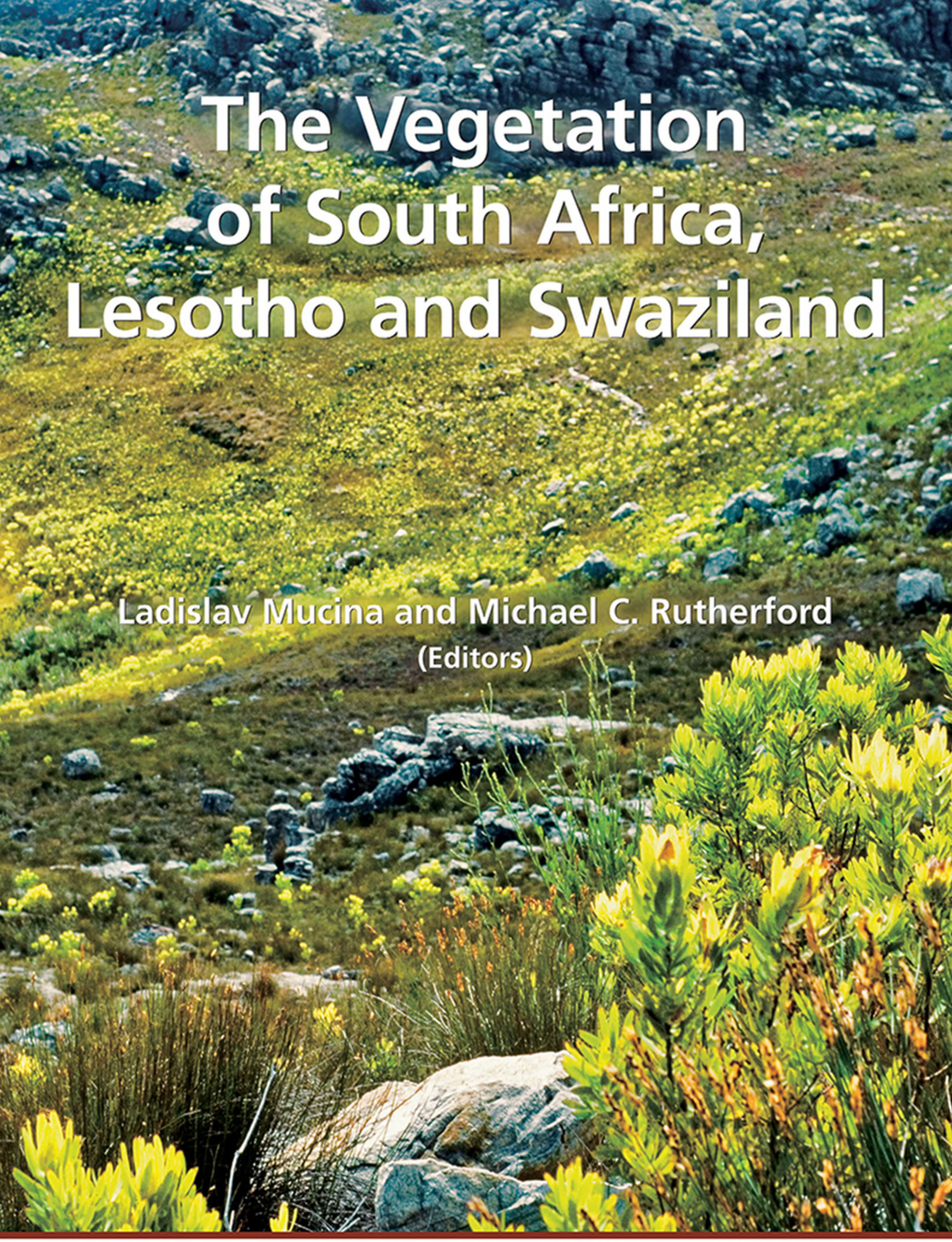
The Vegetation of South Africa, Lesotho and Swaziland



Ladislav Mucina and Michael C. Rutherford
(Editors)

STRELITZIA 19

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SOUTH AFRICAN national biodiversity institute
SANBI

Pretoria

2006

*S*TRELITZIA

This series has replaced *Memoirs of the Botanical Survey of South Africa* and *Annals of Kirstenbosch Botanic Gardens* which SANBI inherited from its predecessor organisations.

The plant genus *Strelitzia* occurs naturally in the eastern parts of southern Africa. It comprises three arborescent species, known as wild bananas, and two acaulescent species, known as crane flowers or bird-of-paradise flowers. The logo of the South African National Biodiversity Institute is based on the striking inflorescence of *Strelitzia reginae*, a native of the Eastern Cape and KwaZulu-Natal that has become a garden favourite worldwide. It symbolises the commitment of the Institute to promote the sustainable use, conservation, appreciation and enjoyment of the exceptionally rich biodiversity of South Africa, for the benefit of all people.

L. Mucina
Department of Botany & Zoology, Stellenbosch University

M.C. Rutherford
Kirstenbosch Research Centre, South African National Biodiversity Institute (SANBI)

TECHNICAL EDITING: G. Germishuizen and E. du Plessis

GIS AND TECHNOLOGY MANAGEMENT: L.W. Powrie

PRODUCTION MANAGEMENT, DESIGN, LAYOUT AND REPRODUCTION: Keith Phillips Images, PO Box 5683, Helderberg, 7135 South Africa images@iafrica.com

COVER DESIGN: Keith Phillips

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(Fynbos vegetation dominated by *Leucadendron laureolum* on the northern slopes of the Riviersonderend Mountains, Western Cape)

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The Authors

Authors who participated in the mapping project and/or the text of the Book, alphabetical according to surname.

Janine B. Adams
Robert J. Anderson
Ronald G. Bennett
Hugo Bezuidenhout
John J. Bolton
Thomas G. Bornman
Charles Boucher
George J. Bredenkamp
John E. Burrows
Kelson G.T. Camp
Sarel S. Cilliers
Richard M. Cowling
Willem de Frey
Philip G. Desmet
Linda Dobson
Anthony P. Dold
Amanda Driver
P. Johann du Preez
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Freddie Ellis
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André Grobler
Nick Helme
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David B. Hoare
Brian J. Huntley
P. Johan H. Hurter
John A.M. Janssen
Steven D. Johnson
Zuziwe Jonas
Norbert Jürgens
Irma C. Knevel
Khotso Kobisi
Lerato Kose
Jan J.N. Lambrechts
Annelise le Roux
Richard G. Lechmere-Oertel
J. Wendy Lloyd †
Amanda T. Lombard
Mervyn C. Lötter
J.-Wouter Lubbinge
John C. Manning
Wayne S. Matthews
David J. McDonald
Bruce McKenzie
Guy F. Midgley
Susanne J. Milton
Bulelwa Mohamed
Theo H. Mostert
Ladislav Mucina
Carl Oellermann
Edward G.H. (Ted) Oliver
Anthony R. Palmer
Michele Pfab
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Şerban M. Procheş
Frans G.T. Radloff
Anthony G. Rebelo
Belinda Reyers
David M. Richardson
Riaan Robesson
Mathieu Rouget
Michael C. Rutherford
Ernst Schmidt
Ute Schmiedel
Robert J. Scholes
Louis Scott
C. Robert Scott-Shaw
Erwin J.J. Sieben
Frances Siebert
Stefan J. Siebert
Andrew L. Skowno
Jacobus H.L. Smit
Walter J. Smit
Valdon R. Smith
Marc Stalmans
Simon W. Todd
Bertie van der Merwe
Johannes H. van der Merwe
Adriaan van Niekerk
Noel van Rooyen
Erich van Wyk
Catharina E. Venter
Jan H.J. Vlok
Graham P. von Maltitz
Benjamin A. Walton
Robert A. Ward
Sandra Williamson
Pieter J.D. Winter
Nick Zambatis

K. Phillips

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Foreword

Why another vegetation map of South Africa, especially considering that Acocks (1953) *Veld types of South Africa* has served two generations of scientists so well?

One answer to this, and to most questions on the purpose of scientific endeavour, is that we live in a knowledge-driven society, where informed, environmentally sensitive and rational decisions are the cornerstones of sustainable socio-economic development. But more directly, despite the utility of Acocks's map for more than half a century, our knowledge base, technologies and demands for detailed spatial information on natural resources make a new, spatially detailed map and description of our vegetation both possible and necessary.

South Africa and the continent as a whole have set ambitious development goals for the 'African Century', goals which simply cannot be met without an underpinning of sound decision support. Such growth initiatives, infrastructure needs and wise land use demands were behind the establishment, in 2004, of the South African National Biodiversity Institute (SANBI), the successor to the former National Botanical Institute (NBI) which itself had roots in the Botanical Research Institute and the National Botanical Gardens of South Africa, established in 1903 and 1913 respectively.

The parliamentary mandate given SANBI through the Biodiversity Act of 2004 includes monitoring and reporting on the status of the Republic's biodiversity, the conservation status of species and ecosystems, and on the diverse impacts on these. Such reporting requires a detailed vegetation baseline and an understanding of the dynamics of constituent ecosystems. The production of *The vegetation of South Africa, Lesotho and Swaziland* (which includes the new Map) is therefore particularly timely, given the high expectations placed by our stakeholders on SANBI and our many partners in biodiversity science.

This volume marks yet another major milestone in the history of biodiversity knowledge development in southern Africa. Over the past two centuries, the process of discovery, description, evaluation and synthesis of information on and understanding of our flora and vegetation has followed a regular cycle. Benchmarks along the way include the early botanical explorations of Thunberg, Sparrman, Masson and others at the close of the 18th century, the publication of *Flora capensis* from the mid-19th century (Harvey & Sonder 1859–1860), the pioneer ecological studies of Marloth, Bews and Adamson in the early 20th century, and the production of the first vegetation map for the country by Pole Evans in 1936.

A new wave of field work and synthesis came with Acocks's 1953 map, and the stimulus to plant taxonomy anticipated by the launch of the *Flora of southern Africa* project in the 1960s. The taxonomic agenda of the late 20th century has focussed on regional floras (Bond & Goldblatt 1984, Retief & Herman 1997, Goldblatt & Manning 2000) and some major monographs (Van Jaarsveld 1994, Goldblatt & Manning 1998, Smith & Van Wyk 1998, Linder & Kurzweil 1999, Van Jaarsveld & Koutnik 2004). Towards the end of the 20th century, slow progress with the *Flora of southern Africa* project resulted in a decision to prepare a 'Concise flora of southern Africa' while a regional programme of taxonomic capacity building—SABONET—addressed the human and institutional resource needs in this field of botany. Significant results of these initiatives are illustrated in the two mega-volumes published this year—*Checklist of flowering plants of Sub-Saharan Africa* (Klopper et al. 2006) and *A checklist of South African plants* (Germishuizen et al. 2006).

Research on the structure and function of South African ecosystems received a significant stimulus during the 1970s and 1980s, through a network of major interdisciplinary studies in the Savanna, Fynbos and Karoo Biomes, leading to several comprehensive syntheses on these (Cowling 1992, Scholes & Walker 1993, Dean & Milton 1999). Cowling et al. (1997) drew together the findings of the surge of ecological activity during these two decades in the multi-authored *Vegetation of southern Africa*, a classic synthesis with few equals elsewhere around the globe.

The succession of field research and resulting taxonomic and ecological syntheses prompted the need for a new generation vegetation map and descriptive memoir. While vegetation surveys had been active through the later decades of the 20th century, they had been widely scattered and unco-ordinated—responding to the needs of conservation agencies and land use planners rather than to establishing an integrated regional synthesis. In 1996 the VEGMAP Project was initiated to prepare a successor to *Veld types of South Africa.*

Acocks's (1953) classic study was the last of the great, single-authored works on the flora or vegetation of South Africa. By the turn of the 20th century, South Africa had built an uncommon ability, by global standards, to bring together large teams of natural scientists to tackle national priorities. The power of electronic information management, while never able to replace the critical importance of humble field natural history observations, has nevertheless made possible the collection and integration of vast databases—not achievable just a few decades ago. In particular, the power of Geographical Information Systems has aided the immense task of integrating spatial information at widely differing scales and detail.

The task of preparing a new Vegetation Map fell to a succession of co-ordinators, and acknowledgement should be made to the initial work of David McDonald and Michael O'Callaghan. It soon became clear that a full-time commitment to the project was needed, and Michael Rutherford's wide experience in southern African vegetation science made him an obvious candidate. In assembling a team of about 100 contributors, further support in the huge task of synthesising diverse datasets was essential, and the wealth of experience of Ladislav Mucina, who had then recently arrived in South Africa from Europe, was perfectly timed.

The VEGMAP Project soon grew into a major intellectual and organisational challenge. The sheer volume of field data, the diversity of vegetation classification and mapping methodologies used, and the 10 000 species included in the survey data, extended the project well beyond its initial five-year timeframe. But the resulting map, released ahead of this descriptive memoir, is already finding wide application and great utility in both its hard copy and electronic formats.

SANBI can be justly proud of the achievements of its professional staff, and those of its many collaborating institutions, as it faces the demands of the new century. This volume, which includes the map, will most surely serve South Africa and beyond as effectively as its remarkable predecessor, Acocks's *Veld types.* The advantages of electronic information systems will allow more regular revisions to both the map and the memoir than was possible for *Veld types*, and users are encouraged to communicate with SANBI should they have suggestions on improvements to future versions of this study.

The continuing support of the national Department of Environmental Affairs and Tourism and of the Norwegian Government to this project, is gratefully acknowledged. Special tribute should also be paid to the many dozens of dedicated fieldworkers whose collective toil under the African sun is reflected in this remarkable volume.

Brian J. Huntley
Chief Executive
South African National Biodiversity Institute
Kirstenbosch
August 2006

References

Acocks, J.P.H. 1953. Veld types of South Africa. *Mem. Bot. Surv. S. Afr.* No. 28: 1–192.

Bond, P. & Goldblatt, P. 1984. Plants of the Cape flora. A descriptive catalogue. *J. S. Afr. Bot.* Suppl. Vol. 13: 1–455.

Cowling, R.M. (ed.) 1992. *The ecology of fynbos: nutrients, fire and diversity*. Oxford Univ. Press, Cape Town.

Cowling, R.M., Richardson, D.M. & Pierce, S.M. (eds) 1997. *Vegetation of southern Africa*. Cambridge Univ. Press, Cambridge.

Dean, W.R.J. & Milton, S.J. (eds) 1999. *The Karoo: ecological patterns and processes*. Cambridge Univ. Press, Cambridge.

Germishuizen, G., Meyer, N.L., Steenkamp, Y. & Keith, M. (eds) 2006. A checklist of South African plants. *Southern African Botanical Diversity Network Report* No. 41: 1–1126. SABONET, Pretoria.

Goldblatt, P. & Manning, J.C. 1998. *Gladiolus in southern Africa*. Fernwood Press, Cape Town.

Goldblatt, P. & Manning, J. 2000. Cape plants. A conspectus of the Cape flora of South Africa. *Strelitzia* 9. National Botanical Institute and Missouri Botanical Garden Press, Pretoria & St Louis.

Harvey, W.H. & Sonder, O.W. 1859–1860. *Flora capensis: being a description of the plants of the Cape Colony, Caffraria & Port Natal. Volume I. Ranunculaceae to Connaraceae*, pp. 1–384. Hodges, Smith & Co., Dublin.

Klopper, R.R., Chatelain, C., Bänninger, V., Habashi, C., Steyn, H.M., De Wet, B.C., Arnold, T.H., Gautier, L., Smith, G.F. & Spichiger, R. 2006. Checklist of the flowering plants of Sub-Saharan Africa. An index of accepted names and synonyms. *Southern African Botanical Diversity Network Report* No. 42: 1–894. SABONET, Pretoria.

Linder, H.P. & Kurzweil, H. 1999. *Orchids of southern Africa*. A.A. Balkema, Rotterdam.

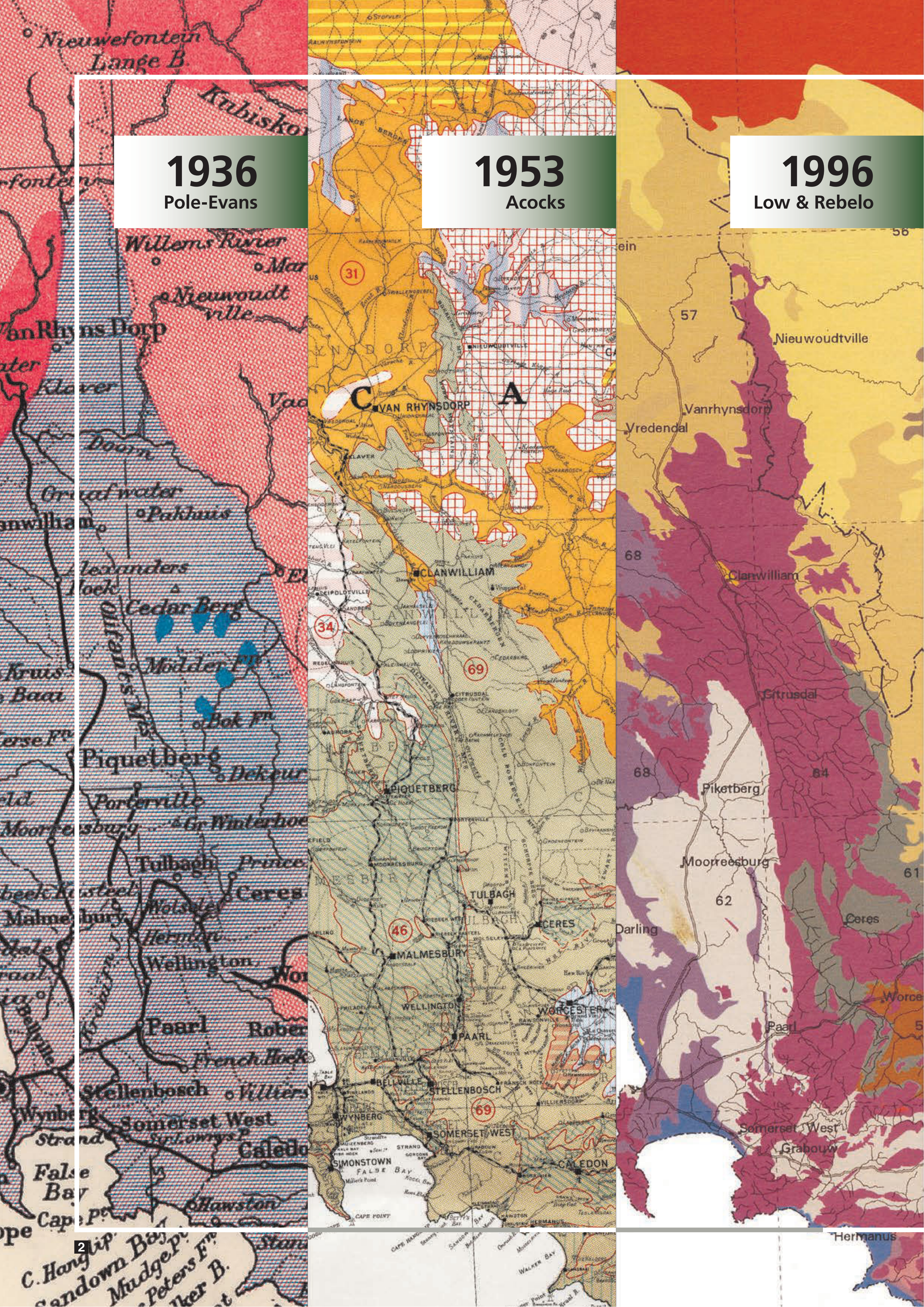
Retief, E. & Herman, P.P.J. 1997. Plants of the northern provinces of South Africa: keys and diagnostic characters. *Strelitzia* 6: 1–681. National Botanical Institute, Pretoria.

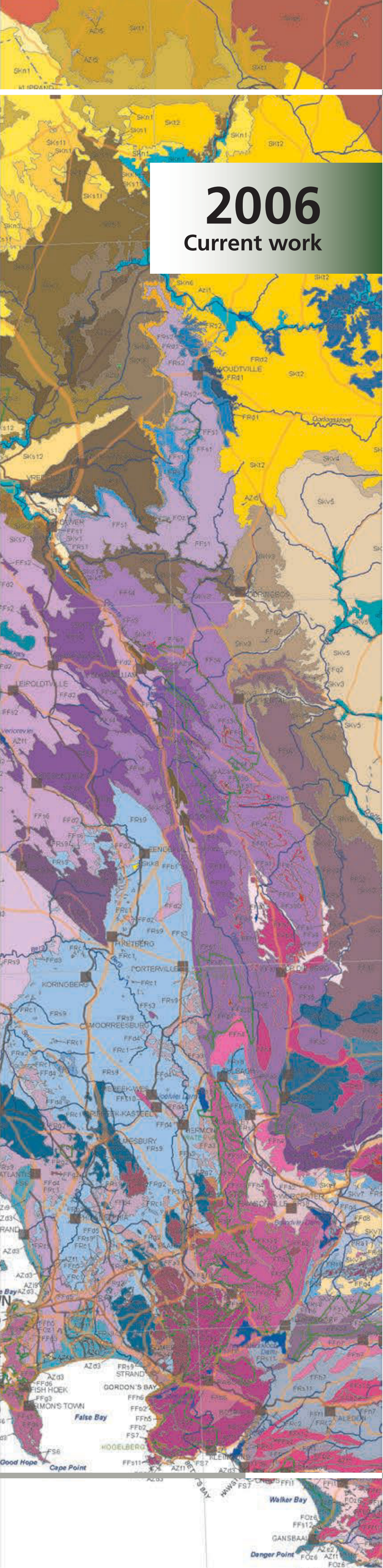
Scholes, R.J. & Walker, B.H. 1993. *An African savanna: synthesis of the Nylsvley study*. Cambridge Univ. Press, Cambridge.

Smith, G.F. & Van Wyk, B-E. 1998. Asphodelaceae. In: K. Kubitzki (ed.), *The families and genera of vascular plants. Flowering plants, Monocotyledons. Lilianae (except Orchidaceae),* Vol. 3: 130–140. Springer-Verlag, Berlin.

Van Jaarsveld, E.J. 1994. *Gasterias of South Africa*. Fernwood Press, in association with the National Botanical Institute, Cape Town.

Van Jaarsveld, E.J. & Koutnik, D. 2004. Cotyledon *and* Tylecodon. Umdaus Press, Hatfield.


1936
Pole-Evans
1953
Acocks
1996
Low & Rebelo
Nieuwoudtville
Vanrhynsdorp
Vredendal
Clanwilliam
Citrusdal
Piketberg
Moorreesburg
Darling
Ceres
Paarl
Somerset West
Grabouw
Hermanus
VAN RHYNSDORP
CLANWILLIAM
PIQUETBERG
TULBAGH
CERES
MALMESBURY
WELLINGTON
WORCESTER
PAARL
STELLENBOSCH
SOMERSET WEST
SIMONSTOWN
CALEDON
Piquetberg
Tulbagh
Wellington
Pearl
Stellenbosch
Somerset West
False Bay



L.W. Powrie

Introduction 1

Michael C. Rutherford and Ladislav Mucina

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Figure 1.1 Snapshots of the history of vegetation mapping in South Africa.

1. Preamble

We present an up-to-date and comprehensive overview of the vegetation of South Africa and the two small neighbouring countries of Lesotho and Swaziland. This account is based on vegetation survey using appropriate tools of contemporary vegetation mapping and vegetation description. We aimed at drawing a new vegetation map that depicts the complexity and macro-scale ecology and reflects the level of (and identifies and reveals gaps in) our knowledge of the vegetation of the region. This is an extensive account of the vegetation of a complex and biologically intriguing part of the world, offering not only insights into structure and dynamics of the vegetation cover, but containing a wealth of base-line data for further vegetation-ecological, biogeographical, and conservation-oriented studies. Our Map and the descriptive account of the vegetation of South Africa, Lesotho and Swaziland targets not only scientific academia and the secondary and tertiary education sectors, but offers a powerful decision-making tool for conservationists, land and resource planners, and politicians as well as the interested public at large.

2. Mapping Spatial Complexity of Vegetation Cover

Vegetation mapping is one of the most important and most widely used tools to simplify spatial complexity of vegetation cover. In the past, floristic-based mapping was invariably linked to syntaxonomy (vegetation systematics) providing a classification system of vegetation in a mapped area. Thus the theory and methods of vegetation mapping has been dominated by the idea of the floristic-sociological approach to vegetation classification and its major schools known as the Braun-Blanquet School and Russian School in particular (see textbooks, chapters relevant to vegetation mapping in general vegetation science works and major review papers such as Gaussen 1961, Sochava 1962, Braun-Blanquet 1964, Küchler 1967, 1984, Ozenda 1986, Küchler & Zonneveld 1988, Faliński 1990–1991, Dierschke 1994, Glavać 1996, Crişţea et al. 2004 and Pedrotti 2004, to mention just a few). Currently vegetation mapping operates on a much broader theoretical and methodological platform by incorporating new approaches of remote sensing and spatial environmental correlation through GIS (Alexander & Millington 2000).

Vegetation mapping has enjoyed a long tradition in Europe, where at least four different 'schools' have been formed. The 'Stolzenau School' named after Stolzenau am Weser—a small town in Niedersachsen, Germany—has been associated with names such as R. Tüxen (the founder of a small research institute devoted to vegetation survey and mapping in Stolzenau), W. Trautmann, K. Buchwald and U. Bohn who definitely influenced the work of other central European (R. Mikyška, R. Neuhäusl, Z. Neuhäuslová, J. Moravec, J. Michalko, Š. Maglocký, W. Matuszkiewicz, H. Wagner and J.B. Faliński) and further afield also Japanese (A. Miyawaki and K. Fujiwara) and American (A.W. Küchler) vegetation scientists. Dierschke (1994) further recognised the so-called 'South French School' associated with names such as L. Emberger, H. Gaussen, R. Molinier and P. Ozenda. This school influenced mapping in southern Europe (S. Rivas-Martínez, F. Pedrotti and R. Venanzoni). The 'ITC School' emerged at the current ITC Institute in Enschede, the Netherlands, and became known for the early application of remote-sensing approach to vegetation mapping. D.C.P. van Thalen and I.S. Zonneveld (see Zonneveld et al. 1979) can be mentioned as prominent personalities of this school. The 'Russian School' has been particularly active at the Komarov Institute of Botany in St Petersburg (earlier also known as Leningrad). This institution is associated with great names such as E.M. Lavrenko, V.B. Sochava, S.A. Gribova, T.K. Yurkovskaya, G.M. Ladygina and I.N. Safronova. The specialist journal (*Geobotanicheskoie Kartirovanyie*) devoted to vegetation mapping is published by this research group. Undoubtedly the Europe-based vegetation mapping research groups influenced further dissemination of the vegetation mapping methodology and the initiation of mapping projects on other continents.

Among the major mapping achievements featuring vegetation on (sub)continental levels, rank: e.g. Lavrenko & Sochava (1954, 1956: former Soviet Union), Küchler (1964: USA), Niklfeld (1973: countries of the Danube basin), Horvat et al. (1974: Balkan Peninsula), Rzedowski (1978: Mexico), Beard (1979: Western Australia), Ozenda et al. (1979: western Europe), Miyawaki (1980–1989: Japan), Hueck & Seibert (1981: South America), Hou et al. (1982: China), Ozenda (1985: the Alps), Rivas-Martínez (1987: Iberian Peninsula), Brown (1994: southwestern USA and northwestern Mexico), Ladygina et al. (1995: Kazakhstan and central Asia), Blasco et al. (1996: tropical continental Asia) and Ni (2001: China). Two large international teams produced the monumental vegetation map of Europe (Bohn et al. 2003) and the map of circum-arctic vegetation (Walker et al. 1995, 2005).

A selective review of maps classified according to mapping scale was presented by Dierschke (1994) and the reader is referred to numerous bibliographies (mainly published in the journal *Excerpta Botanica*) featuring the products of mainly syntaxonomy-based vegetation maps.

For many logistic, developmental and historical reasons, the African continent has experienced only marginal interest of vegetation mappers. The vegetation of the continent has been mapped (as a whole) several times (Keay 1959, White 1983, Burgess et al. 2004), but its large extent (Africa is the second largest continent) and paucity of data did not allow for detail. Several larger regions (Wild & Barbosa 1968: area of the *Flora zambesiaca*) and countries (e.g. Barbosa 1970: Angola, Giess 1971: Namibia, Guillaumet & Adjanohoun 1971: Ivory Coast, Bekker & De Wit 1991: Botswana, etc.) have been mapped using traditional methods. Only recently has application of remote-sensing methods and GIS led to production of more detailed and credible vegetation maps (Frederiksen & Laweson 1992: Senegal, Du Puy & Moat 1998, 1999: Madagascar).

3. Vegetation Mapping in South Africa

The roots of vegetation mapping of the African subcontinent go back to the nineteenth century but at very coarse scales and using mostly very poor information (see review by Werger 1978). Even though the Botanical Survey of the then Union of South Africa was started in 1918, the earliest vegetation map of southern Africa (with some detail) can probably be regarded as that of Pole Evans in 1936 (the actual map is dated 1935). At least parts of his map were more detailed than the broad 'biome level'. Thus, for example, he distinguished three grassland types as well as three types of 'parkland' (savanna). He recognised 12 types of vegetation in total. This work was followed in 1938 by Adamson who mapped 14 types of vegetation in the region with different emphasis of detail, including six types in the 'semi-desert' and four in 'savanna' but only a single grassland type.

In 1953 a major milestone was reached with the publication of *Veld types of South Africa* by John Acocks in which he mapped 70 types of vegetation in South Africa, Lesotho and Swaziland. The scale of the printed map (1:1 500 000) allowed for unparalleled detail and was presented in a form that R.A. Dyer in his foreword described as 'a work of art'. His 1953 book was reprinted with photographs added and plant names updated in 1975 and again in 1988. It is ironic that most of his field data were collected after the publication in 1953 (Rutherford et al. 2003a) and were not incorporated in the later editions. They were, however, available for a revision of his *Veld types* but did not progress beyond an unpublished manuscript (with no map) for the western half of the country (Acocks 1979) shortly before his death in 1979. In a letter to a colleague in 1954 Acocks called his memoir '... a half-baked washout and a disgrace to the Division that was inept enough to hustle me into writing it before my data were complete enough even for a preliminary paper' (Hoffman & Cowling 2003a, b). A re-analysis of Acocks' data for the area of the Nama-Karoo Biome substantiated a number of his veld types while not upholding some others (Rutherford et al. 2003b). Despite Acocks' opinion expressed in 1954, his work became known as the most widely used published product in South African ecology over a period of more than five decades. White's (1983) mapping units within South Africa are less detailed than those of Acocks and he relied heavily on the work of Acocks for this section of his map.

The SAAB (South African Association of Botanists) map of Low & Rebelo (1996 and reprinted as a second edition in 1998) was initiated at a meeting held in Durban in January 1992. At this meeting it was decided that the new map was needed mainly for pedagogical purposes—a map which would essentially be a simplification of Acocks' map. To a large extent this simplification was carried out for the arid areas of Karoo and Namaqualand, often retaining some boundary lines of Acocks' veld types. Much of the Grassland and northern Savanna areas were also mostly simplified but often with different and smoother boundary lines than Acocks. Greater detail was added in the Kalahari areas and parts of the Fynbos Biome and much of the Lowveld area was totally revised. Acocks' Valley Bushveld, Spekboomveld and Noorsveld were reassigned to various 'thicket' vegetation types. A major advance over the Acocks map was the mapping of many patches of forest types. However, the net effect of the simplifications and additions was 68 vegetation units, i.e. slightly fewer than Acocks (Table 1.1). The 'SAAB map' thus consisted of a mixture of less detailed and more detailed parts relative to the map of Acocks. Low & Rebelo's (1996) map was furthermore made at a smaller scale than that of Acocks and it was printed at three different scales, namely 1:1 850 000, 1:2 000 000 and 1:3 880 000.

Even before Low & Rebelo's map was published in January 1996, it was clear that to substantially improve on Acocks' map would require a totally fresh start independent of his map and considering all available data (most of which—including most data of Acocks—were collected after 1953). There was also a realisation that for planning at regional and local levels, a much more detailed approach than that of either Acocks (1953) or Low & Rebelo (1996) should be implemented.

Vegetation mapping is a frequently used tool in nature and especially wildlife conservation practice in South Africa. Since successful, scientifically defendable running of both statutory and private conservation areas requires (by law) formulation and implementation of spatial management plans, vegetation has often been used to stratify land into 'management units'. Hence a large number of vegetation maps of small areas have been constructed. These maps were of great help to the VEGMAP team since in many areas this was the only viable information source of vegetation cover. Many of the local maps were published in local journals such as *South African Journal of Botany, Bothalia, Koedoe* or *Bontebok* or in series of reports (see for instance References in Chapter 14 on Coastal vegetation). Still more maps remain, buried in unpublished reports and management planning documentation of the provincial nature conservation bodies (CapeNature, Ezemvelo KZN Wildlife, Mpumalanga Parks Board, South African National Parks, etc.) and postgraduate masters and doctoral theses. It is beyond the scope of this chapter to list them all—they are, however, exhaustively referred to in particular chapters of this book.

Of great importance to our Project were published maps featuring larger portions of South Africa. They played, alongside the all-country maps mentioned above, a pioneering role in mapping vegetation of the subcontinent. Through the spatial extent of detail covered, distinction was earned by the contributions of Pentz (1945: former Natal Province), Edwards (1967: Tugela/Thukela River basin), Boucher (1972, 1978: part of the Kogelberg massif in the southwestern Cape; 1987: West Coast forelands), Van Rooyen (1978: northern Kruger National Park), Van der Meulen & Westfall (1979: bushveld of former western Transvaal region), Van Rooyen et al. (1981: northern Kruger National Park), Cowling (1982, 1984: Humansdorp region), Gertenbach (1983: Kruger National Park), Moll & Bossi (1983: Fynbos Biome and adjacent areas), Taylor (1984: southern Cape Peninsula), Rebelo et al. (1991: Riversdale Plain), Cowling & Heijnis (2001: southwestern Cape) and Vlok et al. (2003: planning region of STEP including Albany Thicket Biome and neighbouring areas).

There are two basic traits which set our Map apart from other comparable products:

1) Our Map is unique in featuring the vegetation cover of an extremely diverse large geographical region housing nine biomes on the continent and a further two biomes on the islands in great detail. The mapped regions contain the most species-rich temperate flora of the world. It includes one entire biogeographical plant kingdom (Capensis) and parts of phytochoria of two other plant kingdoms, namely of the Palaearctis and of Antarctis (sensu Takhtajan 1986).

2) Our Map, unlike other long-term projects featuring large regions (Europe, former Soviet Union, South America, USA), has been using fully computer-aided (GIS-assisted) tools from the onset of the research throughout the entire process up to publication. The use of aerial photography, satellite imagery, spatial predictive modelling and large databases in combination with traditional field-based ground-truthing is another distinct feature of our product.

4. The Making of VEGMAP

The current work was initiated by Prof. B.J. Huntley, Chief Executive Officer of the then National Botanical Institute (NBI), who convened a workshop at Kirstenbosch, Cape Town, on 7 and 8 August 1995. This was a national workshop of vegetation experts to discuss the feasibility of the project. The NBI commenced work and co-ordination on the project on 1 October 1995, with the official contractual commencement date of 30 January 1996. The administration of the funding and management of the project was an NBI (and later a SANBI) responsibility.

M. O'Callaghan was initially responsible for running the project, soon to be replaced by D.J. McDonald at the Kirstenbosch Research Centre of the NBI. At that stage M.C. Rutherford was the convenor of the project. Upon McDonald's resignation in July 2000, M.C. Rutherford was given direct responsibility for the project through to its completion. In the first year of this period the services of L. Mucina were engaged as scientific co-ordinator and he continued informally in this role. He had also been contracted earlier (since February 2000) to deal with a number of specific issues relating to the project. From April 2003 M.C. Rutherford was placed on the project on a full-time basis, first attending to the completion of the map (the beta electronic version of the map was made publicly available in February 2004) and then joining L. Mucina in compiling some of the chapters and editing the book.

The period before 2000 was primarily one of promoting the buy-in of contributors (a major task at the time given many sensitivities about data-sharing) and assisting with computerisation of data. Various workshops on the project were convened (including ones on the use of TURBOVEG (Hennekens & Schaminée 2001) in February 1997 and October 1998) and the NBI co-ordinator visited many contributors and potential contributors. Numerous presentations on the project were made, the first by M. O'Callaghan at the Annual Congress of the South African Association of Botanists in Stellenbosch in January 1996. Various publications on the project appeared (McDonald 1996, 1997a, b, McDonald & Boucher 1999). A VEGMAP Co-ordination Committee functioned during the first phase of the project with representatives from the NBI, University of Pretoria, Stellenbosch University, the then University of Natal and the Agricultural Research Council in Grahamstown. An important workshop was held at the Kirstenbosch Research Centre on 30 September and 1 October 1999 where it was agreed that data encoding or acquisition for the project should cease by April 2000 and that the analysis and mapping be given a high priority immediately thereafter.

The very first parts of the map were received from some contributors in late 2001. However, many of the initial contributions had to be extensively revised or replaced.

Ultimately, well over 100 people from a wide range of organisations contributed to the map and/or the book (see Acknowledgements towards the end of this chapter). This was a large co-operative project. Even Acocks did not operate in isolation, working, for example, with Louis Irvine (see also Irvine 1941) from 1940 to 1942 while based in the current Limpopo Province. He also assisted Prof. J.M. Hector with an update of his vegetation map of South Africa which was never finished but formed the basis for Acocks' *Veld types of South Africa* (Hoffman & Cowling 2003a, b). Low & Rebelo (1996) list seven contributors to their work.

The current work maps 435 vegetation units in South Africa, Lesotho and Swaziland. This is over six times that of Acocks or Low & Rebelo. The number of individual polygons mapped is 32 times the number in Acocks and almost five times that in Low & Rebelo (Table 1.1). In addition, there are five vegetation units mapped on the Prince Edward Islands (part of South Africa) in the Southern Ocean. Altogether new at the subcontinental level in Africa is the mapping of azonal units, which was not possible at previous mapping scales even if there had been a determination to map these units. The printed map is at a larger scale (1:1 000 000) than any previous vegetation map for the region. Differences in level of detail are most dramatically shown in the Succulent Karoo Biome where Low & Rebelo (1996) recognised only four vegetation units compared to the 63 of the current work.

Table 1.1 Properties of the current vegetation map compared to two major maps published earlier.

Properties	Vegetation maps		
	Acocks (1953)	Low & Rebelo (1996)	Current work (2006)
Published scale	1:1 500 000	1:1 850 000 1:2 000 000 1:3 880 000	1:1 000 000
Vegetation types	70	68	435
Zonal vegetation types	70	68	401
Azonal vegetation types	0	0	34
Polygons	548	3 661	17 796
Average mapped unit area (km^2)	2 313	345	71

International comparisons include the 116 vegetation types of Küchler (1964) for the conterminous United States. The more recent mapping of Europe (about eight times the area of our mapping domain) resulted in many more (around 700) vegetation units (Bohn et al. 2003), but with number of polygons very similar to that of the current work.

5. Structure of the Book

This book is basically constructed as an explanatory account of the new Vegetation Map (Mucina et al. 2005, see also Chapter 18 of this book). The basic unit of the map is 'vegetation type'—these types are described in the forthcoming chapters and grouped either within a biome (in the case of zonal units) or otherwise convenient group (especially the azonal units and insular vegetation). Each vegetation type has a unique code which shows its higher rank classification. The descriptions of vegetation types follow a specific and consistent order. The heading gives the code and name of the specific vegetation unit, followed by the synonymy (mostly defined as a proportion of overlap with previously published mapping units), data on distribution, accounts of vegetation and landscape features, geology and soils, climate, lists of important taxa (including endemics) ordered according to growth form, followed by conservation information, remarks, and ending with literature references relevant to the vegetation unit. Most vegetation types are illustrated by colour photographs. Over 28 500 taxon entries (featuring about 10 000 different taxa) are listed in the descriptions. Four vegetation types are described but not mapped: two are in the marine environment and the remainder on the Prince Edward Islands. The methods and procedures that were followed are described in Chapter 2. The biomes and bioregions are briefly described and compared in Chapter 3; more extensive ecological accounts of the biomes or other groups of featured vegetation types appear in the introductory sections of each chapter. The biome chapters also aim to cover much of the ecological and biogeographical publications relevant to the biome, often with extensive literature lists. The azonal vegetation types are described after the biome chapters, followed by the chapter on the vegetation of the Prince Edward Islands. Just before the atlas section, are two chapters dealing with conservation issues relating to the vegetation types. In some places the mapping detail pushes the bounds of printing at a scale of 1:1 000 000. The electronic version on the CD inside the front cover of the book should be consulted where the user can zoom in at any scale to discern detail. There is a section on Credits at the end of each major chapter indicating specific contributions to the given chapter. The section on Acknowledgements below attempts to list all contributions and organisations that have played a role in the project.

6. *Quo vadis?*—Outlook and Expectations

The results of the VEGMAP Project as presented in this book represent a current account of our knowledge of the variability of the vegetation of this extremely variable, fascinating and beautiful part of the world. Although it might, perhaps, constitute a milestone in vegetation science in South Africa, VEGMAP definitely is—above all—a process. The editors and the authors are well aware of loose ends, deficiencies and omissions that would have to be attended to in new editions of both the Map and the book. VEGMAP has, since being initiated as a nationwide project, inspired new research in less known parts of this region and into poorly known segments of its vegetation cover. New data are being amassed which will shape new editions of our Map. The new knowledge will not only assist in filling the gaps but may also uncover new ones that require attention. The editors therefore encourage readers and users of our products to make us aware of their published and unpublished work and to point out any omissions, errors and deficiencies.

All our efforts would be in vain if our products did not find their way to the user. The map of veld types (1953 and subsequent two editions) by John Acocks served the academic community and the public as a major baseline study in vegetation classification for more than 50 years. The influence of his work was enormous (see the special issue of *South African Journal of Botany*; Hoffman & Cowling 2003a). Cowling (1999), using data of the Institute for Scientific Information, identified the Acocks' account of veld types as the most cited ecological text written in South Africa. It fills us with pride and satisfaction that even before the official release of the major products of VEGMAP (Mucina et al. 2005 and this book), the baseline data (the electronic shape-files of the Vegetation Map; Mucina & Rutherford 2004) have been used in several major scientific and conservation-planning undertakings. Among these rank the Millennium Assessment/Gariep Basin (Bohensky et al. 2004), Succulent Karoo Environmental Project (known as SKEP; Driver 2002, Driver et al. 2003), and last but not least, the *National Spatial Biodiversity Assessment 2004* (Driver et al. 2005; see also www.sanbi.org for a full report). We also notice that the new Map is used by conservation authorities, tertiary institutions as well as a large community of environmental consultants.

VEGMAP is a prime example of good descriptive vegetation science. Vegetation description, finding its expression in modern practically oriented vegetation surveys, should regain its function as a useful tool assisting in the unravelling of the secrets of vegetation. Ultimately, it is the descriptive vegetation science that produces baseline data and aids the formulation of hypotheses which should then undergo rigorous testing to lead us towards understanding the organisation and functioning of our vegetation.

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8. References

Acocks, J.P.H. 1953. Veld types of South Africa. *Mem. Bot. Surv. S. Afr.* No. 28: 1–192.

Acocks, J.P.H. 1975. Veld types of South Africa, edn 2. *Mem. Bot. Surv. S. Afr.* No. 40: 1–128.

Acocks, J.P.H. 1979. *Veld types of the western half of the Republic of South*

Africa. Unpublished manuscript, deposited at the Kirstenbosch Research Centre, South African National Biodiversity Institute, Cape Town.
Acocks, J.P.H. 1988. Veld types of South Africa, edn 3. *Mem. Bot. Surv. S. Afr.* No. 57: 1–146.
Adamson, R.S. 1938. *The vegetation of South Africa.* British Empire Vegetation Committee, London.
Alexander, R. & Millington, A.C. 2000. *Vegetation mapping: from patch to planet.* J. Wiley & Sons, Chichester.
Barbosa, L.A.G. 1970. *Carta fitográphica de Angola.* Luanda Instituto de Investigacão Cientifica de Angola, Luanda.
Beard, J.S. 1979. Vegetation mapping in Western Australia. *J. Roy. Soc. West. Austr.* 62: 75–82.
Bekker, R.P. & De Wit, P.V. 1991. *Contribution to the vegetation classification of Botswana.* FAO/UNDP/Government of Botswana, Soil Mapping and Advisory Services, Gaborone.
Blasco, F., Bellan, M.F. & Aizpuru, M. 1996. A vegetation map of tropical continental Asia at scale 1:5 million. *J. Veg. Sci.* 7: 623–634.
Bohensky, E., Reyers, B., Van Jaarsveld, A.S. & Fabricius, C. (eds) 2004. *Southern African Millennium Ecosystem Assessment. Ecosystem services in the Gariep Basin.* SunMedia, Stellenbosch.
Bohn, U., Gollub, G., Hettwer, C., Neuhäuslová, Z., Schlüter, H. & Weber, H. (eds) 2003. *Map of the natural vegetation of Europe*. Federal Agency for Nature Conservation, Bonn.
Boucher, C. 1972. *The vegetation of the Cape Hangklip area.* M.Sc. thesis, Dept of Botany, Univ. of Cape Town.
Boucher, C. 1978. Cape Hangklip area. II. The vegetation. *Bothalia* 12: 455–497.
Boucher, C. 1987. *A phytosociological study of transects through the Western Cape coastal foreland, South Africa*. Ph.D. thesis, Dept of Botany, Univ. of Stellenbosch.
Braun-Blanquet, J. 1964. *Pflanzensoziologie. Grundzüge der Vegetationskunde*, edn 3. Springer, Wien.
Brown, D.E. 1994. *Biotic communities: southwestern United States and northwestern Mexico.* Univ. of Utah Press, Salt Lake City, UT.
Burgess, N., Hales, J.D., Underwood, E., Dinerstein, E., Olson, D., Itousa, I., Schipper, J., Ricketts, T. & Newman, K. 2004. *Terrestrial ecoregions of Africa and Madagascar. A conservation assessment.* Island Press, Washington.
Cowling, R.M. 1982. *Vegetation studies in the Humansdorp region of the Fynbos Biome.* Ph.D. thesis, Dept of Botany, Univ. of Cape Town.
Cowling, R.M. 1984. A syntaxonomic and synecological study in the Humansdorp region of the Fynbos Biome. *Bothalia* 15: 175–227.
Cowling, R.M. 1999. Classics in physical geography revisited. Acocks, J.P.H. 1953: Veld types of South Africa. Memoirs of the Botanical Survey of South Africa 28, 1–192. *Progr. Phys. Geogr.* 23: 251–255.
Cowling, R.M. & Heijnis, C.E. 2001. The identification of Broad Habitat Units as biodiversity entities for systematic conservation planning in the Cape Floristic Region. *S. Afr. J. Bot.* 67: 15–38.
Crişteа, V., Gafta, D. & Pedrotti, F. 2004. *Fitosociologie.* Presa Universitară Clujeana, Cluj-Napoca.
Dierschke, H. 1994. *Pflanzensoziologie. Grundlagen und Methoden.* E. Ulmer, Stuttgart.
Driver, A. 2002. An introduction to SKEP—the Succulent Karoo Ecosystem Plan. *Aloe* 39: 4–7.
Driver, A., Desmet, P., Rouget, M., Cowling, R. & Maze, K. 2003. *Succulent Karoo Ecosystem Plan. Biodiversity component.* Cape Conservation Unit Report No. CCU 1/03. Botanical Society of South Africa, Kirstenbosch.
Driver, A., Maze, K., Rouget, M., Lombard, A.T., Nel, J., Turpie, J.K., Cowling, R.M., Desmet, P., Goodman, P., Harris, J., Jonas, Z., Reyers, B., Sink, K. & Strauss, T. 2005. National Spatial Biodiversity Assessment 2004: priorities for biodiversity conservation in South Africa. *Strelitzia* 17. South African National Biodiversity Institute, Pretoria.
Du Puy, D.J. & Moat, J. 1998. Vegetation mapping and classification in Madagascar (using GIS): implications and recommendations for the conservation of biodiversity. In: Huxley, C.R., Lock, J.M. & Cutler, D.F. (eds), *Chorology, taxonomy and ecology of the floras of Africa and Madagascar*, pp. 97–117. Royal Botanic Gardens, Kew.
Du Puy, D.J. & Moat, J. 1999. Vegetation mapping and biodiversity conservation in Madagascar using geographical information systems. In: Timberlake, J. & Kativu, S. (eds), *African plants: biodiversity, taxonomy and uses*, pp. 245–251. Royal Botanic Gardens, Kew.
Edwards, D. 1967. *A plant ecological survey of the Tugela River basin*. Natal Town and Regional Planning Commission, Pietermaritzburg.
Faliński, J.B. 1990–1991. *Geobotanical mapping*, Part 1–3. PPWK, Warszawa. (in Polish)
Frederiksen, P. & Lawesson, J.E. 1992. Vegetation types and patterns in Senegal based on multivariate analysis of field and NOAA-A VHRR satellite data. *J. Veg. Sci.* 3: 535–544.
Gaussen, H. 1961. *Méthodes de la cartographie de la végétation.* CNRS, Toulouse.
Gertenbach, W.P.D. 1983. Landscapes of the Kruger National Park. *Koedoe* 26: 9–121.
Giess, W. 1971. A preliminary vegetation map of South West Africa. 'n Voorlopige plantegroeikaart van Suidwes-Afrika. Eine Vegetationskarte von Südwestafrika. *Dinteria* 4: 1–114.
Glavać, V. 1996. *Vegetationsökologie—Grundlagen, Aufgaben, Methoden.* G. Fischer, Jena.
Guillaumet, J.-L. & Adjanohoun, E. 1971. Carte de la vegetation de la Cote d'Ivoire. In: Avenard, J.M. et al. (eds), *Le milieu naturel de la Cote d'Ivoire*. ORSTOM, Paris.
Hennekens, S.M. & Schaminée, J.H.J. 2001. TURBOVEG, a comprehensive data base management system for vegetation data. *J. Veg. Sci.* 12: 589–591.
Hoffman, M.T. & Cowling, R.M. (eds) 2003a. Special Issue Acock's Veld Types. *S. Afr. J. Bot.* 69,1.
Hoffman, M.T. & Cowling, R.M. 2003b. 'Enough to be considered useful': John Acocks' contribution to South African botany. *S. Afr. J. Bot.* 69: 1–6.
Horvat, I., Glavać, V. & Ellenberg, H. 1974. *Vegetation Südosteuropas.* G. Fischer, Stuttgart.
Hou, X.Y., Sun, S.Z., Zhang, J.W., He, M.G., Wang, Y.F., Kong, D.Z. & Wang, S.Q. 1982. *Vegetation map of the People's Republic of China.* Map Press of China, Beijing.
Hueck, K. & Seibert, P. 1981. *Vegetationskarte von Südamerika.* G. Fischer, Stuttgart.
Irvine, L.O.F. 1941. *The major veld-types of the Northern Transvaal and their grazing management in the light of research conducted within the area*, Vols 1 & 2. D.Sc. thesis, Faculty of Agriculture, Univ. of Pretoria.
Keay, R.W. 1959. *Vegetation map of Africa south of the Tropic of Cancer.* Oxford Univ. Press, Oxford.
Küchler, A.W. 1964. *The potential natural vegetation of the conterminous United States.* Special Research Publication No. 36. American Geographical Society, New York.
Küchler, A.W. 1967. *Vegetation mapping.* Roland Press, New York.
Küchler, A.W. 1984. Ecological vegetation maps. *Vegetatio* 55: 3–10.
Küchler, A.W. & Zonneveld, I.S. (eds) 1988. *Vegetation mapping.* Kluwer, Dordrecht.
Ladygina, G.M., Rachkovskaya, E.I. & Safronova, I.N. 1995. *Vegetation map of Kazakhstan and central Asia (limited to desert region), scale 1:2 500 000.* Euro-Asia Association ECORE, Moskva. (in Russian)
Lavrenko, E.M. & Sochava, V.B. 1954. *Geobotanical map of the U.S.S.R.* Komarov Institute of Botany, Academy of Sciences of the U.S.S.R., Leningrad. (in Russian)
Lavrenko, E.M. & Sochava, V.B. 1956. *The legend to the geobotanical map of the U.S.S.R., scale* 1:4 000 000 Komarov Institute of Botany, Academy of Sciences of the U.S.S.R., Leningrad. (in Russian)
Low, A.B. & Rebelo, A.(T.)G. 1996. *Vegetation of South Africa, Lesotho and Swaziland*. Dept of Environmental Affairs and Tourism, Pretoria.
Low, A.B. & Rebelo, A.(T.)G. 1998. *Vegetation of South Africa, Lesotho and Swaziland*, edn 2. Dept of Environmental Affairs and Tourism, Pretoria.
McDonald, D.J. 1996. The national vegetation map of South Africa project. *Veld & Flora* 82: 98, 99.
McDonald, D.J. 1997a. The national vegetation map of South Africa project. *SABONET News* 2: 68, 69.
McDonald, D.J. 1997b. VEGMAP: a collaborative project for a new vegetation map of southern Africa. *S. Afr. J. Sci* 93: 424–426.
McDonald, D.J. & Boucher, C. 1999. Towards mapping the fynbos for the revised vegetation map of South Africa. In: Timberlake, J. & Kativu, S. (eds), *African plants: biodiversity, taxonomy and uses*, pp. 195–206. Royal Botanic Gardens, Kew.
Miyawaki, A. (ed.) 1980–1989. *Vegetation of Japan*, Vols 1–11. Shibundo, Tokyo.
Moll, E.J. & Bossi, L. 1983. *Vegetation of the Fynbos Biome*, 1:1 000 000. Chief Directorate Surveys & Mapping, Mowbray.
Mucina, L. & Rutherford, M.C. 2004. Vegetation map of South Africa, Lesotho and Swaziland: shapefiles of basic mapping units. Beta version 4.0, February 2004. South African National Biodiversity Institute, Cape Town. (CD release)
Mucina, L., Rutherford, M.C. & Powrie, L.W. (eds) 2005. *Vegetation map of South Africa, Lesotho and Swaziland*, 1:1 000 000 scale sheet maps. South African National Biodiversity Institute, Pretoria.
Ni, J. 2001. A biome classification of China based on plant functional types and the BIOME3 model. *Fol. Geobot.* 36: 113–129.
Niklfeld, H. 1973. Natürliche Vegetation. 1:2 000 000. In: *Atlas der Donauländer: Kartentafel 171.* Deuticke, Wien.
Ozenda, P. 1985. *Die Vegetation der Alpenkette im Rahmen der europaischen Bergwelt.* G. Fischer, Stuttgart.
Ozenda, P. 1986. *La cartographie écologique et ses applications.* Masson, Paris.
Ozenda, P. et al. 1979. *Carte de la vegetation d'Europe a 1/3 000 000.* Conseil de l'Europe, Strasbourg.
Pedrotti, F. 2004. *Cartografia geobotanica.* Pitagora Editrice, Bologna.

Pentz, J.A. 1945. An agro-ecological survey of Natal. *Department of Agriculture Forestry Bulletin* 250.
Pole Evans, I.B. 1936. A vegetation map of South Africa. *Mem. Bot. Surv. S. Afr*. No. 15: 1–23.
Rebelo, A.G., Cowling, R.M., Campbell, B.M. & Meadows, M. 1991. Plant communities of the Riversdale Plain. *S. Afr. J. Bot.* 57: 10–28.
Rivas-Martínez, S. 1987. *Memoría de la mapa de series de vegetación de España. 1:400 000.* ICONA, Madrid.
Rutherford, M.C., Mucina, L. & Powrie, L.W. 2003b. Nama-karoo veld types revisited: a numerical analysis of original Acocks' field data. *S. Afr. J. Bot.* 69: 52–61.
Rutherford, M.C., Powrie, L.W. & Midgley, G.F. 2003a. ACKDAT: a digital spatial database of distributions of South African plant species and species assemblages. *S. Afr. J. Bot.* 69: 99–104.
Rzedowski, J. 1978. *Vegetación de México*. Limusa, Mexico.
Sochava, V.B. 1962. *Principles and methods of vegetation mapping.* Nauka, Moscow (in Russian)
Takhtajan, A. 1986. *Floristic regions of the world.* Univ. of California Press, Berkeley, CA.
Taylor, H.C. 1984. A vegetation survey of the Cape of Good Hope Nature Reserve. II. Descriptive account. *Bothalia* 15: 259–291.
Van der Meulen, F. & Westfall, R.H. 1979. A vegetation map of the western Transvaal Bushveld. *Bothalia* 12: 731–735.
Van Rooyen, N. 1978. *'n Ekologiese studie van die plantegroei van die Punda Milia-Pafuri-Wambiya gebied in die Nasionale Krugerwildtuin.* M.Sc. thesis, Dept of Botany, Univ. of Pretoria.
Van Rooyen, N., Theron, G.K. & Grobbelaar, N. 1981. A floristic description and structural analysis of the plant communities of the Punda Milia-Pafuri-Wambiya area in the Kruger National Park, Republic of South Africa. 2. The Sandveld communities. *J. S. Afr. Bot.* 47: 405–449.
Vlok, J.H.J., Euston-Brown, D.I.W. & Cowling, R.M. 2003. Acocks's Valley Bushveld 50 years on: new perspectives on the delimitation, characterisation and origin of subtropical thicket vegetation. *S. Afr. J. Bot.* 69: 27–51.
Walker, D.A., Bay, C., Daniels, F.J.A., Einarsson, E., Elvebakk, A., Johansen, B.E., Kapitsa, A., Kholod, S.S., Nurray, D.F., Talbot, S.S., Yurtsev, B.A. & Zoltai, S.C. 1995. Towards a new arctic vegetation map: a review of existing maps. *J. Veg. Sci.* 6: 427–436.
Walker, D.A., Raynolds, M.K., Daniels, F.J.A., Einarsson, E., Elvebakk, A., Gould, W.A., Katenin, A.E., Kholod, S.S., Markon, C.J., Melnikov, E.S., Moskalenko, N.G., Talbot, S.S., Yurtsev, B.A. & the other members of the CAVM Team. 2005. The Circumpolar Arctic vegetation map. *J. Veg. Sci.* 16: 267–282.
Werger, M.J.A. 1978. Biogeographical division of southern Africa. In: Werger, M.J.A. & Van Bruggen, A.C. (eds), *Biogeography and ecology of southern Africa*, pp. 145–170. Dr W. Junk, The Hague.
White, F. 1983. *Vegetation of Africa: a descriptive memoir to accompany the UNESCO/AETFAT/UNSO vegetation map of Africa*. UNESCO, Paris.
Wild, H. & Barbosa, L.A.G. 1968. *Vegetation map of the Flora Zambesiaca area. Supplement to Flora Zambesiaca.* M.O. Collins, Harare.
Zonneveld, I.S., Van Gils, H.A.M.J. & Thalen, D.C.P. 1979. Aspects of the ITC approach to vegetation survey. *Doc. Phytosociol.* N.S. 4: 1029–1063.


Altitude
Temperature
Rainfall
Land types (soil)
Geology
Current vegetation map
Space image

The Logic of the Map: Approaches and Procedures

2

Ladislav Mucina, Michael C. Rutherford and Leslie W. Powrie

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Figure 1.1 Some of the data layers used to assist in drawing VEGMAP, the end product being the second layer from the bottom.

L.W. Powrie

1. Introduction

This chapter sets out the theoretical background and practical procedures adopted by the VEGMAP Project. We describe how we arrived at the two major products of our Project—the vegetation map of South Africa, Lesotho and Swaziland (Section 6) and the descriptive book (Section 7).

Mapping of vegetation of a region comprising 11 biomes, about 20 000 species (more than 24 000 taxa) of plants, experiencing a wide range of climates, from subtropical to polar, and spanning the oldest and youngest rocks on this planet, was a daunting task. The complexity of this task is clearly mirrored in the complexity of our approach and justifies the detail contained in this particular chapter.

This chapter starts with theoretical sections (1–4) in which we argue our case for the choice of the type of the map and for the basics of the mapping procedures. These are followed by a section (5) on sources of the data used in construction of our Map (as well as other mapping products such as the map of biomes and bioregions), and the Book. There are two methodological sections: Section 6 describes the technical details of the vegetation mapping and Section 7 explains in some detail the structure of the descriptions of vegetation units that form the core of the book.

2. Aims

The aim of the VEGMAP project was to produce a scientifically sound theoretical classification of the vegetation of South Africa, Lesotho and Swaziland, and to depict it as a vegetation map which:

- documents the diversity of the plant cover of southern Africa,
- reflects our current knowledge of the structure and biogeographical patterns of the vegetation of southern Africa,
- determines a baseline for land managers and others concerned with land and biodiversity (including agriculture, forestry, nature conservation, tourism etc.).

Vegetation mapping is a simplification and modelling exercise. We thus attempted to achieve two goals:

1) to produce a map featuring vegetation mapping units represented in simplified forms to create a *graphical spatial model* of vegetation of the region, and
2) to describe these vegetation mapping units using various floristic, vegetation, biogeographical, physico-geographical and environmental descriptors (Distribution, Vegetation and Landscape Features, Geology & Soils, Important Species, Endemic Species etc.)—to create a *verbal model* of the vegetation of the mapped region depicted in the book.

3. Basic Postulates of Vegetation Classification and Mapping

The entire exercise (all stages including preparation, execution and production of the Map) was based on the following postulates which form the basic theory of vegetation ecology:

Postulate 1: Vegetation is a real, tangible object expressed in the form of recognisable patches.

In other words: vegetation is a real phenomenon and can be studied.

Postulate 2: The differences between the vegetation patches in terms of structure, texture (floristic composition) as well as in terms of environmental composition of the habitats supporting the vegetation, make the classification of vegetation (or conceptualisation of theoretical constructs called 'vegetation types') possible.

In other words: we can classify vegetation patches into vegetation types.

Postulate 3: The great complexity of vegetation, both of a discrete and continuous nature, makes the classification of vegetation (or the reduction of information content to a simplified system) necessary.

In other words: classification is one (and a very effective) way of simplifying the complexity of vegetation.

Postulate 4: The levels of difference between vegetation types make building of a hierarchical system (comprising a series of nested vegetation types and their groups) possible. The hierarchical system is another tool for further simplification of vegetation complexity.

In other words: the hierarchical system is another effective way to view important emergent properties of the major patterns of vegetation.

Postulate 5: The structure and dynamics of vegetation is a result of properties of its constituent plant populations and their response to the nature and dynamics of the environment which can aid classification and mapping ('vegetation-environment axiom').

In other words: environmental conditions determine (together with the properties of vegetation itself) the complexity of vegetation.

Postulate 6: Vegetation is composed of populations of plant species (representing taxa). Each taxon often shows an individual response to ecological factors and hence serves as an important ecological indicator. Major efforts to devise an alternative classification of functional types have yet to yield a viable system for widespread application.

In other words: we use floristic composition as the primary entity for the conceptualisation of mapping units.

Postulate 7: Vegetation patches occur in space, hence they can be mapped in spatial models.

In other words: complexity of vegetation can be shown on a map.

4. Vegetation Map as a Model: a Conceptual Framework

A vegetation map is a spatial model construct. It is shaped by various scaling considerations, including both objective scaling elements (e.g. extent of the mapped area and its abiotic and biotic complexity), and subjective scaling elements—which are a result of our intellectual, technical and financial or otherwise socially motivated constraints (including availability and quality of data, power of the mapping techniques, funds available, time schedule, contractor's requirements, presentation limits and market demands).

4.1 Basic Concepts

Several crucial concepts dominate the methodology of vegetation mapping, the most important being *mapping theme* (type of map), *mapping scale* (detail captured and presented), *mapping element* (basic mapping unit), and *unit hierarchy* (the way the mapping units form logical complexes). The latter two concepts relate directly to the *mapping legend*—a catalogue of mapping units often showing their classification as a hierarchical scheme.

4.1.1 Mapping Theme

Mapping vegetation means constructing a model which represents a particular idea about the complexity of vegetation. Hence, vegetation mapping is a modelling exercise aimed at presenting a hypothesis, at its best a hypothesis carrying a predictive message about vegetation patterns and dynamics. As there are many ways to perceive the phenomenon called 'vegetation', many types (themes) of vegetation maps can exist.

Large stretches of natural vegetation of South Africa, Lesotho and Swaziland have been turned into arable land, artificial plantations, towns and villages or have disappeared under the water of large dams. Still, owing to only very recent intensive agricultural activity (less than 350 years of the 'post-Van Riebeeckian period'—a very short time indeed when compared to thousands of years of large-scale agriculture in Europe), even larger stretches of land are blessed to still have a nearly natural vegetation cover. Nevertheless, we have refrained from applying the concept of 'real' (current) vegetation as the leading mapping theme because of the low feasibility of capturing the original character of the real vegetation at the mapping scales used in data collection and especially in presentation (see Section 6.3). In some cases the previous distribution of a vegetation type was simply unknown and only the extant distribution could be mapped. Most important here are forest patches where the heavy demand for timber over the last two to three centuries had very likely reduced areas of forest. Some highly fragmented units representing special habitats (such as SKk 8 Piketberg Quartz Succulent Shrubland, FRc 1 Swartland Silcrete Renosterveld and FRc 2 Rûens Silcrete Renosterveld) have probably been highly transformed prior to our current information on their distribution. Possibly the most extensively transformed areas are those termed 'coastal belts' (including CB 1 Maputaland Coastal Belt, CB 3 KwaZulu-Natal Coastal Belt, CB 5 Transkei Coastal Belt and AT 9 Albany Coastal Belt). Knowledge of the patterns and processes for reconstructing the vegetation in these regions through modelling is lacking. At least the extant forest patches have been mapped within these coastal belt units.

Most of the mapped area is close to the theme of 'potential natural vegetation' of Tüxen (1956, 1963, 1978). According to his approach (for more detail see also review papers by Kowarik 1987, Kalkhoven & Van den Werf 1988, Härdtle 1995 and applications as cited in these papers), the potential natural vegetation is defined as (according to Tüxen 1956 in Härdtle's 1995 translation): 'imagined natural state of vegetation … that could be outlined for the present time or for a certain earlier period, if human influence on vegetation was removed'. Using more current terminology and in simplified terms, Kowarik (1987) suggested that the 'present day potential natural vegetation is a hypothetical (potential) most developed vegetation, corresponding to present (not future) site conditions'. This definition serves especially well for vegetation of extensive southern African veld, especially farm land that has experienced changes through continuous and large-scale exploitation (including grazing by animals, brush-cutting and the like). The concept of 'veld resting' (excluding portions of farms from intensive exploitation for certain periods) is based on the experience of vegetation recovering into, if not an original, at least a more natural state when the human-controlled influence is removed. It is also highly probable that even ploughed land can return to a near natural state of vegetation (such as grassland) after abandonment (see for instance Smits et al. 1999). We acknowledge that the philosophy of a clear distinction between vegetation with humans and vegetation without humans is sometimes fanciful, especially in African savannas with their age-old association with human influence and 'disturbance', especially through the use of fire.

Our Map, however, also features 'reconstructed natural vegetation' (see Neuhäusl 1963, 1968, 1984 for more details). In regions that have experienced irreversible changes (such as in urban settlements through destruction of the natural soil cover as well as through drastic changes to local hydrology) the vegetation has been 'reconstructed' through modelling. In printed form, our Map either shows areas with reconstructed vegetation (under built-up urban areas, with the latter superimposed) to indicate the current extent to which this vegetation has been removed, or follows conventional cartographic practice to override vegetation of areas flooded by the water reservoir of a dam. However, the reconstructed vegetation below the reservoirs of dams can be viewed on the CD accompanying this book. This was needed for correct calculations of the proportion of vegetation transformed for the conservation sections of the book.

As a matter of reference, Acocks (1953, 1975, 1988) also employed the term 'potential' in his definition of 'veld type'. He then mapped his veld types in their 'potential' extent and not as patches of 'real' vegetation.

4.1.2 Mapping Scale

The size of the mapping realm (almost 1.3 million km^2) as well as the remarkable diversity of the flora (hence vegetation) supported by complex geological, climatic and hydrological patterns, proved challenging for mapping the vegetation. The decisions regarding the mapping scale(s) and the scale(s) of map presentation were dictated by our goals (see above) and these were modified by various serious constraints. Most compelling were: (a) the extent of the mapping area, (b) time and budget, (c) available expertise, (d) quality of data, and (e) technical level of mapping tools.

The scale of 1:250 000 was selected as the initial working scale, especially since many of the proxy data sets, such as geology, land types, topography (see Section 5 of this chapter for sources) were available in sufficient detail and precision at that scale. The consequent implementation of GIS technology, and local availability of more detailed sources (at 1:50 000, 1:10 000, etc.), allowed departure from the preliminary scale and facilitated increased detail of mapping where warranted, often resulting in greater refinement of the borders between vegetation units. Although such detail cannot be visible on our printed 1:1 000 000 maps, the electronic version (see CD) has no such limitation and a precision of down to 100 m (and even less in some cases) was possible where necessary.

The Prince Edward Islands were mapped at a working scale of about 1:25 000.

4.2 Vegetation Units, Mapping Units, Mosaics and Transitions

4.2.1 Definition of Vegetation Unit

At the scales of data collection (1:250 000 and sometimes more detailed) and presentation (1:1 000 000) our Map cannot show distribution of plant communities that operate on the habitat level. Our basic units of mapping, here called *vegetation units* (e.g. FFs 11 Kogelberg Sandstone Fynbos, FOa 2 Swamp Forest and AZd 3 Cape Seashore Vegetation), are mostly identical to *mapping units*—those units shown on the map. (Examples where the mapping units are not identical with vegetation units are found in Chapter 15.) Using the general (and neutral) term 'mapping unit' we also designate the high-level units such as bioregions and biomes (see below and Chapter 3).

Vegetation Unit—the basic element of the Map—is defined as a *complex of plant communities ecologically and historically (both in spatial and temporal terms) occupying habitat complexes at the landscape scale.* Our vegetation units are the obvious vegetation complexes that share some general ecological properties such as position on major ecological gradients and nutrient levels, and appear similar in vegetation structure and especially in floristic composition.

The decisions to classify habitat-level communities into vegetation complexes forming the basis for definition of our landscape-level vegetation units, are governed by the following principles:

- close position along dominant ecological gradients

  Example: different estuary plant communities of flooded habitats (differing only in frequency of flooding).

- dominant ecological factor at landscape level

  Example: high salt content in soil selecting for a limited number of plant communities.

- dominant vegetation structure

  Example: fynbos shrublands on sandstone (often differing dramatically in floristic terms, but showing similar vegetation structural traits, especially growth form composition).

- high level of floristic similarity (including shared local and regional endemics)

  Example: various low shrublands in Succulent Karoo.

- close proximity

  Example: patches of distinct plant communities (that also satisfy a number of criteria listed above) in close proximity of one another can have a higher probability of shared elements and hence of being classified into the same vegetation unit than those more widely separated.

- potential

  Example: recovering vegetation of old fields classified as that of the surrounding grasslands.

It is obvious that not all these criteria could be used or would carry the same weight in delimitating our vegetation units. The order of importance or weighting of these criteria depends very much on the character of the vegetation (species-poor to species-rich, structurally simple to complex, clear versus fuzzy borders between patches) or character of ecological gradients shaping the vegetation landscapes within particular biomes (steep gradients versus shallow gradients, many ecologically functional factors versus few factors).

4.2.2 On 'Mosaics'

The concept of *mosaic* automatically implies at least two recognisable elements (in our case at least two vegetation units). The recognition of a mosaic can happen only *à posteriori* (after we have defined the elements). The term mosaic is used in mapping (not only vegetation mapping) to overcome the difficulties emanating from mapping scale. Examples are where local geology, local microclimatic and hydrological conditions, and natural disturbance factors (and various combinations of these) at detailed scales create a complex of clearly demarcated habitats supporting patches of distinct plant communities. In other words, where the grain of patchwork of habitats (supporting distinct vegetation units) encountered cannot translate onto a map of scale of choice, mosaics are often invoked as a concept and name. The patches of respective vegetation units simply become 'dissolved' into neighbouring vegetation units.

The decisions for not mapping mosaics onto a map are often due to lack of (field) mapping precision and lack of suitable small-scale data.

On our Map we have refrained from using the concept of mosaic in mapping the vegetation of continental South Africa, Lesotho and Swaziland for the following reasons: The field mapping scale we adopted (1:250 000) is so coarse that, if our vegetation units represent a landscape-level of complexity, we should almost always have had to disregard small patches of other vegetation units that are embedded. These small patches have indeed been mapped in regions where our data allowed us to work at a mapping scale of 1:50 000, and their coverage is available in electronic (GIS) format. However, these embedded patches had to be masked out ('dissolved') for the map presentation at a 1:1 000 000 scale to avoid creating 'salt-and-pepper patterns'. In fact, technically speaking, all patches of vegetation as represented on our Map at the scale of 1:1 000 000 (Mucina et al. 2005 or Chapter 18) are invariably mosaics! We admit that some of our vegetation units are of extreme mosaic nature—a reflection of the microscale spatial differentiation and often a lack of such precise data. Among the most prominent are the alluvial units (AZa; see also Chapter 13) which can comprise riparian thickets, flooded grasslands, reed beds and even patches of aquatic vegetation found in the streams and in alluvial backwaters.

Of the recent (though unpublished) maps, the one of the STEP region (Vlok & Euston-Brown 2002) uses the concept of 'mosaic' extensively.

The vegetation map of the Prince Edward Islands (see Chapter 15) is a notable exception in our handling of 'mosaics'. Here the intricate local topography and associated hydrology on the one hand and the influence of sea and animals on the other at low altitudes create small-grained mosaics of habitats impossible to depict at a mapping scale 1:25 000 (approximate field mapping scale), but the plant communities supported by these habitat mosaics are sufficiently distinct to qualify as vegetation units. However, since our current data do not allow clear delimitation of these distinct vegetation types as units, we have decided to present them on the map in the format of 'mosaic' mapping units. It is here where the concept of 'mapping unit' does not match the concept of 'vegetation unit'. The mapping unit termed 'Subantarctic Mire-Slope Vegetation' contains three vegetation units (ST 3 Subantarctic Mire, ST 4 Subantarctic Drainage Line and Spring Vegetation and ST 5 Subantarctic Fernbrake Vegetation), while the mapping unit termed 'Subantarctic Coastal Vegetation' comprises two vegetation types (ST 1 Subantarctic Coastal Vegetation and ST 2 Subantarctic Biotic Herbland and Grassland).

4.2.3 On 'Transitions'

Interestingly, exactly the same theoretical framework used to handle mosaics in vegetation mapping can be applied when so-called 'transitional' areas (regions) or ecotones are considered. While the term mosaic implies clearly (crisply) defined ingredients (elements), the term 'transition' entails gradual change between two (and rarely more) entities (for instance vegetation units). The concept of 'transition' in ecology has deep roots in the precept of the continuum in vegetation ecology (the current reigning paradigm). However, the controversy between continual versus discrete variation in vegetation is surely a matter of scale (see the seminal theoretical paper by Austin & Smith 1989 on the matter).

We acknowledge that the borders between some units, especially those where the controlling ecological factors change in a continual manner (for instance climatic factors in areas of uniform topography), are arbitrary and imply a midpoint in the transitional zone. These include the units straddling the border regions of some biomes (defined by climatic factors in the first place), including NKl 1 Gamka Karoo and SKv 6 Koedoesberge-Moordenaars Karoo, NKu 4 Eastern Upper Karoo and Gh 3 Xhariep Karroid Grassland, SKt 3 Roggeveld Karoo and NKu 1 Western Upper Karoo and a few others. There are also examples of some sharp transitions between biomes in places (see Chapter 3).

4.3 Hierarchy of Mapping Units

Following the theoretical principles of zonality of vegetation (discussed in detail in Chapter 13), we have separated the zonal and azonal vegetation units. For practical reasons we maintain all indigenous forest units within one informal group, although they represent a mixture of units belonging to two forest biomes (Afrotemperate Forest Biome and Subtropical Coastal Forest Biome or Indian Ocean Coastal Belt) and azonal forest units (riverine, swamp and mangrove). More information about the azonal versus zonal status of the forests is presented in Table 12.1.

The azonal vegetation units are grouped (for purposes of structuring the legend and the descriptions) in a similar way. Here the ecological (groups of azonal units according to dominant character of hydrology or salt content) and (phyto)geographical (according to embedding within biomes especially) ones prevail.

With most of the remaining vegetation, our Map features a three-level nested hierarchy of the mapping units, namely the levels of (a) vegetation units, (b) bioregions (composed of vegetation units), and (c) biomes (comprising bioregions). To paraphrase the definition of 'bioregion' from Chapter 3: each bioregion is a composite of spatial (vegetation) units sharing similar biotic and physico-geographical features and connected by processes operating on a regional scale. Bioregions and biomes are discussed in Chapter 3.

5. Data Sources and Processing

Data included with the Map (Mucina et al. 2005) and used in the mapping and analysis processes were obtained from (or modified from data supplied mostly by) a number of organisations. Some features were edited and adjustments applied using the rubbersheet method to align the topographic data to scanned 1:50 000 or 1:250 000 maps, and to align the vegetation map and topographic data as required.

Not all data were available at the commencement of the project, and the development of the project may have been somewhat different had they been available at the outset of the project. Data that became available later in the project include topographic data from the Chief Directorate: Surveys and Mapping (CDSM), land types included with the Environmental Potential Atlas (ENPAT) from the Department of Environmental Affairs and Tourism (DEAT), and data on protected areas. Some data became available too late to have been used or included in the map or report.

Details of individual data contributions by authors are given in the Credits section of the chapter describing the relevant biome or other groups of vegetation units (forests, azonal vegetation or vegetation of the subantarctic islands).

5.1 Topography

The 100 m and 20 m contours and the scanned topographic maps were obtained from CDSM. The 200 m Digital Elevation Model (DEM) (Schulze 1997) was used to model some slopes in the process of mapping some vegetation types associated with slopes. Terrain morphology was consulted for describing some vegetation types (Schulze 1997). Some contour heights had to be corrected. Altitude profiles of vegetation types were derived as follows: The DEM was classified into 20 m classes and the class grid converted to polygons. These polygons were then combined with the vegetation map to obtain the intersection of vegetation types with altitude classes. The area of each polygon was then calculated and a single table created with vegetation type, altitude class, and sum of area. Frequencies of altitude classes in each vegetation type were then prepared as histograms which were used for describing the altitude profiles.

Other topographic data were obtained from the Chief Directorate: Surveys and Mapping (national Department of Land Affairs), Mowbray, Cape Town (w3sli.wcape.gov.za), reproduced under Government Printer's Copyright Authority No. 11243 dated 4 January 2005.

5.2 Geology, Soils and Land Types

Digital geological data obtained from the Council for Geoscience included the 1:1 000 000 map, 1:250 000 geology map for selected map sheets limited to the Fynbos Biome area, and the volcanology of Marion and Prince Edward Islands. Soils (Land Types) were obtained from ENPAT. Landsat (contrast-adjusted colour composite of TM bands 7,4,2 as R,G,B) satellite imagery was obtained from NASA. Predicted Soil Loss (erosion) data were supplied by the national Department of Agriculture (NDA).

5.3 Climate

Climate data were obtained from the *South African Atlas of Agrohydrology and Climatology* (see Schulze 1997). Selected temperature maxima and minima were extracted from data for climate stations of the South African Weather Service (SAWeather).

The climate diagrams (Figure 2.2) were prepared by summarising vegetation type zones (using ArcView 3) using the vegetation polygon theme and climate grids. For these diagrams, mean values were taken for each month for the Median Monthly Rainfall, Maximum Temperature and Minimum Temperature. Mean values for Mean Annual Precipitation (MAP), Annual Precipitation Co-efficient of Variation, Mean Annual Temperature, Mean Frost Days (days when screen temperature was below 0°C), Mean Annual Potential Evaporation and Mean Annual Soil Moisture Stress Days (percentage of days when evaporative demand was more than double the soil moisture supply) were taken to give figures for the parameters to the right of each graph.

Vegetation types with small portions in a given grid cell would not be represented in that cell in this summarising process. This resulted in statistics being biased towards parts with larger

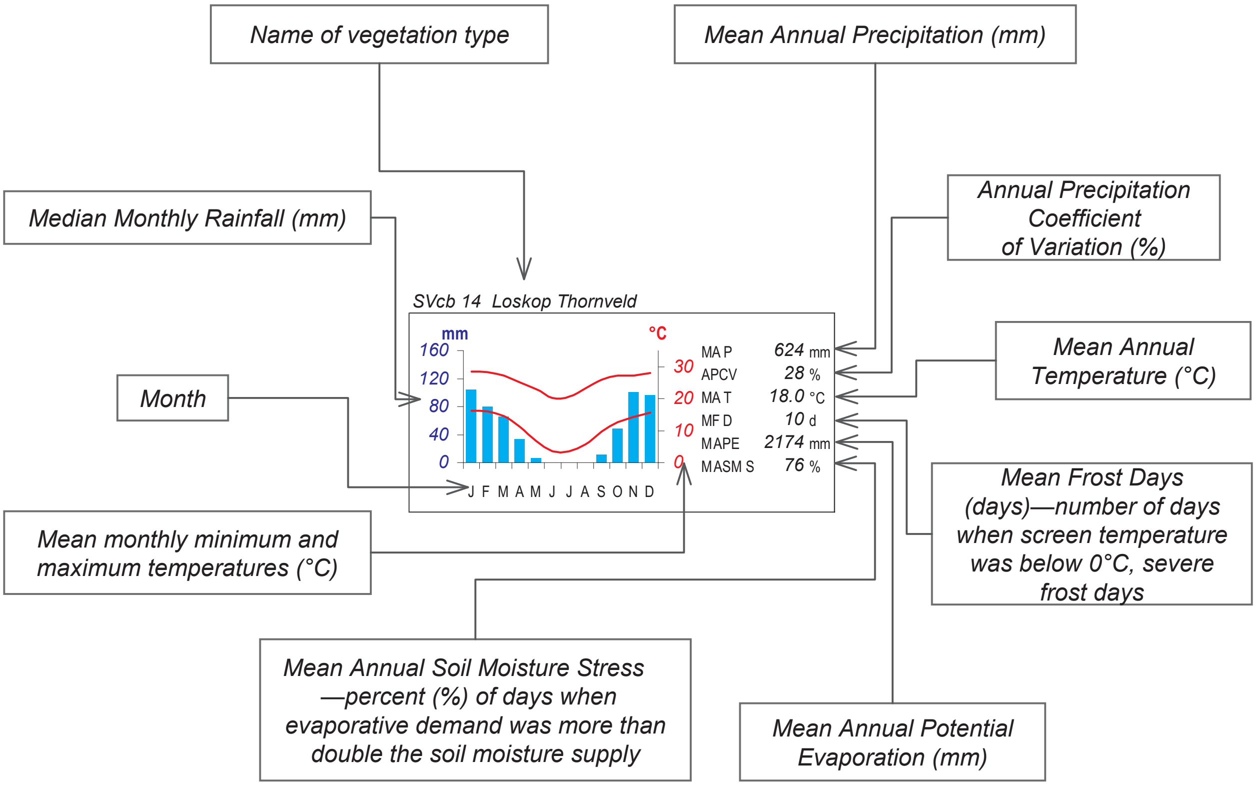

Figure 2.2 Example of a climate diagram with explanation of the elements.

extents of each vegetation type. This has particular relevance for shale bands, koppie units, etc. For example, it is likely that shale bands cross many grid cells but will have no data for many of those grid cells because they are not the majority of the total vegetation in those cells. Thus, for example, the shale bands might have skewed seasonality or other mean climate data over their ranges. Where there is no value for a type in any particular grid cell, each climate grid will have no data for that vegetation type in that grid cell, so in the same cell the data would be absent for each parameter. In some instances, i.e. SVcb 22 VhaVenda Miombo, AZf 2 Cape Vernal Pools and Dn 2 Namib Lichen Fields, each polygon was a minority in its respective grid cell and points were used instead of polygons to derive climate diagrams for these small units. Climate diagrams were not created for the Desert Biome and the Succulent Karoo units of the Richtersveld due to a lack of confidence in the modelled data in that area. In some of these cases, data for weather stations situated in the respective vegetation type were used to create modified climate diagrams.

Crosswalks were used for preparing some descriptions of vegetation types in Sections 7.2, 7.5, 7.6, 7.8. These crosswalks were derived by converting the climate grids to polygons and then overlaying the polygons and getting actual areas of overlap (in ha) of vegetation and each value for the climate. The crosswalks were done with classes of cell values (e.g. 1–10 mm of rainfall).

5.4 Sources of Plant Distribution Data

The main source of plant distribution data was PRECIS (National Herbarium [***PRE***] **C**omputerized **I**nformation **S**ystem)—a database managed from the Pretoria centre of the South African National Biodiversity Institute (Magill et al. 1983, Germishuizen & Meyer 2003). The spatial resolution of specimens in Specimen-PRECIS (about 800 000 records) is generally 1:50 000 map sheets, the so-called 'quarter degree squares' (QDS) (approximately 30 x 30 km). Because of this very coarse scale, the data were considered to be potentially useful only where a QDS was at least 90% within a vegetation type. An intersection of QDS with vegetation types enabled the calculation of the percentage representation of a grid cell in a vegetation type. Azonal types and sea within a QDS were taken into account, reducing the total area of the grid cell to be apportioned to the vegetation type. By referring to the individual collectors' label data, the accuracy could sometimes be greatly improved from incorrect or even missing geographical co-ordinates in PRECIS. In cases of outliers where the geographical co-ordinates and the locality description recorded by the collector on the label disagreed, we used the label data and not the geographical co-ordinates. Place names mentioned on specimens were checked against PRECIS Gazetteer, CDSM Gazetteer, ENPAT2001 (DEAT) cadastral data (farm names), and names of places and parent farms from SAExplorer (MDB). Data were generally used with greater confidence if the point was located within the vegetation type where the collecting locality was recorded by the collector with a precision of less than 2 km, as is the case with some older specimens, and increasingly so for newer specimens where GPS is used.

The ACKDAT database (O'Callaghan 2000) is curated at the Kirstenbosch centre of the South African National Biodiversity Institute and contains about 300 000 records of data on species presence and abundance and sometimes habitat. It was created by the computerisation of J.P.H. Acocks's field notes (Rutherford et al. 2003) recorded during some 44 years of field work throughout South Africa and parts of Swaziland. Geographical co-ordinates generally have a precision of about 1.5 km. We used ACKDAT data for sites specifically selected as being representative of the vegetation type in which each occurred. For example, if sites were close to the edge of a type or if Acocks's description of the site indicated that it was not typical of the vegetation type, the data were generally not used for that type if better alternatives were available. Acocks sometimes specified the habitat of a site as forest or pan, making it unrepresentative of the surrounding type being described. Because of the progress South African taxonomy has made over the past 50 years, many of Acocks's records considered as useful were checked against other sources for identification certainty. In the process, for instance, all records for vygies (Aizoaceae) were disregarded. The Nama-Karoo sites of Acocks served as a basis in preliminary steps towards mapping of the biome (see Section 6.2.2 further on).

The third important source of distribution data was the database of the Protea Atlas Project (Rebelo 1991). It currently contains about 265 000 high-precision records of all Proteaceae occurring in southern Africa, collected by professionals and trained amateurs. Data usually include an estimate of abundance and sometimes habitat. The database is curated at the Kirstenbosch centre of the South African National Biodiversity Institute and served as a major source of data, especially for the descriptions of the vegetation units of the Fynbos Biome.

National Vegetation Database (Mucina et al. 2000) served as a source of vegetation data in some preliminary classification studies in several fynbos regions as well as for classification of the forest data (Von Maltitz et al. 2003, Mucina & Geldenhuys 2002, Geldenhuys & Mucina 2006), the results of which led to the definition of the forest vegetation units in our Map. The vegetation data are stored in the form of relevés (list of taxa per plot) and are managed by the TURBOVEG 2.0 software (Hennekens & Schaminée 2001). This database was used as a source of plant species distributions in relatively few cases because of the frequent lack of geo-referencing of sampling plots.

Gertenbach's (1983) species lists for landscape types in the Kruger National Park were a useful source of species data which helped to shape the species lists of all vegetation units of the Park.

The distribution of alien plant species were sourced from the National Invasive Alien Plant Database (CSIR) (McKelly et al. 2000).

The species lists of the descriptions of vegetation units extracted from the databases listed above were further supplemented by:

- distribution data from all major taxonomic revisions and monographs of southern African genera,
- all major flora field guides featuring various segments of the flora of the region,
- unpublished (and not yet digitised) voucher collections from major herbaria in the region,
- unpublished records collected by many field botanists, both professionals and amateurs (see the sections on Credits in particular chapters as well as general Acknowledgements in Chapter 1).

5.5 Conservation Data

Protected areas network data were compiled in April 2005 for purposes of the National Spatial Biodiversity Assessment (Driver et al. 2005). They are included with the digital data of the Map and were also used for describing the proportion of most vegetation types statutorily conserved. These included national parks from the SANParks, and other data collected for the National Spatial Biodiversity Assessment. SANParks supplied some recent changes and missing data, such as those on the proposed Garden Route National Park. Some conservation areas were digitised from sources at SANBI and SANParks, e.g. Tšehlanyane National Park in Lesotho. See above for the source of the alien plant coverage.

Census data (from SAExplorer from the Municipal Demarcation Board) were consulted in some cases to help locate areas of major human pressures in some vegetation types.

See also Section 5.7 for man-made impacts.

5.6 Other Vegetation Maps as Sources

Vegetation maps used as sources are referred to at their application in Sections 6 and 7. Gertenbach (1983) boundaries were used for our vegetation boundaries within the Kruger National Park.

5.7 Man-made Geographical Features

The basic cartographic data on political boundaries, settlements, roads and dams were conventionally applied, but with numerous necessary modifications to source data.

National and international boundaries were obtained from ENPAT, and borders with countries neighbouring the mapped area were corrected using 1:50 000 map images from CDSM.

Settlements (ranging from selected small groups of huts to cities) data from GlobalMap (supplied by CDSM) were used. Place names were updated according to gazetted names listed on the website of the South African Geographical Names Council on 1 January 2005. Names of some additional built-up areas were taken from data provided by CDSM.

Roads data were obtained from the Council for GeoScience. Some new roads were added, e.g. the stretch of N1 between Polokwane and Mokopane, the road north of Upington to Askam, some roads in the Richtersveld, Namaqualand, Maputaland and in Limpopo Province. The mapping of the road networks in Lesotho and Swaziland was improved. Railway data from GlobalMap were used, with some editing in Swaziland. Data on rivers were obtained from the Council for GeoScience. River courses were reconciled with the position of riverine vegetation and dams. They were checked against CDSM-scanned maps in certain instances.

A coverage representing radically altered landscapes was prepared using the classes 'Forest Plantations', 'Cultivated Lands', 'Urban/Built-up Lands' and 'Mines and Quarries' from the National Land Cover database (Fairbanks et al. 2000). CDSM 1:500 000 roads (excluding footpaths) were buffered (30 m for major roads, 20 m and up to 10 m for lesser roads) using GIS and added to the radically altered layer. Areas transformed by water impoundment were obtained from CDSM. Data on dams were derived mostly from 1:500 000 digital map data and some from 1:50 000 digital data, or by checking against 1:250 000 scanned maps, and some digitised using Landsat 5 images. Dams smaller than 100 ha (making up 3.6% of the total dam area) were omitted to avoid the many farm dams. Vegetation on islands of smaller than 20 ha in dams was not mapped. Dam names were checked against the dams shapefile from DWAF, scanned 1:50 000 and 1:250 000 maps, and independent sources. Certain dams that had not been in the dataset, were digitised, e.g. the Mohale and Marico Dams, and the coverage of some had to be corrected (e.g. Straussfontein Dam, Free State).

6. Vegetation Map as a Graphical Spatial Model

6.1 *Mapping Procedures: Basic Features*

In this section we shall address only the theory of the mapping procedures. The technical details of the mapping are presented in Section 6.2.

The mapping procedures adopted in the VEGMAP project include the following five basic features:

(1) Zonality concept as a major classification criterion.

(2) Recognition of controlling factors at the scale of mapping.

(3) Adoption of proxy data as major source.

(4) Application of a top-down approach in conceptualising mapping units.

(5) Bottom-up approach in building a hierarchy of mapping units.

Zonality. The enormous extent of the mapping realm (almost 1.3 million km^2) corresponds to the scale of the macroclimate which probably plays a major role in differentiating vegetation complexes at the subcontinental scale. The concept of zonality (Walter 1964) has been used as an *a priori* criterion in recognising azonal vegetation types under strong control of factors other than climate. The concept of zonality and related terminology is discussed at length in Chapter 13. Application of this prime criterion in our Map is unique in the history of South African vegetation mapping.

Controlling Factors. Vegetation patterns are a result of a complex of environmental factors co-acting both spatially and temporally. Various ecological factors determine the patterning and dynamics of vegetation and it is therefore essential to identify those most important to understand the distribution of vegetation types in space and time. Application of zonality (identifying those controlling climatic factors in zonal vegetation) was one of these essential steps. We consider those factors that control, for example, the diversity of the azonal (water dynamics, salinity) or zonal vegetation (soil patterns, geology).

Proxy Data. Because of the lack of primary vegetation data (including vegetation samples, interpretable remote-sensing coverage etc.) in many areas, vegetation mapping is forced to use proxy data—soil maps, geological maps, modelled climatic surfaces etc. The proxy data were extensively used in our mapping studies to create physico-geographical units to serve as a basis for recognition of vegetation units.

Top-down Approach. We used this approach in spatial delimitation and conceptualisation of the mapping units. Starting from broad mapping realms representing biomes (or other groups of plant communities) and applying the knowledge of the controlling factors, and aided by proxy data, we proceeded in subdividing the mapping realm into smaller homogeneous (physico-geographical) units. These units were then re-evaluated in terms of vegetation concepts, in other words the physico-geographical unit was characterised in terms of its vegetation cover and composition. Three basic steps constitute the process from the recognition of mapping units to their actual spatial mapping. These are: (1) spatial delimitation of units, followed by (2) conceptualisation (including calibration and verification) of the units, and finally (3) description by which the properties of the established mapping units are expressed in a comprehensive yet condensed text form to accompany the map and aid its interpretation. The last step is handled in more detail in Section 7 of this chapter.

Bottom-up Approach. Using the similarity in terms of vegetation structure and floristic composition as well as several other mainly ecological or physico-geographical traits, the distinguished vegetation (mapping) types were grouped into a nested hierarchy. In our terminology, the *vegetation units* (basic level) group into *bioregions* and these group into *biomes* (see also Section 4.3 in this chapter).

6.2 *Mapping Procedures: Practical Approach*

6.2.1 *General Mapping Procedures*

Commencing with the top-down approach, we handled the mapping of the target region (South Africa, Lesotho and Swaziland) in stages.

Stage 1: Initially we divided the target region into areas to be covered by particular mapping teams using the methodology as indicated in Sections 4.1 and 6.1 and adapted to local conditions (complexity of vegetation, extent of the area, availability of proxy and field data etc.). These areas were (1) Grassland and Savanna Biomes (excluding the Eastern Cape and KwaZulu-Natal), (2) so-called arid biomes, including Nama-Karoo, Succulent Karoo and Desert, (3) Fynbos Biome, (4) Eastern Cape and (5) KwaZulu-Natal. The Eastern Cape team mapped, among other vegetation types, also the southernmost extensions of Grassland and Savanna. Each of these teams (with exception of the arid biomes team) produced a map of the respective areas. The Grassland/Savanna team did not only create a new product for most of the area but relied heavily on existing (although not comprehensively published) maps covering the Kalahari region. The arid biomes were mapped, at this stage, in a different manner: the Nama-Karoo region (with broad buffer zone encroaching into neighbouring biomes such as Savanna/Kalahari, parts of Succulent Karoo and Fynbos and especially summer-rainfall parts of the Desert Biome) was mapped as an entity. The Richtersveld was covered by very detailed, unpublished survey data and the Namaqualand region (excluding the Richtersveld) was initially mapped using satellite imagery (see below for the details of the mapping procedures). The remainder of the target area (the Succulent Karoo area outside the above-mentioned areas) was mapped *de novo*.

The various contributors had been asked to map data and to digitise these and supply ArcView shapefiles in Decimal Degrees, WGS84 spheroid and Hartebeesthoek datum. Those mapping coverages supplied in Cape Datum, Clarke 1884 spheroid, or in mixed datum were reprojected. In cases where the supplied data were more inaccurate than could be attributed to the datum point (1.6 km northeast in the Molopo River area), the spatial adjust method of ArcGIS 8 using a rubbersheet of all features was used to adjust such portions of the map to align them to 1:50 000 data supplied by the CDSM.

Stage 2: This stage proved to be the most complex part of the whole process. After initial screening of the supplied products, we attempted the first stitching of the partial products to identify gaps and incompatibility of units along 'stitched' borders. During this period, new mapping sources, especially valuable unpublished maps, became available. Involvement of new collaborators who were asked to deal with local/regional mapping issues, led to a considerable revision of large portions of the initial mapping products supplied, especially in the Grassland, Savanna and Fynbos Biomes as well as in the Eastern Cape Province, Lesotho and Swaziland. A fresh attempt was made to map the vegetation of Lesotho and an unpublished map of Swaziland was supplied to the VEGMAP team at that stage. Both maps replaced existing initial mapping coverages of the

Grassland and Savanna Biomes within the borders of these two countries. A large part of the Fynbos Biome was mapped in a second attempt assisted by better digital (more detailed geological map) and floristic (improved access to extensive databases) data. The western portion of the initial Eastern Cape mapping coverage was replaced by the very detailed STEP map, which had to be simplified for the purpose of our Map and the limitations imposed by the mapping scales. The original KwaZulu-Natal map also underwent simplification and adjustments resulting from input from experts of Ezemvelo KZN Wildlife (especially in Maputaland, northern KwaZulu-Natal and in the Midlands). At this stage the very detailed Richtersveld map had also been adapted to our aims (simplified and improved in some boundary detail) in the first place and collated to fit the concepts of the neighbouring regions, especially the Namaqualand and northern Bushmanland coverage (originally part of the initial Nama-Karoo map). In summary, this stage saw (1) much improvement in providing more soundly based types and more accurately mapped units in local and regional coverages (through improved access to unpublished mapping sources and powerful proxy data as well as floristic databases), and (2) the 'stitching' process—a phase of reconciliation of different sources in spatial (boundaries) and conceptual terms involving unification of concepts of units subject to stitching.

In practice this meant many iterations operating at very different cycle lengths which, together with the number of vegetation polygons ultimately exceeding 17 000, required close and careful management. Numerous field checks and consultations were undertaken by the VEGMAP management team to improve the quality of the map.

Stage 3: Although less complicated than the previous one, this was a stage of small-scale improvement, including incorporation of comments of consulted experts, refinement of borders (increasing detail of boundaries at more detailed scale), handling of very small polygons for cartographic reasons and, finally, cleaning of the coverage.

Editing was done using ArcView 3.2. Occasional cleaning was done by converting the shapefile to an ArcInfo coverage using the ArcCatalog process to export the shapefile to coverage to generate topology for overlaps and gaps in the combined source data. Slivers resulting from overlaps between various coverages were identified and removed. Almost all polygons smaller than 5 ha were merged to the appropriate adjacent type to avoid a salt-and-pepper effect in the graphical presentation (too fragmented coverage consisting of many spatially separated polygons obstructing the general pattern).

6.2.2 Specific Mapping Examples

Grassland and Savanna

Most of the borders between the Grassland units of the Highveld north and west of Lesotho and much of the eastern Highveld and the Eastern Cape are frequently very similar to land type boundaries. Certain localised units west of Lesotho were mapped independently of land types, e.g. Gh 7 Winburg Grassy Shrubland, Gh 8 Bloemfontein Karroid Shrubland and Gm 7 Northern Free State Shrubland. Vegetation in KwaZulu-Natal has a somewhat lesser correlation with land type boundaries. Northern summit and eastern escarpment units of Grassland (e.g. Gm 20, 23, 27 and 29) as well as Lesotho and Swaziland do not follow land types.

Few vegetation units of the Savanna Biome follow land type boundaries. Those that do are mainly the Savanna Thornveld types of the Central Bushveld (units SVcb 1, 3, 6, 14 and 15) and the separation of SVmp 1 Musina Mopane Bushveld and SVmp 2 Limpopo Ridge Bushveld. Elsewhere there are some units that partially coincide with land type boundaries, such as the northeastern parts of SVl 3 Granite Lowveld, the western edge of SVl 1 Makuleke Sandy Bushveld, part of the eastern side of SVcb 21 Soutpansberg Mountain Bushveld, the southern edge of SVkd 1 Gordonia Duneveld and the northern parts of SVk 4 Kimberley Thornveld.

We also made use of boundaries of previously mapped vegetation types in the delimitation of some Grassland and Savanna units, for instance the landscape types of the Kruger National Park (Gertenbach 1983), units mapped in the Blouberg (Scholes 1979) and those of the Kalahari duneveld (Lubbinge 1998) etc.

While the Sub-Escarpment Grassland and Savanna units in the Eastern Cape (central to eastern regions of the province; D.B. Hoare & A.R. Palmer, unpublished data) were mapped using satellite imagery, the Sub-Escarpment units of KwaZulu-Natal in principle followed the borders of Broad Resources Groups (BRG) and Bioresource Units (BRU) as defined by Camp (2001 and the preceding series of reports). A BRG is defined as 'a specific vegetation type controlled by an interplay of biotic factors such as soil and altitude'. It is formed by one or more Bioresource Units, each of the same vegetation type, and related to one another in terms of climate and broad soil association patterns (Camp 2001). In the same work Camp defined a BRU as '… an area within which the environmental factors such as climate (rainfall, temperature and evaporation), soil type, vegetation and terrain type, have a degree of homogeneity such that land use practices, farming enterprises, production and production techniques, can be clearly defined for practical planning purposes'. Details on the mapping procedures leading to the BRG/BRU classification of KwaZulu-Natal are also given in Camp (2001).

Geology was used as a guide for boundaries of some Grassland and Savanna types, including units such as Gd 7 and 8, Gh 11 and 15, Gm 10, 22, 23 and 26, Gs 2, SVl 5, 6 and 13, SVcb 2, 7, 11, 13, 25, SVmp 4 and 8.

Altitudinal limits were used to approximate boundaries of, for example, Gm 20 Leolo Summit Sourveld, Gm 29 Waterberg-Magaliesberg Summit Sourveld, Gd 10 Drakensberg Afroalpine Heathland and SVl 17 Lebombo Summit Sourveld. Digital Elevation Model (DEM) data were used to calculate minimum slopes to identify some units associated with koppies, for example, Gm 5 Basotho Montane Shrubland and Gh 4 Besemkaree Koppies Shrubland. Topographic maps were used to identify units such as SVl 7 Gravelotte Rocky Bushveld, eastern outliers of SVl 9 Legogote Sour Bushveld and SVl 12 Kaalrug Mountain Bushveld. Gm 2 Senqu Montane Shrubland was mapped on the basis of steep slopes up to a maximum altitude approximating the upper limits of the sandstone. Much of the extent of the units where we applied DEM data extensively were later verified by ground truthing.

The approximate 600 mm isoline for MAP was used as an upper limit for Gh 2 Aliwal North Dry Grassland and for separating Gh 4 Besemkaree Koppies Shrubland on the dry side from Gm 5 Basotho Montane Shrubland.

Albany Thicket

The core (solid) thicket vegetation types of the Subtropical Thicket Ecosystem Planning (STEP) Project were closely followed for our Albany Thicket vegetation types. The mosaic thicket units of STEP were assigned as follows: The Fynbos units identified by the Fynbos mapping team took preference, and the remainder of the mosaics were then individually evaluated against available environmental evidence and either rejected, accepted or many were only partially accepted as a Thicket type.

Below we give various contrasting examples of our approach to assigning these mosaic units, or parts thereof, to vegetation types. Mons Ruber Fynbos Thicket (a STEP unit) was partly accepted as Thicket, with the rest going to the Fynbos Biome. Examples of mosaic types that were assigned in their entirety to the Fynbos Biome include Andrieskraal Fynbos Thicket, Kouga Fynbos Thicket and Alicedale Fynbos Thicket. A three-way split was applied to De Rust Karroid Thicket between AT 2 Gamka Thicket, Succulent Karoo and Fynbos.

In general, the gwarrieveld mosaic units were not assigned to the Albany Thicket, but rather to the Succulent Karoo or Nama-Karoo Biomes. Most of the area of the STEP 'doringveld units' were re-assigned as the azonal alluvial vegetation types.

All of Oudtshoorn Karroid Thicket, Kleinpoort Karroid Thicket and Koedoeskloof Karroid Thicket were accepted as parts of AT 2 Gamka Thicket, AT 3 Groot Thicket and AT 6 Sundays Thicket, respectively. However, all of Beervlei Karroid Thicket and Blossoms Karroid Thicket were assigned to NKl 1 Gamka Karoo and SKv 11 Eastern Little Karoo, respectively.

All of Albany Bontveld and Mountvale Grassland Thicket were assigned to SVs 7 Bhisho Thornveld, and Bedford Savanna Thicket was assigned to mainly Gs 18 Bedford Dry Grassland and SVs 7 Bhisho Thornveld. By contrast, Montcoke Grassland Thicket was all assigned to AT 12 Buffels Thicket. Umtiza Forest Thicket was split between AT 12 Buffels Thicket and FOz 5 Scarp Forest.

Arid Biomes

A multivariate data analysis of the link between the vegetation data (Acocks's species lists) and a set of environmental data harvested from GIS layers in the same localities (B. van der Merwe & W. Lloyd, unpublished data) revealed the controlling importance of environmental characteristics used for definition of land types (see Fairbanks et al. 2000). Therefore almost all the borders of the vegetation types of the large-scale Nama-Karoo units follow those of the land types. In the Richtersveld, mainly floristic surveys, topography and satellite imagery were used to help delineate the vegetation units. This also applied to the Desert units, except in the east and southeast where the MAP of 70 mm approximated the boundary between Dg 9 Eastern Gariep Plains Desert and Dg 10 Eastern Gariep Rocky Desert of the Desert Biome, and NKb 3 Bushmanland Arid Grassland and NKb 4 Bushmanland Sandy Grassland of the Nama-Karoo Biome.

Most of the area of Namaqualand (including Hardeveld, Sandveld and Knersvlakte) was mapped using a supervised-classification approach in interpretation of satellite imagery. Boundaries were improved by ground-truthing in many key regions of Namaqualand. In some of the high-altitude regions of Namaqualand the vegetation types (SKn 6 Kamiesberg Mountains Shrubland, FRg 1 Namaqualand Granite Renosterveld and FFg 1 Kamiesberg Granite Fynbos) we applied a combination of altitude and aspect in modelling the potential occurrence of the units. The vegetation types in the Little Karoo were either based on existing available mapping sources (such as STEP) or we used land types and additional field evidence. Quartz patches of the Little Karoo were mapped using expert field data. SKv 2 Swartruggens Quartzite Karoo was mapped using a combination of quartzite geology and low altitudes.

The extent of the gwarrieveld units (SKv 9 Western Gwarrieveld, SKv 12 Willowmore Gwarrieveld and NKl 3 Lower Karoo Gwarrieveld) in principle followed the STEP mapping coverage.

Fynbos Biome

Initial attempts to use the 1998 Landsat images proved unsuccessful, primarily because veld age was an overriding signature in the images. In addition, it was not clear whether the strong north-south slope dichotomy reflected true vegetation type differences or merely different insolation signatures. However, it was apparent that many of the patterns seemed to reflect geology, and therefore the imaging approach was largely discarded. One major unit carried over from the Landsat images, however, was the dichotomy between Olifants River Sandstone Fynbos and Cederberg Sandstone Fynbos, which differ markedly in the images, separating at the scarp water catchment boundary. It also influenced, together with floristic and structural data for the Langeberg and Swartberg, the separation of the east-west fold mountains into units limited to north-facing and south-facing aspects respectively, rather than regarding each range as a single entity. An electronic version of Moll & Bossi (1984) at 1:250 000 scale, used by Low & Rebelo (1996) was considered too coarse for the delineation, as were Cowling's Broad Habitat Units (Cowling et al. 1999). Consequently the 1:250 000 electronic South African Geology Series maps were used as the baseline for vegetation boundary determination, with geology as the basis. Alluvial bottomlands (mapped as azonal units), shale bands and silcrete and ferricrete patches were captured in detail.

Initially all fynbos (excluding renosterveld and strandveld) units were set to the geological boundaries, at about 250 m resolution. For the many places where recordings existed, the Protea Atlas Project database (which also lists the dominant species, in addition to proteas and importantly also has confirmation of absence of Proteaceae in 'null' plots) was used to help determine the boundaries between Fynbos vegetation and Karoo, and Thicket and Renosterveld vegetation. Vegetation boundaries were checked by ground-truthing the easily accessible regions, and additional mapping of occurrence of proteas was conducted in some of the more novel units.

In some areas (e.g. Robertson Karoo), the vegetation types were delimited by the dominant aspect, rather than separated into northern slopes (supporting predominantly Karoo) and southern slopes (supporting predominantly renosterveld). STEP 'mosaic' units were evaluated and were either used as the basis of a new vegetation type (where phytosociological or Protea Atlas (Rebelo 1991) data supported this), or else subsumed into an appropriate vegetation type (where the mosaic elements were incorporated into the vegetation descriptions, where data existed). Vegetation units with features of both renosterveld and fynbos, were classified as fynbos if the cover of restios exceeded 5–10%, or if Proteaceae (excluding *Leucadendron salignum*) were dominant within the units.

Elevation was used for mapping some units, for example, FFs 30 Western Altimontane Sandstone Fynbos, FFs 31 Swartberg Altimontane Sandstone Fynbos, FFq 2 Swartruggens Quartzite Fynbos and FRs 5 Central Mountain Shale Renosterveld.

Forests

The mapping of forest patches was the least problematic of all vegetation units involved because of the specific structure of forests easily recognisable in the field, on aerial photographs, on satellite images (provided that proper ground-truthing is involved) and in most cases on cartographic products such as physical (topographic) maps at 1:50 000 (and less). Another important element allowing for precise mapping of forests was the available map of forest patches produced by DWAF (Anonymous 1987). This source also known as the Forest

Biome Project Map or simply 'DWAF Map' was available in a GIS format as well. It served as the mapping substrate for the National Forest Classification (Von Maltitz et al. 2003), which yielded 24 Forest Types of floristic-biogeographical character, of which four azonal types were considered stand-alone and the rest were summarised into seven Forest Groups. This classification was based in principle on floristic data such as plots, with (semi)quantitative data on (mainly) woody species. Details of the data collection, collation, elaboration and interpretation leading to the classification scheme were summarised by Mucina & Geldenhuys (2002). Because of unduly great detail for our mapping purposes, the original forest classification (Von Maltitz et al. 2003) was simplified by recognising these seven Forest Groups as well as the original four azonal Forest Types as vegetation units. Furthermore, we have added and mapped one vegetation type that was not part of the National Forest Classification—the Ironwood Dry Forest. The original azonal forest type called 'Licuati Sand Forest' was lumped with Nwambyia Sand Forest (also not part of the National Forest Classification) into a vegetation unit called 'Sand Forest'. Details of the cross-walk between the National Forest Classification of 2003 and the current composition of the vegetation unit on our Map are presented in Table 12.1 in Chapter 12.

The obvious errors of the so-called DWAF Map, especially in the Western Cape, KwaZulu-Natal, Swaziland and northern provinces of South Africa, were corrected using other mapping sources. The forests of KwaZulu-Natal have been re-mapped by FOR-SEA project (Adie & Goodman 2000) and the forests of Mpumalanga by Lötter et al. (2002). The Sand Forest of Maputaland was mapped using coverage based on satellite imagery by Smith (2001). The new data for both provinces available in a GIS format then replaced the original coverage depicted by the DWAF Map (Anonymous 1987). The forest patches of Swaziland were provided by L. Dobson as part of the Swaziland vegetation map (see also Loffler & Loffler 2005). The coverage of the milkwood forests of the Overberg (Western Cape) was provided by D.I.W. Euston-Brown (unpublished data) and that of the Still Bay region (Western Cape) was digitised from a map published by Rebelo et al. (1991). The forest patches on Table Mountain were mapped from a map published by McKenzie et al. (1977). As source of the coverage of the Ironwood Dry Forest (*Androstachys johnsonii*), the Nwambyia Sand Forest as well as some riparian forests along the Limpopo River and its tributaries in the northern Kruger National Park, we used the map by Van Rooyen et al. (1981), digitised by A. Grobler (then Department of Botany, University of Pretoria). The extent of the mangrove forests in the Kosi Bay area was adjusted by digitising the map published by Ward et al. (1986). Additional patches of forest (not depicted by the DWAF Map) were digitised from topographic maps on the basis of information provided by G.P. von Maltitz (Magaliesberg area), L. Mucina (eastern Free State, tallus forests of the Hottentots Holland Mountains and Limietberge), M.C. Lötter (eastern and southern Mpumalanga) and B. McKenzie (Langeberg, Riviersonderend and Outeniqua Mountains).

For the final cartographic presentation on the Wall Map (Mucina et al. 2005) as well as in the Vegetation Atlas (Chapter 18) and correspondingly on the electronic form on CD, the forest patches smaller that 5 ha have been disregarded.

Indian Ocean Coastal Belt

The extent of the IOCB was defined within the borders of the KwaZulu-Natal Province by the extent of the BRG 1 Coastal Belt as mapped by Camp (1999a) for purposes of planning agricultural activities in the province. He distinguished five units within his BRG 1, which we found too detailed to be interpreted unambiguously in terms of our vegetation units. We used floristic data and climate (mainly precipitation and mean annual temperature) to distinguish Maputaland from the rest of the KwaZulu-Natal coast (defined as a composite of the other four Camp subunits within his BRG 1). The borders of the Maputaland Coastal Belt were subject to adjustment based on occurrence of tropical floristic element sand vegetation complexes along the Mtunzini-Mandini coastal segment (as far south as Zinkwazi River mouth) by C.R. Scott-Shaw (unpublished data). The final appearance of the latter unit was further modified by extraction of the azonal units. Embedded within the Maputaland Coastal Belt, the Maputaland Wooded Grassland has been defined on the basis of an unpublished mapping source derived from satellite imagery by Smith (2001). Where the latter source mapped timber plantations, the extent of the former (destroyed) wooded grasslands was reconstructed by C.R. Scott-Shaw using topographic data.

The sandstone-dominated coastal regions of the Ugu District in KwaZulu-Natal and the Pondoland Wild Coast with its sandstone-dominated coastal sourvelds form a natural landscape and vegetation unit, which was already distinguished, also in extent, by Acocks (1953). This vegetation unit strictly follows the extent of the sandstone geology except for the forest and valley bushveld patches mapped as different vegetation units.

The extension of the IOCB along the Transkei coast follows D.B. Hoare & A.R. Palmer (unpublished data), whose approach encompassed multivariate analysis of the vegetation-environment relationships to create a system of land classes to be reclassified later using satellite imagery accompanied by subsequent ground-truthing.

The final appearance of all IOCB vegetation units on the Map (see Mucina et al. 2005) was also influenced by definition of the extant coastal forest patches as well as coastal and inland azonal vegetation units.

Azonal Vegetation

Scanned 1:50 000 maps were used extensively for mapping AZi 5 Bushmanland Vloere, AZi 4 Southern Kalahari Salt Pans and some other pans, wetlands and alluvia. Wetlands mapped for the National Land Cover were used selectively and their extent was also improved through consulting topographic maps. Some alluvia were modified from those mapped for land types (the width of many being reduced, for example, in AZa 5 Highveld Alluvial Vegetation). Some alluvia, estuaries and beaches (seashore vegetation units) were mapped by referring to Landsat 5 images.

A minimum size of 5 ha was generally used for inclusion in the final map, with a general minimum size of 10 ha for selection of many pans. Certain patches smaller than 5 ha such as AZf 2 Cape Vernal Pools were specifically included because they are particularly unique in terms of species.

6.3 Construction of Bioregion and Biome Maps

In preparing the biome and bioregion maps, the bioregions were dissolved to join adjacent polygons in the same bioregion, excluding forest, azonal and infrastructure units. The holes left by excluding forests etc. in the biome and bioregion coverages were filled using the value assigned based on Euclidean Distance in a 200 m grid. Biome polygons smaller than 2 000 ha and bioregion polygons smaller than 600 ha were excluded from the resulting coverage, except for selected smaller polygons such as coastal strips and islands that could not confidently be assigned to another biome. Forests larger than 2 000 ha were then added to the resulting biome map. The process is described in Figure 2.3.

Figure 2.3 The technical steps in mapping the biomes using an example section of the Map. (a) Depicting the vegetation types in the example area. (b) Assigning of vegetation types to biome units and dissolving boundaries between vegetation types within the same biome. (c) Removing Forest, Azonal vegetation types, and polygons that were less than 2 000 ha from any other vegetation types. (d) Converting the resulting polygons to a 200 m grid (raster). (e) Applying the EUCALLOCATION method (ESRI 2006) to fill in the gaps created in (c). (f) Converting the grid back to polygon (vector) and merging with the coverage which had the gaps—see (c). (g) Dissolving boundaries between newly formed slivers of vegetation types within the same biome to obtain smooth boundaries (see magnified section). (h) Restoring Forest polygons greater than 2 000 ha in area.

6.4 Final Production of the Vegetation Maps

Final colours for each vegetation unit were selected attempting to maintain a suite of similar colours within each biome, while trying to ensure good visual distinction between adjacent polygons of different vegetation types at the same time. Colour distinction sometimes required using a very different colour. Additional difficulty arises from the difference between the colour seen on the computer screen and the colour on the printed map, requiring manual adjustment of hue, saturation and value to arrive at suitable printed colours when using the CMYK standard colour model used in offset printing.

The vegetation under the reservoir of dams was reconstructed from evidence of surrounding vegetation and, in certain cases, the topography below the water (by reference to maps that predated the construction of the dam). This coverage can only be viewed on the accompanying CD.

The legend was prepared in a novel way by creating a shapefile with blocks in rows and columns. This enabled colour precision for the legend boxes as well as spacing of headings and subheadings in the legend. Each vegetation type was assigned a column and row value. A table with box identification, row, column and names for biome, group and vegetation type was linked to the polygon (legend box) shapefile. Labels were positioned using these boxes. As the Wall Map was printed in projected units at a scale of 1:1 000 000, the box sizes and spacing were easily calculated based on map units.

The Wall Map was printed by USS Graphics, Cape Town, South Africa, on SAPPI 170 g Magna Gloss paper using 600 dpi PDF files, transferred to offset lithographic plates using computer-to-plate technology. The colour sequence for printing was red (magenta), yellow, black, blue (cyan) and not the normal sequence of black, blue, red, yellow. Colours were converted in ArcGIS to CMYK before PDF files were created. The initial RGB colours did not translate well to CMYK at the printing office, and therefore CMYK colours had to be manually defined in ArcMap. The Wall Map formed the basis for printing the atlas in the current work.

7. Vegetation as a Verbal Model

The verbal model, consisting of descriptive text, is not limited by the constraints of scale inherent in the printed spatial model of the Map. The description has a scale-independent flexibility that can easily allow for inclusion of information on fine-scaled mozaics and can potentially include any nuances that would be impossible to depict on the Map.

Our descriptions of vegetation units are sometimes flanked with short descriptions of groups to which they belong (see for instance Chapter 3 on Fynbos). Each biome is always preceded by an introductory text featuring important physico-geographical, ecological, biogeographical, evolutionary, socio-economical etc. background information on the vegetation units being described (see Chapter 1).

The description of a vegetation unit consists of the following elements:

7.1 Name of Vegetation Unit

Each vegetation unit carries a unique informative name, consisting of four (or three) elements indicating (1) its code, (2) geographic address, (3) major habitat (often geological) characteristic, and (4) vegetation-structural character. The code provides the context of the unit and is useful for identification of the unit on the Map (see Mucina et al. 2005). Take, for example, FRs 9 Swartland Shale Renosterveld. This code consists of four parts, indicating the classification of the vegetation unit into a biome (F: Fynbos Biome), bioregion or major group of units (R: renosterveld), and minor group units (s: shale), followed by the numerical code linked to the minor group. In the case of forest, for instance, we recognise two groups (zonal and azonal), hence a code for the scarp forests would read: FOz 5 Scarp Forest (FO: Forest Biome, z: zonal group, 5: unit no. 5 within the zonal group).

Most of the names of our vegetation units consist of three elements, but some are composed of only two words. These are either well-established geographical (and/or ecological) concepts such as 'Ngongoni Veld' and 'Tanqua Karoo', or shorter two-word names that can reflect all information elements necessary. For example, the name 'Lesotho Mires' clearly indicates the geographic address, while the term 'mire' implies major ecological and vegetation-structural characteristics of the unit.

The way of naming the vegetation units was largely motivated by the paper by Cowling & Heijnis (2001), where they used it for naming their Broad Habitat Units (to a large extent spatially and partly also conceptually similar to our vegetation units). It seems, however, that this terminology has a precursor in the work of Campbell (1985) where it was applied in naming fynbos structural units. We have especially borrowed the novel term 'vygieveld' from Cowling & Heijnis (2001), while the term 'gwarrieveld' comes from Vlok et al. (2003).

We have refrained from using the South African-developed vegetation-structural terminology by Edwards (1983) because it is more suited for vegetation units at the habitat scale.

7.2 Spatial Co-incidence with Other Vegetation Maps

The aim of the paragraph on 'synonymy' is to assist the reader in matching the new concepts of vegetation units presented in this work with the older, previously widely used mapped or unmapped vegetation-classification concepts. It simply indicates the level of spatial correspondence with our vegetation units. Acocks (1953, 1988) and Low & Rebelo (1996) cover the same area as our Map and therefore are automatically referred to within this category of spatial overlap. Here we list those Acocks 'veld types' or Low & Rebelo 'vegetation types' that make up an overlap of at least 50%. We used the same spatial-overlap principle to list the units of Moll & Bossi (1984), Cowling et al. (1999) and Cowling & Heijnis (2001) for the Fynbos Biome (and partly also Succulent Karoo), of Vlok & Euston-Brown (2002) and Vlok et al. (2003) for the Albany Thicket Biome (and some units of the surrounding biomes), and finally the zonal units of Edwards (1967) and Camp (1999a, b) encountered in KwaZulu-Natal.

Especially the synonymy of forest, azonal and subantractic units also contains entries of communities at the habitat level derived by various approaches, including the floristic-sociological, numerical, etc. (see for example the synonymy of AZd 3 Cape Seashore Vegetation).

7.3 Distribution

The section on Distribution gives the major distribution of the vegetation unit. It is introduced by the name of the province (in most cases), followed by a reasonably accurate description of locality or localities (but not an account of every polygon in highly fragmented vegetation types) sufficient for the geographically informed reader to get a good idea of just where the type occurs. We used the names and spelling of towns in South Africa as approved by the South African Geographical Names Council (SAGNC) as gazetted before 1 January 2005.

As a rule the indication of the altitudinal range of most of the area occupied by the unit concludes this particular section.

7.4 Vegetation and Landscape Features

This includes the appearance of the landscapes (including terrain type) and the main structural features (dominant growth forms, layering, canopy openness, patchiness, vegetation mosaics etc.) of major plant communities dominant in these landscapes. Particular attention is paid to these features in the case of units with a distinct mosaic of habitats (such as coastal units, alluvial units etc.).

7.5 Geology and Soils (Geology, Soils and Hydrology)

The geological and pedological section contains information on major rocks, both petrographically (rock types) and stratigraphically (age of geologic substrate). Information from GIS overlays between our vegetation coverage and geology was used and interpreted with care (especially with regard to the different scales of sources). Soils are very broadly described (usually using textural characteristics), but where we have sufficient knowledge (based on local pedological studies), we also list major soil types. Information on land types is given for most vegetation types. In many azonal units we use a slightly different heading (Geology, Soils and Hydrology) and we include a description of hydrology (permanent or intermittent flow of streams/rivers, tidal dynamics) and some other factors underlying the azonality of the unit (e.g. salt content). We use the terminology of the South African Committee for Stratigraphy (1980) for geology, the Soil Classification Working Group (1991) for soils and ENPAT for land types.

7.6 Climate

We provide a brief overview statement of the main features of the relevant climate diagram (see Figure 2.2), often including important geographical ranges of parameters (especially MAP and frost). In some cases, one or two actual climate stations in the unit are used to provide mean monthly maximum and minimum temperatures. Any special climatic factors that are not reflected in the climate diagram, for example extreme temperatures, wind or fog, are given.

7.7 Structure of the Species Lists

The species lists are one of the core elements of the description of a vegetation unit. They are primarily aimed at providing information on floristic composition of the plant communities forming the vegetation unit. The categorisation of the species into Important, Biogeographically Important and Endemic adds value to the species lists in terms of biogeography and conservation.

7.7.1 Taxonomic Nomenclature

The names of taxa occurring in southern Africa cited in the descriptions, and throughout the book for that matter, basically follow the recent checklist of the flora (Germishuizen & Meyer 2003) and the PRECIS system. We also use those species names that have been published after appearance of the checklist cited above as well as some other taxonomic concepts that have not yet found acceptance in PRECIS. A number of

Table 2.1 System of growth forms used in the descriptions of the vegetation units.

Category/ Subcategory	Main Traits	Example	Note
Tree	secondary (woody) thickening of tissues; single-stemmed		
Small Tree	lower than 15 m in forests; lower than 10 m in savanna	*Acacia karroo*	excluding Succulent Trees
Tall Tree	taller than 15 m in forests; lower than 10 m in savanna	*Ekebergia capensis*	excluding Succulent Trees
Emergent Tree	taller than 25 m (overtopping canopy)	*Afrocarpus falcatus*	excluding Succulent Trees; only in tall-grown forests
Succulent Tree	succulent stems and branches; taller than 6 m	*Euphorbia triangularis*	
Tree Fern	fern of tree stature; always less than 5 m tall	*Cyathea capensis*	special category of Small Tree
Shrub	secondary (woody) thickening of tissues (at least at base); multistemmed as a rule; when single-stemmed, then branching from base		excluding all epiphytic forms
Low Shrub	lower than 2 m; no parasitic or semiparasitic feeding; non-succulent	*Pentzia incana*	excluding Soft Shrubs, succulent and (semi)parasitic shrubs
Tall Shrub	taller than 2 m; no parasitic or semiparasitic feeding; non-succulent	*Gymnosporia buxifolia*	excluding Soft Shrubs, succulent and (semi)parasitic shrubs
Soft Shrub	secondary (woody) thickening of tissues along main stem; herbaceous tips of branches	*Plectranthus fruticosus*	a transition category between Herbs and Shrubs, typical of some warm-temperate and subtropical forests
Geoxylic Suffrutex	large underground woody 'rhizome'; usually imitating Low Shrub form above ground	*Dichapetalum cymosum*	excluding Shrubs with smaller lignotubers
Succulent Shrub	succulent leaves and/or stems; any height	*Ruschia caroli*	very common among Aizoaceae; including Stem-succulent Shrub, Stem- & Leaf-succulent Shrub and Leaf-succulent Shrub (recognised only in Chapter 6)
Semiparasitic Shrub	green, but parasitising on xylem of other plants; any height	*Thesium hystrix*	growth form limited to few families (mainly Santalaceae)
Semicarnivorous Shrub	feeding on animal waste resembling carnivory	*Roridula gorgonias*	only 2 species of genus *Roridula*
Climber	using other plants as support for climbing or scrambling		also including scrambler and strangler forms; excluding all epiphytic forms
Woody Climber	secondary (woody) thickening of tissues (at least at base)	*Dalbergia armata*	excluding Succulent Climbers
Woody Succulent Climber	secondary (woody) thickening of tissues (at least at base); succulent leaves and/or stems	*Sarcostemma viminale*	rare growth form
Herbaceous Climber	no secondary (woody) thickening of tissues (at least at base)	*Kedrostis nana*	excluding trailing (creeping) or prostrate herbs
Herbaceous Succulent Climber	no secondary (woody) thickening of tissues (at least at base); succulent leaves and/or stems	*Ceropegia*	rare growth form
Graminoid Climber	climbing and scrambling graminoids	*Prosphytochloa prehensilis*	very rare growth form
Herb	no secondary (woody) thickening of tissues; usually primary root system		excluding all epiphytic forms and Soft Shrubs
Megaherb	herbs taller than 3 m	*Strelitzia nicolai*	'bananoid' herbs: tall and with megaphylls
Herb	including annual, pauciennial or perennial herbs		excluding all those showing typical aquatic adaptations, geophytes, succulent, parasitic and carnivorous forms as well as annual plants
Geophytic Herb	presence of herbaceous underground storage organs such as rhizomes, corms, tubers and bulbs	*Lachenalia carnosa*	excluding all aquatic, succulent, parasitic and carnivorous forms
Succulent Herb	succulent leaves and/or stems	*Cleretum papulosum*	including geophytic forms
Parasitic Herb	lack of assimilation apparatus; fully parasitic feeding	*Hyobanche sanguinea*	
Carnivorous Herb	using additional animal (insect) source for some nutrients	*Drosera capensis*	including all aquatic forms (*Utricularia*)
Aquatic Herb	morphological adaptations to spend at least part of life cycle in under-water environment (aerated tissues, reduction of roots etc.)	*Lemna minor*	using water column or water surface as floating medium; including geophytic forms; including subaquatic mosses
Graminoid	'grassy' appearance (long, narrow, mostly tufted leaves); secondary root system		including all Poaceae, Cyperaceae, Restionaceae, Xyridaceae; excluding Juncaginaceae, Thurniaceae and Eriocaulaceae
Graminoid	lower than 2 m	*Aristida congesta*	excluding climbing forms
Mega-graminoid	taller than 2 m	*Phragmites australis*	tall reeds; also including geophytic forms (*Prionium*)
Bamboo	secondary (woody) thickening of tissues (at least at base)	*Thamnocalamus tessellatus*	woody graminoids
Epiphyte	both woody and non-woody; using other plants as substrate, but necessarily as source of nutrients; not rooting in soil		
Epiphytic Herb	no secondary (woody) thickening of tissues		excluding all succulent and (semi)parasitic forms
Epiphytic Succulent Herb	no secondary (woody) thickening of tissues; succulent leaves and/or stems	*Mystacidium*	usually epiphytic orchids; including geophytic forms
Epiphytic Shrub	secondary (woody) thickening of tissues (at least at base)	*Dermatobotrys saundersii*	excluding all succulent and (semi)parasitic forms; very rare category
Epiphytic Parasitic Herb	no secondary (woody) thickening of tissues	*Cassytha ciliolata*	
Epiphytic Semiparasitic Shrub	secondary (woody) thickening of tissues (at least at base)	*Viscum capense*	mistletoes
Other			
Moss	taxonomic category (Bryopsida)	*Bucklandiella valdon-smithii*	
Liverwort	taxonomic category (Marchantiopsida and Anthocerotopsida)	*Symphyogyna marionensis*	
Lichen	taxonomic category including lichenised fungi	*Cladonia pyxidata*	broadly defined category including crustose, fruticose, gelatinous and other types of lichens
Macroalga	taxonomic category (some representatives of Phaeophyta and Charophyta)	*Ecklonia maxima*	

new taxa pending descriptions, but often already in informal use by the botanical community, have also been listed, usually accompanied by the citation of a voucher specimen.

7.7.2 Growth Forms

All species in the lists are classified into growth forms using a system (Table 2.1) developed within the Ecological Flora of Southern Africa Database (L. Mucina, unpublished data). This system is a pragmatic tool based on several major features of the structural and functional life history of plants such as longevity, architecture, height, woodiness, succulence, parasitism, carnivory, epiphytism and the like.

In some chapters similar basic growth forms have been lumped (e.g. 'Small Trees & Tall Shrubs' in the vegetation units of the Indian Ocean Coastal Belt) or split (e.g. 'Stem-succulent Shrubs' and Leaf-succulent Shrubs' in the Desert chapter). This was done because distinction of the growth forms concerned might not always be clear-cut or both growth forms could be equally important in determining the structure of the vegetation.

7.7.3 Important Taxa

The category of Important Taxa includes those species (and lower taxa) that have a high abundance, a frequent occurrence (not being particularly abundant) or are prominent in the landscape of the unit.

The taxa are arranged according to growth forms, the order depending on the overall character of the vegetation concerned: in forests this sequence starts with Tall Trees and ends with growth forms in the undergrowth (Herbs, Graminoids); in succulent shrubland its starts with Succulent Shrubs etc. Mosses and Lichens are always placed at the end. Dominant taxa are given first in the particular lists within each growth form category—these are the species that are dominant (biomass) in the local communities or that are prominent, e.g. conspicuous quiver trees (*Aloe dichotoma*) scattered in a Succulent Karoo shrubland.

This list forms a basic floristic profile of the vegetation unit.

7.7.4 Endemic Taxa

The concept of endemism is determined by the extent of the vegetation unit. This means that a plant taxon is listed as endemic in the description when it occurs exclusively within the unit concerned. We have relaxed the strict interpretation of the 'unit-based endemism' in the Fynbos Biome, where an endemic plant species may have less than 10% of localities outside the vegetation unit in question. In some other biomes we accepted a relatively narrow interpretation of the notion of 'near-endemic' where the clear concentration of the given taxon is within the vegetation unit and a few outliers occur nearby in one or more adjacent units. We are well aware of the fact that the current endemic status of many plants would change in future as our knowledge about distribution of the species becomes more detailed and the extent of our vegetation units becomes more precisely defined. As our vegetation units are naturally defined entities, we consider the use of the term 'endemism' in this sense more appropriate than using this term in a political context (defined by the boundaries of countries or tourist regions).

7.7.5 Biogeographically Important Taxa

Biogeographically Important Taxa (BIT) are those that do not qualify as endemic (see Section 7.7.4), and may qualify as Important Taxa (as defined in Section 7.7.3), but carry an additional important biogeographical message: they are limited to a small group of vegetation units (hence qualify as regionally endemic), they have been listed as regionally endemic in an established Centre of Endemism, they occur at the limits of their (large) distribution area and they show a very disjunct distribution pattern. We decided to single out these taxa to sometimes strengthen the case for delimitation of vegetation units and to indicate their value in raising interesting academic questions and conservation concerns.

Within the Fynbos Biome, with one of the highest concentrations of regional and local endemics, we have refrained from using the category BIT in most of the vegetation units except for those that fall within the CEs with their core in neighbouring biomes (for instance Nieuwoudtville-Roggeveld Dolerite Renosterveld is considered a part of the Roggeveld-Hantam CE, Namaqualand Sand Fynbos is part of the Namaqualand CE). We also use the BIT category for the strandveld units, and here we recognise two (new) putative CEs, namely the West Coast CE and South Coast CE.

Many of the BIT were recruited from the endemics of the putative phytochoria defined as Centres of Endemism (CE) by Van Wyk & Smith (2001). The spatial delimitation of their CEs is largely defined in approximate terms—the boundaries have been painted with a very thick brush (with a notable exception of the Pondoland CE). The (relatively) crisp spatial definition of our vegetation units, however, allows for re-definition of the boundaries of most of the Van Wyk & Smith's (2001) CEs. This revision is in progress (L. Mucina et al., in preparation) and here, when referring to Van Wyk & Smith's concept, we use them already in revised form. We also added some new concepts resulting from our preliminary studies of local endemism based on the list of endemics of our vegetation units.

Some regions of southern Africa house a number of CEs of Van Wyk & Smith (2001). For example, the northern provinces of South Africa (including Gauteng, Limpopo and Mpumalanga, as well as neighbouring Swaziland and parts of Mozambique and northern KwaZulu-Natal) house five of these CEs—nos. 3.1, 6, 7, 8 and 9. We have observed that some species occur in a number of these CEs and are invariably linked to vegetation units that can be summarised under the informal category called 'sourveld' (some of them straddling the borders of the Savanna and Grassland Biomes). This observation led to the definition of a putative endemic category 'Northern Sourveld Endemic'. Examples are *Encephalartos eugene-maraisii* and *Faurea galpinii*; see also a long list of BIT in unit GM 18 Lydenburg Montane Grassland, etc. We have also been able to identify (see Van Rooyen et al. 2001) a group of endemics for the Kalahari. These taxa are limited to deep sands of the Kalahari Basin and reach South African territory in vegetation units of the groups SVk and SVkd exclusively.

Further we have introduced a number of other informal entities, based on groups of vegetation units as delimited in this book, namely:

(a) Central Bushveld endemics (shared by a number of SVcb units), e.g. *Mosdenia leptostachys*.

(b) Kalahari endemics (shared by a number of SVk and SVkd units), e.g. *Panicum kalaharense, Neuradopsis bechuanensis*.

(c) Camdebo endemics, e.g. *Duvalia modesta*.

(d) Capensis elements (species of typical Cape clades; Linder (2003), occurring in other than Fynbos units), e.g. *Muraltia, Raspalia, Watsonia* and many others in Pondoland.

(e) Northern KwaZulu-Natal endemics (sharing several Gs or SVs units of this region), e.g. *Cissus cussonioides*.

Important long-distance biogeographical links such as a link to mountains of Zimbabwe (e.g. *Eriosema buchananii, Nemesia zimbabwensis*) were useful in classifying some species as carrying an important biogeographical message.

Widely distributed species occurring at the limits of their distribution, such as those reaching southern Africa from the northern hemisphere (*Lycium shawii*), were also noted in BIT category in places.

7.8 Conservation

This section collates important information available on the conservation issues related to the vegetation unit. Here we mention the conservation status (using the scale of categories of Critically endangered, Endangered, Vulnerable, Least threatened after Golding 2002), conservation target and percentage of the surface of the unit currently under protection (listing also the main statutory and private conservation areas). Threats to the unit such as the occurrence of major (mostly woody) alien species and the erosion status (from the Predicted Soil Loss data of the national Department of Agriculture) are also given. The five categories of levels of erosion (soil loss) are as follows: very high (> 60 t/ha/a — tons per hectare per annum), high (26–60 t/ha/a), moderate (13–25 t/ha/a), low (6–12 t/ha/a) and very low (0–5 t/ha/a).

7.9 Remarks

The sections on Remarks are devoted to (1) discussion of any important issue mentioned in the description in more detail, (2) interesting biogeographical phenomena and oddities, (3) problems of delimitation, (4) level of our knowledge about the unit, and any other aspect of particular interest pertaining to the unit.

7.10 References

This section lists (in alphabetical and then chronological order) all references that feature vegetation patterns pertinent to the vegetation unit concerned. We also added some references otherwise useful to elucidate ecology and distribution of the unit or some of its important species. We also attempted to list many 'grey-literature' sources, such as major unpublished reports, university theses and projects. Where no published information was available, we cited the source(s) of unpublished data.

8. Concluding Remarks

Although vegetation surveys and mapping are not the most fashionable topics of contemporary plant ecology (especially outside Europe), their power in providing quick and reliable simplified models of vegetation patterns that assists in important decisions on nature management and on other land uses, is indisputable. The need for understanding (using, protecting, managing) vegetation patterns encourages and will continue to fuel the development of new tools and procedures of vegetation survey. Progress in vegetation mapping will continue to focus more closely on the acquisition and interpretation of remote-sensed data and stocking and utilisation of databanks to assist in the spatial data analysis. We hope that extensive use of our Map (and the accompanying Book) will further enhance especially detailed vegetation surveys—an invaluable source of data for any mapping project, especially when planned and co-ordinated for incorporation in a national scale network. We believe, as we have already alluded to in the Introduction chapter, the VEGMAP is a process; we shall be closely monitoring new methodical developments in vegetation survey and mapping for new editions of both our Map and the Book.

9. Credits

The ideas presented in this chapter are a result of co-operation between members of the core VEGMAP team (M.C. Rutherford, L. Mucina, L.W. Powrie) and by the regional mapping teams and other contributors at large. L. Mucina wrote Sections 1, 2, 3, 4, 7, 8 and 9 and compiled the list of References (Section 10). All these sections were edited (both conceptually and technically) by M.C. Rutherford and L.W. Powrie, whose contribution was vital both to the contents and presentation of all these sections. M.C. Rutherford and L.W. Powrie (assisted by L. Mucina) compiled the text of the Sections 5 and 6. The complex subsection 6.2.2 (featuring the specific examples of mapping various biomes) was written by M.C. Rutherford (assisted by L.W. Powrie) for Albany Thicket, Grassland and Savanna, Azonal vegetation, Fynbos, and most of the arid biomes. In this subsection, L. Mucina contributed text on Forests, Indian Ocean Coastal Belt and Nama-Karoo (part of the arid biomes) as well as on Azonal vegetation.

10. References

Acocks, J.P.H. 1953. Veld types of South Africa. *Mem. Bot. Surv. S. Afr.* No. 28: 1–192.

Acocks, J.P.H. 1975. Veld types of South Africa, edn 2. *Mem. Bot. Surv. S. Afr.* No. 40: 1–128.

Acocks, J.P.H. 1988. Veld types of South Africa, edn 3. *Mem. Bot. Surv. S. Afr.* No. 57: 1–146.

Adie, H. & Goodman, P.S. 2000. Forests. In: Goodman, P.S. (ed.), *Determining the conservation value of land in KwaZulu-Natal*, pp. 30–42. Report, Biodiversity Division, KwaZulu-Natal Nature Conservation Service, Pietermaritzburg.

Anonymous 1987. *Map of South African indigenous evergreen forest.* FRD, Pretoria. (two map sheets)

Austin, M.P. & Smith, T.M. 1989. A new model for the continuum concept. *Vegetatio* 83: 35–47.

Camp, K. 1999a. *The Bioresource Groups of KwaZulu-Natal. Coast & Coast Hinterland.* Cedara Report No. N/A/99/12, KwaZulu-Natal Dept of Agriculture, Cedara.

Camp, K.G.T. (ed.) 1999b. *Bioresource Groups of KwaZulu-Natal*. Natural Resources Section Technology Development and Training, KwaZulu-Natal Dept of Agriculture, Cedara. (electronic shape file and printed poster map)

Camp, K. 2001. *The classification of the units of the bioresource programme of KwaZulu-Natal (A description of the mapping process).* Report, KwaZulu-Natal Dept of Agriculture and Environmental Affairs, Cedara.

Campbell, B.M. 1985. A classification of the mountain vegetation of the Fynbos Biome. *Mem. Bot. Surv. S. Afr*. No. 50: 1–121.

Cowling, R.M. & Heijnis, C.E. 2001. The identification of Broad Habitat Units as biodiversity entities for systematic conservation planning in the Cape Floristic Region. *S. Afr. J. Bot.* 67: 15–38.

Cowling, R.M., Pressey, R.L., Lombard, A.T., Heijnis, C.E., Richardson, D.M. & Cole, N. 1999. *Framework for a conservation plan for the Cape Floristic Region.* IPC Report 9902, Institute for Plant Conservation, Univ. of Cape Town.

Driver, A., Maze, K., Rouget, M., Lombard, A.T., Nel, J., Turpie, J.K., Cowling, R.M., Desmet, P., Goodman, P., Harris, J., Jonas, Z., Reyers, B., Sink, K. & Strauss, T. 2005. National Spatial Biodiversity Assessment 2004: priorities for biodiversity conservation in South Africa. *Strelitzia* 17. South African National Biodiversity Institute, Pretoria.

Edwards, D. 1967. *A plant ecological survey of the Tugela River basin.* Natal Town and Regional Planning Commission, Pietermaritzburg.

Edwards, D. 1983. A broad-scale structural classification of vegetation for practical purposes. *Bothalia* 14: 705–712.

ESRI. 2006. Online GIS dictionary. http://support.esri.com/index.cfm?fa=knowledgebase.gisDictionary.gateway

Fairbanks, D.H.K., Thompson, M.W., Vink, D.E., Newby, T.S., Van den Berg, H.M. & Everard, D.A. 2000. The South African Land-Cover Database: a synopsis of the landscape. *S. Afr. J. Sci.* 96: 69–82.

Geldenhuys, C.J. & Mucina, L. 2006. Towards a new forest classification for South

Africa. In: Ghazanfar, S. & Beentje, H.J. (eds), *Taxonomy and ecology of African plants, their conservation and sustainable use*, pp. 111–129. Royal Botanic Gardens, Kew.

Germishuizen, G. & Meyer, N.L. (eds) 2003. Plants of southern Africa: an annotated checklist. *Strelitzia* 14. National Botanical Institute, Pretoria.

Gertenbach, W.P.D. 1983. Landscapes of the Kruger National Park. *Koedoe* 26: 9–121.

Golding, J.S. (ed.) 2002. *Southern African plant red data lists*. *SABONET Rep*. No. 14: 1–237.

Härdtle, W. 1995. On the theoretical concept of the potential natural vegetation and proposals for an up to date modification. *Fol. Geobot. Phytotax*. 30: 263–276.

Hennekens, S.M. & Schaminée, J.H.J. 2001. TURBOVEG, a comprehensive data base management system for vegetation data. *J. Veg. Sci.* 12: 589–591.

Kalkhoven, J.T.R. & Van den Werf, S. 1988. Mapping the potential natural vegetation. In: Küchler, A.W. & Zonneveld, I.S. (eds), *Vegetation mapping*, pp. 375–386. Kluwer, Dordrecht.

Kowarik, I. 1987. Kritische Anmerkungen zum theoretischen Konzept der potentiellen natürlichen Vegetation mit Anregungen zu einer zeitgemäßen Modifikation. *Tuexenia* 7: 53–67.

Linder, H.P. 2003. The radiation of the Cape flora, southern Africa. *Biol. Rev.* 78: 597–638.

Loffler, L. & Loffler, P. 2005. *Swaziland Tree Atlas including selected shrubs and climbers*. SABONET Report No. 35: 1–196.

Lötter, M.C., Emery, A.J. & Williamson, S.D. 2002. Forests. In: Emery, A.J., Lötter, M.C. & Williamson, S.D. (eds), *Determining the conservation value of land in Mpumalanga*, pp. 28–34. Report, Mpumalanga Parks Board, Nelspruit.

Low, A.B. & Rebelo, A.(T.)G. (eds) 1996. *Vegetation of South Africa, Lesotho and Swaziland*. Dept of Environmental Affairs and Tourism, Pretoria.

Lubbinge, J.W. 1998. *'n Fitososiologiese studie van die suidelike Kalahari duineveld.* M.Sc. thesis, Centre for Wildlife Management, Univ. of Pretoria.

Magill, R.E., Russell, G.E., Morris, J.W. & Gonsalves, P. 1983. PRECIS, the Botanical Research Institute herbarium data bank. *Bothalia* 14: 481–495.

McKelly, D., Nel, J.L., Le Maitre, D. & Robyntjies, R. 2000. *Working for Water Programme: Metadata: National Invasive Alien Plant Database: April 1998.* Report No. ENV-S-C 2000-12, CSIR, Pretoria.

McKenzie, B., Moll, E.J. & Campbell, B.M. 1977. A phytosociological study of Orange Kloof, Table Mountain, South Africa. *Vegetatio* 34: 41–53.

Moll, E.J. & Bossi, L. 1984. *Vegetation map of the Fynbos Biome*. Government Printer, Pretoria.

Mucina, L., Bredenkamp, G.J., Hoare, D.B. & McDonald, D.J. 2000. A national vegetation database for South Africa. *S. Afr. J. Sci.* 96: 497, 498.

Mucina, L. & Geldenhuys, C.J. 2002. How to classify South African indigenous forests: approach, methods, problems, perspectives. In: Seydack, A.H.W., Vorster, T., Vermeulen, W.J. & Van der Merwe, I.J. (eds), *Multiple use management of natural forests & woodlands: policy refinements and scientific progress*, pp. 1–9. Dept of Water Affairs and Forestry, Indigenous Forest Management, Pretoria.

Mucina, L., Rutherford, M.C. & Powrie, L.W. (eds) 2005. *Vegetation Map of South Africa, Lesotho and Swaziland*. 1:1 000 000 scale sheet maps. South African National Biodiversity Institute, Pretoria.

Neuhäusl, R. 1963. Vegetationskarte von Böhmen und Mähren. *Ber. Geobot. Inst. ETH Stiftung Rübel* 34: 107–121.

Neuhäusl, R. 1968. Theoretische Konzeption der geobotanischen Kartierung. In: Mikyška, R. et al. (eds), *Geobotanical map of Czechoslovakia. 1. Czech lands*, pp. 145–148. Academia, Praha.

Neuhäusl, R. 1984. Umwelgemässe natürliche Vegetation, ihre Kartierung und Nutzung für den Umweltschutz. *Preslia* 56: 205–212.

O'Callaghan, M. 2000. National gird of vegetation sites: reality check. *S. Afr. J. Sci.* 96: 231–233.

Rebelo, A. 1991. *Protea Atlas Manual: instruction booklet to the Protea Atlas Project.* National Botanical Institute, Kirstenbosch.

Rebelo, A.G., Cowling, R.M., Campbell, B.M. & Meadows, M. 1991. Plant communities of the Riversdale Plain. *S. Afr. J. Bot.* 57: 10–28.

Rutherford, M.C., Powrie, L.W. & Midgley, G.F. 2003. ACKDAT: a digital database of distributions of South African plant species and species assemblages. *S. Afr. J. Bot.* 69: 99–104.

Scholes, R.J. 1979. The vegetation of the Blouberg, north-western Transvaal. B.Sc.(Hons) project, Dept of Botany, Univ. of the Witwatersrand, Johannesburg.

Schulze, R.E. 1997. *South African Atlas of Agrohydrology and Climatology*. Report TT82/96, Water Research Commission, Pretoria.

Smith, R.J. 2001. *Designing an integrated protected area network for Maputaland.* Ph.D. thesis, Durell Institute of Conservation Ecology, Univ. of Kent, Canterbury, UK.

Smits, N.A.C., Bredenkamp, G.J., Mucina, L. & Granger, J.E. 1999. The vegetation of old-fields in Transkei. *S. Afr. J. Bot.* 65: 414–420.

Soil Classification Working Group. 1991. *Soil classification: a taxonomic system for South Africa*. Dept of Agricultural Development, Pretoria.

South African Committee for Stratigraphy (SACS) (compiled by Kent, L.E.) 1980. Stratigraphy of South Africa. Part 1. Lithostratigraphy of the Republic of South Africa, South West Africa/Namibia and the Republics of Bophuthatswana, Transkei and Venda. *Handb. Geol. Surv. S. Afr.* No. 8: 1–690.

Tüxen, R. 1956. Die heutige potentielle natürliche Vegetation als Gegenstand der Vegetationskartierung. *Angew. Pflanzensoziol.* 13: 1–42.

Tüxen, R. 1963. Typen von Vegetationskarten und ihre Erarbeitung. In: Tüxen, R. (ed.), *Bericht über das Internationale Symposium für Vegetationskartierung vom 23.–26. 3. 1959 in Stolzenau/Weser*, pp. 139–154. J. Cramer, Weinheim.

Tüxen, R. 1978. Die heutige potentielle natürliche Vegetation als Gegenstand der Vegetationskartierung. *Ber. Deutsch. Landeskde.* 19: 323–354.

Van Rooyen, N., Bezuidenhout, H. & De Kock, E. 2001. *Flowering plants of the Kalahari dunes.* Ekotrust, Pretoria.

Van Rooyen, N., Theron, G.K. & Grobbelaar, N. 1981. A floristic description and structural analysis of the plant communities of the Punda Milia-Pafuri-Wambiya area in the Kruger National Park, Republic of South Africa. 2. The sandveld communities. *J. S. Afr. Bot.* 47: 405–449.

Van Wyk, A.E. & Smith, G.F. 2001. *Regions of floristic endemism in southern Africa. A review with emphasis on succulents.* Umdaus Press, Pretoria.

Vlok, J.H.J. & Euston-Brown, D.I.W. 2002. *Subtropical Thicket Ecosystem Planning Project (STEP). Biological Survey Report (plants and birds).* Report, Terrestrial Ecology Research Unit, Univ. of Port Elizabeth. www.zoo.upe.ac.za/step

Vlok, J.H.J., Euston-Brown, D.I.W. & Cowling, R.M. 2003. Acocks' Valley Bushveld 50 years on: new perspectives on the delimitation, characterisation and origin of subtropical thicket vegetation. *S. Afr. J. Bot.* 69: 27–51.

Von Maltitz, G., Mucina, L., Geldenhuys, C.J., Lawes, M., Eeley, H., Adie, H., Vink, D., Fleming, G. & Bailey, C. 2003. *Classification system for South African indigenous forests: an objective classification for the Department of Water Affairs and Forestry.* Report ENV-P-C 2003-017, Environmentek, CSIR, Pretoria.

Walter, H. 1964. *Die Vegetation der Erde in öko-physiologischer Betrachtung. Band I: Die tropischen und subtropischen Zonen.* G. Fischer, Jena.

Ward, C.J., Steinke, T.D. & Ward, M.C. 1986. Mangroves of the Kosi System, South Africa: their re-establishment since a mass mortality in 1965/66. *S. Afr. J. Bot.* 52: 501–512.

Biomes and Bioregions of Southern Africa

3

Michael C. Rutherford, Ladislav Mucina and Leslie W. Powrie

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Figure 3.1 Visual collage of biome diversity.

K. Phillips & L.W. Powrie

1. Biomes

1.1 The Biome Concept

The terms biome, ecoregion and bioregion of academic ecology are becoming increasingly used by those concerned with management and conservation of natural resources. These units have broad-scale applicability to those who have to develop conservation and management strategies over large areas. This chapter attempts to re-define the biome classification of the region encompassing South Africa, Lesotho and Swaziland in the context of the new vegetation map in the atlas section of Chapter 18. We also introduce the first consistent classification of 'bioregions'—subordinate units to a biome.

The key to understanding the concept 'biome' is rooted in the issue of scale and in the concept 'biotic community'. The concept 'community' ('biotic community') itself is marred by a history of inconsistent use and interpretation to such an extent that some view it as a nonconcept (Peters 1991). If we define 'community' very broadly as *an assemblage of living organisms sharing the same portion of space during a certain period of time*, then this all-encompassing definition applies to biome as well. The real difference is in scale. Biome is viewed as a high-level hierarchical (hence simplified) unit having a similar vegetation structure exposed to similar macroclimatic patterns, often linked to characteristic levels of disturbance such as grazing and fire. The biome can be considered a kind of 'subcontinental biotic supercommunity'. Cox & Moore (2000) call it a 'large-scale ecosystem'. As a high-level hierarchy unit, biomes are not characterised by individual species (which appropriately characterise units at the more detailed lower hierarchical levels) but mainly by the emergent properties of vegetation structure and associated climate or any other applicable broad-scale environmental factors (O'Neill et al. 1986). Hierarchy theory also suggests that higher-level spatial hierarchy scales (such as biomes) are associated with longer-term time scales although there is a complex interplay between evolutionary (long-term) and ecological (short-term) time scales. Rutherford & Westfall (1986, 1994) provided (at that stage) an exhaustive review of the complexity in defining biomes, also referring to five criteria (maximum global limits, mapping scale limits, primary and secondary bases for classification, and excluded areas) described further below. The main proponents in biome (or an equivalent) definition were either those emphasising the overriding role of climate acting at broad scales (Schimper 1898, 1903, Rübel 1930, Schimper & Von Faber 1935, Weaver & Clements 1938, Holdridge 1947, 1967, Walter 1973, 1976, Whittaker 1975, Walter & Box 1976, Walter & Breckle 1991, Rivas-Martínez 1995, Polis 1999, Krebs 2001) or those using a combination of life forms matching (not always perfectly) the major climatic patterns (Box 1981, 2002, Rutherford & Westfall 1986, 1994, Cox & Moore 2000, Mucina 2000).

The quantitative link between climate and life form combinations serves as basis for construction of biome models making use of key ecophysiological principles (see below). Bond et al. (2003, 2005), Woodward et al. (2004), Bond (2005) and Bond & Keeley (2005) found that the extent of the modern biomes (especially in C_4-dominated grasslands, savanna as well as in fynbos—all 'fire-driven ecosystems' (FDE) *sensu* Bond et al. 2003) is at variance with classical climate potential models of biomes. These findings strongly suggest that the biome concept has to be revised to recognise the role of large-scale disturbance as an important factor shaping the zonal vegetation.

Strictly speaking the term biome includes both plant and animal communities, as its original American roots (Clements & Shelford 1939) suggest. Because of the dominant nature of vegetation cover in (nearly) all terrestrial ecosystems, biomes have been based only on vegetation characteristics.

In vegetation ecology, the concept of a plant community on a (sub)continental scale was called a 'formation' (Grisebach 1872, Dansereau 1957, Fosberg 1961, Mueller-Dombois & Ellenberg 1974; see Beard 1978 for a review). Probably because the term 'formation' was later used as part of formal syntaxonomic hierarchies of the American and Russian schools (compare Whittaker 1978 and Aleksandrova 1978) in very different ways, the term has largely been abandoned by the scholastic community or is used in an informal context. Although our 'biomes' are thus structural 'formations' in the original sense of Grisebach (1872), we prefer the former term.

This chapter introduces some of this information but mainly compares our units with those of other previous approaches and also makes certain comparisons (including climatic) across our biomes. This main focus is also applied to our bioregions that lie at a level between the biome and the vegetation types. Details on each biome are given in the respective chapters of this book.

1.2 Biomes of Southern Africa: Major Patterns

Southern Africa boasts a wide range of biomes. The relatively moist, mostly winter-rainfall region, encompassing the Fynbos Biome in the west and its drier climatic counterpart termed the Succulent Karoo Biome, forms the smallest of the world's six floristic kingdoms (Takhtajan 1986, but see Cox 2001), often draped over the Cape Fold Mountains and sandy lowlands of the southwestern Cape. The Succulent Karoo Biome of the Richtersveld, Namaqualand and the Little Karoo has not only the highest diversity of succulent plants in the world, but is the most species-rich semidesert on our planet. The summer-rainfall Savanna Biome of the north and east of the region represents the southern extension of the largest biome of Africa. The summer-rainfall Grassland Biome of the cooler, elevated interior is poorly represented elsewhere in Africa and is home to a wealth of species limited to southern Africa. The unique Indian Ocean Coastal Belt (IOCB) of South Africa with its recurrent extant enclaves of forest represents the southernmost extent of coastal (sub)tropical forests of the wet, tropical and subtropical seaboard of East Africa. The Desert occupies a small extent of our mapping area in the extreme northwest but, importantly, forms the southern tip of the winter-rainfall domain of the Namib Desert as well as a summer-rainfall Gariep Desert with affinities to the central-north parts of the Namib Desert. The Albany Thicket Biome, with a combination of plant forms intermediate between Savanna, Nama-Karoo and Subtropical Forest, represents an unusual structural, floristic and evolutionary ancient type of note in the subcontinent. The mostly summer-rainfall Nama-Karoo Biome is possibly the least species-rich, yet it holds many intriguing relationships with its six directly neighbouring biomes. The Afrotemperate Forests in southern Africa are highly distinctive and are also characterised by their small and patchy occurrence over the wetter parts of the winter- and summer-rainfall areas of the region. They are clearly part of the global warm-temperate forest biome. Most of these patches are too small to be shown in Figure 3.2. The Subantarctic Tundra and Polar Desert Biomes on the Prince Edward Islands in the Southern Indian Ocean are discussed in Chapter 15 and are not referred to further in this chapter.

The two most cited sets of previous works on biomes in southern Africa are Rutherford & Westfall (1986, 1994) and Low & Rebelo (1996, 1998) following on the seminal work of Huntley

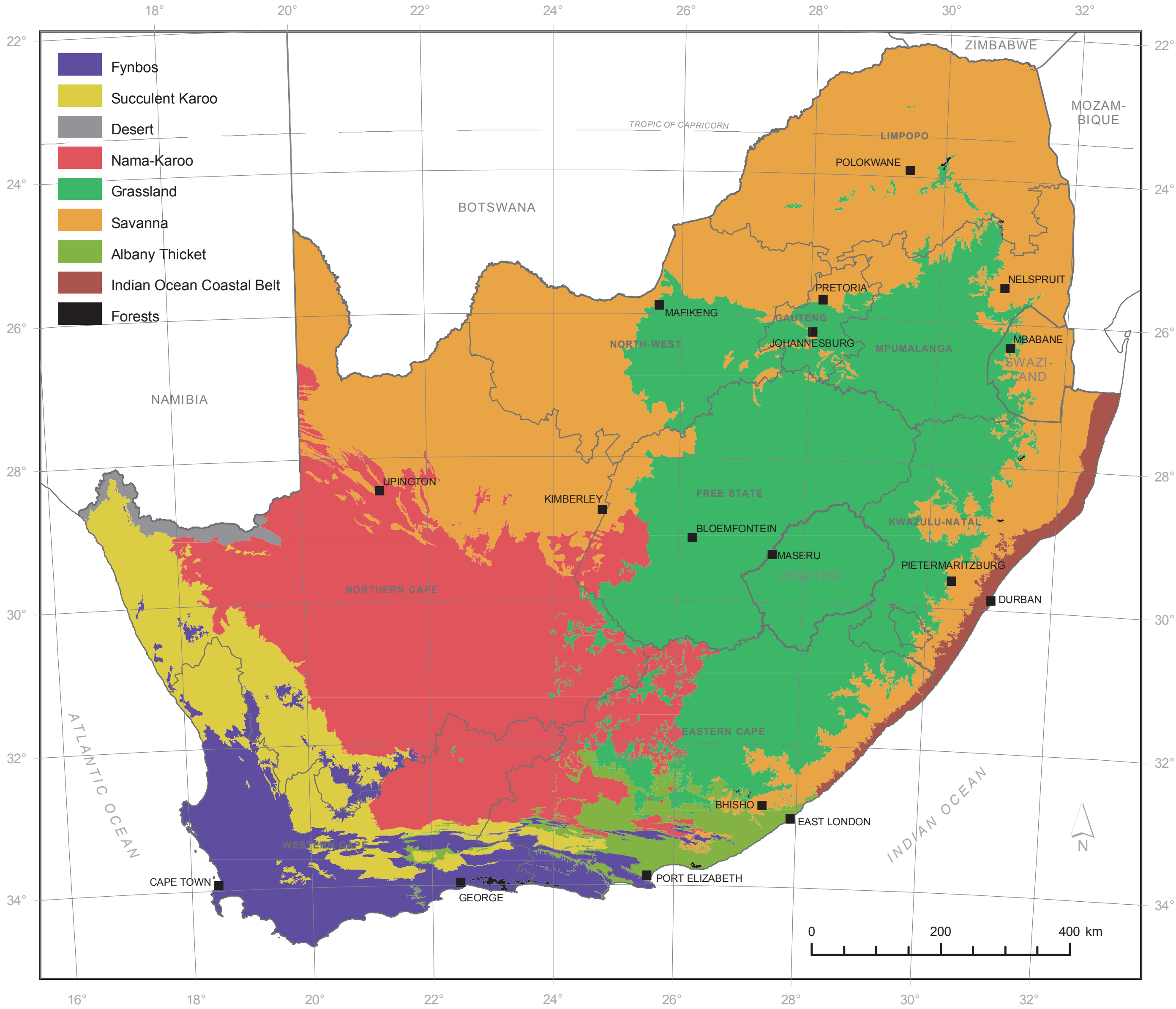


Figure 3.2 Biomes of South Africa, Lesotho and Swaziland.

(1984). The biome concept has been examined in some detail in Rutherford & Westfall (1994) and Rutherford (1997) and applied to southern Africa. In contrast to Low & Rebelo (1996, 1998), the criteria Rutherford & Westfall (1994) applied for a biome were explicit and derived from the globally applicable literature (e.g. Hansen 1962, Odum 1971, Smith 1974, Godman & Payne 1979).

Rutherford & Westfall (1994) emphasised that:

(1) A biome is the largest land community unit recognised at a continental or subcontinental scale and therefore does not recognise any subsets of a biome as a 'biome of lower rank'.

(2) Biome patches should be of a viable and minimum size (also to acknowledge the zoological components of a biome) (about 20 km in shortest cross distance).

(3) Biomes are defined primarily on combinations of dominant life or growth forms and not on the basis of taxonomic characteristics (floristic nor faunal) or nondominant elements.

(4) Biomes are defined secondarily on the basis of major climatic features that most affect the biota, i.e. not climatic indicators that may happen to correlate with the biome but are ecologically insignificant or irrelevant.

(5) Biomes do not include unnatural or major anthropogenic systems, although systems irreversibly changed by man (e.g. long-term, severe overgrazing) that are self-sustaining in their present state, are included.

The current work deviates only from the second and third criteria above largely because we are here deliberately biased towards vegetation and its floristic diversity. Only botanical elements are considered (with no consideration of faunal elements nor of their scale requirements—home ranges etc.). The biomes are made up of vegetation units defined on floristic criteria (not purely structural criteria) and no scale limitation was recognised (other than that the vegetation unit should be above the level of plant community). The biomes are partly derived from a bottom-up approach which accounts for the perfect match between biome boundaries and floristically determined boundaries. This should not distract from the broad yet distinctive floristic links with structurally determined biomes as shown by Gibbs Russell (1987), ultimately also by our approach. The biomes are also clearly in keeping with the climatic criteria of biomes and they correlate with climatic parameters that are biologically meaningful (see below).

The current work recognises two biomes in addition to those of Rutherford & Westfall (1994) and Rutherford (1997). The first is the Albany Thicket Biome which Rutherford & Westfall (1994) referred to as unmappable 'dwarf forest' of the Eastern Cape and included in their Savanna Biome. This biome partly corresponds to the Low & Rebelo's (1996) 'Thicket Biome', but the latter was much more extensive than the Albany Thicket Biome (including much of the Western Strandveld; see Chapter 4 on Fynbos). The second newly distinguished biome is the much transformed IOCB which was mapped as Savanna by Rutherford & Westfall (1994) but, as also pointed out by them (p. 74), was regarded as not fully satisfactory in the area. In this area, the current work retains as Savanna Biome only the inland strip parallel to the IOCB. Given no constraints of scale, the present work also includes many groupings of azonal vegetation units, which are not regarded as part of any biome in zonal terms, but appear as biomes merged into the background on both (scale-limited) biome and bioregion maps. Many biome boundaries are different owing to the different criteria used and to availability of new information, yet many of the boundaries remain nevertheless broadly similar. The greatest relative change (increase) in area of biome compared to that of Rutherford (1997) is in the Desert and Afrotemperate Forests. The most northerly and driest parts of the Succulent Karoo Biome of Rutherford (1997) in the vicinity of the lowest reaches of the Orange River are now regarded as part of a winter-rainfall Desert (although it is clear that at least some patches of the Succulent Karoo Biome will be upheld northwards in southwestern Namibia). Degrees of correspondence between the currently recognised biomes and other recent biome classifications are given in Table 3.1.

1.3 Biogeographical Approaches

There have been a number of other large-scale compartmentalisations into natural areas of our mapping area that approximate our biome scale.

White (1983) distinguished five phytochoria (phytogeographical units) in our region based on richness of their endemic floras at the species level. Degrees of correspondence between the biomes and the phytochoria of White (1983) are given in Table 3.2. There is fair correspondence between the Cape Phytochorion and the Fynbos Biome as well as between the Guineo-Congolian Phytochorion (Usambara-Zululand Domain) and the IOCB. White (1983) recognised most of the more mesic parts of the Grassland Biome as part of his Afromontane Phytochorion.

Gibbs Russell (1987) clearly showed that floristic links were closer between the Succulent Karoo Biome and the Fynbos Biome than between the Succulent Karoo and the Nama-Karoo Biomes. Linder et al.'s (2005) analysis divided our Savanna Biome into an eastern and northern form on the one hand and a Kalahari form (including western parts of the Central Bushveld Bioregion) on the other.

Siegfried (1989) provided a map of the biomes of our mapping region based on Rutherford & Westfall (1986) and for the savanna areas on Huntley (1984). The savanna areas here and in Huntley (1997) were divided into Arid Savanna and Moist Savanna Biomes. These two functionally important groupings are discussed further in the Savanna Chapter in this book.

Burgess et al. (2004) provided a map of the ecoregions of Africa and some of these units as well as some or their hierarchically higher units relate to our biome level. In this section we examine the relationship between their work and our work at biome level. First, it is important not to confuse our terms and concepts of 'biomes' and 'bioregions' with those used by Burgess et al. (2004). They group their most detailed-level units (ecoregions) into a dual hierarchy. (Discussion of various approaches to 'ecoregions' is found in section 2.2 on Bioregions.) In a biogeographical framework they group ecoregions into 'Bioregions' which in turn are grouped into 'Realms'. Within a 'habitat framework' they group ecoregions into 'Sub-biomes' which in turn are grouped into 'Biomes'. Within our mapping area, they recognise only two 'Bioregions'. Areas corresponding to our Fynbos and Succulent Karoo Biomes fall within a 'bioregion' called 'Cape Floristic Region' while the remaining area is part of a bioregion called 'Eastern and Southern Africa'. In our mapping area their 'bioregion' level, contrary to ours, generally lies above that of our biomes and, indeed, their biomes. It is unfortunate that Burgess et al. (2004) failed to be more explicit about their classification criteria. Their terminology shows a curious mixing of phytogeographical and vegetation-ecological systems.

Burgess et al. (2004) recognised six biomes in our mapping region:

Table 3.1 Correspondence between recent biome classifications for South Africa, Lesotho and Swaziland and those presented in the current work.

Biome	Overlapping area (%)			
	Rutherford & Westfall (1986)	Low & Rebelo (1996)	Rutherford (1997)	Simplified biome map (Figure 3.2)
Albany Thicket	0	50	0	100
Desert	0	0	8	100
Forests	23	78	23	100
Fynbos	76	81	75	100
Grassland	85	82	85	100
Indian Ocean Coastal Belt	0	0	0	100
Nama-Karoo	94	93	94	100
Savanna	82	88	80	100
Succulent Karoo	75	78	75	100

The biome termed 'Mediterranean Forests, Woodlands, and Scrub' comprises their 'Albany Thickets' (sic), 'Lowland Fynbos and Renosterveld' and 'Montane Fynbos and Renosterveld' bioregions (and in South Africa these are not divided into sub-biomes). 'Lowland Fynbos and Renosterveld' and 'Montane Fynbos and Renosterveld' together closely approximate the extent of the Fynbos Biome (82%). There is some agreement regarding the core area of the Albany Thickets Ecoregion and the Albany Thicket Biome, but overall correspondence is only 33% (Table 3.3).

The biome termed 'Deserts and Xeric Shrublands' includes areas corresponding to our Desert, Succulent Karoo and Nama-Karoo Biomes as well as to two of our Savanna Bioregions, namely Eastern Kalahari Bushveld and Kalahari Duneveld. Their biome is not divided into

Table 3.2 Degree of correspondence (%) between the biomes and phytochoria after Linder et al. (2005) and White (1983).

Phytochorion	Biome: Albany Thicket	Desert	Forests	Fynbos	Grassland	Indian Ocean Coastal Belt	Nama-Karoo	Savanna	Succulent Karoo
Linder et al. (2005)									
Cape	55		56	77			2		44
Eastern Karoo	21				45		15	24	
Kalahari					5			19	
Karoo Transition							5	4	
Namib-Karoo		100		6	1		77	3	47
Natal	14		29		49	69		46	
Somalian								1	
Zambesian-Central			3					2	
Not classified	10		12	17		31		1	9
White (1983)									
Zambezian			3		2			33	
Cape	10			68			1		11
Karoo-Namib	13	100		25			74	3	89
Afromontane			70	5	17			2	
Kalahari/Highveld	16		5		69		25	43	
Tongaland-Pondoland	61		21	2	12	96	1	19	
Not classified						4			

sub-biomes in South Africa. There is a close correspondence (in South Africa) between their 'Nama Karoo Ecoregion' and the Nama-Karoo Biome (91%) and there is also a reasonably close correspondence between the 'Succulent Karoo Ecoregion' and the Succulent Karoo Biome (77%).

The biome 'Montane Grasslands and Shrublands' corresponds generally to our Grassland Biome, but Burgess et al. (2004) include in their biome their 'Maputaland-Pondoland Bushland and Thickets' Ecoregion, which corresponds closely to our Eastern Valley Bushveld and Thukela Bushveld. With this anomaly excluded, there is an 88% correspondence with the Grassland Biome. They differentiate the high-altitude grassland of the Drakensberg from the rest of the grassland as an 'Alpine Moorland' Sub-biome.

The biome termed 'Tropical and Subtropical Grasslands, Savannas, Shrublands, and Woodlands' corresponds generally to our Savanna Biome (with the notable exception of our Kalahari Bioregions and Zululand Lowveld areas). They differentiate their biome into two sub-biomes, namely '*Acacia* Savanna Woodland' and 'Mopane Woodland'.

Their biome called 'Tropical and Subtropical Moist Broadleaf Forests' corresponds approximately to our Afrotemperate Forests together with the IOCB. At the sub-biome level they separated an 'Afromontane Forest' from an 'Eastern African Lowland Forest-grassland Mosaic', the latter corresponding more closely to our IOCB (87%). In South Africa we recognise their 'Mangroves Biome' only as an azonal vegetation type—Mangrove Forest. Within this unit in South Africa, they do not differentiate at sub-biome level.

Using a cluster analysis of plant species distributions from a variety of sources, Linder et al. (2005) derived seven phytochoria within or entering our mapping domain. These are: (1) 'Namib-Karoo' in Namaqualand, most of the Karoo interior and southern Namibia; (2) 'Cape' in the Western and Eastern Cape Provinces and approximating the area of the Fynbos Biome; (3) 'Kalahari' in the northern parts of the Northern Cape Province and western parts of the North-West and Limpopo Provinces and extending through Botswana to cover most of central and northern Namibia; (4) 'Karoo transition' in scattered parts in the north of the Northern Cape and central Botswana; (5) 'Eastern Karoo' over most of the Free State and some adjoining areas in the North-West and Northern and Eastern Cape Provinces; (6) 'Natal' along the eastern seaboard east of the main escarpment from around East London northwards, including nearly all of KwaZulu-Natal and Mpumalanga, all of Gauteng and most of Limpopo Province; and (7) 'Zambezian-central' in the northeastern extremity of South Africa extending north of the Limpopo through the eastern half of Africa to northern Tanzania. Table 3.2 gives the degree of correspondence of these phytochoria with our biome units. There is good correspondence between the Cape Phytochorion and the Fynbos Biome and fair correspondence between the Eastern Karoo Phytochorion and the less mesic parts of the Grassland Biome. However, the Natal Phytochorion does not distinguish between Savanna, IOCB and the more mesic parts of the Grassland Biome. Similarly, the Namib-Karoo Phytochorion does not distinguish between the Desert, Succulent Karoo and Nama-Karoo Biomes which Linder et al. (2005) suggest may be due to under-sampling and to the coarse resolution of their sampling.

1.4 Biome Modelling

Many other approaches to defining biomes include modelling. Equilibrium models for predicting biome distribution represented the first generation models where biome or biota distribution was assumed to be in equilibrium with climate. Holdridge (1947) was the first to attempt to provide a global classification and distribution of life zones (biomes) based on two climatic parameters. Holdridge's classification (and some other similar schemes, e.g. Whittaker 1975) assumes that biomes act as an amorphous whole—in other words, they are not made up of individual components with different climatic sensitivities. A pioneer and remarkably comprehensive equilibrium model was constructed by Box (1981) who defined close

Table 3.3 Degree of correspondence (%) between the biomes and ecoregions of Burgess et al. (2004). *Full name: Tropical and Subtropical Grasslands, Savannas, Shrublands, and Woodlands.

	Biome								
Biome and Ecoregion according to Burgess et al. (2004)	Albany Thicket	Desert	Forests	Fynbos	Grassland	IOCB	Nama-Karoo	Savanna	Succulent Karoo
Deserts and Xeric Shrublands	**16.1**	**100**		**12.9**	**8.3**		**95.1**	**39.1**	**90.2**
Kalahari Xeric Savanna					0.7		2.5	37.3	
Nama Karoo	15	76.8		1.9	7.6		91.3	1.8	13.1
Succulent Karoo	1.1	23.2		11			1.3		77.1
Mangroves						**5**		**0**	
Southern African Mangroves						5		0	
Mediterranean Forests, Woodlands, and Scrub	**37.8**		**2.4**	**84.7**	**0**		**0.9**	**0.1**	**9.7**
Albany Thickets	32.8			2.5	0		0.9	0.1	2.1
Lowland Fynbos and Renosterveld	2.6		0.7	37.2					0
Montane Fynbos and Renosterveld	2.5		1.7	44.9					7.6
Montane Grasslands and Shrublands	**35.5**		**19.1**	**0.5**	**89.4**	**7.7**	**4**	**17.6**	
Drakensberg Alti-Montane Grasslands and Woodlands					3.3				
Drakensberg Montane Grasslands, Woodlands and Forests	27.8		14.3	0.4	38	2.5	3.7	10.9	
Highveld Grasslands					47		0.3	3.8	
Maputaland-Pondoland Bushland and Thickets	7.8		4.8	0.1	1.1	5.2		2.9	
Tropical and Subtropical Grasslands, Savannas*			**13.8**		**2.1**			**40.2**	
Kalahari Acacia-Baikiaea Woodlands								2.5	
Southern African Bushveld			6.2		0.9			26.4	
Zambezian and Mopane Woodlands			7.6		1.2			11.2	
Tropical and Subtropical Moist Broadleaf Forests	**10.4**		**64.2**	**1.8**	**0.1**	**86.8**	**0**	**3**	
Knysna-Amatole Montane Forests	1.3		58.5	1.8	0.1		0	0	
KwaZulu-Cape Coastal Forest Mosaic	9		5.7		0	59.4		1.2	
Maputaland Coastal Forest Mosaic						27.4		1.8	

to 100 different plant types and the climatic tolerance ranges of each in terms of an array of climatic variables. He used these to map the combinations of these types globally with reasonable success at the macroscale. A similar, but more practically simplified 'functional group' approach was more formally applied in the BIOME foundation model (Prentice et al. 1992), in which 13 functional groups of plants were defined and related to four major bioclimatic controls. The results for the area of South Africa partly matched some of the biomes, but were at variance with a number of others. Subsequent models included coupled models which derive vegetation type (and structure) and biogeochemical fluxes. Examples include BIOME3 (Haxeltine & Prentice 1996) incorporating various physiological and ecosystem processes (see Hallgren & Pitman 2000 for a critical evaluation). This model has evolved into BIOME4, which attempts to cover the diversity of biome types better (Cramer 2002). Choice of climatic variables is crucial. Leemans (1997) observed that the more superior global vegetation models all included a realistic water balance and/or seasonality. Despite the application of many forms of a priori-defined functional types above, defining functional types remains a 'major problem' and 'experiments or natural perturbations may be the only approach which can differentiate functional types; structure may not be a reliable key' (Woodward & Cramer 1996).

Interest in biome models as mentioned above comes to a large extent from the need to estimate likely changes in carbon stores in the terrestrial biosphere, as a consequence of atmospheric carbon dioxide increase and the associated changing climate (Cramer 2002). In other words, there is likely to be less interest in the precision of boundaries of biomes and the identity of small but floristically important biomes such as the Succulent Karoo. It has also been recognised in some global models that shrubland biomes are more difficult to predict (Woodward et al. 2004).

Clustering climatic ranges of plant taxa have been used to produce 'Bioclimatic Affinity Groups' (Laurent et al. 2004), resulting in the co-occurrence of several such units in the same area. But such multiranging units were not synthesised into units of vegetation assembly.

Biomes and other categories have limitations depending on purpose. 'Categories such as that of ecoregions tend to become self-fulfilling prophecies when experimental designs assume their validity instead of testing their usefulness' (Magnussons 2004). Also, the longer-term identities of biome units have to be questioned where there is ample evidence that biomes in the past have not moved as a whole in response to climate change (Huntley 1991) and most models of the effects of future climate change expect species to respond independently of their currently associated species, e.g. see Iverson et al. (2004).

1.5 How the Biomes Compare

More detailed descriptions and considerations of each biome are given in the introductory sections of each biome chapter. Here we concentrate on comparisons across biomes.

The biomes are highly disparate in size. Relative areas of the biomes are given in Figure 3.3. There are three large biomes, namely Savanna, Grassland and Nama-Karoo, together accounting for almost 80% of the total area, while Desert and Afrotemperate Forest together account for less than 1% of the area.

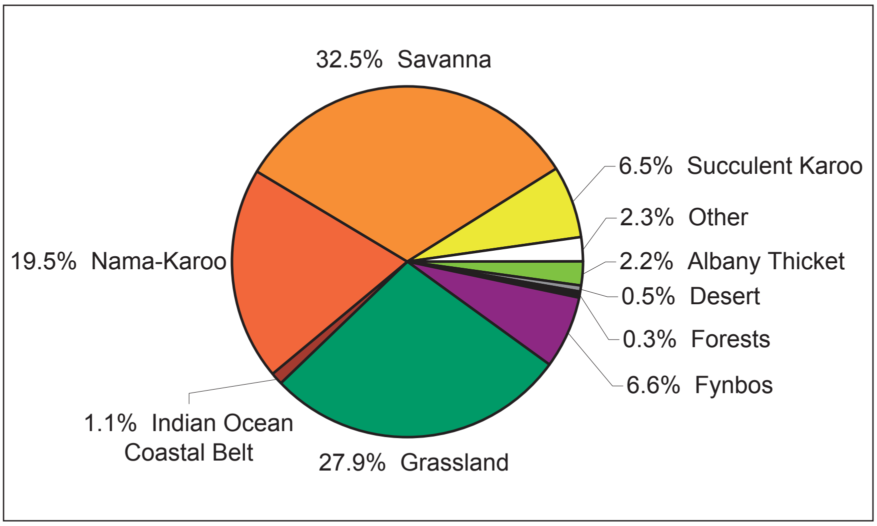


Figure 3.3 Relative proportions of areas of the biomes.

Albany Thicket has the greatest diversity of biome neighbours and borders on seven other biomes (Figure 3.4). This, together with the highly dissected nature and considerable length (> 15 000 km) of the perimeter, allows for possibly high species diversity collectively along this ecotone. Desert borders on the fewest biomes within South Africa (Succulent Karoo and Nama-Karoo), which is what would be expected from the most climatically extreme biome. Just over 40% of potential contacts between biomes in the simplified map (see Chapter 2) do not occur in the region (Figure 3.4). Thus there is little potential exchange of flora between, for example, the Grassland and Succulent Karoo Biomes. Only three of the biomes (Nama-Karoo, Grassland and very marginally Savanna) do not border on an ocean (or at a larger scale on the vegetation of the coastal strips; Chapter 14). Despite Afrotemperate Forest accounting for the smallest biome area of only 0.3% (Figure 3.3), it has the third longest boundary with biomes in the region (Figure 3.4), illustrating its highly fragmented state. More than two thirds of the land boundary of the Succulent Karoo is shared with Fynbos. Much of this interface is highly irregular, thus possibly promoting some floristic intermingling between these two biomes over time (see also below on sharing of taxa). More than half the boundary of Desert borders on Succulent Karoo (in South Africa), while almost half of that of Savanna borders on Grassland.

Boundaries between biomes vary from sharp to very gradual. Examples of sharp boundaries between biomes include those sometimes over only tens of metres between Fynbos on parts of the Cape Fold Mountains and the Succulent Karoo at lower altitude. More intermediate boundaries of a few kilometres wide are often found between the Succulent Karoo and Nama-Karoo Biomes. Very gradual transitions of tens of kilometres can be found, e.g. in some parts of the southern Kalahari between the Nama-Karoo and Savanna Biomes. In a few isolated cases, membership of a biome is equivocal, for example, for some vegetation types at the interface between the Sub-Escarpment Savanna and Sub-Escarpment Grassland of KwaZulu-Natal.

Most of the biome units of this study are incomplete and continue north of the political boundaries of this work. These are: Desert, Afrotemperate Forest, Grassland, IOCB, Nama-Karoo, Savanna and Succulent Karoo. Only Albany Thicket and Fynbos are fully circumscribed within our geographical area. Savanna has by far the longest border with other unmapped savanna to the north of our region (Figure 3.4).

The number of vegetation units per biome varies widely (Figure 3.5a) and is roughly in proportion to the floristic diversity of the biome. Hence the Fynbos Biome with the highest number of vegetation units (119) also has the highest number of species and a high proportion of endemic species (Gibbs Russell 1987). The Nama-Karoo Biome with only 14 vegetation units is also generally species-poor in comparison to other biomes. The IOCB may appear to be somewhat under-represented in terms of number of vegetation types currently recognised, yet on a unit area basis at 0.5 vegetation units per 1 000 km^2, it is intermediate between Savanna and Albany Thicket (Figure 3.5b). Although the diversity and the number of vegetation types in the Desert Biome is probably boosted by almost 90% of its types bordering directly on the relatively species-rich Succulent Karoo Biome, the relatively high number of types in the biome may also reflect a treatment at a greater level of detail. At the same time, the somewhat lower number of vegetation types per unit area in the Fynbos Biome probably reflects the significant under-sampling in the biome. The mean area of vegetation types per biome is by far the greatest in Nama-Karoo and smallest for Afrotemperate Forest (Figure 3.5c). The vegetation types in Desert and Fynbos are only marginally larger than those in Afrotemperate Forests, again emphasising the high species diversity and its level of geographical clustering in Fynbos (see above regarding detail in Desert).

Gibbs Russell's (1987) analysis of the species (and infraspecific taxa) richness of those biomes compatible with those of this book (and omitting biomes that were included in her analysis north of our mapping area) showed the Fynbos Biome to be the most rich with 7 316 taxa (currently with biome edges including almost 9 000 taxa) and about 52% of this amount in Grassland Biome and 29% in the Succulent Karoo Biome. About 67% of Fynbos Biome taxa, 28% of Grassland Biome taxa and 29% of Succulent Karoo Biome taxa were endemic. There was greatest sharing of taxa between the Succulent Karoo and Fynbos Biomes and least sharing of taxa between the Grassland and Succulent Karoo Biomes. Across South Africa, it has been found that numbers of alien and invasive species are significantly correlated with indigenous plant species richness (Richardson et al. 2005).

Using the biomes as defined in this book (but also extended to cover Namibia and Botswana), Chesselet et al. (2003) analysed the distribution of the 1 663 species of Mesembryanthemaceae, one of the most important families in our region. For the biomes compatible with our mapping area, by far the most species (871)

Biome	Albany Thicket	Desert	Forests	Fynbos	Grassland	Indian Ocean Coastal Belt	Nama-Karoo	Savanna	Succulent Karoo
Desert	■								
Forests	649	■							
Fynbos	5 814	■	2 459						
Grassland	2 519	■	9 765	■					
Indian Ocean Coastal Belt	1	■	■*	■	■				
Nama-Karoo	2 993	361	■	448	9 600	■			
Savanna	2 070	■	7 045	273	18 807	3 737	6 560		
Succulent Karoo	1 555	513	■	8 949	■	■	2 354	■	
Northern border		507	25			27	239	3 004	
Ocean	403	12	76	1 442		879		3	455

Figure 3.4 Lengths (km) of shared boundaries between biomes. Black squares indicate no contact between biomes. *Forest patches touching or surrounded by Indian Ocean Coastal Belt were subsumed into the Indian Ocean Coastal Belt.

occur in the Succulent Karoo, a large number (382) in the Fynbos Biome with lower numbers in the Albany Thicket and Grassland Biomes. The IOCB harbours very few (8), but together with the other above-mentioned four biomes each has 75% or more (up to 93% for Fynbos Biome) endemic to the respective biome.

Comparisons of aspects relating to conservation status of biomes are found in Chapter 16.

1.6 Climatic Relations of Biomes

The general climate of each biome (i.e. averaged over the entire area of the biome and, therefore, representing only a central tendency for a biome) is summarised in the climate diagrams in Figure 3.6. Afrotemperate Forests and the area of IOCB experience the highest rainfall. The western parts of the Fynbos Biome and, in the drier areas, the Succulent Karoo Biome have a generally winter-rainfall regime. The Nama-Karoo experiences relatively low levels of rainfall that are concentrated in late summer and early autumn. The Grassland Biome is climatically similar to Savanna but with lower temperatures. The Albany Thicket has a greater and more pronounced bimodal (summer-autumn) rainfall than the Nama-Karoo. The coefficient of variation in annual precipitation is the lowest in the IOCB and the highest in the arid biomes such as the Succulent Karoo and Nama-Karoo Biomes. The number of frost days per year varies from zero in the IOCB to a maximum in the Grassland Biome. The mean annual potential evaporation is the lowest for the IOCB, with high values in the Nama-Karoo, Succulent Karoo and Savanna Biomes. Note how the IOCB occupies the lower extreme (i.e. moderate) for a number of key climatic variables.

Decision Trees have been used to classify biomes at continental scales (Lotsch 1999). Ellery et al. (1991) used a Decision Tree to present the biomes of Rutherford & Westfall (1986) climatically. Similarly, we derived a more specific and diagnostic climatic explanation of the current biomes from a Classification and Regression Tree using the CART method in S-Plus (univariate splits; Clark & Pregibon 1993 and discussion in Hargrove & Hoffman 2005; Figure 3.7). A simpler, more parsimonious, climatic explanation of the biomes was derived using a Hand Constructed Linear Decision Tree (see Murthy 1998) with multivariate splits but with slightly lower overall predictive accuracy (Figure 3.9). The climatic parameters used were deemed biologically meaningful and were: Mean minimum temperature of the coldest month (Tmin), heat units (HtUnt), annual mean evapo-

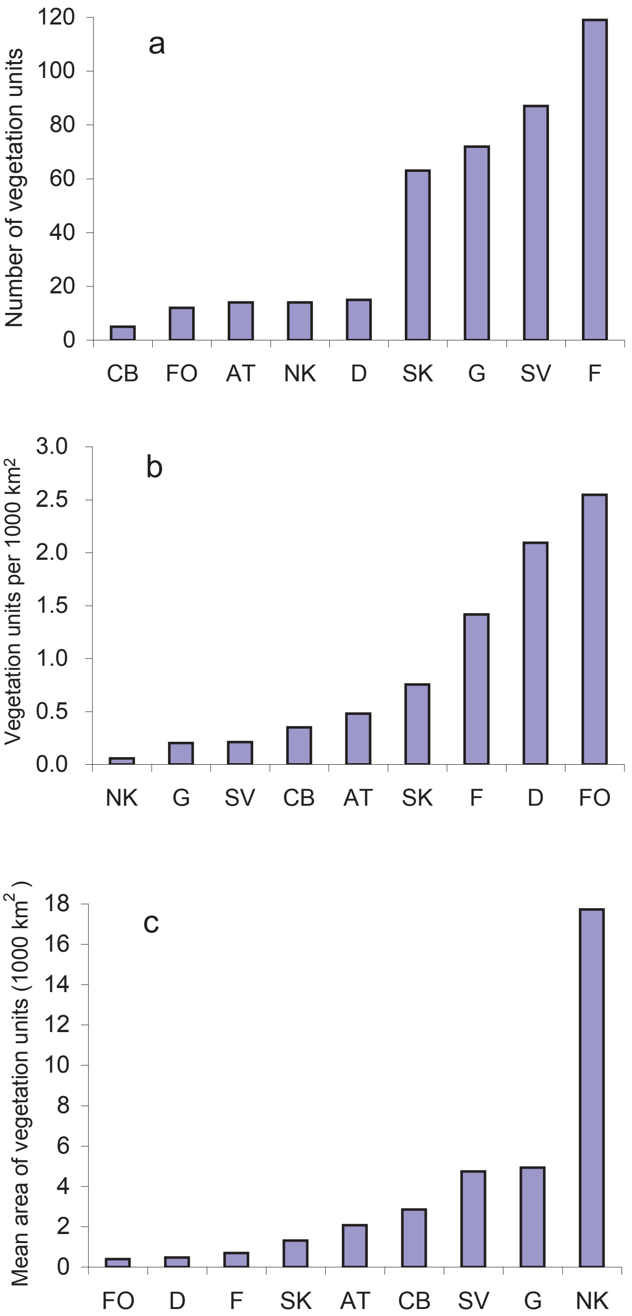


Figure 3.5 (a) Number of vegetation units per biome; (b) mean number of vegetation types per unit area within each biome; (c) mean area of vegetation units per biome. AT Albany Thicket, CB Indian Ocean Coastal Belt, D Desert, F Fynbos, FO Afrotemperate Forests, G Grassland, NK Nama-Karoo, SK Succulent Karoo, SV Savanna.

ration (Evap) and soil moisture days in winter (SMDW) and in summer (SMDS). Forests were not included in these analyses owing to their highly fragmented and widely dispersed nature.

Using the more parsimonious and, therefore, more coherent climatic description, IOCB is found mostly under conditions where soil moisture days are high in summer and relatively high in winter. Desert occurs mainly where soil moisture days both in summer and winter are low and evaporation is high. The Grassland climate differs from that of the IOCB by having a lower number of soil moisture days in winter (becoming lower with greater number of heat units) as well as a lower minimum temperature (dropping with increasing evaporation). Savanna climate differs from that of Grassland mainly in having higher minimum temperatures (level depending on evaporation) and a lower number of soil moisture days in winter (especially in areas of lower annual rainfall). Albany Thicket generally has a moderate number of soil moisture days in summer with moderate levels of evaporation as well as high minimum temperatures (declining with decreasing soil moisture days in winter). Fynbos and Succulent Karoo share some of the climatic attributes of Albany Thicket but differ from it in having lower minimum temperatures (and increasing with number of soil moisture days in winter). Fynbos has a greater number of soil moisture days in winter combined with a fewer number of heat units than in Succulent Karoo. The climatic derivation of Nama-Karoo is in two parts. The southwestern part of the Nama-Karoo has a relatively low number of soil moisture days in summer and moderate minimum temperatures. The northeastern part of the Nama-Karoo shares some of the climatic attributes of Savanna but differs from it in having lower minimum temperatures (declining in areas with higher evaporation).

CART performed between 0.2 and 9.8 percentage points better than the Hand Constructed Linear Decision Tree for seven of the biomes (Table 3.4). However, it was 16.2 and 17.1 percentage points worse for the Desert and IOCB, respectively. The linear extent of these two units was better reflected by the Hand Constructed Linear Decision Tree. Least adequately described climatically by both methods was the Albany Thicket Biome with less than 66% of its area predicted correctly. The biomes as mapped by CART are given in Figure 3.8 which also shows which areas (almost always on the margins) were incorrectly mapped. The correctly predicted areas from climate, therefore, reflect almost all of the core areas of the biomes and most of the error is limited to the transitional areas between biomes.

Climatic relations with biomes are rarely tested experimentally. In a limited study by Agenbach et al. (2004a), using reciprocal transplants of species across a boundary between the Fynbos and Succulent Karoo Biomes, it appeared that at least some Fynbos species were environmentally (including soils) limited, whereas at least some Karoo species may be limited in their distribution by fire and biotic interactions and not by their environment at this biome interface. It is thus clearly demonstrated, from local studies, that climate is not the sole determinant of vegetation distribution (Agenbach et al. 2004b). There may be boundaries between other biomes in the region which are not (only) determined by climate. The interface between our Savanna and Grassland Biomes may be one such possibility (Bond et al. 2003, 2005).

Threats of climatic change on a biome scale are usually discussed within each biome chapter, at least in terms of change in temperature and water availability. Possible effects of future levels of solar ultraviolet-B radiation on plants in South Africa are discussed by Musil et al. (1999). Those areas of South Africa with the highest current levels of UV-B radiation (Gariep Desert, Bushmanland and Kalahari Duneveld) should remain so but at even higher levels at around the middle of the 21st century.

1.7 *Southern African Biomes in Context of Walter's Scheme*

There are several global biome schemes available (see above for ample references), but an alternative one deserves particular attention not only because of its detail of elaboration (the actual map is accompanied by a series of monographs featuring the biome patterns in the light of ecophysiology and community ecology), but also due to its conceptual handling of zonality, intrazonality and azonality—one of the leading principles of the classification philosophy underlying our Map. It is the system of zonobiomes of Heinrich Walter (Walter 1962, 1968, 1973, 1976, Walter & Box 1976, Walter & Breckle 1991, etc.).

Walter (for references see above) subdivided the terrestrial surface of the earth into nine zonobiomes, underpinned by the zonal character of climate (Table 3.5). Recognising the occurrence of broad transitions between these units, he further introduced the concept of zono-ecotones, calling them 'tension zones between two zonobiomes in which one vegetation type is being replaced by another…' (Walter & Box 1976).

According to the insert map in Walter & Box (1976) the territories of South Africa, Lesotho and Swaziland fall within four zonobiomes (II, III, IV and V) and two zono-ecotones (IV-III and III-II). The only direct match between our biome system and that of Walter is the identity of the Fynbos Biome and the zonobiome IV. Walter & Box (1976) classified the Fynbos Biome (explicitly) as one of the sub-zonobiomes of the global mediterranean biome (sometimes also called 'ethesial biome'). Our Succulent Karoo corresponds to zono-ecotone IV-III and partly to the zonobiome III, most probably through the 'sub-zonobiome with winter-rainfall' according to Walter & Box (1976). Walter's zonobiome III in southern Africa further covers the Desert Biome and western and central parts of the Nama-Karoo Biome. The eastern Nama-Karoo and Kalahari are classified by Walter as zono-ecotone III-II. The mapped extent of the zonobiome V in southern Africa is too generous as it comprises most of the southern Cape, Albany Thicket and the IOCB. The last-named should be best served as part of the zonobiome I (generally underestimated on the East African coast by Walter's classification), and the Albany Thicket as part of zono-ecotone I-III (as done for parts of Kenya/Somalia or Venezuela/Colombia). An interesting rare contact between two zonobiomes can be observed along the South Coast—meeting of the zonobiome IV (mainly linked to western oceanic coasts) with the zonobiome V (mainly linked to eastern oceanic coasts), forming a mosaic of the zono-ecotone V-IV (see also Walter & Box 1976). The extent of the zonobiome II (seasonal tropics), as mapped by Walter in southern Africa to encompass all of our Savanna Biome (except for Kalahari) and the Highveld plateau and the Drakensberg Mountain ranges, is also in need of modification—the primary temperate grasslands of our Grassland Biome should rather be re-classified as zono-ecotone II-VII or perhaps zonobiome VII (in the same way as the South American pampas).

2. Bioregions

A bioregion is a composite spatial terrestrial unit defined on the basis of similar biotic and physical features and processes at the regional scale. In this work, the intermediate level of vegetation organisation between that of vegetation type and biome, is the bioregion level.

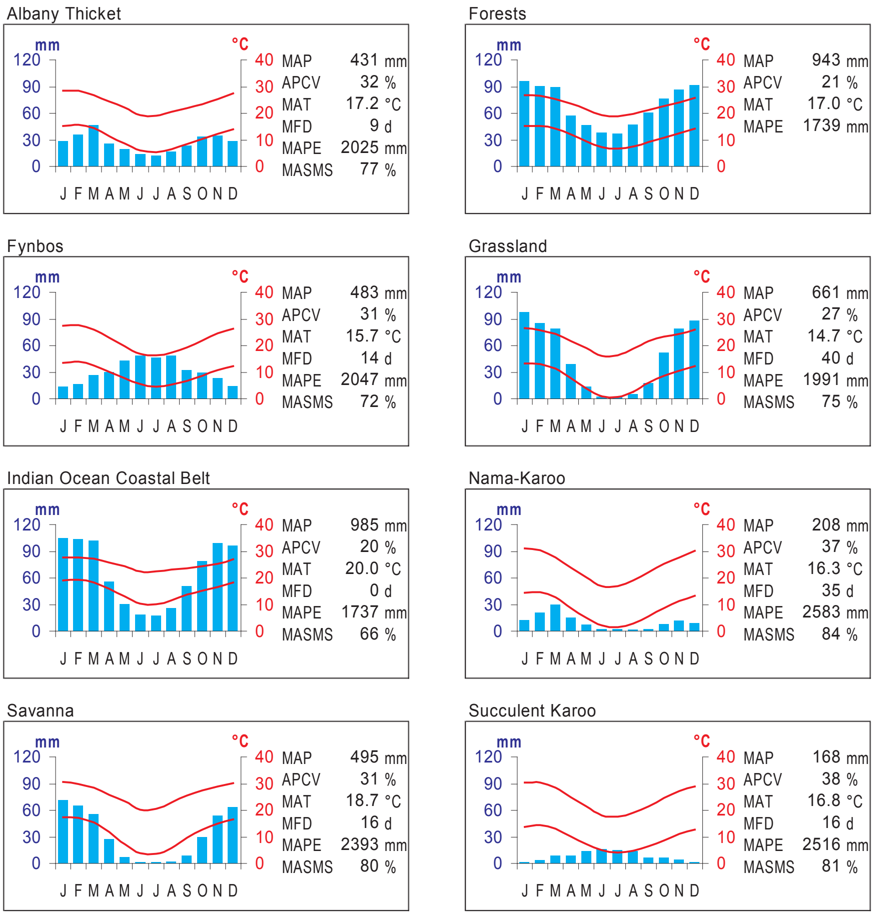


Figure 3.6 Climate diagrams of biomes excluding Desert. Blue bars show the median monthly precipitation. The upper and lower red lines show the mean daily maximum and minimum temperature, respectively. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days (days when screen temperature was below 0°C); MAPE: Mean Annual Potential Evaporation; MASMS: Mean Annual Soil Moisture Stress (% of days when evaporative demand was more than double the soil moisture supply). Note that the diagram for Forests represents the average of a wide range of rainfall seasonality.

The term 'bioregion' has been used less frequently than ecoregion (see below) and in very different ways, also globally. In South Africa, Rowe-Rowe & Taylor (1996) used the term bioregion for nine regions in KwaZulu-Natal, seven based on the original bioclimatic regions of Phillips (1973), with the remaining two bioregions deduced from Acocks (1975) and Camp (1995). The resultant units are generally at a level between our vegetation units and our bioregions for the province. The bioregions of Rowe-Rowe & Taylor (1996) have also been used by others (e.g. Avery et al. 2002). In a very different sense, Laurie & Silander (2002) use the term bioregion to equate to the large Cape Floristic Region. In Australia, the term bioregion has been used with the next more detailed level termed 'sub-bioregion' (Pullar et al. 2004) which, judging by the scale of these 'sub-bioregion' units, may approximate the level of our vegetation units. As has been pointed out in Section 1.3, the 'bioregions' of Burgess et al. (2004) are used at a hierarchical level even higher than that of our biomes. We do not refer further to their 'bioregions' here. It is clear that the term 'bioregion' has been used very loosely in the past. We hope that the current treatment will go some way to stabilising the usage of the term and concept.

Although our bioregions (Figure 3.10) represent a level intermediate between biome and vegetation unit, the IOCB is not divided into bioregions within South Africa but can be regarded as approxi-

Table 3.5 The scheme of Walter's zonobiomes (after Walter 1976, Walter & Box 1976, Walter & Breckle 1991, Box 2002). Simplified names for the zonobiomes were introduced.

Zono-biome	Name	Characteristics	Zonal Vegetation
I	Equatorial	▪ diurnal climate (mean of daily temperature amplitudes is bigger than the difference between the means for temperatures of the warmest and coldest months) ▪ rainfall usually high (above 100 mm per month), mainly aequinoctiale maxima ▪ zone between approx. 10° N and 5–10° S	▪ Tropical rain forest
II	Tropical	▪ clear colder and warmer period ▪ strong summer rainfall and extreme drought during colder period of the year (the drought period becomes longer and precipitation lower with increase of distance from the equator); fire-prone	▪ Tropical and subtropical savannas ▪ Seasonal tropical forests
III	Arid-Subtropical	▪ desert climate: very low precipitation—usually below 200 mm, in extreme desert below 50 mm; high insolation and light reflection; extreme daily temperature amplitude	▪ Deserts ▪ Semidesert shrublands
IV	Mediterranean	▪ winter rain and summer drought; usually on west oceanic coasts, between 35° and 40° in both hemispheres; fire-prone	▪ Evergreen microphyllous shrublands ▪ Seasonal evergreen forests
V	Warm-Temperate	▪ without pronounced cold winter period; ample year-round precipitation, especially high in summer; usually maritime climate due to prevailing location on eastern seaboards	▪ Evergreen broad-leaved forests
VI	Typical Temperate	▪ short cold (often with snow) period in winter (often lacking in oceanic regions) and warm summers; sufficient cyclonal precipitation	▪ Deciduous broad-leaved forests
VII	Arid-Temperate	▪ Extreme temperature differences between summer and winter due to continental position; usually low precipitation (bordering on desert climate); some ecosystems fire-prone	▪ Climatic grasslands (steppe, prairie, pampas) ▪ High-altitude semidesert shrublands
VIII	Cold-Temperate	▪ Cool and wet summers and very cold winters lasting sometimes more than half of the year; absent in southern hemisphere; fire-prone	▪ Boreal conifer forests (taiga)
IX	Arctic-Antarctic	▪ Cold and wet summers and extremely cold winters; evenly distributed precipitation over year; very short vegetation season	▪ Dwarf arctic shrublands (tundra) ▪ Polar deserts

mating a bioregion of the much larger belt that extends northwards into East Africa. The Albany Thicket Biome is not easily divided into bioregions and in effect has some properties that agree with those of the bioregion level. These two areas have, therefore, been included in some of the comparisons below. Afrotemperate Forests were not included owing to their highly fragmented and widely dispersed nature relative to the scale of the bioregion.

Table 3.4 Proportion of each biome correctly predicted (%) by the climatic models using a Hand Constructed Linear Decision Tree (HCLDT) with multivariate splits and a Classification and Regression Tree using the CART method in S-Plus (univariate splits).

Biome	HCLDT	CART
Albany Thicket	63.2	65.1
Desert	86.6	70.4
Fynbos	70.4	80.2
Grassland	77.0	85.1
Indian Ocean Coastal Belt	91.8	74.7
Nama-Karoo	85.6	85.8
Savanna	79.9	86.7
Succulent Karoo	66.7	74.8

2.1 *Bioregional Correspondence*

There is generally a very poor correspondence of the 16 'subdivisions of biomes' of Westfall & Van Staden (1996) with our bioregions. They simply used mean annual precipitation to subdivide the biomes of Rutherford & Westfall (1994). Our bioregions also differ in many respects from the phytochorial subdivisions of southern Africa where the highest level phytochorion is subdivided first into regions and more finely into domains (Werger 1978).

The *bioregion* also differs from the *ecoregion*. However, since the term ecoregion was coined in 1967 (Omernik 1987), it has been used very differently by different sources, complicating the comparisons. Ecoregions, through their availability, have been widely applied for a diversity of purposes (e.g. for units for which plant species diversity could be determined; Kier et al. 2005). Ecoregions have also been used to spawn new units such as combining them with Plant Hardiness Zones to form Plant Adaptation Regions (Vogel et al. 2005).

Ecoregions have often been defined on the basis of a dissection of physical environmental space, i.e. the ecoregion boundaries

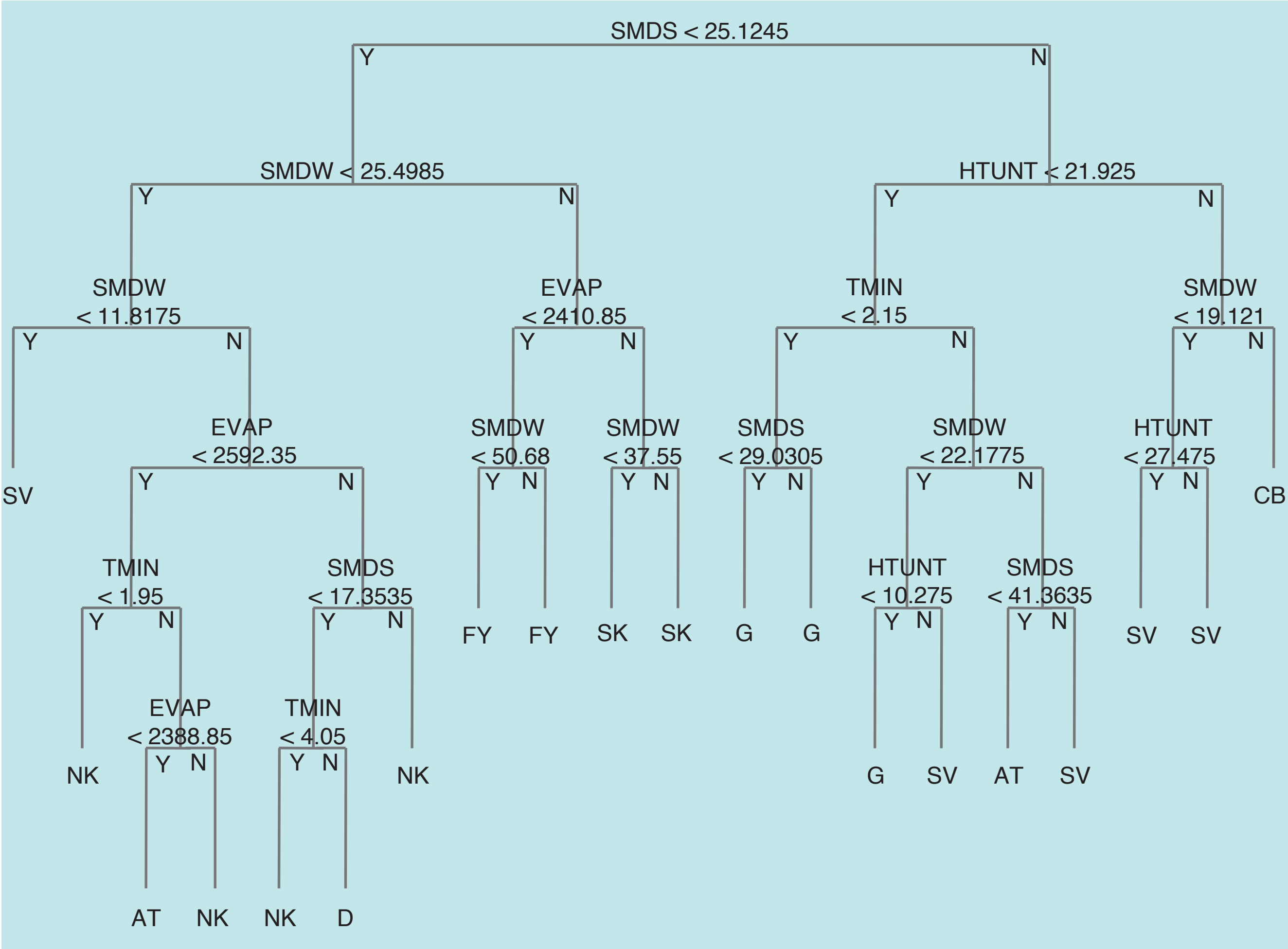


Figure 3.7 Computer printout of the climatic explanation of the biomes from a program for a Classification and Regression Tree using the CART method in S-Plus. TMIN: mean minimum temperature of the coldest month; HTUNT: heat units; EVAP: annual mean (potential) evaporation; SMDW: soil moisture days in winter; SMDS: soil moisture days in summer. AT Albany Thicket, CB Indian Ocean Coastal Belt, D Desert, FY Fynbos, G Grassland, NK Nama-Karoo, SK Succulent Karoo, SV Savanna. Y meets condition, N does not meet condition.

are primarily determined by climate (which 'solves the problem with using other components that are subject to rapid change, such as biota'—Bailey 2004). Ecoregions are sometimes also used at multiple hierarchical levels—e.g. in Australia (Pullar et al. 2004) and in the USA with four levels of ecoregion from the broadest level (Level I) to detailed Level IV (Omernik 2004).

More coherent and biotically inclusive are the ecoregions of Olson et al. (2001) although even within this same lineage, the ecoregions have changed over time (e.g. from Olson & Dinerstein 1998 to Burgess et al. 2004). They have nevertheless attracted a strong following. They have also attracted some criticism e.g. as they have been applied in Indonesia (Jepson & Whittaker 2002).

Our concept of *bioregion* and that of *ecoregion* of Olson et al. (2001) are similar. Both stress that biota are centrally important including distinct assemblages of species. Both are pragmatic units for practical application of conservation and other measures.

However, our bioregions differ from these ecoregions within our mapping area in (1) mapping scale with more detailed units, (2) underpinning by another layer of more detailed sets of biotic assemblages, (3) greater consolidation and coherency of associated climate (in some cases), (4) possible bias toward vegetation and, (5) we believe, more consistent geographical application of the concept. These differences are elaborated below.

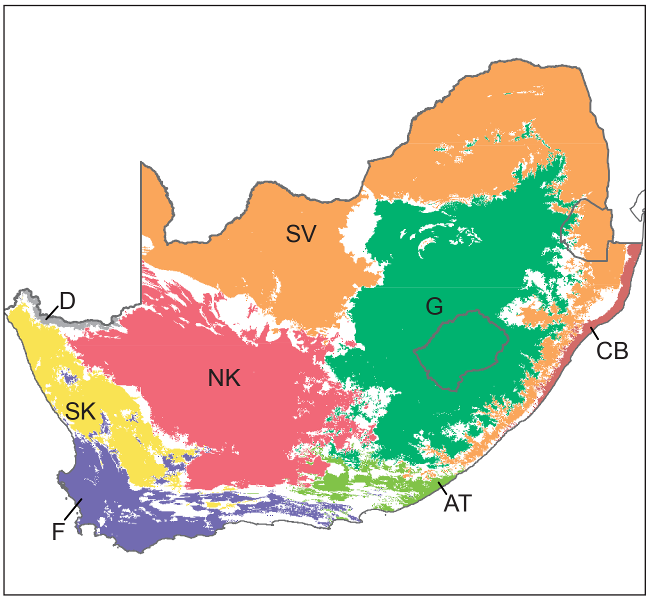


Figure 3.8 Map of the biomes as predicted by the Classification and Regression Tree using the CART method in S-Plus. Areas in white within our domain represent areas of error. AT Albany Thicket, CB Indian Ocean Coastal Belt, D Desert, F Fynbos, G Grassland, NK Nama-Karoo, SK Succulent Karoo, SV Savanna.

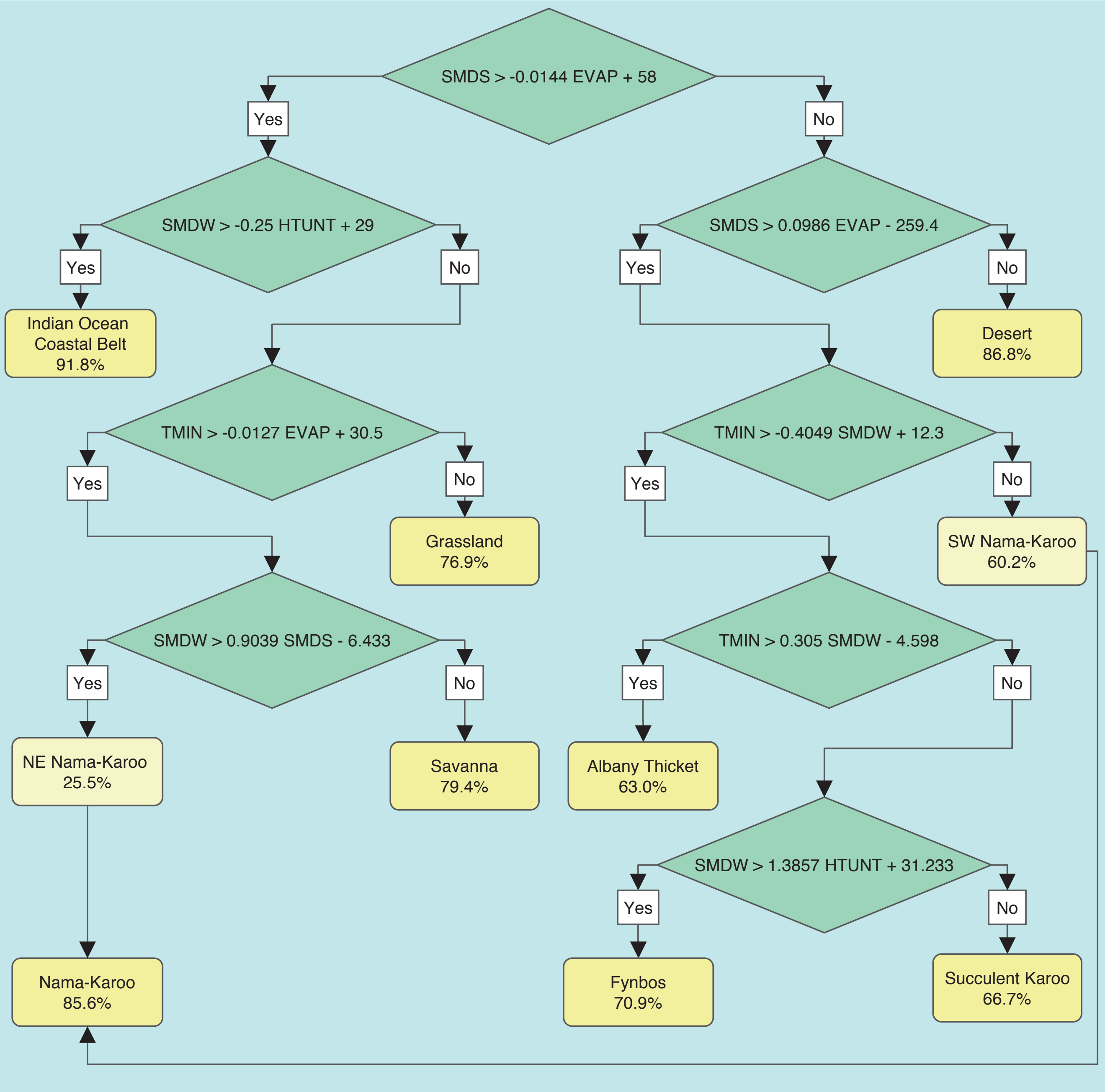


Figure 3.9 Climatic explanation of the biomes using a Hand Constructed Linear Decision Tree. TMIN: mean minimum temperature of the coldest month; HTUNT: heat units; EVAP: annual mean (potential) evaporation; SMDW: soil moisture days in winter; SMDS: soil moisture days in summer. Percentages are the proportion of the biome that was correctly predicted by the decision tree.

The average size of Olson et al.'s (2001) ecoregions globally is about 150 000 km^2 but is about 102 000 km^2 within our mapping area. Our bioregions are more finely divided with an average area of 54 000 km^2, i.e. roughly twice as detailed compared to the ecoregions.

In contrast to the ecoregions, the bioregions are underpinned by another level of biotic detail, namely vegetation types that make up each bioregion. There are on average over 10 vegetation types per bioregion, with the vegetation types (excluding azonal types) averaging just 3 100 km^2 in area.

Our bioregions follow a principle of regional consolidation, which recognises that a region should not consist of a widely dispersed array of areas and should rather be or tend towards being conterminous. In this sense it is similar in practice to one of the requirements for an ecoregion of Bailey (2004), namely to circumscribe contiguous areas. At the same time this was fitted to a coherent climatic profile for each bioregion. In this way we try to avoid recognising, for example, a 'Montane fynbos and renosterveld' Ecoregion (Burgess et al. 2004) which stretches as linear discontinuous bands from near Port Elizabeth in the east via the Cape Peninsula and the Roggeveld Escarpment to the Kamiesberg area in Namaqualand, and covers a wide range of climate. Climate tends to be more uniform within the more consolidated areas. Our principle of spatial consolidation for a bioregion also accepts that, despite distinct floristic differences between vegetation types in a bioregion, there are often also numerous species shared between adjacent vegetation types in a region.

Bioregions are focussed on plant diversity, i.e. on the floristic composition of their component vegetation types (and presum-

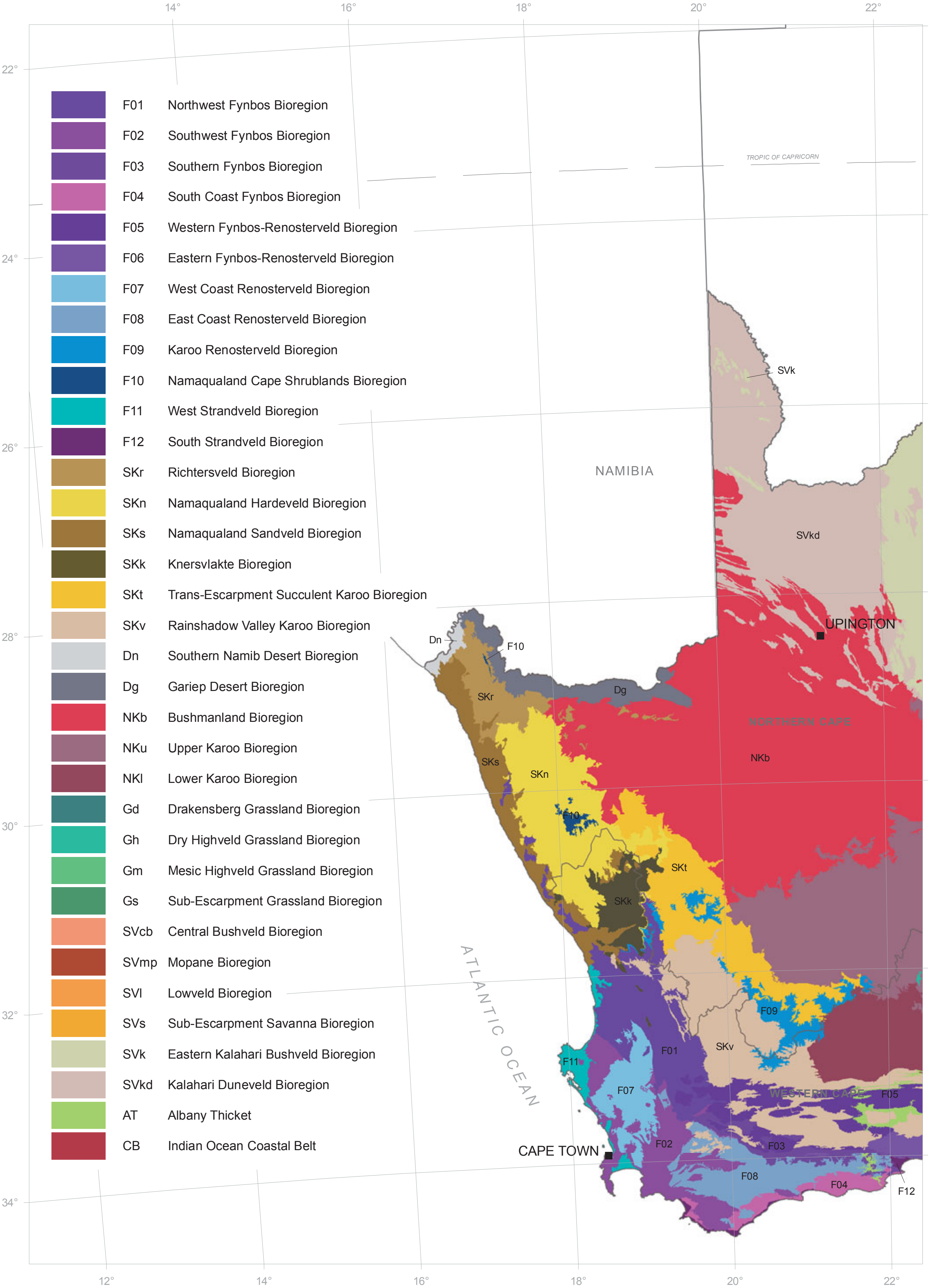
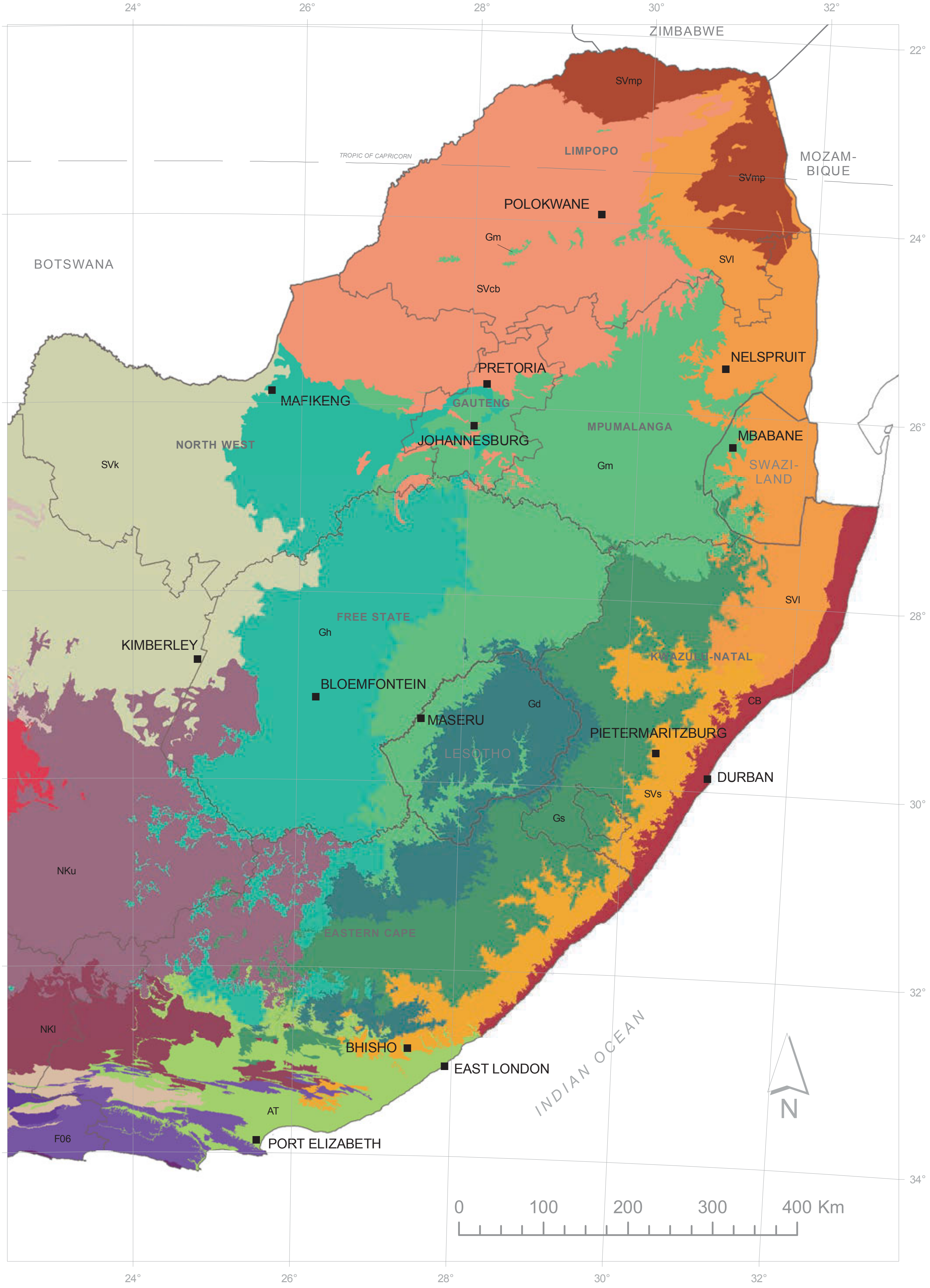


Figure 3.10 Bioregions of South Africa, Lesotho and Swaziland.


24°
26°
28°
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32°
22°
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28°
30°
32°
34°
ZIMBABWE
MOZAM-
BIQUE
BOTSWANA
TROPIC OF CAPRICORN
SVmp
LIMPOPO
SVmp
POLOKWANE
Gm
SVl
SVcb
NELSPRUIT
PRETORIA
MAFIKENG
GAUTENG
JOHANNESBURG
MPUMALANGA
MBABANE
SWAZI-
LAND
NORTH WEST
SVk
Gm
SVl
FREE STATE
Gh
KIMBERLEY
KWAZULU-NATAL
BLOEMFONTEIN
CB
Gd
MASERU
PIETERMARITZBURG
LESOTHO
DURBAN
SVs
Gs
NKu
EASTERN CAPE
NKl
BHISHO
EAST LONDON
INDIAN OCEAN
AT
N
F06
PORT ELIZABETH
0
100
200
300
400 Km

ably an approximate surrogate for animal diversity), whereas ecoregions purport to be based on plants and animals and the imprint of geological history (Olson et al. 2001). However, in mainland Africa, most of these terrestrial ecoregions were derived from the vegetation units of White (1983) with some subsequent further divisions (Burgess et al. 2004). And where widely accepted biogeographical maps were unavailable, ecoregions were delineated on the basis of land forms and vegetation (Olson et al. 2001). This supposed difference between bioregion and ecoregion in bias of the former towards plants might, therefore, turn out to be rather semantic. In the southern African context we would contend that the bioregions are better founded on floristic principles than a number of the ecoregions, although not denying the importance of some ecoregions and their informative descriptions, e.g. those ecoregions in the area corresponding to the Fynbos Biome.

The appropriateness and consistency of the geographical application of ecoregions and their affiliations within our mapping region are dealt with in the paragraphs below.

There is generally a poor correspondence between individual ecoregions and bioregions. The few exceptions include the 'Southern Africa bushveld' Ecoregion which corresponds fairly well to the Central Bushveld Bioregion (78%). There is also some correspondence between the 'Zambesian and mopane woodlands' Ecoregion and the Mopane Bioregion (60%). Otherwise, there is a close correspondence between the 'Kalahari Xeric savanna' Ecoregion and the combination of the Kalahari Duneveld and Eastern Kalahari Bushveld Bioregions (91%). These correspondences are limited to the area of our mapping domain and should the concepts tend to diverge north of this domain, the overall level of correspondence would drop, possibly to a level of poor correspondence.

Widely divergent climate can occur within a single ecoregion (Burgess et al. 2004). For example, included within the Drakensberg montane grasslands, woodlands and forests Ecoregion are both the very high-rainfall grasslands around the Drakensberg in KwaZulu-Natal and the arid grasslands on mountains around Graaff-Reinet in the Karoo. The latter arid grasslands have been more appropriately included in our Dry Highveld Grassland Bioregion. Climatic ranges within ecoregions and bioregions in general do, however, deserve further analysis.

As emerges from the above, the ecoregions of Burgess et al. (2004) for South Africa, Lesotho and Swaziland appear hierarchically diverse and can correspond at multiple levels, i.e. biome level (e.g. 'Succulent Karoo' Ecoregion and Succulent Karoo Biome), bioregion level (e.g. 'Southern Africa bushveld' Ecoregion and Central Bushveld Bioregion), and approximately at vegetation type level (i.e. 'Drakensberg alti-montane grasslands and woodlands' Ecoregion and 'Drakensberg Afroalpine Heathland vegetation type'). Through the current work we would advocate a firmly placed bioregion level which should remain hierarchically stable.

2.2 The Bioregions

The Savanna Biome (in our mapping area) contains six bioregions. The Central Bushveld Bioregion has the highest number of vegetation types and covers most of the high-lying plateau west of the main escarpment from the Magaliesberg in the south to the Soutpansberg in the north. The Mopane Bioregion has the smallest area of the bioregions in the Savanna Biome (Figure 3.11) and lies at relatively low altitude north of the Soutpansberg and on the northeastern flats of the Limpopo Province. The Lowveld Bioregion extends from the eastern foot of the Soutpansberg southwards along the base and lower slopes of the escarpment, through the lower parts of Swaziland to the low-lying parts of Zululand in KwaZulu-Natal. The Sub-Escarpment Savanna Bioregion occurs mainly inland of the IOCB extending farther inland up major river valleys. The Eastern Kalahari Bushveld Bioregion is the largest savanna bioregion and is on average at the highest altitude (Figure 3.12). It is roughly bounded by Mafikeng, Bloemhof, Kimberley, Groblershoop and Van Zylsrus. The Kalahari Duneveld Bioregion has the fewest number of vegetation units and is typically found in the region of parallel dunes mainly in the Gordonia District north of Upington. On structural grounds (derived from satellite imagery), the Kalahari Duneveld Bioregion is, unlike the remainder of the Savanna Biome, not supported as a 'woodland biome' (Fairbanks 2000: Figure 2) and was also rejected on structural grounds as Savanna Biome in Rutherford (1997).

There are four bioregions in the Grassland Biome. The Drakensberg Grassland Bioregion is the highest-lying bioregion in the whole of our mapping area and occurs on the Lesotho highlands and immediate surrounds in KwaZulu-Natal, stretching southwards along the high-lying area of the escarpment in the Eastern Cape Province to reach the Stormberg and Amathole Mountains. It is the grassland bioregion with the fewest number of vegetation types. The Dry Highveld Grassland Bioregion constitutes the western belt (Graaff-Reinet and Aliwal North to Mafikeng) of the biome, mainly with a MAP below 600 mm. The Mesic Highveld Grassland Bioregion is the largest and has the highest number of vegetation types. It is found mainly in the higher-precipitation parts of the highveld and extends northwards along the eastern escarpment. It includes bushveld summit grasslands. The Sub-Escarpment Grassland Bioregion occurs at relatively low altitude on the plains and foothills of the Drakensberg and eastern escarpment from around Volksrus in the north to the Queenstown area in the south.

The Nama-Karoo Biome contains three bioregions, with a relatively even spread of number of vegetation types between them. The Bushmanland Bioregion occurs from the northeastern part of the Namaqualand area in the west to around Prieska in the east and from around Upington in the north to the Brandvlei/Sak River vicinity in the south. The Upper Karoo Bioregion is the largest and highest-altitude bioregion. It ranges from the eastern Calvinia District in the west to Burgersdorp in the east and from around Douglas and Petrusburg in the north to the Great Escarpment in the south. The Lower Karoo Bioregion is the smallest and at the lowest altitude. It mainly occupies the basin between the Great Escarpment in the north and the Cape Fold Mountains in the south, excluding areas of the Albany Thicket in the eastern part of the basin.

Of the two bioregions of the Desert Biome, the smaller is the Southern Namib Desert which stretches as a relatively narrow band up the valley of the Orange River from its mouth at Alexander Bay to around Sendelingsdrif. The much larger Gariep Desert extends farther up the lower Orange River Valley at a higher altitude over rugged terrain to around Onseepkans. (See Section 2.3 of this chapter and Chapter 6 on Desert for biome level considerations of these two groupings.)

All the biome chapters following this chapter are arranged according to the bioregions as set out except for the Fynbos Biome. The text in Chapter 4 is therefore arranged rather according to substrate types, emphasising the edaphic dependences of many Fynbos types but not necessarily their climatic affiliations important in the Fynbos bioregions. The close proximity and interleaving of very different vegetation types in the Fynbos Biome posed a challenge for establishing its bioregions and in terms of our consolidation principle, we have combined

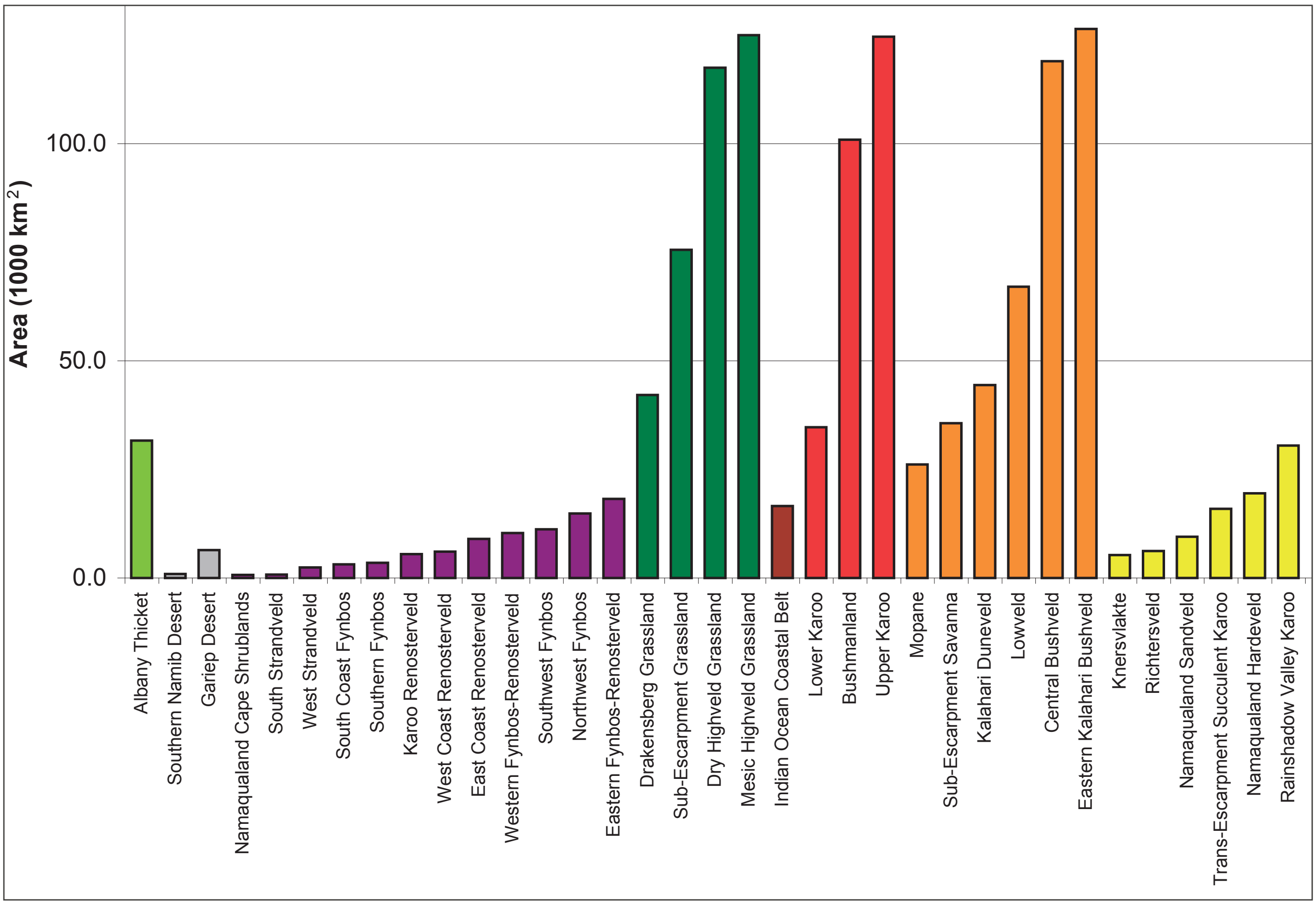


Figure 3.11 Areas of bioregions grouped according to biome.

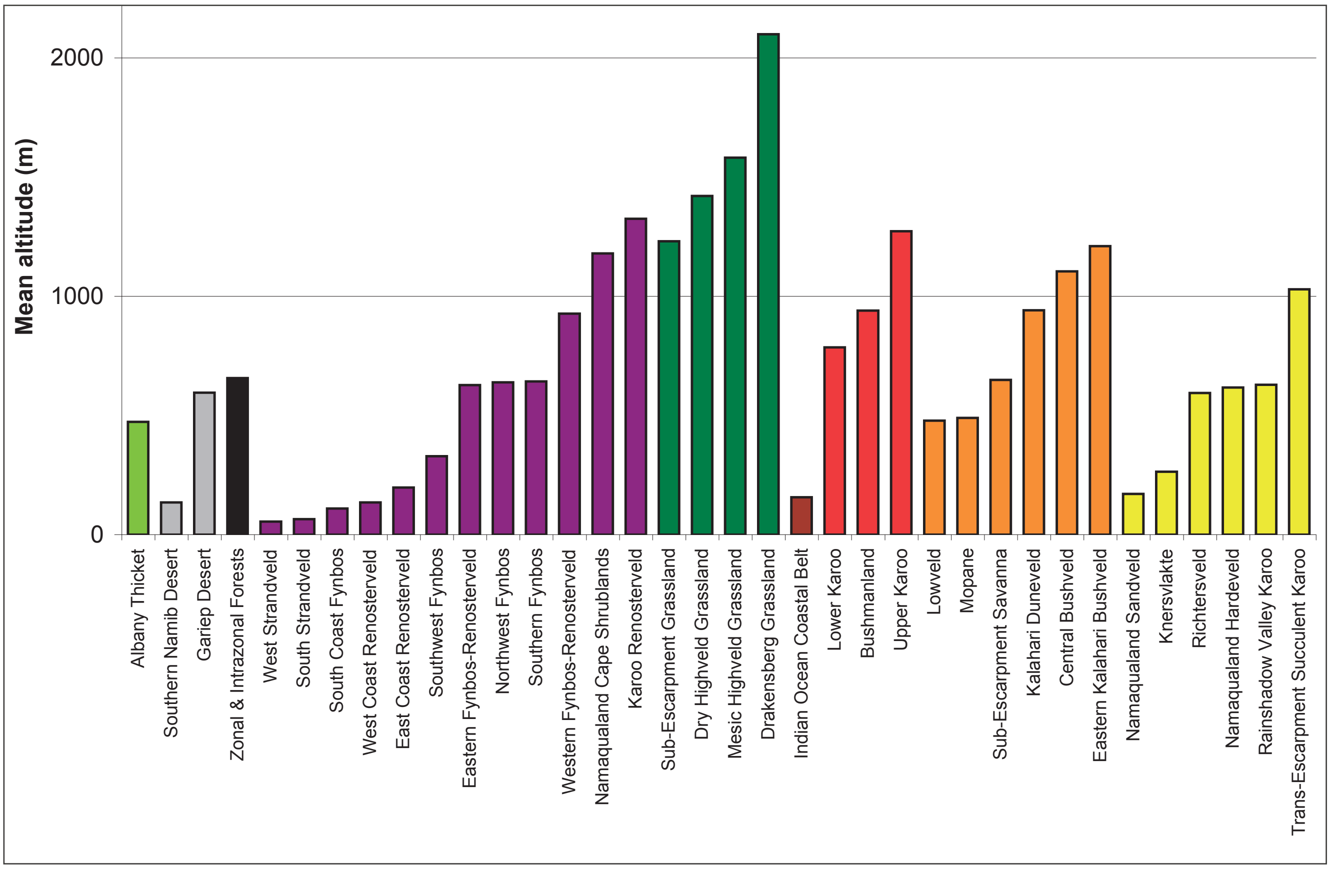
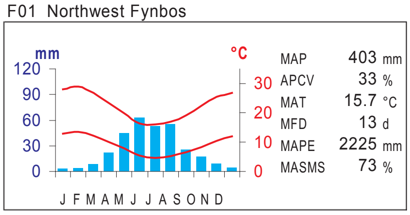
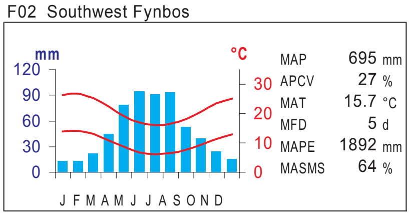


Figure 3.12 Mean altitude of bioregions grouped according to biome.

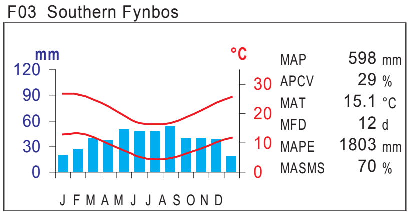
F01 Northwest Fynbos



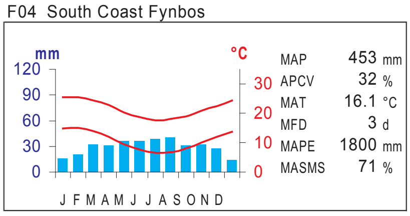
F02 Southwest Fynbos



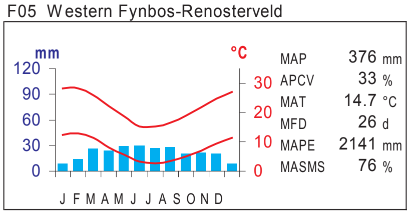
F03 Southern Fynbos



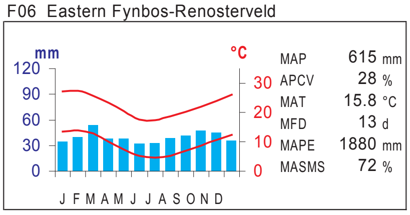
F04 South Coast Fynbos



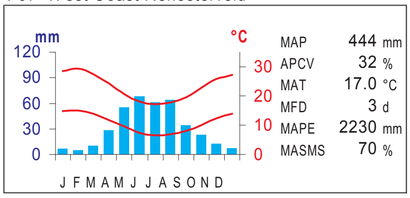
F05 Western Fynbos-Renosterveld



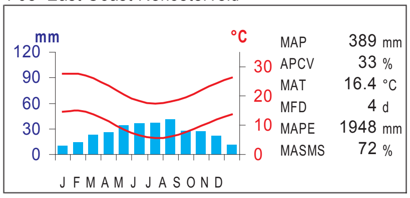
F06 Eastern Fynbos-Renosterveld



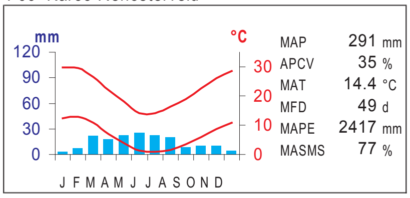
F07 West Coast Renosterveld



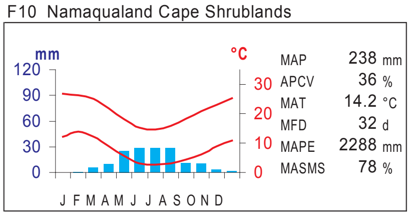
F08 East Coast Renosterveld



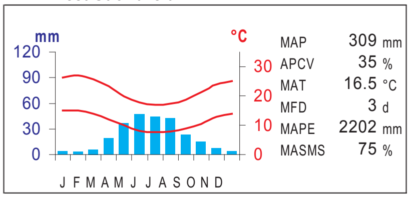
F09 Karoo Renosterveld



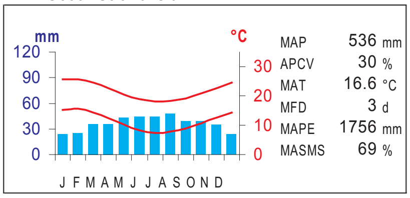
F10 Namaqualand Cape Shrublands



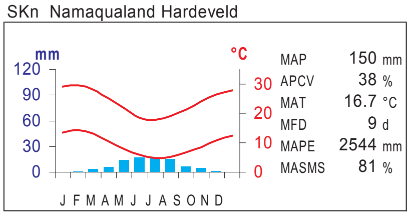
F11 West Strandveld



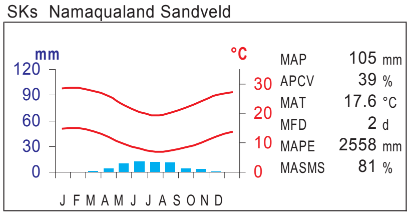
F12 South Strandveld



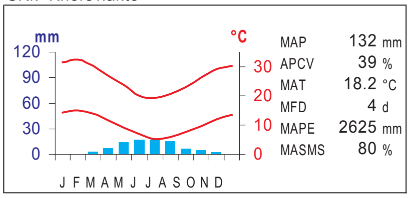
SKn Namaqualand Hardeveld



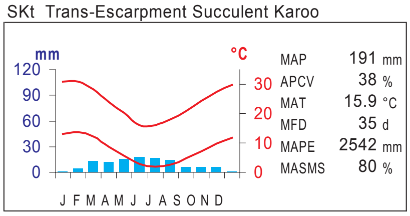
SKs Namaqualand Sandveld



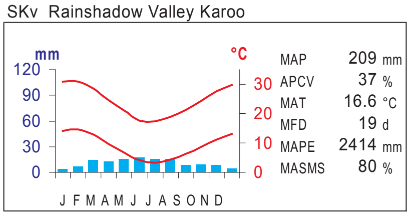
SKk Knersvlakte



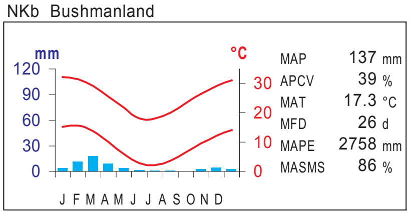
SKt Trans-Escarpment Succulent Karoo



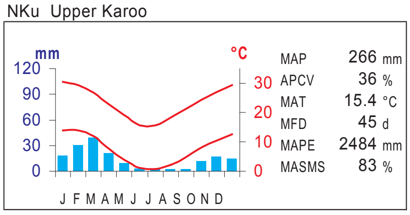
SKv Rainshadow Valley Karoo



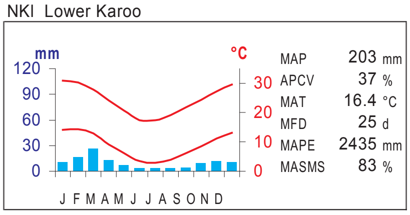
NKb Bushmanland



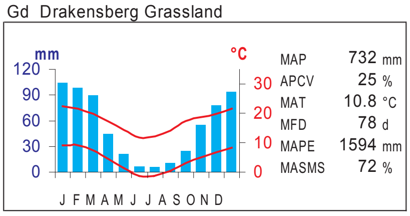
NKu Upper Karoo



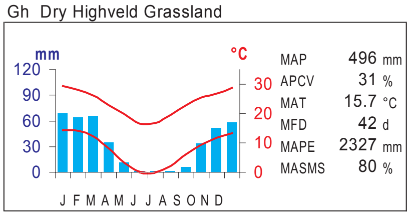
NKl Lower Karoo



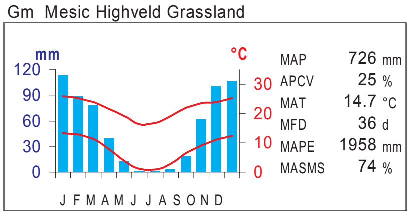
Gd Drakensberg Grassland



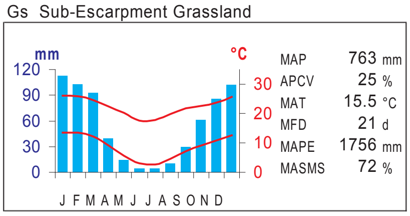
Gh Dry Highveld Grassland



Gm Mesic Highveld Grassland



Gs Sub-Escarpment Grassland



fynbos and renosterveld types in places (as have ecoregions of Burgess et al. (2004) within this biome). Thus the largest bioregion in the biome is the Eastern Fynbos-Renosterveld Bioregion which stretches from around George to Port Elizabeth and Grahamstown. To the northwest and west of this region is the Western Fynbos-Renosterveld Bioregion which mainly circumscribes the higher-elevation outcrops of fynbos in the Little Karoo from Uniondale in the east to the Touws River area in the west (except those associated with the Langeberg).

The floristic heartland of the Fynbos Biome is probably the Southwest Fynbos Bioregion. This is a sandstone (occasionally granite) and sand-defined unit and includes the mountains of the Kogelberg, Du Toitskloof area, Riviersonderend Mountains as well as the Cape Peninsula, Bredasdorp Mountains (including Potberg) and the fynbos of the sandveld on flats such as in the Hopefield District. This bioregion is flanked by two renosterveld bioregions. The West Coast Renosterveld Bioregion encompasses all the renosterveld areas to the west of the mountain chain from around Eendekuil/Piketberg in the north to Somerset West in the south. The East Coast Renosterveld Bioregion stretches from Bot River/Caledon in the west to the vicinity of Albertinia in the east and includes the renosterveld areas of the Breede River Valley. Positioned largely between the East Coast Renosterveld Bioregion and the ocean is the South Coast Fynbos Bioregion mainly on the flats between Bredasdorp and Mossel Bay. Immediately north of the East Coast Renosterveld Bioregion is the Southern Fynbos Bioregion which constitutes the sandstone mountain areas of the Langeberg from Worcester in the west to the vicinity of Herbertsdale in the east and includes higher sandstone outcrops in the Montagu area.

The second largest bioregion in the Fynbos Biome is the Northwest Fynbos Bioregion which covers the sandstone and sand areas of the biome from the Hex River Mountains in the south through the Cederberg to the Bokkeveld Escarpment near Nieuwoudtville in the north. Also included here is the Piketberg Mountain and sand patches north of Aurora on the flats to the Vredendal District and some patches northwards embedded in the Namaqualand Sandveld Bioregion of the Succulent Karoo Biome. Inland of these patches and at much higher altitudes is the smallest bioregion of the biome, namely the Namaqualand Cape Shrublands Bioregion. Most of this bioregion is centred in the Kamiesberg area of Namaqualand. The remaining two bioregions in the Fynbos Biome are strictly coastal and of very limited area. The larger unit is the West Strandveld Bioregion which is centred in the Saldana Bay area and extends northwards to Lambert's Bay and southwards to the Cape Flats bordering False Bay. The South Strandveld Bioregion occurs in patches from Walker Bay (Hermanus) in the west to the vicinity of Oyster Bay (near Port Elizabeth) in the east.

The Succulent Karoo Biome is made up of six bioregions. The Richtersveld Bioregion covers most of the hilly and mountainous Richtersveld except for the desert areas near the Orange River. It contains the largest number of vegetation types despite having the second smallest area. The Namaqualand Hardeveld Bioregion covers much of the higher-lying hilly area between Steinkopf in the north and Nuwerus in the south. To the west of this bioregion lies the Namaqualand Sandveld Bioregion, which is the lowest-lying bioregion occurring along the coastal plains from the Richtersveld in the north to the vicinity of the lower Olifants River in the south. The Knersvlakte Bioregion is the smallest bioregion and also lies at low altitude, but further inland than the last-mentioned. It is found mainly on the plains south of Kliprand in the north southwards to around Vanrhynsdorp. The Trans-Escarpment Succulent Karoo contains the fewest number of vegetation types and is the highest-lying bioregion, occurring on the upland plateau roughly from the Loeriesfontein area in the north to the vicinity of Sutherland in the south. The Rainshadow Valley Karoo Bioregion is the largest bioregion and includes the basins of the Tanqua, Robertson and Little Karoo as well as some areas north and east of the Swartberg.

2.3 *Climatic Relations of Bioregions*

Bioregions are divided into climatic entities with relatively similar climates within the bioregion and usually distinct climatic differences between bioregions. The following key climatic differences between the bioregions are identified.

In the Fynbos Biome, the Namaqualand Cape Shrublands Bioregion has the lowest MAP by a clear margin (Figure 3.13). The West Strandveld and Karoo Renosterveld have a similar, relatively low MAP but the former experiences almost no frost in contrast to the latter which has the highest incidence of frost in the biome. The Eastern Fynbos-Renosterveld Bioregion has the most evenly spread rainfall throughout the year. Less evenly spread rainfall is found in the Southern Fynbos, South

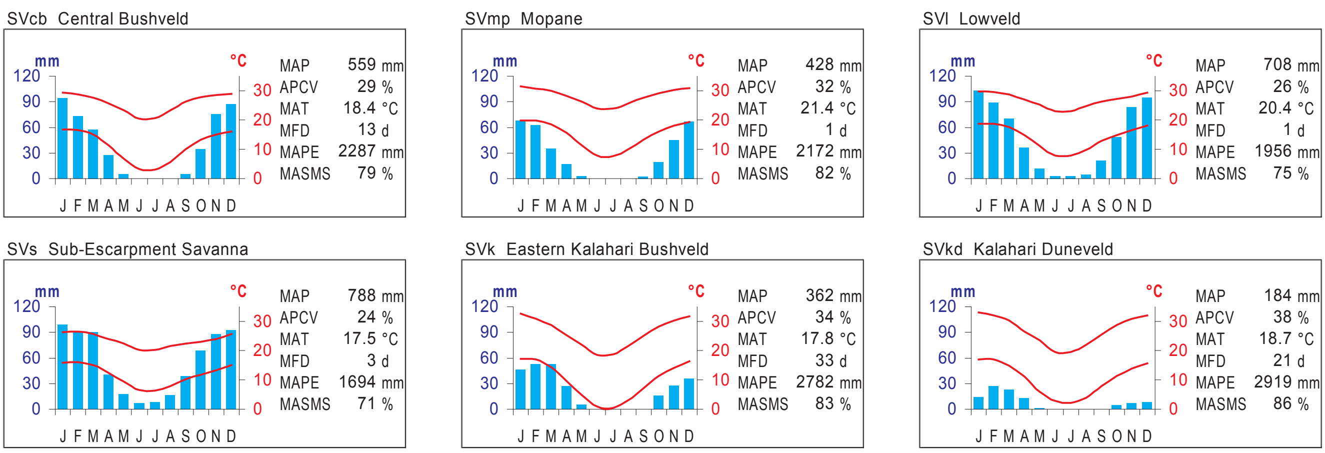


Figure 3.13 Climate diagrams of the bioregions grouped according to biome. Blue bars show the median monthly precipitation. The upper and lower red lines show the mean daily maximum and minimum temperature, respectively. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days (days when screen temperature was below 0°C); MAPE: Mean Annual Potential Evaporation; MASMS: Mean Annual Soil Moisture Stress (% of days when evaporative demand was more than double the soil moisture supply).

Strandveld and South Coast Fynbos Bioregions which have a decreasing MAP in the order given. The remaining five bioregions in the biome have a clear winter-rainfall pattern with low to very low rainfall in summer. Of these, the Southwest Fynbos Bioregion has the highest MAP followed by West Coast Renosterveld, East Coast Renosterveld and Western Fynbos-Renosterveld. The Northwest Fynbos is distinguished from these last-mentioned by its high annual potential evaporation.

In the Succulent Karoo Biome, the Namaqualand Sandveld has the lowest MAP, with the Rainshadow Valley Karoo and the Trans-Escarpment Succulent Karoo Bioregions having the highest MAP. The Trans-Escarpment Succulent Karoo has a much higher incidence of frost than the Rainshadow Valley Karoo. This incidence of frost approaches that of the adjacent Nama-Karoo Biome. The Namaqualand Hardeveld Bioregion has lower temperatures and more frost days than the Knersvlakte Bioregion. Climatic data for the Richtersveld Bioregion are too sparse to make specific comparisons with the other bioregions.

The Southern Namib Desert has a clear winter rainfall and relatively 'reliable' pattern of frequent fog in contrast to the Gariep Desert with precipitation ranging from even less predictable rainfall transitional between winter and summer to clearly summer-autumn rainfall; it experiences no fog. The effects of these climatic differences are so profound that these bioregions could probably each be raised to the level of biome. In the Nama-Karoo, the Bushmanland Bioregion has considerably lower MAP than the other two bioregions. Of the other bioregions, the Upper Karoo Bioregion has about twice as much frost as the Lower Karoo.

Within the Grassland Biome, the Drakensberg Grassland Bioregion has much lower temperatures, with a high incidence of frost compared to the other grassland bioregions. Dry Highveld Grassland has significantly lower precipitation than Mesic Highveld Grassland. Although MAP is similar between Mesic Highveld Grassland and Sub-Escarpment Grassland, the latter differs in its higher temperatures and fewer frost days.

In the Savanna Biome, the two bioregions with the highest MAP are the Sub-Escarpment Savanna and Lowveld, with the latter experiencing a significantly greater annual potential evaporation. The Kalahari Duneveld Bioregion has by far the lowest MAP in the biome. The Eastern Kalahari Bushveld Bioregion has more than twice as much frost as the Central Bushveld Bioregion while the Mopane Bioregion experiences virtually no frost.

It should be clear that the climatic relations indicated above represent climatic averages within a unit and, therefore, the overall trends and these averages do not address the spatial range of climate within a unit.

3. Credits

M.C. Rutherford wrote the text which was edited by L. Mucina who also added sections 1.1 and 1.7 which were in turn edited by M.C. Rutherford. L.W. Powrie was responsible for the technical compilation of the material for the figures and the tables (except for Table 3.5 supplied by L. Mucina). M.C. Rutherford and L.W. Powrie performed the decision tree analyses and W. Thuiller (now Grenoble, France) assisted with the CART decision tree. Data for the climate diagrams were taken or derived from the work of R.E. Schulze. This chapter is directed mainly at comparisons between biomes and between bioregions but we fully acknowledge the individual contributions to biome and bioregion boundaries supplied by the authors of the individual biome chapters in this book (see Credits at the end of each major chapter).

4. References

Acocks, J.H.P. 1975. Veld types of South Africa, edn 2. *Mem. Bot. Surv. S. Afr.* 40: 1–128.

Agenbach, L., Esler, K.J. & Midgley, G.F. 2004b. Studies along an environmental gradient reveal how biome boundaries may respond to climate change. In: Arianoutsou, M. & Papanastasis, V. (eds), *Proceedings 10th MEDECOS Conference April 25–May 1, 2004, Rhodes*. Millpress, Rotterdam.

Agenbach, L., Rutherford, M., Midgley, G. & Esler, K.J. 2004a. Fundamental and realized niches of fynbos and karoo seedlings as revealed by reciprocal transplants. In: Arianoutsou, M. & Papanastasis, V. (eds), *Proceedings 10th MEDECOS Conference April 25–May 1, 2004, Rhodes*. Millpress, Rotterdam.

Aleksandrova, V.D. 1978. Russian approaches to classification of vegetation. In: Whittaker, R.H. (ed.), *Classification of plant communities*, pp. 167–200. Dr W. Junk, The Hague.

Avery, D.M., Avery, G. & Roberts, A. 2002. A contribution from barn owl pellets to known micromammalian distributions in KwaZulu-Natal, South Africa. *Afr. Zool.* 37: 131–140.

Bailey, R.G. 2004. Identifying ecoregion boundaries. *Environ. Manage.* 34, Suppl. 1: S14–S26.

Beard, J.S. 1978. The physiognomic approach. In: Whittaker, R.H. (ed.), *Classification of plant communities*, pp. 33–64. Dr W. Junk, The Hague.

Bond, W.J. 2005. Large parts of the world are brown or black: a different view of the 'Green World' hypothesis. *J. Veg. Sci.* 16: 261–266.

Bond, W.J. & Keeley, J.E. 2005. Fire as a global 'herbivore': the ecology and evolution of flammable ecosystems. *Trends Ecol. Evol.* 20: 387–394.

Bond, W.J., Midgley, G.F. & Woodward, F.I. 2003. What controls South African vegetation—climate or fire? *S. Afr. J. Bot.* 69: 79–91.

Bond, W.J., Woodward, F.I. & Midgley, G.F. 2005. The global distribution of ecosystems in a world without fire. *New Phytol.* 165: 525–537.

Box, E.O. 1981. *Macroclimate and plant forms: an introduction to predictive modeling in phytogeography.* Dr W. Junk, The Hague.

Box, E.O. 2002. Vegetation analogues and differences in the northern and southern hemispheres: a global comparison. *Plant Ecol.* 163: 139–154.

Burgess, N., Hales, J.D., Underwood, E., Dinerstein, E., Olson, D., Itousa, I., Schipper, J., Ricketts, T. & Newman, K. 2004. *Terrestrial ecoregions of Africa and Madagascar. A conservation assessment.* Island Press, Washington, DC.

Camp, K.G.T. 1995. *The bioresource units of KwaZulu-Natal*. Cedara Report N/A/95/32, KwaZulu-Natal Dept of Agriculture, Cedara.

Chesselet, P., Van Wyk, A.E., Griffen, N. & Smith, G.F. 2003. Patterns of floristic diversity in Mesembryanthemaceae. *Aloe* 40: 80–85.

Clark, L.A. & Pregibon, D. 1993. Tree-based models. In: Chambers, J.M. & Hastie, T.J. (eds), *Statistical models in S*, pp. 377–419. Chapman & Hall, London.

Clements, F.E. & Shelford, V.E. 1939. *Bio-ecology.* J. Wiley & Sons, New York.

Cox, C.B. 2001. The biogeographic regions reconsidered. *J. Biogeogr.* 28: 511–523.

Cox, C.B. & Moore, P.D. 2000. *Biogeography: an ecological and evolutionary approach*, edn 6. Blackwell, Oxford.

Cramer, W. 2002. Biome models. In: Mooney, H.A. & Canadell, J.G. (eds), *Encyclopaedia of global environmental change. Volume 2. The earth system: biological and ecological dimensions of global environmental change,* pp. 166–171. J. Wiley, Chichester.

Dansereau, P. 1957. *Biogeography. An ecological perspective.* Ronald Press, New York.

Ellery, W.N., Scholes, R.J. & Mentis, M.T. 1991. An initial approach to predicting the sensitivity of the South African grassland biome to climate change. *S. Afr. J. Sci.* 87: 499–503.

Fairbanks, D.H.K. 2000. Physio-climatic classification of South Africa's woodland biome. *Plant Ecol.* 149: 71–89.

Fosberg, F.R. 1961. A classification of vegetation for general purposes. *Trop. Ecol.* 2: 1–28.

Gibbs Russell, G.E. 1987. Preliminary floristic analysis of the major biomes in southern Africa. *Bothalia* 17: 213–227.

Godman, A. & Payne, E.M.F. 1979. *Longman dictionary of scientific usage.* Longman, London.

Grisebach, A. 1872. *Die Vegetation der Erde nach einer klimatischen Anordnung.* Band 1 & 2. Engelmann, Leipzig.

Hallgren, W.S. & Pitman, A.J. 2000. The uncertainty in simulations by a Global Biome Model (BIOME3) to alternative parameter values. *Glob. Change Biol.* 6: 483–495.

Hansen, H.C. 1962. *Dictionary of ecology*. Philosophical Library, New York.

Hargrove, W.W. & Hoffman, F.M. 2005. Potential of multivariate quantitative methods for delineation and visualization of ecoregions. *Environ. Manage.*

34, Suppl. 1: S39–S60.
Haxeltine, A. & Prentice, I.C. 1996. BIOME 3: An equilibrium terrestrial biosphere model based on ecophysiological constraints, resource availability, and competition among plant functional types. *Glob. Biochem. Cycles* 10: 693–709.
Holdridge, L.R. 1947. Determination of world plant formations from simple climatic data. *Science* 105: 367, 368.
Holdridge, L.R. 1967. *Life-zone ecology*, revised edn. Tropical Science Center, San José, Costa Rica.
Huntley, B. 1991. How plants respond to climate change: migration rates, individualism and the consequences for plant communities. *Ann. Bot*. 67, Suppl. 1: 15–22.
Huntley, B.J. 1984. Characteristics of South African biomes. In: Booysen, P. de V. & Tainton, N.M. (eds), *Ecological effects of fire in South African ecosystems*, pp. 1–17. Springer, Berlin.
Huntley, B.J. 1997. Biomes and habitats of southern Africa. In: Mills, G. & Hes, L. (eds), *The complete book of southern African mammals*, pp. 24–31. Struik Winchester, Cape Town.
Iverson, L.R., Schwartz, M.W. & Prasad, A.M. 2004. How fast and far might tree species migrate in the eastern United States due to climate change? *Glob. Ecol. Biogeogr.* 13: 209–219.
Jepson, P. & Whittaker, R.J. 2002. Ecoregions in context: a critique with special reference to Indonesia. *Conserv. Biol.* 16: 42–57.
Kier, G., Mutke, J., Dinerstein, E., Ricketts, T.H., Küper, W., Kreft, H. & Barthlott, W. 2005. Global patterns of plant diversity and floristic knowledge. *J. Biogeogr*. 32: 1107–1116.
Krebs, C.J. 2001. *Ecology. The experimental analysis of distribution and abundance*, edn 5. Benjamin Cummings, San Francisco, CA.
Laurent, J.-M., Ben-Hen, A., François, L., Ghislain, M. & Cheddadi, R. 2004. Refining vegetation simulation models: from plant functional types to bioclimatic affinity groups of plants. *J. Veg. Sci.* 15: 739–746.
Laurie, H. & Silander, J.A. 2002. Geometric constraints and spatial pattern of species richness: critique of range-based null models. *Divers. Distrib.* 8: 351–364.
Leemans, R. 1997. The use of plant functional type classifications to model global land cover and simulate the interactions between the terrestrial biosphere and the atmosphere. In: Smith, T.M., Shugart, H.H. & Woodward, F.I. (eds), *Plant functional types*, pp. 289–316. Cambridge Univ. Press, Cambridge.
Linder, H.P., Lovett, J., Mutke, J.M., Barthlott, W., Jürgens, N., Rebelo, T. & Küper, W. 2005. A numerical re-evaluation of the sub-Saharan phytochoria of mainland Africa. *Biol. Skr*. 55: 229–252.
Lotsch, A. 1999. *Biome level classification of land cover at continental scales using decision trees.* M.A. thesis, Boston Univ., Boston, MA.
Low, A.B. & Rebelo, A.(T.)G. (eds) 1996. *Vegetation of South Africa, Lesotho and Swaziland.* Dept of Environmental Affairs and Tourism, Pretoria.
Low, A.B. & Rebelo, A.(T.)G. (eds) 1998. *Vegetation of South Africa, Lesotho and Swaziland*, edn 2. Dept of Environmental Affairs and Tourism, Pretoria.
Magnusson, W.E. 2004. Ecoregion as a pragmatic tool. *Conserv. Biol.* 18: 4, 5.
Mucina, L. 2000. Ecosystems of Europe. In: Levin, S.A. (ed.), *Encyclopaedia of Biodiversity.* Volume 2, pp. 635–647. Academic Press, San Diego.
Mueller-Dombois, D. & Ellenberg, H. 1974. *Aims and methods of vegetation ecology.* J. Wiley & Sons, New York.
Murthy, S.K. 1998. Automatic construction of decision trees from data: a multi-disciplinary survey. *Data Mining and Knowledge Discovery* 2: 345–389.
Musil, C.F., Rutherford, M.C., Powrie, L.W., Björn, L.O. & McDonald, D.J. 1999. Spatial and temporal changes in South African solar ultraviolet-B exposure: implications for threatened taxa. *Ambio* 28: 450–456.
Odum, E.P. 1971. *Fundamentals of ecology*. Saunders, Philadelphia.
Olson, D.M. & Dinerstein, E. 1998. The global 200: A representation approach to conserving the earth's most biologically valuable ecoregions. *Conserv. Biol.* 12: 502–515.
Olson, D.M., Dinerstein, E., Wikramanayake, E.D., Burgess, N.D., Powell, G.V.N., Underwood, E.C., D'Amico, J.A., Itousa, I., Strand, H.E., Morrison, J.C., Loucks, C.J., Allnutt, T.F., Ricketts, T.H., Kura, Y., Lamoreux, J.F., Wettengel, W.W., Hedao, P. & Kassem, K.R. 2001. Terrestrial ecoregions of the world: a new map of life on earth. *Bioscience* 51: 933–938.
Omernik, J.M. 1987. Ecoregions of conterminous United States. *Ann. Assoc. Amer. Geogr.* 77: 118–125.
Omernik, J.M. 2004. Perspectives on the nature and definition of ecological regions. *Environ. Manage.* 34, Suppl. 1: S27–S38.
O'Neill, R.V., DeAngelis, D.L., Waide, J.B. & Allen, T.F.H. 1986. *A hierarchical concept of ecosystems.* Princeton Univ. Press, Princeton.
Peters, R.H. 1991. *A critique for ecology.* Cambridge Univ. Press, Cambridge.
Phillips, J. 1973. *The agricultural and related development of the Tugela Basin and its influent surrounds*. Natal Town & Regional Planning Commission, Pietermaritzburg.
Polis, G.A. 1999. Why are parts of the world green? Multiple factors control productivity and the distribution of biomes. *Oikos* 86: 3–15.
Prentice, I.C., Cramer, W., Harrison, S.P., Leemans, R., Monserud, R.A. & Solomon, A.M. 1992. A global biome model based on plant physiology and dominance, soil properties and climate. *J. Biogeogr.* 19: 117–134.
Pullar, D., Low Choy, S. & Rochester, W. 2004. Ecoregion classification using a Bayesian approach and model-based clustering. *Transactions of the 2nd Biennial Meeting of the International Modelling and Software Society,* Vol. 2. International Environmental Modelling & Software Soc. (iEMSs).
Richardson, D.M., Rouget, M., Ralston, S.J., Cowling, R.M., Van Rensburg, B.J. & Thuiller, W. 2005. Species richness of alien plants in South Africa: environmental correlates and the relationship with indigenous plant species richness. *EcoScience* 12: 391–402.
Rivas-Martínez, S. 1995. Clasificación bioclimática de la tierra. *Fol. Bot. Matrit.* 14: 1–25.
Rowe-Rowe, D.T. & Taylor, P.J. 1996. Distribution patterns of terrestrial mammals in KwaZulu-Natal. *S. Afr. J. Zool*. 31: 131–144.
Rübel, E. 1930. *Pflanzengesellschaften der Erde.* Huber, Bern.
Rutherford, M.C. 1997. Categorization of biomes. In: Cowling, R.M., Richardson, D.M. & Pierce, S.M. (eds), *Vegetation of southern Africa*, pp. 91–98. Cambridge Univ. Press, Cambridge.
Rutherford, M.C. & Westfall, R.H. 1986. Biomes of southern Africa—an objective categorization. *Mem. Bot. Surv. S. Afr.* No. 54: 1–98.
Rutherford, M.C. & Westfall, R.H. 1994. Biomes of southern Africa—an objective categorization, edn 2. *Mem. Bot. Surv. S. Afr.* No. 63: 1–94.
Schimper, A.F.W. 1898. *Pflanzen-Geographie auf physiologischer Grundlage.* G. Fischer, Jena.
Schimper, A.F.W. 1903. *Plant geography upon a physiological basis.* Clarendon Press, Oxford.
Schimper, A.F.W. & Von Faber, F.C. 1935. *Pflanzen-Geographie auf physiologischer Grundlage*, 3rd edn. G. Fischer, Jena.
Siegfried, W.R. 1989. Preservation of species in southern African nature reserves. In: Huntley, B.J. (ed.), *Biotic diversity in southern Africa*, pp. 186–201. Oxford Univ. Press, Cape Town.
Smith, R.L. 1974. *Ecology and field biology.* Harper & Row, New York.
Takhtajan, A. 1986. *Floristic regions of the world.* Univ. of California Press, Berkeley, CA.
Vogel, K.P., Schmer, M.R. & Mitchell, R.B. 2005. Plant adaptation regions: ecological and climatic classification of plant materials. *Rangel. Ecol. Manage.* 58: 315–319.
Walter, H. 1962. *Die Vegetation der Erde in ökophysiologischer Betrachtung. Band I: Die tropischen und subtropischen Zonen.* G. Fischer, Jena.
Walter, H. 1968. *Die Vegetation der Erde in öko-physiologischer Betrachtung. Band II: Die gemässigten und artkischen Zonen.* G. Fischer, Jena.
Walter, H. 1973. *Vegetation of the Earth in relation to climate and the eco-physiological conditions.* English Univ. Press, London.
Walter, H. 1976. Globale Gliederung der natürlichen terrestrischen Ökosysteme. *Flora* 165: 315–323.
Walter, H. & Box, E. 1976. Global classification of natural terrestrial ecosystems. *Vegetatio* 32: 75–81.
Walter, H. & Breckle, S.-W. 1991. *Ökologische Grundlagen in globaler Sicht.* G. Fischer, Stuttgart.
Weaver, J.E. & Clements, F.E. 1938. *Plant ecology*, edn 2. McGraw-Hill, New York.
Werger, M.J.A. 1978. Biogeographical division of southern Africa. In: Werger, M.J.A. & Van Bruggen, A.C. (eds), *Biogeography and ecology of southern Africa*, pp. 145–170. Dr W. Junk, The Hague.
Westfall, R.H. & Van Staden, J.M. 1996. Primary divisions of the biomes of South Africa. *S. Afr. J. Sci.* 92: 373–375.
Whittaker, R.H. 1975. *Communities and ecosystems*, edn 2. Macmillan, New York.
Whittaker, R.H. 1978. Dominance-types. In: Whittaker, R.H. (ed.), *Classification of plant communities*, pp. 65–79. Dr W. Junk, The Hague.
White, F. 1983. *Vegetation of Africa: a descriptive memoir to accompany the UNESCO/AETFAT/UNSO vegetation map of Africa.* UNESCO, Paris.
Woodward, F.I. & Cramer, W. 1996. Plant functional types and climatic changes: introduction. *J. Veg. Sci.* 7: 306–308.
Woodward, F.I., Lomas, M.R. & Kelly, C.K. 2004. Global climate and the distribution of plant biomes. *Phil. Trans. Roy. Soc. London* B 359: 1465–1476.

Fynbos Biome 4

Anthony G. Rebelo, Charles Boucher, Nick Helme, Ladislav Mucina and Michael C. Rutherford

with contributions by

Walter J. Smit, Leslie W. Powrie, Freddie Ellis, Jan J.N. Lambrechts, Louis Scott, Frans G.T. Radloff, Steven D. Johnson, David M. Richardson, Robert A. Ward, Şerban M. Procheş, Edward G.H. (Ted) Oliver, John C. Manning, Norbert Jürgens, David J. McDonald, John A.M. Janssen, Benjamin A. Walton, Annelise le Roux, Andrew L. Skowno, Simon W. Todd and David B. Hoare

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Figure 4.1 *Leucospermum cordifolium* (orange-flowered Proteaceae), *Metalasia densa* (white-flowered Asteraceae) and *Berzelia lanuginosa* (yellow-flowered, endemic family Bruniaceae) on the slopes of the Kogelberg at Betty's Bay (Western Cape).

L. Mucina

List of Vegetation Units

1. Introduction: Concepts and Complexity Patterns

1.1 Scope of the Chapter

The primary aim of this chapter is to provide a description of the vegetation units as expressed on the Map (Mucina et al. 2005; see Chapter 18 entitled Vegetation Atlas in this book). Secondly, we attempt to discuss major features of the physical, geographical and evolutionary environment of the region housing the Fynbos Biome of South Africa.

The Fynbos Biome, due to its floristic, evolutionary and ecological peculiarities and conservation appeal, has experienced decades of intensive and dedicated botanical research (see Bond & Goldblatt 1984, Campbell 1985, Cowling 1992, Cowling & Richardson 1995, Cowling et al. 1997, Goldblatt & Manning 2000a and Van Wyk & Smith 2001 for comprehensive reviews as well as Boucher & McDonald 1982 and Boucher et al. 1995, 1996 for compilations of data sources). It may be argued that there is a renewed need to review our knowledge on the ecology of the Fynbos Biome since the last vegetation-focused review (Cowling et al. 1997) of almost a decade ago. Yet it is not our intention to provide still another, albeit possibly updated, review of the ecology of the Fynbos Biome. Our focus here is on the variability and typification of the vegetation of the Fynbos Biome in relation to geographical conditions, and the comparative ecological and evolutionary driving forces that shaped this unique and rich flora.

1.2 Concepts of the Fynbos Biome

The Fynbos Biome takes its name from fynbos—the dominant vegetation in the region. The concept of the biome is a unit defined on basis of climate, corresponding life-form patterns and major natural disturbances (Rutherford & Westfall 1994). Although well defined geographically, the Fynbos Biome strictly comprises three quite different, naturally fragmented vegetation types (fynbos, renosterveld and strandveld) that occur in the winter- and summer-rainfall areas, are dominated by small-leaved, evergreen shrubs and whose regeneration is intimately related to fire. It is one of two (with Albany Thicket) biomes endemic to South Africa. Although this biome concept is well understood, its fragmented nature is not convenient for inventory and regional analyses, and several additional concepts have arisen.

The earliest of these concepts was the 'Cape' as a region, as used by early explorers and botanists. The first concept of the fynbos flora in its modern position—as distinct from the inland Karoo—was that of Bolus (1886). Since then various studies dealing with the region as a phytochorion (a geographical unit based primarily on inventories and classification of species), have been undertaken (Taylor 1978, Cowling 1992). In its modern form, Taylor (1978) defined 'Capensis' and White (1983) the 'Cape regional centre of endemism' based on exceptional richness and high endemicity. Takhtajan (1986) regarded the area as a Cape Floral Kingdom (Capensis)—one of six floral kingdoms in the world. There have also been attempts at uniting the Succulent Karoo and Fynbos Biomes into a single winter-rainfall unit, based on the richness, endemism, the shared richness of the Aizoaceae and geophytes, and possible evolutionary drivers, but these are not relevant here.

However, many modern analyses, inventories and reviews use the concept of a Cape Floristic Region (CFR; e.g. Goldblatt & Manning 2000a). Unlike the above classifications, these include all the vegetation types (i.e. also Succulent Karoo, Albany Thicket and afrotemperate forests) within the area covered by the Fynbos Biome. This has been necessitated by the lack of data allowing species to be assigned to the different vegetation types (or biomes) within the region, and the need to conserve and manage the region as an entity. Furthermore, most of these omit the outlying areas of the Fynbos Biome north of Nieuwoudtville, east of Port Elizabeth and on the Great Escarpment. In this they approximate the area of the geological

Cape Fold Belt and effectively include the entire area underlain by the Cape Sequence geology and its basement rocks.

Most reviews summarise features across all these vegetation types, attributing much of the biodiversity and ecology to fynbos vegetation. It is true that almost all the endemic plant families, most of the spectacular floral diversity and endemism, occur in fynbos vegetation. Furthermore, in these attributes, fynbos vegetation so overwhelms the other vegetation types and biomes present in the CFR that it is tempting to ignore the 'lesser' elements. Indeed, among the tables, lists and literature, it is hard to extract information relevant to fynbos versus the other vegetation types or biomes. By contrast, the omission of the outlying areas underestimates endemism in fynbos taxa. For instance, endemism of species in the Proteaceae is 96.7% for the CFR, but 99.7% if the entire Fynbos Biome is considered.

To the general public, fynbos vegetation, Fynbos Biome, Cape Floristic Region, and Cape Floral Kingdom, are all synonymous, and the other local vegetation types and biomes are generally assumed to be a 'type' of fynbos. This is rendered even more confusing to nonbotanical lay people who mistakenly view 'fynbos' as a particular taxon or species.

In this book, we use the term 'fynbos' only for the vegetation type *sensu stricto*, and explicitly state when we are dealing with the biome or other classifications that incorporate the term.

1.3 Extent of the Fynbos Biome

The Fynbos Biome occupies most of the Cape Fold Belt (both north-south and east-west mountain chains and wetter valleys) as well as the adjacent lowlands between the mountains and the Atlantic Ocean in the west and south, and between the mountains and the Indian Ocean in the south. The northern boundary of the main biome area is delimited approximately by the Olifants River Valley north of Klawer and the Bokkeveld Plateau. However, a few patches extend as far north as Hondeklipbaai on the deep, red sands of the Namaqualand Sandveld, and there are also several patches at the highest altitudes (above approximately 1 100 m) of the Kamiesberg and Vandersterrberg in Namaqualand. The eastern borders of the Fynbos Biome are in the Albany region of the Eastern Cape, where grassy fynbos forms an intricate filigree with subtropical thicket units. The inland delimitation comprises relatively sharp boundaries with Succulent Karoo (see Chapter 18 in this book) approximating the Cape Fold Belt range, but outliers of the Roggeveld Escarpment tend to have broad ecotones. Within the biome, the Little Karoo and Robertson Karoo (supporting vegetation of the Succulent Karoo Biome) are large islands of arid bottomlands within the Cape Fold Belt.

Heathlands are not unique to the Fynbos Biome. Analogous evergreen, sclerophyllous shrublands extend as far as the Ethiopian highlands and even Madagascar, as ericaceous and proteaceous heathland and moorland. In South Africa these are found in patches from the Sneeuberg, Amathole and Drakensberg Mountains, with outliers in Korannaberg and near Nkandla, to the Northern Escarpment, Soutpansberg and Blouberg. Further north they occur at high altitudes in Chimanimani and Inyanga (Phipps & Goodier 1962, Van Wyk & Smith 2001) and East Africa (see Hedberg 1951). These heathlands and moorlands are now thought to be relicts of former wetter climatic periods and contain derived elements of Cape clades (e.g. *Ehrharta*: Verboom et al. 2003; *Protea*: Barraclough & Reeves 2005), rather than evidence of a northern origin for these elements.

1.4 Delimitation of the Fynbos Biome

The Fynbos Biome mainly borders the Succulent Karoo in the north and northeast and the Albany Thicket Biome in the east. The contact between the Fynbos Biome and Nama-Karoo is marginal (through FRs 3 and 5), as is the contact between the Fynbos Biome and Afrotemperate Forest Biome, especially its largest patch—the Knysna-Tsitsikamma forests. Only fynbos and renosterveld vegetation of the Fynbos Biome border on the neighbouring biomes, while strandveld is entirely contained within the Fynbos Biome and does not have any external boundary.

1.4.1 The Fynbos Biome/Afrotemperate Forest Boundary

Most of the fynbos—with the exception of the dry northern types and possible exception of dry asteraceous fynbos on sandstone and quartzite—is bioclimatically suitable for afrotemperate forest (Campbell 1985, Masson & Moll 1987, Manders 1990a, b, Manders & Richardson 1992, Manders et al. 1992). It is mainly the action of regular fire that excludes forest and allows fynbos to dominate the landscape (Figure 4.2). This is because trees are effectively excluded from fynbos by the slow growth rates due to the nutrient-poor soils and the relatively high fire-return intervals. Although most forest plant species are resprouters, they are unable to grow large enough to attain a tree form and reproduce before the next fire. In addition, seedling recruitment is of an inter-fire nature (not exclusively post-fire as is typical for fynbos) and appears to be tied to recycling nutrients within the litter layer, whereas in fynbos nutrients are volatilised or ashed by fire (Cowling & Holmes 1992b, Manders et al. 1992). Only one fynbos species regularly attains a tree form: *Protea nitida* (waboom), although trees exist among fire avoider species such as *Widdringtonia cederbergensis* and *W. schwarzii* in rocky outcrops, and *Leucadendron argenteum*

L. Mucina

Figure 4.2 Southern slopes of the Tsitsikamma Mountains (Groot River gorge north of Nature's Valley) recovering after a devastating fire. While the proteaceous and ericoid sandstone fynbos burned almost completely, patches of afrotemperate forest protected in deeper kloofs and in mesic subscarp positions were scorched only along the edges.

and species of *Virgilia* on the forest/fynbos interface. Even the waboom is confined to lower talus (richer) soils in fynbos and does not attain a tree form in denser vegetation or on poorer substrates. Other groups of trees found in communities of the Fynbos Biome are primary constituents of Cape thickets and riparian thickets well confined to fire-safe habitats (Campbell 1985). Forests are able to establish on richer soils, such as the shale bands of the Cedarberg Formation and shale soils, presumably because their faster growth allows them to establish a high fire-resistance together with low flammability of fuel (Cowling & Holmes 1992b).

Thus the 'true' (evergreen afrotemperate) forests are confined to large screes, deep kloofs and fire-safe zones protected by cliffs and scarps (see also Chapter 12 in this book). There is usually a sharp ecotone, often of the order of only metres in width, between fynbos and forest. The width of the boundary is determined by exposure to fire and the flammability of the vegetation in this zone. In the east, especially in the dissected coastal platform fire refugia driven by berg winds, the boundary is dominated by '*Virgilia divaricata* fynbos'. The fire-adapted shale-forest margin species (*Virgilia divaricata, V. oroboides*) should be considered a fynbos rather than forest element because of their fire-dominated recruitment dynamics and seed germination cues.

Renosterveld never adjoins afrotemperate forest as these habitats are too wet and support fynbos.

1.4.2 The Fynbos Biome/Succulent Karoo Biome Boundary

The interface between the Fynbos and the Succulent Karoo shrublands almost always occurs on sandstone and Tertiary sands in regions experiencing 200–300 mm of rainfall per year. Karoo replaces fynbos where the interplant spacing becomes too large to carry fire. This boundary is not only dynamic in terms of slope, relief, wind channels and fire-protected scarps, but also in that the two main plant protagonists can influence the boundary dynamics. Thus Restionaceae—the primary fire carriers in the fynbos—can carry hot fires into karroid areas, whereas, in the prolonged absence of fire, succulents may establish between the senescing fynbos plants and inhibit spread of fire (Cowling & Holmes 1992b).

It has been proposed that the boundary between Fynbos and Succulent Karoo is determined by the relative costs of evergreenness versus drought deciduousness and succulence, which is turn is determined by soil moisture (Miller 1982). In a review of this biome interface, Cowling et al. (1997) concluded that moisture availability rather than geology is the primary determinant of the Fynbos/Succulent Karoo boundary. In the Matjiesrivier Nature Reserve (MNR) of the eastern Cederberg the boundary can be predicted accurately based on geology and altitude alone: fynbos occurs on sandstone above 800 m (higher rainfall) and Succulent Karoo shrublands below 800 m (Lechmere-Oertel 1998, Lechmere-Oertel & Cowling 1999). In a small glasshouse experiment (Lechmere-Oertel 1998, Lechmere-Oertel & Cowling 2001) it was found that fynbos seedlings could not tolerate xeric conditions, whereas karoo shrub seedlings were able to grow successfully irrespective of moisture regime or soil type. Succulent Karoo vegetation therefore appears to be not limited by the environment, excluding the effects of fire, to the same extent as fynbos. Fire is very destructive in Succulent Karoo and prevents Succulent Karoo species from invading fynbos sites. However, karoo shrubs do not occur in fire-free fynbos habitats occupied by Cape thickets. Thus fire is excluded as an important factor and competition with fynbos excludes Karoo at the MNR. A small transplant experiment across the interface between Fynbos and Succulent Karoo on the Riviersonderend Mountains indicated that at least some karoo species may be limited in their distribution by fire and/or biotic interactions and not by the climate or geology. Here the boundary is determined by the fire-prone fynbos that is confined to sandstone (Agenbach et al. 2004; see also Chapter 3).

The Fynbos/Succulent Karoo boundary patterns are often complex in landscapes dominated by sandstone and quartzitic fynbos, where relief is a major indirect contributor to the boundary. But although the boundary may meander over the landscape, it is usually quite abrupt—in the order of metres. By contrast, in sand fynbos the boundary is often a broad zone of intermediate communities, dominated by *Willdenowia* or *Thamnochortus* stands that may extend over kilometres. Sharper boundaries occur in dune landscapes, but even gentle depressions, such as alongside river courses, can prevent fire and cause quite sharp transitions at a step in a slope.

In the northern extreme of FFd 1 Namaqualand Sand Fynbos, fynbos is not maintained by fire, but primarily by dune or other sand formations, and these communities extend to areas with rainfall below 200 mm rainfall per year on acid soils, presumably over shallow aquifers (A.G. Rebelo, personal observations).

Within fynbos, fire-free habitats may contain succulent vegetation rather than forest or Cape thickets, where the soils are skeletal such as on north-facing cliffs and extensive rock slabs (lithophytes), or in fire-safe enclaves within asteraceous fynbos. This interface is very poorly studied and it is not known whether the species in these patches are largely confined to fynbos or are merely islands of species common within Succulent Karoo vegetation. Some typical fynbos species (such as *Protea glabra*) are largely confined to these fire-free habitats.

Overgrazing, presumably by removing fuel, and thus influencing fire dynamics, can convert fynbos into a karoo shrubland, as observed at fence-line contrasts in the Kamiesberg (A.G. Rebelo, unpublished data).

There is very little area of contact between the Fynbos and the Nama-Karoo Biome (see Chapter 3). For the most part these biomes are separated by intervening areas of Succulent Karoo Biome or in the east by Albany Thicket.

Renosterveld occupies an intermediate zone on shale and alluvium between Fynbos and Succulent Karoo shrublands. The arid boundary between karoo and renosterveld has never been studied. Casual observations suggest that the boundary is plastic at between 250–300 mm, and that it is determined by the interplay between succulence and flammability of the vegetation. Therefore, like fynbos, the boundary between renosterveld and karoo is controlled by fire. This is supported by many apparently suitable habitats for renosterveld—such as southern slopes on small koppies, being karroid shrubland when they are too small or too isolated to carry fire (A.G. Rebelo, personal observations). Under exceptional conditions fire does penetrate well into neighbouring karoo shrublands, but this is rare.

1.4.3 The Fynbos Biome/Albany Thicket Biome Boundary

In regions with a considerable share of summer rainfall, Fynbos Biome communities often border on units of the Albany Thicket Biome. This can, for instance, be observed in the Little Karoo Basin, where AT 2 Gamka Thicket meets several arid fynbos units, in the Koega-Baviaanskloof-Grootrivier Mountains region where both AT 3 Groot Thicket and AT 4 Gamtoos Thicket are found bordering on grassy fynbos units. Further east, fynbos (notably FFq 6 Suurberg Quartzite Fynbos and FFh 10 Suurberg

Shale Fynbos) forms an intricate mosaic with core Albany Thicket units, dominated by either succulent shrubs or C_4 grasses (e.g. AT 9 Albany Coastal Belt and SVs 7 Bhisho Thornveld). Here grassy fynbos is replaced by grassland on drier, more inland, northern slopes, especially under lower-rainfall conditions. All factors describe lower moisture availability, suggesting that fynbos requires wetter conditions. This boundary, reflected by the increase in summer-growing C_4 grasses on the more fertile soils and summer-rainfall conditions, suggests that summer growth season temperature is the overriding factor (Cowling & Holmes 1992b). Southern slopes, with less of a summer growth season due to cooler, wetter conditions, may favour competitively superior Restionaceae, resulting in the formation of fynbos under wetter, coastal and higher-rainfall conditions. This would push the system from a near annual to a longer-rotation fire interval, allowing other fynbos species and communities to persist.

In the western part of the Fynbos/Albany Thicket contact (southern Cape and Little Karoo), experiencing a high share of winter rainfall, the border is determined by local geomorphology that controls runoff (soil moisture), exposure to desiccation (steep slopes) and fire movement. AT 1 Southern Cape Valley Thicket is limited to steep, highly exposed slopes and vertical cliffs in deep river canyons, characterised by skeletal, quickly desiccating soils and lack of fire. At AT 2 Gamka Thicket the boundary is determined by fire, although ultimately it is determined by moisture, except that the dynamics are governed more by the flammability of the constituent species as the vegetation does not become too sparse but too succulent to carry fire (Cowling & Holmes 1992b).

The boundary with the Albany Thicket vegetation units thus differs from that with the Succulent Karoo types in that at the Albany Thicket interface the role of fire is actively modified by the plant growth forms present. As a consequence, there is a marked area effect, not so readily observed at the Karoo interface. As most ignition events are caused by lightning, a certain minimum area is needed for fire to be frequent enough to maintain fynbos at the expense of encroaching thicket. Thus the occurrence of fynbos in the thicket-dominated landscapes is determined by the area of uninterrupted veld suitable for carrying regular fire. This produces characteristic patterns of fynbos extent on linear ranges (especially obvious in several quartzite fynbos types) that do not occur with Karoo. Where extensive areas of sandstone occur, fynbos dominates until aridity prevents fire from spreading, as in the case of Karoo. In many cases spekboom (*Portulacaria afra*) is the dominant plant on this margin.

It is not known if overgrazing, which preferentially removed succulent elements, might favour the encroachment of fynbos into thicket as might be expected—the reverse of the situation in the Karoo.

Renosterveld interfaces with the Albany Thicket Biome along the southern Cape coast, where AT 1 Southern Cape Valley Thicket is embedded within renosterveld units, in the Little Karoo Basin where AT 2 Gamka Thicket meets several renosterveld units, and where AT 3 Groot Thicket and AT 4 Gamtoos Thicket are found bordering on the renosterveld types east of Humansdorp.

On richer soils, renosterveld forms an intermediate zone between fynbos in the wetter areas and subtropical thicket on the arid interface. The boundary between the renosterveld/thicket contact is almost always determined by fire. Although thicket elements are prominent within renosterveld vegetation, the incidence of thicket stands within renosterveld becomes prominent east of Riversdale in FRs 14 Mossel Bay Shale Renosterveld, where the landscape is dissected and fire is unable to spread. Even in this vegetation type, thicket is largely confined to steeper slopes, gullies and outcrops, with renosterveld on the summits. Further east (east of the Kouga Mountains), renosterveld is confined to areas marginal to fynbos where fire is able to exclude thicket and maintain renosterveld. Where fire-prone fynbos does not occur adjacent to richer soils, renosterveld is unable to persist.

1.5 Global Position of the Fynbos Biome

The Fynbos Biome is a member of the global Mediterranean Biome, located on western shores of the continents of the world, at latitudes north (in the northern hemisphere) or south (in the southern hemisphere) of the arid (desert) belt associated with the horse latitudes around the Tropic of Cancer and the Tropic of Capricorn.

The global Mediterranean Biome consists of five geographically remote areas. In the southern hemisphere these areas include: (1) the Cape region housing the Fynbos Biome; (2) a small region in northern Chile, including the surrounds of Valparaiso and Santiago; (3) two separate regions in Australia, including the broad surrounds of Perth in southwestern Australia (also known as South-western Australian Botanical Province) and a smaller region in southeastern Australia (around Adelaide). The northern hemisphere portion includes: (4) the Mediterranean Basin along the coast of southern Europe, the Iberian Peninsula, North Africa, the Middle East, extensive regions in Iran, all Mediterranean islands and small outliers of the Canary Islands; and (5) the Californian Floristic Province (southwestern USA). All these regions are characterised by a mediterranean-type (warm-temperate) climate with warm, dry summers and cool, wet winters and support evergreen sclerophyllous shrublands as the dominant vegetation complex. In the Mediterranean, these are called *macchia* (*maquis*), *garrigue, phrygana, batha, matorral* and *tomillar*. In California they are called *chaparral*, while in Chile the local ecologists also use the Spanish term *matorral*. In Australia they are known as *kwongan* and *mallee*, while fynbos and renosterveld are well-established terms in South Africa (e.g. Di Castri & Mooney 1973, Di Castri et al. 1981, Specht & Moll 1983, Specht 1988, Cowling 1992, Arroyo et al. 1995b, Davis & Richardson 1995, Allen 1996, Cowling et al. 1996a, 1997, Rundel et al. 1998, Arianoutsou & Papanastasis 2004). Australia, South Africa and some regions of the Mediterranean have ecologically comparable nutrient-poor systems.

The flora of the regions have apparently very different evolutionary roots (Raven 1973, Axelrod 1975, Axelrod & Raven 1978, Raven & Axelrod 1978, Calsbeek et al. 2003, Linder 2003, Crisp et al. 2004), but a common set of ecological factors (predictable seasonal climate patterns and importance of fire) has produced a number of notable ecological convergences (Cowling et al. 1996a). The question of convergence (and nonconvergence) was the subject of a number of international meetings (Di Castri & Mooney 1973, Kruger et al. 1983), and subject to controversial discussions in the past and present (e.g. Schimper 1903, Specht 1969a, b, Parsons & Moldencke 1975, Cody & Mooney 1978, Cowling & Campbell 1980, Milewski & Bond 1982, Milewski 1983, Box 1987, Barbour & Minnich 1990, Herrera 1992, Cowling & Witkowski 1994, Arroyo et al. 1995a, Keeley & Bond 1997, Verdú et al. 2003, Cowling et al. 2005).

The mediterranean-climate regions cover less than 5% of the earth's surface, but contribute a disproportionably large number of species (about 20%) to the global flora of vascular plants (Cowling et al. 1996a). This floral richness as well as staggering local and regional endemism (for instance almost 70% in the

Fynbos) qualifies these regions as global hot spots (Mittermeier et al. 2000) and prime targets of conservation efforts.

2. Geography of the Fynbos Biome

2.1 Main Geological Patterns

The regions supporting the Fynbos Biome are a mosaic of various geological substrates—one of the major prerequisites for evolution of the remarkable diversity of taxa and vegetation types, making the Fynbos Biome one of the most fascinating botanical destinations. Sandstone, quartzite, granite, gneiss (marginally), shales and also young limestone sediments are the most prominent rocks of these regions (Figure 4.3).

Very prominent mountain chains mainly built of quartzite and sandstone peaks dominate the landscapes of the Fynbos Biome. These predominantly Cape Supergroup rocks are composed almost entirely of quartz and are thus extremely nutrient-poor. Locally, the Permo-Triassic mountain-building event that resulted in the folding of the Cape Supergroup varied greatly in intensity. For this reason, sandstones are found as flat-lying or gently dipping layers (e.g. Cape Peninsula and Cederberg) or as tightly folded, vertical and even overturned layers (e.g. the Langeberg and Swartberg ranges). Due to their extent and hard-wearing nature, these formations determine the morphology of the landscape in the Fynbos Biome.

The northernmost extent of the region of the Fynbos Biome is somewhat removed from the typical Cape Fold Belt-dominated geology of most of the biome. It is found in the Kamiesberg area, which has a basement of Mokolian gneisses formed during the Proterozoic. The Kamieskroon Gneiss and gneisses of the Stalhoek Complex as well as metasediments of the Bushmanland Group were metamorphosed during the Namaqua-Natal Orogeny to form this basement. These patterns as well as the Gariep Orogeny of the Namibian Erathem are discussed in Chapter 6 featuring South African deserts. The Gariep Orogeny was one of several Pan-African belts that resulted in the amalgamation of the Gondwana Supercontinent around 500 mya. In the Kamiesberg and the adjacent Knersvlakte, Vanrhynsdorp Group sediments overlie the older basement towards the southeast. These correlate with the Nama Group sediments, which were deposited in a basin adjacent to the Saldanian Orogeny, also of the Pan-African cycle.

The rocks of the Cape Supergroup have a Precambrian substratum that consists mostly of sedimentary rocks that were deformed and metamorphosed during mountain building in the Pan-African orogenic event. These include the metasedimentary Malmesbury Group of the southwestern Cape as well as the Kango Group of the southern Cape (which includes a considerable amount of limestone). These rocks formed in the oceans that surrounded the fragments of an earlier supercontinent, Rodinia, which rifted apart over 700 mya. These ocean basins were later to close again during the formation of Gondwana 500 mya, as continental plates were reorganised into this most recent supercontinent.

The orogenic activity that resulted from the convergence and eventual collision of the continents was accompanied by the intrusion of large plutons of granitic material into the Malmesbury metasediments. The granites and their host metasediments of this Saldanian Orogeny (as it is known in the southwestern and southern Cape) are exposed where the younger cover rocks have been eroded away. The rolling and often deeply weathered hills of the Swartland are composed of these metasediments. The granites around Saldanha, the Cape Peninsula, Paarl, Robertson and George are some of the more well known plutons of the Cape Granite Suite. These potassium-rich granites weather to form domes that are conspicuously different from the younger sandstone rocks that overlie them in many areas. Outcrops, such as at Lion's Head and Chapman's Peak on the Cape Peninsula, show that the granites and their host metasediments were exposed to erosion for a considerable period before the earliest Cape Supergroup sediments were deposited on top of them when sedimentation of these sandstones commenced in the Ordovician (see Compton 2004).

The Cape Supergroup has three important subdivisions, namely the Table Mountain, the Bokkeveld and the Witteberg Groups, and they remain remarkably distinct along the entire length of the Cape Fold Belt.

The older Table Mountain Group contains an extremely thick (1 550 m) package of rather homogenous quartzite known as the Peninsula Formation. Table Mountain, the type locality for this group, reveals most of the Peninsula Formation in a huge vertical section overlooking the city of Cape Town. These coarse sand packages formed in a high-energy environment (a wave-dominated delta) under the influence of a wet climate, with the result that the rocks are composed almost entirely of quartz grains. No other minerals less resistant to weathering survived the transport process. Terrestrial vegetation was still absent and thus erosion was much more pronounced in high-rainfall areas than it is today.

On top of the Peninsula Formation are the thin Cedarberg and Pakhuis Formations. These beds serve as fairly distinctive markers throughout the Cape Fold Belt, despite the fact that they are far more easily weathered than the quartzites above and below. They are distinctive because the vegetation that they host forms a green band that contrasts strongly to the bare outcrops of quartzite. The Cedarberg shale bands were formed in a deep-water environment of slow suspension settling of fine mud and organic material. The glaciogenic Pakhuis Formation was deposited on the Peninsula Formation and glacial pavements are still preserved at the top of these quartzites in some places.

The Nardouw Subgroup of the Table Mountain Group is another thick (500 m) package of quartzitic sandstone above the Cedarberg shales. It formed under similar conditions to the Peninsula Formation and is prominent above the Cedarberg shale bands today.

The Bokkeveld Group also consists of sandstones and shale, but differs from the Table Mountain Group in that the shale bands are much thicker and alternate with sandstone units. The greater proportion of shale leaves the Bokkeveld more susceptible to erosion and thus it commonly forms low-lying areas with low sandstone ridges. The area east of Caledon and north of Bredasdorp is fairly typical. Marine fossils, including trilobites and bivalves, are common in the lower part of this group of Devonian sediments.

Overlying the Bokkeveld is another more quartzite-rich Witteberg Group. These sediments were deposited towards the end of the Devonian and probably continued to be laid down during the Carboniferous. The central part of this group is mostly dominated by coarse clastic deposits including well-sorted sandstones, pebble-conglomerates and some siltstones. A prominent, light-coloured quartzite layer is distinctive in the Witteberg Mountains. Above and below this arenaceous (sandy) central part, the Witteberg Group are more argillaceous (shaly) sediments (Truswell 1970).

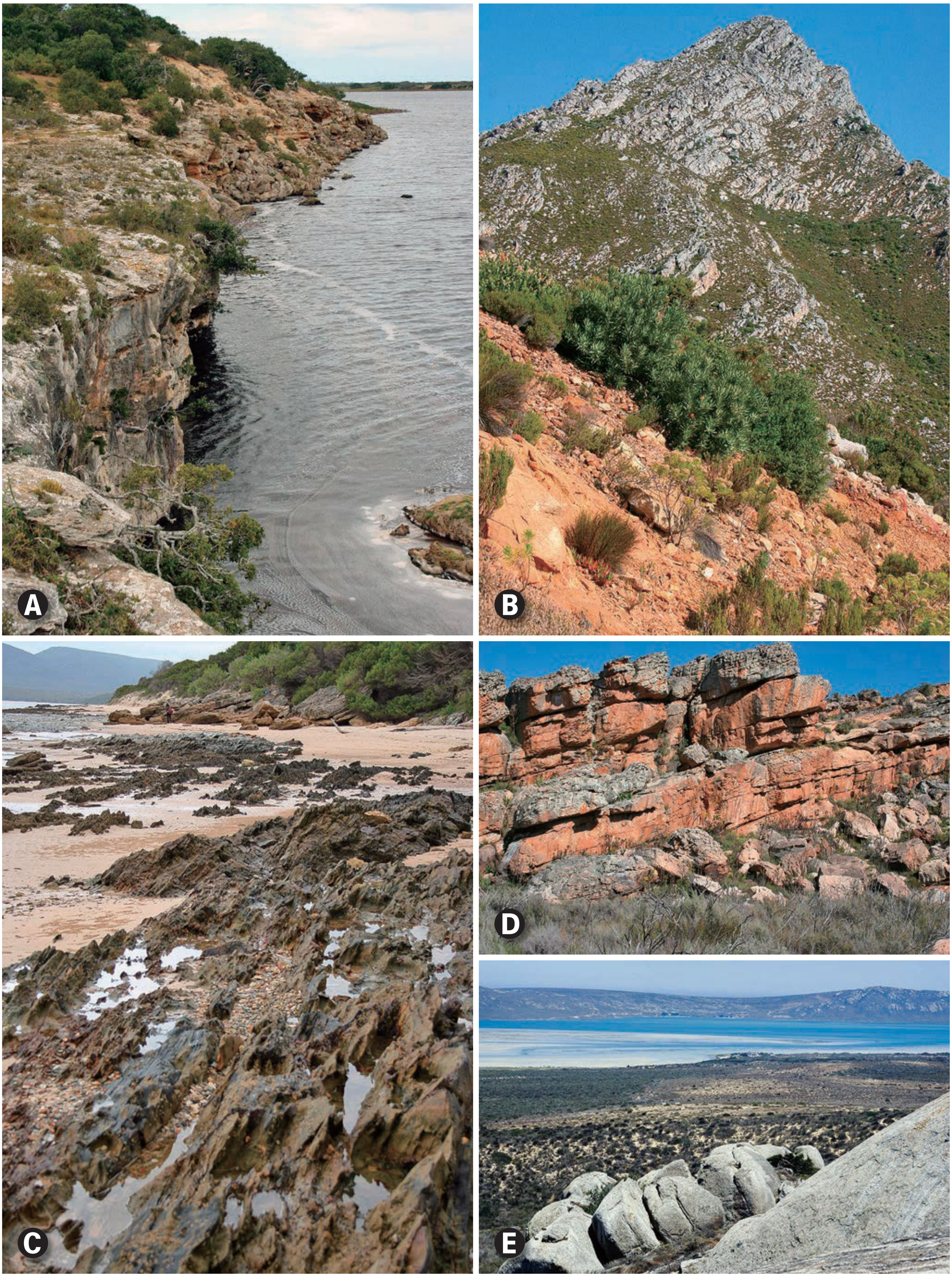


Figure 4.3 The geology of the Fynbos Biome is an important factor underlying the current diversity of the flora and the evolutionary diversification processes in the past. A: Tertiary limestone (De Hoop Vlei, Overberg); B: hard Ordovician Table Mountain Sandstone forms the dramatic peak and soft Cape Shale forms the shale band exposed by a road cutting (marine drive between Gordon's Bay and Rooiels); C: eroded Bokkeveld shales exposed on the seashore near the mouth of the Breede River (Witsand, Overberg); D: Nardouw sandstones of the Table Mountain Group (Op-die-Berg, Koue Bokkeveld); E: smooth topographic forms of a Cape Granite landscape (Langebaan Lagoon, West Coast). Photographs by L. Mucina.

Towards the end of Cape Supergroup sedimentation, Gondwana was taking up its position over the South Pole and the extensive glaciation that deposited the Dwyka Formation at the base of the Karoo Supergroup commenced. (The stratigraphy of the Karoo Basin is discussed in Chapter 8 on Grassland.)

The Cape Fold Belt is a remnant of the foreland fold and thrust belt of the Permo-Triassic Gondwanide Orogeny, formed when the Palaeo-Pacific Plate was subducted beneath southern Gondwana. Other fragments are preserved in South America, Antarctica and Australia (Trouw & De Wit 1999). Several phases of deformation in the Cape Fold Belt occurred from about 280 mya until around 220 mya (Hälbich et al. 1983).

The Cape Fold Belt has two branches that meet in the broad syntaxis domain that stretches from False Bay to Ceres and as far east as Montagu. In the western branch, which stretches to beyond Vanrhynsdorp, the large, gentle folds have a north-northwest strike and fade out towards the north and west. The southern branch has a distinct east-west orientation and experienced much more intense deformation. This branch is characterised by large, tight folds and overfolds as well as thrust faults. These structures verge towards the north and indicate a considerable crustal shortening in this area due to compression from the south (for further reading, see De Beer 1990). The Cape Fold Belt extends as far east as Port Alfred on the coast. Gondwana reconstructions show that the Falkland Islands were situated just to the east of this present-day coastline—they host the same sedimentary rocks.

During the Jurassic, Karoo sedimentation was brought to a close by the volcanic activity that formed the Drakensberg basalts. This period also saw the initiation of the rifting apart of Gondwana, which strongly influenced the geology of the south-western and southern parts of South Africa. The rifting event, which sculpted South Africa's coastline to its present form, also caused a horizontal extension that was manifested in large normal faults producing graben and half-graben structures.

The faulting produced marked changes in elevation that led to the rapid erosion of the high-lying areas. This produced the Enon conglomerates and the other clastic deposits of the Uitenhage Group that can be found in the Cretaceous sedimentary basins adjacent to the grabens. The faults displaced rocks vertically by several kilometres in some areas. The Worcester fault—with a 4–6 km displacement—is an example and red Enon conglomerates are spatially associated with it. Another example to the west of Port Elizabeth illustrates the juxtaposition of older, Namibian Erathem metasediments to the north of the fault, against (to the south) much younger Bokkeveld Group rocks that are partly covered by the Cretaceous erosion products. A similar outcrop pattern has developed near Oudtshoorn.

In the off-shore basins along the South Coast, the Cretaceous sediments host hydrocarbon reservoirs that are being exploited to a limited extent at present. These large, and numerous, faults are also responsible for preserving outcrops of Cape Supergroup quartzites as down-faulted blocks such as Table Mountain and the Cape Peninsula as well as Piketberg. This has preserved them from erosion, while adjacent higher-lying blocks have been eroded down to the pre-Cape basement.

In more recent times, rates of eustatic uplift together with global changes in sea level have influenced the erosion and sedimentation along the coastline as well as the incision of rivers into the Cape Fold Belt. Periods of high relative sea level have left recent deposits of sandstone and limestone on flat wave-cut platforms in many parts of the southwestern Cape. The Tertiary to Quaternary Bredasdorp and Strandveld Groups are examples. Times of low relative sea level have resulted in the down-cutting of rivers as is characteristic of the southern Cape, with streams occurring in deep incised valleys. Other evidence for this can be found on the off-shore Agulhas Bank across which former channels of the Gourits and Breede Rivers can be traced (Truswell 1970, p. 148).

2.2 Landscape Evolution

The West and South Coast lowlands, where most of the lowland renosterveld types are concentrated, have totally different erosion histories. While regions supporting West Coast renosterveld today have had kilometres of sediment removed since Gondwana started separating, erosion of the region of the South Coast renosterveld units has been relatively sedate.

The Witteberg quartzites, Bokkeveld shales and Table Mountain sandstones have been removed over the last 100 my on the West Coast, reducing the geology to the Malmesbury shales and Cape granites up to the Porterville fault. Only three inselbergs of sandstone (with Fynbos) remain on this plain—Piketberg, Riebeek-Kasteel and the Cape Peninsula. A few isolated pockets of silcrete and ferricrete remain, but they are not prominent. Adjacent to the Porterville fault, extensive alluvial fan deposits occur: these are typically covered with fynbos. The topography is relatively flat and low (80–200 m), although there are two elevated watersheds: (1) west of the Berg River comprising the granite hills of the Paarl Mountain, Paardeberg (with fynbos on the summits) and the shale hills of Kanonberg (370 m), Tontelberg (360 m) and Swartberg (480 m), and (2) the shale hills of Tygerberg (460 m), and the granite hills of the Bottelary Hills (480 m, mainly with fynbos), Dassenberg (570 m) and Darling Hills (450 m). North and east of the Berg River the only inselberg is Heuningberg (360 m, with fynbos on its northern end).

East of the Porterville fault, the Cape Group sandstones form a largely flat area—the Cederberg and Bokkeveld covered with fynbos vegetation types, with the exception of the Olifants River and Koue Bokkeveld synclines which are locally strongly down-curved bottomlands with young rocks. The area dips gently to the east, with younger sediments progressing eastwards: the Witteberg quartzites at Swartruggens, and finally the Karoo sediments in the Tanqua Karoo, where the Succulent Karoo Biome abuts the Fynbos Biome.

Over most of the South Coast and interior, only the Witteberg quartzites have been removed, so that the Bokkeveld shales form the bedrock, although in the eastern coastal part of the region even this has been removed. Shale renosterveld of the Rûens region—the largest continuous block of renosterveld—is characterised by undulated hills in the west and deeply dissected hills in the east, at a general elevation of 200–300 m. A single Witteberg quartzite inselberg remains at Riversdale. Extensive silcrete and ferricrete remain on higher areas, often forming flat-topped hills and scarps. Enon conglomerates form an apron along the Langeberg and Outeniqua Mountains—these usually support asteraceous and grassy fynbos, with limited patches of renosterveld. The southern margin adjacent to the coastal limestones is often covered with a thin layer of calcrete, but these areas have been transformed to cropland and their flora is largely unknown. During the Pleistocene glaciations, the Agulhas Plain extended 200 km south of its current range, a fair proportion of this would probably have been renosterveld.

Both the Langeberg and the Swartberg Mountains are major fault zones, the faults being several kilometres south of the current mountain scarp, exposing older rocks which are partly covered by Enon conglomerates deposited as the sandstone scarp retreated. These contain mainly fynbos vegetation. Between the Langeberg and Swartberg ranges the rocks are gently folded, giving rise to gentle mountains with fynbos where the sandstone is exposed and valleys with younger sediments and predominantly karoo and renosterveld vegetation. North of the Swartberg range, the Bokkeveld and Witteberg rocks are narrow ranges, but in the western Karoo these are also gently folded, giving rise to parallel scarps of resistant quartzites, with the Witteberg being the northernmost of these before being replaced by younger karoo sediments. Inland renosterveld occurs predominantly on Bokkeveld shales and on Witteberg shales between the quartzite scarps and ridges. Topography varies from subdued in the west, to valley basins in the east and ridges and scarps in the north.

2.3 Soils of the Fynbos Biome

A wide range of environmental conditions, such as present and past rainfall, parent material, terrain type and the age of different landscapes, resulted in the very large variation in soil types and soil associations that are characteristic of the Fynbos Biome (Lambrechts 1983, Schloms et al. 1983, Lambrechts & Fry 1988). Various developmental soil form sequences or catenae, based on topographic position, age, clay and iron content, drainage and/or soil depth, can be constructed for different combinations of environmental conditions (see Figures 4.4–4.7). However, parent material (i.e. the underlying rock type) or the nature of recent deposits, is probably the primary factor determining the physical and chemical nature of the different soil types. In the following paragraphs the dominant soil types (soil forms) associated with different combinations of parent materials are featured and their link to vegetation is discussed. For detailed description of the soil forms defined in the text, refer to the Soil Classification Working Group (1991).

2.3.1 Heavy-textured Soils

Shales and slates of the Malmesbury Group of the southwestern Cape, Kango Group of the southern Cape (including considerable amount of limestones), and of the Bokkeveld Group are less resistant to weathering than quartzites and sandstones of the Cape Supergroup. Due to their mineral composition these rocks give rise to soils that differ considerably from the quartzite-derived soils. These soils are usually heavy-textured, with large fine-sand and silt fractions, and show a much higher nutrient status, especially potassium. Three soil regions (relict erosional plains, coastal foreland and valley zones) can be distinguished on the basis of combinations of environmental conditions (Figure 4.4).

Among the upland plains, the Koue Bokkeveld and Elgin Basin are prime examples of old Tertiary erosion surfaces underlain by Bokkeveld shales. The terrain is undulating, with small remnants of the old land surface. On these remnants, deep red (Hutton form) or yellow-brown (Clovelly and Oakleaf forms), highly weathered, clayey soils occur, with varying amounts of ferruginous gravels and/or laterite. These soils are generally porous, well-drained, highly leached and acid, and rich in kaolinitic clays. Similar soils occur on remnants of lower erosional surfaces (at altitudes of approximately 200–350 m) along the foothills of mountain ranges such as Simonsberg and the Drakenstein Mountains (Figure 4.4). Shale fynbos is associated with these soils.

On younger dissected slopes, moderately to deep yellow apedal soils (Pinedene and Tukulu forms) developed on slope-creep

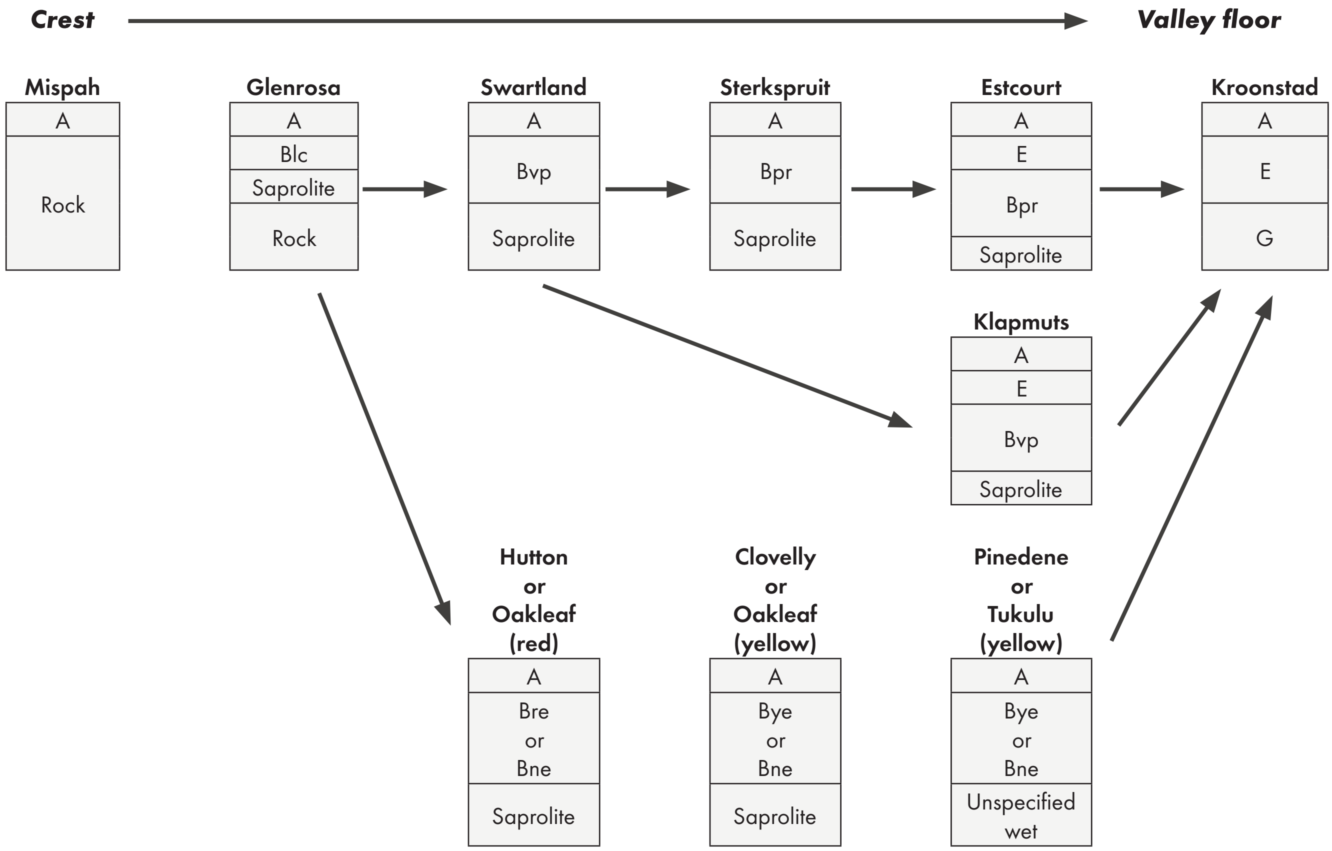


Figure 4.4 Heavy textured and duplex soils from shales, slates and granites. Abbreviations: A = orthic A-horizon; E = E-horizon; Blc = lithocutanic B-horizon; Bvp = pedocutanic B-horizon; Bpr = prismacutanic B-horizon; G = G-horizon; Bre = red apedal B-horizon; Bye = yellow-brown apedal B-horizon; Bnc = neocarbonate B-horizon.

materials from the upland plains; they are associated with soils from residually weathered shales and slates with thin gravelly colluvial surface layers. These yellow soils are generally less well-drained than the red soils. Due to the relatively high rainfall, the weathering of the underlying rock is moderate to high. On mid- and upper slopes the subsoils are clayey, moderate to strongly structured, with red and yellow geogenic mottling, and with a fairly low pH and base status. On lower concave slopes the subsoil becomes gleyed (wet and hydromorphic). The well-leached Pinedene and Tukulu forms are usually associated with shale fynbos or with renosterveld (on the less leached, residual soils).

Large areas of the western and southern coastal forelands and the inland valleys are underlain by shales and slates of the Malmesbury and Bokkeveld Groups. Depending on rainfall, terrain position and slope gradient, a series of progressively more developed soils occur from crest positions to the valley floor. In drier areas and steeper terrains shallow (lithosolic) soils of Mispah and Glenrosa forms are dominant. As the slope gradient deceases and/or the rainfall increases, clay migration and the formation of clay-enriched subsoils become prominent. On midslopes the dominant soils are of Swartland and Sterkspruit forms. Due to a higher degree of wetness as a result of lateral soil water movement, soils on lower slope positions are characterised by a bleached, pale-coloured E-horizon above a structured cutanic B (Klapmuts and Estcourt forms). In concave or level foothill positions the degree of wetness is such that a gleyed G-horizon (Kroonstad form) replaces the cutanic B-horizon. The soils with cutanic and G-horizons are collectively known as duplex soils because of the significant difference in clay content between the A/E and clay-enriched subsoil horizons. The difference in clay content is partially due to clay migration, but it is significantly enhanced by movement of surface soil material from upslope to lower slope positions through creep and slip and removal of the fine silt and clay from the material that develops into the A- and E-horizon. The lower the clay content of the A/E in a specific climatic zone, the lower the pH and base status. The typical vegetation type associated with these soils is shale renosterveld.

The pH and base of the lithosolic and duplex soils vary greatly as a function of prevailing climate. In warm, dry valleys (e.g. the Little Karoo and eastern Breede River Valley) the soils are normally base-saturated with a slightly acid to neutral pH. Free lime may be present as well. In more humid climate zones these soils are generally acid to very acid throughout the profile. It is the rainfall which largely determines the exchange characteristics of the soils. The very high cation exchange capacity values of the cutanic horizons in Caledon compared to those of Witzenberg, are an indication that the Caledon subsoils contain more 2:1 clay minerals and less kaolinite than those of Witzenberg. This might be an indication of greater shrink-swell and stronger structural development that negatively affects porosity, aeration and wetness. The low-rainfall soils are normally associated with the shale renosterveld and the high-rainfall soils with shale fynbos.

Duplex soils underlain by shales and slates are common in synclinal valleys such as the Langkloof and upper Olifants River Valley. Sandy colluvial material from the surrounding quartzite mountain slopes covers the residually weathered clays. The result is soils with a very sandy, pale-coloured A/E-horizon, periodically saturated with water, on gleyed, prismatic, clayey subsoils. Although the residual clay layers might be base-saturated and even saline, the sandy surface horizons are usually acid and base-unsaturated. These are usually covered with sand or sandstone fynbos.

Although granites are generally more resistant to weathering than shales and slates, granites have undergone deep weathering on old erosional surfaces. The granite hills near Darling (supporting granite renosterveld) and Paarl (supporting both fynbos and renosterveld on the crest and lower slopes, respectively), are some of the well-known plutons of the Cape Granite Suite exposed through erosion of the younger cover rocks. Due to resistance of granite, rock outcrops and very shallow soils of the Mispah and Glenrosa forms are dominant on the crest and upper slope positions on these low granite mountains. Where the slope becomes less steep with a straight slope gradient, soils of the Swartland and Sterkspruit forms, similar to those associated with shales and slates, start to develop. On level and concave slopes, soils of the Klapmuts, Estcourt and Kroonstad forms are found. Because of the coarse sand grade of the quartz particles in the weathering products from granite, sorting and removal of the fine soil fraction through creep and wash usually results in a coarse sandy overburden with low clay content. The coarse sandy overburden is highly permeable and leached, even under fairly low rainfall such as in the Kamiesberg Mountains, to form acid, low base-saturated A- and E-horizons. These support granite fynbos.

Heuweltjies are a major micro-relief feature in some units of both the West Coast, in FRs 8 Breede Shale Renosterveld, and of the South Coast, in FRs 11 Western Rûens Shale Renosterveld. These are generally raised mounds of soil, regularly spaced and up to 10–20 m in diameter and 5 m high. The density varies from almost continuous in the Piketberg area, to sparsely scattered. The name Tygerberg ('Leopard Mountain') is derived from the grass-dominated heuweltjie patches that turn yellow in summer. Heuweltjies are not confined to renosterveld: they are prominent in Succulent Karoo and even in Fynbos, where shale layers are within a few metres of the surface. They are particularly prominent in the winter-rainfall region (Lovegrove & Siegfried 1986, Knight et al. 1989). Heuweltjie soils are generally more base-rich, particularly in calcium, compared to the surrounding soils. In low-rainfall areas the subsoil is calcareous and soft or hardpan carbonate horizons and dorbank are common.

Heuweltjies have been attributed to various causes—geomorphic (heave mounds due to mineral accumulation) and biotic. Among the biotic contenders were mole rats *Cryptomys hottentotus* (differential deposition forming mounds in waterlogged areas) and plants (litter accumulation), but the current consensus is that they are (or were in some areas) the underground mounds of harvester termites (*Microhodotermes viator*; Lovegrove & Siegfried 1989). Floristically they are varied and may differ from surrounding communities by supporting predominantly annuals, grasses or thicket elements. These different communities are probably determined by rainfall and grazing pressure (Knight et al. 1989). In many areas, heuweltjies are preferentially used for burrows by aardvarks (*Orycteropus afer*), porcupines (*Hystrix africaeaustralis*) bat-eared foxes (*Otocyon megalotis*) and historically by many other species, and (in waterlogged seasons or when covered by thicket) as resting areas by herbivores, which may also play a role in their community dynamics. The significance of heuweltjies in renosterveld grazing and animal ecology is not known, but presumably harvester termites were, and continue to be, an important ecological component in renosterveld ecology.

2.3.2 Sandy Soils of Quartzitic Fold Ranges

Mountain Slope Soils

The hard, resistant Peninsula and Nardouw Formations and Witteberg sandstones and quartzites weather slowly and generally give rise to stony, very sandy soils (Figure 4.5) with a clay content of less than 5% and extremely low levels of free iron

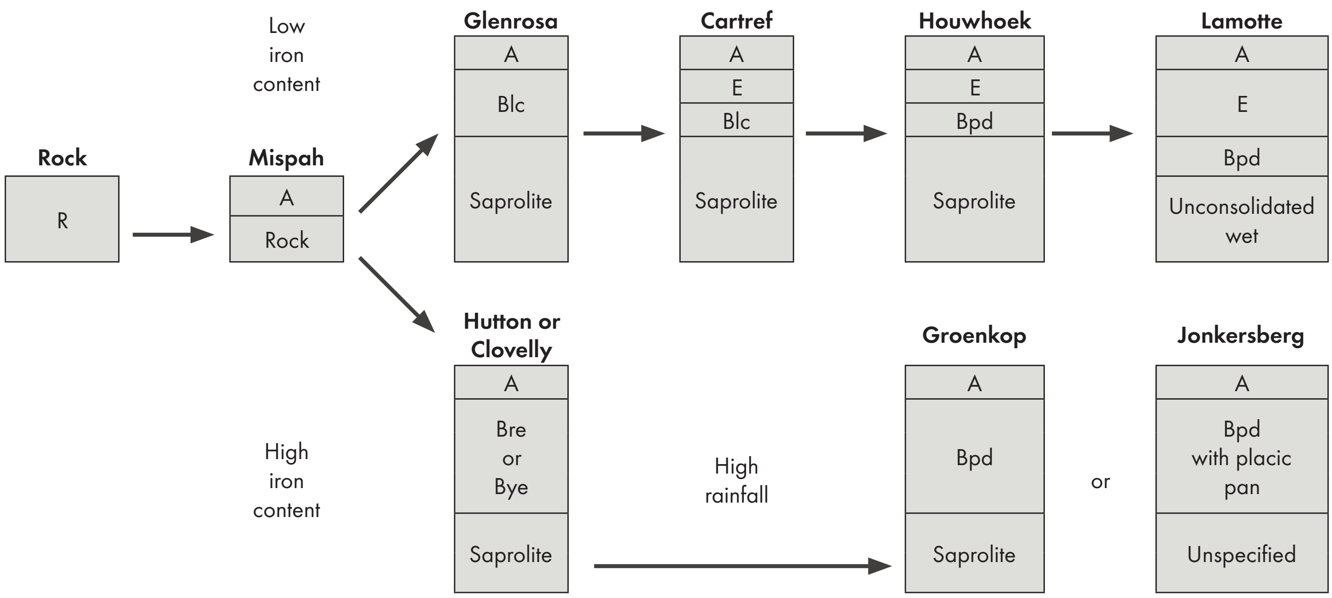


Figure 4.5 Mountain slope soils. Abbreviations: A = orthic A-horizon; E = E-horizon; Blc = lithocutanic B-horizon; Bre = red apedal B-horizon; Bye = yellow-brown apedal B-horizon; Bpd = podzol B-horizon.

oxides. On steeper slopes the weathering products are continuously removed by erosion and accumulate as pediment fan or talus slope materials of varying thickness and extent. On steep sloping mountain ridges, especially the northern slopes in the eastern zone, rock outcrops and very shallow soils predominate. Less steep slopes are generally characterised by pale-coloured, shallow sandy soils of the well-drained Mispah and Glenrosa forms. On more even and concave sites moderate to poorly drained Cartref and Houwhoek forms develop. In lower-lying positions with fairly thick accumulations of weathering products soils of the Lamotte form are found. In areas with a fairly high rainfall (e.g. George and Grabouw) the full range of soil forms from Mispah to Lamotte can occur. As rainfall decreases, soil forms with a podzol B become less prominent and may completely disappear in the relatively dry northern section. Although soils developed from quartzites and sandstones are generally acid, the degree of acidity increases with an increase in rainfall, especially in the podzol B-horizon. All the sandstone and quartzite fynbos vegetation units are associated with these soils.

The less quartzitic layers in the Table Mountain Group with more iron oxides weather faster than the pure quartzite and sandstones and produce a yellowish or reddish material with a higher clay content than the pure quartzites. On upslope positions these materials qualify as Hutton or Clovelly forms. Under high-rainfall conditions, soils with a podzol B without (Groenkop form) or with (Jonkersberg form) a placic pan directly under the orthic A, can develop. The dense and cemented placic pan has a very low permeability and results in localised wet spots in the landscape and restricts root penetration. The absence of an E-horizon is due to the higher clay and iron content that primarily retards the loss of organic carbon required for the soil to become bleached. The soils with a podzol B-horizon are usually extremely acid with pH values as low as 3.5–4.0, while soils of the Hutton and Clovelly forms in the drier regions are only moderately acid with pH values higher than 4.5.

The shale bands associated with the quartzites and sandstones are more weatherable and give rise to deeper, more heavily textured lithosolic soils and even soils of duplex form. Due to the fairly high rainfall in the high-elevation localities where the shale bands occur, these soils are moderately to highly leached with a low base saturation. These soils support shale fynbos, shale renosterveld or karoo vegetation. In many places, however, the weathered shale bands are covered with sandy colluvium from the higher-lying quartzites and sandstones, and carry sandstone fynbos communities.

Pediment and Valley Floor Soil

A great range of sandy soils, usually acid and highly leached, have developed from pedimented colluvial and alluvial accumulation products in intra- and intermountain valleys and on footslopes associated with quartzitic mountain ranges (Figure 4.6). Depending on the source material, the accumulation products vary in free iron oxide content. Sand fynbos is supported by these soils.

On iron-poor parent materials the initial upslope soils usually qualify as Oakleaf or Tukulu forms. With sufficient rain these soils become podzolised. The dominant soil form is Lamotte with a well-developed organic-rich B-horizon and rarely Concordia form with a poorly developed B-horizon. In these soils the E-horizon is usually very thick and the B-horizon might be as deep as 1.5 m. In wetter positions lower down the slopes, the podzol B usually disappears to form Fernwood soils.

In well-drained or drier areas with iron-rich, sandy parent material, yellow (Clovelly form) or red (Hutton form) soils usually develop in upslope positions. With an increase in rainfall or in lower positions, bleached A- and E-horizons develop through removal of iron oxides and, to a lesser extent, clay (Constantia form). In lower positions with a wetter water regime, typical podzolic soils develop with pale-coloured A/E-horizons on a dark reddish brown to yellow, iron- and humus-enriched alluvial B-horizon (Lamotte and Concordia soil forms). The main difference between these soils is that with more leaching in mid- and lower positions, the uniform clay content (5–7%) in the Constantia form differentiates into very sandy A- and E-horizons (<2% clay) and clay increases to up to 10% in the podzol B. The high organic carbon content in the podzol B acts as an absorption reservoir for exchangeable cations as well as

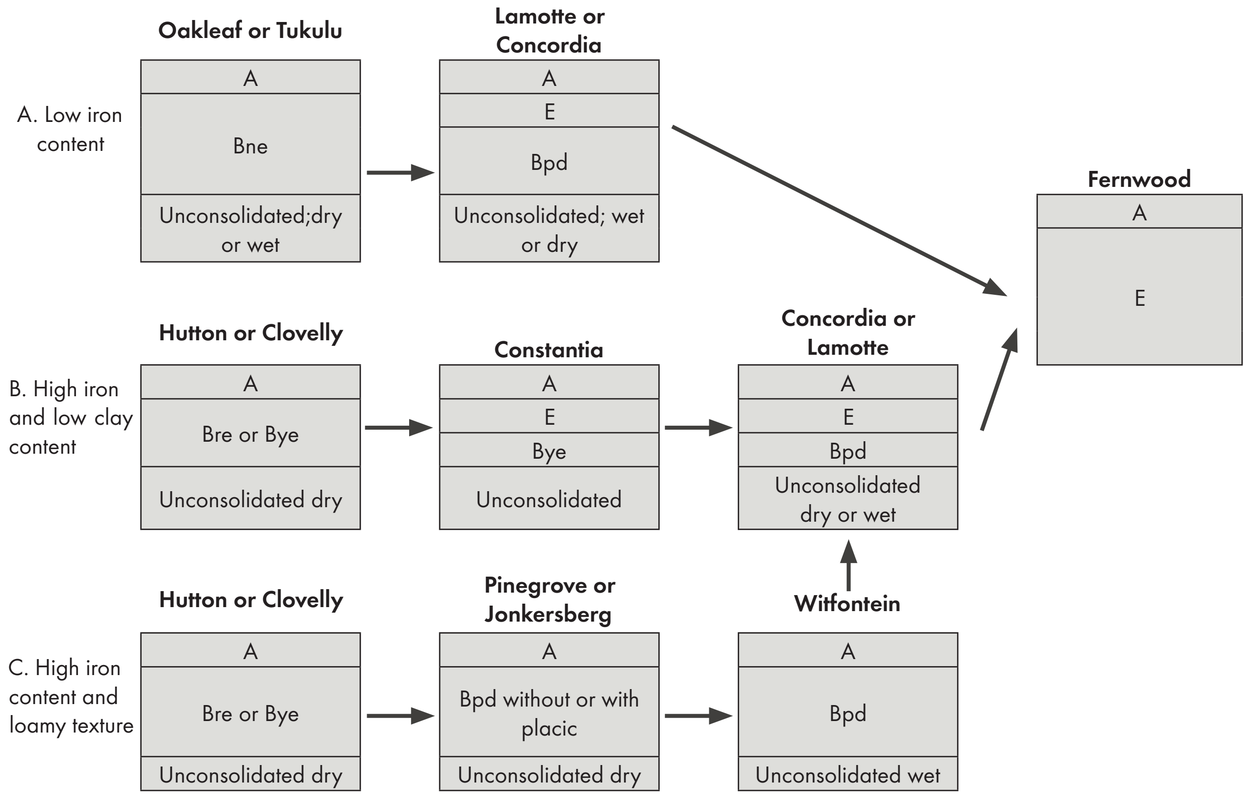


Figure 4.6 Pediment and valley floor soils. Abbreviations: A = orthic A-horizon; E = E-horizon; Bre = red apedal B-horizon; Bye = yellow-brown apedal B-horizon; Bpd = podzol B-horizon; Bnc = neocarbonate B-horizon.

trace elements. There is also a distinct decrease in base saturation at pH 7 from 50–70% in the Clovelly B to lower than 30% in the more leached Lamotte soils.

Although, morphologically, all the soils on the valley slopes appear to be well-drained, the Lamotte and Fernwood in particular may be subject to various degrees of wetness during the rainy season. One of the main causes may be the partially weathered base rock or residual or transported clays below the solum, giving rise to perched water tables. In the Lamotte form, wetness is sometimes manifested in a vesicular hardening (ortstein hardening) of the podzol B-horizon. Along the main drainage channels and depression areas the topsoil of the Lamotte and Fernwood forms is generally dark-coloured and poorly drained, with abnormally high accumulations of slightly decomposed organic material.

The well-drained red and yellow colluvium usually qualifies as soils of the Clovelly and Hutton forms. In midslope positions a podzol B-horizon without (Pinegrove form) or with (Jonkersberg form) a placic pan develops directly below the orthic A-horizon. In lower or concave slope positions that tend to be wet, soils of Witfontein form, similar to Pinegrove, develop on unconsolidated material, with signs of wetness. These soils are extremely acid with pH($CaCl_2$) values usually of < 4.0 and base saturation of ≤ 20% at pH 8. The carbon content in the topsoil ranges from 2.0% to as high as 4.5%.

2.3.3 *Coastal Plain Soils*

Young Dune Sands

Along the West Coast most of the soils (Figure 4.7) have developed from recent drift sands, locally overlying more clayey fluvial deposits or residually weathered clayey materials. Near the coast the sands are highly calcareous and stratified (Namib form). Inland the lime content gradually decreases through leaching. Depending on rainfall and the initial iron content of the recent sand, different combinations of soils could develop. With a low iron content the Namib form can change with age to Augrabies, Fernwood or Lamotte forms. With higher iron content the Fernwood is replaced by Hutton (drier and warmer areas) or Clovelly (wetter and cooler areas) forms. In the Vredendal area the shallower Hutton variants are classified as soils of the Garies form with relict duripans in the subsoil. With increase in age or rainfall, these soils can further change to Constantia and finally to a Lamotte form. The strandveld vegetation units occur on soils of the Namib and Augrabies forms while the sand fynbos is generally associated with other soil forms.

Scattered along the inland section of the West Coast are fairly large areas of red (Hutton form), yellow (Clovelly form) or grey (Fernwood form) aeolian windblown deposits. These soils are older versions of the younger soils that occur closer to the coast and support sand fynbos.

Especially along the northern section of the West Coast with a fairly low annual rainfall (115 mm) the Hutton, Garies and Clovelly sequence of soils is relatively poorly leached, with neutral to slightly acid pH, base-rich especially in the topsoil, with high concentrations of exchangeable magnesium. Although there is a slight decrease in pH and base status from the Hutton to the Clovelly, soils of the Clovelly form are far less leached than similarly textured Clovelly soils near Knysna. The two main reasons for this difference are the difference in rainfall and the salty sea mist which is common along the West Coast. Soils of the Fernwood and Clovelly forms in the Redelinghuys area with an average annual rainfall of 250 mm are extremely acid (pH of < 4.5) with a low base status.

In localities where the sand cover over the more clayey underlying materials is relatively thin, duplex soils (e.g. Estcourt and Kroonstad forms) support renosterveld.

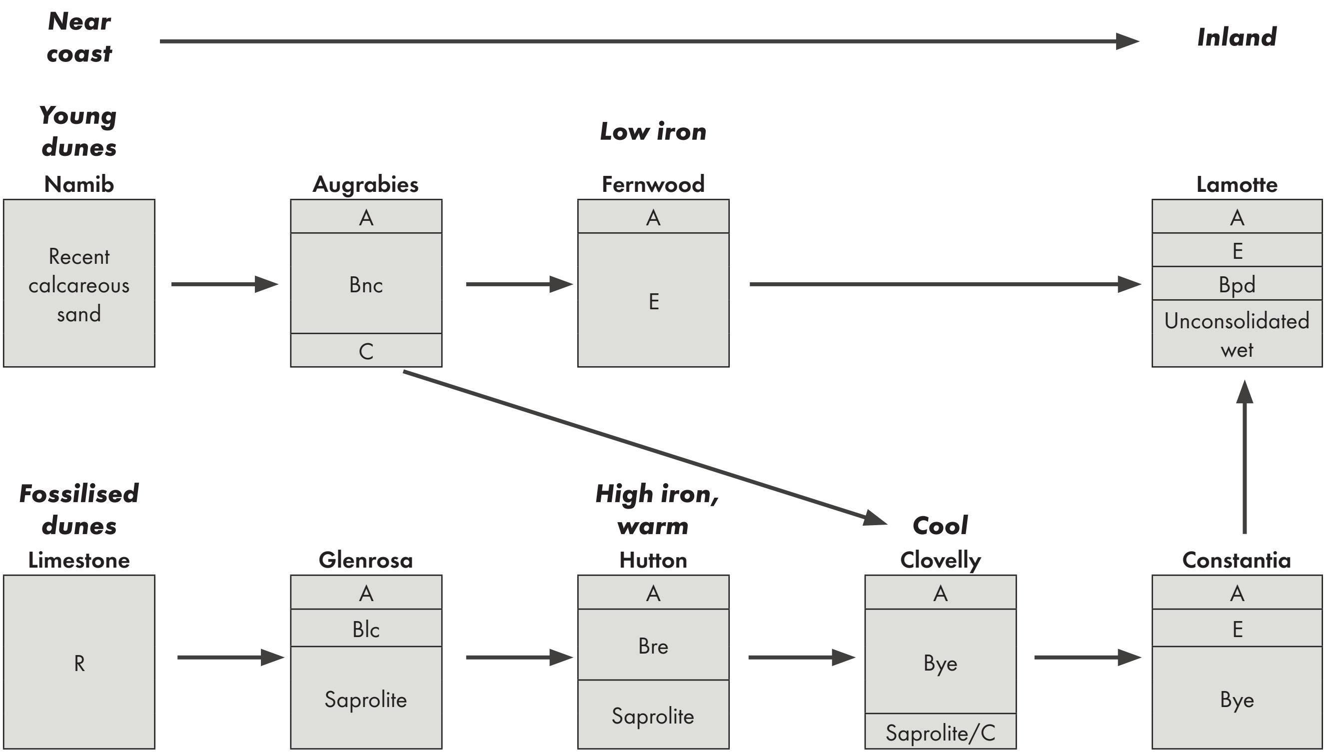


Figure 4.7 Coastal plain soils. Abbreviations: A = orthic A-horizon; E = E-horizon; Blc = lithocutanic B-horizon; Bre = red apedal B-horizon; Bye = yellow-brown apedal B-horizon; Bpd = podzol B-horizon; Bnc = neocarbonate B-horizon.

Fossilised Dunes

In many areas along the West and South Coast old dunes have become fossilised to form lime-rich aeolinites, usually with a thin, hard laminar capping. These aeolinites weather relatively rapidly. Initially shallow soils of the Coega and Glenrosa forms develop from the aeolinites. With age or with increased rainfall, yellow apedal soils (Clovelly form) develop, which with time can develop a bleached E-horizon without (Constantia form) or with (Lamotte form) a podzol B. In warm, dry areas and iron-rich limestone even red apedal soils may develop (Hutton form). The soils of the Coega and Glenrosa forms associated with aeolinites contain free lime and are base-saturated with alkaline pH values. Calcium is the dominant exchangeable cation. Many of these soils contain high levels of extractable phosphorous but it is unavailable to plants due to the formation of water-insoluble calcium phosphates. These soils support strandveld on the West Coast and limestone fynbos on the South Coast.

An interesting weathering feature in the fossilised dune sands and locally in recent dune sands (e.g. Bredasdorp and Knysna) is that the weathering front is not concordant to the soil surface, but has tongue-like extensions resulting in potholes. On the Bredasdorp coastal plain round pockets of moderately to highly leached, usually acid soils of the Clovelly and Constantia forms are found in a predominantly very shallow Coega and Glenrosa soil landscape. This irregular weathering pattern is probably associated with preferential weathering and leaching along roots of deep-rooted perennial shrubs of the local limestone fynbos.

2.3.4 Soils Associated with Silcrete and Ferricrete

Silcrete (supporting silcrete fynbos) and ferricrete (supporting ferricrete fynbos) are respectively silica- and iron-cemented hardpans. Silcrete probably developed during the Miocene and Pliocene in sandy/gravelly quartz-rich, lower-slope surface deposits overlying saline and/or alkaline clays throughout the western and southern forelands. As a result of the high pH in the clays, silica becomes soluble. Through capillary rise the silica-containing groundwater moves up in the profile and silica precipitates and cements on drying (Smale 1973).

Ferricrete develops on old lower slopes with a fluctuating water table. Due to hydromorphic conditions iron is reduced in the permanently saturated zone and moves into the nonreduced overlying zone with a rise of the water table. On drying and lowering of the water table, the reduced iron becomes oxidised and precipitates as iron oxides in the zone of water fluctuation. If this process continues long enough, it forms a continuous, indurate iron pan through the cementation of the individual soil particles (Alexander & Cady 1962). Ferricretisation is ongoing in sandy soils with fluctuating water tables. Ferricretes occur where the sand has been eroded and the iron pan exposed.

Due to a drop in sea level during the Pliocene and later, the coastal foreland was subjected to intense dissection and erosion of the weathered surface material (Hendey 1983a). Today, as a result of their hardness and resistance to weathering, silcrete, in particular, and ferricrete occur as remnants of spatially more extensive hardpans, usually on crests and upper slopes. On exposure, silcrete weathers slowly to produce a quartz-rich, sandy surface layer. Depending on the thickness of the sandy layer and the degree of breakdown of the underlying silcrete, Mispah and Glenrosa soil forms occur. As a result of the sandy and quartzitic nature of the weathering products, these soils are generally acid and base-unsaturated, even under conditions of relatively low rainfall. Ferricrete weathers faster than silcrete. The depth of weathered material can range from less than 40 cm to as deep as 1 m with an increase in rainfall. A variety of soils can develop in the weathered material, including Wasbank, Glencoe and a variety of podzol soils with and without E-horizons. Because these soils have undergone two cycles of soil formation, the clay content is generally low and the soils are highly leached, with low pH.

2.3.5 Other Soils

Many floodplains of the rivers in the Fynbos Biome with surrounding quartzitic and sandstone mountains are covered with deep sandy alluvium. Soils of the Dundee form are found on the youngest alluvium. Depending on iron content, the older alluvium away from the river may develop into a variety of soil forms that may include sandy, apedal yellow (Clovelly and Pinedene) or grey (Oakleaf and Tukulu) soils. Under conditions of relatively high rainfall pale-coloured soils of the Fernwood form and podzolic soils can also develop. These soils are generally acid with a low base status and are characterised by either alluvial fynbos or alluvial renosterveld.

Near Nieuwoudtville and on the Hantam Plateau basic igneous dolerite rocks occur. Dolerite weathers on relatively level land surfaces to form moderately deep, red, swelling clays (Arcadia form). On sloping, steeper land surfaces the depth of weathering is restricted, and shallow soils of the Glenrosa and Hutton forms develop. Due to the fairly low rainfall in the doleritic areas the soils are base-saturated, with a neutral pH. The heavy clayey dolerite-derived soils typically support dolerite renosterveld.

2.4 Current Climatic Patterns

2.4.1 Megaclimatic Framework

The macroclimates of the two African mediterranean-type ecosystems (the North African portion of the Mediterranean and the Fynbos Biome), show symmetric features (Goudie 1996). The summers in both regions are hot and dry, a result of the poleward migration of high-pressure (anticyclonic) Hadley Cells. In the Cape region the Hadley Cell offshore of southern Africa is located near 32° S in winter, while in summer it is centred near 37° S. The hot summers are associated with a high frequency of trade-winds (the Southeaster). In winter the region is under the influence of the westerlies and their associated disturbances (see Tyson 1986 for a detailed account). In the Cape region the major climatic feature in winter is the occurrence of cyclonic fronts and their associated northwesterly winds, bringing abundant rain. The influence of the winter rainfall, diminishes to the east, where the relative contribution of equatorial air is associated with summer rainfall (see Section 2.1 in Chapter 9 on Savanna on the origins and dynamics of the summer-rainfall regime in the eastern part of southern Africa). Especially in spring and autumn southerly winds bring orographic rain to the south-facing coastal mountains lying south of 33° S and east of 20° E—this is associated with frontal systems that pass south of the continent. As a result, the climatic stations to the east of this show a bimodal rainfall pattern (Allen 1996).

It is presumed that the mediterranean-type climate became established in the Cape at the end of the Pliocene, about 3 mya when the Hadley Cell was located above the South Atlantic Ocean and assumed a relatively fixed position relative to southern Africa (Hendey 1983b, Deacon et al. 1992, Allen 1996). However, there is evidence that the Antarctic circumpolar current and the onset of mediterranean-type climates may have been initiated as early as 33 mya (Scher & Martin 2006).

2.4.2 Regional and Local Climate

Mean annual precipitation (MAP) averaged over the total area of the Fynbos Biome is about 480 mm. This is highest for the fynbos (FF units) at about 540 mm, followed by 370 mm for renosterveld (FR units), and 350 mm for strandveld (FS units). These and some other modelled (nonstation) data below (Schulze 1997a) can be regarded only as approximate, especially with the great topographical diversity in the fynbos region and few confirmatory weather stations on the mountains. MAP is lower on the lowlands of the coastal belt (especially west of Mossel Bay), increasing to much higher values on the mountains nearer the coast, but lower on isolated fynbos island mountains in the Karoo of the interior. Thus, for example, the rainfall on the coastal belt in the vicinity of Herold's Bay increases greatly on the first mountain range of the Outeniqua and remains greater than the rainfall on the inland Groot Swartberg range despite the higher altitude of the latter (Figure 4.8). The lowest MAP is found along the northern parts of the western coastal plain, with a minimum of roughly 100 mm for the FFd 1 Namaqualand Sand Fynbos. The highest MAP averaged over the vegetation unit is found in FFs 30 Western Altimontane Sandstone Fynbos and FFs 11 Kogelberg Sandstone Fynbos (both with MAP over 1 300 mm). The station with the highest measured MAP (3 190 mm at an altitude of 1 219 m at Jonkersnek, Jonkershoek) in South Africa is in Kogelberg Sandstone Fynbos. Of all the vegetation types in the whole mapping area (South Africa, Lesotho and Swaziland), MAP most closely approaches equality with mean annual potential evaporation (MAPE) in Kogelberg Sandstone Fynbos (91% of MAPE) and Western Altimontane Sandstone Fynbos (87% of MAPE).

In all the seven north-south pairs of vegetation units on the generally east-west-trending mountain ranges from the Klein Swartberg, Kammanassie and Outeniqua Mountains in the east to the Hex River and Riviersonderend Mountains in the west, MAP is consistently higher in the respective southern unit when compared to that of its northern counterpart. For example, MAP in the FFs 19 South Outeniqua Sandstone Fynbos is more than 50% greater than that in the FFs 18 North Outeniqua Sandstone Fynbos (see also Figure 4.8). There are also large differences in solar radiation between southern and northern slopes in winter. In this season, north-facing slopes of 20° receive three to five times as much energy than equivalent slopes facing south (Fuggle & Ashton 1979). In summer, the solar energy received daily differs little between north- and south-facing slopes of less than 30°.

Coefficient of variation of annual precipitation varies from < 20% on many of the main mountains in the southwest and south of the biome to > 35% in the northern parts of the western coastal belt.

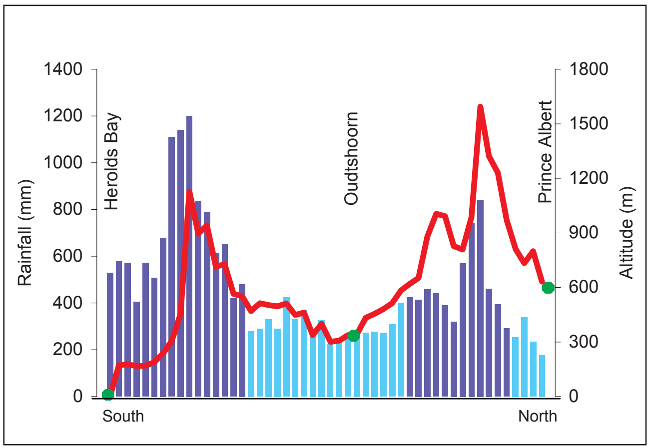


Figure 4.8 Mean annual rainfall along a south–north altitudinal gradient from Herold's Bay on the coast, across the Outeniqua and Swartberg Mountains to Prince Albert, via the Oudtshoorn basin. Dark blue bars represent rainfall in areas in the Fynbos Biome and light blue bars rainfall in karroid and thicket areas. The red line represents altitude above sea level. Green dots represent towns.

The Fynbos Biome has a wide variation in seasonality of precipitation (Figure 4.9). Most of the biome receives either winter or even rainfall (according to definition of Bailey 1979). The area of 'strong winter rainfall' is limited to a section of the West Coast centred on Saldanha and St Helena Bays. However, some of the western parts of the 'winter rainfall' zone are marginal to 'strong winter'. The eastern boundary of the 'winter rainfall' zone extends roughly to the lower Breede River Valley and to the north includes the Roggeveld Escarpment and the Hantam Plateau area north of Calvinia. The 'even rainfall' zone includes much of the southern Cape as well as the renosterveld areas along the Nuweveld Escarpment. Some of the easternmost islands of fynbos, including several vegetation types of the biome (e.g. on the Grootrivierberge and Klein-Winterhoekberge) in the Eastern Cape, lie marginally in the 'summer rainfall' zone.

As a consequence of the winter concentration of rainfall in the west, the solar radiation for winter in the southwestern part of the biome is lower than elsewhere and at any other time of year in South Africa (< 12 $MJ.m^2.day^{-1}$ in July from Saldanha Bay to Cape Agulhas).

Cloud cover on the higher mountains is frequent in the west in the dry summer and driven by strong winds, and occurs predominantly on the summits and southern and southeastern slopes. Over 500 mm of water may be precipitated per year from wet stratus cloud without being recorded in standard rain gauges (Fuggle & Ashton 1979). Schulze (1997b) reports more than 600 mm per annum of orographically induced moisture from fog (not recorded by standard gauges) in the Jonkershoek Mountains near Stellenbosch.

Snowfalls occur on the higher mountains of the southwestern parts of the Western Cape, with a frequency estimated at 5.4 falls per year and peaking in late July (Schulze 1965). The snowline is very seldom seen below an altitude of 1 000 m. Snowdrifts of more than one metre deep can occur on high plateaus such as Fonteintjiesberg (1 989 m) in the Hex River Mountains, with snow cover sometimes persisting for two weeks or more. Snowfalls can occur here into early summer (December). There is anecdotal evidence that the duration of persisting snow has declined over the entire region over the past few decades.

Relative humidity is highest (> 70%) along the coast in summer but with high values also extending inland in winter, especially on the mountains.

Temperatures are generally the lowest on the high mountains (mean annual temperatures of less than 12°C) and higher in the lowlands and tend to be the highest near low-lying parts of the Karoo (mean annual temperatures greater than 19°C), but more ameliorated near the coast with mean annual temperatures closer to 16°C.

The lowlands near the coast are generally frost-free. However, frost does occur on higher-lying regions and towards the interior. Thus, for example, the average number of days with heavy frost (screen minimum temperature < 0°C) is 0.3 for Paarl, 3 for Riversdale, 12 for Grabouw, 14 for Ceres and 93 for Sutherland.

Temperature data for the mountains are limited. On the summit of Table Mountain (Cableway) at an altitude of 1 067 m, mean monthly maximum and minimum temperatures are 30.3°C and –0.2°C for January and July, respectively. To estimate the likely temperatures on two of the highest peaks in the Fynbos Biome, namely Matroosberg, Hex River Mountains (altitude of 2 249 m), and Seweweekspoort Peak, Klein Swartberg range (altitude of 2 325 m), we applied seasonal temperature lapse rates calculated for mountains of the southwestern Cape and separately for the southern Cape (Schulze 1965) to nearby weather stations (Matroosberg–Helpmekaar and Amalienstein, respectively). Mean monthly maximum and minimum temperatures approximate 28.7°C and –8.9°C for the summit of Matroosberg and 30.1°C and –12.2°C for the summit of Seweweekspoort Peak for January and July, respectively.

One of the highest temperatures ever measured (46.1°C) in the biome was in January at a low altitude near the karroid edge of the biome at Clanwilliam. This absolute figure compares with a mean monthly maximum temperature of 44.1°C and a mean daily maximum temperature of 35.4°C for the same station and

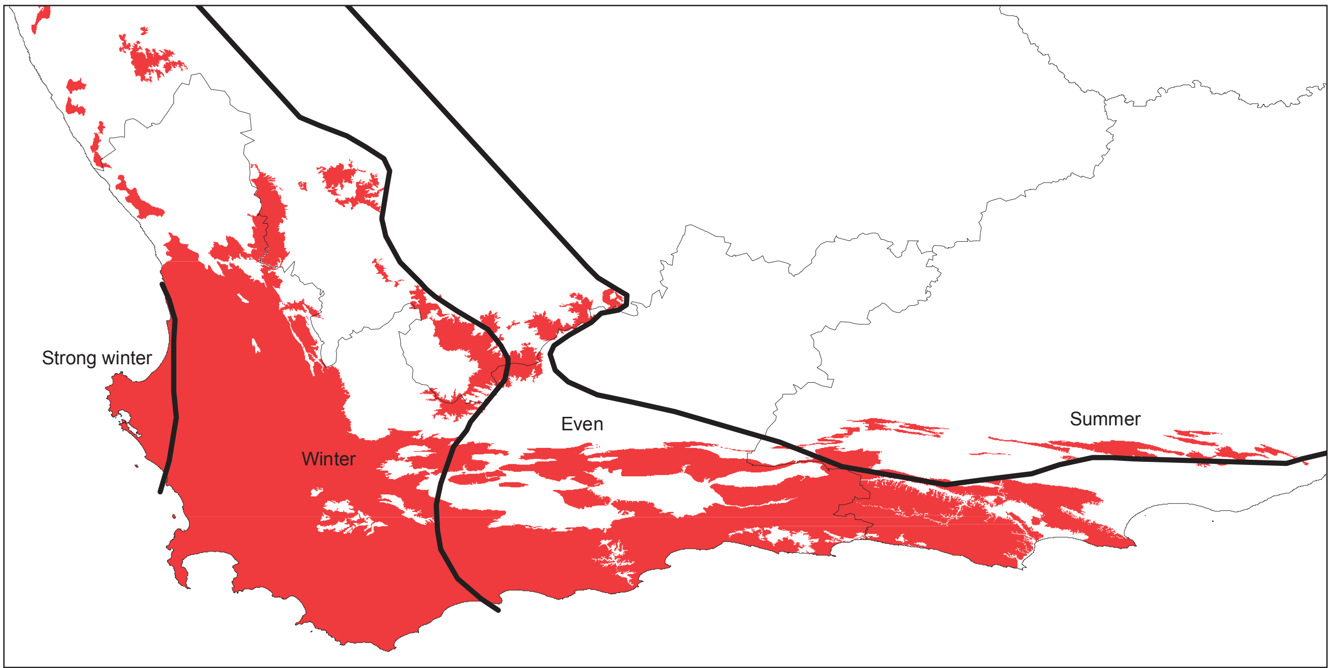


Figure 4.9 Classes of rainfall seasonality for the Fynbos Biome (shown in red) using mean winter rainfall (April to September) as a percentage of mean annual rainfall (after Bailey 1979). Rainfall data were interpolated from rainfall station data. Strong winter (80% and over), winter (60–79%), even (40–59%), summer (20–39%); strong summer (0–19%) is not encountered in the Fynbos Biome.

Figure 4.10 Blanket of fog created by the ascending moisture-laden 'Southeaster' (trade winds) blowing over the Kogelberg (Western Cape).

month. Even well within the biome there are also some areas of high summer temperature. Wellington–MUN recorded an absolute temperature of 45.6°C in January. This figure compares with a mean monthly maximum temperature of 38.5°C and a mean daily maximum temperature of 31.2°C for the same station and month.

Mean annual potential evaporation on the lowlands of the coastal belt south of the Riviersonderend–Langeberg Mountains is < 2 000 mm, dropping to < 1 800 mm and in parts even < 1 600 mm south of the Outeniqua and Tsitsikamma Mountains. By contrast, the lowlands north of False Bay have a higher mean annual potential evaporation, i.e. greater than 2 000 mm, increasing to more than 2 200 mm north of Malmesbury and to greater than 2 400 mm in the Olifants River Valley, the coastal belt of Namaqualand and the Roggeveld Escarpment. Values on the higher mountains close to the coast are below 1 400 mm.

Fuggle & Ashton (1979) provide a useful summary of the occurrence of wind in the Fynbos Biome. The region's entire coastal belt is characterised by strong winds. Summer winds are dominantly southeasterly to southerly, usually picking up in midmorning and reaching greatest strength in the evening, although often persisting at gale force for days. They are responsible for the orographic summer mist precipitation and the associated 'Table Cloth' and 'Hottentot's Blanket' on the mountains (Figure 4.10). Winter winds dominate from the northwest (prefrontal) and southwest (postfrontal). Sea breezes exert an influence when gradient winds are light, appearing as shallow northwesterly to westerly air drifts along the Atlantic coast but as shallow southeasterly flows on the South Coast. In summer the sea breeze over False Bay reinforces the southerly gradient winds, giving rise to maximum wind velocities in the early afternoon. Land breezes do not occur in the southwestern part of the Western Cape due to the very low sea temperatures.

From Cape Hangklip eastwards a slight sea breeze influence is evident throughout the year, but prevailing winds are roughly easterly and westerly. The main difference between winter and summer winds east of Mossel Bay is the high frequency of easterly winds in summer (greater than 25%). The warm Agulhas Current off the coast provides a land-sea temperature gradient sufficient for land breezes to develop on calm, clear nights. Katabatic drainage down the major valleys cutting through the mountain ranges reinforces the land breeze, giving moderately strong offshore winds seaward of major valleys. In the interior there is much less wind than on the coast, the percentage of calms is higher and in the west a greater westerly component is evident in both summer and winter. In the eastern interior the prevailing winds are easterly to southeasterly in summer and northwesterly in winter.

The entire coastal belt is subject to occasional hot desiccating gusty winds (berg winds), especially in winter. These outbreaks of subsiding air heated by compression become more marked eastward along the coast. The wind blows at right angles to the coast and is responsible for temperature rises of over 10°C in just a few hours. They are associated with approaching low pressure systems and often precede frontal systems.

Wind speed can be high, especially in the west. In Cape Town (Wingfield), the wind speed exceeds 26 km per hour, almost half of the time in January (Schulze 1965). For around 20 hours of this month, wind speed exceeds 42 km per hour. Wind speed and frequency can be expected to be considerably higher on mountain tops.

Lightning frequency and hail are rare in the extreme western parts of the biome but increase eastwards. Yet even in the extreme eastern parts, lightning ground-flash densities remain below 2 flashes per km^2 per year (Schulze 1997a).

3. Vegetation Types of the Fynbos Biome

There are three major vegetation complexes within the Fynbos Biome—fynbos, renosterveld and strandveld—described below.

Embedded within the Fynbos Biome are edaphically specialised vegetation units of azonal nature (Table 4.1), such as those of coastal vegetation (see Chapter 14) or inland azonal vegetation, including freshwater wetlands and salt pans and alluvia (see Chapter 13). The remnants of the afrotemperate and coastal subtropical milkwood forests are of intrazonal nature and are described in Chapter 12.

3.1 Fynbos

Fynbos (derived from the Dutch 'fijn-bosch' and pronounced 'feinbos') means 'fine bush', with a Dutch connotation for 'kindling'—as opposed to fire-wood. It is an evergreen, fire-prone shrubland characterised by the presence of restios (wiry, evergreen graminoids of the Restionaceae), a high cover of ericoid shrubs (fine-leaved, principally in the families Ericaceae, Asteraceae, Rhamnaceae, Thymelaeaceae and Rutaceae), and the common occurrence of proteoid shrubs (exclusively Proteaceae). It is thus often considered a 'heathland', which it resembles in structure and function, but strictly only ericaceous fynbos is truly a heathland (Cowling et al. 1997). Other important features of fynbos are the presence of leaf spinescence, high sedge (Cyperaceae) cover and low grass cover in mature phases of some facies (Campbell 1985). Campbell (1985) ascribed the origin of the botanical use of the term 'fynbos' to

Table 4.1 Zonal, intrazonal and azonal vegetation units (or groups of units) within the Fynbos Biome. For the discussion on the concepts related to zonality see Chapter 13 on Inland Azonal Vegetation.

Vegetation unit	Extent (km²)	Zonality status
FF Fynbos	59281	zonal
FFq 1 Stinkfonteinberge Quartzite Fynbos	49	extrazonal [A]
FFd 1 Namaqualand Sand Fynbos	939	extrazonal [A]
FFg 1 Kamiesberg Granite Fynbos	36	extrazonal [A]
FR Renosterveld	27962	zonal
FRg 1 Namaqualand Granite Renosterveld	706	extrazonal [A]
FS Western Strandveld	3001	intrazonal
Cape Thicket[B]	unknown	intrazonal
F I1 Western Case Talus Forest[C] (part of FOz 1)[D]	unknown	intrazonal
F I2 Western Cape Afrotemperate Forest[C] (part of FOz 1) [D]	unknown	intrazonal
F I3 Southern Cape Afrotemperate Forest[C] (part of FOz 1) [D]	unknown	intrazonal [E]
F VII3 Western Cape Milkwood Forest[C] (part of FOz 7) [D]	unknown	intrazonal
AZf 1 Cape Lowland Freshwater Wetlands [G]	72	intrazonal/azonal [F]
AZa 1 Fynbos Riparian Vegetation [G]	17	intrazonal/azonal [F]
AZa 2 Cape Lowland Alluvial Vegetation [G]	358	intrazonal/azonal [F]
AZd 3 Cape Seashore Vegetation [H]	227	intrazonal/azonal [F]

A isolated patches outside the main Biome extent, embedded within other biome (Succulent Karoo)
B not mapped or classified due to very small extent and lack of data
C nomenclature and code as in Von Maltitz et al. (2003); see also Table 12.1 in this book
D codes FOz 1 and FOz 7 refer to the Forest zonal vegetation units (see Chapter 12 in this book)
E the isolated patches embedded within Fynbos Biome are intrazonal; the Knysna-Tsitsikamma forest region is the largest zonal remnant of the Afrotemperate Forest Biome in Southern Africa
F intrazonal on regional scale; azonal on continental scale
G featured in Chapter 13: Inland Azonal Vegetation
H featured in Chapter 14: Coastal Vegetation

Bews (1925), who applied it to fine-leaved shrublands of both the Cape and the Drakensberg.

We define 'fynbos' in structural terms pragmatically as a shrubland or restioland with a cover of more than 5% Restionaceae, usually containing elements of Ericaceae or other ericoid shrubs and Proteaceae. Ecologically it is naturally dominated by the effect of hot summer fires at intervals of 10–30 (or more extremely 5–50) years, which are fuelled by the fine-leaved shrubs and especially by the Restionaceae. Fynbos occurs mainly on nutrient-poor sandy soils, and less frequently on limestone, leached clay soils derived from shale and granite, and gravelly soils derived from duricrust outcrops and alluvial sediments.

3.1.1 Approaches to Typology of Fynbos

Classification of vegetation of the Cape Floristic Region has been, for descriptive vegetation scientists at least, a challenging and daunting task.

To date there have been six major classification attempts for vegetation in the Cape Floristic Region:

(1) Acocks's (1953, 1975, 1988) veld type scheme.

(2) Braun-Blanquet (floristic-sociological) approach, represented by Taylor, Boucher and their students.

(3) Moll and Bossi's large-scale units based on remote-sensing (Moll & Bossi 1983) and used by Low & Rebelo (1996).

(4) Campbell's (1985) structural classification.

(5) Cowling's Broad Habitat Unit classification (Cowling et al. 1999b, Cowling & Heijnis 2001).

(6) Our classification presented here.

The vegetation classifications of Acocks, Moll, Cowling and this chapter address biome-scale patterns, and are therefore well suited to national management and planning of natural resources. Acocks and Moll's schemes contain a small number of broad units and are thus less successful in summarising the diversity of vegetation in the Cape Floristic Region. The Broad Habitat Units (BHUs) and our vegetation types are far more detailed, and also mapped at a far finer scale. The BHUs are based on three basic sources: geology, climate and centres of endemism. Our approach uses the BHUs, but also includes important characters such as: (1) extensive use of floristic data in delimitation and calibration of the units, (2) differentiated weighting of the importance of geology and climate depending on the broad subcategory of the classified object, (3) application (albeit only to a limited extent) of the concepts of zonality in the unit delimitation, and (4) high-level of GIS precision of definition of boundaries by using more detailed (and precise) GIS sources—leading to a high level of detail recognisable down to 1:250 000 and in places even 1:50 000 scales.

Only the floristic-sociological and structural classifications did not produce a biome-wide map of the region, arguably as they focus at much smaller scales.

The Braun-Blanquet (or 'BB') approach, known as 'phytosociology' or 'phytocoenology' (Braun-Blanquet 1964, Westhoff & Van der Maarel 1978), became the most used method in Europe and was exported worldwide (Van der Maarel 1975). In South Africa this approach has been used in the Savanna and Grassland Biomes, but achieved less success in the Fynbos Biome, where it has been used locally in management plans of some conservation areas.

By addressing the vegetation complexity on habitat (or habitat complex) level, the floristic and structural approaches became a focus of controversy, which continues today (Linder & Campbell 1979, Campbell 1986c, Cowling & Holmes 1992b). The use of the BB approach was criticised (if not dismissed) in the Fynbos Biome because of the following flaws and difficulties:

(1) Floristic composition requires cover classes but fynbos takes 8–15 years to mature, during which the species canopy cover changes dramatically. In fact, seral stages recapitulate the fynbos series (see below). Thus, at any one time, a large proportion of fynbos vegetation may be too young for sampling.

(2) The composition of many communities is determined by fire (intensity, season, frequency, veld age, past fire history, lottery recruitment from seed banks following fire), and thus the same community may vary in species composition and abundance between fires. This results in different community classifications for the same site.

(3) As a consequence of focusing on mature communities, fire ephemerals and geophytes are not routinely recorded or included into community descriptions. Phytosociological data do not exist for young fynbos, and it is not known whether the community patterns for young communities reflect or are independent of mature fynbos. Data do not even exist as to which communities have markedly distinctive post-fire communities. Some communities have a dominant and high-cover early seral community (usually Asteraceae or Fabaceae), which is completely absent in mature veld, whereas other communities merely change by overtopping of later seral species without much loss of early seral cover. The dynamics of these community changes are unexplored.

(4) We do not understand the geophytic and spring annual communities. These are routinely excluded from phytosociological surveys as they effectively restrict sampling to two or three months of the year. There is some evidence that geophytes are not as geologically restricted in their distributions as many shrubs (phanerophytes). This affects patterns of endemism, with surprisingly many renosterveld geophytes also present in fynbos on sandstone substrates and thus crossing many shrub-based community boundaries, a rare occurrence in shrubs.

(5) The high gamma diversity results in ecologically analogous communities in different areas having different replacement species, not necessarily in the same genus. Consequently, the proportions of replacements between analogous communities will vary between regions and communities to the extent that analogous communities may not be easily detectable.

(6) There are too many species (many of which are identifiable only for short flowering or seeding periods) for the practical identification of species, so that omitted, indeterminate and incorrectly identified taxa will confound floristic analysis. Adequate sampling to resolve these problems will make sampling too expensive.

(7) There are too many species and too many communities, so that a formal (syn)taxonomic synthesis of communities becomes unlikely even given sufficient resources.

(8) Because of the high species numbers it takes a long time to collect field data and also for herbarium identification, making data collection a slow and tedious process. This is not helped by frequent taxonomic name changes, or, less frequently, changes in species and generic delimitation—a constant problem in a rich and diverse flora.

(9) Because of species turnover, floristics will yield biogeographical rather than ecological insights into fynbos.

(10) Time, budgetary and legal constraints require that many studies—especially for Environmental Impact Assessments, Integrated Environmental Management and development applications—have to be completed within a matter of months. It is simply impossible to undertake community-type analyses under these scenarios, and communities are usually merely 'eye-balled', with a brief summary of dominant and Red Data taxa (De Villiers et al. 2005).

The first four issues question the theoretical soundness of procedures used in floristic classification of vegetation, based on a misunderstanding of the floristic-sociological approach. Exclusive study of 'mature' communities or the deliberate exclusion of a floristic segment is not preached: the floristic approach is suited for communities at any stage of development. The lack of understanding of the short-lived synusia (such as those of geophytes and annuals) within the Fynbos and Succulent Karoo Biomes is not a theoretical drawback of the approach, but is due to the wrong application of its sampling procedures. The issues (5) to (8) lament the high diversity and the concomitant high time and identification investment needed, and taxonomic deficiencies. All of these issues are logistical and certainly valid. However, these are surmountable provided there is change in political will that would result in more support for vegetation surveys (including better funding) and steady and genuine progress in plant systematics.

The success of the floristic-sociological approach lies especially in the researcher's or user's ability to read the ecological message in particular species groups. This implies being able to identify all the species and understand their ecology—admittedly a tall order in a region containing over 9 000 taxa. Consequently only a few areas of the Cape Floristic Region have been studied using the floristic approach—far too few to be of use in the compilation of a detailed vegetation map of the entire Fynbos Biome. The floristic classification of the vegetation of the Cape Floristic Region is possible and necessary, but is still a very distant target. It took European phytosociology more than 100 years to develop a unified vegetation system acceptable to the European Union (EU) legislature (Devilliers et al. 1991, Devilliers & Devilliers-Terschuren 1996, European Commission 1995, Rodwell et al. 2002) and applied on a continent-wide scale (NATURA 2000 network of nature reserves, biotope mapping in the EU, etc.). Despite the lack of manpower and current politically motivated lack of acceptance, South African descriptive vegetation scientists should continue building the floristics-based classification system and ensure that it is used at the proper scale in nature management of the Cape.

Many of these arguments also apply to the alternative structural approach proposed by Campbell (1983, 1985, 1986a, b) for fynbos of the mountainous regions. This system was later tested and extended to the South Coast lowlands by Cowling et al. (1988) and Rebelo et al. (1991). Campbell's scheme has the advantage in that it is relatively quick to sample and does not require many years of taxonomic experience to execute. However, its reliance on certain easily identified taxonomic groups, and their cover/abundance, renders it equally problematic to floristic studies in terms of requiring mature veld for sampling (Cowling & Holmes 1992b). It is also problematic in that a comprehensive map of structural types across the biome has never been attempted, although it was shown to be amenable to fine-scale mapping on the South Coast.

The structural classification approach fails in several important theoretical and practical aspects. The most serious theoretical drawback is the fact that the vegetation structure is of a convergent nature—the same structural phenomena can be encountered under very different habitat conditions. However, this has not proved a drawback in the Fynbos Biome, with the exception of restioid fynbos, where the arid facies and mesotrophic restioid fynbos were easy to separate at the next hierarchical level (Rebelo et al. 1991). Another serious weakness of the approach lies in the link between the vegetation structure and function, assuming that the ecological message can be detected in growth forms. Admittedly, we know even less about it than about the ecological requirements of particular species. Structural classifications are currently the method of choice for rapid, quick appraisals required for conservation monitoring and Environmental Impact Assessments, where floristics are restricted to the documentation of the dominant 10–20 species and the listing of Red Data taxa. Whatever its deficiencies, fine-scale mapping of core areas of the Cape Floristic Region is currently under way based on Campbell's methodology as modified by Cowling et al. (1988) and Rebelo et al. (1991).

There is a clear need for a theoretical integration and development of both floristic and structural approaches as well as for a classification of habitats at a scale finer than vegetation types (Linder 2005a).

3.1.2 Structural Communities in Fynbos

Campbell's (1985) structural approach is based on the cover-abundance in height classes of life or growth forms (e.g. annual grasses, ericoid leaves), single-structural characters (e.g. spinescence, leaf hairiness), higher taxa (e.g. Ericaceae) and dominant species (especially Proteaceae). The interplay between the different structural communities is complex, but clear patterns have been determined.

Within fynbos availability of water appears to be a key element in determining the distribution of structural components across the landscape. Overall, asteraceous fynbos occurs at the most arid extreme, followed by restioid, graminoid, proteoid fynbos and waboomveld, with ericoid and wet restioid fynbos on the moistest extreme. In deep soils with widely fluctuating water tables, shrubs appear to be excluded and restioid and occasionally ericoid fynbos are dominant. This composition appears to be determined by success of post-fire establishment, with shrub seedlings failing to keep in root contact with the dropping water table. In rocky areas, the amount of soil and depth of cracks seem to be important variables for vegetation structure.

Proteoid fynbos (Figure 4.11) is characterised by a high cover of dominant, reseeding overstorey proteoids. These plants are usually tall or emergent, but in ferricrete and silcrete fynbos they may be lower than 1 m. Ferns and evergreen geophytes are prominent, and leafy and wide-leaved sedges are also characteristic. Proteoid fynbos is widespread on the deep and relatively fertile colluvial soils at the foot of mountains. It is often prominent on the Cedarberg shale bands, and more prominent below it than above it. With their deep roots, proteoids exploit deep water unavailable to other fynbos plants, and consequently grow when most other fynbos plants are dormant—the wet season is the major flowering time.

Ericaceous fynbos (Figure 4.11) is dominated by ericoids and a high cover of restioids. Endemic and near-endemic families (Bruniaceae, Penaeaceae and Grubbiaceae) are also characteristic, as is a high cover of sedges. Ericaceous fynbos occurs at higher altitudes than proteoid fynbos, on permanently wet, cool, relatively fine-grained soils with a high organic carbon content. Mists are prominent in summer, especially under southeasterly wind conditions when the orographic cloud known on some local mountains as the 'Table Cloth' or 'Hottentot's Blanket' occurs.

Restioid fynbos (Figure 4.11) is dominated by restioids, with a low cover of shrubs. Because restioid fynbos is dominated by shallow-rooted plants, it occurs on warmer, north-facing slopes that are on shallow or deep soils prone to drought in summer, including dunes and perched sandy plateaus. Restioid fynbos also occurs on waterlogged soils on cooler, south-facing slopes, where root growth is inhibited for much of the year.

Asteraceous fynbos (Figure 4.11) has a relatively low total cover, and often a high grass and elytropappoid cover, and a prominent deep-rooted nonericaceous ericoid shrub component (Asteraceae, Rhamnaceae and Thymelaeaceae). We exclude talus asteraceous fynbos, which does not fit comfortably within this group, as 'waboomveld' (see below). Asteraceous fynbos occurs on the hot, lower, north-facing slopes, on the deeper colluvial soils.

Waboomveld or 'talus asteraceous fynbos' (Figure 4.11) has been long recognised as a fynbos community (Taylor 1963). It is characterised by the presence of *Protea nitida* (waboom), the only stem-resprouting plant in fynbos, a habit which allows it to form a very unusual 2–5 m tall tree overstorey. It is largely confined to the lowest slopes and talus slopes, often on more fertile, deeper soils. The understorey is very varied, but often contains significant nonericaceous ericoids.

Grassy fynbos (Figure 4.11) is characterised by a high grass cover, with an associated high cover of nonproteoid nanophylls and forbs. It is quite distinct from the other fynbos types and has been regarded as a separate grouping, known as 'Eastern Fynbos' (Cowling 1984, Campbell 1985). Grassy fynbos occurs on soils of finer texture and higher nutrient levels, and under conditions of less summer drought than the other fynbos types.

It is apparent that ericaceous and proteoid fynbos are more common on the coastal ranges, whereas restioid and asteraceous fynbos prevail on inland ranges. In addition, higher (wetter) mountains have more ericaceous and proteoid fynbos. Flats and lower ranges are dominated by restioid and asteraceous

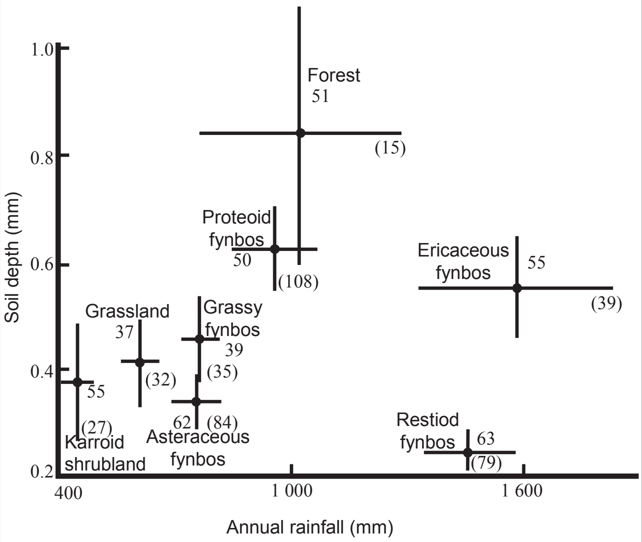


Figure 4.11 Direct ordination of various fynbos shrublands and related vegetation of the southwestern Cape (including forests, karroid shrublands etc.) in relation to annual rainfall and soil depth (courtesy of Oxford University Press, Cape Town).

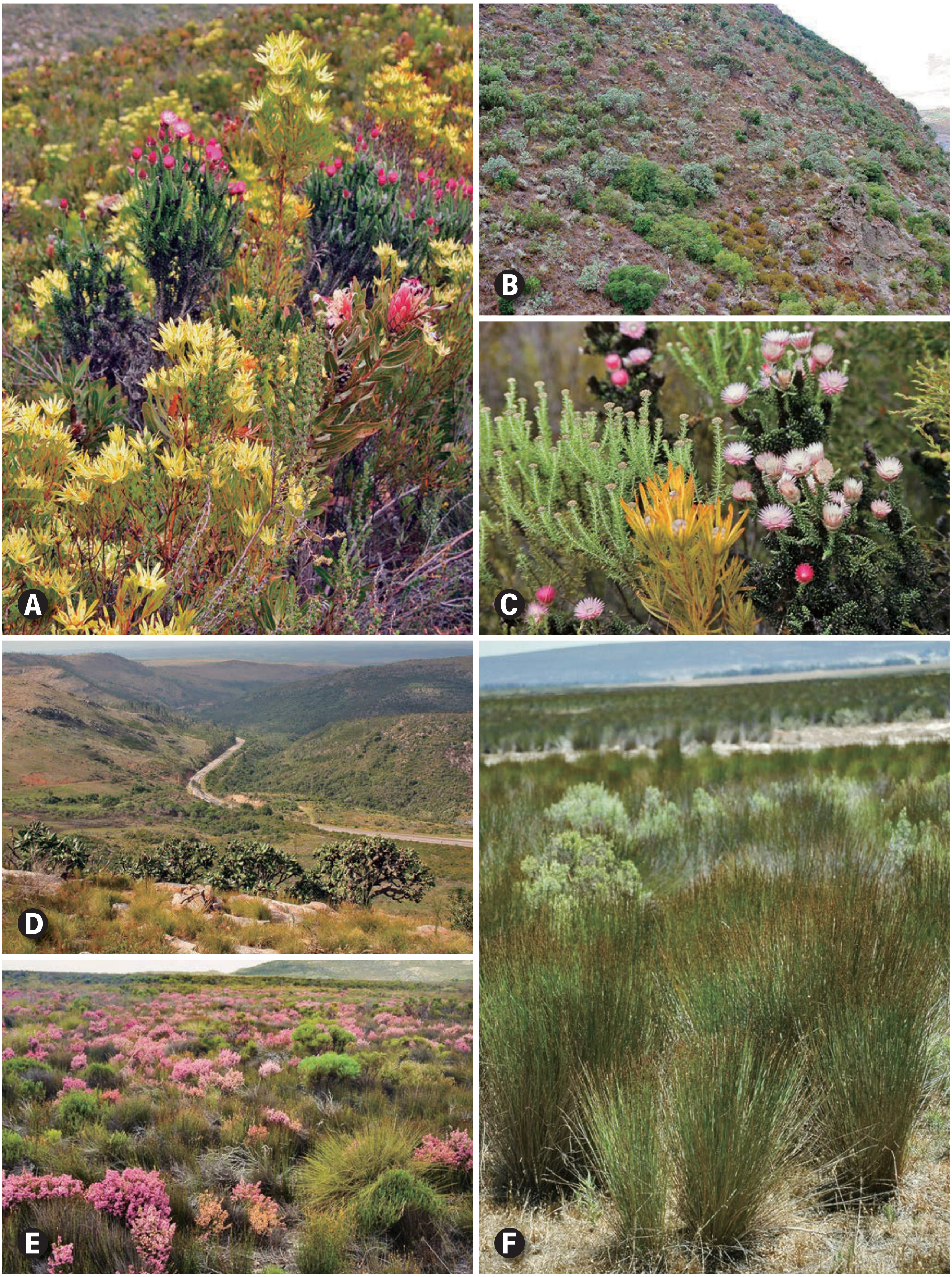


Figure 4.12 Faces of fynbos shrublands: A: proteoid fynbos dominated by *Leucadendron xanthoconus* and prominent *Phaenocoma prolifera* (Potberg); B: waboomveld with tall scattered *Protea nitida* (Du Toitskloof, Limietberg); C: coastal asteraceous shrubland with *Phaenocoma prolifera* and *Metalasia densa* (Betty's Bay); D: grassy fynbos with low tree of *Oldenburgia grandis* (Asteraceae) in the foreground (Howison's Poort near Grahamstown); E: typical ericoid fynbos with *Erica laeta* dominant in temporary wetlands of the Smitswinkelvlakte (Cape of Good Hope); F: restioid fynbos with *Thamnochortus spicigerus* on the Agulhas Plain. Photographs by L. Mucina.

fynbos. In the east, where summer drought is less pronounced and soils are more fertile, grassy types dominate. Thus, in the east, proteoid fynbos is replaced by graminoid fynbos, restioid fynbos is replaced by grassland, and asteraceous fynbos is replaced by grassy shrubland. Richer soils (granites, shales, silcrete and ferricretes), if leached by high rainfall (more than 600 mm per year), contain mainly asteraceous and proteoid fynbos (Figure 4.12). Restioid fynbos also occurs in seasonally waterlogged dune environments.

Although complex, structural types occur predictably across landscapes in fynbos vegetation types. Analogues between units are relatively straightforward and allow easy comparison of ecological gradients between units. Generally there is also an altitudinal zonation in the mountains, with waboomveld, proteoid, ericaceous and restioid fynbos on southern slopes, and asteraceous, proteoid, ericaceous and restioid fynbos on the northern slopes. However, these patterns are modified by soil depth and drainage (Cowling & Holmes 1992b).

3.2 Renosterveld

Renosterveld, or renosterbosveld, literally translates as 'rhinoceros vegetation'. There is confusion as to whether this refers to the historical presence of the hook-lipped or black rhinoceros (*Diceros bicornis*) in this veld type or, more likely, whether it is derived from 'renosterbos-veld' (Boucher 1980). Renosterbos refers to *Elytropappus rhinocerotis*, the dominant plant in this vegetation thought to be so named because reputedly only the black rhinoceros ate it (it is filled with phenolics and eschewed by livestock). A third explanation is the dull, grey appearance of the veld (hence 'Swartveld' and 'Swartland', meaning 'black field' or 'black land'), which is similar in hue to rhino hide (Boucher 1980).

Renosterveld is an evergreen, fire-prone shrubland or grassland dominated by small, cupressoid-leaved, evergreen asteraceous shrubs (principally renosterbos) with an understorey of grasses (Poaceae) and a high biomass and diversity of geophytes (Boucher 1980, Moll et al. 1984, McDowell & Moll 1992). Here we define renosterveld narrowly as excluding (fynbos) types dominated by Proteaceae, Ericaceae or having more than 5–10% cover of Restionaceae. Thus we approximate Campbell (1985) in our approach, in that *Elytropappus*-dominated communities with *Passerina, Phylica* and restioid components considered asteraceous or restioid fynbos types. Our definition is much narrower than that of Moll (Boucher & Moll 1981), but approaches Acocks (1953) for the West Coast. We reject Acocks's 'false' veld types, as a derived type and consider them typical types in their area. However, we include thicket bush-clumps such as those occurring on heuweltjies as a typical renosterveld element. Renosterveld occurs predominantly on clay-rich soils derived from shale and granite and, to a lesser extent, silcrete.

Apart from Asteraceae (including *Elytropappus*, *Eriocephalus, Helichrysum, Oedera, Pteronia* and *Relhania*), other important shrub families represented in renosterveld include Boraginaceae, Fabaceae, Malvaceae, Rosaceae (*Cliffortia*) and Rubiaceae (*Anthospermum*) (Goldblatt & Manning 2002b).

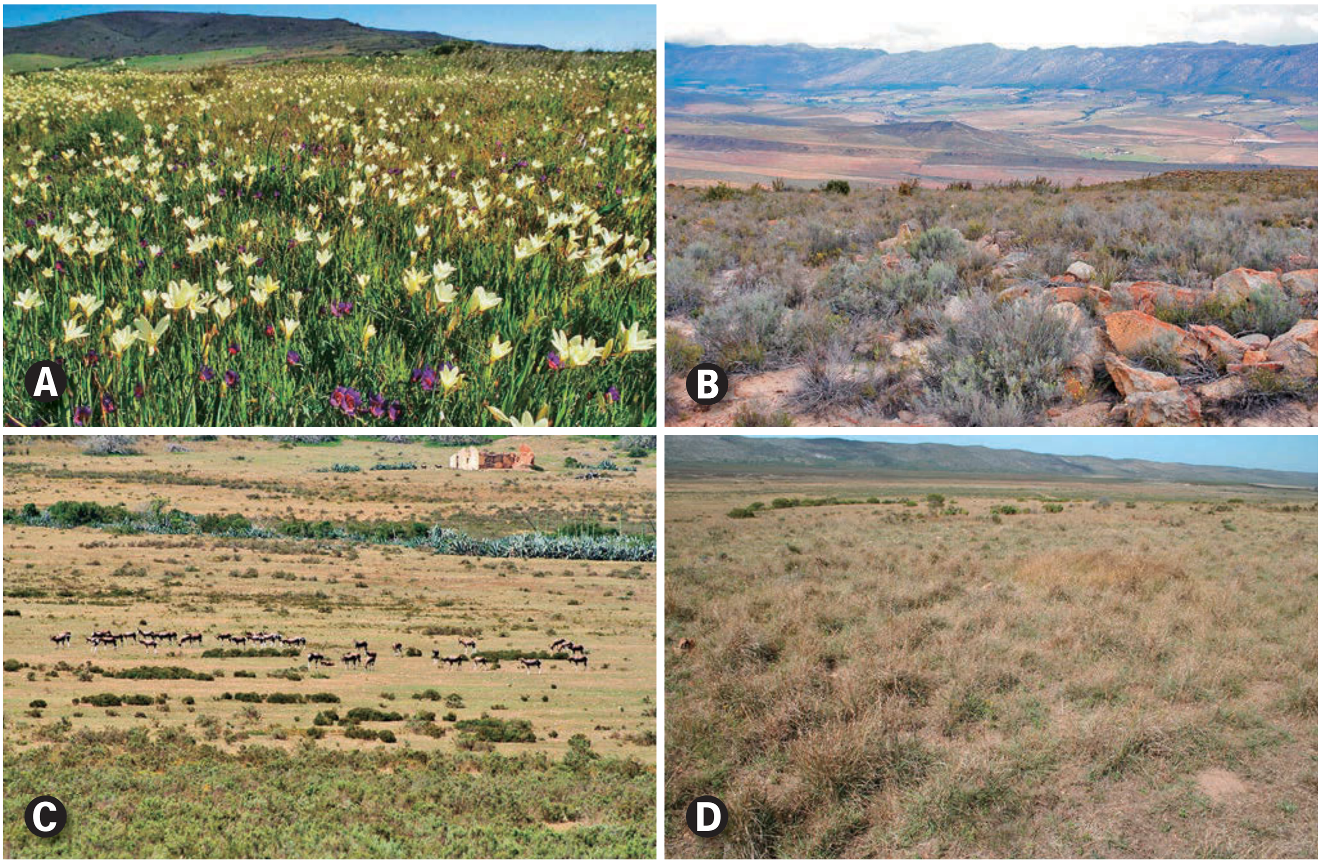


Figure 4.13 Faces of renosterveld: A: 'bulbveld' (bulb-rich herbland) at Waylands near Darling (West Coast) with *Zantedeschia aethiopica, Sparaxis bulbifera* (white), *Geissorhiza radians* (purple and red), *Trachyandra filiformis* (small whitish stars) and a cloud of blue *Heliophila coronopifolia* in the distance; B: typical renosterveld shrubland dominated by renosterbos (*Elytropappus rhinocerotis*) on a slope overlooking the Koo (western Little Karoo); C: extensive grazing lawns in the valley of the Potberg River in the eastern portion of De Hoop Nature Reserve—the major feeding ground of large herds of bontebok *Damaliscus pyrgargus pyrgargus*) and eland (*Taurotragus oryx*); D: tussock grassland with *Cymbopogon pospischilii* and *Themeda triandra* on shale slopes in the Potberg section of De Hoop Nature Reserve. Photographs: A: J.C. Manning, B: L. Mucina, C & D: F.G.T. Radloff.

Among the geophytes are representatives of both the monocots (Amaryllidaceae, Asparagaceae, Asphodelaceae, Iridaceae, Hyacinthaceae, Orchidaceae) and dicots (Oxalidaceae and Geraniaceae) (Duthie 1930, Cowling 1983a, Paterson-Jones 1998, Goldblatt & Manning 2002b, Procheş & Cowling 2004, Procheş et al. 2005, 2006). Indeed the world cut-flower trade owes *Freesia, Ixia, Gladiolus, Ornithogalum* (Chinkerinchee) and *Pelargonium* to plants originally collected from the CFR. The frequency and diversity of geophytes, according to Kruger (1979), increase with that of soil fertility, aridity and fire frequency. Floristic affinities of renosterveld with fynbos are low in spite of their structural similarity (Boucher & Moll 1981). Although many families and genera are shared, apart from geophytes, very few species are shared, with the exception of the shale and granite fynbos types where boundaries are often diffuse.

A major feature of renosterveld, at least the coastal units, is the extensive transformation that has taken place over the last 100 years. Today these areas are predominantly croplands. This follows on a major shift in large herbivore dynamics that took place in the early 18th century, as large game and Khoi cattle herds were replaced by European stock farmers. We will probably never be able to recreate or determine the ecology of renosterveld in any detail (Krug et al. 2004a, b).

Moll et al. (1984) differentiated renosterveld into four distinct (more or less biogeographically defined) types. These exclude the escarpment types, which show strong karroid affiliations.

(1) Renosterveld of the West Coast Centre (west of the Hottentots Holland and Twenty-four River Mountains) tends to have a sparser grass cover, comprising mainly C_3 genera, a higher diversity of deciduous geophytes and annuals, and *Eriocephalus africanus* and *Leysera gnaphaloides* as characteristic subdominants. The overstorey shrubs have a greater canopy cover (50–90%) than in the other centres. Heuweltjies support tall clumps of thicket elements. The unusually high abundance of geophytes is particularly characteristic.

(2) Renosterveld of the South Coast Centre (south of the Langeberg and Riviersonderend Mountains) tends to have less geophytes and more grassy elements (mainly C_4 genera) with typical subdominants *Oedera genistifolia, O. squarrosa* and various species of *Helichrysum* and *Hermannia*. Canopy cover varies from 50–75%. In the east it grades into Albany Thicket types where dissected topography prevents the spread of fire.

(3) Inland renosterveld of the Mountain Centre (from Nieuwoudtville to Oudtshoorn, east of the Cederberg and north of the Langeberg) tends to be more xeric and has a lower cover than the coastal types, but this is determined by moisture; southern aspects may be as dense as in coastal renosterveld types. This renosterveld has a higher proportion of succulents (reflecting a stronger Succulent Karoo influence), and mixtures of renosterbos and *Relhania* as dominants, occasionally with *Pteronia incana*. Total cover is low (25–60%). Grasses (mainly C_4 genera) may be prominent, but are often lost due to overgrazing and may be absent. Locally *Acacia karroo, Euclea undulata* and *Aloe ferox* may be prominent as scattered elements.

(4) Renosterveld of the Eastern Centre is relatively uniform with no emergents above the renosterbos-dominated shrubland. Grasses (mainly C_4 genera) can be a major component, but overgrazing may eliminate them. Renosterveld types of the Eastern Centre have the strongest affinities with Albany Thicket and grasslands to the east. The eastern units of this type are particularly difficult to subdivide.

No further studies on the relationships and determinants of the groupings of Moll et al. (1984) have been undertaken. Despite its structural diversity, renosterveld has so far not been subject to detailed vegetation-structural classification. However four major structural types have been used in an informal way: shrubland, tussock grassland, grazing lawn (low, heavily grazed grasslands), and lately also herblands dominated by bulbous plants ('bulblands') (Figure 4.13).

3.3 Western Strandveld

Strandveld (Figure 4.14) consists of communities of medium dense to closed (sometimes forming an impenetrable tangle) shrublands dominated by sclerophyllous, broad-leaved shrubs (Moll et al. 1984). Along arid stretches (especially at the West Coast) the succulent shrubby element becomes obvious. The shrublands are very low, especially closer to the seashore, but can grow tall in sheltered sites and become replaced by low scrub milkwood forest (especially on the Agulhas Plain; see Cowling et al. 1988). Structural and floristic differences between strandveld and neighbouring fynbos are striking. Although restios (*Ischyrolepis, Thamnochortus, Willdenowia*) can be a common element on deep soils, the Proteaceae are absent and Ericaceae are extremely rare.

Strandveld vegetation is usually found close to the sea (whence the Afrikaans term 'strandveld' or 'beach vegetation') but never in habitats under direct influence of sea spray and other factors associated with the influence of the sea water—these habitats are occupied by the azonal coastal vegetation (see Chapter 14). Immediate coastal hinterland with its stabilised Pleistocene (rarely also post-Holocene) dune cordons showing signs of soil formation is the characteristic habitat of the typical strandveld vegetation of the southwestern and southern Cape. In the coastal hinterland, strandveld also occurs on harder substrates supporting shallow soils, such as on granites (surrounds of Vredenburg, Saldanha and further south in Cape Town on the West Coast and on the coast south of George and Knysna on the South Coast), Tertiary limestones of the West Coast (Langebaan area) and South Coast (from De Kelders to as far as Mossel Bay). Strandveld penetrates deep inland in several localities, such as east of Langebaan and Saldanha (here found over sandy overlying calcrete pavements), along limestone krantzes (cliffs) fringing De Hoop Vlei and in the hinterland of the sedimented portion of Mossel Bay.

As opposed to the sand fynbos (often bordering on the strandveld units, both on the West and South Coasts), the substrate of the strandveld is mineral-rich, with high concentrations of calcium. Intricate relationships between topography, local waterlogging and fire dictate the nature of the delimitation of strandveld and sand fynbos on calcium-rich coastal sands of the South Coast (see Section 9.1.3 on sand fynbos below for further details).

Unlike in fynbos or renosterveld, fire plays a lesser role in the strandveld communities. Despite high cover of the strandveld shrublands, fire frequency is low. However, the succulent nature of strandveld impedes the spread of fire, except under exceptional conditions. Although no data on fire-return intervals for strandveld exist, they are probably in the order to 50–200 years. The early seral stages following fire are dominated by Restionaceae and Rutaceae and have a typical fynbos physiognomy, hence the term 'dune fynbos'. It takes dune fynbos over 20 years before it becomes overtopped by more typical strandveld elements.

The major floristic component of the strandveld communities, especially on the South Coast, shows subtropical biogeographi-

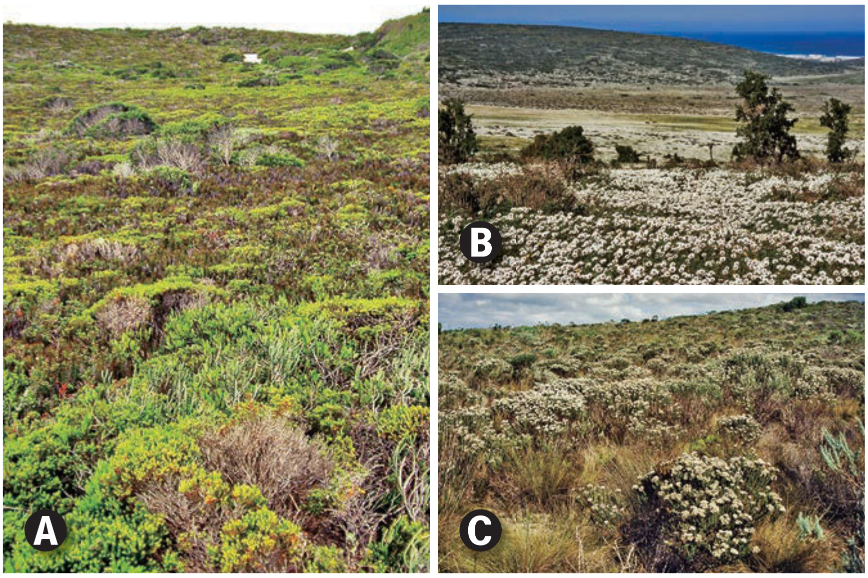


Figure 4.14 Faces of strandveld. A: coastal dune strandveld dominated by aromatic shrubs (buchus) such as *Acmadenia mundiana* and *Agathosma collina* and the restio *Ischyrolepis eleocharis* in De Hoop Nature Reserve (Overberg); B: granite strandveld with spring flower display (*Dimorphotheca pluvialis*) in the Postberg Reserve (West Coast National Park); C: typical dune strandveld with *Metalasia muricata* in De Mond Nature Reserve near Struisbaai. Photographs by L. Mucina.

cal links. The notable genera occurring in strandveld and pointing towards this (sub)tropical link include for example *Aloe*, *Azima*, *Cassine*, *Clausena*, *Cussonia*, *Euclea*, *Diospyros*, *Grewia*, *Gymnosporia*, *Lauridia*, *Maytenus*, *Mystroxylon*, *Pterocelastrus*, *Rhus*, *Robsonodendron*, *Sideroxylon* and *Tarchonanthus*. The strandveld units of the West Coast also show a link to the Succulent Karoo (through the increased occurrence of succulent shrubs of genera such as *Antimima*, *Cheiridopsis*, *Cotyledon*, *Crassula*, *Dorotheanthus*, *Drosanthemum*, *Euphorbia*, *Mesembryanthemum*, *Prenia*, *Ruschia*, *Tetragonia*, *Tylecodon*, *Zygophyllum* etc.). Floristic links to the fynbos and renosterveld (especially the granite renosterveld) are indicated by the occurrence of genera such as *Aspalathus*, *Babiana*, *Ehrharta*, *Ischyrolepis*, *Metalasia*, *Oscularia*, *Oxalis*, *Phylica*, *Psoralea*, *Romulea*, *Thamnochortus*, *Thesium*, *Ursinia* and *Willdenowia*. (For discussion on possible routes of evolution of the strandveld flora, see Section 5.2 below.)

The dune thicket flora represents a westward extension of the subtropical flora into the warm-temperate southern and Western Cape. It is one of the major reasons why Tinley (in Heydoorn & Tinley 1980; see also Moll et al. 1984) extended the concept of 'thicket' to the Western Cape strandveld thickets and why the vegetation map by Low & Rebelo (1996) included the coastal thickets of the Western Cape in the (subtropical) Albany Thicket Biome. The clear 'depauperization' trend in representation of the subtropical element in the dune thicket flora was reported by Cowling & Pierce (1985), who found that of 72 thicket species occurring at Cape St Francis, 56 (hence 79%) were found in the Mossel Bay and Riversdale regions, but only 38 species (52%) in the southwestern Cape.

An interesting phenomenon linked to the dune thicket vegetation of the strandveld complex is the change in growth form in some typically subtropical woody elements. *Sideroxylon inerme* can be a tall tree reaching a height of 15 m in the tropics (and still with a tree stature in dune forest along the KwaZulu-Natal coast), becoming only a low tree or shrub (even showing a creeping habit) on the temperate dunes of the southwestern Cape. This remarkable plasticity has also been observed in *Pterocelastrus tricuspidatus*, *Maytenus procumbens* and *Cassine peragua* (Cowling & Pierce 1985, Taylor & Boucher 1993).

Here we consider the strandveld units FS 1–9 as intrazonal units of the Fynbos Biome, since their extent is strictly linked to that of the Fynbos Biome—the zonal fynbos units form the inland backdrop to the coastal-bound strandveld units. Hence the strandveld units share the basic feature of the macroclimate with the neighbouring zonal fynbos units. We call this group of strandveld units 'Western Strandveld' to distinguish them from those fringing our coasts further east (in the realms of the Albany Thicket Biome and Indian Ocean Coastal Belt). The latter have been handled as azonal (AZs 1–3) and featured in Chapter 14.

Moll et al. (1984) recognised two types within strandveld, namely 'West Coast Strandveld' and 'South Coast Strandveld'. Our current classification builds upon this dichotomy (largely motivated by the differences in growth-form composition) and pursues further subdivision based on regional/local bioclimatic and biogeographical patterns as well as geology (reflected in the separation of the limestone and granite strandveld units).

3.4 Fynbos Thicket

While the strandveld shrublands are linked to coastal (hinterland) habitats, the fynbos thickets are found in fire-sheltered habitats (Figure 4.15) embedded as fragments within fynbos—sandstone, quartzite and granite fynbos, in particular.

We consider 'fynbos thicket' a distinct (from subtropical Albany Thicket, from fynbos *per se*, from riparian thickets typical of the Fynbos Biome as well as from afrotemperate forests) vegetation type characterised by dominant sclerophyllous ('other than nanophyllous' sensu Campbell 1985) shrubs and small trees found in fire-sheltered habitats such as steep rocky slopes, boulder formations, screes and deep kloofs without streams, and embedded within the fire-prone matrix of typical fynbos. The understorey of these small shrublands is sparse. Most importantly, the dominant shrub elements are recruited from taxa with their evolutionary roots (and current centres of diversification) in the (sub)tropics—suggesting 'pre-fynbos' age, hence possibly being relicts of pre-Pliocene subtropical woodlands that possibly dominated the landscapes of the southwestern Cape.

The fynbos thickets have never been a subject of an exclusive scientific enquiry. Many authors have, however, described their local communities but usually focusing on fynbos or forests (e.g. McKenzie et al. 1977, Laidler et al. 1978, Kruger 1979, Taylor 1984b, 1996, Van Wilgen & Kruger 1985, McDonald 1988, Mustart et al. 1993, Cleaver et al. 2005). So far, the most penetrating insight has been provided by structure-oriented studies of Campbell (1985). This author described two structural variations of the fynbos thickets called Cape and Mitchell Thickets. Cowling & Holmes (1992b) introduced an overarching term 'Western Thicket' to encompass both.

In deep kloofs on lower northern sandstone slopes, fynbos thickets with species of *Buddleya*, *Rhus*, *Salvia* and *Pelargonium* occur in fire-safe habitats. These are dominated by aromatic-leaved species, unusual in fynbos, perhaps an adaptation against grazing by animals on their way to summer watering points up the kloofs. They have never been studied ecologically or floristically.

Clumps of the wild olive (*Olea europaea* subsp. *africana*) occurring within renosterveld matrix on rocky outcrops or on termitaria (Boucher 1980) also qualify as patches of 'fynbos thicket'.

The question arises whether thicket patches found within fynbos matrix should rather be considered forest (Afrotemperate Forest Biome) or a Fynbos Biome type. Both may have Restionaceae and other typical fynbos elements as an understorey, in which case they should be considered as 'thicket fynbos'. In these cases the understorey usually burns. In granite fynbos, granite boulders often shelter stands of 'closed-scrub fynbos' and 'thicket fynbos'. Presumably on richer soils the forest elements establish more easily by virtue of the richer soils. However, these patches appear to be far more dynamic, often containing restioid, ericoid and proteoid elements, or patches of typical fynbos within them. Furthermore, the boundaries are far more diffuse. These species are not confined to these small forest habitats, but may occur as isolated plants in fynbos in fire-safe areas, some as small as single large rocks. Most of these species fail the test as 'true forest species' in that they can establish and survive in fynbos vegetation. They are forest pioneer elements, most of which disappear as the forest matures to afrotemperate forest and are more at home in the fynbos landscape than in forest.

Due to the very limited extent of patches of fynbos thicket and virtually no floristic data to address possible subdivision, this type was not mapped and subsumed into the fynbos units in which they occur. We have, however, noted the 'fynbos thicket' elements in the species lists in the descriptions of fynbos vegetation units (Table 4.2).

3.5 The Within-biome Boundaries

Fynbos and Renosterveld

Renosterveld occurs predominantly on clay-rich soils. At drier extremes (usually below 250–300 mm) it is replaced by succulent karoo shrublands, and in wetter areas (usually over 500–800 mm) by fynbos (Cowling & Holmes 1992b). This boundary is not determined by fire, as both communities are dominated by fire, although renosterveld (at least in higher-rainfall areas) typically burns more frequently (3–5 years) than fynbos (10–25 years) because of faster growth rates and dominance by finer fuel grasses. By our definition, the boundary is where Restionaceae stop (or drop to less than 5% cover), usually in mesotrophic asteraceous or graminoid fynbos, but typically Ericaceae and Proteaceae end at these boundaries as well. However, transition zones are broad and diffuse, resulting in different interpretations of the actual renosterveld-fynbos boundary. This transition has been attributed to leaching and consequent loss of soil nutrients supporting fynbos (Cowling & Holmes 1992b).

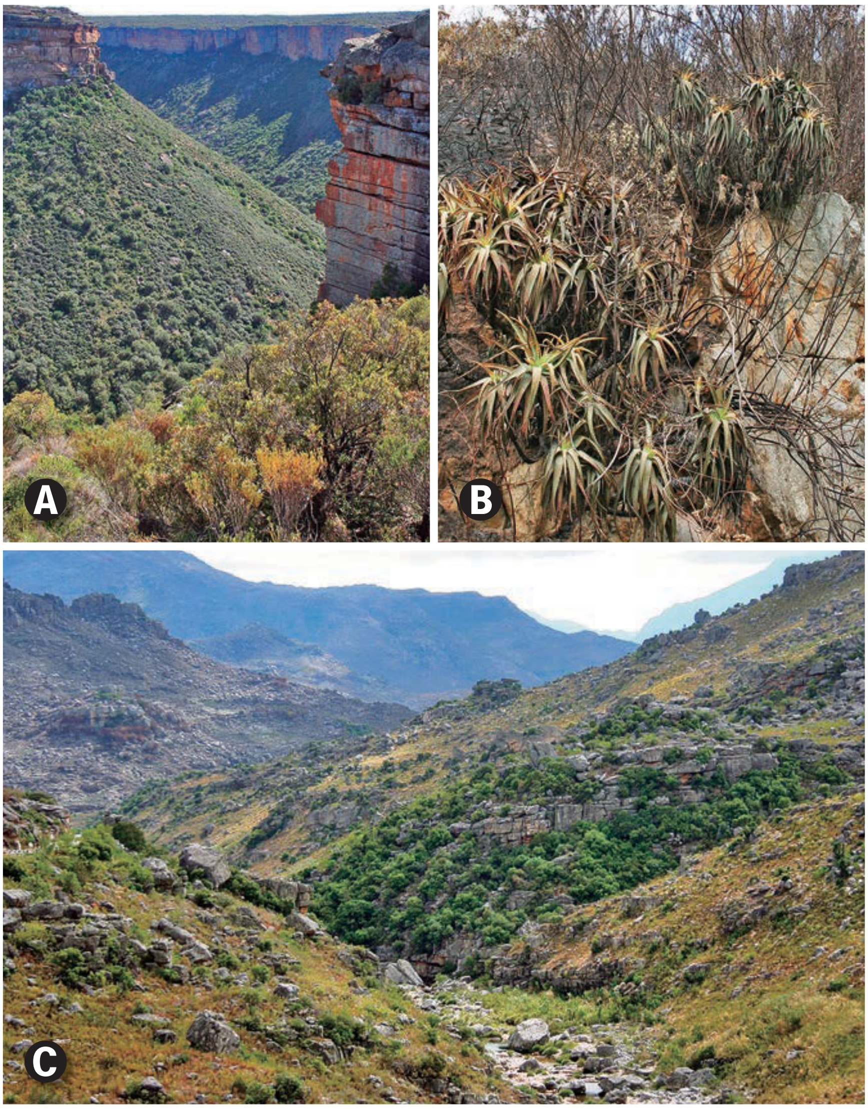


Figure 4.15 Faces of Cape (fynbos) thicket. A: steep slopes of the Oorlogskloof River canyon cutting though the Bokkeveld Plateau, clad in fire-resistant thicket; B: a thicket group with *Aloe arborescens* in the mouth of the Baviaanskloof Valley near Genadendal that survived a recent fire; C: Cape thicket with *Heeria argentea* on rocky slopes of the Witrivier in the Bain's Kloof Pass near Wellington. Photographs by L. Mucina.

The fynbos-renosterveld transition appears related to differences in leaching and is determined by annual precipitation but it is unaffected by seasonality of rainfall. Renosterveld does not typically occur on sandstone and quartzite, but occasionally occurs in more arid facies where a thin clay or silt layer, usually derived from remnants of overlying shale, covers the bedrock. Even skeletal layers of clay appear to exclude Restionaceae and most other fynbos taxa. Typically this only occurs in asteraceous fynbos; as in other fynbos types, the clays would be sufficiently leached to allow fynbos to occur.

Overgrazing and excessive burning may convert fynbos to renosterveld on shales, but the mechanism for this is unclear. Bush-cutting and liming of graminoid fynbos in the Langeberg foothills convert it to a grassland or grassy shrubland that, because of the preferential loss of typical fynbos elements, would be classified as renosterveld (A.G. Rebelo, unpublished data).

Table 4.2 Floristic composition of the fynbos thicket communities embedded within various fynbos units (FFs 1 Bokkeveld Sandstone Fynbos, FFs 4 Cederberg S.F., FFs 10 Hawequas S.F., FFs 9 Peninsula S.F., FFg 2 Boland Granite Fynbos, FFg 3 Peninsula G.F., FFs 25 North Kammanassie S.F.). Status: ^A^found in both western and eastern fynbos thickets, ^Be^presumably endemic to fynbos thickets of the Bokkeveld, ^C^typical of coastal-close fynbos thickets of the Cape Peninsula, ^Ce^presumably endemic to fynbos thickets of the Cederberg, ^E^only in eastern thickets, ^Ge^presumably endemic to granite fynbos thickets, ^He^presumably endemic of the fynbos thickets of the Hawequas Mountains, ^W^only in western thickets. The entries (numbers) within the body of the table refer to the sources of the data: 1: L. Mucina (unpublished data), 2: Taylor (1996; original taxon names: **Protasparagus*, ***Myrsiphyllum*, ****Colpoon*, ^#^*Cassine barbara*, ^&^*E. natalensis*, ^+^*L. lobata*), 3: Mustart et al. (1993; **Protasparagus*, ^#^*Cassine barbara*, ^&^*E. natalensis*, ^+^*L. lobata*, ^%^*G. heterophylla*), 4: Taylor (1983; **T. camphoratus*, ***Colpoon*, ^$^*Cassine barbara*, ^%^*G. heterophylla*), 5: McKenzie et al. (1977; **Cassine capensis*), 6: Van Wilgen & Kruger (1985; **O. europaea*, **probably *R. scytophylla*, ^$^*A. thunbergianus*), 7: McDonald (1988 ; **Protasparagus compactus*), 8: Cleaver et al. (2005; * *Cassine eucleiformis*, ^&^*E. natalensis*), 9: A.G. Rebelo & N. Helme (unpublished data; see the descriptions of the respective units in this Chapter), 10: PRECIS database.

Taxon	Status	FFs 1	FFs 4	FFs 10	FFs 9	FFg 2	FFg 3	FFs 25
Hyaenanche globosa	Be	1, 10						
Clivia mirabilis	Be	1						
Lidbeckia quinqueloba	Ce		2^+^,3^+^					
Aloe plicatilis	He			6				
Chionanthus foveolatus	C				4			
Cussonia thyrsiflora	C				4			
Cynanchum obtusifolium	C				4			
Euclea racemosa	C				4			
Maurocenia frangularia	C				4			
Olea exasperata	C				4			
Phylica buxifolia	C				4			
Pterocelastrus tricuspidatus	C				4			
Rhus glauca	C				4			
Rhus laevigata	C				4			
Sideroxylon inerme	C				4			
Tarchonanthus littoralis	C				4*			
Clutia pterogona	Ge					5	10	
Leucadendron argenteum	Ge					5	1	
Cotyledon woodii	E							8
Cussonia paniculata	E							8
Diospyros lycioides	E							8
Euclea crispa	E							8
Euclea natalensis subsp. *natalensis*	E							8^&^
Euclea polyandra	E							8
Euclea undulata	E							9
Ficus burtt-davyi	E							8
Lachnostylis bilocularis	E							8
Melianthus comosus	E							8
Pelargonium zonale	E							8
Rhus pallens	E							9
Robsonodendron eucleiforme	E							8*
Maytenus acuminata	A	10	10	9	10	10	7	10
Maytenus oleoides	A	9	2,3	6		5		8
Clutia alaternoides	A	10	10	10	10			8
Dodonaea viscosa	A	1	2,3	10	10			8
Gymnosporia buxifolia	A	10	3^%^		4^%^	10		8
Myrsine africana	A	10	2,3	6	4	5	10	8
Rhus tomentosa	A	3	2,3	6	4	5	7	9
Olea europaea subsp. *africana*	A	1	2,3	6*			7	8
Osyris compressa	A		2***		4**			8
Pteridium aquilinum	A			1		5	7	8
Solanum tomentosum	A		2					8
Diospyros glabra	W	10	2,3	6	10	5	7	
Halleria lucida	W	10	10	10		10	7	
Cassine schinoides	W	10	2	6			7	
Viscum pauciflorum	W	10	2				10	

Taxon	Status	FFs 1	FFs 4	FFs 10	FFs 9	FFg 2	FFg 3	FFs 25
Chironia baccifera	W		2,3	6		5	7	
Rhus rosmarinifolia	W		9				7	
Cassine peragua subsp. *peragua*	W	10	2^#^,3^#^	10	4^$^	5*		
Clutia pulchella	W	10	2			10		
Kiggelaria africana	W	10	2,3	10		5		
Knowltonia capensis	W		3	6	4	5		
Heeria argentea	W	1,10	1,2,3	6	10			
Podocarpus elongatus	W	1, 10	2,3	1, 10	1			
Indigofera frutescens	W	10	2,3	10				
Clutia polifolia	W	10	2	10				
Anisodontea bryoniifolia	W	10	2					
Diospyros austro-africana	W	10	2,3					
Euclea acutifolia	W	10	2,3					
Euclea lancea	W	9	2					
Euclea linearis	W	10	3					
Euclea natalensis subsp. *capensis*	W	9	2^&^,3^&^					
Euclea tomentosa	W	1,10	1,10					
Rhus scytophylla	W		2,3	6**				
Rhus undulata	W		2,3	6				
Secamone alpini	W		2,3	6				
Othonna amplexifolia	W		2,3	6				
Pellaea pteroides	W		2	6				
Ficinia acuminata	W		2,3	6				
Asparagus scandens	W		3*		1			
Asparagus rubicundus	W			6^$^	1			
Rhus lucida	W			9	4	5		
Widdringtonia nodiflora	W			1		5		
Olea capensis subsp. *capensis*	W				4	5		
Rapanea melanophloeos	W				10		7	
Tylecodon paniculatus	W	1,9						
Melianthus major	W		2					
Rhus dissecta	W		2,3					
Rhus rimosa	W		2,3					
Senecio vestitus	W		2					
Asparagus aethiopicus	W		2*					
Asparagus kraussianus	W		2**					
Asparagus retrofractus	W		2*					
Asparagus suaveolens	W		2*					
Crassula atropurpurea	W		2					
Crassula decumbens	W		2					
Crassula umbella	W		1,2					
Knowltonia vesicaria	W		2					
Stachys aethiopica	W		2					
Teedia lucida	W			6				
Ursinia abrotanifolia	W			6				
Asparagus asparagoides	W			6				
Asplenium aethiopicum	W			6				
Crassula albiflora	W			6				
Crassula coccinea	W			6				
Mohria caffrorum	W			6				
Rhus angustifolia	W						7	
Asparagus lignosus	W						7*	

Fynbos and Strandveld

Like the fynbos boundaries with the Karoo and Albany Thicket Biomes, the boundary between fynbos and strandveld is largely determined by fire dynamics. Thus sand fynbos tends to occur adjacent to strandveld, with the boundary and its transition zones determined by the interplay of topography (primarily dunes) and succulence associated with more nutrients derived from salt spray from the sea. A dune fynbos occurs as a seral stage to strandveld in areas of intermediate fire. The details of the sand fynbos/strandveld boundary are summarised under sand fynbos.

Renosterveld and Strandveld

Renosterveld does not abut upon strandveld. The two types occur on different soil types and typically the aeolian sand/shale interface is with acid sands supporting sand fynbos rather than strandveld.

4. Evolutionary and Ecological Driving Forces

Four complex factors stand paramount in fynbos ecology, which, taken together, separate the Fynbos Biome from the other biomes of southern Africa. These are: (1) the nutrient-poor soils supporting fynbos, arranged in an archipelago within more nutrient-rich soils containing mainly renosterveld, (2) hot, dry summers alternating with cool, wet winters, typical of other mediterranean-type regions, at least in the west of the biome, (3) recurrent fires at 5–50-year intervals in fynbos and 2–10 years in renosterveld (not nearly annual as in the Grassland and Savanna Biomes, or absent as in the Karoo biomes), and (4) an intricate complex of animal-plant interactions, especially involving grazing, pollination and dispersal (see also Goldblatt & Manning 2002b, Linder 2003, Barraclough 2006).

We do not cover the considerable amount of other information on plant function and ecophysiology in the Fynbos Biome here. Reviews in these fields include those of Lamont (1982), Mooney et al. (1982), Rutherford (1991), Stock & Allsopp (1992), Stock et al. (1992b, 1997).

4.1 Responses to Low Nutrients

The generally nutrient-poor soils of the fynbos proper pose a serious ecological challenge to plants. The significance of the nutrient-poor soils in the Fynbos Biome is overwhelming. Although there is obviously an interplay between fire, climate and biotic interactions, the unique and diverse systems prevalent in fynbos are unsurpassed in all other ecosystems on the subcontinent, and indeed in the world. By contrast, renosterveld and strandveld do not appear to be uniquely unusual in any traits. It is highly likely that further surprises await ecological investigators as ecophysiological and genetic investigations into low-nutrient adaptations progress.

Plants have come up with a number of intriguing answers leading to the evolution of traits of eco-morphological, life-historical and community-assembly rules. Some of the most prominent ecological-evolutionary traits identified that link the composition and dynamics of fynbos to a low soil nutrient status are listed below.

Serotiny: The phenomenon of serotiny (bradyspory) is confined to fynbos vegetation within the Fynbos Biome. It is absent in renosterveld which burns too frequently, and as a fire-related phenomenon it is largely absent in other biomes. In this strategy, species retain the seeds in fire-proof seedheads on the plant and only release them after a fire. This strategy requires thick stems (ca. 10 mm at the flowerhead) to remain standing after the fire and is therefore largely confined to emergent and overstorey plants (where fires are also cooler), and a few resprouters. Serotiny requires predictable fire-return times at greater than 5-year fire intervals—it is thus rare in grassy fynbos. As a strategy elsewhere it is virtually confined to mediterranean-type ecosystems on nutrient-poor soils (Bond 1985) and coniferous forests. It is sparse in communities too dry (especially asteraceous fynbos, or seasonally dry restioid fynbos) or too cool (especially ericaceous fynbos, where it is most prominent in resprouters) to allow growth of thick stems. It occurs in Proteaceae (*Protea, Leucadendron, Aulax*), Bruniaceae (*Brunia, Berzelia, Nebelia*), Ericaceae (*Erica sessiliflora*), Asteraceae (*Phaenocoma*) and Cupressaceae (*Widdringtonia*), totalling just over 100 species. Alien invaders displaying serotiny include species of *Hakea, Banksia* (both Proteaceae), *Pinus* (Pinaceae), *Callistemon* (Myrtaceae) and *Casuarina* (Casuarinaceae). Seed protection in fynbos species (cones and seedheads) is not as robust as in the heathlands of Australia, where there is a parrot seed predator capable of extracting seeds from fire-proof cones. Seed germination cues are simple, usually requiring cool conditions and saturated soils (Le Maitre & Midgley 1992).

Because seeds are exposed to predation after release following a fire, nonseasonal fires (spring or early summer in the summer-drought region, and winter and summer in the all-year rainfall region) may decimate post-fire recruitment (S. Heelemann, personal communication), presumably by prolonging the period between release and germination. Non-resprouting serotinous species may be eliminated by fire in young veld (less than 3–8 years of age, depending on species) where plants have not yet set seed—as all the plants typically burn, no reserve seed bank is possible, as with soil-stored seed banks. This feature is used to control serotinous alien invaders: adults are hacked and after seed release the veld is burned, thereby eliminating the species (Le Maitre & Midgley 1992). Serotinous species also exhibit senescence, in which plants become moribund, lose their seed banks, and die out when veld exceeds 2–3 times the average fire cycle in age (Le Maitre & Midgley 1992).

Myrmecochory: Ant seed dispersal is found in 15% of fynbos species (Bond & Slingsby 1983, 1984, Breytenbach 1988, Bond et al. 1990, 1991, Johnson 1992, Cowling et al. 1994b), of almost all characteristic and dominant plant families (although it is very rare in Ericaceae), and in all growth forms. In many cases, wind-dispersed species in neighbouring vegetation types have myrmecochorous congeners in fynbos (Bond & Slingsby 1983, Bond et al. 1991). These species tend to produce small or large nuts with an ant-fruit or elaiosome. The fruit are buried by indigenous ants in their nests, where they remain dormant until after a fire. The alien Argentine Ant (*Linepithema humile*) consumes the elaiosome above ground and does not bury the seed, resulting in high predation (Bond & Slingsby 1984, Christian 2001, Christian & Stanton 2004, Witt et al. 2004, Witt & Giliomee 2004, Traveset & Richardson 2006). Post-fire germination cues are complex and are determined by fire effects, cyclical soil temperature fluctuations and maturation requirements. Burial removes fruit from rodent and bird predation, and from fire and probably provides protection against fungi, especially *Phytophthora*. Myrmecochorous species are seldom dominants, but they may account for a high cover in the middle strata, and for up to 30% of species in a community.

Apart from a paucity in dry asteraceous fynbos, and low cover in restioid fynbos, myrmecochory has no obvious overall patterns between fynbos communities. Some alien invasive Fabaceae (*Acacia*) are myrmecochorous. Seed-dispersing ants include deep buriers (> 50 mm deep), large ants that disperse the larger fruit, and smaller ants with shallow burial sites (10–50 mm) that are unable to move the larger fruit (Le Maitre & Midgley 1992). Myrmecochory is almost nonexistent in renosterveld and adjacent biomes, and is usually attributed to the need to rapidly store seeds in predator-free, fire-safe refugia (Le Maitre & Midgley 1992).

In total contrast to the prevalence of myrmecochory, is the near total absence of ornithochory (seed dispersal by birds) in fynbos. Frugivorous birds are generally absent from fynbos, the red-winged starling (*Onychognathus morio*) being the notable exception. Fleshy fruit are confined to the aerial parasites *Cassytha* (Lauraceae) and *Viscum* (Viscaceae), the root parasite *Osyris* (Santalaceae) and the fynbos endemic family Grubbiaceae. By contrast, ornithochory is a prominent dispersal strategy in strandveld, subtropical thickets and in forests, which all contain abundant and diverse fauna of frugivorous birds (Le Maitre & Midgley 1992).

Obligate Reseeding versus Resprouting: Fynbos is unusual in the low proportion of woody plants that survive fire by resprouting. Both renosterveld (which burns more frequently) and forest (which hardly ever burns) are characterised by resprouting plants. Similarly, both the Grassland and Savanna Biomes are dominated by resprouters. Because of the predictable fire-return interval, fynbos shrubs appear to invest all their resources in seed production at the expense of regeneration. These species dominate fynbos in terms of cover and comprise most emergent elements. The only true fynbos shrub that is able to regenerate from aerial stems (epicormic resprouter) is the waboom, *Protea nitida*, which occurs on richer, colluvial substrata. In forest, savanna and grassland, epicormic resprouting is the norm.

Obligate reseeders occur in all plant families and comprise most species of the Ericaceae (> 90%), Proteaceae (> 80%), Fabaceae (> 75%), Asteraceae, Rutaceae and Bruniaceae, and is even common in the Restionaceae, in which it has been underestimated in the past (Le Maitre & Midgley 1992). In a study of 10 fynbos species 26 years after a fire at Jonkershoek near Stellenbosch, the ratio between root and shoot mass was lower (0.2) in the obligate reseeders than in the resprouters (2.3) (Higgins et al. 1987, Smith & Higgins 1990). Resprouters can persist at a site through several generations of obligate reseeders (Bond & Midgley 2003). By contrast, reseeders outgrow resprouters, and after 15 years start shading out and reducing the cover of resprouters, resulting in increased species richness in areas dominated by reseeders compared to resprouters (J.H.J. Vlok, personal communication).

Lack of Annuals: Annuals are generally a rare component of fynbos communities, especially when compared to other mediterranean regions (Naveh & Whittaker 1979, Cowling 1983a). Wisheu et al. (2000) attribute the virtual absence of annuals in fynbos to the infertile soils and hypothesise that the soil nutrient status is too low for annuals to complete their life cycles and set seeds in one growing season.

Most annuals in the Fynbos Biome occur in strandveld (especially on granite), some types of renosterveld (especially the dolerite and granite types), sand fynbos and asteraceous fynbos in the more arid facies. By contrast, annuals are prominent in the succulent karoo shrublands. Alien annuals are prominent only along paths in most fynbos types (Vlok 1988). However, alien annuals have become invasive in sand fynbos and renosterveld, where they appear to displace the geophytes (Le Maitre & Midgley 1992).

The lack of fire annuals in fynbos compared to more nutrient-rich renosterveld types is particularly marked. Most early seral species in fynbos live for 3–5 years. Some orchids and bulbs flower only in the year following a fire, but, being geophytic, probably live through several fire cycles.

Sclerophylly: Sclerophylly is a feature of most mediterranean floras and may be a summer-drought strategy. However, it is especially prominent in systems where low nutrients limit the option of drought deciduousness, and long-lived, tough, low-nutrient leaves capable of resisting desiccation are required. The lack of nutrients results in a carbon-rich, and thus woody, sclerophyllous leaf. This effectively eliminates herbivory (the nitrogen-to-carbon ratio is too low to allow animal utilisation, except in young growth). As a consequence, defences against herbivory (thorns, spikes, leaf chemicals) are largely absent in fynbos. In fynbos sclerophylly is manifested as proteoid, ericoid, restioid and spine-tipped leaf forms (Le Maitre & Midgley 1992). On richer soils—bearing strandveld and renosterveld—succulent, orthophyllous and drought-deciduous leaves abound, often protected with thorns, spines and aromatic compounds.

Lack of Mycorrhiza and the Presence of Cluster Roots: Two of the dominant components in fynbos, the Proteaceae and the Restionaceae and Cyperaceae, are characterised by not having fungal associates to extract nutrients from the soil. Instead they have, respectively, proteoid and caudiform rootlets, which resemble dense balls or carrots of fine root hairs (Lamont 2003). These cluster roots form a large surface area releasing phosphate-solubilising compounds and efficiently extracting phosphates in a small soil volume (Lambers et al. 2003). Fertilising with phosphorous or potassium kills the plants and on richer soils these rootlets are not produced. It has been argued that because fungi have nitrogen-rich cell walls they are a liability in nutrient-poor fynbos soils and species utilising them are compromised and never attain emergent dominance, except under special conditions as for instance in Ericaceae with endorhizal mycorrhiza under peaty conditions. However, even then Ericaceae are spindly plants lacking the robustness of the other characteristic dominants (Le Maitre & Midgley 1992). Cluster roots are apparently not prevalent in renosterveld or strandveld.

Carnivory and Digestive Mutualism: Because of the nutrient-poor soils, and especially peaty soils, it is not surprising that carnivorous plants abound, although they are never dominant. Over 10% of the world's species of *Drosera* (15 species) occur in fynbos. Of the other typical plant carnivores, the genus *Utricularia* is also represented in fynbos wetlands (Le Maitre & Midgley 1992). The shrubby endemic family Roridulaceae (two species) superficially resembles *Drosera*, but plants do not digest trapped insects, utilising heteropterans and spiders to process nutrients (Ellis & Midgley 1996, Anderson & Midgley 2002, 2003, Anderson et al. 2004). The pitcher type of carnivorous plant is absent from fynbos (Le Maitre & Midgley 1992).

Low Biomass of Herbivores: The low nutrient status of fynbos makes the soils unsuitable for agriculture, although with modern methods of fertilisation via watering this is no longer true. A characteristic of fynbos is the low number and biomass of animals, especially large animals, but also birds and insects, encountered. Carrying capacity for fynbos is generally lower than 1 small stock unit per 8 ha (Stock et al. 1992b). Although large mammals were generally absent, in the past fynbos was probably well traversed by large animals en route to kloof and high-altitude seeps as a water source during the dry periods, and as migration routes between different renosterveld and karroid shrublands. Use of fynbos by large mammals for food was probably limited to early post-fire regrowth. The absence of antiherbivore defence (both structural and chemical) in fynbos plants is striking (Le Maitre & Midgley 1992). Old kraals and historical bomas have distinct and often well-defined ruderal plant communities, as do dung middens of klipspringer and vaal rhebuck, the largest extant herbivores in fynbos proper today. Mountain zebra tend to frequent shale bands and renosterveld where they have access to these. While biomass of herbivores (and consequently carnivores) is very low, animal diversity is high, especially among insects (Le Maitre & Midgley 1992). The fynbos insect fauna is particularly poorly known, but freshwater, cave and forest faunas are particularly rich in species and endemics. Of the six birds endemic to fynbos, two specialise on seeds and two on insects, and two are nectarivores (Stock et al. 1992b). (The significance of large-mammal herbivory in renosterveld is discussed in Section 4.4.1 below.)

Bird and Mammal Pollination: One of the most striking features of fynbos on nutrient-poor soils is the contrast between the low biomass of herbivores, insectivores and frugivores, and the relative abundance and conspicuousness of nectarivorous birds. The same is true of the plants: bird-pollinated species are conspicuous, abundant and usually dominant (both in cover and structure) in their communities, especially so in proteoid and ericaceous fynbos. This is unparalleled in renosterveld, strandveld, karoo, thicket or forest. Although not so obvious amongst the mammals, mammal-pollinated plants are also abundant and often dominant in terms of cover.

Ornithophily (bird pollination) is most common in fynbos, with 75% of bird-pollinated plant species on the subcontinent occurring in fynbos (Rebelo 1987a). Approximately 5% of fynbos plant taxa are pollinated by birds (Johnson 1992). Nectarivorous birds account for 50% of bird biomass in fynbos, but less than 5% in other vegetation types (Rebelo et al. 1984). Bird-pollinated taxa are concentrated in the Ericaceae (ca. 100 species), Proteaceae (ca. 80 species, especially in *Leucospermum, Mimetes, Protea*) and in geophytes of Amaryllidaceae and Iridaceae (Rebelo et al. 1984, Johnson 1992, Goldblatt et al. 1999), but are also found in Orchidaceae (Johnson 1996a). Although nectarivore diversity is similar to other ecosystems, bird-pollination systems in fynbos show a striking asymmetry, with several hundred plant taxa relying on only 3–5 bird species for their pollination. Two key pollinators, the Cape Sugarbird (*Promerops cafer*) (primarily visiting Proteaceae) and Orange-breasted Sunbird (*Anthobaphes violacea*), primarily visiting *Erica*, are endemic to fynbos. The other significant bird pollinator in fynbos is the Malachite Sunbird, which has been suggested to specialise on geophytes, although it regularly visits other plants as well (Rebelo 1987a).

Plants pollinated by birds invariably exhibit a classic syndrome of tubular or brush-like flowers, or cup-shaped flowerheads with copious amounts of dilute nectar and an absence of discernable scent. Colour, however, does not conform to the classical syndrome, with numerous pale and even green flowers: in fact, most bird-pollinated species are strongly colour polymorphic in fynbos (Rebelo 1987a). The high prevalence of ornithophily is ascribed to a high energy resource, but lack of nutrients to convert this to nonstructural tissue. Ornithophilous nectar is also dilute and abundant, requiring water. It is rare in the drier types (asteraceous and restioid fynbos), but dominates proteoid fynbos, and is prominent in ericaceous fynbos. Flowering tends to peak in winter and spring, depending on the availability of moisture. Seasonal movements of birds within fynbos are unknown (Rebelo 1987b).

Therophily (pollination by nonflying mammals) in shrubby plants is confined to fynbos in *Protea* (with over 20 species) and *Leucospermum* (two species) (Rebelo & Breytenbach 1987). Pollination by rodents is associated with a distinctive floral syndrome that includes geoflory (flowers located close to the ground), dull perianth coloration and yeasty fragrance (Wiens et al. 1983). A few other candidates in *Erica* and *Leucadendron* may also be therophilous. First reported in the 1970s (Rourke & Wiens 1977, Wiens & Rourke 1978, Wiens et al. 1983), therophily has also subsequently been found in the geophytes *Massonia* (Hyacinthaceae) and *Androcymbium* (Colchicaceae) and the parasitic *Cytinus* (Cytinaceae) (Johnson et al. 2001). These plants are not restricted to fynbos, but occur in karoo as well. The arguments for the distribution of therophily within fynbos are similar to those for bird pollination, but the more concentrated nectar lacks the water requirement, allowing therophily to occur in areas too arid for bird pollination. It occurs predominantly in proteoid and asteraceous fynbos. The rodents that visit the flowerheads, appear to rely on nectar only during their breeding season (Fleming & Nicholson 2002a, b). Interestingly, shrews are also pollinators, but appear to be visiting flowerheads for the insects, especially ants, found there (Fleming & Nicholson 2003). Flowering occurs in winter and spring (Rebelo 2001). Based on exclusion experiments, rodents account for about half the seed set in therophilous proteas (Fleming & Nicholson 2002a).

Exclusion experiments have shown that insects, particularly pollen-feeding bees and beetles, can make a substantial contribution to seed production in plants that otherwise appear adapted for bird or mammal pollination (Coetzee & Giliomee 1985, Wright et al. 1991a, Vos et al. 1994, but see Fleming & Nicholson 2002a, Hargreaves et al. 2004). Reciprocal experiments and the genetic fitness of seeds produced by the different pollinators have not been attempted so far.

Interestingly, fynbos is not known to differ markedly from other vegetation types in other pollination syndromes.

4.2 Climate and Growth-form Response

The mediterranean-type and all-year climate regimes have also influenced diversity in the region. The interplay between arid and wet climatic cycles as a species pump for alternatively contracting fynbos and succulent karoo vegetation has resulted in a proposal for a single 'Winter-rainfall Biome' encompassing both Fynbos and Succulent Karoo Biomes. However, only two biotic features stand out that link vegetation types between the two biomes, namely (1) the shared abundance of geophytes, and (2) the lack of trees.

Abundance of Geophytes: Fynbos, especially renosterveld, has a high diversity of bulbous plants—a striking feature shared with the Succulent Karoo (Esler et al. 1999, Procheş & Cowling 2004, Procheş et al. 2005, 2006). This suggests a climatic explanation, as fire and nutrients do not appear to be prime factors in the high diversity of geophytes in the region. The absence of annual grasses (and hence the threat of invasive annual grasses to geophytes) has been suggested as a reason. Geophytic diversity is four to five times the geophytic richness of the other mediterranean floras—geophytes comprise some 17% of the flora of the Cape Floristic Region (Goldblatt & Manning 2000a, Manning et al. 2002). Associated with the prevalence of bulbs is the occurrence of four species of exclusively fossorial rodents (mole rats), which subsist primarily on geophytes. More fynbos geophytic species have adopted an evergreen and woody habit than in renosterveld or karoo, and some fynbos Iridaceae have become uniquely shrub-like (*Aristea, Klattia, Nivenia, Witsenia*). The presence of geophytes in the dicots (e.g. *Oxalis* with 118 species) is very unusual, but again this is not confined to fynbos. Most winter-rainfall geophytes are dormant in summer and flower after leafing in winter, but the Amaryllidaceae—with large particularly poisonous bulbs—leaf in winter and flower in autumn, usually after the first rains (Goldblatt & Manning 2000a). Most fynbos geophytes flower most prolifically after fire, and only rarely in older veld (Le Maitre & Midgley 1992) but in karoo geophytes, flowering is determined more by rainfall.

Interestingly, geophytes appear resilient to both frequent fire and heavy grazing regimes (McDowell 1988). However, it is thought that alien invasive grasses compete directly with the geophytic component (Vlok 1988). Certainly in eutrophic areas and old agricultural land, alien annual grasses are dominant at the expense of geophytes (Milton 2004). Heavy grazing might control the annual grasses, but fire and heavy grazing may favour alien annual grasses by virtue of their larger seed banks compared to those of indigenous grasses (Milton 2004). More research into the control of alien invasive grasses is required to ensure that the rich geophytic flora survives.

Lack of Trees: The absence of trees in fynbos (Moll et al. 1980) is a feature shared with renosterveld, and the Karoo, Desert and Grassland Biomes. As in arid vegetation types, trees are largely confined to riverine habitats. However, this is more a function of topography, with trees occurring in fire-safe habitats, as in grassland. Despite much debate, the reasons for the lack of trees in fynbos have never been resolved. Part of the reason for this is that alien trees (*Pinus, Acacia, Eucalyptus*) flourish in the Fynbos Biome. Arguably with adequate biocontrols these alien plants might not attain tree status in Fynbos (Le Maitre & Midgley 1992).

Climatic Reliability: Climatic variables such as the reliability (or predictability) of rainfall and mist precipitation may be linked to certain plant life-history traits in mediterranean-type ecosystems, as noted by Cowling et al. (2005). They suggest that germination response to soil moisture regimes, allocation of resources to below and above-ground biomass, and seedling mortality in relation to short-term stress are major candidates for further studies.

4.3 Fire as a Non-selective Grazer

Fynbos and renosterveld are fire-maintained systems (Figure 4.16). Of all fynbos and renosterveld vegetation units, perhaps only FFd 1 Namaqualand Sand Fynbos and FFq 1 Stinkfonteinberge Quartzite Fynbos are not exclusively driven by fire. Fire in fynbos burns on a 5–50-year rotation, usually in the order of 15–25 years. Fire regimes in renosterveld are largely unknown, but are assumed to be in the 2–10-year range. The fires naturally occur in late summer and early autumn, towards the end of the dry season, and their natural causes include rockfalls and lightning. With increasing population density in and around fynbos, man-made fires have become more frequent. The increased incidence of man-made fires has probably decreased the average fire size, without changing the fire-return interval at any location (Figure 4.17). Arguably, nutrients and climate are the primary determinants of the fire regime (Van Wilgen et al. 1992a, b, Bond & Van Wilgen 1996). Rather than concentrate on all the ramifications of fire, we will confine ourselves to several community-ecology issues such as the fynbos vegetation boundaries, boundaries of internal units, and alternative states maintained by fire.

4.3.1 Fire and Community Composition

Fynbos

Typically, boundaries within fynbos units are not determined by fire. However, fire does play a major role in determining species composition and community type. These effects are usually mediated by the fire temperature, which is controlled by air temperature, season, time of day, aspect, wind conditions, aeration, humidity, wood moisture content, veld age, and size of fuel storage (Van Wilgen et al. 1992a).

Although much is made about fynbos burning when too young, fynbos cannot burn until there is sufficient fuel to sustain a fire. Very frequent fires eliminate firstly the serotinous species, which being the dominant overstorey group and with its shading effect in veld older than 15–20 years, are the key species in community composition. However, young veld tends not to burn cleanly, and a mosaic of unburned patches is typical of areas where farmers attempt to burn as often as possible. These offer refugia to serotinous species. Species with soil seed banks appear to carry a proportion of the seed bank over to the next fire (Van Wilgen et al. 1992a).

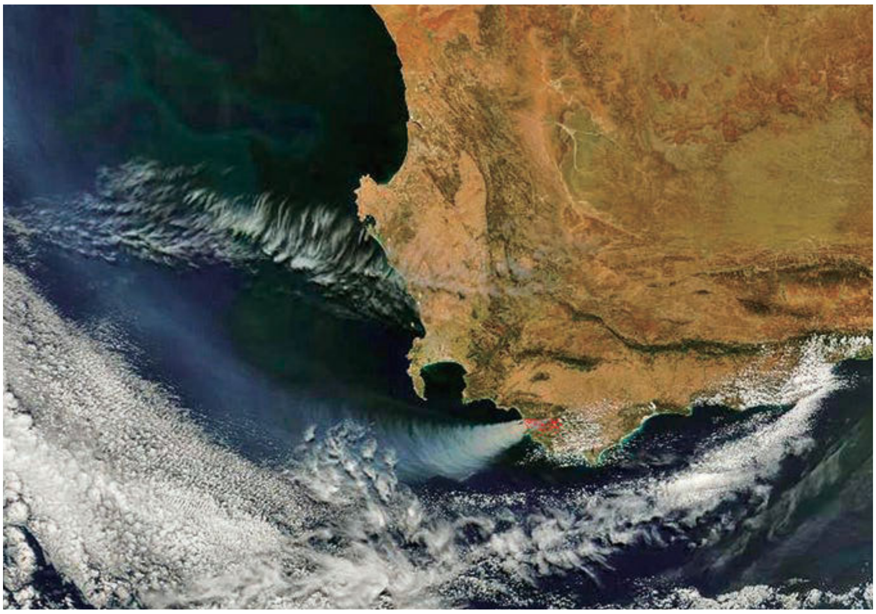


Figure 4.16 Satellite image of the devastating fires in the Overberg region near Cape Agulhas (February 2006) showing a huge smoke plume being carried deep into the southern Atlantic Ocean against a background of a massive western cloud- and precipitation-bearing front approaching the southwestern Cape. (Courtesy of NASA and the University of Maryland.)

Regular frequent fires, as for instance in fire belts, result in bole resprouting species becoming dominant, but the total cover of the area is unaffected. The relative abundance of obligate reseeder species versus resprouters is a good indication of historical fire frequency within any vegetation community. In proteoid fynbos this is complicated by aseasonal (spring) burns that reduce serotinous population sizes, allowing nonserotinous species to increase in cover. Thus very frequent fires or aseasonal burns can convert proteoid fynbos to its understorey equivalent of ericaceous, restioid or asteraceous fynbos, but extinction of the proteoid element is rare (Le Maitre & Midgley 1992, Van Wilgen et al. 1992a).

Aseasonal fires (spring versus the natural late summer or autumn fires) reduce population sizes of serotinous species by exposing seeds to rodent and bird predation for prolonged periods prior to germination in autumn. This reduces the cover of these key species in mature fynbos, allowing resprouters to gain competitive dominance. Resprouter dominance is exerted by usurping space for post-fire seedling regeneration of obligate reseeders. Most aseasonal fires are managed block burns and firebelts (Van Wilgen et al. 1992a).

Hottest fires occur in more mature veld, where there is more fuel, and during the summer fire season. Very hot fires have two major effects on species composition. They incur a higher mortality of resprouting species, and in *Protea nitida* can reduce the plants from epicormic to bole resprouters. Hot fires also eliminate shallow seed banks. Most affected appear to be Asteraceae, with species of *Helichrysum, Stoebe* and *Syncarpha* the most marked of these. Presumably ericoid seeds occur in wetter soils and are less affected. Myrmecochorous and serotinous species appear to benefit most from very hot fires. The former are buried too deep to be killed by fire, and the latter are safe in their fireproof cones. Neither establish well in cool fires that leave a thick litter layer; presumably the germination cues are not triggered in myrmecochorous species, and seedling mortality is high in serotinous species. In myrmecochorous species the dormant seedbanks appear to persist to the next fire. It is not known how long-lived the seed banks are—possibly in the order of 40–80 years. Consequently, the species present in a stand of fynbos may depend as much on fire history as on habitat and species pool. Most management fires are cool, as manageability is a function of fire temperature, but natural fires burn larger areas and account for most of the area burned in any year (Bond 1985, 1997, Bond et al. 1990, Van Wilgen et al. 1992a).

Topography and rockiness drastically affect fire temperature, and favour smaller-seeded species. In addition, these species tend to have soft persistent leaves that retard fire, create much smoke and result in incomplete combustion at ground level due to oxygen starvation (aeration). Occurring in similar habitats, are myrmecochorous species, such as the Rutaceae, which appear to encourage fire with volatile oils. Presumably these two strategies are dominant after a particular fire and attempt to influence future fire temperatures to favour their regeneration niche (Van Wilgen et al. 1992a).

Rocky habitats also cool fires down sufficiently to allow canopy survival. This is a relatively rare strategy—*Leucospermum conocarpodendron* subsp. *viridum* and *Mimetes fimbriifolius* are the best known examples of this strategy. On sandstone both species are dominant in rocky areas and seldom reach tree status in open vegetation. In rugged areas where cooler fires do not penetrate, fire escapers such as *Protea glabra, P. rupicola, Widdringtonia cederbergensis* and *W. swartzii* survive (Van Wilgen et al. 1992a).

Fire also affects the minimum patch size of fynbos within non-fire vegetation types. Thus below 600 ha fynbos loses species, and below 4–15 ha fynbos cannot exist (Bond et al. 1988, Rebelo 1992b). This affects patches on hills and peaks within forest, thicket and karoo shrublands. The size of patches determines the probability of a lightning strike and therefore the fire interval. Where this exceeds 30–50 years, fynbos cannot exist (Bond et al. 1988). In larger blocks of fynbos, ignition is not as important as most fires enter any patch from ignition events outside the patch.

Renosterveld

Although renosterveld is clearly a fire-maintained system, there is little evidence as to what might constitute an ideal fire frequency (Von Hase et al. 2003). Estimates of 3–10 (up to 40) years exist (Rebelo 1992a). Presumably heavily grazed areas seldom burn. By contrast, ungrazed areas can accumulate sufficient fuel to maintain fire. Fire-safe habitats—including heuweltjies in some landscapes—contain thicket elements such as *Rhus* bush clumps. Similarly, fire-protected areas become dominated with *Rhus* bush clumps as on Signal Hill. Most grasses, annuals and bulbs survive under a high fire cycle, but many shrubs (and animals, such as the Geometric Tortoise (*Psammobates geometicus*) require 3–5 years to mature. Season of burn has a profound impact on vegetation composition in fynbos, and presumably also in renosterveld (Cowling et al. 1986). Thus early spring fires would prevent annuals, geophytes and most grasses from setting seed. Summer and autumn fires would not have these negative effects, but may—by virtue of their being hotter—change community composition to those plants with deeper soil seed and bulb banks. Similarly, patterns of grazing after fire would affect species composition, particularly the interplay between grasses and geophytic and shrubby components.

Some fire-associated strategies common in fynbos are absent from (e.g. serotiny) or rare (e.g. obligate reseeding, myrmecochory) in renosterveld. Fruit dispersal by birds is common in species of thicket clumps (Le Maitre & Midgley 1992).

A major complication in the study of renosterveld is the current insularisation of renosterveld. In areas where farmers do not regularly burn for grazing, the vegetation rapidly (within decades) converts to a thicket or a thicket mosaic. Britton & Jackelman (1996) argue that even in 25 year-old renosterveld (protected from grazing, and dominated by *Rhus* and *Hyparrhenia hirta*), the geophytes and perennials are actively growing and flowering and that renosterveld species can therefore survive in a fire-free Cape thicket. However, no controls were done and thickets tend not to contain as many geophytes as renosterveld (A.G. Rebelo, personal observations).

F.G.T. Radloff

Figure 4.17 Controlled fire in renosterveld shrublands on shale in the Potberg section of the De Hoop Nature Reserve (Overberg region).

4.3.2 *Post-fire Regeneration*

Seral succession has been poorly studied in the Fynbos Biome. The constraint of veld age on floristic and structural studies has resulted in a dearth of knowledge of pattern and process in early seral (i.e. immature) fynbos communities. The basic post-fire regeneration pattern is obvious and has general features: immediately after a fire, the 'fire lilies' (such as *Cyrtanthus, Watsonia*, etc.) are the first to emerge, sometimes within a few days of the fire (Figure 4.18). A few geophytic orchids and daisies flower only during these earliest periods, before seeds germinate (Le Maitre & Midgley 1992). If rain is delayed or late in autumn, then seed germination is delayed but most resprouters will commence regrowth. Similarly, early rains result in massive resprouting, but seed germination is usually tied to a strong cold requirement, ensuring that seeds germinate sufficiently well into winter to guarantee follow-up rains. Almost all recruitment appears to occur in the first and possibly second autumn following a fire. Conditions might be laxer in the all-year rainfall area, where it is not known whether spring recruitment might occur. During this period, all species present in later seral stages are present as seedlings, and no further significant recruitment occurs, with the exception of the aerial parasites *Viscum* and *Cassytha* (spread by birds from fire refugia). This lack of recruitment is thought to be a combination of rodent predation of seeds and overwhelming competition from established plants for water so that any seedling dies during the summer drought period. Most fynbos plants have seeds with strong dormancy- and post-fire-related cues for germination (Le Maitre & Midgley 1992).

In spring, large-scale flowering of geophytes and, where present, of annuals occurs. Some species flower only in the first spring, but many flower best two years after a fire. Few species produce more than a small fraction of flowers after the third year (Le Maitre & Midgley 1992).

The first year or two is dominated by resprouting species and fire ephemerals, with seedlings being small and relatively inconspicuous, although non-resprouting Restionaceae and Cyperaceae rapidly become dominant in some communities. The fire ephemerals are mainly Fabaceae, with *Aspalathus* being the most obvious element, Asteraceae (*Othonna quinquedentata* and *Ursinia crithmoides* require special mention), and some other families such as Campanulaceae (endemic genus *Roella*) and the monotypic endemic family Lanariaceae (*Lanaria lanata*). Fire ephemerals can reach 100% cover in shale and granite fynbos as a 0.5–1.5 m layer, but such dominance is rare in other fynbos types. These species peak 3–5 years after a fire, after which senescence eliminates them from the community, where they survive as seeds until the next fire. The effect of these species on seedlings of later seral stages is unknown, but later seral stages do not appear to be compromised by them. Slightly more long-lived, but in the same category, are many grasses and Asteraceae colloquially known as 'everlastings' or 'sewejaartjies' (e.g. of the genera *Anaxeton, Edmondia, Helichrysum, Phaenocoma*), of which many are harvested from young recovering veld for the cut flower trade (Le Maitre & Midgley 1992).

Resprouters remain alive in mature veld, but the flowering of most peaks in year 2 or 3 after which growth and flowering declines. Some species remain vigorous, but many seem to enter stasis with minimal new leaf production and few flowers. These species appear to recruit best when veld is burned when young (about 4–6 years old), with little recruitment following fires in older veld. Most mortality in resprouters occurs after regeneration, but it is characteristically low (< 5%), suggesting that resprouting plants may be hundreds of years old (Le Maitre & Midgley 1992).

Most species maturing after four years remain in the community, but the ericoids start emerging and becoming dominant after 4–5 years and the proteoids start emerging after year 4–7 and reach maximum canopy cover between year 8 (dense stands and wetter habitats) and year 15 (sparser stands and more arid situations). Although no mortality of proteoids is usually apparent until senescence sets in, shading and competition in the understorey do occur, but mortality rates are unknown. Usually after 30–40 years, senescence sets in. With most plants this manifests as shortening lengths of leaves on the branch tips, until the branches die. Serotinous species lose their seed banks, resulting in reduced populations after fire. Some inter-fire recruitment sets in as plants die off, but survival is still relatively low compared to after a fire. Most flowering ceases and skeletons (thanatocoenoses) form prominent features in the fynbos vegetation (Le Maitre & Midgley 1992).


E.G.H. Oliver

Figure 4.18 Explosive post-fire floral display of *Kniphofia tabularis* (Asphodelaceae) in the summit marshlands of the Hottentots Holland Mountains (Western Cape).

Seral succession therefore mirrors structural complexity, with graminoid fynbos being replaced by restioid fynbos, asteraceous or ericaceous fynbos following, and proteoid fynbos dominant until senescence sets in and closed-scrub fynbos starts appearing. Although the species present and the number of plants remain constant, apart from the ephemeral component, dominance in height and cover alters dramatically as the community ages. Too frequent fires reset the seral complexity at lower stages. However, later stages are important, with proteoids a key element in shading and suppressing resprouters and thus maintaining local species diversity (Le Maitre & Midgley 1992).

Seral succession has not been recorded from renosterveld communities—presumably the high fire frequency and grazing maintain renosterveld at an early seral stage.

4.3.3 Fire-adaptive Responses

There are at least three striking adaptation phenomena linked to the selective force of fire in the fynbos and renosterveld ecosystems. Of these, the high incidence of obligate reseeding species versus resprouters (Bond & Midgley 2003) and the occurrence of serotiny are most obvious (Bond 1984, 1985). Although these phenomena are related to fire, they are largely confined to fynbos on nutrient-poor soils. The absence of these strategies from other fire-prone ecosystems suggests that it is interplay between the low-nutrient soils and the predictable long-term (5–30-year) fire cycle that have allowed the evolution of these strategies rather than fire *per se*. A third adaptation is the incidence of smoke-induced seed germination.

Much has been made about the importance of smoke and smoke extracts in inducing germination in seed (De Lange & Boucher 1990, Dixon et al. 1995, Van Staden et al. 2000). Indeed for certain groups it is the only known way of breaking dormancy and obtaining seedlings in cultivation. Still we do not fully understand why natural smoke does not initiate germination in areas that do not burn, and why smoke may initiate germination of species typical of fire-free vegetation types such as karoo shrublands. While the physiological and horticultural importance of smoke is clear (Meets 2000, Brown et al. 2003, Boucher & Meets 2004, Brown & Botha 2004), the ecological significance of smoke requires further investigation, especially by setting *in situ* experiments.

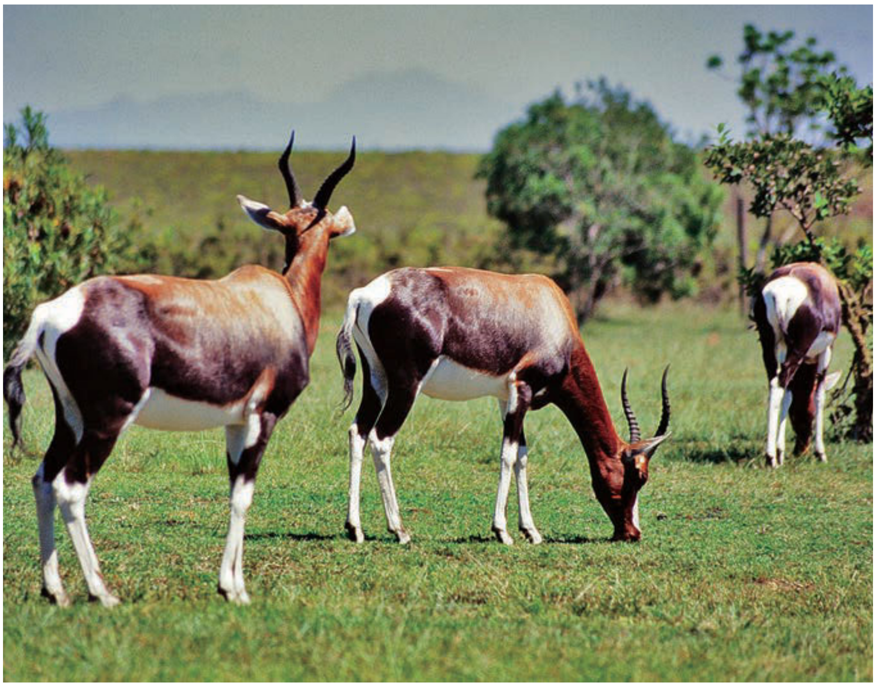
4.4 Animal-plant Interactions

4.4.1 Large Mammal Herbivory

Herbivores change the structure, biomass, production and species composition of vegetation in heavily browsed or grazed areas of numerous and diverse ecosystems around the world. Both feeding strategies and physical disturbance by large vertebrates can alter important ecosystem properties, resulting in long-term changes in communities (Hobbs 1996, Owen-Smith & Danckwerts 1997, Frank et al. 1998, Olofsson et al. 2001, Augustine et al. 2003, Augustine & McNaughton 2004, Archibald et al. 2005). What role did (and do) large herbivores play in the vegetation dynamics of the Fynbos Biome?

Historical accounts indicate that a high and diverse number of large native herbivore species (> 20 kg) occurred in the Fynbos Biome and more specifically in the low-lying areas of the Western Cape at the time of European colonisation (1652) (Du Plessis 1969, Skead 1980, Rookmaaker 1989, Boshoff & Kerley 2001). There is little doubt that lowlands supported African elephant (*Loxodonta africana*), black rhino (*Diceros bicornis bicornis*), hippo (*Hippopotamus amphibius*), eland (*Taurotragus oryx*), mountain zebra (*Equus zebra zebra*), quagga (*Equus burchellii quagga*), ostrich (*Struthio camelus*), red hartebeest (*Alcephalus buselaphus*) and grey rhebuck (*Palea capreolus*). In addition, the lowlands to the east of the Overberg also hosted populations of Cape buffalo (*Syncerus caffer*), blue antelope (*Hippotragus leucophaeus*; extinct around 1800) and bontebok (*Damaliscus pygargus pygargus*: Figure 4.19), with bushbuck (*Tragelapus scriptus*) present in forest and thicket patches. It is not exactly clear how far west quagga (a subspecies of Burchell's zebra; extinct in 1876) ventured and what its ecological relationship with mountain zebra was. On the West Coast, gemsbok (*Oryx gazella*) has been reported as far south as Saldanha but is believed to have been only an occasional visitor to this area and more abundant from Namaqualand northwards. Springbok (*Antidorcas marsupialis*) occurred inland in both the Warme and Koue Bokkeveld regions, but was most likely restricted to these parts within the Fynbos Biome.

In association with these large herbivores all the members of the large carnivore guild of southern Africa were found, including Cape lion (*Panthera leo*), leopard (*Panthera pardus*), wild dog (*Lycaon pictus*), cheetah (*Acinonyx jubatus*), spotted hyaena (*Crocuta crocuta*) and brown hyaena (*Hyaena brunnea*), with attendant vultures and birds of prey. Unfortunately the size of the populations of these animals changed very rapidly after colonial settlement. It is estimated that by the year 1700 there was no game within 200 km of Cape Town and that by 1800 most large mammals (above 50 kg) and birds had been driven close to extinction within the area today known as the CFR (Rebelo 1992a). Most of these extinctions were due to hunting for meat and sport, or the elimination of predators, scavengers and 'problem' animals (Rebelo 1992a, Krug et al. 2004b). Game animals were, however, not the only animals present at the time of colonisation. Around 2 000 years ago, the Khoekhoen introduced livestock (sheep and later also cattle) to the Fynbos Biome and the number of domestic livestock roaming the Cape forelands could have run well into the thousands with the arrival of the Dutch colonisers (Deacon 1992). Entries in Van Riebeeck's diary state that the Khoekhoen, eager to trade, gathered in such numbers with their livestock around the fort in Table Bay in December 1652 that they could easily have captured 12 000 cattle if they were so inclined (Thom 1952). A later entry (14 January 1653) gave an estimate of at least 20 000 cattle and sheep



L. Mucina

Figure 4.19 Bontebok (*Damaliscus pygargus pygargus*)—a conservation symbol of the Fynbos Biome.

present in that December. Whether these animals were permanently kept on the coastal lowlands and at such densities is, however, debatable as the same entry mentioned cattle trade by these Khoekhoen with tribes 'far inland', indicating migration by these people.

Little is known about the past distribution of large herbivores within the Fynbos Biome. It appears that the largely accepted opinion (Bigalke 1979, Cody et al. 1983, Morrow et al. 1983, Johnson 1992, Rebelo 1992b, Owen-Smith & Danckwerts 1997) is that the sandstone, sand and limestone fynbos did not support large resident herbivore populations and that they rather concentrated on renosterveld on the more nutrient-rich soils. However, this is based primarily on the exceptionally low nutritional status of fynbos (Joubert & Stindt 1979, Campbell 1986b, Le Roux 1988, Johnson 1992) rather than on historical records or habitat choice experiments. The reviews of historical accounts (Du Plessis 1969, Skead 1980, Rookmaker 1989) are vague with regard to the exact areas and habitats occupied (Boshoff & Kerley 2001). Even recent reviews (e.g. Hendey 1983a, b) stating that the influence of large mammals must have been 'significant and are under-appreciated' and that they might have been able to keep the vegetation more open and grassy than today, fail to distinguish between fynbos and renosterveld, referring to both as 'fynbos'. This is in contrast to opinions such as that of Rebelo (1992b) suggesting that the large herbivores never played a major role in the dynamics of nutrient-poor fynbos communities, but were largely confined to renosterveld.

The influence of large herbivores on the Fynbos Biome ecosystem has for the most part been a neglected topic. At the Third International Conference on Mediterranean-type Ecosystems held in 1980 it was concluded that there was very little understanding of the relationship between soil nutrient status, plant nutrition and the vertebrate faunas of any of the mediterranean-like ecosystems (Cody et al. 1983, Morrow et al. 1983). It appears that, for at least the Fynbos Biome, very little has changed since then.

Published studies on large native herbivores in the Fynbos Biome have been conducted mainly in the Bontebok National Park and Elandsberg Private Nature Reserve, with some isolated contributions from the Cape of Good Hope Nature Reserve (now part of the Table Mountain National Park) and De Hoop Nature Reserve. In the Bontebok National Park (primarily FFc 1 Swellendam Silcrete Fynbos, with patches of FRs 13 Eastern Rûens Shale Renosterveld) studies focused on some aspects of Grey Rhebuck ecology (Beukes 1984), Bontebok behaviour (David 1973, Van Zyl 1978) and Bontebok population dynamics (De Graaff et al. 1976). Both Novellie (1987) who focused on grassy elements, and Beukes (1987) who studied especially the shrubby component, conducted studies that looked into the interrelationships between fire, herbivory and vegetation cover. Both studies clearly showed the preference of Bontebok and Grey Rhebuck for recently burnt fynbos. Beukes (1987) reported on a dramatic drop in the utilisation of vegetation older than four years. Novellie (1987) found that intense grazing after fire is not necessarily deleterious to the preferred grass species. Luyt (2005) looked into habitat preference and stocking densities for Bontebok within the park found that Bontebok prefer recently burnt areas and may delay the re-establishment of shrubs if too small an area is burnt at a given time. A small burnt patch can attract a very high density of animals that suppress shrub seedling establishment by indiscriminate grazing of any new growth. Bontebok seek out *Cynodon dactylon* grazing lawns and might also create and maintain these lawns by positive feedback nutrient loops.

The Elandsberg Private Nature Reserve recently became the focus point of research regarding the restoration of West Coast renosterveld (Krug et al. 2004a, b), although most of the study area is FFa 3 Swartland Alluvium Fynbos. Midoko-Iponga (2004) found that both browsing and competition with grass played a role in transplanted shrub seedling (5 cm high) establishment on old lands, but that competition between shrubs and grasses was more important, although the role of large herbivores via grazing was not included. Shiponeni (2003) looked at seed dispersal by large herbivores (endozoochory) and found that it played an important role in the dispersal of seeds. *Cynodon dactylon* and several alien invasive grasses were the dominant species dispersed by this means. Here large herbivores may also be instrumental in the establishment and maintenance of *Cynodon dactylon* grazing lawns on old lands. Walton (2006) studied the influence of grazing on vegetation dynamics after ploughing and found that succession on old fields was retarded by grazing, and the establishment of palatable shrubs, such as *Anthospermum* and *Hermannia*, was particularly slow. These results must further be treated with caution with regard to historical/natural ecosystem processes—nearly two thirds of the large herbivores were historically not indigenous to the Elandsberg Reserve, the vegetation is not renosterveld and this study focuses on recovery in fallow lands.

In the Cape of Good Hope Nature Reserve, Langley & Giliomee (1974) found that the introduced population of Bontebok favoured recently burnt areas, fire breaks and well-established *Stenotaphrum secundatum* lawns. In De Hoop Nature Reserve, Cape Mountain Zebra demography (Lloyd & Rasa 1989) and the decline in Bontebok populations experienced between 1984 and 1990 (Scott 1993) have been studied. The main reason for the population decline was attributed to the lack of suitable habitat in the form of recently burnt veld. A rapid improvement in Bontebok body condition did occur after a controlled fire in 1991, but a subpopulation without access to newly burnt areas also showed an improvement in body condition and survival. Here Bontebok also concentrate on *Cynodon dactylon* lawns and recently burnt veld. The last study of relevance is that of Milewski (2002) reporting on the diet of forest elephants roaming the forest/fynbos ecotone near Knysna. Based on opportunistic qualitative data obtained from forest guards, he provides evidence that elephants utilised nutrient-poor fynbos (FFh 9 Garden Route Shale Fynbos). However, in contrast to these, large game numbers at both the Cape of Good Hope Nature Reserve (mainly sandstone fynbos) and in the original Bontebok National Park (limestone fynbos) declined and animal health declined largely due to bone diseases and gut parasites. This resulted in the removal of game from the Cape of Good Hope Nature Reserve and the relocation of the Bontebok National Park from the Bredasdorp area to south of Swellendam.

Grazing lawns have been noted in both recent and old studies (Langley & Giliomee 1974, Scott 1993, Shiponeni 2003, Luyt 2005, Walton 2006) as being an important habitat for large herbivores and especially Bontebok. If large herbivores are capable of establishing and maintaining these grazing lawns, it might provide some new insight on how large herbivores managed to survive on the coastal lowlands. However, apart from Hippo, no short-grass grazer occurred naturally on the West Coast lowlands. Natural grazing lawns may thus have been confined to the regions east of the Overberg Mountains.

McDowell (1988) compared the influence on total cover and species diversity of heavy browsing by sheep with adjacent areas ungrazed by domestic livestock for 14 years at Eensaamheid (primarily FFa 3 Swartland Alluvium Fynbos, with some FRs 9 Swartland Shale Renosterveld also present). There was no significant decline in total cover or species diversity, but a definite change in the species composition of the flora was noted. Species of the Poaceae and Rutaceae declined while Asteraceae and Iridaceae increased. Three Proteaceae species were absent from grazed areas and three Thymelaeaceae species were dependent on grazing for survival. Grazing by stock can thus have either a negative or positive influence, depending on how it is managed. In the Riviersonderend Mountains catchment area, frequent burning and intensive grazing (coupled with trampling) caused a reduction in floral diversity and led to erosion (Le Roux 1988). The latter author recommended that all domestic grazing in mountain fynbos must be stopped as it was not only detrimental to the vegetation, but also economically unviable due to the low nutritional status of the veld.

Some studies suggest that perhaps renosterveld contained more grass (primarily *Themeda*) than is currently the case (Sparrman 1786, Levyns 1956, Joubert & Stindt 1979, Skead 1980, Cowling 1984, Scholtz 1986, Stock et al. 1992a, Rebelo 1995, Krug et al. 2004b, Newton & Knight 2004). About 50 years after European colonisation it was first noted that the amount of grass available for grazing and thatching was declining markedly. At about this time, early naturalists started noting an increase in the abundance of *Elytropappus* throughout the region, apparently due to the increase in grazing pressure. By 1800 this process appeared to have occurred throughout the renosterveld (Cowling et al. 1986).

Isotope analyses yielded no evidence that Swartland Shale Renosterveld could have once been covered by C_4 grass species such as *Themeda triandra* (Stock et al. 1992a). The possibility does, however, exist that the grassland consisted of C_3 grasses but this does not show via isotope analysis.

Severe and continuous overgrazing of freshly burnt veld by domestic stock has been proposed as the cause for the presumed change from a grassland to a shrubland (Sparrman 1786, Du Toit & Du Toit 1938, Joubert & Stindt 1979, McDowell 1988). This followed the advent of settled agriculture, which changed the disturbance regime from an intense and localised, pulsed grazing system by indigenous and domestic livestock coupled with a variable fire frequency, to a system of continuous overgrazing and a fixed burning cycle (Cowling et al. 1986). However, the absence of large native mammals over the past 300 years, more specifically the lack of large browsers that consume the dominant shrubs, has been suggested as a reason for the current existence of renosterveld as a shrubland (Rebelo 1995, Krug et al. 2004b). Until more research is undertaken on the impact of large mammals on renosterveld shrubs, these hypotheses remain speculative.

The interplay between shrubs and grasses in renosterveld is not well understood, and probably was greatly influenced by grazing pressure and fire intervals. Presumably some areas such as natural grazing lawns dominated (as today) by *Cynodon dactylon* and other grasses, were well utilised, whereas others were dominated by shrubs and were relatively less grazed. Thicket probably occurred in fire-safe environments, including heuweltjies and rocky areas. Presumably river margins supported *Acacia karroo*-dominated thickets on the South Coast, although transformation on the West Coast pre-dates any records of the riverine vegetation. Alien grasses are an additional concern: heavy grazing might control the annual grasses, but fire and heavy grazing may favour alien annual grasses by virtue of their larger seed banks compared to those of indigenous grasses (Milton 2004). It is ironical that 300 years after renosterveld was reputedly converted from a tussock grassland to a shrubland by overgrazing, today it is threatened by a conversion to grasslands dominated by short-lived alien flora.

In summary, we know very little about the influence of large mammals on the vegetation of the Fynbos Biome. We know with reasonable confidence which species occurred here in the resent past (last 2 000 years), but are unsure of their exact whereabouts, numbers and impact. We speculate that they focused on the more fertile renosterveld areas, avoiding the nutrient-poor fynbos and strandveld. There is reason to believe that these preferred renosterveld areas might have been grassier in the past, but this is not verifiable. The interplay between shrubs and grasses in renosterveld is still not well understood, and probably was greatly influenced by grazing pressure and fire intervals. Fluctuation between the shrubland and grassland states is presumed to have occurred, but for the moment the exact mechanisms are unclear.

4.4.2 Other Animal-plant Interactions

The Fynbos Biome shows an exceptional diversity of pollination systems (Rebelo 1987b, Johnson 1992, 1996b). Their most outstanding feature is a high degree of specialisation (Johnson & Steiner 2000). A recent synthesis of data on pollination systems in southern Africa, much of it from the Fynbos Biome, revealed that pollination systems in southern Africa tend to be more specialised than those in the temperate regions of the northern hemisphere (Johnson & Steiner 2003). Indeed, pollination by a single animal group, even species, is the norm rather than the exception in many plant families in the Fynbos Biome (Johnson & Steiner 2003). This applies even to abiotic pollination where *Cliffortia* (Rosaceae, 114 species) and most Restionaceae (318 species) are all wind-pollinated.

Plant specialisation for particular pollinators often leads to the evolution of distinctive suites of floral traits known as 'pollination syndromes' (e.g. Faegri & Van der Pijl 1979). The seminal paper on pollination syndromes by Vogel (1954) was, in fact, inspired by his experience with the southern African flora, particularly its representatives in the Cape region. It has been argued that evolutionary specialisation for pollination by different animals has been a key driving force behind the rampant speciation in the Cape region (Johnson 1996b, 2006). This is based largely on the observation that sister taxa often differ in their pollination systems (Johnson & Steiner 1997) and that large genera show great diversity in pollination systems (Johnson 1996b, Johnson et al. 1998, Goldblatt et al. 2000, 2001). On the other hand, many large genera have only a single pollination syndrome, including wind pollination. The existence of specialised pollination systems also has implications for conservation because these plants may be particularly vulnerable to changes in land use that affect the pollinator fauna (Bond 1994, Johnson & Steiner 2000, Donaldson et al. 2002). Here we outline some of the major pollination syndromes in the Fynbos Biome:

Long-proboscid Fly Pollination: Highly specialised pollination systems involving long-proboscid flies belonging to the families Nemestrinidae, Tabanidae, and Bombyliidae are well developed in the CFR (Goldblatt & Manning 2000b). These systems are shared between fynbos, renosterveld and succulent karoo shrublands. The flies are flower specialists that feed mostly on nectar (although female tabanids take blood meals and Bombyliidae feed extensively on pollen). Some nemestrinid and tabanid flies have proboscides longer than 50 mm (Johnson & Steiner 1997, Manning & Goldblatt 1997a). This syndrome is concentrated in the Iridaceae, Orchidaceae, Geraniaceae and Ericaceae and probably involves over 100 species (McDonald & Van der Walt 1992, Manning & Goldblatt 1996, Struck 1997, Goldblatt & Manning 2000b). Flies with shorter proboscides are probably also important as pollinators of small open flowers, but there are fewer documented cases of specific associations between plants and these flies.

Beetle Pollination: A distinctive feature of the winter-rainfall region of South Africa is the syndrome of bright (red, orange or yellow) odourless and bowl- or disc-shaped flowers pollinated by monkey beetles (Scarabaeidae: Rutelinae: Hopliini) (Picker & Midgley 1996, Goldblatt et al. 1998). Scarab beetles often use flowers as mating rendezvous sites, but there is no strong support for the hypothesis (Steiner 1998) that dark patterns in the centre of these flowers attract male beetles (Johnson & Midgley 2001). On the other hand, the attraction of the beetles to the bright long-wavelength colours is now well documented (Picker & Midgley 1996, Johnson & Midgley 2001). Pollination by small beetles (Nitulidae, Alticidae, Curculionidae) has been suggested for many fynbos taxa including *Leucadendron* (Proteaceae) and *Audouinia* (Bruniaceae) (Hattingh & Giliomee 1989, Wright et al. 1991b, Hemborg & Bond 2005). Beetle pollination is widespread across all vegetation types and there is no documented guilds specific to any major vegetation type.

Butterfly Pollination: The relationship between a guild of about 20 mainly fynbos plants (in the Iridaceae and Orchidaceae) and the satyriine butterfly *Aeropetes tulbaghia* is one of the classic examples of floral specialisation in plants. In this system, the butterfly is attracted to large red flowers, leading to convergent evolution in these traits among plants in the guild (Johnson 1994a, Johnson & Bond 1994, Goldblatt & Manning 2002a). The guild includes several very rare species that depend completely on the butterfly for their survival (Bond 1994), and is most prominent in fynbos on southern slopes of the mountains, flowering peaking in late summer. Many other butterflies are also pollinators but few studies have been undertaken on them.

Moth Pollination: Data presented by Johnson (2004) indicate that less than 3% of flowering plants in the CFR are moth-pollinated, as opposed to 6–7% in the eastern summer-rainfall region. The difference is even more striking for hawkmoth-pollinated plants, which are virtually absent from the CFR (Manning & Snijman 2002). The most likely reason is a paucity of plants in families such as Balsaminaceae and Solanaceae that are the typical larval food-plants for hawkmoths (Johnson 1997b). Pollination by small settling moths (Noctuidae and Geometridae) has been recorded for several taxa (Johnson et al. 1993, Johnson 1997a), but the relative contribution of moth pollination within units of the Fynbos Biome is unknown.

Bee Pollination: Bee diversity in southern Africa increases from east to west, with a maximum diversity in Namaqualand (Eardley 1989). There is no doubt that these insects as a group are the most important pollinators in the CFR. The Cape Honeybee, *Apis mellifera capensis*, is confined to this region and is specifically adapted for colony survival during the cold and wet Cape winters (Hepburn & Crewe 1990, 1991, Hepburn & Guillarmod 1991). Carpenter bees also play a major role in the pollination of larger flowers, especially legumes (Watmough 1974, Johnson 1993). They are abundant in the fynbos, especially after fires when charred woody stems are used as nesting sites (Watmough 1974, Johnson 1997b), and also in forests where woody nesting sites are more abundant. Smaller solitary bees have also been implicated in the pollination of several CFR plant species (Johnson 1994b, Johnson & Steiner 1994). Oil-collecting bees in the genus *Rediviva* (Melittidae) pollinate Scrophulariaceae, Orchidaceae and Iridaceae with oil-producing flowers (Steiner 1989, 1993, Manning & Goldblatt 2002, Steiner & Whitehead 2002). On account of their unusual floral reward and the low diversity of *Rediviva* bees, oil-producing plants have extremely specialised pollination systems (Johnson & Steiner 2003). There appears to be no pattern of bee syndrome pollination within vegetation types of the Fynbos Biome, indeed most are shared with succulent karoo shrublands to the north.

Bird Pollination: The significance of bird pollination in fynbos as compared to renosterveld, strandveld and karoo is discussed under the effects of nutrient-poor soils (see Section 4.1). Although the fynbos bird-pollination guild comprises only four pollinators (two endemics), they service almost 400 species of plants. By contrast, strandveld and renosterveld have only two pollinators and a few dozen plant species, comparable with bird pollination systems in the other biomes, although they tend to have more bird species. An unusual strategy is found in *Microloma* (Apocynaceae) by which pollen packets are placed on the tongue of birds (Pauw 1998).

Nonflying Mammal Pollination: Among shrubs in the Fynbos Biome, this syndrome is confined primarily to proteoid and asteraceous fynbos. The syndrome is also known in geophytes (*Massonia depressa*; Johnson et al. 2001) and probably in *Androcymbium* (Colchicaceae) and *Cytinus* (Cytinaceae). A proper appraisal of the geophytic component is required.

Bird Fruit Dispersal: Ornithochory is virtually absent from fynbos, but is well represented both by bird and plant species in strandveld and renosterveld. Its absence in fynbos is attributed to the lack of a regeneration niche, where the fruit and seedlings are killed by fire. By contrast, in other systems, birds target favourable microhabitats most suitable for germination and establishment (Le Maitre & Midgley 1992).

5. Origins of the Cape Flora

5.1 Palaeoecological Framework

Rare evidence of the origins of species of the CFR is available in the form of fossil pollen of Tertiary age while fossil charcoal only provides information about its most recent history during the Late Quaternary. In comparison with pollen and spore records from the rest of the southern hemisphere, the early to middle Cretaceous in South Africa has not yet developed clearly unique features (Scott 1976, McLachlan & Pieterse 1978). Pollen from Banke in Namaqualand, however, suggests that some groups that could have developed into certain fynbos elements like Thymelaeaceae, Restionaceae and Ericaceae, were already developed by the Latest Cretaceous or Palaeogene, although the vegetation in which they occurred was of a subtropical type (Scholtz 1985). According to Linder (2003) who thoroughly reviewed the molecular, geological, climatological, palaeontological and other evidence for diversification of the plants of the CFR, it may have been in existence in isolated locations in the nutrient-poor mountains of the Cape early during the Tertiary period but its dramatic spread in the region may have taken place only by ca. 8–10 mya. Available fossil evidence is not dated well enough to narrow this interval further but the following broad picture of its origin and history can be derived from it.

In Knysna, southern Cape region, subtropical vegetation with Restionaceae, palms and forest elements was reported from lignite deposits (Thiergart et al. 1962, Helgren & Butzer 1977, Coetzee et al. 1983). Tertiary pollen assemblages in the southwestern Cape at Noordhoek and Langebaanweg, suggest a markedly different subtropical woodland vegetation that include palms (Coetzee 1978a, b, Coetzee & Rogers 1982, Coetzee et al. 1983, Coetzee & Muller 1984). Although precise dates have not been established for the Knysna or southwestern Cape assemblages, they are apparently of Neogene age. Controversial opinions about the age of the Knysna deposits have been expressed but on the basis of tectonic evidence they are thought to be of Miocene age (Thiergart et al. 1962, Maud & Partridge 1987, Partridge & Maud 1987). The tropical elements in both regions are probably from a period before the development of the current circum-Antarctic ocean system, the Benguela Current and the enlarged Antarctic Ice Sheet (Shackleton & Kennet 1975, Van Zinderen Bakker 1975, Vail & Hardenbol 1979). These events possibly accompanied a transition from subtropical forest pollen in the Late Miocene to typical fynbos and strandveld elements in the Early Pliocene associated with the well-known fauna from the Varswater Formation at Langebaanweg (Coetzee & Rogers 1982, Hendey 1984, Scott 1995). Asteraceae pollen evolution accompanying the change to Fynbos Biome types showed earlier low-spine *Gerbera*-like pollen (Mutisiae) and later more diverse and typical modern long-spine and other forms, a situation which seems to be paralleled in South America (Coetzee 1978a, Barreda 1993).

Reconstruction of the Quaternary vegetation of the Fynbos Biome on the basis of fossil pollen data suggests that marked changes took place during this period. More extensive woodland at different times before the Late Glacial Maximum (LGM) is suggested by pollen in lagoon deposits (Schalke 1973) and charcoal from Elands Bay Cave of > 24 000 years cal. BP (Parkington & Cartwright 1997, Cowling et al. 1999a, Parkington et al. 2000). Pollen in hyrax dung suggests that the LGM in the northeastern part of the Cederberg range (Pakhuis Pass) bordering on the Karoo, was characterised by asteraceous shrubland (renosterveld) with fynbos elements such as Proteaceae, Ericaceae, *Passerina* and *Lobostemon* etc. (Scott 1994, L. Scott & S. Woodborne, unpublished data). The LGM was by no means a uniform event and showed regular fluctuations in temperature, moisture availability and seasonality (L. Scott & S. Woodborne, unpublished data). In view of climatic forcing of the earth's orbital variations, the latter authors pose the question: What if the fynbos of the LGM experienced a slight shift to more summer rain during the LGM? If so, cool growing seasons prevented it from changing to a more typical summer-rain vegetation type. Variations in ^{18}O values from the Cango Caves ca. 300 km to the east, suggest a temperature difference of ca. 5°C between the LGM and Holocene (Talma & Vogel 1992). It has been suggested that fynbos and renosterveld elements migrated far to the north to northern Namibia during the LGM following northward penetration of winter rain, according to Shi et al. (2000) who found high concentrations of Ericaceae and Restionaceae in marine sediments off the mouth of the Cunene River. On the basis of fossil pollen of LGM age from the Brandberg/Daures (Namibia) and elsewhere in South Africa and an investigation of source areas and long-distance transport, Scott et al. (2004) consider this unlikely and give different explanations for the composition of the pollen assemblages. Temperatures at the end of the LGM started increasing sharply ca. 16 000 years cal. BP as recorded by pollen changes from the Pakhuis Pass and the vegetation accordingly changed to woodland, with *Dodonaea, Olea, Rhus*, Ebenaceae and Proteaceae, etc. (L. Scott & S. Woodborne, unpublished data). Paralleling the transition at Pakhuis Pass, charcoal and pollen from archaeological sediments in Boomplaas Cave (Deacon et al. 1984, Scholtz 1986) adjacent to the Cango Caves, show open renosterveld vegetation (*Elytropappus* and *Euryops*) changing to more woodland. The hyrax dung sequence from the Pakhuis Pass which, however, has a much higher sample resolution than the Boomplaas record, suggests that regular variations persisted throughout the Holocene, indicating markedly contrasting wet and dry phases on a millennial scale, with variations in pollen of Restionaceae, Cyperaceae, Asteraceae and succulent Aizoaceae types (L. Scott & S. Woodborne, unpublished data). The Pakhuis Pass results are, however, in contrast with previous pollen data from the higher mountain peaks of the Cederberg, which suggested that very constant climatic conditions prevailed during the LGM transition and persisted throughout the Holocene, with only *Widdringtonia cederbergensis* showing a very gradual decline (Meadows & Sugden 1991, 1993). A low degree of change in the high mountain fynbos of the Cederberg during the terminal Pleistocene according to Cowling et al. (1999a) might be explained by different climatic regimes between the moist mountain peaks and the area to the east which lies in the rainshadow of the range.

Late Holocene vegetation was apparently more open in the fynbos environment and the change in firewood in Boomplaas Cave from species on adjacent mountain slopes to *Acacia karroo* ca. 2 000 years ago, might have been due to the necessity to collect firewood from valley bottoms (Deacon et al. 1984, Scholtz 1986, Scott & Lee-Thorp 2004). An increase in more C_4 grassland in the area during this time is indicated by the ^{13}C values from a stalagmite in the nearby Cango Caves (Talma & Vogel 1992). According to the pollen contents, present values of *Dodonaea* and *Euclea* pollen at the Pakhuis Pass are much reduced in comparison to the late Holocene. This could possibly be as a result of modern human influence on the vegetation (Scott 1994).

Palynological evidence from coastal lakes and swamps, e.g. Hangklip (Schalke 1973), Groenvlei (Martin 1968) and Verlorenvlei (Baxter & Meadows 1994) suggests that coastal vegetation composition did vary markedly during the Holocene. At Groenvlei the fynbos that occurred during the early Holocene was replaced by coastal forest (Martin 1968). At Verlorenvlei a middle Holocene salt-marsh environment associated with raised sea level changed to a freshwater one, while it has been inferred that anthropogenic disturbance since ca. 1 700 AD is responsible for the development of the current Verlorenvlei environment (Baxter & Meadows 1994).

5.2 Phylogenetic Perspective

The overall lack of fossil plant evidence (Deacon et al. 1983; see also Section 5.1 above) from the region of the current Fynbos Biome makes the inference of palaeo-vegetation patterns very difficult. It is therefore not surprising that alternative sources of information have been sought. Progress in the field of molecular biology driven especially by technological advancement of nucleic acid analysis and the methodological revival of cladistic inference offers unique and powerful tools of phylogenetic inference. Due to its legendary richness, the Cape is in the forefront of phylogenetic studies (Barraclough 2006, Linder 2006), and the Fynbos Biome is possibly one of the best researched biomes in the world in terms of using phylogenies in disentangling its origin and evolution.

It is amazing that much of the richness of the CFR (about 50%) is concentrated in only 33 major clades, which most probably originated and radiated within the CFR (Linder 2003, Linder & Hardy 2004), and are largely confined to fynbos. The taxonomic expression of this is an extraordinary abundance of large genera (containing more than 100 species), e.g. *Erica* with 658 species (Linder & Hardy 2004, Linder 2005b, E.G.H. Oliver personal communication). Another intriguing phenomenon emanating from the high species:genus ratio is the remarkable small-scale (habitat-level) co-occurrence of many congeners, defying entrenched ideas about the role of competition (hence niche differentiation) in community assembly. Procheş et al. (2006) found that in recently radiated classes typical of evolutionary young biomes (such as the Fynbos Biome), the co-occurring species tend to be more closely related than predicted by classical niche theory.

At large temporal scales, the governing paradigm of the past was that the Cape flora is a *mixtum compositum* of three components, namely (1) a Gondwanan element (also called 'Antarctic' by some)—a relict of the Cretaceous Gondwanan flora, (2) an African element, accounting for the bulk of the Cape flora, and (3) an Eurasian element, supposed to have migrated recently along the eastern and southern African mountains to the CFR (see Adamson 1958, Linder et al. 1992, Linder 2005b citing Levyns 1962 as further sources of these ideas). Phylogenetic analyses, however, shed different light on these ideas by pointing towards the importance of post-Gondwanan intercontinental dispersal. In general, large-distance intercontinental dispersal events do not seem to be rare (Sanmartín & Ronquist 2004). The CFR appears to be a long-term assemblage with a strong Austral, rather than African, relationship (Linder 2005b). Furthermore, the dispersal from CFR to the high mountains of the afromontane archipelago has been suggested as the more probable direction, rather than the reverse (Galley & Linder 2006, Reeves et al. 2006; see also Chapter 8 on Grassland).

How old then is the Fynbos Biome? Very roughly we presume that the Mid-Miocene vegetation of the southwestern Cape was (sub)tropical (Axelrod & Raven 1978, Linder 2003, Linder & Hardy 2004) with ancestral lineages of the modern fynbos flora possibly restricted to the mountains. The climate of those times was also (sub)tropical, mesic and with no pronounced dry season. The steepening of the global pole-to-equator climatic gradient linked to complete glaciation of Antarctica and the associated strengthening of the upwelling of cold waters along the Atlantic seaboards of southern Africa which started some 8–10 mya (Siesser 1980), blocked off the summer rainfall, leaving only winter rainfall to dominate the southwestern Cape (Linder & Hardy 2004); the eastern regions of the current Fynbos Biome presumably still retained some share of the summer rainfall. The (sub)tropical flora and vegetation of the southwestern Cape was almost obliterated, perhaps except for the remnants of relict forest and fynbos thicket (see Section 1.4.4) patches, opening vacant habitats for fast-radiating lineages of the Cape clades, facilitated by regular fires in the hot and dry summers (Linder & Hardy 2004). According to Goldblatt (1997) the Cape flora is not older than Pliocene age (less than 5 mya), while Cowling & Pressey (2001) suggest that the major diversification is of Late Pliocene age. Richardson et al. (2001) found that the initiation of the *Phylica* radiation was in the Late Miocene, but other dated phylogenetic studies suggested older radiation dates: Mid-Miocene for *Pelargonium* (Bakker et al. 2005) and *Indigofera* (Schrire et al. 2003), Oligocene or Early Miocene for some tribes of the Iridaceae (Goldblatt et al. 2002), and Oligocene for African clades of Restionaceae (Linder & Hardy 2004). On the other hand, the radiation in *Heliophila* (Mummenhoff et al. 2005) was found to be of Pliocene age. It appears that adaptive nature of the radiations is a common phenomenon (Goldblatt et al. 2002: *Moraea*; Verboom et al. 2004: *Ehrharta*; Linder & Hardy 2005: *Thamnochortus*; Manning & Goldblatt 2005: *Tritoniopsis*).

Although the earliest recruitment of an angiosperm lineage into the Cape flora has been dated to the Cretaceous, more lineages have been incorporated into the flora, not really hindered by the opening of the southern oceans (Linder 2005b). The few dated molecular phylogenies available to us suggest a step-wise birth of the biome through accession of diversity (resulting from radiations) over the past 35 my, rather than a boom-like dramatic change of flora as a consequence of a unique change in environmental conditions in the palaeohistory of the Cape (Linder 2005b).

We hypothesise that also the major floristic component of the intrazonal fynbos thicket and strandveld vegetation is a relict of past subtropical periods (see also Linder 2005b). The dominance of genera of Anacardiaceae (*Rhus*), Celastraceae (*Cassine, Gymnosporia, Lauridia, Maytenus, Mystroxylon, Pterocelastrus, Robsonodendron*), Ebenaceae (*Euclea, Diospyros*) and Sapotaceae (*Sideroxylon*) with their evolutionary roots (and current centres of diversification) in the tropics, supports our claim. We further propose, alongside earlier suggestions (Levyns 1964), that the strandveld shrublands of the Cape might be in part relicts of old resident Mid-Miocene woodlands, which retreated to nutrient-rich and climatically more stable, mild (buffering function of the ocean) and fire-sheltered coastal habitats in times when most of the Cape region had been taken over by fire-prone fynbos and renosterveld shrublands since about the Miocene/Pliocene boundary and later throughout the Pleistocene. The increased aridity in the Plio-Pleistocene either prevented migration of coastal elements or increased depauperisation of the strandveld flora. On the other hand, warmer (and possibly also wetter) interglacial periods during the Pleistocene might have encouraged south-bound migration of tropical elements along the coasts—processes naturally dependent on the dynamics of coastal dune fields (accretion rates, stabilisation and abrasion rates). The glacial periods must have had an adverse effect on both south-bound migrations of the subtropical coastal thicket flora due to a decrease in temperature along the South Coast (as much as 6°C lower yearly average for the LGM) and a decrease in precipitation. West of the Caledon Mountains, the depauperisation of the strandveld ('subtropical') flora might have been further encouraged by intensification of the winter rainfall on the West Coast during the glacial periods.

We suggest that the core of the present-day strandveld expanded especially after the last major marine transgression about 1.5 mya (Compton 2004). This regression exposed major stretches of the coast (and its hinterland) and today is covered by limestone strandveld and extensive sandy plains underlain by calcrete as well as lower slopes of the granite outcrops on the West Coast. It was after this regression when extensive calcareous sand dune systems were initiated on the South Coast, opening new habitats to strandveld vegetation. The tops of the West Coast granites (Vredenburg and Saldanha Batholiths) were exposed for a long time and experienced isolation caused by marine transgressions about 5 and 1.5 mya (Compton 2004) and we suggest that it is here where the evolutionarily oldest (and most endemic-rich) form of strandveld could have developed on the West Coast.

The young age of the 'recent element' in the strandveld flora is documented in genera of typical Cape clades (Linder 2003), which contain species resulting from recent (Plio-Pleistocene) radiations. Such is the case of *Ehrharta villosa* and *E. calycina* (Verboom et al. 2003, 2004), *Thamnochortus spicigerus* and *T. erectus* (Linder & Mann 1998), *Phylica littoralis* (Richardson et al. 2000), *Pelargonium gibbosum* and *P. fulgidum* (Bakker et al. 2004), *Metalasia muricata* (Karis 1989) and *Ischyrolepis eleocharis* (H.P. Linder, personal communication).

6. Taxonomic Diversity, Endemism and Biogeographical Subdivisions

Patterns of species diversity and endemism in the Cape flora have long been the focus of research, both academic and conservation-oriented. These are well reviewed (Kruger & Taylor 1979, Campbell & Van der Meulen 1980, Bond 1983, Cowling et al. 1989, 1992, Cowling & Hilton-Taylor 1994, Goldblatt &

Manning 2000a, Linder 2003, Cowling & Procheş 2005) and analysed and compared to other regions (Cowling 1983a, 1990a, Ojeda et al. 2001, Cowling & Holmes 1992a, Cowling et al. 1996a, 1997, 2003, Wisheu et al. 2000, Cowling & Lombard 2002, Laurie & Silander 2002, Latimer et al. 2005, Etienne et al. 2006). Here we limit ourselves to patterns of biodiversity issues relevant to vegetation types of the Fynbos Biome.

6.1 Plant Diversity along Ecological Scales

The Cape Floristic Region is internationally recognised for its exceptional species diversity, which ultimately led to the recognition of the Cape flora as one of world's floristic kingdoms, on a par with much larger regions (Engler & Gilg 1919, Good 1947, Takhtajan 1986). It has also been recognised as one of 25 'hot spots' of the world's diversity (see also Mittermeier et al. 2000, Van Wyk & Smith 2001).

At the local scale, diversity in the CFR is high, without being exceptional. Where relevé data yield more plant species than tropical rainforest plots, this can be simply explained by the size of individual plants, fynbos, renosterveld and strandveld shrubs occupying less space than large forest trees. In fact, where comparisons of nonepiphytic plant diversity adjust the plot size for plant size, rainforest appears more diverse (Latimer et al. 2005). By comparison with other mediterranean-climate vegetation types, the values recorded in the CFR (10–20 species/10 m^2; 30–40 species/100 m^2; 40–120 species/1 000 m^2) are certainly not extreme (see Bond 1983, Cowling 1990a). Plots dominated by taller shrubs have generally lower diversity values compared to plots entirely dominated by smaller plants.

It is at larger spatial scales that the diversity of the CFR becomes exceptional, not only in a mediterranean-climate context, but in any context. Floristic dissimilarity along transects (often addressed as beta-diversity; Cowling & Campbell 1984, Cowling 1990a) ranging from hundreds of metres to hundreds of kilometres is impressive, with complete turnover of species between vegetation types. It has been alleged that in fynbos vegetation each mountain and valley has a flora of its own (Kruger & Taylor 1979, Cowling 1990a), although endemism levels per mountain unit are typically in the order of 1–10%. The reasons invoked to explain these astounding species numbers are multiple (Table 4.3). While spatial species packing is sufficient at finer scales, broader explanations involving habitat and climatic diversity and speciation-extinction dynamics are necessary at larger scales, most of the recorded species being endemic to fynbos vegetation (Goldblatt & Manning 2000a). Renosterveld diversity is lower in endemic species, with the exception of West Coast renosterveld, and appears to be shared more, with far less turnover, between different vegetation units. It has been suggested that long-term climatic stability was crucial in the attainment of the current levels of species diversity in the CFR (Cowling et al. 2004, Cowling & Procheş 2005).

6.2 Local and Regional Endemism

The CFR's claim to fame is that it contains almost 9 000 plant species (out of the 20 500 plant species in southern Africa: 44%) on 90 000 km^2 (or 4% of the area of the subcontinent). Almost 69% of these plant species are endemic to the CFR. This is comparable with many of the richest tropical forests and is exceptional among temperate and African floras (Goldblatt & Manning 2000a). It is the richest temperate flora in the world (Van Wyk & Smith 2001).

Most plant species in the CFR are limited to fynbos—about 7 500 of the 9 000 species, of which over 80% are endemic to the region and many (proportion is unknown, perhaps 60%) are endemic to fynbos vegetation itself. Floristically it is unique in having large numbers of species belonging to the Ericaceae (all in *Erica* with 658 species), Proteaceae (330 species), Restionaceae (318 species), Rutaceae (273 species), Polygalaceae (141 species, with *Muraltia* accounting for 100 species), Rhamnaceae (137 species, with *Phylica* accounting for 133 species), Thymelaeaceae (124 species) and Rosaceae (120 species, with *Cliffortia* accounting for 114 species). Of the 942 genera of seed plants native to the CFR, about 160 (16%) are endemic (Goldblatt & Manning 2000a).

Recent taxonomic revisions involving molecular-phylogenetic studies confirmed that five families of angiosperms (Figure 4.20) are endemic to the CFR. These are: Penaeaceae (with 23 species), Roridulaceae (2 species), and the monotypic Geissolomataceae, Grubbiaceae and Lanariaceae. All of them are confined to fynbos vegetation. Wardiaceae is the only family of mosses considered endemic to the CFR. The Bruniaceae (with 64 species in the CFR and one species in Pondoland) is near-endemic to the CFR and is also confined to fynbos. When described, the family Prioniaceae (Munro & Linder 1998) comprised only one species (*Prionium serratum*), and was considered near-endemic to the CFR (with populations in Pondoland), but it has since been placed in the Thurniaceae, with further representatives in South America (Chase et al. 2000, Goldblatt et al. 2005). The monotypic family Retziaceae previously considered endemic to the CFR (and fynbos vegetation), is now classified in the

Table 4.3 Factors and mechanisms underlying the rapid and localised diversification of the Cape flora.

	Extent	Mechanisms of fine-scale subdivision	Underlying factors
Spatial component	≈ 90 000 km^2 (small by global standards)	Landscape patchiness	Climatic diversity
			Topographical heterogeneity
			Fire-derived age mosaics
		Limited seed dispersal	Limited investment in dispersal, determined by low productivity
		Packing of individuals and species	Small plant stature and niche separation
Temporal component	5–15 million years (of relatively high climatic stability, long by global standards)	Short generation time	Connected to fire and small plant stature
		Separation between generations	Fire-driven simultaneous cohort death

Stilbaceae (Kornhall 2004). The Stilbaceae were in turn also previously considered endemic to the CFR (and fynbos vegetation), but a new circumscription of the family (Olmstead et al. 2001, Kornhall 2004) extends it to tropical Africa.

The fact that the CFR endemics belong to families such as the Ericaceae, Proteaceae, Restionaceae, Rhamnaceae and Rutaceae (all with over 90% endemism to the Cape flora; Goldblatt & Manning 2000a)—all families predominant in fynbos vegetation and not a taxonomically representative sample, suggests that fynbos vegetation types contribute significantly to overall levels of endemism. Cowling et al. (1992) have argued that most of the endemics are edaphic specialists, but this might be an artefact of their lowland sampling—the large number of local endemics presented in the descriptions of particular vegetation units as defined in this chapter suggests that on sandstone substrates at least, endemism is strongly influenced by topography. Endemics (on the lowlands) tend to be small shrubs, nonsprouting, with soil-stored, ant-dispersed seeds, and with microsymbiont-mediated nutrient uptake (Cowling et al. 1992), but whether these patterns hold within fynbos throughout the region and how they vary between local and subregional scales and the entire Fynbos Biome, is unknown.

A major problem with studies of endemism requires that detailed and comprehensive distributional data exist for the entire area. This is not generally available, the most comprehensive data being available only at a broad scale (25 x 25 km). Although it is therefore not possible to evaluate subregional or proportional endemism, it is reasonably easy to obtain data on extremely

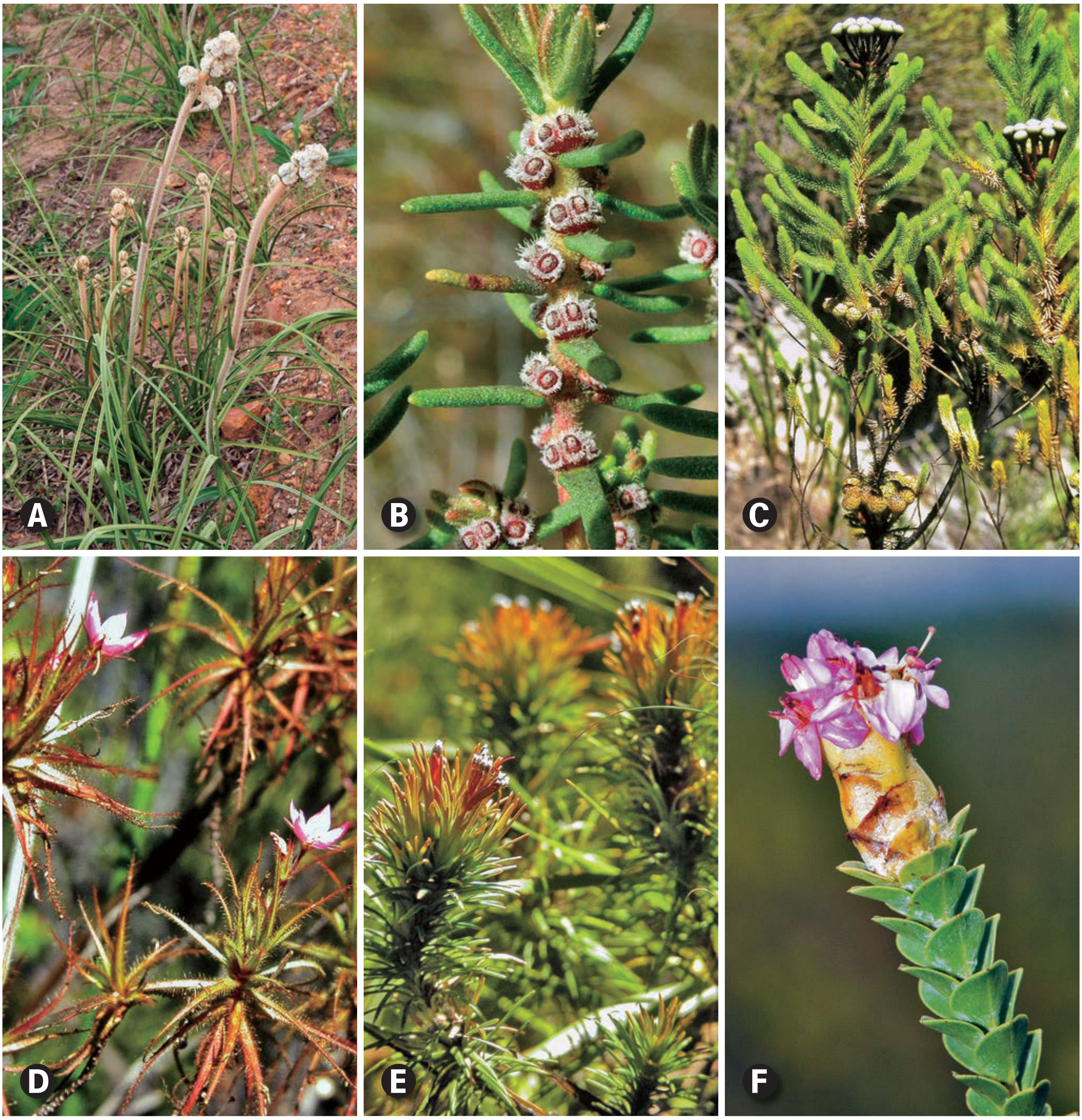


Figure 4.20 Representatives of the endemic and near-endemic families of the Cape Floristic Region: A: *Lanaria lanata* (Lanariaceae); B: *Grubbia rosmarinifolia* (Grubbiaceae); C: *Brunia albiflora* (Bruniaceae); D: *Roridula gorgonias* (Roridulaceae); E: *Retzia capensis* (Stilbaceae); F: *Saltera sarcocolla* (Penaeaceae). Photographs: A, C–F: L. Mucina, B: D. Gwynne-Evans.

localised endemics. Preliminary comparisons of the lists of endemic taxa compiled for each of our vegetation units support the general view of endemism being greatest in the fynbos units of the southwestern mountain ranges, with a strong northern trend and much reduced richness on the eastern ranges east of the Langeberg, paralleling overall trends of species richness of taxa studied by Oliver et al. (1983) and Moline & Linder (2006). For instance, it seems that the extremely high figure for FFs 4 Cederberg Sandstone Fynbos possibly reflects the extensive collecting in the past. With more research, many of these species might be found to be more widespread in the neighbouring fynbos units. This is also supported by the high proportion of the Red Data category 'Uncertain' scored by many of the Cederberg endemics (A.G. Rebelo, unpublished data). On the other hand, the endemic accounts for well-researched areas such as Langeberg and Cape Peninsula (e.g. McDonald 1999, Helme & Trinder-Smith 2006) are probably reliable.

Renosterveld has much lower levels of endemism at the local scale (the scale of the vegetation units as defined in this chapter) than most of the units of sandstone fynbos in the western regions of the fynbos, but the endemic counts in many of the shale, granite and dolerite renosterveld units match those of the sandstone fynbos in the eastern regions as well as sand fynbos in general. When groups of ecologically analogous and geographically juxtaposed renosterveld units are considered (for instance West Coast renosterveld, South Coast renosterveld), the regional levels of endemism are considerable (N. Helme, unpublished data).

In strandveld, local endemism is considerably higher in the western units than in the strandveld units fringing the Garden Route. This is probably due to edaphic as well as occasional topographic isolation (formation of islands during marine transgressions). The endemism of the granite and limestone strandveld units of the Saldanha and Langebaan Peninsulas is comparable to those of the endemic-rich fynbos units.

A more detailed analysis of the pattern of endemism and its correlations is imminent, but it remains confounded by the lack of data for the total richness of the different vegetation units, so that the relative importance of endemism to the local and regional species pool cannot be computed.

6.3 Sources of Species Diversity and Endemism

The key to understanding the complexity of the flora and vegetation of the CFR is in understanding the sources of its extraordinary species diversity and endemism. Of the ecological factors correlated with high species diversity and endemism in the fynbos of the Langeberg (McDonald 1995), the most important is limited dispersal of seeds with a high prevalence of ant dispersal (myrmecochory) and species with no obvious adaptations to seed dispersal. Wind-dispersed species generally have broader geographical ranges. Obligate reseeding (i.e. plants incapable of resprouting) is also important, with spatially fluctuating and temporally discrete populations mediated by fire, resulting in more species. Resprouters can survive several successive fire events, and genetic intermixing between the longer-lived generations is possible, impeding speciation, so that richness approaches that of forest or thicket habitats. Consequently, reseeders usually have smaller geographical ranges than resprouters (Cowling 1987). Within the same dispersal and fire survival categories, low shrubs are generally more likely to be local endemics than other growth forms. Of all these factors, limited dispersal is particularly important, as it applies to many plant groups, irrespective of fire survival strategy and growth form (McDonald et al. 1995). This potentially contributes to the understanding of high species diversity in fynbos for groups that are fire-resistant (e.g. geophytes; Procheş et al. 2006).

From the point of view of evolutionary processes, the roots of the species diversity should be sought in the nature of speciation and extinction, and their relationship. Lately, Barraclough (2006) has summarised the causes of speciation in the Cape flora under six headings, including topographical complexity, edaphic complexity, pollinator specialisation, fire and short-dispersal distances (see Sections 2 and 4 of this chapter for more details). The patterns of extinction have not been formally analysed in the Cape, but climatic stability (see Section 2.4 for more details) has been cited most often as one of the major reasons for presumably low levels of extinction. For further analyses and insights of the intriguing hot topics forcing functions influencing the patterns of speciation and extinction, consult Dynesius & Jansson (2000), Jansson & Dynesius (2002), Linder (2003, 2005b), Linder & Hardy (2004) and Cowling & Procheş (2005).

6.4 Biogeographical Compartmentalisation

The regional distribution of endemism in the CFR was first described by Weimark (1941), who recognised 'Centres' of endemism based on the distribution of range-restricted species. These centres, updated to include a limestone centre, are still used as phytogeographical subunits of the CFR in summarising plant distributions (Goldblatt & Manning 2000a). These centres were only partly confirmed in an analytical study on major groups with fynbos endemics (Restionaceae, Ericaceae, Proteaceae, *Aspalathus*, *Muraltia*; Oliver et al. 1983), although further division between the western centres is possible (the Southwest Centre is broken down into the Peninsula Centre, West Coastal Centre, Bredasdorp Centre, and Southwest Centre proper), whereas the eastern centres (Karoo Mountain Centre, Langeberg Centre and Southeast Centre) are comparatively uniform. More advanced multivariate techniques showed even further division in the west, at least as far as the Restionaceae are concerned (Linder & Mann 1998, Linder 2001, Moline & Linder 2006). This has led to a more conservative approach by which the CFR is referred to simply as represented by a western part, rich in local endemics, and an eastern part, comparatively poor in local endemics (Cowling & Lombard 2002, Procheş et al. 2003).

Comparison of four schemes of phytogeographical subdivision of the CFR (Weimark 1941, Oliver et al. 1983, Linder & Mann 1998, Goldblatt & Manning 2000a) indeed reveals a number of important spatial congruencies, but also leaves us with many open questions, one of the most important ones being the delimitation of lowland phytochoria. However, the lowlands feature prominently in centres of endemism for the Proteaceae (Rebelo & Siegfried 1990, Cowling et al. 1992), placing them clearly within the Centres recognised by Weimark, and suggesting that Weimark's gaps were due to inadequate data. The resolution was too coarse to delimit the 'limestone floras', which are clearly a major centre of endemism (Goldblatt & Manning 2000a). At present, data for most taxa are not available at a fine enough scale (as is available for the Proteaceae) for more detailed analysis, but finer-scale data are becoming available through the geo-referencing of herbarium data and conservation projects such as CREW (Raimondo & Ebrahim 2006). It is likely that species from strandveld and renosterveld within the CFR will show different patterns.

7. Status and Threats

The degree of transformation of the Fynbos Biome vegetation types is strongly linked to topography and geographical location.

Among the 'Critically Endangered' and 'Endangered' ecosystems rank especially those of the shale, granite, ferricrete and alluvium fynbos in the Southwest Centre, converted to vineyards, fruit orchards and pine plantations to a great extent as well as those of sand fynbos, much of which has been obliterated by urban sprawl of the Cape Town metropolitan area, small holdings and alien plant invasions. All the sandstone fynbos types in the Southwest Centre rank as 'Least Threatened', highlighting the lack of transformation in the mountains. A similar pattern is apparent in the Eastern Centre, where lowland types of the granite, shale and sand fynbos are affected primarily by agriculture and afforestation, with the low-lying FFs 29 Algoa Sandstone Fynbos (endangered) due to urbanisation. However, sandstone fynbos units of the Outeniqua and Tsitsikamma Mountains are listed as 'Vulnerable' due primarily to afforestation by pines. In the other centres, it is again the lowland (both coastal and inland) and units supported by rich soil that suffered considerable transformation. Predictably, the least transformed units are the best conserved, although the northern and western extent of the Northwest Centre is poorly conserved. The distribution pattern of threatened ecosystems with the highest threat in the lowlands of the Southwest Centre is mirrored in the distribution of threatened butterflies, amphibians, reptiles and plants. Only fish species—most threatened in the Cederberg section of the Northwest Centre—differ from this pattern (Rebelo 1992a). Details of the ecosystem and conservation status are presented in the individual accounts of the vegetation types, and are summarised in Chapter 16.

The above mirrors the threats for the Fynbos Biome identified in the 1980s. In the fynbos of the lowlands, agriculture and afforestation accounted for 49% of the area transformed, with alien invasive *Acacia* species accounting for a further 36%. By contrast, in the mountains, 26% was transformed by *Hakea* and *Pinus* infestations, a further 10% by *Acacia* infestations and only 7% by agriculture and afforestation (Rebelo 1992a). These vegetation-based threats also mirror those based on Red Data plant species: alien invasive plants are the biggest threat, with agriculture and urbanisation next in line (Rebelo 2001). Among the major modern threats to sand fynbos is the increase in central pivot irrigation, mainly for potatoes, and the extraction of ground water for urban and agricultural use (A.G. Rebelo, unpublished data). The urban Cape Town metropolitan area, which has almost obliterated the FFd 5

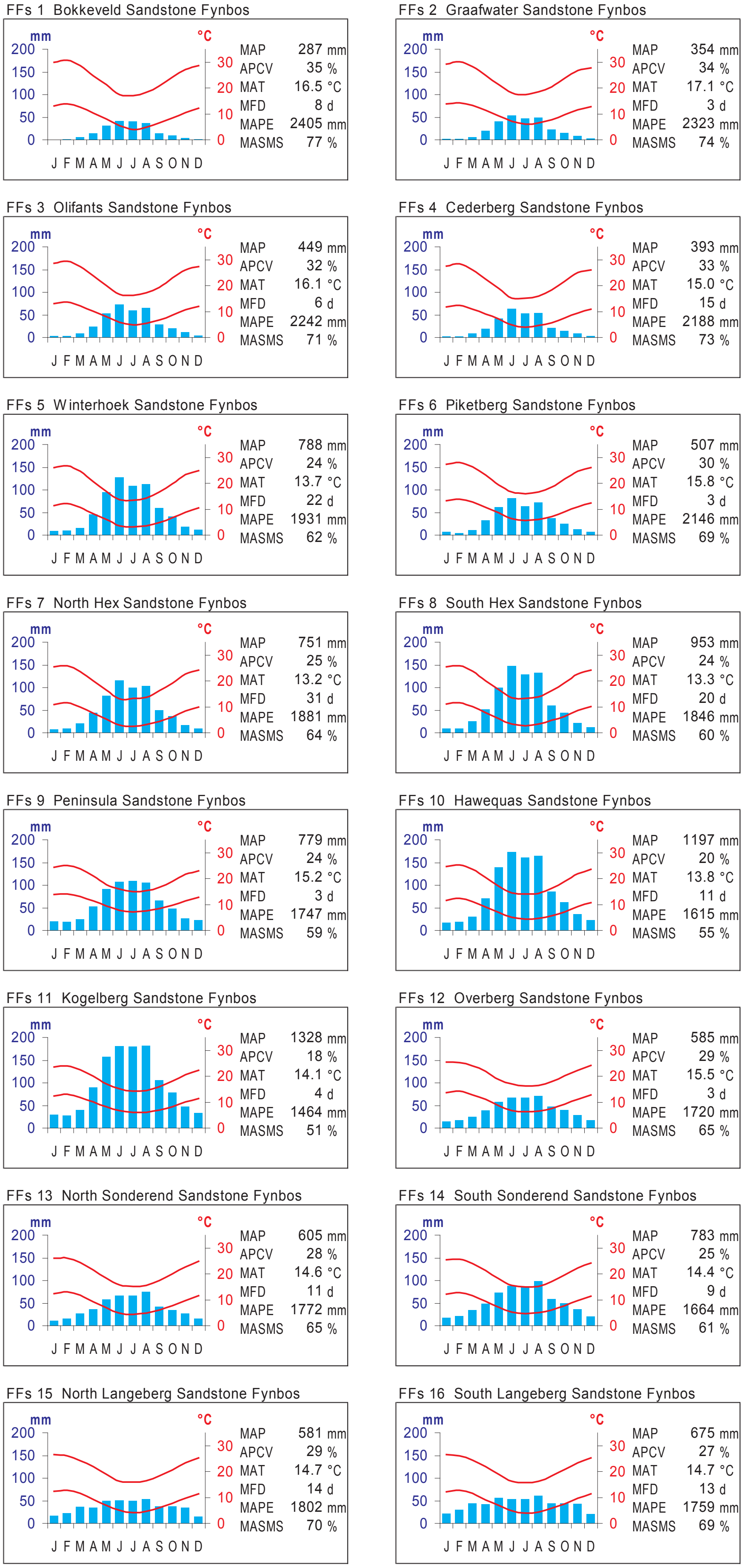
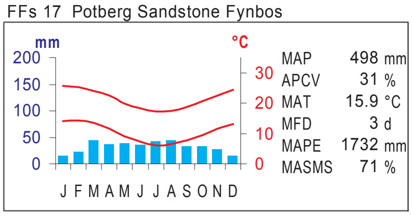
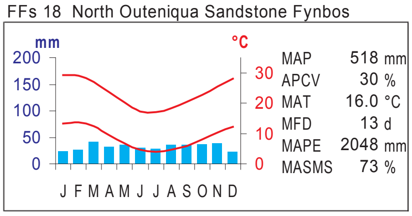


Figure 4.21 Climate diagrams of sandstone fynbos units. For the remainder of the Figure and for its full caption see the opposite page.

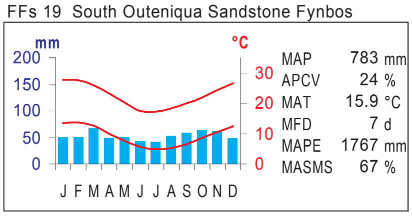
FFs 17 Potberg Sandstone Fynbos



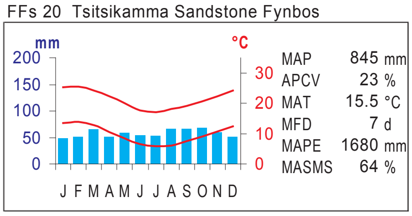
FFs 18 North Outeniqua Sandstone Fynbos



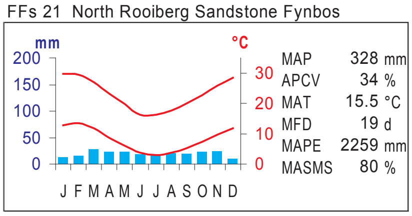
FFs 19 South Outeniqua Sandstone Fynbos



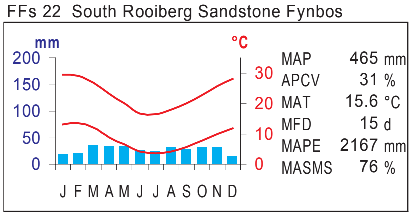
FFs 20 Tsitsikamma Sandstone Fynbos



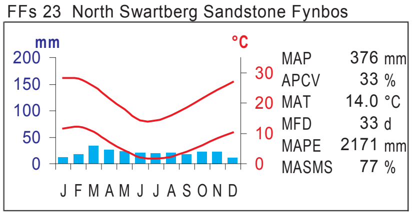
FFs 21 North Rooiberg Sandstone Fynbos



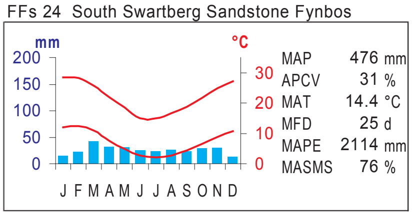
FFs 22 South Rooiberg Sandstone Fynbos



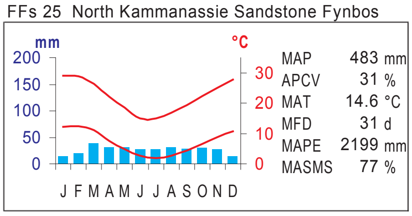
FFs 23 North Swartberg Sandstone Fynbos



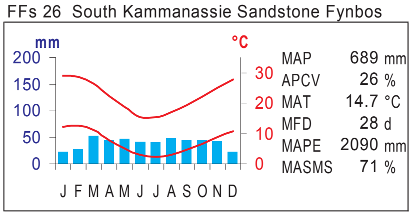
FFs 24 South Swartberg Sandstone Fynbos



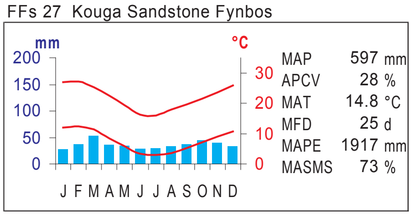
FFs 25 North Kammanassie Sandstone Fynbos



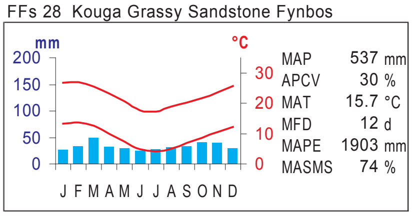
FFs 26 South Kammanassie Sandstone Fynbos



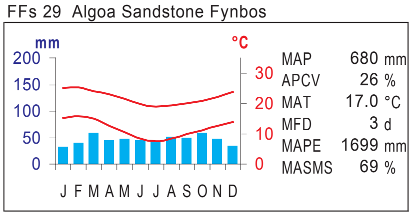
FFs 27 Kouga Sandstone Fynbos



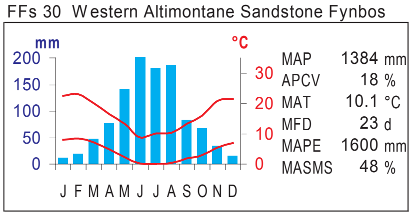
FFs 28 Kouga Grassy Sandstone Fynbos



FFs 29 Algoa Sandstone Fynbos



FFs 30 Western Altimontane Sandstone Fynbos



FFs 31 Swartberg Altimontane Sandstone Fynbos

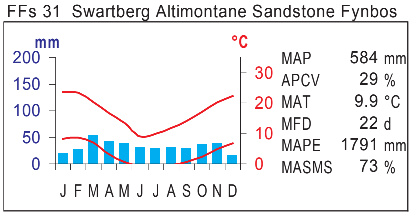


Figure 4.21 Climate diagrams of sandstone fynbos units. Blue bars show the median monthly precipitation. The upper and lower red lines show the mean daily maximum and minimum temperature respectively. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days (days when screen temperature was below 0°C); MAPE: Mean Annual Potential Evaporation; MASMS: Mean Annual Soil Moisture Stress (% of days when evaporative demand was more than double the soil moisture supply).

Cape Flats Sand Fynbos, is also a major threat to the vegetation types in its vicinity (Wood et al. 1994).

The first prescriptions for the preservation of fynbos for aesthetic and scientific value were made by Wicht (1945). These were followed by more detailed optimal strategies based on vegetation types and biogeographical regions, and iterative approaches (Rebelo 1992a). However, the network of reserves was de facto allocated on nonagricultural land as forestry land (now mainly nature conservation areas) for water catchment areas. Effectively this meant that over half of the mountains (sandstone fynbos) was conserved, but less than 3% of the lowlands was afforded any protection (Rebelo 1992a). This situation remains unchanged today.

A comprehensive action plan for fynbos and other vegetation types within the CFR has been completed (Cowling et al. 1999b) and elaborated upon both regionally and nationally (Pressey et al. 2003, Rouget et al. 2003a, b, 2004, Driver et al. 2005). In the 2000s, the Cape Action Plan for People and the Environment (CAPE) was established to effect conservation in the Fynbos Biome. Among the more significant conservation plans is the construction of 'megareserves' focused on the existing conservation areas in sandstone fynbos, but linking them to relatively unconserved renosterveld, karoo shrublands and sand fynbos of the lowlands.

Very little coastal renosterveld remains: most vegetation types are 'Critically Endangered'—with over 80% of the vegetation transformed to agriculture, chiefly for growing cereals and pastures. The inland units of renosterveld are relatively intact, although farming of these units is increasing and their status may well change over the next decade. The remnants are not representative of the communities that used to occur within renosterveld, being largely in areas that were too steep or shallow to plough mechanically, or otherwise unsuitable for agriculture (Von Hase et al. 2003).

Currently, renosterveld remnants are regularly sprayed with herbicides and insecticides—usually accidentally as drift. Fertiliser runoff also has a major influence on patches downslope of agriculture, and especially valley bottoms, river courses and seepage areas may become eutrophic. Exotic alien grasses are a major threat—apparently competing with the bulb flora. Insularisation of remnants is another major force, with many remnants predicted to experience imbalances of pollinators, seed dispersers, herbivores and predators. Obligate reseeders and specialist (e.g. oil-bee and long-tongue fly pollination, bird seed dispersal, etc.) species will be more affected than geophytic and generalist species. Overwintering requirements and fidelity to renosterveld are little understood for insects (Rebelo 1995, Von Hase et al. 2003).

Some of these aspects, including restoration of agricultural land back to renosterveld, are currently being investigated. It appears that seeds are produced and dispersed into agricultural land, but that seedlings do not establish. However, geophytes and hemicryptophytes have short seed dispersal distances, limiting dispersal to remnants in the immediate vicinity. Both grazing and competition with agricultural grasses inhibit this establishment, but changes in soil chemistry, nursery plants and fine-scale heterogeneity after ploughing are probably paramount in affecting establishment of seedlings (Krug et al. 2004b). Unpalatable daisies (*Elytropappus, Oedera, Relhania*) or *Galenia* often form dense monospecific stands—with a near-total absence of geophytes and grasses—in old fallow lands, which appear to be stable for decades.

Invasive alien species are a major threat to biodiversity in the Fynbos Biome. Although alien organisms from many higher taxonomic groups have invaded the fynbos and renosterveld, alien plants have had by far the greatest and most direct impact on vegetation in the region.

Many plant species were introduced to the Fynbos Biome from Europe and Asia between 1653 and 1806 to fulfil the need of the Dutch colonists to cultivate a wide range of agricultural and horticultural species from their homeland and from Dutch possessions in the East. Introductions continued in the 19th century, with a concerted effort to increase the cover of trees in the tree-poor fynbos. Many tree species were introduced for forestry *sensu lato*, including plantings to supply timber and to stabilise dune sands in sand fynbos and strandveld. Such efforts resulted in very large plantings of trees, especially of species of *Acacia* and *Pinus*.

The spread and potential threat of alien plants in fynbos was first documented in the 1920s. For example, Sim (1927) noted 'the extent to which *Pinus pinaster* can take possession indicates that, if given a long enough period without check, it would probably kill out some of the endemic monotypes.'

A dozen species of trees and shrubs constitute by far the most obvious and damaging aspect of alien plant invasions. Several Australian *Acacia* species (notably *A. cyclops, A. longifolia, A. mearnsii* and *A. saligna*), three Australian *Hakea* species (*H. drupacea, H. gibbosa* and *H. sericea*), several *Pinus* species (especially *P. halepensis, P. pinaster* and *P. radiata*) have been spectacularly successful invaders in fynbos. *A. cyclops* and *Myoporum serratum* are most problematic in strandveld. The prominence of trees in the invasive flora of fynbos vegetation is unusual among mediterranean-climate regions of the world (Kruger et al. 1989) and also sets the Fynbos Biome apart from other South African biomes (Richardson et al. 1997). Many nonwoody alien plants are widespread in the Fynbos Biome, but most occur under highly disturbed conditions. Some lowland sites—primarily sand fynbos and renosterveld—are highly invaded by alien grasses (e.g. Vlok 1988), but the extent and impacts of such invasions are poorly known, although they are predicted to seriously impact on geophytes. Research into their control has recently been initiated (Musil et al. 2005).

How much of the Fynbos Biome is invaded by alien plants? Several assessments have been made, using a variety of methods. The most recent and thorough survey found that 1.6% of the CFR was covered with dense stands of woody alien plants (the same area as that under urban areas), with another 30% of the area at risk of being heavily invaded within 20 years (Rouget et al. 2004). The most detailed, species-level assessment of the extent of invasions for smaller regions within the Fynbos Biome was done for the Cape Peninsula (49 000 ha in extent). This survey showed that about 11% of the area that was not transformed by urbanisation and agriculture was under dense stands (> 25% canopy cover) of invasive alien trees and shrubs, with another 33% lightly invaded (Richardson et al. 1996). The most widespread invader was *Acacia cyclops*, occurring in both fynbos and strandveld vegetation types.

In most areas of sandstone and quartzite fynbos, the dominant invasive plants are *Hakea* and *Pinus* species. These plants are killed by fire and serotinous (with winged seeds stored in woody heat-proof cones/follicles). They initially behave much like the native shrubs, but their short juvenile periods and large reserves of highly mobile seeds buffer them against fire-induced population crashes. The prevailing nonequilibrium system is disrupted, and cyclical replacement of native overstorey shrubs is prevented. As the invaders proliferate after each fire, competition with indigenous elements is intensified, eventually leading to the local extinction of the latter as residual seed stores are depleted. There is no cyclical replacement without human intervention (such as felling of pines), and a depauperate steady-state results (Richardson & Cowling 1992). Pines and hakeas spread rapidly in fynbos, and landscapes are sometimes transformed from natural shrublands to dense alien-dominated forests over two or three fire cycles (< 50 years) (e.g. Richardson & Brown 1986). The most prominent woody invaders in sand and limestone fynbos and strandveld are several species of *Acacia*, especially *A. cyclops* and *A. saligna*. Riparian vegetation throughout the CFR is heavily invaded by alien tree species, notably *A. longifolia, A. mearnsii, Eucalyptus camaldulensis* and *Paraserianthes lophantha*, and the reed *Arundo donax* (Galatowitsch & Richardson 2005).

What is known about the impact of invasive plants in the Fynbos Biome? Dense stands of alien trees and shrubs rapidly reduce abundance and diversity of native plants at the scale of small plots. Regarding mechanisms of this attrition, studies in dense stands of *Acacia saligna* have documented the decline of soil-stored seed banks of native plants, leading to the local extinction of native species. Such invasions also greatly increase biomass, and change litter-fall dynamics and nutrient cycling. These changes have marked, and varied, effects on fire regimes. Sand fynbos has far more transient seed banks than sandstone fynbos, and nitrogen enrichment results in grassy elements replacing shrubs in sand fynbos, but not in sandstone fynbos. In the lowlands, alien annuals reduce small-scale diversity of native herbs in sand fynbos and renosterveld. Tree and shrub invasions in fynbos change many aspects of faunal communities. Studies have documented altered abundance and composition in native ant communities, with implications for the seed dispersal functions of native plants. The altered feeding behaviour of native generalist birds that disperse seeds, with likely detrimental effects on native plant species, has also been described in strandveld (see Richardson & Van Wilgen 2004 for references).

Invasive trees and shrubs also have a marked effect on the delivery of goods and services from Fynbos Biome ecosystems. In water catchment areas, besides the marked direct effects in the form of reduced stream flow, invasive alien plants have clear consequences for the ecological integrity of the catchments. For example, invasion of fynbos catchment areas increases biomass and fuel loads, leading to an increased fire hazard and soil erosion. This compromises the ability of fynbos catchments to store water for steady release throughout the year. Invaded and burnt watersheds are denuded of soil, and runoff after rain is rapid, causing flooding, damage to property and infrastructure, and siltation. The extent and consequences of these impacts at regional scales are poorly understood. In coastal zones, stabilisation of naturally mobile sand dunes through increased plant cover and root biomass of planted and invasive *Acacia cyclops* has radically altered coastal sediment movements, leading to massive beach depletion which is threatening coastal developments along the Eastern and Western Cape coasts (see Richardson & Van Wilgen 2004 for references).

Considerable progress has been made with the management of alien plant invasions in fynbos and riparian zones of the Fynbos Biome. A milestone was the initiation of the Working for Water (WfW) programme in 1995 (Van Wilgen et al. 1996, Van Wilgen & Cowling 1998). Although successful control operations against invasive species were in place before this date, WfW provided the foundation for the initiation and, more importantly, the sustainability of control programmes at local and regional scales in the Fynbos Biome (and throughout South Africa). As its name implies, WfW initially focused largely on the control of invasive species with the specific aim of alleviating the well-documented impacts on water resources. As such, it represents a model case of the leverage of conservation action based on a scientific evaluation of the value of ecosystem services and the threats from invasive species to these services. The focus of the programme has been expanded to deal with all invasive plant species, not only those with a clear impact on water resources.

8. Action and Further Research

Although the Fynbos Biome was subject to intensive study from 1977 to 1989 under the Fynbos Biome Project (Kruger 1978, Day et al. 1979, Kruger 1979, Campbell et al. 1981, Jarman et al. 1981, Boucher & McDonald 1982, Deacon et al. 1983, Bond & Goldblatt 1984, Jarman 1984, MacDonald & Jarman 1984, Moll et al. 1984, Pierce 1984, Hall & Veldhuys 1985, Kruger et al. 1985, MacDonald et al. 1985, Cowling et al. 1987, Manders & Dicks 1987, Rebelo 1987a, Cowling 1992), it is clear that many gaps in our knowledge still exist (Huntley 1992). Thus, although fire ecology was a major research theme under the Fynbos Biome Project, and much was learned, it is still not possible to obtain figures on average fire size and differences in fire-return intervals between major mountain catchments. Although a Red Data Book was published (Hall & Veldhuys 1985), in which the presence of many rare species with small (less than 50 mature plants) isolated (with no seed dispersal) populations was documented, it is still not understood how such small populations can be self-sustaining over the time scales during which they have been observed (over 200 years). What is alarming about these deficiencies, and many others not mentioned, is that they are the cornerstone of management and monitoring of fynbos communities, especially in a world of habitat destruction, alien invasive plant infestations and global climate change. The new initiatives to complete the conservation status of species in a new Red Data List before 2006 (Foden 2006), and the Red Data List for Proteaceae (A.G. Rebelo, unpublished data), highlight these problems, but do not address them.

An understanding of the biogeography of the Fynbos Biome requires detailed inventories of species for the different vegetation types. However, due to the high species richness and turnover, the data required to map the biodiversity of the region do not exist, except for a few isolated units. We know that endemism is high for the biome—it appears to be exceptionally high also for individual mountains and vegetation types, but we do not have the data to discern patterns at any scale finer than 25 x 25 km grid units (Oliver et al. 1983), and even these are patchy. The Protea Atlas Project (Rebelo 1991), running over 10 years from 1991–2001, discovered more than 10 new taxa of Proteaceae, one of the best researched plant families of the Fynbos Biome. More importantly, it hints that much subspecific diversity exists locally that has never been adequately documented. Primary taxonomy and vegetation inventories are totally inadequate and more work is urgently needed.

Although detailed and comprehensive plans exist for the CFR (Cowling et al. 1999b, Pressey et al. 2003, Rouget et al. 2003a, b, 2004), two key assumptions require more detailed research—the long-term effects of fragmentation, and the significance of corridors. The proposed network is robust enough to cater for the inadequacies of current knowledge, but it is highly unlikely that the ambitious programmes will be comprehensively realised, especially in the lowlands. We need to understand which units and links are indispensable and which can be sacrificed. Another key assumption of the conservation plan is that invasive alien plants will be brought under control and that future invasive species will be controlled timeously. Legislation, in particular the Conservation of Agricultural Resources Act (Act No. 43 of 1983) and National Environmental Management: Biodiversity Act (Act No. 10 of 2004), to achieve this, is in effect. However, it remains to be seen whether it will work in practice. Guidelines to assessing environmental impact are also available (De Villiers et al. 2005)

Given the threat of global climate change in the region, we must be able to predict what changes will occur within the region. Unfortunately, the models are not very robust at predicting possible future rainfall patterns. Specifically, to determine the degree of habitat transformation that global climate change will effect, we have to know the annual distribution of precipitation and changes in predictability. We also have to profile which taxa and vegetation types are likely to be most affected and what mitigation (if any) is required. This must take into account that suitable alternative habitats are sometimes already occupied by sister taxa that are also under stress.

A further problem is the conservation of fynbos and renosterveld in urban areas. Current antipollution and fire legislation prevents burning of fynbos areas during peak fire periods. Mowing, which effectively destroys the communities, is preferred as an alternative to fire by some managers. Remnants become invaded with bird-dispersed strandveld species and invasive alien *Acacia* and grasses. The net effect is that prime conservation land—including some Critically Endangered vegetation units such as FFd 5 Cape Flats Sand Fynbos—are not being conserved, even though they are in conservation areas and in conservation-managed road reserves.

We know very little about renosterveld ecology, despite it having been used for livestock for over 300 years. It is unique among productive ecosystems worldwide by its very high geophytic flora. The most urgent actions required are to protect sufficient remnants to safeguard the threatened flora in the coastal renosterveld types. To this end, CAPE has identified all lowland renosterveld remnants as 'critically endangered' and 'irreplaceable' (Cowling et al. 1999b). These are flagged in regional plans as not available for conversion to agriculture or other land uses (Cowling et al. 1999b). Whether this strategy will be sufficient to prevent the further loss of these vegetation types remains to be seen. However, the remnants are too fragmented and too small for effective conservation and any effective conservation plan will require large-scale restoration of agricultural land linking these fragments into coherent units (Krug et al. 2004b).

Opportunities currently exist to reintroduce large mammals into renosterveld ecosystems in the Little Karoo and to attempt to reconstitute extinct grazing and browsing regimes. This is currently being done at various places between Barrydale and Touws River. This is an opportunity to study and recreate a lost ecosystem that should be carefully and vigorously researched.

9. Descriptions of Vegetation Units

9.1 Fynbos

Fynbos vegetation occupies 67% of the area of the Fynbos Biome and 56% of the area of the CFR. By far the most fynbos vegetation units (81%) occur on nutrient-poor sandy substrates derived from sandstone, quartzite and Tertiary sands of the Cape Fold Belt. The classification of the units into groups follows the geology.

All fynbos units contain habitats characterised as 'wetland'. These vary from seeps of varying permanency and origin, narrow restio alluvia of mountain streams, as well as fynbos peats and mires (see Sieben 2003, Sieben et al. 2004). Within these wetlands, often a single species is dominant, sometimes in zones within the wetlands, and different species may occupy apparently identical ecological niches in different geographical areas, or even in neighbouring wetlands. These communities are often localised and not detectable at the mapping scale adopted in this project (1:250 000), being best mapped at scales finer than 1:25 000 (Boucher 1978). Structurally, the fynbos wetlands are mainly restioid (dominated by *Anthochortus* and *Elegia*) or ericaceous (dominated by *Berzelia, Brunia*, *Erica*), but many are dominated by Poaceae.

In compiling species lists, two factors stand out. Firstly, the lack of constant (mono)dominance across communities. The sandstone fynbos units are usually polydominant and even their distribution patterns are not consistent across larger geographic scales. Secondly, it is often impossible to reconcile communities based on localised fine scale with those described in generalised studies. With localised studies the 'characteristic' and 'dominant' species that define broader types are often absent or insignificant. Hence, an inevitable consequence for our descriptions is that the number of communities and types recognisable is directly proportional to the number of studies undertaken, and at current levels of data, shows no sign of tapering off. Thus, even within FFs 11 Kogelberg Sandstone Fynbos, for example, it is difficult to reconcile communities from Kogelberg, Jonkershoek and Groenlandberg: even edaphically matched sites are not easily defined using only floristic composition. This is hardly surprising in the light of the renowned large beta and gamma diversity of the flora (e.g. Kruger & Taylor 1979, Cowling 1983a, 1990a, Cowling et al. 1992, Cowling & Lombard 2002, Procheş et al. 2003) and notorious functional redundancy (Cody & Mooney 1978, Cody 1986, Cowling et al. 1994a). Furthermore, most units have never had a comprehensive vegetation survey, so that species lists reflect more about levels of sampling than about ecology or biogeographical effects. There is still much basic survey research required to provide a less distorted image of the diversity of fynbos vegetation assemblages, and indeed in the Fynbos Biome on the whole.

9.1.1 Sandstone Fynbos

Sandstone Fynbos is the most extensive vegetation group in the Fynbos Biome, at 301 km^2 covering almost four times the area of the next most prominent fynbos group, Sand Fynbos, and about one third the area of the Fynbos Biome. It occurs in high-relief areas underlain by Devonian and Ordovician sandstones of the Table Mountain Group which are very resistant to erosion, except where underlain by softer sediments prone to erosion. Thus the Groot Swartberg uppermost sandstone beds (Nardouw-Baviaanskloof) have retreated northwards by a maximum of 25 km in the Swartberg, with a more typical retreat of 5–10 km from the faults along both the Worcester-Outeniqua and the Swartberg faults. The predominant east-west ranges have been stable since the break-up of Gondwana 120 mya, although some of the synclinal exposures in the Little Karoo are probably much younger. By contrast, the sandstones overlaying the West Coast were removed millions of years ago, probably largely during the Cretaceous/Pliocene, and pushed back to the Olifants fault. Remnants of this sandstone sheet still occur as Piketberg, Riebeek-Kasteel and Table Mountain—all synclinal exposures with the higher anticlines removed. Thus an area almost twice as large as the current sandstone exposure has been eroded away since the Gondwana split. Furthermore, these exposures, being anticlinal would have been higher than the current remnants, probably situated at altitudes between 1 000 and 2 000 m (see Compton 2004). The biogeographical evolutionary significance of this historical, large expanse of fynbos has not been explored.

The early post-Cretaceous would have seen a large expanse of exposed sandstone on the West Coast, and the beginnings of the large Cederberg and Kouga Mountains visible today, connected by the linear Langeberg, Riviersonderend and Swartberg scarps. These latter and the 'Karoo Island' sandstone outcrops would have become wider as erosion removed sediments from above the sandstone and decreased the steepness of the fault (South African Committee for Stratigraphy 1980).

Given these substrate patterns, the high richness of fynbos taxa in the west versus that in the east, may be the result of past differences in climate, with the westward and eastward movement of the summer-rainfall area resulting in extinction of fynbos taxa in the east. Under this scenario, the summer-rainfall zones would not have moved west of Riversdale/Swellendam (Goldblatt & Manning 2000a). During these periods, fynbos east of Swellendam would have survived only at higher altitudes: many endemics to the southern Cape sandstone fynbos areas are high-altitude species. The high relief of sandstone has resulted in most of it being above the post-Cretaceous marine incursions, with the exception of the Soetanysberg at Agulhas.

Altitudinal zonation has not been formally described for the Cape fynbos, unlike in other mediterranean-type biomes, such as the Mediterranean region itself (Rivas-Martínez 1976, 1981). Such zonation exists, and numerous bands, based both on structural and floristic types, can be observed altitudinally on both northern and southern mountain slopes. Typical idealised north-slope sequences would be encompassing asteraceous, dry restioid, proteoid, ericaceous and wet restioid fynbos, and proteoid, ericaceous and wet restioid on the southern slopes. However, these are too fine to map and have been subsumed into the geographical units. The upper limits above 1 800 m have, however, been documented (Linder et al. 1993, McDonald et al. 1993, Taylor 1996) and have been recognised in this work. Nevertheless, this is the first attempt at comprehensively mapping these zones within the Fynbos Biome. The recognition of two altimontane fynbos units is preliminary, with available data ambivalent as to their being coherent units as presented herein or subunits of the sandstone types in which they occur. The altimontane fynbos occurs on sandstone substrates, but shale bands also enter this altitudinal zone in a few places, but have been retained with the relevant shale band vegetation unit pending more appropriate data. We refrain from using the term 'alpine' or 'subalpine' since it may invoke unjustified links to altitudinal zonation patterns of the Alps.

FFs 1 Bokkeveld Sandstone Fynbos

VT 28 Western Mountain Karoo (45%), VT 69 Macchia (41%) (Acocks 1953). Dry Mountain Fynbos (78%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (92%) (Low & Rebelo 1996). BHU 45 Bokkeveld Mountain Fynbos Complex (51%), BHU 46 Gifberg Mountain Fynbos Complex (41%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Northern and Western Cape Provinces: From the Bokkeveld Escarpment in the north along the Kobee and Matsikamma Mountains to the Gifberge between the Doring (Hantams) River (north of Nieuwoudtville) to the Doring (Tankwa) River (south of Klawer). Altitude 200–1 000 m, with the highest peak being Matsikammaberg (1 016 m).

Vegetation & Landscape Features A flat tableland, on the Bokkeveld Escarpment, elsewhere gently sloping to the east and south, without any faulting or folding in the sandstone beds. Major exposures of sandstone are at the edge of the Escarpment and where younger sediments have been removed. Topography resulting from rivers cutting through the resistant sandstone, forming deep gorges (such as Oorlogskloof) in an otherwise flat sandstone landscape. Although the shale bands of the Cedarberg Formation are largely absent, rugged 'Cederberg' landscape is formed on the eastern edge, where shale outcrops with flat-topped hills occur (and support outliers of Bokkeveld Sandstone Fynbos on their summits). Vegetation mainly closed restiolands in deeper moister sands with low, sparse shrubs that become denser with decreased restioid dominance in drier areas. Restioid, proteoid and asteraceous fynbos predominate; some waboomveld found as well.

Geology & Soils Acidic lithosol soils derived from Ordovician sandstones of the Table Mountain Group (Cape Supergroup), very variable from Glenrosa and Mispah forms to red-yellow apedal to grey regic sands or skeletal. Land types mainly Fa, Ai, Ib and Hb.

Climate MAP 160–430 mm (mean: 290 mm), peaking May to August. The most arid of the Sandstone Fynbos types. Mean daily maximum and minimum temperatures 30.8°C and 4.0°C for February and July, respectively. Frost incidence 3–10 days per year. See also climate diagram for FFs 1 Bokkeveld Sandstone Fynbos (Figure 4.21).

Important Taxa ([T]Cape thickets, [W]Wetlands) Small Trees: *Brabejum stellatifolium*[T], *Protea nitida*. Tall Shrubs: *Dodonaea viscosa* var. *angustifolia* (d), *Euryops speciosissimus* (d), *Leucadendron pubescens* (d), *Olea europaea* subsp. *africana*[T] (d), *Protea laurifolia* (d), *Aspalathus linearis*, *Diospyros glabra*[T], *Euclea lancea*[T], *E. natalensis* subsp. *capensis*[T], *Euryops tenuissimus* subsp. *tenuissimus*, *Gymnosporia buxifolia*[T], *Leucadendron procerum*, *Leucospermum praemorsum*, *Protea glabra*. Low Shrubs: *Aspalathus acocksii*, *A. pulicifolia*, *Asparagus capensis* var. *capensis*, *Athanasia microphylla*, *Ballota africana*, *Chrysocoma oblongifolia*, *Clutia alaternoides*, *Diospyros austro-africana*[T], *Erica parilis*, *E. rigidula*, *Euclea tomentosa*[T], *Felicia bergeriana*, *Gomphocarpus cancellatus*, *Leucadendron salignum*, *Leucospermum calligerum*, *Lobostemon glaucophyllus*, *Maytenus oleoides*[T], *Metalasia brevifolia*, *M. dregeana*, *M. fastigiata*, *Oedera squarrosa*, *Paranomus bracteolaris*, *Passerina truncata* subsp. *truncata*, *Pteronia divaricata*, *Serruria millefolia*, *Solanum tomentosum*, *Ursinia punctata*. Succulent Shrubs: *Braunsia maximilianii*, *Didelta spinosa*, *Euphorbia mauritanica*, *Tylecodon paniculatus*. Woody Climbers: *Asparagus aethiopicus*, *Microloma sagittatum*. Herbs: *Hemimeris racemosa*, *Rumex cordatus*, *Ursinia macropoda*. Geophytic Herbs: *Asplenium cordatum*, *Lapeirousia jacquinii*, *Melasphaerula ramosa*, *Ornithogalum maculatum*, *Romulea flexuosa*, *R. hirta*, *R. luteoflora*, *R. montana*, *R. multisulcata*[W], *R. schlechteri*[W], *R. stellata*, *R. viridibracteata*. Succulent Herbs: *Conophytum obcordellum* subsp. *obcordellum* var. *obcordellum*, *Crassula muscosa.* Graminoids: *Ehrharta longiflora*, *Ischyrolepis gaudichaudiana*, *Willdenowia incurvata*.

Endemic Taxa ([T]Cape thickets) Tall Shrubs: *Anginon ternatum*, *Hyaenanche globosa*[T]. Low Shrubs: *Leucadendron remotum* (d), *Agathosma dregeana*, *A. elata*, *Amphithalea minima*, *Aspalathus isolata*, *A. obliqua*, *A. proboscidea*, *A. venosa*, *Athanasia leptocephala*, *A. spathulata*, *Cliffortia acutifolia*, *Cullumia pectinata*, *Erica aristifolia*, *E. rusticula*, *Euryops virgatus*, *Gnidia leipoldtii*, *Gymnostephium leve*, *Leucadendron meyerianum*, *L. roodii*, *L. sheilae*, *Phylica affinis*, *P. agathosmoides*, *P. pustulata*, *Podalyria pearsonii*, *Prismatocarpus pilosus*, *Psammotropha spicata*, *Selago inaequifolia*, *Serruria lacunosa*, *Staavia phylicoides*, *Sutera longipedicellata*, *Wiborgia humilis*, *Xiphotheca canescens*. Succulent Shrubs: *Antimima insidens*, *A. lokenbergensis*, *A. paucifolia, Drosanthemum expersum*, *Lampranthus arenarius*, *L. globosus*, *L. neostayneri*, *L. obconicus*, *L. paucifolius*. Herbs: *Cephalaria decurrens*, *Haplocarpha parvifolia*, *Steirodiscus schlechteri*, *Ursinia dregeana*, *Zaluzianskya acrobareia*. Geophytic Herbs: *Babiana mucronata* var. *minor*, *B. sambucina* var. *longibracteata*, *B. vanzyliae*, *Bulbinella latifolia* subsp. *toximontana*, *Chlorophytum monophyllum*, *Drimia involuta*, *Eriospermum exigium*, *Geissorhiza arenicola*, *G. divaricata*, *G. subrigida*, *G. sulphurascens*, *Gladiolus mostertiae*, *G. sufflavus*, *Hessea pusilla*, *H. undosa*, *Ixia brunneobractea*, *Moraea macgregorii*, *M. vallisbelli*, *M. verecunda*, *Oxalis comptonii*, *O. oculifera*, *O. oligophylla*, *O. oreithala*, *O. porphyriosiphon*, *O. rubro-*


L. Mucina

Figure 4.22 FFs 1 Bokkeveld Sandstone Fynbos: Dry restioid fynbos with a strong fynbos thicket element, abundant *Euryops tenuissimus* and a rich annual flora on a shallow-soil sandstone plateau overlooking the Oorlogskloof Canyon on the Farm Krantzkloof, south of Nieuwoudtville (Northern Cape).

punctata, *O. suteroides*, *O. tenuis*, *Pelargonium connivens*, *P. nephrophyllum*, *P. reflexum*, *Romulea amoena*, *R. monticola*, *R. sanguinalis*, *R. sladenii*, *R. toximontana*, *Sparaxis auriculata*, *Strumaria watermeyeri*. Succulent Herbs: *Conophytum comptonii*, *C. minusculum*, *C. swanepoelianum* subsp. *rubrolineatum*. Graminoid: *Ischyrolepis longiaristata*.

Conservation Least threatened. Target 29%. Statutorily conserved (3%) in the Oorlogskloof Nature Reserve. Some 18% transformed (cultivation). The biggest threat to the original vegetation is rooibos tea farming, which results in the ploughing up of the deeper sands. The absence of aliens is very unusual among fynbos types. Erosion very low.

Remarks This is a very poorly studied type. The high endemism within this type has not been appreciated up to now.

References Van Jaarsveld (1982), L. Mucina (unpublished data), Protea Atlas Project (unpublished data).

FFs 2 Graafwater Sandstone Fynbos

VT 69 Macchia (66%), VT 34 Strandveld of the West Coast (32%) (Acocks 1953). Dry Mountain Fynbos (60%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (88%) (Low & Rebelo 1996). BHU 48 Olifants River Mountain Fynbos Complex (53%), BHU 10 Leipoldtville Sand Plain Fynbos (39%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: West Coast region, with the main block from Traval in the Olifants River Valley in the north, through areas east of Graafwater and Redelinghuys to Het Kruis (north of Piketberg) in the south. Smaller isolated patches to the west of this main body include Koeivleiberg, Klipfonteinkoppe and Muishoekberg. This fynbos type reaches the Atlantic Ocean through several unmapped patches near Elands Bay. Altitude 100–650 m. It excludes the higher mountains such as Engelsman se Berg and Swartberg (FFs 4 Cederberg Sandstone Fynbos), which are embedded in the unit.

Vegetation & Landscape Features Low mountains and gently undulating plains. Low scrub with scattered tall shrubs. Structurally it is asteraceous and scrub fynbos, with proteoid and restioid fynbos on deeper soils. In this arid environment numerous so-called 'woody' nonfynbos shrubs occur, mainly in fire-safe environments, within the fynbos matrix. This Cape thicket and scrub fynbos communities are the dominant feature of this vegetation type in rocky areas and cliffs. This is an arid version of FFs 3 Olifants Sandstone Fynbos and lacks denser and wetter vegetation. The Cape thicket communities occur in an arid facies. This type grades imperceptibly into FFd 2 Leipoldtville Sand Fynbos on the western edge, depending on sand depth and water table level.

Geology & Soils Acidic lithosol soils derived from Ordovician sandstones of the Table Mountain Group (Cape Supergroup), predominantly red-yellow apedal or Glenrosa and Mispah forms. Land types mainly Ai, Ib and Fa.

Climate MAP 200–499 mm (mean: 355 mm), peaking May to August when 70% of rain falls. Mean daily maximum and minimum temperatures 30.2°C and 6.1°C for February and July, respectively. Frost incidence 3 or 4 days per year. Mists common in winter. See also climate diagram for FFs 2 Graafwater Sandstone Fynbos (Figure 4.21).

Important Taxa ([T]Cape thickets) Small Trees: *Heeria argentea*[T] (d), *Protea nitida* (d), *Ficus cordata*, *Podocarpus elongatus*[T]. Tall Shrubs: *Diospyros ramulosa*[T] (d), *Euryops speciosissimus* (d), *Leucadendron pubescens* (d), *Olea europaea* subsp. *africana*[T] (d), *Protea laurifolia* (d), *Rhus undulata*[T] (d), *Aspalathus linearis*, *Cassine schinoides*[T], *Diospyros glabra*[T], *Euclea linearis*[T], *Leucospermum rodolentum*. Low Shrubs: *Agathosma bisulca*, *A. marifolia*, *Anthospermum galioides* subsp. *galioides*, *Aspalathus perfoliata* subsp. *phillipsii*, *Euclea tomentosa*[T], *Felicia scabrida*, *Leucadendron loranthifolium*, *Leucospermum calligerum*, *Maytenus oleoides*[T], *Metalasia fastigiata*, *Passerina truncata* subsp. *truncata*, *Rhus dissecta*[T], *Salvia lanceolata*, *Serruria decipiens*, *S. effusa*, *S. fucifolia*, *Solanum tomentosum*, *Struthiola leptantha*. Succulent Shrub: *Euphorbia mauritanica*. Woody Climbers: *Asparagus asparagoides*, *A. retrofractus*. Herb: *Arctotis cuprea* (d). Geophytic Herbs: *Geissorhiza exscapa*, *Romulea flexuosa*, *R. leipoldtii*. Succulent Herb: *Stapelia paniculata*. Graminoids: *Cannomois scirpoides*, *Ischyrolepis gaudichaudiana*.

Endemic Taxa Low Shrub: *Athanasia sertulifera*. Succulent Shrubs: *Lampranthus candidus*, *Oscularia cremnophila*, *Ruschia filipetala*. Herb: *Wahlenbergia constricta*. Geophytic Herb: *Gladiolus comptonii*.

Conservation Vulnerable. Target 29%. None conserved in statutory conservation areas. Some 28% transformed (cultivation), mainly in valley bottoms. Alien woody plants include *Acacia cyclops* and *A. saligna*. Erosion very low and low.

D. Gwynne-Evans

Figure 4.23 FFs 2 Graafwater Sandstone Fynbos: Small sandstone outcrop with shrybby *Heeria argentea* (Anacardiaceae) overlooking Verlorenvlei Lake near Elands Bay (Western Cape).

Remark Also a feature of this vegetation type, especially on the eastern edge, are heuweltjie communities which are often dominated by succulents (*Didelta spinosa, Ruschia decurvans, Tetragonia rosea*) in the north, or thicket species (*Berkheya fruticosa, Rhus dissecta, Zygophyllum spinosum*) in the south.

References Milton (1978), Lane (1980), Boucher (1991).

FFs 3 Olifants Sandstone Fynbos

VT 69 Macchia (91%) (Acocks 1953). Mesic Mountain Fynbos (85%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (100%) (Low & Rebelo 1996). BHU 47 Cederberg Mountain Fynbos Complex (72%), BHU 48 Olifants River Mountain Fynbos Complex (19%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Figure 4.24 FFs 3 Olifants Sandstone Fynbos: West-facing slopes of the Cederberg below Middelberg Pass (Western Cape) covered with dense *Leucadendron*-dominated fynbos, with a small patch of waboomveld (*Protea nitida*) in the foreground.

Distribution Western Cape Province: Western Cederberg and Koue Bokkeveld Mountains from Bulshoek Dam to Keerom adjacent to Olifants River Valley and to Saron on the lower western slopes of the Vier-en-twintig Riviere (Voorberg) Mountains (but see Remark 1 below). Altitude 200–1 200 m.

Vegetation & Landscape Features Gentle to steep slopes to the Cederberg scarp as well as broad valley bottoms. The Cedarberg Shale Band (supporting vegetation of the FFb group of units) gives this landscape its distinctive flat plateau in the west and dissected back-valley to the east. This unit comprises a combination of communities tending to occur on the rocky west-facing slopes of the Cederberg where bare rock and cliffs are dominant and there is less accumulation of sand. The rock provides fire protection, resulting in the dominance of Cape thicket and asteraceous fynbos with interspersed low trees and tall shrubs forming a medium tall shrub matrix. Proteoid fynbos is most prominent on the lowermost slopes and sandy plateaus and restioid fynbos occurs on deeper sands and shallower soils.

Geology & Soils Acidic lithosol soils derived from Ordovician sandstones of the Table Mountain Group (Cape Supergroup). Land types mainly Ic, Ib and Fa.

Climate MAP 250–700 mm (mean: 450 mm), peaking May to August when 70% of rain falls. Mean daily maximum and minimum temperatures 29.6°C and 4.9°C for February and July, respectively. Frost incidence from 3–10 days per year. See also climate diagram for FFs 3 Olifants Sandstone Fynbos (Figure 4.21).

Important Taxa (^{T}Cape thickets, ^{W}Wetlands) Small Trees: *Heeria argentea*^{T}, *Kiggelaria africana*^{T}, *Metrosideros angustifolia*^{T}, *Podocarpus elongatus*^{T}, *Protea nitida*. Tall Shrubs: *Euryops speciosissimus* (d), *Leucadendron pubescens* (d), *Olea europaea* subsp. *africana*^{T} (d), *Protea laurifolia* (d), *Anisodontea bryoniifolia*, *Aspalathus aemula*, *A. linearis*, *Cassine peragua* subsp. *peragua*^{T}, *C. schinoides*^{T}, *Diospyros glabra*^{T}, *Dodonaea viscosa* var. *angustifolia*, *Euclea lancea*^{T}, *E. natalensis* subsp. *capensis*^{T}, *E. undulata*^{T}, *Euryops abrotanifolius*, *E. tenuissimus* subsp. *trifurcatus*, *Leucadendron rubrum*, *Myrsine africana*^{T}, *Protea glabra*, *Rhus rimosa*^{T}, *R. tomentosa*^{T}, *R. undulata*^{T}. Low Shrubs: *Agathosma marifolia*, *Anthospermum galioides* subsp. *galioides*, *Aspalathus acidota*, *A. acifera*, *A. bracteata*, *A. galeata*, *A. perfoliata* subsp. *phillipsii*, *A. tridentata* subsp. *rotunda*, *Asparagus suaveolens*, *Diospyros austro-africana*^{T}, *Elytropappus adpressus*, *Eriocephalus africanus* var. *paniculatus*, *Leucadendron salignum*, *Maytenus oleoides*^{T}, *Metalasia fastigiata*, *Paranomus bracteolaris*, *Passerina truncata* subsp. *truncata*, *Phylica oleaefolia*, *Rhus dissecta*^{T}, *Serruria aitonii*, *S. cygnea*, *S. effusa*, *S. millefolia*, *Stoebe plumosa*, *Stachys linearis*. Succulent Shrubs: *Crassula atropurpurea* var. *watermeyeri*, *C. dejecta*, *Pelargonium alternans*. Semiparasitic Shrub: *Osyris compressa*. Geophytic Herbs: *Babiana mucronata* var. *mucronata*, *Geissorhiza confusa*, *Romulea hirta*, *R. luteoflora*, *R. saxatilis*. Graminoids: *Calopsis paniculata*, *Ehrharta calycina*, *Elegia capensis*^{W}, *Ischyrolepis gaudichaudiana*, *I. sieberi*, *Restio perplexus*.

Endemic Taxa Tall Shrub: *Halleria ovata*. Low Shrub: *Aspalathus ulicina* subsp. *kardouwensis*. Succulent Shrub: *Lampranthus dulcis*. Herb: *Lotononis macrocarpa*.

Conservation Least threatened. Target 29%. Statutorily conserved (23%) in the Cederberg Wilderness Area with an additional 44% protected in private conservation areas such as Winterhoek and Sederberg. Some 8% transformed (cultivation). *Pinus radiata* occurs as an alien invader in places. Erosion very low.

Remark 1 This unit was the most obviously discernable on satellite images. There are no floristic data to determine whether the Vier-en-twintig Riviere Mountains south of Piekenierskloof Pass should be included in this unit, so we deferred to the satellite images. Similarly, the boundary with FFs 2 Graafwater Sandstone Fynbos is based on satellite coverage, as there are no floristic data to suggest an alternative.

Remark 2 This unit differs from FFs 2 Graafwater Sandstone Fynbos—probably because of the higher rainfall, with Cape thicket grading into afrotemperate forest in the kloofs and valleys (the largest of these are mapped). Asteraceous fynbos is the dominant fynbos type, but even this has a high abundance of Cape thicket elements. Proteoid fynbos is most common on the lowermost slopes and on sandy plateaus, with restioid fynbos on deep sands and shallower soils.

References Boucher (1990, 1991, 1997c), Taylor (1996).

FFs 4 Cederberg Sandstone Fynbos

VT 69 Macchia (87%) (Acocks 1953). Mesic Mountain Fynbos (60%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (96%) (Low & Rebelo 1996). BHU 47 Cederberg Mountain Fynbos Complex (40%), BHU 46 Gifberg Mountain Fynbos Complex (31%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Mountains and rocky flats south of the Doring River from the Nardousberge through the Cederberg Mountains including the Pakhuisberge, Krakadouberge, Middelberg, Sneeukoppe, Tafelberg, Sneeuberg (but excluding the uppermost parts of the last-mentioned three), Breekkransberge and Sandfontein Peaks, and terminating on the Skurweberg (excluding the summit area of Sneeukop).

Also included are the higher peaks (for example, Engelsman se Berg, Swartberg and Maanberg) west of the Olifants River Valley. Substantial sections of the western parts of the central and northern Cederberg are excluded from this unit. Altitude 300 to just below the border of FFs 30 Western Altimontane Sandstone Fynbos (at about 1 800 m).

Vegetation & Landscape Features Flat to gently east- or north-sloping tableland, with steeper west-facing slopes (only upper parts in this unit)—both being rugged and dominated by rocky outcrops with gullies and flats of deep sand. Isolated mountain peaks occur and a more dissected mountainous terrain occurs in the west. The character of the Cederberg—the long, linear step or plateau that dominates the landscape between the upper and lower blocks of rugged sandstone—is given by the Cedarberg Shale Band (see FFb 1 Northern Inland Shale Band Vegetation). Vegetation consists of closed restiolands on deeper moister sands, with low, sparse shrubs that become denser and Restionaceae less dominant in the drier areas. Structurally it is predominantly asteraceous, restioid and proteoid fynbos. North of Pakhuis Pass towards the Doring River this grades through asteraceous fynbos to SKv 1 Doringrivier Quartzite Karoo.

Geology & Soils Acidic lithosol soils derived from Ordovician sandstones of the Table Mountain Group (Cape Supergroup). Land types mainly Ic, Ib, Ai and Fa.

Climate MAP 180–600 mm (mean: 395 mm), peaking May to August. Mean daily maximum and minimum temperatures 28.4°C and 4°C for February and July, respectively. Frost incidence 3–30 days per year. See also climate diagram for FFs 4 Cederberg Sandstone Fynbos (Figure 4.21).

Important Taxa ([T]Cape thickets, [W]Wetlands) Small Trees: *Protea nitida* (d), *Aspalathus pendula*. Tall Shrubs: *Cassine schinoides*[T] (d), *Diospyros glabra*[T] (d), *Heeria argentea*[T] (d), *Leucadendron pubescens* (d), *Maytenus oleoides*[T] (d), *Metalasia densa* (d), *Metrosideros angustifolia*[T] (d), *Morella serrata* (d), *Olea europaea* subsp. *africana*[T] (d), *Phylica buxifolia* (d), *Podocarpus elongatus*[T] (d), *Protea glabra* (d), *P. laurifolia* (d), *Rhus undulata*[T] (d), *Anisodontea bryoniifolia*, *Aspalathus aemula*, *A. linearis*, *Dodonaea viscosa* var. *angustifolia*, *Euclea lancea*[T], *E. linearis*[T], *E. undulata*[T], *Euryops speciosissimus*, *E. tenuissimus* subsp. *tenuissimus*, *E. tenuissimus* subsp. *trifurcatus*, *Hypocalyptus sophoroides*, *Leucadendron rubrum*, *Montinia caryophyllacea*, *Myrsine africana*[T], *Protea magnifica*, *P. repens*, *Rhus rimosa*[T]. Low Shrubs: *Cliffortia ruscifolia* (d), *Diosma acmaeophylla* (d), *D. meyeriana* (d), *Elytropappus adpressus* (d), *Erica maximiliani* (d), *Eriocephalus africanus* var. *africanus* (d), *Metalasia agathosmoides* (d), *Passerina truncata* subsp. *truncata* (d), *Phylica rigidifolia* (d), *Rafnia diffusa* (d), *Stoebe intricata* (d), *S. plumosa* (d), *Aspalathus acifera*, *A. acocksii*, *A. altissima*, *A. argyrella*, *A. bodkinii*, *A. bracteata*, *A. ciliaris*, *A. divaricata* subsp. *divaricata*, *A. filicaulis*, *A. galeata*, *A. heterophylla*, *A. lanceifolia*, *A. perfoliata* subsp. *phillipsii*, *A. pinea* subsp. *pinea*, *A. retroflexa* subsp. *angustipetala*, *A. rupestris*, *A. shawii* subsp. *shawii*, *A. tridentata* subsp. *rotunda*, *A. tridentata* subsp. *tridentata*, *A. villosa*, *Asparagus lignosus*, *Athanasia flexuosa*, *A. microphylla*, *Cliffortia hexandra*, *Clutia alaternoides, Dolichothrix ericoides*, *Elytropappus gnaphaloides*, *E. rhinocerotis*, *Erica daphniflora*, *E. parilis*, *E. plumosa*, *Eriocephalus ericoides* subsp. *ericoides*, *Euryops othonnoides*, *E. wageneri*, *Felicia scabrida*, *Gnidia geminiflora*, *Leucadendron arcuatum*, *L. brunioides* var. *brunioides*, *L. nitidum*, *L. salignum*, *Leucospermum tottum, Linconia cuspidata*, *Lobostemon glaucophyllus*, *Metalasia dregeana*, *Muraltia pillansii, Oedera sedifolia*, *O. squarrosa*, *Paranomus bracteolaris*, *Passerina truncata* subsp. *monticola*, *Pelargonium laevigatum*, *Phylica alpina*, *P. ambigua*, *P. insignis*, *P. leipoldtii*, *P. odorata*, *P. oleaefolia*, *P. rigida*, *Prismatocarpus brevilobus*, *Protea acaulos*, *P. pendula*, *P. recondita*, *P. witzenbergiana*, *Pteronia camphorata*, *P. incana*, *Rhus rosmarinifolia*[T], *Serruria aitonii*, *Sorocephalus lanatus*, *Stachys linearis*, *Stoebe aethiopica*, *S. fusca*, *S. leucocephala*, *Tephrosia capensis*, *Ursinia pilifera*, *U. punctata, Zyrphelis pilosella*. Succulent Shrubs: *Crassula dejecta* (d), *Ruschia dichroa* (d), *Antimima dasyphylla*, *Crassula atropurpurea* var. *watermeyeri*, *Othonna parviflora*. Pseudocarnivorous Shrub: *Roridula dentata*. Herbs: *Centella recticarpa*, *Indigofera humifusa*, *Lebeckia longipes*, *Ursinia macropoda*. Geophytic Herbs: *Babiana mucronata* var. *mucronata*, *Geissorhiza aspera*, *G. bolusii*[W], *G. confusa*, *G. exscapa*, *G. juncea*, *G. leipoldtii*, *G. longifolia*, *G. parva*, *G. scillaris*, *G. umbrosa*, *G. unifolia*, *Romulea biflora*, *R. flexuosa*, *R. leipoldtii*, *R. montana*, *R. schlechteri*[W], *R. stellata*, *R. viridibracteata*. Succulent Herbs: *Senecio crassulaefolius*, *Stapelia cedrimontana*. Carnivorous Herb: *Utricularia bisquamata*[W]. Graminoids: *Cannomois parviflora* (d), *Cyathocoma ecklonii*[W] (d), *Ehrharta calycina* (d), *E. villosa* var. *villosa* (d), *Elegia asperiflora* (d), *E. filacea* (d), *E. macrocarpa* (d), *Ficinia dunensis* (d), *F. nigrescens* (d), *Hypodiscus neesii* (d), *Ischyrolepis curviramis* (d), *I. gaudichaudiana* (d), *I. monanthos* (d), *I. nana* (d), *I. ocreata* (d), *I. sieberi* (d), *I. virgea* (d), *Merxmuellera arundinacea* (d), *Pentaschistis eriostoma* (d), *Restio filiformis* (d), *R. occultus* (d), *R. perplexus* (d), *Staberoha aemula* (d), *Tetraria cuspidata* (d), *T. ustulata* (d), *Thamnochortus platypteris* (d), *Willdenowia arescens* (d), *W. incurvata* (d), *Andropogon appendiculatus*, *Calopsis paniculata*, *Chrysitrix junciformis*, *Ehrharta ramosa* subsp. *aphylla*, *Elegia capensis*[W], *Epischoenus dregeanus*, *E. gracilis*, *Ficinia bul-

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Figure 4.25 FFs 4 Cederberg Sandstone Fynbos: Dry restioid fynbos with *Arctotis revoluta* (Asteraceae) in the foreground and a small tree of *Protea nitida* against a background of craggy formations of Nardouw sandstone, Pakhuis Pass near Clanwilliam (Western Cape).

bosa, *Ficinia* sp. nov. ('*petitiana*'), *Fuirena hirsuta*[W], *Hypodiscus laevigatus*, *Juncus capensis*, *Pentaschistis densifolia*, *Restio strobolifer*, *Tetraria compar*, *T. nigrovaginata*, *T. triangularis*, *Thamnochortus schlechteri*.

Endemic Taxa ([W]Wetlands) Small Tree: *Widdringtonia cedarbergensis* (d). Tall Shrubs: *Aspalathus decora*, *Leucospermum reflexum*[W], *Paranomus tomentosus*. Low Shrubs: *Acmadenia bodkinii*, *A. flaccida*, *A. patentifolia*, *A. rourkeana*, *A. tenax*, *A. tetracarpellata*, *Agathosma aemula*, *A. bathii*, *A. bicolor*, *A. conferta*, *A. dentata*, *A. distans*, *A. esterhuyseniae*, *A. humilis*, *A. krakadouwensis*, *A. longicornu*, *A. pattisoniae*, *A. pubigera*, *A. rubricaulis*, *A. salina*, *A. stilbeoides*, *A. viviersii*, *Amphithalea cedarbergensis*, *Anisodontea gracilis*, *Aspalathus comptonii*, *A. polycephala* subsp. *lanatifolia*, *A. polycephala* subsp. *polycephala*, *A. polycephala* subsp. *rigida*, *A. tridentata* subsp. *fragilis*, *Athanasia calophylla*, *Athrixia crinita*, *Berkheya dregei*, *Chrysocoma candelabrum*, *Erica aspalathoides*, *E. cavartica*, *E. cederbergensis*, *E. cedromontana*, *E. cernua*[W], *E. eugenea*, *E. hanekomii*, *E. incarnata*, *E. lateriflora*, *E. senilis*, *Euchaetis glomerata*, *Heliophila cedarbergensis*, *Hermannia helicoidea*, *Lachnaea leipoldtii*, *L. naviculifolia*, *Leucadendron bonum*, *L. concavum*, *L. dubium*, *L. sericeum*, *Leucospermum spathulatum* (Cederberg form), *Liparia congesta*, *Macrostylis hirta*, *Manulea rigida*, *Metalasia albescens*, *Pelargonium caespitosum*, *Pharnaceum rubens*, *Phylica barbata*, *P. fruticosa*, *P. maximiliani*, *P. plumigera*, *Phyllosma capensis*, *Polygala brachyphylla*, *Prismatocarpus altiflorus*, *P. pauciflorus*, *Protea cryophila*, *P. inopina*, *Psammotropha anguina*, *Rafnia globosa*, *Raspalia staavioides*, *Selago cedrimontana*, *S. dolichonema*, *S. dregeana*, *S. pustulosa*, *Serruria flava*, *S. leipoldtii*, *Struthiola lineariloba*, *Trieenea lanciloba*, *T. lasiocephala*, *T. laxiflora*, *Ursinia subflosculosa*, *Zyrphelis ecklonis*. Succulent Shrubs: *Antimima brevicarpa*, *A. distans*, *A. minutifolia*, *A. tuberculosa*, *Cephalophyllum parvulum*, *Drosanthemum longipes*, *D. pulchellum*, *Erepsia distans*, *Esterhuysenia drepanophylla*, *Lampranthus cyathiformis*, *L. longistamineus*, *L. lunulatus*, *L. macrostigma*, *L. pakhuisensis*, *L. staminodiosus*, *L. virgatus*, *Octopoma rupigenum*, *Oscularia cedarbergensis*, *O. compressa*, *O. ornata*, *O. thermarum*, *Phyllobolus viridiflorus*, *Ruschia bolusiae*, *R. cedarbergensis*, *R. intricata*, *R. lapidicola*, *R. misera*, *R. radicans*, *R. rariflora*, *R. rigidicaulis*, *R. triflora*. Herbs: *Annesorhiza filicaulis*, *Arctotis adpressa*, *Centella lasiophylla*, *C. ternata*, *Cotula montana*, *Galium monticolum*, *Haplocarpha oocephala*, *Helichrysum aureofolium*, *Lobelia comptonii*, *Manulea adenodes*, *M. arabidea*, *M. montana*, *Monopsis acrodon*, *Oligothrix gracilis*, *Oncosiphon intermedium*, *Pharnaceum serpyllifolium*, *Phyllopodium pubiflorum*, *Polycarena exigua*, *P. nardouwensis*, *Pseudoselago guttata*, *P. humilis*, *Sutera subsessilis*, *Trieenea elsiae*, *T. schlechteri*, *T. taylorii*, *Wahlenbergia adamsonii*, *W. brachycarpa*, *Zaluzianskya glandulosa*. Geophytic Herbs: *Apodolirion cedarbergense*, *Aristea rupicola*, *A. singularis*, *Babiana auriculata*, *B. cedarbergensis*, *B. geniculata*, *B. unguiculata*, *Disa cedarbergensis*[W], *Disperis bolusiana* subsp. *macrocorys*, *Geissorhiza cedarmontana*, *G. ciliatula*, *G. minuta*[W], *G. stenosiphon*, *Gladiolus buckerveldii*, *G. delpierrei*, *G. taubertianus*, *Haemanthus nortieri*, *Hesperantha elsiae*, *Lachenalia margaretae*, *L. maximiliani*, *Moraea autumnalis*, *M. barkerae*, *M. cedarmonticola*, *M. maximiliani*, *M. patens*, *Oxalis aridicola*, *O. leipoldtii*, *O. oreophila*, *O. petiolulata*, *O. phloxidifora*, *O. simplex*, *O. xantha*, *Romulea cedarbergensis*, *R. sulphurea*, *R. vinacea*, *Sparaxis caryophyllacea*, *Tritoniopsis latifolia*, *T. nemorosa*. Succulent Herbs: *Crassula elsieae*, *Tetragonia galenioides*. Parasitic Herb: *Harveya sulphurea*. Graminoids: *Askidiosperma albo-aristatum*, *Ficinia cedarbergensis*, *F. mucronata*, *Ischyrolepis setiger*, *Restio brunneus*.

Conservation Least threatened. Target 29%. Statutorily conserved (17%) in the Cederberg Wilderness Area, with 29% enjoying protection in private reserves such as Sederberg and Koue Bokkeveld. However, in both the north and south distinctive communities are not conserved. Some 15% transformed, mainly for cultivation of rooibos and vineyards. *Pinus radiata* is a serious alien intruder. Erosion very low.

Remarks Cederberg Sandstone Fynbos has been mapped from the watershed eastwards, based on satellite images. The Krakadouwberg-Welbedacht area was very well sampled by Taylor (1996), but other areas are poorly known. The number of endemics is extraordinary high for the size and location of this type. It is possible that they may occur in neighbouring types as well, but currently they appear to be confined to this type. The boundary between this unit and FFs 3 Olifants Sandstone Fynbos can only be very approximate at this stage.

References Kruger (1979), Mustart et al. (1993), Taylor (1996), Boucher (1997c, 1999d), Van Rooyen et al. (1999).

FFs 5 Winterhoek Sandstone Fynbos

VT 69 Macchia (100%) (Acocks 1953). Mesic Mountain Fynbos (89%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (90%) (Low & Rebelo 1996). BHU 51 Groot Winterhoek Mountain Fynbos Complex (59%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Groot Winterhoek Mountains from Dasklip Pass in the north to Saronsberg and

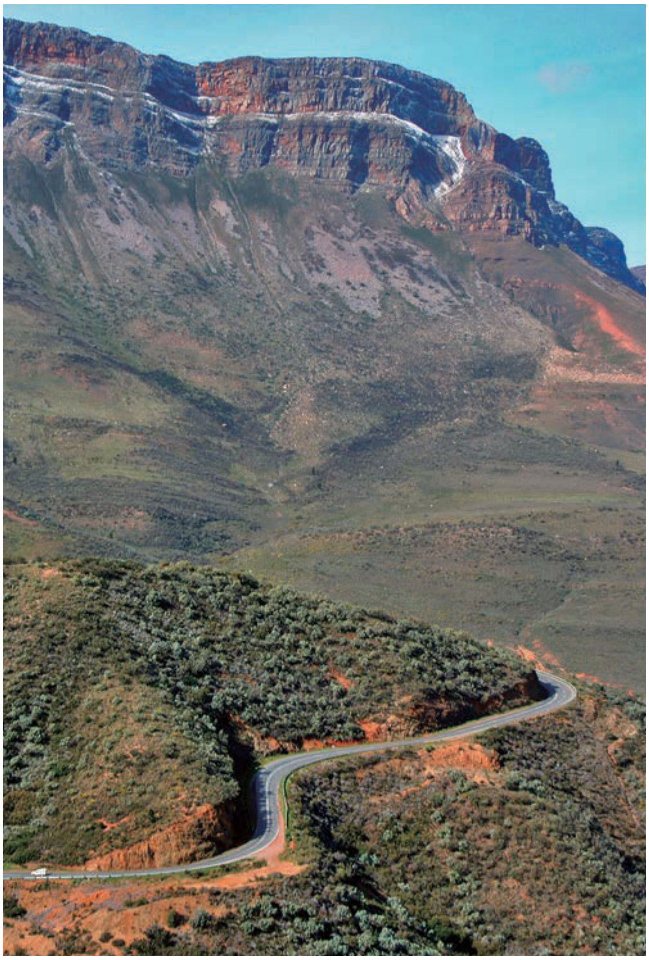

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Figure 4.26 FFs 5 Winterhoek Sandstone Fynbos: Western slopes of the Waboomberg covered with extensive sandstone screes—a view from Gydo Pass north of Ceres (Western Cape). The dominant vegetation below the cliffs is FFh 1 Kouebokkeveld Shale Fynbos with extensive waboomveld (*Protea nitida*-dominated fynbos) in the foreground along the pass.

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Figure 4.27 FFs 5 Winterhoek Sandstone Fynbos: Proteoid fynbos with stands of *Protea punctata* in a matrix of restios on the Skurweberg, north of Ceres (Western Cape).

Nuwekloof Pass, including the Witsenberg and Skurweberge (west of Gydo Pass) (which encircle a large patch of FFh 1 Kouebokkeveld Shale Fynbos in the Agter-Witsenberg) to the vicinity of Ceres and including the Gydo, Waboom, Vaalkloof and Houdenbek Mountains in the east. Altitude 350–1 800 m. (The highest peaks of the Groot Winterhoek Mountains bear vegetation of FFs 30 Western Altimontane Sandstone Fynbos.)

Vegetation & Landscape Features Moderately undulating high plain in the west, with rugged high peaks in the south and southeast, and two linear parallel north-south high mountains in the east, dissected by the Olifants River Valley. The eastern blocks are relatively flat, south- and north-sloping, dissected tablelands. Vegetation is mainly closed restioland in deeper moister sands, with low, sparse shrubs that become denser and restios less dominant in the drier habitats. Proteoid and ericaceous fynbos are found on higher slopes while asteraceous fynbos is more common on lower slopes. Cape thicket is prominent on the lowest slopes.

Geology & Soils Acidic lithosol soils derived from Ordovician sandstones of the Table Mountain Group (Cape Supergroup). Land types mainly Ic, Fa and Ib.

Climate MAP 370–1 350 mm (mean: 790 mm), peaking markedly May to August. Southeasterly cloud occasionally brings heavy mist precipitation at higher altitudes in summer. This is the wettest of the northern Sandstone Fynbos types. Mean daily maximum and minimum temperatures 26.7°C and 3.1°C for February and July, respectively. Frost incidence 10–30 days per year. See also climate diagram for FFs 5 Winterhoek Sandstone Fynbos (Figure 4.21).

Important Taxa ([W]Wetlands) Small Tree: *Protea nitida* (d). Tall Shrubs: *Protea repens* (d), *Aspalathus aemula*, *A. linearis*, *Euryops abrotanifolius*, *E. serra*, *E. speciosissimus*, *E. tenuissimus* subsp. *trifurcatus*, *Leucadendron rubrum*, *Metalasia muraltiifolia*, *Protea laurifolia*. Low Shrubs: *Ursinia pinnata* (d), *Aspalathus argyrella*, *A. commutata*, *A. filicaulis*, *A. perfoliata* subsp. *perfoliata*, *A. perforata*, *A. pinea* subsp. *pinea*, *A. retroflexa* subsp. *angustipetala*, *A. rugosa*, *A. rupestris*, *A. ulicina* subsp. *ulicina*, *A. villosa*, *Erica parilis*, *E. rigidula*, *E. tenuis*, *E. totta*, *Euryops rupestris* var. *dasycarpus*, *Leucadendron arcuatum*, *L. glaberrimum* subsp. *erubescens*, *L. salignum*, *Metalasia rogersii*, *Paranomus lagopus*, *Passerina nivicola*, *Phylica chionocephala*, *P. obtusifolia*, *Protea acaulos*, *P. effusa*, *P. nana*, *P. pendula*, *P. piscina*, *P. pityphylla*, *P. recondita*, *P. witzenbergiana*, *Serruria cygnea*, *S. effusa*, *Sorocephalus lanatus*, *Spatalla caudata*[W], *Ursinia coronopifolia*, *U. punctata*. Pseudocarnivorous Shrub: *Roridula dentata*. Herb: *Ursinia sericea*. Geophytic Herbs: *Geissorhiza bolusii*[W], *G. intermedia*, *G. ovalifolia*, *G. ovata*, *G. parva*, *G. ramosa*, *G. scillaris*, *Romulea saxatilis*. Graminoids: *Cyathocoma ecklonii*[W], *Elegia macrocarpa*.

Endemic Taxa ([W]Wetlands) Low Shrubs: *Agathosma alligans*, *A. cordifolia*, *Aspalathus corniculata*, *A. empetrifolia*, *A. fasciculata*, *A. juniperina* subsp. *gracilifolia*, *A. suaveolens*, *A. sulphurea, Capelio tomentosa*, *Disparago gongylodes*, *Erica amalophylla*, *E. greyi*, *E. irrorata*, *E. leucosiphon*, *Euchaetis ericoides*, *E. esterhuyseniae*, *Euryops longipes* var. *lasiocarpus*, *Lachnaea villosa*, *Leucadendron diemontianum*, *L. gydoense*, *Macrostylis barbigera*, *M. ramulosa*, *Metalasia juniperoides*, *M. serrulata, Pelargonium capillare*, *Phylica alticola*, *P. bolusii*, *P. nervosa*, *P. salteri*, *P. trachyphylla*, *Prismatocarpus implicatus*, *Selago valliscitri*, *Serruria reflexa*, *Sheilanthera pubens*, *Sorocephalus scabridus*, *Spatalla tulbaghensis*, *Stoebe montana*, *Thamnea hirtella*, *Thesmophora scopulosa*, *Wahlenbergia brachyphylla*. Succulent Shrubs: *Lampranthus antonii*, *L. microsepalus*, *Oscularia guthriae*, *Ruschia intermedia*. Herbs: *Centella umbellata*, *Globulariopsis obtusiloba*, *Lotononis laticeps*, *Pseudoselago quadrangularis*, *Steirodiscus gamolepis*, *Trieenea frigida*, *Vellereophyton felinum*, *V. lasianthum*, *Zaluzianskya isanthera*. Geophytic Herbs: *Disa introrsa*, *Geissorhiza esterhuyseniae*, *Romulea albomarginata*, *Tritoniopsis lesliei*[W]. Succulent Herb: *Crassula alcicornis*. Graminoids: *Carpha schlechteri*, *Isolepis minuta*.

Conservation Least threatened. Target 29%. Statutorily conserved (24%) in the Grootwinterhoek Wilderness Area, with an additional 59% protected in private reserves such as Koue Bokkeveld and Winterhoek. Only 5% transformed (cultivation: protea nurseries and fruit orchards). Aliens *Pinus radiata*, *P. pinaster* and *Hakea sericea* are scattered. Erosion very low.

Remarks Groot Winterhoek is a poorly studied region, mainly due to difficulty of access. The fynbos on quartzite of Gydoberg, Waboomsberg and Houdenbeksberg have been included in this type based on the distribution of proteas—these are wetter than normal quartzite and their floras appear to be more similar to Winterhoek Sandstone Fynbos than to FFq 2 Swartruggens Quartzite Fynbos.

References Boucher (1987, 1990, 1996a, 1997c, 2000), Rourke (1993).

FFs 6 Piketberg Sandstone Fynbos

VT 69 Macchia (51%), VT 47 Coastal Macchia (27%), VT 46 Coastal Renosterbosveld (20%) (Acocks 1953). Mesic Mountain Fynbos (84%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (86%) (Low & Rebelo 1996). BHU 50 Piketberg Mountain Fynbos Complex (86%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Mainly on the Piketberg Mountains in a triangle formed by Aurora, Het Kruis and the town of Piketberg but also on isolated hills to the north of the mountain including Driefonteinberg, Tiernesberg, Dassieberg and Klein Tafelberg. The low altitude boundary lies at 100 m, while the highest coincides with the highest peak of the Piketberg (Sebrakop 1 458 m).

Vegetation & Landscape Features Large inselberg built of slowly eroding hard rocks towering over the surrounding sandy and shale plains of the West Coast. Mostly steep slopes, with some small plateaus and peaks. Vegetation is mainly closed restioland on deeper moister sands with low, sparse shrubs that become denser and the restios less pronounced in the drier habitats. Asteraceous and proteoid fynbos predominate in rocky areas, and Cape thicket is prominent as well.

Geology & Soils Acidic lithosol soils derived from Ordovician sandstones of the Table Mountain Group (Cape Supergroup). Land type mainly Ib.

Climate MAP 320–860 mm (mean: 510 mm), peaking May to August. Mean daily maximum and minimum temperatures 28.1°C and 5.6°C for February and July, respectively. Frost incidence 2–4 days per year. See also climate diagram for FFs 6 Piketberg Sandstone Fynbos (Figure 4.21).

Important Taxa ([T]Cape thickets, [W]Wetlands) Small Trees: *Heeria argentea*[T] (d), *Kiggelaria africana*[T] (d), *Podocarpus elongatus*[T] (d), *Aspalathus pendula*, *Brabejum stellatifolium*[T], *Metrosideros angustifolia*[T], *Protea nitida*. Tall Shrubs: *Cassine schinoides*[T] (d), *Halleria lucida*[T] (d), *Leucadendron rubrum* (d), *Metalasia densa* (d), *Olea europaea* subsp. *africana*[T] (d), *Protea laurifolia* (d), *P. repens* (d), *Cunonia capensis*[T], *Euryops speciosissimus*, *Maytenus acuminata*[T], *Rhus angustifolia*[T]. Low Shrubs: *Asparagus rubicundus* (d), *Cliffortia ruscifolia* (d), *Elytropappus gnaphaloides* (d), *E. rhinocerotis* (d), *Erica nudiflora* (d), *Eriocephalus africanus* var. *africanus* (d), *Leucospermum calligerum* (d), *Maytenus oleoides*[T] (d), *Passerina truncata* subsp. *truncata* (d), *Phylica villosa* (d), *Serruria aitonii* (d), *Stoebe plumosa* (d), *Aspalathus acidota*, *A. altissima*, *A. bracteata*, *A. perfoliata* subsp. *phillipsii*, *Diosma hirsuta*, *Elytropappus glandulosus*, *Erica parilis*, *E. phillipsii*, *Leucadendron glaberrimum* subsp. *erubescens*, *L. loranthifolium*, *L. salignum*, *Metalasia fastigiata*, *Oedera squarrosa*, *Phylica cylindrica*, *Protea acaulos*, *P. piscina*, *P. recondita*, *Rhus rosmarinifolia*[T], *Sorocephalus capitatus*, *Trichocephalus stipularis*, *Ursinia rigidula*. Succulent Shrub: *Aloe glauca*. Woody Climber: *Asparagus retrofractus*. Herb: *Syncarpha canescens*. Geophytic Herbs: *Adiantum capillus-veneris*[W], *Blechnum capense*, *Osmunda regalis*[W], *Othonna lingua*. Succulent Herbs: *Stapelia cedrimontana, S. paniculata*. Graminoids: *Elegia macrocarpa* (d), *Ischyrolepis gaudichaudiana* (d), *I. sieberi* (d), *Calopsis paniculata*, *Elegia capensis*[W], *Ischyrolepis capensis*, *Staberoha distachyos*, *Tetraria ustulata*, *Willdenowia arescens*, *W. incurvata*.

Endemic Taxa Tall Shrub: *Psoralea peratica*. Low Shrubs: *Acmadenia macradenia*, *Agathosma capitata*, *Aspalathus chrysantha*, *A. complicata*, *A. glossoides*, *A. latifolia*, *Erica piquetbergensis*, *Euchaetis tricarpellata*, *Euryops pectinatus* subsp. *lobulatus*, *Hermannia cordifolia*, *H. hispidula*, *Leucadendron discolor*, *Leucospermum profugum*, *Manulea ovatifolia*, *Muraltia arachnoidea*, *Phylica piquetbergensis*, *Rafnia inaequalis*. Succulent Shrubs: *Erepsia pillansii*, *Lampranthus acrosepalus*, *L. falciformis*, *L. martleyi*, *L. matutinus*, *L. profundus*, *L. subtruncatus*, *Oscularia piquetbergensis*, *O. prasina*, *O. primiverna*, *Ruschia strubeniae*. Herbs: *Corymbium theileri*, *Globulariopsis pumila*, *Lotononis densa* subsp. *congesta*, *Nemesia acornis*. Geophytic Herbs: *Aristea fimbriata*, *Bobartia orientalis* subsp. *occidentalis*, *Geissorhiza brevituba*, *Gladiolus insolens*, *Ixia splendida*, *Tritonia lancea*.

Conservation Least threatened. Target 29%. None conserved in statutory conservation areas and only 4% protected in private nature reserves. Some 17% transformed (cultivation: fruit orchards on deeper soils). *Acacia saligna* scattered over large area. The most transformed 'mountain fynbos' unit in the biome. Erosion very low.

Remarks The lower slopes have affinities with FFs 2 Graafwater Sandstone Fynbos, but the high altitude communities share species with FFs 5 Winterhoek Sandstone Fynbos. The unit is rich in endemic species.

References Linder (1976), Moss & Mettlerkamp (1979).

FFs 7 North Hex Sandstone Fynbos

VT 69 Macchia (69%), VT 46 Coastal Renosterbosveld (24%) (Acocks 1953). Mesic Mountain Fynbos (82%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (81%) (Low & Rebelo 1996). BHU 52 Matroosberg Mountain Fynbos Complex (81%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Northern slopes of the Hex River Mountains from Mitchell's Pass near Ceres to Sonklip Ridge extending along the northern slope of the lower-altitude Witberg Ridge to Grootstraat west of Touws River. Altitude 500–1 800 m. (The highest ridges and peaks of the mountains support FFs 30 Western Altimontane Sandstone Fynbos.)

Vegetation & Landscape Features North-facing steep and gentle slopes from foothills to high mountain peaks. The dominant restiolands often have a proteoid overstorey. Asteraceous fynbos found on lower slopes.

Geology & Soils Acidic lithosol soils derived from Ordovician sandstones of the Table Mountain Group (Cape Supergroup). Land types mainly Ib and Ic.

Climate MAP 300–1 800 mm (mean: 750 mm), peaking markedly May to August. Snow regular in winter on higher slopes and may last for a week or more. Mean daily maximum and

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Figure 4.28 FFs 7 North Hex Sandstone Fynbos: Restioid fynbos on sandstone slopes under a fresh June snow cover in the Spekrivierkloof Valley, Matroosberg Private Reserve, Hex River Mountains (Western Cape).

minimum temperatures 26.0°C and 2.5°C for February and July, respectively. Frost incidence 10–50 days per year. See also climate diagram for FFs 7 North Hex Sandstone Fynbos (Figure 4.21).

Important Taxa Tall Shrubs: *Protea laurifolia* (d), *P. repens* (d), *Leucadendron rubrum*, *Metalasia muraltiifolia*, *Protea magnifica*. Low Shrubs: *Stoebe plumosa* (d), *Aspalathus crenata*, *A. rugosa*, *A. rupestris*, *Athanasia elsiae*, *Dolichothrix ericoides*, *Euryops othonnoides*, *Leucadendron arcuatum*, *L. salignum*, *Metalasia phillipsii* subsp. *incurva*, *M. rogersii*, *Paranomus candicans*, *Phylica chionocephala*, *Prismatocarpus brevilobus*, *Protea amplexicaulis*, *P. effusa*, *P. pityphylla*, *P. witzenbergiana*, *Ursinia pinnata, Zyrphelis pilosella*. Herbs: *Edmondia fasciculata*, *Ursinia sericea*. Geophytic Herb: *Ornithogalum esterhuyseniae*. Graminoids: *Askidiosperma capitatum*, *Calopsis marlothii*, *Elegia filacea*, *Ficinia gydomontana*, *Ischyrolepis laniger*, *Pentaschistis ampla*, *P. colorata*, *P. rosea* subsp. *purpurascens*.

Figure 4.29 FFs 8 South Hex Sandstone Fynbos: Restioid fynbos on ridge below Waaihoek Mountain in the Hex River Mountains (Western Cape).

Endemic Taxa Low Shrubs: *Erica atrovinosa*, *E. cereris*, *Lachnaea funicaulis*.

Conservation Least threatened. Target 29%. Statutorily conserved (34%) in the Ben Etive, Bokkeriviere and Ceres Mountain Fynbos Nature Reserves, with an additional 46% conserved in the Matroosberg Private Nature Reserve. Only 6% transformed (cultivation), mostly along the low-altitude edge of the unit. *Pinus radiata* is an occasional alien. Erosion is very low.

Remarks The Hex River Mountains are still botanically poorly researched: our knowledge of vegetation patterns is insufficient as most of the area is very difficult to access. The largest blocks of FFs 30 Western Altimontane Sandstone Fynbos are embedded within this unit.

Reference L. Mucina & E. Pienaar (unpublished data).

FFs 8 South Hex Sandstone Fynbos

VT 69 Macchia (96%) (Acocks 1953). Mesic Mountain Fynbos (98%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (97%) (Low & Rebelo 1996). BHU 52 Matroosberg Mountain Fynbos Complex (91%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Southern slopes of the Hex River Mountains from Mosterthoek Twins southeast of Wolseley to Kleinstraat west of Touws River. Altitude 400–1 800 m. (The highest ridges and peaks of the mountains support FFs 30 Western Altimontane Sandstone Fynbos.)

Vegetation & Landscape Features Rugged mountainous terrain with steep, high cliffs and steep slopes facing south and deeply dissected down to valley floors, creating some of the most dramatic relief in the country, for example at Baboon Peak. Vegetation is restioid shrubland with proteoid overstorey. Structurally it is mainly proteoid and restioid fynbos, also with some asteraceous fynbos. Ericaceous fynbos becomes prominent at higher altitudes.

Geology & Soils Acidic lithosol soils derived from Ordovician sandstones of the Table Mountain Group (Cape Supergroup). Land types mainly Ic.

Climate MAP 300–2 300 mm (mean: 955 mm), peaking markedly May to August. Snow regular in winter. Southeasterly cloud may bring heavy mist precipitation at higher altitudes in summer. This is the third wettest type of the Cape vegetation. Mean daily maximum and minimum monthly temperatures 26.0°C and 2.7°C for February and July, respectively. Frost incidence 10–30 days per year. See also climate diagram for FFs 8 South Hex Sandstone Fynbos (Figure 4.21).

Important Taxa ([T]Cape thickets) Small Trees: *Brabejum stellatifolium*[T], *Protea nitida*. Tall Shrubs: *Dodonaea viscosa* var. *angustifolia* (d), *Protea laurifolia* (d), *Leucadendron rubrum*, *Protea repens*. Low Shrubs: *Cliffortia ruscifolia* (d), *Oedera sedifolia* (d), *Stoebe cinerea* (d), *Amphithalea spinosa*, *Aspalathus bracteata*, *A. nigra*, *A. pachyloba* subsp. *villicaulis*, *A. radiata* subsp. *radiata*, *A. rugosa*, *Erica cymosa* subsp. *grandiflora*, *Leucadendron salignum*, *L. tinctum*, *Protea effusa*, *Serruria dodii*. Herb: *Ursinia sericea*. Geophytic Herbs: *Geissorhiza rupicola*, *G. scopulosa*. Graminoid: *Elegia stokoei*.

Endemic Taxa Tall Shrub: *Xiphotheca cordifolia*. Low Shrubs: *Agathosma concava*, *Anaxeton angustifolium*, *Aspalathus pachyloba* subsp. *rugulicarpa*, *A. pilantha*, *Athanasia alba*, *Disparago barbata*, *Erica coacervata*, *E. erasmia*, *E. hexensis*, *E. navigatoris*, *E. rimarum*, *E. salicina*, *E. tarantulae*, *Heliophila filicaulis*, *Leucospermum tottum* var. *glabrum, Muraltia serrata*, *Phylica chionophila*, *P. reversa*, *P. subulifolia*, *Phyllosma barosmoides*, *Prismatocarpus tenellus*, *Selago michelliae*, *Thamnea thesioides*, *Ursinia merxmuelleri*. Succulent Shrubs: *Delosperma burtoniae*, *Esterhuysenia inclaudens*, *Lampranthus brevistamineus*. Semiparasitic Shrubs: *Thesium annulatum*, *T. microcephalum*. Herbs: *Chamarea esterhuyseniae*, *Pseudoselago prolixa*. Geophytic Herb: *Moraea nubigena*. Graminoid: *Ischyrolepis fuscidula*.

Conservation Least threatened. Target 29%. Statutorily conserved (16%) in the Fonteintjiesberg Nature Reserve, with an additional about 10% in Matroosberg Private Nature Reserve. Only very small portion transformed and alien woody plants are rare (*Pinus radiata*). Erosion very low.

Remarks This vegetation unit has the largest area of Western Altimontane Sandstone Fynbos (FFs 30) embedded in it. Altitudinal zonation is clearly evident here, as in a number of other 'mountain fynbos' units but remains undocumented. For example, *Protea punctata* stands out as a typical tall shrub near the upper limits of this unit (i.e. immediately below FFs 30 Western Altimontane Sandstone Fynbos).

Reference Chesselet (1985).

FFs 9 Peninsula Sandstone Fynbos

VT 69 Macchia (90%) (Acocks 1953). Mesic Mountain Fynbos (91%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (93%) (Low & Rebelo 1996). BHU 55 Cape Peninsula Mountain Fynbos Complex (100%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Confined to the Cape Peninsula, from the top of Lion's Head and Table Mountain (Cape Town) to Cape Point and Cape of Good Hope and including Constantiaberg and Swartkopsberge. Altitude range 20–1 086 m at Maclear's Beacon on Table Mountain.

Vegetation & Landscape Features Gentle to steep slopes, with cliffs in the north, over a 50 km long peninsula. Vegetation is a medium dense, tall proteoid shrubland over a dense moderately tall, ericoid-leaved shrubland—mainly proteoid, ericaceous and restioid fynbos, with some asteraceous fynbos.

Geology & Soils Acidic lithosol soils derived from Ordovician sandstones of the Table Mountain Group (Cape Supergroup), Lamotte forms prominent. Land types mainly Ib, Ga and Ic.

Climate MAP 520–1 690 mm (mean: 780 mm), peaking May to August. Mean daily maximum and minimum temperatures 25.0°C and 7.2°C for February and July, respectively. Frost incidence 2 or 3 days per year. Southeasterly cloud (the famous 'Table Cloth'), accompanied by high wind, brings heavy mist precipitation at higher altitudes to southern and eastern slopes in summer. The region is under strong maritime influence—no part is more than 7 km from the sea. See also climate diagram for FFs 9 Peninsula Sandstone Fynbos (Figure 4.21).

Important Taxa ([W]Wetlands) Small Tree: *Leucospermum conocarpodendron* subsp. *viridum*. Tall Shrubs: *Metalasia densa* (d), *Phylica buxifolia* (d), *Protea lepidocarpodendron* (d), *Psoralea aphylla* (d), *Aspalathus linearis*, *Erica tristis*, *Euryops abrotanifolius*. Low Shrubs: *Anthospermum galioides* subsp. *galioides* (d), *Berzelia lanuginosa*[W] (d), *Cliffortia drepanoides* (d), *C. ruscifolia* (d), *C. subsetacea* (d), *Cryptadenia grandiflora* (d), *Elytropappus gnaphaloides* (d), *Erica axillaris* (d), *E. ericoides* (d), *E. hispidula* (d), *E. imbricata* (d), *E. labialis* (d), *E. muscosa* (d), *Felicia fruticosa* subsp. *fruticosa* (d), *Helichrysum cymosum* (d), *Leucadendron laureolum* (d), *L. xanthoconus* (d), *Otholobium hirtum* (d), *Penaea mucronata* (d), *Roella ciliata* (d), *Saltera sarcocolla* (d), *Stoebe cinerea* (d), *S. fusca* (d), *Syncarpha speciosissima* (d), *S. vestita* (d), *Anthospermum aethiopicum*, *Aspalathus argyrella*, *A. aspalathoides*, *A. callosa*, *A. commutata*, *A. cordata*, *A. crenata*, *A. filicaulis*, *A. macrantha*, *A. psoraleoides*, *A. quinquefolia* subsp. *compacta*, *A. retroflexa* subsp. *retroflexa*, *A. tridentata* subsp. *tridentata*, *Capelio tabularis*, *Clutia polygonoides*, *Cullumia ciliaris*, *Erica benthamiana*, *E. corifolia*, *E. exleeana*, *E. hirtiflora*, *E. lutea*, *E. multumbellifera*, *E. parviflora*[W], *E. plukenetii* subsp. *plukenetii*, *E. pulchella*, *E. sessiliflora*, *E. similis*, *E. viscaria* subsp. *viscaria*, *Euryops pectinatus* subsp. *pectinatus*, *Helichrysum pandurifolium*, *Metalasia brevifolia*, *Muraltia pageae*, *Osmitopsis asteriscoides*[W], *Otholobium fruticans*, *Passerina truncata* subsp. *monticola*, *Pelargonium cucullatum*, *Phylica imberbis*, *Protea cynaroides*, *Struthiola ciliata* subsp. *angustifolia*, *Stylapterus fruticulosus*, *Ursinia paleacea*, *Witsenia maura*[W], *Zyrphelis foliosa*, *Z. taxifolia*. Semiparasitic Shrub: *Thesium virgatum* (d). Herbs: *Corymbium africanum*, *Indigofera psoraloides*, *Ursinia nudicaulis*. Geophytic Herbs: *Aristea bakeri*, *Geissorhiza aspera*, *G. bolusii*[W], *G. hispidula*, *G. imbricata* subsp. *imbricata*[W], *G. juncea*, *G. ovata*, *G. similis*, *G. tenella*, *G. umbrosa*, *Trachyandra hirsutiflora*. Graminoids: *Anthochortus crinalis* (d), *Ehrharta ramosa* subsp. *aphylla* (d), *Elegia ebracteata* (d), *E. hookeriana* (d), *E. mucronata* (d), *E. neesii* (d), *E. racemosa* (d), *E. stipularis* (d), *E. thyrsifera* (d), *E. vaginulata* (d), *Ficinia acuminata* (d), *F. bulbosa* (d), *F. nigrescens* (d), *F. oligantha* (d), *F. trichodes* (d), *Hypodiscus aristatus* (d), *Ischyrolepis cincinnata* (d), *I. gaudichaudiana* (d), *Pentameris macrocalycina* (d), *Platycaulos compressus* (d), *Pseudopentameris macrantha* (d), *Restio bifidus* (d), *R. perplexus* (d), *Staberoha distachyos* (d), *S. vaginata* (d), *Tetraria flexuosa* (d), *T. involucrata* (d), *Thamnochortus fruticosus* (d), *T. lucens* (d), *T. obtusus* (d), *Ehrharta villosa* var. *villosa*, *Ischyrolepis capensis*, *Pentaschistis colorata*, *Restio dodii*[W], *Tetraria cuspidata*, *T. ligulata*, *T. microstachys*.

Endemic Taxa ([W]Wetlands) Small Tree: *Mimetes fimbriifolius*. Tall Shrubs: *Erica caterviflora*, *Leucadendron macowanii*, *L. strobilinum*, *Liparia laevigata*. Low Shrubs: *Diastella divaricata* subsp. *divaricata* (d), *Agathosma lanceolata*, *A. pulchella*, *Anaxeton arborescens*, *Aspalathus barbata*, *A. borboniifolia*, *A. capensis*, *A. capitata*, *A. chenopoda* subsp. *chenopoda*, *A. incurva*, *Brachysiphon fucatus*, *Cliffortia discolor*, *Cyclopia galioides*, *C. latifolia*, *Erica abietina* subsp. *abietina*, *E. abietina* subsp. *atrorosea*, *E. abietina* subsp. *constantiana*, *E. abietina* subsp. *diabolis*, *E. amoena*[W], *E. annectens*, *E. capensis*[W], *E. clavisepala*[W], *E. cyrilliflora*[W], *E. depressa*, *E. diosmifolia*, *E. eburnea*, *E. empetrina*, *E. fairii*, *E. fontana*[W], *E. haematocodon*, *E. halicacaba*, *E. heleogena*[W], *E. limosa*[W], *E. marifolia*, *E. mollis*[W], *E. nevillei*, *E. oxycoccifolia*, *E. paludicola*[W], *E. physodes*, *E. pilulifera*[W], *E. planifolia*, *E. pyxidiflora*, *E. quadrisulcata*, *E. salteri*[W], *E. sociorum*, *E. subcapitata*, *E. urna-viridis*, *Indigofera candolleana*, *I. filiformis*, *I. mauritanica*, *Lebeckia macowanii*, *Liparia parva*, *Metalasia compacta*, *M. divergens* subsp. *divergens*, *M. divergens* subsp. *fusca*, *Microdon nitidus*, *Morella diversifolia*, *Muraltia acipetala*, *M. brachypetala*,

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Figure 4.30 FFs 9 Peninsula Sandstone Fynbos: Proteoid fynbos with prominent ericaceous and restioid elements at Cape Point in the Table Mountain National Park (Western Cape). The broad recurved leaves belong to *Tetraria thermalis* (Cyperaceae).

M. comptonii, *M. curvipetala*, *M. demissa*, *M. diabolica*, *M. mixta*, *M. orbicularis*, *Osmitopsis dentata*, *Phylica schlechteri*, *Prismatocarpus nitidus*, *Roella amplexicaulis*, *R. decurrens*, *R. goodiana*, *R. recurvata*, *R. squarrosa*, *R. triflora*, *Serruria collina*, *S. cyanoides*, *S. decumbens*, *S. hirsuta*, *S. villosa*, *Staavia dodii*, *S. glutinosa*, *Stoebe rosea*, *Wahlenbergia pyrophila*[W]. Succulent Shrubs: *Aloe commixta*, *Erepsia forficata*, *Lampranthus austricola*, *L. incurvus*, *L. multiradiatus*, *L. promontorii*, *L. roseus*, *L. tenuis*. Semiparasitic Shrub: *Thesium pseudovirgatum*. Herbs: *Gerbera wrightii*, *Helichrysum fruticans*, *H. grandiflorum*, *Heliophila promontorii*, *H. tabularis*, *Lobelia eckloniana*[W], *Nemesia micrantha*, *Pseudoselago peninsulae*, *Scabiosa africana*, *Senecio verbascifolius*, *Ursinia tenuifolia* subsp. *tenuifolia*, *Villarsia goldblattiana*[W]. Geophytic Herbs: *Bobartia gladiata* subsp. *major*[W], *Disa nubigena*, *Geissorhiza bonaspei*, *G. tabularis*[W], *Gethyllis kaapensis*, *Gladiolus aureus*[W], *G. bonaspei*, *G. monticola*, *G. vigilans*, *Lachenalia capensis*, *Pterygodium connivens*, *Watsonia tabularis*[W], *Wurmbea hiemalis*. Carnivorous Herb: *Drosera cuneifolia*[W]. Graminoids: *Thamnochortus nutans* (d), *Anthochortus capensis*, *Calopsis gracilis*, *Elegia intermedia*[W], *Eleocharis lepta*[W], *Ficinia anceps*, *F. fastigiata*, *F. micrantha*, *Isolepis bulbifera*, *I. pusilla*, *Restio communis*, *Tetraria graminifolia*, *T. paludosa*, *Thamnochortus levynsiae*.

Conservation Least threatened. Target 30%. Statutorily well conserved (90%) in the Table Mountain National Park. About 75% transformed (urban sprawl, pine plantations). *Acacia melanoxylon* and *Pinus pinaster* are occasional woody aliens. Many local patches of alien vegetation are very dense. Erosion very low.

Remarks This unit is, not surprisingly, the best explored and described vegetation type in the biome due to its locality in the Cape Town metropolitan area and near the University of Cape Town as a major research institution. A finer-scale mapping of the structural-floristic types can be found in Taylor (1984b) and Simmons (1996).

References Adamson (1927), Adamson & Salter (1950), Taylor (1969, 1981, 1983, 1984a, b), Cowling (1976), McKenzie (1976), McKenzie et al. (1977), Glyphis et al. (1978), Laidler et al. (1978), Kathan (1981), Jeffery & Wilson (1987), Barnes (1992), Greenfield (1992), Irwing (1992), Kirkwood (1992), Rule (1992), Simmons (1992, 1996), Cowling et al. (1996b), Privett (1998), Boucher (1999a).

FFs 10 Hawequas Sandstone Fynbos

VT 69 Macchia (95%) (Acocks 1953). Mesic Mountain Fynbos (94%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (94%) (Low & Rebelo 1996). BHU 53 Hawequas Mountain Fynbos Complex (92%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Between the Nuwekloof Pass near Gouda in the north to Franschhoek Pass near Franschhoek including the Elandskloof, Hawequas, Slanghoek, Klein-Drakenstein, Wemmershoek, Du Toitskloof and Stettyns Mountains. Altitude 250–1 800 m. Patches of FFs 30 Western Altimontane Sandstone Fynbos on some of the few peaks above 1 800 m.

Vegetation & Landscape Features Mountains with slopes of various steepness, flanks of intermontane valleys and upland plateaus. A band of Cedarberg Shale Formation forms a prominent step at high altitude. Vegetation a low closed shrubland dotted with emergent tall shrubs—mainly proteoid, restioid and asteraceous fynbos with much waboomveld at lower altitudes, ericaceous fynbos at higher altitudes and abundant Cape thickets (especially in the north of the unit) on cliffs and very steep rocky (scree) slopes.

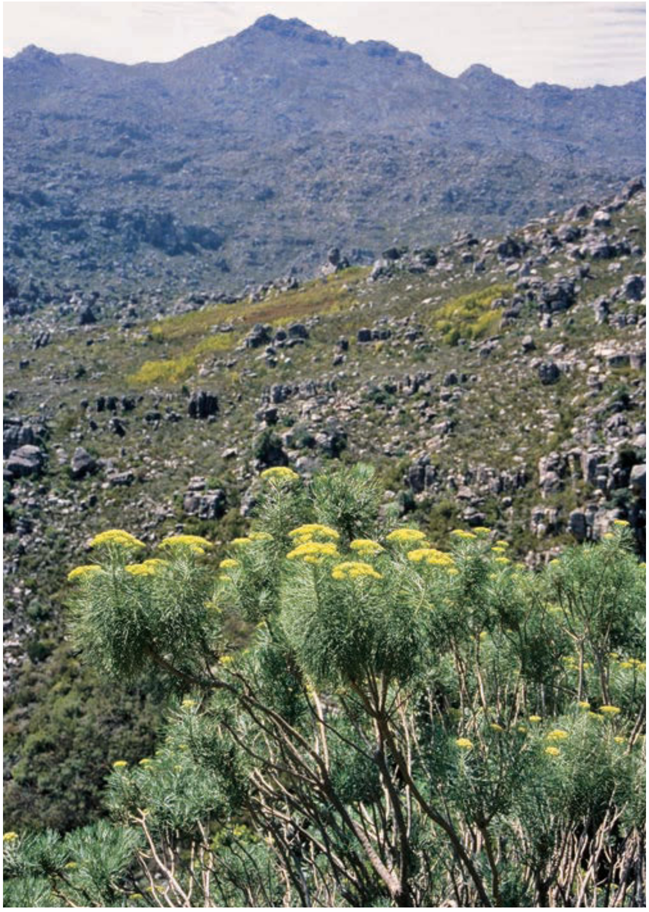
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Figure 4.31 FFs 10 Hawequas Sandstone Fynbos: *Hymenolepis parviflora* (Asteraceae) on the rocky slopes of the Bain's Kloof near Wellington (Western Cape) covered by dense fynbos shrublands with seeps (green-yellow patches in the background) dominated by *Leucadendron salicifolium*.

Geology & Soils Acidic lithosol soils derived from Ordovician sandstones of the Table Mountain Group (Cape Supergroup). Land types mainly Ic and Ib.

Climate MAP 530–2 140 mm (mean: 1 200 mm), peaking markedly May to August. Mean daily maximum and minimum temperatures 25.4°C and 4.4°C for February and July, respectively. Frost incidence 3–20 days per year. Southeasterly cloud brings heavy mist precipitation to southern and eastern slopes at higher altitudes in summer. See also climate diagram for FFs 10 Hawequas Sandstone Fynbos (Figure 4.21).

Important Taxa ([T]Cape thickets, [W]Wetlands) Small Trees: *Brabejum stellatifolium*[T] (d), *Heeria argentea*[T] (d), *Metrosideros angustifolia*[T] (d), *Protea nitida* (d), *Widdringtonia nodiflora* (d). Succulent Tree: *Aloe plicatilis*. Tall Shrubs: *Cassine schinoides*[T] (d), *Leucadendron salicifolium* (d), *Maytenus acuminata*[T] (d), *Metalasia densa* (d), *Morella serrata* (d), *Myrsine africana*[T] (d), *Olea europaea* subsp. *africana*[T] (d), *Protea laurifolia* (d), *P. repens* (d), *Psoralea pinnata*[W] (d), *Aspalathus linearis*, *Diospyros glabra*[T], *Euryops abrotanifolius*, *Liparia rafnioides*, *Metalasia muraltiifolia*, *Rhus lucida*[T], *R. tomentosa*[T], *R. undulata*[T]. Low Shrubs: *Berzelia lanuginosa*[W] (d), *Brunia nodiflora* (d), *Cliffortia dregeana*[W] (d), *C. graminea* (d), *C. ruscifolia* (d), *Erica hispidula* (d), *E. nudiflora* (d), *E. plukenetii* subsp. *plukenetii* (d), *E. totta* (d), *Leucadendron salignum* (d), *Maytenus oleoides*[T] (d), *Osmitopsis asteriscoides*[W] (d), *Penaea mucronata* (d), *Stoebe cinerea* (d), *S. plumosa* (d), *Anthospermum aethiopicum*, *A. prostratum*, *Aspalathus attenuata*, *A. bracteata*, *A. ciliaris*, *A. commutata*, *A. cordata*, *A. crenata*, *A. cytisoides*, *A. divaricata* subsp. *gra-*

cilior, *A. filicaulis*, *A. lanceifolia*, *A. pachyloba* subsp. *pachyloba*, *A. perfoliata* subsp. *perfoliata*, *A. perforata*, *A. pinea* subsp. *caudata*, *A. quinquefolia* subsp. *compacta*, *A. radiata* subsp. *radiata*, *A. rugosa*, *A. ulicina* subsp. *ulicina*, *Clutia alaternoides*, *Diosma hirsuta*, *Elytropappus glandulosus*, *Erica benthamiana*, *E. daphniflora*, *E. parilis*, *E. phillipsii*, *E. rigidula*, *E. ventricosa*, *Euryops pectinatus* subsp. *pectinatus*, *E. rupestris* var. *dasycarpus*, *E. rupestris* var. *rupestris*, *Gnidia anomala*, *G. oppositifolia*, *Leucadendron spissifolium* subsp. *spissifolium*, *Leucospermum tottum*, *Linconia cuspidata*, *Lobelia coronopifolia*, *Metalasia cephalotes*, *M. dregeana*, *M. fastigiata*, *M. rhoderoides*, *Paranomus capitatus*, *Passerina truncata* subsp. *monticola*, *Pelargonium cucullatum*, *P. tabulare*, *Printzia aromatica*, *Protea acaulos*, *P. effusa*, *P. nana*, *Psoralea lucida*, *Rhus scytophylla*[T], *Stoebe incana*, *Thamnea uniflora*, *Ursinia filipes*[W], *U. paleacea*, *U. pinnata*, *U. punctata*. Succulent Shrubs: *Oscularia deltoides* (d), *Crassula coccinea*. Woody Climber: *Secamone alpini*[T] (d). Herbs: *Knowltonia capensis*[T] (d), *Corymbium scabrum*, *Dianthus bolusii*, *Grammatotheca bergiana*[W], *Ursinia oreogena*. Geophytic Herbs: *Lanaria lanata* (d), *Mohria caffrorum* (d), *Aristea africana*, *A. capitata*, *Geissorhiza alticola*, *G. aspera*, *G. bolusii*[W], *G. confusa*, *G. grandiflora*, *G. ovalifolia*, *G. ovata*, *G. pseudinaequalis*, *G. ramosa*, *G. scillaris*, *Romulea flexuosa*. Graminoids: *Anthochortus graminifolius* (d), *Askidiosperma paniculatum* (d), *Cannomois parviflora* (d), *Chrysitrix capensis* (d), *Cymbopogon marginatus* (d), *Ehrharta dura* (d), *E. ramosa* subsp. *aphylla* (d), *Elegia capensis*[W] (d), *E. neesii* (d), *E. thyrsifera* (d), *E. vaginulata* (d), *Hypodiscus argenteus* (d), *H. aristatus* (d), *Ischyrolepis curviramis* (d), *I. gaudichaudiana* (d), *Neesenbeckia punctoria* (d), *Pentaschistis eriostoma* (d), *Restio pedicellatus* (d), *R. perplexus* (d), *Staberoha cernua* (d), *Tetraria crinifolia* (d), *T. cuspidata* (d), *T. fasciata* (d), *T. ustulata* (d), *Cannomois virgata*, *Elegia asperiflora*, *Ficinia distans*, *F. oligantha*, *Ischyrolepis capensis*, *I. sieberi*, *Merxmuellera rufa*, *Pentaschistis curvifolia*, *Restio filiformis*, *Tetraria involucrata*, *Thamnochortus fruticosus*, *Willdenowia sulcata*.

Endemic Taxa ([W]Wetlands) Low Shrubs: *Acmadenia faucitincta*, *Agathosma decurrens*, *A. lancifolia*, *A. rudolphii*, *Amphithalea bodkinii*[W], *A. concava*, *Aspalathus caespitosa*, *A. erythrodes*, *A. linearifolia*, *A. radiata* subsp. *pseudosericea*, *A. secunda* (limited to Riebeek-Kasteel Mt), *A. truncata*, *Cliffortia lanata*, *C. pilifera*, *C. rigida*, *C. strigosa*, *C. subdura*, *Cyclopia squamosa*, *Diastella myrtifolia*, *Erica blandfordia*, *E. chionophila*[W], *E. chrysocodon*[W], *E. cremea*[W], *E. cylindrica*, *E. cymosa* subsp. *cymosa*, *E. feminarum*[W], *E. hibbertii*, *E. intricata*[W], *E. limnophila*[W], *E. praecox*, *E. purgatoriensis*[W], *E. rehmii*[W], *E. schumannii*, *E. walkeria*, *E. wittebergensis*, *Euryops decipiens*, *Euthystachys abbreviata*, *Gnidia insignis*, *Hydroidea elsiae*, *Lachnaea pusilla*, *Metalasia montana*, *Muraltia alba*, *Nivenia corymbosa*, *Osmitopsis tenuis*, *Phylica ampliata*, *P. comosa*, *P. nodosa*, *Polyarrhena prostrata*, *Psoralea oreophila*, *Rafnia capensis* subsp. *elsieae*, *Salvia thermaruma*, *Serruria rosea*, *S. triternata*, *Sorocephalus teretifolius*, *Spatalla salsoloides*, *Stylapterus ericoides* subsp. *ericoides*, *S. ericoides* subsp. *pallidus*, *S. sulcatus*, *Ursinia abrotanifolia*, *Zyrphelis decumbens*, *Z. montana*. Succulent Shrubs: *Erepsia insignis*, *Lampranthus acutifolius*, *L. capillaceus*, *L. villiersii*. Semiparasitic Shrub: *Thesium diversifolium*. Herbs: *Arctotis macrosperma*, *A. rotundifolia*, *Centella restioides*, *Nemesia picta*. Geophytic Herbs: *Gladiolus phoenix*, *G. rhodanthus*, *Ixia metelerkampiae*, *Oxalis pseudo-hirta*, *Pelargonium nummulifolium*, *Spetaea lachenaliiflora*[W], *Thereianthus ixioides*, *Tritoniopsis pulchella*. Carnivorous Herb: *Drosera regia*[W]. Graminoids: *Ischyrolepis coactilis*, *Restio alticola*, *R. inveteratus*, *R. montanus*, *R. singularis*.

Conservation Least threatened. Target 30%. More than half statutorily conserved in the Limietberg, Theewaters and Waterval Nature Reserves, with an additional 36% protected in the Hawequas Mountain Catchment Area. Only 4% transformed (pine plantations, cultivation). Local occurrences of alien *Hakea sericea* and *Pinus pinaster* are of concern. Erosion very low.

Remarks Like the neighbouring (to the south) FFs 11 Kogelberg Sandstone Fynbos, this unit has high specific endemism. Endemic genera include *Spetaea* (Hyacinthaceae) and *Hydroidea* (Asteraceae). *Empleuridium* and *Euthystachys* are Cape endemic genera shared only with FFs 11 Kogelberg Sandstone Fynbos.

References Kruger (1974, 1979), Parkman (1978), Van Wilgen & Kruger (1981, 1985), Boucher (1988b, 1994a, 1996b), L. Mucina (unpublished data).

FFs 11 Kogelberg Sandstone Fynbos

VT 69 Macchia (98%) (Acocks 1953). Mesic Mountain Fynbos (81%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (93%) (Low & Rebelo 1996). BHU 56 Kogelberg Mountain Fynbos Complex (63%), BHU 54 Franschhoek Mountain Fynbos Complex (32%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: From Franschhoek, Groot-Drakensteinberge and Simonsberg (near Stellenbosch) in the north passing southwards between Gordon's Bay and Bot River to Cape Hangklip and Kleinmond in the south including the Jonkershoek, Stellenbosch, Franschhoek, Groenland, Hottentots Holland, Kogelberg and Palmietberge Mountains. Altitude 20–1 590 m at summit of Somerset Sneeukop.

Vegetation & Landscape Features High mountains with steep to gentle slopes, and undulating plains and hills of varied aspect. General appearance of vegetation low, closed shrub-

Figure 4.32 FFs 11 Kogelberg Sandstone Fynbos: Proteoid fynbos (with local endemic *Leucospermum bolusii*) on sandstone colluvium on a sea-facing slope of the Kogelberg massif (near Steenbras River mouth in False Bay, Western Cape).

land with scattered emergent tall shrubs. Proteoid, ericaceous and restioid fynbos dominate, while asteraceous fynbos is rare. Patches of Cape thicket are common in the northern areas; in the south similar habitats are occupied by scrub fynbos. Numerous seeps and seasonally saturated mountain-plateau wetlands (locally called 'suurvlakte') are very common and support restioid and ericaceous (dominated by Bruniaceae) fynbos.

Geology & Soils Acidic lithosol soils derived from Ordovician sandstones of the Table Mountain Group (Cape Supergroup). Deep sandy blankets (whitish, nutrient-poor acidic sand) develop in depressions and on slopes resisting erosion. Land types mainly Ic, Ib and Gb.

L. Mucina

Figure 4.33 FFs 11 Kogelberg Sandstone Fynbos: Species-rich proteoid fynbos on coastal sandy plains in the Kleinmond Nature Reserve at the Palmiet River mouth near Kleinmond (Western Cape), with small trees of *Leucospermum conocarpodendron* subsp. *viridum* and pink-flowered *Pelargonium cucullatum* (Geraniaceae).

Climate MAP 670–3 000 mm (mean: 1 330 mm), peaking markedly May to August. This region has the highest recorded rainfall in the Cape (see Section 2.4.2 of this chapter). Mean daily maximum and minimum temperatures 24.0°C and 6.1°C for February and July, respectively. Frost incidence 2 or 3 days per year. The summit cloud (the 'Hottentot's Blanket') is a regular feature in summer when the Southeaster (part of the global system of trade-winds) brings heavy mist precipitation to the summits and adjacent south-facing and east-facing slopes. See also climate diagram for FFs 11 Kogelberg Sandstone Fynbos (Figure 4.21).

Important Taxa (^{T}Cape thickets, ^{W}Wetlands) Small Trees: *Brabejum stellatifolium*^{T} (d), *Widdringtonia nodiflora* (d), *Heeria argentea*^{T}, *Leucospermum conocarpodendron* subsp. *viridum*, *Metrosideros angustifolia*^{T}, *Podocarpus elongatus*^{T}, *Protea nitida*. Tall Shrubs: *Brunia albiflora*^{W} (d), *Cliffortia cuneata* (d), *Diospyros glabra*^{T} (d), *Leucadendron salicifolium* (d), *Liparia myrtifolia* (d), *Metalasia densa* (d), *Mimetes argenteus* (d), *Protea neriifolia* (d), *P. repens* (d), *Psoralea pinnata*^{W} (d), *Aspalathus linearis*, *A. willdenowiana*, *Cunonia capensis*^{T}, *Erica perspicua* var. *perspicua*^{W}, *Euryops abrotanifolius*, *E. serra*, *Laurophyllus capensis*^{T}, *Liparia rafnioides*, *Myrsine africana*^{T}, *Pseudobaeckea africana*, *Psoralea aphylla*, *Rapanea melanophloeos*^{T}, *Rhus tomentosa*^{T}. Low Shrubs: *Agathosma ovata* (d), *A. serratifolia* (d), *Aulax cancellata* (d), *Berzelia lanuginosa*^{W} (d), *B. squarrosa* (d), *Brunia alopecuroides*^{W} (d), *Cliffortia graminea* (d), *C. hirsuta* (d), *C. pedunculata* (d), *C. polygonifolia* (d), *C. ruscifolia* (d), *Cullumia setosa* (d), *Diosma hirsuta* (d), *Erica coccinea* subsp. *coccinea* (d), *E. desmantha* (d), *E. equisetifolia* (d), *E. fastigiata* (d), *E. hispidula* (d), *E. imbricata* (d), *E. labialis* (d), *E. lutea* (d), *E. muscosa* (d), *E. parviflora*^{W} (d), *E. pulchella* (d), *E. similis* (d), *E. viscaria* subsp. *longifolia* (d), *Euryops pinnatipartitus* (d), *Grubbia tomentosa* (d), *Leucadendron gandogeri* (d), *L. platyspermum* (d), *L. salignum* (d), *L. spissifolium* subsp. *spissifolium* (d), *L. xanthoconus* (d), *Leucospermum oleifolium* (d), *Mimetes cucullatus* (d), *Nebelia fragarioides* (d), *N. paleacea* (d), *N. sphaerocephala* (d), *Osmitopsis asteriscoides*^{W} (d), *Otholobium obliquum* (d), *Penaea mucronata* (d), *Phaenocoma prolifera* (d), *Phylica anomala* (d), *Protea cynaroides* (d), *P. grandiceps* (d), *Retzia capensis* (d), *Roella ciliata* (d), *Saltera sarcocolla* (d), *Serruria inconspicua* (d), *Stoebe incana* (d), *S. plumosa* (d), *Syncarpha vestita* (d), *Ursinia paleacea* (d), *Amphithalea ericifolia* subsp. *scoparia*, *Anaxeton asperum*, *Anthospermum aethiopicum*, *A. galioides* subsp. *galioides*, *Aspalathus angustifolia* subsp. *angustifolia*, *A. aspalathoides*, *A. attenuata*, *A. bracteata*, *A. caledonensis*, *A. callosa*, *A. ciliaris*, *A. commutata*, *A. cordata*, *A. crenata*, *A. cytisoides*, *A. divaricata* subsp. *divaricata*, *A. divaricata* subsp. *gracilior*, *A. dunsdoniana*, *A. filicaulis*, *A. intervallaris*, *A. macrantha*, *A. marginata*, *A. oblongifolia*, *A. perfoliata* subsp. *perfoliata*, *A. perforata*, *A. pinea* subsp. *caudata*, *A. radiata* subsp. *radiata*, *A. ramulosa*, *A. stenophylla*, *A. tridentata* subsp. *tridentata*, *Asparagus lignosus*, *A. rubicundus*, *Berzelia abrotanoides*, *B. intermedia*, *Brunia laevis*, *B. nodiflora*, *Capelio tabularis*, *Cliffortia atrata*, *C. exilifolia*, *Clutia polygonoides*, *Diastella divaricata* subsp. *montana*, *Dolichothrix ericoides*, *Elytropappus gnaphaloides*, *Erica axillaris*, *E. benthamiana*, *E. corifolia*, *E. corydalis*, *E. curviflora*, *E. ericoides*, *E. exleeana*, *E. intervallaris*^{W}, *E. massonii*, *E. odorata*, *E. petrophila*, *E. pilosiflora* subsp. *pilosiflora*, *E. plukenetii* subsp. *plukenetii*, *E. rigidula*, *E. serrata*, *E. sessiliflora*, *E. taxifolia*, *E. totta*, *E. transparens*, *E. ventricosa*, *Euryops rupestris* var. *dasycarpus*, *E. rupestris* var. *rupestris*, *Gnidia pinifolia*, *Halleria elliptica*, *Hermas villosa*, *Hippia pilosa*, *Indigofera glomerata*, *I. trita* subsp. *subulata*, *Klattia partita*, *Leucadendron laureolum*, *L. microcephalum*, *Linconia cuspidata*, *Liparia splendens*, *Lobelia pinifolia*, *Maytenus oleoides*^{T}, *Metalasia brevifolia*, *M. cephalotes*, *M. erubescens*, *M. inversa*, *M. plicata*, *M. tenuifolia*, *Microdon dubius*, *Osteospermum ciliatum*, *Otholobium fruticans*, *Paranomus sceptrum-gustavianus*, *Passerina truncata* subsp. *monticola*, *Phylica lasiocarpa*, *Polygala pottebergensis*, *Prismatocarpus diffusus*, *P. schlechteri*, *Protea angustata*, *P. lorea*, *P. scabra*, *P. speciosa*, *Raspalia microphylla*, *Roella incurva*, *Serruria acrocarpa*, *S. flagellifolia*, *S. phylicoides*, *S. rostellaris*, *S. rubricaulis*, *Spatalla longifolia*, *S. propinqua*^{W}, *S. racemosa*, *Teedia lucida*, *Thamnea uniflora*, *Ursinia pinnata*, *U. quinquepartita*^{W}, *Zyrphelis foliosa*, *Z. lasiocarpa*, *Z. taxifolia*. Succulent Shrubs: *Othonna quinquedentata* (d), *Crassula coccinea*, *Oscularia deltoides*. Semiparasitic Shrubs: *Thesium carinatum*, *T. ericaefolium*. Pseudocarnivorous Shrub: *Roridula gorgonias*. Herbs: *Arctotis semipapposa* (d), *Carpacoce spermacocea*, *Centella difformis*, *C. eriantha*, *C. virgata*, *Chironia decumbens*, *Corymbium congestum*, *C. glabrum*, *Edmondia sesamoides*, *Helichrysum litorale*, *Nemesia acuminata*, *Pseudoselago serrata*, *Ursinia nudicaulis*, *U. oreogena*, *Villarsia capensis*^{W}. Geophytic Herbs: *Blechnum punctulatum* (d), *Lanaria lanata* (d), *Pteridium aquilinum* (d), *Schizaea pectinata* (d), *Watsonia borbonica* subsp. *borbonica* (d), *Agapanthus africanus*, *Aristea africana*, *A. capitata*, *Blechnum capense*, *Bobartia indica*, *Bulbinella nutans* subsp. *turfosicola*[W], *Disa pillansii*[W], *Eriospermum bakerianum* subsp. *bakerianum*, *Geissorhiza aspera*, *G. burchellii*, *G. cataractarum*[W], *G. hesperanthoides*, *G. hispidula*, *G. intermedia*, *G. nubigena*, *G. ovata*, *G. parva*, *G. ramosa*, *G. schinzii*, *G. similis*, *G. umbrosa*, *Romulea flava*, *R. gracillima*, *R. schlechteri*[W], *Rumohra adiantiformis*, *Trachyandra tabularis*, *Wachendorfia thyrsiflora*[W]. Succulent Herb: *Crassula pellucida* subsp. *pellucida*. Carnivorous Herb: *Drosera glabripes*[W]. Graminoids: *Anthochortus crinalis* (d), *A. graminifolius* (d), *Askidiosperma paniculatum* (d), *Calopsis paniculata* (d), *Cannomois parviflora* (d), *C. virgata* (d), *Ceratocaryum argenteum* (d), *Cymbopogon marginatus* (d), *Elegia capensis*[W] (d), *E. deusta* (d), *E. ebracteata* (d), *E. filacea* (d), *E. grandis*[W] (d), *E. hookeriana* (d), *E. juncea* (d), *E. racemosa* (d), *E. spathacea* (d), *E. mucronata* (d), *E. thyrsifera* (d), *Hypodiscus albo-aristatus* (d), *H. aristatus* (d), *Ischyrolepis capensis* (d), *I. sieberi* (d), *I. tenuissima* (d), *Mastersiella digitata* (d), *Merxmuellera stricta* (d), *Nevillea obtusissima* (d), *Pentameris macrocalycina* (d), *Pentaschistis colorata* (d), *Restio bifidus* (d), *R. egregius* (d), *R. filiformis* (d), *R. perplexus* (d), *R. purpurascens* (d), *R. similis* (d), *Staberoha aemula* (d), *S. cernua* (d), *Tetraria bromoides* (d), *T. capillacea* (d), *T. compar* (d), *T. fasciata* (d), *T. flexuosa* (d), *T. involucrata* (d), *T. thermalis* (d), *Thamnochortus gracilis* (d), *T. pulcher* (d), *Willdenowia glomerata* (d), *Calopsis hyalina*, *C. membranacea*, *Carpha glomerata*, *Chrysitrix capensis*, *Cyathocoma hexandra*[W], *Ehrharta ramosa* subsp. *aphylla*, *Elegia stokoei*, *Epischoenus quadrangularis*, *Ficinia acuminata*, *F. albicans*, *F. ecklonea*, *F. trichodes*, *Hypodiscus willdenowia*, *Ischyrolepis gaudichaudiana*, *I. subverticillata*[W], *Neesenbeckia punctoria*, *Pentaschistis curvifolia*, *Platycaulos cascadensis*[W], *Restio ambiguus*, *R. dispar*, *R. occultus*, *R. triticeus*, *R. versatilis*, *Tetraria burmannii*, *T. ligulata*, *Willdenowia humilis*, *W. sulcata*.

Endemic Taxa ([W]Wetlands) Small Tree: *Mimetes arboreus*. Tall Shrubs: *Protea stokoei* (d), *Aspalathus globosa*, *A. stokoei*, *Cliffortia heterophylla*, *Liparia calycina*, *Mimetes hottentoticus*, *Orothamnus zeyheri*[W] (small population also in FFs 12), *Podalyria cordata*. Low Shrubs: *Berzelia dregeana* (d), *Erica cristata* (d), *E. sitiens* (d), *Leucospermum bolusii* (d), *Spatalla setacea*[W] (d), *Ursinia caledonica*[W] (d), *Acmadenia candida*, *A. nivea*, *Adenandra multiflora*, *Agathosma rosmarinifolia*, *A. stokoei*, *Amphithalea bowiei*, *A. oppositifolia*, *A. stokoei*, *Anaxeton ellipticum*, *Aspalathus acanthiloba*, *A. concava*, *A. monosperma*, *A. salicifolia*, *A. vacciniifolia*, *Berzelia ecklonii*, *Brunia stokoei*, *Capelio caledonica*, *Cliffortia hermaphroditica*, *C. ovalis*, *C. viridis*, *Diastella fraterna*, *D. thymelaeoides* subsp. *meridiana*, *D. thymelaeoides* subsp. *thymelaeoides*, *Erica amphigena*, *E. atricha*, *E. banksii* subsp. *banksii*, *E. banksii* subsp. *comptonii*, *E. bibax*[W], *E. cabernetea*, *E. campanularis*[W], *E. ceraria*, *E. chiroptera*, *E. cincta*, *E. cunoniensis*, *E. cygnea*, *E. extrusa*, *E. foliacea*, *E. gysbertii*, *E. hameriana*, *E. hottentotica*[W], *E. humidicola*[W], *E. intonsa*, *E. jacksoniana*[W], *E. kogelbergensis*, *E. krugeri*, *E. lananthera*, *E. latiflora*, *E. leucotrachela, E. lycopodiastrum*, *E. macroloma*, *E. magistrati*, *E. multiflexuosa*, *E. nana*, *E. notholeeana*, *E. oreophila*, *E. pageana*[W], *E. perplexa*, *E. pillansii* subsp. *fervida*[W], *E. pillansii* subsp. *pillansii*[W], *E. pycnantha*, *E. retorta*, *E. ribisaria*, *E. salax*, *E. squarrosa*, *E. stokoeanthus*[W], *E. stokoei*, *E. suffulta*, *E. thomae*, *E. truncata*, *E. tubercularis*, *E. vallis-aranearum*, *E. viridimontana* subsp. *nivicola*, *E. viridimontana* subsp. *viridimontana*, *E. viscaria* subsp. *gallorum*, *Euchaetis glabra*, *Euryops indecorus*, *Glischrocolla formosa*, *Grubbia rourkei*, *Heliophila ramosissima*, *Klattia flava*, *K. stokoei*, *Leucospermum cordatum*, *Liparia bonaespei*, *L. boucheri*, *Metalasia confusa*, *M. humilis*, *M. lichtensteinii*, *M. quinqueflora*, *Mimetes capitulatus*, *M. stokoei* (extinct in wild), *Muraltia aciphylla*, *M. aspalatha*, *M. asparagifolia*, *M. capensis*, *M. chamaepitys*, *M. guthriei*, *M. hyssopifolia*, *M. occidentalis*, *M. paludosa*, *M. pubescens*, *M. stokoei*, *M. vulpina*, *Nivenia concinna*, *N. levynsiae*, *N. stokoei*, *Osmitopsis glabra*, *O. parvifolia*, *Paranomus spicatus*, *Phylica guthriei*, *P. linifolia*, *P. variabilis*, *Prismatocarpus cordifolius*, *Rafnia racemosa* subsp. *pumila*, *Raspalia globosa*, *Senecio speciosissimum*[W], *Serruria deluvialis*, *Sonderothamnus petraeus*, *Sorocephalus clavigerus*, *S. palustris*[W], *S. tenuifolius*, *Spatalla mollis*[W], *S. prolifera*[W], *Staavia brownii*, *Stylapterus barbatus*, *S. micranthus*, *Syncarpha lepidopodium*, *Thaminophyllum multiflorum, Ursinia eckloniana*[W]. Succulent Shrubs: *Lampranthus middlemostii*, *L. wordsworthiae*, *Ruschia lavisii*. Semiparasitic Shrubs: *Thesium brachygyne*, *T. quinqueflorum*. Herbs: *Centella pilosa*, *Charadrophila capensis*[W], *Galium rourkei*, *Peucedanum triternatum*. Geophytic Herbs: *Agapanthus walshii*, *Disa begleyi*, *D. brevipetala*, *Geissorhiza lithicola*, *Gladiolus nerineoides*, *Ixia esterhuyseniae*, *Watsonia distans*[W]. Carnivorous Herb: *Drosera esterhuyseniae*[W]. Graminoids: *Restio bifarius* (d), *Askidiosperma esterhuyseniae*, *Calopsis nudiflora*, *C. sparsa*, *Ficinia minutiflora*, *Hypodiscus alternans*, *Ischyrolepis saxatilis*, *Restio distans*, *R. fusiformis*, *R. involutus*, *R. nuwebergensis*, *R. verrucosus*, *Tetraria crassa*, *Willdenowia purpurea*, *W. rugosa*.

Conservation Least threatened. Target 30%. The unit is statutorily well conserved (58%) in the Hottentots Holland and Groenlandberg Nature Reserves and especially in the Kogelberg Biosphere Reserve (including Kogelberg and Kleinmond Nature Reserves). An additional 18% protected in the Hottentots-Holland Mountains catchment area. Some 17% transformed (pine plantations, cultivation, urban sprawl and spread of informal settlements). Aliens *Pinus pinaster* and *Hakea sericea* have been targeted for clearing, but remain of concern in some areas. Erosion very low.

Remark 1 Vegetation of this unit was reasonably well surveyed at Kogelberg, Jonkershoek, Jakkalshoek and Haasvlakte. Data suggest that this vegetation unit might perhaps be divided into two or three units, but the boundaries are not obvious—Sir Lowry's and Viljoen's Passes appear to be the boundary of a northern Jonkershoek subunit, and the Kogelberg subunit may perhaps be further subdivided with a northern Groenlandberg subunit separated between the Highlands and Houwhoek Passes. However, at present there are insufficient data to verify this.

Remark 2 In this unit, more than any other, Sandstone Fynbos communities are floristically quite distinctive in that local patches may be dominated by species that are rare in similar communities elsewhere. Matching communities floristically from similar habitats across the region is therefore very difficult. Even structural types vary from ericaceous to restioid to proteoid across matched habitats for no obviously discernable reasons.

Remark 3 This is the heart of the Cape flora—a true crown jewel of the temperate flora of the world. The species-level endemism is staggering and this unit contains two endemic genera, *Charadrophila* (still unclear whether Stilbaceae or Scrophulariaceae) and *Glischrocolla* (Penaeaceae). Monotypic genera occurring also outside this unit include *Atrichantha, Audouinia, Bryomorphe, Capeobolus, Empleuridium, Euthystachys, Evotella, Glia, Itasina, Lanaria, Mystropetalon, Neesenbeckia, Oreoleysera, Phaenocoma, Saltera* and *Witsenia*. Endemic Cape genera such as *Retzia, Orothamnus, Pillansia* and *Sonderothamnus* are shared only with FFs 12 Overberg Sandstone Fynbos. Genera such as *Anaxeton, Aulax, Bolusafra, Brunia, Capelio, Calopsis, Chrysitrix, Cliffortia, Diastella, Dilatris, Disa, Elegia, Erica, Euryops, Grubbia, Helichrysum, Hermas, Hypocalyptus, Klattia, Liparia, Metalasia, Mimetes, Muraltia, Oldenburgia, Osmitopsis, Prismatocarpus, Protea, Raspalia, Restio, Siphocodon, Spatalla, Staavia, Syncarpha, Thaminophyllum, Thesium, Ursinia* and *Wachendorfia* are either remarkably species-rich in this unit or have most of the extant species of the genus in this area. The unit contains representatives of almost all endemic families of the CFR (or of the Cape Floristic Kingdom) (the only notable exception being Geissolomataceae of the Langeberg). Many of the endemics are confined to vulnerable wetland habitats (mainly seeps) or are found in sheltered rocky habitats such as on steep cliffs. Many species still await formal description.

Remark 4 Shale bands are a prominent feature in the landscape, with areas below the shale band predominantly proteoid fynbos, whereas above the shale band ericaceous and restioid fynbos predominate. It is unclear whether this is due to the Nardouw sandstones being relatively nutrient-poor compared to the Peninsula sandstones, or due to nutrient input from the shale.

References Van der Merwe (1962, 1966), Boucher (1972, 1977, 1978, 1988a, 1996b), Werger et al. (1972a, b), Kruger (1979), Durand (1981), Burman & Bean (1985), McDonald (1985, 1987, 1988), Davis (1988), Boucher & Stindt (1992), Sieben (2003), Sieben et al. (2004), Bean & Johns (2005).

FFs 12 Overberg Sandstone Fynbos

VT 69 Macchia (64%), VT 47 Coastal Macchia (31%) (Acocks 1953). Mesic Mountain Fynbos (85%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (85%) (Low & Rebelo 1996). BHU 13 Springfield Sand Plain Fynbos (25%), BHU 57 Klein River Mountain Fynbos Complex (25%), Bredasdorp Mountain Fynbos Complex (23%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Spread irregularly from Bot River and Hawston in the northwest to the Soetanysberg and Bredasdorp in the southeast, including the Caledon Swartberg, Babilonstoring, Kleinrivier and Bredasdorp Mountains and Agulhas hills such as Franskraal se Berge and Buffeljachtsberg. Altitude 20–1 167 m on the summit of Babilonstoringberg.

Vegetation & Landscape Features Low mountains, undulating hills and moderately undulating plains supporting moderately tall, dense restioid, ericoid-leaved and proteoid shrublands. Structurally these are mainly proteoid and ericaceous fynbos, with restioid fynbos also occurring locally.

Geology & Soils Acidic lithosol soils derived from Ordovician sandstones of the Table Mountain Group (Cape Supergroup), Houwhoek, Glenrosa and Mispah forms prominent. Land types mainly Ib and Gb.

Climate MAP 450–830 mm (mean: 585 mm), peaking May to August. Southeasterly cloud brings mist precipitation to eastern and southern slopes at higher altitudes in summer. Mean daily maximum and minimum temperatures 25.6°C and 6.3°C for January and July, respectively. Frost incidence 2 or 3 days per year. See also climate diagram for FFs 12 Overberg Sandstone Fynbos (Figure 4.21).

Important Taxa ([W]Wetlands) Small Tree: *Leucospermum conocarpodendron* subsp. *viridum*. Tall Shrubs: *Protea repens* (d), *Euryops abrotanifolius*, *Passerina corymbosa*, *Protea compacta*. Low Shrubs: *Erica globiceps* subsp. *globiceps* (d), *E. pulchella* (d), *Phaenocoma prolifera* (d), *Serruria fasciflora* (d), *Agathosma serpyllacea*, *Aspalathus angustifolia* subsp. *angustifolia*, *A. aspalathoides*, *A. caledonensis*, *A. callosa*, *A. dunsdoniana*, *A. elliptica*, *A. intervallaris*, *A. marginata*, *A. oblongifolia*, *A. pachyloba* subsp. *pachyloba*, *A. psoraleoides*, *A. quinquefolia* subsp. *compacta*, *A. ramulosa*, *A. retroflexa* subsp. *retroflexa*, *A. securifolia*, *Aulax umbellata*, *Brunia laevis*, *Campylostachys cernua*, *Cliffortia ferruginea*, *Erica coccinea* subsp. *coccinea*, *E. corifolia*, *E. nudiflora*, *E. plukenetii* subsp. *plukenetii*, *E. regia* subsp. *regia*, *E. serrata*, *E. sessiliflora*, *E. similis*, *E. vestita*, *E. viscaria* subsp. *longifolia*, *Grubbia rosmarinifolia*, *Leucadendron salignum* (d), *L. gandogeri* (d), *L. laureolum*, *L. platyspermum*, *L. tinctum*, *L. xanthoconus*, *Leucospermum cordifolium*, *L. prostratum*, *L. truncatulum, Linconia cuspidata*, *Lobostemon sanguineus*, *Metalasia brevifolia*, *M. erubescens*, *M. inversa*, *Mimetes cucullatus*, *Muraltia collina*, *Nebelia paleacea*, *Passerina truncata* subsp. *monticola*, *Phylica brevifolia*, *P. imberbis*, *Protea angustata*, *P. aspera*, *P. cordata*, *P. cynaroides*, *P. longifolia*, *P. speciosa*, *Retzia capensis*, *Roella incurva*, *Serruria elongata*, *S. flagellifolia*, *S. heterophylla*, *S. rostellaris*, *S. rubricaulis*, *Spatalla curvifolia*, *S. racemosa*, *Staavia radiata*, *Stoebe aethiopica*, *S. capitata*, *Ursinia paleacea*, *U. quinquepartita*[W], *Zyrphelis foliosa*, *Z. lasiocarpa*. Pseudocarnivorous Shrub: *Roridula gorgonias*. Herbs: *Edmondia sesamoides* (d), *Mairia burchellii*, *M. coriacea*. Geophytic Herbs: *Lanaria lanata* (d), *Geissorhiza cataractarum*[W], *G. hesperanthoides*, *G. hispidula*, *G. imbricata* subsp. *imbricata*[W], *G. juncea*, *G. parva*, *G. schinzii*, *G. similis*, *Romulea dichotoma*, *R. gracillima*, *R. triflora*. Graminoids: *Mastersiella digitata* (d), *Calopsis hyalina*, *C. membranacea*, *Ceratocaryum argenteum*, *Cyathocoma hexandra*[W], *Elegia deusta*, *E. filacea*, *E. juncea*, *E. persistens*, *E. recta*, *E. tectorum*, *Ficinia tristachya*, *Hypodiscus argenteus*, *Ischyrolepis capensis*, *Restio dodii*[W], *R. similis*, *Rhodocoma fruticosa*, *Staberoha cernua*, *S. multispicula*, *Tetraria bromoides*, *T. capillacea*, *T. compar*, *T. cuspidata*, *T. fasciata*, *T. thermalis*, *Thamnochortus erectus*, *T. guthrieae*.

Endemic Taxa ([W]Wetlands) Tall Shrubs: *Aspalathus excelsa*, *Cliffortia curvifolia*, *Erica perspicua* var. *latifolia*[W], *Indigofera superba*. Low Shrubs: *Adenandra lasiantha*, *A. schlechteri*, *Amphithalea rostrata*, *A. speciosa*, *Aspalathus chenopoda* subsp. *gracilis*, *A. juniperina* subsp. *grandis*, *A. rosea*, *Berzelia incurva*, *B. rubra*, *Brachysiphon rupestris*, *Cliffortia geniculata*, *C. monophylla*, *C. tenuis*, *Erica agglutinans*, *E. ampullacea*, *E. aristata*, *E. axilliflora*, *E. banksii* subsp. *purpurea*, *E. bodkinii*[W], *E. chonantha*, *E. collina*, *E. colorans*[W], *E. crateriformis*, *E. ecklonii*, *E. erina*, *E. filipendula*, *E. flavicoma*, *E. galpinii*, *E. gerhardii*, *E. grisbrookii*, *E. hendricksei*[W], *E. hermani*, *E. innovans*, *E. irbyana*, *E. lageniformis*, *E. lanuginosa*, *E.*

L. Mucina

Figure 4.34 FFs 12 Overberg Sandstone Fynbos: Proteoid fynbos with *Protea compacta* and *Leucadendron xanthoconus* on deep acid sands overlying Table Mountain sandstones near Elim (Western Cape).

latituba, *E. longiaristata*, *E. melanacme*, *E. nigrimontana*, *E. oligantha*[W], *E. oliveri*, *E. pauciovulata*[W], *E. penduliflora*, *E. plena*[W], *E. pogonanthera*, *E. pulchelliflora*, *E. russakiana*, *E. shannonea*, *E. tenella*, *E. trichophora*[W], *E. turrisbabylonica*[W], *E. venustiflora* subsp. *venustiflora*, *E. villosa*, *E. vogelpoelii*, *E. williamsiorum*, *E. xeranthemifolia*, *Euryops lasiocladus*, *E. tenuilobus*, *Gnidia sonderiana*, *Lachnaea aurea*, *Leucospermum gracile*, *Macrostylis cauliflora*, *Metalasia bodkinii*, *M. cymbifolia*, *M. seriphiifolia*, *M. serrata*, *Mimetes palustris*, *Muraltia gillettiae*, *M. spicata*, *Osteospermum elsieae*, *Otholobium dreweae*, *Phylica floribunda*, *Prismatocarpus fastigiatus*, *Pseudobaeckea stokoei*, *Rhigiophyllum squarrosum*[W], *Serruria meisneriana*, *S. rebeloi*, *Sonderothamnus speciosus*, *Spatalla squamata*, *Thaminophyllum latifolium, Zyrphelis spathulata*. Succulent Shrubs: *Acrodon quarcicola*, *Delosperma guthriei*, *Erepsia babiloniae*, *E. oxysepala*, *E. polypetala*, *Lampranthus framesii*. Semiparasitic Shrubs: *Thesium bathyschistum*, *T. fallax*, *T. sertulariastrum*. Herbs: *Arctotis schlechteri*, *Centella rupestris*, *Pseudoselago pulchra*. Geophytic Herbs: *Aristea palustris*[W], *Cyrtanthus guthrieae*, *Geissorhiza bryicola*[W], *Gladiolus overbergensis*, *Lachenalia sargeantii*, *Moraea barnardii*, *M. longiaristata*, *M. vallisavium*, *Tritoniopsis williamsiana*. Carnivorous Herb: *Drosera slackii*[W]. Graminoids: *Ceratocaryum pulchrum*, *Elegia decipiens*, *Ficinia dura*, *Pentaschistis scandens*, *Restio scaber*.

Conservation Least threatened. Target 30%. Only 6% statutorily conserved in the Agulhas National Park, Fernkloof, Babilonstoring, Heuningberg, Maanschynkop, Salmonsdam and Caledon Nature Reserves. Additional area protected in private conservation areas such as Vogelgat, Brandfontein, Jan Malherbe, Groothagelkraal, Fynbosrand, Brandfontein-Rietfontein and Waterfall. About 6% transformed (cultivation). Alien *Pinus pinaster*, *Acacia cyclops*, *A. saligna*, *Hakea sericea*, *H. gibbosa* and *Leptospermum laevigatum* occur in places. Erosion very low and low.

Remarks The Babylonstoring and Kleinrivier Mountains have many local endemic taxa and could perhaps be separated (together with Caledon Swartberg) at the Klein River as a separate unit. There are no reliable data to suggest that the Caledon Swartberg warrants a separate unit, unlike Piketberg and Potberg. More data and further research are needed.

References Cowling et al. (1988), Thwaites & Cowling (1988), De Lange (1992), Richards (1994), Richards et al. (1995, 1997a, b), Mustart et al. (1997).

FFs 13 North Sonderend Sandstone Fynbos

VT 69 Macchia (82%) (Acocks 1953). Mesic Mountain Fynbos (45%), Dry Mountain Fynbos (37%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (83%) (Low & Rebelo 1996). BHU 59 Riviersonderend Mountain Fynbos Complex (84%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Northern slopes of the Riviersonderend Mountains from Villiersdorp to Bromberg and Luiperdsberg east of Stormsvlei, including Klipberg and Sandberg towards Robertson. Altitude from 150 m, with the highest peaks exceeding 1 600 m (Jonaskop, Pilaarkop and an unnamed peak).

Figure 4.35 FFs 13 North Sonderend Sandstone Fynbos: Rugged midslopes and plateaus of the Riviersonderend Mountains on Jonaskop (Western Cape), with restioid fynbos dominated by *Elegia racemosa* in the foreground.

Vegetation & Landscape Features Gentle to steep north-facing slopes, highly dissected in a few places, with a midslope sandy plateau and extensive gentle lower slopes. Vegetation is an open, tall, proteoid-leaved evergreen shrubland with a dense moderately tall, ericoid-leaved shrubland as understorey. This is mainly asteraceous fynbos on the western and lower slopes, but extensive proteoid and restioid fynbos dominate the middle slopes. Ericaceous fynbos is restricted to the highest peaks. This unit (in facies with extensive asteraceous fynbos—with emergent *Aloe ferox*) borders on succulent karoo shrublands at the lowest elevations and to the east. The deep sand habitat of the northern plateau, which runs along the length of the mountain, is a distinctive feature associated with many endemic species.

Geology & Soils Acidic lithosol soils derived from Ordovician sandstones of the Table Mountain Group (Cape Supergroup). Land types mainly Ic.

Climate MAP 250–1 410 mm (mean: 605 mm), peaking May to August. Mean daily maximum and minimum temperatures 26.2°C and 4.4°C for February and July, respectively. Frost incidence 7–10 days per year. See also climate diagram for FFs 13 North Sonderend Sandstone Fynbos (Figure 4.21).

Important Taxa ([T]Cape thickets) Small Trees: *Acacia karroo*, *Cunonia capensis*[T], *Metrosideros angustifolia*[T], *Protea nitida*. Tall Shrubs: *Protea neriifolia* (d), *P. repens* (d), *Polygala fruticosa*, *Protea laurifolia*, *Rhus pyroides*[T]. Low Shrubs: *Agathosma leptospermoides*, *Athanasia oocephala*, *Cliffortia ruscifolia*, *Elytropappus glandulosus*, *Erica denticulata*, *E. globiceps* subsp. *zeyheri*, *E. jonasiana*, *E. lateralis*, *E. modesta*, *E. plukenetii* subsp. *plukenetii*, *E. serrata*, *E. taxifolia*, *E. vestita*, *Leucadendron laureolum*, *L. microcephalum*, *L. salignum*, *Leucospermum calligerum*, *Muraltia ferox, Paranomus adiantifolius*, *P. capitatus*, *Passerina burchellii*, *Phaenocoma prolifera*, *Prismatocarpus lycioides*, *Protea amplexicaulis*, *P. cynaroides*, *P. humiflora*, *P. lorifolia*, *P. scabra*, *P. subulifolia, Serruria gremialis*, *S. viridifolia, Stoebe spiralis*. Succulent Shrubs: *Drosanthemum leptum*, *Ruschia acutangula*. Herbs: *Edmondia sesamoides*, *Ursinia oreogena*. Geophytic Herb: *Gladiolus atropictus*. Graminoids: *Ehrharta ramosa* subsp. *aphylla*, *Hypodiscus squamosus*, *H. striatus*, *Ischyrolepis capensis*, *I. distracta*, *I. gaudichaudiana*, *Pentaschistis eriostoma*, *Restio filiformis*, *Thamnochortus cinereus*.

Endemic Taxa Low Shrubs: *Leucadendron burchellii*, *L. immoderatum*, *L. nervosum*, *Leucospermum harpagonatum*, *Serruria stellata*, *S. williamsii*, *Spatalla argentea*.

Conservation Least threatened. Target 30%. Statutorily conserved (21%) in the Riviersonderend Nature Reserve, with an additional 51% mainly in a private conservation area of the same name. Only 2% transformed by cultivation for protea nurseries and fruit orchards—these being on the deep sand habitat of the northern plateau supporting many threatened taxa. The threat of transformation in this area is serious since none of the deep-sand northern plateau is under formal conservation. Alien *Pinus pinaster* and *Hakea sericea* occasionally occur over about half of the area. Erosion is very low.

Remark 1 The northern slopes of the Riviersonderend Mountains is a poorly explored area. The data of the Protea Atlas Project suggest that the sandstone units FFs 13 and FFs 14 (see below) form the centre of specific diversity in Proteaceae; especially the genus *Serruria* is very speciose here. This may well be found to be true of other genera and families after more exploration. *Endonema* (Penaeaceae) is endemic to the Riviersonderend.

Remark 2 Jonaskop (1 646 m) and the slopes facing the renosterveld and karoo regions to the north have become the focus of observational and experimental research into a range of ecological questions along the elevational gradient. These studies include work on plant functional types, phenology, transplant experiments and predictions of the effects of climate change.

References Rutherford (1978), Agenbag & Esler (2004a, b), Agenbag et al. (2004), Vile et al. (2005), C. Boucher (unpublished data), Protea Atlas Project (unpublished data).

FFs 14 South Sonderend Sandstone Fynbos

VT 69 Macchia (87%) (Acocks 1953). Mesic Mountain Fynbos (77%), South West Coast Renosterveld (11%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (79%) (Low & Rebelo 1996). BHU 59 Riviersonderend Mountain Fynbos Complex (73%), BHU 18 Genadendal Grassy Fynbos (22%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Southern slopes of the Riviersonderend Mountains from Villiersdorp and Eseljagsberg in the west to Stormsvlei in the east. Altitude from 200 m, with the highest peaks exceeding 1 600 m (Jonaskop, Pilaarkop and an unnamed peak).

Vegetation & Landscape Features Steep to gentle southern slopes, with extensive cliffs in places. Vegetation a moderately tall, dense ericoid-leaved shrubland with open emergent proteoids. Ericaceous and restioid fynbos most common, with proteoid fynbos found mainly on lower slopes.

Geology & Soils Acidic lithosol soils derived from Ordovician sandstones of the Table Mountain Group (Cape Supergroup). Land types mainly Ib, Ic and Fa.

Climate MAP 380–1 650 mm (mean: 785 mm), peaking May to August. Southeasterly cloud brings heavy mist precipitation at higher altitudes in summer. Mean daily maximum and minimum monthly temperatures 25.7°C and 4.6°C for February and July, respectively. Frost incidence 3–10 days per year. See also climate diagram for FFs 14 Sonderend Sandstone Fynbos (Figure 4.21).

Important Taxa (WWetlands) Small Tree: *Protea nitida* (d). Tall Shrubs: *Protea neriifolia* (d), *P. repens* (d), *Leucadendron salicifolium*. Low Shrubs: *Leucadendron salignum* (d), *Ursinia pinnata* (d), *Amphithalea ericifolia* subsp. *scoparia*, *Aspalathus ramulosa*, *A. stenophylla*, *Aulax cancellata*, *Erica hispidula*, *E. lutea*, *E. multumbellifera*, *E. sessiliflora*, *E. taxifolia*, *E. transparens*, *Leucadendron microcephalum*, *L. spissifolium* subsp. *spissifolium*, *Metalasia tenuifolia*, *Mimetes cucullatus*, *Passerina burchellii*, *Protea amplexicaulis*, *P. cynaroides*, *P. scabra*, *P. subulifolia*, *Raspalia microphylla*, *Spatalla propinqua*W, *Ursinia scariosa* subsp. *subhirsuta*. Succulent Shrub: *Acrodon subulatus*. Herb: *Edmondia pinifolia*. Geophytic Herb: *Geissorhiza grandiflora*. Graminoids: *Elegia aggregata*, *E. grandis*W.

Endemic Taxa (WWetlands) Tall Shrub: *Endonema lateriflora*W. Low Shrubs: *Erica trichophylla* (d), *Adenandra gracilis*, *Amphithalea ericifolia* subsp. *minuta*, *Anaxeton brevipes*, *Aspalathus taylorii*, *Athanasia scabra*, *Cliffortia crenulata*, *C. pungens*, *Diosma fallax*, *D. pilosa*, *D. thyrsophora*, *Endonema retzioides*, *Erica accommodata*, *E. alfredii*, *E. botryoides*, *E. caledonica*, *E. columnaris*, *E. diotiflora*, *E. embothriifolia*, *E. galgebergensis*, *E. goatcheriana* var. *petrensis*, *E. ignita*, *E. insolitanthera*, *E. lachnaeifolia*, *E. lanipes*, *E. lawsonia*, *E. oakesiorum*, *E. orthiocola*W, *E. ovina*, *E. pannosa*, *E. pellucida*, *E. perlata*, *E. permutata*, *E. petricola*, *E. physophylla*, *E. pilaarkopensis*, *E. polycoma*, *E. praenitens*, *E. remota*, *E. rufescens*, *E. rupicola*, *E. sicifolia*, *E. tomentosa*, *E. vallis-gratiae*, *E. xanthina*, *Euryops longipes* var. *longipes*, *Gymnostephium angustifolium*, *G. corymbosum*, *G. hirsutum*, *Helichrysum rotundatum*, *Indigofera quinquefolia*, *Lachnaea greytonensis*, *L. pudens*, *Linconia ericoides*, *Lonchostoma esterhuyseniae*, *Metalasia alfredii*, *M. tenuis*W, *Muraltia concava*, *M. tenuifolia*, *Nebelia laevis*, *Nivenia dispar*, *Pelargonium divisifolium*, *Phylica burchellii*, *P. lucens*, *P. stenantha*, *P. tubulosa*, *Senecio coleophyllus*, *S. retortus*, *Sorocephalus alopecurus*, *S. crassifolius*W, *S. pinifolius*, *Staavia zeyheri*, *Stilbe serrulata*. Succulent Shrub: *Lampranthus vallis-gratiae*. Herbs: *Centella cryptocarpa*, *C. dolichocarpa*, *C. thesioides*, *Helichrysum marifolium*, *Pseudoselago prostrata*. Geophytic Herbs: *Babiana foliosa*, *Gladiolus stokoei*, *Nerine pudica*, *Ornithogalum oreo-*

L. Mucina

Figure 4.36 FFs 14 South Sonderend Sandstone Fynbos: Deep valley of the Baviaanskloof near Genadendal (Western Cape) showing a mosaic of mainly restioid fynbos on the slopes, riparian thickets along the river and small relict patches of afrotemperate forests below the steep slopes of Jonaskop.

genes, *Thereianthus montanus*, *Watsonia minima*. Graminoids: *Nevillea singularis*, *Restio ingens*.

Conservation Least threatened. Target 30%. Statutorily conserved (40%) in the Riviersonderend Nature Reserve, with an additional 39% mainly in a private conservation area carrying the same name. Only 7% transformed (cultivation, pine plantations). Alien *Hakea sericea* and *Pinus pinaster* occur occasionally, the latter in very dense stands between Genadendal and Jonaskop. Erosion very low.

Remarks To date this vegetation has not received attention from vegetation ecologists and it remains floristically poorly described. The distribution data on Proteaceae (Protea Atlas Project) suggest that the eastern end of this unit has affinities with FFs 16 South Langeberg Sandstone Fynbos, whereas the western edge shares many species with FFs 10 Hawequas Sandstone Fynbos, the boundary being around Pilaarkop above Riviersonderend.

Reference Protea Atlas Project (unpublished data).

FFs 15 North Langeberg Sandstone Fynbos

VT 70 False Macchia (47%), VT 69 Macchia (24%) (Acocks 1953). Mesic Mountain Fynbos (30%), Dry Mountain Fynbos (30%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (67%) (Low & Rebelo 1996). BHU 64 Southern Langeberg Mountain Fynbos Complex (46%), BHU 60 Koo Langeberg Mountain Fynbos Complex (20%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Northern slopes of the Langeberg from the Keerom Mountains near Worcester in the west to Cloete's Pass north of Albertinia in the east, and to the interior on the Waboomsberg and Warmwaterberg Mountains north of Montagu and Barrydale, respectively. Also includes Aasvoëlberg hills from Albertinia to Mossel Bay. Altitude range very broad, 100–1 800 m, with several high peaks such as Misty Point (1 709 m) and Grootberg (1 637 m), generally higher in the west than the east. FFs 30 Western Altimontane Sandstone Fynbos on the western peaks above 1 800 m.

Vegetation & Landscape Features Gentle to steep, north-facing slopes, not much dissected over much of the range. Surface is gently sloping foothills of Waboomsberg, Warmwaterberg and Aasvoëlberg. The Cedarberg Shale Band is prominent in the west, mainly as a smooth-sided valley, along which most of the hiking trails are orientated. Vegetation is mainly proteoid and restioid fynbos, with ericaceous fynbos at higher altitudes and asteraceous fynbos on the lower slopes. Old African surface conglomerates (mapped as part of this unit) on the lower slopes have asteraceous fynbos dominated by *Dodonaea viscosa* var. *angustifolia*. Ravines support Cape thicket, dominated by *Buddleja saligna*, and species of *Pelargonium*, *Rhus* and *Salvia*.

Geology & Soils Acidic lithosol soils derived from Ordovician sandstones of the Table Mountain Group (Cape Supergroup). Land types mainly Ic, Ib, Db and Fc.

Climate MAP 250–1 200 mm (mean: 580 mm), peaking very slightly in winter and with a slight low from December to February. Mean daily maximum and minimum temperatures 26.5°C and 4.1°C for January and July, respectively. Frost incidence 3–20 days per year. See also climate diagram for FFs 15 North Langeberg Sandstone Fynbos (Figure 4.21).

Important Taxa ([W]Wetlands) Small Tree: *Protea nitida* (d). Tall Shrubs: *Leucadendron eucalyptifolium* (d), *Metalasia densa* (d), *Protea neriifolia* (d), *P. repens* (d), *Chrysanthemoides monilifera*, *Dodonaea viscosa* var. *angustifolia*, *Protea eximia*, *Psoralea pinnata*[W]. Low Shrubs: *Agathosma ovata* (d), *Diosma tenella* (d), *Erica anguliger* (d), *E. hispidula* (d), *E. melanthera* (d), *E. rosacea* subsp. *rosacea* (d), *E. versicolor* (d), *Leucadendron salignum* (d), *Leucospermum calligerum* (d), *Passerina obtusifolia* (d), *Phylica pinea* (d), *Agathosma cerefolium*, *Anthospermum spathulatum* subsp. *spathulatum*, *Aspalathus granulata*, *A. inops*, *A. vulpina*, *Berzelia galpinii*[W], *Brunia macrocephala*, *Cyclopia bowieana*, *Elytropappus hispidus*, *Erica articularis*, *E. coarctata*, *E. cubica*, *E. tenuis*, *Euryops pinnatipartitus*, *Gnidia francisci*, *Indigofera pappei*, *Leucadendron cordatum*, *Leucospermum cuneiforme*, *L. mundii*, *Lobelia capillifolia*, *Lobostemon decorus*, *Metalasia massonii*, *M. pulcherrima* f. *pallescens*, *Mimetes cucullatus*, *Muraltia heisteria*, *Paranomus candicans*, *Penaea cneorum* subsp. *ruscifolia*, *Phaenocoma prolifera*, *Phylica axillaris*, *Protea aspera*, *P. lorifolia, Stoebe aethiopica*, *S. cinerea, S. saxatilis*, *Syncarpha milleflora*, *Ursinia hispida*, *U. rigidula*, *Wahlenbergia tenella*. Succulent Shrubs: *Adromischus triflorus*, *Crassula atropurpurea* var. *atropurpurea*, *Machairophyllum albidum*, *Oscularia deltoides*, *Senecio aizoides*. Woody Succulent Climber: *Zygophyllum fulvum*. Semiparasitic Shrub: *Thesium subnudum*. Herbs: *Lobelia pubescens* var. *pubescens* (d), *Centella virgata*, *Linum gracile*, *Peucedanum ferulaceum*, *Polygala refracta*, *Ursinia nudicaulis*. Geophytic Herbs: *Lanaria lanata* (d), *Aristea racemosa*. Herbaceous Parasitic Climber: *Cassytha ciliolata*. Graminoids: *Ceratocaryum decipiens* (d), *Ehrharta dura* (d), *E. ramosa* subsp. *aphylla* (d), *Elegia filacea* (d), *E. galpinii* (d), *Heteropogon contortus* (d), *Hypodiscus argenteus* (d), *H. aristatus* (d), *H. striatus* (d), *Merxmuellera decora* (d), *Pentaschistis colorata* (d), *P. eriostoma* (d), *Restio filiformis* (d), *R. inconspicuus* (d), *Staberoha cernua* (d), *Tetraria bromoides* (d), *T. flexuosa* (d), *T. ustulata* (d), *Willdenowia bolusii* (d), *Calopsis filiformis*, *C. rigida*, *Cannomois parviflora*, *Elegia asperiflora*, *Ficinia acuminata*, *F. laciniata*, *F. trichodes*, *Hypodiscus laevigatus*, *H. montanus*, *Ischyrolepis capensis*, *I. sieberi*, *Mastersiella purpurea*, *Pentameris macrocalycina*, *Pentaschistis malouinensis*, *Restio peculiaris*, *R. stric-*

L. Mucina

Figure 4.37 FFs 15 North Langeberg Sandstone Fynbos: Dry proteoid fynbos dominated by *Protea punctata* on upper slopes of the Langeberg facing the Koo, west of Montagu (Western Cape).

tus, *R. triticeus*, *Rhodocoma fruticosa*, *Tetraria involucrata*, *T. thermalis*, *Thamnochortus cinereus*.

Endemic Taxa (W Wetlands) Low Shrubs: *Serruria balanocephala* (d), *Acmadenia latifolia*, *A. nivenii*, *A. trigona*, *Amphithalea cymbifolia*, *Anderbergia fallax*, *Aspalathus longifolia*, *A. verbasciformis*, *Cliffortia alata*, *C. pulchella*, *Clutia govaertsii*, *Erica atropurpurea* W, *E. barrydalensis*, *E. chlorosepala*, *E. gigantea*, *E. langebergensis*, *E. leucodesmia*, *E. rhodantha*, *E. rudolfii*, *Felicia cana*, *F. comptonii*, *Leucospermum erubescens*, *L. saxatile*, *Lobostemon muirii*, *Lotononis purpurescens*, *Metalasia galpinii*, *Paranomus spathulatus*, *Pelargonium denticulatum*, *Phylica brachycephala*, *P. mairei*, *Polygala langebergensis*, *Prismatocarpus lasiophyllus*, *Protea holosericea*, *Wahlenbergia fruticosa*, *W. oligantha*. Succulent Shrubs: *Antimima verrucosula*, *Drosanthemum croceum*, *Erepsia polita*, *Lampranthus laetus*, *L. marcidulus*, *L. verecundus*. Geophytic Herbs: *Disa schlechteriana*, *Ixia stolonifera*. Graminoids: *Platycaulos acutus*, *Restio implicatus*, *R. perseverans*, *Thamnochortus amoena*, *T. ellipticus*, *T. karooica*.

Conservation Least threatened. Target 30%. Statutorily conserved (13%) in the Boosmansbos Wilderness Area, with an additional 45% in mountain catchment areas such as Langeberg-oos, Langeberg-wes and Matroosberg. Some 8% transformed (cultivation). Aliens include *Pinus pinaster*, *Hakea sericea* and *Acacia mearnsii*. Erosion very low and moderate.

Remark 1 The eastern boundary of North Langeberg Sandstone Fynbos has been set at Cloete's Pass, but could equally well have been set at Robinson Pass. The area between the Robinson and Cloete's Passes has at least two near endemic Proteaceae (*Leucospermum saxatile, Paranomus longicaulis*), which extend west of the Gouritz River gap. More data are needed to determine an optimal boundary between the North Langeberg Sandstone Fynbos and FFs 18 North Outeniqua Sandstone Fynbos based on species distributions and associated vegetation patterns.

Remark 2 The coastal range of the Aasvoëlberg, although isolated, clearly fits within FFs 15 North Langeberg Sandstone Fynbos. However, we have tentatively included the southern slopes of the Aasvoëlberg within this unit, pending further investigation.

References Muir (1929), McDonald (1993a, b, c, 1995, 1999), McDonald et al. (1995, 1996).

FFs 16 South Langeberg Sandstone Fynbos

VT 70 False Macchia (51%), VT 69 Macchia (26%) (Acocks 1953). Mesic Mountain Fynbos (61%), Dry Mountain Fynbos (24%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (89%) (Low & Rebelo 1996). BHU 64 Southern Langeberg Mountain Fynbos Complex (56%), BHU 64 Koo Langeberg Mountain Fynbos Complex (30%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Southern slopes of the Langeberg from the Keerom Mountains near Worcester to Cloete's Pass north of Albertinia, Waboomsberg (north of Montagu), Warmwaterberg (north of Barrydale) and Amandelbosberg (northeast of Heidelberg) Mountains. Altitude 200–1 800 m with several high peaks such as Misty Point (1 709 m) and Grootberg (1 637 m), generally higher in the west than the east. FFs 30 Western Altimontane Sandstone Fynbos on the western peaks above 1 800 m.

Vegetation & Landscape Features Complex of gentle to very steep, south-facing slopes, not much dissected over most of the range, but deeply dissected in parts. The Cedarberg Shale Band is prominent in the east, in an almost vertical orientation, as a narrow, smooth-sided valley along which the hiking trails are orientated. Ericaceous and restioid fynbos predominate at higher altitudes, with moderately tall to tall proteoid fynbos on middle and lower slopes. Scrub and restioid fynbos are found in habitats with much groundwater.

Figure 4.38 FFs 16 South Langeberg Sandstone Fynbos: Proteoid fynbos with *Leucadendron eucalyptifolium* and *Erica melanthera* dominant in a seep on top of the Tradouw Pass in the Langeberg (Western Cape).

Geology & Soils Acidic lithosol soils derived from Ordovician sandstones of the Table Mountain Group (Cape Supergroup). Land types mainly Ib and Ic.

Climate MAP 320–1 440 mm (mean: 675 mm), peaking very slightly in winter and with a slight low from December to February. Southeasterly cloud brings heavy mist precipitation at higher altitudes in summer. Mean daily maximum and minimum temperatures 26.6°C and 4.0°C for January and July, respectively. Frost incidence 3–20 days per year. See also climate diagram for FFs 16 South Langeberg Sandstone Fynbos (Figure 4.21).

Important Taxa (W Wetlands) Small Trees: *Protea nitida* (d), *Widdringtonia nodiflora* (d). Tall Shrubs: *Cliffortia grandifolia* (d), *Leucadendron eucalyptifolium* (d), *Protea eximia* (d), *Psoralea pinnata* W (d), *Aspalathus willdenowiana*, *Euryops abrotanifolius*, *Leucospermum formosum*, *Podalyria calyptrata*. Low Shrubs: *Berzelia galpinii* W (d), *B. intermedia* (d), *Brunia alopecuroides* W (d), *Erica hispidula* (d), *E. longimontana* (d), *E. melanthera* (d), *Grubbia rosmarinifolia* (d), *Leucadendron salignum* (d), *L. spis-*

sifolium subsp. *spissifolium* (d), *Penaea cneorum* subsp. *ruscifolia* (d), *P. mucronata* (d), *Acmadenia matroosbergensis*, *A. tetragona*, *Anthospermum aethiopicum*, *Aspalathus angustifolia* subsp. *angustifolia*, *A. ciliaris*, *A. diffusa*, *A. grandiflora*, *A. inops*, *A. nigra*, *A. securifolia*, *A. stenophylla*, *A. vulpina*, *Asparagus rubicundus*, *Clutia laxa*, *Erica albens*, *E. cerinthoides* var. *cerinthoides*, *E. conferta*, *E. cordata*, *E. cubica*, *E. curviflora*[W], *E. cymosa* subsp. *grandiflora*, *E. daphniflora*, *E. glandulosa*, *E. multumbellifera*, *E. nematophylla*, *E. regerminans*, *E. tenuis*, *E. transparens*, *E. versicolor*, *E. vestita*, *Indigofera concava*, *Lachnaea penicillata*, *Leucadendron tinctum, Linconia alopecuroidea*, *Lobelia coronopifolia*, *Mimetes cucullatus*, *Paranomus candicans*, *Pelargonium candicans*, *Protea cynaroides*, *P. rupicola*, *P. speciosa*, *Raspalia virgata*, *Syncarpha eximia*, *S. vestita*, *Ursinia coronopifolia*[W], *U. hispida*, *U. scariosa* subsp. *subhirsuta*, *U. trifida*, *Zyrphelis microcephala*. Succulent Shrub: *Othonna quinquedentata*. Herbs: *Edmondia sesamoides* (d), *Carpacoce spermacocea*, *Chironia jasminoides*, *Helichrysum capense*, *H. crispum*, *Lobelia pubescens* var. *rotundifolia*, *Mairia hirsuta*, *Pseudoselago serrata*, *Senecio hastatus*. Geophytic Herbs: *Lanaria lanata* (d), *Blechnum tabulare*, *Geissorhiza burchellii*, *G. fourcadei*, *G. inconspicua*. Herbaceous Climber: *Cyphia zeyheriana*. Graminoids: *Anthochortus crinalis* (d), *Ehrharta dura* (d), *E. setacea* subsp. *scabra* (d), *Elegia asperiflora* (d), *E. filacea* (d), *E. juncea* (d), *Hypodiscus aristatus* (d), *Pentameris macrocalycina* (d), *Pentaschistis colorata* (d), *P. malouinensis* (d), *Platycaulos anceps* (d), *P. compressus* (d), *Restio inconspicuus* (d), *R. triticeus* (d), *Staberoha cernua* (d), *Tetraria bromoides* (d), *T. cuspidata* (d), *T. flexuosa* (d), *T. ustulata* (d), *Themeda triandra* (d), *Calopsis filiformis*, *Chrysitrix capensis*, *Cymbopogon marginatus*, *Elegia mucronata*, *E. stokoei*, *Eragrostis capensis*, *Hypodiscus montanus*, *Restio peculiaris*, *R. strictus*.

Endemic Taxa ([W]Wetlands) Tall Shrub: *Cliffortia densa*. Low Shrubs: *Erica blenna* var. *blenna* (d), *Spatalla parilis*[W] (d), *Acmadenia burchellii*, *Adenandra fragrans*, *Agathosma linifolia*, *A. subteretifolia*, *A. umbonata*, *Amphithalea bullata*, *A. dahlgrenii*, *Anderbergia elsiae*, *A. ustulata*, *A. vlokii*, *Anisothrix kuntzei*, *Aspalathus cordicarpa*, *A. hypnoides*, *A. shawii* subsp. *glabripetala*, *Athanasia inopinata*, *Berzelia burchellii*, *Carpacoce gigantea*, *Cliffortia lanceolata*, *Coleonema pulchrum*, *C. virgatum, Elytropappus* sp. nov. ('*monticola*'), *Empleurum fragrans*[W], *Erica albescens*, *E. amicorum*[W], *E. ardens*, *E. blenna* var. *grandiflora*, *E. bracteolaris*, *E. chartacea*, *E. comata*, *E. condensata*, *E. crassisepala*, *E. cubitans*, *E. dysantha*, *E. elsieana*, *E. garciae*, *E. grata*, *E. heleophila*, *E. inclusa*, *E. ixanthera*, *E. keeromsbergensis*, *E. macilenta*, *E. macrophylla*, *E. miniscula*, *E. obconica*, *E. ocellata*, *E. omninoglabra*, *E. oophylla*, *E. oxyandra*, *E. papyracea*, *E. parviporandra*, *E. podophylla*, *E. polifolia*, *E. procaviana*, *E. racemosa*, *E. stenantha*, *E. tetrathecoides*[W], *E. tradouwensis*, *E. vallisfluminis*, *E. winteri*, *Euchaetis avisylvana*, *Gymnostephium fruticosum*, *Helichrysum plebeium*, *Hippia hutchinsonii*, *Indigofera langebergensis*, *Kogelbergia phylicoides*, *Lachnaea ericoides*, *L. oliverorum*, *L. stokoei*, *Langebergia canescens*, *Lebeckia leptophylla*, *Leucadendron radiatum*, *L. tradouwense*, *Leucospermum winteri*, *Metalasia oligocephala*, *Mniothamnea bullata*, *M. callunoides*, *Muraltia langebergensis*, *Oedera laevis*, *Osteospermum burttianum*, *O. pyrifolium*, *Otholobium bowieanum*, *O. saxosum*, *Penaea dahlgrenii*, *Phylica lasiantha*, *P. longimontana*, *P. propinqua*, *P. recurvifolia*, *Raspalia barnardii*, *Spatalla colorata*, *S. nubicola*[W], *Stilbe gymnopharyngia*, *Stylapterus dubius*, *S. ericifolius*, *Thamnea gracilis*. Succulent Shrubs: *Drosanthemum acuminatum*, *D. subcompressum*, *Erepsia pentagona*, *Lampranthus hallii*, *L. laxifolius*. Semiparasitic Shrub: *Thesium susannae*. Herbs: *Aster bowiei*, *Galium undulatum*, *Lobelia dasyphylla*, *L. hypsibata*, *L. muscoides*, *Lyperia formosa, Mairia* sp. nov. ('*petiolaris*'), *Sebaea laxa*, *Sutera langebergensis*, *Wahlenbergia riversdalensis*, *Wimmerella longitubus*. Geophytic Herbs: *Bobartia macrospatha* subsp. *anceps*, *B. parva*, *Disa aurata*, *D. cardinalis*[W], *D. subtenuicornis*, *Geissoloma marginatum*, *Gladiolus crispulatus*, *Ixia stohriae*, *Lachenalia leomontana*, *Pachites appressa*. Graminoids: *Restio arcuatus* (d), *Calopsis monostylis*, *Ceratocaryum fistulosum*, *Ischyrolepis affinis*, *Restio fragilis*, *R. secundus*.

Conservation Least threatened. Target 30%. Statutorily conserved (23%) in the Marloth Nature Reserve and Boosmansbos Wilderness Area. An additional 54% enjoys protection in mountain catchment areas such as Langeberg-wes, Langeberg-oos and Matroosberg. Only 3% transformed (pine plantations, cultivation). Alien *Pinus pinaster*, *Hakea sericea* and *Acacia mearnsii* are found in places. Erosion very low and moderate.

Remark 1 Fire-safe kloofs support afrotemperate forest, with the westernmost extent of large forests at Grootvadersbos. There are indications that the MAP modelled in parts of this unit is an underestimate.

Remark 2 There are insufficient data to determine whether the Keerom Mountains (north and west of the Nuy Valley) should be grouped with FFs 8 South Hex Sandstone Fynbos or with this unit. Protea Atlas data suggest strong links to the Hex unit.

Remark 3 We have assumed that the eastern boundary of FFs 16 South Langeberg Sandstone Fynbos is at Cloete's Pass, based on FFs 15 North Langeberg Sandstone Fynbos. However, this assumption may not be valid, and more data are needed to determine an optimal boundary with FFs 19 South Outeniqua Sandstone Fynbos based on species distributions and associated vegetation patterns.

References Muir (1929), Kruger (1979), Rebelo et al. (1991), McDonald (1993a, b, c, 1995, 1999), McDonald et al. (1995, 1996).

FFs 17 Potberg Sandstone Fynbos

VT 47 Coastal Macchia (97%) (Acocks 1953). Mesic Mountain Fynbos (84%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (85%) (Low & Rebelo 1996). BHU 65 Potberg Mountain Fynbos Complex (84%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Mainly on the inselberg-like Potberg Mountain south of the lower Breede River to Melkhoutrivier, with an extension on to the flats towards Noetsie and an outlier on the coastal flats at Infanta. Altitude from the coast to 611 m on the highest peak of Potberg.

Vegetation & Landscape Features Prolonged, moderately steep sandstone coastal inselberg supporting moderately tall, dense restioid, ericoid-leaved and mainly proteoid shrublands. Proteoid and restioid fynbos predominate, other structural types are rare. Deeper kloofs support broad-leaved Cape thicket.

Geology & Soils Acidic lithosol soils derived from Ordovician sandstones of the Table Mountain Group (Cape Supergroup), Glenrosa and Mispah forms are prominent. Land types mainly Ic, Ib and Fb.

Climate MAP 410–550 mm (mean: 500 mm), fairly evenly throughout the year, but with a low from December to February. Mists covering the ridge are common in summer. Mean daily maximum and minimum temperatures 25.7°C and 6.1°C for January and July, respectively. Frost incidence 2 or 3 days per year. See also climate diagram for FFs 17 Potberg Sandstone Fynbos (Figure 4.21).

Important Taxa ([T]Cape thickets) Tall Shrubs: *Protea neriifolia* (d), *P. repens* (d), *Leucadendron eucalyptifolium* (d), *Aloe arborescens*[T], *Diospyros dichrophylla*[T], *Euclea polyandra*[T], *Euryops*

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Figure 4.39 FFs 17 Potberg Sandstone Fynbos: Proteoid fynbos with *Leucadendron xanthoconus* and *Protea neriifolia* on the slopes of the Potberg—a sandstone inselberg in the southeastern Overberg (Western Cape).

linearis, *Podalyria calyptrata*, *Psoralea aphylla*. Low Shrubs: *Leucadendron salignum* (d), *L. xanthoconus* (d), *Aspalathus aspalathoides*, *A. caledonensis*, *A. ciliaris*, *A. incurvifolia*, *Aulax umbellata*, *Erica coccinea* subsp. *uniflora*, *E. plukenetii* subsp. *bredensis*, *Indigofera angustifolia*, *Leucospermum calligerum*, *L. cuneiforme*, *L. utriculosum* (Potberg form), *Mimetes cucullatus*, *Nebelia paleacea*, *Oedera capensis*, *Paranomus abrotanifolius*, *Penaea mucronata*, *Phaenocoma prolifera*, *Polygala pottebergensis*, *Protea cynaroides*, *Roella incurva*, *Senecio paniculatus*, *Serruria acrocarpa*, *S. fasciflora*. Geophytic Herbs: *Acrolophia ustulata*, *Geissorhiza hispidula*, *Ornithogalum dubium*. Graminoids: *Ficinia zeyheri*, *Staberoha cernua.*

Endemic Taxa Tall Shrub: *Protea aurea* subsp. *potbergensis*. Low Shrubs: *Adenandra gummifera*, *Aspalathus potbergensis*, *Cliffortia incana*, *Muraltia pottebergensis*, *Prismatocarpus spinosus*, *Protea denticulata*, *Selago neglecta*. Herb: *Centella pottebergensis*. Geophytic Herb: *Bobartia longicyma* subsp. *microflora*.

Conservation Least threatened. Target 30%. Statutorily conserved (49%) in De Hoop Nature Reserve, with an additional 2% in the San Sebastian Private Nature Reserve. Only 5% transformed (cultivation). Aliens *Acacia cyclops* and *Eucalyptus* species occur in places. Erosion very low.

Remarks This is a very poorly explored unit from a vegetation-ecological point of view. Potberg Sandstone Fynbos has floristic links to both Langeberg (to the north), generally the higher altitude species, and to the Overberg sandstone mountains (to the west).

References C. Burgers (unpublished data), L. Mucina (unpublished data).

FFs 18 North Outeniqua Sandstone Fynbos

VT 70 False Macchia (67%), VT 43 Mountain Renosterbosveld (29%) (Acocks 1953). Dry Mountain Fynbos (48%), Mesic Mountain Fynbos (22%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (74%) (Low & Rebelo 1996). BHU 69 Outeniqua Mountain Fynbos Complex (71%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Northern slopes of the Outeniqua Mountains from the Cloetesberg northeast of Albertinia in the west to Vlug se Berg south of Uniondale in the east, and eastwards along the low range north of the N9 road. Altitude 300–1 579 m on Cradock's Berg north of George.

Vegetation & Landscape Features Gentle to steep north-facing slopes, with some intramontane valleys over a 135 km long area. Vegetation is a tall, open to medium dense shrubland with medium dense, medium tall shrub or restioid understorey with scattered, emergent, tall Proteaceae shrubs. Restioid and proteoid fynbos is the dominant vegetation-structural feature of the Outeniqua landscapes, with ericaceous and asteraceous fynbos becoming widespread at higher and lower altitudes, respectively. The lower boundary north of the N9 road becomes more arid as asteraceous fynbos approaches renosterveld. The old African surface conglomerates that occur on the northern slopes, especially west of Robinson Pass—and are mapped as part of this unit—are covered with *Dodonaea*-dominated asteraceous fynbos.

Geology & Soils Acidic lithosol soils (Glenrosa and Mispah forms prominent) derived from Ordovician sandstones of the

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Figure 4.40 FFs 18 North Outeniqua Sandstone Fynbos: Ericaceous fynbos with *Erica discolor* var. *hebecalyx* and proteoid fynbos (dominated by *Leucadendron salignum*) on the northern slopes of the Outeniqua Mountains, north of George (Western Cape).

Table Mountain Group (Cape Supergroup). Land types mainly Ib and Fc.

Climate MAP 240–950 mm (mean: 520 mm), evenly throughout the year. Mean daily maximum and minimum temperatures 29.2°C and 3.9°C for January and July, respectively. Frost incidence varies around 10 days per year. See also climate diagram for FFs 18 North Outeniqua Sandstone Fynbos (Figure 4.21).

Important Taxa ([W]Wetlands) Small Tree: *Protea nitida* (d). Tall Shrubs: *Aspalathus sceptrum-aureum*, *Chrysanthemoides monilifera*, *Leucadendron eucalyptifolium*, *Protea neriifolia*. Low Shrubs: *Erica brachycentra* (d), *Leucadendron salignum* (d), *Phylica axillaris* (d), *Acmadenia tetragona*, *Agathosma recurvifolia*, *Aspalathus granulata*, *Cliffortia ilicifolia*, *C. stricta, Diosma apetala*, *Elytropappus adpressus*, *E. gnaphaloides*, *Erica rosacea* subsp. *rosacea*, *E. uberiflora*, *Felicia filifolia* subsp. *filifolia*, *Leucospermum cuneiforme*, *Metalasia pulcherrima* f. *pallescens, Paranomus dispersus*, *Passerina obtusifolia*, *Stoebe capitata*, *Zygophyllum maculatum*. Geophytic Herbs: *Lanaria lanata* (d), *Geissorhiza roseoalba*, *Romulea jugicola*[W]. Graminoids: *Heteropogon contortus* (d), *Hypodiscus striatus* (d), *Pentaschistis eriostoma* (d), *Tetraria cuspidata* (d), *Aristida diffusa*, *Brachiaria serrata*, *Cannomois parviflora*, *Elegia galpinii*, *Mastersiella purpurea*, *Merxmuellera decora*, *Restio triticeus*, *Rhodocoma fruticosa*, *Themeda triandra*.

Endemic Taxa Tall Shrub: *Paranomus longicaulis*. Low Shrubs: *Aspalathus glabrescens*, *A. pedunculata*, *Erica croceovirens*, *E. inflaticalyx*, *E. solandra*, *E. zebrensis*, *Rafnia vlokii*. Geophytic Herb: *Oxalis attaquana*. Succulent Herb: *Haworthia outeniquensis*.

Conservation Least threatened. Target 23%. Statutorily conserved (11%) in the Doringrivier, Ruitersbos and Witfontein Nature Reserves. Some 14% transformed (cultivation). Alien *Hakea sericea* and *Pinus pinaster* scattered over part of the area. Erosion very low and low.

Remarks The western boundary of this unit is discussed under FFs 15 North Langeberg Sandstone Fynbos. The eastern boundary is also more of a transition zone and is somewhat arbitrary in its easternmost extremes. It could be located somewhere between Dieprivier (selected herein) and Prince Alfred's Pass, and can be refined only when sufficient distributional data become available.

Reference Bond (1981).

Figure 4.41 FFs 19 South Outeniqua Sandstone Fynbos: Slopes of deep valleys north of George clad in dense species-rich ericaceous fynbos and remnants of afrotemperate forests on the Outeniqua Mountains, north of George (Western Cape).

FFs 19 South Outeniqua Sandstone Fynbos

VT 4 Knysna Forest (80%), VT 70 False Macchia (18%) (Acocks 1953). Wet Mountain Fynbos (48%), Mesic Mountain Fynbos (32%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (78%) (Low & Rebelo 1996). BHU 69 Outeniqua Mountain Fynbos Complex (54%), BHU 71 Tsitsikamma Mountain Fynbos Complex (23%), BHU 100 Knysna Afromontane Forest (17%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Southern slopes of the Outeniqua Mountains from the Cloetesberg northeast of Albertinia in the west to the upper reaches of the Keurbooms River where it borders on FFs 20 Tsitsikamma Sandstone Fynbos. It includes sandstone outcrops on the lowlands from the vicinity of the Goukamma River near Knysna in the west and Komkromma Point near Nature's Valley in the east. Altitude from the coast to 1 579 m on Cradock's Berg north of George.

Vegetation & Landscape Features Gentle to steep south-facing slopes, over a 160 km long area, relatively broad with some moderately sloping intramontane valleys in the west where it is over 10 km wide. The dominant vegetation is a tall, open to medium dense shrubland with medium dense, medium tall shrub understorey—mainly proteoid and restioid fynbos, with extensive ericaceous fynbos on the upper slopes. Some grassy fynbos at lower altitudes, and scrub fynbos in riverine areas. Patches of this unit are not confined to south-facing slopes, but are found on all slopes south of the highest peaks in the range. Thus there are extensive northern slopes in some intramontane valley systems, the most significant of those found in the Doring River Wilderness Area.

Geology & Soils Acidic lithosol soils derived from Ordovician sandstones of the Table Mountain Group (Cape Supergroup). Land types mainly Ib, Gb and Fa.

Climate MAP 360–1 170 mm (mean: 785 mm), with a slight bimodal winter and a low in December. Mean daily maximum and minimum temperatures 27.8°C and 4.8°C for January and July, respectively. Frost incidence 2–10 days per year. See also climate diagram for FFs 19 South Outeniqua Sandstone Fynbos (Figure 4.21).

Important Taxa ([T]Cape thickets, [W]Wetlands) Small Tree: *Widdringtonia nodiflora*. Tall Shrubs: *Chrysanthemoides monilifera* (d), *Laurophyllus capensis*[T] (d), *Leucadendron conicum* (d), *L. eucalyptifolium* (d), *L. uliginosum* subsp. *uliginosum* (d), *Metalasia densa* (d), *Protea neriifolia* (d), *P. repens* (d), *Anginon difforme*, *Dodonaea viscosa* var. *angustifolia*, *Halleria lucida*[T], *Leucospermum glabrum*, *Liparia hirsuta*, *Metalasia trivialis*, *Mimetes pauciflorus*, *Osteospermum junceum*, *Passerina falcifolia*, *Podalyria burchellii*, *P. sericea*, *Protea mundii*, *Psoralea affinis*, *Pterocelastrus tricuspidatus*[T]. Low Shrubs: *Berzelia intermedia* (d), *Brunia nodiflora* (d), *Erica cordata* (d), *E. densifolia* (d), *E. glomiflora* (d), *E. triceps* (d), *E. uberiflora* (d), *Leucadendron ericifolium* (d), *Penaea cneorum* subsp. *cneorum* (d), *P. cneorum* subsp. *gigantea* (d), *Acmadenia maculata*, *A. tetragona*, *Anisodontea scabrosa*, *Aspalathus angustifolia* subsp. *angustifolia*, *A. ciliaris*, *A. rubens*, *Cliffortia ilicifolia*, *C. stricta*, *Erica deflexa*, *E. dis-*

color variant '*speciosa*', *E. formosa*, *E. fuscescens*, *E. gracilis*, *E. hispidula*, *E. lanata*, *E. nabea*, *E. similis*, *E. simulans*, *E. sparsa*, *E. versicolor*, *Euryops pinnatipartitus*, *Lachnaea diosmoides*, *Leucadendron comosum* subsp. *comosum*, *L. salignum*, *L. spissifolium* subsp. *fragrans*, *Leucospermum cuneiforme*, *L. wittebergense*, *Linconia alopecuroidea*, *Lobelia neglecta*, *Mimetes cucullatus*, *Otholobium carneum*, *Phaenocoma prolifera*, *Phylica confusa*, *Protea cynaroides*, *P. lorifolia*, *Pseudobaeckea cordata*, *Relhania calycina*, *Senecio glastifolius*, *Stoebe alopecuroides*, *Struthiola eckloniana*, *Syncarpha paniculata*, *Ursinia coronopifolia*, *U. scariosa* subsp. *scariosa*, *U. trifida*. Semiparasitic Shrub: *Thesium virgatum*. Herbs: *Carpacoce spermacocea*, *Centella affinis*, *C. virgata*, *Dichrocephala integrifolia* subsp. *integrifolia*, *Helichrysum felinum*, *Mairia crenata*. Geophytic Herbs: *Pteridium aquilinum* (d), *Blechnum attenuatum*, *Caesia contorta*, *Geissorhiza bracteata*, *G. fourcadei*, *G. inconspicua*, *Lanaria lanata*, *Romulea fibrosa*, *Tritoniopsis caffra*, *Watsonia fourcadei*. Carnivorous Herb: *Drosera trinervia*[W]. Herbaceous Parasitic Climber: *Cassytha ciliolata*. Graminoids: *Cannomois parviflora* (d), *C. virgata* (d), *Ehrharta dura* (d), *E. rupestris* subsp. *tricostata* (d), *Elegia fistulosa* (d), *E. galpinii* (d), *E. juncea* (d), *Epischoenus adnatus* (d), *Hypodiscus albo-aristatus* (d), *H. aristatus* (d), *H. striatus* (d), *H. synchroolepis* (d), *Ischyrolepis gaudichaudiana* (d), *Merxmuellera rufa* (d), *Pentameris distichophylla* (d), *Platycaulos anceps* (d), *P. compressus* (d), *Restio fourcadei* (d), *R. triticeus* (d), *Rhodocoma gigantea*[W] (d), *Tetraria cuspidata* (d), *T. involucrata* (d), *T. microstachys* (d), *Andropogon appendiculatus*, *Anthochortus ecklonii*, *Cannomois scirpoides*, *Capeobolus brevicaulis*, *Chrysitrix capensis*, *Cyathocoma hexandra*[W], *Ficinia gracilis*, *Mastersiella purpurea*, *Merxmuellera decora*, *Pentaschistis colorata*, *P. malouinensis*, *P. pallida*, *Restio strictus*, *Staberoha aemula*, *Tetraria capillacea*, *T. fimbriolata*, *T. sylvatica*, *T. thermalis*, *T. ustulata*, *Thamnochortus cinereus*, *Themeda triandra*, *Willdenowia teres*.

Endemic Taxa ([W]Wetlands) Low Shrubs: *Erica unicolor* (d), *Penaea acutifolia* (d), *Acmadenia gracilis*, *A. rupicola*, *Agathosma alaris*, *A. planifolia*, *Amphithalea flava*, *Aspalathus bowieana*, *A. digitifolia*, *Erica aneimena*, *E. gillii*, *E. inconstans*, *E. juniperina*, *E. lehmannii*, *E. outeniquae*, *E. priorii*, *E. velatiflora*, *Leucadendron olens*, *Leucospermum hamatum*, *Phylica curvifolia*, *Prismatocarpus rogersii*, *Psoralea vlokii*, *Xiphotheca phylicoides*, *Zyrphelis outeniquae*. Succulent Shrub: *Lampranthus pauciflorus*. Herb: *Linum villosum*. Geophytic Herb: *Geissorhiza outeniquensis*[W].

Conservation Vulnerable. Target 23%. Statutorily conserved (47%) in the proposed Garden Route National Park, Doring River Wilderness Area as well as in Ruitersbos and Witfontein Nature Reserves. About 2% protected in private nature reserves. Some 28% transformed (pine plantations, cultivation). Alien *Pinus pinaster* and *Hakea sericea* scattered over part of the area. Erosion very low.

Remarks The western boundaries of this unit are discussed under FFs 16 South Langeberg Sandstone Fynbos. The Cedarberg Shale Bands were not adequately mapped within this unit due to a lack of proper geological coverage. The eastern boundary is also more of a transition zone and is somewhat arbitrarily taken as approximating the Keurbooms River (for the mountain section). It can be refined when sufficient distributional data become available.

References Bond (1978b, 1981), Cameron (1980), Van Daalen (1984), Vermeulen (1995).

FFs 20 Tsitsikamma Sandstone Fynbos

VT 4 Knysna Forest (58%), VT 70 False Macchia (42%) (Acocks 1953). Wet Mountain Fynbos (33%), Mesic Mountain Fynbos (21%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (54%) (Low & Rebelo 1996). BHU 71 Tsitsikamma Mountain Fynbos Complex (49%), BHU 100 Knysna Afromontane Forest (19%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western and Eastern Cape Provinces: Tsitsikamma Mountains from Uniondale to Cape St Francis, north of the Keurbooms River and south of Langkloof. Altitude 100–1 675 m (at the highest Peak Formosa).

Vegetation & Landscape Features A relatively low mountain range with gentle to steep both northern and southern slopes over 140 km, with a few high peaks and moderately undulating plains. Relatively broad compared to the other coastal mountain ranges varying from 10–20 km in width. Vegetation is a medium dense, tall proteoid shrubland over a dense moderately tall, ericoid-leaved shrubland—mainly proteoid, restioid and ericoid fynbos, with fynbos thicket in wetter areas.

Geology & Soils Acidic lithosol soils derived from Ordovician sandstones of the Table Mountain Group (Cape Supergroup), plinthic catenas prominent. Land types mainly Ib, Ca and Bb.

Climate MAP 480–1 230 mm (mean: 845 mm), fairly even throughout the year. Mean daily maximum and minimum temperatures 25.5°C and 5.8°C for February and July, respectively. Frost incidence 2–10 days per year. See also climate diagram for FFs 20 Tsitsikamma Sandstone Fynbos (Figure 4.21).

Important Taxa ([T]Cape thickets) Tall Shrubs: *Cliffortia serpyllifolia* (d), *Leucadendron conicum* (d), *L. eucalyptifolium* (d), *L. uliginosum* subsp. *glabratum*, *Leucospermum glabrum*, *Metalasia densa*, *M. trivialis*, *Mimetes pauciflorus*, *Passerina corymbosa*, *P. falcifolia*, *Protea eximia*, *P. mundii*, *P. neriifolia*,

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Figure 4.42 FFs 20 Tsitsikamma Sandstone Fynbos: Wet proteoid fynbos with dominant *Leucadendron* and abundant *Erica* on the south-facing slopes of the Tsitsikamma Mountains.

Pterocelastrus tricuspidatus[T]. Low Shrubs: *Erica discolor* variant '*speciosa*' (d), *E. sparsa* (d), *Ursinia scariosa* subsp. *scariosa* (d), *Agathosma ovata*, *Anisodontea scabrosa*, *Aspalathus ciliaris*, *Berzelia intermedia*, *Carpacoce vaginellata*, *Erica diaphana*, *E. glandulosa*, *E. rosacea* subsp. *rosacea*, *E. uberiflora*, *Euryops munitus*, *E. pinnatipartitus*, *Helichrysum teretifolium*, *Indigofera flabellata*, *Leucadendron salignum*, *L. spissifolium* subsp. *phillipsii*, *Leucospermum cuneiforme*, *Metalasia pulcherrima* f. *pallescens*, *Otholobium carneum*, *Passerina pendula*, *Penaea cneorum* subsp. *gigantea*, *Phylica axillaris*, *P. imberbis*, *Protea cynaroides*, *Stoebe plumosa*. Herbs: *Commelina africana*, *Gazania krebsiana* subsp. *krebsiana*. Geophytic Herbs: *Geissorhiza fourcadei*, *G. inconspicua*, *Romulea pratensis*. Graminoids: *Restio triticeus* (d), *Tetraria capillacea* (d), *Diheteropogon filifolius*, *Elegia juncea*, *Epischoenus adnatus*, *Heteropogon contortus*, *Hypodiscus synchroolepis*, *Tetraria robusta*, *Thamnochortus fruticosus*, *T. glaber*, *Themeda triandra*, *Tristachya leucothrix*.

Endemic Taxa Low Shrubs: *Aspalathus teres* subsp. *thodei*, *Erica trachysantha*, *E. zitzikammensis*, *Felicia tsitsikamae*, *Helichrysum outeniquense*.

Conservation Vulnerable. Target 23%. Statutorily conserved (about 40%) in the proposed Garden Route National Park (including Tsitsikamma and Soetkraal). Some 33% transformed (cultivation, pine plantations). With scattered alien *Pinus pinaster* and *Hakea sericea*. Erosion very low.

Remark 1 Wetter habitats, especially in berg wind shadows east of dissected valleys, support afrotemperate forests. Most of the bigger patches of the forest are positioned on and around the shales of the Gydo Formation.

Remark 2 The coastal strip contains a narrow shoreward band of dune fynbos communities that were not mapped, but included within this unit.

References Bond (1978a), Cowling (1984), Bond et al. (1988), Hanekom et al. (1989).

FFs 21 North Rooiberg Sandstone Fynbos

VT 70 False Macchia (73%), VT 25 Succulent Mountain Scrub (Spekboomveld) (27%) (Acocks 1953). Dry Mountain Fynbos (84%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (92%) (Low & Rebelo 1996). BHU 67 Rooiberg Mountain Fynbos Complex (95%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Northern slopes of the mountains of Rooiberg, Gamka and the Amalienstein Ridge-Sandberg-Bakenkop range. Altitude 500–1 490 m on the summit of Rooiberg.

Vegetation & Landscape Features Systems of gentle to steep north-facing slopes, deeply dissected in parts. The Cedarberg Shale Band is prominent in parts. Vegetation is mainly asteraceous (lowest slopes), proteoid and restioid fynbos. Proteoid overstorey often found over restioid shrubland.

Geology & Soils Acidic lithosol soils derived from Ordovician sandstones of the Table Mountain Group (Cape Supergroup). Land types mainly Ic.

Climate MAP 160–710 mm (mean: 330 mm), with no prominent peak, but a low from December to February. Mean daily maximum and minimum temperatures 29.7°C and 3.0°C for January and July, respectively. Frost incidence 10–20 days per year. See also climate diagram for FFs 21 North Rooiberg Sandstone Fynbos (Figure 4.21).

Important Taxa ([T]Cape thickets) Small Tree: *Protea nitida* (d). Tall Shrubs: *Passerina corymbosa* (d), *Protea repens* (d), *Diospyros dichrophylla*[T], *Leucadendron rubrum*, *Leucospermum pluridens*, *Protea eximia*. Low Shrubs: *Agathosma ovalifolia* (d), *Elytropappus rhinocerotis* (d), *Leucadendron salignum* (d), *Phylica purpurea* (d), *Protea lorifolia* (d), *Syncarpha paniculata* (d), *Anthospermum aethiopicum*, *Aspalathus granulata*, *A. rubens*, *Cullumia bisulca*, *Dolichothrix ericoides*, *Elytropappus glandulosus*, *Euryops erectus*, *Felicia filifolia* subsp. *filifolia*, *Leucospermum wittebergense*, *Lobelia coronopifolia*, *Metalasia pallida, Oedera squarrosa*, *Paranomus dispersus*, *Pelargonium tricolor*, *Phylica rigidifolia*, *Struthiola martiana*, *Ursinia heterodonta*, *Wahlenbergia neorigida*. Herbs: *Centella virgata* (d), *Gazania linearis*. Geophytic Herb: *Geissorhiza roseoalba*. Graminoids: *Ehrharta ramosa* subsp. *aphylla* (d), *Hypodiscus striatus* (d), *Ischyrolepis capensis* (d), *Mastersiella purpurea* (d), *Merxmuellera arundinacea* (d), *Pentaschistis eriostoma* (d), *Rhodocoma fruticosa* (d), *Tetraria ustulata* (d), *Thamnochortus cinereus* (d), *Ehrharta calycina*, *Elegia galpinii*, *Pentaschistis colorata*, *Tetraria exilis*.

Endemic Taxa Tall Shrubs: *Freylinia vlokii*, *Paranomus roodebergensis*. Low Shrub: *Lotononis dahlgrenii*.

Conservation Least Threatened. Target 27%. Statutorily conserved (33%) in the Gamkaberg, Groenefontein and Rooiberg Nature Reserves, with an additional 25% protected in Rooiberg Mountain Catchment Area. No transformation recorded and aliens *Pinus halepensis* and *Hakea sericea* are rare. Erosion very low and low.

Remarks Arid lower slopes at the bottom margin of fynbos give way to karoo shrublands and spekboomveld, the boundary being a fire-maintained mosaic of fynbos with karoo shrubland in the more fire-protected areas. Deep kloofs have a thicket with *Buddleja saligna* as well as various species of *Pelargonium* and *Salvia*.

References Taylor (1979), Taylor & Van der Meulen (1981).

FFs 22 South Rooiberg Sandstone Fynbos

VT 70 False Macchia (64%), VT 25 Succulent Mountain Scrub (Spekboomveld) (33%) (Acocks 1953). Dry Mountain Fynbos (66%), Mesic Mountain Fynbos (28%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (95%) (Low & Rebelo 1996). BHU 67 Rooiberg Mountain Fynbos Complex (93%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Southern slopes of the mountains of Rooiberg, Gamka and the Amalienstein Ridge-Sandberg-Bakenskop range. Altitude 350–1 490 m on the summit of Rooiberg.

Vegetation & Landscape Features Steep to gentle south-facing slopes, deeply dissected in a few places. Ericaceous fynbos found at high altitudes, with proteoid and restioid fynbos at middle levels, and waboomveld and asteraceous fynbos at the lowest altitudes within the unit. The lower edge with a tendency to patches of restioid fynbos within asteraceous fynbos, being too dry in the central and eastern sections to support proteoid fynbos.

Geology & Soils Acidic lithosol soils derived from Ordovician sandstones of the Table Mountain Group (Cape Supergroup). Land types mainly Ib and Ic.

Climate MAP 250–710 mm (mean: 465 mm), fairly even but with a low from December to February. Mean daily maximum and minimum temperatures 29.4°C and 3.5°C for January and July, respectively. Frost incidence 10–20 days per year. See also climate diagram for FFs 22 South Rooiberg Sandstone Fynbos (Figure 4.21).

Figure 4.43 FFs 22 South Rooiberg Sandstone Fynbos: Proteoid fynbos dominated by *Leucadendron salignum* in the Rooiberg Mountains near Ladismith (Western Cape).

Important Taxa (WWetlands) Small Tree: *Protea nitida* (d). Tall Shrubs: *Leucadendron eucalyptifolium* (d), *Protea eximia* (d), *P. neriifolia* (d), *P. punctata* (d), *P. repens* (d), *Psoralea pinnata*W (d). Low Shrubs: *Berzelia intermedia* (d), *Elytropappus glandulosus* (d), *Erica hispidula* (d), *Leucadendron comosum* subsp. *comosum* (d), *L. salignum* (d), *Protea lorifolia* (d), *Anthospermum galioides* subsp. *galioides*, *Leucospermum wittebergense*, *Mimetes chrysanthus*, *Paranomus dispersus*, *Wahlenbergia neorigida*. Herb: *Sutera subnuda*. Geophytic Herbs: *Geissorhiza delicatula*, *Romulea fibrosa*. Graminoids: *Cannomois virgata* (d), *Elegia juncea* (d), *Mastersiella purpurea* (d), *Merxmuellera arundinacea* (d), *Tetraria ustulata* (d), *Cymbopogon marginatus*, *Ficinia deusta*, *Pentaschistis eriostoma*, *Themeda triandra*.

Endemic Taxa Low Shrubs: *Anderbergia rooibergensis*, *Argyrolobium rarum*, *Aspalathus karrooensis*, *Asparagus oliveri*, *Cliffortia concinna*, *Metalasia tricolor*, *Selago rubromontana*.

Conservation Least Threatened. Target 27%. Statutorily conserved (34%) in the Rooiberg Nature Reserve, with an additional 10% protected in the Rooiberg Mountain catchment area. Only very little transformed. The alien tree *Pinus halepensis* occurs, but is generally rare. Erosion generally low.

Remarks Vegetation data are from a provisional and structural survey addressing the westernmost regions of the unit. No data exist for the eastern section, which contains the Gamka Nature Reserve. South Rooiberg Sandstone Fynbos forms a partial corridor between fynbos types at a similar aspect on the Swartberg and Langeberg Mountains, and this probably partly accounts for the higher richness of the Klein Swartberg compared to the Groot Swartberg (A.G. Rebelo unpublished data).

References Taylor (1979), Taylor & Van der Meulen (1981).

FFs 23 North Swartberg Sandstone Fynbos

VT 70 False Macchia (83%) (Acocks 1953). Dry Mountain Fynbos (26%), Mesic Mountain Fynbos (20%), South Coast Renosterveld (16%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (79%) (Low & Rebelo 1996). BHU 68 Groot Swartberg Mountain Fynbos Complex (51%), BHU 66 Klein Swartberg Mountain Fynbos Complex (32%) (Cowling et al. 1999b, Cowling & Heijnis 2001). Anysberg Arid Fynbos, Anysberg Grassy Fynbos, Anysberg Proteoid Fynbos p.p. (Vlok 2002).

Distribution Western and Eastern Cape Provinces: Stretching 270 km along the northern slopes of the Anysberg, Klein and Groot Swartberg to Slypsteenberg and Resbosrand in the east. Also includes the northern slope of the Touwsberg. Altitude 700–1 800 m. Peaks higher than 1 800 m constitute FFs 31 Swartberg Altimontane Sandstone Fynbos.

Vegetation & Landscape Features Steep to very steep, mostly north-facing slopes, deeply dissected in parts. East-west-trending rugged mountain ranges. Structurally this is mainly asteraceous, proteoid and restioid fynbos; graminoid fynbos rare.

Geology & Soils Acidic lithosol soils derived from Ordovician sandstones of the Table Mountain Group (Cape Supergroup). Land types mainly Ic and Ib.

Climate MAP 160–580 mm (mean: 375 mm), peaking slightly in March, but otherwise even with a low from December to February. Mean daily maximum and minimum temperatures 28.3°C and 1.6°C for January and July, respectively. Frost incidence 10–40 days per year. See also climate diagram for FFs 23 North Swartberg Sandstone Fynbos (Figure 4.21).

Important Taxa Small Tree: *Protea nitida*. Tall Shrubs: *Protea repens* (d), *Aspalathus hystrix*, *A. sceptrum-aureum*, *Leucadendron rubrum*, *Protea eximia*, *P. punctata*. Low Shrubs: *Protea lorifolia* (d), *Acmadenia sheilae*, *Agathosma capensis*, *A. mundtii*, *Anthospermum galioides* subsp. *galioides*, *A. spathulatum* subsp. *spathulatum*, *Cliffortia setifolia*, *Elytropappus* sp. nov. ('*aridus*'), *Erica rosacea* subsp. *glabrata*,

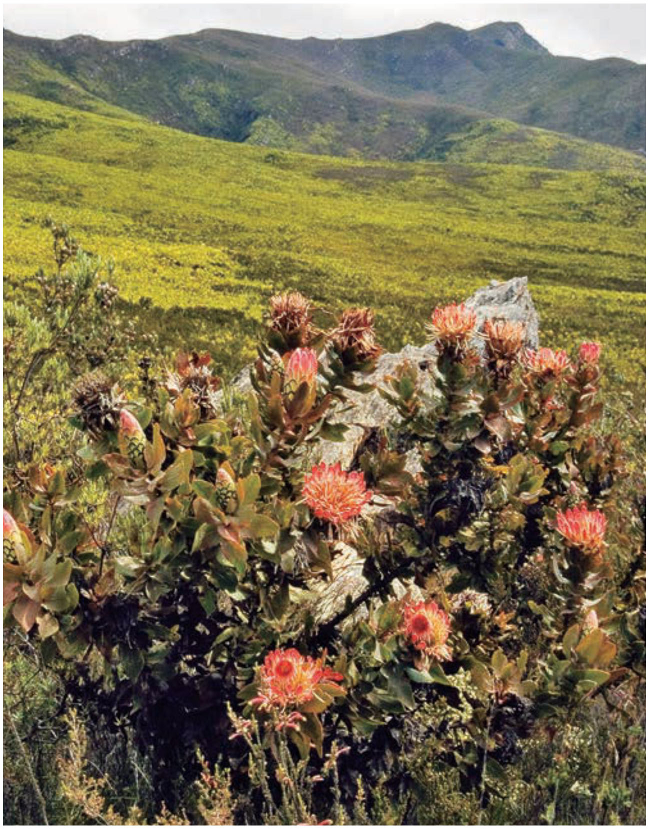


Figure 4.44 FFs 23 North Swartberg Sandstone Fynbos: Proteoid fynbos with *Protea eximia* against the backdrop of *Leucadendron*-clad north-facing slopes of the Swartberg Pass, Klein Swartberg Mountains (Western Cape).

E. strigilifolia, *E. zwartbergensis*, *Euryops bolusii*, *E. erectus*, *E. glutinosus*, *Felicia filifolia* subsp. *filifolia*, *Leucadendron salignum*, *Leucospermum wittebergense*, *Metalasia pallida*, *M. pungens*, *Paranomus centaureoides*, *P. dregei*, *Passerina obtusifolia*, *Protea canaliculata*. Graminoids: *Restio triticeus* (d), *Rhodocoma fruticosa* (d), *Tetraria ustulata* (d), *Cannomois scirpoides*, *Cymbopogon marginatus*, *Ehrharta calycina*, *Hypodiscus striatus*, *Ischyrolepis hystrix*, *Pentaschistis eriostoma*, *Themeda triandra*, *Willdenowia teres*.

Endemic Taxa Low Shrubs: *Acmadenia fruticosa*, *Aspalathus lamarckiana*, *Cliffortia nivenioides*, *Erica insignis*, *Indigofera thesioides*. Succulent Shrub: *Lampranthus pocockiae*. Succulent Herb: *Haworthia vlokii*.

Conservation Least threatened. Target 27%. Statutorily conserved (70%) in the Groot Swartberg, Towerkop, Anysberg and Swartberg East Nature Reserves, with an additional 5% protected in private conservation areas such as Klein Swartberg. Only 2% transformed (cultivation). Alien woody plants include *Pinus pinaster* and *P. radiata*. Erosion very low.

Remark 1 At very low rainfall conditions (< 300 mm) at lower altitudes, asteraceous fynbos is replaced by a grassy shrubland—a thicket type—in a wide transition zone. Deep fire-protected kloofs have thickets with *Buddleja saligna*, and species of *Pelargonium* and *Salvia.*

Remark 2 Despite the prominence and importance of especially the Swartberg, this is a poorly known vegetation unit.

References Bond (1981), Vlok (2002).

FFs 24 South Swartberg Sandstone Fynbos

VT 70 False Macchia (83%) (Acocks 1953). Mesic Mountain Fynbos (65%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (87%) (Low & Rebelo 1996). BHU 68 Groot Swartberg Mountain Fynbos Complex (49%), BHU 66 Klein Swartberg Mountain Fynbos Complex (36%) (Cowling et al. 1999b, Cowling & Heijnis 2001). Anysberg Wet Fynbos, Anysberg Proteoid Fynbos p.p. (Vlok 2002).

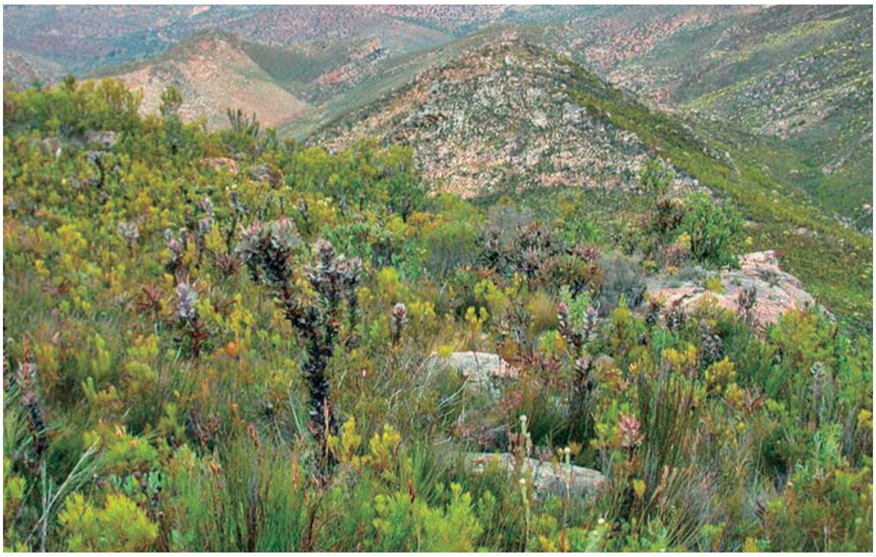
Distribution Western and Eastern Cape Provinces: Southern slopes of the Anysberg, Klein and Groot Swartberg to Slypsteenberg and Resbosrand in the east. Also includes the southern slope of the Touwsberg. Altitude 550 m to the lower boundary of the FFs 31 Swartberg Altimontane Sandstone Fynbos at about 1 800 m.

Vegetation & Landscape Features Steep, very steep, and precipitous south-facing slopes, deeply dissected in parts, of rugged mountain ranges. Vegetation is a medium tall shrubland and heathland. Proteoid and restioid fynbos dominate, with ericaceous fynbos at higher altitudes and scrub fynbos at lower altitudes.

Geology & Soils Acidic lithosol soils derived from Ordovician sandstones of the Table Mountain Group (Cape Supergroup). Land types mainly Ib and Ic.

Climate MAP 170–850 mm (mean: 475 mm), peaking slightly in March, but otherwise even with a low from December to February. Mean daily maximum and minimum temperatures 28.5°C and 2.0°C for January and July, respectively. Frost incidence 10–30 days per year. See also climate diagram for FFs 24 South Swartberg Sandstone Fynbos (Figure 4.21).

Important Taxa Small Tree: *Protea nitida*. Tall Shrubs: *Phylica paniculata* (d), *Protea eximia* (d), *P. punctata* (d), *P. repens* (d), *Euryops tenuissimus* subsp. *tenuissimus*, *E. virgineus*, *Leucadendron eucalyptifolium*, *L. rubrum*, *Metalasia densa*. Low Shrubs: *Erica andreaei* (d), *E. fimbriata* (d), *E. petraea* (d), *Leucadendron album* (d), *L. comosum* subsp. *comosum* (d), *Agathosma capensis*, *A. mundtii*, *Anthospermum aethiopicum*, *Aspalathus congesta*, *A. pachyloba* subsp. *villicaulis*, *A. patens*, *Brunia nodiflora*, *Cliffortia robusta*, *C. setifolia*, *C. tuberculata*, *Cyclopia burtonii*, *Disparago ericoides, Erica discolor* variant '*speciosa*', *E. esterhuyseniae*, *E. hispidula*, *E. melanthera*, *E. nervata*, *E. strigilifolia*, *E. tenuis*, *E. uberiflora*, *E. umbelliflora*, *E. zwartbergensis*, *Euryops bolusii*, *E. rehmannii*, *Heliophila rimicola*, *Leucadendron barkerae*, *L. dregei*, *L. salignum*, *L. spissifolium* subsp. *fragrans*, *Leucospermum cuneiforme*, *L. wittebergense*, *Metalasia strictifolia*, *Otholobium swartbergense*, *Paranomus centaureoides*, *Passerina obtusifolia*, *Pelargonium ovale*, *Protea intonsa*, *P. lorifolia*, *P. montana*, *P. venusta*, *Stoebe cinerea*, *Syncarpha paniculata*, *Ursinia scariosa* subsp. *scariosa*. Succulent Shrub: *Crassula obtusa*. Geophytic Herbs: *Cheilanthes eckloniana*, *Geissorhiza delicatula*, *Moraea monticola*. Graminoids: *Cannomois scirpoides* (d), *Cymbopogon pospischilii* (d), *Hypodiscus striatus* (d), *Ischyrolepis distracta* (d), *Merxmuellera stricta* (d), *Restio triticeus* (d), *Tetraria cuspidata* (d), *T. ustulata* (d), *Willdenowia teres* (d), *Brachiaria serrata*, *Hypodiscus alboaristatus*, *H. synchroolepis*, *Rhodocoma fruticosa*, *Tetraria involucrata*, *Themeda triandra*.



D. Gwynne-Evans

Figure 4.45 FFs 24 South Swartberg Sandstone Fynbos: Proteoid fynbos on southern slopes of the Touwsberg (Western Cape) with *Protea eximia, Leucadendron eucalyptifolium* and *Hypocalyptus oxalidifolia*.

Endemic Taxa ([W]Wetlands) Tall Shrubs: *Cliffortia conifera*, *Hymenolepis cynopus*, *Liparia racemosa*, *Protea aristata*, *Stirtonanthus chrysanthus*, *S. taylorianus*. Low Shrubs: *Adenandra dahlgrenii*, *Agathosma purpurea*, *Anderbergia epaleata*, *Anisothrix integra*, *Aspalathus ramosissima*, *Cliffortia aculeata*, *C. cervicornu*, *C. crassinervis*, *C. montana*, *C. verrucosa*, *Erica astroites*[W], *E. atromontana*, *E. chionodes*[W], *E. jananthus*, *E. kirstenii*, *E. phaeocarpa*, *E. umbratica*, *E. viridiflora* subsp. *redacta*, *Helichrysum saxicola*, *Leucospermum secundifolium*, *Liparia confusa*, *Muraltia carnosa*, *M. elsieae*, *Nivenia parviflora*, *N. stenosiphon*, *Otholobium rubicundum*, *Phylica costata*, *P. nigromontana*, *P. sericea*, *P.*

stokoei, *Phymaspermum appressum, Selago adenodes*, *S. exigua*, *S. oppositifolia*. Succulent Shrubs: *Lampranthus affinis*, *Sceletium strictum*. Herbs: *Berkheya francisci*, *Heliophila ephemera*, *Lobelia eurypoda* var. *fissurarum*, *Osteospermum asperulum*, *Sutera tenuicaulis*. Geophytic Herbs: *Geissorhiza nigromontana*[W], *G. uliginosa*[W], *Gladiolus aquamontanus*, *G. nigromontanus*, *Moraea exiliflora*. Succulent Herb: *Crassula peculiaris*. Graminoids: *Ficinia petrophila*, *Restio rarus*.

Conservation Least threatened. Target 27%. Some 47% statutorily conserved in the Groot Swartberg, Swartberg East and Anysberg Nature Reserves, with an additional 35% conserved in mountain catchment areas (Klein Swartberg, Groot Swartberg, Swartberg-oos). Only very small portion has been transformed. Alien woody species worth mentioning are *Pinus pinaster* and *P. radiata*. Erosion very low.

Remarks The Klein Swartberg portion deserves to be recognised as a centre of endemism in its own right and should perhaps have been separated as a unit herein. However, at this stage it is not clear how much of this is an effect of altitude, since many near-endemics to this portion have been found at higher peaks to the east, most notably Blesberg (including FFs 31 Swartberg Altimontane Sandstone Fynbos). The logical boundary (based on Proteaceae) is the Gamka River gap. In the west there appear to be few species confined to Anysberg, with one confined to Touwsberg. In the east Antoniesberg shares marginally more species with FFs 28 Kouga Grassy Sandstone Fynbos than with Swartberg and has been linked with the former, although the eastern Groot Swartberg also tends to share many species with the Kouga Mountains.

References Bond (1981), Vlok (2002), C. Boucher (unpublished data), Protea Atlas Project (unpublished data).

FFs 25 North Kammanassie Sandstone Fynbos

VT 70 False Macchia (77%), VT 25 Succulent Mountain Scrub (Spekboomveld) (22%) (Acocks 1953). Dry Mountain Fynbos (65%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (74%), VT 63 South & South-east Coast Renosterveld (22%) (Low & Rebelo 1996). BHU 70 Kamanassie Mountain Fynbos Complex (77%), BHU 44 Uniondale Inland Renosterveld (19%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: On northern slopes of the Kammanassie Mountains with an extension on to Keurfonteinrant between Dysselsdorp and Uniondale. Altitude 500–1 800 m. (The highest peak of the Kammanassie—Mannetjiesberg at 1 955 m—probably supports altimontane fynbos; see FFs 31 Swartberg Altimontane Sandstone Fynbos.)

Vegetation & Landscape Features Steep to gentle, rugged northern slopes with extensive upland plateau. The vegetation comprises restiolands, often with a proteoid overstorey. Proteoid, restioid and grassy fynbos present, with prominent asteraceous fynbos. Lower slopes grade into Succulent Karoo at lowermost reaches.

Geology & Soils Acidic lithosol soils derived from Ordovician sandstones of the Table Mountain Group (Cape Supergroup). Land types mainly Ic, Ib and Fc.

Climate MAP 290–940 mm (mean: 485 mm), peaking slightly in March, but otherwise even with a low from December to February. Mean daily maximum and minimum temperatures 29.1°C and 2.0°C for January and July, respectively. Frost incidence 10–40 days per year. See also climate diagram for FFs 25 North Kammanassie Sandstone Fynbos (Figure 4.21).

Important Taxa ([T]Cape thickets) Small Tree: *Protea nitida* (d). Succulent Tree: *Aloe ferox*. Tall Shrubs: *Aspalathus hystrix* (d), *Chrysanthemoides monilifera* (d), *Dodonaea viscosa* var. *angustifolia*, *Euclea undulata*[T], *Montinia caryophyllacea*, *Phylica paniculata*, *Polygala fruticosa*, *Protea eximia*, *P. neriifolia*, *P. punctata*, *P. repens*, *Rhus pallens*[T], *R. tomentosa*[T]. Low Shrubs: *Elytropappus adpressus* (d), *Eriocephalus africanus* var. *africanus* (d), *Metalasia pungens* (d), *Agathosma affinis*, *Anthospermum aethiopicum*, *Clutia polifolia*, *Elytropappus gnaphaloides*, *Felicia filifolia* subsp. *filifolia*, *Helichrysum teretifolium*, *Leucadendron rubrum*, *L. salignum*, *Leucospermum wittebergense*, *Lobostemon fruticosus*, *Metalasia pallida*, *Muraltia dispersa*, *M. ericaefolia*, *Oedera squarrosa*, *Pelargonium myrrhifolium*, *Pentzia elegans*, *Printzia polifolia*, *Protea lorifolia*, *Pteronia stricta*, *Senecio juniperinus*. Succulent Shrub: *Crassula biplanata*. Herb: *Corymbium africanum*. Geophytic Herbs: *Androcymbium capense*, *Asplenium cordatum*, *Eriospermum capense*, *Oxalis punctata*. Graminoids: *Pentaschistis tortuosa* (d), *Themeda triandra* (d), *Cannomois scirpoides*, *Ficinia ramosissima*, *Ischyrolepis triflora*.

Endemic Taxa Low Shrubs: *Erica annalis*, *E. kammanassieae*. Geophytic Herbs: *Bobartia paniculata*, *Romulea vlokii*.

Conservation Least threatened. Target 27%. Statutorily conserved (66%) in the Kammanassie Nature Reserve, with an additional 13% in the Kammanassie Mountain catchment area. Only very little transformed and the only notable woody alien is *Hakea sericea*. Erosion low and moderate.

Reference Cleaver et al. (2005).

FFs 26 South Kammanassie Sandstone Fynbos

VT 70 False Macchia (85%) (Acocks 1953). Mesic Mountain Fynbos (64%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (88%) (Low & Rebelo 1996). BHU 70 Kamanassie Mountain Fynbos Complex (86%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: On the southern slopes of the Kammanassie Mountains between Dysselsdorp and Uniondale. Altitude 600–1 800 m. (Mannetjiesberg at 1 955 m—the highest peak of the Kammanassie—supports altimontane fynbos; see FFs 31 Swartberg Altimontane Sandstone Fynbos.)

Vegetation & Landscape Features Steep to precipitous upper southern slopes, with gentler foot slopes, well dissected and rugged. Vegetation comprises a tall proteoid shrubland and heathland. Predominantly restioid, ericaceous and proteoid fynbos, with some asteraceous fynbos on lower slopes. The old African surface conglomerates support *Dodonaea*-dominated fynbos.

Geology & Soils Acidic lithosol soils derived from Ordovician sandstones of the Table Mountain Group (Cape Supergroup), Glenrosa and Mispah forms prominent. Land types mainly Ib, Ic and Fb.

Climate MAP 310–1 150 mm (mean: 690 mm), even with no peak, but with a low from December to February. Mean daily maximum and minimum temperatures 29.0°C and 2.3°C for January and July, respectively. Frost incidence 10–30 days per year. See also climate diagram for FFs 26 South Kammanassie Sandstone Fynbos (Figure 4.21).

Important Taxa Small Tree: *Protea nitida* (d). Tall Shrubs: *Leucadendron rubrum*, *Protea eximia*, *P. neriifolia*, *P. punctata*, *P. repens*. Low Shrubs: *Acmadenia maculata*, *Amphithalea parvifolia*, *Aspalathus collina* subsp. *luculenta*, *A. patens*, *Cyclopia intermedia*, *Dolichothrix ericoides*, *Erica simulans*, *E. uberiflora*,

L. Mucina

Figure 4.46 FFs 26 South Kammanassie Sandstone Fynbos: Young proteoid fynbos with *Protea neriifolia* in the Potjiesrivier Pass near Uniondale (Western Cape).

Euryops bolusii, *Felicia esterhuyseniae*, *Helichrysum teretifolium*, *Lachnaea glomerata*, *Leucadendron salignum*, *L. singulare*, *L. spissifolium* subsp. *fragrans*, *Leucospermum royenifolium*, *Metalasia strictifolia*, *Protea intonsa*, *P. tenax*. Geophytic Herb: *Moraea cookii*. Graminoid: *Thamnochortus stokoei*.

Endemic Taxa Low Shrubs: *Erica inordinata*, *E. montis-hominis*, *Phylica floccosa*. Succulent Shrub: *Ruschia esterhuyseniae*. Geophytic Herb: *Geissorhiza elsiae*. Graminoid: *Elegia altigena*.

Conservation Least threatened. Target 27%. Statutorily conserved (13%) in the Kammanassie Nature Reserve, with an additional 57% enjoying protection in a private conservation area also carrying the name Kammanassie. Only 4% has been transformed. Alien *Hakea sericea* and *Pinus pinaster* scattered over large areas. Erosion low. Extraction of water is apparently drying up seepages and springs on the western edge of this unit.

Remarks The southern slopes of the Kammanassie are poorly explored. This unit is clearly related to the Swartberg Sandstone Fynbos units and could possibly have been included within it. However, many of the shared taxa are high-altitude species, with low-altitude species having more in common with FFs 27 Kouga Sandstone Fynbos.

Reference Cleaver et al. (2005).

FFs 27 Kouga Sandstone Fynbos

VT 70 False Macchia (87%) (Acocks 1953). Mesic Mountain Fynbos (76%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (81%) (Low & Rebelo 1996). BHU 72 Kouga Mountain Fynbos Complex (44%), BHU 73 Baviaanskloof Mountain Fynbos Complex (16%), BHU 74 Cockscomb Mountain Fynbos Complex (16%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western and Eastern Cape Provinces: Main area from the Dieprivier and the ridge of Bak se Baken in the west, through Uniondale, eastwards along the main chain of the Kouga Mountains (and continuous with some small ridges such as Ouposberg and Dwarsberg to the northwest), interrupted by the thicket of the Kouga River, and terminating in the vicinity of Blouberg. A narrower band occurs along the upper and generally south-facing parts of the Baviaanskloofberge on the northern side of Baviaanskloof from the Winterhoekberge in the west and continuing up to the gorge of the Groot River. The unit is found at high altitudes (with a southerly aspect) on the main ridge of the Groot Winterhoekberge to the high mountain parts above Uitenhage (e.g. Vermaakskop) and also occurs on some subsidiary high ridges to the south. Also found along the higher and south-facing parts of the Elandsberg as well as on the Van Stadensberg to near Fitches Corner. A narrow band occurs on the southern slopes of the Suuranysberge on the northern side of the lower Langkloof Valley, Kareedouw. Altitude 400–1 758 m (Cockscomb Peak in the Groot Winterhoekberge).

Vegetation & Landscape Features Mainly long, rounded mountain chains with moderately steep to gentle slopes. The high-altitude slopes support communities dominated by low fynbos. As is typical for this fynbos, the intermediate slopes support three strata, with Proteaceae shrubs forming the dominant tall shrub stratum. Wet, mesic and dry variations occur.

Geology & Soils Acidic lithosol soils derived from sandstones of the Table Mountain Group as well as quartzitic sandstones of the Witteberg Group (Nardouw Subgroup). Land types mainly Ib, Ic and Fa.

Climate MAP 270–910 mm (mean: 600 mm), with a slight bimodal peak in March and October. Mean daily maximum and minimum temperatures 27.3°C and 2.9°C for February and July, respectively. Frost incidence 10–40 days per year. See also climate diagram for FFs 27 Kouga Sandstone Fynbos (Figure 4.21).

Important Taxa (^{T}Cape thickets) Small Trees: *Protea nitida*, *Widdringtonia schwarzii*. Tall Shrubs: *Euryops virgineus*, *Leucadendron eucalyptifolium*, *L. loeriense*, *L. uliginosum* subsp. *glabratum*, *Metalasia trivialis*, *Passerina falcifolia*, *Protea lorifolia*, *P. mundii*, *P. neriifolia*, *P. punctata*, *P. repens*, *Rhus lucida*^{T}, *Smelophyllum capense*^{T}. Low Shrubs: *Leucadendron comosum* subsp. *comosum* (d), *Agathosma capensis*, *A. kougaense*, *Anisodontea scabrosa*, *Anthospermum galioides* subsp. *galioides*, *Aspalathus collina* subsp. *collina*, *Cliffortia arcuata*, *Diosma prama*, *D. rourkei*, *Erica angulosa*, *E. copiosa*, *E. cordata*, *E. demissa*, *E. hispidula*, *E. nabea*, *E. newdigateae*, *E. pectinifolia*, *E. simulans*, *E. strigilifolia*, *E. thamnoides*, *E. umbelliflora*, *Euryops munitus*, *E. rehmannii*, *E. spathaceus*, *Leucadendron pubibracteolatum*, *L. salignum*, *Leucospermum cuneiforme*, *Metalasia strictifolia*, *Otholobium pictum*, *Passerina obtusifolia*, *P. pendula*, *Penaea cneorum* subsp. *ovata*, *Phylica axillaris*, *P. lachneaeoides*, *Protea foliosa*, *P. vogtsiae*, *Pteronia teretifolia*, *Stoebe spiralis*. Herb: *Senecio pauciflosculosus*. Succulent Herbs: *Quaqua pillansii*, *Stapelia obducta*, *S. paniculata*. Graminoids: *Anthochortus crinalis*, *Brachiaria serrata*, *Elegia vaginulata*, *Ficinia gracilis*, *Hypodiscus aristatus*, *H. striatus*, *Ischyrolepis gaudichaudiana*, *Mastersiella purpurea*, *Merxmuellera arundinacea*, *M. stricta*, *Pentameris distichophylla*, *P. macrocalycina*, *Restio triticeus*, *Rhodocoma fruticosa*, *Tetraria cuspidata*.

Endemic Taxa Tall Shrub: *Cyclopia longifolia*. Low Shrubs: *Agathosma martiana*, *A. unicarpellata*, *Aspalathus lanceicarpa*, *Cyclopia filiformis*, *Erica abelii*, *E. affinis*, *E. bolusanthus*, *E. flocciflora*, *E. harveyana*, *E. humansdorpensis*, *E. kougabergensis*, *E. sagittata*, *E. saptouensis*, *Euryops integrifolius*, *E. ursinoides*,

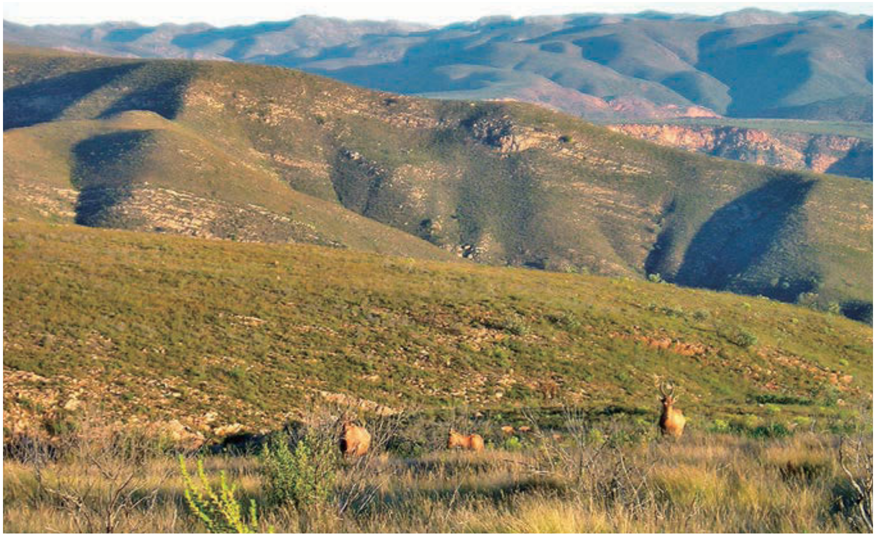


Figure 4.47 FFs 27 Kouga Sandstone Fynbos: Dry grassy fynbos with abundant *Ehrharta*-dominated undergrowth and grazing red hartebeest (*Alcelaphus buselaphus*) in the Baviaanskloof Conservation Area (Eastern Cape).

the Kouga and Baviaanspoort Mountains in Baviaanspoort as well as the northern slopes of the Baviaanspoort Mountains and the northern and lower slopes of the Groot Winterhoekberge, Elandsberge and Van Stadensberg including the valleys of the upper reaches of the Elands and Kwa-Zunga Rivers. Also on various ridges embedded in FRs 16 Uniondale Shale Renosterveld south to east of Willowmore including Antoniesberg and Witberg. Altitude 220–1 220 m, mainly 300–900 m (concentrated around 480–560 m).

Vegetation & Landscape Features Low shrubland with sparse, emergent tall shrubs and dominated by grasses in the undergrowth, or grassland with scattered ericoid shrubs. The lower dry slopes, where leaching is less severe and nutrient levels are higher, support a higher grassy cover.

Leucadendron orientale, *L. sorocephalodes*, *Paranomus esterhuyseniae*, *P. reflexus*, *Senecio oederiifolius*.

Conservation Least threatened. Target 23%. About 40% statutorily conserved in wilderness areas such as the Kouga, Guerna, Groendal, Baviaanskloof and Berg Plaatz as well as in other nature reserves such as Stinkhoutsberg and Lady Slipper and in Longmore State Forest. An additional 4% protected in private conservation areas such as Hankey Forest Reserve, Kouga, Sepree River, Sustersdal and Van Stadensberg. About 8% transformed (pine plantations, cultivation). *Pinus pinaster*, *Hakea sericea* and *Acacia saligna* are the main alien woody plants of concern. Much transformed by conversion to grassy pasture by too frequent burning. Erosion mostly low and very low.

Remark This unit also comprises patches of renosterveld vegetation on the heavier soils with higher clay content, which we did not map due to lack of information.

References Cowling & Campbell (1983a, b, 1984), Cowling (1984), Campbell (1985), Euston-Brown (1995), Boshoff et al. (2000), Vlok & Euston-Brown (2002).

Geology & Soils Acidic lithosol soils derived from sandstones of the Table Mountain Group as well as quartzitic sandstones of the Witteberg Group (Nardouw Subgroup). Glenrosa and Mispah forms prominent. Land types mainly Ib and Fa.

Climate MAP 270–800 mm (mean: 540 mm), evenly throughout the year with a slight peak in March and October–November. Mean daily maximum and minimum temperatures 27.0°C and 4.2°C for February and July, respectively. Frost incidence 2–10 days per year. See also climate diagram for FFs 28 Kouga Grassy Sandstone Fynbos (Figure 4.21).

Important Taxa Small Tree: *Protea nitida*. Succulent Tree: *Aloe ferox*. Tall Shrubs: *Aspalathus kougaensis*, *A. nivea*, *Dodonaea viscosa* var. *angustifolia*. Low Shrubs: *Agathosma mucronulata*, *A. pilifera*, *A. puberula*, *A. spinosa*, *Aspalathus fourcadei*, *Cliffortia drepanoides*, *Clutia alaternoides*, *C. polifolia*, *Diosma prama*, *D. rourkei*, *Disparago ericoides*, *Erica demissa*, *E. pectinifolia*, *E. sparsa*, *E. thamnoides*, *Euryops euryopoides*, *Helichrysum teretifolium*, *Leucadendron salignum*, *Leucospermum cuneiforme*, *Otholobium carneum*, *Passerina obtusifolia*, *P. pen-*

FFs 28 Kouga Grassy Sandstone Fynbos

VT 70 False Macchia (82%) (Acocks 1953). Mesic Grassy Fynbos (81%) (Moll & Bossi 1983). LR 65 Grassy Fynbos (83%) (Low & Rebelo 1996). BHU 21 Humansdorp Grassy Fynbos (26%), BHU 74 Cockscomb Mountain Fynbos Complex (24%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western and Eastern Cape Provinces: Between Uniondale and Uitenhage, generally surrounding FFs 27 Kouga Sandstone Fynbos at lower altitudes and often on northerly aspects. Along the lower flanks of the Kouga Mountains in the Langkloof north of Joubertina and the northern and lower slopes of the Suuranysberge to the low mountains and flats north of Humansdorp. Along the lower slopes of

Figure 4.48 FFs 28 Kouga Grassy Sandstone Fynbos: Grassy fynbos patch in sandstone fynbos with *Themeda triandra* and *Aloe ferox* above Geelhoutbos in the Baviaanskloof Conservation Area (Eastern Cape).

dula, *Phylica axillaris*, *P. lachneaeoides*, *Polygala myrtifolia*, *Protea foliosa*, *Pteronia incana*, *Stoebe plumosa*, *Tephrosia capensis*. Herbs: *Alepidea capensis*, *Centella virgata*, *Gazania krebsiana* subsp. *krebsiana*, *Helichrysum felinum*, *Knowltonia capensis*. Geophytic Herbs: *Bobartia orientalis* subsp. *orientalis*, *Geissorhiza roseoalba*, *Watsonia meriana*. Graminoids: *Anthochortus crinalis*, *Brachiaria serrata*, *Cannomois scirpoides*, *C. virgata*, *Cymbopogon marginatus*, *Digitaria eriantha*, *Diheteropogon filifolius*, *Eragrostis curvula*, *Heteropogon contortus*, *Hypodiscus albo-aristatus*, *H. striatus*, *H. synchroolepis*, *Ischyrolepis capensis*, *I. gaudichaudiana*, *Mastersiella purpurea*, *Melinis repens* subsp. *repens*, *Merxmuellera papposa*, *M. stricta*, *Pentameris distichophylla*, *Pentaschistis eriostoma*, *P. pallida*, *Restio triticeus*, *Rhodocoma fruticosa*, *Tetraria capillacea*, *T. cuspidata*, *T. fourcadei*, *T. involucrata*, *Thamnochortus fruticosus*, *Themeda triandra*, *Trachypogon spicatus*, *Tristachya leucothrix*.

Endemic Taxa Tall Shrub: *Freylinia crispa*. Low Shrubs: *Argyrolobium parviflorum*, *A. trifoliatum*, *Cullumia cirsioides*, *Eriocephalus tenuipes*, *Euchaetis vallis-simiae*, *Sutera cinerea*. Succulent Shrub: *Lampranthus lavisii*. Herbs: *Annesorhiza thunbergii*, *Aster laevigatus*, *Centella didymocarpa*, *Peucedanum dregeanum*. Geophytic Herbs: *Cyrtanthus flammosus*, *C. labiatus*, *C. montanus*, *Gladiolus uitenhagensis*. Succulent Herb: *Gasteria glauca*. Graminoid: *Restio vallis-simius*.

Conservation Least threatened. Target 23%. About 20% conserved in wilderness and conservation areas including the Baviaanskloof, Berg Plaatz, Groendal, Guerna, Kouga, Welbedacht State Forest, and in Mierhoopplaat and Stinkhoutsberg Nature Reserves. About 2% in addition enjoy protection in private reserves such as Jumanji Game Farm, Rooi Banke Forest Reserve, Paardekop Game Farm, Thaba Manzi Game Farm, and in Beakosneck, Kouga and Sepree River Private Nature Reserves. Some 9% transformed (cultivation) but in addition much transformed to grassy pasture by too frequent burning. Notable aliens include *Pinus pinaster*, *Acacia cyclops* and *A. mearnsii*. Erosion very low and low, but also high in some areas.

References Cowling & Campbell (1983a, b, 1984), Cowling (1984), Campbell (1985), Euston-Brown (1995), Boshoff et al. (2000), Vlok & Euston-Brown (2002).

FFs 29 Algoa Sandstone Fynbos

VT 70 False Macchia (74%), VT 2 Alexandria Forest (26%) (Acocks 1953). South Coast Renosterveld (28%) (Moll & Bossi 1983). LR 63 South and South-west Coast Renosterveld (75%), LR 65 Grassy Fynbos (23%) (Low & Rebelo 1996). BHU 22 Algoa Grassy Fynbos (62%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Eastern Cape Province: Coastal flats at Port Elizabeth from Van Stadens River in the west to Southdene-Summerstrand in the east, located mostly some kilometres from the coast and close to the coast at only Maitland River Mouth and urbanised Summerstrand. Altitude 20–300 m.

Vegetation & Landscape Features Flat to slightly undulating plain supporting grassy shrubland (mainly graminoid fynbos). Grasses become dominant especially in wet habitats. In the south this fynbos unit borders on AT 9 Albany Coastal Belt and AZs 1 Algoa Dune Strandveld and forms transitional mosaics with both. It also borders on patches of FOz 6 Southern Coastal Forest in this area.

Geology & Soils Acidic lithosol soils derived from Ordovician sandstones of the Table Mountain Group (Cape Supergroup). Land types mainly Db and Ha.

Climate MAP 560–890 mm (mean: 680 mm), evenly throughout the year, with a slight peak in March and October. Mean daily maximum and minimum temperatures 25.2°C and 7.6°C for February and July, respectively. Frost incidence about 3 days per year. See also climate diagram for FFs 29 Algoa Sandstone Fynbos (Figure 4.21).

Important Taxa Tall Shrubs: *Protea eximia*, *P. neriifolia*, *P. repens*. Low Shrubs: *Agathosma hirta*, *A. ovata*, *Erica zeyheriana*, *Euryops ericifolius*, *Helichrysum appendiculatum*, *H. teretifolium*, *Leucadendron salignum*, *L. spissifolium* subsp. *phillipsii*, *Leucospermum cuneiforme*, *Protea cynaroides*, *P. foliosa*, *Tephrosia capensis*. Succulent Herb: *Crassula pellucida* subsp. *marginalis*. Graminoids: *Andropogon eucomus*, *Brachiaria serrata*, *Cymbopogon pospischilii*, *Cynodon dactylon*, *Digitaria eriantha*, *Ehrharta calycina*, *Eustachys paspaloides*, *Ischyrolepis capensis*, *Pentaschistis heptamera*, *P. pallida*, *Thamnochortus cinereus*, *Themeda triandra*, *Tristachya leucothrix*.

Endemic Taxa ([W]Wetlands) Low Shrubs: *Agathosma gonaquensis*, *Cyclopia pubescens*[W], *Erica etheliae*. Geophytic Herb: *Holothrix longicornu*.

Conservation Endangered. Target 23%. About 2% conserved in the Van Stadens Wild Flower Reserve, The Island Nature Reserve as well as in several private nature reserves. More than 50% transformed (cultivation, urban sprawl of the Nelson Mandela Metropolitan Area). Several Australian *Acacia* species occur as invasive aliens, but only to a limited extent. Erosion moderate and very low.

Reference Vlok & Euston-Brown (2002).

FFs 30 Western Altimontane Sandstone Fynbos

VT 69 Macchia (100%) (Acocks 1953). Mesic Mountain Fynbos (95%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (100%) (Low & Rebelo 1996). BHU 52 Matroosberg Mountain Fynbos Complex (70%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Summits and top ridges from around 1 800 m upwards including patches on Jurie se Berg (Sneeukoppe; 1 930 m), Shadow Peak (1 898 m) and Sneeuberg (2 026 m) in the Cederberg, Sneeukop (2 071 m) in Skurweberge, Groot Winterhoek Peak (2 078 m), Eureka Peak (1 987 m), Medina Peak (1 905 m) and Sneeugat Peak (1 884 m), Groot Winterhoek, as well as a series of larger patches along the Hex River Mountains on Mosterthoek Twins (2 030 m), Waaihoek Peak (1 948 m), Mount Superior (1 913 m), Fonteintjiesberg (1 989 m), Sentinel Peak (1 939 m), Buffelshoek Peak (2 059 m), Milner Peak (1 995 m), Groothoek Peak (2 099 m), Rooiberg (2 209 m), Sonkliprug (2 100 m) and Matroosberg (2 249 m). This unit includes Keeromsberg (2 071 m) situated in the extreme west of the Langeberg as well as Du Toits Peak (1 994 m) in the Du Toitsberge.

Vegetation & Landscape Features High-altitude summit peaks, generally fragmented and localised, but relatively extensive in the Hex River Mountains. Vegetation in these high-altitude positions is low, open to medium dense restioid fynbos, with ericaceous and asteraceous fynbos occurring locally. Proteoid fynbos generally absent.

Geology & Soils Skeletal and rocky acidic lithosol soils derived from Ordovician sandstones of the Table Mountain Group (Cape Supergroup). Land types mainly Ic and Ib.

Climate MAP generally 450–3 140 mm (mean: 1 385 mm), peaking May to August. Mean daily maximum and minimum

L. Mucina

Figure 4.49 FFs 30 Western Altimontane Sandstone Fynbos: View of the Matroosberg massif (Hex River Mountains, Western Cape) with Conical Peak on the left and precipices of the head of the Groothoek Valley on the right. The mountain tops support altimontane sandstone fynbos, while the smooth slopes of Conical Peak and the Matroosberg show the position of the shale band of Cedarberg Formation.

temperatures 22.9°C and 0.1°C for February and July, respectively. Microclimatical measurements at altitudes of about 1 900 m on Waaihoek Peak (Boelhouwers 1998) revealed that diurnal frost cycles occur from May to September. The annual precipitation totals 2 488 mm at Waaihoek Peak, 77% of which falls during the freeze/thaw season. Presence of snow estimated to occur on 31 days per year. Unlike on shale (see a note under FFb 2), despite 74 frost days a year at Waaihoek Peak, no evidence in favour of soil needle-ice formation observed. See also climate diagram for FFs 30 Western Altimontane Sandstone Fynbos (Figure 4.21).

Important Taxa Tall Shrub: *Protea punctata*. Low Shrubs: *Acmadenia teretifolia*, *Aspalathus aristata*, *A. bodkinii*, *A. brevicarpa*, *A. pedicellata*, *Athanasia elsiae*, *Brunia macrocephala*, *Cyclopia alpina*, *C. montana* var. *glabra*, *Disparago pilosa*, *Dolichothrix ericoides*, *Erica oresigena*, *Euryops glutinosus*, *E. othonnoides*, *Helichrysum zwartbergense*, *Lachnaea alpina*, *L. laniflora*, *L. macrantha*, *L. pendula*, *Metalasia phillipsii* subsp. *incurva*, *Oreoleysera montana*, *Passerina truncata* subsp. *monticola*, *Polyarrhena imbricata*, *Prismatocarpus alpinus*, *P. decurrens*, *Protea effusa*, *P. scabriuscula*, *P. scolopendriifolia*, *Selago oresigena*, *Spatalla confusa*, *S. incurva*, *Syncarpha dykei*, *Tittmannia laxa*. Semiparasitic Shrub: *Thesium oresigenum*. Herbs: *Trieenea glutinosa*, *Ursinia sericea*. Geophytic Herbs: *Geissorhiza alticola*, *G. hesperanthoides*, *G. rupicola*, *G. scopulosa*, *G. unifolia*. Graminoids: *Askidiosperma insigne*, *Cannomois nitida*, *Ehrharta calycina*, *E. rupestris* subsp. *rupestris*, *Elegia esterhuyseniae*, *E. filacea*, *Ficinia gydomontana*, *Ischyrolepis laniger*, *I. nana*, *I. ocreata*, *I. pygmaea*, *I. virgea*, *Pentaschistis alticola*, *P. ampla*, *P. densifolia*, *P. montana*, *P. pallida*, *P. pyrophila*, *P. rigidissima*, *P. rosea* subsp. *purpurascens*, *Restio nodosus*, *R. strobolifer*, *Thamnochortus acuminatus*, *Willdenowia stokoei*.

Endemic Taxa Low Shrubs: *Agathosma foleyana*, *A. tulbaghensis*, *Amphithalea esterhuyseniae*, *A. purpurea*, *Cliffortia esterhuyseniae*, *Cyclopia glabra*, *Erica brevicaulis*, *E. cameronii*, *Phylica intrusa*. Succulent Shrub: *Esterhuysenia alpina*. Herb: *Helichrysum solitarium*.

Conservation Least threatened. Target 29%. Statutorily conserved (35%) in the Cederberg and Groot Winterhoek Wilderness Areas as well as Bokkeriviere Nature Reserve, with an additional 65% in areas such as the Matroosberg and Koue Bokkeveld Mountains catchment areas. No signs of transformation. Erosion very low.

Remark 1 This is a poorly researched unit confined to the highest mountain peaks. Although there are a few patches of this unit embedded within FFs 4 Cederberg Sandstone Fynbos and FFs 5 Winterhoek Sandstone Fynbos, most of this type lies within FFs 7 North Hex Sandstone Fynbos and FFs 8 South Hex Sandstone Fynbos. We used the 1 800 m contour to map these communities—an exploration of the variation in altitude of this type is required. In some instances it appears to occur at lower and in other cases it is still transitional at higher altitudes. Mapped areas should therefore be treated as approximate. A minimum mapping patch area of about 40 ha was applied, meaning that peaks such as Goudini Sneeukop (1 863 m) and the Cederberg's Tafelberg (1 969 m) were not included in this unit. This area requirement resulted in all mapped patches reaching an altitude of more than 1 900 m. Other possible candidates (currently unmapped) for this unit include Bokkeveld Tafelberg (1 910 m) and Baviaansberg (1 946 m) in the Kouebokkeveld and the Klein-Winterhoek Peak (1 955 m) in the Winterhoek. The question remains whether vegetation of some somewhat lower mountain peaks such as the Stettynsberge (Stettynspiek: 1 821 m) and Heksberg (1 801 m) in the northern Kouebokkeveld should be classified within this vegetation unit as well.

Remark 2 Some shale bands (Cedarberg Formation, Cape Supergroup) are found at high altitudes, but their vegetation has been mapped elsewhere (FFb 1 and FFb 2).

References Marloth (1902), Linder et al. (1993), McDonald et al. (1993), Taylor (1996).

FFs 31 Swartberg Altimontane Sandstone Fynbos

VT 70 False Macchia (100%) (Acocks 1953). Mesic Mountain Fynbos (88%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (96%) (Low & Rebelo 1996). BHU 68 Groot Swartberg Mountain Fynbos Complex (49%), BHU 66 Klein Swartberg Mountain Fynbos Complex (47%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Altitudes above 1 800 m on sandstone, from a high plateau (1 933 m) west of Towerkop, Towerkop (2 189 m), Toringberg (2 127 m) and from here stretching eastwards continuously along a long ridge culminating in the highest point in the Fynbos Biome, namely Seweweekspoort Peak (2 325 m) also occurring on the peak (1 999 m) east of the Poort, all in the Klein Swartberg Mountains. Further patches occur along the Groot Swartberg Mountains from the ridge of the Kangoberg (2 034 m) to Waboomberg (1 942 m), via various other high points including Tierberg (1 948 m) as far as Blesberg (2 084 m) in the east. The summit(s) of Mannetjiesberg (1 955 m) in the Kammanassie Mountains probably also carries this vegetation type (not mapped).

Vegetation & Landscape Features High-altitude summit peaks. The patches of this vegetation type are generally linear, trending in an east-west direction. The vegetation is low, open to medium dense restioid fynbos, also with some more localised ericaceous and asteraceous fynbos. As in FFs 30 Western Altimontane Sandstone Fynbos, proteoid fynbos is generally absent.

Geology & Soils Skeletal and rocky acidic lithosol soils derived from Ordovician sandstones of the Table Mountain Group (Cape Supergroup). Narrow shale bands run across some ridges in both the Klein and Groot Swartberg. Land types mainly Ic and Ib.

Climate MAP 310–900 mm (mean: 585 mm), peaking slightly in March, but relatively even with a low from December to February. Mean daily maximum and minimum temperatures 23.6°C and –1.1°C for January and July, respectively. Frost incidence 10–30 days per year. See also climate diagram for FFs 31 Swartberg Altimontane Sandstone Fynbos (Figure 4.21).

C. Boucher

Figure 4.50 FFs 31 Swartberg Altimontane Sandstone Fynbos: Dramatic sandstone ridges, peaks and rocky slopes with screes at the highest altitudes of the Klein Swartberg Mountains (Western Cape).

Important Taxa Low Shrubs: *Acmadenia teretifolia* (d), *Anthospermum spathulatum* subsp. *spathulatum* (d), *Erica esterhuyseniae* (d), *E. strigilifolia* (d), *Spatalla confusa* (d), *Aspalathus pedicellata*, *A. rubens*, *Cyclopia alopecuroides*, *C. burtonii*, *Helichrysum zwartbergense*, *Heliophila rimicola*, *Lachnaea buxifolia*, *L. elsieae*, *Leucadendron dregei*, *Otholobium swartbergense*, *Protea montana*, *P. rupicola*, *P. scolopendriifolia*, *P. venusta*, *Raspalia variabilis*, *Selago pulchra*, *Syncarpha montana*, *Tittmannia laxa*. Herb: *Dianthus laingsburgensis*. Geophytic Herb: *Watsonia marlothii* (d). Graminoids: *Cannomois nitida* (d), *Ehrharta rupestris* subsp. *tricostata* (d), *Elegia filacea* (d), *Ischyrolepis laniger* (d), *I. schoenoides* (d), *Pentameris macrocalycina* (d), *Rhodocoma alpina* (d), *Willdenowia stokoei* (d), *Ischyrolepis wittebergensis*, *Pentaschistis montana*, *P. rigidissima*.

Endemic Taxa Low Shrubs: *Erica toringbergensis* (d), *Calotesta alba*, *Cyclopia aurescens*, *C. bolusii*, *Erica gossypioides*, *E. hebdomadalis*, *E. jugicola*, *E. lignosa*, *E. oreotragus*, *E. roseoloba*, *Protea pruinosa*, *Selago esterhuyseniae*. Graminoids: *Pentameris glacialis* (d), *P. swartbergensis* (d), *Restio papyraceus* (d), *Thamnochortus papyraceus* (d), *Staberoha stokoei*.

Conservation Least threatened. Target 29%. Almost the entire area of the unit enjoys protection in conservation areas, including Towerkop, Klein Swartberg, Groot Swartberg and Swartberg-oos. Almost none of the area has been transformed. *Hakea sericea* can pose some invasion threat. Erosion very low.

Remark 1 There is no abrupt interface between altimontane and other sandstone fynbos types. There is a gradual change between middle-altitude communities and high-altitude communities, both structurally and floristically. More important factors are water-logging, soil depth and rockiness, which determine floristic and structural composition irrespective of altitude. Endemism and dominants are characteristic of the local species pools, with an equal amount of local and regional endemism shared between distinct altimontane sandstone fynbos sites.

Remark 2 A minimum mapping patch area of about 40 ha was applied, meaning that, for example, several small peaks on the Kammanassie Mountains (especially those around the highest point of Mannetjiesberg (1 955 m) were not included in this unit. This area requirement resulted in almost all mapped patches reaching an altitude of more than 1 900 m.

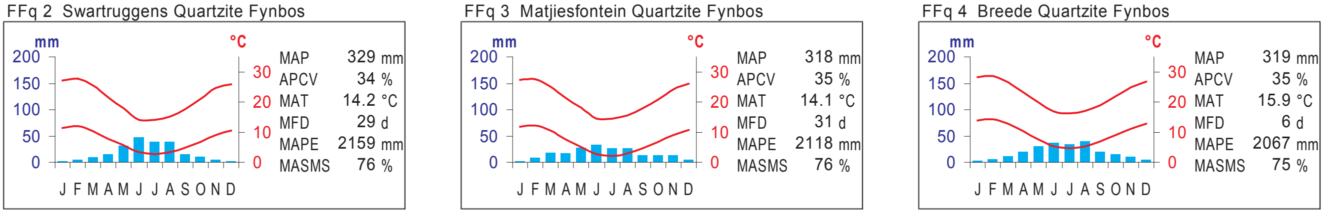
References Marloth (1902), Linder et al. (1993), McDonald et al. (1993).

9.1.2 Quartzite Fynbos

Quartzite fynbos comprises almost 10% of the area of fynbos vegetation, being the third most extensive fynbos group, after sandstone and sand fynbos. Within the Fynbos Biome it is largely confined to the more arid areas. Two vegetation types within quartzite fynbos are the only fynbos types not known to have endemic species.

Unlike most of the sandstones of the Cape Supergroup, quartzites have undergone drastic changes in location over the past 120 million years since the break-up of Gondwana. All coastal remnants (with an exception at Riversdale) and Little Karoo exposures (with the exception of remnants at Montagu and Bethal Dam) have been totally removed by erosion. Exposures on the West Coast were probably well eroded during the Cretaceous. Extensive exposures still occur on the borders of the Tanqua and Great Karoo from Wuppertal to Laingsburg. These are now generally 40 km east of the Olifants fault, 15 km north of the Swartberg fault, and—exposing the Steytlerville Karoo—some 35 km north of the Baviaanskloof fault.

Quartzite fynbos is not a geological type per se—it is merely named after the Witteberg quartzites on which it occurs most frequently. It is primarily an arid unit, characterised and distinguished from sandstone fynbos by the typically linear nature of the units, and/or by much higher levels of remnant surface clays. These appear to be derived not only from overlying geology, but also from wind and water erosion. Even a rudimentary clay soil is sufficient to exclude fynbos and result in renosterveld or karoo vegetation, except in wetter areas where it has features and species more typical of shale fynbos, and is mapped as such. Quartzite fynbos may occur in very small patches within this environment, usually along scarps and ridges. In drier areas they may be confined to a narrow linear zone (sometimes only



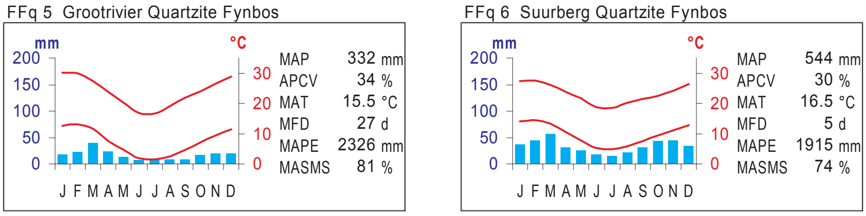


Figure 4.51 Climate diagrams of quartzite fynbos units excluding FFq 1 Stinkfonteinberge Quartzite Fynbos. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days; MAPE: Mean Annual Potential Evaporation; MASMS: Mean Annual Soil Moisture Stress.

some metres across) at the base of these scarps. It is probably a historical and topographical accident that almost all Witteberg quartzite exposures now occur in relatively arid areas. Erosion has effectively moved exposures to the inland margins of the Cape Fold Belt. It is generally true that 'quartzite fynbos' could equally be described as 'arid fynbos'. Thus the fynbos on the Witteberg quartzite in the wetter Koue Bokkeveld is grouped with FFs 5 Winterhoek Sandstone Fynbos, and not with the drier FFq 2 Swartruggens Quartzite Fynbos.

Due to its aridity, the dominant communities on quartzite fynbos are asteraceous and proteoid fynbos. Restioid fynbos occurs locally, but ericaceous fynbos is rare. Afrotemperate forest seldom occurs in quartzitic fynbos, and the fire-protected habitats tend toward Succulent Karoo or Albany Thicket vegetation instead, in the west and east of the Fynbos Biome, respectively. The two eastern units are dominated by graminoid fynbos. Waboomveld is never found to be part of quartzite fynbos.

The drier edge of these communities has not been adequately mapped. Until better data are available we have included the basal Succulent Karoo vegetation within this mapped unit. This extends further up on north facies, is usually absent on south facies, and may occur within areas expected to have fynbos where patches are too small to maintain fire (e.g. where the surrounding veld is Succulent Karoo or Albany Thicket).

FFq 1 Stinkfonteinberge Quartzite Fynbos

VT 28 Western Mountain Karoo (69%) (Acocks 1953). LR 56 Upland Succulent Karoo (100%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Central Richtersveld—a narrow belt along the top mountain ridges of the Vandersterrberg (1 366 m) east of Koeboes in the north, Cornellsberg (1 377 m) and Stinkfonteinberge (1 230 m) immediately north of Eksteenfontein in the south. Altitude about 1 100–1 377 m.

Vegetation & Landscape Features This unit forms the upper north-south-trending backbone of the Richtersveld. The landscape at the high altitudes above 1 100 m is as diverse as the geomorphology of the longitudinal mountain range. While over long distances it forms a ridge, in other places steep or rounded mountain tops are embedded, separated by saddles and valleys. In other parts, a plateau has been formed, allowing accumulation of soils above bedrock. Therefore, habitat types differ greatly and are controlled by rock structure, overlying soil depth, slope and inclination. Dense shrublands can form where soil depth and rock structure allow water storage over longer periods of the year. Flatter plateau positions on leached quartzite soils can bear open *Merxmuellera dura* grasslands, while very shallow soils and bare rock support the presence or dominance of leaf-succulent dwarf shrubs.

Geology & Soils A wide spectrum of different rocks, mostly quartzite, as well as other metamorphosed clastic sediments and minor volcanic rocks of the Stinkfontein Subgroup of the Precambrian Gariep Supergroup. Soils mainly loams or loamy sands. Land types mainly Ic.

Climate MAP probably slightly over 200 mm. Fog occurs especially on the western side. Mean daily maximum and minimum temperatures 28.8°C and 2.8°C for January and July, respectively. Frost incidence 10–20 days per year.

Important Taxa Tall Shrubs: *Euryops tenuissimus* (d), *Diospyros ramulosa*, *Helichrysum hebelepis*, *Montinia caryophyllacea*, *Rhus incisa*, *R. populifolia*. Low Shrubs: *Elytropappus rhinocerotis* (d), *Anthospermum dregei* subsp. *dregei*, *Asparagus exuvialis*, *Berkheya canescens*, *Blepharis furcata*, *Chrysocoma oblongi-*

N. Jürgens

Figure 4.52 FFq 1 Stinkfonteinberge Quartzite Fynbos: Low grassy shrubland on top of the ridge of the Stinkfonteinberge in the Richtersveld showing a matrix of *Merxmuellera dura*, *Didelta spinosa*, *Elytropappus rhinocerotis* and *Lobostemon echioides*.

folia, *Cryptolepis decidua*, *Eriocephalus africanus* var. *africanus*, *E. ericoides* subsp. *ericoides*, *Galenia africana*, *Lobostemon echioides*, *Osteospermum sinuatum*, *Pelargonium praemorsum*, *Pteronia divaricata*, *P. glauca*, *Tripteris sinuata*. Succulent Shrubs: *Othonna furcata* (d), *Aloe dichotoma* var. *ramosissima*, *Antimima pilosula*, *Aridaria brevicarpa*, *Cephalophyllum goodii*, *Ceraria fruticulosa*, *Crassula macowaniana*, *Didelta spinosa*, *Euphorbia quadrata*, *Manochlamys albicans*, *Pelargonium echinatum*, *Prenia sladeniana*, *Tylecodon paniculatus*. Woody Climbers: *Asparagus retrofractus*, *Dioscorea elephantipes*. Herbs: *Amellus epaleaceus*, *A. nanus*, *Arctotis fastuosa*, *Dimorphotheca sinuata*, *Senecio sisymbriifolius*. Geophytic Herbs: *Albuca maxima*, *Cheilanthes robusta*, *Chlorophytum namaquense*. Succulent Herbs: *Adromischus marianiae*, *Crassula expansa* subsp. *pyrifolia*, *C. hemisphaerica*, *C. muscosa*, *Tetragonia reduplicata*. Graminoids: *Merxmuellera dura* (d), *Bromus pectinatus*, *Ehrharta calycina*, *E. delicatula*, *E. longiflora*, *Fingerhuthia africana*, *Ischyrolepis sieberi*.

Conservation Least threatened (due to poor accessibility and low economic attractiveness). Conservation target (28%) already achieved since more than 30% is conserved in the Richtersveld National Park, but its southern somewhat mesic part is not formally protected. Grazing is light, with very little disturbance, and erosion is very low.

Remarks Better developed on the Stinkfonteinberge than on the Vandersterrberg, following the northward gradient of increased aridity. Apparently absent from the east-branching mountains of similar altitude, for example the Rosyntjieberg (1 332 m) associated with an eastward gradient of increased aridity in this area.

References Van Jaarsveld (1981), Van Wyk & Smith (2001), Schüttler (2002), Jürgens (2004).

FFq 2 Swartruggens Quartzite Fynbos

VT 69 Macchia (76%) (Acocks 1953). Central Mountain Renosterveld (31%), Mosaic of Dry Mountain Fynbos & Karroid Shrublands (15%), Dry Mountain Fynbos (4%) (Moll & Bossi 1983). LR 57 Lowland Succulent Karoo (54%) (Low & Rebelo 1996). BHU 49 Swartruggens Mountain Fynbos Complex (42%), BHU 36 Kouebokkeveld Inland Renosterveld (29%), BHU 78 Tanqua Vygieveld (23%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

L. Mucina

Figure 4.53 FFq 2 Swartruggens Quartzite Fynbos: *Protea glabra* on a quartzite outcrop covered with succulent shrubs (*Ruschia*, *Crassula*, *Othonna*) and annual herbs (*Ursinia anthemoides* subsp. *versicolor*) in the Swartruggens Mountains near Op-die-Berg (Western Cape).

Distribution Western and Northern Cape Provinces: West of the Cederberg from the Tra-Traberge north of Wuppertal, interrupted by the Tra-Tra River Valley, continuing on the high plateau including the Vaalheuningberge, Matjiesrivier, Klipbokberg, Rietriviersberg, eastern Blinkberg, continuing on the Swartruggens Plateau, Vleieberg, Watervalsberg, Baviaansberg and Kwarrieberg at Karoopoort in the south. Altitude 800–1 800 m. The area above 1 800 m on Baviaansberg (summit 1 946 m) probably qualifies for FFs 30 Western Altimontane Sandstone Fynbos.

Vegetation & Landscape Features Mountains alternating with broad ridges and plains, supporting medium dense, moderately tall, restioid and ericoid shrubland with open, emergent, tall proteoid shrubs. This is a diverse fynbos, with all structural types of fynbos (except graminoid fynbos) represented. In drier, lower areas it is replaced by karoo shrublands on sandstone. The boundary between the fynbos and karoo occurs where the restioids thin out to the point where succulent plants become dominant.

Geology & Soils Sandy and skeletal soils (usually of Glenrosa or Mispah forms) derived from Witteberg Group quartzite. Land types mainly Ib and Fa.

Climate Subarid, winter-rainfall regime with MAP 200–620 mm (mean: 330 mm), peaking from May to August. Mean daily maximum and minimum temperatures 27.9°C and 2.7°C for February and July, respectively. Frost incidence 10–20 days per year. See also climate diagram for FFq 2 Swartruggens Quartzite Fynbos (Figure 4.51).

Important Taxa ([T]Cape thickets) Tall Shrubs: *Phylica buxifolia* (d), *Protea glabra* (d), *Dodonaea viscosa* var. *angustifolia*, *Euryops speciosissimus*, *Leucadendron pubescens*, *Metalasia densa*, *Passerina corymbosa*, *Protea laurifolia*. Low Shrubs: *Elytropappus rhinocerotis* (d), *Erica maximiliani* (d), *Agathosma squamosa*, *Aspalathus altissima*, *A. bodkinii*, *Athanasia flexuosa*, *Diosma acmaeophylla*, *Dolichothrix ericoides*, *Elytropappus glandulosus*, *Erica rigidula*, *Eriocephalus africanus* var. *africanus*, *E. africanus* var. *paniculatus*, *E. ericoides* subsp. *ericoides*, *Euryops brevilobus*, *E. othonnoides*, *E. rehmannii*, *E. tagetoides*, *Felicia scabrida*, *Leucadendron brunioides* var. *brunioides*, *L. glaberrimum* subsp. *glaberrimum*, *L. loranthifolium*, *L. nitidum*, *Leucospermum calligerum*, *Maytenus oleoides*[T], *Metalasia agathosmoides*, *Muraltia lignosa, Passerina obtusifolia*, *P. truncata* subsp. *truncata*, *Phylica odorata*, *P. rigidifolia*, *Protea laevis*, *P. pendula*, *P. witzenbergiana*, *Pteronia incana*, *Stoebe fusca*, *Ursinia pilifera*. Succulent Shrub: *Othonna coronopifolia*. Geophytic Herb: *Romulea sphaerocarpa*. Succulent Herb: *Stapelia arenosa*. Graminoids: *Ficinia dunensis* (d), *Ischyrolepis unispicata* (d), *Willdenowia incurvata* (d), *Cannomois scirpoides*, *C. taylorii*, *Elegia filacea*, *Ischyrolepis capensis*, *I. ocreata*, *Pentaschistis eriostoma*, *Thamnochortus schlechteri*.

Endemic Taxa Low Shrubs: *Amphiglossa susannae*, *Nenax elsieae*, *Oedera epaleacea*, *O. foveolata*, *Phylica pauciflora*, *Vexatorella amoena*. Succulent Shrubs: *Esterhuysenia mucronata*, *Ruschia littlewoodii*. Herb: *Phyllopodium viscidissimum*. Geophytic Herbs: *Moraea fuscomontana*, *Romulea lilacina*.

Conservation Least threatened. Target 29%. Only 4% statutorily conserved in the Matjiesrivier Nature Reserve, with an additional 5% protected in Groenfontein Private Nature Reserve. Only 2% has been transformed (mainly cultivation). Erosion generally low.

Remark The delimitation of this unit and the neighbouring SVk 2 Swartruggens Quartzite Karoo follows the boundary rules as suggested by Lechmere-Oertel (1998).

References Boucher (1996a), Lechmere-Oertel (1998), Lechmere-Oertel & Cowling (1999, 2001), H.C. Taylor (unpublished data).

FFq 3 Matjiesfontein Quartzite Fynbos

VT 70 False Macchia (43%), VT 69 Macchia (19%) (Acocks 1953). Central Mountain Renosterveld (65%) (Moll & Bossi 1983). LR 61 Central Mountain Renosterveld (66%) (Low & Rebelo 1996). BHU 39 Matjies Inland Renosterveld (30%), BHU 62 Witteberg Mountain Fynbos Complex (22%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: A complex of ridges and low mountains mostly in the Western Little Karoo extending from Saalberg near Karoopoort and Skulpiesklip in the west to Elandsberg near the Gamkapoort Dam in the east. This includes parts of the Bontberg, Voetpadsberg and Koegaberge in the vicinity of Touws River, the Witteberg south of Matjiesfontein including many ridges between the Witteberg and Anysberg, and the higher ridges north of, and running parallel to, the Klein Swartberg. Also between Ouberg Pass and Gatskraal (Mont Eco) west of Warmwaterberg and on hill summits around Ladismith, including Ladismith Hill. Altitude 750–1 684 m at an unnamed point north of Towerkop.

Vegetation & Landscape Features Low flat mountains and parallel ridges in a west-east orientation. Apart from the Witteberg and Elandsberg, this vegetation type consists of narrow, linear bands surrounded by FFh 2 Matjiesfontein Shale Fynbos and Succulent Karoo vegetation. It is a medium dense, medium tall shrubland, structurally classified mainly as asteraceous and proteoid fynbos, although restioid fynbos is also present. The lower northern slopes in the east, where there is a rainshadow effect due to the Swartberg Mountains, support Succulent Karoo vegetation.

Geology & Soils Sandy and skeletal soils derived from Witteberg Group quartzites. Land types mainly Ic, Ib and Fc.

Climate MAP 150–450 mm (mean: 320 mm), peaking slightly from May to August. Mean daily maximum and minimum temperatures 27.5°C and 2.2°C for February and July, respectively. Frost incidence 10–40 days per year. See also climate diagram for FFq 3 Matjiesfontein Quartzite Fynbos (Figure 4.51).

Important Taxa Tall Shrubs: *Protea laurifolia* (d), *P. repens* (d), *Leucadendron pubescens*, *L. rubrum*, *Nylandtia spinosa*, *Phylica buxifolia*. Low Shrubs: *Agathosma squamosa*, *Amphiglossa tomentosa, Diosma hirsuta*, *Elytropappus rhinocerotis*, *Erica cerinthoides* var. *cerinthoides*, *E. plukenetii* subsp. *plukenetii*, *E. rigidula*, *Euryops erectus*, *E. oligoglossus* subsp. *oligoglossus*, *E. rehmannii*, *Leucadendron barkerae*, *L. cadens*, *L. salignum*, *L. teretifolium*, *Polygala myrtifolia*, *Protea canaliculata*, *P. lorifolia*, *P. pendula*, *P. revoluta*, *P. sulphurea*, *Stoebe plumosa*, *Vexatorella obtusata* subsp. *albomontana*. Succulent Herb: *Quaqua pillansii*. Graminoids: *Ischyrolepis capensis*, *Thamnochortus fruticosus*, *Willdenowia incurvata*.

Endemic Taxa Tall Shrub: *Leucadendron osbornei*. Low Shrubs: *Acmadenia argillophila*, *Aspalathus intricata* subsp. *anthospermoides*, *Chrysocoma acicularis*, *Erica mira*, *Globulariopsis montana*, *G. wittebergensis*, *Helichrysum archeri*, *Hermannia pillansii*, *Phylica retorta*, *Selago albomontana*. Succulent Shrubs: *Drosanthemum archeri*, *D. wittebergense*, *Ruschia altigena*. Herb: *Senecio wittebergensis*. Geophytic Herb: *Ornithogalum unifolium* var. *vestitum*. Succulent Herb: *Haworthia wittebergensis*. Graminoids: *Ischyrolepis esterhuyseniae*, *I. karooica*.

Conservation Least threatened. Target 27%. Statutorily conserved in the Anysberg Nature Reserve (5%) and a further 3% in Vaalkloof Private Nature Reserve. Only about 15% has been transformed (cultivation). Erosion low and moderate.

Remarks This little known vegetation requires detailed study. The southern outliers (largely unknown) near Bellair Dam (the lowest MAP in the basin of the Little Karoo) may comprise a separate unit, being biogeographically allied to the Warmwaterberg and Waboomsberg. Similarly, the outliers around Ladismith are currently unknown and their affiliation with this unit is speculative. The northernmost border with Succulent Karoo on quartzite is largely unknown and has not been accurately mapped, except at a few mountain passes, from which it has been extrapolated.

References Vlok (2002), C. Boucher (unpublished data).

P. Goldblatt

Figure 4.54 FFq 3 Matjiesfontein Quartzite Fynbos: Dry proteoid fynbos with *Leucadendron teretifolium, Protea canaliculata* and *P. lorifolia* on the summit of the Witteberg near the FM tower south of Matjiesfontein (Western Cape).

FFq 4 Breede Quartzite Fynbos

VT 26 Karroid Broken Veld (52%) (Acocks 1953). Central Mountain Renosterveld (46%), Mesic Mountain Fynbos (23%) (Moll & Bossi 1983). LR 61 Central Mountain Renosterveld (51%), LR 58 Little Succulent Karoo (25%), LR 64 Mountain Fynbos (23%) (Low & Rebelo 1996). BHU 38 Ashton Inland Renosterveld (60%), Robertson Broken Veld (29%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Southern Breede River Valley from the Brandvlei Dam at Die Nekkies near Worcester to northeast of Bonnievale, but with by far the largest extent on the Hammansberg, Ouhangsberge, Gemsbokkop, Gannaberg and Rooiberg. Altitude 200–876 m on the summit of Gannaberg.

Vegetation & Landscape Features A single range of parallel ridges and flat-topped hills in the west, and high hills and low mountains in the east. The vegetation is an open tall shrubland in a medium dense, medium tall shrub matrix, structurally classified as asteraceous, restioid and proteoid fynbos. Northern slopes tend to support karoo shrublands, especially at lower reaches.

Geology & Soils Sandy and skeletal soils (Glenrosa and Mispah forms prominent) derived from Witteberg Group quartzites. Land types mainly Ic and Fb.

Climate MAP 190–550 mm (mean: 320 mm), peaking slightly from May to August. Mean daily maximum and minimum temperatures 28.6°C and 4.7°C for February and July, respectively. Frost incidence 5–8 days per year. See also climate diagram for FFq 4 Breede Quartzite Fynbos (Figure 4.51).

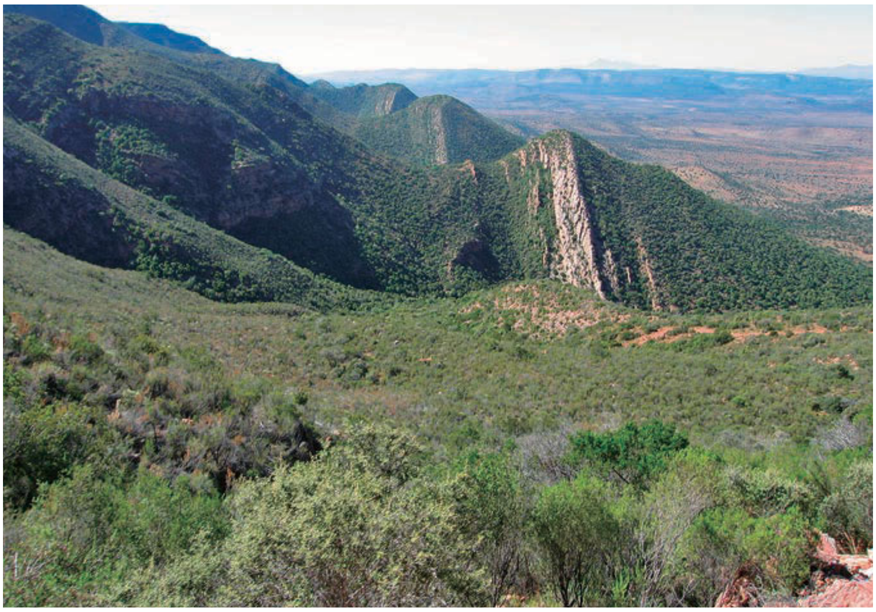


Figure 4.55 FFq 5 Grootrivier Quartzite Fynbos: Dry fynbos on the ridges of the Grootrivier Mountains, north of Steytlerville (Eastern Cape).

Important Taxa Small Tree: *Protea nitida* (d). Tall Shrubs: *Protea repens* (d), *P. laurifolia*. Low Shrubs: *Diosma ramosissima*, *Leucadendron salignum* (d), *L. teretifolium*, *Leucospermum calligerum*, *L. utriculosum* (Robertson form), *Protea humiflora*, *P. restionifolia*, *Serruria acrocarpa*.

Endemic Taxa Low Shrubs: *Erica boucheri*, *Lobostemon gracilis*.

Conservation Least threatened. Target 30%. Only very small portion statutorily conserved in the Vrolijkheid Nature Reserve, but 9% enjoys protection in the Quaggas Berg and Drooge Riviers Berg Private Nature Reserves. Some 6% has been transformed (cultivation). No aliens are found at significant densities, although *Hakea sericea* is prominent in places. Erosion very low and moderate.

Remarks This is a very poorly known unit related to FFs 13 North Sonderend Sandstone Fynbos, and perhaps best considered as part of it, but markedly more arid and typically linear. At present its delimitation is largely based on the occurrence of Proteaceae. The karoo shrublands on the northern slopes at lower reaches have simply been mapped as fynbos as their lower limits are unknown and their communities are different to Succulent Karoo shrublands on shales.

Reference Protea Atlas Project (unpublished data).

FFq 5 Grootrivier Quartzite Fynbos

VT 25 Succulent Mountain Scrub (Spekboomveld) (61%), VT 70 False Macchia (28%) (Acocks 1953). Dry Grassy Fynbos (25%) (Moll & Bossi 1983). LR 8 Spekboom Succulent Thicket (49%), LR 65 Grassy Fynbos (22%) (Low & Rebelo 1996). BHU 98 Willowmore Xeric Succulent Thicket (56%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western and Eastern Cape Provinces: Ridges north of the Groot Swartberg and Baviaanskloof Mountains, from Prince Albert to Wolwefontein west of Kirkwood, but mainly in the Grootrivierberge mostly north of the Groot River between Willowmore and Steytlerville as well as on the adjoining Witteberg north of the Grootrivierberge. Generally a very narrow strip (< 1 km wide) west of the Boesmanspoortberg at Willowmore. Separated from the most easterly quartzite fynbos unit (FFq 6 Suurberg Quartzite Fynbos) by the Wolwefontein-Baroe Valley. Altitude 650–1 579 m on the summit of the Witteberg.

Vegetation & Landscape Features A series of narrow parallel scarps, much broader, higher and more extensive in the west at Witberg. Typical vegetation is a medium dense, moderately tall, restioid and ericoid shrubland dotted with emergent, tall proteoid shrubs in the wetter west, and containing more grassy elements in the east. Proteoid fynbos is confined to the higher peaks, with asteraceous fynbos the dominant component in the west and grassy fynbos in the east. The northern edge is primarily determined by Spekboomveld, and the southern edge by other Albany Thicket communities. Grasses are relatively abundant, especially on northern slopes.

Geology & Soils Sandy and skeletal soils, often red-yellow, apedal and shallow, derived from Witteberg Group quartzite. Land types mainly Ib, Ag and Ic.

Climate MAP 160–560 mm (mean: 330 mm), peaking in March, with a low from June to September. Mean daily maximum and minimum temperatures 30.1°C and 1.4°C for January and July, respectively. Frost incidence 10–30 days per year. See also climate diagram for FFq 5 Grootrivier Quartzite Fynbos (Figure 4.51).

Important Taxa Tall Shrubs: *Leucadendron loeriense*, *L. nobile*, *Phylica paniculata*, *Protea lorifolia*, *P. punctata*, *P. repens*. Low Shrubs: *Agathosma ovalifolia*, *Cliffortia castanea*, *C. neglecta*, *Dolichothrix ericoides*, *Erica demissa*, *E. pectinifolia*, *E. petraea*, *Leucospermum wittebergense*, *Muraltia ericaefolia*, *Passerina obtusifolia*, *Struthiola argentea*. Succulent Shrub: *Euphorbia polygona*. Succulent Herb: *Stapelia obducta*. Graminoids: *Calopsis andreaeana*, *Ficinia nigrescens*, *Ischyrolepis gaudichaudiana*, *I. sieberi*, *Mastersiella purpurea*, *Thamnochortus rigidus*.

Endemic Taxa Low Shrub: *Theilera capensis*. Succulent Herb: *Ophionella willowmorensis*.

Conservation Least threatened. Target 23%. None conserved in statutory conservation areas and only 1% protected in Timbili Game Reserve. Only very small portion has been transformed, incidence of alien flora is insignificant. Erosion low and very low.

Remarks This is a very poorly explored vegetation type. This unit could, based on edaphic criteria, be more widespread than it is at present, but the extent of suitable habitat complex is too small to support fires and too linear to allow their spread. Consequently, much of the quartzites is covered by dense Albany Thicket vegetation. Judging from the extent of the remnants, the unit must have been much more extensive in the past.

Reference Protea Atlas Project (unpublished data).

FFq 6 Suurberg Quartzite Fynbos

VT 70 False Macchia (64%) (Acocks 1953). Valley Bushveld (64%), Dry Grassy Fynbos (22%) (Moll & Bossi 1983). LR 65 Grassy Fynbos (37%), LR 6 Xeric Succulent Thicket (28%) (Low & Rebelo 1996). BHU 23 Zuurberg Grassy Fynbos (12%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Eastern Cape Province: From Baroe in the west along the Kleinwinterhoekberge, the Suurberge north of Kirkwood, multiple ridges in the vicinity of Somerset East and Alicedale, immediately south of Grahamstown some slopes and hills, e.g. Signal Hill to the Kaprivierberge east of Grahamstown. Altitude 350–1 010 m at the highest point in the Kleinwinterhoekberge.

Vegetation & Landscape Features Low rounded hills and mountains supporting low to medium high, closed, ericoid shrubland or grassland, with closed restioid and/or grass understorey. Grassy fynbos is the most typical structural type, with localised patches of dense proteoid and ericaceous fynbos. On drier, north-facing slopes grassland replaces this unit, but the south-facing slopes always carry fynbos unless converted to grassland by over-burning, or to thicket by over-protection from fire. Thicket is found on the richer soils at the base of the formation and in gullies.

Geology & Soils Sandy soils, predominantly Glenrosa and Mispah forms, derived from Witteberg Group quartzite. Land types mainly Fa, Fb and Ib.

Climate MAP 220–820 mm (mean: 545 mm), peaking bimodally from October–November and February–March. Mean daily maximum and minimum temperatures 27.7°C and 4.7°C for February and July, respectively. Frost incidence 2–10 days per year. See also climate diagram for FFq 6 Suurberg Quartzite Fynbos (Figure 4.51).

Important Taxa (TCape thickets) Small Tree: *Loxostylis alata*. Succulent Tree: *Aloe ferox*. Tall Shrubs: *Cliffortia burchellii* (d), *C. linearifolia* (d), *Euryops latifolius* (d), *Cliffortia serpyllifolia*, *Diospyros scabrida*T, *Grewia occidentalis*, *Montinia caryophyllacea*, *Protea lorifolia*, *P. repens*. Low Shrubs: *Clutia heterophylla* (d), *Erica chamissonis* (d), *E. demissa* (d), *E. pectinifolia* (d), *E. simulans* (d), *E. triceps* (d), *Helichrysum odoratissimum* (d), *Leucadendron salignum* (d), *Phylica axillaris* (d), *Tephrosia capensis* (d), *Acalypha peduncularis*, *Anthospermum aethiopicum*, *A. spathulatum* subsp. *uitenhagense*, *Aspalathus teres* subsp. *teres*, *Berzelia commutata*, *Cliffortia graminea*, *Clutia alaternoides*, *Disparago ericoides*, *Erica cerinthoides* var. *cerinthoides*, *E. copiosa*, *E. decipiens*, *E. glumiflora*, *E. nutans*, *Euryops brachypodus*, *E. euryopoides*, *Gnidia coriacea*, *G. oppositifolia*, *Gomphocarpus cancellatus*, *Helichrysum anomalum*, *H. cymosum*, *Leucadendron spissifolium* subsp. *phillipsii*, *Leucospermum cuneiforme*, *Muraltia squarrosa*, *Passerina obtusifolia*, *Pelargonium reniforme*, *Polygala microlopha*, *Protea cynaroides*, *P. foliosa*, *Pteronia teretifolia*, *Ursinia anethoides*. Succulent Shrubs: *Crassula cultrata* (d), *Euphorbia polygona*, *Lampranthus spectabilis*, *Othonna carnosa*. Semiparasitic Shrub: *Thesium strictum*. Herbs: *Alepidea capensis* (d), *Amellus strigosus* (d), *Cineraria saxifraga* (d), *Helichrysum nudifolium* (d), *H. subglomeratum* (d), *Senecio othonniflorus* (d), *Centella eriantha*, *Helichrysum felinum*, *Knowltonia cordata*, *Linum thunbergii*, *Sutera polyantha*, *Ursinia anthemoides* subsp. *anthemoides*. Geophytic Herbs: *Pteridium aquilinum* (d), *Agapanthus africanus*, *Bulbine latifolia*, *Oxalis imbricata* var. *violacea*, *O. punctata*, *Watsonia knysnana*. Succulent Herb: *Stapelia grandiflora*. Graminoids: *Alloteropsis semialata* subsp. *eckloniana* (d), *Cannomois virgata* (d), *Diheteropogon filifolius* (d), *Eragrostis curvula* (d), *Festuca costata* (d), *Merxmuellera stricta* (d), *Pentaschistis eriostoma* (d), *Poa binata* (d), *Restio sejunctus* (d), *R. triticeus* (d), *Schoenoxiphium sparteum* (d), *Tetraria capillacea* (d), *Themeda triandra* (d), *Tristachya leucothrix* (d), *Calopsis paniculata*, *Elegia asperiflora*, *Ficinia acuminata*, *Hyparrhenia hirta*, *Hypodiscus striatus*, *Ischyrolepis gaudichaudiana*, *I. triflora*, *Rhodocoma capensis*, *Tetraria cuspidata*.

Endemic Taxa Small Tree: *Oldenburgia grandis* (d). Low Shrubs: *Euryops hypnoides*, *E. polytrichoides*.

Conservation Least threatened. Target 23%. Statutorily conserved in the Greater Addo Elephant National Park (15%), with an additional 16% protected in the private Rockdale Game Ranch and Frontier Safaris Game Farm. Only 1% has been transformed (cultivation), but over-burning (occurring quite frequently) resulting in conversion of fynbos to grassland should be considered as transformation as well. Erosion moderate and very low.

Remarks Historically, there has been no obvious attempt to separate fynbos on quartzite and shale in this region. Protea Atlas data suggest that there may be a separation, but the lack of references in the literature suggests that any such differ-

L. Mucina

Figure 4.56 FFq 6 Suurberg Quartzite Fynbos: Quartzite ridge southwest of Grahamstown (Eastern Cape) with grassy fynbos with enigmatic local endemic tree daisy *Oldenburgia grandis* (Asteraceae).

ences are not obvious. Hence the proper delimitation of FFq 6 Suurberg Quartzite Fynbos and FFh 10 Suurberg Shale Fynbos remains a challenge.

References Dyer (1937), Martin & Noel (1960), Martin (1965, 1966), Kruger (1979), Cowling (1983b), Lubke (1983), Richardson et al. (1984), Lubke et al. (1986), Van Wyk et al. (1988), Euston-Brown (1995), Vlok & Euston-Brown (2002).

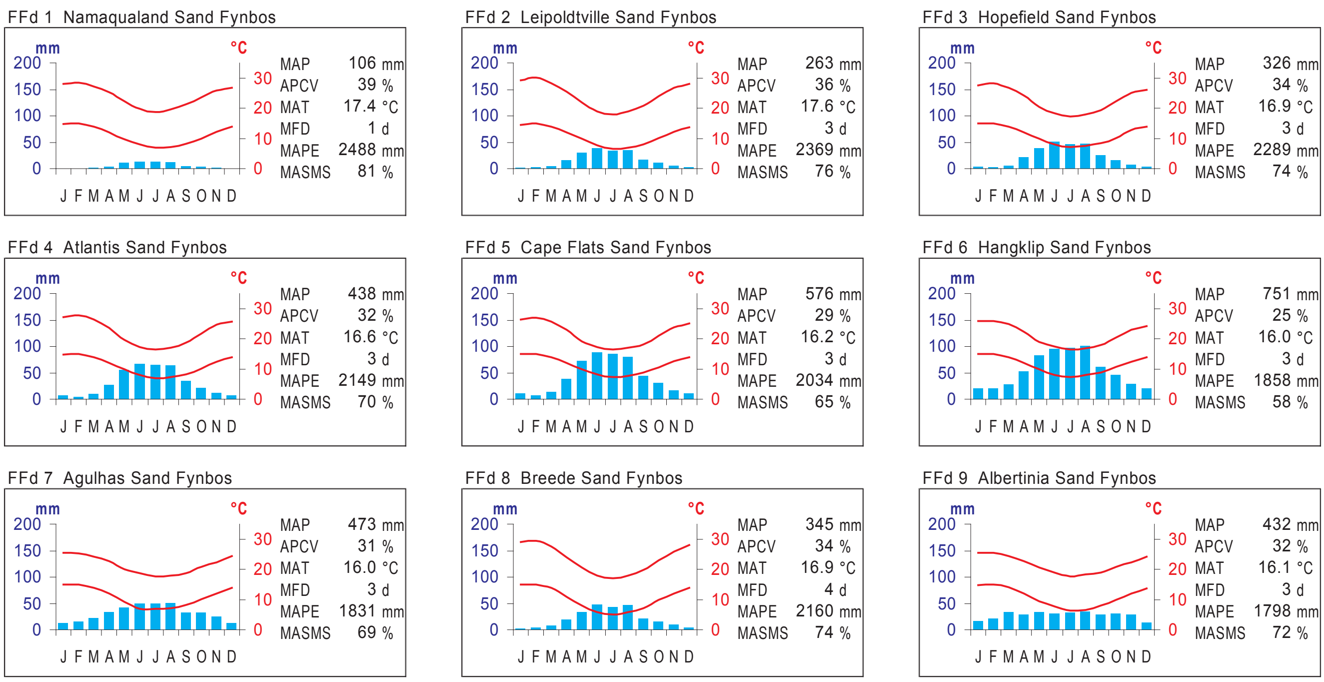
9.1.3 Sand Fynbos

Sand fynbos is the second largest unit accounting for 15% of the area of Fynbos. It is almost entirely coastal, occurring on Quaternary and Tertiary sands of marine and aeolian origin. Deep sand on the West and South Coasts reflects a broad soil-reaction gradient—spanning acidic, neutral to alkaline. All alkaline sands on the West Coast support strandveld, and on the South Coast they carry either thicket (strandveld) or dune fynbos, depending on the underlying topography and fire regime. With time the sands become leached and are invaded by sand fynbos, which should therefore strictly be called 'acid sand fynbos', although some communities may also occur on soils of neutral reaction (pH 6–7). The dominant structural type of sand fynbos depends on the water table. Where water tables are deep (access to rainfall is only in winter), restioid fynbos dominates, usually with marked absence of shrubs. Where the water table is more accessible, asteraceous fynbos may occur, usually dominated by species of *Passerina* and *Phylica*. This type usually has a marked spring-flower component, comprising both annuals and geophytes. At relatively shallow and non-fluctuating water tables proteoid fynbos dominates—one with a more closed canopy and relatively fewer annuals and geophytes. Depending on water depth, soil fertility and topography, different communities within these types can be distinguished. Ericaceous fynbos is relatively localised and rare, especially to the north, and is associated with seeps and peaty soils.

On the aridity gradient to the north on the West Coast, Ericaceae are the first to disappear, so that only FFd 5 Cape Flats Sand Fynbos and FFd 4 Atlantis Sand Fynbos retain a marked ericaceous component. Proteoids drop out next, and the restioid component is the most persistent, but diminishes as cover gets too sparse to support fire. Stands of Restionaceae persist beyond the fire margin in dune slacks where the water table prevents shrub growth by fluctuating from waterlogged in winter to rather dry in summer (and strandveld persists on the dunes and their crests). A curious exception to the role of fire in fynbos occurs in the FFd 1 Namaqualand Sand Fynbos, where Proteaceae persist on moving dune ridges, with restios in dune slacks, where sands are acidic and water tables shallow. Regeneration of proteoids occurs in deflation hollows and most populations are dominated by gnarled, senescent plants.

The boundary of sand fynbos with strandveld is a dynamic one, powered both by sparseness of the vegetation not supporting fire and by dune topography. However, the boundary is a broad one and probably relates to a diminishing return time between fires as one approaches true strandveld. The boundary is often appreciably broader, with adjacent strandveld communities dominated by succulent species, than those dominated by thicket elements. Usually thicket elements are confined to fire-safe environments of dunes, old deflation hollows and emergent rock outcrops.

A gradation occurs from proper sand fynbos inland, to transitional communities, and further to proper strandveld at the coast. The intermediate habitats are dominated by those fynbos species (chiefly Asteraceae and Restionaceae including *Elegia, Thamnochortus* and *Willdenowia* species) that are able to grow



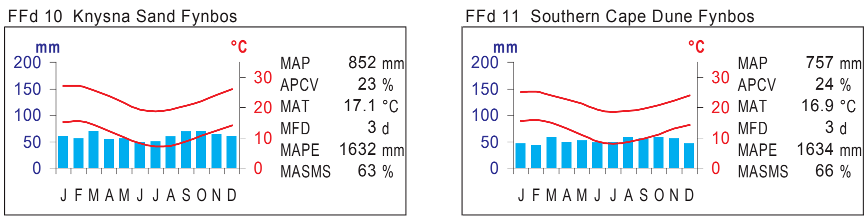


Figure 4.57 Climate diagrams of sand fynbos units. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days; MAPE: Mean Annual Potential Evaporation; MASMS: Mean Annual Soil Moisture Stress.

in very infrequently burned habitats. The margin mapped here tends to be the strandveld (coastal) end of the mosaic of intermediate communities. Fynbos stops at any dune topography, often not very prominent, which retards the spread of fire. Similarly, scarps adjacent riverine or wetland vegetation often support strandveld. Where the topography is flat, acid sands, and thus sand fynbos, may approach the beach cordon, but this is rare. The width of the ecotone from pure strandveld to pure fynbos may vary from quite abrupt to 2–5 km in certain areas. In the wider zones, several zones of transitional communities may be apparent, typically being species-poor and dominated by *Willdenowia incurvata* and a few other species (e.g. *Eriocephalus africanus*, *Wiborgia obcordata*). The strandveld boundary of these ecotone communities is more accurately mapped as adjacent succulent-dominated thicket. With thicket-dominated strandveld, fine-scale patterns may result in a mosaic with pockets of strandveld and patches of fynbos embedded in the dominant vegetation type, at a scale too fine to map.


L. Mucina

Figure 4.58 FFd 1 Namaqualand Sand Fynbos: *Leucospermum praemorsum* (Proteaceae) and restio *Willdenowia incurvata* on old inland dunes of Namaqualand Sandveld supporting relicts of fynbos, east of Hondeklipbaai (Northern Cape).

The proneness of sand fynbos to invasion by alien annual grasses—in marked contrast to other fynbos vegetation types—suggests some important, but poorly understood, ecosystem processes operating in the system. One possibility is that grazing is more important and that it is required to remove ephemeral species, especially after fire. This is paralleled by the restoration problem occurring after alien *Acacia* invaders have been removed, whereby the shrubland is effectively converted to an *Eragrostis* or *Cynodon* grassland—due to the increased nitrogen levels—preventing re-establishment of shrubs. Possibly this may relate to the relatively sedentary water table which does not flush nutrients downslope, but retains them in the system. The net effect in grazed areas is a conversion to grassland, with near-annual fires, which eliminate fynbos. In areas where fire is prevented, a stable-state grassland appears to persist and recolonisation by fynbos species from the edges is very slow (metres per fire cycle), suggesting that recruitment rather than seed availability is the problem to fynbos recolonisation.

With liming and bush-cutting, sand fynbos can be converted to pasture, especially on the South Coast, and especially on more neutral soils. Any such conversion leads to an explosion of mole rat (*Bathyergus suillus*) populations, underscoring their importance in sand fynbos and suggesting a possible key role in this system. Sand fynbos is often subject to bush-cutting and converted from proteoid fynbos to restioid fynbos by the thatching industry. Because of its low relief, sand fynbos might be expected to be heavily impacted by increased evaporation and lower rainfall when the effects of global climate change are realised.

FFd 1 Namaqualand Sand Fynbos

VT 31 Succulent Karoo (72%), VT 34 Strandveld of West Coast (24%) (Acocks 1953). LR 57 Lowland Succulent Karoo (78%) (Low & Rebelo 1996). BHU 77 Knersvlakte Vygieveld (37%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western and Northern Cape Provinces: Coastal plains with a well-separated patch between Kommagas and Koingnaas in the north, and a series of patches south of the Spoeg River, to the Olifants River near Koekenaap extending to close (around 2 km) to the coast at places, for example near Geelwal and Ruitersvlei. Altitude 60–300 m.

Vegetation & Landscape Features Slightly undulating plains comprising both isolated streets and dune fields of aeolian sand. Scattered 1–1.5 m tall shrubs 1–3 m in diameter, but dominated by Restionaceae in between, can have a dense canopy cover (50%), but is easily overgrazed to a sparse cover (20%). Restioid and asteraceous fynbos predominate, with localised pockets of proteoid fynbos. There are substantial differences between dune ridges and dune slacks, with dune slacks far more succulent, often tending to Succulent Karoo, and a much higher diversity than surrounding strandveld habitats. Ericaceae are absent, proteoids seldom numerically important, and restioids often dominant. Related to FFd 2 Leipoldtville Sand Fynbos south of the Olifants River, mainly due to the dominance of *Willdenowia incurvata* and the presence of proteoids, but Namaqualand Sand Fynbos has fewer species and less cover.

Geology & Soils Aeolian, deep, loose, red sand overlying marine or other sediments. Land types mainly Ah, Hb and Ai.

Climate Winter-rainfall regime, with very low precipitation (MAP 70–150 mm; mean: 105 mm), peaking between May and August. This is the driest of all fynbos types, with less than half the rainfall of the driest classical sand fynbos types, and almost qualifying as desert but with probably multiple alternative sources of water. Dense mists are common in winter and may contribute significantly to precipitation. Thicker deposits of sand (dunes) allow for water storage and some localised water aquifers occur. Mean daily maximum and minimum temperatures 28.4°C and 7.0°C for February and July, respectively. Very low frost incidence (1 or 2 days per year). See also climate diagram for FFd 1 Namaqualand Sand Fynbos (Figure 4.57).

Important Taxa Tall Shrubs: *Leucospermum praemorsum* (d), *L. rodolentum* (d), *Wiborgia obcordata* (d), *Gymnosporia buxifolia*. Low Shrubs: *Elytropappus rhinocerotis* (d), *Stoebe nervigera* (d), *Trichogyne repens* (d), *Chrysanthemoides incana*, *Clutia daphnoides*, *Diospyros austro-africana*, *Eriocephalus africanus* var. *africanus*, *Justicia cuneata*, *Leucadendron brunioides* var. *brunioides*, *Macrostylis decipiens*, *Metalasia adunca*, *Nenax arenicola*, *Salvia lanceolata*. Succulent Shrubs: *Othonna pro-*

tecta, *Ruschia caroli*, *R. extensa*, *R. subpaniculata*. Herbs: *Grielum grandiflorum*, *Limeum fenestratum*, *Wahlenbergia asparagoides*. Geophytic Herb: *Watsonia meriana*. Graminoids: *Ehrharta villosa* var. *villosa* (d), *Thamnochortus bachmannii* (d), *Willdenowia incurvata* (d), *Ehrharta calycina*, *Ficinia capitella*, *Ischyrolepis macer*, *I. monanthos*, *Stipagrostis zeyheri* subsp. *macropus*.

Biogeographically Important Taxa (Namaqualand endemics) Herb: *Helichrysum marmarolepis*. Succulent Herb: *Quaqua armata* subsp. *maritima*.

Endemic Taxa Succulent Shrub: *Lampranthus procumbens*. Geophytic Herbs: *Albuca decipiens*, *Babiana brachystachys*.


L. Mucina

Figure 4.59 FFd 2 Leipoldtville Sand Fynbos: Arid proteoid fynbos with *Leucadendron pubescens* and restios dominant on deep sands near Verlorenvlei on the West Coast (Western Cape).

Conservation Least threatened. Target 29%. At present only 1% statutorily conserved (Namaqua National Park), but proclamation of the proposed new national park at the coast between the mouths of the Groen and Spoeg Rivers may extend the area under protection. About 2% has been transformed for cultivation. The area is subject to extensive sheep grazing on some farms. Aliens *Acacia cyclops* and *A. saligna* occur as scattered. Erosion very low at present, but heavy grazing can lead to remobilisation of the stabilised dunes.

Remarks These dune fields are probably the leached remnants of northerly dune plumes originating from the major river mouths during pluvial periods. At the northern limits of these dune plumes dominant proteoids are usually senescent and recruitment occurs on the dunes in deflation hollows and bare areas after the death of old plants. These areas are too arid to support fire. This is the only known case of nonfire-maintained fynbos (other than waterlogged dune slacks in strandveld, where restios occur as 'sedge' communities).

References Boucher & Le Roux (1989, 1994), N. Helme (unpublished data), L. Mucina (unpublished data).

FFd 2 Leipoldtville Sand Fynbos

VT 34 Strandveld of West Coast (71%) (Acocks 1953). West Coast Strandveld (16%) (Moll & Bossi 1983). LR 68 Sand Plain Fynbos (43%), LR 64 Mountain Fynbos (25%) (Low & Rebelo 1996). BHU 10 Leipoldtville Sand Plain Fynbos (47%), BHU 83 Lamberts Bay Strandveld (15%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: On the coastal plains on either side of the Olifants River to Aurora and extending deep inland to the foot of the Graafwater Mountains and Piketberg. It also occurs in the Olifants River Valley from the Bulshoek Dam to The Baths (Keerom), with a gap between Klawer Vlei and Sandkop. Outliers are found scattered in the Swartveld from Het Kruis to the vicinity of Porterville. Altitude 50–350 m.

Vegetation & Landscape Features Plains, slightly rolling in places, covered with shrublands with an upper open stratum of emergent, 2–3 m tall shrubs in clumps. The vegetation matrix is formed by fairly dense, 1–1.2 m tall restiolands, with numerous medium tall to low shrubs scattered in between. Understorey with a conspicuous winter to spring herbaceous complement of annuals and geophytes occurs in years with good rain. Structurally, these are mainly restioid and asteraceous fynbos types, with localised patches of proteoid fynbos also present. This is a dry form of sand fynbos, lacking Ericaceae and with proteoid elements relatively rare. Sward communities, associated with grazing, are dominated by *Aizoon canariense* and *Tribolium echinatum*. At its northern (arid) boundary the sand fynbos structure becomes very diffuse and is progressively replaced by strandveld.

Geology & Soils Deep, acid, Tertiary sands, generally pale yellow to reddish brown, or grey. Land types mainly Ai, Hb, and Ca.

Climate Winter-rainfall regime with precipitation peaking from May to August. MAP 130–450 mm (mean: 260 mm). Dense mists are common in winter. Mean daily maximum and minimum temperatures 30.2°C and 6.6°C for February and July, respectively. Frost incidence 3 or 4 days per year. See also climate diagram for FFd 2 Leipoldtville Sand Fynbos (Figure 4.57).

Important Taxa Tall Shrubs: *Aspalathus acuminata* subsp. *acuminata* (d), *Leucadendron foedum* (d), *Leucadendron pubescens* (d), *Nylandtia spinosa* (d), *Aspalathus linearis*, *Chrysanthemoides monilifera*, *Diospyros glabra*, *Euclea racemosa* subsp. *racemosa*, *Euryops speciosissimus*, *Leucospermum rodolentum*, *Montinia caryophyllacea*, *Passerina corymbosa*, *Phylica paniculata*, *Wiborgia obcordata*. Low Shrubs: *Aspalathus divaricata* subsp. *divaricata* (d), *Diosma acmaeophylla* (d), *Eriocephalus africanus* var. *africanus* (d), *Passerina truncata* subsp. *truncata* (d), *Afrolimon longifolium*, *Anthospermum galioides* subsp. *galioides*, *Aspalathus ternata*, *Athanasia trifurcata*, *Metalasia adunca*, *Muraltia obovata*, *Nenax arenicola*, *Phylica cephalantha*, *P. oleaefolia*, *Rhus dissecta*[T], *Serruria fucifolia*. Succulent Shrubs: *Ruschia decurvans* (d), *Crassula nudicaulis*, *Euphorbia burmannii*. Herbs: *Senecio arenarius* (d), *Ursinia anthemoides* subsp. *anthemoides*. Geophytic Herbs: *Aristea dichotoma*, *Geissorhiza aspera*, *Lachenalia unicolor*, *Ornithogalum thyrsoides*, *Oxalis flava*. Succulent Herb: *Quaqua incarnata* subsp. *incarnata*. Graminoids: *Ehrharta calycina* (d), *Willdenowia incurvata* (d), *Cannomois scirpoides*, *Cladoraphis spinosa*, *Cynodon dactylon*, *Ischyrolepis gaudichaudiana*.

Endemic Taxa Low Shrubs: *Agathosma insignis*, *A. involucrata*, *Aspalathus rostripetala*, *Erica dregei*, *Leucadendron brunioides* var. *flumenlupinum*, *Leucospermum arenarium*, *Lotononis racemiflora*, *Manulea pillansii*, *Selago hetero-*

tricha, *S. linearifolia*. Succulent Shrubs: *Antimima triquetra*, *Drosanthemum prostratum*, *Lampranthus intervallaris*, *L. peersii*, *L. purpureus*, *L. saturatus*, *L. vernalis*, *Ruschia copiosa*, *R. maxima*, *R. victoris*. Herbs: *Adenogramma teretifolia*, *Manulea psilostoma*, *Wahlenbergia massonii*. Geophytic Herbs: *Albuca clanwilliamigloria*, *Babiana scabrifolia*, *Geissorhiza louisabolusiae*, *Pelargonium appendiculatum*, *P. attenuatum*, *P. fasciculaceum*.

Conservation Endangered. Target 29%. At present none of the unit is conserved in statutory or private conservation areas, which is alarming since 55% has already undergone transformation, including cultivation (primarily potatoes, rooibos) with central pivot irrigation, and pastures. Water extraction for central pivot irrigation and other agricultural uses is reputedly drying out this vegetation type. Alien *Acacia saligna* and *A. cyclops* are a problem. Erosion very low.

Remarks The southern boundary is not clear-cut and, being transitional, could justifiably be taken at the Berg River, the area where some elements are shared with FFd 3 Hopefield Sand Fynbos. The northern boundary is very diffuse and becomes progressively arid, gradually grading into SKs 7 Namaqualand Strandveld. Heuweltjies occur on shallower sands and support karoo shrublands (*Didelta spinosa, Rhus dissecta, Tetragonia fruticosa, Zygophyllum morgsana*).

References Milton (1978), Lane (1980), Boucher (1991, 1998d, f).


L. Mucina

Figure 4.60 FFd 3 Hopefield Sand Fynbos: Restioid fynbos with scattered shrubs of *Leucadendron foedum* on deep soils, east of Hopefield (Western Cape).

FFd 3 Hopefield Sand Fynbos

VT 47 Coastal Macchia (84%) (Acocks 1953). Sand Plain Fynbos (27%) (Moll & Bossi 1983). LR 68 Sand Plain Fynbos (88%) (Low & Rebelo 1996). BHU 11 Hopefield Sand Plain Fynbos (87%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: West Coast lowlands from Aurora to Rondeberg, just south of Yzerfontein, with an outlier in the Strandveld at Kleinberg north of Langebaanweg. Altitude 20–150 m.

Vegetation & Landscape Features Coastal sand plains, flat to undulating, and also including localised inland dune fields. Vegetation is a moderately tall, ericoid-leaved shrubland with dense herbaceous stratum of aphyllous hemicryptophytes. This is mostly asteraceous and restioid fynbos, although proteoid fynbos is extensive and ericaceous fynbos occurs in seeps and along watercourses. Hopefield Sand Fynbos has all three typical fynbos elements, but with a paucity (in species richness and density) of Ericaceae. This unit is most diverse in the Hopefield area, where extensive stands of *Leucadendron foedum, Leucospermum rodolentum* and *Serruria fucifolia* are dominant.

Geology & Soils Deep, acid, tertiary sands, generally grey regic sands, sometimes pale yellow to reddish brown. Land types mainly Hb, Ha and Db.

Climate MAP 210–430 mm (mean: 325 mm), peaking from May to August. Mists common in winter. Mean daily maximum and minimum temperatures 28.3°C and 7.1°C for February and July, respectively. Frost incidence 3 or 4 days per year. See also climate diagram for FFd 3 Hopefield Sand Fynbos (Figure 4.57).

Important Taxa Tall Shrubs: *Leucadendron foedum* (d), *Leucospermum rodolentum* (d), *Leucadendron pubescens*, *Putterlickia pyracantha*. Low Shrubs: *Diosma hirsuta* (d), *Phylica cephalantha* (d), *Anaxeton asperum*, *Anthospermum spathulatum* subsp. *spathulatum*, *Aspalathus lotoides* subsp. *lagopus*, *A. ternata*, *Erica mammosa*, *E. plumosa*, *Leucadendron cinereum*, *L. salignum*, *Leucospermum hypophyllocarpodendron* subsp. *canaliculatum*, *Metalasia capitata*, *Pharnaceum lanatum*, *Phylica harveyi*, *Serruria decipiens*, *S. fucifolia*, *Trichocephalus stipularis*. Succulent Shrub: *Euphorbia muirii*. Herbs: *Helichrysum tinctum*, *Indigofera procumbens*, *Knowltonia vesicatoria*. Geophytic Herbs: *Geissorhiza purpurascens*, *Lachenalia reflexa*, *Romulea obscura*. Graminoids: *Cannomois parviflora* (d), *Cynodon dactylon* (d), *Ehrharta villosa* var. *villosa* (d), *Elegia tectorum* (d), *Staberoha cernua* (d), *Thamnochortus erectus* (d), *T. punctatus* (d), *Willdenowia incurvata* (d), *Elegia verreauxii*.

Endemic Taxa Low Shrubs: *Leucospermum tomentosum* (d), *Relhania rotundifolia*. Herbs: *Heliophila patens*, *Lepidium flexuosum*. Geophytic Herb: *Oxalis suavis*.

Conservation Endangered. Target 30%. Very small portion statutorily conserved in the West Coast National Park, with an additional 2% protected in Hopefield and Jakkalsfontein Nature Reserves. Already 40% transformed for cultivation (especially cash crops) and grazing land. Increased occurrence of aliens such as *Acacia saligna*, *A. cyclops* as well as various species of *Pinus* and *Eucalyptus* is of concern. Erosion very low. Local farmers claim that water extraction is drying out rivers, marshes and wetlands.

Remarks The northern boundary of this unit grades into FFd 2 Leipoldtville Sand Fynbos between the Berg River and Aurora; the mapped boundary coincides with the distribution limits of most proteoid elements. On pockets of limestone, usually associated with higher relief and on the coastal edge on alkaline sands, this sand fynbos acquires strandveld elements and is replaced by FS 3 Saldanha Flats Strandveld. On the inland border, it forms mosaics with FRs 9 Swartland Shale Renosterveld as the sand thins out over the shale—most of these communities have been ploughed up for wheatlands.

References Boucher (1983, 1987, 1989a, 1996b), Boucher & Rode (1999).

FFd 4 Atlantis Sand Fynbos

VT 46 Coastal Renosterbosveld (64%) (Acocks 1953). Sand Plain Fynbos (22%) (Moll & Bossi 1983). LR 68 Sand Plain Fynbos (73%) (Low & Rebelo 1996). BHU 11 Hopefield Sand Plain Fynbos (64%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Rondeberg to Blouberg on the West Coast coastal flats; along the Groen River on the eastern side of the Dassenberg-Darling Hills through Riverlands to the area between Atlantis and Kalbaskraal, also between Klipheuwel and the Paardeberg with outliers west of the Berg River east and north of Riebeek-Kasteel between Hermon and Heuningberg. Altitude 40–250 m.

Vegetation & Landscape Features Moderately undulating to flat sand plains with a dense, moderately tall, ericoid shrubland dotted with emergent, tall sclerophyllous shrubs and an open, short restioid stratum. Restioid and proteoid fynbos are dominant, with asteraceous fynbos and patches of ericaceous fynbos in seepages.

Geology & Soils Acidic tertiary, grey regic sands, usually white or yellow. Land types mainly Db, Ha, Hb and Ca.

Climate Winter-rainfall regime with precipitation peaking from May to August. MAP 290–660 mm (mean: 440 mm). Mists (fogs) common in winter and supplying additional precipitation. Mean daily maximum and minimum temperatures 27.9°C and 7.0°C for February and July, respectively. Frost incidence about 3 days per year. See also climate diagram for FFd 4 Atlantis Sand Fynbos (Figure 4.57).

Important Taxa ([T]Cape thickets) Tall Shrubs: *Diospyros glabra*[T] (d), *Euclea racemosa* subsp. *racemosa*[T] (d), *Metalasia densa* (d), *Passerina corymbosa* (d), *Protea burchellii* (d), *P. repens* (d), *Putterlickia pyracantha*[T] (d), *Rhus laevigata*[T] (d), *Gymnosporia buxifolia*[T], *Hymenolepis parviflora*, *Wiborgia obcordata*. Low Shrubs: *Anthospermum aethiopicum* (d), *Berzelia abrotanoides* (d), *Diastella proteoides* (d), *Elytropappus rhinocerotis* (d), *Erica plumosa* (d), *Leucadendron salignum* (d), *Phylica cephalantha* (d), *Salvia lanceolata* (d), *Staavia radiata* (d), *Trichocephalus stipularis* (d), *Amphithalea ericifolia*, *Aspalathus lotoides* subsp. *lotoides*, *A. quinquefolia* subsp. *quinquefolia*, *A. ternata*, *Athanasia trifurcata*, *Cliffortia drepanoides*, *C. ferruginea*, *C. polygonifolia*, *Cryptadenia grandiflora*, *Erica ferrea*, *E. mammosa*, *Helichrysum tomentosulum*, *Hermannia alnifolia*, *Hippia pilosa*, *Lachnospermum imbricatum*, *Leonotis leonurus*, *Leucadendron cinereum*, *L. lanigerum* var. *lanigerum*, *Leucospermum hypophyllocarpodendron* subsp. *canaliculatum*, *Leysera gnaphalodes*, *Metalasia adunca*, *M. capitata*, *M. distans*, *Oedera imbricata*, *Otholobium hirtum*, *Protea acaulos*, *P. scolymocephala*, *Psoralea ensifolia*, *P. laxa*, *Rhus dissecta*[T], *Serruria decipiens*, *S. fasciflora*, *S. trilopha*. Succulent Shrub: *Crassula flava*. Woody Climbers: *Asparagus asparagoides*, *Microloma sagittatum*. Semiparasitic Shrubs: *Thesium nigromontanum* (d), *T. scabrum*. Herbs: *Annesorhiza macrocarpa*, *Arctopus echinatus*, *Castalis nudicaulis*, *Haplocarpha lanata*, *Nemesia bicornis*, *Phyllopodium cephalophorum*. Geophytic Herbs: *Aristea africana*, *Disa obtusa*, *Geissorhiza humilis*, *G. purpurascens*, *Othonna stenophylla*, *Satyrium bicorne*. Herbaceous Climber: *Cynanchum africanum*. Herbaceous Parasitic Climber: *Cassytha ciliolata*. Graminoids: *Aristida diffusa* (d), *Cannomois parviflora* (d), *Ehrharta calycina* (d), *E. villosa* var. *villosa* (d), *Ischyrolepis monanthos* (d), *Scirpoides thunbergii* (d), *Staberoha distachyos* (d), *Thamnochortus obtusus* (d), *T. punctatus* (d), *Willdenowia incurvata* (d), *W. sulcata* (d), *Cyperus textilis*, *Elegia nuda*, *Ficinia nigrescens*, *Pentaschistis curvifolia*.

Endemic Taxa Low Shrubs: *Leucospermum parile* (d), *Erica malmesburiensis*, *Serruria linearis*, *S. roxburghii*, *S. scoparia*. Herb: *Steirodiscus speciosus*.

Conservation Vulnerable. Target 30%. About 6% conserved in Riverlands, Paardenberg and at Pella Research Site. Some 40% has been transformed, mainly for cultivation (agricultural smallholdings and pastures), by urban sprawl of Atlantis and for setting up pine and gum plantations. Woody aliens include *Acacia saligna*, *A. cyclops* and various species of *Eucalyptus* and *Pinus*. Erosion very low and low.

Remark 1 This unit has greater species diversity than the sand fynbos units to the north, and exemplifies the northern limit of extensive ericaceous fynbos in sand fynbos. A record 76 species in a 5 x 10 m plot have been counted (C. Boucher, unpublished data).

Remark 2 This is probably the best researched sand fynbos type due to the location of the Pella Research Site which served as base for intensive research into fynbos ecology of the sand plain lowlands in the 1980s. Because of its history of past research (and valuable historical data), the site should be revitalised for long-term research and monitoring purposes.

References Boucher (1983, 1986, 1987, 1992, 1996b), Hoffman et al. (1987), Boucher & Shepherd (1988), Jarman (1988), Jarman & Mustart (1988), Witkowski & Mitchell (1989), Musil & De Witt (1990).

L. W. Powrie

Figure 4.61 FFd 4 Atlantis Sand Fynbos: *Leucospermum parile*, endemic to the unit, dominant together with *Protea repens* surrounded by *Passerina* and *Thamnochortus* in the Pella Nature Reserve near Atlantis, Western Cape.

FFd 5 Cape Flats Sand Fynbos

VT 47 Coastal Macchia (66%) (Acocks 1953). LR 68 Sand Plain Fynbos (85%) (Low & Rebelo 1996). BHU 12 Blackheath Sand Plain Fynbos (83%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Cape Flats from Blouberg and Koeberg Hills west of the Tygerberg Hills to Lakeside and Pelican Park in the south

L. W. Powrie

Figure 4.62 FFd 5 Cape Flats Sand Fynbos: One of the largest surviving remnants is located under power lines in the Plattekloof Natural Heritage Site, here with *Serruria aemula*, *Diastella proteoides*, *Metalasia densa* and *Passerina vulgaris*. *Thamnochortus erectus* is showing signs of senescence due to the reluctance of the managers to burn under the power lines.

near False Bay, from Bellville and Durbanville to Klapmuts and Joostenberg Hill in the east, and to the southwest of the Bottelary Hills to Macassar and Firgrove in the south. Altitude 20–200 m.

Vegetation & Landscape Features Moderately undulating and flat plains, with dense, moderately tall, ericoid shrubland containing scattered emergent tall shrubs. Proteoid and restioid fynbos are dominant, with asteraceous and ericaceous fynbos occurring in drier and wetter areas, respectively.

Geology & Soils Acid, tertiary, deep, grey regic sands, usually white, often Lamotte form. Land types mainly Ga, Hb and Db.

Climate Winter-rainfall regime with precipitation peaking from May to August. MAP 580–980 mm (mean: 575 mm). Mists occur frequently in winter. Mean daily maximum and minimum monthly temperatures 27.1°C and 7.3°C for February and July, respectively. Frost incidence about 3 days per year. This is the wettest and the coolest of the West Coast sand fynbos types. See also climate diagram for FFd 5 Cape Flats Sand Fynbos (Figure 4.57).

Important Taxa ([T]Cape thickets, [W]Wetlands) Tall Shrubs: *Metalasia densa*, *Morella cordifolia*, *M. serrata*, *Passerina corymbosa*, *Protea burchellii*, *P. repens*, *Psoralea pinnata*[W], *Pterocelastrus tricuspidatus*[T], *Rhus lucida*[T], *Wiborgia obcordata*. Low Shrubs: *Diastella proteoides* (d), *Diosma hirsuta* (d), *Erica lasciva* (d), *E. muscosa* (d), *Phylica cephalantha* (d), *Senecio halimifolius* (d), *Serruria glomerata* (d), *Stoebe plumosa* (d), *Anthospermum aethiopicum*, *Aspalathus callosa*, *A. hispida*, *A. quinquefolia* subsp. *quinquefolia*, *A. sericea*, *A. spinosa* subsp. *spinosa*, *A. ternata*, *Berzelia abrotanoides*, *Chrysanthemoides incana*, *Cliffortia eriocephalina*, *C. juniperina*, *C. polygonifolia*, *Erica articularis*, *E. axillaris*, *E. capitata*, *E. corifolia*, *E. ferrea*, *E. imbricata*, *E. mammosa*, *E. plumosa*, *E. pulchella*, *Eriocephalus africanus* var. *africanus*, *Galenia africana*, *Gnidia spicata*, *Helichrysum cymosum*, *Leucadendron floridum*, *L. salignum*, *Leucospermum hypophyllocarpodendron* subsp. *canaliculatum*, *Metalasia adunca*, *M. pulchella*, *Morella quercifolia*, *Passerina ericoides*, *Pharnaceum lanatum*, *Phylica parviflora*, *Plecostachys polifolia*, *P. serpyllifolia*, *Polpoda capensis*, *Protea scolymocephala*, *Serruria fasciflora*, *S. trilopha*, *Staavia radiata*, *Stilbe albiflora*, *Stoebe cinerea*, *Syncarpha vestita*, *Trichocephalus stipularis*. Succulent Shrub: *Crassula flava*. Herbs: *Berkheya rigida*, *Conyza pinnatifida*, *Edmondia sesamoides*, *Helichrysum tinctum*, *Indigofera procumbens*, *Knowltonia vesicatoria*. Geophytic Herbs: *Watsonia meriana* (d), *Aristea dichotoma*, *Geissorhiza tenella*, *Othonna heterophylla*, *Pelargonium longifolium*, *Wachendorfia paniculata*, *Zantedeschia aethiopica*[W]. Succulent Herb: *Carpobrotus acinaciformis*. Herbaceous Climber: *Dipogon lignosus*. Graminoids: *Cynodon dactylon* (d), *Ehrharta villosa* var. *villosa* (d), *Elegia tectorum* (d), *Restio quinquefarius* (d), *Sporobolus virginicus* (d), *Thamnochortus erectus* (d), *Willdenowia incurvata* (d), *Calopsis impolita*, *Elegia juncea*, *E. microcarpa*, *E. nuda*, *Hordeum capense*, *Hypodiscus aristatus*, *Ischyrolepis capensis*, *I. paludosa*, *Juncus capensis*, *Restio bifurcus*, *R. micans*, *R. quadratus*, *Willdenowia sulcata*, *W. teres*.

Endemic Taxa ([W]Wetlands) Low Shrubs: *Erica margaritacea* (d), *Aspalathus variegata* (probably extinct), *Athanasia capitata*, *Cliffortia ericifolia*, *Erica pyramidalis*[W], *E. turgida*, *E. verticillata*, *Leucadendron levisanus*, *Liparia graminifolia*, *Serruria aemula*, *S. foeniculacea*, *S. furcellata*. Succulent Shrub: *Lampranthus stenus*. Geophytic Herb: *Ixia versicolor*. Graminoids: *Tetraria variabilis*, *Trianoptiles solitaria*.

Conservation Critically endangered. Target 30%. Less than 1% statutorily conserved as small patches in the Table Mountain National Park as well as some private conservation areas such as Plattekloof 430 and Blaauw Mountain. This is the most transformed of the sand fynbos types—more than 80% of the area has already been transformed (hence the conservation target remains unattainable) by urban sprawl (Cape Town metropolitan area) and for cultivation. Most remaining patches are small pockets surrounded by urban areas, for example Rondevlei, Kenilworth, Milnerton, 6BKD, Plattekloof, and Rondebosch Common. Most of these patches have been identified as 'Core Conservation Sites' (Wood et al. 1994). They are mismanaged by mowing, fire protection and by alien plant invasion. Mowing eliminates serotinous and taller species, while fire protection results in a few common thicket species (e.g. *Carpobrotus edulis*, *Chrysanthemoides monilifera*), replacing the rich fynbos species. Alien woody species include *Acacia saligna*, *A. cyclops* and species of *Pinus* and *Eucalyptus*. Dumping and spread of alien grasses (both annual and *Pennisetum clandestinum*) are also a major problem. Alien acacias result in elevated nutrient levels and a conversion to *Eragrostis curvula* grassland and near-annual fires. Some 84 Red Data sand fynbos plant species occur on the remnants within Cape Town. The endemics include six species listed as extinct in the wild, some of which are being reintroduced from botanical gardens. Erosion very low.

Remark Cape Flats Sand Fynbos is richer than the other West Coast sand fynbos types, not only in Proteaceae, but also in other woody shrubs.

References Acocks (1935), Taylor (1972b), Boucher (1983, 1987, 1996b, 1997b, 1999a, g), Boshoff (1985), Wood et al. (1994), McKenzie & Rebelo (1997), Maze & Rebelo (1999a, b), Helme (2002).

FFd 6 Hangklip Sand Fynbos

VT 69 Macchia (78%) (Acocks 1953). Coastal Plain Fynbos p.p. (Boucher 1978). Mesic Mountain Fynbos (39%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (55%), LR 68 Sand Plain Fynbos (19%) (Low & Rebelo 1996). BHU 56 Kogelberg Mountain Fynbos Complex (41%), BHU 55 Cape Peninsula Mountain Fynbos Complex (31%), BHU 6 Agulhas Fynbos/Thicket Mosaic (23%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Cape Peninsula on old dune fields at Hout Bay, in the Fish Hoek gap (between Fish Hoek and Noordhoek) and on Smith's Farm (Cape Point Nature Reserve). Further on it occurs on the coastal flats from Rooiels and Cape Hangklip to Hermanus and it is well developed at the Bot River estuary. Altitude 20–150 m.

Vegetation & Landscape Features Sand dunes and sandy bottomlands supporting moderately tall, dense ericoid shrubland. Emergent, tall shrubs in places. Proteoid, ericaceous and restioid fynbos are dominant, with some asteraceous fynbos also present. On the coastal fringe this unit borders on strandveld. The deep soils of the coastal plains are replaced by shallow soils on mountain slopes on the northern edge. Hangklip Sand Fynbos occurs mainly on old dunes, but the high rainfall and leaching allows many typical sandstone fynbos species to occur on older deposits as well, so that this unit is not as floristically distinct as other sandstone fynbos units.

Geology & Soils Leached, acid Tertiary sand in coastal areas, derived mostly from dunes. Soils generally of Lamotte or Houwhoek forms or grey, regic sands. Land types mainly Ga, Hb and Gb.

Climate MAP 520–1 170 mm (mean: 750 mm), peaking from May to August. By far this is the wettest of all the sandstone fynbos types. Mean daily maximum and minimum temperatures 25.9°C and 7.5°C for January–February and July, respectively. Frost incidence about 3 days per year. See also climate diagram for FFd 6 Hangklip Sand Fynbos (Figure 4.57).

Important Taxa (^{T}Cape thickets, ^{W}Wetlands) Tall Shrubs: *Euclea racemosa* subsp. *racemosa* (d), *Leucadendron coniferum* (d), *Metalasia densa* (d), *Passerina corymbosa* (d), *Psoralea pinnata*^{W} (d), *Rhus laevigata*^{T} (d), *Erica perspicua* var. *perspicua*^{W}, *E. tristis*, *Halleria lucida*^{T}, *Mimetes hirtus*, *Protea compacta*, *Pterocelastrus tricuspidatus*^{T}, *Rhus glauca*^{T}, *R. lucida*^{T}. Low Shrubs: *Aspalathus nigra* (d), *Berzelia abrotanoides* (d), *Brunia alopecuroides*^{W} (d), *Coleonema album* (d), *Erica mammosa* (d), *E. multumbellifera* (d), *E. muscosa* (d), *Eriocephalus africanus* var. *africanus* (d), *Osmitopsis asteriscoides*^{W} (d), *Protea scolymocephala* (d), *Serruria glomerata* (d), *Adenandra viscida*, *Agathosma imbricata*, *Aspalathus forbesii*, *Berzelia lanuginosa*^{W}, *B. squarrosa*, *Cassine peragua* subsp. *barbara*, *Cliffortia graminea*, *Diosma hirsuta*, *Erica coccinea* subsp. *coccinea*, *E. fastigiata*, *E. patersonii*, *E. pulchella*, *Eriocephalus racemosus*, *Indigofera brachystachya*, *Leucadendron gandogeri*, *L. laureolum*, *L. salignum*, *Leucospermum hypophyllocarpodendron* subsp. *hypophyllocarpodendron*, *Metalasia pulchella*, *Mimetes cucullatus*, *Morella quercifolia*, *Orphium frutescens*^{W}, *Passerina ericoides*, *Pelargonium betulinum*, *P. cucullatum*, *Phylica ericoides*, *Polyarrhena reflexa* subsp. *reflexa*, *Protea cynaroides*, *Stilbe ericoides*, *Struthiola ciliata* subsp. *schlechteri*, *Trichocephalus stipularis*, *Trichogyne repens*. Succulent Shrub: *Tetragonia fruticosa*. Herbs: *Carpacoce spermacocea*, *Cineraria geifolia*. Geophytic Herbs: *Corycium bifidum*, *Geissorhiza humilis*, *Romulea triflora*, *Wachendorfia thyrsiflora*^{W}. Succulent Herbs: *Carpobrotus edulis* (d), *C. acinaciformis*. Herbaceous Climber: *Cynanchum obtusifolium*. Graminoids: *Elegia filacea* (d), *E. nuda* (d), *Epischoenus gracilis* (d), *Imperata cylindrica*^{W} (d), *Ischyrolepis eleocharis* (d), *Thamnochortus erectus* (d), *T. obtusus* (d), *T. spicigerus* (d), *Merxmuellera cincta*, *Staberoha cernua*, *Tetraria thermalis*.

Endemic Taxa Low Shrub: *Muraltia minuta*. Succulent Shrub: *Lampranthus serpens*. Herb: *Hypertelis trachysperma*. Geophytic Herb: *Haemanthus canaliculatus*. Graminoid: *Ischyrolepis feminea*.

Conservation Vulnerable. Target 30%. About 20% statutorily conserved in the Table Mountain National Park and Kogelberg Biosphere Reserve, with an additional 3% protected in private conservation areas such as Sea Farm and Hoek-van-die-Berg. There are several reserves between Pringle Bay and Hermanus, but they are badly mismanaged with a continual attrition of reserves with sewerage farms, graveyards, golf courses and squatters and over-harvesting of flowers and plants for oils. Some 31% has been transformed, mostly by development of holiday home settlements (coastal platform between Pringle Bay and Hermanus), but also by cultivation and building of roads. Alien woody plants include *Pinus pinaster*, *Acacia cyclops*, *A. saligna*, various *Eucalyptus* species and very many other species in localised patches. Erosion very low.

Remark 1 Pockets of *Sideroxylon*-dominated thicket and small forests occur in fire-safe hollows and dune edges, throughout the region. There are some limestone deposits associated with the old dunes, but these are localised and do not have a typical limestone fynbos community; they share species with sandstone fynbos and FS 7 Overberg Dune Strandveld.

Remark 2 Hangklip Sand Fynbos is well-sampled only in the west; there are no representative data available for patches found east of the Palmiet River.

L. Mucina

Figure 4.63 FFd 6 Hangklip Sand Fynbos: Restioid fynbos on a narrow bypass dune above the Catholic church on Slangkop above Kommetjie on the Cape Peninsula (Western Cape), with prominent *Agathosma* (Rutaceae), *Thamnochortus* (Restionaceae) and *Othonna* (Asteraceae).

References Adamson (1927), Boucher (1972, 1974, 1977, 1978), Taylor (1983, 1984a, b), Cowling (1991), Boix (1992), Simmons (1996), Privett (1998), Stofberg (2000).

FFd 7 Agulhas Sand Fynbos

VT 47 Coastal Macchia (98%) (Acocks 1953). Limestone Fynbos (20%) (Moll & Bossi 1983). LR 63 South and South-west Coast Renosterveld (54%), LR 67 Limestone Fynbos (23%) (Low & Rebelo 1996). BHU 15 Hagelkraal Limestone Fynbos (71%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Very fragmented patches on the Agulhas forelands from around the lower Uilkraalsrivier near Gansbaai, Hagelkraal, flats west of the Soetanysberg, small patches east of Elim to the largest patch northwest of Struisbaai, west of Arniston and south of Bredasdorp, with unmapped patches to Hermanus in the west, and De Hoop Vlei in the east. Altitude 20–100 m.

Vegetation & Landscape Features Low-lying coastal plains supporting dense moderately tall, ericoid shrubland or tall, medium dense shrubland, with some emergent tall shrubs. Communities of this fynbos unit are structurally defined either as restioid or proteoid fynbos.

Geology & Soils Neutral to acid Tertiary sands over various substrates, but most commonly over limestone of the Bredasdorp Formation. Land types mainly Db and Hb.

Climate MAP 380–660 mm (mean: 475 mm), peaking slightly in winter. Mean daily maximum and minimum temperatures 25.6°C and 7.0°C for January and July, respectively. Frost incidence about 3 days per year. See also climate diagram for FFd 7 Agulhas Sand Fynbos (Figure 4.57).

Important Taxa ([T]Cape thickets, [W]Wetlands) Tall Shrubs: *Leucadendron coniferum*, *Metalasia densa*, *Passerina corymbosa*, *Protea susannae*, *Rhus laevigata*[T]. Low Shrubs: *Amphithalea tomentosa*, *Cliffortia ferruginea*, *Elytropappus rhinocerotis*, *Erica discolor*, *E. plukenetii* subsp. *lineata*, *E. rhopalantha*, *Euchaetis burchellii*, *Leucadendron linifolium*, *Morella quercifolia*, *Orphium frutescens*[W], *Serruria nervosa*. Herb: *Senecio laevigatus*. Graminoids: *Cynodon dactylon*, *Elegia filacea*, *E. recta*, *E. tectorum*, *Hypodiscus albo-aristatus*, *Restio triticeus*, *Thamnochortus erectus*, *T. insignis*.

Endemic Taxa Low Shrubs: *Erica albertyniae*, *E. berzelioides*, *E. globulifera*, *E. interrupta*, *Lobostemon collinus*, *Wahlenbergia microphylla*. Succulent Shrubs: *Caryotophora skiatophytoides*, *Erepsia simulans*, *Lampranthus arbuthnotiae*. Graminoid: *Ficinia latifolia*.

Conservation Vulnerable. Target 32%. Some 7% statutorily conserved in the Agulhas National Park, with a further 1% found in private conservation areas such as Brandfontein, Groot Hagelkraal, Heunings River and Andrewsfield. About 27% transformed, mainly for cultivation, but alien plants (*Acacia cyclops*, *A. saligna* and *Leptospermum laevigatum*) have caused a much larger transformed area. Erosion low and very low.

Remark 1 The more alkaline communities can be arbitrarily assigned to either limestone fynbos or sand fynbos, whereas proteoid fynbos communities can be readily assigned. Some restioid and asteraceous fynbos communities are more contentious. We have defined this unit largely by *Leucadendron coniferum* in deeper sands and *L. linifolium* in seasonal vleis. The latter also occurs extensively on shallow sands over limestone that could justifiably be classified as limestone fynbos. The asteraceous fynbos communities also intergrade with FFf 1 Elim Ferricrete Fynbos.

Remark 2 This vegetation unit is more extensive than mapped, mainly within what is mapped as limestone fynbos—we lack adequate field surveys to map them accurately. The border with FFd 9 Albertinia Sand Fynbos has been chosen at about De Hoop Vlei. This boundary coincides with the easternmost *Leucadendron coniferum* (near Arniston), and the westernmost *L. eucalyptifolium*, *L. galpinii*, *Protea lanceolata* and the large form of *Leucospermum truncatum* (morphologically approaching the appearance of *L. praecox*) near Koppie Alleen.

References Van der Merwe (1977a), Cowling et al. (1988), Thwaites & Cowling (1988), Richards et al. (1995, 1997a, b), Mustart et al. (1997), Boucher (1998c).

FFd 8 Breede Sand Fynbos

VT 43 Mountain Renosterbosveld (66%), VT 26 Karroid Broken Veld (32%) (Acocks 1953). Central Mountain Renosterveld (24%), Karroid Shrublands (19%) (Moll & Bossi 1983). LR 61 Central Mountain Renosterveld (64%), LR 58 Little Succulent Karoo (26%) (Low & Rebelo 1996). BHU 26 Breede Fynbos/Renosterveld Mosaic (50%), BHU 87 Robertson Broken Veld (27%), BHU 38 Ashton Inland Renosterveld (23%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Small patches usually in close proximity to the Breede River from the Brandvlei Dam to near Robertson. Altitude 200–350 m.

L. Mucina

Figure 4.64 FFd 7 Agulhas Sand Fynbos: Patch of *Agathosma collina* (green shrub) within restioid fynbos dominated by *Thamnochortus insignis* in De Hoop Nature Reserve near Arniston (Western Cape).

Vegetation & Landscape Features Very fragmented, occurring as dune plumes and dune seas in the valley bottoms primarily south of the Breede River, and extending up the sides of adjacent hills. Vegetation is an open proteoid tall shrubland combined with an open to medium dense restioid herbland in undergrowth. Proteoid and restioid fynbos are dominant, with some asteraceous fynbos also found.

Geology & Soils Recent aeolian sand accumulations of riverine origin (Breede River). Land types mainly Fc, Bb and Hb.

Climate MAP 230–560 mm (mean: 345 mm), peaking from May to August. Mean daily maximum and minimum temperatures 29.6°C and 5.0°C for February and July, respectively. Frost incidence 3–6 days per year. See also climate diagram for FFd 8 Breede Sand Fynbos (Figure 4.57).

Figure 4.65 FFd 8 Breede Sand Fynbos: *Leucadendron rodolentum* in restioid fynbos covering a slope dune near Aan de Doorns in the Breede River Valley (Western Cape).

Important Taxa Tall Shrubs: *Leucospermum rodolentum* (d), *Metalasia densa*, *Protea laurifolia*. Low Shrubs: *Afrolimon longifolium*, *Aspalathus heterophylla*, *Euchaetis pungens*, *Lachnospermum fasciculatum*, *Leucadendron brunioides* var. *brunioides*, *L. salignum*, *Wiborgia fusca*. Succulent Shrub: *Ruschia caroli*. Herb: *Pelargonium senecioides*. Geophytic Herb: *Romulea setifolia*. Graminoids: *Cynodon dactylon*, *Ehrharta villosa* var. *villosa*, *Ficinia lateralis*, *Willdenowia incurvata*.

Endemic Taxon Geophytic Herb: *Ixia pumilio*.

Conservation Vulnerable. Target 30%. None of the unit conserved in statutory conservation areas and only 2% protected in the Hawequas and Quaggas Berg Private Nature Reserves. The unit enjoys conservation interest for isolated, southeasternmost populations of West Coast species. Some 45% of the area has been transformed, mainly for cultivation (pasture and vineyards) and by building of the Brandvlei and Kwaggaskloof Dams. By far the largest patch of this unit is now almost entirely under water of these reservoirs. Low levels of infestation by alien *Eucalyptus, Acacia saligna* and *Hakea sericea* have been recorded. Erosion very low and moderate, but also high in some places.

Remarks This is a poorly studied vegetation unit. Whereas most of the species are shared with FFs 13 North Sonderend Sandstone Fynbos and FFq 4 Breede Quartzite Fynbos, and a few with the South Coast FFd 9 Albertinia Sand Fynbos, it is the affinities with FFd 2 Leipoldtville Sand Fynbos that are most striking, suggesting that dunes once straddled the Hawequas Mountains, probably west of Tulbagh, allowing species to move across.

References C. Boucher (unpublished data), L. Mucina (unpublished data).

FFd 9 Albertinia Sand Fynbos

VT 47 Coastal Macchia (86%) (Acocks 1953). Limestone Fynbos (49%), Dune Fynbos (20%) (Moll & Bossi 1983). LR 67 Limestone Fynbos (53%) (Low & Rebelo 1996). BHU 17 Canca Limestone Fynbos (27%), BHU 34 Riversdale Coast Renosterveld (25%), BHU 14 Albertinia Sand Plain Fynbos (23%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Generally longitudinally east-west-trending patches on the coastal plain from Potberg in the west to the Gouritz River in the east. Also found from Kleinberg to west of Mossel Bay, with isolated unmapped outliers near Groot Brak River and between Potberg and De Hoop Vlei. The patches of this vegetation unit almost always border a limestone fynbos type. When enclosed by limestone, it is often found in depressions which can be extensive, for example the Wankoe south of Riversdale and Canca se Leegte south of Albertinia. Altitude 20–260 m.

Vegetation & Landscape Features Plains and undulating hills with numerous dune slacks—forming the most extensive area of sand fynbos within the limestone fynbos area and occupying most of the depressions, valleys and lower slopes. Vegetation is characterised by medium tall (1.5–2 m tall) open shrub layer, together with a dense stratum of 1–1.2 m tall shrubs and hemicryptophytes. It is structurally predominantly proteoid fynbos, but with extensive restioid fynbos in the watercourses and coastal edges.

Geology & Soils Deep neutral to acid, usually red, Tertiary sands associated with limestone of Bredasdorp Formation, but also acid sands derived from alluvial deposits from the Gouritz River. Acid Tertiary sands, usually grey, from Potberg and Aasvogelberg are locally prominent. Land types mainly Fc, Hb and Db.

Climate MAP 230–620 mm (mean: 430 mm), with no clear peak and a slight low in December–January. Mean daily maximum and minimum temperatures 25.5°C and 6.4°C for January–February and July, respectively. Frost incidence about

Figure 4.66 FFd 9 Albertinia Sand Fynbos: Proteoid fynbos with *Leucospermum praecox* and *Thamnochortus insignis* on deep neutral sands at Gouritzmond (Western Cape).

3 days per year. See also climate diagram for FFd 9 Albertinia Sand Fynbos (Figure 4.57).

Important Taxa ([T]Cape thickets, [W]Wetlands) Tall Shrubs: *Cassine peragua* subsp. *peragua*[T] (d), *Leucadendron eucalyptifolium* (d), *Metalasia densa* (d), *Protea repens* (d), *P. susannae* (d), *Nylandtia spinosa*, *Passerina corymbosa*, *Psoralea pinnata*[W]. Low Shrubs: *Chironia baccifera* (d), *Cliffortia ilicifolia* (d), *C. stricta* (d), *Erica imbricata* (d), *Lachnaea axillaris* (d), *Agathosma bifida*, *A. scaberula*, *Amphithalea tomentosa*, *Anthospermum prostratum*, *Aulax umbellata*, *Carpacoce vaginellata*, *Chrysocoma ciliata*, *Cliffortia drepanoides*, *Diospyros dichrophylla*[T], *Erica discolor*, *E. pulchella*, *E. sessiliflora*, *E. versicolor*, *Euryops ericoides*, *Leucadendron meridianum*, *L. salignum*, *Muraltia ciliaris*, *Passerina galpinii*, *P. rigida*, *Phylica parviflora*, *Psoralea laxa*, *Senecio ilicifolius*, *Staavia radiata*, *Struthiola ciliata* subsp. *incana*, *Syncarpha paniculata*, *Trichocephalus stipularis*, *Trichogyne repens*. Herbs: *Edmondia sesamoides*, *Senecio laevigatus*. Geophytic Herbs: *Pteridium aquilinum* (d), *Bobartia robusta*, *Bulbine frutescens*, *Romulea dichotoma*, *R. gigantea*[W]. Graminoids: *Calopsis adpressa* (d), *Elegia stipularis* (d), *Ischyrolepis leptoclados* (d), *Mastersiella purpurea* (d), *Thamnochortus insignis* (d), *Cynodon dactylon*, *Elegia muirii*, *E. tectorum*, *Mastersiella spathulata*, *Staberoha distachyos*, *Thamnochortus erectus*, *T. fruticosus*, *Willdenowia teres*.

Endemic Taxa Tall Shrubs: *Leucospermum praecox* (d), *Leucadendron galpinii* (d), *Leucospermum fulgens*. Low Shrubs: *Euchaetis albertiniana* (d), *Agathosma pallens*, *Aspalathus acutiflora*, *A. dasyantha*, *A. odontoloba*, *A. quadrata*, *A. sanguinea* subsp. *foliosa*, *Diosma sabulosa*, *Erica baueri* subsp. *baueri*, *E. dispar*, *E. viscosissima*, *Lebeckia fasciculata*, *Leucospermum muirii*, *Lobelia valida*. Succulent Shrubs: *Lampranthus antemeridianus*, *L. creber*, *L. diutinus*, *L. fergusoniae*, *L. multiseriatus*. Herb: *Zaluzianskya muirii*. Graminoid: *Thamnochortus muirii*.

Conservation Vulnerable. Target 32%. About 5% statutorily conserved in De Hoop, Pauline Bohnen, Geelkrans, Kleinjongensfontein, Skulpiesbaai and Blomboschfontein Nature Reserves, with an additional 2% protected in private conservation areas such as Rein's Coastal (Gouriqua) Nature Reserve, Die Duine etc. Some 26% transformed for cultivation (pasture) and pine plantations, but a large proportion has also been transformed by alien plants (*Acacia cyclops* and *A. saligna*). In addition, large areas have been converted from proteoid fynbos to restioid fynbos by bush-cutting for thatching. Erosion very low.

Remark 1 The boundary between the limestone and sand fynbos is often one of soil depth, with limestone fynbos being largely confined to skeletal soils. In permanently wet areas and fire-safe habitats, thicket may occur, often in association with *Protea lanceolata*, *Elegia microcarpa* and *Thamnochortus erectus*—these are usually at the interface between sand and limestone fynbos. *Leucospermum muirii* is an endemic to the grey, sandstone-derived soils—it is not known whether other endemics to this soil type occur or whether this deserves special recognition.

Remark 2 This unit is still not accurately mapped and is more extensive than shown. Pockets occur in valleys and depressions within limestone fynbos as far west as De Hoop Vlei and as far east as the Groot Brak River. Disturbed areas on the coastal fringe sometimes converted to *Cynodon* grazing, with extensive mole rat (*Bathyergus suillus*) activity.

Remark 3 The tall tussock restios typical of this sand fynbos are an important source for the thatching industry.

References Muir (1929), Rebelo et al. (1991), Boucher (1995, 1997d, 1998c), Boucher & Rode (1995a, b).

FFd 10 Knysna Sand Fynbos

VT 4 Knysna Forest (85%) (Acocks 1953). LR 2 Afromontane Forest (72%), LR 4 Dune Thicket (24%) (Low & Rebelo 1996). BHU 100 Knysna Afromontane Forest (72%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Garden Route coastal flats from Wilderness, generally to the north of the system of lakes, several patches around the Knysna Lagoon, with more isolated patches eastwards to the Robberg peninsula near Plettenberg Bay. Altitude 40–300 m.

Vegetation & Landscape Features Undulating hills and moderately undulating plains covered with a dense, moderately tall, microphyllous shrubland, dominated by species more typical of sandstone fynbos.

Geology & Soils Deep, acid Tertiary sand inland of coastal dunes forming regic sands and soils of Lamotte form. Land types mainly Hb and Ga.

Climate MAP 670–1 090 mm (mean: 850 mm), with a slight peak in autumn and spring. Mean daily maximum and minimum temperatures 27.3°C and 7.3°C for February and July, respectively. Frost incidence 2 or 3 days per year. See also climate diagram for FFd 10 Knysna Sand Fynbos (Figure 4.57).

Important Taxa Small Tree: *Widdringtonia nodiflora*. Tall Shrubs: *Cliffortia linearifolia*, *Leucadendron eucalyptifolium*, *Metalasia densa*, *Passerina corymbosa*. Low Shrubs: *Anthospermum aethiopicum*, *Berzelia intermedia*, *Cliffortia drepanoides*, *Clutia rubricaulis*, *Erica diaphana*, *E. glandulosa* subsp. *fourcadei*, *E. glumiflora*, *E. sessiliflora*, *Helichrysum asperum* var. *asperum*, *Lachnaea diosmoides*, *Leucadendron salignum*, *Leucospermum cuneiforme*, *Lobelia coronopifolia*, *Morella quercifolia*, *Muraltia squarrosa*, *Oedera imbricata*, *Protea cynaroides*, *Stoebe plumosa*, *Tephrosia capensis*. Herbs: *Geranium incanum*, *Helichrysum felinum*. Graminoids: *Aristida junciformis* subsp. *galpinii*, *Brachiaria serrata*, *Cynodon dactylon*, *Eragrostis capensis*, *Ficinia bulbosa*, *Heteropogon contortus*, *Ischyrolepis eleocharis*, *Tetraria cuspidata*, *Thamnochortus cinereus*, *Themeda triandra*, *Tristachya leucothrix*.

Conservation Endangered. Target 23%. Patches are statutorily conserved in the proposed Garden Route National Park (about 3%) as well as 2% in several private nature reserves. Almost 70% already transformed (pine and gum plantations, cultivation, Knysna urban sprawl, building of roads). Alien *Acacia melanoxylon, A. mearnsii* and *A. longifolia* occur locally at low densities. Erosion very low and moderate.

Remark This is a very poorly researched vegetation unit.

References Taylor (1970b), Drews (1980a).

FFd 11 Southern Cape Dune Fynbos

Psammophilous Macchia (Phillips 1931). VT 70 False Macchia (51%) (Acocks 1953). Maritime Heath (Martin & Noel 1960). South Coast Dune Fynbos (Cowling 1984). Mosaic of Dune Fynbos & Kaffrarian Thicket (79%) (Moll & Bossi 1983). Dune Fynbos (Lubke & Van Wijk 1988). LR 4 Dune Thicket (82%) (Low & Rebelo 1996). BHU 9 St Francis Fynbos/Thicket Mosaic (39%), BHU 8 Goukamma Fynbos/Thicket Mosaic (38%) (Cowling et al. 1999b, Cowling & Heijnis 2001). STEP Goukamma Dune Thicket (46%), STEP St. Francis Dune Thicket (10%), STEP Kiwane Dune Thicket p.p. (Vlok & Euston-Brown 2002, Vlok et al. 2003).

Distribution Western and Eastern Cape Provinces: Two large mapped patches on the Indian Ocean Coast span the Wilderness Estuary and Buffels Bay near Knysna (Western Cape), and Tsitsikamma River mouth to Oyster Bay (Eastern

Figure 4.67 FFd 11 Southern Cape Dune Fynbos: Steep slope of leached sand dune at the edge of the Alexandria Dunefield supporting dense *Olea exasperata* fynbos near Alexandria (Eastern Cape).

Cape). Smaller cordons occur further east between Oyster and St Francis Bays. A series of smaller unmapped patches occur as far west as Mossel Bay and eastwards to near East London. Altitude 20–220 m.

Vegetation & Landscape Features Coastal dune cordons (those towering above the Groenvlei near Sedgefield considered the tallest vegetated dunes in southern Africa) often with steep slopes. The vegetation is fynbos heath dominated by sclerophyllous shrubs with a rich restio undergrowth. The dominant shrubs include *Olea exasperata* and *Phylica litoralis*, while among restios *Ischyrolepis eleocharis* is most prominent. The relatively recent (last 100 years) exclusion of fire from a large percentage of this unit enabled many woody species to displace the fynbos vegetation. The alien *Acacia cyclops* often acted as a precursor for the establishment of thicket vegetation in sites where fynbos or coastal dunes used to occur. These thicket clumps occurring within this dune fynbos are not rich in species and have *Pterocelastrus tricuspidatus, Rhus lucida, Sideroxylon inerme* and *Tarchonanthus littoralis* as the dominant species.

Geology & Soils Stabilised old calcareous or neutral dunes (some as old as 120 000 years) outside the influence of salt spray built of deep sands, moving in places. Soils of Lamotte form, main land types Hb and Ga.

Climate MAP 600–900 mm (mean: 757 mm), with a slight peak in autumn and spring. Mean daily maximum and minimum temperatures 25.3°C and 8.0°C for February and July, respectively. Frost is a rare phenomenon due to the strong marine influence of the ocean. See also climate diagram for FFd 11 Southern Cape Dune Fynbos (Figure 4.57).

Important Taxa Tall Shrubs: *Olea exasperata* (d), *Passerina corymbosa*, *Rhus crenata*, *R. glauca*, *R. laevigata*, *R. lucida*. Low Shrubs: *Agathosma ovata* (d), *Metalasia muricata* (d), *Passerina rigida* (d), *Phylica litoralis* (d), *Agathosma apiculata*, *A. stenopetala*, *Anthospermum aethiopicum*, *Aspalathus spinosa* subsp. *spinosa*, *Chironia baccifera*, *Erica fourcadei*, *E. glumiflora*, *E. zeyheriana*, *Felicia echinata*, *Gnidia anthylloides*, *Helichrysum teretifolium*, *Indigofera sulcata*, *Jamesbrittenia microphylla*, *Leucadendron salignum*, *Morella quercifolia*, *Muraltia satureioides*, *M. squarrosa*, *Otholobium bracteolatum*, *Pelargonium betulinum*, *Phylica ericoides*, *Polygala ericaefolia*, *Struthiola parviflora*. Semiparasitic Shrub: *Thesidium fragile*. Geophytic Herbs: *Satyrium princeps* (d). *Cyrtanthus loddigesianus*, *C. obliquus*. Graminoids: *Ischyrolepis eleocharis* (d), *Ehrharta calycina*, *Ficinia dunensis*, *Ischyrolepis leptoclados*, *Pentaschistis heptamera*, *Tetraria cuspidata*, *Thamnochortus cinereus*, *Tribolium obtusifolium*.

Endemic Taxa Low Shrubs: *Aspalathus cliffortiifolia* (possibly extinct), *Erica chloroloma*. Succulent Shrub: *Lampranthus algoensis*. Graminoids: *Pentaschistis barbata* subsp. *orientalis*.

Conservation Least threatened. Target 36%. More than 16% statutorily conserved in the Goukamma (housing the most prominent examples of this vegetation unit) and Huisklip Nature Reserves as well as in the proposed Garden Route National Park. An additional 4% is protected in private conservation areas such as Thyspunt, Rebelsrus and Klasies River Cave. About 17% has been transformed, mainly for cultivation, plantations and by urban development. Dense stands of alien *Acacia cyclops* and *A. saligna* are of conservation concern and are being targeted for removal. *A. mearnsii* and *Leptospermum laevigatum* also occur in places. Erosion very low and low.

Remarks Taylor & Morris (1981) made an explicit link between (coastal) 'Grassland' and 'Calcrete Fynbos' and claimed that the balance between these two is a delicate one, being controlled by the depth of soil (hence nutrient status) as well as by degree of grazing and trampling. According to local farmers in the Port Elizabeth area, fire is supposed to be of minor importance. Cowling & Pierce (1985) observed that in areas with pronounced summer rainfall, the dune fynbos is almost entirely replaced by grasslands dominated by *Themeda triandra, Stenotaphrum secundatum* and species of *Cymbopogon*. They suggested that the dune fynbos would extend along the eastern seaboards of South Africa as far north as KwaZulu-Natal. Indeed the elements of coastal dune fynbos representing geographically outlying taxa of the genera *Metalasia* (*M. muricata*), *Passerina* (*P. corymbosa, P. rigida*), *Morella* (*M. quercifolia*), *Phylica* (*P. ericifolia*) etc. occur along those coastal stretches on exposed dune slopes and crests. This narrow belt thins out towards the north to become only few metres broad on the KwaZulu-Natal coast. A report by Vlok & Euston-Brown (2002; see their description of the Kiwane Dune Thicket) supplies further thoughts about the link between coastal grasslands and coastal fynbos. *Acmadenia kiwanensis* (at present considered by us as endemic to AT 9 Albany Coastal Belt) may be an indicator of former transformations of this fynbos-grassland complex.

References Phillips (1931), Martin & Noel (1960), Van der Merwe (1976), Taylor & Morris (1981), Cowling (1982, 1983d, 1984), Olivier (1983), Cowling & Pierce (1985, 1988), Lubke & Van Wijk (1988), Hanekom et al. (1989), Lubke & De Villiers (1991), Vlok & Euston-Brown (2002), Vlok et al. (2003), D. Hoare (unpublished data), L. Mucina (unpublished data).

9.1.4 Shale Fynbos

Shale fynbos occurs in areas with leached soils derived from shale. It is almost always found at higher altitudes, usually on southern slopes abutting the mountains. Most shale fynbos units (except those associated with the inland Witteberg Quartzite) abut granite fynbos and share many of their species with it. In many high-rainfall areas, the shales are covered by silcrete and ferricrete, dealt with as separate vegetation units. Shale fynbos is the forth largest group of fynbos types and comprises 5% of the area of fynbos.

Floristically and structurally the shale fynbos is very similar to granite fynbos, except that it lacks the rocky outcrops and boulders typical of granite fynbos and thus lacks the scrub forest and thicket elements. The much smoother terrain results in a far more uniform landscape, with seeps and slopes generating most habitat heterogeneity. In proteoid fynbos in the Western Cape, *Protea coronata* and *P. lepidocarpodendron* are more prominent than in granite fynbos. There is a preponderance of grasses, with graminoid fynbos being prominent, especially in the eastern units of shale fynbos.

Shale fynbos grades into shale renosterveld on lower slopes and in drier areas. Shale fynbos has been poorly studied and it is not known how the interface between frequent fires (every 2–5 years) in renosterveld and rarer fires (15–30 years) typical of fynbos varies across the two vegetation types. Presumably shale fynbos burns on an intermediate cycle and may form the zone in which the apparently disparate fire regimes intergrade. Too frequent burning can convert shale fynbos to grassland (and often used for pasture), especially when coupled with bush-cutting, liming and the introduction of aggressive pasture grasses.

A prominent feature of shale fynbos is the abundance of grasses and herbs in the early seral stages. In the wettest areas the fire ephemerals may become 1 m tall in the first spring—dying back after three to four years, and the asteraceous and proteoid components then begin to dominate the vegetation. Shale fynbos in the winter-rainfall area is very dense when mature, with tall proteoids in the overstorey, and a dense understorey of ericoids. In the more even-rainfall areas, the mature veld is typically a dense, low shrubland with prominent grassy elements.

The current structural classification (Campbell 1985) for shale and silcrete fynbos types is inadequate. Most key out as mesotrophic asteraceous fynbos, primarily because low (< 1.5 m) serotinous proteas do not feature in the key. However, the recognition of key species (*Leucadendron elimense, L. globosum, L. laxum, L. modestum, L. teretifolium, L. stelligerum*) as characteristic taxa of mesotrophic proteoid fynbos is required for these fynbos types. Waboomveld—characterised by *Protea nitida*—is curiously lacking in certain units within this type. Where present, *P. nitida* is often found as the dwarf form resprouting at the base, or occurs in screes which possibly provide some fire protection, although this species is remarkably fire-resistant elsewhere.

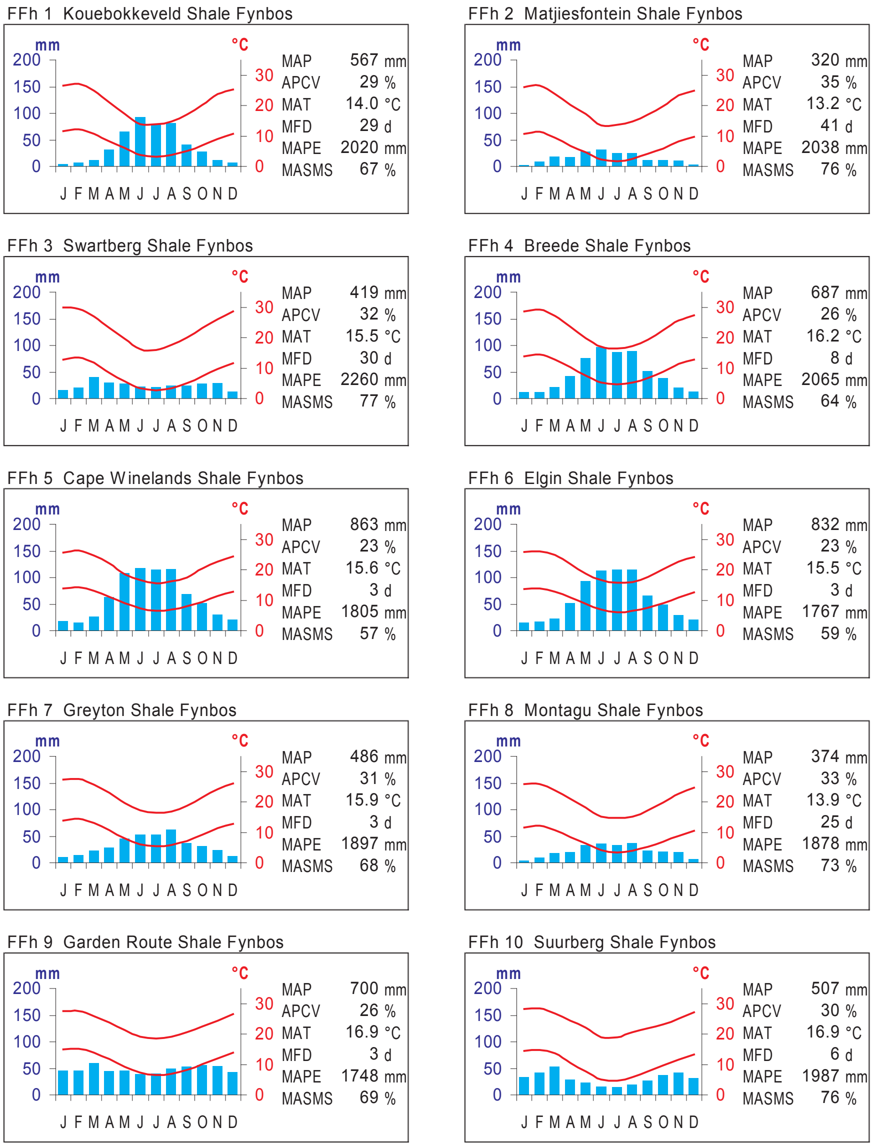


Figure 4.68 Climate diagrams of shale fynbos units. Blue bars show the median monthly precipitation. The upper and lower red lines show the mean daily maximum and minimum temperature respectively. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days (days when screen temperature was below 0°C); MAPE: Mean Annual Potential Evaporation; MASMS: Mean Annual Soil Moisture Stress (% of days when evaporative demand was more than double the soil moisture supply).

FFh 1 Kouebokkeveld Shale Fynbos

VT 69 Macchia (89%) (Acocks 1953). Mesic Mountain Fynbos (42%), Central Mountain Renosterveld (8%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (67%) (Low & Rebelo 1996). BHU 49 Swartruggens Mountain Fynbos Complex (44%), BHU 37 Waveren-Bokkeveld Inland Renosterveld (26%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Koue Bokkeveld Valley from Waboomrivier and Rosendal (Koue Bokkeveld) to Gydo Pass (north of Ceres), edge of the Warm Bokkeveld from Gydo Pass along the lower slopes of the Gydoberg and Waboomberg to the upland plateau with Klondyke and Muilbergsvlakte, and Agter Witzenberg valleys, from Rosendal (Swartruggens) to Wakkerstroom. Altitude 900–1 100 m.

Vegetation & Landscape Features Slightly undulating plains and steep slopes in valleys between high mountains, supporting mainly moderately tall and dense proteoid shrubland. Asteraceous, proteoid and waboomveld fynbos shrublands are dominant, with fynbos restiolands occurring in the bottomlands.

Geology & Soils Acidic, moist clay-loam prismacutanic or pedocutanic soils,

Figure 4.69 FFh 1 Kouebokkeveld Shale Fynbos: Waboomveld with *Protea nitida* on the Gydo Pass, north of Ceres (Western Cape).

derived from Bokkeveld Shales. Land types mainly Db, Fb, Fa, Bb and Ib.

Climate MAP 300–920 mm (mean: 570 mm). Mean daily maximum and minimum temperatures 27.1°C and 3.1°C for February and July, respectively. Frost incidence 10–30 days per year. See also climate diagram for FFh 1 Kouebokkeveld Shale Fynbos (Figure 4.68).

Important Taxa ([W]Wetlands) Small Tree: *Protea nitida* (d). Tall Shrubs: *Leucadendron rubrum*, *Montinia caryophyllacea*, *Protea laurifolia*, *P. repens*. Low Shrubs: *Acmadenia matroosbergensis*, *Anthospermum aethiopicum*, *Aspalathus alpestris*, *A. desertorum*, *A. intricata* subsp. *intricata*, *A. lanifera*, *A. nudiflora*, *Cliffortia ruscifolia*, *Elytropappus rhinocerotis*, *Lachnaea pedicellata*, *Leucadendron salignum*, *Phylica odorata*. Geophytic Herbs: *Geissorhiza geminata*[W], *G. ornithogaloides* subsp. *marlothii*, *Romulea minutiflora*, *R. setifolia*, *R. tortuosa*. Graminoids: *Pentaschistis colorata*, *P. eriostoma*, *Themeda triandra*.

Endemic Taxa Low Shrubs: *Aspalathus compacta*, *Erica florifera*. Succulent Shrub: *Lampranthus lewisiae*. Geophytic Herbs: *Geissorhiza silenoides*, *Moraea variabilis*.

Conservation Endangered. Target 29%. No statutory reserves, but almost 20% protected in the Koue Bokkeveld (mountain catchment area) and private nature reserves such as Wakkerstroom and Opdrag. About 40% has been transformed, mostly for fruit orchards and grazing land, with large areas of seeps and lower areas converted to farm dams. North of Gydo Pass it is largely transformed, so that the remaining areas are not representative of the vegetation type. Alien *Pinus radiata* occurs occasionally. Erosion very low and moderate.

Remarks This is a poorly studied vegetation type. The listed taxa are not representative of the diversity in this type, since most of the accessible landscape has been transformed. In the east it is predominantly grassy, whereas in the west the proteas form a dense overstorey.

Reference Campbell (1985).

FFh 2 Matjiesfontein Shale Fynbos

VT 70 False Macchia (99%) (Acocks 1953). Central Mountain Renosterveld (66%) (Moll & Bossi 1983). LR 61 Central Mountain Renosterveld (78%) (Low & Rebelo 1996). BHU 62 Witteberg Mountain Fynbos Complex (67%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Very fragmented unit on the higher peaks of mountain ranges in the extreme western Little Karoo south of Witberg from Suurberg (southeast of Touws River) to Ezelsfontein (southwest of Laingsburg). Confined to summits and southern slopes. Altitude 1 000–1 500 m.

Vegetation & Landscape Features Gentle and steep southern slopes south of quartzitic outcrops, covered by moderately tall and dense proteoid shrubland. This vegetation is primarily asteraceous and proteoid (mesotrophic) fynbos.

Geology & Soils Acidic, moist clay-loam, red-yellow apedal or skeletal soils derived from shales of the Devonian Witteberg Group, and associated with quartzitic outcrops. Land types mainly Ic and Ah.

Climate MAP 210–470 mm (mean: 320 mm), peaking from May to August. Mean daily maximum and minimum temperatures 26.5°C and 1.7°C for February and July, respectively. Frost incidence 20–40 days per year. The most arid of shale fynbos types, probably only maintained by runoff from quartzite fynbos and cool nocturnal temperatures. Occurring at well below the usual rainfall limits for fynbos on shale. See also climate diagram for FFh 2 Matjiesfontein Shale Fynbos (Figure 4.68).

Important Taxa Tall Shrubs: *Protea repens* (d), *Leucadendron pubescens*, *L. rubrum*, *Protea laurifolia*, *P. punctata*. Low Shrubs: *Aspalathus intricata* subsp. *intricata*, *Cliffortia ruscifolia*, *Elytropappus rhinocerotis*, *Euryops imbricatus*, *Leucadendron barkerae*, *L. brunioides* var. *brunioides*, *L. cadens*, *L. salignum*, *L. teretifolium*, *Leucospermum wittebergense*, *Passerina obtusifolia*, *Protea canaliculata*, *P. humiflora*, *P. lorifolia*, *P. revoluta*, *P. scolopendriifolia*, *P. sulphurea*, *Relhania relhanioides*, *R. tri-*

Figure 4.70 FFh 2 Matjiesfontein Shale Fynbos: Dry restioid fynbos with scattered shrubs of *Protea laurifolia* on the Farm Elandsfontein at the southern foot of the Witteberge near Touwsrivier.

cephala, *Spatalla confusa*, *Vexatorella obtusata* subsp. *albomontana*. Graminoids: *Hypodiscus neesii*, *H. sulcatus*, *Pentaschistis eriostoma*.

Conservation Least threatened. Target 27%. Almost 30% statutorily conserved in the Anysberg Nature Reserve in the eastern part of its distribution area. The western portion does not enjoy any formal protection. About 3% transformed for cultivation. Erosion low and very low.

Remarks A very poorly studied vegetation type, requiring detailed study. It shares many species with FFq 3 Matjiesfontein Quartzite Fynbos, but often contains far more grasses. It grades into renosterveld, which covers all the northern slopes and most of the bottomlands on shales within the landscape.

References Vlok (2002), N. Helme (unpublished data).

FFh 3 Swartberg Shale Fynbos

VT 70 False Macchia (82%) (Acocks 1953). South Coast Renosterveld (58%) (Moll & Bossi 1983). LR 63 South and South-west Coast Renosterveld (56%) (Low & Rebelo 1996). BHU 43 Kango Inland Renosterveld (93%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: A very fragmented unit from the southern foothills of the Klein and Groot Swartberge, occurring in isolated pockets from the vicinity of Ladismith to Matjiesrivier and north of the Groot Swartberge around Gideonshoop southwest of Klaarstroom. Altitude 650–1 150 m.

Vegetation & Landscape Features Steep to gentle slopes below sandstone mountains, supporting moderately tall and dense shrublands, structurally classified as asteraceous and proteoid (mesotrophic) fynbos.

Geology & Soils Acidic, moist clay-loam, Glenrosa or Mispah forms derived from shales of the Bokkeveld Group (Devonian) and the Cango Group (Namibian Erathem). Land types mainly Fc, Fb and Ib.

Climate MAP 230–780 mm (mean: 420 mm), with no clear peak and a slight low from December to February. Mean daily maximum and minimum temperatures 29.9°C and 2.6°C for January and July, respectively. Frost incidence 10–30 days per year. See also climate diagram for FFh 3 Swartberg Shale Fynbos (Figure 4.68).

Important Taxa (TCape thickets) Small Tree: *Protea nitida* (d). Succulent Tree: *Aloe ferox*. Tall Shrubs: *Phylica paniculata* (d), *Protea repens* (d), *Dodonaea viscosa* var. *angustifolia*, *Leucadendron rubrum*, *Protea eximia*, *P. punctata*, *Rhus lucida*T. Low Shrubs: *Protea lorifolia* (d), *Anthospermum aethiopicum*, *Elytropappus rhinocerotis*, *Leucadendron barkerae*, *L. salignum*, *Leucospermum cuneiforme*, *L. wittebergense*, *Metalasia pulcherrima* f. *pallescens*, *Mimetes cucullatus*, *Oedera genistifolia*, *Paranomus dispersus*, *Passerina obtusifolia*, *Ursinia heterodonta*. Geophytic Herb: *Cheilanthes eckloniana*. Graminoids: *Brachiaria serrata*, *Cannomois scirpoides*, *Cymbopogon pospischilii*, *Hypodiscus striatus*, *H. synchroolepis*, *Rhodocoma fruticosa*, *Themeda triandra*, *Willdenowia teres*.

Conservation Least threatened. Target 27%. Statutorily conserved in the Groot Swartberg (9%) and Klein Swartberg Nature Reserves (3%). About 12% of the area has been transformed, mostly for cultivation. Erosion very low and low.

Remark This is a poorly studied vegetation unit, confined to the higher foothills of the Swartberg, mostly as transition to renosterveld.

References Bond (1981), N. Helme (unpublished data).


L. Mucina

Figure 4.71 FFh 3 Swartberg Shale Fynbos: Asteraceous fynbos with scattered *Protea nitida* and undergrowth rich in asteraceous shrubs such as *Metalasia pulcherrima, Ursinia heterodonta* and various species of *Oedera, Relhania* and *Athanasia* north of Ladismith on southern slopes of the Klein Swartberg Mountains (Western Cape).

FFh 4 Breede Shale Fynbos

VT 69 Macchia (83%) (Acocks 1953). Central Mountain Renosterveld (36%), Mesic Mountain Fynbos (31%) (Moll & Bossi 1983). LR 61 Central Mountain Renosterveld (65%) (Low & Rebelo 1996). BHU 37 Waveren-Bokkeveld Inland Renosterveld (52%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Breede River and Slanghoek Valleys discontinuously from Tulbagh (Winterhoek 'Kom') to Swellendam, on the lower southern slopes of the Groot Winterhoek, Witsenberg, Hex and Langeberg Mountains and at places along the base of the Slanghoekberge and western Badsberg. Altitude 150–750 m, with pockets up to 900 m.

Vegetation & Landscape Features Steep upper slopes below mountains grading to slightly undulating plains, well dissected by rivers. Vegetation is a moderately tall and dense shrubland—mostly restioid, proteoid and asteraceous (mesotrophic) fynbos. A remarkably tall and dense post-fire component dominates early seral communities on wetter slopes.

Geology & Soils Acidic, moist clay-loam, Glenrosa or Mispah forms derived from Bokkeveld Shales, underlain by rocks of the Malmesbury Group. Land types mainly Fa, Fb and Ic.

Climate Winter-rainfall climate with MAP 300–1 300 mm (mean: 690 mm), peaking from May to August. Mean daily maximum and minimum temperatures 29.2°C and 4.6°C for February and July, respectively. Frost incidence 3–10 days per year. See also climate diagram for FFh 4 Breede Shale Fynbos (Figure 4.68).

Important Taxa Small Tree: *Protea nitida* (d). Tall Shrubs: *Cliffortia serpyllifolia* (d), *Dodonaea viscosa* var. *angustifolia* (d), *Leucadendron eucalyptifolium* (d), *L. rubrum*, *Protea burchellii*, *P. laurifolia*, *P. neriifolia*, *P. repens*. Low Shrubs: *Aspalathus spinosa* subsp. *spinosa* (d), *Cliffortia ruscifolia* (d), *Elytropappus rhinocerotis* (d), *Erica hispidula* (d), *E. versicolor* (d), *Oedera squarrosa* (d), *Penaea cneorum* subsp. *ruscifolia* (d), *Stoebe cinerea* (d), *Aulax cancellata*, *Erica pubigera*, *Eriocephalus africanus* var. *africanus*, *Felicia filifolia* subsp. *filifolia*, *Leucadendron salignum*, *L. spissifolium* subsp. *spissifolium*, *Passerina obtusifolia*, *Pteronia paniculata*. Succulent Shrubs: *Ruschia caroli* (d), *Adromischus filicaulis* subsp. *filicaulis*, *Erepsia gracilis*, *Tetragonia fruticosa*. Herb: *Edmondia sesamoides*. Geophytic Herb: *Lanaria lanata* (d). Graminoids: *Tetraria flexuosa* (d), *Capeobolus brevicaulis*, *Cymbopogon marginatus*, *Ehrharta ramosa* subsp. *ramosa*, *Ischyrolepis capensis*, *I. curviramis*, *I. gaudichaudiana*, *Rhodocoma fruticosa*, *Tetraria ustulata*.

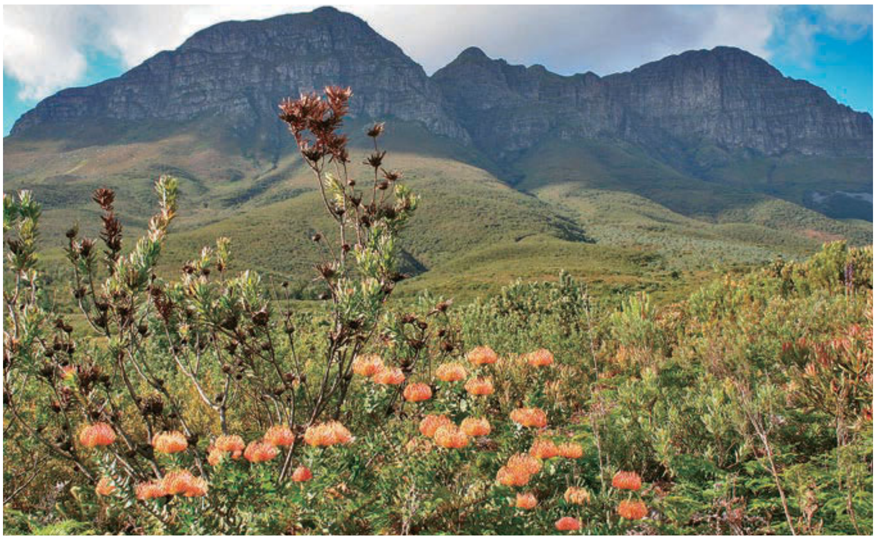

L. Mucina

Figure 4.72 FFh 5 Cape Winelands Shale Fynbos: Proteaceous fynbos dominated by *Protea coronata, Leucadendron sessile* and *Leucospermum gueinzii* on shale slopes below the Helderberg Mountain (Western Cape).

Endemic Taxa Low Shrubs: *Rafnia angulata* subsp. *thunbergii*, *Vexatorella latebrosa*. Succulent Shrubs: *Drosanthemum opacum*, *Lampranthus dregeanus*, *L. tulbaghensis*, *Oscularia vernicolor*. Geophytic Herb: *Oxalis lindaviana*.

Conservation Vulnerable. Target 30%. About 30% conserved in Cape Nature and other statutory nature reserves such as Grootwinterhoek Wilderness Area, Dassieshoek, Marloth, Wittebrug and Witzenberg and in mountain catchment areas such as Langeberg-wes, Matroosberg and Winterhoek. About 30% of the area is transformed, mostly for cultivation. *Pinus pinaster* and *Hakea sericea* are the most serious woody aliens in the unit. Erosion very low and moderate.

Remark This is a very poorly studied vegetation unit.

References Chesselet (1985), Boschoff (1989), McDonald (1993b).

FFh 5 Cape Winelands Shale Fynbos

VT 69 Macchia (81%) (Acocks 1953). Mesic Mountain Fynbos (53%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (61%), LR 62 West Coast Renosterveld (27%) (Low & Rebelo 1996). BHU 32 Boland Coast Renosterveld (39%), BHU 54 Franschhoek Mountain Fynbos Complex (28%), BHU 56 Kogelberg Mountain Fynbos Complex (18%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Higher hills and lower mountain slopes in the Stellenbosch and Somerset West areas, in patches from Blousteen on Clarence Drive at Koeëlbaai to south of Elsenberg and within the Jonkershoek Valley, with pockets on the Cape Peninsula at Devils Peak, the Tygerberg Hills on Kanonkop, Groenberg near Wellington and the upper Franschhoek Valley. Altitude 0–700 m.

Vegetation & Landscape Features Moderately undulating plains and steep slopes against the mountains. Vegetation is a moderately tall and dense shrubland dominated by proteoid and closed-scrub fynbos in structural terms.

Geology & Soils Acidic, moist clay-loamy, red-yellow apedal and Glenrosa and Mispah forms derived from Malmesbury Shales. Land types mainly Ac, Fa and Ic.

Climate MAP 520–1 690 mm (mean: 865 mm), peaking from May to August. This is the shale fynbos unit with the highest rainfall. Mean daily maximum and minimum temperatures 26.4°C and 6.6°C for February and July, respectively. Frost incidence 2 or 3 days per year. See also climate diagram for FFh 5 Cape Winelands Shale Fynbos (Figure 4.68).

Important Taxa ([T]Cape thickets, [W]Wetlands) Small Trees: *Kiggelaria africana*[T], *Leucadendron argenteum*, *Leucospermum conocarpodendron* subsp. *viridum*, *Protea nitida*. Tall Shrubs: *Aspalathus uniflora* (d), *Cliffortia cuneata* (d), *C. phillipsii* (d), *Halleria lucida*[T] (d), *Maytenus acuminata*[T] (d), *Myrsine africana*[T] (d), *Olea europaea* subsp. *africana*[T] (d), *Protea coronata* (d), *P. repens* (d), *Rhus angustifolia*[T] (d), *Chrysanthemoides monilifera*, *Cunonia capensis*[T], *Diospyros glabra*[T], *Metalasia densa*, *Protea lepidocarpodendron*, *Rhus tomentosa*[T]. Low Shrubs: *Aspalathus cephalotes* subsp. *violaceae* (d), *Brunia nodiflora* (d), *Cliffortia polygonifolia* (d), *C. ruscifolia* (d), *Cullumia ciliaris* (d), *C. setosa* (d), *Erica equisetifolia* (d), *E. hirta* (d), *E. hispidula* (d), *E. nudiflora* (d), *E. parviflora*[W] (d), *Leucadendron sessile* (d), *L. spissifolium* subsp. *spissifolium* (d), *Stoebe cinerea* (d), *Anthospermum aethiopicum*, *A. spathulatum* subsp. *spathulatum*, *Aspalathus lebeckioides*, *Elytropappus gnaphaloides*, *E. rhinocerotis*, *Erica paniculata*, *Eriocephalus africanus* var. *africanus*, *Helichrysum pandurifolium*, *H. teretifolium*, *Leucadendron salignum*, *Maytenus oleoides*[T], *Protea acaulos*, *P. lorea*, *P. scabra*, *Salvia africana-caerulea*, *Senecio pubigerus*, *Stoebe plumosa*. Geophytic Herbs: *Bobartia indica* (d), *Mohria caffrorum* (d), *Pteridium aquilinum* (d), *Watsonia borbonica* subsp. *borbonica* (d), *Aristea cantharophila*, *A. capitata*, *Babiana villosula*, *Micranthus junceus*, *Romulea rosea*. Herbaceous Parasitic Climber: *Cassytha ciliolata*. Graminoids: *Cannomois virgata* (d), *Ehrharta ramosa* subsp. *ramosa* (d), *Elegia juncea* (d), *Ficinia oligantha* (d), *F. trichodes* (d), *Ischyrolepis capensis* (d), *I. gaudichaudiana* (d), *Merxmuellera stricta* (d), *Pentaschistis colorata* (d), *P. eriostoma* (d), *Restio triticeus* (d), *Schoenoxiphium lanceum* (d), *Staberoha cernua* (d), *Tetraria cuspidata* (d), *Ehrharta calycina*, *Ficinia indica*.

Endemic Taxon Geophytic Herb: *Moraea aristata*.

Conservation Endangered, but well conserved. Target 30% already reached since about 25% is statutorily conserved in the Table Mountain National Park, Helderberg and Hottentots Holland Nature Reserves. An additional 25% enjoys protection in mountain catchment areas (Hottentots Holland, Hawequas). The rest of the area has been transformed, mainly for pine plantations and vineyards as well as by urban development of the Cape Town metropolitan area. Essentially only the steeper upper portions remain. The notable woody aliens include *Pinus pinaster* and *Hakea sericea*. Erosion very low.

Remarks This is a poorly studied vegetation type. Vegetation should be subjected to detailed analysis. This type may occur in FFb 2 Western Coastal Shale Band Vegetation but in this region the shale band occurs at altitudes (500–1 500 m) well above that typical of the vegetation described for this unit. Many species are shared with the FFg 3 Peninsula Granite Fynbos and include several local endemics (e.g. *Leucadendron argenteum*, *L. daphnoides, Leucospermum grandiflorum, L. gueinzii, Serruria kraussii*).

References Andrag (1970), Anonymous (1979), Lamprecht (1979), Boucher (1983, 1987), Swart (1983), Lötter & Van Wageningen (1988), Raitt (1999), N. Helme (unpublished data), L. Mucina (unpublished data).

FFh 6 Elgin Shale Fynbos

VT 69 Macchia (98%) (Acocks 1953). Mesic Mountain Fynbos (17%) (Moll & Bossi 1983). LR 63 South and South-west Coast Renosterveld (75%), LR 64 Mountain Fynbos (24%) (Low & Rebelo 1996). BHU 25 Elgin Fynbos/Renosterveld Mosaic (39%), BHU 33 Overberg Coast Renosterveld (21%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Elgin Basin east of Grabouw and Villiersdorp Basin around Vyeboom, with pockets to the north at the uppermost part of Stettynskloof, Kaaimansgat and Rooihoogte Pass, and at the Steenbras Dam to the west. Altitude 200–450 m.

Vegetation & Landscape Features Undulating hills and moderately undulating plains and steep slopes of adjacent mountains. An open to medium dense tall proteoid shrubland over a matrix of moderately tall and dense evergreen shrubs, dominated by proteoid, asteraceous and closed-scrub fynbos, and ericaceous fynbos in the wetter facies.

Geology & Soils Acidic, moist clay-loam, Glenrosa or Mispah forms derived from Bokkeveld Group shales. Land types mainly Fa.

Climate Winter-rainfall regime, with MAP 560–1 300 mm (overall mean: 830 mm), peaking from May to August. Mean daily maximum and minimum temperatures 26.2°C and 6.2°C for February and July, respectively. Frost incidence 2 or 3 days per year. See also climate diagram for FFh 6 Elgin Shale Fynbos (Figure 4.68).

Important Taxa ([T]Cape thickets) Tall Shrubs: *Cliffortia cuneata*, *Freylinia longiflora*, *Leucadendron salicifolium*, *Protea coronata*, *P. lepidocarpodendron*, *P. repens*, *Rhus angustifolia*[T], *R. rehmanniana*[T]. Low Shrubs: *Erica quadrangularis* (d), *Anthospermum spathulatum* subsp. *saxatile*, *Aspalathus millefolia*, *A. nigra*, *A. nudiflora*, *Brunia laevis*, *B. neglecta*, *Cliffortia apiculata*, *C. atrata*, *Elytropappus rhinocerotis*, *Erica bruniifolia*, *E. plukenetii* subsp. *plukenetii*, *E. setacea*, *E. sphaeroidea*, *E. viscaria* subsp. *longifolia*, *Helichrysum cymosum*, *H. patulum*, *Hermannia grossularifolia*, *Leucadendron laureolum*, *L. salignum*, *L. xanthoconus*, *Nenax acerosa*, *Otholobium rotundifolium*, *Phylica spicata*, *Printzia polifolia*, *Protea longifolia*, *P. scabra*. Herbs: *Berkheya herbacea*, *Corymbium africanum*, *Peucedanum strictum*. Geophytic Herbs: *Aristea cantharophila*, *Bobartia indica*, *Geissorhiza inflexa*, *Micranthus junceus*, *Oxalis compressa*. Graminoids: *Askidiosperma rugosum*, *Ehrharta calycina*, *Elegia stipularis*, *Festuca caprina*, *Ficinia indica*, *Ischyrolepis capensis*, *Merxmuellera rufa*, *M. stricta*, *Tetraria bromoides*, *Themeda triandra*, *Tribolium brachystachyum*.

Endemic Taxa Low Shrubs: *Leucadendron elimense* subsp. *vyeboomense*, *L. globosum*.

Conservation Critically endangered. The target of 30% is double that of the remaining natural distribution. Some patches of the unit are statutorily conserved in the Theewaters and Limietberg Nature Reserves. The privately owned Solva Farm (near Grabouw) has probably the best preserved patch of this rare fynbos type. Almost 80% of the areas have been transformed, with cultivation accounting for almost 60% (mainly fruit orchards, pine plantations and the flooded area of the Theewaterskloof and Steenbras Dams). This region is characterised by very intensive and profitable agricultural land. Aliens *Pinus pinaster* and *Hakea sericea* are problems in the remaining remnants. Erosion very low.

Remarks Many of the remnants are too small to burn regularly and diversity in the stands is declining. This is the only winter-rainfall shale fynbos type with extensive ericaceous fynbos. Amongst the shale fynbos types, this unit has few succulents. This type may occur in FFb 2 Western Coastal Shale Band Vegetation, but in this region the shale band occurs at altitudes (500–1 500 m) well above that typical of the vegetation described for this unit.

References Boucher (1977, 1978), Rode (1994), N. Helme (unpublished data).

L. Mucina

Figure 4.73 FFh 6 Elgin Shale Fynbos: Proteoid fynbos dominated by *Protea repens* and *Leucadendron elimense* subsp. *vyeboomensis* near Vyeboom, south of Villiersdorp (Western Cape).

FFh 7 Greyton Shale Fynbos

VT 69 Macchia (64%) (Acocks 1953). Dry Mountain Fynbos (30%), South West Coast Renosterveld (27%) (Moll & Bossi 1983). LR 63 South and South-west Coast Renosterveld (63%), LR 64 Mountain Fynbos (37%) (Low & Rebelo 1996). BHU 18 Genadendal Grassy Fynbos (72%), BHU 33 Overberg Coast Renosterveld (20%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: South of Riviersonderend and Caledon Swartberg Mountains on higher-altitude

Figure 4.74 FFh 7 Greyton Shale Fynbos: Proteoid fynbos with *Leucadendron salignum* and *Protea repens* (and scattered alien *Hakea sericea* and *Pinus pinaster*, in the background) on shale slopes below a sandstone ridge south of Genadendal (Western Cape).

shales from Theewaterskloof Dam to Stormsvlei, including the Bergfontein and Spitskop hills north of Caledon. Altitude 200–550 m.

Vegetation & Landscape Features Moderately undulating plains and steep slopes of adjacent mountains. The vegetation is a moderately tall and dense shrubland, predominantly proteoid and asteraceous fynbos, with some graminoid fynbos.

Geology & Soils Acidic, moist clay-loam and colluvium with various, often Glenrosa and Mispah forms, derived from Bokkeveld Group shales, often with Ordovician sandstones of the Table Mountain Group (Cape Supergroup). Land types mainly Fa, Fb and Db.

Climate Rainfall peaks slightly in winter (August high). MAP 320–710 mm (mean: 485 mm). Mean daily maximum and minimum temperatures 27.6°C and 5.4°C for February and July, respectively. Frost incidence 2 or 3 days per year. See also climate diagram for FFh 7 Greyton Shale Fynbos (Figure 4.68).

Important Taxa Small Tree: *Protea nitida*. Tall Shrubs: *Leucadendron salicifolium* (d), *Protea neriifolia* (d), *P. repens* (d), *P. aurea* subsp. *aurea*, *P. coronata*. Low Shrubs: *Clutia tomentosa*, *Elytropappus rhinocerotis*, *Erica cruenta*, *E. paniculata*, *E. peltata*, *E. vestita* (pink form), *Helichrysum petiolare*, *Leucadendron salignum*, *L. spissifolium* subsp. *spissifolium*, *L. teretifolium*, *Muraltia caledonensis*, *Paranomus dispersus*, *Printzia polifolia*, *Protea acaulos*, *P. lorea*, *P. restionifolia*, *P. scabra*, *Serruria acrocarpa*, *S. gremialis*, *S. zeyheri*. Herb: *Corymbium cymosum*. Geophytic Herbs: *Aristea cantharophila*, *Bobartia longicyma* subsp. *longicyma*, *Geissorhiza inflexa*, *Ixia longituba* var. *bellendenii*, *Tritoniopsis elongata*. Graminoids: *Merxmuellera stricta*, *Themeda triandra*.

Endemic Taxa Low Shrubs: *Podalyria orbicularis*, *P. reticulata*. Semiparasitic Shrub: *Thesium micropogon*. Geophytic Herbs: *Aristea biflora*, *Moraea atropunctata*, *M. insolens*.

Conservation Vulnerable. Target 30%. Only 1% statutorily conserved in the Riviersonderend Nature Reserve with an additional 6% enjoying protection in a private conservation area of the same name. Some 30% of the area already transformed, mostly for cultivation. Lower-lying areas are the most heavily converted. Woody aliens include *Hakea sericea*, various *Pinus* species and *Acacia cyclops*. Erosion very low and moderate.

Remarks This is a poorly researched vegetation unit. Amongst the shale fynbos types, it has few succulents.

Reference N. Helme (unpublished data).

FFh 8 Montagu Shale Fynbos

VT 70 False Macchia (45%), VT 43 Mountain Renosterbosveld (23%) (Acocks 1953). Central Mountain Renosterveld (60%), Karroid Shrublands (23%) (Moll & Bossi 1983). LR 61 Central Mountain Renosterveld (63%), LR 58 Little Succulent Karoo (22%) (Low & Rebelo 1996). BHU 41 Montagu Inland Renosterveld (63%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: A fragmented unit from the western Little Karoo at relatively high altitudes north of the Langeberg Mountains from Keerom to Langkloof east of Garcia's Pass (north of Riversdale). Includes parts of The Koo, Ouberg Pass area (between Montagu and Ladismith), Kleinberg (MontEco) and Wildehondskloofhoogte (between Montagu and Barrydale). Altitude 680–1 150 m.

Vegetation & Landscape Features Moderately undulating uplands and undulating foothills to steep mountains, supporting moderately tall and dense shrublands, with proteoid fynbos and asteraceous fynbos with scattered proteoid emergents. Localised waboomveld also occurs.

Figure 4.75 FFh 8 Montagu Shale Fynbos: Asteracecous fynbos on shale in the Koo Valley east of Montagu (Western Cape) in the rainshadow of the Langeberg. A group of planted *Eucalyptus* is in the background.

Geology & Soils Acidic, moist clay-loamy Glenrosa and Mispah forms derived from Bokkeveld Group shales. Land types mainly Fc and Fb.

Climate Rainfall at the edge of semi-aridity, with MAP 240–800 mm (mean: 375 mm), peaking slightly in winter. Mean daily maximum and minimum temperatures 25.9°C and 3.4°C for January–February and July, respectively. Frost incidence 10–30 days per year. See also climate diagram for FFh 8 Montagu Shale Fynbos (Figure 4.68).

Important Taxa Small Tree: *Protea nitida*. Tall Shrubs: *Protea laurifolia* (d), *P. neriifolia* (d), *P. repens* (d), *Dodonaea viscosa* var. *angustifolia*, *Lebeckia cytisoides*, *Leucadendron rubrum*. Low Shrubs: *Athrixia heterophylla* subsp. *heterophylla*, *Cliffortia ramosissima*, *Elytropappus rhinocerotis*, *Leucadendron salignum*, *L. teretifolium*, *Leucospermum calligerum*, *Protea humiflora*, *P. lorifolia*, *P. scolopendriifolia*, *P. sulphurea*, *Senecio pinifolius*, *Ursinia heterodonta*, *Vexatorella obtusata* subsp. *obtusata*. Geophytic Herbs: *Geissorhiza ornithogaloides* subsp. *marlothii*, *Ixia leipoldtii*, *Romulea sphaerocarpa*, *Wurmbea compacta*. Graminoids: *Ehrharta calycina*, *E. capensis*, *Ischyrolepis capensis*, *Karroochloa purpurea*, *Tribolium hispidum*.

Biogeographically Important Taxon Geophytic Herb: *Ixia gloriosa* (Little Karoo endemic).

Endemic Taxa Low Shrubs: *Amphithalea pageae*, *Aspalathus rostrata*, *Lotononis argentea*, *Stirtonanthus insignis*.

Conservation Least threatened. Target 30%. Conserved in the Garcia Nature Reserve and Langeberg-wes mountain catchment area. Some 15% transformed for cultivation. Alien *Pinus pinaster* and *Acacia cyclops* scattered in some areas. Erosion high in most of the unit, but very low in some areas.

Remark This is an almost unknown vegetation unit, revealed only recently by the Protea Atlas Project activities—another type well below lower rainfall limits of about 600 mm for shale fynbos.

Reference Protea Atlas Project (unpublished data).

FFh 9 Garden Route Shale Fynbos

VT 4 Knysna Forest (58%) (Acocks 1953). Mesic Mountain Fynbos (17%), South Coast Renosterveld (17%), Afro-Montane Forest (16%) (Moll & Bossi 1983). LR 2 Afromontane Forest (46%), LR 64 Mountain Fynbos (27%) (Low & Rebelo 1996). BHU 100 Knysna Afromontane Forest (41%), BHU 28 Blanco Fynbos/Renosterveld Mosaic (21%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western and Eastern Cape Provinces: Patches along the coastal foothills of the Langeberg at Grootberg (northeast of Heidelberg), the Outeniqua Mountains from Cloete's Pass via the Groot Brak River Valley, Hoekwil, Karatara, Barrington and Knysna to Plettenberg Bay. Patches from the Bloukrans Pass along coastal platform shale bands south of the Tsitsikamma Mountains via Kleinbos and Fynboshoek to south of both Clarkson and the Kareedouw Mountains. Altitude 0–500 m.

Vegetation & Landscape Features Undulating hills and moderately undulating plains on the coastal forelands. Structurally this is tall, dense proteoid and ericaceous fynbos in wetter areas, and graminoid fynbos (or shrubby grassland) in drier areas. Fynbos appears confined to flatter more extensive landscapes that are exposed to frequent fires—most of the shales are covered with afrotemperate forest. Fairly wide belts of *Virgilia oroboides* occur on the interface between fynbos and forest. Fire-safe habitats nearer the coast have small clumps of thicket, and valley floors have scrub forest (Vlok & Euston-Brown 2002).

Geology & Soils Acidic, moist clay-loam, prismacutanic and pedocutanic soils derived from Caimans Group and Ecca (in the east) shales. Land types mainly Db and Fa.

Climate MAP 310–1 120 mm (mean: 700 mm), relatively even throughout the year, but with a slight low in winter. Mean daily maximum and minimum temperatures 27.6°C and 6.5°C for January and July, respectively. Frost incidence 2 or 3 days per year. See also climate diagram for FFh 9 Garden Route Shale Fynbos (Figure 4.68).

Important Taxa ([T]Cape thickets) Tall Shrubs: *Leucadendron eucalyptifolium* (d), *Protea aurea* subsp. *aurea* (d), *P. coronata* (d), *Leucospermum formosum*, *Metalasia densa*, *Passerina corymbosa*, *Protea neriifolia*, *Rhus lucida*[T]. Low Shrubs: *Acmadenia alternifolia*, *A. tetragona*, *Anthospermum aethiopicum*, *Cliffortia ruscifolia*, *Elytropappus rhinocerotis*, *Erica hispidula*, *Helichrysum cymosum*, *Leucadendron salignum*, *Pelargonium cordifolium*, *Phylica axillaris*, *P. pinea*, *Psoralea monophylla*, *Selago corymbosa*. Herb: *Helichrysum felinum*. Geophytic Herbs: *Pteridium aquilinum* (d), *Eriospermum vermiforme*. Succulent Herb: *Crassula orbicularis*. Herbaceous Succulent Climber: *Crassula roggeveldii*. Graminoids: *Ischyrolepis sieberi* (d), *Aristida junciformis* subsp. *galpinii*, *Brachiaria serrata*, *Cymbopogon marginatus*, *Elegia juncea*, *Eragrostis capensis*, *Ischyrolepis gaudichaudiana*, *Restio triticeus*, *Themeda triandra*, *Tristachya leucothrix*.

Endemic Taxa Geophytic Herbs: *Cyphia georgica*, *Disa newdigateae*, *Gladiolus roseovenosus*.

Conservation Endangered. Target 23%. Statutorily conserved in the proposed Garden Route National Park (4%) and Boosmansbos Wilderness Area (1%). A further 3% are protected in other (mainly private) conservation areas such as the Robbe Hoek Forest Reserve. More than half of the area has already been transformed for cultivation and pine plantations. Much of the remaining veld has been converted to pasture. Remnants are found largely on steep inclines and in areas unsuitable for agriculture. Alien plants such as *Hakea sericea* and various species of *Acacia* locally infest natural remnants. Erosion very low and moderate.

Remarks This is a poorly studied vegetation type. Rebelo et al. (1991) have incorrectly placed this unit on sandstone in the Riversdale area.

References Taylor (1970b), Drews (1980a, b), Rebelo et al. (1991), Vlok & Euston-Brown (2002).

FFh 10 Suurberg Shale Fynbos

VT 70 False Macchia (64%) (Acocks 1953). Valley Bushveld (61%) (Moll & Bossi 1983). LR 65 Grassy Fynbos (42%), LR 6 Xeric Succulent Thicket (37%) (Low & Rebelo 1996). BHU 23 Zuurberg Grassy Fynbos (19%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Eastern Cape Province: East-west-trending, complex and multiple bands from the Klein Winterberg at Baroe in the west, Suurberg, and highly fragmented distributions around Riebeek East and Grahamstown. Altitude 400–900 m.

Vegetation & Landscape Features Low mountains or hills, supporting low to medium high, closed, ericoid shrubland or grassland, with closed restioid and/or grass understorey. Graminoid fynbos, with localised patches of dense proteoid fynbos, also occurs.

Figure 4.76 FFh10 Suurberg Shale Fynbos: Ericaceous fynbos on ridges of the Suurberg Mountains north of Addo (Eastern Cape). Patches of afrotemperate forest are found in the gullies.

Geology & Soils Acidic, moist clay-loam Mispah and Glenrosa forms derived from Witteberg Group shales, associated with quartzite. Land types mainly Fa, Ib and Fb.

Climate MAP 210–770 mm (mean: 510 mm), with a bimodal peak in October–November and January–February and a low in winter. Mean daily maximum and minimum temperatures 28.4°C and 4.6°C for February and July, respectively. Frost incidence 2–10 days per year. See also climate diagram for FFh 10 Suurberg Shale Fynbos (Figure 4.68).

Important Taxa ([T]Cape thickets) Tall Shrubs: *Aspalathus setacea* (d), *Metalasia densa* (d), *Montinia caryophyllacea*, *Phylica paniculata*, *Protea lorifolia*, *Rhus lucida*. Low Shrubs: *Selago corymbosa* (d), *Agathosma ovata, Diospyros dichrophylla*[T], *Elytropappus rhinocerotis*, *Erica thamnoides*, *Felicia filifolia* subsp. *filifolia*, *Leucadendron salignum*, *Leucospermum cuneiforme*, *Metalasia pungens*, *Protea cynaroides*, *P. foliosa*. Succulent Shrub: *Cotyledon orbiculata* var. *oblonga*. Geophytic Herbs: *Bobartia orientalis* subsp. *orientalis*, *Oxalis punctata*. Graminoids: *Themeda triandra* (d), *Diheteropogon filifolius*, *Ehrharta ramosa* subsp. *ramosa*, *Harpochloa falx*, *Hypodiscus striatus*, *Restio triticeus*, *Tetraria cuspidata*, *T. exilis*, *Tristachya leucothrix*.

Conservation Least threatened. Target 23%. About 40% statutorily conserved in the Greater Addo Elephant National Park, and 6% in addition in the private Rockdale Game Ranch and Kuzuko Game Reserve. Only about 1% has been transformed and levels of alien infestation (*Acacia mearnsii*, species of *Eucalyptus* and *Pinus pinaster*) are low. Erosion very low and low.

Remark Few studies have separated the quartzite from the shale fynbos types in the Eastern Cape and therefore the distinction we suggest is tentative, pending detailed studies.

References Martin & Noel (1960), Jessop & Jacot Guillarmod (1969), Campbell (1985).

9.1.5 Fynbos Shale Band Vegetation

Between the two massive sandstone blocks (Peninsula and Nardouw Formations) in the Table Mountain Group (Cape Supergroup) lies a series of only 40–140 m wide shale bands (vertical) of the Cedarberg Formation. Despite their limited spatial extent, they are a major topographical feature in the mountains due to special geomorphological features (smoother landscape) and vegetation quite distinct from that of the surrounding sandstones, although sandstone overburden on the shales can blur distinctions in places. Because the bands weather preferentially, they form 20–500 m steps or shelves in horizontal beds or smooth U-valleys in more vertical beds, extending for hundreds of kilometres (Figure 4.78). The exposed shale width varies depending on its erosion at the lower edge and on sandstone-derived screes and deposits (colluvial sediments) on the upper edge. However, because the rainfall limits for the succulent karoo, renosterveld, fynbos and forest are higher for shale than sandstone, different vegetation types often occur juxtaposed on the two substrates. Where fynbos occurs on both geologies almost invariably different structural fynbos units juxtapose. Due to a lack of studies, we have been unable to separate these different communities within the shale bands other than to note that they are distinct from the surrounding sandstone fynbos communities and—based on the studies to date—from more extensive shale communities as well. We therefore predict that at lower altitudes these communities will resemble nearby shale communities (renosterveld, succulent karoo), but with increasing altitude these communities will become more unique and less associated with neighbouring vegetation types irrespective of substrate. The uppermost shale band will have altimontane fynbos.

Important microclimatic differences were found between soils derived from sandstone and shale at high altitude by Boelhouwers (1998). His measurements made in the Hex River Mountains (at an altitude of about 1 900 m) suggested that while the porous and light-coloured sandstone-derived soils failed to provide evidence for needle-ice formation, the high water content in the loamy soil derived from shale was favourable for needle-ice formation during the freeze/thaw cycles from April to November.

Patterns of vegetation on the shale bands are complicated by the sandstone colluvium and mixing of this with clays from the shale bands. Shale bands often show signs of silcrete and ferricrete formation. More important, though, is that the shale bands are relatively impervious to water and so often become associated with seep communities, often much wetter and waterlogged than those on the associated sandstones. It is possible then that the shale bands of the Cedarberg Formation are refugia for renosterveld elements and those shale fynbos communities that tolerate a much wetter climate than at present.

Based on patterns within fynbos, we have divided them tentatively into six major geographical units, based primarily on the known phytogeographic centres of endemism (Goldblatt & Manning 2000a). This is entirely an interim classification and we expect that when sufficient data become available, the larger area of these units to be subsumed into the current vegetation types within Succulent Karoo, shale renosterveld and shale fynbos. A few new high-altitude shale fynbos types might be warranted.

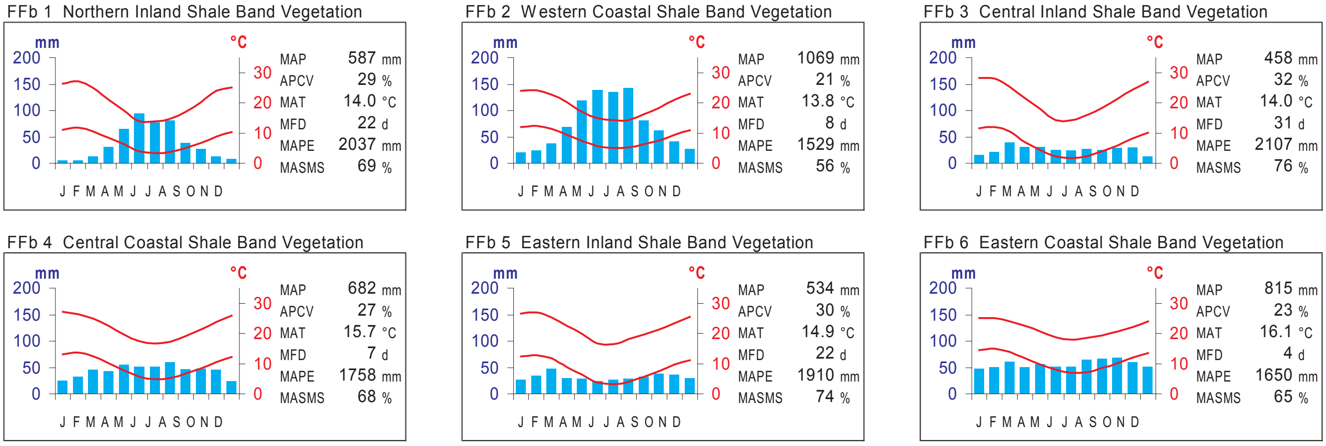


Figure 4.77 Climate diagrams of shale band vegetation units. Blue bars show the median monthly precipitation. The upper and lower red lines show the mean daily maximum and minimum temperature respectively. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days (days when screen temperature was below 0°C); MAPE: Mean Annual Potential Evaporation; MASMS: Mean Annual Soil Moisture Stress (% of days when evaporative demand was more than double the soil moisture supply).

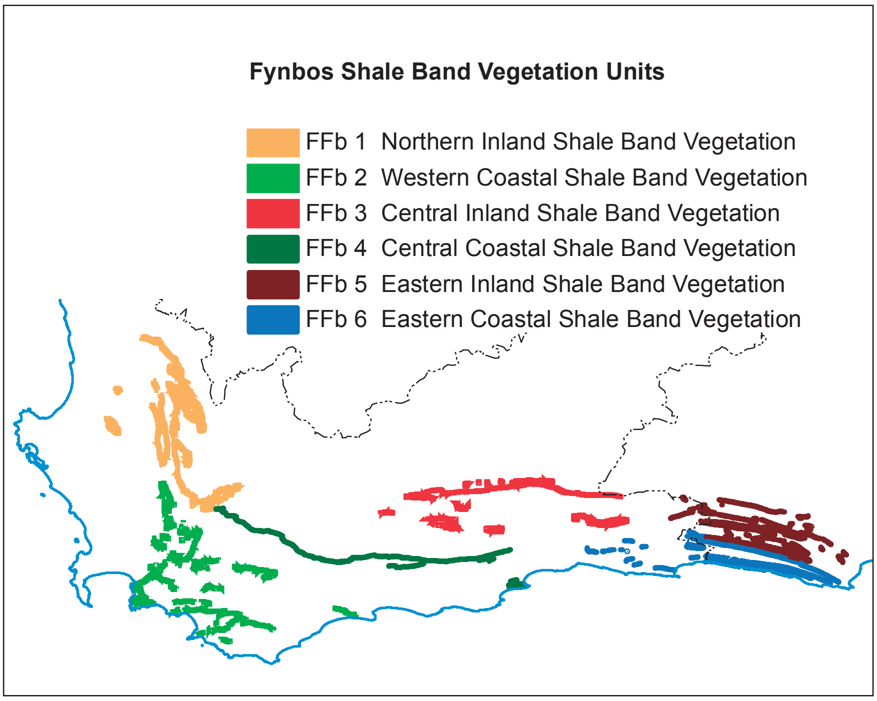


Figure 4.78 Schematic map of the shale-band vegetation units (FFb) in the Fynbos Biome.

Vegetation & Landscape Features A narrow 80–200 m linear feature, smooth and flat in profile compared to surrounding areas and thus favoured for paths and roads. The dominant landscape of the Cederberg (the long, linear plateaus) is often associated with the shale bands. At present the vegetation of this unit encompasses diverse shrublands ranging from karoo at lower altitudes and northerly aspects, renosterveld at low and medium altitudes on various aspects, to fynbos at higher altitudes and also much lower on southern aspects. Fynbos includes all structural types; it is often quite grassy in character, and usually waboomveld occurs at the lowest altitudes. Heuweltjies prominent in northern portion of the band.

Geology & Soils Clays derived from shales of the Cedarberg Formation. Land types mainly Ic and Ib.

Climate MAP 250–1 360 mm (mean: 590 mm), peaking from May to August. Mean daily maximum and minimum temperatures 27.2°C and 3.4°C for February and July, respectively. Frost incidence 10–30 days per year. See also climate diagram for FFb 1 Northern Inland Shale Band Vegetation (Figure 4.77).

FFb 1 Northern Inland Shale Band Vegetation

VT 69 Macchia (Fynbos) (97%) (Acocks 1953). Mesic Mountain Fynbos (94%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (100%) (Low & Rebelo 1996). BHU 47 Cederberg Mountain Fynbos Complex (53%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Narrow shale band from Mount Synnott near the Pakhuis Pass in the Cederberg, to the Skurweberg, Koue Bokkeveld, Groot Winterhoek, Hex River and Keeroms Mountains. Small portions of this shale band unit are found at Piketberg and Breëvlei north of Het Kruis. Altitude 400–1 650 m, with extremes from 100 m to lower altitude limits of FFs 30 Western Altimontane Sandstone Fynbos. See also Figure 4.78 featuring the simplified distribution of this unit.

Important Taxa ([A]Altimontane shale bands) Small Tree: *Protea nitida*. Tall Shrubs: *Metalasia densa* (d), *Dodonaea viscosa* var. *angustifolia*, *Leucadendron pubescens*, *L. rubrum*, *Liparia umbellifera*[A], *Protea laurifolia*, *P. punctata*. Low Shrubs: *Aspalathus triquetra* (d), *Elytropappus adpressus* (d), *E. rhinocerotis* (d), *Helichrysum dasyanthum* (d), *Leucadendron glaberrimum* subsp. *glaberrimum* (d), *Protea acuminata* (d), *Agathosma capensis*, *Anthospermum aethiopicum*, *Aspalathus grandiflora*, *A. juniperina* subsp. *monticola*[A], *A. lanifera*, *Athanasia cuneifolia*, *A. microphylla*, *Cliffortia baccans*, *C. ruscifolia*, *Cyclopia montana* var. *glabra*[A], *Gnidia geminiflora*, *Helichrysum cylindriflorum*, *Lachnaea elsieae*, *L. pedicellata*, *Leucadendron salignum*, *Lobostemon trichotomus*, *Microdon dubius*, *M.*

parviflorus, *Muraltia rhamnoides*, *Phylica leipoldtii*, *Polyarrhena imbricata*, *Protea scolopendriifolia*, *P. witzenbergiana*, *Serruria confragosa*. Succulent Shrub: *Ruschia lineolata*. Herbs: *Cotula andreae*[A], *Gazania serrata*. Geophytic Herbs: *Geissorhiza longifolia*, *Oxalis obtusa*, *O. stokoei*[A]. Graminoids: *Calopsis viminea* (d), *Cannomois parviflora* (d), *Ischyrolepis pygmaea*[A] (d), *I. unispicata* (d), *I. virgea* (d), *Pentaschistis eriostoma*[A] (d), *Willdenowia arescens* (d), *W. incurvata* (d), *Cannomois virgata*, *Ehrharta calycina*, *Elegia ebracteata*, *Ficinia deusta*, *Hypodiscus alboaristatus*, *H. neesii*, *Ischyrolepis capensis*, *I. laniger*, *I. sieberi*, *Merxmuellera rufa*, *M. stricta*, *Pentameris macrocalycina*, *Pentaschistis alticola*[A], *P. pallida*[A], *P. rosea* subsp. *purpurascens*[A], *Restio filiformis*, *Staberoha vaginata*[A], *Tetraria cuspidata*, *Tribolium hispidum*, *Willdenowia stokoei*.

L. Mucina

Figure 4.80 FFb 1 Northern Inland Shale Band Vegetation: Smooth shale slopes of the Cederberg Formation on the southern slopes of Conical Peak opposite the Matroosberg Peak of the Hex River Mountains (Western Cape). The vegetation is a high-altitude (1 900 m) restioid fynbos dominated by *Ischyrolepis pygmaeus* and with prominent asteraceous (*Helichrysum, Metalasia*) and spine-leaved (*Cliffortia*) shrubby components.

Endemic Taxa ([A]Altimontane shale bands) Low Shrubs: *Agathosma bodkinii*, *Aspalathus keeromsbergensis*, *A. orbiculata*, *A. shawii* subsp. *longispica*, *Athanasia bremeri*, *Metalasia phillipsii* subsp. *phillipsii*[A]. Herbs: *Bolandia argillacea*[A], *Lamprocephalus montanus*[A], *Roodebergia kitamurana*[A], *Wimmerella mariae*[A]. Geophytic Herb: *Geissorhiza erubescens*. Graminoids: *Cannomois aristata*, *Pentaschistis caulescens*.

Conservation Least threatened. Target 29%. More than 80% statutorily conserved in the Cederberg and Grootwinterhoek Wilderness Areas, Ceres Mountain Fynbos, Bokkeriviere and Ben Etive Nature Reserves as well as in mountain catchment areas such as Sederberg, Koue Bokkeveld, Matroosberg and Winterhoek. Only 4% transformed (cultivation). The only alien woody species of concern is *Pinus radiata*. Erosion very low.

Remarks The classification of the low-altitude (below altitude of 1 000 m) patches of this shale band unit, especially those in the central and southern Cederberg (so-called Pakhuis shale band of Taylor 1996), those of the Olifants River Valley south of Citrusdal as well as those embedded within FFs 6 Piketberg Sandstone Fynbos and FFs 2 Graafwater Sandstone Fynbos, is only tentative. According to available data, a small portion of these low-altitude shale bands at Pakhuis (see Community 8 in Taylor 1996) has a dry form of renosterveld (FRs 4 Ceres Shale Renosterveld), but the geographical limits of this type have not been mapped. At lower altitudes in the Olifants River Valley those portions of the shale band with SKk 7 Citrusdal Vygieveld have been mapped as such.

References Linder (1976), Nordenstam (1976), Taylor (1996).

D. Gwynne-Evans

Figure 4.79 FFb 1 Northern Inland Shale Band Vegetation: Proteoid fynbos with *Leucadendron nitidum* on the Cedarberg Formation shale band with sandstone boulders on the Skurweberg northeast of Ceres (Western Cape).

FFb 2 Western Coastal Shale Band Vegetation

VT 69 Macchia (Fynbos) (90%) (Acocks 1953). Mesic Mountain Fynbos (94%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (96%) (Low & Rebelo 1996). BHU 53 Hawequas Mountain Fynbos Complex (34%), BHU 59 Riviersonderend Mountain Fynbos Complex (17%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Embedded within the mountain ranges of Elandskloof, Limietberge, Wellington Sneeukop, Slanghoek, Du Toitsberge, Klein Drakenstein, Wemmershoek, Stettyns, Franschhoek (including Victoria Peak and Emerald Dome), Groenland, Hottentots Holland (including Triplets and Somerset Sneeukop), and Kogelberg. These bands extend eastwards through the Kleinrivierberge, Caledon Swartberg and Bredasdorpberge. Also included are the shale bands of the Riviersonderend Mountains and of Potberg. Altitude 50–1 800 m. See also Figure 4.78 featuring the simplified distribution of this unit.

Vegetation & Landscape Features A narrow 80–200 m linear feature (up to 1 km wide in a few places and also forming rings on some 'Sneeukop' peaks),

Figure 4.81 FFb 2 Western Coastal Shale Band Vegetation: Proteoid fynbos dominated by *Leucadendron xanthoconus* with *Erica pillansii* with restioid fynbos dominated by *Elegia mucronata* on seeps on the Cedarberg Formation shale band above Kleinmond, Kogelberg (Western Cape).

smooth and flat in profile compared to surrounding areas. The band supports diverse renosterveld and fynbos shrublands of all structural types including waboomveld at lower altitudes.

Geology & Soils Clays derived from shale of the Cedarberg Formation. Land types mainly Ic and Ib.

Climate MAP 280–2 000 mm (mean: 1 070 mm), peaking from May to August. Southeasterly cloud brings heavy mist precipitation at higher altitudes in summer. Mean daily maximum and minimum temperatures 24.3°C and 5.0°C for February and July, respectively. Frost incidence 2–10 days per year. See also climate diagram for FFb 2 Western Coastal Shale Band Vegetation (Figure 4.77).

Important Taxa ([T]Cape thickets, [W]Wetlands) Small Trees: *Protea nitida* (d), *Widdringtonia nodiflora*. Tall Shrubs: *Leucadendron salicifolium* (d), *Montinia caryophyllacea* (d), *Protea neriifolia* (d), *Curtisia dentata*[T], *Diospyros glabra*[T], *Maytenus acuminata*[T], *Protea eximia*, *P. lepidocarpodendron*, *P. mundii*, *P. repens*, *Rapanea melanophloeos*[T]. Low Shrubs: *Anthospermum aethiopicum* (d), *Aulax umbellata* (d), *Berzelia lanuginosa*[W] (d), *Diastella divaricata* subsp. *montana* (d), *Elytropappus glandulosus* (d), *Erica equisetifolia* (d), *E. hispidula* (d), *E. quadrangularis* (d), *Leucadendron xanthoconus* (d), *Protea scabra* (d), *Agathosma capensis*, *Anthospermum galioides* subsp. *galioides*, *A. prostratum*, *Brunia neglecta*, *B. nodiflora*, *Cliffortia atrata*, *C. eriocephalina*, *C. polygonifolia*, *Clutia polygonoides*, *Diosma hirsuta*, *Erica filiformis*, *E. plukenetii* subsp. *plukenetii*, *E. viscaria* subsp. *longifolia*, *Euryops pinnatipartitus*, *Helichrysum tomentosulum*, *Leucadendron salignum*, *L. spissifolium* subsp. *spissifolium*, *Leucospermum cordifolium*, *Lonchostoma purpureum*, *Paranomus adiantifolius*, *Phylica spicata*, *Polyarrhena reflexa* subsp. *reflexa*, *Protea acaulos*, *P. cordata*, *P. longifolia*, *Rhus rosmarinifolia*[T], *Stoebe plumosa*. Herbs: *Peucedanum ferulaceum*, *P. strictum*. Geophytic Herbs: *Aristea racemosa* (d), *A. capitata*, *Blechnum capense*, *Elaphoglossum angustatum*, *Rumohra adiantiformis*. Graminoids: *Askidiosperma nitidum* (d), *Elegia filacea* (d), *E. hookeriana* (d), *E. mucronata* (d), *Ischyrolepis gaudichaudiana* (d), *I. monanthos* (d), *Pentaschistis colorata* (d), *Tetraria bromoides* (d), *T. cuspidata* (d), *Themeda triandra* (d), *Elegia juncea*, *E. stipularis*, *Epischoenus quadrangularis*, *Hypodiscus albo-aristatus*, *Ischyrolepis sieberi*, *Platycaulos cascadensis*[W], *Restio stokoei*, *Tetraria fimbriolata*.

Endemic Taxa Tall Shrub: *Protea lacticolor* (d). Low Shrubs: *Prismatocarpus cliffortioides*, *Protea caespitosa*. Succulent Shrub: *Lampranthus walgateae*. Geophytic Herbs: *Bobartia lilacina*, *Moraea lilacina*. Graminoid: *Pentameris hirtiglumis*.

Conservation Least threatened. The target of 30% has been achieved since almost 45% of the unit is protected in statutory and local authority reserves such as Limietberg, Kogelberg, Riviersonderend, Hottentots Holland, Theewaters, De Hoop and Waterval, while an additional almost 30% is protected in mountain catchment areas such as Hawequas, Riviersonderend and Hottentots Holland. Small patches are protected in a number of private reserves. Some 6% transformed by pine plantations. Aliens *Pinus pinaster* and *Hakea sericea* scattered on about half of the area of the unit. Erosion generally very low.

Remark 1 Although classified within this shale band unit, the shale band of Potberg has several prominent species (e.g. *Protea aurea*, *P. coronata*) shared with the FFb 3 Central Inland Shale Band Vegetation. Further vegetation studies are needed to clarify these links.

Remark 2 These shale bands often support small patches of afrotemperate forest in gullies and on saddles.

References Boucher (1972, 1977, 1978), Kruger (1974, 1979), Anonymous (1979), Van Wilgen & Kruger (1985), Sieben (2003).

FFb 3 Central Inland Shale Band Vegetation

VT 70 False Macchia (93%) (Acocks 1953). Mesic Mountain Fynbos (58%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (94%) (Low & Rebelo 1996). BHU 68 Groot Swartberg Mountain Fynbos Complex (35%), BHU 67 Rooiberg Mountain Fynbos Complex (23%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Shale bands of the Klein and Groot Swartberge, Touwsberg, Sandberg, Rooiberg, Gamkaberg and Kammanassie. Altitude 500–1 800 m. See also Figure 4.78 featuring the simplified distribution of this unit.

Vegetation & Landscape Features A narrow 80–200 m (wider in places), linear, smooth and flat feature of high-altitude slopes or mountain ridges. Vegetation diverse, from karoo shrublands at lower altitudes, to renosterveld and fynbos shrublands. Fynbos includes all structural types including graminoid fynbos, and usually waboomveld and asteraceous fynbos at lowest altitudes.

Geology & Soils Clays derived from shale of the Cedarberg Formation. Land types mainly Ic and Ib.

Climate MAP 140–980 mm (mean: 460 mm), relatively even with a bimodal peak in March and November and a low in

December–January. Mean daily maximum and minimum temperatures 28.2°C and 1.7°C for January and July, respectively. Frost incidence 10–40 days per year. See also climate diagram for FFb 3 Central Inland Shale Band Vegetation (Figure 4.77).

Important Taxa ([A]Altimontane shale bands) Small Tree: *Protea nitida*. Tall Shrubs: *Cliffortia burchellii*, *Leucadendron rubrum*, *Protea eximia*, *P. punctata*, *P. repens*. Low Shrubs: *Anthospermum galioides* subsp. *galioides*, *Aspalathus juniperina* subsp. *monticola*, *Cliffortia tuberculata*, *Leucadendron album*, *L. salignum*, *L. spissifolium* subsp. *fragrans*, *Leucospermum wittebergense*, *Metalasia pallida*, *M. rhoderoides*, *Protea lorifolia*, *Stoebe plumosa*. Herbs: *Corymbium glabrum*, *Cotula andreae*[A]. Geophytic Herb: *Aristea pusilla* subsp. *pusilla*. Graminoids: *Willdenowia teres* (d), *Hypodiscus aristatus*, *H. synchroolepis*, *Ischyrolepis nana*, *Merxmuellera stricta*, *Tetraria ustulata*.

Figure 4.82 FFb 4 Central Coastal Shale Band Vegetation: Wet proteoid fynbos on the Cedarberg Formation shale band (continuing up the valley in the background) on Garcia Pass, Langeberg (Western Cape).

Endemic Taxa ([A]Altimontane shale bands) Low Shrub: *Acmadenia baileyensis*. Succulent Shrub: *Lampranthus swartbergensis*[A].

Conservation Least threatened. The target of 27% has been achieved since 68% of the unit already protected in statutory reserves such as Groot Swartberg, Kammanassie, Towerkop, Swartberg East, Gamkaberg and Rooiberg. Additionally almost 25% is protected in mountain catchment areas such as Kammanassie, Klein Swartberg, Rooiberg, Swartberg-oos and Groot Swartberg. Only about 1% transformed so far. Woody aliens include *Pinus pinaster*, *P. radiata*, *P. halepensis* and *Hakea sericea*. Erosion very low and low.

Reference Bond (1981).

FFb 4 Central Coastal Shale Band Vegetation

VT 70 False Macchia (57%) (Acocks 1953). Mesic Mountain Fynbos (76%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (82%) (Low & Rebelo 1996). BHU 64 Southern Langeberg Mountain Fynbos Complex (52%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: A virtually continuous band traversing the entire length of the Langeberg, with bands in the eastern regions of the Outeniqua Mountains and of the Grootberg-Amandelbosberg as well as some areas, for example Die Bergies, west of Mossel Bay. The extent of the shale band in the Outeniqua Mountains has not been adequately mapped and its eastern boundary remains unknown. Altitude 50–1 700 m. See also Figure 4.78 featuring the simplified distribution of this unit.

Vegetation & Landscape Features A narrow 80–200 m linear feature (wider in places), smooth and flat in profile compared to surrounding areas. Vegetation comprises various fynbos shrublands.

Geology & Soils Clays derived from shale band of the Cedarberg Formation. Land types mainly Ib, Ic and Db.

Climate MAP 280–1 560 mm (mean: 680 mm), relatively even with a low in December–January. Southeasterly cloud brings heavy mist precipitation at higher altitudes in summer. Mean daily maximum and minimum temperatures 27.2°C and 4.8°C for January and July, respectively. Frost incidence 3–10 days per year. See also climate diagram for FFb 4 Central Coastal Shale Band Vegetation (Figure 4.77).

Important Taxa Tall Shrubs: *Leucadendron eucalyptifolium* (d), *Protea aurea* subsp. *aurea* (d), *P. neriifolia* (d), *P. coronata*, *P. eximia*. Low Shrubs: *Erica hispidula* (d), *Phylica pinea* (d), *P. rubra* (d), *Aspalathus juniperina* subsp. *monticola*, *Aulax cancellata*, *Cliffortia atrata*, *Cyclopia sessiliflora*, *Erica pubigera*, *Helichrysum pandurifolium*, *Hermannia stricta*, *Indigofera sarmentosa*, *Leucadendron salignum*, *Mimetes cucullatus*, *Pelargonium cordifolium*, *Protea cynaroides*, *P. grandiceps*, *Senecio lineatus, Serruria fasciflora*, *Stoebe plumosa*. Herbs: *Alepidea capensis*, *Carpacoce spermacocea*, *Knowltonia capensis*. Geophytic Herbs: *Lanaria lanata* (d), *Geissorhiza hesperanthoides*, *G. nubigena*. Graminoids: *Cannomois virgata* (d), *Ischyrolepis hystrix* (d), *Tetraria bromoides* (d), *T. flexuosa* (d), *Ehrharta dura*, *Pentaschistis malouinensis*.

Conservation Least threatened. Target 27%. About 25% conserved in statutory and local-authority reserves such as Boosmansbos Wilderness Area, Marloth, Garcia, Tygerberg, Montagu Mountain, Ruitersbos, Twistniet and Spioenkop. In addition 43% enjoys protection in mountain catchment areas such as Langeberg-wes, Langeberg-oos and Matroosberg. Some 15% transformed (mainly cultivation, but also pine plantations). Aliens such as *Pinus pinaster*, *Hakea sericea* and *Acacia mearnsii* are locally of concern. Erosion very low and low.

References Boucher (1972, 1977, 1978, 1988a), McDonald (1993a, b, c, 1995).

FFb 5 Eastern Inland Shale Band Vegetation

VT 70 False Macchia (94%) (Acocks 1953). Mesic Grassy Fynbos (55%) (Moll & Bossi 1983). LR 65 Grassy Fynbos (55%) (Low & Rebelo 1996). BHU 73 Baviaanskloof Mountain Fynbos Complex (40%), BHU 72 Kouga Mountain Fynbos Complex (31%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Eastern and Western Cape Provinces: Shale bands of the Kougaberge and Baviaanskloofberge with parallel occurrences to the south but remaining north of the Langkloof. Also on Antoniesberg, south of Willowmore. Altitude 250–1 650 m. See also Figure 4.78 featuring the simplified distribution of this unit.

Vegetation & Landscape Features A narrow 80–200 m (greater widths in the uppermost Baviaanskloof area), linear, smooth and flat landscape feature supporting various shrublands, from thicket, renosterveld and fynbos at higher altitudes. Fynbos includes all structural types, but predominantly graminoid fynbos.

Geology & Soils Clays derived from shale of the Cedarberg Formation. Land types mainly Ib, Fa, Fb and Ic.

Climate MAP 290–910 mm (mean: 535 mm), relatively even with a slight peak in March. Mean daily maximum and minimum temperatures 26.9°C and 3.3°C for February and July, respectively. Frost incidence 2–40 days per year. See also climate diagram for FFb 5 Eastern Inland Shale Band Vegetation (Figure 4.77).

Important Taxa Small Tree: *Protea nitida*. Tall Shrubs: *Protea neriifolia* (d), *P. repens* (d), *Leucadendron eucalyptifolium*, *Protea punctata*. Low Shrubs: *Elytropappus rhinocerotis*, *Lachnaea glomerata*, *Leucadendron salignum*, *Leucospermum cuneiforme*, *Protea intonsa*, *P. tenax*. Herb: *Hebenstretia integrifolia*. Graminoid: *Themeda triandra*.

Endemic Taxon Low Shrub: *Aspalathus incana*.

Conservation Least threatened. Target 27%. Statutorily conserved (38%) in the Kouga, Guerna and Berg Plaatz Wilderness Areas. Small patches also protected in private nature reserves (Sustersdal). Some 7% transformed (cultivation). Alien *Pinus pinaster* occurs in places. Erosion is low and very low.

FFb 6 Eastern Coastal Shale Band Vegetation

VT 70 False Macchia (54%) (Acocks 1953). Mesic Grassy Fynbos (30%), Wet Mountain Fynbos (12%), Mesic Mountain Fynbos (7%), Afro-Montane Forest (4%) (Moll & Bossi 1983). LR 65 Grassy Fynbos (46%), LR 2 Afromontane Forest (34%) (Low & Rebelo 1996). BHU 100 Knysna Afromontane Forest (34%), BHU 29 Langkloof Fynbos/Renosterveld Mosaic (22%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western and Eastern Cape Provinces: Shale bands in the eastern Outeniqua (often also bearing forest patches), Langkloof, Tsitsikamma and Kareedouw Mountains and along the southern Cape coastal plains to around Oyster Bay with the most seaward belt reaching the coast at, for example, Clinton's Bank south of Bloukrans Pass. Altitude 0–1 100 m. See also Figure 4.78 featuring the simplified distribution of this unit.

Vegetation & Landscape Features Shale bands form narrow 80–200 m, linear, smooth and flat landscape features and support various shrublands, ranging from thicket to renosterveld and fynbos at higher altitudes. Fynbos includes all structural types, quite often grassy in character.

Geology & Soils Clays derived from shale of the Cedarberg Formation. Land types mainly Db, Ca, Bb, and Ib.

Climate MAP 500–1 140 mm (mean: 815 mm), relatively even with a bimodal peak in March and August–November. Mean daily maximum and minimum temperatures 25.1°C and 7.0°C for January–February and July, respectively. Frost incidence 0–20 days per year. See also climate diagram for FFb 6 Eastern Coastal Shale Band Vegetation (Figure 4.77).

Important Taxa Tall Shrubs: *Leucadendron eucalyptifolium*, *Protea neriifolia*. Low Shrubs: *Leucadendron salignum*, *Leucospermum cuneiforme*.

Conservation Endangered. Target 27%. Statutorily conserved (16%) in the proposed Garden Route National Park (including Tsitsikamma National Park), Koomans Bush State Reserve as well as in Lottering Forest Reserve, Plaatbos Nature Reserve, Kwaaibrand and Langebosch Forest Reserves and several other private conservation areas. Some 65% transformed, with cultivation accounting for most of the transformation, followed by pine plantations. Alien *Pinus pinaster* and *Hakea sericea* occur as scattered. Erosion is very low.

Remark Large portions of the shale band in this area support FOz 6 Southern Coastal Forest and these areas are mapped as such.

Reference Bond (1981).

9.1.6 Silcrete, Ferricrete and Conglomerate Fynbos

Silcrete, ferricrete and conglomerate fynbos types are intermediate between shale and sandstone fynbos in character. Like shale fynbos, their ecology is poorly known, but probably approximates shale fynbos rather than sandstone fynbos in most features. They thus fit in the zone between renosterveld and fynbos and are dominated by mesotrophic asteraceous and proteoid fynbos types.

The designation of units within this category is largely arbitrary, and does not necessarily apply to the most abundant or characteristic unit. Few are in fact a single geology—most include silcrete, laterite, conglomerate and some igneous rocks. Together these units comprise less than 5% the area of fynbos.

FFc 1 Swellendam Silcrete Fynbos

VT 46 Coastal Renosterbosveld (59%) (Acocks 1953). South Coast Renosterveld (62%) (Moll & Bossi 1983). LR 63 South and South-west Coast Renosterveld (85%) (Low & Rebelo 1996). BHU 19 Suurbraak Grassy Fynbos (41%), BHU 34 Riversdale Coast Renosterveld (29%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Relatively large patches on southern foothills of the Langeberg from around Swellendam to north of Dekriet/Soutpan (between Riversdale and Albertinia), becoming highly fragmented between Albertinia and the southern side of Robinson Pass to around Molenrivier (north of Klein-Brak River). Altitude 100–400 m.

Vegetation & Landscape Features Mainly undulating hills on the coastal forelands, the remains of the old African surface. Structurally it is a medium tall evergreen shrubland or grassland. Predominantly asteraceous fynbos, but graminoid fynbos on summits and northern slopes where disturbed. Proteoid fynbos occurs on southern slopes and ericaceous fynbos is found in wetter habitats. Afrotemperate forest occurs in fire-safe alluvial areas, such as along perennial rivers. It is uncertain whether proteoid fynbos, renosterveld or thicket was the dominant type in some of the eastern plateaus—it has all been converted to pasture.

Geology & Soils Silcrete and conglomerate with dry, shallow, loamy sand of Houwhoek form. Land types mainly Db and Gb.

Climate MAP 320–860 mm (mean: 520 mm), with no clear peak, but a low in December–January. Mean daily maximum and minimum temperatures 28°C and 5.5°C for January and July, respectively. Frost incidence about 3 days per year. See also climate diagram for FFc 1 Swellendam Silcrete Fynbos (Figure 4.83).

Important Taxa Tall Shrubs: *Erica prolata* (d), *Leucadendron eucalyptifolium*, *Metalasia densa*, *Passerina corymbosa*, *Protea*

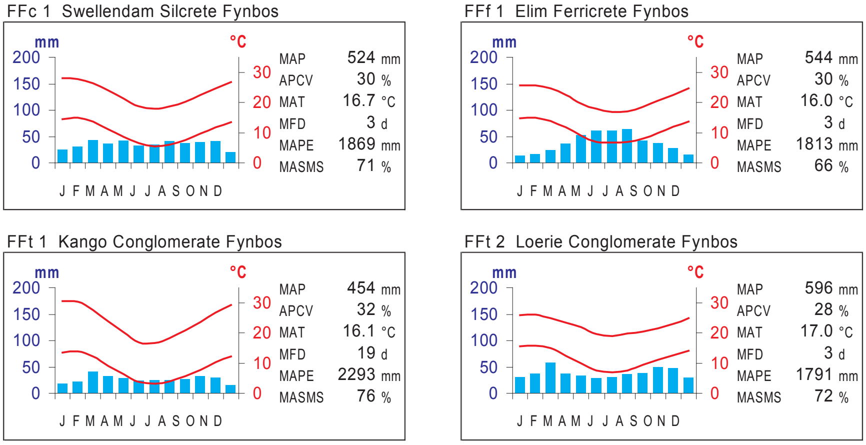


Figure 4.83 Climate diagrams of silcrete, ferricrete and conglomerate fynbos units. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days; MAPE: Mean Annual Potential Evaporation; MASMS: Mean Annual Soil Moisture Stress.

coronata, *P. neriifolia*, *P. repens*. Low Shrubs: *Cliffortia ruscifolia* (d), *Leucadendron salignum* (d), *Agathosma foetidissima*, *Elytropappus rhinocerotis*, *Erica klotzschii*, *E. peltata*, *Euchaetis longicornis*, *Leucadendron brunioides* var. *brunioides*, *L. teretifolium*, *Leucospermum calligerum*, *L. cuneiforme*, *Morella quercifolia*, *Oedera imbricata*, *Pelargonium ovale*, *Protea decurrens*, *Salvia chamelaeagnea*, *Serruria acrocarpa*, *Stoebe plumosa*. Herbs: *Berkheya armata*, *Helichrysum crispum*. Geophytic Herbs: *Bobartia macrospatha* subsp. *macrospatha*, *Lanaria lanata*. Herbaceous Climber: *Cyphia volubilis*. Graminoids: *Cymbopogon marginatus*, *Cynodon dactylon*, *C. incompletus*, *Ehrharta ramosa* subsp. *aphylla*, *Eragrostis capensis*, *Ischyrolepis triflora*, *Juncus scabriusculus*, *Merxmuellera stricta*, *Pentaschistis eriostoma*, *Restio triticeus*, *Themeda triandra*.

Endemic Taxa Tall Shrub: *Psoralea filifolia*. Low Shrubs: *Acmadenia laxa*, *Chrysocoma flava*, *Erica burchelliana*, *E. filamentosa*, *E. physantha*, *Gnidia strigillosa*, *Wahlenbergia effusa*. Succulent Shrub: *Ruschia cymbifolia*. Geophytic Herbs: *Cyrtanthus leptosiphon*, *Geissorhiza foliosa*, *Gladiolus bilineatus*, *G. engysiphon*. Graminoid: *Isolepis brevicaulis*.

Conservation Endangered. Target 30%. Only 4% statutorily conserved in the Bontebok National Park and small patches also in Langeberg-oos (mountain catchment area). More than 40% already transformed for cultivation (pastures) and pine plantations. Alien *Acacia cyclops* occurs in places. Erosion generally moderate and very low, but also high in some places.

Remarks This little known vegetation unit shows floristic features of both fynbos and of renosterveld. Overgrazing converts this to graminoid fynbos on the northern slopes and to a species-poor renosterveld elsewhere. It appears to be easily converted to pasture by frequent burning and liming.

References Grobler & Marais (1967), Taylor (1972a), Rebelo et al. (1991), McDonald (1993b), C. Boucher (unpublished data), L. Mucina (unpublished data).

L. Mucina

Figure 4.84 FFc 1 Swellendam Silcrete Fynbos: Regenerating one-year old proteoid fynbos with resprouting *Leucadendron salignum* on gravel terraces, regularly burned for grazing, in the Bontebok National Park near Swellendam (Western Cape).

FFf 1 Elim Ferricrete Fynbos

VT 47 Coastal Macchia (65%) (Acocks 1953). Mesic Mountain Fynbos (22%), Elim Fynbos (20%) (Moll & Bossi 1983). LR 66 Laterite Fynbos (55%) (Low & Rebelo 1996). BHU 27 Elim Fynbos/Renosterveld Mosaic (60%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Extensive areas between the Bot River Valley, Hemel en Aarde Valley, Stanford environs, Salmonsdam and Baardskeerdersbos, with the most extensive parts around Elim on the Agulhas Plain spanning the area from Soetmuisberg in the north to Buffeljags and the Soetanysberg in the south. Outliers found on the northern slopes of the mountains adjacent to those of the Rûens around Napier and at Perdekamp north of Arniston. Altitude 20–300 m.

Vegetation & Landscape Features Undulating hills and plains covered with open to closed dwarf shrubland with occasional scattered tall shrubs. It is a diverse unit, with all structural fynbos types present, but with extensive areas of asteraceous fynbos dominated by low proteoid elements. To differentiate mesotrophic asteraceous from mesotrophic proteoid fynbos the following proteoid types are recognised: *Leucadendron elimense*, *L. laxum*, *L. modestum*, *L. stelligerum* and *L. teretifolium*. When degraded, this vegetation type becomes dominated by *Elytropappus rhinocerotis*. On transitions to deep sandy soils, *Protea repens* may be dominant, and these transitional communities are often much richer in species than associated FFs 12 Overberg Sandstone Fynbos.

Figure 4.85 FFf 1 Elim Ferricrete Fynbos: Remnant patch of proteoid fynbos dominated by *Leucadendron salignum* and *L. elimense* subsp. *elimense*, with *Acacia*-invaded river course in the background, near Viljoenshof on the Agulhas Plain (Western Cape).

cuspifolia, *M. cyclolopha*, *M. hirsuta*, *Otholobium lanceolatum*, *Phylica diosmoides*, *P. incurvata*, *P. laevifolia*, *Protea pudens*, *Pteronia scabra*. Succulent Shrub: *Acrodon parvifolius*. Geophytic Herb: *Gladiolus acuminatus*. Graminoid: *Calopsis pulchra*.

Conservation Endangered. Target 30%. This vegetation type is known to be a major node of Red Data plant taxa. Statutorily conserved in the Agulhas National Park (5%) and small patches in the Oude Bosch Private Nature Reserve. Some 42% transformed (cultivation of wheat, pastures, vineyards). Alien *Acacia cyclops*, *A. saligna*, *Pinus pinaster*, *Hakea gibbosa*, *H. sericea*, species of *Eucalyptus* and *Leptospermum laevigatum* are common invaders. Erosion low and very low.

Remarks This unit is a major regional centre of endemism located on the Agulhas Plain, significant especially for the high number of endemic Proteaceae. Some regional endemic taxa are shared with FRc 2 Rûens Silcrete Renosterveld.

References Cowling et al. (1988), Thwaites & Cowling (1988), Mustart et al. (1997), N. Helme (unpublished data), J.A.M. Janssen (unpublished data).

Geology & Soils Glenrosa and Mispah and prismacutanic and pedocutanic soils, derived from Bokkeveld Shale, Cape Granite (of the Hermanus Suite), and ferricrete and silcrete. Land types mainly Fb and Db.

Climate Mainly winter-rainfall regime, also with some summer rain. MAP 350–770 mm (mean: 545 mm), peaking from May to August. Mean daily maximum and minimum temperatures 25.8°C and 6.7°C for January and July, respectively. Frost incidence about 3 days per year. See also climate diagram for FFf 1 Elim Ferricrete Fynbos (Figure 4.83).

Important Taxa Tall Shrub: *Protea repens* (d). Low Shrubs: *Elytropappus rhinocerotis* (d), *Erica klotzschii* (d), *E. puberuliflora* (d), *Leucadendron modestum* (d), *Metalasia acuta* (d), *Stoebe capitata* (d), *Aspalathus pycnantha*, *Aulax umbellata*, *Cliffortia ruscifolia*, *Cymbopappus adenosolen*, *Disparago anomala*, *Erica brachysepala*, *E. bruniifolia*, *E. lasciva*, *E. nudiflora*, *E. plukenetii* subsp. *bredensis*, *E. regia* subsp. *regia*, *Leucadendron linifolium*, *L. salignum*, *L. teretifolium*, *L. xanthoconus*, *Leucospermum pedunculatum*, *Mimetes cucullatus*, *Phylica ericoides*, *Protea aspera*, *P. longifolia*, *P. subulifolia*, *Serruria fasciflora*, *Xiphotheca guthriei*. Succulent Shrub: *Drosanthemum asperulum*. Herb: *Corymbium africanum*. Geophytic Herb: *Tritoniopsis flexuosa*. Graminoids: *Ficinia oligantha*, *F. tristachya*, *Ischyrolepis caespitosa*, *I. capensis*, *I. triflora*, *Karroochloa purpurea*, *Merxmuellera stricta*, *Pentaschistis colorata*, *P. eriostoma*, *Rhodocoma fruticosa*, *Tribolium brachystachyum*.

Endemic Taxa ([W]Wetlands) Low Shrubs: *Leucadendron laxum* (d), *L. stelligerum* (d), *Leucospermum heterophyllum* (d), *Agathosma joubertiana*, *A. minuta*, *A. virgata*, *Cliffortia phyllanthoides*, *Cliffortia* sp. nov. (*N. Helme 2088* BOL), *Erica brownii*, *E. flexistyla*[W], *E. jasminiflora*, *E. rubiginosa*, *E. ustulescens*, *Euchaetis diosmoides*, *Gnidia ornata*, *Leucadendron elimense* subsp. *elimense*, *L. elimense* subsp. *salteri*, *Muraltia*

FFf 2 Potberg Ferricrete Fynbos

VT 46 Coastal Renosterbosveld (72%) (Acocks 1953). Mesic Mountain Fynbos (13%) (Moll & Bossi 1983). LR 63 South and South-west Coast Renosterveld (79%) (Low & Rebelo 1996). BHU 34 Riversdale Coast Renosterveld (78%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Northern and western lowermost slopes of Potberg Mountain from Potberg to Poortsrivier and bordered on the north by the Breede River from Diepkloof eastwards. Altitude 20–220 m.

Vegetation & Landscape Features Slight slopes and moderately undulating plains perched on the northern slopes below Potberg. A medium tall evergreen shrubland. Asteraceous and

Figure 4.86 FFf 2 Potberg Ferricrete Fynbos: Proteoid fynbos with *Leucadendron modestum* dominant on ferricrete plains in the Potberg section of De Hoop Nature Reserve in the Overberg (Western Cape).

proteoid fynbos are dominant, with localised stands of restioid fynbos.

Geology & Soils Ferricrete with dry, shallow loamy sand; also silcrete and Ordovician sandstone of the Table Mountain Group (Cape Supergroup) colluvium over shales. Shallow stony soils and sandy loams derived from shale. Rounded ferricrete stones, gravel and cobble covering the surface are locally called 'koffieklip' due to their brown colour. They are considered to be remains of the old African surface. Land types mainly Db, Fc, Fa and Fb.

Climate MAP 300–540 mm (mean: 455 mm), with no clear peak but a low from December to February. Mean daily maximum and minimum temperatures 26.0°C and 6.2°C for January–February and July, respectively. Frost incidence about 3 days per year. See also climate diagram for FFf 2 Potberg Ferricrete Fynbos (Figure 4.83).

Important Taxa Tall Shrubs: *Protea repens* (d), *P. neriifolia*, *Rhus pallens*. Low Shrubs: *Elytropappus rhinocerotis* (d), *Erica quadrangularis* (d), *Leucadendron modestum* (d), *Amphithalea ciliaris*, *Chrysanthemoides monilifera*, *Erica imbricata, E. puberuliflora, E. viscaria* subsp. *longifolia, Leucadendron coriaceum*, *L. cryptocephalum*, *L. salignum*, *L. teretifolium*, *Oedera squarrosa*, *Serruria ludwigii*. Graminoids: *Cymbopogon pospischilii*, *Ficinia oligantha*, *Ischyrolepis capensis*, *Karroochloa purpurea*, *Merxmuellera stricta*.

Endemic Taxon Geophytic Herb: *Bulbinella potbergensis*.

Conservation Endangered. Target 30%. According to current coverage, about 6% of the unit is statutorily conserved in De Hoop Nature Reserve. About 40% of the area transformed (cultivation). *Acacia cyclops* and *A. saligna* are notable invading aliens. Erosion moderate and very low.

Remark This little known vegetation unit has features of both fynbos and of renosterveld. *Elytropappus rhinocerotis* is present but not very conspicuous. It shares features with similar communities occurring on ferricrete or silcrete surfaces, and has the largest extant populations of Red Data silcrete endemics such as *Leucadendron coriaceum*, *L. cryptocephalum* and *Protea decurrens*.

FFt 1 Kango Conglomerate Fynbos

VT 25 Succulent Mountain Scrub (Spekboomveld) (38%), VT 43 Mountain Renosterbosveld (30%) (Acocks 1953). South Coast Renosterveld (72%) (Moll & Bossi 1983). LR 63 South and South-west Coast Renosterveld (74%) (Low & Rebelo 1996). BHU 43 Kango Inland Renosterveld (75%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Northern foothills of the Little Karoo basin, south of the Groot Swartberg, from Gamkapoort to Barandas. Usually at higher altitude than the adjacent FRl 1 Kango Limestone Renosterveld such as on the Andriesberg. Altitude 400–1 200 m.

Vegetation & Landscape Features High foothills, tending to have flat summits, but well dissected. Vegetation a dense shrubland, especially on southern aspects and higher slopes where it is represented by proteoid and asteraceous fynbos and some graminoid fynbos. Upper southern slopes very dense proteoid fynbos.

Geology & Soils Shallow to deep, often yellow-red apedal soils derived chiefly from Cango sandstones, but also Buffelskloof conglomerate and dolerite intrusions. Land types mainly Ib.

Climate MAP 230–730 mm (mean: 455 mm), relatively even, but with a peak in March and a low in December–January. Mean daily maximum and minimum temperatures 30.6°C and 3.1°C for January and July, respectively. Frost incidence 10–20 days per year. See also climate diagram for FFt 1 Kango Conglomerate Fynbos (Figure 4.83).

Important Taxa ([T]Cape thickets) Small Tree: *Protea nitida*. Tall Shrubs: *Dodonaea viscosa* var. *angustifolia* (d), *Leucadendron rubrum* (d), *Protea repens* (d), *Freylinia lanceolata*, *Rhus angustifolia*[T], *R. incisa*[T]. Low Shrubs: *Anthospermum aethiopicum* (d), *Elytropappus rhinocerotis* (d), *Muraltia ericaefolia* (d), *Paranomus dregei* (d), *Passerina obtusifolia* (d), *Agathosma recurvifolia*, *A. roodebergensis*, *Anisodontea scabrosa*, *Athanasia filiformis*, *A. trifurcata*, *Cliffortia ruscifolia*, *Hermannia holosericea*, *Leucadendron salignum*, *Leucospermum cuneiforme*, *L. wittebergense*, *Muraltia ericoides*, *Paranomus dispersus*, *Protea intonsa*, *P. lorifolia*, *Psoralea oligophylla*. Succulent Shrub: *Crassula nudicaulis*. Geophytic Herb: *Drimia intricata*. Graminoids: *Cannomois scirpoides*, *Carex glomerabilis*, *Cymbopogon marginatus*, *Ischyrolepis gaudichaudiana*, *Karroochloa curva*, *Thamnochortus fruticosus*.

Endemic Taxa Low Shrub: *Lessertia lanata*. Succulent Herbs: *Conophytum truncatum* subsp. *truncatum* var. *wiggettiae*, *Haworthia blackburniae* var. *derustensis*, *H. monticola* var. *asema*. Graminoid: *Rhodocoma arida*.

Conservation Least threatened. Target 27%. Conserved for instance in the Swartberg Nature Reserve, Swartberg-oos (mountain catchment area) and Groot Swartberg. Only about 2% has been transformed (cultivation). This is largely an unploughable unit occurring on the summit of rugged hills. Erosion low and very low.

Remarks The ecology and floristics of this unit are largely unknown. The name 'conglomerate' is for expediency only as it occurs equally on sandstones and dolerites in this area. This unit grades into FRl 1 Kango Limestone Renosterveld in the south and at lower altitudes and shares with it the high abundances and dominance of *Dodonaea viscosa* var. *angustifolia*. On steep north-facing slopes, and especially in kloofs, spekboom thickets dominated by *Portulacaria afra* border on the vegetation of this 'conglomerate fynbos'. Narrow, fire-protected ravines on the southern slopes shelter remnants of afrotemperate forest.

References Moffett & Deacon (1977), Vlok & Euston-Brown (2002).

FFt 2 Loerie Conglomerate Fynbos

VT 70 False Macchia (59%) (Acocks 1953). Mesic Grassy Fynbos (29%), Valley Bushveld (28%) (Moll & Bossi 1983). LR 63 South and South-west Coast Renosterveld (34%), LR 65 Grassy Fynbos (28%) (Low & Rebelo 1996). BHU 30 Kromme Fynbos/Renosterveld Mosaic (41%), BHU 21 Humansdorp Grassy Fynbos (40%) (Cowling et al. 1999b, Cowling & Heijnis 2001). STEP Loerie Fynbos Thicket (31%), STEP Andrieskraal Fynbos Thicket (15%), STEP Zuurberg Forest Thicket (5%) (Vlok & Euston-Brown 2002).

Distribution Eastern Cape Province: Hankey Valley on both sides of the Gamtoos River, from Andrieskraal to Mondplaas on the southwestern side, and Patensie to Thornhill on the north-eastern side. Also found in the lower Kwazunga Valley above Springfield and Rooikrans near Uitenhage. Altitude 80–400 m.

Vegetation & Landscape Features Moderately undulating plains dissected by major rivers. Vegetation low shrubland or grassland with sparse emergent tall shrubs, and rich in succulents and geophytes. Structurally these are graminoid, asteraceous and proteoid fynbos types.

Geology & Soils Acidic, moist clay-loam, Glenrosa and Mispah soils and conglomerates associated with shales and conglomer-


A.V. Köcke

Figure 4.87 FFt 2 Loerie Conglomerate Fynbos: Mixed *proteaceous-ericaceous* fynbos with *Leucadendron salignum* and *Erica* species near Hankey (Eastern Cape).

ates of the Karoo Uitenhage sequence. Land types mainly Fc, Fa and Ib.

Climate MAP 360–780 mm (mean: 600 mm), even throughout the year with a slight bimodal peak in March and October–November. Mean daily maximum and minimum temperatures 26.1°C and 6.9°C for February and July, respectively. Frost incidence about 3 days per year. See also climate diagram for FFt 2 Loerie Conglomerate Fynbos (Figure 4.83).

Important Taxa ([T]Cape thickets) Tall Shrubs: *Aspalathus nivea*, *Azima tetracantha*[T], *Cliffortia linearifolia*, *Diospyros pallens*[T], *Dodonaea viscosa* var. *angustifolia*, *Euclea undulata*[T], *Grewia occidentalis*[T], *Gymnosporia capitata*[T], *Protea neriifolia*, *P. repens*, *Schotia afra* var. *afra*[T]. Low Shrubs: *Anthospermum galioides* subsp. *galioides*, *Asparagus subulatus*, *Barleria pungens*, *Cliffortia ruscifolia*, *Clutia polifolia*, *Elytropappus rhinocerotis*, *Erica demissa*, *E. pectinifolia*, *Felicia muricata* subsp. *cinerascens*, *Galenia secunda*, *Helichrysum anomalum*, *H. odoratissimum*, *H. zeyheri*, *Indigofera denudata*, *Leucadendron salignum*, *Leucospermum cuneiforme*, *Otholobium pictum*, *Passerina obtusifolia*, *Pelargonium odoratissimum*, *Protea foliosa*, *Senecio linifolius*. Succulent Shrubs: *Cotyledon orbiculata* var. *oblonga*, *Crassula cultrata*, *C. tetragona*, *Euphorbia polygona*. Woody Climbers: *Capparis sepiaria* var. *citrifolia*, *Rhoicissus digitata*. Woody Succulent Climber: *Zygophyllum foetidum*. Small Tree: *Protea nitida*. Herbs: *Commelina africana*, *Hibiscus pusillus*, *Salvia triangularis*. Geophytic Herbs: *Babiana patersoniae*, *Drimia intricata*, *Geissorhiza bracteata*, *Gladiolus longicollis*, *Polyxena ensifolia*, *Sansevieria hyacinthoides*, *Spiloxene trifurcillata*. Succulent Herbs: *Crassula nemorosa*, *Haworthia cooperi*. Herbaceous Climber: *Cyphia sylvatica*. Herbaceous Succulent Climbers: *Ceropegia cancellata*, *Pelargonium peltatum*. Graminoids: *Aristida junciformis* subsp. *galpinii*, *Brachiaria serrata*, *Cymbopogon marginatus*, *Cynodon dactylon*, *Eragrostis obtusa*, *Eustachys paspaloides*, *Ficinia tristachya*, *Ischyrolepis gaudichaudiana*, *I. sieberi*, *Pentaschistis angustifolia*, *P. colorata*, *Restio triticeus*, *Sporobolus africanus*, *Stipa dregeana*, *Tetraria cuspidata*, *Themeda triandra*, *Trachypogon spicatus*.

Endemic Taxon Succulent Shrub: *Erepsia aristata*.

Conservation Least threatened. Target 23%. Some 11% statutorily conserved in the Groendal Wilderness Area. Small patches are also found in the private Kabeljous River Natural Heritage Site. About 9% transformed (cultivation). Erosion very variable, including significant areas of high and moderate erosion, but also very low in some areas.

Remarks Fire-protected gullies with AT 4 Gamtoos Thicket and a forest (dominated by *Ficus sur*) form an intricate mosaic with the fynbos. The boundary towards adjacent renosterveld is particularly indistinct and very broad, supporting communities of transitional character. The flatter, old African surfaces are dominated by *Cliffortia ruscifolia* and *Dodonaea viscosa* var. *angustifolia*.

References Cowling & Campbell (1983a, b), Cowling (1984), Cowling & Campbell (1984), Vlok & Euston-Brown (2002).

9.1.7 Alluvium Fynbos

Alluvium fynbos has previously been mapped as renosterveld. It covers relatively large blocks where there is a fine sediment talus adjacent to mountains in wetter areas. It is essentially a high-rainfall version of alluvium renosterveld, the major difference relating to the coarser nature of the sediments, the higher rainfall associated with elevated areas and adjacency to mountains and the consequent higher levels of leaching. It is also far wetter than can be gauged by its rainfall, as it is a conduit for

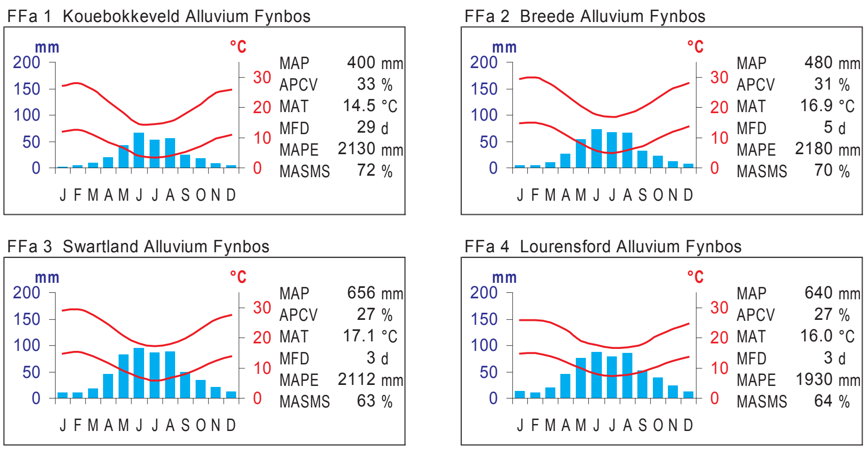


Figure 4.88 Climate diagrams of alluvium fynbos units. Blue bars show the median monthly precipitation. The upper and lower red lines show the mean daily maximum and minimum temperature respectively. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days (days when screen temperature was below 0°C); MAPE: Mean Annual Potential Evaporation; MASMS: Mean Annual Soil Moisture Stress (% of days when evaporative demand was more than double the soil moisture supply).

streams and rivers adjacent to mountains, which braid out in alluvial taluses before coalescing into the rivers of the plains. Floristically the alluvial fynbos therefore contains large portions of Restionaceae, Proteaceae and Ericaceae and classifies as true fynbos rather than renosterveld.

From its topographical position at the foot of the mountains, alluvium fynbos is well traversed with alluvial (riverine) vegetation patches, ranging from seeps to open to deep channels, with different amounts of colluvial rock. It also usually grades into adjacent shale fynbos units, but these have fine-grained sediments.

Typically the dominant communities are asteraceous, proteoid (*Leucadendron chamaelea*, *L. corymbosum* are prominent emergents) and restioid fynbos types. Considering its small aerial extent, some units are relatively rich in endemics, mainly bulbs, Fabaceae and Proteaceae. High levels of historical transformation may have resulted in high levels of extinction of endemics prior to intensive botanical collection. Still today, with the notable exception of FFa 3 Swartland Alluvium Fynbos (see Walton 2006) at Elandsberg Private Nature Reserve (north of Wellington), this is a poorly studied group of vegetation types.

FFa 1 Kouebokkeveld Alluvium Fynbos

VT 69 Macchia (100%) (Acocks 1953). Mesic Mountain Fynbos (31%), Central Mountain Renosterveld (17%), Dry Mountain Fynbos (6%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (81%) (Low & Rebelo 1996). BHU 47 Cederberg Mountain Fynbos Complex (47%), BHU 49 Swartruggens Mountain Fynbos Complex (35%) (Cowling et al. 1999b, Cowling & Heijnis 2001).


L. Mucina

Figure 4.89 FFa 1 Kouebokkeveld Alluvium Fynbos: Restio-dominated fynbos with emergent *Protea laurifolia* on an alluvial fan at the foot of Hex River Mountains on the Farm Erfdeel in the Warm Bokkeveld, east of Ceres (Western Cape).

Distribution Western Cape Province: Fringes of the northern Koue Bokkeveld valleys from Op Die Berg (north of Ceres) northwards to Tandfontein and eastwards to Excelsior, extending to the Blinkberg Pass and Winkelhaak. Smaller unmapped patches are also found at north-facing entrances to valleys of the Hex River Mountains. Altitude 850–1 000 m.

Vegetation & Landscape Features Slightly undulating plains in mountain valleys where alluvium has accumulated alongside rivers and as alluvial fans. Vegetation is emergent proteoids in a low medium dense grassy shrubland, structurally primarily asteraceous and proteoid fynbos, with prominent ericaceous fynbos in numerous seeps.

Geology & Soils Sandy to silty alluvium with small cobbles embedded over Bokkeveld shales. Soils are duplex and dystrophic plinthic catenas and grey regic sands. Land types mainly Ca, Bb and Hb.

Climate Winter-rainfall climate with MAP 240–730 mm (mean: 400 mm), peaking from May to August. Mean daily maximum and minimum temperatures 28.0°C and 3.4°C for February and July, respectively. Frost incidence fairly infrequent, 10–30 days per year. This is the driest and coolest of all alluvium fynbos types due to the rainshadow effect and high elevation. See also climate diagram for FFa 1 Kouebokkeveld Alluvium Fynbos (Figure 4.88).

Important Taxa ([W]Wetlands) Tall Shrubs: *Protea laurifolia* (d), *Leucadendron chamelaea*, *Protea repens*. Low Shrubs: *Cliffortia amplexistipula*, *Elytropappus rhinocerotis*, *Erica muscosa*, *Leucadendron brunioides* var. *brunioides*, *L. glaberrimum* subsp. *glaberrimum*, *L. salignum*, *Protea laevis, Serruria cygnea*, *Spatalla caudata*[W], *Stoebe cinerea*, *S. plumosa.* Herb: *Dianthus bolusii*. Geophytic Herb: *Satyrium pumilum*. Graminoids: *Cymbopogon marginatus*, *Cynodon dactylon*, *Hyparrhenia hirta*, *Ischyrolepis capensis*.

Conservation Endangered. Target 29%. None statutorily conserved, with 1.4% conserved in Koue Bokkeveld mountain catchment area. Almost half of the area transformed for cultivation for orchards and pastures. Erosion very low and low.

Remarks This is a poorly studied vegetation unit. It grades into FFh 1 Kouebokkeveld Shale Fynbos as alluvium thins out.

Reference C. Boucher (unpublished data).

FFa 2 Breede Alluvium Fynbos

VT 69 Macchia (88%) (Acocks 1953). LR 61 Central Mountain Renosterveld (81%) (Low & Rebelo 1996). BHU 26 Breede Fynbos/Renosterveld Mosaic (54%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Upper Breede River Valley flats from Tulbagh to the Brandvlei Dam near Worcester including the Slanghoek and Brandwag Valleys, and extending to the Hex River Valley. Altitude 200–350 m, with few patches reaching altitudes as high as 600 m.

Vegetation & Landscape Features Slightly undulating plains and adjacent high mountains, with numerous alluvial fans and streams. Open emergent tall proteoids in a moderately tall shrub matrix with a graminoid understorey. Asteraceous and proteoid fynbos are dominant, with localised restioid fynbos and ericaceous fynbos.

Geology & Soils Quaternary alluvial deposits consisting of round cobbles embedded in fine loamy sand, over metasediments of the Malmesbury Group and Bokkeveld Group shales. Soils are usually of alluvial land type Ia, with some Fa land type (with typical Glenrosa and Mispah forms). Hb and Ad land types also present.

Climate Seasonal, winter-rainfall climate peaking June–August. MAP 90–970 mm (mean: 480 mm). Mean daily maximum and minimum temperatures 29.9°C and 4.8°C for February and July, respectively. MAT close to 17°C. Frost incidence infrequent. Although in the rainshadow of the Hawequas Mountains, the area is well fed with water from the mountains. See also climate diagram for FFa 2 Breede Alluvium Fynbos (Figure 4.88).

Important Taxa ([T]Cape thickets, [W]Wetlands) Small Tree: *Protea nitida*. Tall Shrubs: *Diospyros glabra*[T], *Leucadendron chamelaea*, *L. rubrum*, *Leucospermum vestitum*, *Protea burchellii*, *P. laurifolia*, *P. repens*, *Rhus angustifolia*[T]. Low Shrubs: *Acmadenia matroosbergensis*, *Aspalathus spinosa* subsp. *flavispina*, *Athanasia trifurcata*, *Cliffortia ruscifolia*, *Leucadendron brunioides* var. *brunioides*, *L. corymbosum*, *L. salignum*, *Protea acaulos, Serruria fasciflora*, *Stoebe plumosa*. Herbs: *Adenogramma glomerata*, *Felicia tenella*. Geophytic Herbs: *Geissorhiza geminata*[W], *G. ornithogaloides* subsp. *ornithogaloides*. Graminoids: *Cynodon dactylon*, *C. incompletus*, *Ficinia indica*, *Hyparrhenia hirta*, *Ischyrolepis sieberi*, *Juncus cephalotes*, *Merxmuellera stricta*, *Pentaschistis airoides*, *Tetraria compar*, *Themeda triandra*, *Tribolium echinatum*.

Endemic Taxa ([W]Wetlands) Tall Shrub: *Leucadendron flexuosum*. Low Shrubs: *Aspalathus acanthoclada*, *A. amoena*, *A. singuliflora*, *A. tulbaghensis*, *Diastella parilis*, *Erica hansfordii*[W], *Leucadendron lanigerum* var. *laevigatum*, *L. spirale*, *Leucospermum calligerum* (prostrate form), *Rafnia crispa*. Succulent Shrub: *Lampranthus woodburniae*. Herb: *Manulea minor*. Geophytic Herbs: *Ixia mostertii*, *I. rouxii*, *Lachenalia moniliformis*, *Moraea worcesterensis*.

Conservation Endangered. Target 30%. Small patches conserved in the statutory Fonteintjiesberg and Limietberg Nature Reserves, Matroosberg and Hawequas (both mountain catchment areas) as well as in the private Quaggas Berg. Almost 60% already transformed for cultivation (vineyards, pastures, pine plantations), road building and urban sprawl. This area is susceptible to transformation through long-term continuous grazing and repeated short-interval burning. This disturbance eliminates palatable grasses and increases the unpalatable shrubs that sprout after fire or have a short life cycle. Aliens do not play a major role except for *Acacia saligna*, *Hakea sericea* and a number of alien annual grasses. Erosion very low and low.

Remarks This unit shares ecological and floristic features with FRa 1 Breede Alluvium Renosterveld, with which it grades to the east in the lower valleys. It also contains elements of the FFd 4 Atlantis Sand Fynbos, suggesting an ancient link, possibly as dune corridors over the Hawequas Mountains north of the Nuwekloof Pass.

References Boucher (1988b, 1994a).

FFa 3 Swartland Alluvium Fynbos

VT 69 Macchia (54%) (Acocks 1953). LR 62 West Coast Renosterveld (88%) (Low & Rebelo 1996). BHU 32 Boland Coast Renosterveld (89%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Swartland lowlands at west-facing piedmonts of the Groot Winterhoekberge near Porterville, Saronberg, Elandskloofberge to the Limietberge near Wellington; broad valley bottoms of the Paarl, Drakenstein, Franschhoek and Banhoek Valleys, with some extensions west of Paarl Mountain and to Klapmuts. Altitude 60–250 m, rarely reaching 350 m.

Vegetation & Landscape Features Moderately undulating plains, adjacent mountains and in river basins. The vegetation is a matrix of low, evergreen shrubland with emergent sparse, moderately tall shrubs and a conspicuous graminoid layer. Proteoid, restioid and asteraceous fynbos types are dominant, with closed-scrub fynbos common along the river courses. Ericaceous and restioid fynbos found in seeps.

Geology & Soils Alluvial gravel and cobble fields typically resting over Malmesbury Group schists and phyllites (in the northern part of the area) as well as over Cape Suite granites (in Drakenstein Valley from Wellington to Franschhoek) and on Malmesbury Group sandstones from Simondium to Klipheuwel. Dominant land types Db (soils with prismacutanic and pedocutanic horizons) and Ga (soils with ferrihumic horizon).

Climate Seasonal, winter-rainfall regime, peaking from May to August. MAP (mean: 655 mm) varies broadly from 320–980 mm (close to foot of mountains). Mean daily maximum and minimum temperatures 29.5°C and 6.0°C for February and July, respectively. Frost an infrequent phenomenon. This is the wettest and hottest alluvium fynbos type. See also climate diagram for FFa 3 Swartland Alluvium Fynbos (Figure 4.88).

Important Taxa ([T]Cape thickets, [W]Wetlands) Tall Shrubs: *Diospyros glabra*[T] (d), *Olea europaea* subsp. *africana*[T] (d), *Psoralea aphylla* (d), *Rhus angustifolia*[T] (d), *Dodonaea viscosa* var. *angustifolia*, *Metalasia densa*, *Morella cordifolia*, *Passerina corymbosa*, *Phylica buxifolia*, *Protea repens*, *Rhus incisa*[T], *Rubus rigidus*. Low Shrubs: *Cliffortia ferruginea* (d), *Elytropappus rhinocerotis* (d), *Eriocephalus africanus* var. *africanus* (d), *Leucadendron corymbosum* (d), *Leucospermum calligerum* (d), *Passerina truncata* subsp. *truncata* (d), *Senecio halimifolius* (d), *Serruria candicans* (d), *Athanasia trifurcata*, *Cliffortia juniperina*, *C. ruscifolia*, *Elytropappus gnaphaloides*,

L. Mucina

Figure 4.90 FFa 2 Breede Alluvium Fynbos: Proteoid fynbos dominated by *Leucadendron salignum* with emergent *Cliffortia ruscifolia* near Worcester (Western Cape).

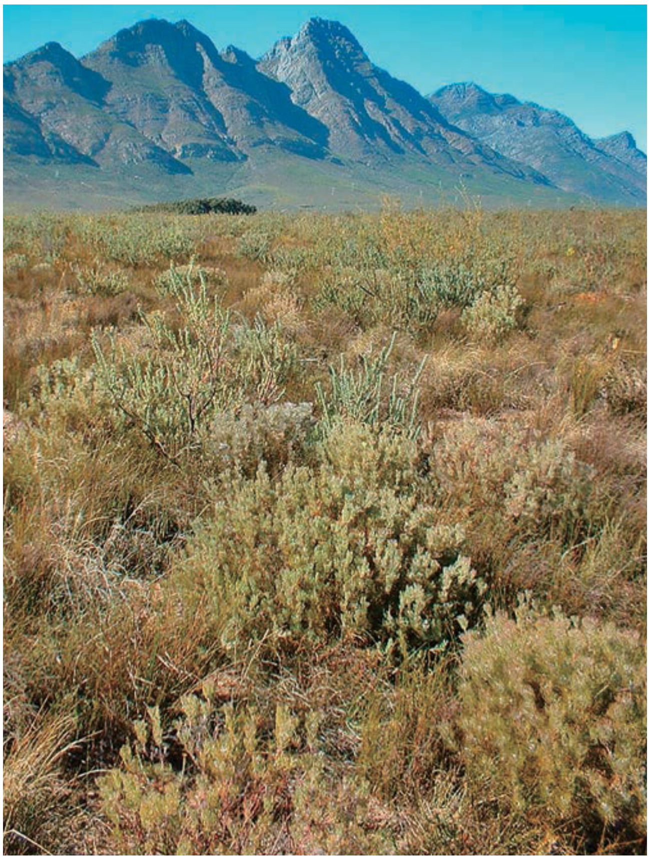


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Figure 4.91 FFa 3 Swartland Alluvium Fynbos: Proteoid fynbos with *Leucospermum calligerum* and *Serruria candicans* (foreground) and *Leucadendron corymbosum* (background) on alluvial fans in the Elandsberg Private Nature Reserve north of Wellington (Western Cape).

Euryops pinnatipartitus, *Galenia africana*, *Leucadendron lanigerum* var. *lanigerum*, *L. salignum*, *L. stellare, Oftia africana*, *Plecostachys serpyllifolia*, *Stoebe plumosa*, *Trichocephalus stipularis*. Woody Climber: *Microloma sagittatum*. Herbs: *Conyza pinnatifida*, *Corymbium africanum*, *Dischisma arenarium*, *Lebeckia sepiaria*. Geophytic Herbs: *Pteridium aquilinum* (d), *Zantedeschia aethiopica*[W] (d), *Geissorhiza imbricata* subsp. *bicolor*[W], *G. setacea*, *Mohria caffrorum*, *Oxalis goniorrhiza*, *Spiloxene flaccida*. Herbaceous Climber: *Dipogon lignosus*. Graminoids: *Calopsis paniculata* (d), *Cynodon dactylon* (d), *Elegia filacea* (d), *Ficinia brevifolia* (d), *Ischyrolepis capensis* (d), *I. tenuissima* (d), *Juncus capensis* (d), *Merxmuellera cincta* (d), *Calopsis rigorata*, *Cannomois parviflora*, *Elegia nuta*, *E. recta*, *Eragrostis curvula*, *Pentaschistis curvifolia*, *P. pallida*, *Pycreus polystachyos*[W], *Restio filiformis*, *Thamnochortus fruticosus*, *T. punctatus*, *Willdenowia glomerata*, *W. incurvata*, *W. sulcata*, *W. teres*.

Endemic Taxa ([W]Wetlands) Low Shrubs: *Diastella buekii*, *Erica alexandri*, *E. bakeri*[W], *Marasmodes duemmeri*, *M. undulata*, *Phylica stenopetala*, *Protea mucronifolia*. Succulent Shrub: *Lampranthus schlechteri*. Geophytic Herbs: *Brunsvigia elandsmontana*, *Bulbine monophylla*, *Geissorhiza furva*, *Moraea villosa* subsp. *elandsmontana*.

Conservation Critically endangered. Target 30%. Nearly 10% conserved in the Waterval Nature Reserve, Winterhoek (mountain catchment area) and private reserves such as Elandsberg, Langerug and Wiesenhof Wildpark. More than 75% already transformed for vineyards, olive orchards, pine plantations, urban settlements and by building of the Voëlvlei and Wemmershoek Dams. Alien *Acacia saligna* and *Hakea sericea* are prominent in places. Erosion moderate and very low.

Remarks Previously this was considered to be part of renosterveld (e.g. Moll & Bossi 1983, Low & Rebelo 1996), but it is clearly a fynbos type. This unit forms a complicated mosaic with FRs 9 Swartland Shale Renosterveld at its lower extremity, and some of the communities have an ecotonal character, for example where the soils are dominated by clay-rich silts.

References Boucher (1983, 1987), Jones (1986), Diemer (2000), Walton (2006), N. Helme (unpublished data).

FFa 4 Lourensford Alluvium Fynbos

VT 47 Coastal Macchia (52%) (Acocks 1953). LR 62 West Coast Renosterveld (46%), LR 68 Sand Plain Fynbos (29%), LR 64 Mountain Fynbos (21%) (Low & Rebelo 1996). BHU 32 Boland Coast Renosterveld (42%), BHU 12 Blackheath Sand Plain Fynbos (30%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Low-lying areas between Firgrove and Gordon's Bay, including much of the Strand and Somerset West, extending up the Lourens River Valley to the Sawmill above Lourensford Estate. Altitude 20–150 m.

Vegetation & Landscape Features Low-lying plains supporting low, medium dense shrubland with short graminoid understorey. Restioid and asteraceous fynbos are dominant, although there is some evidence that proteoid fynbos might once have been dominant. Some remnants are exceptionally rich in geophytes.

Geology & Soils Plinthic, duplex, silty soils often with small cobbles and pebbles embedded. Found over Cape Suite granite and metasediments of the Tygerberg Formation (Malmesbury Group). Land types mainly Ca and Ac.

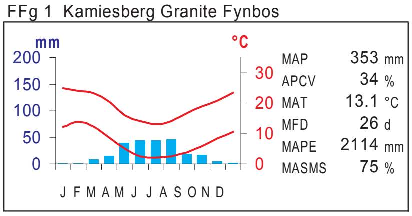
Climate Winter-rainfall climate peaking from May to August. MAP 470–980 mm (mean: 640 mm). Mean daily maximum and minimum temperatures 26.0°C and 7.4°C for February and July, respectively. Frost incidence infrequent. This is the only alluvium fynbos under strong maritime influence. See also climate diagram for FFa 4 Lourensford Alluvium Fynbos (Figure 4.88).

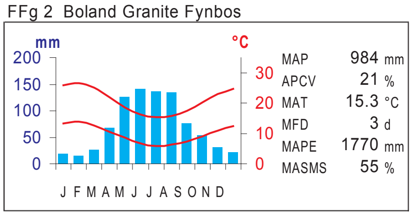
Important Taxa Small Tree: *Protea nitida*. Tall Shrubs: *Protea burchellii*, *P. coronata*, *P. repens*. Low Shrubs: *Asparagus rubicundus*, *Athanasia juncea*, *A. trifurcata*, *Cliffortia marginata*, *Erica imbricata*, *E. paniculata*, *Leucadendron lanigerum* var. *lanigerum*, *L. salignum*, *Lotononis prostrata*, *Marasmodes polycephala*, *Protea cynaroides*, *P. scolymocephala*, *Senecio pubigerus*, *Stoebe plumosa*. Herb: *Helichrysum crispum*. Geophytic Herbs: *Ammocharis longifolia*, *Geissorhiza setacea*, *Ixia dubia*. Graminoids: *Cymbopogon marginatus*, *Cynodon dactylon*, *Elegia recta*, *Ficinia indica*, *Hyparrhenia hirta*, *Ischyrolepis capensis*, *Staberoha cernua*, *Tetraria compar*, *Themeda triandra*, *Tribolium uniolae*.

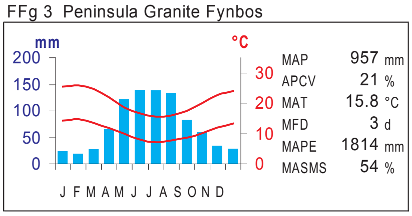
Conservation Critically endangered. About 3% conserved in the Helderberg and Harmony Flats Nature Reserves and a further 22% in Lourens River (protected natural area). The conservation target of 30% is unattainable since more than 90% of the area has been transformed for urban development (Helderberg Municipality), cultivation, pine plantations and roads. Erosion very low and moderate.

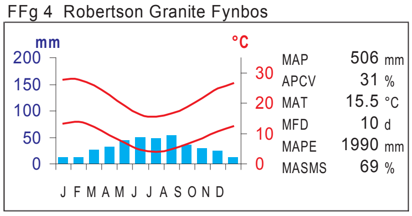
Remarks This unit falls within areas farmed since earliest colonial times (Farm Vergelegen of W.A. van der Stel since 1700). Most of the remnants are transformed by grazing, mowing and changes in fire regime, and it is uncertain what has been lost and whether the remaining patches are representative of the original vegetation type.

References C. Boucher (unpublished data), N. Helme (unpublished data).









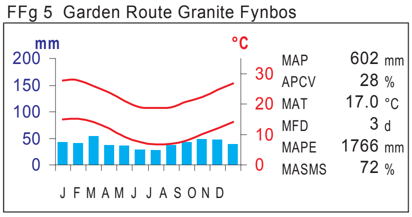


Figure 4.92 Climate diagrams of granite fynbos units. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days; MAPE: Mean Annual Potential Evaporation; MASMS: Mean Annual Soil Moisture Stress.

9.1.8 Granite Fynbos

Granite fynbos occurs on only 2% of the area of fynbos vegetation. It has two major facies. In wetter areas on steeper slopes it is usually on a deep, well-drained soil, prone to further erosion by large dongas that extend from a watercourse upslope of the base of the overlying sandstone cliffs. These usually have pure fynbos communities, although in screes and canalised watercourses, closed-scrub fynbos and Cape thicket occur. In drier areas and areas of harder rock, large granite domes are prominent, with pockets of deep soil. Here, in relatively fire-safe environments, the Cape thicket element is dominant on the lower edges of the boulders, within boulder fields and in gullies, with fynbos in the open areas in between. In addition, rock communities are prominent, and characteristically support a succulent flora.

Granite fynbos is characteristically tall and dense, often with *Cliffortia* and other spiny-leaved species. Floristically and structurally this type shares most elements with shale fynbos, except for the dominance of patches of closed-scrub fynbos and Cape thicket elements. Being more fertile than sandstone fynbos, granite fynbos has a very distinctive post-fire seral phase dominated by dense 1–1.5 m tall stands of Asteraceae and Fabaceae, primarily *Aspalathus*. These stands last for two to three years before they die away and the asteraceous, restioid and proteoid fynbos grow through and become dominant. Structurally this vegetation is taller and denser than typical fynbos. Drier slopes support asteraceous fynbos, dominated by spine-leaved species and large resprouting shrubs, whereas proteoid fynbos is dominant in wetter areas. Waboomveld is dominant in the mid-lower slopes.

FFg 1 Kamiesberg Granite Fynbos

VT 69 Macchia (75%) (Acocks 1953). LR 64 Mountain Fynbos (74%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Namaqualand, summits and upper slopes of Rooiberg in the north (1 395 m) on the Farm Pedroskloof, Sneeukop (1 589 m), Kamiesberg (1 527 m), Johannes se Berg (1 550 m), Sittenberg (1 553 m), Eselkop (1 664 m) and Rooiberg (1 705 m) south of Rhebokskloof in the south, in the Kamiesberg Mountains (roughly in the area between Kamieskroon, Leliefontein and Garies). Rather anomalously, the unit is not very strongly correlated with altitude. Although the low altitude limit is roughly 1 450 m, outliers occur as low as 1 200 m including some sporadic occurrences on flats between the mountains. It is absent from many areas above 1 200 m in the region. The upper altitude limit is the summit of Rooiberg (1 705 m), the highest peak in Namaqualand.

Vegetation & Landscape Features System of round-top mountains and broad-shoulder ridges dominated by granite domes and slabs. The dominant vegetation is usually medium tall (1–2 m), sparse (cover 30–40%, up to 60%) shrubland dominated by malacophyllous shrubs. In structural terms this shrubland ranks as asteraceous fynbos. Localised patches of fynbos may occur lower in the landscape within renosterveld in seepages and in alluvial washes. When heavily grazed, this vegetation type is transformed into karoo, resulting in fence-line contrasts of succulent karoo shrubs versus asteraceous fynbos. When burned or bush-cut, the annual and bulb flora result in spectacular displays.

Geology & Soils Granites and gneisses of the Mokolian Kamieskroon Gneiss and Stalhoek Complex. Soils skeletal, shallow and sandy, typical of Ic land type.

Climate Precipitation low, with the lowest average values at the semi-arid limit. MAP 240–450 mm (mean: 355 mm), peaking from May to August. This type is near the lower-rainfall limits for fynbos on granite, and is the driest of the granite types. Mean daily maximum and minimum temperatures 24.9°C and 2.1°C for January and July, respectively. Frost incidence 10–40 days per year. See also climate diagram for FFg 1 Kamiesberg Granite Fynbos (Figure 4.92).

Important Taxa Low Shrubs: *Erica plukenetii* subsp. *plukenetii* (d), *Metalasia densa* (d), *Anginon difforme*, *Anthospermum spathulatum* subsp. *spathulatum*, *Arctotis revoluta*, *Chrysanthemoides monilifera* subsp. *pisiformis*, *Cliffortia ruscifolia*, *Diosma hirsuta*, *Euryops tenuissimus*, *Lobostemon glaucophyllus*, *Passerina truncata* subsp. *truncata*, *Phylica cryptandroides*, *P. montana*, *Selago glutinosa* subsp. *glutinosa*. Herbs: *Heliophila schulzii*, *Peucedanum khamiesbergense*. Geophytic Herb: *Gladiolus hyalinus*. Graminoids: *Calopsis marlothii*, *C. viminea*, *Ischyrolepis gossypina*, *I. ocreata*, *I. rottboellioides*, *I. sieberi*, *Restio cymosus*.

Biogeographically Important Taxa (all Kamiesberg endemics) Low Shrubs: *Aspalathus angustifolia* subsp. *robusta*, *Muraltia rigida*. Herbs: *Centella tridentata* var. *dregeana, Lotononis acutiflora*. Geophytic Herb: *Hesperantha latifolia*.

Endemic Taxa ([W]Wetlands) Low Shrubs: *Agathosma namaquensis*, *Amphithalea obtusiloba*, *Cullumia rigida*, *Lotononis magnifica*, *Oedera conferta*, *Phylica retrorsa*, *Protea namaquana*, *Vexatorella alpina*. Herbs: *Hebenstretia kamiesbergensis*, *Peucedanum pearsonii*. Geophytic Herbs: *Gladiolus kamiesbergensis*, *Hesperantha minima*, *Oxalis creaseyi*, *Romulea rupestris*, *Watsonia rourkei*, *Xenoscapa uliginosa*[W]. Succulent Herb:

L. Mucina

Figure 4.93 FFg 1 Kamiesberg Granite Fynbos: Dry asteraceous fynbos with *Agathosma namaquana*, *Metalasia densa* and *Ischyrolepis sieberi* on a granite dome of the Rooiberg (1 706 m) in the Kamiesberg Mountains, Namaqualand (Northern Cape).

Conophytum khamiesbergense. Graminoids: *Ischyrolepis vilis*, *Pentaschistis lima*.

Conservation Least threatened. Target 27%. None conserved in statutory or private conservation areas. Only about 2% transformed (cultivation), but much of the 'natural veld' is degraded by heavy grazing. Erosion is moderate.

Remark 1 The proteoid affinities of this vegetation are with derived elements in quartzitic fynbos, suggesting that only arid-adapted species crossed the Krom River gap to the south. Some fynbos elements (e.g. *Erica plukenetii*, *Ischyrolepis sieberi*) occur well north of Kamiesberg in the Springbok area, but in these habitats these 'tramp' species are generally found as a rare admixture within a matrix of renosterveld.

Remark 2 The FFg 1 Kamiesberg Granite Fynbos is embedded within the FRg 1 Namaqualand Granite Renosterveld. These two vegetation units form the core of the Kamiesberg Centre of Endemism (Van Wyk & Smith 2001). The lower boundary of the granite fynbos with renosterveld is complex and the transition varies. In places it is clear-cut, but in other areas broad transition zones can be found, with fynbos elements persisting within renosterveld in rocky and moist facies, and renosterveld elements found on the deeper soils within fynbos. The large bare slabs of granite support small and shallow-soil grit pans filled with coarse granite sand. These habitats as well as crevices in the granite slabs contain lithophytic communities dominated by *Polymita albescens, Othonna euphorbioides*, and many other succulent taxa (*Anacampseros, Conophytum, Cotyledon, Crassula* etc.) and geophytes. These patches of vegetation should be classified within the SKn 1 Namaqualand Klipkoppe Shrubland (see also the Chapter on Succulent Karoo).

References Adamson (1958), Van Wyk & Smith (2001), N. Helme (unpublished data), L. Mucina (unpublished data).

FFg 2 Boland Granite Fynbos

VT 69 Macchia (82%) (Acocks 1953). Mesic Mountain Fynbos (56%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (59%) (Low & Rebelo 1996). BHU 32 Boland Coast Renosterveld (41%), BHU 54 Franschhoek Mountain Fynbos Complex (29%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Upper slopes and summits of Paardeberg and Paarl Mountain as well as the lower slopes of mountains spanning the Groenberg and Hawequasberge (western foothills near Wellington), Pniel (Simonsberg and Groot Drakenstein Mountains and Klapmutskop), Franschhoek (Middelberg, Dassenberg, Skerpheuwel, Middagkransberg), Stellenbosch (Jonkershoek Valley and northern side of the Helderberg) and Helderberg Municipality (including lower south- and west-facing slopes of Haelkop and the Hottentots Holland Mountains and also the free-standing Skapenberg). It also occurs in the Du Toitskloof and Wemmershoek Valleys, Kaaimansgat and lower Stettynskloof, with outcrops on the Bottelary Hills and Kanonkop (near Pella). Altitude 150–650 m, reaching 850 m in places.

Vegetation & Landscape Features Moderately undulating plains and hills, varying from extensive deep soils, to localised deep soils between large granite domes and sheets. A fairly dense, 1–2 m tall closed shrubland with occasional low, gnarled trees dotted through the landscape. A diverse type, dominated by scrub, asteraceous and proteoid fynbos (with *Protea repens, P. burchelli, P. laurifolia* with *Leucadendron rubrum* and *L. daphnoides* as dominants on drier slopes, *Leucospermum grandiflorum* or *L. gueinzii* dominant in seepage areas, and *P. neriifolia* and *Leucadendron sessile* on moist slopes), but with patches of restioid and ericaceous fynbos in wetter areas. Waboomveld is very typical and very extensive within this unit.

Geology & Soils Cape Granite Suite rocks (Paardeberg, Paarl, Stellenbosch and Wellington Plutons). Soils usually of Glenrosa,

L. Mucina

Figure 4.94 FFg 2 Boland Granite Fynbos: Proteoid fynbos dominated by *Protea burchellii* and *Leucadendron salignum* below granite domes of the Paarl Mountain near Paarl (Western Cape).

Mispah forms, or red-yellow apedal. Freely draining soils are dominant, with exposed dome rock and large boulders. Land types mainly Fa, Ic and Ac.

Climate MAP 610–2 220 mm (mean: 985 mm), peaking from May to August. Mean daily maximum and minimum temperatures 26.6°C and 5.9°C for February and July, respectively. Frost incidence 2 or 3 days per year. The mean rainfall for this type is well below the 1 400 mm limit suggested by Campbell (1985) for fynbos on granite. Mists are common in winter. See also climate diagram for FFg 2 Boland Granite Fynbos (Figure 4.92).

Important Taxa ([T]Cape thickets, [W]Wetlands) Small Trees: *Protea nitida* (d), *Brabejum stellatifolium*[T], *Heeria argentea*[T], *Leucospermum conocarpodendron* subsp. *viridum*, *Podocarpus elongatus*[T]. Tall Shrubs: *Cliffortia cuneata* (d), *Diospyros glabra*[T] (d), *Euclea racemosa* subsp. *racemosa*[T] (d), *Leucadendron rubrum* (d), *Olea europaea* subsp. *africana*[T] (d), *Protea neriifolia* (d), *P. repens* (d), *Putterlickia pyracantha*[T] (d), *Rhus angustifolia*[T] (d), *R. laevigata*[T] (d), *Cassine schinoides*[T], *Chrysanthemoides monilifera*, *Cliffortia phillipsii*, *Cunonia capensis*[T], *Dodonaea viscosa* var. *angustifolia*, *Euryops abrotanifolius*, *Gymnosporia buxifolia*, *Halleria lucida*[T], *Maytenus acuminata*[T], *Montinia caryophyllacea*, *Myrsine africana*[T], *Passerina corymbosa*, *Podalyria myrtillifolia*, *Protea burchellii*, *Rapanea melanophloeos*[T], *Rhus glauca*[T], *R. lucida*[T], *R. tomentosa*[T], *Wiborgia obcordata*. Low Shrubs: *Anthospermum aethiopicum* (d), *Berzelia lanuginosa*[W] (d), *Brunia nodiflora* (d), *Cliffortia ruscifolia* (d), *Elytropappus rhinocerotis* (d), *Erica muscosa* (d), *E. plukenetii* subsp. *plukenetii* (d), *Eriocephalus africanus* var. *africanus* (d), *Helichrysum teretifolium* (d), *Leucadendron salignum* (d), *Osmitopsis asteriscoides*[W] (d), *Salvia lanceolata* (d), *Agathosma imbricata*, *A. serpyllacea*, *Aspalathus bracteata*, *A. elliptica*, *A. lebeckioides*, *Cliffortia dentata*, *Clutia pubescens*, *Erica abietina* subsp. *aurantiaca*, *E. hispidula*, *E. imbricata*, *E. sphaeroidea*, *Eriocephalus africanus* var. *paniculatus*, *Euclea tomentosa*[T], *Euphorbia genistoides*, *Euryops thunbergii*, *Helichrysum zeyheri*, *Hermannia cuneifolia*, *H. scabra*, *Leucadendron daphnoides*, *L. sessile*, *Microdon dubius*, *Muraltia decipiens*, *Otholobium obliquum*, *O. rotundifolium*, *Pelargonium tabulare*, *Phylica thunbergiana*, *Printzia polifolia*, *Protea acaulos*, *P. scorzonerifolia*, *Salvia africana-lutea, Serruria kraussii*, *Stoebe plumosa*, *Ursinia paleacea*, *Xiphotheca lanceolata*. Succulent Shrubs: *Aloe perfoliata*, *Antimima granitica*, *Lampranthus spiniformis*, *Tetragonia spicata*. Woody Climbers: *Asparagus scandens*, *Microloma sagittatum*, *Secamone alpini*, *Zygophyllum sessilifolium*. Semiparasitic Shrub: *Thesium funale*. Herbs: *Annesorhiza macrocarpa*, *Corymbium scabrum*, *Galium mucroniferum*, *Gazania ciliaris*, *Helichrysum crispum*, *Knowltonia vesicatoria*, *Lichtensteinia obscura*, *Mairia burchellii*, *Nemesia affinis*, *Polycarena capensis*, *Pseudoselago serrata*, *Senecio arenarius*, *Tripteris tomentosa*, *Wimmerella bifida*[W]. Geophytic Herbs: *Aristea capitata* (d), *Pteridium aquilinum* (d), *Blechnum australe*, *Bobartia indica*, *Cyphia phyteuma*, *Lachenalia aloides*, *Lapeirousia corymbosa*, *Moraea galaxia*, *Oxalis bifida*, *Romulea hirsuta*, *Rumohra adiantiformis*, *Spiloxene serrata*, *Trachyandra filiformis*, *Wachendorfia paniculata*, *Watsonia borbonica* subsp. *borbonica*, *Zantedeschia aethiopica*[W]. Herbaceous Climber: *Cynanchum africanum*. Graminoids: *Cymbopogon marginatus* (d), *Ehrharta calycina* (d), *E. villosa* var. *villosa* (d), *Elegia asperiflora* (d), *Ischyrolepis capensis* (d), *I. gaudichaudiana* (d), *Merxmuellera cincta* (d), *M. rufa* (d), *M. stricta* (d), *Restio filiformis* (d), *Tetraria fasciata* (d), *Aristida vestita*, *Cannomois virgata*, *Ehrharta ottonis*, *Eragrostis curvula*, *Ficinia indica*, *F. nigrescens*, *F. trichodes*, *Hyparrhenia hirta*, *Ischyrolepis sieberi*, *Neesenbeckia punctoria*, *Pentaschistis aristidoides*, *Platycaulos depauperatus*, *Schoenoxiphium ecklonii*, *S. lanceum*, *Tetraria bromoides*, *T. burmannii*, *T. sylvatica*, *Themeda triandra*, *Willdenowia incurvata*.

Endemic Taxa Tall Shrub: *Leucospermum grandiflorum*. Low Shrubs: *Aspalathus cephalotes* subsp. *cephalotes*, *A. stricticlada*, *Erica fausta*, *E. hippurus*, *E. lerouxiae*, *E. setosa*, *Leucospermum lineare*, *Lobostemon hottentoticus*, *Psoralea gueinzii*, *Pteronia centauroides*, *Serruria gracilis*, *Xiphotheca elliptica*. Succulent Shrubs: *Erepsia lacera*, *Lampranthus leptaleon*, *L. rupestris*, *Oscularia paardebergensis*. Herb: *Argyrolobium angustissimum*. Geophytic Herbs: *Babiana noctiflora*, *Ixia cochlearis*, *Lapeirousia azurea*, *Watsonia amabilis*. Succulent Herb: *Conophytum turrigerum*.

Conservation Endangered. Target 30%. Some 14% statutorily conserved in the Hawequas, Hottentots Holland and Paarl Mountain Nature Reserves, with a further 34% found in Hawequas, Hottentots Holland mountain catchment areas and Helderberg and Paardenberg Nature Reserves. More than half of the area has been transformed for vineyards, olive groves and pine plantations. Most common woody aliens include *Pinus pinaster, Hakea sericea* and *Acacia saligna*. Erosion very low and moderate.

Remark 1 Many species common to this unit are shared with FFh 5 Cape Winelands Shale Fynbos, to which this unit is closely related—the two share many endemics (e.g. *Leucadendron daphnoides*, *Leucospermum gueinzii*, *Serruria kraussii*). Although many species are shared, granite fynbos extends to lower rainfall than shale fynbos does (although the mean is higher due to higher relief of granite), so that species found in narrow, upper zones within shale fynbos are often quite widespread in granite fynbos.

Remark 2 Cape thicket and occasionally also forest patches occur within fire-protected sites against the granite outcrops, on sandstone rock-fall screes and in steeper river courses. Succulent and geophytic 'gardens' (*Oscularia* and *Crassula* are well represented here) are found on extensive granite domes and slabs which also support epilithic lichen flora.

References Adamson (1927), Duthie (1929), Acocks (1935), Rycroft (1953), Van der Merwe (1962, 1966), Werger et al. (1972a, b), Kruger (1979), Boucher (1983, 1987, 1988b, 1994a, 1996b, 1997a), McDonald (1985, 1987, 1988), Neethling (1986), Le Maitre (1987), Sieben (2003), N. Helme (unpublished data).

FFg 3 Peninsula Granite Fynbos

VT 69 Macchia (74%) (Acocks 1953). LR 64 Mountain Fynbos (53%) (Low & Rebelo 1996). BHU 55 Cape Peninsula Mountain Fynbos Complex (63%), BHU 12 Blackheath Sand Plain Fynbos (36%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Lower slopes on the Cape Peninsula from Lion's Head to Smitswinkel Bay almost completely surrounding Table Mountain, Karbonkelberg and Constantiaberg through to the Kalk Bay Mountains. South of the Fish Hoek gap, it is limited to the eastern (False Bay) side of the Peninsula from Simon's Bay to Smitswinkel Bay, with a few small patches between Fish Hoek and Ocean View. Altitude 0–450 m.

Vegetation & Landscape Features Steep to gentle slopes below the sandstone mountain slopes, and undulating hills on the western edge of the Cape Flats. Medium dense to open trees in tall, dense proteoid shrubland. A diverse type, dominated by asteraceous and proteoid fynbos, but with patches of *Restio* and ericaceous fynbos in wetter areas. Waboomveld is extensive in the north and heavily encroached by afrotemperate forest in places. South of Hout Bay, the dwarf form of *Protea nitida* is dominant, so that there are no emergent proteoids.

Figure 4.95 FFg 3 Peninsula Granite Fynbos: Ericaceous fynbos housing seven *Erica* species (with *E. ericoides* and *E. glabella* dominating) and *Pelargonium cucullatum* on the eastern slopes of Table Mountain in Kirstenbosch National Botanical Garden, Cape Town. A small, fire-protected grove of *Widdringtonia nodiflora* is visible in the background.

Groves of Silver Trees (*Leucadendron argenteum*) occur on the wetter slopes.

Geology & Soils Deep loamy, sandy soils, red-yellow apedal or Glenrosa and Mispah forms, derived from Cape Peninsula Pluton of the Cape Granite Suite. Land types mainly Ac, Fa and Bc.

Climate Typical winter-rainfall climate peaking from May to August. MAP 590–1 320 mm (mean: 960 mm). Mean daily maximum and minimum temperatures 26.0°C and 7.2°C for February and July, respectively. Frost incidence 2 or 3 days per year. The climate of this unit is almost identical to that of FFg 2 Boland Granite Fynbos, but shows a far stronger maritime influence. See also climate diagram for FFg 3 Peninsula Granite Fynbos (Figure 4.92).

Important Taxa ([T]Cape thickets, [W]Wetlands) Small Trees: *Brabejum stellatifolium*[T] (d), *Kiggelaria africana*[T] (d), *Leucadendron argenteum* (d), *Protea nitida* (d), *Widdringtonia nodiflora* (d), *Leucospermum conocarpodendron* subsp. *conocarpodendron*. Tall Shrubs: *Diospyros whyteana*[T] (d), *Leucadendron rubrum* (d), *Metalasia densa* (d), *Passerina corymbosa* (d), *Podalyria calyptrata* (d), *Protea coronata* (d), *P. lepidocarpodendron* (d), *Rhus lucida*[T] (d), *R. tomentosa*[T] (d), *Cassine peragua* subsp. *peragua*[T], *Chrysanthemoides monilifera*, *Euryops abrotanifolius*, *Montinia caryophyllacea*, *Myrsine africana*[T], *Psoralea aphylla*, *P. pinnata*[W], *Putterlickia pyracantha*[T], *Rhus laevigata*[T]. Low Shrubs: *Cliffortia stricta* (d), *Elytropappus gnaphaloides* (d), *E. rhinocerotis* (d), *Erica hirtiflora* (d), *E. plukenetii* subsp. *plukenetii* (d), *Leucadendron salignum* (d), *L. xanthoconus* (d), *Stoebe cinerea* (d), *Anthospermum aethiopicum*, *Aspalathus astroites*, *Berzelia lanuginosa*[W], *Brunia nodiflora*, *Cliffortia drepanoides*, *C. ruscifolia*, *Clutia polifolia*, *Erica baccans*, *E. ericoides*, *E. mauritanica*, *Eriocephalus racemosus*, *Euryops pinnatipartitus*, *Felicia aethiopica*, *Heliophila callosa*, *Maytenus oleoides*[T], *Morella quercifolia*, *Osteospermum ciliatum*, *Otholobium fruticans*, *Pelargonium cucullatum*, *Penaea mucronata*, *Phylica imberbis*, *Psoralea lucida*, *Stilbe vestita*, *Stoebe alopecuroides*, *S. fusca*, *Trichocephalus stipularis*. Semiparasitic Shrub: *Osyris compressa*. Herbs: *Edmondia sesamoides*, *Pseudoselago spuria*. Geophytic Herbs: *Aristea bakeri* (d), *A. capitata* (d), *Pteridium aquilinum* (d), *Amaryllis belladonna*, *Geissorhiza pusilla*, *Romulea cruciata*. Graminoids: *Cannomois virgata* (d), *Ischyrolepis eleocharis* (d), *I. gaudichaudiana* (d), *Mastersiella digitata* (d), *Restio triticeus* (d), *Cymbopogon marginatus*, *Elegia racemosa*, *Ficinia angustifolia*, *F. filiformis*, *F. oligantha*, *Hypodiscus albo-aristatus*, *Restio filiformis*, *Thamnochortus erectus*.

Endemic Taxa Low Shrubs: *Cliffortia carinata*, *Gnidia parvula*, *Hermannia micrantha*, *Leucadendron grandiflorum*. Succulent Shrubs: *Erepsia patula*, *Lampranthus curvifolius*. Herb: *Polycarena silenoides*. Geophytic Herb: *Aristea pauciflora*. Graminoid: *Willdenowia affinis*.

Conservation Endangered. Target 30%. Conserved in the Table Mountain National Park as well as on the premises of the Kirstenbosch National Botanical Garden. However, much of the conserved fynbos has been transformed into afrotemperate forest due to fire protection policies at Orangekloof and Kirstenbosch and a reluctance to use fire in green belts and on the urban fringe. The effective fynbos area conserved is thus much lower. A total of 56% transformed, mostly Cape Town urban areas (40%) on low-lying flat areas, including vineyards and pine plantations (13%). The most common alien woody species include *Acacia melanoxylon*, *Pinus pinaster* and numerous other more localised invasive alien species, reflecting the long history of colonisation and the relatively fertile soils. Erosion is very low.

Remarks Although well studied, published knowledge is largely confined to Kirstenbosch and Orangekloof. There are almost no data for the eastern and northern slopes of Table Mountain, and none for the area south of Constantia Neck. The northern tip of this unit was visited by the much venerated Charles Darwin in 1844 at the point of contact of the granite with the neighbouring shale.

References Adamson (1925, 1927, 1935), McKenzie (1976), McKenzie et al. (1977), Jeffrey & Wilson (1987), Tritton (1992), Lotz (1993), Simmons (1996).

FFg 4 Robertson Granite Fynbos

VT 69 Macchia (56%) (Acocks 1953). Central Mountain Renosterveld (57%) (Moll & Bossi 1983). LR 61 Central Mountain Renosterveld (58%) (Low & Rebelo 1996). BHU 38 Ashton Inland Renosterveld (58%), BHU 64 Southern Langeberg Mountain Fynbos Complex (26%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Confined to southern foothills of the Langeberg, namely the higher parts of Tierberg northwest of Robertson and the Langeberg from the Kabous River at Bergenheim to Bakoondshoogte west of Swellendam. Altitude 250–400 m for the belt near Swellendam, and 550–949 m at Graanpunt, the summit of Tierberg.

Vegetation & Landscape Features Steep, undulating hills covered with a dense proteoid shrubland, or shrubland with high grass cover. Structurally it is mostly graminoid and proteoid fynbos.

Geology & Soils Deep loamy sands, Glenrosa and Mispah forms, derived from Cape Granites (Robertson and Dassenheuwel Plutons of Cambrian age). Land types mainly Fb and Fa.

Climate MAP 190–1 000 mm (mean: 505 mm), peaking from May to August. Mean daily maximum and minimum temperatures 27.8°C and 4.0°C for January–February and July, respectively. Frost incidence 5–10 days per year. See also climate diagram for FFg 4 Robertson Granite Fynbos (Figure 4.92).

Important Taxa Tall Shrubs: *Protea neriifolia* (d), *Euryops abrotanifolius*, *Leucadendron eucalyptifolium*, *L. rubrum*, *Metalasia densa*. Low Shrubs: *Anthospermum galioides* subsp. *galioides* (d), *A. spathulatum* subsp. *spathulatum* (d), *Hermannia alnifolia* (d), *Athanasia trifurcata*, *Cliffortia erectisepala*, *Clutia marginata*, *Erica plukenetii* subsp. *plukenetii*, *E. setacea*, *Eriocephalus africanus* var. *africanus*, *Gnidia laxa*, *Leucadendron salignum*, *L. spissifolium* subsp. *spissifolium*, *Muraltia ericaefolia*, *Protea nitida* (dwarf form). Herb: *Berkheya armata*. Graminoids: *Ehrharta calycina* (d), *E. thunbergii* (d), *Merxmuellera stricta* (d), *Themeda triandra* (d).

Conservation Least threatened. Target 30%. About 2% statutorily conserved in the Dassieshoek Nature Reserve as well as (about 39%) in Langeberg-wes mountain catchment area. More than 10% already transformed for cultivation (pastures and vineyards). Aliens *Acacia saligna* and *Pinus pinaster* are of local concern. Erosion moderate and very low.

Remarks This is an almost completely unknown, isolated unit, conspicuous from afar because of its grassy nature. An additional small area in the Riviersonderend Mountains southwest of Pilaarkop, classified as FFh 7 Greyton Shale Fynbos, is also on Cape Granite, but it is predominantly covered by afrotemperate forest. The two areas share curious disjunct populations of *Leucospermum formosum*, but in both cases this species occurs on the shales adjacent to these patches.

Reference N. Helme (unpublished data).

FFg 5 Garden Route Granite Fynbos

VT 46 Coastal Renosterbosveld (70%) (Acocks 1953). South Coast Renosterveld (22%) (Moll & Bossi 1983). LR 2 Afromontane Forest (67%) (Low & Rebelo 1996). BHU 100 Knysna Afromontane Forest (64%), BHU 28 Blanco Fynbos/Renosterveld Mosaic (36%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Garden Route—three main blocks south of the Outeniqua Mountains on the coastal plain from Botterberg west of Brandwaghoogte (south of Robinson Pass) to Groot Brak River; the largest block from Groot Brak River to Woodfield near the Wilderness (with a few strips along the coast from Bothastrand to the Wilderness); lastly, north of the lakes from Woodville to Hoogekraal Pass, west of Karatara. Altitude 0–300 m.

Vegetation & Landscape Features Moderately undulating plains and undulating hills on the coastal forelands. Dense proteoid and ericoid shrubby grassland. Proteoid and graminoid fynbos are dominant with ericaceous fynbos in seeps. In the west, most remnants of this type are dominated by proteas. Eastwards graminoid and ericaceous fynbos are dominant on the flat plateaus, with proteas confined to the steep slopes.

Geology & Soils George Batholith of the Cape Granite Suite. Deep, prismacutanic- and pedocutanic-dominated soils typical of Db land types (mainly).

Climate MAP 350–880 mm (mean: 600 mm), with a slight low in early winter. Mean daily maximum and minimum temperatures 27.8°C and 6.8°C for January–February and July, respectively. Frost incidence 2 or 3 days per year. See also climate diagram for FFg 5 Garden Route Granite Fynbos (Figure 4.92).

Important Taxa Tall Shrubs: *Passerina corymbosa* (d), *Cliffortia serpyllifolia*, *Protea coronata*, *P. lanceolata*, *P. neriifolia*. Low Shrubs: *Erica discolor* variant '*speciosa*' (d), *E. peltata* (d), *Phylica confusa* (d), *Syncarpha paniculata* (d), *Agathosma ovata*, *Anthospermum prostratum*, *Aspalathus asparagoides*, *Cliffortia falcata*, *Cullumia bisulca*, *Erica canaliculata*, *E. diaphana*, *E. formosa*, *Eriocephalus africanus*, *Hermannia angularis*, *Leucadendron salignum*, *Lobelia tomentosa*, *Metalasia pungens*, *Mimetes cucullatus*, *Pelargonium fruticosum*, *Relhania calycina*. Succulent Shrub: *Lampranthus sociorum*. Semiparasitic Shrubs: *Osyris compressa*, *Thesium virgatum*. Semiparasitic Epiphytic Shrub: *Viscum capense*. Geophytic Herb: *Schizaea pectinata*. Graminoids: *Tetraria cuspidata* (d), *Brachiaria serrata*, *Eragrostis capensis*, *Ficinia nigrescens*, *Heteropogon contortus*, *Pentaschistis eriostoma*, *Restio triticeus*, *Themeda triandra*.

Conservation Endangered. Target 23%. Only about 1% conserved in the proposed Garden Route National Park. About 70% has been transformed for cultivation (56%), pine plantations (7%) and by urban development (6%). Remnants are largely confined to isolated pockets on steeper slopes. Erosion moderate and high. Very few patches of this type remain in a pristine condition as most of it has been converted to pasture by liming, bush-cutting and frequent burning, and augmented with pasture grasses. Western remnants suggest that proteoid fynbos might have been dominant historically. It is easily converted to graminoid fynbos by regular fires and augmentation with pasture grasses.

References Drews (1980b), Hoare et al. (2000).

L. Mucina

Figure 4.96 FFg 5 Garden Route Granite Fynbos: Regenerating asteraceous fynbos on granite, with *Passerina glomerata*, *Phylica confusa*, *Syncarpha paniculata* and *Relhania calycina* on the southern Cape coast at Herolds Bay near George (Western Cape).

9.1.9 Limestone Fynbos

Limestone fynbos is a coherent edaphic unit floristically very different from the other fynbos vegetation. Even at detailed scales, limestone fynbos shares very few species with sandstone fynbos, and only a few with sand fynbos. Although intermediate communities do exist where neutral sand overlies limestone, the vegetation

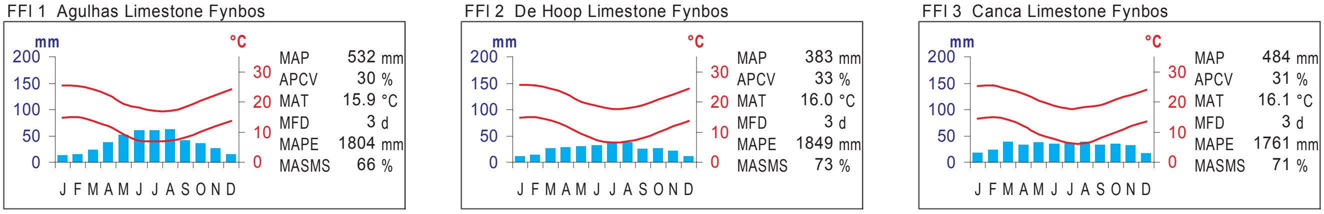


Figure 4.97 Climate diagrams of limestone fynbos units. Blue bars show the median monthly precipitation. The upper and lower red lines show the mean daily maximum and minimum temperature respectively. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days (days when screen temperature was below 0°C); MAPE: Mean Annual Potential Evaporation; MASMS: Mean Annual Soil Moisture Stress (% of days when evaporative demand was more than double the soil moisture supply).

boundaries are usually marked and in the order of less than a metre. Typically, however, the adjacent vegetation types are of similar structural types, even though they are floristically distinct. Many sister taxa exist across the boundaries—as exemplified by the Proteaceae genera *Protea* (*P. obtusifolia* on limestone, *P. susannae* on neutral sands, *P. compacta* on acid sands—all sister species), *Leucadendron* (*L. meridianum* on limestone, the unrelated *L. coniferum* or *L. galpinii* on neutral sands west and east of De Hoop Vlei, respectively, and *L. eucalyptifolium* or *L. xanthoconus* on acid sands), and *Leucospermum* (*L. truncatum* on limestone, *L. fulgens* and *L. praecox* on neutral sands—phylogenetically all sister species). Similar patterns exist in other plant families. Structurally, the limestone fynbos is dominated by asteraceous, restioid and proteoid fynbos. Graminoid and ericaceous fynbos structural types are largely absent. It has been proposed that limestone fynbos is a young unit, having evolved on sediments deposited during marine incursions in the Plio-Pleistocene and that endemic species must therefore be derived. During the period characterised by lower sea levels, the area of limestone would have been far larger—extending as far as 90 m below the current sea level and 200 km further south.

Limestone fynbos is restricted to the South Coast, with minor outliers at Cape Point and Macassar, reaching its greatest expanse from Agulhas to Mossel Bay. Similar limestone hills along the West Coast contain only strandveld communities—all markedly succulent and not able to support fire. Thus the high endemism and diversity of limestone on the South Coast have no analogue on the West Coast. However, the lack of deep acid sands means that sand fynbos is not nearly as extensive on the South Coast as on the West. The South Coast is characterised by more neutral sands. Succulent communities occur only on the littoral fringe along the South Coast, except where dune fields and raised platform topography retard the spread of fire.

Although limestone fynbos is a very distinct type, rich in endemic species and sharing very few species with other fynbos types, based on the distribution of endemic species, it can be divided into three natural units separated by gaps at Bredasdorp (a flat shale incursion) and Witsand (the Breede River flats).

The mapped extent of limestone and sand fynbos within the limestone fynbos area is not accurate. Only larger expanses of sand are mapped geologically, whereas even shallow (< 0.25 m deep) neutral sands are enough to displace limestone fynbos species completely and replace them with sand fynbos communities. While these communities are floristically distinct, some communities are structurally identical and cannot be distinguished on satellite images or aerial photographs. Therefore it is not possible to map the two types accurately at this stage. Small limestone lenses at Onrus, Hangklip, Macassar, Wolfgat and Cape Point were not mapped. Brief descriptions of these areas are found in Britton (1972), Taylor (1972b, 1983, 1984b), Low (1989) and Privett (1998). West of Hermanus, proper limestone communities do not seem to occur on the small outcrops present. Although these are spatially well defined, they do not appear to contain most of the characteristic limestone species, having depauperate, if distinct, sand fynbos communities.

Limestone fynbos contains all structural types of fynbos, determined primarily by slope and soil depth. Restioid fynbos and *Leucadendron muirii* proteoid fynbos occur on skeletal soils and limestone pavements. *Protea obtusifolia–Leucadendron meridianum* proteoid and scrub fynbos occur on deeper soils, with asteraceous fynbos on the drier northern slopes and ericaceous fynbos restricted to a few higher-altitude southern facies. The interface of sand and limestone fynbos often contains stands of Cape thicket, presumably relating to availability of water and fire protection where limestone outcrops form steeper slopes. Similarly, old sink holes (filled with a sand base) and shafts (leading to caves) are usually fringed with thicket elements, especially *Sideroxylon inerme*. Where rivers have deposited silt on the limestone, even in very thin layers, renosterveld elements become dominant. These are extremely localised and have not been mapped. A prime example of such 'limestone renosterveld' is found in De Hoop Nature Reserve (just south of the headquarters). Similarly, the areas of Bokkeveld shale that were covered by calcretes washed from the limestone have all been ploughed up (except for thicker expanses which are either limestone fynbos or, where protected from fire, have become thicket stands) and the nature of original vegetation types remains uncertain. These have been mapped as renosterveld.

FFl 1 Agulhas Limestone Fynbos

VT 47 Coastal Macchia (75%) (Acocks 1953). South Coast Strandveld (38%), Mesic Mountain Fynbos (27%) (Moll & Bossi 1983). LR 67 Limestone Fynbos (40%), LR 64 Mountain Fynbos (27%) (Low & Rebelo 1996). BHU 15 Hagelkraal Limestone Fynbos (44%), BHU 6 Agulhas Fynbos/Thicket Mosaic (25%), BHU 13 Springfield Sand Plain Fynbos (25%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Agulhas Plain from the vicinity of Hermanus to Bredasdorp and Struisbaai. The largest expanses of limestone are found between the Klein River Lagoon and Grootbos, around Hagelkraal, Heuningrug and Soetanysberg. Some unmapped outliers occur at Hangklip, Macassar (False Bay) and Buffels Bay (Cape Peninsula). The most southerly patch of the unit extends to within 300 m of the southern tip of Africa. Altitude 20–400 m, with some patches found at 500 m.

Vegetation & Landscape Features Low hills in plains, fragmented on the coastal margin of the Agulhas coastal forelands. Mainly on the plains, but with significant patches at higher altitudes such as on Soetanysberg. Moderately dense, low shrublands contain tall, emergent proteoids. Structurally it is mainly asteraceous and proteoid fynbos, with restioid fynbos in sandy areas and on limestone pavements. Wetter areas, such as waterlogged bottomlands, are dominated by *Leucadendron linifolium* restioid fynbos, grading to FFd 7 Agulhas Sand Fynbos where sands become deeper.

Geology & Soils Shallow alkaline bedrock and alkaline, grey, regic sands on limestones of the Bredasdorp Formation. Land types mainly Hb, Db and Fa.

Climate MAP 410–660 mm (mean: 530 mm), peaking slightly from June to August. This is the wettest of all the limestone fynbos units. Mean daily maximum and minimum temperatures 25.5°C and 7.0°C for January and July, respectively. Frost incidence about 3 days per year. See also climate diagram for FFl 1 Agulhas Limestone Fynbos (Figure 4.97).

Important Taxa Tall Shrubs: *Chrysanthemoides monilifera*, *Protea obtusifolia*. Low Shrubs: *Leucadendron meridianum* (d), *L. muirii* (d), *Leucospermum truncatum* (d), *Adenandra obtusata*, *Aspalathus calcarea*, *A. pinguis* subsp. *australis*, *Erica propinqua*, *E. regia* subsp. *mariae*, *Euryops hebecarpus*, *Helichrysum dasyanthum*, *Indigofera brachystachya*, *Metalasia calcicola*, *Morella quercifolia*, *Passerina paleacea*, *Phylica ericoides*, *Wahlenbergia tenella*. Herb: *Ursinia tenuifolia* subsp. *ciliaris*. Geophytic Herb: *Freesia leichtlinii*. Graminoids: *Elegia microcarpa* (d), *Ficinia lateralis*, *F. truncata*, *Ischyrolepis leptoclados*, *Pentaschistis calcicola*, *P. pallida*, *Thamnochortus guthrieae*, *T. lucens*, *T. paniculatus*, *T. pluristachyus*.

Endemic Taxa Tall Shrubs: *Leucospermum patersonii* (d), *Erica magnisylvae*, *Mimetes saxatilis*. Low Shrubs: *Adenandra odoratissima*, *Agathosma abrupta*, *A. florulenta*, *A. paralia*, *A. sedifolia*, *Aspalathus aciloba*, *Diosma arenicola*, *D. awilana*, *D. demissa*, *D. guthriei*, *D. haelkraalensis*, *Erica aghillana*, *E. arenaria*, *E. calcareophila*, *E. excavata*, *E. glabella* subsp. *laevis*, *E. gracilipes*, *E. irregularis*, *E. occulta*, *E. pulvinata*, *E. saxicola*, *Felicia canaliculata*, *Indigofera hamulosa*, *Lobelia barkerae*, *Metalasia umbelliformis*, *Muraltia calycina*, *M. lewisiae*, *Osteospermum australe*, *Phylica selaginoides*, *Selago prostrata*, *Spatalla ericoides*. Succulent Shrubs: *Braunsia vanrensburgii*, *Delosperma mariae*, *Erepsia dunensis*. Herbs: *Centella gymnocarpa*, *Polygala dasyphylla*. Geophytic Herbs: *Cyrtanthus fergusoniae*, *Gladiolus miniatus*, *G. variegatus*, *Hesperantha juncifolia*. Succulent Herb: *Dorotheanthus ulularis*. Graminoids: *Hypodiscus procurrens*, *Thamnochortus fraternus*, *Tribolium ciliare*.


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Figure 4.98 FFl 1 Agulhas Limestone Fynbos: Shrubland with prominent orange-flowered *Leucospermum patersonii* (endemic to the vegetation unit), between Pearly Beach and Buffelsjags (Western Cape).

Conservation Least threatened. Target 32%. Statutorily conserved (8%) especially in the Agulhas National Park (small patches also in Kogelberg Biosphere Reserve, Table Mountain National Park and Wolfgat Nature Reserve), with a further 4% protected in private conservation areas such as Groot Hagelkraal and Oude Bosch. Only 5% has been transformed for cultivation and by urban development. Woody aliens *Acacia cyclops*, *A. saligna* and *Leptospermum laevigatum* are of conservation concern. Erosion very low and low.

Remark 1 Compared to the other two areas of limestone fynbos, this is the smallest but the most diverse. Given the lack of distinct structural types recorded in this vegetation, the floristic diversity is astounding.

Remark 2 In fire-safe habitats, such as depressions and on calcrete ridges, milkwood forests occur (Cowling et al. 1988, Von Maltitz et al. 2003).

References Boucher (1972, 1977, 1978, 1994b, 1995, 1997d), Kruger (1979), Cowling et al. (1988), Thwaites & Cowling (1988), Cowling (1990a, b), Heydenrych (1994), Richards (1994), Richards et al. (1995, 1997a, b), Willis & Cowling (1996), Willis et al. (1996), Mustart et al. (1997).

FFl 2 De Hoop Limestone Fynbos

VT 47 Coastal Macchia (95%) (Acocks 1953). Limestone Fynbos (91%) (Moll & Bossi 1983). LR 67 Limestone Fynbos (91%) (Low & Rebelo 1996). BHU 16 De Hoop Limestone Fynbos (87%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Broad swathe on the coastal forelands from Struisbaai and Bredasdorp to Infanta at the Breede River Mouth, remaining seawards of the Potberg and including the hills of Bobbejaanskrans and Voëlneskrans north of De Hoop Vlei. Altitude 20–240 m.

Vegetation & Landscape Features An inland range of hills, with plains and moderately undulating plains on the seaward foreland, in places dotted with karstic sinkholes and dry valleys (poljes). Some of the depressions can be longer than 2 km. Structurally it is mainly asteraceous and proteoid fynbos, with restioid fynbos in sandy areas. These areas were converted to grazing lawns in formerly disturbed (ploughed) areas currently with high game concentrations. Neutral to acid sands support FFd 7 Agulhas Sand Fynbos and FFd 9 Albertinia Sand Fynbos. Extensive skeletal calcrete over shale on the inland border may once also have held limestone fynbos or renosterveld ecotone communities, but these have all been converted to pasture and wheatland, and their vegetation was not documented before their conversion.

Geology & Soils Shallow, alkaline to neutral sand and bedrock, Glenrosa and Mispah forms on limestone of the Bredasdorp Formation. Topographically with less variegated relief than in the other limestone fynbos units, characterised by distinctive karstic valleys, sinkhole depressions and caves. Land types mainly Fc, Ib and Ic.

Climate MAP 250–530 mm (mean: 385 mm), peaking slightly in autumn and

L. Mucina

Figure 4.99 FFl 2 De Hoop Limestone Fynbos: Species-rich proteoid fynbos in De Hoop Nature Reserve (Overberg, Western Cape), with a prominent coastal limestone endemic *Leucadendron muirii* (left) and a local endemic *Metalasia calcicola* (Asteraceae).

Remark 1 Curiously, the boundary between two sand fynbos units (FFd 7 Agulhas Sand Fynbos and FFd 9 Albertinia Sand Fynbos) is De Hoop Vlei—not the Bredasdorp Gap as in the case of limestone fynbos units.

Remark 2 Fire-safe habitats such as steep krantzes support dense sclerophyllous thickets and small *Sideroxylon inerme* forest patches. Fire-safe sinkhole depressions have *Sideroxylon inerme* stands and occasionally dune thicket. These are sometimes converted to grazing lawns of creeping grass (mainly dominated by *Cynodon dactylon*) in areas of high antelope populations (bontebok, eland, rheebok) and zebras.

References Van der Merwe (1977a), Uys (1983), Heydenrych (1994), Willis & Cowling (1996), Willis et al. (1996), C. Boucher (unpublished data), L. Mucina (unpublished data).

winter with a low from December to February. This is the driest of the limestone fynbos types. Mean daily maximum and minimum temperatures 25.6°C and 6.6°C for January–February and July, respectively. Frost incidence about 3 days per year. See also climate diagram for FFl 2 De Hoop Limestone Fynbos (Figure 4.97).

Important Taxa Low Shrubs: *Leucadendron meridianum* (d), *L. muirii* (d), *Leucospermum truncatum* (d), *Metalasia calcicola* (d), *Passerina galpinii* (d), *Acmadenia densifolia*, *Adenandra obtusata*, *Agathosma serpyllacea*, *Aspalathus calcarea*, *A. incurvifolia*, *Asparagus capensis* var. *capensis*, *Erica propinqua*, *E. regia* subsp. *mariae*, *E. spectabilis*, *Euryops ericoides*, *E. hebecarpus*, *Metalasia erectifolia*, *Oedera squarrosa*, *Syncarpha canescens*, *Ursinia dentata*. Tall Shrubs: *Chrysanthemoides monilifera* (d), *Euryops linearis* (d), *Protea obtusifolia* (d), *P. lanceolata*. Herbs: *Cotula turbinata* (d), *Ursinia tenuifolia* subsp. *ciliaris*. Geophytic Herbs: *Cyanella lutea* (d), *Freesia leichtlinii*, *Haemanthus coccineus*, *Lachenalia muirii*, *Ledebouria ovalifolia*, *Neopatersonia uitenhagensis*, *Polyxena ensifolia*, *Strumaria squarrosa*. Graminoids: *Cynodon dactylon* (d), *Ficinia truncata* (d), *Thamnochortus paniculatus* (d), *Elegia microcarpa*, *Ficinia praemorsa*, *Ischyrolepis leptoclados*, *Pentaschistis calcicola*, *Thamnochortus erectus*, *T. guthrieae*, *T. lucens*, *T. pluristachyus*.

Endemic Taxa Low Shrubs: *Acmadenia mundiana*, *Argyrolobium harmsianum*, *Aspalathus pallescens*, *A. prostrata*, *Brachysiphon mundii*, *Cliffortia burgersii*, *Erica scytophylla*, *E. sperata*, *E. uysii*, *Euchaetis intonsa*, *Felicia ebracteata*, *Lobostemon daltonii*, *Pteronia diosmifolia*, *Sutera titanophila*. Herb: *Galium bredasdorpense*.

Conservation Least threatened. Target 32%. Statutorily conserved in De Hoop Nature Reserve (27%), with an additional 1% enjoying protection in the Andrewsfield Private Nature Reserve. Only 2% has been transformed (cultivation). Alien *Acacia cyclops* is dense in places. Erosion very low.

FFl 3 Canca Limestone Fynbos

VT 47 Coastal Macchia (91%) (Acocks 1953). Limestone Fynbos (63%) (Moll & Bossi 1983). LR 67 Limestone Fynbos (63%) (Low & Rebelo 1996). BHU 17 Canca Limestone Fynbos (56%) (Cowling et al. 1999b, Cowling & Heijnis 2001). STEP Stillbay Dune Thicket (26%) (Vlok & Euston-Brown 2002).

Distribution Western Cape Province: Coastal forelands from Witsand at the mouth of the Breede River to Mossel Bay, with narrow outliers close to the coast between Hartenbos and Groot Brak River. Furthest occurrence inland is at about 10 km south of Riversdale or roughly 25 km from the coast. Altitude 20–300 m.

Vegetation & Landscape Features A series of hills with parallel crests, sand-filled plains and undulating hills. Neutral and acid sands support FFd 9 Albertinia Sand Fynbos, which dominates the valleys and is far more extensive than in the other limestone fynbos units. This landscape is dominated by the Canca se Leegte and Wankoe depressions, with most of the limestone fynbos on the hill tops and ridges. This vegetation

L. Mucina

Figure 4.100 FFl 3 Canca Limestone Fynbos: Proteoid fynbos with *Protea obtusifolia* (foreground) and *Leucadendron meridianum* (background), on limestone ridges north of Still Bay (Western Cape).

has tall, emergent proteoids in a medium dense low shrubland—mainly asteraceous and proteoid fynbos, with restioid fynbos on skeletal soils. Communities east of the Gouritz River lack the proteoid overstorey and are poorer in species, with *Erica* particularly rare. Rutaceae are dominant and succulents and geophytes are more abundant, grading into succulent thicket on the coast. Local diversity east of the Gouritz River depends on the extent of limestone patches, with smaller outcrops lacking characteristic species.

Geology & Soils Shallow alkaline to neutral grey regic sands and Glenrosa and Mispah forms on limestone of the Bredasdorp Formation. Land types mainly Fc and Hb.

Climate MAP 310–630 mm (mean: 485 mm), relatively constant throughout the year, but with a low from December to February. Mean daily maximum and minimum temperatures 25.5°C and 6.3°C for February and July, respectively. A mild temperature regime, with frost incidence only about 3 days per year. This is a marginally warmer unit than the other two limestone fynbos units. See also climate diagram for FFl 3 Canca Limestone Fynbos (Figure 4.97).

Important Taxa ([T]Cape thickets) Tall Shrubs: *Protea obtusifolia* (d), *Chrysanthemoides monilifera*, *Erica prolata*, *Protea lanceolata*. Low Shrubs: *Erica spectabilis* (d), *Leucadendron meridianum* (d), *L. muirii* (d), *Acmadenia densifolia*, *A. obtusata*, *Agathosma muirii*, *Aspalathus alopecurus*, *A. calcarea*, *A. incurvifolia*, *A. sanguinea* subsp. *sanguinea*, *Chascanum cernuum*, *Diospyros dichrophylla*[T], *Erica regia* subsp. *mariae*, *E. vestita*, *Euryops ericoides*, *Indigofera zeyheri*, *Metalasia calcicola*, *Phylica pubescens* var. *orientalis*. Herb: *Osteospermum scariosum*. Geophytic Herb: *Freesia leichtlinii*. Graminoids: *Ischyrolepis leptoclados* (d), *Ceratocaryum argenteum*, *Elegia microcarpa*, *Ficinia truncata*, *Pentaschistis calcicola*, *Thamnochortus erectus*, *T. lucens*, *T. pluristachyus*.

Endemic Taxa Low Shrubs: *Aspalathus candidula*, *Athanasia cochlearifolia*, *Erica baueri* subsp. *gouriquae*, *E. platycalyx*, *Euryops muirii*, *Hermannia muirii*, *Lobostemon belliformis*, *Metalasia luteola*, *Muraltia barkerae*, *M. depressa*, *Oedera steyniae*. Succulent Shrubs: *Delosperma virens*, *Ruschia leptocalyx*. Herb: *Sutera placida*. Geophytic Herb: *Tritonia squalida*. Succulent Herb: *Haworthia mirabilis* var. *paradoxa*.

Conservation Least threatened. Target 32%. Only very small portion statutorily conserved in the Pauline Bohnen and Geelkrans Nature Reserves, with an additional 3% protected in private reserves such as Rein's Coastal (Gouriqua), Stilbaai Fynbos, Die Duine, Mosselbankfontein and Annet. Some 14% has already been transformed, mainly for cultivation. Aliens *Acacia cyclops* and *A. saligna* are common. Erosion is very low.

Remarks Fire-safe habitats such as depressions and limestone ridges support Cape Milkwood Forests (see Von Maltitz et al. 2003), often with notably darker soils and extending well into the sandy soils. *Protea lanceolata* is a marked dominant in wetter areas and in ecotones, with dune thicket patches away from the coast. West of Blombos a small transitional form between *Leucospermum praecox* and *L. truncatum* is as much at home in the limestone as in the sand fynbos. There are still remnants of the shallow calcretes over shale north of the limestone deposits (not mapped). These do bear limestone fynbos, but more often have thicket communities, but this may be due to conversion of the veld into pasture and wheatlands, with only thicker calcretes remaining and protected from fire.

References Muir (1929), Rebelo et al. (1991), Heydenrych (1994), Boucher & Rode (1995a, b), Willis & Cowling (1996), Willis et al. (1996), Boucher (1998c).

9.2 Renosterveld

Renosterveld vegetation occupies 29% of the area of the Fynbos Biome and 25% of the area of the CFR. By far most renosterveld vegetation units (86%) occur on shale, but it can be found on any substrate except sandstone and quartzite (on which it may be found locally where there are overlying remnants of shale or colluvial clay layers).

9.2.1 Shale Renosterveld

Shale renosterveld is the predominant renosterveld group, accounting for 86% of the area of renosterveld. Renosterveld, unlike fynbos, extends beyond the Fynbos Biome on the Cape Fold Belt onto the karoo shales, where rainfall patterns allow a high grass cover (chiefly *Merxmuellera stricta*) and abundance of nonsucculent shrubs such as *Elytropappus rhinocerotis*. Affinities are more with neighbouring karoo types than with other renosterveld types, which show strong affinities to their neighbouring fynbos types, especially regarding geophytes. Within the classical Fynbos Biome, shale renosterveld accounts for 90% of the area of renosterveld.

Low & Rebelo (1996) mapped an extensive patch of renosterveld in the Spektakelberg Pass area on the Escarpment west of Springbok in northern Namaqualand. Surrounded by the unique and endemic-rich SKn 2 Namaqualand Shale Shrubland, some renosterbos-dominated shrublands do occur here on the exposed edge of the Escarpment (see Van Jaarsveld & Koutnik 2004, p. 54), probably linked to more frequent fog precipitation and possibly also orographic rain in the region. Low & Rebelo's coverage (see above) is too extensive and comprises much of the succulent shrubland on shale as well. Due to lack of adequate field data, we have mapped this area as part of SKn 2 Namaqualand Shale Shrubland pending better data.

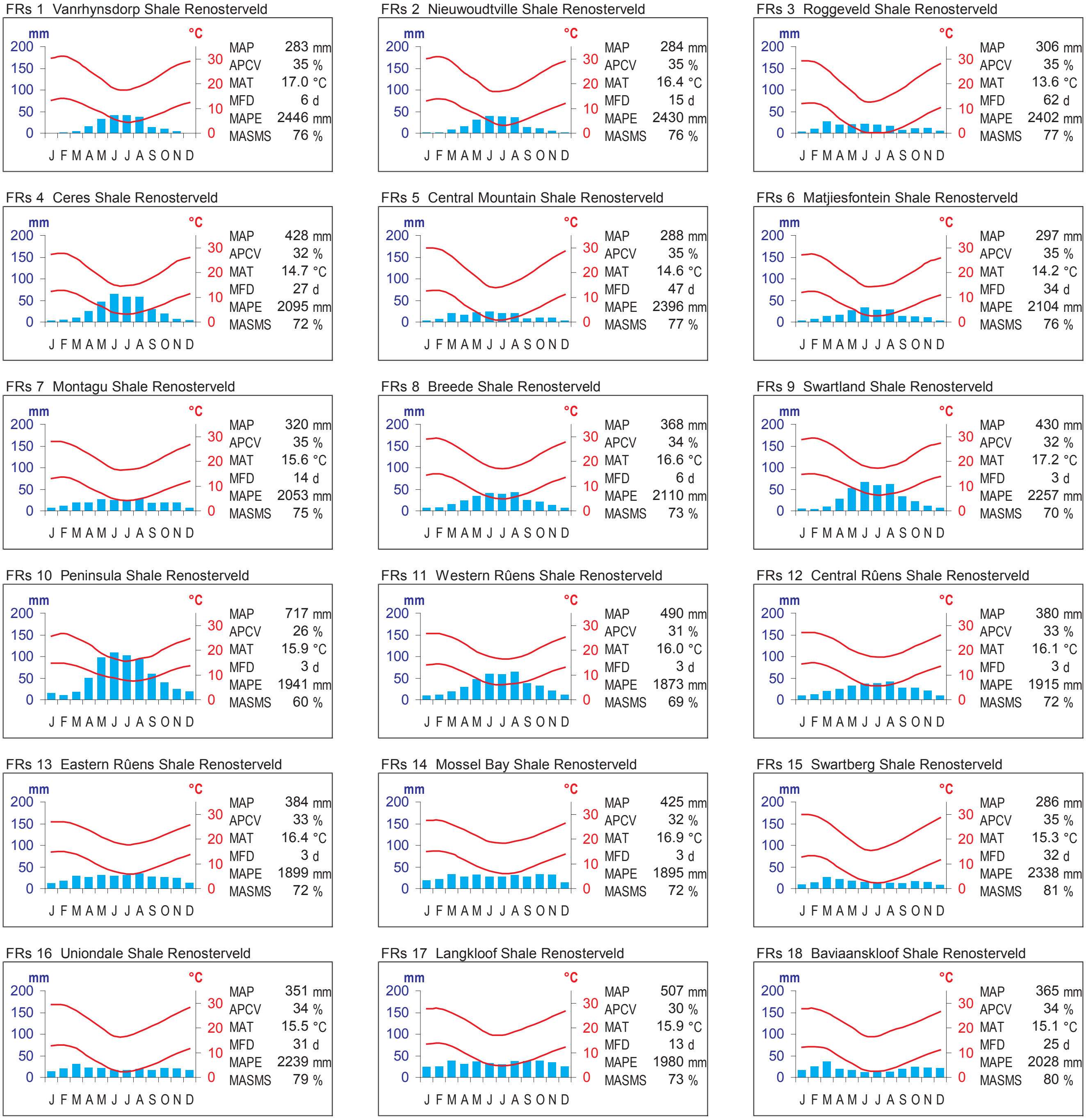
FRs 1 Vanrhynsdorp Shale Renosterveld

VT 69 Macchia (56%), VT 28 Western Mountain Karoo (32%), VT 31 Succulent Karoo (12%) (Acocks 1953). Dry Mountain Fynbos (58%), Mesic Mountain Fynbos (32%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (92%) (Low & Rebelo 1996). BHU 45 Bokkeveld Mountain Fynbos Complex (75%), BHU 46 Gifberg Mountain Fynbos Complex (16%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Northern and Western Cape Provinces: Below generally west- and north-facing sandstone cliffs of the Bokkeveld Escarpment and Matsikamma Mountains from Die Toring north of Van Rhyns Pass to the Gifberge near Klawer. Also extensive in internal valleys of the Koebee in the area of the confluence of the Oorlogs River and the Klein Kobee River. Altitude 150–880 m.

Vegetation & Landscape Features Valley bottoms and steep slopes below often sheer sandstone cliffs, supporting moderately tall, cupressoid-leaved shrublands dominated by renosterbos. Geophytes and annuals are common and conspicuous in spring. In some areas, transitional to Succulent Karoo shrublands, extensive *Montinia caryophyllacea* stands occur (see SKs 13 Klawer Sandy Shrubland).

Geology & Soils Clays and clayey loams primarily derived from mudstone and siltstone of the Knersvlakte Subgroup (Vanrhynsdorp Group) and schist and phyllite of the older Gariep Supergroup (last two are of Namibian Erathem). Soils are primarily of Glenrosa and Mispah form, closely associated with quartzite and shale of Nardouw Subgroup (Table Mountain Group) forming neighbouring cliffs and screes. Land types mainly Fa and Ib.



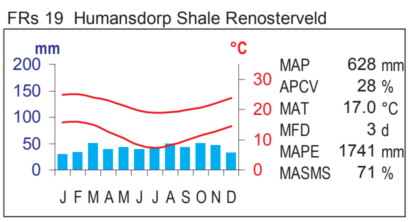


Figure 4.101 Climate diagrams of shale renosterveld units. Blue bars show the median monthly precipitation. The upper and lower red lines show the mean daily maximum and minimum temperature respectively. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days (days when screen temperature was below 0°C); MAPE: Mean Annual Potential Evaporation; MASMS: Mean Annual Soil Moisture Stress (% of days when evaporative demand was more than double the soil moisture supply).

Climate MAP 180–450 mm (mean: 285 mm), peaking from May to August. Mean daily maximum and minimum temperatures 31.2°C and 4.4°C for February and July, respectively. Frost incidence 3–10 days per year. See also climate diagram for FRs 1 Vanrhynsdorp Shale Renosterveld (Figure 4.101).

Important Taxa Tall Shrubs: *Dodonaea viscosa* var. *angustifolia* (d), *Montinia caryophyllacea* (d), *Nylandtia scoparia* (d), *Rhus incisa* (d), *Diospyros austro-africana*, *D. glabra*[T], *Halleria lucida*[T], *Maytenus acuminata*, *Olea europaea* subsp. *africana*, *Wiborgia sericea*. Low Shrubs: *Berkheya fruticosa* (d), *Elytropappus rhinocerotis* (d), *Helichrysum revolutum* (d), *Passerina truncata* subsp. *truncata* (d), *Pteronia pallens* (d), *Amphiglossa tomentosa*, *Anthospermum spathulatum* subsp. *spathulatum*, *Asparagus capensis* var. *capensis*, *Eriocephalus africanus* var. *africanus*, *E. microphyllus* var. *pubescens*, *Felicia dubia*, *Galenia africana*, *Helichrysum cylindriflorum*, *Maytenus oleoides*, *Pelargonium praemorsum*, *Pharnaceum dichotomum*, *Pteronia paniculata*, *Struthiola leptantha*. Succulent Shrubs: *Didelta spinosa* (d), *Euphorbia burmannii* (d), *E. loricata*, *E. mauritanica*, *Othonna* *coronopifolia*, *Tylecodon paniculatus*, *T. wallichii* subsp. *wallichii*. Woody Climber: *Secamone alpini*. Herbs: *Cotula bipinnata*, *Dimorphotheca pluvialis*, *Gorteria diffusa* subsp. *diffusa*, *Nemesia anisocarpa*, *Osteospermum pinnatum*, *Plantago cafra*, *Rhynchopsidium pumilum*, *Ursinia cakilefolia*. Geophytic Herb: *Oxalis purpurea*. Succulent Herbs: *Tetragonia hirsuta*, *T. robusta* var. *psiloptera*. Herbaceous Climber: *Cyphia angustifolia*. Graminoids: *Ehrharta thunbergii* (d), *Stipa capensis* (d), *Ehrharta barbinodis*, *E. longiflora*, *E. ramosa* subsp. *aphylla*, *Pentaschistis patula*, *Schismus barbatus*, *Tribolium echinatum*.

Endemic Taxon Geophytic Herb: *Eriospermum minutipustulatum*.

Conservation Least threatened. Target 27%. Statutorily conserved (4%) in the Oorlogskloof Nature Reserve. About 2% transformed (cultivation). Erosion very low and moderate.

Remarks This unit is distinct from FRs 2 Nieuwoudtville Shale Renosterveld primarily by the lack of endemic geophytes characteristic of the latter, but also by abundant succulents found in this vegetation at the lower transitions towards the Succulent Karoo shrublands. Vanrhynsdorp Shale Renosterveld and FFs 1 Bokkeveld Sandstone Fynbos share a number of regional endemics, such as *Athanasia leptocephala* and *Podalyria pearsonii*. Fynbos and Cape thicket communities occur on the scree and talus cones at the base of the sandstone cliffs, but these have not been mapped.

References Van Jaarsveld (1982), N. Helme (unpublished data).

Figure 4.102 FRs 2 Nieuwoudtville Shale Renosterveld: Shale outcrops with traces of Permian glacial activity (striae) surrounded by shrublands (*Elytropappus*, *Eriocephalus*, *Hermannia*) and herblands dominated by annual and geophytic spring flora (*Felicia*, *Geissorhiza*, *Lapeirousia*, *Lachenalia*, *Leysera*, *Ursinia* etc.) south of Nieuwoudtville (Bokkeveld, Northern Cape).

FRs 2 Nieuwoudtville Shale Renosterveld

VT 28 Western Mountain Karoo (83%) (Acocks 1953). Mosaic of Dry Mountain Fynbos & Karroid Shrublands (93%) (Moll & Bossi 1983). LR 56 Upland Succulent Karoo (91%) (Low & Rebelo 1996). BHU 35 Nieuwoudtville Inland Renosterveld (57%), BHU 75 Western Mountain Vygieveld (34%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Northern Cape Province: Bokkeveld Plateau at Nieuwoudtville extending in a 1–4 km wide strip 13 km south of Boererus on the Oorlogskloof River near Papkuilsfontein and almost 20 km north of Nieuwoudtville in the vicinity of Kleinplaas. Altitude 600–850 m.

Vegetation & Landscape Features Flat tableland covered with uniformly structured low renosterveld shrubland with small, woody shrubs (0.5–1.6 m tall) and a variable grass layer. A diverse geophyte and annual community is prevalent in the wet season. Dominants are strongly related to soil, displaying large compositional turnover with soil texture, depth and aspect. The transition to fynbos in the west is abrupt and determined by sandstone geology. Progressively increasing aridity results in a more gradual transition to SKt 2 Hantam Karoo in the east.

Geology & Soils The soils have a well-developed clay E-horizon (leading to seasonal water-logging of soils) in places and are derived from Dwyka Group diamictites (tillites) that have a fine-grained (shale) matrix. There are even areas with only skeletal clays over the Nardouw Subgroup rocks (Cape Supergroup). Land types mainly Db and Fb.

Climate MAP 190–350 mm (mean: 285 mm), peaking from May to August. Mean daily maximum and minimum temperatures 31.0°C and 3.2°C for February and July, respectively. Frost incidence about 10 days per year. See also climate diagram for FRs 2 Nieuwoudtville Shale Renosterveld (Figure 4.101).

Important Taxa Low Shrubs: *Elytropappus rhinocerotis* (d), *Eriocephalus purpureus* (d), *Asparagus capensis* var. *capensis*, *Pentzia incana*, *Wiborgia tetraptera*. Herbs: *Arctotheca calendula* (d), *Cotula nudicaulis* (d), *Leysera tenella* (d), *Nemesia cheiranthus* (d), *Senecio cakilefolius* (d). *S. erosus*. Geophytic Herbs: *Hesperantha cucullata*, *Moraea bifida*, *Ornithogalum conicum* subsp. *strictum*. Graminoids: *Merxmuellera stricta* (d), *Chaetobromus involucratus* subsp. *dregeanus*, *Ehrharta calycina*.

Endemic Taxa Low Shrubs: *Euryops mirus*, *Hermannia johanssenii*, *Selago chalarantha*. Geophytic Herbs: *Babiana pauciflora*, *Bulbinella eburniflora*, *Corycium ingeanum*, *Eriospermum erinum*, *E. glaciale*, *Geissorhiza splendidissima*, *Lachenalia alba*, *Moraea aspera*, *M. pseudospicata*, *Romulea discifera*, *R. sabulosa*, *Sparaxis tricolor*, *Strumaria picta*.

Conservation Endangered. Target 27%. None conserved in statutory or private conservation areas. Almost 50% transformed, mainly for cultivation. While most of the area of this vegetation unit has been transformed into croplands, the remaining portions are threatened by fire, overgrazing and by infestation by aliens such as *Medicago polymorpha*. This unit is a major node of geophytic diversity requiring a higher conservation status. Erosion moderate and high.

Remarks Together with FRd 1 Nieuwoudtville-Roggeveld Dolerite Renosterveld, this region represents the highest known concentration of geophytes, with bulbous species constituting 40% of the flora. Of interest are the number of sister taxa, with one species in this unit and the other in the neighbouring FRd 1 Nieuwoudtville-Roggeveld Dolerite Renosterveld.

References Snijman & Perry (1987), Manning & Goldblatt (1997b), S.A. Todd & J. Donaldson (unpublished data).

FRs 3 Roggeveld Shale Renosterveld

VT 43 Mountain Renosterbosveld (65%), VT 28 Western Mountain Karoo (33%) (Acocks 1953). LR 60 Escarpment Mountain Renosterveld (52%), LR 56 Upland Succulent Karoo (43%) (Low & Rebelo 1996).

Distribution Northern and Western Cape Provinces: Major part of the Roggeveld bordered by the edge of the western Great Escarpment mostly above the Tanqua Basin. South of the Hantam Plateau region in the upper parts of the range of the Keiskieberge and isolated high plateaus to the south including plateaus such as Grootberg, Saalfontein se Berg, Sneewkrans and Swaarweerberg encompassing the vicinity of Middelpos and Sutherland, reaching as far east as the higher-lying areas of the Teekloof Pass south of Fraserburg along the northwest summit plateaus of the Nuweveldberge. Altitude 1 200–1 900 m.

Vegetation & Landscape Features Undulating, slightly sloping plateau landscape, with low hills and broad shallow valleys, supporting mainly moderately tall shrublands dominated by renosterbos, with a rich geophytic flora in the wetter and rocky habitats.

Geology & Soils Mudrocks and sandstones of the Adelaide Subgroup (Beaufort Group of the Karoo Supergroup) dominate the geology. Some intrusions of the Karoo Dolerite Suite are also present. Glenrosa and Mispah forms are prominent. Land types mainly Fc and Da.

Climate MAP 180–430 mm (mean: 305 mm), even throughout the year, showing a slight peak in March. Mean daily maximum and minimum temperatures 29.3°C and 0.2°C for January and July, respectively. Frost incidence is remarkably high for a renosterveld type (30–70 days per year). See also climate diagram for FRs 3 Roggeveld Shale Renosterveld (Figure 4.101).

Important Taxa Tall Shrub: *Euryops lateriflorus*. Low Shrubs: *Asparagus capensis* var. *capensis*, *Chrysocoma oblongifolia, Dimorphotheca cuneata*, *Diospyros austro-africana*, *Elytropappus rhinocerotis*, *Eriocephalus africanus* var. *africanus*, *E. ericoides* subsp. *ericoides*, *E. eximius*, *Euryops cuneatus*, *E. imbricatus*, *E. marlothii*, *E. microphyllus*, *E. trifidus*, *Felicia filifolia* subsp. *filifolia*, *F. muricata* subsp. *cinerascens*, *F. scabrida*, *Helichrysum hamulosum*, *H. lucilioides*, *Hermannia multiflora*, *Lessertia fruticosa*, *Nenax microphylla*, *Passerina nivicola*, *Pteronia erythrochaeta*, *Rosenia oppositifolia*, *Selago articulata*, *S. saxatilis*, *Ursinia pilifera*, *Zygophyllum spinosum*. Succulent Shrub: *Stomatium rouxii*. Herbs: *Cotula microglossa*, *Diascia parviflora*, *Lasiopogon muscoides*, *Pharnaceum croceum*, *Senecio hastatus*. Geophytic Herbs: *Drimia intricata*, *Geissorhiza heterostyla*, *Hesperantha cucullata*, *Oxalis obtusa*, *Romulea atrandra*, *R. diversiformis*, *R. rosea*, *R. tetragona*, *R. tortuosa*, *Spiloxene capensis*. Succulent Herb: *Crassula corallina* subsp. *corallina*. Herbaceous Succulent Climber: *Crassula roggeveldii*. Graminoids: *Ehrharta calycina*, *Pentaschistis aristifolia*, *P. patula*, *Schismus inermis*, *S. scaberrimus*.

Biogeographically Important Taxa (both Roggeveld-Hantam endemics) Herb: *Zaluzianskya violacea*. Geophytic Herb: *Androcymbium hantamense*.

Endemic Taxa Low Shrub: *Euryops sulcatus*. Herbs: *Lasiospermum poterioides*, *Manulea diandra*. Geophytic Herbs: *Daubenya aurea*, *Gladiolus marlothii*, *Ixia thomasiae*, *Polyxena longituba*, *Romulea hallii*, *R. komsbergensis*, *R. multifida*, *R. subfistulosa*, *R. syringodeoflora*.

Conservation Least threatened. Target 27%. None conserved in statutory or private conservation areas. Only 1% transformed, but danger of overgrazing is locally high. Erosion mainly moderate, with the remainder low.

Remarks The Roggeveld is named after the indigenous rye species (*Secale africana*) now almost extinct due to grazing pressure. The Roggeveld region is rich in endemic geophytes, most notably the monotypic *Devia xeromorpha.* It is an important centre of radiation for several other genera such as *Hesperantha* and *Romulea* (Iridaceae), *Zaluzianskya* (Scrophulariaceae) as well as *Lachenalia* and *Polyxena* (both Hyacinthaceae). Most of the endemics of this vegetation type are found on the dolerite cappings. This unit belongs to the core of the Hantam-Roggeveld Centre of Endemism (Van Wyk & Smith 2001).

Reference Van Wyk & Smith (2001).

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Figure 4.103 FRs 3 Roggeveld Shale Renosterveld: Renosterbos (*Elytropappus rhinocerotis*) shrubland on the top of Verlatenkloof near Sutherland (Northern Cape).

FRs 4 Ceres Shale Renosterveld

VT 69 Macchia (62%), VT 46 Coastal Renosterbosveld (35%) (Acocks 1953). Central Mountain Renosterveld (20%) (Moll & Bossi 1983). LR 61 Central Mountain Renosterveld (88%) (Low & Rebelo 1996). BHU 37 Waveren-Bokkeveld Inland Renosterveld (54%), BHU 36 Kouebokkeveld Inland Renosterveld (28%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Warm Bokkeveld Valley at Ceres and Laastedrift to the east; Cederberg from Matjiesrivier (not mapped) to Koue Bokkeveld at Blinkberg Pass, the Odessa area north of Gydoberg and Baviaanshoek. Altitude 500–1 300 m.

Vegetation & Landscape Features Moderately undulating plains and lower mountain slopes supporting medium tall cupressoid-leaved shrubland dominated by renosterbos. Heuweltjies are prominent in places.

Geology & Soils Clays derived from shale and sandstone of the Ceres (mostly) and the Bidouw Subgroups of the Bokkeveld Group. Some Nardouw Subgroup shales (Table Mountain Group) and Dwyka diamictites (Karoo Supergroup) also

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Figure 4.104 FRs 4 Ceres Shale Renosterveld: Renosterbos (*Elytropappus rhinocerotis*) dominating shrublands of the Warm Bokkeveld on the Swaarmoed Pass, southeast of Ceres (Western Cape).

occur. Glenrosa and Mispah forms are prominent. Land types mainly Fb, Fa and Bb.

Climate MAP 290–720 mm (mean: 430 mm), peaking from May to August. The Warm Bokkeveld communities are much more arid than those in the Koue Bokkeveld. Mean daily maximum and minimum temperatures 27.9°C and 3.2°C for February and July, respectively. Frost incidence 10–40 days per year. See also climate diagram for FRs 4 Ceres Shale Renosterveld (Figure 4.101).

Important Taxa Low Shrubs: *Agathosma squamosa*, *Aspalathus desertorum*, *Elytropappus rhinocerotis*, *Galenia africana*, *Pteronia incana*, *Stoebe plumosa*. Herbs: *Helichrysum crispum*, *Lotononis longicephala*. Geophytic Herbs: *Geissorhiza heterostyla*, *G. ornithogaloides* subsp. *marlothii*, *G. pappei*, *Lachenalia ameliae*, *Romulea flava*, *R. tetragona*, *R. tortuosa*, *Wurmbea variabilis*. Succulent Herb: *Crassula muscosa*.

Endemic Taxa Succulent Shrub: *Didymaotus lapidiformis*. Herb: *Lotononis exstipulata*.

Conservation Vulnerable. Target 27%. Few patches conserved in the Ben Etive Nature Reserve, an additional 1% in the Koue Bokkeveld (mountain catchment area) and the Matroosberg Private Nature Reserve. Some 36% of the area transformed, mainly by cultivation; also threatened by short-interval burning and overgrazing. Erosion varies widely, from very low to high.

Remarks This unit possibly also occurs in the FFb 1 Northern Inland Shale Band Vegetation at lower altitudes from Pakhuis Pass southwards, and also locally within SKv 3 Agter-Sederberg Shrubland, where it occurs at the upper reaches in wetter areas from Matjiesrivier to Blinkberg—these occurrences were too localised or too poorly surveyed to be mapped.

References Taylor (1996), C. Boucher (unpublished data).

FRs 5 Central Mountain Shale Renosterveld

VT 43 Mountain Renosterbosveld (85%) (Acocks 1953). LR 60 Escarpment Mountain Renosterveld (94%) (Low & Rebelo 1996). BHU 40 Roggeveld Inland Renosterveld (59%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Northern and Western Cape Provinces: Southern and southeastern slopes of the Klein-Roggeveldberge and Komsberg below the Roggeveld section of the Great Escarpment (facing the Moordenaars Karoo) as well as farther east below Besemgoedberg and Suurkop west of Merweville and in the west in the Karookop area between Losper se Berg and high points around Thyshoogte. Altitude 1 050–1 500 m.

Vegetation & Landscape Features Slopes and broad ridges of low mountains and escarpments, with tall shrubland dominated by renosterbos and large suites of mainly non-succulent karoo shrubs and with a rich geophytic flora in the undergrowth or in more open, wetter or rocky habitats.

Geology & Soils Clayey soils overlying Adelaide Subgroup (Beaufort Group of the Karoo Supergroup) mudstones and subordinate sandstones. Glenrosa and Mispah forms are prominent. Land types mainly Ib and Fc.

Climate Arid to semi-arid climate. MAP 180–410 mm (mean: 290 mm), with relatively even rainfall, but still showing a slight high in autumn-winter. Mean daily maximum and minimum temperatures 29.9°C and 0.9°C for January and July, respectively. Frost incidence 20–50 days per year. See also climate diagram for FRs 5 Central Mountain Shale Renosterveld (Figure 4.101).

Important Taxa Low Shrubs: *Elytropappus rhinocerotis* (d), *Amphiglossa tomentosa*, *Asparagus capensis* var. *capensis*, *Chrysocoma ciliata*, *C. oblongifolia*, *Diospyros austro-africana*, *Eriocephalus africanus* var. *africanus*, *E. ericoides* subsp. *eri-*

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Figure 4.105 FRs 5 Central Mountain Shale Renosterveld: Renosterbos (*Elytropappus rhinocerotis*) shrubland with numerous geophytes including white *Bulbinella elegans* and *Oxalis obtusa* in the Klein Roggeveld north of Matjiesfontein (Western Cape).

coides, *E. eximius*, *E. grandiflorus*, *E. microphyllus* var. *pubescens*, *E. pauperrimus*, *E. purpureus*, *Euryops imbricatus*, *Exomis microphylla*, *Felicia filifolia* subsp. *filifolia*, *F. muricata* subsp. *muricata*, *F. ovata*, *Galenia africana*, *Helichrysum dregeanum*, *H. lucilioides*, *Hermannia multiflora*, *Lessertia fruticosa*, *Lycium cinereum*, *Nenax microphylla*, *Pelargonium abrotanifolium*, *Pentzia incana*, *Pteronia ambrariifolia*, *P. glauca*, *P. glomerata*, *P. incana*, *P. sordida*, *Rosenia glandulosa*, *R. humilis*, *R. oppositifolia*, *Selago albida*, *Tripteris sinuata*, *Zygophyllum spinosum*. Succulent Shrubs: *Delosperma subincanum*, *Drosanthemum lique*, *Euphorbia stolonifera*, *Trichodiadema barbatum*, *Tylecodon reticulatus* subsp. *reticulatus*, *T. wallichii* subsp. *wallichii*. Woody Climber: *Asparagus aethiopicus*. Herbs: *Dianthus caespitosus* subsp. *caespitosus*, *Heliophila pendula*, *Lepidium desertorum*, *Osteospermum acanthospermum*, *Senecio hastatus*. Geophytic Herbs: *Bulbine asphodeloides*, *Drimia intricata*, *Othonna auriculifolia*, *Oxalis obtusa*. Succulent Herbs: *Crassula deceptor*, *C. muscosa*, *C. tomentosa* var. *glabrifolia*, *Senecio radicans*. Graminoids: *Ehrharta calycina*, *Karroochloa purpurea*, *Merxmuellera stricta*.

Conservation Least threatened. Target 27%. None conserved in statutory or private conservation areas. Only about 1% transformed. Erosion moderate.

Remark This is a very poorly known renosterveld type despite its interesting biogeographical borderline position—the unit straddles the Fynbos, Succulent Karoo and marginally the Nama-Karoo Biomes. It does not appear to have any endemic species.

Reference Acocks (1988).

FRs 6 Matjiesfontein Shale Renosterveld

VT 43 Mountain Renosterbosveld (38%), VT 70 False Macchia (25%) (Acocks 1953). Karroid Shrublands (51%), Central Mountain Renosterveld (44%) (Moll & Bossi 1983). Inland Renoster Shrubland (Campbell 1985). LR 61 Central Mountain Renosterveld (46%), LR 58 Little Succulent Karoo (40%) (Low & Rebelo 1996). BHU 81 Touws Vygieveld (34%), BHU 39 Matjies Inland Renosterveld (21%) (Cowling et al. 1999b, Cowling & Heijnis 2001). Witteberg Renosterveld (Vlok 2002).

Distribution Western Cape Province: From De Doorns and the top of the Theronsberg Pass in the west to Gamka Poort in the east, remaining north of the Waboomberg and Warmwaterberg in the Little Karoo and north of the Anysberg and Groot Swartberg and positioned south of the Tanqua Karoo, the Grootrivier near Matjiesfontein and the Floriskraal Dam south-east of Laingsburg. This type surrounds the many higher elevation ridges of FFq 3 Matjiesfontein Quartzite Fynbos and FFh 2 Matjiesfontein Shale Fynbos. Altitude 750–1 300 m.

Vegetation & Landscape Features Low mountains, parallel hills and mid-altitude plateaus supporting a low, open to medium dense, leptophyllous shrubland with a medium dense matrix of short, divaricate shrubs, dominated by renosterbos. Heuweltjies present at low densities in places.

Geology & Soils Clays and loams derived from Witteberg and Bokkeveld Group shales of the Cape Supergroup; Glenrosa and Mispah forms prominent. Land types mainly Fc, Ic, Ib and Fb.

Climate MAP 150–470 mm (mean: 300 mm), peaking slightly from May to August. Mean daily maximum and minimum temperatures 27.4°C and 2.4°C for February and July, respectively. Frost incidence 10–40 days per year. See also climate diagram for FRs 6 Matjiesfontein Shale Renosterveld (Figure 4.101).

Important Taxa Low Shrubs: *Elytropappus rhinocerotis* (d), *Aspalathus alpestris*, *Asparagus capensis* var. *capensis*, *Athanasia flexuosa*, *Chrysocoma ciliata*, *C. oblongifolia*,

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Figure 4.106 FRs 6 Matjiesfontein Shale Renosterveld: Post-fire regeneration of renosterveld shrubland on the Hex River Pass, with flora rich in dwarf shrubs (*Hermannia*, *Indigofera*), annuals and geophytes (*Cotula macroglossa*, *Kniphofia sarmentosa*). The snow-clad summit of Matroosberg (2 249 m) is in the background.

Eriocephalus ericoides subsp. *ericoides*, *Euryops cuneatus*, *E. imbricatus*, *E. microphyllus*, *Helichrysum simulans*, *Oedera genistifolia*, *Passerina truncata* subsp. *truncata*, *Pteronia sordida*. Succulent Shrub: *Antimima dasyphylla*. Herbs: *Cotula macroglossa*, *Foveolina dichotoma*, *Lepidium desertorum*, *Rhynchopsidium sessiliflorum*, *Rumex lanceolatus*, *Ursinia nana*. Geophytic Herbs: *Chlorophytum lewisiae*, *Gethyllis campanulata*, *Romulea atrandra*, *R. sphaerocarpa*, *R. tortuosa*, *Trachyandra thyrsoidea*. Succulent Herb: *Crassula lanceolata* subsp. *lanceolata*. Graminoids: *Bromus pectinatus*, *Ehrharta calycina*, *E. capensis*, *E. delicatula*, *Hyparrhenia hirta*, *Hypodiscus sulcatus*, *Pentaschistis rigidissima*.

Endemic Taxa Low Shrub: *Lotononis comptonii*. Geophytic Herbs: *Disa cochlearis*, *Hesperantha truncatula*, *Romulea malaniae*.

Conservation Least threatened. Target 27%. About 7% in total conserved in the Anysberg Nature Reserve (CapeNature) and private conservation areas such as Rooikrans. Some 9% totally transformed (mainly cultivation). Erosion moderate to very low as well as very high in places.

Remarks This is a very poorly studied vegetation unit. Although grouped with FRs 5 Central Mountain Shale Renosterveld by Acocks (1988), this unit has more fynbos and fewer karoo elements. This unit also occurs in the FFb 3 Central Inland Shale

Band Vegetation at moderate altitudes (1 300 m), but has not been mapped as its extent is uncertain.

References Acocks (1988), Vlok (2002).

FRs 7 Montagu Shale Renosterveld

VT 26 Karroid Broken Veld (44%), VT 43 Mountain Renosterbosveld (32%) (Acocks 1953). Central Mountain Renosterveld (64%), Karroid Shrublands (21%) (Moll & Bossi 1983). LR 61 Central Mountain Renosterveld (71%), LR 58 Little Succulent Karoo (21%) (Low & Rebelo 1996). BHU 41 Montagu Inland Renosterveld (54%) (Cowling et al. 1999b, Cowling & Heijnis 2001). Montagu Renosterveld, Touwsfontein Renosterveld (Vlok 2002).

Distribution Western Cape Province: Patches in the western Little Karoo south of the Waboomberg and Warmwaterberg and south of the Anysberg and Klein Swartberg as well as along the northern foothills of the Langeberg and the southern foothills of the Anysberg, Klein Swartberg, Rooiberg and Gamkaberg, from The Koo in the west to Calitzdorp and Cloete's Pass in the east. The largest patch occurs between Montagu and Barrydale. Altitude 200–1 020 m.

Vegetation & Landscape Features Undulating hilly landscape with broad valleys supporting open, tall shrubland in a medium dense matrix of short, divaricate shrubs, dominated by renosterbos. Transitions with Succulent Karoo units can be observed at lower altitudes.

Geology & Soils Clays mostly derived from Bokkeveld and some Witteberg Group shales; Glenrosa and Mispah forms prominent. Some extensive quartzitic pebble fields occur. Land types mainly Fc and Fb.

Figure 4.107 FRs 7 Montagu Shale Renosterveld: Renosterbos (*Elytropappus rhinocerotis*) shrubland in the Koo near Montagu, Western Little Karoo (Western Cape).

Climate MAP 140–560 mm (mean: 320 mm), with a slight peak in winter. Mean daily maximum and minimum temperatures 28.1°C and 4.1°C for January and July, respectively. Frost incidence 10–20 days per year. See also climate diagram for FRs 7 Montagu Shale Renosterveld (Figure 4.101).

Important Taxa Small Tree: *Acacia karroo*. Succulent Tree: *Aloe ferox*. Tall Shrubs: *Diospyros pallens*, *Dodonaea viscosa* var. *angustifolia*, *Euclea undulata*, *Metalasia densa*, *Rhus pterota*. Low Shrubs: *Athanasia vestita* (d), *Chrysocoma oblongifolia* (d), *Elytropappus rhinocerotis* (d), *Felicia filifolia* subsp. *filifolia* (d), *Oedera genistifolia* (d), *O. squarrosa* (d), *Pteronia pallens* (d), *Tripteris sinuata* (d), *Artemisia afra*, *Athanasia microcephala*, *Chrysocoma ciliata*, *Cymbopappus adenosolen*, *Diospyros austro-africana*, *Gnidia inconspicua*, *G. sericea*, *Helichrysum hamulosum*, *Hermannia flammea*, *Leucadendron salignum*, *Lycium cinereum*, *Passerina comosa*, *P. obtusifolia*, *Pteronia incana*, *Selago corymbosa*. Succulent Shrubs: *Aloe arborescens*, *Crassula ciliata*. Herbs: *Arctotheca calendula*, *Cotula turbinata*, *Helichrysum crispum*. Geophytic Herb: *Romulea sphaerocarpa*. Graminoids: *Merxmuellera stricta* (d), *Cynodon dactylon*.

Biogeographically Important Taxon Geophytic Herb: *Ixia gloriosa* (Little Karoo endemic).

Endemic Taxa Low Shrubs: *Anginon tenuior*, *Argyrolobium crinitum*, *Diosma strumosa*, *Macledium relhanioides*. Succulent Shrubs: *Antimima biformis*, *Drosanthemum albiflorum*, *Tylecodon albiflorus*. Geophytic Herbs: *Ixia superba*, *Syringodea saxatilis*, *Tritonia watermeyeri*.

Conservation Least threatened. Target 27%. Statutorily conserved in the Anysberg Nature Reserve (2%), and an additional 4% protected in private reserves such as Botterboom, Kanaland and Doornkloof. Some 15% transformed (cultivation). Local low levels of infestation with alien *Acacia cyclops* and *A. saligna*. Erosion mainly high, but also very low in some areas.

Remark This vegetation type is in urgent need of research attention.

References Muir (1929), Vlok (2002).

FRs 8 Breede Shale Renosterveld

VT 26 Karroid Broken Veld (45%), VT 69 Macchia (33%) (Acocks 1953). Central Mountain Renosterveld (39%), Karroid Shrublands (17%) (Moll & Bossi 1983). LR 61 Central Mountain Renosterveld (70%), LR 58 Little Succulent Karoo (23%) (Low & Rebelo 1996). BHU 38 Ashton Inland Renosterveld (56%), BHU 87 Robertson Broken Veld (23%), BHU 37 Waveren-Bokkeveld Inland Renosterveld (14%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Patches in the Breede River Valley from Tulbagh to Swellendam; more specifically, most of the valley floor between Tulbagh and Wolseley, isolated small patches to the vicinity of Worcester, diverse patches between Stettyn and McGregor south of the Breede River, a near continuous but irregular band on the southern foothills of the Langeberg from Philipsdale near Worcester to Ashton. The most extensive area occurs near Ashton. McGregor and the confluence of the Riviersonderend and Breede Rivers west of Swellendam. Altitude 100–650 m.

Vegetation & Landscape Features Low hills, slightly undulating to undulating plains and lower mountain slopes. In the western regions low, cupressoid-leaved shrubland (with scattered emergent small trees) is dominated by renosterbos. Elements

Figure 4.108 FRs 8 Breede Shale Renosterveld: Renosterveld shrublands with rich geophyte flora (*Lachenalia*, *Cyphia bulbosa*, *Spiloxene capensis* etc.) near Tulbagh Station, south of Tulbagh (Western Cape).

of shale fynbos are present. In the eastern regions open, tall shrublands (possibly closely affiliated to FRs 12 Central Rûens Shale Renosterveld) are found, with microphyllous shrubs forming the dominant layer. Breede Shale Renosterveld grades into SKv 7 Robertson Karoo in the central valley, with karoo shrublands usually occurring on the northern aspects and renosterveld found on the southern aspects, with a decline in the extent of the karoo shrublands to the south. Heuweltjies are very prominent, with either bush clumps in moister areas or succulent shrubs in drier habitats.

Geology & Soils Clays and loams mostly derived from Bokkeveld and some Witteberg Group shales as well as Porterville Formation phyllite shale of the Malmesbury Group (Namibian Erathem) in the northwest. Glenrosa and Mispah forms are dominant. Land types mainly Fb, Fa and Ic.

Climate MAP 210–610 mm (mean: 370 mm), peaking from May to August. Mean daily maximum and minimum temperatures 29.3°C and 4.8°C for February and July, respectively. Frost incidence 3–8 days per year. See also climate diagram for FRs 8 Breede Shale Renosterveld (Figure 4.101).

Important Taxa Tall Shrubs: *Euclea undulata* (d), *Lycium ferocissimum* (d), *Dodonaea viscosa* var. *angustifolia*, *Euryops tenuissimus*, *Rhus angustifolia*, *R. undulata*. Low Shrubs: *Aspalathus steudeliana* (d), *Elytropappus rhinocerotis* (d), *Galenia africana* (d), *G. herniariaefolia* (d), *G. secunda* (d), *Oedera sedifolia* (d), *O. squarrosa* (d), *Pentzia incana* (d), *Pteronia incana* (d), *P. paniculata* (d), *Anthospermum aethiopicum*, *Aspalathus candicans*, *A. pachyloba* subsp. *macroclada*, *A. submissa*, *A. varians*, *Carissa bispinosa* subsp. *bispinosa*, *Chrysocoma ciliata*, *C. coma-aurea*, *Felicia filifolia* subsp. *filifolia*, *F. flanaganii*, *Freylinia undulata*, *Hermannia vestita*, *Heterolepis peduncularis*, *Metalasia octoflora*, *Oedera genistifolia*, *Passerina obtusifolia*, *Pteronia fasciculata*, *Selago fruticosa*, *Senecio pinifolius*, *Wahlenbergia tenella*. Succulent Shrubs: *Delosperma pageanum* (d), *Euphorbia burmannii* (d), *E. mauritanica* (d), *Ruschia caroli* (d), *R. festiva* (d), *Tylecodon paniculatus* (d), *Adromischus filicaulis* subsp. *filicaulis*, *Aloe microstigma* subsp. *microstigma*, *Crassula atropurpurea* var. *atropurpurea*, *C. pubescens* subsp. *pubescens*, *C. rupestris*, *C. tetragona*, *Pelargonium alternans*, *Psilocaulon coriarium*, *Ruschia multiflora*, *Tetragonia fruticosa*, *T. sarcophylla*, *Tylecodon grandiflorus*. Herb: *Hypericum lalandii*. Geophytic Herbs: *Babiana melanops*, *Freesia caryophyllacea*, *Geissorhiza heterostyla*, *G. inflexa*, *G. ornithogaloides* subsp. *ornithogaloides*, *G. purpureolutea*, *G. tulbaghensis*, *Lachenalia polyphylla*, *Ornithogalum dubium*, *Oxalis goniorrhiza*, *Wurmbea monopetala*. Succulent Herbs: *Crassula aphylla*, *C. muscosa*. Graminoids: *Ehrharta calycina*, *E. villosa* var. *villosa*, *Ficinia ramosissima*, *Hyparrhenia hirta*, *Ischyrolepis gaudichaudiana*, *Merxmuellera stricta*.

Endemic Taxa Low Shrubs: *Aspalathus macrocarpa*, *Cliffortia varians*, *Lotononis rigida*. Succulent Shrubs: *Acrodon purpureostylus*, *Drosanthemum aureopurpureum*, *D. hallii*, *Lampranthus hurlingii*. Geophytic Herbs: *Babiana villosa*, *Freesia fucata*, *Ixia vanzijliae*, *I. vinacea*, *Moraea incurva*, *M. radians*.

Conservation Vulnerable. Target 27%. The unit is statutorily conserved in the Vrolijkheid Nature Reserve (2%) as well as in Langeberg-wes and Matroosberg mountain catchment areas. Some 31% transformed, mainly by cultivation. Alien *Pinus pinaster* and several species of *Acacia* occur locally, at low levels. Erosion spans high and very low.

Remarks Little known and in urgent need of detailed study before totally modified by agriculture and mining. Around Noree (between Robertson and Worcester) there are small exposed dolomite lenses (partly subject to mining), supporting species such as *Aloe microstigma*, *Antimima leipoldtii* and a new species of *Gazania* pending formal description. The identity of this vegetation and its possible recognition as a separate vegetation unit needs further study. This unit extends onto FFb 4 Central Coastal Shale Band Vegetation in the Langeberg near Nuy but as the extent of this is unknown it has not been mapped.

References Olivier (1966), Joubert (1968), Norton (1977), Van der Merwe (1977b), Boucher & Moll (1981), Chesselet (1985), Boschoff (1989), Smitheman & Perry (1990), Wood (1990).

FRs 9 Swartland Shale Renosterveld

VT 46 Coastal Renosterbosveld (85%) (Acocks 1953). LR 62 West Coast Renosterveld (86%) (Low & Rebelo 1996). BHU 31 Swartland Coast Renosterveld (63%), BHU 32 Boland Coast Renosterveld (27%) (Cowling et al. 1999b, Cowling & Heijnis 2001). Coast Renoster Shrubland (Campbell 1985).

Distribution Western Cape Province: Large, generally continuous areas of the Swartland and the Boland on the West Coast lowlands, from Het Kruis in the north, southwards between the Piketberg and Olifantsrivierberge, widening appreciably in the region around Moorreesburg between Gouda and Hopefield, and encompassing Riebeek-Kasteel, Klipheuwel, Philadelphia, Durbanville, Stellenbosch to the south and Sir Lowry's Pass Village near Gordon's Bay. Altitude 50–350 m.

Vegetation & Landscape Features Moderately undulating plains and valleys supporting low to moderately tall leptophyllous shrubland of varying canopy cover as well as low, open shrubland dominated by renosterbos. Heuweltjies are a very prominent local feature of the environment, forming 'hummockveld' near Piketberg and giving the Tygerberg Hills their name. Stunted trees and thicket are often associated with the

Figure 4.109 FRs 9 Swartland Shale Renosterveld: Renosterbos (*Elytropappus rhinocerotis*) shrublands on Malmesbury shales at the foot of Spitskop, near Piketberg, with *Moraea tulbaghensis* (orange, Red Data species), *Lampranthus dilutus* (mauve-flowered vygie) and *Ixia lutea* (cream-coloured in the background).

heuweltjies. Disturbed areas are dominated by *Athanasia trifurcata* and *Otholobium hirtum*. Patches of *Cynodon dactylon* 'grazing lawns' also occur in abundance.

Geology & Soils Clay soils derived from Malmesbury Group shales (specifically the Porterville Formation in the north and east and the Moorreesburg Formation in the west). The soils contain prismacutanic and pedocutanic diagnostic horizons and Glenrosa and Mispah forms are predominant. Land types mainly Db, Fb and Da.

Climate Winter-rainfall regime, with MAP 270–670 mm (mean: 430 mm), peaking from May to August. Mean daily maximum and minimum temperatures 29.6°C and 6.3°C for February and July, respectively. Frost incidence 3 or 4 days per year. Mists are common in winter. See also climate diagram for FRs 9 Swartland Shale Renosterveld (Figure 4.101).

Important Taxa (^{W}Wetlands) Tall Shrubs: *Aspalathus acuminata* subsp. *acuminata* (d), *Olea europaea* subsp. *africana* (d), *Rhus angustifolia* (d), *R. incisa* (d), *Chrysanthemoides monilifera*, *Euryops speciosissimus*, *E. tenuissimus*, *Gymnosporia buxifolia*, *Lebeckia cytisoides*. Low Shrubs: *Anthospermum aethiopicum* (d), *A. spathulatum* subsp. *tulbaghense* (d), *Elytropappus rhinocerotis* (d), *Eriocephalus africanus* var. *africanus* (d), *Euryops thunbergii* (d), *Galenia secunda* (d), *Helichrysum cymosum* (d), *H. teretifolium* (d), *Osteospermum spinosum* (d), *Otholobium hirtum* (d), *Agathosma glandulosa*, *Aspalathus aculeata*, *A. pinguis* subsp. *pinguis*, *A. spinosa* subsp. *flavispina*, *A. tridentata* subsp. *staurantha*, *A. varians*, *Asparagus rubicundus*, *Athanasia trifurcata*, *Cliffortia marginata*, *Diosma hirsuta*, *Euclea acutifolia*, *Felicia filifolia* subsp. *filifolia*, *F. hyssopifolia*, *Galenia africana*, *Lebeckia cinerea*, *Leucadendron lanigerum* var. *lanigerum*, *Marasmodes polycephala*, *Metalasia dregeana*, *M. octoflora*, *Muraltia decipiens*, *M. ononidifolia*, *Oftia africana*, *Passerina truncata* subsp. *truncata*, *Phylica gracilis*, *Plecostachys serpyllifolia*, *Pteronia divaricata*, *P. incana*, *Rhus dissecta*, *Senecio pubigerus*, *Stoebe plumosa*. Succulent Shrubs: *Euphorbia burmannii* (d), *E. mauritanica*, *Lampranthus elegans*. Woody Climber: *Microloma sagittatum*. Herbs: *Berkheya armata* (d), *B. rigida*, *Cotula turbinata*, *Echiostachys spicatus*, *Lichtensteinia obscura*, *Manulea cephalotes*, *Senecio laxus*, *Stachys aethiopica*. Geophytic Herbs: *Cyanella hyacinthoides* (d), *Melasphaerula ramosa* (d), *Albuca maxima*, *Aristea africana*, *Babiana melanops*, *Cheilanthes capensis*, *Disa physodes*, *Geissorhiza imbricata* subsp. *bicolor*^{W}, *G. inflexa*, *G. juncea*, *G. purpureolutea*, *G. tulbaghensis*, *Lachenalia longibracteata*, *L. pallida*, *L. polyphylla*, *Mohria caffrorum*, *Ornithogalum thyrsoides*, *Oxalis pes-caprae*, *Romulea flava*, *R. leipoldtii*, *R. rosea*, *R. tabularis*, *Watsonia marginata*. Graminoids: *Cynodon dactylon* (d), *Ehrharta calycina* (d), *Elegia capensis* (d), *E. recta* (d), *E. tectorum* (d), *Ficinia brevifolia* (d), *Ischyrolepis capensis* (d), *Merxmuellera stricta* (d), *Ehrharta delicatula*, *E. thunbergii*, *Hordeum capense*, *Merxmuellera arundinacea*, *Tribolium hispidum*.

Endemic Taxa Low Shrubs: *Leucadendron verticillatum* (d), *Aspalathus acanthophylla*, *A. horizontalis*, *A. pinguis* subsp. *longissima*, *A. pinguis* subsp. *occidentalis*, *A. puberula*, *A. rectistyla*, *Cliffortia acockii*, *Lotononis complanata*, *Serruria incrassata*. Succulent Shrubs: *Erepsia ramosa*, *Ruschia patens*, *R. pauciflora*. Herb: *Indigofera triquetra*. Geophytic Herbs: *Aristea lugens*, *Babiana angustifolia*, *B. odorata*, *B. secunda*, *Hesperantha pallescens*, *H. spicata* subsp. *fistulosa*, *Lachenalia liliflora*, *L. mediana* var. *rogersii*, *L. orthopetala*, *Lapeirousia fastigiata*, *Moraea gigandra*, *M. tulbaghensis*, *Oxalis fragilis*, *O. involuta*, *O. leptocalyx*, *O. levis*, *O. macra*, *O. perineson*, *O. strigosa*, *Pelargonium viciifolium*.

Figure 4.110 FRs 9 Swartland Shale Renosterveld: A typical landscape mosaic of the West Coast renosterveld region—arable fields surround renosterveld shrublands which become limited to solitary hills (below Piekenierskloof Pass, Western Cape).

Conservation This is a critically endangered vegetation unit. Target 26%, but since 90% of the area has been totally transformed (mainly for cropland), the target remains unattainable. The remnants are found in isolated pockets, usually on steeper ground. So far only a few patches have been included in conservation schemes (e.g. Elandsberg, Paardenberg). Aliens include *Acacia saligna* (very scattered over 65%), *A. mearnsii* (very scattered over 62%) as well as several species of *Prosopis* and *Eucalyptus*. Alien annual grasses of the genera *Avena*, *Briza*, *Bromus*, *Lolium*, *Phalaris* and *Vulpia* are a primary problem in remnant patches. Other serious aliens include herbs such as *Erodium cicutarium*, *E. moschatum*, *Echium plantagineum* and *Petrorhagia prolifera*. Erosion very low and low.

Remark 1 No floristic or phytosociological support for the north-south split into Swartland and Boland BHUs (Cowling & Heijnis 2001) could be found. Nor could we find any patterns associated with the coastal-inland geological belts (Tygerberg, Moorreesburg and Brandwacht Formations).

Remark 2 Various special vegetation units are embedded within the West Coast renosterveld matrix, composed of vernal pools, ferricrete gravels, quartz patches and seasonally wet lowlands—all ranking among the most threatened Cape habitats and housing many endemic taxa.

References Linder (1976), Boucher (1977, 1978, 1980, 1983, 1987, 1989a), Boucher & Moll (1981), Paterson (1982), Jones (1986), Lötter & Van Wageningen (1988), Landman & Nel (1989), Duvenhage (1993), Von Hase et al. (2003), Walton (2006), N. Helme (unpublished data).

FRs 10 Peninsula Shale Renosterveld

VT 69 Macchia (57%), VT 34 Strandveld of West Coast (40%) (Acocks 1953). West Coast Renosterveld (7%) (Moll & Bossi 1983). LR 62 West Coast Renosterveld (63%), LR 68 Sand Plain Fynbos (32%) (Low & Rebelo 1996). BHU 55 Cape Peninsula Mountain Fynbos Complex (71%), BHU 12 Blackheath Sand Plain Fynbos (29%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Signal Hill and on the lower northern slopes of Table Mountain and Devil's Peak; approximately centred on the city bowl of Cape Town. Altitude 0–350 m.

Vegetation & Landscape Features Gentle to steep lower slopes with tall, open shrubland and grassland, typically with renosterbos not appearing very prominent. This vegetation is very grassy due to frequent fires and lack of grazing. On Devil's Peak these 'renosterveld grasslands' are frequently mowed for grazing. On south-facing slopes and upper slopes this unit merges into fynbos. The early seral stages are dominated by *Asparagus capensis*, *Hyparrhenia hirta*, *Haemanthus sanguineus*, various *Oxalis* species and resprouting *Rhus lucida*, after which tussock grasses, shrubs and ferns emerge. After only 12 months the reseeding species start to become more obvious.

Geology & Soils Clay soils derived from shale of the Tygerberg Formation, Malmesbury Group; Glenrosa, Mispah and Lamotte forms prominent. Land types mainly Fa and Ga.

Climate MAP 480–870 mm (mean: 720 mm), peaking markedly from May to August. This is the wettest renosterveld type by far. Mean daily maximum and minimum temperatures 26.7°C and 7.8°C for February and July, respectively. Frost incidence 2 or 3 days per year. See also climate diagram for FRs 10 Peninsula Shale Renosterveld (Figure 4.101).

Important Taxa ([T]Cape thickets) Tall Shrubs: *Gymnosporia buxifolia*[T] (d), *Noltea africana* (d), *Rhus angustifolia*[T] (d), *R. glauca*[T] (d), *R. lucida*[T] (d), *R. tomentosa*[T] (d), *Myrsine africana*[T], *Olea europaea* subsp. *africana*[T], *Putterlickia pyracantha*[T], *Rhus laevigata*[T]. Low Shrubs: *Cliffortia polygonifolia* (d), *Elytropappus rhinocerotis* (d), *Eriocephalus africanus* var. *africanus* (d), *Helichrysum cymosum* (d), *H. patulum* (d), *Lobostemon argenteus* (d), *Salvia africana-caerulea* (d), *Stoebe cinerea* (d), *Anthospermum spathulatum* subsp. *spathulatum*, *Chrysanthemoides incana*, *Clutia pulchella*, *Diosma hirsuta*, *Erica baccans*, *Gnidia inconspicua*, *Otholobium hirtum*, *Salvia africana-lutea*. Succulent Shrubs: *Erepsia anceps*, *Tylecodon grandiflorus*. Herbs: *Stachys aethiopica* (d), *Knowltonia capensis*, *Pseudoselago serrata*. Geophytic Herbs: *Cheilanthes capensis* (d), *Mohria caffrorum* (d), *Asplenium aethiopicum*, *Geissorhiza inflexa*, *G. pusilla*. Graminoids: *Hyparrhenia hirta* (d), *Cymbopogon marginatus*, *Ehrharta erecta*, *Eragrostis curvula*, *Merxmuellera stricta*, *Pentaschistis aspera*, *Themeda triandra*, *Tribolium uniolae*.

Conservation Critically endangered vegetation unit. Target of 26% is unattainable since 77% of the area has been totally transformed (urban sprawl, cultivation and building of road infrastructure). It is statutorily conserved in the Table Mountain National Park (19%). A fair proportion of the conserved area on Devil's Peak is covered by pine and gum parkland. These should be restored to renosterveld as soon as possible. Notable aliens include various species of *Acacia* (especially *A. melanoxylon*). Erosion very low.

Remarks This vegetation burns every 3–5 years to the consternation of Cape Town citizens. Large portions of Signal Hill have been, however, protected from fire for up to 25 years. The upper reaches of this mapped unit on the northern slopes of Devil's Peak should be FFh 5 Cape Winelands Shale Fynbos.

References Adamson (1927), Boucher & Moll (1981), Joubert (1991), Joubert & Moll (1992), Britton & Jackelman (1995, 1996), Cowling et al. (1996b), Simmons (1996).

L.W. Powrie

Figure 4.111 FRs 10 Peninsula Shale Renosterveld: Shrubland on Signal Hill, Cape Town, showing *Elytropappus rhinocerotis, Rhus lucida, Lobostemon fruticosus, Anthospermum spathulatum, Cliffortia polygonifolia* and *Helichrysum patulum*.

FRs 11 Western Rûens Shale Renosterveld

VT 46 Coastal Renosterbosveld (79%), VT 69 Macchia (21%) (Acocks 1953). LR 63 South and South-west Coast Renosterveld (94%) (Low & Rebelo 1996). BHU 33 Overberg Coast Renosterveld (92%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Western parts of the Rûens region (Overberg)—from Bot River and Villiersdorp eastwards, surrounding the Caledon Swartberg, and approximately to a line between Napier and Genadendal. Altitude 60–450 m.

Vegetation & Landscape Features Moderately undulating plains, today mostly stripped of natural vegetation and where preserved, supporting an open to medium dense, cupressoid and small-leaved, low to moderately tall grassy shrubland dominated by renosterbos. Heuweltjies are not conspicuous. This unit is distinguished from other Rûens renosterveld types by the absence of *Hermannia flammea* and rare occurrence of *Aloe ferox* and *Acacia karroo* complex. Shrubby Asteraceae increase as grazing reduces the palatable grass component (mostly *Hyparrhenia hirta*), resulting in subsequent erosion.

Geology & Soils Clays and loams derived from Bokkeveld Group shales, particularly the Ceres Subgroup. Glenrosa and Mispah forms are dominant. Land types mainly Fb and Fa.

Climate MAP 360–700 mm (mean: 490 mm), with a peak in winter (May to August). Mean daily maximum and minimum temperatures 26.9°C and 6.1°C for February and July, respectively. Frost incidence about 3 days per year. See also climate diagram for FRs 11 Western Rûens Shale Renosterveld (Figure 4.101).

Figure 4.112 FRs 11 Western Rûens Shale Renosterveld: *Watsonia alectroides* (Asphodelaceae) in a remnant of a shale renosterveld along the road between Bredasdorp and Caledon (Western Cape).

Important Taxa Tall Shrub: *Rhus pallens* (d). Low Shrubs: *Aspalathus nigra* (d), *A. spinosa* subsp. *flavispina* (d), *A. submissa* (d), *Asparagus capensis* var. *capensis* (d), *Athanasia trifurcata* (d), *Elytropappus rhinocerotis* (d), *Erica setacea* (d), *Felicia filifolia* subsp. *filifolia* (d), *Helichrysum petiolare* (d), *Metalasia acuta* (d), *Oedera squarrosa* (d), *Printzia polifolia* (d), *Stoebe plumosa* (d), *Aspalathus steudeliana*. Succulent Shrub: *Drosanthemum flavum*. Herb: *Corymbium cymosum* (d). Geophytic Herbs: *Bobartia indica* (d), *Micranthus junceus* (d), *Geissorhiza ornithogaloides* subsp. *ornithogaloides*, *Oxalis duriuscula*, *O. livida* var. *altior*. Graminoids: *Cymbopogon pospischilii* (d), *Cynodon dactylon* (d), *Ehrharta calycina* (d), *Ficinia nigrescens* (d), *Hyparrhenia hirta* (d), *Ischyrolepis capensis* (d), *Merxmuellera stricta* (d), *Themeda triandra* (d).

Endemic Taxa Tall Shrub: *Freylinia helmei*. Low Shrubs: *Agathosma* sp. nov. (*N. Helme 2530* BOL), *Cullumia selago*. Succulent Shrubs: *Drosanthemum insolitum*, *Erepsia villiersii*. Herbs: *Felicia nigrescens*, *Peucedanum pungens*. Geophytic Herbs: *Ixia stricta*, *Moraea barnardiella*, *M. comptonii*, *M. debilis*, *Sparaxis fragrans*, *S. maculosa*.

Conservation Critically endangered. Target 27%. None of the area is conserved statutorily and only a small portion (about 1%) enjoys protection in the Witdraai Private Nature Reserve. Some 86% has already been transformed (thus target is unattainable), mostly by cultivation. Only the steepest slopes carry remnants of the natural vegetation. Erosion very low and low.

References Boucher & Moll (1981), Cowling et al. (1988), Boucher (1999d), Von Hase et al. (2003), N. Helme (unpublished data).

FRs 12 Central Rûens Shale Renosterveld

VT 46 Coastal Renosterbosveld (88%) (Acocks 1953). South Coast Renosterveld (2%) (Moll & Bossi 1983). LR 63 South and South-west Coast Renosterveld (96%) (Low & Rebelo 1996). BHU 33 Overberg Coast Renosterveld (90%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Central parts of the Rûens region (Overberg) from Greyton and Stormsvlei (and Bromberg) to Napier and Bredasdorp and centred on Klipdale and Protem; also on the coastal flats southeast of Bredasdorp towards Arniston. Fragmented outliers are found on the southern part of the Agulhas Plain between Soetendalsvlei and Waskraalsvlei. Altitude 20–340 m.

Vegetation & Landscape Features Moderately undulating plains and pans. Vegetation is open to medium dense cupressoid and small-leaved, low to moderately tall grassy shrubland, usually dominated by renosterbos. It is distinguished from the Eastern Rûens Shale Renosterveld by the absence of *Aloe ferox*. Shrubby Asteraceae increase as grazing reduces the palatable grassy component (mostly *Hyparrhenia hirta*) and subsequent erosion results. Heuweltjies not conspicuous, except in the south of the area. South of Bredasdorp this type is restricted and replaced by FFf 1 Elim Ferricrete Fynbos in wetter areas.

Geology & Soils Clays and loams derived from Bokkeveld Group shales, with Glenrosa and Mispah forms dominant. Land types mainly Fb.

Climate MAP 300–480 mm (mean: 380 mm), with a slight peak in winter (August), 49% of rain falling from May to August. Mean daily maximum and minimum temperatures 27.3°C and 5.6°C for January and July, respectively. Frost incidence about

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Figure 4.113 FRs 12 Central Rûens Shale Renosterveld: Renosterbos (*Elytropappus rhinocerotis*) shrublands south of Genadendal in the Overberg (Western Cape).

3 days per year. See also climate diagram for FRs 12 Central Rûens Shale Renosterveld (Figure 4.101).

Important Taxa Tall Shrub: *Rhus pallens* (d). Low Shrubs: *Aspalathus steudeliana* (d), *A. submissa* (d), *Asparagus capensis* var. *capensis* (d), *Athanasia dentata* (d), *A. trifurcata* (d), *Elytropappus rhinocerotis* (d), *Helichrysum petiolare* (d), *Hermannia flammea* (d), *H. saccifera* (d), *Oedera genistifolia* (d), *O. squarrosa* (d), *Printzia polifolia* (d), *Pteronia incana* (d), *Stoebe plumosa* (d), *Aspalathus campestris*, *A. pinguis* subsp. *pinguis*, *A. pycnantha*, *Relhania garnotii*. Succulent Shrubs: *Ruschia lineolata* (d), *Drosanthemum flavum*. Geophytic Herbs: *Geissorhiza nana*, *Romulea minutiflora*. Graminoids: *Cymbopogon pospischilii* (d), *Ficinia nigrescens* (d), *F. oligantha* (d), *Merxmuellera disticha* (d), *M. stricta* (d), *Themeda triandra* (d).

Endemic Taxa Low Shrubs: *Aspalathus barbigera*, *A. smithii*, *Relhania spathulifolia*. Succulent Shrubs: *Drosanthemum lavisii*, *Erepsia dubia*. Herb: *Arctotis dregei*. Geophytic Herb: *Moraea minuta*.

Conservation Critically endangered vegetation unit. Target of 27% cannot be attained since 87% of the area has already been transformed by cultivation. Small patches are conserved in the Agulhas National Park. Remnants are mainly on the sides of steeper hills. There is a notable absence of alien woody plants. Erosion very low and moderate.

References Boucher & Moll (1981), Cowling et al. (1988), Mustart et al. (1997), Von Hase et al. (2003), C. Boucher (unpublished data), N. Helme (unpublished data).

FRs 13 Eastern Rûens Shale Renosterveld

VT 46 Coastal Renosterbosveld (89%) (Acocks 1953). LR 63 South and South-west Coast Renosterveld (97%) (Low & Rebelo 1996). BHU 34 Riversdale Coast Renosterveld (53%), BHU 33 Overberg Coast Renosterveld (34%), BHU 19 Suurbraak Grassy Fynbos (10%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Eastern Rûens (Overberg) from Bredasdorp (Patryskraal) and the area of the Breede River near Swellendam, between the coastal limestone (and sandstone) belt in the south and vegetation types of the southern foothills of the Langeberg, encompassing the areas in the vicinity of Malgas and Heidelberg, to the Goukou River at Riversdale. Altitude 40–320 m.

Vegetation & Landscape Features Moderately undulating hills and plains supporting cupressoid and small-leaved, low to moderately tall grassy shrubland, dominated by renosterbos. The southern limits are often covered by a thin layer of calcrete. Little of this vegetation remains, but some thicker calcrete deposits, too thick to be ploughed, support mesotrophic asteraceous 'fynbos' with *Crassula expansa*, *Leucadendron linifolium* and *Nylandtia spinosa*. It is not known whether the thinner deposits supported renosterveld or intermediate communities. In some places, especially closer to the mountains (Langeberg), *Themeda triandra* grasslands are found (see Raitt 2005).

Geology & Soils Clays and loams derived from Bokkeveld Group shales with some contribution from Mesozoic Uitenhage Group sediments in the northeast; Glenrosa and Mispah forms dominant. Land types mainly Fb, Fc and Db.

Climate MAP 270–540 mm (mean: 385 mm), with an even distribution and a slight low from December to February. Mean daily maximum and minimum temperatures 26.9°C and 5.9°C for January and July, respectively. Frost incidence about 3 days per year. See also climate diagram for FRs 13 Eastern Rûens Shale Renosterveld (Figure 4.101).

Important Taxa Succulent Tree: *Aloe ferox* (d). Tall Shrub: *Rhus pallens* (d). Low Shrubs: *Athanasia trifurcata* (d), *Elytropappus rhinocerotis* (d), *Helichrysum petiolare* (d), *Hermannia flammea* (d), *H. saccifera* (d), *Oedera genistifolia* (d), *O. squarrosa* (d),

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Figure 4.114 FRs 13 Eastern Rûens Shale Renosterveld: Island of renosterveld (with prominent *Elytropappus rhinocerotis* and *Stoebe plumosa*) and scattered emergent *Aloe ferox* (here at the western limit of its distribution) in the Overberg (Western Cape).

O. uniflora (d), *Stoebe plumosa* (d), *Acmadenia macropetala*, *Anthospermum prostratum*, *Aspalathus alpestris*, *A. calcarata*, *A. campestris*, *A. millefolia*, *A. pinguis* subsp. *pinguis*, *A. zeyheri*, *Diosma passerinoides*, *Metalasia pungens*, *Polhillia pallens*, *Relhania garnotii*, *Ursinia discolor*. Herbs: *Arctotis acaulis*, *Peucedanum striatum*. Geophytic Herbs: *Freesia caryophyllacea*, *Geissorhiza nana*, *Oxalis purpurea*, *Romulea minutiflora*. Succulent Herbs: *Duvalia elegans*, *Haworthia marginata*. Graminoids: *Cymbopogon pospischilii* (d), *Eragrostis curvula* (d), *Merxmuellera stricta* (d), *Themeda triandra* (d), *Ehrharta calycina*, *E. melicoides*, *Elegia recta*, *Festuca scabra*, *Koeleria capensis*, *Tribolium hispidum*.

Endemic Taxa Low Shrubs: *Agathosma gnidiiflora*, *Aspalathus grobleri*, *A. opaca* subsp. *pappeana*, *Gnidia ericoides*, *Lebeckia bowieana*, *Polhillia brevicalyx*, *Pteronia beckeoides*. Tall Shrub: *Aspalathus incompta*. Succulent Shrubs: *Drosanthemum vandermerwei*, *Trichodiadema pygmaeum*. Semiparasitic Shrub: *Thesium rufescens*. Geophytic Herb: *Hesperantha muirii*. Succulent Herbs: *Haworthia heidelbergensis*, *H. mutica*, *H. serrata*.

Conservation Critically endangered. Target of 27% cannot be attained since over 80% of the area has been transformed, mostly for cropland. Only patches on the steepest slopes remain in a more or less natural state. Small fractions conserved in the Bontebok National Park, De Hoop and Werner Frehse Nature Reserves as well as in the private Grootvadersbosch Conservancy. Invasion of alien woody plants does not seem to constitute a problem; only *Acacia cyclops* occurs in places. Erosion moderate and very low.

Remarks River valleys, watercourses and bottomlands support AZa 2 Cape Lowland Alluvial Vegetation dominated by *Acacia karroo*, *Aloe ferox*, *Buddleja saligna* and *Rhus pallens*. These are extensive, but have not been mapped so far.

References Muir (1929), Grobler & Marais (1967), Taylor (1970a), Boucher & Moll (1981), Rebelo et al. (1991), Von Hase et al. (2003), Raitt (2005), C. Boucher (unpublished data), N. Helme (unpublished data).

FRs 14 Mossel Bay Shale Renosterveld

VT 46 Coastal Renosterbosveld (76%) (Acocks 1953). South Coast Renosterveld (38%) (Moll & Bossi 1983). LR 63 South and South-west Coast Renosterveld (93%) (Low & Rebelo 1996). BHU 34 Riversdale Coast Renosterveld (64%), BHU 28 Blanco Fynbos/Renosterveld Mosaic (24%) (Cowling et al. 1999b, Cowling & Heijnis 2001). STEP Herbertsdale Renoster Thicket (46%), STEP Gouritz Valley Thicket (10%) (Vlok & Euston-Brown 2002).

Distribution Western Cape Province: Coastal plains and valleys from the Kruisrivier near Riversdale to Botterberg, west of the Robinson Pass, centred on the Gouritz River and bordered by mountains (Langeberg, Outeniqua) to the north and the N2 road to the south, except for a few small patches further south (south of Cooper). Altitude 120–360 m.

Vegetation & Landscape Features Undulating hills and tablelands, steeply dissected by rivers. The vegetation of the area is mainly a medium dense, medium tall cupressoid-leaved shrubland dominated by renosterbos, dotted by sparse, tall shrubs. Thicket patches and thicket elements are common, possibly because the landscape is more rugged than in the case of the Rûens shale renosterveld types, and therefore less prone to fire. Fire-safe habitats, such as steep slopes, gullies and termitaria have thicket clumps, dominated by *Euclea undulata*, *Putterlickia pyracantha* and *Rhus lucida*. Steep north-facing slopes have succulent thicket elements. The southern reaches may be covered with a calcrete layer bearing South Coast limestone fynbos elements.

Geology & Soils Clays and loams mostly derived from Bokkeveld Group shales as well as Uitenhage Group clastics in the west and east. Prismacutanic or pedocutanic diagnostic horizons occur in soils. Glenrosa and Mispah forms dominant. Land types mainly Db, Ea and Fc.

Climate MAP 270–620 mm (mean: 425 mm), even throughout the year with a slight low in December. Mean daily maximum and minimum temperatures 27.6°C and 6.1°C for January–February and July, respectively. Frost incidence about 3 days per year. See also climate diagram for FRs 14 Mossel Bay Shale Renosterveld (Figure 4.101).

Important Taxa Succulent Trees: *Aloe ferox*, *A. speciosa*. Tall Shrubs: *Diospyros dichrophylla*, *Rhus glauca*, *R. pterota*. Low Shrubs: *Aspalathus alpestris*, *Barleria pungens*, *Blepharis capensis*, *Carissa bispinosa* subsp. *bispinosa*, *Elytropappus rhinocerotis*, *Eriocephalus africanus* var. *africanus*, *Indigofera denudata*, *Metalasia pungens*, *Oedera genistifolia*, *Pentzia incana*, *Ursinia discolor*. Succulent Shrubs: *Aloe arborescens*, *Crassula perforata*, *Drosanthemum intermedium*. Woody Climber: *Asparagus racemosus*. Geophytic Herb: *Romulea luteoflora*. Succulent Herbs: *Carpobrotus acinaciformis*, *Senecio crassulaefolius*. Graminoids: *Brachiaria serrata*, *Ehrharta calycina*, *Ischyrolepis capensis*, *Pentaschistis eriostoma*, *P. pallida*, *Sporobolus africanus*, *Themeda triandra*.

Endemic Taxa Low Shrubs: *Anisodontea pseudocapensis*, *Aspalathus obtusifolia*, *Polhillia connata*, *Ruellia pilosa*, *Salvia muirii*. Succulent Herbs: *Haworthia chloracantha* var. *denticulifera*, *H. chloracantha* var. *subglauca*, *H. magnifica* var. *dekenahii*, *H. magnifica* var. *splendens*, *H. retusa*.

Conservation Endangered. Target 27%. None conserved in statutory conservation areas and only small patches protected in Langeberg-oos mountain catchment area. Some 58% has been transformed (croplands and pastures). Erosion mainly moderate and high, but with some areas ranking as very low.

Remarks Overgrazing can eliminate grasses, resulting in a grass-free shrubland or thicket. FFc 1 Swellendam Silcrete Fynbos can be converted to Mossel Bay Shale Renosterveld by overgrazing.

References Muir (1929), Boucher & Moll (1981), Rebelo et al. (1991), H.C. Taylor (unpublished data).

FRs 15 Swartberg Shale Renosterveld

VT 70 False Macchia (54%), VT 26 Karroid Broken Veld (42%) (Acocks 1953). South Coast Renosterveld (60%), Karroid Shrublands (37%) (Moll & Bossi 1983). Grassy Renoster Shrubland (Campbell 1985). LR 63 South and South-west Coast Renosterveld (62%), LR 54 Central Lower Nama Karoo (26%) (Low & Rebelo 1996). BHU 43 Kango Inland Renosterveld (65%), BHU 68 Prince Albert Broken Veld (28%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western and Eastern Cape Provinces: Mainly northern slopes of the Groot Swartberg and some parallel ridges in the Oukloof and Droëkloof from near Prince Albert in the west to Vartjiesrivier in the east; an outlier further west on the Swartberg in the upper reaches of the Waterkloofrivier catchment between Elandspad and Kliphuisvlei (above and east of Gamkaskloof or Die Hel). Altitude 750–1 200 m.

Vegetation & Landscape Features Steep and gentle intermontane valleys with low, medium dense cupressoid-leaved shrubland having an open grassy understorey and dominated by renosterbos. Heuweltjies are rare.

Geology & Soils The soils derived from several shale sources within the Table Mountain Group (particularly the Nardouw Subgroup) as well as the Witteberg and Bokkeveld Groups of the Cape Supergroup that underlie this area. Prismacutanic and pedocutanic and Glenrosa or Mispah forms are prominent. Land types mainly Ib, Ic and Fc.

Climate MAP 150–440 mm (mean: 285 mm), even throughout the year. Mean daily maximum and minimum temperatures 30.0°C and 2.3°C for January and July, respectively. Frost incidence 10–30 days per year. See also climate diagram for FRs 15 Swartberg Shale Renosterveld (Figure 4.101).

Important Taxa (^{T}Cape thickets) Succulent Tree: *Aloe ferox*. Tall Shrubs: *Buddleja salviifolia*^{T}, *Cliffortia strobilifera*, *Diospyros pallens*^{T}, *Dodonaea viscosa* var. *angustifolia*, *Euclea undulata*^{T}, *Rhus lucida*^{T}, *R. pallens*^{T}, *R. pyroides*^{T}, *R. undulata*^{T}. Low Shrubs: *Athanasia trifurcata* (d), *Chrysocoma ciliata* (d), *Elytropappus rhinocerotis* (d), *Oedera genistifolia* (d), *Polygala bracteolata* (d), *Pteronia incana* (d), *Anthospermum aethiopicum*, *Ballota africana*, *Cliffortia ilicifolia*, *Dimorphotheca cuneata*, *Diospyros austro-africana*, *Eriocephalus africanus* var. *africanus*, *Felicia filifolia* subsp. *filifolia*, *Lebeckia pungens*, *Leysera gnaphalodes*, *Oedera squarrosa*, *Pteronia glauca*, *P. pallens*. Woody Succulent Climber: *Zygophyllum debile*. Semiparasitic Epiphytic Shrub: *Viscum capense*. Herbs: *Conium chaerophylloides*, *Galium tomentosum*, *Sutera patriotica*. Graminoids: *Ehrharta calycina*, *E. erecta*, *Eragrostis curvula*, *Karroochloa purpurea*.

Conservation Least threatened. Target 29%. Statutorily conserved in the Groot Swartberg (8%), with additional 1% protected in the Swartberg East mountain catchment area. Only 3% transformed (cultivation). Erosion very low and low.

Remark This is a poorly known vegetation type. Unmapped portions of this unit have been subsumed into FFb 3 Central Inland Shale Band Vegetation.

FRs 16 Uniondale Shale Renosterveld

VT 43 Mountain Renosterbosveld (50%), VT 26 Karroid Broken Veld (27%) (Acocks 1953). Karroid Shrublands (48%), South Coast Renosterveld (24%), Mosaic of South Coast Renosterveld (19%) (Moll & Bossi 1983). Grassy Renoster Shrubland (Campbell 1985). LR 63 South and South-west Coast Renosterveld (49%), LR 54 Central Lower Nama Karoo (23%) (Low & Rebelo 1996). BHU 44 Uniondale Inland Renosterveld (32%), BHU 98 Willowmore Xeric Succulent Thicket (21%) (Cowling et al. 1999b, Cowling & Heijnis 2001). STEP Willowmore Renoster Thicket (35%) (Vlok & Euston-Brown 2002).

Distribution Western and Eastern Cape Provinces: Little Karoo from Sebrasfontein (south of Oudtshoorn) to Uniondale on the northern slopes of the Outeniqua Mountains, lower southern slopes of the Kammanassie Mountains, northern slopes of the western end of the Kouga Mountains as well as ridges, plateaus and valleys to Willowmore in the north; a few outliers in the Grootrivierberge, west of Naroegas Poort. Altitude 500–1 150 m.

Vegetation & Landscape Features Intermontane valleys and lower slopes covered with low, medium dense, cupressoid-leaved shrubland having an open grassy understorey, and dominated by renosterbos. North-facing slopes have thicket clumps. Eastern extent very much limited by fire-retardant thicket vegetation, and thus associated mainly with the fynbos areas at higher altitudes.

Geology & Soils Clays and loams derived from Bokkeveld (and Witteberg) Group shales. Glenrosa and Mispah forms prominent. Land types mainly Fc and Fb.


L. Mucina

Figure 4.115 FRs 16 Uniondale Shale Renosterveld: Renosterbos shrublands with *Elytropappus rhinocerotis*, *Athanasia furcata* and *Cotyledon orbiculata* (in the foreground) in the Klein Langkloof Valley along the northern foot of the Outeniqua Mountains (Western Cape).

Climate MAP 170–660 mm (mean: 350 mm), even throughout the year with a slight peak in March. Mean daily maximum and minimum temperatures 29.6°C and 2.4°C for January and July, respectively. Frost incidence 10–40 days per year. See also climate diagram for FRs 16 Uniondale Shale Renosterveld (Figure 4.101).

Important Taxa Small Tree: *Acacia karroo* (d). Succulent Tree: *Aloe ferox* (d). Tall Shrubs: *Rhus lucida* (d), *Diospyros austro-africana*, *Dodonaea viscosa* var. *angustifolia*, *Euclea undulata*. Low Shrubs: *Elytropappus rhinocerotis* (d), *Oedera squarrosa* (d), *Carissa bispinosa* subsp. *bispinosa*, *Chrysocoma oblongifolia*, *Felicia filifolia* subsp. *filifolia*, *Galenia africana*, *Helichrysum asperum* var. *albidulum*, *Lessertia fruticosa*, *Lotononis nutans*, *Pteronia incana*, *Selago saxatilis*, *Zygophyllum spinosum*. Succulent Shrubs: *Aloe perfoliata* (d), *A. microstigma* subsp. *microstigma*, *Crassula dependens*, *Drosanthemum lique*, *Glottiphyllum salmii*. Semiparasitic Shrub: *Thesium strictum*. Herbs: *Lepidium africanum* subsp. *africanum*, *Limeum aethiopicum* subsp. *aethiopicum*. Geophytic Herbs: *Drimia anomala*, *D. intricata*, *Romulea jugicola*. Succulent Herb: *Crassula muscosa*. Graminoids: *Aristida diffusa*, *Ehrharta calycina*, *Melica decumbens*.

Endemic Taxa Low Shrub: *Amphithalea vlokii*. Succulent Shrubs: *Carruanthus ringens*, *Glottiphyllum oligocarpum*. Geophytic Herb: *Tritonia chrysantha*.

Conservation Least threatened. Target 29%. Only a few patches (less than 1%) are protected in the private Sunnyside Game Farm and in Welbedacht State Forest. Some 15% transformed (cultivation). Woody aliens include *Hakea sericea* and *Pinus pinaster*. Erosion mainly high and moderate.

Remark This is a poorly known vegetation type.

References Boucher & Moll (1981), Vlok & Euston-Brown (2002).

FRs 17 Langkloof Shale Renosterveld

VT 70 False Macchia (92%) (Acocks 1953). Mesic Grassy Fynbos (23%) (Moll & Bossi 1983). LR 63 South and South-west Coast Renosterveld (48%), LR 65 Grassy Fynbos (33%) (Low & Rebelo 1996). BHU 29 Langkloof Fynbos/Renosterveld Mosaic (74%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western and Eastern Cape Provinces: Narrow belt from Herold on the northern side of the Outeniqua Mountains to Kykoe, then descending along the upper reaches of the Keurbooms River Valley, south of the Prince Alfred Pass, to Vleitjie se Berg; in the Langkloof Valley from Harmonie via Avontuur to Haarlem and further from Krakeelrivier via Joubertina and Kareedouw to Salielaagte. Small outlier at Brandhoek northeast of Joubertina. Altitude 220–950 m.

Vegetation & Landscape Features Intermontane valleys and lower slopes with low, medium dense graminoid, dense cupressoid-leaved shrubland, dominated by renosterbos and surrounded by fynbos.

Geology & Soils A very narrow east-west distribution of clays and loams derived from shales of the Nardouw Subgroup of the Table Mountain Group as well as the Ceres Subgroup of the Bokkeveld Group. Prismacutanic and pedocutanic and Glenrosa and Mispah forms are prominent. Land types mainly Db, Fa and Bb.

Climate MAP 280–770 mm (mean: 505 mm), relatively even with a bimodal peak in March and October–November. Mean daily maximum and minimum temperatures 27.9°C and 4.6°C for January–February and July, respectively. Frost incidence 2–10 days per year. See also climate diagram for FRs 17 Langkloof Shale Renosterveld (Figure 4.101).

Important Taxa Tall Shrubs: *Metalasia densa*, *Passerina corymbosa*. Low Shrubs: *Anthospermum aethiopicum*, *A. galioides* subsp. *galioides*, *Argyrolobium pauciflorum*, *Aspalathus nigra*, *Chaetacanthus setiger*, *Eriocephalus africanus* var. *africanus*, *Helichrysum anomalum*, *H. teretifolium*, *Hermannia flammea*, *Indigofera denudata*, *Passerina rubra*, *Pentzia dentata*, *Selago mediocris*, *Senecio hollandii*. Herb: *Hibiscus pusillus*. Herbaceous Climber: *Thunbergia capensis*. Graminoids: *Brachiaria serrata*, *Cymbopogon marginatus*, *Cynodon dactylon*, *Ehrharta calycina*, *E. capensis*, *Festuca scabra*, *Ficinia tristachya*, *Helictotrichon hirtulum*, *Merxmuellera stricta*, *Pentaschistis angustifolia*, *Sporobolus africanus*, *Themeda triandra*.

Endemic Taxon Herb: *Senecio euryopoides*.

Conservation Endangered. Target 29%. None conserved in statutory or private conservation areas. Some 61% transformed (mainly fruit orchards and pastures). Important woody aliens are *Hakea sericea* and *Pinus pinaster*. Erosion very low and low.

Remark This is a poorly known vegetation type. Unmapped portions have been included within the mapped patches of FFb 6 Eastern Coastal Shale Band Vegetation.

References Boucher & Moll (1981), H.C. Taylor (unpublished data).

FRs 18 Baviaanskloof Shale Renosterveld

VT 70 False Macchia (47%), VT 25 Succulent Mountain Scrub (Spekboomveld) (45%) (Acocks 1953). Mesic Grassy Fynbos (99%) (Moll & Bossi 1983). LR 65 Grassy Fynbos (99%) (Low & Rebelo 1996). BHU 73 Baviaanskloof Mountain Fynbos Complex (98%) (Cowling et al. 1999b, Cowling & Heijnis 2001). STEP Baviaans Renoster Thicket (96%) (Vlok & Euston-Brown 2002).

Distribution Eastern Cape Province: Two relatively small groups of digitally shaped lower hillslopes dissected by many ravines (kloofs) containing AT 3 Groot Thicket on the southern side of the Baviaanskloof Valley from Voorkloof to Vleikloof in the west and from Kleinkommandokloof to Drinkwaterkloof in the east. Altitude 600–1 150 m.

Vegetation & Landscape Features Flat, lower mountain bases covered with low, medium dense, cupressoid-leaved shrubland, dominated by renosterbos and with graminoid undergrowth. Rocky areas have small localised thicket patches. This renosterveld type often grades into the surrounding fynbos.

Geology & Soils Often skeletal clays and loams derived from shales of the Nardouw Subgroup (Table Mountain Group). Glenrosa and Mispah forms prominent. Land types mainly Ib and Fb.

Climate MAP 200–620 mm (mean: 365 mm), even throughout the year, with a peak in March. Mean daily maximum and minimum temperatures 27.9°C and 2.5°C for February and July, respectively. Frost incidence 10–30 days per year. See also climate diagram for FRs 18 Baviaanskloof Shale Renosterveld (Figure 4.101).

Important Taxa Succulent Tree: *Aloe ferox*. Low Shrubs: *Elytropappus rhinocerotis* (d), *Chascanum cuneifolium*, *Passerina obtusifolia*, *Phylica axillaris*, *Pteronia incana*. Herb: *Hibiscus aethiopicus*. Graminoids: *Eragrostis curvula*, *E. obtusa*, *Eustachys paspaloides*, *Themeda triandra*.

Endemic Taxon Succulent Shrub: *Delosperma esterhuyseniae*.

Conservation Least threatened. Target 29%. It is statutorily conserved in the Guerna (16%) and Baviaanskloof Wilderness Areas (4%), with some small patches also conserved on private land (Beakosneck). The unit has not experienced notable transformation so far, except for the occurrence of aliens such as *Acacia mearnsii, A. saligna*, *Pinus pinaster* and *Opuntia ficus-indica*. Erosion mainly low and moderate.

Remark This is a rare and poorly studied vegetation type.

References Boucher & Moll (1981), Euston-Brown (1995), Vlok & Euston-Brown (2002).

FRs 19 Humansdorp Shale Renosterveld

VT 70 False Macchia (91%) (Acocks 1953). Mosaic of South Coast Renosterveld (83%) (Moll & Bossi 1983). LR 63 South and South-west Coast Renosterveld (89%) (Low & Rebelo 1996). BHU 30 Kromme Fynbos/Renosterveld Mosaic (90%) (Cowling et al. 1999b, Cowling & Heijnis 2001). STEP Kabeljous Renoster Thicket (17%), STEP Rocklands Renoster Thicket (8%) (Vlok & Euston-Brown 2002).

Distribution Eastern Cape Province: Three swathes: from Jeffreys Bay and Marina Glades near the coast inland past Humansdorp to the lower reaches of the Dieprivier near Two Streams; the Mondplaas/Mondhoek area near the mouth of the Gamtoos River stretching inland in a series of patches south of the Gamtoos River to west of Patensie; between thicket and fynbos types from Burghley Hills to Rocklands and the Dell to Nooitgedacht southwest of Uitenhage. Coastal forelands from Humansdorp to Port Elizabeth. Altitude 20–360 m.

Vegetation & Landscape Features Moderately undulating plains and undulating hills supporting vegetation composed of low, medium dense graminoid, dense cupressoid-leaved shrubland, dominated by renosterbos. There are both grassland and shrubland forms of the renosterveld present, probably depending on grazing and fire regimes. In wetter areas (> 550 mm) it grades into FFt 2 Loerie Conglomerate Fynbos. Thicket patches are common on termitaria (heuweltjies are absent) and in fire-safe enclaves, especially in the east. It is dominated by *Aspalathus nivea* in the post-fire, early seral stages.

Geology & Soils Clays and loams derived from the Ceres Subgroup of the Bokkeveld Group shales. Plinthic catenas prominent. Land types mainly Ca and Bb.

Climate MAP 500–850 mm (mean: 630 mm), peaking slightly in March, but otherwise even. Mean daily maximum and minimum temperatures 25.1°C and 7.5°C for February and July, respectively. Frost incidence about 3 days per year. See also climate diagram for FRs 19 Humansdorp Shale Renosterveld (Figure 4.101).

Important Taxa ([W]Wetlands) Succulent Tree: *Aloe africana*. Tall Shrubs: *Cliffortia strobilifera*, *Metalasia densa*, *Morella serrata*. Low Shrubs: *Elytropappus rhinocerotis* (d), *Helichrysum anomalum* (d), *Oedera genistifolia*, (d), *Anthospermum galioides* subsp. *galioides*, *Barleria pungens, Chaetacanthus setiger*, *Clutia rubricaulis*, *Euryops munitus, Felicia filifolia* subsp. *filifolia*, *Hermannia flammea*, *Indigofera denudata*, *I. heterophylla*, *Lotononis acuminata*, *Metalasia aurea, Muraltia alopecuroides*, *Passerina rubra*, *Pelargonium sidoides, Tephrosia capensis*. Herbaceous Climber: *Thunbergia capensis.* Herbs: *Arctotis acaulis*, *Berkheya heterophylla* var. *radiata*, *Centella asiatica*[W], *Gazania linearis*, *Gerbera piloselloides*, *Helichrysum nudifolium*, *Hibiscus pusillus*, *Senecio othonniflorus*. Geophytic Herbs: *Bobartia orientalis*, *Geissorhiza heterostyla*, *Ledebouria cooperi, Oxalis punctata*, *O. smithiana*, *Satyrium membranaceum*. Graminoids: *Eustachys paspaloides* (d), *Themeda triandra* (d), *Aristida junciformis* subsp. *galpinii*, *Brachiaria serrata*, *Cymbopogon marginatus*, *Cynodon dactylon*, *Eragrostis capensis*, *E. curvula*, *Ficinia nigrescens*, *F. tristachya, Merxmuellera disticha*, *Paspalum dilatatum*, *Pentaschistis pallida, Restio tetragonus*, *Sporobolus africanus*, *Tribolium hispidum*, *Tristachya leucothrix*.

Endemic Taxa Succulent Shrubs: *Delosperma patersoniae*, *Trichodiadema fourcadei*. Geophytic Herb: *Cyrtanthus wellandii*.


L. Mucina

Figure 4.116 FRs 19 Humansdorp Shale Renosterveld: Renosterveld shrubland with *Elytropappus rhinocerotis* and *Oedera genistifolia* on coastal flats near Jeffreys Bay (Eastern Cape).

Conservation Endangered. Target 29%. None conserved in statutory conservation areas and only 6% enjoys protection on private land (Thaba Manzi and Lombardini Game Farms). Some 61% already transformed (cultivation). Erosion very low and low.

Remark Locally, thicket is burnt and converted to renosterveld for grazing.

References Boucher & Moll (1981), Cowling (1984), Vlok & Euston-Brown (2002).

9.2.2 Granite and Dolerite Renosterveld

Granite renosterveld is the second most widespread renosterveld group, comprising 6% the area of renosterveld. Only three units, in the Kamiesberg, Swartland and at Robertson, are recognised. All are quite distinct and unrelated to one another.

Granite renosterveld has very strong affinities with granite fynbos. This edaphic transition appears to have been responsible for a fynbos 'derivation' of renosterveld on the West Coast, or at least a high proportion of fynbos elements within the renosterveld (chiefly geophytes). Prominent on granites are high bulb diversity and a very strong forest-thicket element, especially on rocky outcrops and fire-safe habitats which abound in granite landscapes.

Dolerite renosterveld is confined to the Western Escarpment between Nieuwoudtville and Calvinia, with outliers to Sutherland. Like granite renosterveld, this has a high bulb diversity, with Nieuwoudtville being recognised as the bulb capital of the world—an unusually high proportion of species within the vegetation type are geophytes, and exceptional bulb densities can be found here.

FRg 1 Namaqualand Granite Renosterveld

VT 43 Mountain Renosterbosveld (63%), VT 33 Namaqualand Broken Veld (Acocks 1953). LR 59 North-western Mountain Renosterveld (53%), LR 56 Upland Succulent Karoo (39%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Namaqualand, east of Kamieskroon and northeast of Garies in the higher-altitude parts of the Kamiesberg area from Os Plaat se Berge and the Dounabesberge in the north to Stalberg and Grasberg in the south and including a central area around Leliefontein. The most easterly extension is in the vicinity of Paulshoek. Embedded within this unit are several patches of generally highest-altitude FFg 1 Kamiesberg Granite Fynbos. Altitude 1 100–1 450 m.

Vegetation & Landscape Features Plateaus, low mountains and broken veld of typical granite landscapes, covered with dense, 1–1.5 m tall shrublands dominated by renosterbos (*Elytropappus rhinocerotis*) and other, mainly asteraceous (*Euryops*, *Arctotis*) shrubs. Overgrazing increases the cover of karoo elements. Abandoned ploughed fields on the plateaus present spectacular annual floral displays.

Geology & Soils In this area granitic gneiss of the Stalhoek Complex, the Kamieskroon Gneiss and the Nababeep Gneiss is partly overlain by quartzite and other metasediments of the Bitterfontein

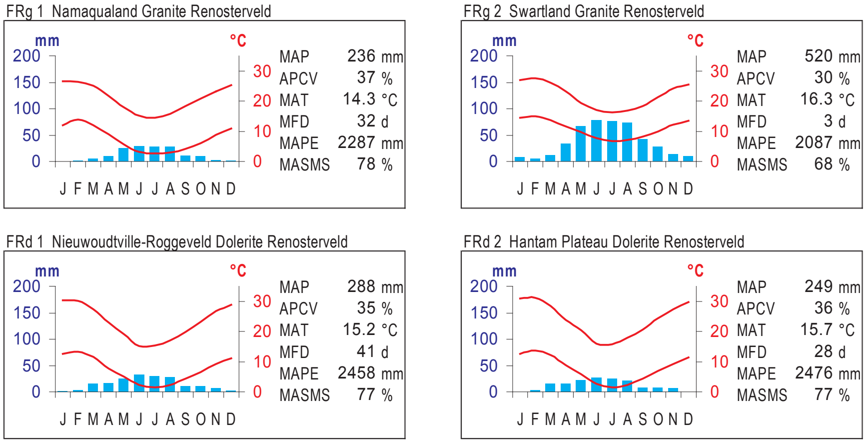

Figure 4.117 Climate diagrams of granite and dolerite renosterveld units. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days; MAPE: Mean Annual Potential Evaporation; MASMS: Mean Annual Soil Moisture Stress.

Formation (Bushmanland Group). The above Mokolian age rocks form level to gentle rocky slopes. The soils are sandy; yellow-brown to brown loamy sand. Land types mainly Ic, IB and Ag.

Climate MAP 130–370 mm (mean: 235 mm), peaking from May to August. This is the most arid of the renosterveld types. Mean daily maximum and minimum temperatures 26.6°C and 2.7°C for January and July, respectively. Frost incidence 10–30 days per year. See also climate diagram for FRg 1 Namaqualand Granite Renosterveld (Figure 4.117).

Important Taxa Tall Shrubs: *Dodonaea viscosa* var. *angustifolia* (d), *Montinia caryophyllacea*, *Nylandtia spinosa*, *Rhus undulata*. Low Shrubs: *Elytropappus rhinocerotis* (d), *Clutia imbricata*, *Hermannia meyeriana*, *Lessertia microcarpa*, *Phylica montana*, *Pteronia pillansii*, *Rhus horrida*. Succulent Shrub: *Othonna retrorsa*. Herbs: *Arctotheca calendula* (d), *Cotula leptalea* (d), *Leysera gnaphalodes* (d), *L. tenella* (d), *Gorteria diffusa* subsp. *calendulacea* (d), *Gazania leiopoda*, *Gymnodiscus capillaris*, *Heliophila schulzii*, *Manulea altissima*, *Ursinia speciosa*. Geophytic Herbs: *Babiana curviscapa*, *Bulbinella ciliolata*, *Ferraria kamiesbergensis*, *Geissorhiza namaquensis*, *Haemanthus amarylloides* subsp. *polyanthus*, *Hesperantha flexuosa*, *Hessea stenosiphon*, *Ixia latifolia* var. *ramulosa*, *Lachenalia unicolor*, *Moraea kamiesensis*, *M. rivulicola*, *Oftia revoluta*, *Oxalis ambigua*, *O. comosa*, *O. furcillata*, *Romulea citrina*, *R. kamisensis*, *R. namaquensis*, *R. neglecta*, *Tritonia kamisbergensis*.

Biogeographically Important Taxa (all Kamiesberg endemics, [W]Wetlands) Low Shrubs: *Antithrixia flavicoma*, *Aspalathus angustifolia* subsp. *robusta*, *Felicia diffusa* subsp. *khamiesbergensis*, *Muraltia rigida*. Herb: *Centella tridentata* var. *dregeana*. Geophytic Herbs: *Crocosmia fucata*, *Disa macrostachya*, *Hesperantha latifolia*, *Moraea kamiesmontana*, *Romulea pearsonii*[W].

Endemic Taxa Low Shrubs: *Euryops subcarnosus* subsp. *minor*, *Lotononis polycephala*, *Otholobium hamatum*. Succulent Shrubs: *Cheiridopsis pearsonii*. Herb: *Ursinia* sp. nov. ('*kamiesbergensis*') (*Mucina & Swelankomo 060905/2* STEU). Geophytic Herbs: *Haemanthus graniticus*, *Moraea longiflora*, *M. pendula*, *Oxalis kamiesbergensis*.

Conservation Least threatened. Target 27%. None conserved in statutory or private conservation areas. About 5% transformed (cultivation), but large portions suffer from heavy overgrazing. Erosion moderate and low.

Remark 1 This unit and FFg 1 Kamiesberg Granite Fynbos form the core of the Kamiesberg Centre of Endemism (Van Wyk & Smith 2001), which also comprises parts of the SKn 6 Kamiesberg Mountains Shrubland. The boundary between fynbos and renosterveld in this unit is determined by both rainfall and the composition of the granite, so that clay-rich south-facing slopes may contain renosterveld up to 1 500 m. The lower boundary with karoo is often diffuse, with karoo incursions on northern slopes, shallow soils and heuweltjies, and renosterveld extending into karoo on deeper soils, southern slopes and wetter facies. Overgrazing increases the cover of karroid elements, leading to replacement of renosterveld by karoo.

References Adamson (1958), Boucher & Moll (1981), Van Wyk & Smith (2001).

K. Phillips

Figure 4.118 FRg 1 Namaqualand Granite Renosterveld: Spring-floral display of *Arctotis*, *Cotula*, *Ursinia* and *Grielum humifusum* on old fields dotted by renosterbos shrubs on a plateau north of Leliefontein, in the Kamiesberg Mountains, Namaqualand (Northern Cape).

FRg 2 Swartland Granite Renosterveld

VT 46 Coastal Renosterbosveld (66%), VT 47 Coastal Macchia (30%) (Acocks 1953). LR 62 West Coast Renosterveld (77%), LR 68 Sand Plain Fynbos (22%) (Low & Rebelo 1996). BHU 31 Swartland Coast Renosterveld (59%), BHU 32 Boland Coast Renosterveld (32%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Discrete areas in the Swartland and

Figure 4.119 FRg 2 Swartland Granite Renosterveld: Bulb-rich veld dominated by *Lachenalia pustulata* in the Tienie Versveld Flower Reserve near Darling (Western Cape).

Boland: largest patch centred on Darling from Ratelberg in the north to Dassenberg near Mamre and Pella; several centred on Malmesbury from Darmstadt in the north to the lower slopes of the Perdeberg (and small patches to the west towards Atlantis); east of Wellington from Micha to Valencia, lower surrounds of Paarl Mountain; Joostenberg, Muldersvlei, Bottelaryberg, Papegaaiberg (Stellenbosch West), to Firgrove and northern Somerset West. Altitude 50–350 m.

Vegetation & Landscape Features Moderate foot slopes and undulating plains supporting a mosaic of grasslands/herblands and medium dense, microphyllous shrublands dominated by renosterbos. Groups of small trees and tall shrubs are associated with heuweltjies and rock outcrops. The boundary with FFg 2 Boland Granite Fynbos is diffuse and patchy.

Geology & Soils Coarse sandy to loamy soils of a variety of forms ranging from Glenrosa and Mispah, to prismacutanic and pedocutanic diagnostic horizons to red-yellow apedal soils—all derived from Cape Granite. The soils can contain a considerable volume of moisture in winter and spring. Land types mainly Fa, Ca, Db and Ac.

Climate MAP 360–790 mm (mean: 520 mm), peaking from May to August. Mists common in winter. This is the wettest renosterveld unit. Mean daily maximum and minimum temperatures 27.7°C and 6.7°C for February and July, respectively. Frost incidence about 3 days per year. See also climate diagram for FRg 2 Swartland Granite Renosterveld (Figure 4.117).

Important Taxa (^{T}Cape thickets) Tall Shrubs: *Euclea racemosa* subsp. *racemosa*^{T} (d), *Olea europaea* subsp. *africana*^{T} (d), *Putterlickia pyracantha*^{T} (d), *Rhus laevigata*^{T} (d), *Aspalathus acuminata* subsp. *acuminata*, *Chrysanthemoides monilifera*, *Diospyros glabra*^{T}, *Dodonaea viscosa* var. *angustifolia*, *Myrsine africana*^{T}, *Passerina corymbosa*, *Rhus angustifolia*^{T}, *R. crenata*^{T}, *R. tomentosa*^{T}, *R. undulata*^{T}, *Wiborgia obcordata*. Low Shrubs: *Anthospermum aethiopicum* (d), *Elytropappus rhinocerotis* (d), *Eriocephalus africanus* var. *africanus* (d), *Felicia filifolia* subsp. *filifolia* (d), *Maytenus oleoides* (d), *Salvia lanceolata* (d), *Anthospermum galioides* subsp. *galioides*, *Aspalathus hispida*, *Asparagus rubicundus*, *Athanasia trifurcata*, *Chironia baccifera*, *Erica paniculata*, *Galenia africana*, *Gnidia squarrosa*, *Helichrysum cymosum*, *H. dasyanthum*, *H. revolutum*, *H. teretifolium*, *Hermannia alnifolia*, *H. hyssopifolia*, *H. prismatocarpa*, *Leucadendron lanigerum* var. *lanigerum*, *Lobostemon argenteus*, *L. fruticosus*, *Nenax hirta* subsp. *hirta*, *Oftia africana*, *Phylica thunbergiana*, *Rhus dissecta*, *R. rosmarinifolia*, *Salvia africana-caerulea*, *Stoebe cinerea*. Succulent Shrub: *Lampranthus sociorum*. Woody Climbers: *Cissampelos capensis*, *Microloma sagittatum*. Herbs: *Helichrysum crispum* (d), *Annesorhiza macrocarpa*, *Cotula turbinata*, *Hebenstretia paarlensis*, *Lichtensteinia obscura*, *Stachys aethiopica*. Geophytic Herbs: *Mohria caffrorum* (d), *Chlorophytum undulatum*, *Geissorhiza monanthos*, *Moraea papilionacea*, *Oxalis obtusa*, *O. pes-caprae*, *O. purpurea*, *Pelargonium longifolium*, *Romulea eximia*, *R. rosea*, *Sparaxis parviflora*, *Watsonia borbonica* subsp. *borbonica*. Succulent Herb: *Crassula capensis*. Herbaceous Climber: *Cynanchum africanum*. Graminoids: *Ehrharta calycina* (d), *E. villosa* var. *villosa* (d), *Ischyrolepis gaudichaudiana* (d), *Cymbopogon marginatus*, *Ehrharta longiflora*, *E. ottonis*, *E. thunbergii*, *Ischyrolepis capensis*, *Thamnochortus bachmannii*, *Themeda triandra*, *Tribolium uniolae*.

Endemic Taxa Low Shrubs: *Agathosma hispida*, *A. latipetala*, *Aspalathus glabrata*, *A. rycroftii*. Succulent Shrubs: *Antimima menniei*, *Erepsia hallii*, *Lampranthus citrinus*, *L. scaber*, *Phyllobolus suffruticosus*, *Ruschia klipbergensis*. Herbs: *Arctopus dregei*, *Oncosiphon glabratum*. Geophytic Herbs: *Babiana pygmaea*, *B. regia*, *B. rubrocyanea*, *Geissorhiza darlingensis*, *G. eurystigma*, *G. malmesburiensis*, *G. mathewsii*, *G. radians*, *Haemanthus pumilio*, *Ixia aurea*, *I. curta*, *Lachenalia purpureocaerulea*, *Moraea amissa*, *Oxalis stictocheila*, *Watsonia humilis*.

Conservation This is a critically endangered vegetation unit of which almost 80% has already been transformed due to prime quality of the land for agriculture (vineyards, olive orchards, pastures) and also by urban sprawl. Hence the conservation target of 26% remains unattainable. Only very small portions (0.5%) enjoy statutory protection in the Paarl Mountain Nature Reserve and Pella Research Site, and also (2%) in the Paardenberg, Tienie Versveld Flower Reserve near Darling and in the Duthie Nature Reserve in Stellenbosch. Alien grasses are particularly pervasive, the most important being *Lolium multiflorum*, *Avena fatua* and *Bromus diandrus* (Musil et al. 2005). Alien woody species include *Acacia saligna*, *Pinus pinaster* as well as various species of *Eucalyptus*. Erosion very low, low and moderate.

Remarks The grassland phases of this vegetation unit as well as the rocky outcrops are particularly rich in geophytes. Several regional and local endemic taxa are shared with FRs 9 Swartland Shale Renosterveld.

References Acocks (1935), Boucher & Moll (1981), Boucher (1983, 1987, 1999b), Jacobs (1984), Landman & Nel (1989), Boucher & Rode (1994, 1999), Nel (1995), Von Hase et al. (2003), Musil et al. (2005), N. Helme (unpublished data).

FRg 3 Robertson Granite Renosterveld

VT 26 Karroid Broken Veld (74%), VT 69 Macchia (26%) (Acocks 1953). LR 61 Central Mountain Renosterveld (99%) (Low & Rebelo 1996). Central Mountain Renosterveld (97%) (Moll & Bossi 1983). BHU 38 Ashton Inland Renosterveld (96%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Extremely limited area: confined to low altitudes of the Tierberg north of La Colline near Robertson in the Breede River Valley. Altitude 250–850 m.

Vegetation & Landscape Features Gentle to steep slopes of a granite dome, with fairly dense 1–2 m tall, closed grassy shrubland with a greater than average succulent element and with scattered small trees. Bulbs are lacking diversity and grasses are currently dominant. Heuweltjies are present, but do not appear as a prominent feature. This unit is largely surrounded by shale renosterveld at lower elevations. At upper elevations, especially in the south, it grades into granite fynbos.

Geology & Soils Loamy soils, primarily of Glenrosa and Mispah forms derived from the Robertson Pluton of the Cape Granite Suite. Land type mainly Fb.

Climate MAP 360–740 mm (mean: 440 mm), with a slight peak from May to August. Mean daily maximum and minimum temperatures 28.7°C and 4.0°C for February and July, respectively. Frost incidence 6–10 days per year. See also climate diagram for FRg 3 Robertson Granite Renosterveld (Figure 4.117).

Important Taxa ([T]Cape thickets) Tall Shrubs: *Dodonaea viscosa* var. *angustifolia* (d), *Euclea undulata*[T], *Euryops tenuissimus*, *Myrsine africana*[T], *Olea europaea* subsp. *africana*[T], *Rhus lucida*[T], *R. pallens*[T], *R. tomentosa*[T]. Low Shrubs: *Elytropappus rhinocerotis* (d), *Eriocephalus africanus* var. *africanus* (d), *Oedera squarrosa* (d), *Pteronia incana* (d), *P. pallens* (d), *Senecio pinifolius* (d), *Euryops rehmannii*, *Maytenus oleoides*. Succulent Shrubs: *Ruschia caroli* (d), *Tylecodon paniculatus* (d), *Euphorbia burmannii*. Graminoids: *Ehrharta calycina* (d), *Ficinia ramosissima* (d), *Pentaschistis eriostoma* (d), *Ehrharta thunbergii*, *Ischyrolepis gaudichaudiana*.

Conservation Least threatened. Target 27%. About 30% protected in Langeberg-wes mountain catchment area. Only a small fraction has been transformed. The lowest-lying areas have been converted to vineyards and orchards, but slopes are generally too steep for further transformation. Erosion moderate.

Remark This unit is a virtually unknown vegetation type deserving scientific attention due to the isolated character of the granite pluton.

Reference N. Helme (unpublished data)

FRd 1 Nieuwoudtville-Roggeveld Dolerite Renosterveld

VT 28 Western Mountain Karoo (53%) (Acocks 1953). LR 56 Upland Succulent Karoo (62%) (Low & Rebelo 1996). Karroid Shrublands (73%), Mosaic of Dry Mountain Fynbos & Karroid Shrublands (27%) (Moll & Bossi 1983). BHU 75 Western Mountain Vygieveld (14%), BHU 35 Nieuwoudtville Inland Renosterveld (13%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Northern Cape Province: Dolerite ridges and surrounding plains east of the Bokkeveld Plateau, immediately east and northeast of Nieuwoudtville between the Doring River in the vicinity of Grasberg in the north and Schoongezicht in the south as well as similar small areas but collectively larger areas on the Roggeveld Plateau, between Middelpos and Sutherland. Altitude 740–1 500 m.

Vegetation & Landscape Features Ridges composed of rounded-block koppies and surrounding plains. The plains support species-rich herbland, seasonally dominated by geophytes and annuals, with an overstorey of nonsucculent shrubs, while the koppies supporting scattered shrubbery with low trees also occur in places. The vegetation of the dolerite plains is unique in being almost devoid of shrubs or perennial grasses. The koppies generally consist of cosmopolitan species derived from the adjacent karoo and renosterveld. Geophytes and annuals compose 90% of the cover and 80% of the species.

Geology & Soils Intrusive dolerites of the Jurassic Karoo Dolerite Suite giving rise to clay soils varying from fine-textured sands on the koppies to heavy red-clay vertisols on the lower slopes and plains. Land types mainly Fc, Ea, Da and Ib.

Climate MAP 140–530 mm (mean: 290 mm), peaking slightly from May to August. Mean daily maximum and minimum temperatures 30.3°C and 1.5°C for January and July, respectively. Frost incidence 10–50 days per year. See also climate diagram for FRd 1 Nieuwoudtville-Roggeveld Dolerite Renosterveld (Figure 4.117).

Important Taxa ([K]Koppies) Tall Shrubs: *Olea europaea* subsp. *africana*[K] (d), *Rhus undulata*[K] (d), *Montinia caryophyllacea*[K], *Melianthus comosus*. Low Shrubs: *Pentzia incana*[K], *Pteronia glauca*, *Stachys rugosa*[K]. Woody Climber: *Microloma sagittatum*. Woody Succulent Climber: *Zygophyllum foetidum*[K].

J.C. Manning

Figure 4.120 FRd 1 Nieuwoudtville-Roggeveld Dolerite Renosterveld: Spring aspect with flowering *Bulbine latifolia* var. *doleritica* (Asphodelaceae) on Glen Lyon Farm near Nieuwoudtville (Northern Cape).

Semiparasitic Shrub: *Thesium lineatum*. Herbs: *Arctotis acaulis* (d), *Berkheya glabrata* (d), *Cotula nudicaulis* (d), *Senecio sisymbriifolius* (d), *Annesorhiza altiscapa*, *Hemimeris racemosa*[K], *Nemesia cheiranthus*, *Othonna auriculifolia*. Geophytic Herbs: *Brunsvigia bosmaniae* (d), *Oxalis callosa* (d), *Babiana spathacea*, *Gethyllis campanulata*[K], *Melasphaerula ramosa*, *Oxalis flava*, *Romulea austinii*, *Sparaxis elegans*, *Veltheimia capensis*[K]. Graminoids: *Ehrharta melicoides* (d), *Merxmuellera stricta* (d).

Biogeographically Important Taxa (both Roggeveld-Hantam endemics) Succulent Herb: *Quaqua arenicola* subsp. *pilifera*. Geophytic Herb: *Androcymbium pulchrum*.


J.C. Manning

Figure 4.121 FRd 2 Hantam Plateau Dolerite Renosterveld: Temporary wetlands on the top of the Hantam Plateau (Northern Cape) supporting clay dolerite renosterveld, dominated by *Bulbine latifolia* var. *latifolia* (Asphodelaceae).

Endemic Taxa ([K]Koppies, [W]Wetlands) Low Shrub: *Euryops rosulatus*. Herbs: *Emilia hantamensis* (d), *Heliophila collina* (d). Geophytic Herbs: *Bulbinella latifolia* subsp. *doleritica* (d), *Cyanella aquatica*[W], *Daubenya alba*, *D. capensis*, *D. stylosa*, *Diascia cardiosepala, Geissorhiza inaequalis*, *Hesperantha vaginata*, *Lachenalia neilii, Lapeirousia oreogena*, *Moraea fragrans*, *M. vespertina*[K], *Romulea monadelpha*, *Sparaxis pillansii*, *Trachyandra prolifera, Zantedeschia odorata*[K].

Conservation Least threatened. Target 27%. Partly conserved in the Nieuwoudtville Flower Reserve as well as on Glenlyon Farm (by local farmer and conservationist Neil McGregor). About 4% transformed (mainly cultivation). The unit is under threat from overgrazing and invasion by alien grasses and herbs (*Avena fatua*, *Bromus pectinatus*, *Hordeum murinum*, *Lolium rigidum* and *Medicago polymorpha*) which are becoming dominant in many areas and suppressing the unique bulb flora. Erosion moderate and low.

Remarks Concentrations of number of geophytes near Nieuwoudtville have been verified as extremely high, reaching up to 25 000 bulbs per square metre (S.W. Todd & J.S. Donaldson, unpublished data). Together with FRs 2 Nieuwoudtville Shale Renosterveld, this as well as several SKv and SKt units form the core of the Roggeveld-Hantam Centre of Endemism (Van Wyk & Smith 2001), which contains the richest geophytic flora in the Cape flora. Geophytes constitute 40% of the local flora.

References Snijman & Perry (1987), Manning & Goldblatt (1997b), Van Wyk & Smith (2001), L. Mucina (unpublished data), S.W. Todd & J.S. Donaldson (unpublished data).

FRd 2 Hantam Plateau Dolerite Renosterveld

VT 28 Western Mountain Karoo (62%), VT 43 Mountain Renosterbosveld (26%) (Acocks 1953). LR 56 Upland Succulent Karoo (78%), LR 60 Escarpment Mountain Renosterveld (21%) (Low & Rebelo 1996). BHU Loeriesfontein Broken Veld (4%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Northern Cape Province: Plateau of the Hantamberg in the triangle between Sandkop, Downes and Driekuilspunt north of Calvinia as well as surrounding points such as Toringkop, Blomberg and to the south, Rebunieberg. Altitude 550–1 672 m at the (unnamed) highest point on the Hantam Plateau.

Vegetation & Landscape Features Plateau of tafelbergs supporting low shrubland with rich herblands containing a wealth of geophytes, especially in the more open, wetter or rocky habitats.

Geology & Soils Heavy, clayey soils and outcrops of intrusive dolerites (Jurassic Karoo Dolerite Suite) as well as (to a small extent) shales of the Ecca Group (Karoo Supergroup). Land type mainly Ib.

Climate MAP 160–440 mm (mean: 250 mm), peaking slightly from May to August. Mean daily maximum and minimum temperatures 31.1°C and 1.4°C for February and July, respectively. Frost incidence 10–40 days per year. See also climate diagram for FRd 2 Hantam Plateau Dolerite Renosterveld (Figure 4.117).

Important Taxa Tall Shrubs: *Cliffortia arborea*, *Diospyros austro-africana*. Low Shrubs: *Elytropappus rhinocerotis* (d), *Aptosimum spinescens*, *Argyrolobium collinum*, *Asparagus capensis* var. *capensis*, *Chrysocoma oblongifolia*, *Dimorphotheca cuneata*, *Eriocephalus africanus* var. *africanus*, *E. ericoides* subsp. *ericoides*, *E. spinescens*, *Euryops cuneatus*, *E. marlothii*, *E. trifidus*, *Felicia filifolia* subsp. *filifolia*, *F. macrorrhiza*, *Helichrysum hamulosum*, *H. lucilioides*, *Pteronia glauca*, *P. incana*, *Rosenia glandulosa*, *Stachys rugosa*, *Ursinia pilifera*. Succulent Shrubs: *Euphorbia mauritanica*, *E. stolonifera*. Semiparasitic Shrubs: *Thesium lineatum*, *T. namaquense*. Herbs: *Heliophila pendula*, *Senecio hastatus*. Geophytic Herbs: *Bulbinella nutans* subsp. *nutans*, *Geissorhiza heterostyla*, *Romulea diversiformis*, *R. luteoflora*, *Saniella occidentalis*. Succulent Herb: *Tetragonia robusta* var. *psiloptera*. Graminoids: *Chaetobromus involucratus* subsp. *dregeanus*, *Ehrharta calycina*, *E. capensis*, *E. melicoides*, *Merxmuellera dura*, *Schismus inermis*.

Endemic Taxa Geophytic Herbs: *Babiana praemorsa*, *Hesperantha hantamensis*, *H. oligantha*, *Moraea reflexa*, *Romulea hantamensis*.

Conservation Least threatened. Target 27%. Only 1% conserved (Akkerendam Nature Reserve near Calvinia). Only a very small portion has been transformed, but part of the area is exposed to grazing. Erosion moderate.

Remarks The Hantamberg is home to several endemic geophytes. These species are restricted to seasonally moist or inundated flats on the summit plateau. Disjunct links to the higher-lying, wetter parts of the Roggeveld Escarpment include *Cliffortia arborea*, *Romulea diversiformis* and *Saniella occidentalis*. This unit forms part of the Roggeveld-Hantam Centre of Endemism (Van Wyk & Smith 2001).

References Manning & Goldblatt (1997b), Van Wyk & Smith (2001).

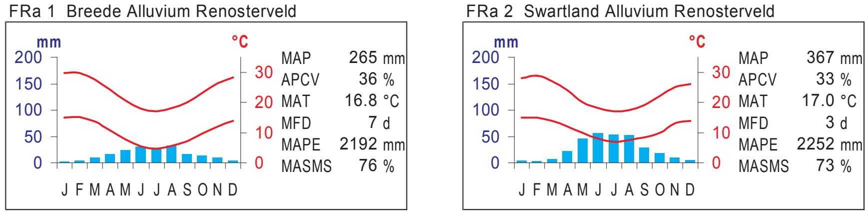

Figure 4.123 Climate diagrams of alluvium renosterveld units. Blue bars show the median monthly precipitation. The upper and lower red lines show the mean daily maximum and minimum temperature respectively. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days (days when screen temperature was below 0°C); MAPE: Mean Annual Potential Evaporation; MASMS: Mean Annual Soil Moisture Stress (% of days when evaporative demand was more than double the soil moisture supply).

9.2.3 Alluvium Renosterveld

Alluvium renosterveld is relatively rare, being confined to gravelly valley bottoms that usually contain either fynbos or riparian vegetation. It contains elements typical of fynbos (locally where sand predominates) or of succulent karoo—the latter especially in rocky and fire-safe habitats. This is an unusual azonal renosterveld straddling the ecotone between azonal saline (heavy soils) vegetation on one hand and AZa 2 Cape Lowland Alluvial Vegetation on the other. Only two types are recognised.

FRa 1 Breede Alluvium Renosterveld

VT 26 Karroid Broken Veld (90%) (Acocks 1953). LR 58 Little Succulent Karoo (69%), LR 61 Central Mountain Renosterveld (24%) (Low & Rebelo 1996). BHU 87 Robertson Broken Veld (69%), BHU 38 Ashton Inland Renosterveld (24%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Breede River, broad areas and narrow bands on valley bottomlands from Worcester to Ashton including the largest patch from Worcester to Nuy and Toontjiesrivier, and the belt in the vicinity of the Breede River also with many of its tributaries such as the Doringrivier south of Kwaggaskloof, Poesienetsrivier, Vinkrivier and Keisersrivier. Altitude 150–450 m.

Vegetation & Landscape Features Flat alluvial fans and valley bottoms supporting short grassy cupressoid-leaved shrubland usually dominated by renosterbos.

Geology & Soils Fine loamy sand with high gravel and cobble contents of alluvial fans and river terraces, overlying a variety of rocks from the Cape and Karoo Supergroups as well as the Uitenhage Group. Glenrosa and Mispah forms and soils with prismacutanic and/or pedocutanic diagnostic horizons are dominant. Land types mainly Fc, Db, Da, Ae and Ia.

Climate MAP 170–470 mm (mean: 265 mm), peaking slightly from July to August. Mean daily maximum and minimum temperatures 29.8°C and 4.7°C for February and July, respectively. Frost incidence 4–10 days per year. See also climate diagram for FRa 1 Breede Alluvium Renosterveld (Figure 4.123).

Important Taxa Tall Shrubs: *Montinia caryophyllacea*, *Rhus lucida*. Low Shrubs: *Amphithalea spinosa*, *Aspalathus candicans*, *A. spinosa* subsp. *spinosa*, *Athanasia trifurcata*, *Cliffortia ruscifolia*, *Elytropappus rhinocerotis*, *Diosma passerinoides*, *Helichrysum incarnatum*, *Oedera imbricata*, *O. squarrosa*, *Pentzia incana*. Succulent Shrub: *Ruschia caroli* (d). Herbs: *Corymbium glabrum*, *Senecio erysimoides*. Geophytic Herbs: *Gladiolus permeabilis* subsp. *permeabilis*, *Moraea gawleri*. Succulent Herb: *Crassula expansa* subsp. *expansa*. Graminoids: *Willdenowia incurvata* (d), *Cynodon dactylon*, *Ehrharta longiflora*, *E. villosa* var. *villosa*, *Eragrostis curvula*, *Themeda triandra*.

Endemic Taxon Geophytic Herb: *Ixia collina*.

Conservation Endangered. Target 27%. Small patches conserved in the Vrolijkheid and Riviersonderend Nature Reserves. Some 57% already transformed (cultivation, mainly vineyards). Alien species of *Acacia* occur locally at low densities. Erosion generally moderate and very low, but also high in some places.

Remark Breede Alluvium Renosterveld becomes replaced by AZi 8 Muscadel Riviere on heavier and more saline soils in the eastern parts of the Breede River Valley.

References Grobler & Marais (1967), C. Boucher (unpublished data).

L. Mucina

Figure 4.122 FRa 1 Breede Alluvium Renosterveld: Disturbed renosterveld shrubland with *Elytropappus rhinocerotis* and *Galenia africana* at the bottom of the Breede River Valley near Worcester (Western Cape).

FRa 2 Swartland Alluvium Renosterveld

VT 47 Coastal Macchia (63%), VT 46 Coastal Renosterbosveld (37%) (Acocks 1953). LR 68 Sand Plain Fynbos (79%), LR 62 West Coast Renosterveld (21%) (Low & Rebelo 1996). Sand Plain Fynbos (22%) (Moll & Bossi 1983). BHU 11 Hopefield Sand Plain Fynbos (67%), BHU 31 Swartland Coast Renosterveld (31%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Narrow belts in the southern Swartland encompassed by Klipheuwel, Malmesbury, Moorreesburg and Darling along the Groen and Diep Rivers. Altitude 40–150 m.

Vegetation & Landscape Features Riverine plains and bottomlands. Open, low, short cupressoid and low to moderately tall, grassy shrubland, dominated by renosterbos.

Geology & Soils Mainly fine silty and sandy alluvial sediments, mainly derived from Cape Granite. Soils with prismacutanic and/or pedocutanic diagnostic horizons are dominant. Land types mainly Db.

Climate MAP 300–490 mm (mean: 370 mm), peaking from May to August. Mists common in winter. Mean daily maximum and minimum temperatures 28.8°C and 7.0°C for February and July, respectively. Frost incidence about 3 days per year. See also climate diagram for FRa 2 Swartland Alluvium Renosterveld (Figure 4.123).

Important Taxa ([W]Wetlands) Tall Shrubs: *Psoralea aphylla* (d), *Rhus angustifolia* (d), *R. laevigata*. Low Shrubs: *Cliffortia ferruginea* (d), *Galenia secunda* (d), *Aspalathus spinosa* subsp. *spinosa*, *Asparagus capensis* var. *capensis*, *Cliffortia juniperina*, *Diospyros austro-africana*, *Eriocephalus africanus* var. *africanus*, *Galenia africana*, *Oftia africana*, *Stoebe plumosa*, *Xiphotheca lanceolata*. Herbs: *Adenogramma glomerata*, *Berkheya rigida*, *Dischisma ciliatum* subsp. *ciliatum*, *Echiostachys spicatus*. Geophytic Herbs: *Pteridium aquilinum* (d), *Zantedeschia aethiopica*[W] (d), *Ornithogalum thyrsoides*[W], *Oxalis gonIorrhiza*. Graminoids: *Cynodon dactylon* (d), *Ficinia brevifolia* (d), *Sporobolus virginicus* (d), *Calopsis paniculata*, *Elegia tectorum*, *Isolepis antarctica*[W], *I. trachysperma*[W], *Juncus capensis*[W], *Pycreus polystachyos*[W], *Tribolium echinatum*.

Conservation Vulnerable. Target 26%. None conserved in statutory or private conservation areas. Total transformed 40% (mainly cultivation). Infestation by alien woody species is serious and involves various species of *Acacia*, *Eucalyptus*, *Pinus* and *Prosopis*. Erosion low and very low.

Remarks We presume that this vegetation type might have been much more extensive in the past and might have had a greater tree component along the river courses. On heavier and more saline soils this vegetation becomes replaced on alluvia of (often intermittent) West Coast rivers by azonal inland saline vegetation of the AZi 9 Cape Inland Salt Pans and AZa 2 Cape Lowland Alluvial Vegetation.

References Boucher (1983, 1987, 1999b).

9.2.4 Silcrete and Limestone Renosterveld

These miscellaneous renosterveld types tend to be transitional to fynbos. They are unrelated to one another and share species with their neighbouring types. All are extremely poorly known and given their peculiar substrates and circumstances, may well yield new and endemic species. Together they comprise less than 3% of the area of renosterveld vegetation.

FRc 1 Swartland Silcrete Renosterveld

VT 46 Coastal Renosterbosveld (92%) (Acocks 1953). LR 62 West Coast Renosterveld (76%), LR 68 Sand Plain Fynbos (24%) (Low & Rebelo 1996). BHU 31 Swartland Coast Renosterveld (63%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: A highly fragmented type, scattered in the form of small patches throughout the Swartland from near Firgrove and Kuils River in the south to Eendekuil to Piketberg in the north. Mostly embedded within FRs 9 Swartland Shale Renosterveld followed by FRg 2 Swartland Granite Renosterveld. The largest patch is at Oupas between Moorreesburg and Mamre. Altitude 40–220 m.

Vegetation & Landscape Features Moderately undulating lowlands, often on elevated areas. An open, low, cupressoid- and small-leaved, low to moderately tall shrubland with many succulents, dominated by renosterbos.

Geology & Soils Remnants of silcrete layers over Malmesbury Group Shale and Cape Granite. Soils with prismacutanic and/or pedocutanic diagnostic horizons or plinthic catena are dominant. Land types mainly Db, Ca and Fc.

Climate MAP 250–650 mm (mean: 425 mm), peaking from May to August. Mists common in winter. Mean daily maximum and minimum temperatures 28.7°C and 6.8°C for February and July, respectively. Frost incidence 3 or 4 days per year. See also climate diagram for FRc 1 Swartland Silcrete Renosterveld (Figure 4.124).

Important Taxa Tall Shrubs: *Montinia caryophyllacea*, *Protea burchellii*. Low Shrubs: *Erica muscosa* (d), *Agathosma marifolia*, *Anthospermum spathulatum* subsp. *tulbaghense*, *Elytropappus rhinocerotis*, *Erica brachysepala*, *Eriocephalus africanus* var. *africanus*, *Helichrysum teretifolium*, *Lobostemon fruticosus*, *Muraltia macropetala*, *M. origanoides*, *M. trinervia*. Succulent Shrubs: *Drosanthemum asperulum*, *Euphorbia burmannii*, *Lampranthus filicaulis*. Geophytic Herbs: *Geissorhiza purpureolutea*, *G. setacea*, *Lachenalia longibracteata*, *L. pallida*. Succulent Herb: *Psilocaulon parviflorum*. Graminoids: *Ehrharta calycina*, *E. thunbergii*, *Ischyrolepis capensis*.

Endemic Taxa Low Shrub: *Marasmodes oligocephala*. Succulent Shrubs: *Lampranthus dilutus*, *Ruschia serrulata*. Geophytic Herb: *Babiana longiflora*.

Conservation Critically endangered and the conservation target of 26% remains unattainable due to total transformation of 90% (mainly turned into agricultural land). Small patches

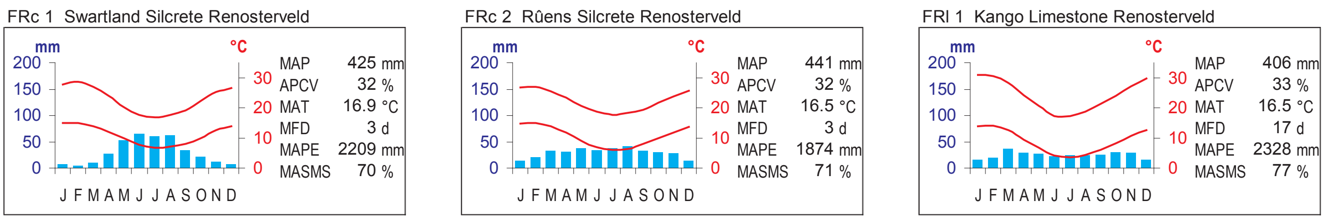

Figure 4.124 Climate diagrams of silcrete and limestone renosterveld units. Blue bars show the median monthly precipitation. The upper and lower red lines show the mean daily maximum and minimum temperature respectively. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days (days when screen temperature was below 0°C); MAPE: Mean Annual Potential Evaporation; MASMS: Mean Annual Soil Moisture Stress (% of days when evaporative demand was more than double the soil moisture supply).

Figure 4.125 FRc 1 Swartland Silcrete Renosterveld: Ferricrete patches with rich geophytic spring flora (*Ornithogalum*, *Lachenalia*, *Micranthus alopecuroides*) and scattered solitary shrubs of *Leucadendron stellare* near the Boland Agricultural College in Wellington (Western Cape).

(about 1%) are statutorily conserved in the Pella Research Site, and additionally in Paardenberg and Elandsberg. Remaining patches undergo transformation by overgrazing, fire protection, and spraying with herbicides and insecticides. Alien *Acacia saligna*, *A. mearnsii*, *Prosopis* and *Eucalyptus* are also a problem in places. Erosion very low and low.

Remarks This unit has strong fynbos elements. It has been heavily impacted by road building and agriculture, and the remaining remnants are usually transformed by overgrazing and bush-cutting so that their original floras are unknown.

References Acocks (1935), Boucher (1987), Walton (2006), N. Helme (unpublished data).

FRc 2 Rûens Silcrete Renosterveld

VT 46 Coastal Renosterbosveld (80%) (Acocks 1953). LR 63 South and Southwest Coast Renosterveld (100%) (Low & Rebelo 1996). BHU 34 Riversdale Coast Renosterveld (75%), BHU 33 Overberg Coast Renosterveld (19%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Rûens coastal forelands from Riviersonderend to Riversdale, with isolated outliers westwards to Bot River, but only really common within FRs 13 Eastern Rûens Shale Renosterveld. A highly fragmented unit by nature of its tendency to occur on the well-dissected, old African surface. Particularly common along the lower Breede River south of Buffeljagsrivier to Malgas and further downstream, and also south of Heidelberg and Riversdale (particularly in the Brakrivier area). Altitude 50–350 m.

Vegetation & Landscape Features Highly fragmented patches on the summits and highlands of undulating hills and plains, larger patches often associated with drainage systems. In contrast to the isolated and rare occurrence of silcrete renosterveld on the West Coast, on the South Coast this is a major landscape feature on the uplands, where it forms a remnant African surface. These isolated habitats support open, low, cupressoid and small-leaved, low to moderately tall shrubland characterised by many succulents and usually dominated by renosterbos.

Geology & Soils Shallow soils with silcrete caps over deep pink and orange shales of the Bokkeveld Group, on hill tops. Occasionally they also occur on ferricrete or in quartz patches. Soils are prismacutanic and pedocutanic. Land types mainly Db, Fc and Fb.

Climate MAP 280–770 mm (mean: 440 mm), relatively even throughout the year with a slight low from December to February. Mean daily maximum and minimum temperatures 26.9°C and 6.0°C for January–February and July, respectively. Frost incidence about 3 days per year. See also climate diagram for FRc 2 Rûens Silcrete Renosterveld (Figure 4.124).

Important Taxa Tall Shrub: *Rhus lucida*. Low Shrubs: *Cymbopappus adenosolen* (d), *Elytropappus rhinocerotis* (d), *Erica karooica* (d), *Hermannia saccifera* (d), *Oedera squarrosa* (d), *Relhania garnotii* (d), *Agathosma foetidissima*, *Euchaetis longicornis*, *Macledium spinosum*, *Polhillia pallens*, *Selago corymbosa*, *Sutera aethiopica*. Succulent Shrubs: *Drosanthemum asperulum* (d), *Crassula subulata* var. *subulata*. Herb: *Tripteris tomentosa* (d). Geophytic Herbs: *Bulbinella barkeriae*, *Tritoniopsis flexuosa*. Succulent Herbs: *Psilocaulon parviflorum*, *Stapeliopsis breviloba*. Graminoids: *Cymbopogon pospischilii* (d), *Ficinia oligantha* (d), *Merxmuellera stricta* (d), *Eragrostis curvula*, *Merxmuellera disticha*, *Themeda triandra*.

Endemic Taxa Low Shrubs: *Erica venustiflora* subsp. *glandulosa* (d), *Liparia striata*, *Polhillia canescens*. Succulent Shrubs: *Acrodon deminutus*, *Antimima* sp. nov. (*N. Helme 2101* NBG), *Brownanthus fraternus*, *Drosanthemum quadratum*, *Gibbaeum esterhuyseniae*, *G. haagei*. Succulent Herbs: *Haworthia variegata* var. *hemicrypta*, *Stapelia divaricata*, *Stapeliopsis saxatilis* subsp. *stayneri*.

Conservation Critically endangered. The target of 27% remains unattainable since 78% of the area has already been

Figure 4.126 FRc 2 Rûens Silcrete Renosterveld: Sparse renosterveld shrubland on silcrete outcrops with *Cliffortia ruscifolia* and *Aloe ferox* (in the background) on the Farm Kekkel en Kraai near Swellendam (Western Cape).

transformed for intensive agricultural land. Very small portion (less than 1%) statutorily conserved in the Werner Frehse Nature Reserve (near Riversdale). Alien *Acacia cyclops* scattered over parts of the area. Erosion moderate and low.

Remarks A number of regional taxa are shared with the Rûens renosterveld units. Some of the succulent elements (*Drosanthemum*, *Gibbaeum*) provide a biogeographical link to SKv 7 Robertson Karoo.

References Schmiedel (2002), Von Hase et al. (2003), Schmiedel & Mucina (2006).

FRl 1 Kango Limestone Renosterveld

VT 25 Succulent Mountain Scrub (Spekboomveld) (65%), VT 43 Mountain Renosterveld (27%) (Acocks 1953). South Coast Renosterveld (58%) (Moll & Bossi 1983). LR 63 South and South-west Coast Renosterveld (67%), LR 8 Spekboom Succulent Thicket (26%) (Low & Rebelo 1996). BHU 43 Kango Inland Renosterveld (68%), BHU 97 Spekboom Xeric Succulent Thicket (27%) (Cowling et al. 1999b, Cowling & Heijnis 2001). STEP Meiringspoort Fynbos Thicket (20%), STEP Mons Ruber Fynbos Thicket (16%), STEP Cango Renoster Thicket (4%) (Vlok & Euston-Brown 2002).

Distribution Western Cape Province: Northeastern regions of the Little Karoo south of the Groot Swartberg, from near Gamkapoort, north of Calitzdorp eastwards including Matjiesrivier and the Cango Caves area, with another band extending from upper Schoemanspoort and De Rust to north of the Stompdrift Dam. Altitude 450–950 m.

Vegetation & Landscape Features Low mountains and steep hills, supporting low, medium dense graminoid and medium to tall, dense, cupressoid-leaved shrubland, dominated by renosterbos and *Dodonaea*. The upper and wetter slopes are dominated by *Dodonaea viscosa* var. *angustifolia*, which although it is the visual signature of this type, extends onto neighbouring fynbos types. Frequent burning leads to a *Themeda* grassland. The early post-fire stages are characterised by a high diversity of herbaceous species—on limestone *Hermannia holosericea* is dominant in the early seral stages. A feature of the type is the marked lack of geophytes (only *Hypoxis villosa*).

Geology & Soils Clays and loams derived from the Cango Caves Group shales and limestone of the Namibian Erathem; in the south the area overlies clastic sediments of the Mesozoic Uitenhage Group; soils of Glenrosa and Mispah forms or red-yellow apedal soils dominant. Land types mainly Ib, Fc and Ag.

Climate MAP 200–720 mm (mean: 405 mm), peaking in March but otherwise even with a slight low from December to February. Mean daily maximum and minimum temperatures 31.0°C and 3.5°C for January and July, respectively. Frost incidence 10–20 days per year. See also climate diagram for FRl 1 Kango Limestone Renosterveld (Figure 4.124).

Important Taxa ([T]Cape thickets) Small Tree: *Acacia karroo*. Succulent Tree: *Aloe ferox*. Tall Shrubs: *Cussonia paniculata* subsp. *paniculata*[T] (d), *C. spicata*[T] (d), *Dodonaea viscosa* var. *angustifolia* (d), *Euclea undulata*[T] (d), *Rhus laevigata*[T] (d), *R. undulata*[T] (d), *Anginon difforme*, *Maytenus heterophylla*[T], *Olea europaea* subsp. *africana*[T], *Pterocelastrus tricuspidatus*[T]. Low Shrubs: *Elytropappus rhinocerotis* (d), *Hermannia holosericea* (d), *Carissa bispinosa* subsp. *bispinosa*. Succulent Shrubs: *Cotyledon orbiculata* var. *orbiculata*, *Crassula arborescens*, *Euphorbia heptagona*, *E. mauritanica*, *Portulacaria afra*. Semiparasitic Shrub: *Osyris compressa*. Herb: *Sutera patriotica*. Geophytic Herbs: *Hypoxis villosa*, *Romulea austinii*. Succulent Herb: *Senecio ficoides*. Graminoids: *Hyparrhenia hirta* (d), *Eustachys paspaloides*, *Themeda triandra*.

Endemic Taxa Herb: *Phyllopodium dolomiticum*. Geophytic Herb: *Ornithogalum sardienii*. Succulent Herbs: *Haworthia blackburniae* var. *graminifolia*, *H. scabra* var. *lateganiae*, *H. scabra* var. *morrisiae*, *H. scabra* var. *starkiana*.

Conservation Least threatened. Target 29%. Very small portion conserved in Groot Swartberg and Rietvlei. Only 14% transformed (cultivation), but almost exclusively on the valley bottoms. Erosion low and very low.

Remarks Although centred on limestone, this unit also occurs on other geological substrates occupied by renosterveld in the Cango Valley of the Swartberg foothills. Compared to the richness of other limestone areas in the Cape flora, this unit is unusually poor—probably because it is poorly explored. In fire-protected sites such as steep rocky slopes and ravines this renosterveld is replaced by dense succulent thickets of AT 2 Gamka Thicket.

References Moffett & Deacon (1977), Vlok & Euston-Brown (2002).

9.3 Western Strandveld

Western Strandveld currently consists of nine vegetation units that basically reflect phytogeographical (hence climatic to an extent) and geological patterns. Six of the units are found on the dry West Coast. Those occurring on and around Langebaan Peninsula (especially on granite, limestone) are floristically diverse and possibly also evolutionary older as they contain a high number of local endemics. FS 1 Lambert's Bay Strandveld and FS 5 Langebaan Dune Strandveld are rich in succulent elements. The classification of the remaining three strandveld types reflects floristic gradients between the western and eastern portions of the South Coast. More data are needed to judge the

L. Mucina

Figure 4.127 FRl 1 Kango Limestone Renosterveld: Renosterveld shrubland dominated by *Dodonaea viscosa* var. *angustifolia* with *Aloe ferox* on Cango Caves Group limestones near the entrance to Meiringspoort at De Rust in the Little Karoo (Western Cape).

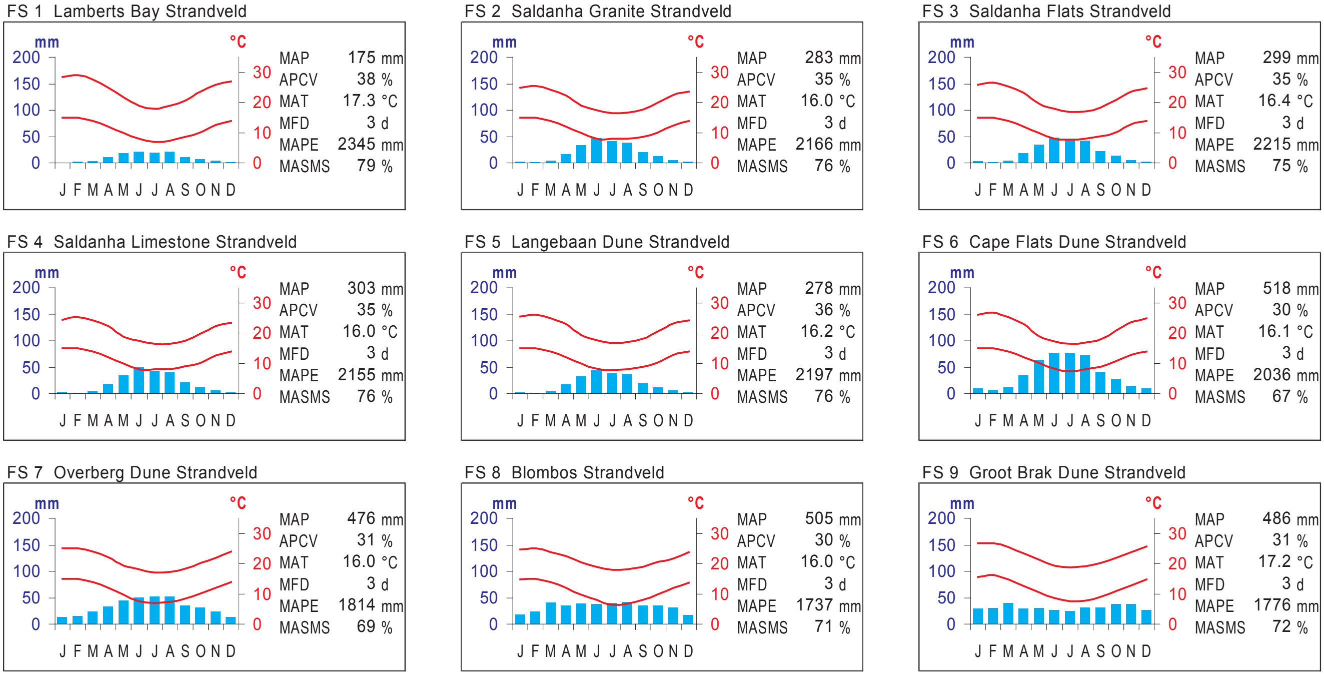

Figure 4.128 Climate diagrams of Western Strandveld units. Blue bars show the median monthly precipitation. The upper and lower red lines show the mean daily maximum and minimum temperature respectively. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days (days when screen temperature was below 0°C); MAPE: Mean Annual Potential Evaporation; MASMS: Mean Annual Soil Moisture Stress (% of days when evaporative demand was more than double the soil moisture supply).

role of geology in the differentiation of the Western Strandveld types, especially along those parts of the South Coast that do not have limestone geology. Basic ecological characteristics of the Western Strandveld are discussed in Section 3.3.

FS 1 Lambert's Bay Strandveld

VT 34 Strandveld of West Coast (100%) (Acocks 1953). LR 55 Strandveld Succulent Karoo (57%) (Low & Rebelo 1996). West Coast Strandveld (49%), Sand Plain Fynbos (39%) (Moll & Bossi 1983). BHU 83 Lambert's Bay Strandveld (57%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Broad coastal strip between Donkin Bay (north of Lambert's Bay) and Elands Bay (Verlorenvlei), penetrating deeply inland north of and along the Jakkals and Langvlei Rivers. Altitude 20–180 m.

Vegetation & Landscape Features Series of old dunes and slightly undulating, consolidated sand-dune fields supporting mixed, 1.2–1.5 m tall, dense shrubland composed of evergreen, sclerophyllous and fleshy, drought-deciduous-leaved shrubs, with a dense understorey of low (0.2–0.5 m), unpalatable, succulent shrubs. Perennial herbs and annuals are dominant in degraded areas.

Geology & Soils Table Mountain Group sandstones form a rocky coastline and occur as sporadic outcrops throughout the area. The substrate is mainly deep, Tertiary to Quaternary, white to pale red, calcareous, aeolian, sandy to sandy loam soil of the hillocky veld. Local white sand of Pleistocene origin forms unstable blow-out dunes north of the mouths of the Verlorenvlei River at Elands Bay and the Jakkals River at Lambert's Bay. Recent calcareous sands of marine origin also line the coastal strip. Dominant land types Hb and Ha.

Climate Mainly cyclonic annual rainfall varying from approximately 125 mm in the north to 200 mm in the south (overall MAP: 175 mm), occurring on average over six days in winter. Fog and dew contribute to the moisture in summer and autumn. Mean daily maximum and minimum temperatures 29.1°C and 7.0°C for February and July, respectively. Frost and hail are rare phenomena. The winds tend to be strong southerly in summer and northerly in winter. Hot, dry, desiccating offshore winds occur in both winter and summer. Salt-laden on-shore winds stunt shrubs along the coast. See also climate diagram for FS 1 Lambert's Bay Strandveld (Figure 4.128).

Important Taxa Tall Shrubs: *Euclea racemosa* subsp. *racemosa*, *Rhus undulata*. Low Shrubs: *Chrysanthemoides monilifera*, *Eriocephalus racemosus*, *Hebenstretia cordata*, *Lebeckia multiflora*, *Salvia lanceolata*. Succulent Shrubs: *Euphorbia mauritanica* (d), *Zygophyllum morgsana* (d), *Cotyledon orbiculata* var. *dactylopsis*, *C. orbiculata* var. *spuria*, *Didelta carnosa*, *Euphorbia rhombifolia*, *Lycium tetrandrum*, *Manochlamys albicans*, *Othonna carnosa*, *Pelargonium carnosum*, *Ruschia caroli*, *R. cymosa*, *Tetragonia decumbens*, *T. fruticosa*, *T. namaquensis*, *T. spicata*. Herbs: *Oncosiphon suffruticosum* (d), *Senecio arenarius* (d), *Helichrysum litorale*, *Oncosiphon piluliferum*, *Wahlenbergia annularis*, *Zaluzianskya villosa*. Geophytic Herbs: *Lachenalia rubida*, *Trachyandra divaricata*. Succulent Herbs: *Carpobrotus edulis*, *Crassula expansa* subsp. *expansa*, *Mesembryanthemum guerichianum*. Herbaceous Climber: *Cynanchum africanum*. Graminoids: *Chaetobromus involucratus* subsp. *dregeanus*, *Ehrharta calycina*, *E. villosa* var. *villosa*, *Willdenowia incurvata*.

Biogeographically Important Taxa (all West Coast endemics) Low Shrubs: *Afrolimon peregrinum* (d), *Pteronia onobromoides* (d), *Asparagus capensis* var. *litoralis*, *Lycium strandveldense*. Succulent Shrubs: *Euphorbia caput-medusae*, *Pelargonium gibbosum*. Herbs: *Amellus asteroides*, *Arctotis stoechadifolia*, *Grielum grandiflorum*. Geophytic Herbs: *Babiana thunbergii*, *Ferraria densepunctulata*. Graminoid: *Cladoraphis cyperoides*.

Endemic Taxa Herb: *Felicia josephinae*. Succulent Herb: *Conophytum obcordellum* subsp. *rolfii*.

Conservation Vulnerable. Target 24%. Only about 1.5% statutorily conserved in the Elandsbaai Nature Reserve and a further about 7% in private conservation areas such as Soopjeshoogte,

L. Mucina

Figure 4.129 FS 1 Lambert's Bay Strandveld: Low strandveld shrubland with dominant *Afrolimon peregrinum* (Plumbaginaceae) and abundant succulents (*Amphibolia*, *Conicosia*, *Euphorbia*, *Mesembryanthemum, Ruschia*) near Lambert's Bay (Western Cape).

Donkins Bay, Zeven Puts and Doorspring Nature Reserves. About a quarter transformed for cultivation. This vegetation has been exposed to 2 000 years of stock farming. *Acacia cyclops* and *A. saligna* are serious invading aliens. Erosion generally very low.

Remarks Increased occurrence of Succulent Karoo elements underlines the similarity of this vegetation unit to SKs 7 Namaqualand Strandveld. The white calcareous dunes lining the Atlantic seaboard support vegetation, with close affinity to FS 5 Langebaan Dune Strandveld occurring further south.

References Boucher (1982), Liengme (1987), Boucher & Le Roux (1993), Boucher (1998d, f), Venter & Venter (2003), Downing & Van der Merwe (undated).

FS 2 Saldanha Granite Strandveld

VT 46 Coastal Renosterbosveld (51%) (Acocks 1953). *Galenia–Senecio* Hillside Closed Dwarf Shrubland, *Ehrharta–Maurocenia* Hillside Dense Shrubland (Boucher & Jarman 1977). West Coast Strandveld p.p. (Boucher 1983). LR 4 Dune Thicket (99%) (Low & Rebelo 1996). BHU 4 Langebaan Fynbos/Thicket Mosaic (99%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: On the West Coast, granite domes from Vredenburg to St Helena Bay and many points along the coast including Paternoster and Saldanha's North Head; also around Langebaan town and at Postberg on the Langebaan Peninsula. Altitude 0–180 m.

Vegetation & Landscape Features Rounded forms of granite sheets and smooth forms at their feet dominate the landscapes of this vegetation unit. Low to medium shrubland, containing some succulent elements, alternates with grassy and herb-rich spots supporting a rich geophyte flora.

Geology & Soils Deep, coarse sandy to loamy soils derived from the Vredenburg Batholith in the north and the Saldanha Batholith in the south (both of the Cape Granite Suite). Dominant land type Ab, followed by Fc.

Climate Mainly cyclonic annual rainfall varying from approximately 250 mm in the north to 350 mm in the south, almost exclusively in winter. Mean daily maximum and minimum temperatures 25.4°C and 7.9°C for February and July, respectively. Advective sea fog and dew contribute significantly to the moisture in summer and autumn. Frost rare. Winds tend to be strong northwesterly in winter and southerly in summer. See also climate diagram for FS 2 Saldanha Granite Strandveld (Figure 4.128).

Important Taxa Tall Shrubs: *Euclea racemosa* subsp. *racemosa*, *Passerina corymbosa*, *Rhus glauca*. Low Shrubs: *Pteronia divaricata* (d), *Agathosma bifida*, *Eriocephalus africanus* var. *africanus*, *Exomis microphylla*, *Otholobium hirtum*, *Polygala myrtifolia*, *Pterocelastrus tricuspidatus*, *Putterlickia pyracantha*. Succulent Shrubs: *Aloe perfoliata*, *Drosanthemum floribundum*, *Euphorbia mauritanica*, *Lycium tetrandrum*, *Othonna floribunda*, *Tetragonia fruticosa*, *T. spicata*, *Tylecodon paniculatus*, *Zygophyllum morgsana*. Woody Climber: *Cissampelos capensis*. Semiparasitic Shrub: *Osyris compressa*. Herbs: *Dimorphotheca pluvialis* (d), *Oncosiphon suffruticosum* (d), *Adenogramma glomerata*, *Nemesia versicolor*, *Senecio arenarius*, *Ursinia anthemoides* subsp. *anthemoides*. Geophytic Herbs: *Amaryllis belladonna*, *Chasmanthe floribunda*, *Freesia viridis*, *Geissorhiza monanthos*, *Lachenalia pustulata*, *Melasphaerula ramosa*, *Romulea hirsuta*. Succulent Herb: *Dorotheanthus bellidiformis* (d). Graminoids: *Chaetobromus involucratus* subsp. *dregeanus*, *C. involucratus* subsp. *involucratus*, *Cynodon dactylon*, *Ehrharta*

J.C. Manning

Figure 4.130 FS 2 Saldanha Granite Strandveld: Succulent-rich shrublands on steep slopes of a granite koppie near Langebaan (Western Cape) with *Aloe mitriformis*, *Othonna arborescens* and *Cheiridopsis rostrata*.

K. Phillips

Figure 4.131 FS 2 Saldanha Granite Strandveld: Spectacular spring display of *Dimorphotheca pluvialis* (Asteraceae) on granite in the Postberg Reserve within the West Coast National Park near Langebaan (Western Cape).

calycina, *E. villosa* var. *villosa*, *Festuca scabra*, *Tribolium echinatum*, *Willdenowia incurvata*.

Biogeographically Important Taxa (all West Coast endemics) Low Shrub: *Afrolimon peregrinum* (d). Herb: *Cotula duckittiae* (d). Geophytic Herbs: *Polyxena corymbosa*, *Sparaxis parviflora*. Succulent Herb: *Quaqua incarnata* subsp. *incarnata*.

Endemic Taxa Succulent Shrubs: *Lampranthus aureus*, *Oscularia steenbergensis*, *O. vredenburgensis*, *Ruschia langebaanensis*. Geophytic Herbs: *Lachenalia mathewsii* (d), *Hesperantha saldanhae*, *Lachenalia viridiflora*, *Moraea loubseri* (extinct in the wild), *Ornithogalum rupestre*, *Oxalis burtoniae*, *Pauridia longituba*, *Polyxena paucifolia*, *Romulea saldanhensis*, *Strumaria chaplinii*, *Watsonia hysterantha*.

Conservation Endangered. Target 24%. Almost 10% statutorily conserved in the West Coast National Park, SAS Saldanha and Columbine Nature Reserves, and a small portion in private reserves such as West Point, Groot Paternoster and Swartriet. About 70% transformed for cultivation or by urban development. This vegetation type is regularly utilised for grazing. Australian *Acacia saligna*, *A. cyclops* and *A. baileyana* are causing serious infestations in many places. Coastal development is a further threat to this vegetation type. Erosion low and very low.

Remarks The most northerly distribution of *Erica tristis* trees are found at Langebaan, with a gap of at least 100 km to the nearest other plants commonly found in rocky coastal habitats between the Cape Peninsula and Gansbaai.

References Boucher & Jarman (1977), Boucher (1982, 1983, 1987), Boucher & Rode (1999).

FS 3 Saldanha Flats Strandveld

VT 47 Coastal Macchia (64%) (Acocks 1953). West Coast Strandveld p.p. (Boucher 1983). LR 4 Dune Thicket (84%) (Low & Rebelo 1996). BHU 4 Langebaan Fynbos/Thicket Mosaic (78%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Extensive coastal flats from St Helena Bay and the southern banks of the Great Berg River near its mouth in the north to Saldanha and Langebaan in the south, with the southernmost extension at the coast near Yzerfontein and Rietduin. Altitude 0–120 m.

Vegetation & Landscape Features Sclerophyllous shrublands built of a sparse emergent and moderately tall shrub layer, with an open succulent shrub layer forming the undergrowth. With conspicuous displays of geophytes and annual herbaceous flora in spring.

Geology & Soils The main geology is shallow calcareous sand over a fossiliferous Pleistocene limestone hardpan layer along an old marine terrace. The hardpan of the Sandveld Group is exposed in places while farmers often rip the hardpan and accumulate rock piles in cultivated fields. The Sandveld Group overlies the Cape Granites as well as the Malmesbury Group metasediments into which the granites intruded. Dominant land type Hb (almost 50%), followed by Db and Ha.

Climate Mainly cyclonic rainfall varying from approximately 250 mm in the north to 380 mm in the south (overall MAP: 300 mm), almost exclusively in winter. Mean daily maximum and minimum temperatures 26.6°C and 7.9°C for February and July, respectively. Mean monthly maximum and minimum temperatures for Langebaanweg 36.5°C and 2.2°C for January/February and July/August, respectively. Advective sea fog and dew contribute to the moisture balance in summer and autumn. Frost infrequent. Strong southeasterly winds typical of the summer period, northerly winds more frequent in the winter months, especially between May and August. See also climate diagram for FS 3 Saldanha Flats Strandveld (Figure 4.128).

Important Taxa Tall Shrubs: *Euclea racemosa* subsp. *racemosa* (d), *Nylandtia spinosa*, *Rhus glauca*. Low Shrubs: *Aspalathus lotoides* subsp. *lagopus*, *Clutia daphnoides*, *Euryops linifolius*,

L. Mucina

Figure 4.132 FS 3 Saldanha Flats Strandveld: Strandveld on deep calcareous sands with *Afrolimon capense* (Plumbaginaceae) and *Tylecodon wallichii* (Crassulaceae) near Saldanha (Western Cape).

Exomis microphylla, *Hermannia pinnata*, *Lebeckia sericea*, *Leysera gnaphalodes*, *Nenax hirta* subsp. *calciphila*, *Pterocelastrus tricuspidatus*, *Pteronia divaricata*, *P. ovalifolia*, *P. uncinata*. Succulent Shrubs: *Euphorbia mauritanica*, *Ruschia macowanii*, *Tetragonia decumbens*, *T. fruticosa*, *Zygophyllum cordifolium*, *Z. morgsana*. Herbs: *Dimorphotheca pluvialis* (d), *Oncosiphon suffruticosum* (d), *Arctotheca calendula*, *Foveolina tenella*, *Hebenstretia repens*, *Helichrysum litorale*, *Nemesia versicolor*, *Senecio arenarius*, *Ursinia anthemoides* subsp. *anthemoides*. Geophytic Herbs: *Trachyandra ciliata*, *T. divaricata*. Succulent Herbs: *Dorotheanthus bellidiformis* (d), *Conicosia pugioniformis* subsp. *pugioniformis*, *Mesembryanthemum guerichianum*, *Senecio littoreus*. Graminoids: *Bromus pectinatus* (d), *Ehrharta calycina*, *E. villosa* var. *villosa*, *Schismus barbatus*, *Tribolium echinatum*.

Figure 4.133 FS 4 Saldanha Limestone Strandveld: Outcrops of Tertiary limestone sediments in the Langebaan area (West Coast) supporting endemic-rich flora also containing notable succulent elements (including *Antimima ventricosa*, *Dorotheanthus bellidiformis Ruschia* species, *Zygophyllum* species and the like).

Biogeographically Important Taxa (all West Coast endemics) Low Shrub: *Afrolimon capense* (d). Succulent Shrub: *Prenia pallens* subsp. *pallens*. Herbs: *Amellus asteroides*, *Grielum grandiflorum*. Geophytic Herb: *Ferraria densepunctulata*. Succulent Herb: *Tetragonia chenopodioides*. Graminoids: *Cladoraphis cyperoides*, *Thamnochortus spicigerus*.

Endemic Taxa Geophytic Herbs: *Hessea mathewsii*, *Romulea elliptica*.

Conservation Endangered. Target 24%. Some 11% statutorily conserved in the West Coast National Park and Yzerfontein Nature Reserve and a very small portion also in private conservation areas such as Jakkalsfontein and West Point. More than a half has already been transformed for cultivation, road building or by urban development. Serious alien infestation is caused by trees such as *Acacia cyclops* and *A. saligna* and herbs including *Bromus diandrus* and *Medicago hispida*. Erosion generally very low.

References Boucher (1982, 1983, 1987, 1996c), Boucher & Rode (1996a, b, 1997a, b, c, d, 1999).

FS 4 Saldanha Limestone Strandveld

VT 34 Strandveld of West Coast (92%) (Acocks 1953). *Nenax–Maytenus–Zygophyllum* Limestone Evergreen Shrubland, *Pteronia uncinata* Limestone Evergreen Dwarf Shrubland (Boucher & Jarman 1977). West Coast Strandveld p.p. (Boucher 1983). LR 4 Dune Thicket (100%) (Low & Rebelo 1996). BHU 4 Langebaan Fynbos/Thicket Mosaic (100%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Very limited area with a larger patch on the Kliprug ridge between Saldanha and Paternoster, with several smaller outliers including those between Saldanha and north of Club Mykonos on the Langebaan Lagoon. Unmapped are small outcrops at Yzerfontein and on the tip of Langebaan Peninsula. Altitude 20–120 m.

Vegetation & Landscape Features Slightly undulating ridges and steeper coastal slopes supporting low shrublands built of low succulent-stemmed and deciduous, fleshy leaved shrubs in deeper soils. Patches of prostrate, succulent-leaved dwarf shrubs and annual or geophytic herbs occupy cracks or shallow depressions in the exposed limestone.

Geology & Soils Shallow sandy soil on hardpan Tertiary limestone of the Sandveld Group. Dominant land types Fc and Hb.

Climate Mainly cyclonic rainfall varying from approximately 250 mm in the north to 350 mm in the south, almost exclusively in winter (overall MAP is around 300 mm). Mean daily maximum and minimum temperatures 25.3°C and 8.0°C for February and July/August, respectively. For other climate characteristics, see FS 2 Saldanha Granite Strandveld as well the climate diagram for FS 4 Saldanha Limestone Strandveld (Figure 4.128).

Important Taxa Tall Shrubs: *Euclea racemosa* subsp. *racemosa* (d), *Nylandtia spinosa*, *Rhus glauca*. Low Shrubs: *Chrysanthemoides monilifera* (d), *Exomis microphylla*, *Pteronia divaricata*. Succulent Shrubs: *Aloe perfoliata*, *Cheiridopsis rostrata*, *Euphorbia mauritanica*, *Jordaaniella dubia*, *Lycium tetrandrum*, *Othonna cylindrica*, *O. floribunda*, *Ruschia tumidula*, *Zygophyllum cordifolium*, *Z. morgsana*. Semiparasitic Shrub: *Thesium spinosum*. Herbs: *Dimorphotheca pluvialis* (d), *Arctotis hirsuta*, *Lyperia tristis*, *Nemesia versicolor*, *Oncosiphon grandiflorum*, *Ursinia anthemoides* subsp. *anthemoides*, *Zaluzianskya villosa*. Geophytic Herbs: *Babiana tubulosa* var. *tubiflora*, *Oxalis compressa*, *O. obtusa*. Succulent Herbs: *Dorotheanthus bellidiformis* (d), *Mesembryanthemum guerichianum*. Graminoids: *Ehrharta calycina*, *E. villosa* var. *villosa*, *Festuca scabra*, *Ficinia lateralis*, *Ischyrolepis eleocharis*.

Biogeographically Important Taxa (all West Coast endemics) Low Shrubs: *Afrolimon capense* (d), *Asparagus capensis* var. *litoralis*. Herb: *Zaluzianskya parviflora*. Graminoid: *Thamnochortus spicigerus*.

Endemic Taxa Low Shrub: *Muraltia harveyana*. Succulent Shrub: *Cephalophyllum rostellum*. Herbs: *Felicia elongata*, *Limonium acuminatum*, *Manulea augei*. Geophytic Herbs: *Daubenya zeyheri*, *Gladiolus caeruleus*, *Ixia purpureorosea*, *Moraea calcicola*, *Romulea barkerae*.

Conservation Endangered. Target 24%. None conserved in statutory conservation areas and only a small fraction protected in the Swartriet Private Nature Reserve. About 40% has been transformed for cultivation or by development of coastal settlements. Some portions are under heavy grazing pressure. Aliens *Acacia cyclops* and *A. saligna* can become a problem in places. Erosion generally very low. This vegetation unit is rich in Red Data plants (at least 20 species, some of them restricted to this unit).

References Boucher & Jarman (1977), Boucher (1982, 1983, 1987, 1995, 1996c), Bloemhoff & Craven (1990), Boucher & Rode (1996a, b, 1997a, b, c, d, 1999), Boucher & Schloms (1999), L. Mucina (unpublished data).

FS 5 Langebaan Dune Strandveld

VT 34 Strandveld of West Coast (73%) (Acocks 1953). LR 4 Dune Thicket (73%) (Low & Rebelo 1996). West Coast Strandveld (61%) (Moll & Bossi 1983). BHU 4 Langebaan Fynbos/Thicket Mosaic (95%) (Cowling et al. 1999b, Cowling & Heijnis 2001). Including *Maytenus–Kedrostis* Consolidated-dune Dense Evergreen Shrubland, *Willdenowia striata* Consolidated-dune Dense Evergreen Restioid Shrubland, *Thamnochortus spicigerus* Dune Dense Tall Restioid Herbland (Boucher & Jarman 1977). West Coast Strandveld p.p. (Boucher 1983). *Euclea racemosa–Zygophyllum morgsana* Shrublands (Boucher 1987).

Distribution Western Cape Province: This strandveld occurs in three large disconnected patches: one is a narrow coastal strip from Elands Bay to the mouth of the Great Berg River at Velddrif, the second one covers parts from Britannia Bay past Paternoster to Danger Bay near Saldanha Bay, while the last one surrounds Langebaan Lagoon from the north on the Langebaan Peninsula at Donkergat west of the lagoon and Langebaan, east of the lagoon, via Geelbek to Yzerfontein continuing as a very narrow strip along the West Coast seaboard as far south as Silverstroomstrand at Bokbaai (west of Atlantis). Altitude 0–100 m.

Vegetation & Landscape Features Flat to slightly undulating old coastal dune systems and stabilised inland duneveld supporting closed, evergreen, up to 2 m tall, sclerophyllous shrubland with prominent annual herbaceous flora occurring in gaps (and forming spectacular displays, especially after good rain in late winter).

Geology & Soils Deep Tertiary to Recent sands and calcrete of marine origin. Dominant land types Hb (slightly prevailing), Fc and Ha.

Climate Mainly cyclonic rainfall varying from approximately 230 mm in the north to 355 mm in the south, almost exclusively in winter and accompanied by frequent and strong north-westerly winds and cooler temperatures. Mean daily maximum and minimum temperatures 26.1°C and 7.8°C for February and July, respectively. Mean monthly maximum and minimum temperatures for Cape Columbine 29.8°C and 6.1°C for March and July, respectively. Southeasterly winds prevail in summer. Fog and dew contribute to the moisture in summer and autumn (especially in the northern part of the unit). Frost an infrequent phenomenon. See also climate diagram for FS 5 Langebaan Dune Strandveld (Figure 4.128).


L. Mucina

Figure 4.135 FS 5 Langebaan Dune Strandveld: Coastal dune strandveld with *Chrysanthemoides incana* (Asteraceae) and prominent *Euphorbia gorgonias* at St Helena Bay, north of Vredenburg (Western Cape).


L. Mucina

Figure 4.134 FS 5 Langebaan Dune Strandveld: Dense strandveld shrubland with *Pteronia divaricata* (yellow Asteraceae) and *Euphorbia burmannii* on coastal dunes on the northeastern bank of the Langebaan Lagoon in the West Coast National Park (Western Cape).

Important Taxa Tall Shrubs: *Euclea racemosa* subsp. *racemosa* (d), *Metalasia muricata*, *Morella cordifolia*, *Olea exasperata*, *Rhus glauca*, *R. laevigata*. Low Shrubs: *Chrysanthemoides monilifera* (d), *Pteronia divaricata* (d), *Salvia africana-lutea* (d), *Ballota africana*, *Chironia baccifera*, *Chrysanthemoides incana*, *Clutia daphnoides*, *Eriocephalus africanus* var. *africanus*, *E. racemosus*, *Helichrysum niveum*, *Lebeckia multiflora*, *Maytenus lucida*, *Pterocelastrus tricuspidatus*, *Putterlickia pyracantha*. Succulent Shrubs: *Zygophyllum morgsana* (d), *Cotyledon orbiculata* var. *dactylopsis*, *C. orbiculata* var. *spuria*, *Crassula dichotoma*, *Didelta carnosa*, *Euphorbia burmannii*, *E. mauritanica*, *Jordaaniella dubia*, *Othonna carnosa*, *O. floribunda*, *Pelargonium fulgidum*, *Ruschia caroli*, *R. cymosa*, *Tetragonia fruticosa*, *Tylecodon paniculatus*. Woody Climber: *Cissampelos capensis*. Semiparasitic Shrubs: *Osyris compressa*, *Thesium spinosum*. Herbs: *Oncosiphon suffruticosum* (d), *Helichrysum litorale*. Geophytic Herbs: *Babiana tubulosa* var. *tubiflora*, *Trachyandra divaricata*. Succulent Herbs: *Carpobrotus acinaciformis* (d), *Dorotheanthus bellidiformis* (d), *Carpobrotus edulis*, *Conicosia pugioniformis* subsp. *pugioniformis*, *Crassula ammophila*, *Mesembryanthemum guerichianum*. Herbaceous Climbers: *Didymodoxa capensis*, *Kedrostis nana*. Graminoids: *Ehrharta villosa* var. *villosa* (d), *Willdenowia incurvata* (d), *Chaetobromus involucratus* subsp. *dregeanus*, *C. involucratus* subsp. *involucratus*, *Festuca scabra*, *Ficinia secunda*, *Ischyrolepis eleocharis*, *Stipa dregeana*, *Thamnochortus erectus*.

Biogeographically Important Taxa (all West Coast endemics) Low Shrubs: *Afrolimon peregrinum* (d), *Asparagus capensis* var. *litoralis*. Succulent Shrubs: *Euphorbia caput-medusae*, *Pelargonium gibbosum*, *Ruschia geminiflora*. Woody Succulent Climber: *Zygophyllum fulvum*. Herbs: *Grielum grandiflorum*, *Zaluzianskya parviflora*. Geophytic Herbs: *Babiana tubulosa* var. *tubulosa*, *Gladiolus griseus*. Graminoid: *Cladoraphis cyperoides*.

Endemic Taxon Semiparasitic Shrub: *Thesium litoreum*.

Conservation Vulnerable. Target 24%. Almost 30% statutorily conserved in the West Coast National Park and in Rocherpan, SAS Saldanha, Columbine and Yzerfontein Nature Reserves. An additional 1% is protected in private reserves such as Groot Paternoster, Jakkalsfontein, Swartriet and Grotto Bay. Some 35% already transformed for cultivation and by urban sprawl. Alien *Acacia cyclops* and *A. saligna* have infested broad stretches of this vegetation unit. Erosion generally very low.

Remarks This is an intermediate strandveld type containing elements from the north and from the south. Sporadic local patches of FS 1 Lambert's Bay Strandveld (not mapped due to small extent) intrude into the Langebaan Dune Strandveld as far south as St Helena Bay. Species such as *Maytenus lucida*, *Rhus pterota* and *Osyris compressum*, conspicuous in this vegetation unit, are absent in the strandveld communities further north along the West Coast.

References Boucher & Jarman (1977), Van Rooyen (1981), Boucher (1982, 1983, 1986, 1987, 1989a, b, 1992, 1993, 1998e, 1999e, f), Bloemhoff & Craven (1990), Heydenrych (1995), Gray (1997), Boucher & Rode (1999), Boucher & Schloms (1999).

FS 6 Cape Flats Dune Strandveld

VT 47 Coastal Macchia (61%) (Acocks 1953). *Pterocelastrus* Coast Dune Scrub, *Metalasia* Coast Dune Fynbos (Taylor 1972b). *Colpoon–Rhus* Dune Scrub (Boucher 1978). Broad-Leaved Thicket (Taylor 1984a). West Coast Strandveld p.p. (Boucher 1983). *Cassine barbara–Polygala myrtifolia* Coastal Community, *Tetragonia decumbens–Sideroxylon inerme* Mature Hind-dune Community, *Tetragonia decumbens–Metalasia muricata* Dune Community (O'Callaghan 1990). LR 4 Dune Thicket (76%) (Low & Rebelo 1996). BHU 5 Cape Flats Fynbos/Thicket Mosaic (48%), BHU 1 South West Dune Pioneer (22%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: This unit occurs as four discontinuous regions—the largest patch spans the south coast of False Bay (between Gordon's Bay and Muizenberg) and penetrates deep into the Cape Flats as a broad wedge as far north as Bellville, the other patch spans Silverstroomstrand and Table Bay (Cape Town) and includes the Atlantis dune plume, the third region is a series of small patches covering coastal dune pockets on the Cape Peninsula, while the last patch is situated on Robben Island. Altitude 0–80 m, but reaching 200 m in places.

Vegetation & Landscape Features Flat to slightly undulating (dune fields) landscape covered by tall, evergreen, hard-leaved shrubland with abundant grasses and annual herbs in gaps.

Geology & Soils Built mainly of Tertiary to Recent calcareous sand of marine origin and overlying metasediments of the Tygerberg Formation (Malmesbury Group, Namibian Erathem). Outcrops of Sandveld Group limestone (hardpan) are found on the False Bay coast (Cape Peninsula and especially the Wolvengat area). Dominant land type Ha (about 50%), with Hb and Ga playing subordinate roles.

Climate Exclusive winter-rainfall regime with mean annual rainfall varying from approximately 350 mm in the north to 560 mm in the south. The winter rains are accompanied by strong northwesterly winds and cooler temperatures. Mean daily maximum and minimum temperatures 26.7°C and 7.5°C for February and July, respectively. Mean monthly maximum and minimum temperatures for Cape Town International Airport 34.3°C and 1.1°C for February and July, respectively. Winds are southerly or southeasterly in summer. Frost very infrequent. See also climate diagram for FS 6 Cape Flats Dune Strandveld (Figure 4.128).

Important Taxa Tall Shrubs: *Euclea racemosa* subsp. *racemosa* (d), *Metalasia muricata* (d), *Rhus glauca* (d), *Morella cordifolia*, *Nylandtia spinosa*, *Olea exasperata*, *Rhus crenata*, *R. laevigata*, *R. lucida*. Low Shrubs: *Chrysanthemoides monilifera* (d), *Cullumia squarrosa* (d), *Pterocelastrus tricuspidatus* (d), *Salvia africana-lutea* (d), *Cassine peragua* subsp. *barbara*, *Chironia baccifera*, *Eriocephalus africanus* var. *africanus*, *E. racemosus*, *Helichrysum niveum*, *H. teretifolium*, *Lessertia fruticosa*, *Otholobium bracteolatum*, *Passerina paleacea*, *Phylica ericoides*, *Putterlickia pyracantha*, *Robsonodendron maritimum*. Succulent Shrubs:

Figure 4.136 FS 6 Cape Flats Dune Strandveld: Strandveld shrublands with typical hemispheric cushion-forming shrubs *Metalasia muricata* (Asteraceae) and *Tetragonia fruticosa* (Aizoaceae) dominant here at the Cape of Good Hope (with the famous Cape itself in the background, right).

Tetragonia fruticosa (d), *Cotyledon orbiculata* var. *spuria*, *Euphorbia mauritanica*, *Jordaaniella dubia*, *Pelargonium fulgidum*, *Ruschia macowanii*, *Tylecodon grandiflorus*, *Zygophyllum flexuosum*. Woody Climbers: *Cissampelos capensis*, *Solanum africanum*. Semiparasitic Shrubs: *Osyris compressa*, *Thesidium fragile*. Semiparasitic Epiphytic Shrub: *Viscum capense*. Herbs: *Helichrysum crispum* (d), *Adenogramma glomerata*, *Arctotheca calendula*, *Cineraria geifolia*, *Galium tomentosum*, *Helichrysum litorale*, *Knowltonia capensis*, *Lyperia tristis*, *Nemesia versicolor*, *Senecio elegans*, *Ursinia anthemoides* subsp. *anthemoides*, *Zaluzianskya villosa*. Geophytic Herbs: *Babiana tubulosa* var. *tubiflora*, *Brunsvigia orientalis*, *Chasmanthe aethiopica*, *Geissorhiza exscapa*, *Trachyandra ciliata*. Succulent Herbs: *Carpobrotus acinaciformis*, *C. edulis*, *Conicosia pugioniformis* subsp. *pugioniformis*, *Senecio littoreus*. Herbaceous Climbers: *Astephanus triflorus*, *Cynanchum africanum*, *C. obtusifolium*, *Didymodoxa capensis*, *Kedrostis nana*. Graminoids: *Ehrharta villosa* var. *villosa* (d), *Ischyrolepis eleocharis* (d), *Chaetobromus involucratus* subsp. *dregeanus*, *C. involucratus* subsp. *involucratus*, *Ehrharta calycina*, *Ficinia lateralis*, *F. ramosissima*, *F. secunda*, *Thamnochortus erectus*, *Willdenowia teres*.


L. Mucina

Figure 4.137 FS 7 Overberg Dune Strandveld: Coastal dune vegetation dominated by *Thamnochortus insignis* (large-tussock Restionaceae), *Metalasia muricata* (Asteraceae) and *Ischyrolepis eleocharis* (creeping Restionaceae) in De Mond Nature Reserve near Arniston (Western Cape).

Biogeographically Important Taxa (all West Coast endemics) Low Shrub: *Afrolimon peregrinum* (d). Succulent Shrubs: *Pelargonium gibbosum*, *Ruschia geminiflora*. Herb: *Grielum grandiflorum*. Geophytic Herb: *Gladiolus griseus*. Graminoids: *Cladoraphis cyperoides*, *Thamnochortus spicigerus*.

Endemic Taxon Succulent Shrub: *Lampranthus tenuifolius*.

Conservation Endangered. Target 24%. More than 6% statutorily conserved in the Table Mountain National Park, Blouberg, Driftsands, Wolfgat and Raapenberg Nature Reserves as well as in Rondevlei and Zandvlei Bird Sanctuaries. Private nature reserves protect about 4% of the unit (Blaauw Mountain, Koeberg, Lourens River, Rietvlei, Somchem). Almost 40% already transformed by urban sprawl, road building or by cultivation. Alien species of *Acacia*, pines and gum trees (*Eucalyptus*) have replaced the original strandveld vegetation in large areas. Erosion generally very low.

Remark *Sideroxylon inerme*, a conspicuous common species along the southern coastal strandveld, finds its westernmost distribution limit in this vegetation type and it does not extend northwards into the drier strandveld types.

References Taylor (1972b, 1984a), Milton (1976), Boucher (1978, 1982, 1983, 1987, 1997b, 1998b, 1999a, g), O'Callaghan (1990), Berry (1991), Privett (1998).

FS 7 Overberg Dune Strandveld

VT 47 Coastal Macchia (90%) (Acocks 1953). South Coast Strandveld (78%) (Moll & Bossi 1983). LR 4 Dune Thicket (84%) (Low & Rebelo 1996). BHU 6 Agulhas Fynbos Thicket Mosaic (81%) (Cowling et al. 1999b, Cowling & Heijnis 2001). Including South Coast Strandveld (Moll et al. 1984). Dune Thicket (Rebelo et al. 1991).

Distribution Western Cape Province: Scattered patches from Rooiels (Cape Hangklip area) as far east as Cape Infanta at the mouth of the Breede River, with the largest one surrounding the Agulhas Peninsula—as a rule bordering on coastal limestone formations. Altitude 0–100 m, but reaching 160 m in places.

Vegetation & Landscape Features Flat or slightly undulating dune fields of Die Plaat near Stanford and those of De Hoop, supporting up to 4 m tall, closed, evergreen, hard-leaved shrublands in moist dune slacks and wind-protected valleys and up to 1 m tall, coastal thicket in many places wind-shorn along exposed littoral situations.

Geology & Soils Deep, Recent marine-derived calcareous sands forming dunes that line the coast (Quaternary Strandveld Formation of the Bredasdorp Group), to shelly, shallow-marine sandstones and limestones of the Bredasdorp Group deposited on underlying Table Mountain Group sandstone. The most important land types include Hb (37%), Ha (31%) and Fc (18%).

Climate Mainly cyclonic rainfall varying from approximately 400 mm in the east to 600 mm in the west, mainly in winter, but still with considerable summer rainfall in the eastern regions of the unit. The winter rains are accompanied by strong northwesterly winds and cooler temperatures. The winds tend to be strong southwesterly (trade winds with average velocity of 35 km per hour) in summer. Mean daily maximum and minimum temperatures 25.1°C and 7.0°C for January and July, respectively. Mean monthly maximum and minimum temperatures for Cape Agulhas 27.1°C and 7.3°C for January and June, respectively. No incidences of snowfalls have been recorded; frost is infrequent and hail occurs occasionally. Dense mist banks regularly occur through the Overberg region in autumn and winter. See also climate diagram for FS 7 Overberg Dune Strandveld (Figure 4.128).

Important Taxa Tall Shrubs: *Euclea racemosa* subsp. *racemosa* (d), *Metalasia muricata* (d), *Rhus crenata* (d), *R. glauca* (d), *R. laevigata* (d), *Chionanthus foveolatus*, *Cussonia thyrsiflora*, *Gymnosporia buxifolia*, *Morella cordifolia*, *Myrsine africana*, *Olea exasperata*, *Passerina corymbosa*, *Rhus lucida*, *R. undulata*, *Sideroxylon inerme*, *Tarchonanthus littoralis*. Low Shrubs: *Chrysanthemoides monilifera* (d), *Passerina paleacea* (d), *P. rigida* (d), *Pterocelastrus tricuspidatus* (d), *Aspalathus forbesii*, *Ballota africana*, *Carissa bispinosa* subsp. *bispinosa*, *Cassine peragua* subsp. *barbara*, *Chironia baccifera*, *Eriocephalus africanus* var. *africanus*, *Felicia amelloides*, *Helichrysum niveum*, *H. teretifolium*, *Lauridia tetragona*, *Otholobium bracteolatum*, *Phylica axillaris*, *P. ericoides*, *Polygala myrtifolia*, *Psoralea repens*, *Robsonodendron maritimum*. Succulent Shrubs: *Crassula nudicaulis*, *Drosanthemum candens*, *Jordaaniella dubia*, *Osteospermum fruticosum*, *Othonna dentata*, *Tetragonia decumbens*, *T. fruticosa*, *T. spicata*. Woody Climbers: *Asparagus aethiopicus*, *Cissampelos capensis*, *Solanum africanum*. Semiparasitic Shrubs: *Thesidium fragile* (d), *Osyris compressa*. Herbs: *Helichrysum crispum* (d), *Senecio elegans* (d), *Cineraria geifolia*, *Hebenstretia repens*, *Helichrysum litorale*, *Knowltonia capensis*, *Silene crassifolia*, *Stachys aethiopica*. Geophytic Herbs: *Brunsvigia orientalis*, *Chasmanthe aethiopica*, *Romulea obscura*. Succulent Herbs: *Carpobrotus acinaciformis* (d), *C. edulis*, *Crassula expansa* subsp. *expansa*. Herbaceous Climbers: *Astephanus triflorus*, *Cynanchum africanum*, *Kedrostis nana*. Graminoids: *Ischyrolepis eleocharis* (d), *Cynodon dactylon*, *Ehrharta erecta*, *E. villosa* var. *villosa*, *Ficinia lateralis*, *Thamnochortus erectus*.

Biogeographically Important Taxon (South Coast endemic) Low Shrub: *Berkheya coriacea*.

Endemic Taxa Succulent Shrub: *Lampranthus salteri*. Geophytic Herb: *Gladiolus carmineus*.

Conservation Least threatened. Target 36%. Some 30% statutorily conserved in De Hoop, Walker Bay and De Mond Nature Reserves and in the Agulhas National Park. A further 11% of the unit is protected in private conservation areas, such as Andrewsfield, Brandfontein-Rietfontein, Groot Hagelkraal, Hoek-van-die-Berg, Kleinrivier, Paapekuilfontein and Waterkop. More than 5% has been transformed by urban development and cultivation. Established thickets of alien *Acacia cyclops*, *A. saligna* and *Leptospermum laevigatum* are of serious concern. Erosion very low and low.

Remarks Parts of this vegetation unit have a drier climate than the FS 8 Blombos Strandveld with fewer components typical of coastal thickets fringing the seaboards further east. It has also fewer succulents than the strandveld types along the western seaboard.

References Boucher (1974, 1977, 1978, 1994b, 1995, 1998a, 1999c), Van der Merwe (1977a), Cowling et al. (1988), Taylor & Boucher (1993), De Hoop Nature Reserve Planning Committee (2001), Zietsman & Bredenkamp (2006), L. Mucina (unpublished data).

FS 8 Blombos Strandveld

VT 47 Coastal Macchia (91%) (Acocks 1953). Dune Fynbos (93%) (Moll & Bossi 1983). LR 4 Dune Thicket (97%) (Low & Rebelo 1996). BHU 7 Stilbaai Fynbos/Thicket Mosaic (81%) (Cowling et al. 1999b, Cowling & Heijnis 2001). STEP Gouritz Dune Thicket (36%), STEP Still Bay Dune Thicket (27%) (Vlok & Euston-Brown 2002, Vlok et al. 2003).

Distribution Western Cape Province: Narrow strip of interrupted patches along the coast of the Indian Ocean between Witsand and Gouritsmond (bordering on the easternmost occurrence of coastal limestone). Altitude 0–180 m.

Vegetation & Landscape Features Flat or slightly undulating coastal landscapes with dense, evergreen, sclerophyllous shrublands and thickets, with a poorly developed undergrowth layer. The thicket vegetation is best developed in dune slacks, where it is well protected from occasional fires that may penetrate the coastal zone from the inland areas and from salt-laden onshore winds that cause stunting (0.5 m tall, dense vegetation) in exposed littoral situations.

Geology & Soils Mainly on the Bredasdorp Group limestones and sandstones, but also on younger, unconsolidated lime-rich Strandveld and Waenhuiskrans Formations, which consist of white dune sands with fine shell material and occasionally with calcrete lenses present; in places with an admixture of littoral calcareous or sandstone cobbles. Most important land types Hb (39%), Ha (29%) and Fc (13%).

Climate Mainly cyclonic rainfall varying from approximately 300 mm in the east to 600 mm in the west. Precipitation is weakly bimodal, with peaks in spring and autumn. Morning fogs are common in winter. Mean daily maximum and minimum temperatures 25.0°C and 6.4°C for February and July, respectively. The prevailing winds are easterly and westerly, with a sea breeze influence on the vegetation. Strong and dry off-shore berg winds occur in late autumn and early winter, increasing the chance of veld fires. Frost incidence infrequent. See also climate diagram for FS 8 Blombos Strandveld (Figure 4.128).

Important Taxa Small Trees: *Chionanthus foveolatus*, *Clausena anisata*, *Zanthoxylum capense*. Tall Shrubs: *Chrysanthemoides monilifera* (d), *Metalasia muricata* (d), *Pterocelastrus tricuspidatus* (d), *Azima tetracantha*, *Cussonia thyrsiflora*, *Euclea racemosa* subsp. *racemosa*, *Grewia occidentalis*, *Gymnosporia capitata*, *Maytenus procumbens*, *Morella cordifolia*, *Mystroxylon aethiopicum*, *Olea exasperata*, *Ptaeroxylon obliquum*, *Putterlickia pyracantha*, *Rhus crenata*, *R. glauca*, *R. longispina*, *R. lucida*, *Sideroxylon inerme*, *Tarchonanthus littoralis*. Low Shrubs:

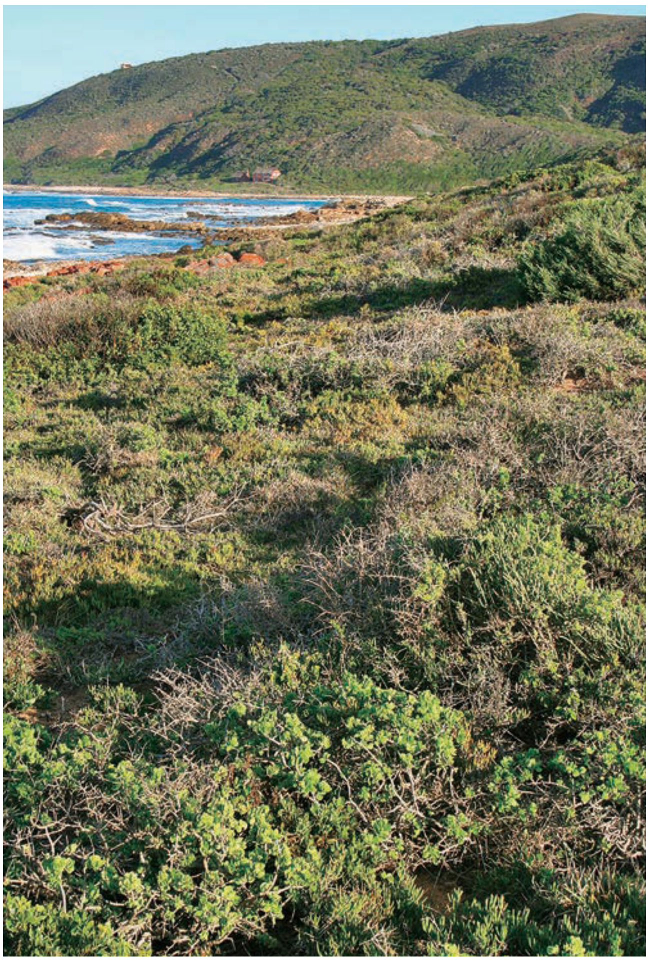

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Figure 4.138 FS 8 Blombos Strandveld: Dense coastal thicket kept low by strong winds and the influence of salt spray, with *Exomis microphylla* (Chenopodiaceae), *Tetragonia fruticosa* (Aizoaceae) and *Rhus crenata* (Anacardiaceae) at Groot Jongensfontein near Still Bay (Western Cape).

Exomis microphylla (d), *Passerina rigida* (d), *Salvia africana-lutea* (d), *Aspalathus alopecurus*, *Ballota africana*, *Carissa bispinosa* subsp. *bispinosa*, *Cassine peragua* subsp. *barbara*, *Chironia baccifera*, *Eriocephalus africanus* var. *africanus*, *Lauridia tetragona*, *Passerina galpinii*, *Phylica axillaris*, *Polygala myrtifolia*, *Robsonodendron maritimum*. Succulent Shrubs: *Zygophyllum morgsana* (d), *Osteospermum fruticosum* (d), *Crassula nudicaulis*, *C. pubescens* subsp. *pubescens*, *Euphorbia mauritanica*, *Jordaaniella dubia*. Woody Climbers: *Rhoicissus digitata*, *Solanum africanum*. Woody Succulent Climber: *Sarcostemma viminale*. Semiparasitic Shrub: *Thesidium fragile* (d). Soft Shrub: *Hypoestes aristata*. Herbs: *Cineraria geifolia*, *Commelina africana*, *Galium tomentosum*, *Helichrysum litorale*, *Stachys aethiopica*. Geophytic Herbs: *Brunsvigia orientalis*, *Chasmanthe aethiopica*, *Trachyandra divaricata*. Succulent Herbs: *Carpobrotus acinaciformis* (d), *C. edulis*, *Crassula expansa* subsp. *expansa*. Herbaceous Climbers: *Astephanus triflorus*, *Cynanchum ellipticum*. Herbaceous Succulent Climber: *Pelargonium peltatum*. Graminoids: *Cynodon dactylon*, *Ehrharta delicatula*, *E. villosa* var. *villosa*, *Ficinia indica*, *F. lateralis*, *F. ramosissima*, *Thamnochortus erectus*.

Biogeographically Important Taxa (both South Coast endemics) Low Shrub: *Berkheya coriacea*. Geophytic Herb: *Freesia alba*.

Endemic Taxa Low Shrub: *Aspalathus arenaria*. Succulent Shrub: *Lampranthus galpiniae*.

Conservation Least threatened. Target 36%. More than 20% statutorily conserved in the Kleinjongensfontein, Geelkrans, Blomboschfontein, Skulpiesbaai and Pauline Bohnen Nature Reserves. A further 11% enjoys protection in private reserves such as Duiwenhoksriviermond, Rein's Coastal (Gouriqua), Vergaderingskop, Blombos, Die Duine and Orca. The vegetation is relatively well preserved and has not experienced much transformation, except for local infestation by alien *Acacia cyclops* and *A. saligna*. Erosion generally very low.

References Muir (1929), Rebelo et al. (1991), Boucher & Rode (1995a, b), Boucher (1997d), Vlok & Euston-Brown (2002), Vlok et al. (2003).

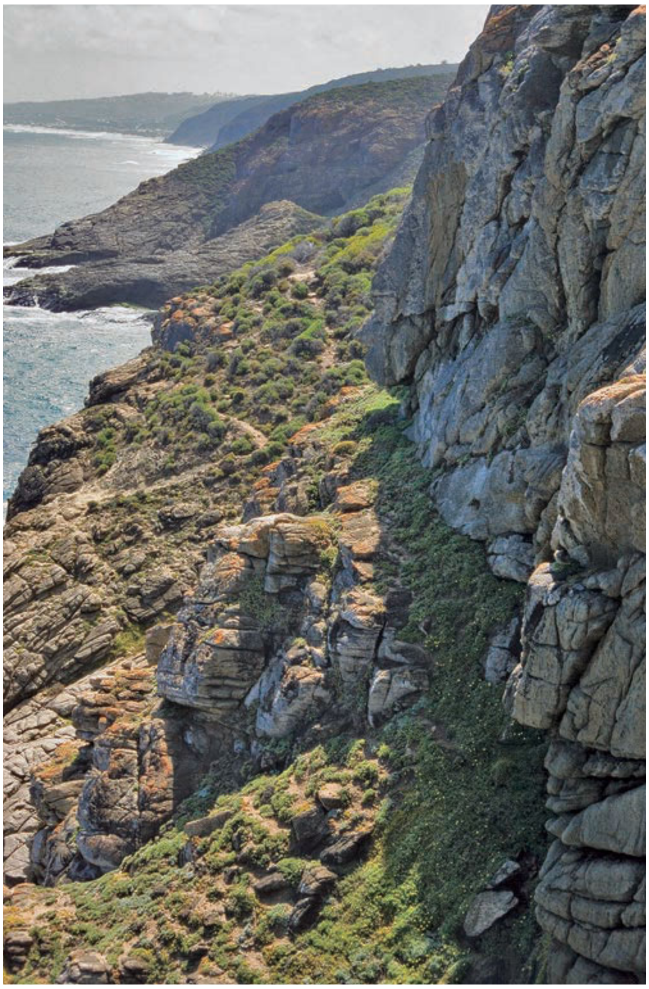

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Figure 4.139 FS 9 Groot Brak Dune Strandveld: Steep coastal granite cliffs supporting low wind-sheared coastal thickets, near Herolds Bay south of George (Western Cape).

FS 9 Groot Brak Dune Strandveld

VT 46 Coastal Renosterbosveld (53%) (Acocks 1953). Gouritz River Scrub (Acocks 1988). LR 63 South and South-west Coast Renosterveld (86%) (Low & Rebelo 1996). BHU 34 Riversdale Coast Renosterveld (47%), BHU 28 Blanco Fynbos/Renosterveld Mosaic (27%) (Cowling et al. 1999b, Cowling & Heijnis 2001). STEP Herbertsdale Renoster Thicket (67%) (Vlok & Euston-Brown 2002, Vlok et al. 2003).

Distribution Western Cape Province: Coastal stretches between the mouth of the Gouritz River as far east as Victoria Bay near the Wilderness, with by far the largest area covering the flats north of Mossel Bay (along the lower reaches of the Groot Brak, Klein Brak and Hartenbos Rivers) and extending up to 17 km from the coast. Altitude 0–180 m.

Vegetation & Landscape Features Flats, undulating landscapes (stabilised dunes) and steep coastal slopes, covered by dense and tall (up to 3 m), spiny, sclerophyllous scrub with gaps supporting shrublands with ericoids or succulent-leaved shrubs. The graminoid layer is sparse and short.

Geology & Soils Mostly underlain by the clastic sedimentary rocks of the Kirkwood Formation (Mesozoic Uitenhage Group). In the east, quartzite, schist and phyllite of the Kaaimans Group (Namibian Erathem) and Cape Granite (edges of high coastal cliffs) are also present. In parts along the coast, these rocks are covered by the unconsolidated dune sand of the Strandveld Formation (Bredasdorp Group). Most important land types Db and Dc.

Climate MAP varies between approximately 350 mm in the west to 750 mm in the east, with approximately 40% of the rain falling in summer (October–March) and 60% in winter (April–September). Mean daily maximum and minimum temperatures 26.8°C and 7.7°C for February and July, respectively. Mean monthly maximum and minimum temperatures for Cape St Blaize 29.0°C and 7.1°C for April and August, respectively. See also climate diagram for FS 9 Groot Brak Dune Strandveld (Figure 4.128).

Important Taxa Small Trees: *Chionanthus foveolatus*, *Clausena anisata*. Tall Shrubs: *Azima tetracantha*, *Cussonia thyrsiflora*, *Diospyros dichrophylla*, *Euclea racemosa* subsp. *racemosa*, *Grewia occidentalis*, *Gymnosporia buxifolia*, *Maytenus procumbens*, *Metalasia muricata*, *Morella cordifolia*, *Myrsine africana*, *Mystroxylon aethiopicum*, *Olea exasperata*, *Pterocelastrus tricuspidatus*, *Putterlickia pyracantha*, *Rhus crenata*, *R. glauca*, *R. longispina*, *R. lucida*, *Schotia afra* var. *afra*, *Sideroxylon inerme*, *Tarchonanthus littoralis*. Low Shrubs: *Asparagus suaveolens*, *Ballota africana*, *Carissa bispinosa* subsp. *bispinosa*, *Chironia baccifera*, *Clutia daphnoides*, *Eriocephalus africanus* var. *africanus*, *Helichrysum teretifolium*, *Lauridia tetragona*, *Phylica axillaris*, *Polygala myrtifolia*. Succulent Shrubs: *Aloe arborescens* (d), *Cotyledon orbiculata* var. *dactylopsis*, *Crassula perforata*, *C. pubescens* subsp. *pubescens*, *Euphorbia burmannii*, *E. mauritanica*, *Tetragonia fruticosa*, *Zygophyllum morgsana*.

Woody Climbers: *Asparagus aethiopicus*, *Cissampelos capensis*, *Rhoicissus digitata*. Woody Succulent Climber: *Sarcostemma viminale*. Semiparasitic Shrubs: *Osyris compressa*, *Thesidium fragile*. Soft Shrub: *Hypoestes aristata*. Herb: *Commelina africana*. Geophytic Herbs: *Brunsvigia orientalis*, *Chasmanthe aethiopica*, *Hesperantha falcata*. Succulent Herbs: *Carpobrotus edulis*, *Crassula expansa* subsp. *expansa*, *Senecio radicans*. Herbaceous Climbers: *Astephanus triflorus*, *Cynanchum obtusifolium*, *Kedrostis nana*. Herbaceous Succulent Climber: *Pelargonium peltatum*. Graminoids: *Cynodon dactylon*, *Ehrharta erecta*, *Ficinia indica*, *Panicum deustum*, *Stipa dregeana*.

Biogeographically Important Taxa (both South Coast endemics) Herb: *Indigofera tomentosa*. Geophytic Herb: *Freesia alba*.

Conservation Endangered. Target 36%. None conserved in statutory conservation areas and only about 1% protected in private reserves (George, Kanon, Blydskap, Kwelanga). Almost half of the region has been transformed for cultivation, by building of roads or by development of coastal settlements. Erosion generally moderate and high, with some areas ranking as low.

References Vlok & Euston-Brown (2002), Vlok et al. (2003), C. Boucher (unpublished data), H.C. Taylor (unpublished data).

10. Credits

The first draft of the introductory text was written by A.G. Rebelo. L. Mucina wrote most of Sections 1.1, 1.3, 1.5, 2.4.1, 5.2, and contributed to 1.4.3. The following sections were rewritten or contributed to by: R.A. Ward wrote most of the geological patterns (Section 2.1), F. Ellis and J.J.N. Lambrechts wrote Section 2.3 (soils), M.C. Rutherford wrote most of the regional climate (Section 2.4.2) and contributed to discussion on boundaries of the Fynbos and Karoo (Section 1.4.2), as well as to the section on climate and ecophysiological response (4.2), F.G.T. Radloff wrote most of the section on large mammal herbivory (Section 4.4.1), L. Scott contributed the section featuring the palaeoecological framework (Section 5.1), Ş.M. Procheş contributed to endemism and species diversity patterns (Sections 6.1 and 6.3), S.D. Johnson contributed extensively to section 4.4.2 (pollination and dispersal), D.M. Richardson wrote the account of the role of alien flora in the Fynbos Biome (Section 7.2) and B.A. Walton made a contribution to the section on renosterveld (3.2). All sections were extensively edited and adapted by A.G. Rebelo, L. Mucina and M.C. Rutherford.

An initial theoretical framework was done by C. Boucher and L. Mucina based on satellite imagery supplied by CapeNature (then Western Cape Nature Conservation Service) and digitised by R.S. Knight and S. Jonas (then Univ. of Western Cape). These were discarded and a redefinition of fynbos and renosterveld units based on geology was done by A.G. Rebelo in consultation with C. Boucher, N. Helme, R.M. Cowling, J.H.J. Vlok, A.B. Low, L. Mucina and M.C. Rutherford. Mapping was done by A.G. Rebelo with GIS help from W.J. Smit. Map units used or used to inform units included unpublished digitised versions provided for the Cederberg by D. Bands (Jonkershoek), Little Karoo by J.H.J. Vlok, Agulhas by D.I.W. Euston-Brown, South and West Coast renosterveld units by N. Helme, and Cape Flats by A.B. Low. Further GIS assistance in the final stages was provided by L.W. Powrie.

The conceptual scheme for the mapping of the Kamiesberg units (FFg 1 and FRg 1) was conceived by A. le Roux, L. Mucina and M.C. Rutherford in concert with the establishment of the mapping boundaries of the surrounding Succulent Karoo units. The boundaries of the unit FFg 1 were replaced by A.G. Rebelo based on the distribution of Proteaceae: this was chosen as the 1 400 m altitude. The original mapped extent of FFq 1 (as suggested by N. Jürgens) has been modified by M.C. Rutherford and L. Mucina.

A.G. Rebelo is sole author of the descriptions of FFh 1, 8–10, FFq 4–6, FFs 1, 5, 8, 20–22, 26, 29, FFt 1–2, FRl 1 and FRs 6, and further contributed to all other vegetation units (for most of which he is the leading author) except for FFd 11, FFq 1 and FS 1–9. L. Mucina is the sole author of the description of FFd 11, wrote all FS units, is the leading author of the units FFs 27–28 and 30–31 as well as of FRd 1–2, FRg 1 and FRs 3 and 5. He further co-authored all FFa units, all FFb units, FFc 1, FFd 1 and 8–9, FFf 2, FFg 1–2, 5, all FFl units, FFs 6–7, 10–12, 17, 19, 25, all FRa units, FRc 2, FRg 2 and FRs 8–10, 13 and 19. C. Boucher participated in all FS units, is the leading author of FFa 4, FFd 8, 10, FRs 4, 17 and further co-authored FFa 1–3, FFc 1, FFd 2–7, 9, FFf 1, FFg 2–3, FFh 6, all FFl units, FFq 2–3, FFs 2–4, 9–16, 19, 23–24, both FRa units, FRg 2, FRs 8–9, 11–15 and 18. N. Helme is the leading author of FFd 1, FRg 3, FRs 11–13 and further co-authored descriptions of FFa 3, both FFf units, FFg 1–4, FFh 2–7, FRa 1, FRc 1, FRg 2 and FRs 1, 7–10 and 15–16. M.C. Rutherford co-authored FFb 2, FFh 4, FFq 1 and 3, FFs 8, 13, 16–18, 23, 27–30 and FRg 1. A.L. Skowno and S.A. Todd co-authored the description of FRs 2. J.A.M. Janssen contributed to the descriptions of FFf 1 and FFs 12. A. le Roux contributed to FFd 1 and FFg 1. B.A. Walton contributed to FFa 3, D.B. Hoare to FFd 11, FRs 19 and D.J. McDonald to FFs 16. N. Jürgens is the sole author of FFq 1.

M.C. Rutherford and L.W. Powrie prepared all climate diagrams and their captions. M.C. Rutherford contributed to the editing of the climate characteristics of all FS units. For all vegetation units M. Rouget, and others within the Directorate of Biodiversity Programmes, Policy & Planning of SANBI, provided quantitative information on conservation status and targets, areas currently conserved and areas transformed for each vegetation unit. W.J. Smit and L.W. Powrie assisted in preparing the data on conservation and transformation, correspondence with other classification schemes, climate, altitude ranges, alien invasive species and distribution of Proteaceae, which were used in the text for all vegetation unit descriptions except for FFs. Introductory texts to the fynbos and renosterveld units (within the section on Descriptions) were written by A.G. Rebelo and edited by L. Mucina. Within the same section L. Mucina contributed the short characteristics of the sandstone and limestone fynbos as well as strandveld.

The initial species lists for most of the FF and FR units have been prepared by A.G. Rebelo, assisted by N. Helme (especially in FR units) and C. Boucher. The lists have been revised in depth by L. Mucina, especially FFs 7, 10–12, 17, 24–26, FFq 2, 5 and 6, FFd 1, 7–8 and 10, FFh 1–2, 5–6 and 10, FFb 1–6 (here also assisted by M.C. Rutherford and L.W. Powrie), FFa 1, 3 (assisted by B.A. Walton) and 4, FFg 1 (using an unpublished list of endemics by N. Helme as an important source), 2, 4 and 5, FFf 2, FFl 1–3, FRs 2–4, 6–7, 9 (assisted by B.A. Walton), 11–15, 18 (assisted by M.C. Rutherford and L.W. Powrie) and 19, FRg 1 (using unpublished lists of species by A. le Roux and N. Helme as important sources) and 3, FRd 1–2, FRa 2 (assisted by B.A. Walton), FRc 1 (assisted by B.A. Walton) and 2. L. Mucina also provided completely new lists for FFs 27–28 and 30–31, FFd 11 and FRs 5. The original species list of FFq 1 was provided by N. Jürgens.

The major sources of the species lists were the unpublished data from the PRECIS system, Acocks database, Protea Atlas Project, conspectus of Cape flora (Goldblatt & Manning 2000b), published phytosociological literature (for details see the References further on) as well as unpublished field records of all authors

involved in this chapter. L.W. Powrie and W.J. Smit assisted with extraction of species lists from the SANBI databases (PRECIS, ACKDAT). We thank the Data Management Section of SANBI (Pretoria) for making these databases accessible to the VEGMAP Project. E.G.H. (Ted) Oliver checked the affiliation of the *Erica* species against particular species lists, while J.C. Manning checked the affiliation of the bulbous plants (including Iridaceae, Hyacinthaceae, Tecophilaeaceae, etc.). The initial species lists of the FS units by C. Boucher have been extensively edited by L. Mucina. The link to all Proteaceae to the Fynbos units were corrected by A.G. Rebelo.

Endemic species lists were extracted from Protea Atlas Project data and the conspectus of Cape flora (Goldblatt & Manning 2000b) by A.G. Rebelo, and from unpublished lists by N. Helme for West and South Coast renosterveld and by A. le Roux and N. Helme for the Kamiesberg. These were checked by E.G.H. (Ted) Oliver and R. Turner (Ericaceae), J.C. Manning (Iridaceae, Hyacinthaceae, Tecophilaeaceae), D. Snyman (Amaryllidaceae), P. Chesselet (Aizoaceae), and A. Schutte-Vlok (Fabaceae) among others, except for Restionaceae, which were checked using Linder (1999) as the major source. N. Helme checked the endemic species lists of the renosterveld units. All lists of endemics were extensively checked by L. Mucina in the final leg of editing.

Most of the photographs were contributed by L. Mucina. Other photographers include D. Gwynne-Evans, J.C. Manning, F.G.T. Radloff, K.J.C. Melvin-Phillips, P. Goldblatt, C. Boucher, A. van Niekerk, L.W. Powrie, M.C. Rutherford, C. Paterson-Jones, J.P. Groenewald and A.V. Köcke. Figures 4.4 to 4.7 were supplied by F. Ellis and J.J.N. Lambrechts and Figures 4.8 and 4.9 were prepared by M.C. Rutherford and L.W. Powrie. Figure 4.78 was constructed by L.W. Powrie and L. Mucina. Tables 4.1 and 4.2 were contributed by L. Mucina and Table 4.3 was prepared by Ş.M. Procheş. The captions to the photographs were created by L. Mucina (with the help of other photographers and expert advice) and edited by A.G. Rebelo.

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These Credits were compiled by L. Mucina, revised by A.G. Rebelo and edited by M.C. Rutherford

11. References

Acocks, J.P.H. 1935. *Vegetation of a portion of the Cape Flats and list of plants so far found there*. M.Sc. thesis, Dept of Botany, Univ. of Cape Town.

Acocks, J.P.H. 1953. Veld types of South Africa. *Mem. Bot. Surv. S. Afr.* No. 28: 1–192.

Acocks, J.P.H. 1975. Veld types of South Africa, edn 2. *Mem. Bot. Surv. S. Afr.* No. 40: 1–128.

Acocks, J.P.H. 1988. Veld types of South Africa, edn 3. *Mem. Bot. Surv. S. Afr.* No. 57: 1–146.

Adamson, R.S. 1925. The native vegetation of Kirstenbosch. *J. Bot. Soc. S. Afr.* 11: 19–23.

Adamson, R.S. 1927. Plant communities of Table Mountain: preliminary account. *J. Ecol.* 15: 278–284.

Adamson, R.S. 1935. The plant communities of Table Mountain. III. A six years' study of regeneration after burning. *J. Ecol.* 23: 44–55.

Adamson, R.S. 1958. The Cape as an ancient African flora. *Adv. Sci.* 58: 1–10.

Adamson, R.S. & Salter, T.M. 1950. *Flora of the Cape Peninsula.* Juta & Co., Cape Town.

Agenbag, L. & Esler, K.J. 2004a. An environmental gradient reveals how climate influences phenophases in fynbos growth forms. In: Arianoutsou, M. & Papanastasis, V. (eds), *10th MEDECOS Conference April 25–May 1, 2004, Rhodes*. Millpress, Rotterdam.

Agenbag, L. & Esler, K.J. 2004b. Studies along an environmental gradient reveal how biome boundaries may respond to climate change. In: Arianoutsou, M. & Papanastasis, V. (eds), *10th MEDECOS Conference April 25–May 1, 2004, Rhodes*. Millpress, Rotterdam.

Agenbag, L., Rutherford, M., Midgley, G. & Esler, K.J. 2004. Fundamental and realized niches of fynbos and karoo seedlings as revealed by reciprocal transplants. In: Arianoutsou, M. & Papanastasis, V. (eds), *Proceedings 10th MEDECOS Conference April 25–May 1, 2004, Rhodes*. Millpress, Rotterdam.

Alexander, L.T. & Cady, J.G. 1962. *Genesis and hardening of laterite in soils.* Technical Bulletin No. 1282. Soil Conservation Service, United States Dept of Agriculture, Washington, D.C.

Allen, H.D. 1996. Mediterranean environments. In: Adams, W.M., Goudie, A.S. & Orme, A.R. (eds), *The physical geography of Africa*, pp. 307–325. Oxford Univ. Press, Oxford.

Anderson, B. & Midgley, J.J. 2002. It takes two to tango but three is a tangle: mutualists and cheaters on the carnivorous plant *Roridula*. *Oecologia* 132: 369–373.

Anderson, B. & Midgley, J.J. 2003. Digestive mutualism, an alternate pathway in plant carnivory. *Oikos* 102: 221–224.

Anderson, B., Olivieri, I., Lourmas, M. & Stewart, B.A. 2004. Comparative population genetic structures and local adaptation of two mutualists. *Evolution* 58: 1730–1747.

Andrag, R.H. 1970. *Plantopname van Helderberg-Natuurreservaat.* B.Sc.(Hons) project, Forestry Faculty, Univ. of Stellenbosch.

Anonymous 1979. *Grabouw Staatsbos bedryfsplan/natuurbewaringplan vir die periode 1980/81–1984/85*. B.Sc.(Hons) project, Dept of Forestry Conservation, Univ. of Stellenbosch.

Archibald, S., Bond, W.J., Stock, W.D. & Fairbanks, D.H.K. 2005. Shaping the landscape: fire-grazer interactions in an African savanna. *Ecol. Appl.* 15: 96–109.

Arianoutsou, M. & Papanastasis, V. (eds) 2004. *10th MEDECOS Conference April 25–May 1, 2004, Rhodes*. Millpress, Rotterdam.

Arroyo, M.T.K., Cavieres, L, Marticorena, C. & Muñoz-Schick, M. 1995a. Convergence in the mediterranean floras in central Chile and California: insights from comparative biogeography. In: Arroyo, M.T.K., Zedler, P.H. & Fox, M.D. (eds), *Ecology and biogeography of mediterranean ecosystems in Chile, California and Australia*, pp. 43–88. Springer, Berlin.

Arroyo, M.T.K., Zedler, P.H. & Fox, M.D. (eds) 1995b. *Ecology and biogeography of mediterranean ecosystems in Chile, California and Australia.* Springer, Berlin.

Augustine, D.J. & McNaughton, S.J. 2004. Regulation of shrub dynamics by native browsing ungulates on East African rangeland. *J. Appl. Ecol.* 41: 45–58.

Augustine, D.J., McNaughton, S.J. & Frank, D.A. 2003. Feedbacks between soil nutrients and large herbivores in a managed savanna ecosystem. *Ecol. Appl.* 13: 1325–1337.

Axelrod, D.I. 1975. Evolution and biogeography of Madrean-Tethyan sclerophyll vegetation. *Ann. Missouri Bot. Gard.* 62: 280–334.

Axelrod, D.I. & Raven, P.H. 1978. Late Cretaceous and Tertiary vegetation history of Africa. In: Werger, M.J.A. & Van Bruggen, A.C. (eds), *Biogeography and ecology of southern Africa*, pp. 77–130. Dr W. Junk, The Hague.

Bailey, H.P. 1979. Semi-arid climates: their definitions and distribution. In: Hall, A.E., Cannell, G.H. & Lawton, H.W. (eds), *Agriculture in semi-arid environments*, pp. 73–97. Springer, Berlin.

Bakker, F.T., Culham, A., Hettiarachi, P., Touloumenidou, T. & Gibby, M. 2004. Phylogeny of *Pelargonium* (Geraniaceae) based on DNA sequences from three genomes. *Taxon* 53: 17–28.

Bakker, F.T., Marais, E.M., Culham, A. & Gibby, M. 2005. Nested radiation in Cape *Pelargonium*. In: Bakker, F.T., Chatrou, L.W., Gravendeel, B. & Pelser, P.B. (eds), *Plant species-level systematics: a new perspective on pattern and process*, pp. 75–100. Koeltz, Königstein.

Barbour, M. & Minnich, R.A. 1990. The myth of chaparral convergence. *Isr. J. Bot.* 39: 453–463.

Barnes, K. 1992. *The community structure of the Bokkop Steenberg Region of Silvermine Nature Reserve.* 3rd year project, Dept of Botany, Univ. of Cape Town.

Barraclough, T.G. 2006. What can phylogenetics tell us about speciation in the Cape flora? *Divers. Distrib.* 12: 21–26.

Barraclough, T.G. & Reeves, G. 2005. The causes of speciation in flowering plant lineages: species level DNA trees in the African genus *Protea*. In: Bakker, F.T., Chatrou, T., Gravendeel, B. & Pelser, P. (eds), *Plant species level systematics: patterns, processes and new applications*, pp. 31–46. Koeltz,

Königstein.
Barreda, V.D. 1993. Late Oligocene? Miocene pollen of the families Compositae, Malvaceae and Polygonaceae from the Chenque Formation, Golfo San Jorge Basin, southeastern Argentina. *Palynology* 17: 169–186.
Baxter, A.J. & Meadows, M.E. 1994. Palynological evidence for the impact of colonial settlement within lowland fynbos: a high-resolution study from the Verlorenvlei, Southwestern Cape Province, South Africa. *Hist. Biol.* 9: 61–70.
Bean, A. & Johns, A. 2005. *South African Wild Flower Guide 5. Stellenbosch to Hermanus, including Kogelberg and Hottentots Holland.* Botanical Society of South Africa, Cape Town.
Berry, M.G. 1991. *Die flora en plantegroei van die Swart-Produkte eiendom, te Kaapse Vlakte*. B.Sc.(Hons) project, Dept of Botany, Univ. of Stellenbosch.
Beukes, P.C. 1984. *Sommige aspekte van die ekologie van die Vaalribbok (*Pelea capreolus, *Forster 1790) in die Bontebok Nasionale Park*. M.Sc. thesis, Univ. of Stellenbosch.
Beukes, P.C. 1987. Responses of grey rhebuck and bontebok to controlled fires in coastal renosterveld. *S. Afr. J. Wildl. Res.* 17: 103–108.
Bews, J.W. 1925. *Plant forms and their evolution in South Africa.* Longmans, Green & Co., London.
Bigalke, R.C. 1979. Aspects of vertebrate life in Fynbos, South Africa. In: Specht, R.L. (ed.), *Ecosystems of the world. 9A. Heathlands and related shrublands,* pp. 81–95. Elsevier, Amsterdam.
Bloemhoff, A. & Craven, A. 1990. *Gedetailleerde plantkundige opname van moontlike padbelyning deur 'n gedeelte van die Weskus Nasionale Park en die voorkoms van skaars en bedreigde plante daarin.* B.Sc.(Hons) project, Dept of Botany, Univ. of Stellenbosch.
Boelhouwers, J.C. 1998. Environmental controls on soil frost activity in the Western Cape mountains, South Africa. *Earth Surface Processes and Landforms* 23: 211–221.
Boix, C. 1992. *A vegetation survey of the Wildevoëlvlei flats and adjacent areas.* 3rd year project, Dept of Botany, Univ. of Cape Town.
Bolus, H. 1886. *Sketch of the flora of South Africa*. Richards & Sons, Cape Town.
Bond, P. & Goldblatt, P. 1984. Plants of the Cape flora. A descriptive catalogue. *J. S. Afr. Bot.* Suppl. Vol. 13. National Botanic Gardens, Kirstenbosch.
Bond, W. 1978a. *A management plan of De Vasselot Nature Reserve*. Report, Dept of Forestry, Saasveld Forestry Research Station, George.
Bond, W. 1978b. *A management plan of Ysternek Nature Reserve.* Report, Dept of Forestry, Saasveld Forestry Research Station, George.
Bond, W. 1981. *Vegetation gradients in southern Cape mountains.* M.Sc. thesis, Dept of Botany, Univ. of Cape Town.
Bond, W. 1983. On alpha diversity and the richness of the Cape flora: a study in southern Cape fynbos. In: Kruger, F.J., Mitchell, D.T. & Jarvis, J.U.M. (eds), *Mediterranean type ecosystems—the role of nutrients*, pp. 337–356. Springer, Berlin.
Bond, W.J. 1984. Fire survival of Cape Proteaceae—influence of fire season and seed predators. *Vegetatio* 56: 65–74.
Bond, W.J. 1985. Canopy-stored seed reserves (serotiny) in Cape Proteaceae. *S. Afr. J. Bot.* 51: 181–186.
Bond, W.J. 1994. Do mutualisms matter? Assessing the impact of pollinator and disperser disruption on plant extinction. *Phil. Trans. Roy. Soc. London, Ser. B* 344: 83–90.
Bond, W.J. 1997. Functional types for predicting changes in biodiversity: a case study in Cape fynbos. In: Smith, T.M, Shugart, H.H. & Woodward, F.I. (eds), *Plant functional types: their relevance to ecosystem properties and global change*, pp. 174–194. Cambridge Univ. Press, Cambridge.
Bond, W.J., Le Roux, D. & Erntzen, R. 1990. Fire intensity and regeneration of myrmecochorous Proteaceae. *S. Afr. J. Bot.* 56: 326–330.
Bond, W. & Midgley, J.J. 2003. The evolutionary ecology of sprouting in woody plants. *Int. J. Plant Sci.* 164: S103–S114.
Bond, W.J., Midgley, J. & Vlok, J. 1988. When is an island not an island? Insular effects and their causes in fynbos shrublands. *Oecologia* 77: 515–521.
Bond, W.J. & Slingsby, P. 1983. Seed dispersal by ants in shrublands of the Cape Province and its evolutionary implications. *S. Afr. J. Sci.* 79: 231–233.
Bond, W. & Slingsby, P. 1984. Collapse of an ant-plant mutualism: the Argentine ant (*Iridomyrmex humilis*) and myrmecochorous Proteaceae. *Ecology* 65: 1031–1037.
Bond, W.J. & Van Wilgen, B.W. 1996. *Fire and plants.* Chapman & Hall, London.
Bond, W.J., Yeaton, R. & Stock, W.D. 1991. Myrmecochory in Cape fynbos. In: Huxley, C.R. & Cutler, D.F. (eds), *Ant-plant interactions*, pp. 448–462. Oxford Univ. Press, Oxford.
Boschoff, C.R. 1989. *Structure, distribution and phenology of perennial plant species in the Worcester Veld Reserve*. M.Sc. thesis, Dept of Botany, Univ. of Cape Town.
Boshoff, A., Cowling, R.M. & Kerley, G. 2000. *The Baviaanskloof Conservation Area*. TERU Report No. 27, Terrestrial Ecology Research Unit, Univ. of Port Elizabeth.
Boshoff, A.F. & Kerley, G.I.H. 2001. Potential distribution of the medium- to large-size mammals in the Cape Floristic Region, based on historical accounts and habitat requirements. *Afr. Zool.* 36: 245–273.
Boshoff, C.R. 1985. *A vegetation survey at Kenilworth Race Course—implications for conservation*. B.Sc.(Hons) project, Dept of Botany, Univ. of Cape Town.
Boucher, C. 1972. *The vegetation of the Cape Hangklip area.* M.Sc. thesis, Dept of Botany, Univ. of Cape Town.
Boucher, C. 1974. Dune vegetation in the South Western Cape. *Veld & Flora* 4, 4: 67–69.
Boucher, C. 1977. Cape Hangklip area. I. The application of association-analysis, homogeneity functions and Braun-Blanquet techniques in the description of south-western Cape vegetation. *Bothalia* 12: 293–300.
Boucher, C. 1978. Cape Hangklip area. II. The vegetation. *Bothalia* 12: 455–497.
Boucher, C. 1980. Notes on the use of the term 'Renosterveld'. *Bothalia* 13: 237.
Boucher, C. 1982. Some thoughts about the West Coast Strandveld vegetation. *Veld & Flora* 68, 4: 108, 109.
Boucher, C. 1983. Floristic and structural features of the coastal foreland vegetation south of the Berg River, Western Cape Province, South Africa. *Bothalia* 14: 669–674.
Boucher, C. 1986. *The vegetation of the Greater Silverstroomstrand Development Area*. Ecological Research Report 1, Dept of Botany, Univ. of Stellenbosch.
Boucher, C. 1987. *A phytosociological study of transects through the Western Cape coastal foreland, South Africa*. Ph.D. thesis, Dept of Botany, Univ. of Stellenbosch.
Boucher, C. 1988a. *A report on the flora and vegetation of the Buffelstalberg Flats*. Ecological Research Report 2, Dept of Botany, Univ. of Stellenbosch.
Boucher, C. 1988b. Botanical survey of the lower Du Toitskloof. In: *Du Toitskloof Environmental Impact Assessment. National Road Route 1—Sections 1 & 2 (Huguenot Tunnel to Gevonden). Volume 2—Appendices: Appendix 3.* National Transport Commission, Chief Directorate: National Roads, Pretoria.
Boucher, C. 1989a. *A brief report on some aspects of the flora and vegetation observed on the Farm Modderrivier 721, Malmesbury.* Ecological Research Report 6, Dept of Botany, Univ. of Stellenbosch.
Boucher, C. 1989b. *Comments on the restoration of disturbed areas on Portion 1 of Farm 1014 near Paternoster (Groot Paternoster), Western Cape*. Ecological Research Report 5b, Dept of Botany, Univ. of Stellenbosch.
Boucher, C. 1990. *Report on inspection and study of some proposed Olifants River Dam sites*. Ecological Research Report 45, Dept of Botany, Univ. of Stellenbosch.
Boucher, C. 1991. *Vegetation survey of Rondegat Farm, Clanwilliam*. Ecological Research Report 8, Dept of Botany, Univ. of Stellenbosch.
Boucher, C. 1992. *A vegetation survey of Granzekraal Recreational Area*. Ecological Research Report 9, Dept of Botany, Univ. of Stellenbosch.
Boucher, C. 1993. *The vegetation of part of the farms Swartriet & Trekossenkraal, Saldanha Bay*. Ecological Research Report 10, Dept of Botany, Univ. of Stellenbosch.
Boucher, C. 1994a. *Botanical evaluation of two potential dam sites in the Molenaars River, Du Toitskloof*. Ecological Research Report 11, Dept of Botany, Univ. of Stellenbosch.
Boucher, C. 1994b. *The vegetation of Erf 1092, Gansbaai*. Ecological Research Report 12, Dept of Botany, Univ. of Stellenbosch.
Boucher, C. 1995. *Hoek-van-die-Berg: brief comments about the vegetation.* Ecological Research Report 18, Dept of Botany, Univ. of Stellenbosch.
Boucher, C. 1996a. *Plantkundige aangeleenthede te Saron*. Ecological Research Report 47, Dept of Botany, Univ. of Stellenbosch.
Boucher, C. 1996b. *Restoration in the Fynbos Biome*. Unpublished lecture, Fynbos Forum Annual Research Meeting, 17–18 July 1996, The Nekkies near Worcester.
Boucher, C. 1996c. *Saldanha Staalontwikkeling. Plantkundige rehabilitasie aangeleenthede.* Ecological Research Report 22c, Dept of Botany, Univ. of Stellenbosch.
Boucher, C. 1997a. *Comments on the indigenous vegetation on Die Vleie, Grote Zalze, Kleine Zalze and Rose Farm, Stellenbosch District.* Ecological Research Report 24, Dept of Botany, Univ. of Stellenbosch.
Boucher, C. 1997b. *Conservation worthy vegetation on the Capricorn Park site: being an evaluation of a report submitted by A.B. Low (1966).* Ecological Research Report 48, Dept of Botany, Univ. of Stellenbosch.
Boucher, C. 1997c. *Doring-Olifants Rivers: preliminary conservation assessment of vegetation.* Ecological Research Report 29, Dept of Botany, Univ. of Stellenbosch.
Boucher, C. 1997d. *Vegetation description and management guidelines for the Blombos Private Nature Reserve, Riversdale District*. Ecological Research Report 26, Dept of Botany, Univ. of Stellenbosch.

Boucher, C. 1998a. *Kleinmond Harbour Project: botanical scoping report.* Ecological Research Report 34, Dept of Botany, Univ. of Stellenbosch.
Boucher, C. 1998b. *Report on preliminary scoping of the proposed Pelican Park Extension: botany*. Ecological Research Report 33, Dept of Botany, Univ. of Stellenbosch.
Boucher, C. 1998c. *The importance of the flora and vegetation on Rein's Nature Reserve.* Ecological Research Report 32, Dept of Botany, Univ. of Stellenbosch.
Boucher, C. 1998d. *The vegetation of portions of the farms Modderfontein A & E, Aurora*. Ecological Research Report 38, Dept of Botany, Univ. of Stellenbosch.
Boucher, C. 1998e. *The vegetation of the farm Stofbergsfontein 365, West Coast National Park*. Ecological Research Report 37, Dept of Botany, Univ. of Stellenbosch.
Boucher, C. 1998f. *Vegetation and management recommendations for 'Die Duine'*. Ecological Research Report 35, Dept of Botany, Univ. of Stellenbosch.
Boucher, C. 1999a. *Botanical aspects relevant to the lower Silvermine River development*. Ecological Research Report 41, Dept of Botany, Univ. of Stellenbosch.
Boucher, C. 1999b. *Die plantegroei van die parkie te Simonswyk, Stellenbosch*. Ecological Research Report 53, Dept of Botany, Univ. of Stellenbosch.
Boucher, C. 1999c. *Kleinmond Harbour Project: evaluation of impacts of proposed development on botanical features*. Ecological Research Report 41, Dept of Botany, Univ. of Stellenbosch.
Boucher, C. 1999d. *The riparian vegetation of the lower Hopies River, Hawston*. Ecological Research Report 39, Dept of Botany, Univ. of Stellenbosch.
Boucher, C. 1999e. *The vegetation of Gonnemanskraal extension, Saldanha Bay*. Ecological Research Report 52, Dept of Botany, Univ. of Stellenbosch.
Boucher, C. 1999f. *The vegetation of portion 6 of the farm Dyker Eiland No. 6, St. Helena Bay*. Ecological Research Report 49, Dept of Botany, Univ. of Stellenbosch.
Boucher, C. 1999g. *The vegetation of the western portion adjacent to the lower Silvermine River, Clovelly, Cape Peninsula*. Ecological Research Report 51, Dept of Botany, Univ. of Stellenbosch.
Boucher, C. 2000. *Botanical evaluation of potential housing sites on the farm Berg-en-Dal, Koue Bokkeveld.* Ecological Research Report No. 57, Dept of Botany, Univ. of Stellenbosch.
Boucher, C., Erasmus, D., Marais, C. & McDonald, D.J. 1995. *An inventory of sources of data pertaining to the Fynbos Biome. Volume 1.* FRD, Pretoria.
Boucher, C., Erasmus, D., Marais, C. & McDonald, D.J. 1996. *An inventory of sources of data pertaining to the Fynbos Biome. Volume 2.* FRD, Pretoria.
Boucher, C. & Jarman, M.L. 1977. The vegetation of the Langebaan area, South Africa. *Trans. Roy. Soc. S. Afr.* 42: 241–272.
Boucher, C. & Le Roux, A. 1989. *Heavy metal sand-mining project assessment—vegetation report*. Ecological Research Report 4a, Dept of Botany, Univ. of Stellenbosch.
Boucher, C. & Le Roux, A. 1993. Dry coastal ecosystems of the South African west coast. In: Van der Maarel, E. (ed.), *Ecosystems of the world. 2B. Dry coastal ecosystems. Africa, America and Oceania*, pp. 75–88. Elsevier, Amsterdam.
Boucher, C. & Le Roux, A. 1994. *Vegetation of the proposed national park between the Spoeg and Groen Rivers on the Namaqualand coast*. Ecological Research Report 4b, Dept of Botany, Univ. of Stellenbosch.
Boucher, C. & McDonald, A.E. 1982. An inventory of plant communities recorded in the western, southern and eastern Cape Province, South Africa up to the end of 1980. *S. Afr. Natl. Sci. Progr. Rep.* No. 57: 1–58.
Boucher, C. & Meets, M. 2004. Determination of the relative activity of aqueous plant-derived smoke solutions used in seed germination. *S. Afr. J. Bot.* 70: 313–318.
Boucher, C. & Moll, E.J. 1981. South African mediterranean shrublands. In: Di Castri, F., Goodall, D.W. & Specht, R.L. (eds.), *Ecosystems of the world. 11. Mediterranean-type shrublands,* pp. 233–248. Elsevier, Amsterdam.
Boucher, C. & Rode, E. 1994. *Plankenburg River: explanation of present condition including a rehabilitation plan*. Ecological Research Report 15, Dept of Botany, Univ. of Stellenbosch.
Boucher, C. & Rode, E. 1995a. *The flora and vegetation of Rein's Nature Reserve, Riversdale District*. Ecological Research Report 16, Dept of Botany, Univ. of Stellenbosch.
Boucher, C. & Rode, E. 1995b. *The flora and vegetation of Rein's Nature Reserve, Riversdale District. Supplementary report.* Ecological Research Report 17, Dept of Botany, Univ. of Stellenbosch.
Boucher, C. & Rode, E. 1996a. *A preliminary description of the vegetation of the Saldanha Steel Project site*. Ecological Research Report 22a, Dept of Botany, Univ. of Stellenbosch.
Boucher, C. & Rode, E. 1996b. *Saldanha Steel Project. Vegetation and rare plants*. Ecological Research Report 22b, Dept of Botany, Univ. of Stellenbosch.
Boucher, C. & Rode, E. 1997a. *A report on the vegetation of parts of the farms Holvlei, Jacobsbaai, Oranjevlei and Prospect Hill, Vredenburg District, Western Cape*. Ecological Research Report 23, Dept of Botany, Univ. of Stellenbosch.
Boucher, C. & Rode, E. 1997b. *The vegetation of the Longacres development site, Langebaan*. Ecological Research Report 27, Dept of Botany, Univ. of Stellenbosch.
Boucher, C. & Rode, E. 1997c. *The vegetation of the Oliphantskop Estate at Langebaan*. Ecological Research Report 30, Dept of Botany, Univ. of Stellenbosch.
Boucher, C. & Rode, E. 1997d. *The vegetation on the Duferco Steel Mill site at Saldanha Bay*. Ecological Research Report 25, Dept of Botany, Univ. of Stellenbosch.
Boucher, C. & Rode, E. 1999. *Vegetation conservation importance ratings for the Saldanha-Vredenburg regional structure plan*. Ecological Research Report 50, Dept of Botany, Univ. of Stellenbosch.
Boucher, C. & Schloms, B. 1999. *The soils and rehabilitation guidelines for the proposed Saldanha cement mining area*. Ecological Research Report 43, Dept of Botany, Univ. of Stellenbosch.
Boucher, C. & Shepherd, P.A. 1988. Plant communities of the Pella site. In: Jarman, M.L. (ed.), *A description of the Fynbos Biome Project intensive study site at Pella*, pp. 38–76. FRD, Pretoria.
Boucher, C. & Stindt, M. 1992. The vegetation of the Haasvlakte, Houhoek, South Africa. *S. Afr. J. Bot.* 58: 510–524.
Box, E.O. 1987. Plant life forms and mediterranean environments. *Ann. Bot. (Roma)* 45: 7–42.
Braun-Blanquet, J. 1964. *Pflanzensoziologie. Grundzüge der Vegetationskunde,* edn 3. Springer, Wien.
Breytenbach, G.J. 1988. Why are myrmecochorous plants limited to fynbos (macchia) vegetation types? *S. Afr. For. J.* 144: 3–5.
Britton, P. 1972. *A report on the proposed nature reserve at Swartklip*. B.Sc.(Hons) project, Dept Forestry Conservation, Univ. of Stellenbosch.
Britton, P. & Jackelman, J. 1995. Wolfgat Nature Reserve. A desolate wasteland destined for housing or a dynamic community conservation project? *Veld & Flora* 81: 46–48.
Britton, P. & Jackelman, J. 1996. Biological management of Renosterveld: some questions and lessons from Signal Hill and Devil's Peak. In: Low, A.B. & Jones, F.E. (eds), *The sustainable use and management of renosterveld remnants in the Cape Floristic Region*, pp. 58–62. FCC Report 1995/4, Botanical Society of South Africa, Kirstenbosch.
Brown, N.A.C. & Botha, P.A. 2004. Smoke seed germination studies and a guide to seed propagation of plants for the major families of the Cape Floristic Region, South Africa. *S. Afr. J. Bot.* 70: 559–581.
Brown, N.A.C., Van Staden, T., Daws, M.I. & Johnson, T. 2003. Patterns in seed germination response to smoke in plants from the Cape Floristic Region, South Africa. *S. Afr. J. Bot.* 69: 514–525.
Burman, L. & Bean, A. 1985. *South African Wild Flower Guide 5. Stellenbosch to Hermanus.* Botanical Society of South Africa, Cape Town.
Calsbeek, R., Thompson, J.N. & Richardson, J.E. 2003. Patterns of molecular evolution and diversification in a biodiversity hotspot: the California Floristic Province. *Mol. Ecol.* 12: 1021–1029.
Cameron, M.J. 1980. Fynbos islands in the Knysna forests. *S. Afr. For. J.* 112: 27–29.
Campbell, B.M. 1983. Montane plant environments in the Fynbos Biome. *Bothalia* 14: 293–298.
Campbell, B.M. 1985. A classification of the mountain vegetation of the Fynbos Biome. *Mem. Bot. Surv. S. Afr.* No. 50: 1–121.
Campbell, B.M. 1986a. Montane plant communities of the Fynbos Biome. *Vegetatio* 66: 3–16.
Campbell, B.M. 1986b. Plant spinescence and herbivory in a nutrient poor ecosystem. *Oikos* 47: 168–172.
Campbell, B.M. 1986c. Vegetation classification in a floristically complex area: the Cape Floristic Region. *S. Afr. J. Bot.* 52: 129–140.
Campbell, B.M., Cowling, R.M., Bond, W., Kruger, F.J., Bands, D.P., Boucher, C., Moll, E.J., Taylor, H.C. & Van Wilgen, B.W. 1981. *Structural characterization of vegetation in the Fynbos Biome*. South African National Scientific Programmes Report No. 52: 1–15.
Campbell, B.M. & Van der Meulen, F. 1980. Patterns of plant species diversity in fynbos. *Vegetatio* 43: 43–47.
Chase, M.W., Soltis, D.E., Soltis, P.S., Rudall, P.J., Fay, M.F., Hahn, W.H., Sullivan, S., Joseph, J., Molvray, M., Kores, P.J., Givnish, T.J., Sytsma, K.J. & Pires, J.C. 2000. Higher-level systematics of the monocotyledons: an assessment of current knowledge and a new classification. In: Wilson, K. & Weston, P. (eds), *Systematics and biology of the monocots*, pp. 3–16. Royal Botanic Gardens, Sydney.
Chesselet, P. 1985. *Vegetation analyses in the Worcester ecotone*. 3rd year project, Dept of Botany, Univ. of Cape Town.
Christian, C.E. 2001. Consequences of a biological invasion reveal the importance of mutualism for plant communities. *Nature* 413: 635–639.
Christian, C.E. & Stanton, M.L. 2004. Cryptic consequences of a dispersal mutualism: Seed burial, elaiosome removal, and seed-bank dynamics.

Ecology 85: 1101–1110.
Cleaver, G., Brown, L.R. & Bredenkamp, G.J. 2005. The phytosociology of the Vermaaks, Marnewicks and Buffelsklip valleys of the Kammanassie Nature Reserve, Western Cape. *Koedoe* 48: 1–16.
Cody, M.L. 1986. Structural niches in plant communities. In: Diamond, J.M. & Case, T.J. (eds), *Community ecology*, pp. 381–405. Harper & Row, New York.
Cody, M.L., Breytenbach, G.J., Fox, A.E., Newsome, A.E., Quinn, R.D. & Siegfried, W.R. 1983. Animal communities: diversity, density and dynamics. In: Day, J.A. (ed.), *Mineral nutrients in mediterranean ecosystems*, pp. 91–110. CSIR, Pretoria.
Cody, M.L. & Mooney, H.A. 1978. Convergence versus nonconvergence in mediterranean-climate ecosystems. *Annu. Rev. Ecol. Syst.* 9: 265–321.
Coetzee, J.A. 1978a. Late Cainozoic palaeoenvironments of southern Africa. In: Van Zinderen Bakker, E.M. (ed.), *Antarctic glacial history and world palaeoenvironments*, pp. 115–127. A.A. Balkema, Rotterdam.
Coetzee, J.A. 1978b. Climate and biological changes in south-western Africa during the Late Cainozoic. *Palaeoecology of Africa* 10: 13–29.
Coetzee, J.A. & Muller, J. 1984. The phytogeographic significance of some extinct Gondwana pollen types from the Tertiary of the southwestern Cape (South Africa). *Ann. Missouri Bot. Gard.* 71: 1088–1099.
Coetzee, J.A. & Rogers, J. 1982. Palynological and lithological evidence for the Miocene palaeoenvironment in the Saldanha region (South Africa). *Palaeogeogr. Palaeoclimatol. Palaeoecol*. 39: 71–85.
Coetzee, J.A., Scholtz, A. & Deacon, H.J. 1983. Palynological studies and the vegetation history of the fynbos. In: Deacon, H.J., Hendey, Q.B. & Lambrechts, J.J.N. (eds), *Fynbos palaeoecology: a preliminary synthesis*, pp. 156–173. CSIR, Pretoria.
Coetzee, J.H. & Giliomee, J.H. 1985. Insects in association with the inflorescence of *Protea repens* L. (Proteaceae) and their role in pollination. *J. Entomol. Soc. S. Afr*. 48: 303–314.
Compton, J.S. 2004. *The rocks and mountains of Cape Town.* Double Storey, Cape Town.
Cowling, R. 1976. The ecological status of the understorey communities of pine forests on Table Mountain. In: Moll, E.J. & Campbell, B.M. (eds), *The ecological status of Table Mountain. Appendix 1.* Report, Dept of Botany, Univ. of Cape Town.
Cowling, R.M. 1982. *Vegetation studies in the Humansdorp region of the Fynbos Biome.* Ph.D. thesis, Dept of Botany, Univ. of Cape Town.
Cowling, R.M. 1983a. Diversity relations in Cape shrublands and other vegetation in the southeastern Cape, South Africa. *Vegetatio* 54: 103–127.
Cowling, R.M. 1983b. The occurrence of C3 and C4 grasses in fynbos and allied shrublands in the south-eastern Cape, South Africa. *Oecologia* 58: 121–127.
Cowling, R.M. 1984. A syntaxonomic and synecological study in the Humansdorp region of the Fynbos Biome. *Bothalia* 15: 175–227.
Cowling, R.M. 1987. Fire and its role in coexistence and speciation in Gondwanan shrublands. *S. Afr. J. Sci.* 83: 106–111.
Cowling, R.M. 1990a. Diversity components in a species-rich area of the Cape Floristic Region. *J. Veg. Sci.* 1: 699–710.
Cowling, R. 1990b. Who will save Hagelkraal? *Veld & Flora* 76, 2: 52, 53.
Cowling, R.M. 1991. *A preliminary report on the flora and vegetation of the Wildevoëlvlei Flats in the Noordhoek-Kommetjie basin*. FCC Report 91/2, Botanical Society of South Africa, Kirstenbosch.
Cowling, R.M. (ed.) 1992. *The ecology of fynbos: nutrients, fire and diversity*. Oxford Univ. Press, Cape Town.
Cowling, R.M. & Campbell, B.M. 1980. Convergence in vegetation structure in the mediterranean communities of California, Chile and South Africa. *Vegetatio* 43: 191–197.
Cowling, R.M. & Campbell, B.M. 1983a. A comparison of fynbos and nonfynbos coenoclines in the lower Gamtoos River Valley, southeastern Cape, South Africa. *Vegetatio* 53: 161–178.
Cowling, R.M. & Campbell, B.M. 1983b. The definition of leaf consistence categories in the Fynbos Biome and their distribution along an altitudinal gradient in the South Eastern Cape. *J. S. Afr. Bot.* 49: 87–101.
Cowling, R.M. & Campbell, B.M. 1984. Beta diversity along fynbos and nonfynbos coenoclines in the lower Gamtoos River Valley, south-eastern Cape. *S. Afr. J. Bot.* 3: 187–189.
Cowling, R.M., Campbell, B.M., Mustart, P., McDonald, D.J., Jarman, M.L. & Moll, E.J. 1988. Vegetation classification in a floristically complex area: the Agulhas Plain. *S. Afr. J. Bot.* 54: 290–300.
Cowling, R.M., Cartwright, C.R., Parkington, J.E. & Allsopp, J.C. 1999a. Fossil wood charcoal assemblages from Elands Bay Cave, South Africa: implications for Late Quaternary vegetation and climates in the winter-rainfall Fynbos Biome. *J. Biogeogr.* 26: 367–378.
Cowling, R.M., Gibbs Russell, G.E., Hoffman, M.T. & Hilton-Taylor, C. 1989. Patterns of plant species diversity in southern Africa. In: Huntley, B.J. (ed.), *Biotic diversity in southern Africa: concepts and conservation*, pp. 19–50. Oxford Univ. Press, Cape Town.
Cowling, R.M. & Heijnis, C.E. 2001. The identification of Broad Habitat Units as biodiversity entities for systematic conservation planning in the Cape Floristic Region. *S. Afr. J. Bot.* 67: 15–38.
Cowling, R.M. & Hilton-Taylor, C. 1994. Patterns of plant diversity and endemism in southern Africa: an overview. In: Huntley, B.J. (ed.), Botanical diversity in southern Africa. *Strelitzia* 1: 31–52. National Botanical Institute, Pretoria.
Cowling, R.M. & Holmes, P.M. 1992a. Endemism and speciation in a lowland flora from the Cape Floristic Region. *Biol. J. Linn. Soc.* 47: 367–383.
Cowling, R.M. & Holmes, P.M. 1992b. Flora and vegetation. In: Cowling, R.M. (ed.), *The ecology of fynbos: nutrients, fire and diversity*, pp. 23–61. Oxford Univ. Press, Cape Town.
Cowling, R.M., Holmes, P.M. & Rebelo, A.G. 1992. Plant diversity and endemism. In: Cowling, R.M. (ed.), *The ecology of fynbos: nutrients, fire and diversity*, pp. 62–112. Oxford Univ. Press, Cape Town.
Cowling, R.M., Le Maitre, D.C., McKenzie, B., Prys-Jones, R.P. & Van Wilgen, B.W. (eds) 1987. Disturbance and dynamics of fynbos communities. *S. Afr. Natl. Sci. Progr. Rep*. No. 135: 1–73.
Cowling, R.M. & Lombard, A.T. 2002. Heterogeneity, speciation/extinction history and climate: explaining regional plant diversity patterns in the Cape Floristic Region. *Divers. Distrib.* 8: 163–179.
Cowling, R.M., MacDonald, I.A.W. & Simmons, M.T. 1996b. The Cape Peninsula, South Africa: physiographical, biological and historical background to an extraordinary hot-spot of biodiversity. *Biodiv. Conserv.* 5: 527–550.
Cowling, R.M., Mustart, P.J., Laurie, H. & Richards, M.B. 1994a. Species diversity; functional diversity and functional redundancy in fynbos communities. *S. Afr. J. Sci.* 90: 333–337.
Cowling, R.M., Ojeda, F., Lamont, B.B. & Rundel, P.W. 2004. Climate stability in Mediterranean-type ecosystems: implications for the evolution and conservation of biodiversity. In: Arianoutsou, M. & Papanastasis, V. (eds), *Proceedings 10th MEDECOS Conference April 25–May 1, 2004, Rhodes*. Millpress, Rotterdam.
Cowling, R.M., Ojeda, F., Lamont, B.B., Rundel, P.W. & Lechmere-Oertel, R. 2005. Rainfall reliability, a neglected factor in explaining convergence and divergence of plant traits in fire-prone mediterranean-climate ecosystems. *Glob. Ecol. Biogeogr.* 14: 509–519.
Cowling, R.M. & Pierce, S.M. 1985. Southern Cape coastal dunes—an ecosystem lost? *Veld & Flora* 71,4: 99–103.
Cowling, R.M. & Pierce, S.M. 1988. Secondary succession in coastal dune fynbos: variation due to site and disturbance. *Vegetatio* 76: 131–139.
Cowling, R.M., Pierce, S.M. & Moll, E.J. 1986. Conservation and utilisation of south coast renosterveld, an endangered South African vegetation type. *Biol. Conserv.* 37: 363–377.
Cowling, R.M., Pierce, S.M., Stock, W.D. & Cocks, M. 1994b. Why are there so many myrmecochorous species in the Cape fynbos? In: Arianoutsou, M. & Groves, R.H. (eds), *Plant-animal interactions in mediterranean-type ecosystems*, pp. 159–168. Kluwer, Dordrecht.
Cowling, R.M. & Pressey, R.L. 2001. Rapid plant diversification: planning for an evolutionary future. *Proc. Natl. Acad. Sci.* 98: 5452–5457.
Cowling, R.M., Pressey, R.L., Lombard, A.T., Heijnis, C.E., Richardson, D.M. & Cole, N. 1999b. *Framework for a conservation plan for the Cape Floristic Region.* IPC Report 9902, Institute for Plant Conservation, Univ. of Cape Town.
Cowling, R.M., Pressey, R.L., Rouget, M. & Lombard, A.T. 2003. A conservation plan for a global biodiversity hotspot—the Cape Floristic Region, South Africa. *Biol. Conserv.* 112: 191–216.
Cowling, R.M. & Procheş, Ş. 2005. Patterns and evolution of plant diversity in the Cape Floristic Region. *Biol. Skrif.* 55: 273–288.
Cowling, R.M. & Richardson, D.M. 1995. *Fynbos.* Fernwood Press, Vlaeberg.
Cowling, R.M., Richardson, D.M. & Mustart, P.J. 1997. Fynbos. In: Cowling, R.M., Richardson, D.M. & Pierce, S.M. (eds), *Vegetation of southern Africa*, pp. 99–130. Cambridge Univ. Press, Cambridge.
Cowling, R.M., Rundel, P.W., Lamont, B.B., Arroyo, M.K. & Arianoutsou, M. 1996a. Plant diversity in mediterranean-climate regions. *Trends Ecol. Evol.* 11: 362–366.
Cowling, R.M. & Witkowski, E.T.F. 1994. Convergence and non-convergence of plant traits in climatically and edaphically matched sites in Mediterranean Australia and South Africa. *Austr. J. Ecol.* 19: 220–232.
Crisp, M., Cook, L. & Steane, D. 2004. Radiation of the Australian flora: what can comparisons of molecular phylogenies across multiple taxa tell us about the evolution of diversity in present-day communities. *Phil. Trans. Roy. Soc. London, Ser. B* 359: 1551–1571.
David, J.H.M. 1973. The behaviour of the Bontebok, *Damaliscus dorcas dorcas* (Pallas 1766), with special reference to territorial behaviour. *Zeitschrift für Tierpsychologie* 33: 38–107.
Davis, G. 1988. Description of a proteoid-restioid stand in Mesic Mountain Fynbos of the south-western Cape and some aspects of its ecology. *Bothalia* 18: 279–287.
Davis, G.W. & Richardson, D.M. (eds) 1995. *Mediterranean-type ecosystems.*

The function of biodiversity. Springer, Berlin.
Day, J., Siegfried, W.R., Louw, G.N. & Jarman, M.L. (eds) 1979. Fynbos palaeoecology: a preliminary synthesis. *S. Afr. Natl. Sci. Progr. Rep*. No. 40: 1–163.
Deacon, H.J. 1992. Human settlement. In: Cowling, R.M. (ed.), *The ecology of fynbos: nutrients, fire and diversity*, pp. 260–270. Oxford Univ. Press, Cape Town.
Deacon, H.J., Deacon, J., Scholtz, A., Thackeray, J.F. & Brink, J.S. 1984. Correlation of palaeoenvironmental data from the Late Pleistocene and Holocene deposits at Boomplaas Cave, southern Cape. In: Vogel, J.C. (ed.), *Late Cainozoic palaeoclimates of the southern hemisphere*, pp. 339–351. A.A. Balkema, Rotterdam.
Deacon, H.J., Hendey, Q.B. & Lambrechts, J.J.N. (eds) 1983. Fynbos palaeoecology: a preliminary synthesis. *S. Afr. Natl. Sci. Progr. Rep*. No. 75: 1–204.
Deacon, H.J., Jury, M.R. & Ellis, F. 1992. Selective regime and time. In: Cowling, R.M. (ed.), *The ecology of fynbos: nutrients, fire and diversity*, pp. 6–22. Oxford Univ. Press, Cape Town.
De Beer, C.H. 1990. Simultaneous folding in the Western and Southern Branches of the Cape Fold Belt. *S. Afr. J. Geol.* 93: 583–591.
De Graaff, G., Van der Walt, P.T. & Van Zyl, L.J. 1976. Populasiesamestelling van die Bontebok *Damaliscus dorcas dorcas* in die Bontebok Nasionale Park gedurende Januarie 1974. *Koedoe* 19: 67–74.
De Hoop Nature Reserve Planning Committee. 2001. *Management plan for De Hoop Nature Reserve*. Cape Nature Conservation Board Report, Cape Nature Conservation Board, Cape Town.
De Lange, C. 1992. *Floristic analysis of the Vogelgat Nature Reserve, Cape Province, South Africa.* M.Sc. thesis, Dept of Botany, Univ. of Cape Town.
De Lange, J.H. & Boucher, C. 1990. Autecological studies on *Audouinia capitata* (Bruniaceae). I. Plant derived smoke as a seed germination cue. *S. Afr. J. Bot*. 56: 700–703.
De Villiers, C., Driver, A., Clarke, B., Euston-Brown, D., Day, L., Job, N., Helme, N., Holmes, P., Brownlie, S. & Rebelo, T. 2005. *Ecosystem guidelines for environmental assessment in the Western Cape.* Report, Fynbos Forum, Cape Town.
Devilliers, P. & Devilliers-Terschuren, J. (comp.) 1996. *A classification of Palaearctic habitats.* Report, Nature and Environment No. 78, Council of Europe Publishing, Strasbourg.
Devilliers, P. & Devilliers-Terschuren, J. & Ledant, J.-P. (comp.) 1991. *Habitats of the European Community. CORINE biotopes manual—Part 2*. Report, Office for Official Publications of the Commission of the European Communities, Luxembourg.
Di Castri, F., Goodall, D.W. & Specht, R.L. (eds) 1981. *Ecosystems of the world. 11. Mediterranean-type shrublands.* Elsevier, Amsterdam.
Di Castri, F. & Mooney, H.A. (eds) 1973. *Mediterranean-type ecosystems. Origin and structure.* Springer, Berlin.
Diemer, N. 2000. *Fire management at Elandsberg Nature Reserve.* B.Sc.(Hons) project, Dept of Conservation, Univ. of Stellenbosch.
Dixon, K.W., Roche, S. & Pate, J.S. 1995. The promotive effect of smoke derived from burnt native vegetation on seed germination of Western Australian plants. *Oecologia* 101: 185–192.
Donaldson, J., Nänni, I., Zachariades, C. & Kemper, J. 2002. Effects of habitat fragmentation on pollinator diversity and plant reproductive success in Renosterveld shrublands of South Africa. *Conserv. Biol.* 16: 1267–1276.
Downing, B.H. & Van der Merwe, P. Undated. *Veld grazing studies at the Nortier Experimental Farm*. Winter Rainfall Region Subject Report, Dept of Agricultural Technical Services, Pretoria.
Drews, B.K. 1980a. *Report on conservation worthy areas of fynbos in the Knysna-Wilderness-Plettenberg Bay guide-plan area*. Report, Botanical Research Institute, Pretoria.
Drews, B.K. 1980b. *Report on conservation worthy areas of fynbos in the George guide-plan area*. Report, Botanical Research Institute, Pretoria.
Driver, A., Maze, K., Rouget, M., Lombard, A.T., Nel, J., Turpie, J.K., Cowling, R.M., Desmet, P., Goodman, P., Harris, J., Jonas, Z., Reyers, B., Sink, K. & Strauss, T. 2005. National Spatial Biodiversity Assessment 2004: priorities for biodiversity conservation in South Africa. *Strelitzia* 17. South African National Biodiversity Institute, Pretoria.
Du Plessis, S.E. 1969. *The past and present geographical distribution of the Perissodactyla and Artiodactyla in southern Africa.* M.Sc. thesis, Univ. of Pretoria.
Durand, B.J. 1981. *A study of the short-term responses of fynbos to fire in the Kogelberg State Forest, South Africa.* M.Sc. thesis, Dept of Botany, Univ. of Cape Town.
Duthie, A.V. 1929. Vegetation and flora of the Stellenbosch Flats. *Ann. Univ. Stellenbosch,* Sect. A7: 1–22.
Duthie, A.V. 1930. List of vascular cryptogams and flowering plants of the Stellenbosch Flats. *Ann. Univ. Stellenbosch* 8, Sect. A4: 1–52.
Du Toit, R. & Du Toit, E. 1938. Rhenoster bush as a weed. *Farming in South Africa* 1938: 429–445.
Duvenhage, A.J. 1993. *Die voorkoms van uitheemse kruidgewasse in die natuurlike plategroei van die Stellenbosch omgewing.* M.Sc. thesis, Dept of Botany, Univ. of Stellenbosch.
Dyer, R.A. 1937. The vegetation of the divisions of Albany and Bathurst. *Mem.* Bot. Surv. S. Afr. No. 17: 1–138.
Dynesius, M. & Jansson, R. 2000. Evolutionary consequences of changes in species' geographical distributions driven by Milankovitch climate oscillations. *Proc. Natl. Acad. Sci.* 97: 9115–9120.
Eardley, C.D. 1989. Diversity and endemism of southern African bees. *Plant Protection News* 18: 1, 2.
Ellis, A.G. & Midgley, J.J. 1996. A new plant animal mutualism involving a plant with sticky leaves and a resident hemipteran insect. *Oecologia* 106: 478–481.
Engler, A. & Gilg, E. 1919. *Syllabus der Pflanzenfamilien*, edn 8. Gebrüder Borntraeger, Berlin.
Esler, K.J., Rundell, P.W. & Vorster, P. 1999. Biogeography of prostrate-leaved geophytes in semi-arid South Africa: hypotheses on functionality. *Plant Ecol.* 142: 105–120.
Etienne, R.S., Latimer, A.M., Silander Jr., J.A. & Cowling, R.M. 2006. Comment on "Neutral Ecological Theory Reveals Isolation and Rapid Speciation in a Biodiversity Hot Spot". *Science* 311: 610.
European Commission 1995. *Interpretation manual of European Union habitat. Annex I of Council Directive 92/43/EEC. Version EUR12, April 1995.* European Commission, Brussels.
Euston-Brown, D. 1995. *Environmental and dynamic determinants of vegetation distribution in the Kouga and Baviaanskloof Mountains, Eastern Cape.* M.Sc. thesis, Dept of Botany, Univ. of Cape Town.
Faegri, K. & Van der Pijl, L. 1979. *The principles of pollination ecology*. Pergamon, Oxford.
Fleming, P.A. & Nicolson, S.W. 2002a. How important is the relationship between *Protea humiflora* (Proteaceae) and its non-flying mammal pollinators? *Oecologia* 132: 361–368.
Fleming, P.A. & Nicolson, S.W. 2002b. Opportunistic breeding in the Cape spiny mouse *Acomys subspinosus. Afr. Zool.* 37: 101–105.
Fleming, P.A. & Nicolson, S.W. 2003. Arthropod fauna of mammal-pollinated *Protea humiflora*: ants as an attractant for insectivore pollinators? *Afr. Entomol*. 11: 9–14.
Foden, W. 2006. Threatened Species Programme. *The Conservation Leaflet* 4: 2.
Frank, D.A., McNaughton, S.J. & Tracy, B.F. 1998. The ecology of the earth's grazing ecosystems. *Bioscience* 48: 513–521.
Fuggle, R.F. & Ashton, E.R. 1979. Climate. In: Day, J., Siegfried, W.R., Louw, G.N. & Jarman, M.L. (eds), *Fynbos ecology: a preliminary synthesis*, pp. 7–15. South African National Scientific Programmes Report No. 40. 7–15.
Galatowitsch, S.M. & Richardson, D.M. 2005. Riparian scrub recovery after clearing of invasive alien trees in headwater streams of the Western Cape, South Africa. *Biol. Conserv.*122: 509–521.
Galley, C. & Linder, H.P. 2006. Geographic affinities of the Cape flora, South Africa. *J. Biogeogr.* 33: 236–250.
Glyphis, J., Moll, E.J. & Campbell, B.M. 1978. Phytosociological studies on Table Mountain, South Africa: 1. The Back Table. *J. S. Afr. Bot.* 44: 281–289.
Goldblatt, P. 1997. Floristic diversity in the Cape flora of South Africa. *Biol. Conserv.* 6: 359–377.
Goldblatt, P., Bernhardt, P. & Manning, J.C. 1998. Pollination of petaloid geophytes by monkey beetles (Scarabaeidae: Rutelinae: Hopliini) in southern Africa. *Ann. Missouri Bot. Gard.* 85: 215–230.
Goldblatt, P., Bernhardt, P. & Manning, J.C. 2000. Adaptive radiation of pollination mechanisms in *Ixia* (Iridaceae: Crocoideae). *Ann. Missouri Bot. Gard*. 87: 564–577.
Goldblatt, P. & Manning, J. 2000a. Cape plants. A conspectus of the Cape flora of South Africa. *Strelitzia* 9. National Botanical Institute & Missouri Botanical Garden Press, Pretoria & St Louis.
Goldblatt, P. & Manning, J.C. 2000b. The long-proboscid fly pollination system in southern Africa. *Ann. Missouri Bot. Gard.* 87: 146–170.
Goldblatt, P. & Manning, J.C. 2002a. Evidence for moth and butterfly pollination in *Gladiolus* (Iridaceae-Crocoideae). *Ann. Missouri Bot. Gard*. 89: 110–124.
Goldblatt, P. & Manning, J.C. 2002b. Plant diversity of the Cape Region of southern Africa. *Ann. Missouri Bot. Gard.* 89: 281–302.
Goldblatt, P., Manning, J.C. & Bernhardt, P. 1999. Evidence of bird pollination in Iridaceae of southern Africa. *Adansonia* 21: 25–40.
Goldblatt, P., Manning, J.C. & Bernhardt, P. 2001. Radiation of pollination systems in *Gladiolus* (Iridaceae: Crocoideae) in southern Africa. *Ann. Missouri Bot. Gard*. 88: 713–734.
Goldblatt, P., Manning, J.C. & Snijman, D. 2005. Cape plants: corrections and additions to the flora. 1. *Bothalia* 35: 35–46.
Goldblatt, P., Savolainen, V., Porteous, O., Sostaric, I., Powell, M., Reeves, G., Manning, J.C., Barraclough, T.G. & Chase, M.W. 2002. Radiation in the Cape flora and the phylogeny of peacock irises *Moraea* (Iridaceae) based on four plastid DNA regions. *Mol. Phylogen. Evol*. 25: 341–360.

Good, R. 1947. *Geography of the flowering plants.* Longmans, Green & Co., London.
Goudie, A.S. 1996. Climate: past and present. In: Adams, W.M, Goudie, A.S. & Orme, A.R. (eds), *The physical geography of Africa*, pp. 34–59. Oxford Univ. Press, Oxford.
Gray, D. 1997. *A phytosociological study of Rocherpan Nature Reserve*. 3rd year project, Faculty of Forestry, Southern Cape Technikon, Saasveld.
Greenfield, A. 1992. *A vegetation survey of the Swartkopberge at an altitude greater than 500 m above sea level*. 3rd year project, Dept of Botany, Univ. of Cape Town.
Grobler, P.J. & Marais, J. 1967. Die plantegroei van die Nasionale Bontebokpark, Swellendam. *Koedoe* 10: 132–148.
Hälbich, I.W., Fitch, F.J. & Miller, J.A. 1983. Dating the Cape Orogeny. *Spec. Publ. Geol. Soc. S. Afr.* 12: 149–164.
Hall, A.V. & Veldhuys, H.A. 1985. *South African Red Data Book. Plants—fynbos and karoo biomes*. South African National Scientific Programmes Report No. 117: 1–157.
Hanekom, N., Southwood, A. & Ferguson, M. 1989. A vegetation survey of the Tsitsikamma Coastal National Park. *Koedoe* 32: 47–66.
Hargreaves, A.L., Johnson, S.D. & Nol, E. 2004. Do floral syndromes predict specialization in plant pollination systems? An experimental test in an 'ornithophilous' African Protea. *Oecologia* 140: 295–301.
Hattingh, V. & Giliomee, J.H. 1989. Pollination of certain *Leucadendron* species (Proteaceae). *S. Afr. J. Bot*. 55: 387–393.
Hedberg, O. 1951. Vegetation belts of East African mountains. *Svensk Bot. Tidskr.* 45: 140–199.
Helgren, D.M. & Butzer, K.W. 1977. Palaeosols of the southern Cape coast, South Africa: implications for laterite definition, genesis and age. *Geogr. Rev.* 67: 430–445.
Helme, N. 2002. The Vegetation. In: Maze, K. (ed.) *Biodiversity of the Edith Stephens Wetland Park*. Report, Botanical Society of South Africa, Kirstenbosch.
Helme, N. & Trinder-Smith, T.H. 2006. The endemic flora of the Cape Peninsula, South Africa. *S. Afr. J. Bot.* 72: 205–210.
Hemborg, A.M. & Bond, W.J. 2005. Different rewards in female and male flowers can explain the evolution of sexual dimorphism in plants. *Biol. J. Linn. Soc.* 85: 97–109.
Hendey, Q.B. 1983a. Cenozoic geology and palaeogeography of the fynbos region. In: Deacon, H.J., Hendey, Q.B. & Lambrechts, J.J.N. (eds), *Fynbos palaeoecology: a preliminary synthesis*, pp. 35–60. CSIR, Pretoria.
Hendey, Q.B. 1983b. Palaeontology and palaeoecology of the fynbos region: an introduction. In: Deacon, H.J., Hendey, Q.B. & Lambrechts, J.J.N. (eds), *Fynbos palaeoecology: a preliminary synthesis*, pp. 87–99. CSIR, Pretoria.
Hendey, Q.B. 1984. Southern African late Tertiary vertebrates. In: Klein, R.G. (ed.), *Southern African prehistory and palaeoenvironments*, pp. 81–106. A.A. Balkema, Rotterdam.
Hepburn, H.R. & Crewe, R.M. 1990. Defining the Cape honeybee: reproductive traits of queenless workers. *S. Afr. J. Bot.* 86: 524–527.
Hepburn, H.R. & Crewe, R.M. 1991. Portrait of the Cape honeybee, *Apis mellifera capensis*. *Apidologie* 22: 567–580.
Hepburn, H.R. & Guillarmod, J. 1991. The Cape honeybee and the fynbos biome. *S. Afr. J. Sci.* 87: 70–73.
Herrera, C.M. 1992. Historical effects and sorting processes as explanations for contemporary ecological patterns: character syndromes in mediterranean woody plants. *Amer. Nat.* 140: 421–446.
Heydenrych, A.J. 1995. *'n Evaluering van sommige plantkundige faktore wat kleinwild-digthede in die Weskus Nasionale Park beïnvloed.* Ph.D. thesis, Dept of Botany, Univ. of Stellenbosch.
Heydenrych, B. 1994. *Limestone Fynbos—unique but threatened: an investigation into the conservation status of Limestone Fynbos in the southern Cape.* FCC Report 94/1, Botanical Society of South Africa, Kirstenbosch.
Heydorn, A.E.F. & Tinley, K.L. 1980. *Estuaries of the Eastern Cape. Part I. Synopsis of the Cape coast: natural features, dynamics and utilisation.* CSIR Report No. 380. CSIR, Stellenbosch.
Higgins, K.B., Lamb, A.J. & Van Wilgen, B.W. 1987. Root systems of selected plant species in mesic mountain fynbos in the Jonkershoek Valley, southwestern Cape Province. *S. Afr. J. Bot.* 53: 249–257.
Hoare, D.B., Victor, J.E., Lubke, R.A. & Mucina, L. 2000. Vegetation of the coastal fynbos and rocky headlands south of George, South Africa. *Bothalia* 30: 87–96.
Hobbs, N.T. 1996. Modification of ecosystems by ungulates. *J. Wildl. Manage.* 60: 695–713.
Hoffman, M.T., Moll, E.J. & Boucher, C. 1987. Post fire succession at Pella, a South African lowland fynbos site. *S. Afr. J. Bot.* 53: 370–374.
Huntley, B.J. 1992. The Fynbos Biome Project. In: Cowling, R.M. (ed.), *The ecology of fynbos: nutrients, fire and diversity*, pp. 1–5. Oxford Univ. Press, Cape Town.
Irving, N. 1992. *A study of the fynbos communities of Else's Peak*. 3rd year project, Dept of Botany, Univ. of Cape Town.
Jacobs, L.D. 1984. *Die plantegroei en flora van die Duthie-natuurreservaat.* B.Sc.(Hons) project, Dept of Botany, Univ. of Stellenbosch.
Jansson, R. & Dynesius, M. 2002. The fate of clades in a world of recurrent climatic change: Milankovitch. *Annu. Rev. Ecol. Syst.* 33: 741–777.
Jarman, M.L. (ed.) 1984. Conservation priorities in lowland regions of the fynbos biome. *S. Afr. Natl. Sci. Progr. Rep*. No. 87: 1–53.
Jarman, M.L. 1988. *A description of the Fynbos Biome Project. Intensive study site at Pella*. FRD, Pretoria.
Jarman, M.L., Cowling, R.M., Haynes, R., Kruger, F.H., Pierce, S.M. & Moll, E.G. 1981. A bibliography of fynbos ecology. *S. Afr. Natl. Sci. Progr. Rep*. No. 53: 1–73.
Jarman, M.L. & Mustart, P. 1988. Introduction. In: Jarman, M.L. (ed.), *A description of the Fynbos Biome Project. Intensive study site at Pella,* pp. 1–9. FRD, Pretoria.
Jeffery, D.J. & Wilson, N. 1987. *A survey of the plant communities in the Greater Kirstenbosch region*. Report. Kirstenbosch National Botanic Gardens, Cape Town.
Jessop, J.P. & Jacot Guillarmod, A. 1969. The vegetation of Thomas Baines Nature Reserve. *J. S. Afr. Bot*. 35: 367–392.
Johnson, S.D. 1992. Plant-animal relationships. In: Cowling, R.M. (ed.), *The ecology of fynbos: nutrients, fire and diversity*, pp. 175–205. Oxford Univ. Press, Cape Town.
Johnson, S.D. 1993. Carpenter bee pollination of *Herschelianthe graminifolia* (Orchidaceae) on the Cape Peninsula. *Flora* 188: 383–386.
Johnson, S.D. 1994a. Evidence for Batesian mimicry in a butterfly-pollinated orchid. *Biol. J. Linn. Soc.* 53: 91–104.
Johnson, S.D. 1994b. The pollination of *Disa versicolor*, Orchidaceae by anthophorid bees in South Africa. *Lindleyana* 9: 209–212.
Johnson, S.D. 1996a. Bird pollination in South African species of *Satyrium* (Orchidaceae). *Plant Syst. Evol*. 203: 91–98.
Johnson, S.D. 1996b. Pollination, adaptation and speciation models in the Cape flora of South Africa. *Taxon* 45: 59–66.
Johnson, S.D. 1997a. Insect pollination and floral mechanisms in South African species of *Satyrium* (Orchidaceae). *Plant Syst. Evol*. 204: 195–206.
Johnson, S.D. 1997b. Pollination ecotypes of *Satyrium hallackii* (Orchidaceae) in South Africa. *Bot. J. Linn. Soc*. 123: 225–235.
Johnson, S.D. 2004. An overview of plant-pollinator relationships in southern Africa. *Int. J. Trop. Insect Sci.* 24: 45–54.
Johnson, S.D. 2006. Pollinator-driven speciation in plants. In: Harder, L.D. & Barrett, S.C.H. (eds), *The ecology and evolution of flowers*, pp. 295–306. Oxford Univ. Press, Oxford.
Johnson, S.D. & Bond, W.J. 1994. Red flowers and butterfly pollination in the fynbos of South Africa. In: Arianoutsou, M. & Groves, R.H. (eds), *Plant-animal interactions in mediterranean-type ecosystems,* pp. 137–148. Kluwer, Dordrecht.
Johnson, S.D., Ellis, A., Carrick, P., Swift, A., Horner, N., Van Rensburg, S.J. & Bond, W.J. 1993. Moth pollination and rhythms of advertisement and reward in *Crassula fascicularis* (Crassulaceae). *S. Afr. J. Bot*. 59: 511–513.
Johnson, S.D., Linder, H.P. & Steiner, K.E. 1998. Phylogeny and radiation of pollination systems in *Disa* (Orchidaceae). *Amer. J. Bot*. 85: 402–411.
Johnson, S.D. & Midgley, J.J. 2001. Pollination by monkey beetles (Scarabaeidae: Hopliini): do color and dark centers of flowers influence alighting behavior? *Environ. Entomol.* 30: 861–868.
Johnson, S.D., Pauw, A. & Midgley, J. 2001. Rodent pollination in the African lily *Massonia depressa* (Hyacinthaceae). *Amer. J. Bot*. 88: 1768–1773.
Johnson, S.D. & Steiner, K.E. 1994. Pollination by megachilid bees and determinants of fruit-set in the Cape orchid *Disa tenuifolia*. *Nord. J. Bot*. 14: 481–485.
Johnson, S.D. & Steiner, K.E. 1997. Long-tongued fly pollination and evolution of floral spur length in the *Disa draconis* complex (Orchidaceae). *Evolution* 51: 45–53.
Johnson, S.D. & Steiner, K.E. 2000. Generalization versus specialization in plant pollination systems. *Trends Ecol. Evol.* 15: 190–193.
Johnson, S.D. & Steiner, K.E. 2003. Specialized pollination systems in southern Africa. *S. Afr. J. Sci.* 99: 345–348.
Jones, C. 1986. *Vegetation analysis of the Eensaamheid Reserve and extension*. 3rd year project, Dept of Botany, Univ. of Cape Town.
Joubert, C. 1991. *History and description of contemporary vegetation, Signal Hill, Cape Town*. M.Sc. thesis, Dept of Botany, Univ. of Cape Town.
Joubert, C. & Moll, E.J. 1992. A phytosociological study of Signal Hill, Cape Town, utilizing both perennial and ephemeral species. *Bothalia* 22: 255–282.
Joubert, J.G. & Stindt, H.W. 1979. The nutritive value of natural pastures in the district of Swellendam in the winter rainfall area of the Republic of South Africa. *Department of Agriculture Technical Communication* No. 156: 1–10.
Joubert, J.G.V. 1968. *Die ekologie van die weiveld van die Robertson-Karoo*. D.Sc. thesis, Dept of Botany, Univ. of Stellenbosch.
Jürgens, N. 2004. A first classification of the vegetation of the Richtersveld (RSA) and directly adjacent regions in Namibia and South Africa. *Schumania* 4: 149–180.

Karis, P.O. 1989. Systematics of the genus *Metalasia* (Asteraceae–Gnaphalieae). *Opera Bot*. 99: 1–150.
Kathan, L. 1981. *A study of certain autoecological aspects pertaining to a* Leucadendron laureolum *community at the Silvermine Nature Reserve, South Africa*. M.Sc. thesis, Dept of Botany, Univ. of Cape Town.
Keeley, J.E. & Bond, W.J. 1997. Convergent seed germination in South African fynbos and Californian chaparral. *Plant Ecol.* 133: 153–167.
Kirkwood, D. 1992. *A vegetation survey of Constantiaberg's eastern slopes*. 3rd year project, Dept of Botany, Univ. of Cape Town.
Knight, R.S., Rebelo, A.G. & Siegfried, W.R. 1989. Plant assemblages on mima-like earth mounds in the Clanwilliam district, South Africa. *S. Afr. J. Bot*. 55: 465–472.
Kornhall, P. 2004. *Phylogenetic studies in the Lamiales with special focus on Scrophulariaceae and Stilbaceae.* Uppsala Univ., Uppsala.
Krug, C.B., Krug, R.M., Iponga, D.M., Walton, B.A., Milton, S.J. & Shiponeni, N.N. 2004a. Restoration of West Coast Renosterveld: facilitating the return of a highly threatened vegetation type. In: Arianoutsou, M. & Papanastasis, V. (eds), *10th MEDECOS Conference April 25–May 1, 2004, Rhodes*. Millpress, Rotterdam.
Krug, R.M., Krug, C.B., Iponga, D.M., Walton, B.A., Milton, S.J., Newton, I.P., Farley, N. & Shiponeni, N.N. 2004b. Reconstructing West Coast Renosterveld: past and present ecological processes in a mediterranean shrubland of South Africa. In: Arianoutsou, M. & Papanastasis, V. (eds), *10th MEDECOS Conference April 25–May 1, 2004, Rhodes*. Millpress, Rotterdam.
Kruger, F.J. 1974. *The physiography and plant communities of Jakkalsrivier catchment.* M.Sc. thesis, Faculty of Forestry, Univ. of Stellenbosch.
Kruger, F.J. 1978. A description of the Fynbos Biome Project. *S. Afr. Natl. Sci. Progr. Rep*. No. 28: 1–25.
Kruger, F.J. 1979. South African heathlands. In: Specht, R.L. (ed.), *Ecosystems of the world. 9A. Heathlands and related shrublands of the world. A. Descriptive studies*, pp. 19–80. Elsevier, Amsterdam.
Kruger, F.J., Breytenbach, G.J., MacDonald, I.A.W. & Richardson, D.M. 1989. Characteristics of invaded mediterranean-type regions. In: Drake, J., Di Castri, F., Groves, R., Kruger, F.J., Mooney, H.A., Rejmánek, M. & Williamson, M. (eds), *Biological invasions: a global synthesis*, pp. 181–213. J. Wiley & Sons, Chichester.
Kruger, F.J., Miller, P.M., Miller, J. & Oechel, W.C. (eds) 1985. Simulation modelling of fynbos ecosystems: systems analysis and conceptual models. *S. Afr. Natl. Sci. Progr. Rep*. No. 105: 1–99.
Kruger, F.J., Mitchell, D.T. & Jarvis, J.U.M. (eds) 1983. *Mediterranean-type ecosystems. The role of nutrients.* Springer, Berlin.
Kruger, F.J. & Taylor, H.C. 1979. Plant species diversity in Cape fynbos: gamma and delta diversity. *Vegetatio* 41: 85–93.
Laidler, D., Moll, E.J., Campbell, B.M. & Glyphis, J. 1978. Phytosociological studies on Table Mountain, South Africa: 2. The Front Table. *J. S. Afr. Bot.* 44: 291–295.
Lambers, H., Cramer, M.D., Shane, M.W., Wouterlood, M., Poot, P. & Veneklaas, E.J. 2003. Structure and functioning of cluster roots and plant responses to phosphate deficiency. *Plant & Soil* 248: ix–xix.
Lambrechts, J.J.N. 1983. Soils, soil processes and soil distribution in the fynbos region: an introduction. In: Deacon, H.J., Hendey, Q.B. & Lambrechts, J.J.N. (eds), *Fynbos palaeoecology: a preliminary synthesis*, pp. 61–69. CSIR, Pretoria.
Lambrechts, J.J.N. & Fry, M. 1988. Soils of the Pella site. In: Jarman, M.L. (ed.), *A description of the Fynbos Biome Project. Intensive study site at Pella*, pp. 30–37. FRD, Pretoria.
Lamont, B. 1982. Mechanisms for enhancing nutrient uptake in plants, with particular reference to mediterranean South Africa and western Australia. *Bot. Rev.* 48: 597–689.
Lamont, B.B. 2003. Structure, ecology and physiology of root clusters—a review. *Plant & Soil* 248: 1–19.
Lamprecht, E. 1979. *'n Floristiese opname van 'n deel van die Jan Marais-natuurreservaat*. B.Sc.(Hons) project, Dept of Botany, Univ. of Stellenbosch.
Landman, A. & Nel, E. 1989. *Opname van die inheemse en uitheemse plantegroei te Pappegaaiberg, Stellenbosch*. B.Sc.(Hons) project, Dept of Botany, Univ. of Stellenbosch.
Lane, S.B. 1980. *Interpretation of Digital Landsat-1 Imagery from Verlorenvlei, South Western Cape*. M.Sc. thesis, Univ. of Cape Town.
Langley, C.H. & Giliomee, J.H. 1974. Behaviour of the bontebok (*Damaliscus d. dorcas*) in the Cape of Good Hope Nature Reserve. *J. S. Afr. Wild. Manage. Assoc*. 4: 117–121.
Latimer, A.M., Silander Jr, J.A. & Cowling, R.M. 2005. Neutral ecological theory reveals isolation and rapid speciation in a biodiversity hot spot. *Science* 309: 1722–1725.
Laurie, H. & Silander Jr, J. 2002. Geometric constraints and spatial pattern of species richness: critique of range-based null models. *Divers. Distrib*. 8: 351–364.
Lechmere-Oertel, R.G. 1998. *The environmental determinants of the fynbos/succulent karoo boundary in the Matjiesrivier Nature Reserve, Western Cape*. M.Sc. thesis, Dept of Botany, Univ. of Cape Town.
Lechmere-Oertel, R.G. & Cowling, R.M. 1999. Predicting the distribution of Fynbos and Succulent Karoo Biome boundaries and plant communities using linear models and geographic information systems. *S. Afr. J. Bot.* 65: 89–96.
Lechmere-Oertel, R.G. & Cowling, R.M. 2001. Abiotic determinants of the fynbos/succulent karoo boundary, South Africa. *J. Veg. Sci.* 12: 75–80.
Le Maitre, D.C. 1987. Effects of season of burn on species populations and composition of fynbos in the Jonkershoek Valley. *S. Afr. J. Bot.* 53: 284–292.
Le Maitre, D.C. & Midgley, J.J. 1992. Plant reproductive ecology. In: Cowling, R.M. (ed.), *The ecology of fynbos: nutrients, fire and diversity*, pp. 135–174. Oxford Univ. Press, Cape Town.
Le Roux, G.H. 1988. Die gebruik van die Kaapse fynbos vir weiding en die probleme wat dit skep. *Suid-Afrikaanse Bosboutydskrif* 146: 51–54.
Levyns, M.R. 1956. Notes on the biology and distribution of the Rhenoster bush. *S. Afr. J. Sci.* 52: 141–143.
Levyns, M.R. 1962. Possible Antarctic elements in the South African flora. *S. Afr. J. Sci.* 58: 237–241.
Levyns, M.R. 1964. Presidential address, migrations and origins of the Cape flora. *Trans. R. Soc. S. Afr.* 37: 85–107.
Liengme, C.A. 1987. *West Coast Strandveld, a Mediterranean-type shrubland*. M.Sc. thesis, Dept of Botany, Univ. of Cape Town.
Linder, H.P. 1976. *A preliminary study of the vegetation of Piketberg Mountain, Cape Province*. B.Sc.(Hons) project, Dept of Botany, Univ. of Cape Town.
Linder, H.P. 1999. A review of the southern African Restionaceae. *Contrib. Bolus Herb*. 13: 209–264.
Linder, H.P. 2001. On areas of endemism, with an example from the African Restionaceae. *Syst. Biol.* 50: 892–912.
Linder, H.P. 2003. The radiation of the Cape flora, southern Africa. *Biol. Rev.* 78: 597–638.
Linder, H.P. 2005a. A protocol for the systematic documentation of the ecology of Cape plants. *S. Afr. J. Bot.* 71: 201–210.
Linder, H.P. 2005b. Evolution of diversity: the Cape flora. *Trends Plant Sci.* 10: 536–541.
Linder, H.P. 2006. Investigating the evolution of floras: problems and progress—an introduction. *Divers. Distrib.* 12: 3–5.
Linder, H.P. & Hardy, C.R. 2004. Evolution of the species-rich Cape flora. *Phil. Trans. R. Soc. London, Ser. B* 359: 1623–1632.
Linder, H.P. & Hardy, C.R. 2005. Species richness in the Cape flora: a macroevolutionary and macroecological perspective. In: Bakker, F.T., Chatrou, L.W., Gravendeel, B. & Pelser, P.B. (eds), *Plant species-level systematics: a new perspective on pattern and process*, pp. 47–73. Koeltz, Königstein.
Linder, H.P. & Mann, D.M. 1998. The phylogeny and biogeography of *Thamnochortus* (Restionaceae). *Bot. J. Linn. Soc*. 128: 319–357.
Linder, H.P., Meadows, M.E. & Cowling, R.M. 1992. History of the Cape flora. In: Cowling, R.M. (ed.), *The ecology of fynbos: nutrients, fire and diversity*, pp. 113–134. Oxford Univ. Press, Cape Town.
Linder, H.P., Vlok, J.H., McDonald, D.J., Oliver, E.G., Boucher, C., Van Wyk, B.-E. & Schutte, A. 1993. The high altitude flora and vegetation of the Cape Floristic Region, South Africa. *Opera Bot.* 121: 247–261.
Linder, P. & Campbell, B.M. 1979. Towards a structural-functional classification of fynbos: a comparison of methods. *Bothalia* 12: 723–729.
Lloyd, P.H.L. & Rasa, O.A.E. 1989. Status, reproductive success and fitness in Cape mountain zebra (*Equus zebra zebra*). *Behav. Ecol. Sociobiol*. 25: 411–420.
Lötter, M. & Van Wageningen, M. 1988. *Die plantegroei van die berggrond bokant Coetzenburg.* B.Sc.(Hons) project, Dept of Botany, Univ. of Stellenbosch.
Lotz, C.N. 1993. *Ordination of plant communities between Simonstown and Miller's Point, Cape Peninsula.* 3rd year project, Dept of Botany, Univ. of Cape Town.
Lovegrove, B.G. & Siegfried, W.R. 1986. Distribution and formation of mima-like earth mounds in the Western Cape Province of South Africa. *S. Afr. J. Sci.* 82: 432–436.
Lovegrove, B.G. & Siegfried, W.R. 1989. Spacing and origin(s) of mima-like earth mounds in the Cape Province of South Africa. *S. Afr. J. Sci.* 85: 108–112.
Low, A.B. 1989. *The Macassar dune system and its utilization.* Report, COASTEC, Cape Town.
Low, A.B. & Rebelo, A.(T.)G. 1996. *Vegetation of South Africa, Lesotho and Swaziland. A companion to the vegetation map of South Africa, Lesotho and Swaziland.* Dept of Environmental Affairs and Tourism, Pretoria.
Lubke, R.A. 1983. A survey of the coastal vegetation near Port Alfred, Eastern Cape. *Bothalia* 14: 725–738.
Lubke, R.A. & De Villiers, G. 1991. The vegetation of the Joan Muirhead Nature Reserve, Kenton-on-Sea. *The Naturalist* 35: 21–30.
Lubke, R.A., Everard, D.A. & Jackson, S.Y. 1986. The biomes of the Eastern

Cape with emphasis on their conservation. *Bothalia* 16: 251–261.

Lubke, R.A. & Van Wijk, Y. 1988. Terrestrial plants and coastal vegetation. In: Lubke, R.A., Gess, F.N. & Bruton, M.N. (eds), *A field guide to the Eastern Cape coast*, pp. 167–240. Grahamstown Centre of the Wildlife Society of Southern Africa, Grahamstown.

Luyt, E. du C. 2005. *Models of Bontebok (*Damaliscus pygargus pygargus, *Pallas 1766) habitat preferences in the Bontebok National Park and sustainable stocking rates*. M.Sc. thesis, Dept of Conservation Ecology, Stellenbosch Univ.

Macdonald, I.A.W. & Jarman, M.L. (eds) 1984. Alien invasive organisms in the terrestrial ecosystems of the Fynbos Biome, South Africa. *S. Afr. Natl. Sci. Progr. Rep*. No. 85: 1–66.

Macdonald, I.A.W., Jarman, M.L. & Beeston, P. (eds) 1985. Management of invasive alien plants in the Fynbos Biome. *S. Afr. Natl. Sci. Progr. Rep*. No. 111: 1–138.

Manders, P.T. 1990a. Fire and other variables as determinants of forest/fynbos boundaries in the Cape Province. *J. Veg. Sci.* 1: 483–490.

Manders, P.T. 1990b. Soil seed bank and post-fire seed deposition across a forest/fynbos ecotone in the Cape Province. *J. Veg. Sci.* 1: 491–498.

Manders, P.T. & Dicks, F.M. 1987. A bibliography of fynbos ecology, edn 2. *S. Afr. Natl. Sci. Progr. Rep*. No. 166: 1–162.

Manders, P.T. & Richardson, D.M. 1992. Colonization of Cape fynbos communities by forest species. *For. Ecol. Manage*. 48: 277–293.

Manders, P.T., Richardson, D.M. & Masson, P.H. 1992. Is fynbos a stage in the succession to forest? Analysis of the perceived ecological distinction between two communities. In: Van Wilgen, B.W., Richardson, D.M., Kruger, F.J. & Van Hensbergen, H.J. (eds), *Fire in South African mountain fynbos*, pp. 81–107. Springer, Berlin.

Manning, J.C. & Goldblatt, P. 1996. The *Prosoeca peringueyi* (Diptera: Nemestrinidae) pollination guild in southern Africa: long-tongued flies and their tubular flowers. *Ann. Missouri Bot*. Gard. 83: 67–86.

Manning, J.C. & Goldblatt, P. 1997a. The *Moegistorhynchus longirostris* (Diptera: Nemestrinidae) pollination guild: long-tubed flowers and a specialized long-proboscid fly pollination system in southern Africa. *Plant Syst. Evol*. 206: 51–69.

Manning, J. & Goldblatt, P. 1997b. *South African Wild Flower Guide 9. Nieuwoudtville, Bokkeveld Plateau & Hantam*. Botanical Society of South Africa, Kirstenbosch.

Manning, J. & Goldblatt, P. 2002. The pollination of *Tritoniopsis parviflora* (Iridaceae) by the oil-collecting bee *Rediviva gigas* (Hymenoptera: Melittidae): the first record of oil-secretion in African Iridaceae. *S. Afr. J. Bot*. 68: 171–176.

Manning, J.C. & Goldblatt, P. 2005. Radiation of pollination systems in the Cape genus *Tritoniopsis* (Iridaceae: Crocoideae) and the development of bimodal pollination strategies. *Int. J. Plant Sci*. 166: 459–474.

Manning, J., Goldblatt, P. & Snijman, D. 2002. *The color encyclopedia of Cape bulbs.* Timber Press, Portland OR.

Manning, J. & Snijman, D. 2002. Hawkmoth pollination in *Crinum variabile* (Amaryllidaceae) and the biogeography of sphingophily in southern African Amaryllidaceae. *S. Afr. J. Bot*. 68: 212–216.

Marloth, R. 1902. Notes on the occurrence of alpine types in the vegetation of the higher peaks of the south-western region of the Cape. *Trans. S. Afr. Phil. Soc.* 11: 161–168.

Martin, A.R.H. 1965. Plant ecology of the Grahamstown Nature Reserve. I. Primary communities and plant succession. *J. S. Afr. Bot*. 31: 1–54.

Martin, A.R.H. 1966. Plant ecology of the Grahamstown Nature Reserve. II. Some effects of burning. *J. S. Afr. Bot.* 32: 1–39.

Martin, A.R.H. 1968. Pollen analysis of Groenvlei lake sediments, Knysna (South Africa). *Rev. Palaeobot. Palynol.* 7: 107–144.

Martin, A.R.H. & Noel, A.R.A. 1960. *The flora or Albany and Bathurst.* Rhodes Univ., Grahamstown.

Masson, P.H. & Moll, E.J. 1987. The factors affecting forest colonisation of fynbos in the absence of recurrent fire at Orange Kloof, Cape Province, South Africa. *S. Afr. For. J.* 143: 5–10.

Maud, R.R. & Partridge, T.C. 1987. Regional evidence for climate change in southern Africa since the Mesozoic. *Palaeoecology of Africa* 18: 337–348.

Maze, K.E. & Rebelo, A.G. 1999a. *Core flora conservation areas on the Cape Flats*. FCC Report 99/2, Botanical Society of South Africa, Kirstenbosch.

Maze, K.E. & Rebelo, A.G. 1999b. *Core flora conservation areas on the lowlands of the Cape Metropolitan Area.* FCC Report 99/1, Botanical Society of South Africa, Kirstenbosch.

McDonald, D.J. 1985. The plant communities of Swartboschkloof, Jonkershoek. *S. Afr. Natl. Sci. Progr. Rep*. No. 104: 1–54.

McDonald, D.J. 1987. Ordination by detrended correspondence analysis (DCA) of the vegetation of Swartboschkloof, Jonkershoek, Cape Province. *Bothalia* 17: 121–129.

McDonald, D.J. 1988. A synopsis of the plant communities of Swartboschkloof, Jonkershoek, Cape Province. *Bothalia* 18: 233–260.

McDonald, D.J. 1993a. The vegetation of the southern Langeberg, Cape Province. 1. The plant communities of the Boosmansbos Wilderness Area. *Bothalia* 23: 129–151.

McDonald, D.J. 1993b. The vegetation of the southern Langeberg, Cape Province. 2. The plant communities of the Marloth Nature Reserve. *Bothalia* 23: 153–174.

McDonald, D.J. 1993c. The vegetation of the southern Langeberg, Cape Province. 3. The plant communities of the Bergfontein, Rooiwaterspruit and Phesantefontein areas. *Bothalia* 23: 239–263.

McDonald, D.J. 1995. *Phytogeography, endemism and diversity of the fynbos of the southern Langeberg*. Ph.D. thesis, Dept of Botany, Univ. of Cape Town.

McDonald, D.J. 1999. Montane flora of the southern Langeberg, South Africa: a checklist of the flowering plants and ferns. *Bothalia* 29: 119–137.

McDonald, D.J., Cowling, R.M. & Boucher, C. 1996. Vegetation environment relationships on a species-rich coastal mountain range in the Fynbos Biome (South Africa). *Vegetatio* 123: 165–182.

McDonald, D.J., Juritz, J.M., Cowling, R.M. & Knottenbelt, W.J. 1995. Modelling the biological aspects of local endemism in South African fynbos. *Plant Syst. Evol*. 195: 137–147.

McDonald, D.J., Oliver, E.G.H., Linder, H.P. & Boucher, C. 1993. Is there alpine vegetation on the mountains of the south-western Cape? *Veld & Flora* 79,1: 17–19.

McDonald, D.J. & Van der Walt, J.J.A. 1992. Observations on the pollination of *Pelargonium tricolor*, section Campylia (Geraniaceae). *S. Afr. J. Bot*. 58: 386–392.

McDowell, C.R. 1988. *Factors affecting the conservation of renosterveld by private landowners.* Ph.D. thesis, Univ. of Cape Town.

McDowell, C.R. & Moll, E.J. 1992. The influence of agriculture on the decline of West Coast Renosterveld, south-western Cape, South Africa. *J. Environ. Manage.* 35: 173–192.

McKenzie, B. 1976. A phytosociological study of Orange Kloof, Table Mountain. In: Moll, E.J. & Campbell, B.M. (eds), *The ecological status of Table Mountain.* Report, Dept of Botany, Univ. of Cape Town.

McKenzie, B., Moll, E.J. & Campbell, B.M. 1977. A phytosociological study of Orange Kloof, Table Mountain, South Africa. *Vegetatio* 34: 41–53.

McKenzie, B. & Rebelo, T. 1997. *Core flora conservation areas on the Cape Flats.* FCC Report 97/1, Botanical Society of South Africa, Kirstenbosch.

McLachlan, I.R. & Pieterse, E. 1978. Preliminary Palynological Results: Site 361, Leg 40, Deep Sea Drilling Project. In: Bolli, H.M. et al. (eds), *Initial Reports of the Deep Sea Drilling Project 50*, pp. 857–881. Scripps Institution of Oceanography, La Jolla, CA.

Meadows, M.E. & Sugden, J.M. 1991. A vegetation history of the last 14 000 years on the Cederberg, south-western Cape Province. *S. Afr. J. Sci.* 87: 34–43.

Meadows, M.E. & Sugden, J.M. 1993. The late Quaternary palaeoecology of a floristic kingdom: the southwestern Cape, South Africa. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* 101: 271–281.

Meets, M. 2000. *The determination of the concentration of aqueous smoke solutions used in restoration projects.* M.Sc. thesis, Dept of Botany, Univ. of Stellenbosch.

Midoko-Iponga, D. 2004. *Renosterveld restoration: the role of competition, herbivory and other disturbances.* M.Sc. thesis, Dept of Conservation Ecology, Stellenbosch Univ.

Milewski, A.V. 1983. A comparison of ecosystems in mediterranean Australia and southern Africa: nutrient-poor soil sites at the Barrens and the Caledon Coast. *Annu. Rev. Ecol. Syst.* 14: 57–76.

Milewski, A.V. 2002. Elephant diet at the edge of the Fynbos Biome, South Africa. *Pachyderm* 32: 29–38.

Milewski, A.V. & Bond, W.J. 1982. Convergence of myrmecochory in mediterranean Australia and South Africa. In: Buckley, R.C. (ed.), *Ant-plant interactions in Australia*, pp. 89–98. Dr W. Junk, The Hague.

Miller, P.C. 1982. Some bioclimatic and pedologic influences on the vegetation in the mediterranean-type region of South Africa. *Ecol. Mediterr.* 8: 141–156.

Milton, S.J. 1976. *A phytosociological survey of the dune vegetation of part of the northern False Bay coast*. B.Sc.(Hons) (Botany) project, Univ. of Cape Town.

Milton, S.J. 1978. *Plant communities of Andriesgrond, Clanwilliam District.* Report, Dept of Botany, Habitat Working Group, Univ. of Cape Town.

Milton, S.J. 2004. Grasses as invasive alien plants in South Africa. *S. Afr. J. Sci.* 100: 69–74.

Mittermeier, R.A., Meyers, N., Robles, G.P. & Mittermeier, G.C. 2000. *Hotspots: earth's biologically richest and most endangered terrestrial ecoregions.* CEMEX Conservation International, Mexico City.

Moffett, R.O. & Deacon, H.J. 1977. The flora and vegetation in the surrounds of Boomplaas Cave: Cango Valley. *S. Afr. Archaeol. Bull*. 32: 127–145.

Moline, P.M. & Linder, H.P. 2006. Input data, analytical methods and biogeography of *Elegia* (Restionaceae). *J. Biogeogr*. 33: 47–62.

Moll, E.J. & Bossi, L. 1983. *Vegetation of the Fynbos Biome*, 1:1 000 000. Chief Directorate Surveys & Mapping, Mowbray.

Moll, E.J., Campbell, B.M., Cowling, R.M., Bossi, L., Jarman, M.L. & Boucher, C. 1984. *A description of major vegetation categories in and adjacent to the Fynbos Biome*. South African National Scientific Programmes Report No. 83: 1–29.

Moll, E.J., McKenzie, B. & McLachlan, D. 1980. A possible explanation for the lack of trees in the fynbos, Cape Province, South Africa. *Biol. Conserv.* 17: 221–228.

Mooney, H.A., Kummerow, J., Moll, E.J., Orshan, G., Rutherford, M.C. & Sommerville, J.E.M. 1982. Plant form and function in relation to nutrient gradients. In: Day, J.A. (ed.), *Mineral nutrients in mediterranean ecosystems*, pp. 55–76. CSIR, Pretoria.

Morrow, P.A., Day, J.A., Fox, M.D., Frost, P.G.H., Jarvis, J.U.M., Milewski, A.V. & Norton, P.M. 1983. Interaction between plants and animals. In: Day, J.A. (ed.), *Mineral nutrients in mediterranean ecosystems*, pp. 111–124. CSIR, Pretoria.

Moss, H. & Mettlerkamp, W. 1979. *Survey of the vegetation of Kapteinskloofberg, with special emphasis on floristic composition and structure.* 3rd year project, Dept of Botany, Univ. of Cape Town.

Mucina, L., Rutherford, M.C. & Powrie, L.W. (eds) 2005. *Vegetation map of South Africa, Lesotho and Swaziland*, 1:1 000 000 scale sheet maps. South African National Biodiversity Institute, Pretoria.

Muir, J. 1929. The vegetation of the Riversdale area Cape Province. *Mem. Bot. Surv. S. Afr.* No. 13: 1–82.

Mummenhoff, K., Al-Shebhaz, I.A., Bakker, F.T., Linder, H.P. & Mülhausen, A. 2005. Phylogeny, morphological evolution, and speciation of endemic Brassicaceae genera in the Cape flora of southern Africa. *Ann. Missouri Bot. Gard.* 92: 399–423.

Munro, S.L. & Linder, H.P. 1998. The phylogenetic position of *Prionium* (Juncaceae) within the tribe Juncales based on morphological and *rbcL* sequence data. *Syst. Bot*. 23: 43–55.

Musil, C.F. & De Witt, D.M. 1990. Post-fire regeneration in a sand plain lowland fynbos community. *S. Afr. J. Bot.* 56: 167–184.

Musil, C.F., Milton, S.J. & Davis, G.W. 2005. The threat of alien invasive grasses to lowland Cape floral diversity: an empirical appraisal of the effectiveness of practical control strategies. *S. Afr. J. Sci.* 101: 337–344.

Mustart, P., Cowling, R.M. & Albertyn, J. 1997. *South African Wild Flower Guide 8. Southern Overberg.* Botanical Society of South Africa, Kirstenbosch.

Mustart, P.J., Moll, E.J. & Taylor, H.C. 1993. The efficient use of small plots in a fynbos phytosociological study in the northern Cederberg: a quick way to collect plant-environment data. *Bothalia* 23: 265–269.

Naveh, Z. & Whittaker, R.H. 1979. Structural and floristic diversity of shrublands and woodlands in northern Israel and other mediterranean areas. *Vegetatio* 41: 171–190.

Neethling, D.-M. 1986. *'n Strukturele en floristiese opname van die plantegroei in die kleinsoogdiernavorsingsterrein te Swartboschkloof, Jonkershoek naby Stellenbosch*. B.Sc.(Hons) project, Dept of Botany, Univ. of Stellenbosch.

Nel, P.L. 1995. *The vegetation and flora of the Veldwachters River, Stellenbosch*. B.Sc.(Hons) project, Dept of Botany, Univ. of Stellenbosch.

Newton, I.P. & Knight, R. 2004. The matrix. The evolutionary development of coastal renosterveld. *Veld & Flora* 90,4: 162–165.

Nordenstam, B. 1976. *Lamprocephalus* B. Nord., a new senecioid genus from South Africa. *Bot. Notis*. 128: 323–326.

Norton, J. 1977. *Vegetation survey of the Worcester Botanic Gardens.* B.Sc. project, Dept of Botany, Univ. of Cape Town.

Novellie, P. 1987. Interrelationship between fire, grazing and grass cover at the Bontebok National Park. *Koedoe* 30: 1–17.

O'Callaghan, M. 1990. The ecology of the False Bay estuarine environments, Cape, South Africa. 1. The coastal vegetation. *Bothalia* 20: 105–111.

Ojeda, F., Simmons, M.T., Arroyo, J., Marañón, T. & Cowling, R.M. 2001. Biodiversity in South African fynbos and mediterranean heathland. *J. Veg. Sci.* 12: 867–874.

Oliver, E.G.H., Linder, H.P. & Rourke, J.P. 1983. Geographical distribution of present-day Cape taxa and their phytogeographical significance. *Bothalia* 14: 427–440.

Olivier, M.C. 1966. *Die plantegroei en flora van die Worcesterse Veldreservaat*. D.Sc. thesis, Univ. of Stellenbosch.

Olivier, M.C. 1983. An annotated systematic checklist of the Angiospermae of the Cape Receife Nature Reserve, Port Elizabeth. *J. S. Afr. Bot.* 49: 161–174.

Olmstead, R.G., dePamphilis, C.W., Wolfe, A.D., Young, N.D., Elisons, W.J. & Reeves, P.A. 2001. Disintegration of the Scrophulariaceae. *Amer. J. Bot.* 88: 348–361.

Olofsson, J., Kitti, H., Rautiainen, P., Stark, S. & Oksanen, L. 2001. Effects of summer grazing by reindeer on composition of vegetation, productivity and nitrogen cycling. *Ecography* 24: 13–24.

Owen-Smith, N. & Danckwerts, J.E. 1997. Herbivory. In: Cowling, R.M., Richardson, D.M. & Pierce, S.M. (eds), *Vegetation of southern Africa*, pp. 397–420. Cambridge Univ. Press, Cambridge.

Parkington, J. & Cartwright, C. 1997. The wood charcoal assemblages from Eland's Bay Cave, southwestern Cape: principles, procedures and preliminary interpretation. *S. Afr. Archaeol. Bull.* 52: 59–72.

Parkington, J., Cartwright, J., Cowling, R.M., Baxter, A. & Meadows, M. 2000. Palaeovegetation at the last glacial maximum in the western Cape, South Africa: wood charcoal and pollen evidence from Eland's Bay Cave. *S. Afr. J. Sci.* 96: 543–546.

Parkman, N.C. 1978. *A structural-functional classification of the fynbos vegetation of the Bain's Kloof area*. B.Sc.(Hons) project, Dept of Botany, Univ. of Cape Town.

Parsons, D.J. & Moldenke, A.R. 1975. Convergence of vegetation structure along analogous climatic gradients in California and Chile. *Ecology* 56: 950–957.

Partridge, T.C. & Maud, R.R. 1987. Geomorphic evolution of southern Africa since the Mesozoic. *S. Afr. J. Geol.* 902: 179–208.

Paterson, C.C. 1982. *A phytosociological classification of the vegetation of the Tygerberg Nature Reserve and De Grendel Farm, Bellville.* 3rd year project, Dept of Botany, Univ. of Cape Town.

Paterson-Jones, C. 1998. Renosterveld's floral treasure: headed for extinction. *Africa–Environment and Wildlife* 6: 27–32.

Pauw, A. 1998. Pollen transfer on bird's tongues. *Nature* 394: 731, 732.

Phillips, J.F.V. 1931. Forest-succession and ecology in the Knysna region. *Mem. Bot. Surv. S. Afr*. No. 14: 1–327.

Phipps, J.B. & Goodier, R. 1962. A preliminary account of the plant ecology of the Chimanimani Mountains. *J. Ecol*. 50: 291–319.

Picker, M.D. & Midgley, J.J. 1996. Pollination by monkey beetles (Coleoptera: Scarabaeidae: Hopliini): flower and colour preferences. *Afr. Entomol.* 4: 7–14.

Pierce, S.M. 1984. Synthesis of plant phenology in the Fynbos Biome. *S. Afr. Natl. Sci. Progr. Rep*. No. 88: 1–57.

Pressey, R.L., Cowling, R.M. & Rouget, M. 2003. Formulating conservation targets for biodiversity pattern and process in the Cape Floristic Region, South Africa. *Biol. Conserv.* 112: 99–127.

Privett, S.D.J. 1998. *Determinants of pattern in fynbos vegetation. Physical site factors, disturbance regime, species attributes and temporal change*. M.Sc. thesis, Dept of Botany, Univ. of Cape Town.

Procheş, Ş. & Cowling, R.M. 2004. Cape geophytes: putting the pieces together. In: Arianoutsou, M. & Papanastasis, V. (eds), *10th MEDECOS Conference April 25–May 1, 2004, Rhodes*. Millpress, Rotterdam.

Procheş, Ş., Cowling, R.M. & Du Preez, D.R. 2005. Patterns of geophyte diversity and storage organ size in the winter-rainfall region of southern Africa. *Divers. Distrib.* 11: 101–109.

Procheş, Ş., Cowling, R.M., Goldblatt, P., Manning, J.C. & Snijman, D.A. 2006. An overview of the Cape geophytes. *Biol. J. Linn. Soc.* 87: 27–43.

Procheş, Ş., Cowling, R.M. & Mucina, L. 2003. Species-area curves based on relevé data for the Cape Floristic Region. *S. Afr. J. Sci.* 99: 474–476.

Procheş, Ş., Wilson, J.R.U. & Cowling, R.M. 2006. How much evolutionary history in a 10 x 10 m plot? *Proc. R. Soc. London, Ser. B* 273: 1143–1148.

Raimondo, D. & Ebrahim, I. 2006. CREW—Custodians of Rare and Endangered Wildflowers Programme. *The Conservation Leaflet* 4: 3.

Raitt, G.R. 1999. *Management plan for the Silwerboom Kloof Natural Heritage Site*. B.Sc.(Hons) project, Forestry Conservation Dept, Univ. of Stellenbosch.

Raitt, G.R. 2005. Themeda triandra *renosterveld in the Heidelberg District.* M.Sc. thesis, Dept of Botany & Zoology, Stellenbosch Univ.

Raven, P.H. 1973. The evolution of Mediterranean floras. In: Di Castri, F. & Mooney, H.A. (eds), *Mediterranean type ecosystems. Origin and structure*, pp. 213–224. Springer, Berlin.

Raven, P.H. & Axelrod, A.I. 1978. Origin and relationships of the California flora. *Univ. Calif. Publ. Bot.* 72: 1–234.

Rebelo, A.G. (ed.) 1987a. A preliminary synthesis of pollination biology in the Cape flora. *S. Afr. Natl. Sci. Progr. Rep*. No. 141: 1–254.

Rebelo, A.G. 1987b. Bird pollination in the Cape flora. In: Rebelo, A.G. (ed.), A preliminary synthesis of pollination biology in the Cape flora. *S. Afr. Natl. Sci. Progr. Rep*. No. 141: 83–108.

Rebelo, A. 1991. *Protea Atlas Manual: instruction booklet to the Protea Atlas Project.* National Botanical Institute, Kirstenbosch.

Rebelo, A.G. 1992a. Red Data Book species in the Cape Floristic Region: threats, priorities and target species. *Trans. Royal Soc. S. Afr*. 48: 55–86.

Rebelo A.G. 1992b. Preservation of biotic diversity. In: Cowling, R.M. (ed.), *The ecology of fynbos: nutrients, fire and diversity*, pp. 309–344. Oxford Univ. Press, Cape Town.

Rebelo, A.G. 1995. Renosterveld: conservation and research. In: Low, A.B. & Jones, F.E. (eds), *The sustainable use and management of renosterveld remnants in the Cape Floristic Region*. Botanical Society of South Africa, Cape Town.

Rebelo, A.G. 2001. The state of plants in the Cape flora. In: Verdoorn, G.H. & Le Roux, J. (eds), *The state of South Africa's species*, pp. 18–43. Endangered Wildlife Trust, Pretoria.

Rebelo, A.G. & Breytenbach, G.J. 1987. Mammal pollination in the Cape flora. In: Rebelo, A.G. (ed.), *A preliminary synthesis of pollination biology in the Cape flora*, pp. 109–125. CSIR, Pretoria.

Rebelo, A.G., Cowling, R.M., Campbell, B.M. & Meadows, M. 1991. Plant communities of the Riversdale Plain. *S. Afr. J. Bot.* 57: 10–28.

Rebelo, A.G. & Siegfried, W.R. 1990. Protection of fynbos vegetation: ideal and real-world options. *Biol. Conserv.* 54: 15-31.

Rebelo, A.G., Siegfried, W.R. & Crowe, A.A. 1984. Avian pollinators and the pollination syndromes of selected Mountain Fynbos plants. *S. Afr. J. Bot.* 3: 285–296.

Reeves, G., Barraclough, T.G., Rebelo, T.G., Fay, M.F. & Chase, M.W. 2006. Molecular phylogenetics of African *Protea*: evidence from DNA sequences and AFLP markers for a Cape origin. *Ann. Missouri Bot. Gard*. (in press)

Richards, M.B. 1994. *Soil factors and competition as determinants of fynbos plant species distributions in the south-western Cape, South Africa.* Ph.D. thesis, Dept of Botany, Univ. of Cape Town.

Richards, M.B., Cowling, R.M. & Stock, W.D. 1995. Fynbos plant communities and vegetation-environment relationships in the Soetanysberg hills, Western Cape. *S. Afr. J. Bot.* 61: 298–305.

Richards, M.B. Cowling, R.M. & Stock, W.D. 1997a. Soil factors and competition as determinants of the distribution of six fynbos Proteaceae species. *Oikos* 79: 394–406.

Richards, M.B., Stock, W.D. & Cowling, R.M. 1997b. Soil nutrient dynamics and community boundaries in the fynbos vegetation of South Africa. *Plant Ecol.* 130: 143–153.

Richardson, D.M. & Brown, P.J. 1986. Invasion of mesic mountain fynbos by *Pinus radiata*. *S. Afr. J. Bot*. 52: 529–536.

Richardson, D.M. & Cowling, R.M. 1992. Why is mountain fynbos invasible and which species invade? In: Van Wilgen, B.W., Richardson, D.M., Kruger, F.J. & Van Hensbergen, H.J. (eds), *Fire in South African mountain fynbos*, pp. 161–181. Springer, Berlin.

Richardson, D.M., MacDonald, I.A.W., Hoffmann, J.H. & Henderson, L. 1997. Alien plant invasions. In: Cowling, R.M., Richardson, D.M. & Pierce, S.M. (eds), *Vegetation of southern Africa*, pp. 535–570. Cambridge Univ. Press, Cambridge.

Richardson, D.M. & Van Wilgen, B.W. 2004. Invasive alien plants in South Africa: how well do we understand the ecological impacts? *S. Afr. J. Sci.* 100: 45–52.

Richardson, D.M., Van Wilgen, B.W., Higgins, S.I., Trinder-Smith, T.H., Cowling, R.M. & McKell, D.H. 1996. Current and future threats to plant biodiversity on the Cape Peninsula, South Africa. *Biodiv. Conserv.* 5: 607–647.

Richardson, G.R., Lubke, R.A. & Guillarmod, A. 1984. Regeneration of grassy fynbos near Grahamstown (Eastern Cape) after fire. *S. Afr. J. Bot.* 3: 153–162.

Richardson, J.E., Fay, M.F., Cronk, Q.C.B., Bowman, D. & Chase, M.W. 2000. A phylogenetic analysis of Rhamnaceae using *rbc*L and *trn*L-F plastid DNA sequences. *Amer. J. Bot*. 87: 1309–1324.

Richardson, J.E., Weitz, F.M., Fay, M.F., Cronk, Q.C.B., Linder, H.P., Reeves, G. & Chase, M.W. 2001. Rapid and recent origin of species richness in the Cape flora of South Africa. *Nature* 412: 181–183.

Rivas-Martínez, S. 1976. Phytosociological and chorological aspects of the mediterranean region (1). *Doc. Phytosociol.* 15–18: 137–145.

Rivas-Martínez, S. 1981. Les étages bioclimatiques de la végétation de la péninsule Ibérique. *Anal. Jard. Bot. J. A. Cavanilles* 37: 251–268.

Rode, E. 1994. *Die plantegroei van die plaas Solva in die Elgin-kom, Suidwes-Kaap.* B.Sc.(Hons) project, Dept of Botany, Univ. of Stellenbosch.

Rodwell, J.S., Schaminée, J.H.J., Mucina, L., Pignatti, S., Dring, J. & Moss, D. 2002. *The diversity of European vegetation: an overview of phytosociological alliances and their relationships to EUNIS habitats.* National Reference Centre for Agriculture, Nature and Fisheries, Wageningen.

Rookmaaker, L.C. 1989. *The zoological exploration of southern Africa 1650–1790.* A.A. Balkema, Rotterdam.

Rouget, M., Cowling, R.M., Pressey, R.L. & Richardson, D.M. 2003a. Identifying spatial components of ecological and evolutionary process for regional conservation planning in the Cape Floristic Region, South Africa. *Divers. Distrib.* 9: 191–210.

Rouget, M., Reyers, B., Jonas, Z., Desmet, P., Driver, A., Maze, K., Egoh, B. & Cowling, R.M. 2004. *South African National Spatial Biodiversity Assessment 2004: Technical Report. Volume 1: Terrestrial Component.* South African National Biodiversity Institute, Pretoria.

Rouget, M., Richardson, D.M., Cowling, R.M., Lloyd, J.W. & Lombard, A.T. 2003b. Current patterns of habitat transformation and future threats to biodiversity in the Cape Floristic Region, South Africa. *Biol. Conserv.* 112: 63–85.

Rourke, J.P. 1993. *Thesmophora*, a new genus of Stilbaceae from South Africa. *Edinb. J. Bot*. 50: 89–95.

Rourke, J.P. & Wiens, D. 1977. Convergent floral evolution in South African and Australian Proteaceae and its possible bearing on pollination by non-flying mammals. *Ann. Missouri Bot. Gard.* 64: 1–17.

Rule, S. 1992. *A vegetation survey of Elsepeak in Fishhoek, Cape Province*. 3rd year project, Dept of Botany, Univ. of Cape Town.

Rundel, P.W., Montenegro, G. & Jaksić, F. (eds) 1998. *Landscape degradation and biodiversity in mediterranean-type ecosystems*. Springer, Berlin.

Rutherford, M.C. 1978. Karoo-Fynbos biomass along an elevational gradient in the western Cape. *Bothalia* 12: 555–560.

Rutherford, M.C. 1991. Diversity of photosynthetic responses in the mesic and arid mediterranean-type climate regions of southern Africa. In: Esser, G. & Overdieck, D. (eds), *Modern ecology, basic and applied aspects*, pp. 133–160. Elsevier, Amsterdam.

Rutherford, M.C. & Westfall, R.H. 1994. Biomes of southern Africa—an objective categorization, edn 2. *Mem. Bot. Surv. S. Afr.* No. 63: 1–94.

Rycroft, H.B. 1953. *A quantitative ecological study of the vegetation of Biesievlei, Jonkershoek*. Ph.D. thesis, Univ. of Cape Town.

SACS (South African Committee for Stratigraphy) (compiled by Kent, L.E.) 1980. Stratigraphy of South Africa. Part 1. Lithostratigraphy of the Republic of South Africa, South West Africa/Namibia and the Republics of Bophuthatswana, Transkei and Venda. *Handb. Geol. Surv. S. Afr.* No. 8: 1–690.

Sanmartín, I. & Ronquist, F. 2004. Southern hemisphere biogeography inferred by event-based models: plant versus animal patterns. *Syst. Biol.* 53: 216–243.

Schalke, H.J.W.G. 1973. The upper Quaternary of the Cape Flats area (Cape Province, South Africa). *Scripta Geol.*15: 1–57.

Scher, H.D. & Martin, E.E. 2006. Timing and climatic consequences of the opening of Drake Passage. *Science* 312: 428–430.

Schimper, A.F.W. 1903. *Plant geography upon a physiological basis.* Clarendon Press, Oxford.

Schloms, B.H.A., Ellis, F. & Lambrechts, J.J.N. 1983. Soils of the Cape coastal platform. In: Deacon, H.J., Hendey, Q.B. & Lambrechts, J.J.N. (eds), *Fynbos palaeoecology: a preliminary synthesis*, pp. 70–86. CSIR, Pretoria.

Schmiedel, U. 2002. *The quartz fields of southern African flora, phytogeography, vegetation, and habitat ecology.* Ph.D. thesis, Botanisches Institut, Univ. zu Köln.

Schmiedel, U. & Mucina, L. 2006. Vegetation of quartz fields in the Little Karoo, Tanqua Karoo and eastern Overberg (Western Cape Province, South Africa). *Phytocoenologia* 36: 1–44.

Scholtz, A. 1985. Palynology of the Upper Cretaceous lacustrine sediments of the Arnot pipe, Banke, Namaqualand. *Ann. S. Afr. Mus.* 95: 1–109.

Scholtz, A. 1986. *Palynological and palaeobotanical studies in the southern Cape.* M.A. thesis, Univ. of Stellenbosch.

Schrire, B.D., Lavin, M., Barker, N.P., Cortes-Burns, H., Von Senger, I. & Kim, J.-H. 2003. Towards a phylogeny of *Indigofera* (Leguminosae–Papilionoideae): identification of major clades and relative ages. In: Klitgaard, B.B. & Bruneau, A. (eds), *Advances in legume systematics. Part 10. Higher level systematics*, pp. 269–302. Royal Botanic Gardens, Kew.

Schulze, B.R. 1965. *Climate of South Africa. Part 8. General Survey. WB 28.* The Government Printer and Weather Bureau, Pretoria.

Schulze, R.E. 1997a. *South African atlas of agrohydrology and climatology.* Report TT82/96, Water Research Commission, Pretoria.

Schulze, R.E. 1997b. Climate. In: Cowling, R.M., Richardson, D.M. & Pierce, S.M. (eds), *Vegetation of southern Africa*, pp. 21–42. Cambridge Univ. Press, Cambridge.

Schüttler, G. 2002. *Floristische und vegetationsökologische Analyse eines Höhengradienten im südlichen Richtersveld, Republik Südafrika.* Diploma thesis, Botanisches Institut, Universität zu Köln.

Scott, H.A. 1993. *An investigation into possible reasons for a decline in numbers of bontebok* Damaliscus dorcas dorcas (*Pallas, 1766*) *in the De Hoop Nature Reserve, southwestern Cape*. M.Tech. thesis, Saasveld School of Forestry, Port Elizabeth Technikon.

Scott, L. 1976. Palynology of Lower Cretaceous deposits from the Algoa Basin (Republic of South Africa). *Pollen et Spores* 18: 563–609.

Scott, L. 1994. Palynology of Late Pleistocene hyrax middens, southwestern Cape Province, South Africa: a preliminary report. *Hist. Biol.* 9: 71–81.

Scott, L. 1995. Pollen evidence for vegetation and climate change in southern Africa during the Neogene and Quaternary. In: Vrba, E., Denton, G., Burckle, L.H. & Partridge, T.C. (eds), *Palaeoclimate and evolution with emphasis on human origins*, pp. 65–76. Yale Univ. Press, New Haven, CT.

Scott, L. & Lee-Thorp, J.A. 2004. Holocene climatic trends and rhythms in southern Africa. In: Battarbee, R.W., Gasse, F. & Stickley, C.E. (eds), *Past climate variability through Europe and Africa*, pp. 69–91. Springer, Dordrecht.

Scott, L., Marais, E. & Brook, G.A. 2004. Fossil hyrax dung and evidence of Late Pleistocene and Holocene vegetation types in the Namib Desert. *J. Quarter. Sci.* 19: 829–832.

Shackleton, N.J. & Kennet, J.P. 1975. Palaeotemperature history of the Cenozoic and the initiation of the Antarctic glaciation: oxygen and carbon isotope analyses in DSDP sites 277, 279 and 281. *Initial Reports of the DSDP* 29: 743–755.

Shi, N., Dupont, L.M., Beug, H.-J. & Schneider, R. 2000. Correlation between vegetation in southwestern Africa and oceanic upwelling in the past 21,000 years. *Quarter. Res.* 54: 72–80.

Shiponeni, N.N. 2003. *Dispersal of seeds as a constraint in revegetation of old fields in renosterveld vegetation in the Western Cape, South Africa.* M.Sc. thesis, Dept of Conservation Ecology, Stellenbosch Univ.

Sieben, E.J.J. 2003. *The riparian vegetation of the Hottentots Holland Mountains, Western Cape, South Africa.* Ph.D. thesis, Dept of Botany, Univ. of Stellenbosch.

Sieben, E.J.J., Boucher, C. & Mucina, L. 2004. Vegetation of high-altitude fens and restio marshlands of the Hottentots Holland Mountains, Western Cape, South Africa. *Bothalia* 34: 141–153.

Siesser, W.G. 1980. Late Miocene origin of the Benguela upwelling system of northern Namibia. *Science* 208: 283–285.

Sim, T.R. 1927. Some effects of man's influence on the South African flora. *S. Afr. J. Sci.* 23: 492–507.

Simmons, M. 1992. *Ordination using two methods of plant communities on Chapman's Peak, Cape Province*. 3rd year project, Dept of Botany, Univ. of Cape Town.

Simmons, M.T. 1996. *Vegetation, diversity and rarity on the Cape Peninsula, South Africa*. M.Sc. thesis, Dept of Botany, Univ. of Cape Town.

Skead, C.J. 1980. *Historical mammal incidence in the Cape Province. Volume 1: The western and northern Cape.* Dept of Nature and Environmental Conservation of the Cape Provincial Administration, Cape Town.

Smale, D. 1973. Silcretes and associated silica diagenesis in southern Africa and Australia. *J. Sedim. Petrol.* 43: 1077–1089.

Smith, R.E. & Higgins, K.B. 1990. The root systems of three species of *Protea* shrubs in the Jonkershoek Valley, Cape Province (South Africa). *S. Afr. J. Plant & Soil* 7: 238–240.

Smitheman, J. & Perry, P. 1990. A vegetation survey of the Karoo National Botanic Garden Reserve, Worcester. *S. Afr. J. Bot.* 56: 525–541.

Snijman, D. & Perry, P. 1987. A floristic analysis of the Nieuwoudtville Wild Flower Reserve, north western Cape. *S. Afr. J. Bot*. 53: 445–454.

Soil Classification Working Group 1991. Soil classification: a taxonomic system for South Africa. *Mem. Nat. Agric. Res. S. Afr.* No. 15: 1–257.

Sparrman, A. 1786. *A voyage to the Cape of Good Hope, towards the Antarctic Polar Circle, and round the world: but chiefly into the country of the Hottentots and Caffres, from the year 1772 to 1776,* Vol. 2, edn 2. G.G.J. & J. Robinson, London.

Specht, R.L. 1969a. Comparison of sclerophyllous vegetation characteristics of mediterranean type climates in France, California and southern Australia. I. Structure, morphology and succession. *Aust. J. Bot.* 17: 277–292.

Specht, R.L. 1969b. Comparison of sclerophyllous vegetation characteristics of mediterranean type climates in France, California and southern Australia. II. Dry matter, energy and nutrient accumulation. *Aust. J. Bot.* 17: 293–308.

Specht, R.L. (ed.) 1988. *Mediterranean-type ecosystems. A data source book*. Kluwer, Dordrecht.

Specht, R.L. & Moll, E.J. 1983. Mediterranean-type heathlands and sclerophyllous shrublands of the world: an overview. *Ecol. Stud.* 43: 41–65.

Steiner, K.E. 1989. The pollination of *Disperis* (Orchidaceae) by oil-collecting bees in southern Africa. *Lindleyana* 4: 164–183.

Steiner, K.E. 1993. Has *Ixianthes* (Scrophulariaceae) lost its special bee? *Plant Syst. Evol*. 185: 7–16.

Steiner, K.E. 1998. Beetle pollination of peacock moraeas (Iridaceae) in South Africa. *Plant Syst. Evol.* 209: 47–65.

Steiner, K.E. & Whitehead, V.B. 2002. Oil secretion and the pollination of *Colpias mollis* (Scrophulariaceae). *Plant Syst. Evol*. 235: 53–66.

Stock, W.D. & Allsopp, N. 1992. Functional perspective of ecosystems. In: Cowling, R.M. (ed.), *The ecology of fynbos: nutrients, fire and diversity*, pp. 241–259. Oxford Univ. Press, Cape Town.

Stock, W.D., Allsopp, N., Van der Heyden, F. & Witkowski, E.T.F. 1997. Plant form and function. In: Cowling, R.M., Richardson, D.M. & Pierce, S.M. (eds), *Vegetation of southern Africa*, pp. 376–396. Cambridge Univ. Press, Cambridge.

Stock, W.D., Bond, W.J. & Le Roux, D. 1992a. Isotope evidence from soil carbon to reconstruct vegetation history in the south-western Cape Province. *S. Afr. J. Sci.* 89: 153, 154.

Stock, W.D., Van der Heyden, F. & Lewis, O.A.M. 1992b. Plant structure and function. In: Cowling, R.M. (ed.), *The ecology of fynbos: nutrients, fire and diversity*, pp. 226–239. Oxford Univ. Press, Cape Town.

Stofberg, T. 2000. *Management plan for the greater lakes of Betty's Bay: Groot Wit Vlei and Rondevlei*. B.Sc.(Hons) project, Dept of Forestry Conservation, Univ. of Stellenbosch.

Struck, M. 1997. Floral divergence and convergence in the genus *Pelargonium* (Geraniaceae) in southern Africa: ecological and evolutionary considerations. *Plant Syst. Evol*. 208: 71–97.

Swart, E.C. 1983. *Die plantegroei en flora van die Jan Marais-natuurreservaat.* B.Sc.(Hons) project, Dept of Botany, Univ. of Stellenbosch.

Takhtajan, A. 1986. *Floristic regions of the world.* Univ. of California Press, Berkeley, CA.

Talma, A.S. & Vogel, J.C. 1992. Late Quaternary paleotemperatures derived from a speleothem from Cango Caves, Cape Province, South Africa. *Quarter. Res.* 37: 203–213.

Taylor, H.C. 1963. A bird's-eye view of Cape mountain vegetation. *J. S. Afr. Bot.* 59: 17–19.

Taylor, H.C. 1969. *A vegetation survey of the Cape of Good Hope Nature Reserve.* M.Sc. thesis, Dept of Botany, Univ. of Cape Town.

Taylor, H.C. 1970a. *I.B.P. checksheet for the Riversdale Nature Reserve.* Report, Botanical Research Institute, Stellenbosch.

Taylor, H.C. 1970b. *I.B.P. checksheet for the Robberg Nature Reserve.* Report, Botanical Research Institute, Stellenbosch.

Taylor, H.C. 1972a. *I.B.P. checksheet: Bontebok National Park, Swellendam. Notes on the vegetation classification.* Report, Botanical Research Institute, Stellenbosch.

Taylor, H.C. 1972b. Notes on the vegetation of the Cape Flats. *Bothalia* 10: 637–646.

Taylor, H.C. 1978. Capensis. In: Werger, M.J.A. & Van Bruggen, A.C. (eds), *Biogeography and ecology of southern Africa*, pp. 171–229. Dr W. Junk, The Hague.

Taylor, H.C. 1979. Observations on the flora and phytogeography of Rooiberg, a dry fynbos mountain in the southern Cape Province, South Africa. *Phytocoenologia* 6: 524–531.

Taylor, H.C. 1981. *Red Hill, Simons Town flora and vegetational survey. Preliminary hydrological survey, Informal Settlement 1991.* FCC Report, Botanical Society of South Africa, Kirstenbosch.

Taylor, H.C. 1983. The vegetation of the Cape of Good Hope Nature Reserve. *Bothalia* 14: 779–784.

Taylor, H.C. 1984a. A vegetation survey of the Cape of Good Hope Nature Reserve. I. The use of association-analysis and Braun-Blanquet methods. *Bothalia* 15: 245–258.

Taylor, H.C. 1984b. A vegetation survey of the Cape of Good Hope Nature Reserve. II. Descriptive account. *Bothalia* 15: 259–291.

Taylor, H.C. 1996. Cederberg vegetation and flora. *Strelitzia* 3. National Botanical Institute, Pretoria.

Taylor, H.C. & Boucher, C. 1993. Dry coastal ecosystems of the South African South Coast. In: Van der Maarel, E. (ed.), *Ecosystems of the world. 2B. Dry coastal ecosystems. Africa, America and Oceania,* pp. 89–107. Elsevier, Amsterdam.

Taylor, H.C. & Morris, J.W. 1981. A brief account of coast vegetation near Port Elizabeth. *Bothalia* 13: 519–525.

Taylor, H.C. & Van der Meulen, F. 1981. Structural and floristic classifications of Cape Mountain Fynbos on Rooiberg, southern Cape. *Bothalia* 13: 557–567.

Thiergart, F., Frantz, U. & Raukopf, K. 1962. Palynologische Untersuchungen von Tertiärkohlen und einer Oberflächenprobe nahe Knysna, Südafrika. *Adv. Front. Plant Sci.* 4: 151–178.

Thom, H.B. 1952. *Journal of Jan Van Riebeeck, Volume 1, 1651–1652*. Van Riebeeck Society & A.A. Balkema, Cape Town.

Thwaites, R.N. & Cowling R.M. 1988. Soil-vegetation relationships on the Agulhas Plain, South Africa. *Catena* 15: 333–345.

Traveset, A. & Richardson, D.M. 2006. Biological invasions as disruptors of plant reproductive mutualisms. *Trends Ecol. Evol.* 21: 208–216.

Tritton, R. 1992. *Sandy Bay vegetation survey.* 3rd year project, Dept of Botany, Univ. of Cape Town.

Trouw, R.A.J. & De Wit, M.J. 1999. Relation between the Gondwanide Orogen and contemporaneous intracratonic deformation. *J. Afr. Earth Sci.* 28: 203–213.

Truswell, J.F. 1970. *An introduction to the historical geology of South Africa.* Purnell & Sons, Cape Town.

Tyson, P.D. 1986. *Climatic change and variability in southern Africa*. Oxford Univ. Press, Cape Town.

Uys, C.J. 1983. Portrait of a fynbos habitat extraordinary—De Hoop Vlei. *African Wildlife* 37: 5–8.

Vail, P.R. & Hardenbol, J. 1979. Sea-level changes during the Tertiary. *Oceanus* 22: 71–79.

Van Daalen, J.C. 1984. Distinguishing features of forest species on nutrient-poor soils in the southern Cape. *Bothalia* 15: 229–239.

Van der Maarel, E. 1975. The Braun-Blanquet approach in perspective. *Vegetatio* 30: 213–219.

Van der Merwe, C.J. 1976. *Plantekologiese aspekte en bestuursprobleme van die Goukamma-natuurreservaat*. M.Sc. thesis, Univ. of Pretoria.

Van der Merwe, C.V. 1977a. 'n Plantegroei-opname van die De Hoop-natuurreservaat. *Bontebok* 1: 1–29.

Van der Merwe, C.V. 1977b. *'n Plantegroeibeskrywing van die Vrolijkheid-natuurbewaringstasie.* Report, Dept van Natuur- en Omgewingsbewaring, Cape Town.

Van der Merwe, P. 1962. *Floristiese opname van Swartboskloof, Stellenbosch en die herstel van die flora na 'n brand.* M.Sc. thesis, Univ. of Stellenbosch.

Van der Merwe, P. 1966. Die flora van Swartboskloof, Stellenbosch en die herstel van die soorte na 'n brand. *Ann. Univ. Stellenbosch*, Ser. A 41: 687–736.

Van Jaarsveld, E. 1981. A preliminary report on the vegetation of the Richtersveld with specific reference to the trees and shrubs of the area. *Trees in South Africa* 33: 58–84.
Van Jaarsveld, E. 1982. Plantegroei van die Gifberg met spesifieke verwysing na bome, struike en die gifboom. *Trees in South Africa* 34: 10–27.
Van Jaarsveld, E. & Koutnik, D. 2004. Cotyleon *and* Tylecodon. Umdaus Press, Hatfield, Pretoria.
Van Rooyen, G., Steyn, H. & De Villiers, R. 1999. *South African Wild Flower Guide 10. Cederberg, Clanwilliam & Biedouw Valley.* Botanical Society of South Africa, Kirstenbosch.
Van Rooyen, L. 1981. *'n Fitososiologiese studie van die Rocherpan-natuurreservaat*. B.Sc.(Hons) project, Dept of Nature Conservation, Univ. of Stellenbosch.
Van Staden, J., Brown, N.A.C., Jäger, A.K. & Johnson, T.A. 2000. Smoke as a germination cue. *Plant Spec. Biol.* 15: 167–178.
Van Wilgen, B.W., Bond, W.J. & Richardson, D.M. 1992a. Ecosystem management. In: Cowling, R.M. (ed.), *The ecology of fynbos: nutrients, fire and diversity*, pp. 345–371. Oxford Univ. Press, Cape Town.
Van Wilgen, B.W. & Cowling, R.M. 1998. Ecosystem services, efficiency, sustainability and equity: South Africa's Working for Water programme. *Trends Ecol. Evol.* 13: 378.
Van Wilgen, B.W., Cowling, R.M. & Burgers, C.J. 1996. Valuation of ecosystem services. A case study from South African fynbos ecosystems. *BioScience* 46: 184–189.
Van Wilgen, B.W. & Kruger, F.J. 1981. Observations on the effects of fire in mountain fynbos at Zachariashoek, Paarl. *J. S. Afr. Bot.* 47: 195–212.
Van Wilgen, B.W. & Kruger, F.J. 1985. The physiography and fynbos vegetation communities of the Zachariashoek catchments, south western Cape Province. *S. Afr. J. Bot.* 51: 379–398.
Van Wilgen, B.W., Richardson, D.M., Kruger, F.J. & Van Hensbergen, H.J. (eds) 1992b. *Fire in South African mountain fynbos.* Springer, Berlin.
Van Wyk, A.E. & Smith, G.F. 2001. *Regions of floristic endemism in southern Africa. A review with emphasis on succulents.* Umdaus Press, Hatfield.
Van Wyk, B.-E., Novellie, P.A. & Van Wyk, C.M. 1988. Flora of the Zuurberg National Park. 1. Characterization of major vegetation units. *Bothalia* 18: 211–220.
Van Zinderen Bakker, E.M. 1975. The origin and palaeoenvironment of the Namib Desert Biome. *J. Biogeogr.* 2: 65–73.
Van Zyl, L.J. 1978. *Die waterbehoeftes en drinkgewoontes van die Bontebok* Damaliscus dorcas dorcas (*Pallas, 1766*) *in die Bontebok Nasionale Park*. M.Sc. thesis, Univ. of Stellenbosch.
Venter, A.M. & Venter, H.J.T. 2003. *Lycium strandveldense* (Solanaceae), a new species from the western coast of South Africa. *S. Afr. J. Bot*. 69: 476–479.
Verboom, G.A., Linder, H.P. & Stock, W.D. 2003. Phylogenetics of the grass genus *Ehrharta*: evidence for radiation in the summer-arid zone of the South African Cape. *Evolution* 57: 1008–1021.
Verboom, G.A., Linder, H.P. & Stock, W.D. 2004. Testing the adaptive nature of radiation: growth form and life history divergence in the African grass genus *Ehrharta* (Poaceae: Ehrhartoideae). *Amer. J. Bot*. 91: 1364–1370.
Verdú, M., Dávila, P., García-Fayos, P., Flores-Hernández, N. & Valiente-Banuet, A. 2003. 'Convergent' traits of mediterranean woody plants belong to pre-mediterranean lineages. *Biol. J. Linn. Soc.* 78: 415–427.
Vermeulen, W.J. 1995. *'n Fitososiologiese studie van die Ysternek-natuurreservaat in Suid-Kaapland.* M.Sc. thesis, Dept of Botany, Univ. of Stellenbosch.
Vile, D., Garnier, E., Shipley, B., Laurent, G., Navas, M., Roumet, C., Lavorel, S., Díaz, S., Hodgson, J.G., Lloret, F., Midgley, G.F., Poorter, H., Rutherford, M.C., Wilson, P.J. & Wright, I.J. 2005. Specific leaf area and dry matter content estimate thickness in laminar leaves. *Ann. Bot.* 96: 1129–1136.
Vlok, J.H.J. 1988. Alpha diversity of lowland fynbos herbs at various levels of infestation by alien annuals. *S. Afr. J. Bot*. 54: 623–627.
Vlok, J.H.J. 2002. *The vegetation of the Anysberg Nature Reserve and surrounding properties.* Report, Regalis Environmental Services, Oudtshoorn.
Vlok, J.H.J. & Euston-Brown, D.I.W. 2002. *Subtropical Thicket Ecosystem Planning Project (STEP). Biological Survey Report (plants and birds)*. Report, Terrestrial Ecology Unit, Univ. of Port Elizabeth. www.zoo.upe.ac.za/step (downloaded 1 July 2004).
Vlok, J.H.J., Euston-Brown, D.I.W. & Cowling, R.M. 2003. Acocks' Valley Bushveld 50 years on: new perspectives on the delimitation, characterisation and origin of subtropical thicket vegetation. *S. Afr. J. Bot.* 69: 27–51.
Vogel, S. 1954. *Blütenbiologische Typen als Elemente der Sippengliederung, dargestellt anhand der Flora Südafrikas*. G. Fischer, Jena.
Von Hase, A., Rouget, M., Maze, K. & Helme, N. 2003. *A fine-scale conservation plan for Cape Lowlands Renosterveld: Technical Report*. Report CCU2/03, Botanical Society of South Africa, Kirstenbosch.
Von Maltitz, G., Mucina, L., Geldenhuys, C.J., Lawes, M., Eeley, H., Adie, H., Vink, D., Fleming, G. & Bailey, C. 2003. *Classification system for South African indigenous forests: an objective classification for the Department of Water Affairs and Forestry.* Report ENV-P-C 2003-017, Environmentek, CSIR, Pretoria.
Vos, W.T., Edwards, T.J. & Van Staden, J. 1994. Pollination biology of annual and perennial *Leonotis* species (Lamiaceae). *Plant Syst. Evol*. 192: 1–9.
Walton, B.A. 2006. *Vegetation patterns and dynamics of renosterveld at the Agter-Groenberg Conservancy, Western Cape, South Africa.* M.Sc. thesis, Dept of Conservation Ecology, Stellenbosch Univ.
Watmough, R.H. 1974. Biology and behaviour of Carpenter bees in southern Africa. *J. Entomol. Soc. S. Afr.* 37: 261–281.
Weimark, H. 1941. Phytogeographical groups, centres and intervals within the Cape flora. *Lunds Universitets Arrskrift. N. F. Avd. 2,* 37: 1–143.
Werger, M.J.A., Kruger, F.J. & Taylor, H.C. 1972a. A phytosociological study of the Cape Fynbos and other vegetation at Jonkershoek, Stellenbosch. *Bothalia* 10: 599–614.
Werger, M.J.A., Kruger, F.J. & Taylor, H.C. 1972b. Pflanzensociologische Studie der Fynbosvegetation am Kap der Guten Hoffnung. *Vegetatio* 24: 71–89.
Westhoff, V. & Van der Maarel, E. 1978. The Braun-Blanquet approach. In: Whittaker, R.H. (ed.), *Classification of plant communities*, pp. 287–399. Dr W. Junk, The Hague.
White, F. 1983. *Vegetation of Africa: a descriptive memoir to accompany the UNESCO/AETFAT/UNSO vegetation map of Africa*. UNESCO, Paris.
Wicht, C. L. 1945. *Preservation of the vegetation of the South-western Cape*. Royal Society of South Africa, Cape Town.
Wiens, D. & Rourke, J.P. 1978. Rodent pollination in southern African *Protea* spp. *Nature* 276: 71–73.
Wiens, D., Rourke, J.P., Casper, B.B., Richkart, E.A., LaPine, T.R., Peterson, J. & Channing, A. 1983. Nonflying mammal pollination of southern African proteas: a non-coevolved system. *Ann. Missouri Bot. Gard.* 70: 1–31.
Willis, C.K. & Cowling, A.T. 1996. Patterns of endemism in the limestone flora of South African lowland fynbos. *Biodiv. Conserv*. 5: 55–73.
Willis, C.K., Lombard, A.T., Cowling, R.M., Heydenrych, B.J. & Burgers, C.J. 1996. Reserve systems for limestone endemic flora of the Cape lowland fynbos: iterative versus linear programming. *Biol. Conserv.* 77: 53–62.
Wisheu, I.C., Rosenzweig, M.L., Olsvig-Whittaker, L. & Shmida, A. 2000. What makes nutrient-poor mediterranean heathlands so rich in plant diversity? *Evol. Ecol. Res.* 2: 935–955.
Witkowski, E.T.F. & Mitchell, D.T. 1989. The effects of nutrient additions on above ground phytomass and its phosphorus and nitrogen contents of sand plain lowland fynbos. *S. Afr. J. Bot.* 55: 243–249.
Witt, A.B.R., Geertsema, H. & Giliomee, J.H. 2004. The impact of an invasive ant, *Linepithema humile* (Mayr) (Hymenoptera: Formicidae), on the dispersal of the elaiosome-bearing seeds of six plant species. *Afr. Entomol*. 12: 223–230.
Witt, A.B.R. & Giliomee, J.H. 2004. The impact of an invasive ant, *Linepithema humile* (Mayr), on the dispersal of *Phylica pubescens* Aiton seeds in South Africa. *Afr. Entomol*. 12: 179–185.
Wood, J.C. 1990. *The natural vegetation of the Robertson Karoo: an evaluation of its conservation status.* M.Sc. thesis, Dept of Botany, Univ. of Cape Town.
Wood, J.C., Low, A.B., Donaldson, J.S. & Rebelo, A.G. 1994. Threats to plant species diversity through urbanization and habitat fragmentation in the Cape Metropolitan Area, South Africa. In: Huntley, B.J. (ed.), *Botanical diversity in southern Africa*, pp. 259–274. National Botanical Institute, Pretoria.
Wright, M.G., Visser, D., Coetzee, J.H. & Giliomee, J.H. 1991a. Insects and bird pollination of *Protea* species in the western Cape: further data. *S. Afr. J. Sci*. 87: 214, 215.
Wright, M.G., Visser, D. & De Lange, J.H. 1991b. Autoecological studies on *Audouinia capitata* (Bruniaceae). 2. Insects as pollen vectors. *S. Afr. J. Bot*. 57: 260–263.
Zietsman, M.M. & Bredenkamp, G.J. 2006. Dune vegetation and coastal thicket plant communities in threatened limestone fynbos of Andrew's Field and Tsaba-Tsaba Reserve, Struisbaai, Western Cape. *Koedoe* 49: 33–47.