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The identification of Broad Habitat Units as biodiversity entities for systematic conservation planning in the Cape Floristic Region

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Despite many decades of vegetation-related research, the globally significant Cape Floristic Region (CFR) lacks a system of land classes that can be used as surrogates for biodiversity in conservation planning at the region-wide scale. Here we present a system of Broad Habitat Units (BHUs), suitable for planning at the 1:250 000 scale or larger. The BHUs were derived by intersecting coverages of Homogeneous Climate Zones, geology and topography in a geographic information system. A vegetation type coverage (Low and Rebelo 1996) was used to guide the classification under certain circumstances. A total of 15 primary and 88 secondary BHUs were identified in the CFR (87 892 km²). Of the latter, 69 were included in the Fynbos biome, which covered 81.5% of the CFR. At the primary BHU level, the system is very similar to existing vegetation treatments. The system is a good surrogate for biodiversity pattern and process, and therefore has good potential to provide meaningful entities for systematic and strategic conservation planning in the region.

Introduction

South Africa's Cape Floristic Region (CFR) (Figure 1) is a global priority for conservation action. Owing to its high concentration of endemic taxa, especially of plants (Goldblatt 1978, Cowling and McDonald 1999, Goldblatt and Manning 2000) and invertebrates (e.g. Picker and Samways 1996), and its vulnerability to processes that threaten this unique biodiversity (Rebelo 1992, Richardson *et al.* 1996), the CFR is recognised globally as a biodiversity hotspot (Myers 1990, Mittermeier *et al.* 1998). Globally, the region is also listed as a Centre of Plant Diversity (WWF and IUCN 1994), an Endemic Bird Area (Bibby *et al.* 1992) and a Global 200 Ecoregion (Olson and Dinerstein 1998). The area is currently home to 1406 Red Data Book plant species, the highest known concentration of such species in the world (Cowling and Hilton Taylor 1994).

High concentrations of locally endemic species are usually symptomatic of unusual evolutionary processes (Gentry 1986, Cowling and McDonald 1999). Disturbingly, it is these areas – the global hotspots of endemism – that are likely to bear the brunt of the impending global extinction crisis (Pimm *et al.* 1995). Therefore, it is essential to design systems of conservation areas within these endemic-rich regions that are representative of biodiversity patterns as well as the processes that sustain these (Cowling *et al.* 1999a). In order to retain biodiversity in the long term, the reserve system should be implemented according to priority ranking based on the conservation value of sites, assessed in terms of pattern and process, and their vulnerability to threatening processes (Pressey *et al.* 1996). A plan for such a conservation system in the CFR is an outcome of the Global Environmental Facility funded Cape Action Plan for the Environment (CAPE) Project (World Bank 1998, Cowling *et al.* 1998,1999b). This initiative will also contribute to fulfilling South Africa's obligations to the Convention on Biological Diversity, particularly with regard to the establishment of 'a more flexible and representative protected area system' (Van Jaarsveld and Chown 1996).

A plan for conserving biodiversity should address two basic questions: what to conserve and where? Considerable advances have been made regarding the latter. There is now a large battery of techniques that can identify the minimum set of areas required to fulfill specified conservation targets in an efficient and flexible manner (e.g. Margules *et al.* 1988, Rebelo and Siegfried 1992, Pressey *et al.* 1993, Lombard *et al.* 1992). However, most applications have focused on the representation of biodiversity pattern alone, only recently have there been attempts to additionally accommodate process goals in an explicitly spatial context (e.g. Baker 1992, Cowling *et al.* 1999).

With regard to what to conserve, there is still considerable debate on appropriate measures of biodiversity for conservation planning. Much attention has been given to the importance of taxonomic rank and character differences between species (e.g. Vane-Wright *et al.* 1991, Faith 1994). Only rarely are genealogical analyses used to provide spatially explicit recommendations for conservation planning that

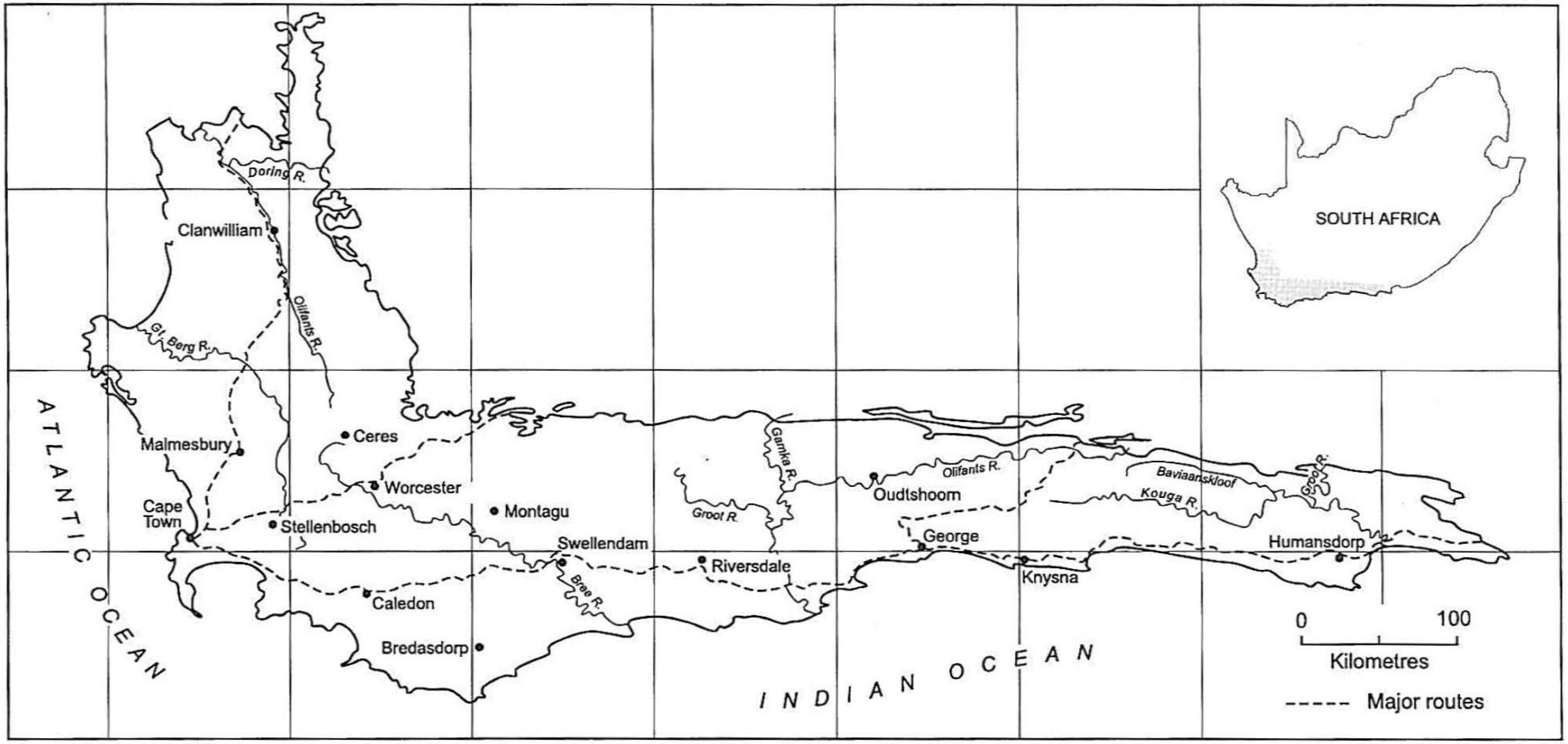

Figure 1: Map of Cape Floristic Region (CFR). The delimitation is based on Bond and Goldblatt (1984) with the outer boundary corresponding to the line of contact between fynbos and non-fynbos Broad Habitat Units (BHUs)

consider phylogenetic pattern as well as evolutionary processes (e.g. Linder 1995). Similarly, the discussion on land classes (environmental domains, vegetation types etc.) as surrogates for species- community- and ecosystem-level patterns (Kirkpatrick and Brown 1994, Faith and Walker 1996a) has seldom considered these higher order units as the framework for sustaining the ecological and evolutionary processes that maintain and generate taxa (Franklin 1993, Noss 1996).

In practice, much of the taxon-based debate on what to conserve is of academic interest. This is especially true of species-rich and poorly studied regions, where adequate species-level inventories, let alone cladograms, are lacking for even higher plants and vertebrates. Moreover, many of these regions lack land class maps that are sufficiently detailed for conservation planning. In these situations there is no alternative but to use surrogates for biodiversity (Margules and Austin 1991). These surrogates include higher taxon richness for characters (Williams and Humphrey 1994), indicator taxa for lesser known taxa (Rebelo and Siegfried 1990, Beccaloni and Gaston 1995) and environmentally characterised land classes for vegetation and species patterns (e.g. Kirkpatrick and Brown 1994). Moreover, even in countries such as South Africa with a relatively long history of botanical exploration (Gunn and Codd 1981), species-level databases are problematic. Most South African plant species data, including the PRECIS database, are stored at the quarter degree scale (QDS) (24 x 27km). Owing to the pronounced environmental heterogeneity of the CFR (Goldblatt 1978, Cowling *et al.* 1997), this scale is too crude for effective conservation planning (Rebelo 1992). Furthermore, most species-based data sets record only presence: the absence of a record does not imply that the species is not found in that area. Records have also been accumulated in an *ad hoc* manner (Margules and Austin 1994, Lawes and Piper 1998) resulting in biases towards favoured collecting localities (e.g. Gibbs Russell *et al.* 1984), and often have a large error in distribution records (Rebelo and Cowling 1991).

Nonetheless, binary plant species data have been used for conservation planning at the regional (Rebelo and Siegfried 1992, Lombard *et al.* 1997, 1999) and subcontinental scale (Rebelo 1994) in southern Africa. Using a standard iterative procedure, and the plant species (PRECIS) database, Rebelo (1994) showed that more than 90% of the QDS in the fynbos biome component of the CFR were required in a reserve system that conserved each plant species at least once. This result clearly reflects the very high compositional turnover along habitat (beta) and geographical (gamma) gradients in the CFR (Cowling *et al.* 1992). Within the CFR, Rebelo and Siegfried (1992) identified an optimal reserve system using an iterative procedure based on a data set comprising records for species of Proteaceae stored at the eighth degree scale. Although this data set was a considerable advance over PRECIS in attaining presence-absence status, the assumption that the Proteaceae are an effective indicator taxon for the CFR is untenable. For example, the Aizoaceae (including Mesembryanthemaceae) – the fourth largest familiy in the CFR – are concentrated in dry, lowland habitats (Hartmann 1991) that generally lack Proteaceae (Rebelo 1995). Therefore, the minimum set of complementary areas, selected on the basis of Proteaceae records only, will exclude sites important for the conservation of Aizoaceae (and other taxa concentrated in the arid, succulent-rich parts of the CFR). However, when area selection is based on entities (taxa or surrogates) that reflect the range of environmental features in a region, then the minimum set is more likely to be representative of the full spectrum of taxon diversity (Faith and Walker 1996b).

Another problem with the use of species data in conservation planning is that they may not be suitable for achieving process goals (Franklin 1993, Noss 1996, Lawes and Piper 1998). The accommodation of process goals often requires the establishment of large conservation areas that span long environmental gradients and encompass entire drainage basins (Graham 1988, Baker 1992, Halpin 1997, Cowling *et al.* 1999a, 1999b). Environmentally characterised land classes provide a better basis for identifying spatial surrogates for processes, and hence the establishment of a reserve system designed to achieve long-term persistence of biodiversity, than do disjunct populations of different species (Cowling *et al.* 1999a, Desmet *et al.* 1999)

Up until now the CFR has lacked a system of land classes as surrogates for biodiversity that are appropriate for conservation planning. The goal of such planning should be – in the absence of adequate species-, or genetic-level data – the achievement of explicit and defensible targets for the conservation of biodiversity pattern and process. We assume that by representing a threshold area of each land class (Faith and Walker 1996a), and by designing systems of conservation areas that span a diversity of land classes and, hence, encompass long environmental gradients, we will effectively conserve not only biodiversity patterns (ecosystems, species and genes), but also the processes that maintain and generate these (Cowling *et al.* 1999a). Moreover, such a conservation system is likely to afford a greater measure of resilience to climate change than one based purely on the representation of species (e.g. Graham 1988, Peters and Lovejoy 1992). Given the severity of the predicted impacts of climate change in the western, winter-rainfall sector of the CFR, consideration of this phenomenon in conservation planning is of paramount importance (Rutherford *et al.* 1999).

Although there are several region-wide vegetation classifications (Table 1, Figure 2), none covers environmental and associated floristic heterogeneity at a sufficiently fine scale for effective conservation planning (Kruger 1977, Rebelo 1997). The aim of this contribution is to present a system of land classes, termed Broad Habitat Units (BHUs), as biodiversity entities for conservation planning. The BHUs are essentially surrogates for plant biodiversity. They have been derived by intersecting coverages of physical data that are well-established correlates of plant species and vegetation patterns in the CFR. In addition to presenting a map[1] of the BHUs and listing their biophysical attributes, we also assess them in relation to existing vegetation coverages, discuss their potential as surrogates for biodiversity pattern and process in the CFR, and discuss some problems of scale.

[1] Owing to reduction for publication purposes the map, presented in Figures 3a and 3b, is intended only to provide a schematic impression of the distribution of the BHUs across the CFR. An A0-sized map in full colour is available from the Institute for Plant Conservation (rich@botzoo.uct.ac.za) at a nominal fee.

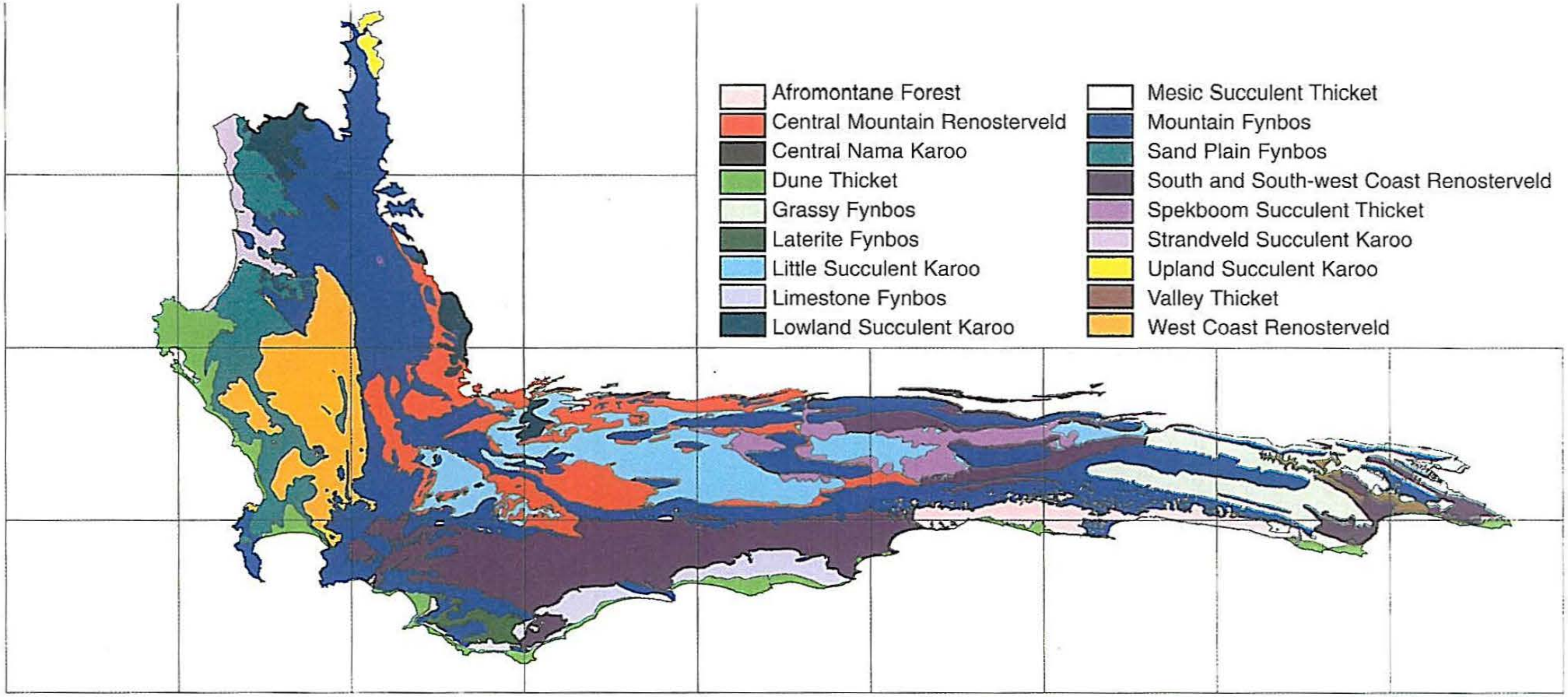

Figure 2: Map of Cape Floristic Region (CFR) showing the vegetation types of Low and Rebelo (1996)

Table 1: Vegetation typologies in and adjacent to the Cape Floristic Region and their relationship to primary classes of Broad Habitat Units (BHUs) described in this paper (see also text and Appendix 1). Numbers in brackets refer to number of secondary classes of BHUs within each primary class

Broad Habitat Units (this study) 1:250 000	Low and Rebelo (1996) 1:1000 000	Moll *et al.* (1984) 1:250 000	Acocks (1953) 1:1000 000
Fynbos biome			
Fynbos/Thicket Mosaic (6)	Dune Thicket	Dune Fynbos, South & West (in part) Coast Strandveld	Strandveld (Dense Scrub & Proper)
Sand Plain Fynbos (5)	Sand Plain Fynbos	Sand Plain Lowland Fynbos	Fynbos
Limestone Fynbos (3)	Limestone Fynbos	Limestone Lowland Fynbos	Fynbos
Grassy Fynbos (6)	Grassy Fynbos	Mesic & Dry Grassy Fynbos	False Fynbos
Fynbos/Renosterveld Mosaic (7)	Mountain Fynbos, S & SW Coast Renosterveld, Central Mountain Renosterveld, Laterite Fynbos, Grassy Fynbos	Mesic Mountain Fynbos, Mesic Grassy Fynbos, Elim Lowland Fynbos, W, SW & S Coast Renosterveld, Central Mountain Renosterveld	Mountain Renosterveld; Coastal Renosterveld
Coast Renosterveld (4)	W Coast Renosterveld, S & SW Coast Renosterveld	W, SW & S Coast Renosterveld	Coastal Renosterveld
Inland Renosterveld (10)	Central Mountain Renosterveld, Escarpment Mt. Renosterveld, S & SW Renosterveld	Central Mountain Renosterveld, SW Coast Renosterveld	Mountain Renosterveld
Mountain Complexes (30)	Mountain Fynbos, Central Mountain Renosterveld	Wet, Mesic & Dry Mountain Fynbos, Mesic & Dry Grassy Fynbos, Central Mountain Renosterveld	Fynbos, False Fynbos
Succulent Karoo biome			
Vygieveld (7)	Lowland Succulent Karoo, Upland Succulent Karoo	Karroid Shrublands	Succulent Karoo (Namaqualand, Tanqua), Western Mountain Karoo (Lower)
Strandveld (2)	Strandveld Succulent Karoo	W Coast Strandveld (in part)	Strandveld (Proper)
Broken Veld (7)	Upland Succulent Karoo, Little Succulent Karoo	Karroid Shrublands	Namaqualand Broken Veld (Typical), Karroid Broken Veld (Little Karoo, Great Karoo)
Nama Karoo biome			
Broken Veld (2)	Great Nama Karoo, Central Nama Karoo	Karroid Shrublands	Karroid Broken Veld (Great Karoo), Central Lower Karoo, Succulent Karoo (Steytlerville)
Thicket biome			
Mesic Succulent Thicket (4)	Mesic Succulent Thicket, Valley Thicket	Valley Bushveld	Valley Bushveld (Sundays & Gouritz)
Xeric Succulent Thicket (3)	Spekboom Succulent Thicket, Xeric Succulent Thicket	Valley Bushveld, Karroid Shrublands	Valley Bushveld (Addo), Spekboomveld
Forest biome			
Afromontane Forest (2)	Afromontane Forest	Afromontane Forest	Knysna Forest
Indian Ocean Forest (1)	Dune Thicket	Kaffrarian Thicket	Alexandria Forest

Methods

Data layers

The study used four data layers, described in Table 2 and depicted in Figure 2, to derive the BHUs in the planning domain. This domain was extended beyond the boundaries of the CFR since a requirement of effective conservation planning is to capture processes that transcend biophysical boundaries (Cowling *et al.* 1999a, 1999b).

Derivation of Broad Habitat Units

The BHUs were derived primarily from the intersection of boundaries within the physical themes, namely geology (as a surrogate for substratum), topography (as a surrogate for temperature) and climate. Analyses were performed in a geographical information system (ArcView Version 3.0, Environmental Systems Research Institute, Redlands CA). The factors considered here are the major determinants of most vegetation patterns within the CFR (Cowling and Holmes 1992, Cowling *et al.* 1997 and refs therein). However, they are often poor predictors of the distribution of forest and thicket vegetation, which is usually determined by factors that afford protection from recurrent fire (Geldenhuys 1994, Euston-Brown 1995).Therefore, polygons were initially derived on the basis of the coincidence of homogeneous areas of geology, climate and topography. These polygons

Table 2: Data layers that were used as themes in a geographical information system to derive Broad Habitat Units (BHUs) for the CFR

Theme	Scale	Description	Source
Geology	1:250 000	Digitised geology and lithology adapted from Geological Survey maps	Geology Department, University of Cape Town
Homogeneous Climate Zone	Various	Homogeneous zones based on precipitation statistics, aspect and topographical complexity	Dent *et al.* (1990)
Topography	1:250 000	400m interval digital terrain model	Chief Directorate of Surveys and Land Information, Mowbray
Vegetation	1:250 000	Homogeneous vegetation units	Low and Rebelo (1996)

were then intersected with the boundaries of the vegetation types. At this stage, adjustments to boundaries of some of the derived themes were made, based on more detailed studies of vegetation-environment relations within specific areas across the CFR (see refs in Appendix 1). Therefore, the BHUs are not entirely homogeneous with regard to the physical themes. For example, most Succulent Karoo, Thicket and Forest biome BHUs straddle a wide range of geologies (since substratum type is relatively unimportant in predicting their occurrence), and some lowland fynbos BHUs encompass high climatic diversity since they are delimited primarily on the basis of substratum.

The typology was arranged in a three-tier hierarchy: biomes (1st tier) > primary BHUs (2nd, e.g. Limestone Fynbos) > secondary BHUs (3rd, e.g. Hagelkraal Limestone Fynbos) (Appendix 1). The biomes correspond to those identified by Rutherford and Westfall (1986) whereas the primary BHUs correspond more-or-less with established schemes of vegetation types mapped at the subcontinental scale (Table 1). The secondary BHUs have no precedent at the CFR scale but do correspond to vegetation types mapped in some regional studies (e.g. Cowling *et al.* 1988, Rebelo *et al.* 1991).

Evaluation of the Broad Habitat Units

Since the BHUs were not solely derived from the intersection of themes, and some interpretation of patterns was required as a final step for delimitation, we subjected the BHU map to peer review. Responses were received from C Boucher (University of Stellenbosch), CJ Burgers (Western Cape Nature Conservation), N Fairall (University of Stellenbosch), R Knight (University of the Western Cape), A le Roux (Western Cape Nature Conservation), HP Linder (University of Cape Town), DJ McDonald (National Botanical Institute), AV Rebelo (National Botanical Institute) and J Vlok (private consultant).

Data presentation

The output of the analysis is presented in the form of a map (Figure 3). The largest scale at which the map can be used reliably is 1: 250 000. An A0 sized and full-colour version of the map, a size suitable for ecological and environmental research, is available from the Institute for Plant Conservation (see footnote 1). We have not provided detailed descriptions of the biological and physical attributes of each of the BHUs. Instead, we refer readers to the references listed in Appendix 1, as well as to the broad-scale vegetation treatments referenced in Tables 1 and 3.

Some descriptive data (area, geology, climate, topography) for each BHU are presented in Appendix 1. These data were derived directly from the themes used to identify the BHUs (Table 2). In addition, we present available data for BHUs on the number of communities recognised, using formal phytosociological methods, within specified sampling areas.

Table 3: Number of structurally characterised communities and dominant higher order vegetation types in Broad Habitat Units (BHUs) sampled by Campbell (1995). Data for the Cape Peninsula are from Simmons (1996). All BHUs are Mountain Complexes. They are arranged according to Campbell's mountain regions (shown in boldface)

BHU	No. comm.	Dominant[1] vegetation types
North-Western		
Cederberg	17	Restioid Fynbos; Asteraceous Fynbos
Groot Winterhoek	19	Restioid Fynbos; Asteraceous Fynbos
Central		
Matroosberg	17	Restioid Fynbos
Hawequas	18	Proteoid Fynbos; Restioid Fynbos
South-Western		
Cape Peninsula	12	Proteoid Fynbos
Kogelberg	17	Restioid Fynbos; Ericaceous Fynbos
Riviersonderend	10	Restioid Fynbos; Proteoid Fynbos
Southern Interior		
Swartruggens	6	Asteraceous Fynbos; Karroid & Renoster Shrubland
Witteberg	7	Asteraceous Fynbos
Rooiberg	16	Asteraceous Fynbos; Proteoid Fynbos
Groot Swartberg	22	Restioid Fynbos; Proteoid Fynbos
Kamanassie	14	Asteraceous Fynbos
Kouga	22	Proteoid Fynbos
Southern Coastal		
Southern Langeberg	17	Restioid Fynbos; Proteoid Fynbos
Outeniqua	21	Proteoid Fynbos
Tsitsikamma	13	Proteoid Fynbos; Ericaceous Fynbos
Eastern		
Baviaanskloof	8	Grassland and Grassy Shrubland;
Cockscomb	16	Grassy Fynbos; Proteoid Fynbos Grassland and Grassy Shrubland

[1] >20% of plots sampled in each BHU

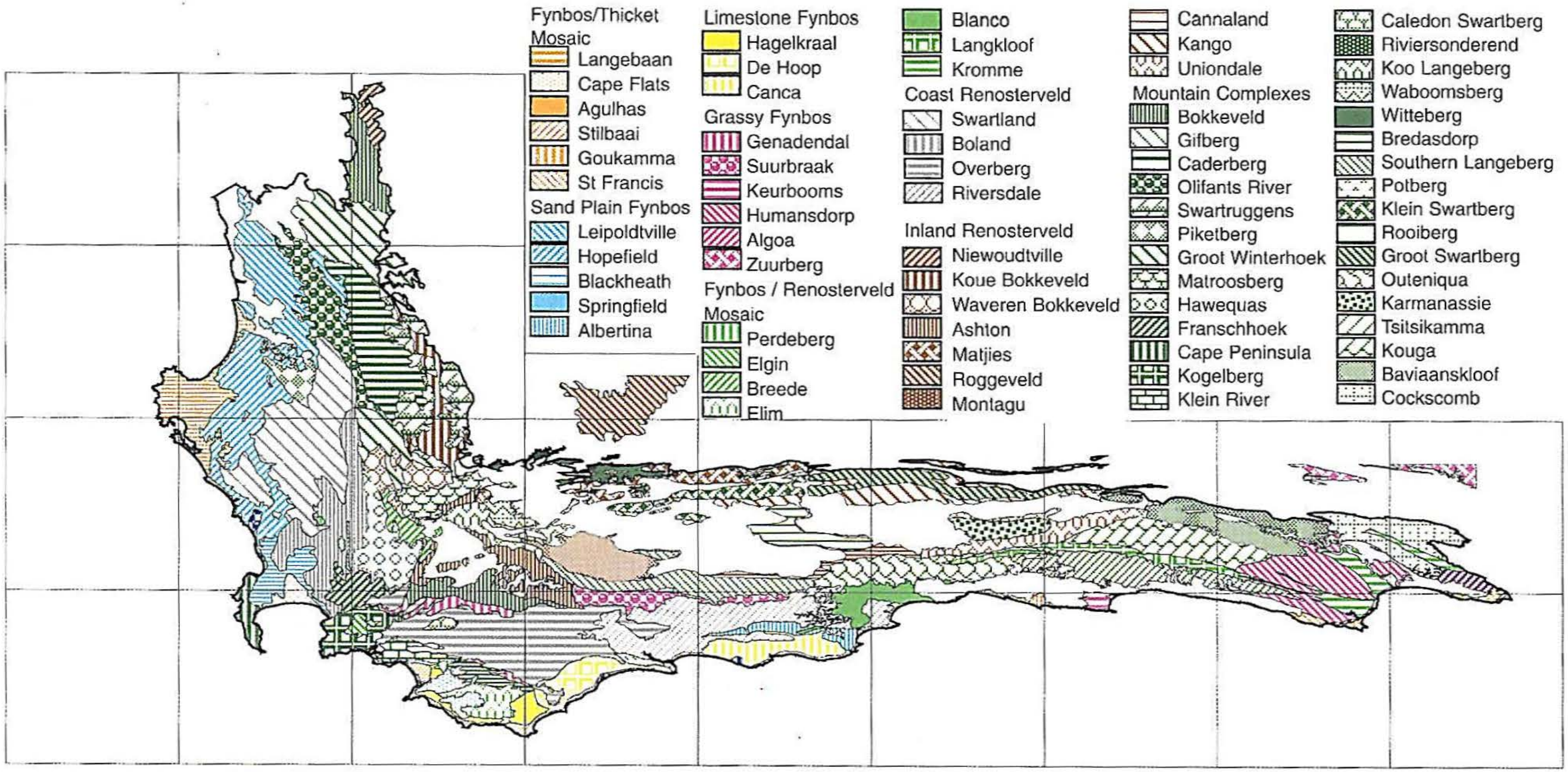

Figure 3a: Map showing Broad Habitat Units (BHUs) in the entire planning domain identified for the fynbos biome

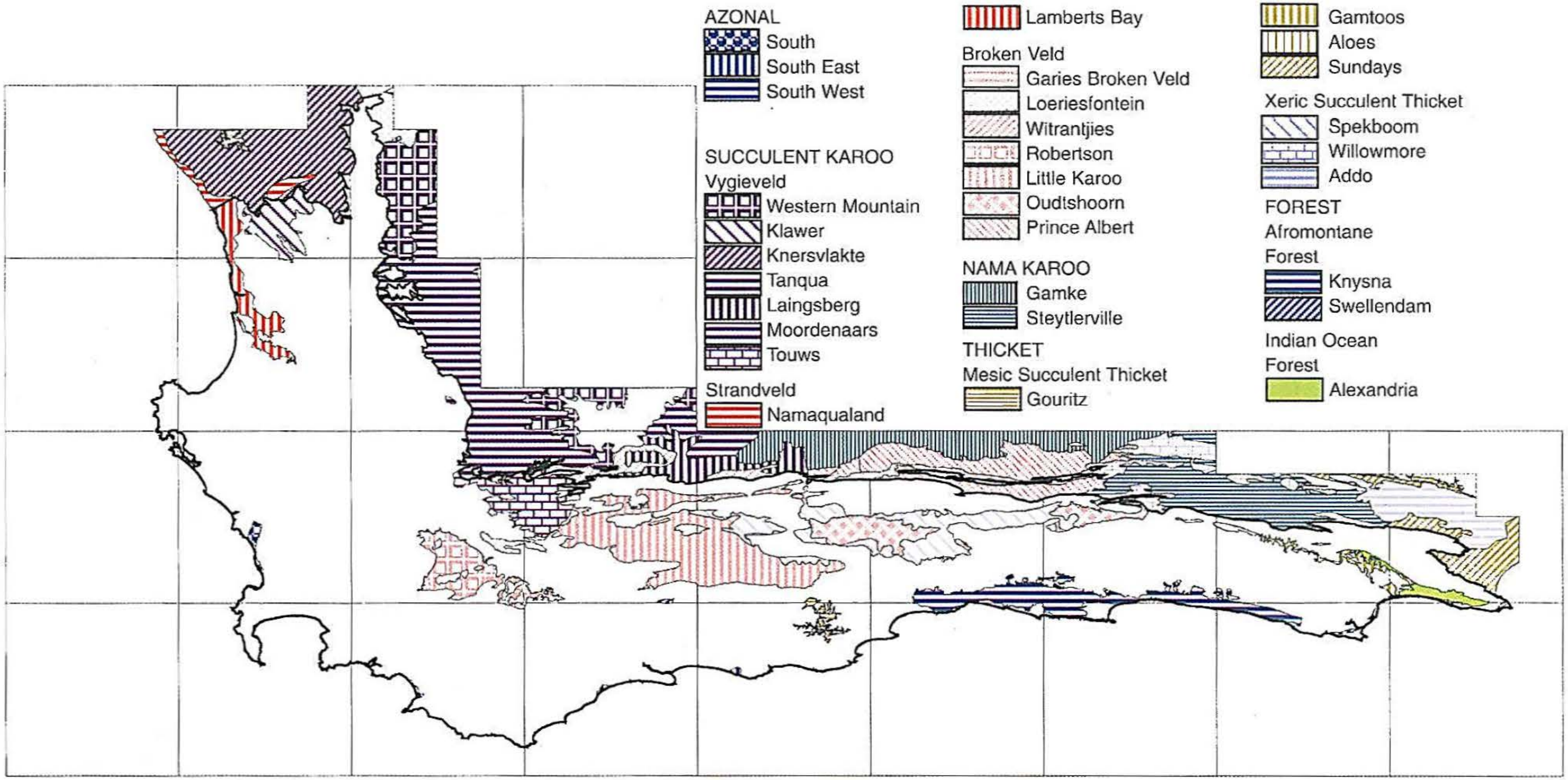

Figure 3b: Map showing Broad Habitat Units (BHUs) in the entire planning domain identified for the forest, Nama-karoo, succulent karoo and thicket biomes

Results and Discussion

We recognised 16 primary and 102 secondary BHUs in the planning domain (122 590 km²), and 15 primary and 88 secondary BHUs in the CFR (87 892 km²) (Figure 3, Appendix 1). Within the CFR, the Fynbos biome covered the largest area (81.5%) and included the highest number of primary (8) and secondary (69) BHUs (Table 4). The second largest biome in the CFR is the Succulent Karoo (12.0%), followed by Thicket (3.4%) and Forest (2.8%). The Nama Karoo biome is not represented in the CFR. Within the Fynbos biome (71 672 km²) Mountain Complexes covered the largest area (33.5%), followed by Coast Renosterveld (15.9%) and Inland Renosterveld (10.4%) BHUs. Lowland fynbos BHUs – Fynbos/Thicket Mosaic, Sand Plain Fynbos, Limestone Fynbos, Grassy Fynbos and Fynbos/Renosterveld Mosaic – together covered 21.6% of the CFR.

Generally, most respondents supported the delineation. However, as a result of the external assessment, we identified four additional BHUs (24. Perdeberg, 52. Matroosberg, 58. Caledon Swartberg and 61. Waboomsberg), and minor changes were made to some BHU boundaries. Other substantive comments made by the respondents are dealt with below, some of these (e.g. the absence of a floristically-based hierarchy) cannot be accommodated within the scope of this study.

Comparison with CFR vegetation classifications

It is important to stress that the BHUs are not actual vegetation types but surrogates for these. Nonetheless, as mentioned above, the physical factors used in the delimitation are good predictors of most vegetation patterns in the CFR. Therefore, it is not surprising that there was generally good correspondence between primary BHUs and the vegetation typologies of Moll *et al.* (1984) and Low and Rebelo (1996). However, our system differed from these in a number of ways. These differences are discussed below.

We treated vegetation on calcareous coastal sands within the CFR differently to previous studies, and mapped it as a Fynbos/Thicket Mosaic. Moll *et al.* (1984) mapped this habitat as Dune Fynbos and Strandveld, although a limited area of 'Dune Fynbos and Kaffrarian Thicket' mosaic is mapped on the south coast. Low and Rebelo (1996) mapped most of this habitat as Dune Thicket, a component of the Thicket biome. Although vegetation on lime-rich coastal sands in the CFR is phytochorologically complex, the Cape element predominates at the landscape level in terms of both species and endemics (Cowling 1984, 1990).

We also recognised a Fynbos/Renosterveld Mosaic, a lowland unit associated with moderately fertile, usually fine-grained soils, at relatively high rainfall. Under these conditions, fynbos may occupy more mesic sites, and renosterveld more xeric sites, at a very fine grain (certainly not mappable at 1: 250 000 scale). Alternatively, heavy grazing and inappropriate burning regimes may result in the conversion of fynbos to renosterveld. This mosaic structure has been described by Cowling (1984) in the Humansdorp area (30. Kromme), by Boucher (1987) on the West Coast forelands (24. Perdeberg), and by Cowling *et al.* (1988) on the Agulhas Plain (27. Elim). Both Moll *et al.* (1984) and Low and Rebelo (1996) have mapped this mosaic as either fynbos or renosterveld (Table 1).

Another departure from previous vegetation treatments is our assessment of Grassy Fynbos. We mapped BHUs corresponding to this concept as far west as Houwhoek on the south-western coastal forelands, whereas both Moll *et al.* (1984) and Low and Rebelo (1996) restrict Grassy Fynbos to the eastern parts of the CFR. However, habitats characterised by colluvial soils derived from softer Cape sandstones, and shale-derived soils on the lower slopes and pediments at the foot of the Langeberg, Riviersonderend and minor coastal ranges, support the western equivalent of Grassy Fynbos (18. Genadendal, 19. Suurbraak) (see also Campbell 1985 and Rebelo *et al.* 1991).

Our treatment of the Succulent Karoo biome introduces a new concept, namely the Vygieveld BHU. This habitat supports a dwarf, open shrubland dominated by leaf-succulent members of the Aizoaceae. Within and adjacent to the CFR, Vygieveld is invariably associated with areas of low (50-220 mm yr⁻¹) winter rainfall, and shallow soils (Cowling and Pierce 1999). It corresponds more-or-less to Low and Rebelo's (1996) Lowland Succulent Karoo. Vygieveld penetrates into the CFR along the lower Olifants River Valley (76. Klawer), at the western edges of the Tanqua Basin (78. Tanqua), and in the Touws River Basin (81. Touws).

Perhaps the most controversial aspect of our typology is the recognition of 30 Mountain Complexes that encompass the impressive fynbos plant biodiversity of the Cape mountains. Previously, Moll *et al.* (1984) recognised five fynbos types (three forms of Mountain Fynbos and two forms of

Table 4: Area of biomes and primary Broad Habitat Units (BHUs) (see Appendix 1) within the Cape Floristic Region (CFR). Numbers in brackets refer to number of secondary classes of BHUs within each primary class

Units	Area(km²)	% of CFR	Units	Area(km²)	% of CFR
Fynbos biome	71 672	81.5	**Succulent Karoo biome**	10 587	12.0
Fynbos/Thicket Mosaic (6)	2 995	3.4	Vygieveld (3)	2 331	2.6
Sand Plain Fynbos (5)	6 771	7.7	Strandveld (1)	963	1.1
Limestone Fynbos (3)	2 068	2.3	Broken Veld (4)	7 293	8.3
Grassy Fynbos (5)	3 656	4.2	**Thicket biome**	2 974	3.4
Fynbos/Renosterveld Mosaic (7)	3 532	4.0	Mesic Succulent Thicket (3)	531	0.6
Coast Renosterveld (4)	13 990	15.9	Xeric Succulent Thicket (1)	2 443	2.8
Inland Renosterveld (9)	9 185	10.4	**Forest biome**	2 454	2.8
Mountain Complexes (30)	29 475	33.5	Afromontane Forest (2)	2 097	2.4
			Indian Ocean Forest (1)	357	0.4

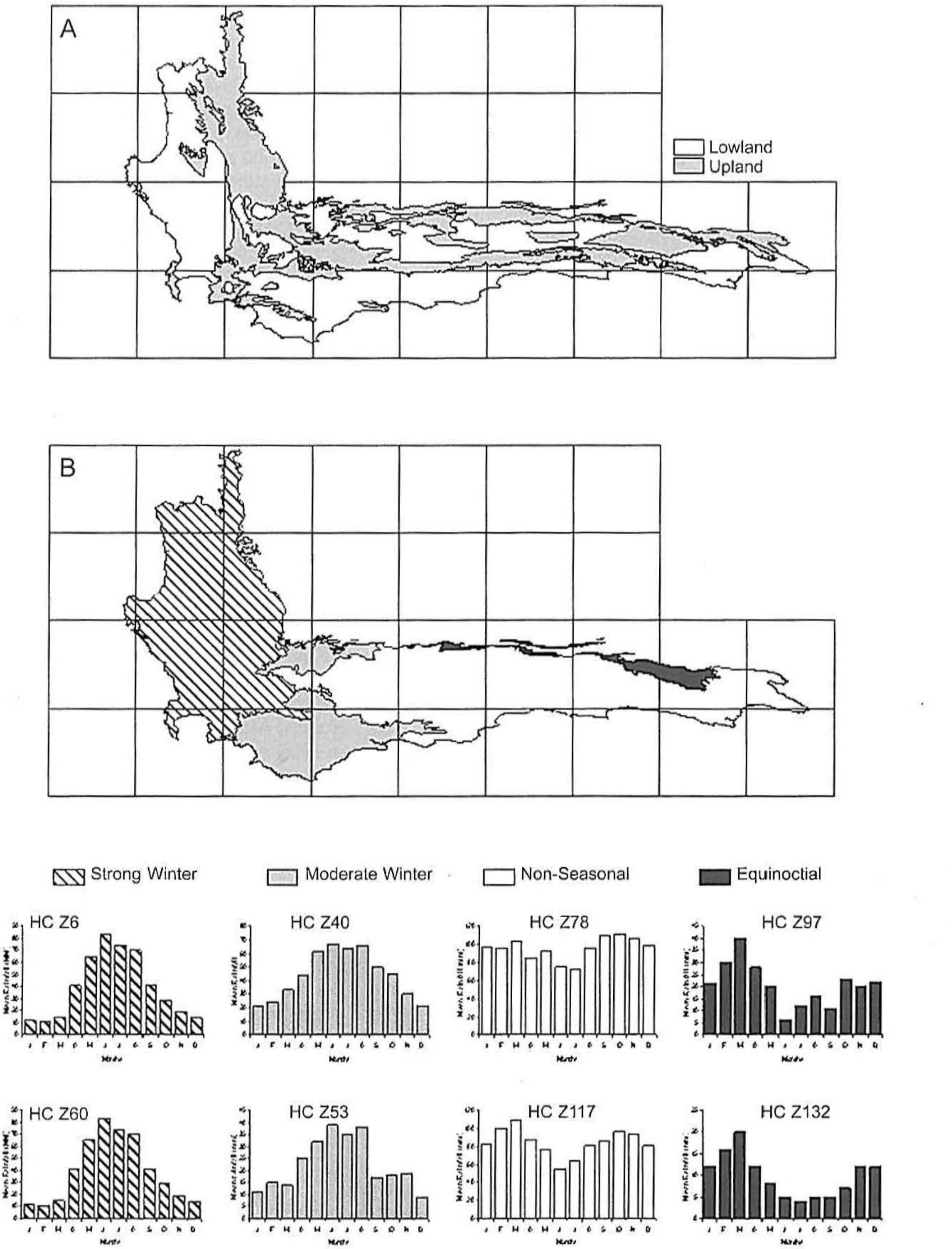

Figure 4: Subdivision of Broad Habitat Units (BHUs) in the Cape Floristic Region (CFR) according to a) lowland/upland topographical categories, and b) rainfall seasonality patterns. Also shown are monthly rainfall diagrams showing seasonality patterns typical of strong-winter (Homogeneous Climate Zones (HCZ) 6 and 60), moderate-winter (HCZ 40 and 53), non-seasonal (HCZ 78 and 117) and equinoctial (HCZ 97 and 132) regimes

Grassy Fynbos) in CFR montane habitats. Campbell (1985) identified seven mountain regions in the CFR, the boundaries of which coincide with Mountain Complex boundaries (Table 3). Between 8 and 22 structurally characterised communities were recognised by Campbell (1985) within Mountain Complexes that he sampled (Table 3). Low and Rebelo (1996), however, mapped almost all of the Cape mountains as Mountain Fynbos (Figure 1).

Reviewers of our scheme have suggested that montane habitats harbour considerably greater environmental heterogeneity, and hence plant biodiversity than adjacent lowland habitats, therefore, montane environments should be subject to a finer-scale subdivision than those of the lowlands (see also Linder 1991). Although there was considerable homogeneity within Mountain Complexes in terms of geology (predominantly Table Mountain Group rocks) and climate, the latter must be treated with caution since Cape mountains are poorly covered by climate stations (Campbell 1983). Interestingly, community richness (see Appendix 1) was not significantly different between lowland and montane habitats (Figure 4a) across the CFR, however, regional plant richness of montane habitats was significantly higher than lowland habitats in the winter rainfall region of the CFR (Figure 4b), but this was not the case in the non-seasonal region (RM Cowling, unpublished data). Thus, there appear to be no consistent differences in plant biodiversity between montane and lowland habitats in the CFR.

Representation of pattern

There are many advantages of using habitat-based surrogates for biodiversity in conservation planning, especially when species-based data are lacking or are spatially or taxonomically biased (Margules and Austin 1991, Faith and Walker 1996b). Most importantly, land class classifications – such as the BHU scheme presented here – comprise a presence-absence data set. Therefore, reserve systems identified on the basis of explicit targets for the representation of biodiversity pattern will not be spatially biased in favour of data-rich areas. Furthermore, in areas such as the CFR, where biodiversity patterns are characterized by very high compositional change along habitat and geographical gradients, species-based methods are extremely land-hungry (Rebelo 1997, Lombard *et al.* 1999). The relative efficiency (in terms of land requirements) of taxon- and land class-based conservation planning, does however, remain to be tested. Finally, by setting targets for the representation of every land class, the resultant reserve system will include examples of habitats that lack charismatic, species-based features, e.g. some of the renosterveld and eastern fynbos BHUs.

A disadvantage of using land classes such as BHUs as sole entities for representation is that many species (and other taxa) may fall through the cracks in this 'coarse filter' (Noss 1987), especially if hot spots of biodiversity and endemism are missed (Kirkpatrick and Brown 1994). The extent to which the achievement of conservation targets for land classes is effective for conserving populations of taxa occurring in those classes is a function of both the extent and location of the resultant reserve system. There is no general consensus on targets as expressed as a proportion of a land class. Van Jaarsveld and Chown (1996) recommend the adoption in South Africa of the Caracas Action Plan target (IUCN 1993), namely to represent 10% of each vegetation type (or other land class) in the reserve system (see also Rebelo 1997). Higher targets have been mooted, for example the Brundtland Commission recommended 12% (Brundtland 1987) whereas 15% is the agreed baseline target for Australian forests (Pressey *et al.* 1997), Noss and Cooperrider (1994) suggest baseline targets of between 25 and 75% for certain ecosystems. A major problem with uniform targets is the implicit assumption that all land classes have the same conservation value. However, this is not normally the case. For example, there is a much higher concentration of species, including Red Data Book taxa, in western than eastern BHUs (Figure 5). The application of uniform targets across all BHUs in the CFR would not be consistent with a conservation goal that seeks to represent all biodiversity pattern (ecosystems, species, genes) in the reserve system. Differential patterns in species diversity can, however, be accommodated by setting different baseline targets for land classes. For example, based on known species-area patterns, Cowling *et al* (1999b) set 2.5-fold and 1.5-fold higher baseline targets for western montane and western lowland BHUs, respectively, than eastern BHUs, irrespective of topographical locality. The extent to which the resultant notional reserve system, which is based on the achievement of these differential BHU targets (Cowling *et al.* 1999b), is actually effective for species conservation, remains to be tested.

Representation of process

If the biodiversity in reserve systems is to persist, these systems should not only represent biodiversity patterns but also the processes that maintain and produce them (Noss 1987, Graham 1988, Baker 1992, Halpin 1997, Cowling *et al.* 1999a). Reserve systems identified on the basis of biased records of subsets of biotas are unlikely to achieve process goals. For example, the persistence of biological migrations, the maintenance of whole-catchment hydrological processes, or the continuance of lineage diversification, will all require the conservation of juxtaposed land classes nested within entire landscapes (Noss 1987, Cowling *et al.* 1999a). The big challenge is to design for persistence by establishing reserve systems that will allow ecosystems to change, not only at the rate at which change has occurred in the past, but in response to the accelerated pace that the globe is now experiencing (Lawton 1997, Rutherford *et al.* 1999). Land classes such as BHUs are essential biodiversity entities in conservation plans that have persistence as a goal. This is because individual units and, especially, juxtaposed complexes of units are good spatial surrogates for ecological and evolutionary processes (Noss 1996, Lawes and Piper 1997). For example, the CFR BHUs are good predictors of the diversity of large mammal processes that can be sustained (Boshoff and Kerley 1999). As we argue below, they are also an essential component of the ecological hierarchy that underpins the genealogical hierarchy in the CFR. Diversification of many plant lineages in the CFR is largely

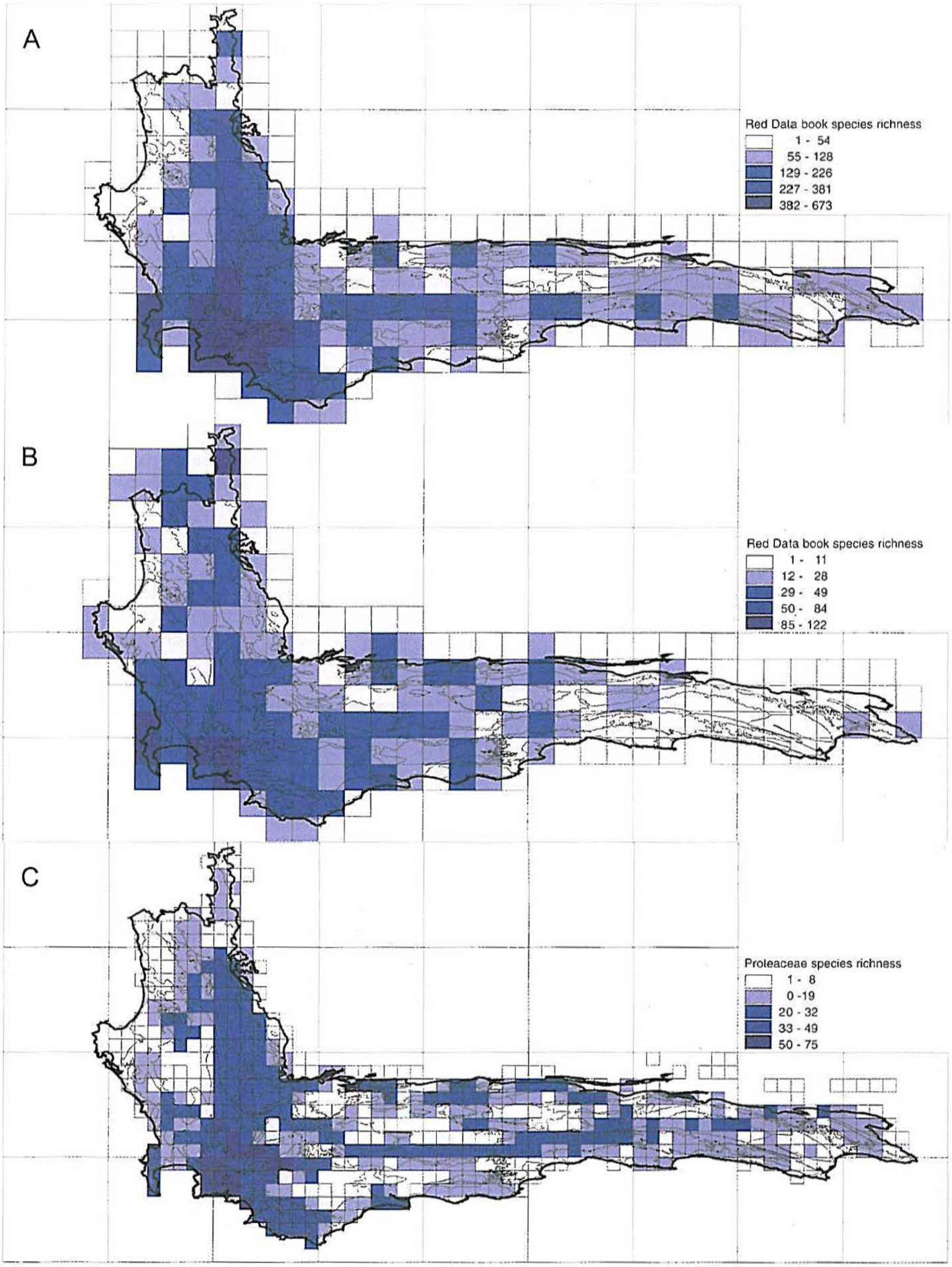

Figure 5: Map of Broad Habitat Units (BHUs) with superimposed patterns of species richness of a) Red Data Book taxa, plus all (additional) species of *Aspalathus*, Bruniaceae, Ericaceae, Geissolomaceae, Grubbiaceae, *Muraltia*, Penaeaceae, Proteaceae, Restionaceae and Stilbaceae comprising 3298 species and 24 438 records at the quarter degree scale (QDS), b) Red Data Book taxa comprising 1588 species and 4949 records at the QDS and c) Proteaceae comprising 347 species and 9632 records at the eighth degree scale

the response to fine-scale differences in soil nutrient and moisture status (Linder 1985, Cowling 1987). Evidence for this process comes from lineages in several families, including Proteaceae (Rourke 1972), Restionaceae (Linder and Vlok 1991, Linder and Mann 1998), Fabaceae (Schutte *et al.* 1995), Orchidaceae (Linder 1995) and Iridaceae (Goldblatt and Manning 1996). There is also good evidence that the boundaries between winter and non-seasonal rainfall zones, and between high and low zones at least within the winter rainfall zone, are important not only as determinants of contemporary distributions (e.g Weimarck 1941, Nordenstam 1969, Williams 1972, Oliver *et al.* 1983), but also reflect evolutionary patterns (Bruyns and Linder 1991, Cowling *et al.* 1992, Manning and Linder 1992, Linder and Mann 1998, Ojeda 1998). Furthermore, older surfaces of the uplands harbour basal taxa, whereas species with derived traits within the same lineage are endemic to younger surfaces on the lowlands (Linder 1995). If these evolutionary processes are to be maintained, then it is important not only to conserve lineages with evolutionary potential (Brooks *et al.* 1992, Linder 1995, Desmet *et al.* 1999), but also the habitats that provide the template for speciation. In this respect, BHUs are appropriate surrogates.

Finally, since it will not be possible to include many large-scale ecological processes (e.g. whole-catchment hydrological processes and top predator-herbivore interactions, both of which will require in excess of 500 000ha for their maintenance) within the areas designated for strict reservation (Franklin 1993, Cowling *et al.* 1999a), the identification of spatial surrogates for these processes, namely juxtaposed complexes of BHUs, will enable the identification priorities for off-reserve management.

Problems of scale

When land classes such as BHUs are regarded as biodiversity entities in conservation planning, they are invariably scored for their conservation value or irreplaceability, usually based on their contribution to achieving a reservation target (Pressey *et al.* 1994). When this measure of value is combined with vulnerability to transformation (e.g. urbanisation or land clearance), it is possible to rank the classes according to priority for conservation action: classes with the highest combined scores are the top priorities (Pressey *et al.* 1997).

Two scale-related problems arise with relatively large-scale classes, such as the BHUs, especially those that encompass considerable environmental heterogeneity (see Appendix 1). First, low-priority parts of high-priority regions (e.g. steep, rocky slopes in renosterveld) are targeted for protection, second, high-priority parts of low-priority regions (e.g. threatened, endemic-rich wetlands in well-conserved Mountain Complexes) are often ignored (R.L. Pressey pers. comm.). What is required to overcome these scale-related problems is a finer-scale assessment of threats for all BHUs, irrespective of their irreplaceability.

Conclusions

Owing to deadlines associated with the CAPE Project, the system of BHUs presented in this study was produced over a period of thee months, including the external review. The units were derived in a GIS from the intersection of data layers derived from decades of research and monitoring. Modern computing facilities enable the use of existing data to derive products in an extremely cost-effective manner.

The fact that none of the previous CFR-wide treatments (Acocks 1953, Moll *et al.* 1984, Campbell1985, Low and Rebelo 1996) has produced a map at a scale fine enough for effective conservation planning, suggests that this is not a trivial task. We do not claim that our treatment is perfect, the extent to which the achievement of targets for the representation of BHUs is effective for the representation of taxa remains to be tested. We stress, however, that the map is only suitable for planning at the scale of 1:250 000 or greater. For effective implementation, the conservation system thus identified must be subject to finer-scale planning probably at the 1:50 000 scale or less.

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Appendix 1: Broad Habitat Units (BHUs) identified for the planning domain (including the Cape Floristic Region) (see Figure 1) and mapped at a 1:250 000 scale (Figure 3). Primary units are shown in boldface italics; secondary units are numbered. Shown here are the biological and environmental characteristics (vegetation type, geology, Homogeneous Climate Zones (HCZ) and altitude - themes in a geographical information system) that were used to delineate the BHUs. Only those features in themes, collectively covering 75% of each secondary BHU, are shown. The ruggedness index (RI) of a BHU is the standard deviation of all spot heights within a digital terrain model. See text for details on the derivation of themes and explanation of sources of plant community data. M = moderate, S = strong (winter rainfall), NA = data not available. BHUs not represented in the CFR are shown in italics

BHU	Vegetation type (sensu Low & Rebelo 1996)	Geology	Area (km²) (%)	HCZ No.	Rainfall characteristics: Mean mmyr⁻¹	Rainfall characteristics: Seasonality	Topography: Altitudinal range (m)	Topography: Modal altitude(m)	Topography: RI	Plant community data: No. communities (no plots) [area (km²)]	Plant community data: References
AZONAL											
Dune Pioneer											
1. South West	Dune Thicket	Alluvium, sand & calcrete	120 (0.1)	5	366	S winter	0-192	100	58.4	NA	Boucher & Le Roux (1993)
2. South	Dune Thicke	Alluvium, sand & calcrete	58 (<0.1)	83	438	Non seasonal	0-179	100	50.9	NA	Taylor & Boucher (1993)
				137	684						
		Breadasdorp		47	318						
3. South East	Dune Thicket	Alluvium, sand & calcrete	28 (<0.1)	139	755	Non seasonal	0-143	100	28.1	NA	Weisser & Cooper (1993)
				140	647						
		Nanaga		136	512						
FYNBOS BIOME											
Fynbos/ Thicket Mosaic											
4. Langebaan	Dune Thicket	Alluvium, sand & calcrete	783 (0.6)	24	230	S winter	0-256	100	39.0	24 (157)	Boucher (1987)
		Bredasdorp		22	314					[ca 250]	
5. Cape Flats	Dune Thicket	Alluvium, sand & calcrete	267 (0.2)	6	472	S winter	0-73	500	16.7	11 (60)	Boucher (1987)
										[ca 175]	
6. Agulhas	Dune Thicket	Bredasdorp	492 (0.4)	46	470	M winter	0-237	100	40.8	NA	Cowling *et al.* (1988)
		Alluvium, sand & calcrete		43	528						
7. Stilbaai	Dune Thicke	Alluvium, sand & calcrete	230 (0.2)	47	318	Non seasonal	0-203	100	47.5	NA	Rebelo *et al.* (1991)
	S & SW Coast Renosterveld			84	362						
		Bredasdorp		83	438						
8. Goukamma	Dune Thicket	Alluvium, sand & calcrete	142 (0.1)	116	728	Non seasonal	0-273	100	62.5	NA	Van der Merwe (1976)
9. St Francis	Dune Thicket	Nanaga	259 (0.2)	137	684	Non seasonal	0-246	100	44.7	4 (42)	Cowling (1982)
				139	755					[ca 220]	
Sand Plain Fynbos											
10. Leipoldtville	Sand Plain Fynbos	Alluvium, sand & calcrete	2111 (1.7)	26	184	S winter	0-560	300	72.6		
	Mountain Fynbos	Graafwater & Piekenierskloof		27	266						
11. Hopefield	Sand Plain Fynbos	Alluvium, sand & calcrete	2976 (2.4	22	393	S winter	0-411	100	44.6	16 (139)	Boucher (1987)
				24	472					[ca 345]	
12. Blackheath	Sand Plain Fynbos	Alluvium, sand & calcrete	796 (0.6)	7	605	S winter	0-594	100	57.7	6 (20)	Boucher (1987)
				6	472					[ca 110]	
	Tygerberg			5	366						
				25	625						
13. Springfield	Mountain Fynbos	Peninsula, Nardouw	440 (0.4)	43	528	M winter	2-485	300	88.4	3 (42)	Richards *et al.* (1995)
	Laterite Fynbos	Cedarberg & Pakhuis								[0.15]	
										NA	Cowling *et al.* (1988)
14. Albertinia	Limestone Fynbos	Alluvium, sand & calcrete	448 (0.4)	84	362	Non seasonal	0-331	200	62.3	NA	Rebelo *et al.* (1991)
	S & SW Coast Renosterveld		83	438							

BHU	Vegetation type (sensu Low & Rebelo 1996)	Geology	Area (km²) (%)	HCZ No.	Rainfall characteristics Mean mmyr⁻¹	Seasonality	Topography Altitudinal range (m)	Modal altitude(m)	RI	Plant community data No. communities (no plots) [area (km²)]	References
Limestone Fynbos											
15. Hagelkraal	Limestone Fynbos	Bredasdorp	440 (0.4)	46	470	M winter	0-330	100	55.5	2 (33)	Richards *et al.* (1995)
	S & SW Coast Renosterveld									[0.15]	
										NA	Cowling *et al* (1988)
16. De Hoop	Limestone Fynbos	Bredasdorp	776 (0.6)	47	318	M winter	0-277	200	61.8		
17. Canca	Limestone Fynbos	Bredasdorp	852 (0.7)	83	438	Non seasonal	0-307	200	53.4	NA	Rebelo *et al.* (1991)
	Dune Thicket										
Grassy Fynbos											
18. Genadendal	Mountain Fynbos	Witpoort & Weltevrede	489 (0.4)	39	417	M winter	64-735	400	100.5		
	S & SW Coast Renosterveld	Ceres		40	528						
		Peninsula		45	466						
19. Suurbraak	S & SW Coast Renosterveld	Bokkeveld	742 (0.6)	79	638	Non seasonal	49-400	300	72.7	NA	Grobler & Marais (1967)
		Enon		81	528					NA	Rebelo *et al.* (1991)
20. Keurbooms	Mountain Fynbos	Enon, Peninsula, Nardouw	141 (0.1)	119	1115	Non seasonal	0-329	100	74.1		
		Cedarberg & Pakhuis									
21. Humansdorp	Grassy Fynbos	Peninsula, Nardouw	1987 (1.6)	137	684	Non seasonal	0-962	500	162.8	6 (42)	Cowling (1982)
	Mountain Fynbos	Cedarberg & Pakhuis		136	512					[ca 175]	
22. Algoa	S & SW Coast Renosterveld	Peninsula, Nardouw	297 (0.2)	140	647	Non seasonal	34-477	200	59.1		
	Grassy Fynbos	Cedarberg & Pakhuis		139	755						
23. *Zuurberg*	Xeric Succulent Thicket	Witpoort & Weltevrede	477 (0.4)	132	248	Equinoctial	152-1020	800	165.8		
	Central Nama Karoo	Kommadagga & Lake Mentz		145	737						
	Grassy Fynbos										
Fynbos / Renosterveld Mosaic											
24. Perdeberg	Mountain Fynbos	Cape Granite Suite	44 (<0.1)	19	855	S winter	151-722	600	120.8		
				31	647						
25. Elgin	S & SW Coast Renosterveld	Ceres	136 (0.1)	14	659	S winter	109-625	200	65.2		
	Mountain Fynbos	Bidouw									
26. Breede	Central Mountain	Alluvium, sand & calcrete	378 (0.3)	36	589	S winter	186-486	300	32.5		
	Renosterveld			50	263						
27. Elim	Laterite Fynbos	Ceres	594 (0.5)	46	470	M winter	6-404	300	51.6	NA	Cowling *et al.* (1988)
		Malmesbury		43	528						
28. Blanco	S & SW Coast Renosterveld	Cape Granite Suite, Enon	1689 (1.4)	85	509	Non seasonal	0-472	200	78.8		
		Kaaimans, Grahamstown		86	645						
29. Langkloof	Grassy Fynbos	Nardouw,	783 (0.6)	121	422	Non seasonal	304-1261	600	176.0		
	Mountain Fynbos	Cedarberg & Pakhuis		114	476						
		Ceres		120	523						
30. Kromme	S & SW Coast Renosterveld	Ceres	846 (0.7)	136	512	Non seasonal	0-731	300	126.7	3 (27)	Cowling (1982)
		Enon		137	684					[ca 375]	

BHU	Vegetation type (sensu Low & Rebelo 1996)	Geology	Area (km^2) (%)	HCZ No.	Rainfall characteristics: Mean $mmyr^{-1}$	Rainfall characteristics: Seasonality	Topography: Altitudinal range (m)	Topography: Modal altitude(m)	Topography: RI	Plant community data: No. communities (no plots) [area (km^2)]	Plant community data: References
Coast Renosterveld											
31. Swartland	West Coast Renosterveld	Moorreesburg	4113 (3.4)	22	314	S winter	0-518	100	61.7	11 (42)	Boucher (1987)
		Porterville		27	266					[ca 420]	
		Cape Granite Suite		21	393						
		Porseleinberg									
32. Boland	West Coast Renosterveld	Porterville	2417 (2.0)	30	460	S winter	6-1288	300	101.2	16 (66)	Boucher (1987)
		Cape Granite Suite		7	605					[ca 480]	
		Moorreesburg		32	470						
		Tygerberg		5	470						
		Porseleinberg		31	647						
				33	607						
				34	748						
33. Overberg	S & SW Coast Renosterveld	Bokkeveld	4297 (3.5)	48	384	M winter	0-515	300	81.5	3 (23)	Kemper (1997)
		Bidouw		39	417					[49]	
		Ceres		47	318						
				44	378						
34. Riversdale	S & SW Coast Renosterveld	Bokkeveld	3163 (2.6)	47	318	Non seasonal	0-375	200	59.4	NA	Rebelo *et al.* (1991)
		Bredasdorp		82	454						
				84	362						
Inland Renosterveld											
35. Nieuwoudtville	Upland Succulent Karoo	Knersvlakte, Dwyka, Nardouw	322 (0.3)	202	339	S winter	306-835	600	122.5		
		Cedarberg & Pakhuis									
36. Koue-bokkeveld	Central Mountain Renosterveld	Witpoort & Weltevrede	985 (0.8)	61	377	S winter	427-1851	1000	210.6		
		Bidouw, Ceres		56	650						
37. Waveren-Bokkeveld	Central Mountain Renosterveld	Brandwacht	803 (0.7)	56	650	S winter	91-1323	600	264.8		
		Ceres		55	378						
				54	954						
38. Ashton	Central Mountain Renosterveld	Bokkeveld	1267 (1.0)	49	266	M winter	79-1306	300	172.4		
		Malmesbury		51	322						
		Witpoort & Weltevrede		50	263						
		Ceres, Nardouw		48	384						
		Cedarberg & Pakhuis		52	496						
39. Matjies	Central Mountain Renosterveld	Witpoort & Weltevrede	1141 (0.9)	73	269	M winter	374-1586	1100	179.1		
		Kommadagga & Lake Mentz		74	183						
				95	520						
				96	165						
40. *Roggeveld*	Escarpment Mt. Renosterveld	Adelaide & Estcourt	1496 (1.2)	64	155	M winter	781-1470	1200	110.9		
				69	277						
41. Montagu	Central Mountain Renosterveld	Bidouw	1280 (1.0)	75	173	Non seasonal	208-1158	500	194.3		
		Ceres		74	183						
				77	279						
42. Cannaland	Central Mountain Renosterveld	Ceres, Nardouw	495 (0.4)	74	183	Non seasonal	76-704	500	106.8		
		Cedarberg & Pakhuis		89	241						
				77	279						

BHU	Vegetation type (sensu Low & Rebelo 1996)	Geology	Area (km²) (%)	HCZ No.	Rainfall characteristics Mean $mm yr^{-1}$	Seasonality	Topography Altitudinal range (m)	Modal altitude(m)	RI	Plant community data No. communities (no plots) [area (km²)]	References
43. Kango	S & SW Coast Renosterveld	Kango	1688 (1.4)	93	423	Non seasonal	239-1914	800	205.8	NA	Moffet & Deacon (1977)
		Ceres, Nardouw		110	186						
		Cedarberg & Pakhuis		91	318						
		Witpoort & Weltevrede		92	242						
44. Uniondale	S & SW Coast Renosterveld	Ceres, Nardouw	1203 (1.0)	92	242	Non seasonal	393-1375	1100	212.6		
		Cedarberg & Pakhuis		89	241						
				113	312						
Mountain Complex											
45. Bokkeveld	Mountain Fynbos	Nardouw	984 (0.8)	201	466	S winter	229-1012	800	135.6		
		Cedarberg & Pakhuis		202	339						
46. Gifberg	Mountain Fynbos	Nardouw	2003 (1.6)	62	220	S winter	50-1123	300	188.2		
		Cedarberg & Pakhuis		200	360						
47. Cederberg	Mountain Fynbos	Peninsula, Nardouw	2278 (1.9)	60	683	S winter	78-2046	300	392.4	26 (197)	Taylor (1996)
		Cedarberg & Pakhuis								[1260]	
48. Olifants River	Mountain Fynbos	Peninsula	1461 (1.2)	58	498	S winter	63-1227	600	169.3	NA	Campbell (1995)
		Graafwater & Piekenierskloof		59	207						
49. Swartruggens	Mountain Fynbos	Witpoort & Weltevrede	1538 (1.3)	61	377	S winter	502-1797	1200	167.4	9 (125)	Lechmere-Oertel
	Lowland Succulent Karoo	Nardouw, Cedarberg								[127]	(1998)
		& Parkhouse								NA	Campbell (1995)
50. Piketberg	Mountain Fynbos	Peninsula	516 (0.4)	29	838	S winter	53-1442	700	231.5		
		Graafwater & Piekenierskloof		28	464						
		Alluvium, sand & calcrete									
51. Groot Winterhoek	Mountain Fynbos	Nardouw	866 (0.7)	56	650	S winter	75-1971	1200	342.5	NA	Campbell (1995)
		Cedarberg & Pakhuis, Peninsula		54	954						
52. Matroosberg	Mountain Fynbos	Nardouw	714 (0.6)	56	650	S winter	342-2226	1800	377.6		
		Cedarberg & Pakhuis, Peninsula									
53. Hawequas	Mountain Fynbos	Peninsula	1218 (1.0)	18	818	S winter	94-1915	1200	366.4	10 (105)	Van Wilgen & Kruger
		Nardouw		35	998					[9.68]	(1985)
		Cedarberg & Pakhuis		36	589					NA	Campbell (1995)
				34	748						
54. Franschhoek	Mountain Fynbos	Peninsula	551 (0.4)	9	1605	S winter	96-1545	1100	328.7	8 (44)	Werger *et al.* (1972)
		Cape Granite Suite		15	778					[0.4]	
		Nardouw		10	1067					5(201)	McDonald (1988)
				17	1838					[0.4]	
		Cedarberg & Pakhuis								NA	Campbell (1995)
55. Cape Peninsula	Mountain Fynbos	Peninsula	359 (0.3)	4	596	S winter	0-1080	300	203.9	3 (48)	Glyphis *et al.* (1978)
		Cape Granite Suite		2	1282					[2]	
										NA	Taylor (1969)
										2 (53)	Joubert & Moll (1992
										[1.24]	
										2 (38)	Laidler *et al.* (1978)
										[1.4]	
										18 (78)	McKenzie *et al.* (1977)
										[ca 4]	

BHU	Vegetation type (sensu Low & Rebelo 1996)	Geology	Area (km²) (%)	HCZ No.	Rainfall characteristics: Mean mmyr⁻¹	Rainfall characteristics: Seasonality	Topography: Altitudinal range (m)	Topography: Modal altitude(m)	Topography: RI	Plant community data: No. communities (no plots) [area (km²)]	Plant community data: References
										10 (87)	Privett (1998)
										[77]	
56. Kogelberg	Mountain Fynbos	Nardouw	729 (0.6)	14	659	S winter	0-1227	500	224.0	11 (367)	Kruger (1974)
		Cedarberg & Pakhuis		13	931					[1.6]	
				10	1067					29 (250)	Boucher (1978)
		Peninsula		11	1258					[240]	
				12	1104					NA	Campbell (1995)
57. Klein River	Mountain Fynbos	Nardouw	368 (0.3)	41	493	M winter	6-1106	600	185.2		
		Cedarberg & Pakhuis		40	528						
		Peninsula		42	637						
58. Caledon Swartberg	Mountain Fynbos	Nardouw	98 (0.1)	40	528	M winter	290-1054	800	161.9		
		Cedarberg & Pakhuis									
		Peninsula									
59. Riviersonderend	Mountain Fynbos	Nardouw	820 (0.7)	38	614	M winter	88-1603	400	301.0	NA	Campbell (1995)
		Cedarberg & Pakhuis		49	266						
		Peninsula									
60. Koo Langeberg	Mountain Fynbos	Nardouw	737 (0.6)	52	496	Non seasonal	281-2054	1500	312.8		
		Cedarberg & Pakhuis		75	173						
		Peninsula									
61. Waboomsberg	Little Succulent Karoo	Ceres	280 (0.2)	53	272	M winter	742-1429	1200	69.7		
		Nardouw,		52	496						
		Cedarberg & Pakhuis		63	219						
62. Witteberg	Central Mountain Renosterveld	Witpoort & Weltevrede	450 (0.4)	73	269	M winter	956-1507	1200	101.9	NA	Campbell (1995)
	Little Succulent Karoo	Ceres		53	272						
		Kommadagga & Lake Mentz		52	496						
				64	155						
63. Bredasdorp	Mountain Fynbos	Peninsula, Nardouw	334 (0.3)	45	466	M winter	20-787	500	148.1		
		Cedarberg & Pakhuis		43	528						
64. Southern Langeberg	Mountain Fynbos	Nardouw	1506 (1.2)	78	1016	Non seasonal	47-1568	1200	293.4	13 (119)	McDonald (1993a)
		Cedarberg & Pakhuis								[142]	
		Peninsula								17 (83)	McDonald (1993b)
										[110]	
										NA	Campbell (1995)
65. Potberg	Mountain Fynbos	Nardouw	119 (0.1)	48	384	M winter	0-568	400	125.8		
		Cedarberg & Pakhuis		47	318						
66. Klein Swartberg	Mountain Fynbos	Nardouw	814 (0.7)	74	183	Non seasonal	296-2268	1300	336.7		
		Cedarberg & Pakhuis		94	718						
		Peninsula		95	520						
67. Rooiberg	Mountain Fynbos	Nardouw	778 (0.6)	91	318	Non seasonal	154-1433	1000	224.9	NA	Taylor & van der Meulen (1981)
		Cedarberg & Pakhuis		90	192						
		Peninsula								NA	Campbell (1995)
68. Groot Swartberg	Mountain Fynbos	Nardouw	1156 (0.9)	94	718	Non seasonal	374-2098	1800	301.7	9 (50)	Bond (1981)
		Cedarberg & Pakhuis		92	242					[ca 100]	
		Peninsula								NA	Campbell (1995)

BHU	Vegetation type (sensu Low & Rebelo 1996)	Geology	Area (km²) (%)	HCZ No.	Rainfall characteristics Mean mmyr⁻¹	Seasonality	Topography Altitudinal range (m)	Modal altitude(m)	RI	Plant community data No. communities (no plots) [area (km²)]	References
69. Outeniqua	Mountain Fynbos	Nardouw	1689 (1.4)	114	476	Non seasonal	142-1531	800	210.4	11 (65)	Bond (1981)
		Cedarberg & Pakhuis		88	961					[ca 150]	
		Peninsula		86	645					NA	Campbell (1995)
				87	1030						
70. Kamanassie	Mountain Fynbos	Nardouw	550 (0.4)	113	312	Non seasonal	418-1832	1100	262.4	NA	Campbell (1995)
		Cedarberg & Pakhuis									
71. Tsitsikamma	Mountain Fynbos	Peninsula, Nardouw	1619 (1.3)	117	1145	Non seasonal	29-1597	600	262.6	NA	Campbell (1995)
		Cedarberg & Pakhuis	119	1115							
72. Kouga	Mountain Fynbos	Peninsula, Nardouw	1749 (1.4)	121	422	Non seasonal	270-1721	1400	298.8	8 (75)	Euston-Brown (1995)
		Cedarberg & Pakhuis								[ca 400]	
	Grassy Fynbos									NA	Campbell (1995)
73. Baviaanskloof	Grassy Fynbos	Nardouw	1683 (1.4)	122	297	Equinoctial	136-1593	1100	253.8	6 (38)	Euston-Brown (1995)
	Mountain Fynbos	Cedarberg & Pakhuis								[ca 200]	
		Peninsula								NA	Campbell (1995)
74. Cockscomb	Grassy Fynbos	Nardouw	1465 (1.2)	135	609	Non seasonal	76-1606	600	218.5	5 (28)	Cowling (1982)
	Mountain Fynbos	Cedarberg & Pakhuis		139	755					[ca 200]	
		Peninsula								NA	Campbell (1995)
SUCCULENT KAROO BIOME											
Vygieveld											
75. *Western Mountain*	Upland Succulent Karoo	Dwyka	3025 (2.5)	203	233	S winter	170-1258	900	147.7		
		Ceres		64	155						
		Adelaide & Estcourt		62	220						
		Prince Albert, Koedoesberg									
		Karoo dolerite									
76. Klawer	Lowland Succulent Karoo	Gifberg	878 (0.7)	199	147	S winter	2-524	300	90.1		
		Peninsula		27	266						
		Alluvium, sand & calcrete		59	207						
77. *Knersvlakte*	Lowland Succulent Karoo	Alluvium, sand & calcrete	4650 (3.8)	199	147	S winter	0-796	200	84.4		
		Knersvlakte		198	104						
		Gifberg		191	102						
78. Tanqua	Lowland Succulent Karoo	Dwyka	6194 (5.1)	62	220	M winter	15-1439	900	197.0		
	Central Mountain Renosterveld	Witpoort & Weltevrede									
	Upland Succulent Karoo	Ceres, Tierberg, Bidouw									
		Skoorsteenberg									
		Whitehill & Prince Albert									
79. *Laingsberg*	Lowland Succulent Karoo	Adelaide & Estcourt	1340 (1.1)	72	114	Non seasonal	397-1150	900	147.0		
		Laingsburg,		97	118						
		Whitehill & Prince Albert		64	155						
		Fort Brown, Dwyka									
80. *Moordenaars*	Great Nama Karoo	Adelaide & Estcourt	953 (0.8)	71	135	Non seasonal	662-1280	400	114.4		
				64	155						
81. Touws	Little Succulent Karoo	Witpoort & Weltevrede	1419 (1.2)	63	219	M winter	695-1290	1000	108.9		
	Central Mountain Renosterveld	Ceres, Bidouw									
		Alluvium, sand & calcrete									

BHU	Vegetation type (sensu Low & Rebelo 1996)	Geology	Area (km^2) (%)	HCZ No.	Rainfall characteristics: Mean mmyr^{-1}	Rainfall characteristics: Seasonality	Topography: Altitudinal range (m)	Topography: Modal altitude (m)	Topography: RI	Plant community data: No. communities (no plots) [area (km^2)]	Plant community data: References
Strandveld											
82. *Namaqualand*	Strandveld Succulent Karoo	Alluvium, sand & calcrete	433 (0.4)	191	102	S winter	0-184	100	48.4		
83. Lamberts Bay	Strandveld Succulent Karoo	Alluvium, sand & calcrete	963 (0.8)	26	184	S winter	0-310	200	62.8		
Broken Veld											
84. *Garies*	Upland Succulent Karoo	Little Namaqualand Suite	98 (0.1)	197	154	S winter	284-454	400	30.3		
	Lowland Succulent Karo	Spektakel Suite									
85. *Loeriesfontein*	Upland Succulent Karoo	Knersvlakte, Dwyka	517 (0.4)	204	117	M winter	320-792	500	96.4		
86. Witrantjies	Little Succulent Karoo	Laingsburg	971 (0.8)	64	155	M winter	332-1339	1000	143.7		
		Whitehill & Prince Albert		73	269						
		Dwyka		96	165						
		Kommadagga & Lake Mentz		52	496						
		Ceres, Fort Brown		75	173						
87. Robertson	Little Succulent Karoo	Ceres	1277 (1.0)	50	263	M winter	83-721	300	102.8	NA	Olivier (1966)
		Alluvium, sand & calcrete		49	266						
		Laingsburg									
		Whitehill & Prince Albert									
		Dwyka, Bidouw									
		Witpoort & Weltevrede									
88. Little Karoo	Little Succulent Karoo	Ceres, Bidouw	4457 (3.6)	74	183	Non seasonal	68-1638	400	205.8		
89. Oudtshoorn	Little Succulent Karoo	Alluvium, sand & calcrete	1352 (1.1)	92	318	Non seasonall	185-1128	400	230.7		
		Enon, Traka									
90. *Prince Albert*	Great Nama Karoo	Laingsburg	2931 (2.4)	110	118	Equinoctial	367-1261	900	129.8		
		Whitehill & Prince Albert		111	186						
		Fort Brown		112	130						
		Witpoort & Weltevrede									
		Dwyka, Traka									
NAMA KAROO BIOME											
91. *Gamka Broken Veld*	Great Nama Karoo	Adelaide & Escourt	3118 (2.5)	97	118	Equinoctial	381-1073	900	184.7		
		Fort Brown, Laingsburg		109	183						
		Whitehill & Prince Albert									
92. *Steytlerville Broken Veld*	Central Nama Karoo	Traka	3475 (2.8)	123	237	Equinoctial	308-1134	600	163.8		
		Witpoort & Weltevrede, Ceres									
THICKET BIOME											
Mesic Succulent Thicket											
93. Gouritz	S & SW Coast Renosterveld	Bokkeveld, Enon	183 (0.1)	84	362	Non seasonal	7-200	100	33.7	NA	Rebelo *et al.* (1991)
94. Gamtoos	Valley Thicket	Gamtoos	322 (0.3)	136	512	Non seasona	0-754	100	144.0	3 (18)	Cowling (1982)
	Mesic Succulent Thicket	Alluvium, sand & calcrete								[ca 100]	
	S & SW Coast Renosterveld	Nardouw, Cedarberg & Pakhuis									
95. *Sundays*	Mesic Succulent Thicket	Kirkwood, Alexandria	1513 (1.2)	142	585	Non seasonal	0-1035	500	217.9		
	Xeric Succulent Thicket	Alluvium, sand & calcrete		141	492						
		Sundays River		134	467						
		Ceres, Traka		132	248						

BHU	Vegetation type (sensu Low & Rebelo 1996)	Geology	Area (km^2) (%)	HCZ No.	Rainfall characteristics Mean $mm yr^{-1}$	Seasonality	Topography Altitudinal range (m)	Modal altitude(m)	RI	Plant community data No. communities (no plots) [area (km^2)]	References
96. Aloes	Dune Thicket	Enon	26 (<0.1)	136	512	Non seasonal	I 0-69	50?	15.1	1 (5)	Cowling (1982)
	S & SW Coast Renosterveld	Nanaga		137	684					[ca 20]	
Xeric Succulent Thicket											
97. Spekboom	Spekboom Succulent Thicket	Ceres	2443 (2.0)	92	242	Non seasonal	115-1366	500	137.8		
		Enon		74	183						
		Kango		89	241						
				91	318						
98. *Willowmore*	Spekboom Succulent Thicket	Witpoort & Weltevrede	1949 (1.6)	123	237	Equinoctial	296-1529	1000	197.3		
	S & SW Coast Renosterveld	Ceres, Dwyka		96	165						
		Kommadagga & Lake Mentz									
99. *Addo*	Xeric Succulent Thicket	Kirkwood, Enon, Traka	1799 (1.5)	143	326	Equinoctial	6-904	500	154.8	NA	Archibald (1955)
		Alluvium, sand & calcrete		133	251						
		Sundays River									
		Witpoort & Weltevrede									
FOREST BIOME											
Afromontane Forest											
100. Knysna	Afromontane Forest	Nardouw,	2079 (1.7)	119	1115	Non seasonal	0-1346	200	162.9	NA	Phillips (1931)
		Cedarberg & Pakhuis		115	880						
		Peninsula		118	880						
		Cape Granite Suite		118	856						
		Kaaimans		138	951						
				86	645						
101. Swellendam	Afromontane Forest	Nardouw	18 (<0.1)	79	638	Non seasonal	182-478	300	70.5	3 (94)	Campbell & Moll (1977)
		Cedarberg & Pakhuis								[ca 1]	
		Enon								9 (103)	McKenzie (1978)
										[ca 50 - fragmented]	
Indian Ocean Forest											
102. Alexandria	S & SW Coast Renosterveld	Nanaga	357 (0.3)	139	755	Non seasonal	0-534	200	85.6	1 (5)	Cowling (1982)
	Valley Thicket	Gamtoos								[ca 2]	
	Mesic Succulent Thicket										
	Dune Thicket										