolia Vahl. [X] LSH NS MSS V
tomentosa L. [Haynes 658 STE] MSH NS MSS V

AQUIFOLIACEAE
Ilex
mitis (L.) Radkl. [X] T NS MSS V

CELASTRACEAE
Maytenus
acuminata (L.f.) Loes var. acuminata [Bohnen 7770 STE] T NS MSS V
heterophylla (Eckl. & Zeyh.) N.K.B. Robson [CJG] T NS MSS V
oleoides (Lam.) Loes. [Burger 75 STE] T S MSS V
Pterocelastrus
tricuspidatus (Lam.) Sond. [Esterhuysen 10 373 BOL] T NS MSS V
rostratus (Thunb.) Walp. [McDonald 1268 STE] T NS MSS V
Cassine
eucleiformis (Eckl. & Zeyh.) Kuntze [CJG] T NS MSS V
papillosa (Hochst.) Kuntze [CJG] T NS MSS V
peragua L. [Kruger 1261 STE] T S MSS V
Hartogiella
schinoides (Spreng.) Codd [Taylor 2959 STE] T NS MSS V

ICACINACEAE
Cassinopsis
ilicifolia (Hochst.) Kuntze [Taylor 306 NBG] MSH NS MSS V
Apodytes
dimidiata E. Mey. ex Arn. subsp. dimidiata [Kruger 1292 STE] T NS MSS V
Pyrenacantha
scandens Planch. ex Harv. [Barker 8813 NBG] V NS MSS V

SAPINDACEAE
Dodonaea
angustifolia L.f. [Johnson 140 STE] TSH S AR W

BALSAMINACEAE

Impatiens
hochstetteri Warb. [CJG] F NS MSS B

RHAMNACEAE

Phylica
alba Pillans [T.P. Stokoe s.n. BOL 21331] LSH NS MSS P
axillaris Lam. subsp. microphylla Pillans [Lewis 5397 STE] LSH NS MSS P
brachycephala Sond. [X] LSH NS HAD P
debilis Eckl. & Zeyh. [X] LSH NS MSS P
imberbis Berg. [Salter 6796] LSH S MSS P
longimontana Pillans [Schlechter 1838 BOL] **Endemic** LSH NS MSS P
mairei Pillans [McDonald 1128 STE] LSH NS AR P
mundii Pillans [T.J. van der Merwe 116 STE] LSH NS MSS P
pinea Thunb. [McDonald 1464 STE] TSH NS MSS P
propinqua Sond. [T.J. van der Merwe 140 STE] LSH NS MSS P
purpurea Sond. var. floccosa Pillans [McDonald 2038 STE] MSH NS MSS P
recurvifolia Eckl. & Zeyh. [X] **Endemic** LSH NS MSS P
rogersii Pillans [Taylor 10 271 STE] LSH NS MSS P
rubra Willd. [McDonald 1604 STE] TSH NS MSS P
velutina Sond. [T.J. van der Merwe 279 STE] DSH NS MSS P
Rhamnus
prinoides L'Herit. [Levyns 698 BOL] T NS MSS V
Scutia
myrtina (Burm. f.) Kurz [Taylor 197 NBG] T NS MSS V

VITACEAE

Rhoicissus
digitata (L.f.) Gilg & Brandt [Taylor 307 NBG] V NS MSS V
tomentosa (Lam.) Wild & Drum. [Taylor 304 NBG] V NS MSS V

TILIACEAE

Sparrmannia
africana L.f. [X] T NS MSS V
Grewia
occidentalis L. [McDonald & Morley 1072 STE] T NS MSS V

MALVACEAE

Anisodontea
pseudocapensis D. Bates [X] DSH NS MSS P

STERCULIACEAE

Hermannia
angularis Jacq. [McDonald 1333 STE] LSH S AR P
aspera Wendl. [X] MSH S AR P
flammula Harv. [52/5] LSH S AR P
hyssopifolia L. [McDonald 1823 STE] LSH S HAD P
multiflora Jacq. [McDonald 1024 STE] LSH S MSS P
odorata Ait. [McDonald 1332 STE] LSH NS AR P
saccifera K. Schum. [McDonald 1335 STE] DSH S AR P

salviifolia L.f. var. salviifolia [McDonald 1345 STE] MSH NS AR P

FLACOURTIACEAE
Kiggelaria
africana L. [X] T S MSS V
Scolopia
mundii (Eckl. & Zeyh.) Warb. [van Wyk 1221 STE] T NS MSS V

GEISSOLOMATACEAE
Geissoloma
marginatum (L.) Juss. [McDonald 1413 STE] **Endemic** MSH S MSS P

PENAEACEAE
Penaea
cneorum Meerb. subsp. ovata (Eckl. & Zeyh. ex DC.) R. Dahlg. [McDonald 1775 STE] MSH S HAD P
cneorum Meerb. subsp. ruscifolia R. Dahlgr. [McDonald 1452 STE] MSH S HAD P
dahlgrenii Rourke [McDonald 1818a STE] **Endemic** MSH NS HAW A
mucronata L. [McDonald 2086 STE] LSH S AR P
Stylapterus
dubius (Steph.) Dahlg. [McDonald 1837 STE] **Endemic** MSH NS HAW P
ericifolius (Juss.) R. Dahlg. [du Plessis 85 STE] **Endemic** MSH NS MSS P

OLINIACEAE
Olinia
ventosa (L.) Cufod [Levyns 669 BOL] T NS MSS V

THYMELAEACEAE
Gnidia
decurrens Meisn. [McDonald 2047 STE] LSH S AR P
denudata Lindl. [CJG] LSH S MSS P
francisci H. Bol. [McDonald 2075 STE] LSH NS AR P
galpinii C.H. Wr. [McDonald 1682 STE] DSH S MSS P
juniperifolia Lam. [McDonald 1234 STE] DSH NS HAD P
laxa Gilg [McDonald 1819 STE] LSH NS HAD P
oppositifolia L. [McDonald 1053 STE] MSH S MSS P
scabrida Meisn. [Burchell 7404 STE] MSH S MSS P
Cryptadenia
filicaulis Meisn. [McDonald 1989 STE] DSH S MSS P
Lachnaea
ericoides Meisn. [McDonald 1945 STE] **Endemic** DSH S MSS P
macrantha Meisn. [McDonald 1552 STE] LSH NS HAW P
penicillata Meisn. [McDonald 1353 STE] DSH S AR P
sp. nov. [McDonald 1963 STE] **Endemic** DSH S MSS P
Passerina
obtusifolia Thoday [McDonald 1005 STE] MSH NS AR P
Struthiola
argentea Lehm. [Oliver & Fellingham 9144 STE] LSH NS AR P
ciliata (L.) Lam. [McDonald 902 STE] DSH S MSS P
eckloniana Meisn. [McDonald 1479 STE] MSH S HAW P
ericoides C.H. Wr. [Taylor 7579 STE] DSH S MSS P
garciana C.H. Wr. [McDonald 1960 STE] LSH NS MSS P

martiana Meisn. [McDonald 1288 STE] LSH NS HAW P
myrsinites Lam. [McDonald 1961 STE] LSH NS MSS P

MYRTACEAE
Metrosideros
angustifolia (L.) J.E. Sm. [T.J. van der Merwe 232 STE] T NS MSS P

ARALIACEAE
Cussonia
spicata Thunb. [McDonald 1499 STE] T NS AR V
thyrsiflora Thunb. [CJG] T NS MSS V

APIACEAE
Centella
affinis (Eckl. & Zeyh.) var. richardiana Adamson [X] F NS MSS P
cf. debilis [X] F NS MSS P
dentata Adamson [McDonald 1173 STE] F NS MSS P
eriantha (Rich.) Drude [Taylor 3855 STE] F NS MSS P
glabrata L. var. glabrata [Marsh 1100 STE] F NS MSS P
lanata Compton [McDonald 1517 STE] F NS MSS P
linifolia (L.f.) Druce [X] F NS MSS P
montana (Cham. & Schlechtd.) Domin [McDonald 1083a STE] F NS MSS P
sessilis Adamson [X] F NS MSS P
stenophylla Adamson [McDonald 1607 STE] F NS MSS P
virgata (L.f.) Druce var. congesta Adamson [McDonald 1996 STE] F NS MSS P
virgata (L.f.) Druce var. virgata [McDonald 1246 STE] F NS MSS P
Hermas
capitata L.f. [Esterhuysen 4803 NBG] F NS MSS P
ciliata L.f. [McDonald 1510 STE] F NS MSS P
Sanicula
elata Buch.-Ham. [Taylor 1041] F NS MSS P
Alepidea
capensis R.A. Dyer [Stokoe s.n. STE] F NS MSS P
Heteromorpha
trifoliata (Wendl.) Eckl. & Zeyh. [CJG] MSH NS MSS P
Anginon
difforme (L.) B.L. Burtt [McDonald 1639 STE] F NS AR P
Chamarea
capensis (Thunb.) Eckl. & Zeyh. [X] F NS MSS P
Peucedanum
ferulaceum Thunb. var. ferulaceum [McDonald 2033 STE] F NS MSS P
galbanum (L.) Benth. & Hook. f. [X] MSH NS MSS P
hypoleucum Benth. & Hook. f. [Wurts 453 NBG] F NS MSS P
tenuifolium Thunb. [McDonald 1880 STE] F NS MSS P

CORNACEAE
Curtisia
dentata (Burm. f.) C.A. Sm. [P.J. van der Merwe 1309 STE] T S MSS V

ERICACEAE
Erica
adunca Benth. [McDonald 958 STE] LSH NS MSS P
albens L. [McDonald 1079 STE] MSH NS MSS P
albescens Klotzsch ex Benth. [X] **Endemic** DSH NS MSS P

amicorum E.G.H. Oliver [X] **Endemic** DSH NS MSS P
ardens Andr. [McDonald 1657 STE] **Endemic** DSH NS HAW P
articularis L. [McDonald 2058 STE] DSH NS MSS P
atropurpurea Dulfer [McDonald 1650 STE] **Endemic** DSH NS HAW P
barrydalensis L. Bol. [McDonald 1238 STE] **Endemic** TSH NS AR P
bergiana L. [McDonald 1899 STE] DSH NS AR P
blenna Salisb. [McDonald 959 STE] **Endemic** MSH NS MSS P
bracteolaris Lam. [McDonald 1877 STE] DSH NS MSS P
brevifolia Soland. ex Salisb. [McDonald 1664 STE] DSH NS HAW P
caffra L. [McDonald 1600 STE] TSH NS MSS P
calycina L. [McDonald 1660 STE] LSH NS HAW P
carduifolia Salisb. [McDonald 1208 STE] DSH NS HAW P
caterviflora Salisb. [Zeyher 40730 SAM] **Endemic** (possibly extenct) TSH NS MSS P
cerinthoides L. [McDonald 1351 STE] LSH S AR P
chartacea Guth. & Bol. [McDonald 1686 STE] **Endemic** DSH NS MSS P
chlorosepala Benth. [McDonald 1674 STE] **Endemic** LSH NS HAD P
coccinea L. [McDonald 1256 STE] LSH NS MSS P
comata Guth. & Bol. [X] **Endemic** DSH NS HAW P
condensata Benth. [McDonald 1219 STE] DSH NS HAW P
conferta Andr. [McDonald 1264 STE] DSH NS HAW P
conspicua Sol. [Van Breda 1525 PRE] MSH NS MSS P
copiosa Wendl. [McDonald 964 STE] DSH NS HAW P
cordata Andr. [McDonald 1090 STE] DSH NS HAW P
corifolia L. [Bayliss 5860 NBG] LSH NS MSS P
crassisepala Benth. [Schlechter 7354 BOL] **Endemic** DSH NS HAW P
cubica L. [McDonald 1611 STE] DSH NS MSS P
curviflora L. [McDonald 2063 STE] MSH NS HAW P
cyathiformis Salisb. [Taylor 7607 STE] LSH NS MSS P
daphniflora Salisb. [McDonald 1101 STE] LSH NS HAD P
deliciosa Wendl. f. ex Benth. [McDonald 2051 STE] DSH NS MSS P
densifolia Andr. [McDonald 1642 STE] LSH NS AR P
dianthifolia Salisb. [McDonald 1169 STE] DSH NS HAW P
diaphana Spreng. [Dekenah STEU 10020] DSH NS HAW P
dodii Guth. & Bol. [McDonald 2112 STE] DSH NS HAW P
dysantha Benth. [Rourke 302] **Endemic** DSH NS HAW P
elsieana (E.G.H. Oliver) E.G.H. Oliver [Esterhuysen 24 490 BOL] DSH NS HAW P
georgica Guth. & Bol. [McDonald 1548 STE] DSH NS HAW P
gigantea Klotzsch ex Benth. [Galpin 3626 BOL] **Endemic** MSH NS MSS P
glandulosa Thunb. [McDonald 2024 STE] LSH NS MSS P
gracilis Wendl. [McDonald 899 STE] LSH NS MSS P
grandiflora L.f. var grandiflora [McDonald 878 STE] LSH NS HAD P
granulatifolia H.A. Baker [McDonald 1275 STE] **Endemic** LSH NS HAW P
grata Guth. & Bol. [McDonald 1531 STE] **Endemic** LSH NS MSS P
hispidula L. [McDonald 896 STE] MSH NS HAW P
heleophila Guth. & Bol. [Schlechter 2112 BOL] **Endemic** LSH NS MSS P
heterophylla Guth. & Bol. [Zeyher 40777 SAM] **Endemic** DSH NS MSS P
imbricata L. [McDonald 1284 STE] LSH NS HAW P
inclusa Wendl. [Kirsten 431 NBG] **Endemic** LSH NS MSS P
ixanthera Benth. [Muir 5143 PRE] **Endemic** LSH NS MSS P
kougabergensis H.A. Bak. [Esterhuysen 10 792 NBG] DSH NS HAW P
langebergensis H.A. Bak. [X] **Endemic** DSH NS HAD P
lateralis Willd. [X] DSH NS MSS P
leucodesmia Benth. [McDonald 1460a STE] LSH NS HAD P
longimontana E.G.H. Oliver [McDonald 2064 STE] DSH NS HAW P
macrophylla Klotzsch [McDonald 1545 STE] **Endemic** LSH NS HAW P
macilenta Guth. & Bol. [Schlechter 2043 SAM] **Endemic** MSH NS MSS P
madida E.G.H. Oliver [Stokoe 62 522 SAM] TSH NS MSS P
melanthera L. [McDonald 895 STE] LSH NS MSS P
microcodon Guth. & Bol. [McDonald 1418 STE] LSH NS MSS P
monadelphia Andr. [Burchell 7002] LSH S MSS P

mucronata Andr. [McDonald 2029 STE] DSH NS HAW P
multumbellifera Berg. [McDonald 870 STE] DSH NS HAD P
mundii Guth. & Bol. [Esterhuysen 26 212 BOL] DSH NS MSS P
nematophylla Guth. & Bol. [Vogelpoel & Baker 2472 NBG] **Endemic** LSH NS MSS P
obconica H.A. Bak. [Esterhuysen 31 780 NBG] LSH NS HAW P
obtusata Klotzsch ex Benth. [McDonald 1661 STE] DSH NS HAW P
ocellata Guth. & Bol. [McDonald 1217 STE] **Endemic** LSH NS HAW P
omninoglabra H.A. Baker [McDonald 1836 STE] **Endemic** DSH NS HAW P
oophylla Benth. [X] **Endemic** DSH NS HAW P
oxyandra Guth. & Bol. [X] **Endemic** DSH NS MSS P
palliiflora Salisb. [McDonald 1949 STE] LSH NS MSS P
papyracea Guth. & Bol. [McDonald 1954 STE] **Endemic** MSH NS HAW P
parviflora L. [McDonald 1798 STE] LSH NS MSS P
peltata Andr. [Taylor 7685 STE] LSH NS MSS P
penicilliformis Salisb. [McDonald 1145 STE] LSH NS HAW P
peziza Lodd. [van Wyk 334 NBG] LSH NS MSS P
placentiflora Salisb. [Chater 2822 NBG] LSH NS MSS P
plukenetii L. [McDonald 1987 STE] LSH NS AR P
podophylla Benth. [McDonald 1407 STE] **Endemic** DSH NS HAW P
polifolia Salisb. ex Benth. [McDonald 1417 STE] LSH NS HAW P
pubigera Salisb. [McDonald 905 STE] **Endemic** DSH NS MSS P
quadrangularis Salisb. [McDonald 1620 STE] LSH NS MSS P
racemosa Thunb. [Thompson 633 STE] LSH NS MSS P
regerminans L. [McDonald 1221 STE] LSH NS HAW P
rhodantha Guth. & Bol. [Oliver 10242 STE] **Endemic** LSH NS AR P
rudolfii H. Bol. [McDonald 1460 STE] **Endemic** LSH NS HAD P
seriphiifolia Salisb. [McDonald 1958 STE] LSH NS MSS P
sonderiana Guth & Bol. [Esterhuysen 29 457 NBG] LSH NS HAW P
spectabilis Klotzsch ex Benth. [Marloth 2532 STE] LSH NS MSS P
steinbergiana Wendl. ex Klotzsch var. abbreviata Bol. [McDonald 2066 STE] LSH NS HAW P
stenantha Klotzsch ex Benth [McDonald 1889 STE] LSH NS HAW P
tenuis Salisb. [McDonald 1658 STE] DSH NS HAW P
tenuicaulis Klotzsch ex Benth. [Barnard 45676 SAM] DSH NS HAW P
tetragona L. [McDonald 1782 STE] LSH NS HAD P
tetrathecoides Benth. [McDonald 2026 STE] DSH NS MSS P
tradouwensis Compton [Schumann 305 STE] **Endemic** LSH NS MSS P
transparens Berg. [McDonald 1535 STE] DSH S HAW P
triceps Link [McDonald 1966 STE] LSH NS MSS P
versicolor Wendl. [Thompson 625 STE] MSH NS MSS P
vestita Thunb. [McDonald 1103 STE] MSH NS HAD P
walkeria Andr. [Barnard 28923 SAM] LSH NS MSS P
winteri H.A. Bak. [McDonald 916 STE] **Endemic** LSH NS MSS P
sp. nov. [McDonald 1129 STE] TSH NS HAD P
sp. nov. 'amica-amicorum' [X] **Endemic** DSH NS MSS P
sp. nov. [McDonald 1549 STE] **Endemic** DSH NS HAW P
sp. nov. (Swell. Trail) [McDonald 1862 STE] **Endemic** DSH NS HAW P
sp. nov. [Boucher 1588 STE] **Endemic** DSH NS MSS P
sp. nov. [Esterhuysen 35 152 BOL] **Endemic** DSH NS HAW P
sp. nov. [Esterhuysen 35 157 BOL] **Endemic** DSH NS HAW P
sp. nov. near albescens [Esterhuysen 24 481 BOL] **Endemic** DSH NS HAW P
sp. nov. near amicorum/oligantha [Esterhuysen 18 247 BOL] **Endemic** DSH NS MSS P
sp. nov. near corifolia [Esterhuysen 29 111 BOL] **Endemic** LSH NS HAD P
sp. nov. near obconica/mucronata [Esterhuysen 32 915 BOL] **Endemic** DSH NS HAW P
sp. nov. [Schumann 780 STE] **Endemic** DSH NS HAW P
sp. nov. white flowers [Esterhuysen 24 480 BOL] **Endemic** DSH NS HAW P

Grisebachia

parviflora Klotzsch subsp. pubescens E.G.H. Oliver [McDonald 1967 STE] LSH NS MSS P

Syndesmanthus

articulatus (L.) Klotzsch [McDonald 2060 STE] DSH NS MSS P
scaber Klotzsch [Esterhuysen 16 980 BOL] DSH NS MSS P

similis N.E. Br. [McDonald 2065 STE] DSH NS MSS P
Anomalanthus
scoparius Klotzsch [McDonald 2069 STE] DSH NS MSS P
Thoracosperma
galpinii N.E. Br. [McDonald 996 STE] LSH NS AR P
Sympieza
gracilis (Bartl.) E.G.H. Oliver [McDonald 977 STE] DSH NS MSS P
Scyphogyne
muscosa (Ait.) Druce [McDonald 1878 STE] LSH NS MSS P
tenuis (Benth.) E.G.H. Oliver [Burchell 7034 PRE] **Endemic** DSH NS MSS P
Coccosperma
parviporandrum E.G.H. Oliver [McDonald 1193 STE] LSH NS MSS P

MYRSINACEAE
Myrsine
africana L. [Compton 5727 NBG] T NS MSS V
Rapanea
melanophloeos (L.) Mez [X] T NS MSS V

EBENACEAE
Euclea
polyandra (L.f.) E. Mey ex Hiern. [T.J. van der Merwe 125 STE] LSH NS AR V
racemosa Murray [Bolus 30680 BOL] T NS MSS V
schimperi (A. DC.) Dandy [CJG] T NS MSS V
Diospyros
austro-africana de Winter [X] TSH NS AR V
dichrophylla (Gand.) de Winter [Hugo 1075 STE] TSH NS MSS V
glabra (L.) de Winter [McDonald 2043 STE] LSH NS MSS V
simii (Kuntze) de Winter [CJG] MSH NS MSS V
whyteana (Hiern.) F. White [Zeyher 3352 BOL] TSH NS MSS V

OLEACEAE
Chionanthus
foveolata (E. Mey.) Stearn [CJG] T NS MSS P
Olea
capensis L. subsp. capensis [Bohnen 7769 STE] T S MSS V
capensis L. subsp. macrocarpa (C.H. Wr.) Verdoorn [X] T S MSS V
europaea L. subsp. africana (Mill.) P.S. Green [X] T S MSS V

LOGANIACEAE
Nuxia
floribunda Benth. [CJG] T NS MSS P
Buddleja
saligna Willd. [Willems 82 NBG] T NS MSS P
salviifolia (L.) Lam. [CJG] TSH NS MSS P

GENTIANACEAE
Sebaea
capitata Cham. & Schlechtd. var. sclerosepala (Schinz.) Marais [McDonald 1223 STE] NS HAW P
elongata E. Mey. [McDonald 1434 STE] F NS MSS P

laxa N.E. Br. [Galpin 4337 NBG] **Endemic** F NS MSS P
stricta (E. Mey.) Gilg [McDonald 2097 STE] F NS HAD P
sulphurea Cham. & Schlechtd. [Esterhuysen 25 030 BOL] F NS HAW P

Chironia
jasminoides L. [McDonald 1868 STE] F NS HAW P
linoides L. subsp. linoides [McDonald 1792 STE] LSH NS AR P

APOCYNACEAE
Carissa
bispinosa (L.) Desf. ex Brenan var. bispinosa [CJG] MSH NS MSS V

ASCLEPIADACEAE
Microloma
tenuifolium (L.) K. Schum. [X] F NS AR W
Asclepias
cancellata Burm. f. [Haynes 1462 STE] LSH NS MSS W
Oncinema
lineara (L.f.) Bullock [CJG] V NS MSS W
Secamone
alpinii Schultes [T.J. van der Merwe 77 STE] V NS MSS W

CONVOLVULACEAE
Cuscuta
africana Willd. [McDonald 1414 STE] Pa NS MSS V

BORAGINACEAE
Lobostemon
decorus Levyns [X] LSH S AR P
echioides Lehm. [McDonald 1822 STE] DSH S AR P
muirii Levyns [McDonald 2090 STE] **Endemic** LSH S AR P
strigosus (Lehm.) Buek. [X] LSH S AR P

STILBACEAE
Stilbe
albiflora E. Mey. [X] DSH NS MSS P
phylicoides A. DC. [Taylor 3876, 7203 STE] **Endemic** LSH S MSS P
vestita Berg. [X] LSH NS MSS P

LAMIACEAE
Stachys
aethiopica L. [Wurts 461 NBG] F NS MSS P
sublobata Skan [McDonald 1748 STE] F NS AR P
Plectranthus
fruticosus L'Herit. [McDonald 1281 STE] MSH NS MSS P

SOLANACEAE
Solanum
giganteum Jacq. [CJG] LSH NS MSS P

SCROPHULARIACEAE
Halleria
lucida L. [van der Walt 1537 STE] TSH S MSS V
Oftia
africana (L.) Bocq. [Hugo 62 STE] LSH NS MSS P
Teedia
lucida Rudolphi [McDonald 1044 STE] LSH S MSS V
Sutera
revoluta Kuntze [McDonald 1883 STE] LSH NS AR P
subnuda (N.E. Br.) Hiern. [Burger 29 STE] **Endemic** LSH NS AR P
Polycarena
linearifolia (H. Bol.) Levyns [Esterhuysen 24 579 NBG] DSH NS MSS P
pumila (Benth.) Levyns [X] F NS HAW P
Harveya
bolusii Kuntze [McDonald 1542 STE] HE/Pa NS HAW P
capensis Hook. [McDonald 1790 STE] HE/Pa NS AR P
stenosiphon Hiern. [McDonald 1503 STE] HE/Pa NS MSS P

SELAGINACEAE
Selago
brevifolia Rolfe [McDonald 1136 STE] DSH NS AR P
cylindrica Levyns [Bouls 8072 BOL] DSH NS MSS P
dregei Rolfe [de Kock 100 STE] LSH NS MSS P
eckloniana Choisy [McDonald 1497 STE] LSH NS HAD P
elata Choisy [X] LSH NS MSS P
glabrata Choisy [X] LSH NS MSS P
ramulosa E. Mey. [McDonald 941 STE] LSH NS MSS P
serrata Berg. [McDonald 2041 STE] LSH NS MSS P
spuria L. [Marsh 1118 STE] LSH NS MSS P
verbenacea L.f. [Thompson 639 STE] LSH NS MSS P
Tetraselago
langebergensis
Walafrida
cinerea (L.f.) Rolfe [X] LSH NS MSS P
gracilis Rolfe [X] DSH NS MSS P
squarrosa Rolfe [X] DSH NS MSS P

LENTIBULARIACEAE
Utricularia
capensis Spreng. [Levyns & Levyns 694 STE] HE NS MSS P

RUBIACEAE
Burchellia
bubalina (L.f.) J. Sims [T.J. van der Merwe 1383] T NS MSS P
Rothmannia
capensis Thunb. [Taylor 336 NBG] T NS MSS P
Canthium
inerme (L.f.) Kuntze [Taylor 180 NBG] T NS MSS P

mundianum Cham. & Schlechtd. T NS MSS P
Psydrax
obovata (Eckl. & Zeyh.) Bridson subsp. obovata [CJG] T NS MSS P
Galopina
circaeoides Thunb. [CJG] F NS MSS P
Anthospermum
aethiopicum L. [Bohnen 7599 STE] MSH NS MSS P
galioides Reichb. f. subsp. reflexifolium (Kuntze) Puff [McDonald 1598 STE] DSH NS MSS P
spathulatum Sprengel subsp. spathulatum [McDonald 1000 STE] MSH NS AR P
Nenax
acerosa Gaertn. subsp. acerosa [McDonald 2090a STE] LSH NS AR P
Carpacoce
gigantea Puff [McDonald 1055a STE] **Endemic** LSH NS MSS P
spermacocea (Reichb. f.) Sond. subsp. spermacocea [McDonald 1838 STE] DSH NS HAW P
vaginellata [X] LSH NS MSS P

Galium
mucroniferum Sond. [CJG] F NS MSS P
undulatum Puff McDonald 1263 STE] F NS MSS P

DIPSACACEAE
Scabiosa
columbaria L. [T.J. van der Merwe 286] F NS MSS W

CUCURBITACEAE
Zehneria
scabra (L.f.) Sond. [Taylor 1026 NBG] V NS MSS P

CAMPANULACEAE
Roella
prostrata E. Mey ex A. DC. [Taylor 7690 STE] LSH NS MSS P
Prismatocarpus
brevilobus A. DC. DSH NS MSS P
campanuloides (L.f.) Sond. DSH NS AR P
candolleanus Cham. LSH NS AR P
cliffortioides Adam. LSH NS MSS P
debilis Adam. [Wurts 581 NBG] F NS HAD P
lasiophyllus Adam. [Adamson 3883 BOL (Type)] **Endemic** F NS HAD P
tenerrimus Buek DSH NS HAW P
Siphocodon
spartioides Turcz. [McDonald 1900 STE] LSH NS AR P
Wahlenbergia
cernua (Thunb.) A. DC. [Bohnen 7971] F NS MSS P
exilis A. DC. [X] F NS AR P
fruticosa V. Brehm. [Bohnen 8437] **Endemic** LSH NS MSS P
obovata V. Brehm. [Bohnen 8955] F NS MSS P
subrosulata V. Brehm. F NS MSS P
Lightfootia
albens Spreng ex A. DC. [McDonald 1111 STE] DSH NS AR P
diffusa Buek var. palustris Adamson [Taylor 4775 STE] LSH NS MSS P
fasciculata (L.f.) A. DC. [McDonald 2048 STE] LSH NS AR P
pauciflora Adamson [Adamson 4832 SAM] LSH NS MSS P
planifolia Adamson [Muir 2628 STE] LSH NS MSS P
rigida Adamson LSH NS AR P
tenella Lodd. LSH NS AR P

LOBELIACEAE

Cyphia
volubilis (Burm. f.) Willd. [McDonald 1439 STE] F NS MSS P
zeyheriana Presl [X] F NS MSS P
Lobelia
capillifolia (Presl.) A. DC. F NS AR P
chamaepitys Lam. [X} DSH NS MSS P
coronopifolia L. [McDonald 1676 STE] F S MSS P
dasyphylla E. Wimm. [Esterhuysen 4805 BOL] **Endemic** F S MSS P
erinus L. [McDonald 862 STE] F NS MSS P
hypsibata E. Wimm. **Endemic** F NS MSS P
jasionoides (A. DC.) E. Wimm. [Marsh 1113 STE] F S MSS P
linearis Thunb. [Burger 102 STE] F NS MSS P
muscoides Cham. [McDonald 1888 STE] **Endemic** F NS HAW P
neglecta Roem. et Schult. [McDonald 1605 STE] F NS MSS P
patula L.f. [Muir 2698 BOL] F NS MSS P
pinifolia L. [McDonald 1061 STE] F NS AR P
pubescens Dryand ex Ait. var. pubescens [Thompson 671 STE] F NS HAW P
pubescens Dryand ex Ait. var. rotundifolia E. Wimm. [McDonald 1995 STE] F NS HAW P
Laurentia
bifida (Thunb.) Sond. [McDonald 1888a STE] HE NS MSS P
longitubus E. Wimm. [Schlechter s.n. BOL (Isotype)] **Endemic** HE NS MSS P
pygmaea (Thunb.) Sond. [F.W. Thoms s.n. NBG] F NS MSS P

ASTERACEAE

Corymbium
africanum L. subsp. scabridum (Berg.) Weitz var. gramineu (Burm. f.) Weitz [McDonald 1461 STE] F S HAD P
africanum L. subsp. scabridum (Berg.) Weitz var. scabridum [McDonald 1485 STE] F S HAD P
glabrum L. var. glabrum [McDonald 1471 STE] F S HAD P
Pteronia
beckioides DC. **Endemic** LSH NS MSS W
Pteronia camphorata (L.) L. var. longifolia Harv. [McDonald 1266] LSH NS HAW W
Pteronia stricta Ait. MSH NS HAW W
Mairia
crenata (Thunb.) Nees [McDonald 1409] F NS HAW P
hirsuta DC. [McDonald 1582] F NS HAW P
lasiocarpa DC. (to change to Zyrphelis lasiocarpa (DC.) Kuntze [Taylor 7689 STE] F NS MSS P
microcephala (Less.) DC. [McDonald 1462 STE] F NS HAW P
Gymnostephium
fruticosum DC. [X] **Endemic** LSH NS HAW P
gracile Less. [X] LSH NS MSS P
Felicia
cana DC. [Thompson 2680 STE] DSH NS AR W
comptonii Grau [Esterhuysen 23 800 NBG (Type)] **Endemic** LSH NS AR W
denticulata Grau [Hall 1431 STE] LSH NS MSS W
filifolia (Vent.) Burtt Davy subsp. bodkinii (Compton) Grau [McDonald 1009 STE] MSH NS AR W
cf. hirsuta DC. [113/20] LSH NS HAD W
minima (Hutch.) Grau [Bohnen 9118 STE] F NS AR W
muricata (Thunb.) Nees LSH NS AR W
Chrysocoma
flava E. Bayer F NS MSS W
tenuifolia Berg. [McDonald 1342 STE] F NS AR W
Brachylaena
neriifolia (L.) R. Br. [McDonald 1589 STE] T NS MSS W
Troglophyton
capillaceum (Thunb.) Hilliard & Burtt [Lewis s.n. BOL] F NS MSS W

Plecostachys
polifolia (Thunb.) Hilliard & Burtt [McDonald 1447 STE] LSH NS AR W
Langebergia
canescens (DC.) Anderb. [McDonald 1228 STE] **Endemic** DSH NS HAW W
Petalacte
epaleata Hilliard & Burtt [McDonald 1630 STE] DSH NS AR W
Phaenocoma
prolifera (L.) D. Don [Burger 19 STE] LSH NS AR W
Syncarpha
eximia (DC.) B. Nord [McDonald 1259 STE] MSH NS MSS W
gnaphaloides (L.) DC. [van Wyk 661 STE] LSH NS AR W
milleflora (L.f.) B. Nord. [McDonald 1784 STE] MSH NS AR W
paniculata (L.) B. Nord. [McDonald 1113 STE] LSH NS AR W
speciosissima (L.) B. Nord. subsp. angustifolia (DC.) B. Nord. [du Plessis 79 STE] LSH NS MSS W
vestita (L.) B. Nord. [McDonald 1456 STE] LSH NS MSS W
virgata (Berg.) B. Nord. [McDonald 1634 STE] LSH NS AR W
Helichrysum
capense Hilliard [McDonald 1550 STE] DSH NS HAW W
cymosum (L.) D. Don subsp. cymosum [Taylor 7580a STE] LSH NS HAW W
dasyanthum (Willd.) Sweet [McDonald 2007 STE] LSH NS MSS W
felinum (Thunb.) Less. [McDonald 1421 STE] F NS MSS W
foetidum (L.) Moench [McDonald 1881 STE] F NS MSS W
lancifolium Thunb. [McDonald 1739 STE] LSH NS AR W
nudifolium (L.) Less. [Taylor 7581 STE] F NS MSS W
oxyphyllum DC. [McDonald 1541 STE] F NS HAW W
odoratissimum (L.) Sweet [Taylor 4769 STE] LSH NS MSS W
plebium DC. **Endemic** DSH NS MSS W
rotundifolium (Thunb.) Less (cf.) [42/12; 110/12; 104/21] F NS HAD W
spiralepis Hilliard & Burtt [McDonald 1538 STE] F NS HAW W
tinctum (Thunb.) Hilliard & Burtt [Taylor 7582 STE] F NS MSS W
zeyheri Less. [Burger 42 STE] LSH NS MSS W
zwartbergense H. Bol. F NS HAD W
Edmondia
pinifolia (Lam.) Hilliard [McDonald 2030 STE] F NS HAW W
sesamoides (L.) Hilliard [McDonald 1033 STE] F NS HAW W
Stoebe
aethiopica L. [Burger 61 STE] MSH NS AR W
alopecuroides (Lam.) Less. [Bohnen 8371 STE] MSH NS MSS W
capitata Berg. [Bohnen 5322] LSH NS AR W
cinerea (L.) Thunb. [McDonald 1037 STE] LSH NS MSS W
incana Thunb. [Bohnen 8434] LSH NS MSS W
intricata Levyns LSH NS AR W
microphylla DC. [McDonald 999] DSH NS MSS W
plumosa (L.) Thunb. [Bohnen 8366] MSH NS MSS W
saxatilis Levyns [McDonald 1155 STE] LSH NS HAD W
spiralis Less. [McDonald 1927 STE] LSH NS AR W
Disparago
ericoides Gaertn. [McDonald 1781 STE] DSH NS AR W
Elytropappus
cyathiformis DC. [McDonald 1247 STE] LSH NS AR W
glandulosus Less. [McDonald 1100 STE] LSH NS AR W
gnaphaloides (L.) Levyns [McDonald 1110 STE] LSH NS AR W
rhinocerotis (L.f.) Less. [Schlieben & Ellis 12372 STE] MSH NS AR W
scaber (L.f.) Levyns [Kruger 1273] LSH NS AR W
Metalasia
densa (Lam.) Karis [McDonald 1007 STE] MSH NS MSS W
galpinii L. Bol. [McDonald 1973 STE] MSH NS AR W
massonii S. Moore [McDonald & Morley 1007 STE] MSH NS AR W
pallida H. Bol. [McDonald 2046 STE] MSH NS AR W
pungens D. Don [Haynes 625 STE] MSH NS AR W

Dolicothrix
ericoides (Lam.) Hilliard & Burtt DSH NS AR W
Relhania
calycina (L.f.) L'Herit. subsp. apiculata (DC.) Bremer [McDonald 1133 STE] LSH NS AR P
pungens L'Herit. subsp. pungens [Bohnen 8670 STE] LSH NS AR P
Athrixia
heterophylla (Thunb.) Less. subsp. heterophylla [McDonald 1583 STE] F NS MSS P
Heterolepis
peduncularis DC. [Schlechter 2124 STE] DSH NS AR W
sp. nov. [McDonald 2091 STE] **Endemic** DSH NS AR W
Osmitopsis
osmitoides (Less.) Bremer [McDonald 978 STE] LSH NS MSS P
Eriocephalus
brevifolius (DC.) M. Müller [McDonald 992 STE] LSH NS AR V
Oedera
imbricata Lam. [Ruiters 10 STE] DSH NS MSS P
prolifera L.f. [McDonald 1340 STE] DSH NS AR P
Athanasia
incisa (DC.) Harv. [McDonald 966 STE] MSH NS HAW P
inopinata (Hutch.) Källersjö [Levyns 640 NBG] **Endemic** DSH NS MSS P
juncea (DC.) D. Dietr. [Taylor 7604 STE] LSH NS AR P
trifurcata (L.) L. [Lewis 5393 NBG] LSH NS MSS P
Hymenolepis
parviflora (L.) DC. [McDonald 1847 STE] MSH NS AR P
Hippia
frutescens L. [McDonald 1441 STE] LSH NS MSS P
hirsuta DC. DSH NS MSS P
hutchinsonii Merxm. [McDonald 1892 STE] DSH NS HAW P
integrifolia Less. [McDonald 1153 STE] **Endemic** DSH NS HAW P
pilosa (Berg.) Druce [van Wyk 704] DSH NS MSS P
Artemisia
afra Jacq. ex Willd. [CJG] F NS MSS W
Pentzia
dentata (L.) Kuntze [Schlechter 2004 STE] LSH NS AR P
elegans DC. [Burger 35] DSH NS AR P
Senecio
amabilis DC. [McDonald 861 STE] LSH NS MSS W
aquifoliaceous DC. **Endemic** F NS MSS W
azoides (DC.) Sch. Bip. [McDonald 1191 STE] SUC NS MSS W
bipinnatus (Thunb.) Less [McDonald 873 STE] LSH NS MSS W
cordifolius L.f. [McDonald 1925 STE] F S HAW W
crenatus Thunb. [Taylor 7580 STE] LSH NS MSS W
cymbalariifolius Less. [McDonald 1956 STE] F NS MSS W
deltoideus Less. [Viviers 358 STE] F NS MSS W
erosus L.f. F NS MSS W
erubescens Ait. [Taylor 3850 STE] F NS MSS W
hastatus L. [Compton 8739 NBG] F NS MSS W
ilicifolius (L.) Thunb. [McDonald 1074 STE] LSH NS MSS W
incisus Thunb. **Endemic** LSH NS MSS W
lineatus DC. [McDonald 1267 STE] LSH NS HAW W
lyratus L.f. [McDonald 1480 STE] MSH NS MSS W
muirii L.Bol. **Endemic** LSH NS MSS W
oliganthus DC. DSH NS MSS W
paniculatus Berg. [McDonald 1482 STE] F NS MSS W
pinifolius (L.) Lam. [McDonald 1269 STE] LSH NS MSS W
quinquelobus (Thunb.) DC. [Taylor 723 NBG] V NS MSS W
rehmannii H. Bol. [McDonald 1928 STE] LSH NS HAW W
cf. sophioides DC. [84/25] F NS MSS W
subcanescens Compton [McDonald 1511 STE] F NS MSS W
crassulaefolia (DC.) Sch. Bip. [Levyns 10117 NBG] F MSS P

Euryops
abrotanifolius (L.) DC. [McDonald 1190 STE] LSH NS MSS P
erectus (Compt.) B. Nord. LSH NS MSS P
pinnatipartitus (DC.) B. Nord. [McDonald 1273 STE] LSH NS HAW P
tenuissimus (L.) DC. [Taylor 10077 STE] MSH NS AR P
Othonna
mucronata Harv. [McDonald 1337 STE] LSH NS AR W
gymnodiscus (DC.) Sch. Bip. F NS AR W
parviflora Berg. [McDonald 1336 STE] MSH NS AR W
quinquedentata Thunb. [McDonald 1148 STE] LSH NS HAW W
Osteospermum
acutifolium (Hutch.) T. Norl. [McDonald 1496 STE] F NS AR P
bolusii (Compton) T. Norl. [Lewis 5388 NBG] MSH NS HAW P
corymbosum L. [McDonald 1870 STE] TSH NS AR P
glabrum N.E. Br. [Ruiters 6 STE] LSH NS AR P
imbricatum L. subsp. imbricatum [McDonald 1354 STE MSH NS AR P
junceum Berg. [McDonald 2104 STE] MSH NS AR P
polygaloides L. LSH NS MSS P
pyrifolium T. Norl. [Ruiters 13 STE] **Endemic** F NS MSS P
cf. scareosum DC. var. integrifolium (DC.) T. Norl. [64/9] LSH NS HAW W
spinosum L. [Compton 8754 NBG] LSH NS MSS P
triquetrum L.f. [McDonald 2025 STE] DSH NS MSS P
Chrysanthemoides
monilifera (L.) T. Norl. subsp. pisifera (L.) T. Norl. [McDonald 1588 STE] MSH NS MSS V
Ursinia
anethoides (DC.) N.E. Br. [Taylor 4248 STE] F NS MSS W
chrysanthemoides (Less.) Harv. F NS MSS W
heterodonta (DC.) N.E. Br. [McDonald 1339 STE] F NS AR W
hispida (DC.) N.E. Br. [McDonald 979 STE] **Endemic** F NS MSS W
punctata (Thunb.) N.E. Br. [T.P.Stokoe s.n. NBG] F NS MSS W
nudicaulis (Thunb.) N.E. Br. F NS MSS W
paleacea (L.) Moench [Taylor 3858 STE] F S MSS W
scariosa (Ait.) Poir. subsp. scariosa [McDonald 1632 STE] F NS AR W
scariosa (Ait.) Poir. subsp. subhirsuta (DC.) Prassl. [McDonald 1678 STE] F NS MSS W
serrata (L.f.) Poir. [McDonald 1508 STE] F NS MSS W
tenuifolia (L.) Poir. F NS MSS W
trifida (Thunb.) N.E. Br. [McDonald 1509 STE] F NS MSS W
Arctotis
acaulis L. [McDonald 1338 STE] F NS AR W
stoechadifolia Berg. [McDonald 1746 STE] F NS AR W
discolor (Less.) Beauv. [van Wyk 707 STE] F NS AR W
virgata Jacq. [Barker 8942 NBG] **Endemic** F NS AR W
Haplocarpha
lanata Less. [X] F NS MSS W
Gazania
ciliaris DC. [Galpin 4263] F NS MSS W
Cullumia
aculeata (Houtt) Roesl. var. sublanata (DC.) Roesl. [McDonald 1223a STE] DSH NS HAD P
aculeata (Houtt.) Roesl. var. aculeata [McDonald 2005 STE] DSH NS MSS P
Berkheya
armata (Vahl) Druce [Hugo 2741 STE] F NS MSS P
carduoides (Less.) Hutch. [T.P. Stokoe s.n. NBG] F NS MSS P
carlinoides (Vahl) Willd. [Wurts 166 NBG] F NS MSS P
Oldenburgia
paradoxa Less. [Taylor 12116 STE] LSH NS AR V/W
Dicoma
spinosa (L.) Druce [Taylor 10272 STE] DSH NS AR P
Gerbera
crocea (cf.) [X] F S MSS W
linnaei Cass. F S MSS W

serrata (Thunb.) Druce [McDonald 1486 STE] F S MSS W

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