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Vegetation of the coastal fynbos and rocky headlands south of George, South Africa

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ABSTRACT

Community structure and composition of the coastal fynbos and rocky headland plant communities south of George, southern Cape, were studied. Vegetation was analysed using standard sampling procedures of the floristic-sociological approach of Braun-Blanquet. The relevé data were subject to TWINSPAN-based divisive classification, and ordinated by Principal Coordinates Analysis with the aim to identify vegetation coenocline subsequently interpreted in terms of underlying environmental gradients. Most of the sampled vegetation was classified as coastal fynbos. The *Leucadendron salignum–Tetraria cuspidata* Fynbos Community was found to occupy sheltered habitats, whereas the *Relhania calycina–Passerina vulgaris* Fynbos Community was found in exposed habitats. The other two communities characterise strongly exposed rocky headlands. The *Pterocelastrus tricuspidatus–Ruschia tenella* Community is wind-sheared scrub, and the *Gazania rigens– Limonium scabrum* Rocky Headland Community is a loose-canopy, low-grown herbland, characterised by the occurrence of partly salt-tolerant and succulent herbs. The ordination of the fynbos communities revealed a horseshoe structure allowing a direct recognition of a coenocline spanning two fynbos communities along the Axis 1 interpreted in terms of exposure to wind and salt spray. A considerable amount of alien plant infestation was also present. This appears to be the largest threat to the continued existence of this coastal fynbos.

INTRODUCTION

Fynbos occurring in close vicinity of the coast has been studied in detail in many regions of South Africa (Boucher 1977; Van der Merwe 1979; Cowling 1984; Taylor 1985; Hellström 1990; Taylor & Boucher 1993; Hoare 1994). There are, however, still many portions of the coastline, especially outside formal reserves, which remain only poorly known. Only 79 km of the central south coast falls into existing protected areas, namely the Goukamma Nature Reserve, the Robberg Nature Reserve and the Tsitsikamma Coastal National Park (Jarman 1986). The promulgation of the Agulhas National Park may alter these statistics (World Wide Fund for Nature 1999).

The area along the coast south of George, the present study area, is of interest because of its scenic beauty and its location in the centre of the popular Garden Route. Interest in coastal development for recreational purposes throughout the Garden Route is likely to impact on areas which have not yet been encroached upon. The extent of vegetation cover outside formally protected areas has been considerably transformed, and of the remaining natural areas large portions have been invaded by alien species. It was therefore suggested by Cape Nature Conservation (George) that a detailed study be undertaken along the coast south of George to provide information on the local vegetation and flora and possible importance of the study area for conservation (G. Hellström pers. comm.). This particular study features descriptions of the plant communities of habitats close to the coastline.

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STUDY AREA

The study area extended from Rooiklip, SE of Pacaltsdorp, to Ghwanobaai, 3 km E of Glentana (Figure 1), and covered ± 190 hectares. Glentana, and the area west of it, has been extensively developed and was therefore found unsuitable for the intended study. The fynbos vegetation in the study area has been classified as Asteraceous Fynbos by Cowling & Holmes (1992) and it was broadly classified by Acocks (1988) as ‘cultivated land, plantations, dense alien communities and open sandy areas’, a description which gives a clear indication of the transformed state of the vegetation. The vegetation of the coastline area is classified as Dune Thicket (Low & Rebelo 1996), which forms a mosaic with Dune Fynbos (Low & Rebelo 1996) in the region including the study area.

The coastline consists of steep coastal cliffs ranging in height from 50 to 70 metres, forming rocky headlands. The plenitude of alternating bays and headlands has resulted in microhabitats with varying degrees of exposure to the prevailing winds, salt spray and sun. Coastal soils vary markedly according to substrate, but are often calcareous and coarse-grained. Topography is the dominant factor affecting soil formation and the removal of the products of weathering may exceed their formation, especially on slopes. The coastal cliffs of the study area are Rooiklip Granite-Gneiss of the Kaaimans Group and are pre-Cape intrusive granite rocks (South African Committee for Stratigraphy 1980). These rocks are important because, upon weathering, they form base-rich substrates containing exchangeable cations that are important for soil formation and plant nutrient cycling (Deacon *et al.* 1992).

The Köppen’s climate classification code for the George coastal area is Cfb, which indicates warm, temperate climate (Schulze & McGee 1978). The mean annual temperature is ± 17°C, with a mean temperature range

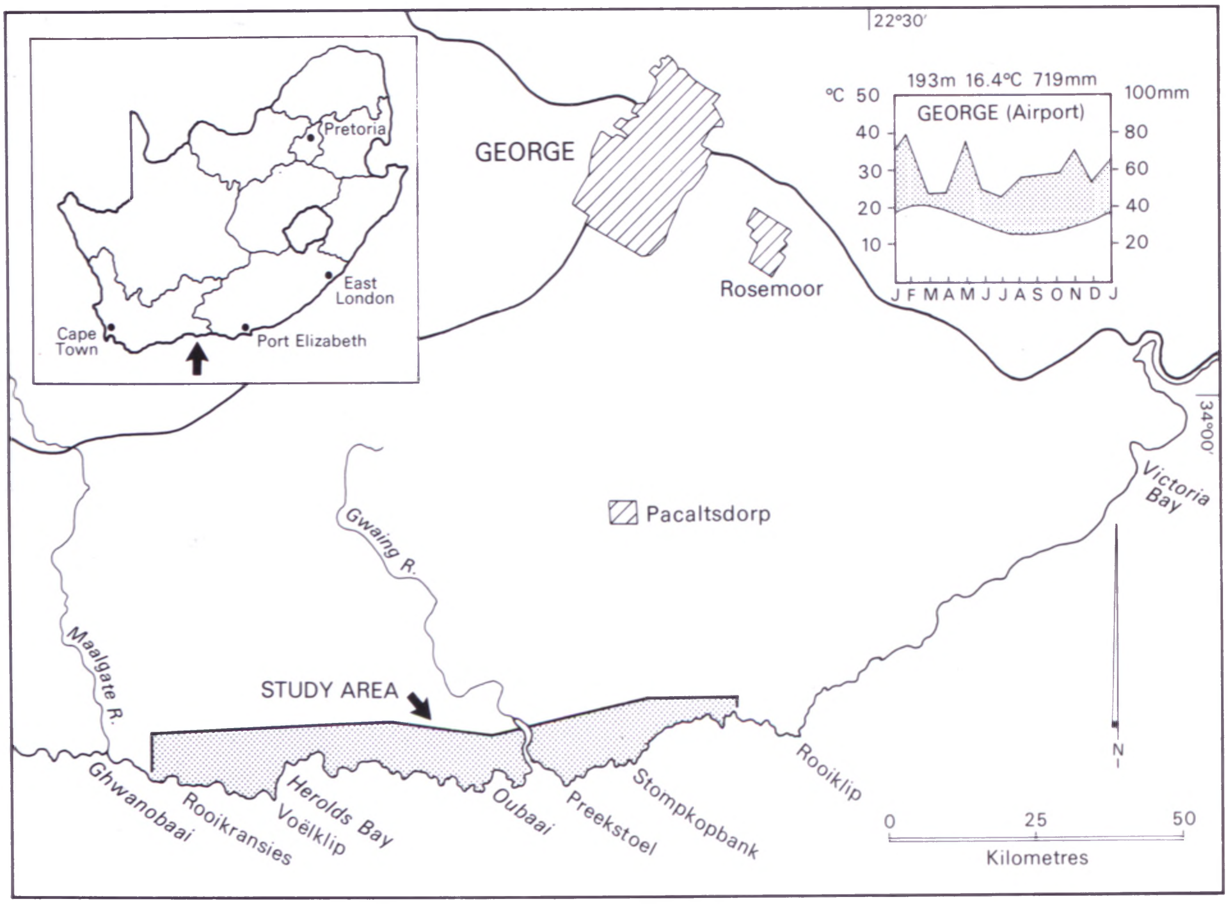

FIGURE 1.—Map of the study area and climate diagram for George.

of 8°C near the coast. The area has precipitation during all months of the year, with three prominent peaks in spring, summer and autumn, although there is no precipitation deficit at any time of the year (Figure 1). Sea mists may provide additional moisture on seaward-facing slopes. Pronounced strong winds blow along the entire coastal belt, varying in direction according to location and season. In the study area, wind from the southwest and west were found to be more important, since their frequency was higher (Weather Bureau 1994). Wind velocity has been found to be important in coastal plant communities, since the greater the velocity of the wind, the higher the salt load of the moving air, which may have a serious detrimental effect on the growth of plants (Avis & Lubke 1985). Importance values (Table 1) were determined which took into account the velocity and frequency of winds from different directions (IV = mean monthly direction frequency multiplied by mean monthly velocity expressed as percentage of total of all values for year). Westerly winds had the highest importance values throughout the year but were of greatest importance during the winter months. Southwesterlies showed a similar pattern. Easterlies and southeasterlies had the second highest importance values, but these were most prevalent during spring and summer (September to March).

MATERIAL AND METHODS

Aerial photographs were used to stratify the region into broad vegetation complexes based on vegetation structure and relevés (25 m^2 each) were made within these zones. The quadrat size was determined from species/area curves drawn from data collected in the study area, but also conformed to a scale-related approach to vegetation sampling, i.e. the size of the relevé was related to the scale at which the vegetation was studied (Rutherford & Westfall 1994). Riparian thicket, dune thicket, dense alien stands and agricultural lands were not sampled. Standard field techniques and the 7-grade sampling scale of Braun-Blanquet (Westhoff & Van der Maarel 1973; Werger 1974) were used to record the cover/abundance values for each vascular species encountered in the relevés. Topographic information, including slope, aspect and altitude were also

TABLE 1.—Importance values of winds from different directions in the months of the year. Bold text shows cells with importance values greater than 1. (IV's calculated from data from Weather Bureau. See text for method)

Month	N	NE	E	SE	S	SW	W	NW
J	0.01	0.07	**2.6**	**2.3**	**1.7**	**1.8**	**1.1**	0.3
F	0	0.1	**2.8**	**1.8**	**1.6**	**1.4**	1.0	0.4
M	0.03	0.04	**1.7**	**1.6**	**1.2**	**1.1**	1.0	0.3
A	0.08	0.04	0.8	1.0	0.9	1.0	**1.6**	0.8
M	0.35	0.08	0.5	0.5	0.5	1.0	**3.5**	**2.1**
J	0.48	0.05	0.4	0.3	0.4	0.7	**2.7**	**2.7**
J	0.39	0.1	0.5	0.5	0.5	0.7	**2.5**	**2.0**
A	0.38	0.1	0.9	0.8	0.8	1.0	**2.5**	**1.5**
S	0.24	0.1	**1.2**	**1.3**	0.9	**1.3**	**2.3**	0.9
O	0.10	0.06	**2.3**	**1.6**	**1.2**	**2.0**	**1.8**	0.7
N	0.03	0.02	**2.9**	**2.0**	**1.6**	**1.7**	**1.5**	0.4
D	0.01	0.05	**2.3**	**2.2**	**1.7**	**1.8**	**1.5**	0.3
TOTAL	2.1	0.8	18.9	15.9	13.0	15.5	23.0	12.4

recorded. Physical soil properties, such as pH, conductivity, organic matter content, water-holding capacity, as well as the relative fraction of coarse, medium and fine sand, silt and clay, were ascertained in a subset of 20 relevés. The general methodology used by the US Department of Agriculture (USDA 1972) was followed for analysing soils.

The vegetation data were initially classified using TWINSPAN (Hill 1979), producing a rough species-by-relevé matrix, which was further rearranged in order to finely tune the relevé/species coincidence patterns supposed to carry meaningful ecological information. The data from only the fynbos communities were subject to ordination by Principal Coordinates Analysis based on similarity ratio as resemblance measure with no *à priori* data transformation using the programme package SYNTAX-5 (Podani 1993, 1994).

For the descriptions of vegetation communities, three informal ranks of vegetation units are recognised: community, subcommunity, and facies. Facies (Braun-Blanquet 1964) represents the lowest-ranked unit and corresponds to vegetation stands dominated by a single species, mostly an alien element.

RESULTS AND DISCUSSION

Classification of plant communities

The rearranged species-quadrat matrix (Table 2) revealed two groups of plant communities: the majority of the relevés were classified as coastal fynbos (Communities A & B) and the remainder of the relevés as (non-fynbos) rocky headland communities (Communities C & D). A summary of the community environmental and floristic relationships is given in Figure 2. The following communities, subcommunities and facies were identified:

A. *Leucadendron salignum–Syncarpha paniculata* Fynbos Community

This community occurs in areas that are protected from coastal winds either by headlands or the proximity of coastal thicket (Figure 3) and has a different species composition to the fynbos on the exposed summit of the coastal cliffs. Diagnostic species: *Leucadendron salignum, Aspalathus asparagoides, Hermannia angularis, Metalasia acuta, Helichrysum cymosum* and *Bobartia aphylla*. Dominant species: *Syncarpha paniculata* and *Passerina vulgaris*. Common species: *Tetraria cuspidata, Cliffortia falcata, Metalasia pungens, Lobelia tomentosa, Erica discolor* and *Phylica confusa*. Many stands of this community have been seriously invaded by the alien species *Acacia cyclops, Leptospermum laevigatum* and *Pinus* spp.

Slopes vary from moderate to steep and soils are generally deeper and finer-grained than on cliff summits. There is high species richness (19 species on average) in this community. The habitat is more variable than on the cliff summits, thus leading to a greater species turnover between localities. The geographic distribution of this community beyond the present study area is unknown. Four subcommunities are recognised and described.

Aa. *Thamnochortus cinereus* Subcommunity

Diagnostic species: *Thamnochortus cinereus, Polygala microlopha* and *Cliffortia* sp. (*Victor 313*). It is situated below a housing development at Herold's Bay Extension; there was no evidence of recent fire and the subcommunity is possibly one form of a fire-climax vegetation in protected areas.

Ab. *Protea neriifolia* Subcommunity

Diagnostic species: *Protea neriifolia*. It has developed in the absence of fire and is possibly a fire-climax vegetation of protected areas. *Bobartia aphylla* and *Pelargonium fruticosum* serve as common linking species to subcommunites Aa and Ab.

Ac. Typical Subcommunity

Lacks the diagnostic species of the other three subcommunities, but contains the diagnostic species of the *Leucadendron salignum–Syncarpha paniculata* Fynbos Community. There was evidence of recent fires in a number of the relevés.

Ad. *Hermannia althaeifolia* Subcommunity

Diagnostic species: *Hermannia althaeifolia, Hibiscus aethiopicus, Ficinia albicans* and *Ursinia saxatilis* as well as a number of infrequently occurring species (Table 2). Most of the relevés had evidence of being burnt recently, suggesting that it is an early post-fire successional stage.

The vegetation height varies from 1 m, where dwarf shrubs are dominant, to over 2.5 m where shrubs of the exotic *Leptospermum laevigatum* are found. The mean species richness of this subcommunity is 20 species on average, but this may be reduced to only eight species where invasion by exotic shrubs has taken place, as is the case of the *Acacia mearnsii* facies (Table 2, rel. 23).

B. *Relhania calycina–Phylica confusa* Fynbos Community

This community makes up the greatest proportion of the fynbos in the study area and also extends beyond the boundaries of the present study area along the summit of the coastal cliffs towards Knysna (Figure 3). Diagnostic species: *Relhania calycina* subsp. *calycina* and *Viscum capensis*. Dominant species: *Erica discolor, Phylica confusa, Passerina vulgaris* and *Tetraria cuspidata*. Common species: *Thesium virgatum, Agathosma ovata, Erica peltata, Syncarpha paniculata* and *Cliffortia serpyllifolia*.

The dwarf shrub layer of this community is usually about 1 m in height and the herb layer about 0.4 m. The total cover of the vegetation is slightly lower than for

TABLE 2.—Classification of the vegetation of the coastal cliff habitats south of George, South Africa

Key to communities and subcommunities:

A: *Leucadendron salignum–Syncarpha paniculata* Fynbos Community
- Aa: *Thamnochortus cinereus* Subcommunity
- Ab: *Protea neriifolia* Subcommunity
- Ac: Typical Subcommunity
- Ad: *Hermannia althaeifolia* Subcommunity
  - F: *Acacia mearnsii* facies

B: *Relhania calycina–Phylica confusa* Fynbos Community
- Ba: *Tetraria cuspidata* Subcommunity
- Bb: *Eriocephalus africanus* Subcommunity

C: *Pterocelastrus tricuspidatus–Ruschia tenella* Coastal Scrub Community
- S: *Sporobolus virginicus* facies

D: *Gazania rigens–Limonium scabrum* Rocky Headland Community
- G: *Gazania rigens* facies

Legend to vegetation layers: hl, herb layer; jl, juvenile woody species; s1, upper shrub layer; s2, low shrub layer; t3, low tree layer. Taxonomic notes, *Gazania rigens* = *Gazania rigens* var. *uniflora*; *Limonium scabrum* agg. is a new taxon pending formal description (L. Mucina, in prep.) and is closely related to *L. scabrum* (Thunb.) Kuntze; *Drosanthemum marinum* agg. is a complex of *D. marinum* and *D. delicatulum* and might represent one taxon after a revision (P. Burgoyne pers. comm.).

		A	B	C	D
Relevé number		| | 11|1111111122 2|2	222222333333333444|444444555	55555556 6|6	66666|6
		12|34567|8901|2345678901 2|3	456789012345678901 2|3456789012	345678901|2	34567|8
Community		AA|AAAAA|AAAA|AAAAAAAAAA|A	BBBBBBBBBBBBBBBBBB|BBBBBBBBB	CCCCCCCCC|C	DDDDD|D
Subcommunity		aa|bbbbb|cccc|dddddddddd|d	aaaaaaaaaaaaaaaaaa|bbbbbbbbb	|	|
Facies		| | | |F	|	|S	|G
Aspect (degrees)		22|22221|2112|2112111211 1|1	112211121112221112 1|2212 1111	12222121 3|1	12222|2
		42|99998|0881|2894838288 8|7	887088378882008880 8|2780968585	29202808 6|8	84422|1
		05|33330|3004|5008050500 0|5	000300500005330003 0|5003080808	03035030 0|0	08850|0
Slope (degrees)		22|33221| 1| 11 2 1 1|	2 111 2 1| 43 1 1	23151 431|	43332|3
		23|00066|3545|3322868577 6|7	802013389999406505 8|9005841918	00802555 2|2	02005|6
Altitude (metres)		1 1 1	1		
		66|34660|6451|0996999699 9|9	554778434454169398 9|4284146665	25433131 3|2	11144|4
		50|55000|0055|0500000000 0|0	005000500500000000 5|0005550000	55055500 0|5	24800|5
Number of species		21|12211|1122|2112212211 2|	211212121111111122 2|1221111112	1 11 111 |	1 1|
		23|70345|8665|3567360776 0|8	483591736435699017 0|2343596052	05407829 7|8	46073|1
Coastal Fynbos					
Tetraria cuspidata	-hl	ar|rrr.a|+..+|..a+.+.+rr+|r	++3b1+.+a3b+a..maba|b....+...a	.........|.	.....|.
Thesium virgatum	-s2	..|rrr..|.+++|+......+...|.	++++.+++++++.+....r|r+r++++.+.	.........|.	..r..|.
Syncarpha paniculata	-hl	..|33a.r|.33b|..rb+1a+bb+|.	++a+++++++1+++.+a.a|r+..+....r	.........|.	.....|.
Erica formosa	-s2	3b|.....|4...|3.a.......|.	+..............a.a|.........	.........|.	.....|.
Cliffortia falcata	-s2	..|..rrr|a+++|.a.++++.aa.|.	++........++..m...|.....+.+..	.........|.	.....|.
Metalasia pungens	-s2	..|..rra|.a.a|...++aa1aa.|.	+....+.+....++..r..|.........	.........|.	.....|.
Erica peltata	-s2	..|.....|..+.|.a.4+3b3bba|b	++.3a++a++....aa...|.++...+a+a	.......+.|a	.....|.
Schizaea pectinata	-hl	rr|rr..r|+.+.|+.........|.	...+.+....+...+.r.r|.........	.........|.	.....|.
Restio triticeus	-hl	.a|.raaa|+...|43...++...+|.	.3.+.+.........+.r.r|.........	.........|.	.....|.
Lobelia tomentosa	-hl	r.|rr...|r+.+|r...+.arrr.|r	+....r.........r...|.........	.........|.	.....|.
Centella virgata	-hl	r.|ba...|....|...+...+...|.	+..................|.+.......	.........|.	.....|.
Pentaschistis eriostoma	-hl	..|..a3.|....|.1..3..a..+|.	+..r.........a.a.r|.3...1...3	.........|.	.....|.
Ficinia nigrescens	-hl	..|rrrrr|.+++|....+...rr.|.	......+.......+..r..|.+.......	.........|.	.....|.
Carissa edulis	-s2	..|..ab.|.+rr|......+....|.	...........+.+.....|..r.+r...	.........|.	.....|.
Aspalathus alopecurus	-s2	..|.b...|.a+.|..........|.	.......++..+...r...|.....r...r	.........|.	.....|.
Anthospermum prostratum	-hl	..|....r|.++.|a+.++..+aa.|.	...+.++...++.++....|........+r	.........|.	.....|.
Cullumia bisulca	-hl	..|....r|..++|..a+..++rr.|.	.+.r..++..+......+r|r........	.........|.	.....|.
Aspalathus florifera	-s2	..|.....|....|....+....b.|.	..r.............m...|.........	.........|.	.....|.
Falkia repens	-hl	..|....r|.+.+|......+....|.	.+.......+..++.+...|..r.....+.	.....r...|.	.....|.
Crassula subulata	-hl	..|.rr..|...+|....+......|.	...............+r.r|.........	.........|.	.....|.
Disparago kraussii	-hl	..|....r|...+|...+...+...|.	.+..............r..|.........	.........|.	.....|.
Erica ericoides	-s2	..|.....|r..+|..........|.	+..........+........|...r.....	.........|.	.....|.
Rhus lucida	-s2	..|.....|..r.|+..........|.	...................|.r.....+..	.........|.	.....|.
Wahlenbergia desmantha	-hl	..|.r...|...+|...+.......|.	...................|........+..	.........|.	.....|.
***Leucadendron salignum–Syncarpha paniculata* Fynbos Community**					
Leucadendron salignum	-s2	ba|.ar.b|1...|r3ra..+.b..|.	aa...............b|.........	.........|.	.....|.
Aspalathus asparagoides	-s2	aa|..a..|+a..|...+.+++..a|.	...1...............|.........	.........|.	.....|.
Hermannia angularis	-hl	..|rrr..|....|+.r+.+++rr+|r	..................|.........	.........|.	.....|.
Metalasia acuta	-s2	..|.....|..+.|...+a+....a|b	..................|.........	.........|.	.....|.
Helichrysum cymosum	-hl	..|.....|..r.|+...+..r...|.	..................|.........	.........|.	.....|.
Bobartia aphylla	-hl	a.|arar.|b...|..........|.	..................|.........	.........|.	.....|.
Pelargonium fruticosum	-hl	.b|bbra.|..r.|..........|.	..................|.........	.........|.	.....|.

***Thamnochortus cinereus* Subcommunity**

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Thamnochortus cinereus       -h1 |bb|.....|+...|...........|.|....r..............|..........|.........|.|.....|.|
Polygala microlopha          -s2 |aa|.....|....|...........|.|...................|..........|.........|.|.....|.|
Cliffortia sp. (Victor 313)  -s2 |aa|.....|....|...........|.|...................|..........|.........|.|.....|.|
Helichrysum felinum          -h1 |b.|.....|....|...........|.|...................|..........|.........|.|.....|.|
Fuirena hirsuta              -h1 |a.|.....|....|...........|.|...................|..........|.........|.|.....|.|
Tetraria microstachys        -h1 |a.|.....|....|...........|.|...................|..........|.........|.|.....|.|
Printzia polifolia           -h1 |.b|.....|....|...........|.|...................|..........|.........|.|.....|.|
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***Protea neriifolia* Subcommunity**

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Protea neriifolia            -s2 |..|br3.b|....|...........|.|.+............r....|..........|.........|.|.....|.|
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***Hermannia althaeifolia* Subcommunity**

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Hermannia althaeifolia       -h1 |..|.....|....|...+a.++rr+|.|.......+...........|..........|.........|.|.....|.|
Hibiscus aethiopicus         -h1 |..|.....|....|++.+......+|.|...................|..........|.........|.|.....|.|
Ursinia saxatilis            -h1 |..|.....|....|.+r....rrr.|.|..........r........|..........|.........|.|.....|.|
Ficinia albicans             -h1 |..|.....|....|aa...++....|.|...................|..........|.........|.|.....|.|
Clutia alaternoides          -s2 |..|....r|....|++........+|.|................r..|..........|.........|.|.....|.|
Relhania pungens             -s2 |..|.....|....|+..+.......|.|...................|..........|.........|.|.....|.|
Chrysanthemoides monilifera  -s2 |..|.....|....|....+...a.+|.|...................|..........|.........|.|.....|.|
Diospyros lycioides          -s2 |..|.....|....|+....+....b|.|.....a.............|..........|.........|.|.....|.|
Aspalathus kougaensis        -s2 |..|.....|....|........aa.|.|...................|..........|.........|.|.....|.|
Tritoniopsis antholyza       -h1 |..|.....|r...|.+.+..+....|.|...................|..........|.........|.|.....|.|
Gerbera serrata              -h1 |..|..r..|....|..b+...+...|.|...................|..........|.........|.|.....|.|
Ficinia quinquangularis      -h1 |..|.....|....|...+...+...|.|...................|..........|.........|.|.....|.|
Ischyrolepis triflora        -h1 |..|.....|....|...+...+...|.|...................|..........|.........|.|.....|.|
Themeda triandra             -h1 |..|.....|....|.....+....3|.|...................|..........|.........|.|.....|.|
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***Acacia mearnsii* facies**

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Acacia mearnsii              -t3 |..|.....|....|...........|b|...r...............|..........|.........|.|.....|.|
Leptospermum laevigatum      -t3 |..|.....|....|...........|b|...................|..........|.........|.|.....|.|
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***Relhania calycina–Phylica confusa* Fynbos Community**

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Relhania calycina            -h1 |..|rr.r.|..++|...........|.|m+++a+1maaab++++a+a|b+++++++1+|.........|.|.....|.|
Viscum capense               -h1 |..|..r..|....|+..........|.|+.+...+++++++++.r.r|r.....+.++|.........|.|.....|.|
Helichrysum teretifolium     -h1 |..|.....|....|..r.+......|.|...+.........+..r..|..+.+....+|.........|.|.....|.|
Cassytha ciliolata           -h1 |..|.....|.r..|...........|.|............+......|.....+...+|.........|.|.....|.|
Carpobrotus edulis           -h1 |..|.....|....|...........|.|..+....a...........|.r........|.........|.|.....|.|
Stoebe microphylla           -h1 |..|r....|....|...........|.|+......+.......+...|.....+...r|.........|.|.....|.|
Secamone alpini              -h1 |..|.....|....|...........|.|.......+...........|..+..+....|.........|.|.....|.|
Tetraria robusta             -h1 |..|.....|....|...........|.|b..r...............|..........|.........|.|.....|.|
Tetraria compressa           -h1 |..|.....|....|...........|.|..................3|..........|.........|.|.....|.|
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***Eriocephalus africanus* Subcommunity**

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Eriocephalus africanus       -s2 |..|...r.|....|..r........|.|....+..++..+.+.....|b+b+a+aaa1|b.3..r.3.|.|.....|.|
Ficinia repens               -h1 |..|.....|....|...........|.|...................|......+++.|.........|.|.....|.|
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***Ruschia tenella–Gazania rigens* Coastal Rocky Headland Community**

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Ruschia tenella              -h1 |..|.....|....|...........|.|............+......|..........|b.a+r..+b|b|rrr.+|.|
Limonium scabrum agg.        -h1 |..|.....|....|...........|.|...................|..r.......|r.r+a+1+.|.|.bbam|.|
Gazania rigens               -h1 |..|.....|....|...+...r...|.|...................|..........|..r.r+..r|r|aaa3a|4|
Drosanthemum marinum agg.    -h1 |..|.....|...+|...........|.|............+......|...+r.....|...a.a+..|.|arraa|.|
Tetragonia decumbens         -h1 |..|.....|....|...........|.|...................|..........|..b......|.|....+|.|
Sporobolus virginicus        -h1 |..|.....|....|...........|.|...................|..........|r....+..r|4|..a.+|.|
Sarcocaulon natalense        -h1 |..|.....|....|...........|.|...................|..........|.........|.|.aa..|.|
Carpobrotus deliciosus       -h1 |..|.....|....|...........|.|...................|..........|.........|.|...b+|.|
Thesidium fragile            -h1 |..|.....|....|...........|.|...................|..........|.........|.|...ma|.|
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***Pterocelastrus tricuspidatus–Ruschia tenella* Coastal Scrub Community**

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Pterocelastrus tricuspidatus -s2 |..|..r..|r.r.|...........|.|.......+...........|.ra...a..1|bb45..++.|.|.....|.|
Sideroxylon inerme           -s2 |..|.....|....|...........|.|...................|..........|...r...b.|.|.....|.|
Delosperma edwardsiae        -h1 |..|.....|..r.|...........|.|...................|..........|..a.b....|.|.....|.|
Cineraria britteniae         -h1 |..|.....|....|...........|.|...................|..r.......|..a...+..|.|.....|.|
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Other native spp. common to coastal fynbos and rocky headland habitats

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Passerina vulgaris           -s2 |..|..rab|..a+|4a31b3+3..3|a|.++aa+aaa+.+++aab4b|aabaa+1aaa|3.3a.a4m3|b|..a..|.|
Erica discolor               -s2 |ra|aa...|r+++|..b.+.a+...|.|a33ab3abbbbb3b333b3|31.+.3a+bb|.......ar|a|.....|.|
Phylica confusa              -s2 |ra|ra...|.aa+|+.r.b++b...|.|33a3+333b3b.33aabbb|3+aa3133bb|b.3..r.+.|.|.....|.|
Cliffortia serpyllifolia     -s2 |..|.....|..+.|....+......|.|..+a....+m.+..+1b.a|.a+4.....a|......ba.|.|.....|.|
Agathosma ovata              -s2 |..|...r.|....|...........|.|...a.+m+b+.+.+.m..a|r1r+b+...a|.ar..r.+.|.|.....|.|
Colpoon compressum           -s2 |..|...r.|...+|...........|.|...rr.r...+..b1.a..|.rr.......|.b3..r.+.|.|.....|.|
Agathosma apiculata          -s2 |..|.....|..r.|...........|.|+....r++...........|..+.......|..a......|.|.....|.|
Indigofera heterophylla      -h1 |..|.....|..++|...+.++....|.|.++...+.++..+..+...|..+++.+++.|r....++..|.|.....|.|
Lampranthus sociorum         -h1 |..|.....|.1+1|....+++.rr+|.|....+..++....+.+...|.++.+++..+|.ar....+.|.|..r..|.|
Thesidium podocarpum         -h1 |..|.....|...+|.......+...|.|....+.........++...|.........+|.......+.|.|.....|.|
Chironia baccifera           -h1 |..|.....|..r.|...........|.|...................|..r...+.+.|.....r++.|.|.....|.|
Crassula sp.                 -h1 |..|.....|....|...........|.|...................|.r..rr...r|rr....++r|r|rrr..|.|
Oxalis sp.                   -h1 |r.|.....|....|.+..+.....+|.|.............+..r.r|.........+|.......+.|.|.....|.|
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Invasive alien spp.

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Acacia cyclops               -s2 |..|..r3.|rr++|r.r.a..ra.+|.|.+r.3ra.a33b+++ab..|a+4+..+b+.|3....br+r|3|.....|.|
Acacia cyclops               -j1 |..|.....|....|...........|.|+..................|..........|.........|.|.....|.|
Pinus pinaster               -t1 |..|.....|r...|r..r...r...|.|r..rrr........r....|..........|.........|.|.....|.|
Pinus pinaster               -j1 |..|.....|....|...........|.|......r............|..........|.........|.|.....|.|
Leptospermum laevigatum      -s2 |..|.....|....|.+r+...r.b.|.|...................|..........|.........|.|.....|.|
Casuarina sp.                -s2 |..|.....|....|.......a...|.|...................|..........|.........|.|.....|.|
Leptospermum laevigatum      -s1 |..|.....|....|...........|.|...rr..............|..........|.........|.|.....|.|
Acacia mearnsii              -s1 |..|.....|....|...........|.|.....r.............|..........|.........|.|.....|.|
Hakea sericea                -s2 |..|.....|....|...........|.|..............r...a|..........|.........|.|.....|.|
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TABLE 2.—Classification of the vegetation of the coastal cliff habitats south of George, South Africa (cont.)

Infrequently occurring spp. (sp. name; vegetation layer; relevé number(s), cover/abundance score)	
Adromischus caryophyllaceus	-h1: 48,+
Agathosma capensis	-s2: 1,r
Amphithalea fourcadei	-h1: 4,r; 24,+
Anthospermum littoreum	-h1: 67,+
Aspalathus nigra	-h1: 22,+
Bassia diffusa	-h1: 66,+
Cassine papillosa	-s2: 56,+; 59,+
Cineraria geifolia	-h1: 28,r
Cineraria saxifraga	-h1: 60,+
Commelina africana	-h1: 5,r
Cotyledon orbiculata	-h1: 58,r
Crassula expansa	-h1: 28,r; 47,+
Crassula fascicularis	-h1: 28,r
Crassula rupestris	-h1: 44,r; 48,+
Crassula tetragona	-h1: 67,+
Cynodon dactylon	-h1: 58,+
Delosperma litorale	-h1: 57,r
Disperis capensis	-h1: 14,r
Disphyma crassifolium	-h1: 11,+
Drosera sp. *(Victor 318)*	-h1: 1,r
Ehrharta capensis	-h1: 18,r
Ehrharta erecta	-h1: 45,+; 56,r; 59,r
Eragrostis capensis	-h1: 27,r
Erica hispidula	-h1: 3,r; 5,r
Erica versicolor	-s2: 12,r; 47,r
Euchaetis albertiniana	-h1: 37,+; 51,+
Euclea crispa	-s2: 16,+
Ficinia gracilis	-h1: 1,r
Freesia alba	-h1: 83,+
Herschelianthe hians	-h1: 41,+
Hermannia salvifolia	-h1: 13,+; 24,+
Ischyrolepis helenae	-h1: 3,r
Knowltonia vesicatoria	-h1: 12,+
Lampranthus sp. *(Victor 220)*	-h1: 57,r
Lampranthus conspicuus	-h1: 15,+
Lobelia bicolor	-h1: 56,r
Myrica quercifolia	-h1: 27,r
Ornithogalum sp.	-h1: 66,+; 67,+
Phylica strigulosa	-s2: 8,+; 29,+; 46,+
Plecostachys serpyllifolia	-h1: 29,r
Rhus crenata	-s2: 56,+; 58,r
Rhus glauca	-s2: 37,+; 45,r; 58,+
Rhynchosia capensis	-h1: 1,r
Rhynchosia ciliata	-h1: 22,+
Sarcostemma viminale	-s2: 58,+
Sutera aethiopica	-h1: 45,r
Syncarpha canescens	-h1: 25,+
Tarchonanthus camphoratus	-s1: 12,+
Tarchonanthus camphoratus	-s2: 44,r
Thesium lisae-mariae	-h1: 1,r
Tribolium uniolae	-h1: 31,+
Vicia sativa	-h1: 44,+

other fynbos communities in the study area, mostly due to an absence of a distinct restioid stratum. The community is exposed to sun and wind and is consequently hot and dry. Compounding this dryness, the soils are generally shallow and stony due to natural surface erosion at the summit of these cliffs. Slopes vary from flat to moderate. The community tends to grade into thicket inland, often with a tall *Passerina* belt before the true thicket. There is a high degree of invasion by *Acacia cyclops* (present in 78% of relevés), possibly causing habitat modification, which could ultimately lead to irreversible changes in species composition and vegetation structure.

Ba. *Tetraria cuspidata* Subcommunity

This subcommunity has the same dominant and common species as the Community itself, but with *Viscum capense* as a common species. It is usually found more inland of the other subcommunity suggesting that the two subcommunities form a gradient from lower altitude to wind-protected inland plant communities.

Bb. *Eriocephalus africanus* Subcommunity

Transition to lower altitude, steep-slope communities. It has slightly steeper slopes than the typical cliff summit community and is often moderately exposed to the influence of salt spray. There are also higher soil conductivity levels, which can be attributed to higher levels of wind-borne salt effects (see below). *Pterocelastrus tricuspidatus* and *Lampranthus sociorum* are occasionally present. This community is further marked by the absence of: *Tetraria cuspidata, Viscum capense* and *Syncarpha paniculata*.

C. *Pterocelastrus tricuspidatus–Ruschia tenella* Coastal Scrub Community

The woody component of this community reflects the species composition of the coastal scrub in the deeply incised valleys along this coastline and there is possibly a floristic gradient from this community into thicket on other steep slopes. Diagnostic species: *Pterocelastrus tricuspidatus* as well as infrequent occurrence of *Sideroxylon inerme, Delosperma edwardsiae* and *Cineraria britteniae*.

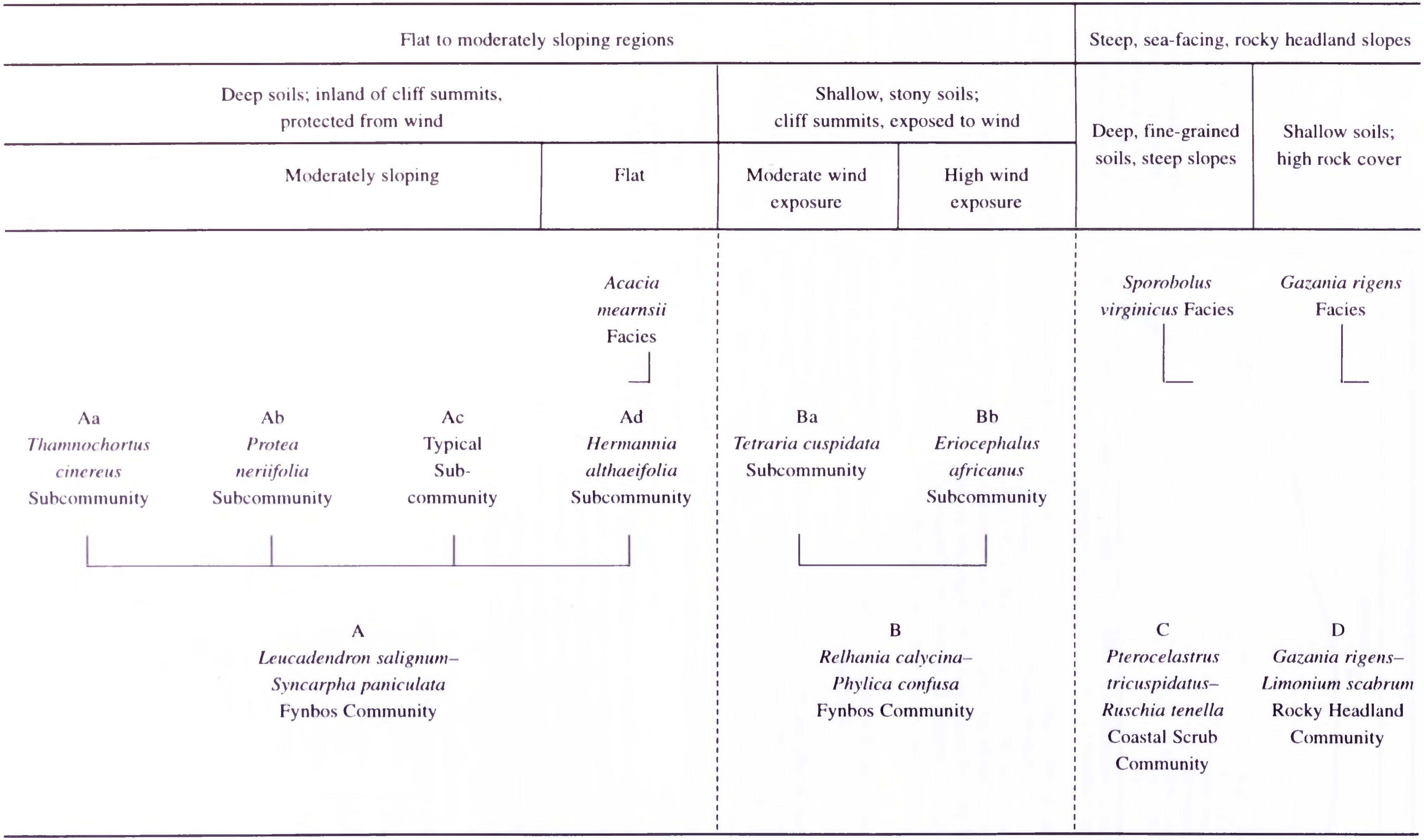

FIGURE 2.—Community environmental and floristic relationships in the coastal fynbos between Rooiklip and Ghwanobaai, south of George, South Africa.

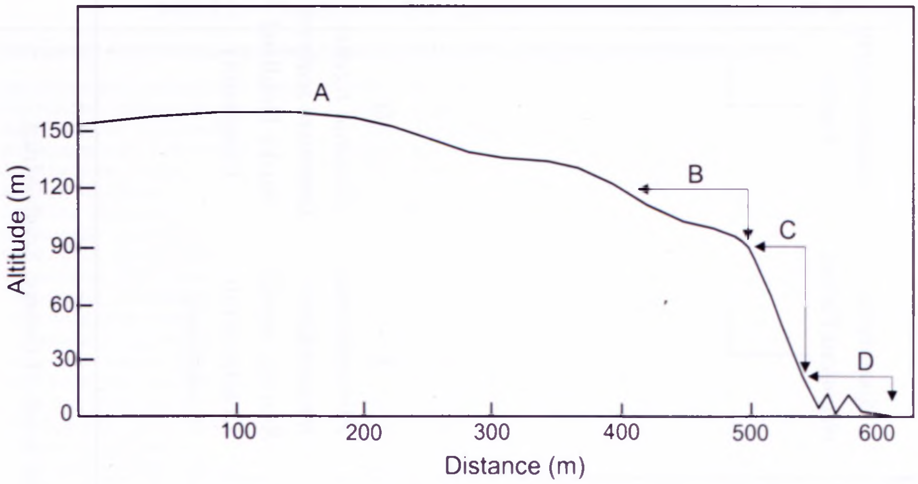

FIGURE 3.—Generalised profile diagram of coastal area south of George indicating the spatial relationship of communities to one another and the sea.

Common or dominant species: *Passerina vulgaris, Phylica confusa, Lampranthus sociorum, Agathosma ovata* and *Eriocephalus africanus*, as well as the shrub *Colpoon compressum*. Shrubs are wind-cropped to a maximum of 1 m, and the total aerial cover of the vegetation averages 60%. A facies, dominated by *Sporobolus virginicus* (Table 2, rel. 62), was distinguished within this community.

D. *Gazania rigens–Limonium scabrum* Rocky Headland Community

Salt-tolerant asteraceous *Gazania rigens* var. *uniflora* and a taxon from the *Limonium scabrum* complex accompanied by mesembs such as *Drosanthemum marinum* and *Ruschia tenella*, as well as other leaf succulents such as *Crassula* sp. and *Sarcocaulon natalense*, form an assemblage typical of the exposed rocky headlands in the southern Cape.

Community C and the rocky headland 'herbland' Community D have many species in common, which can be ascribed to a so-called neighbourhood effect (or mass effect; Shmida & Wilson 1985). Naturally, the exposed Community D is virtually lacking (except of *Sarcocaulon natalense*) in its 'own' diagnostic species because of the environmental stress in the form of deposition of wind-borne salt that poses a major selective pressure on the potential species pool.

Due to the low altitude this community is greatly exposed to the influence of the wind and especially to salt spray (Figure 3). The vegetation has a very low cover and is wind-cropped. The average height of the vegetation is between 0.13 and 0.33 m. Of all the community types, this one is lowest in species richness with a mean of 10 species on average. Shallow soil covering granite rocks is characteristic, and is often less than 5 cm deep and very stony. Surface boulders are often present and modify the microhabitat to some degree. A facies with *Gazania rigens* var. *uniflora* was distinguished within this community (Table 2, rel. 68).

This species composition corresponds with the description of similar rocky headland communities described for other parts of the coastline at Plettenberg Bay (Hellström 1990) and Port Alfred (Lubke 1983).

Gradient analysis

The ordination of the fynbos communities (Figure 4) revealed a horseshoe structure allowing the direct recognition of a coenocline spanning two fynbos communities

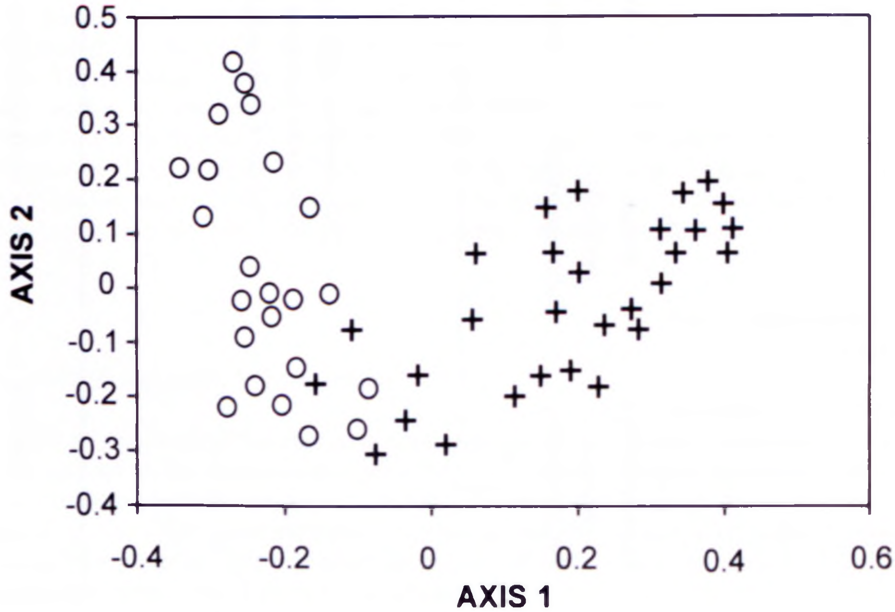

FIGURE 4.—Ordination of fynbos vegetation using Principal Coordinates Analysis. +, relevés of the *Relhania calycina–Phylica confusa* Fynbos Community; ○, relevés of the *Leucadendron salignum–Syncarpha paniculata* Fynbos Community.

TABLE 3.—Soil properties for communities (mean with standard deviation in brackets)

Soil parameter	Community			
	A	B	C	D
Moisture (%)	2.6 (2.3)	3.2 (2.8)	4.2	1.9 (1.5)
Water-holding capacity (ml/g)	0.7 (0.1)	0.9 (0.2)	0.7	0.5 (0.1)
Organic material (%)	7.0 (3.1)	12.3 (5.0)	7.8	4.4 (1.1)
pH	6.1 (0.2)	5.9 (0.2)	6.3	6.4 (0.1)
Conductivity (mS/m)	18.3 (9.2)	29.5 (18.9)	40.2	26.8 (10.5)
Coarse sand (%)	53.6 (10.9)	64.2 (6.5)	56.9	59.5 (15.9)
Medium sand (%)	11.2 (3.7)	11.0 (2.2)	14.5	13.9 (6.4)
Fine sand (%)	21.4 (6.8)	13.8 (3.2)	16.0	14.2 (6.4)
Silt (%)	11.9 (1.6)	10.1 (2.7)	6.6	8.2 (1.1)
Clay (%)	1.8 (0.8)	0.9 (0.5)	6.0	4.3 (2.0)
Number of samples	5	12	1	2

A, *Leucadendron salignum–Syncarpha paniculata* Fynbos Community; B, *Relhania calycina–Phylica confusa* Fynbos Community; C, *Pterocelastrus tricuspidatus–Ruschia tenella* Coastal Scrub Community; D, *Gazania rigens–Limonium scabrum* Rocky Headland Community.

along Axis 1 of the scatter diagram. There was a clear separation along this coenocline between the *Relhania calycina–Phylica confusa* Fynbos Community and the *Leucadendron salignum–Tetraria cuspidata* Fynbos Community. This pattern is interpreted in terms of exposure to wind and salt spray as reflected in topographical features and soil properties.

A classification scheme accompanied by associated environmental relationships (Figure 2) suggests that the *Leucadendron salignum–Tetraria cuspidata* Fynbos Community occurs on deep soils inland of the cliff summits where the vegetation is protected from wind and salt spray. The *Relhania calycina–Passerina vulgaris* Fynbos Community occurs on shallow, stony soils on the cliff summits, where there is a higher exposure to wind and salt spray.

Physical soil properties varied from community to community (Table 3). Cliff summits had the highest proportion of coarse sand, slopes above the cliff summits had the highest proportion of silt, and steep tallus slopes and rocky headland slopes had the highest proportions of medium sand, fine sand and clay. This is a trend in decreasing sand particle size away from the cliff summit (below and above) and larger proportion of clay to silt below the cliff summits (steep tallus slopes and rocky headland slopes).

Soil conductivity levels showed a decreasing trend as exposure to wind from the sea decreased. High levels were recorded on the steep tallus slopes, the cliff summits and the rocky headland slopes. The two cliff summit communities showed a difference in conductivity levels with the *Eriocephalus africanus* Subcommunity having higher conductivity measures than the *Tetraria cuspidata* Subcommunity. These higher conductivity levels were attributed to higher salinity levels from wind-borne salt spray effects.

Fire appeared to play an important role in the nature of the communities especially in the *Leucadendron salignum–Syncarpha paniculata* Fynbos Community where the subcommunities Aa and Ab could be separated from the subcommunities Ac and Ad based on evidence of recent burning. We suggest that the subcommunities are distributed along a fire-induced succession gradient, but with site-specific effects also coming into play.

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