The phytosociology of the Vermaaks, Marnewicks and Buffelsklip valleys of the Kammanassie Nature Reserve, Western Cape

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Long-term conservation ecosystems require a broader understanding of the ecological processes involved. Because ecosystems react differently to different management practices, it is important that a description and classification of the vegetation of an area are completed. A vegetation survey of the valley areas of the Kammanassie Nature Reserve was undertaken as part of a larger research project to assess the environmental impacts of large-scale groundwater abstraction from Table Mountain Group aquifers on ecosystems in the reserve. From a TWINSPAN classification, refined by Braun-Blanquet procedures, 21 plant communities, which can be grouped into 13 major groups, were identified. A classification and description of these communities, as well as a vegetation map of the different areas are presented. Associated gradients in habitat were identified by using an ordination algorithm (DECORANA). The diagnostic species as well as the prominent and less conspicuous species of the tree, shrub, forb and grass strata are outlined. The study also resulted in a total number of 481 species being identified and the discovery of a new *Erica* species. These vegetation surveys and descriptions provide baseline information for management purposes and that allows monitoring as well as similar surveys to be conducted in future.

Key words: Braun-Blanquet, plant communities, TWINSPAN, vegetation classification.

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Introduction

The Department of Water Affairs and Forestry (DWAF) is responsible for the management of the Klein Karoo Rural Water Supply Scheme (KKRWSS). The scheme supplies purified domestic water, at subsidised rates, to the town of Dysselsdorp, to farms in the Olifants River Valley, to tributary valleys downstream of the Stompdrift and Kammanassie dams, and to the Gamka River Valley downstream of Calitzdorp. The KKRWSS commenced abstraction in 1993 and today abstracts approximately 1.1 x 106 m^3/a of groundwater (Cleaver *et al.* 2003). A total of four production boreholes were drilled into the Peninsula Formation on the Kammanassie Nature Reserve and one production borehole is on declared private catchment and has been drilled into the Nardouw Formation, within the Vermaaks River catchment. The Vermaaks River well field in the eastern sector abstracts approximately 0.65 x 106 m^3/a from these five boreholes (Cleaver *et al.* 2003).

Large-scale groundwater abstraction was highlighted as one of the activities that could have a detrimental impact on the environment, and was listed by the Minister of Environmental Affairs under Section 21 of the National Environmental Conservation Act No. 73 of 1998. Unfortunately no Ecological Impact Assessment (EIA) had been carried out prior to the KKRWSS, as this was not a requirement by legislation at the time. The full implication of the effects of large-scale groundwater abstraction on the environment

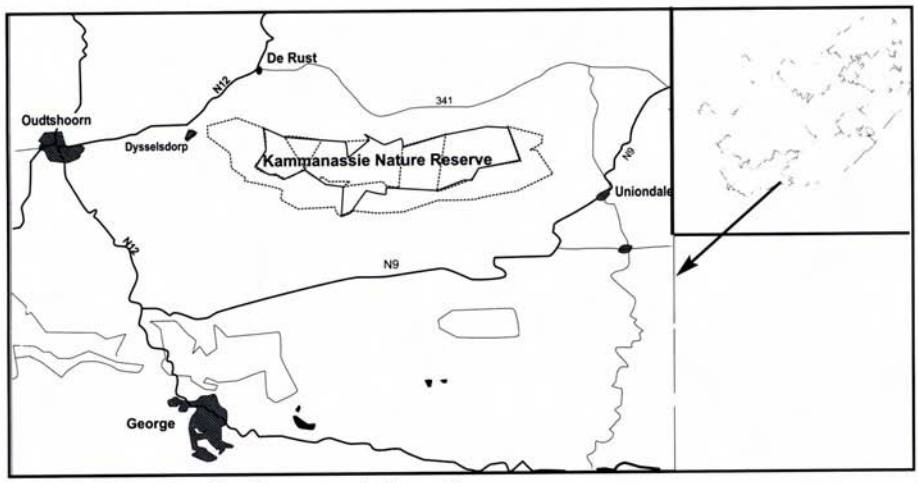

Fig. 1. The locality of the Kammanassie Nature Reserve.

is not clearly understood and this has resulted in the Western Cape Nature Conservation Board (WCNCB) adopting a conservative approach. To date research has concentrated on understanding the geology and geohydrology of the Kammanassie Mountain while very few of the studies have taken the environment, especially the non-aquatic ecosystems, into consideration.

In order to plan for the future it is imperative that a better understanding is achieved of the effects of large-scale groundwater abstraction on the environment. As early as 1995, Cape Nature Conservation officials expressed concern that large-scale groundwater abstraction by the KKRWSS was having a negative impact on the environment. It was observed that numerous springs on the Kammanassie Mountain had started drying up and vegetation in the Vermaaks River Valley started showing signs of water stress.

Because ecosystems react differently to different management practices (Brown & Bezuidenhout 2000; Bredenkamp 1982; Bezuidenhout 1993), it is important that a description and classification of the vegetation of an area is done (Brown & Bezuidenhout 2000; Van Rooyen *et al.* 1981). The purpose of this paper is therefore to classify, describe and map the different vegetation types found in the valley areas of the Kammanassie Mountain. This data will then be used in the long-term monitoring of the affected ecosystems as well as for reserve management purposes.

This study forms part of a larger research project funded by the Water Research commission to assess the environmental impacts of large-scale groundwater abstraction from Table Mountain Group aquifers on ecosystems in the Kammanassie Nature Reserve.

Study area

The Kammanassie Mountain complex is situated between the towns of Uniondale in the east and De Rust/Dysselsdorp in the northwest and west (Fig. 1). The mountain is an inselberg within the Little Karoo between the Swartberg and Outeniqua mountains. The total area of the mountain range managed by the WCNCB is 49 430 ha, of which 21 532 ha are privately owned, declared mountain catchment. The remaining 27 898 ha are state land, of which 17 661 ha have been declared forest. The Kammanassie Nature Reserve is situated between 33°33'50"S–33°37'10"S and 22°27'29"E–23°01'55"E, was proclaimed a protected area

in 1978 (Cleaver 2002), and is an important water catchment area.

Vegetation

According to Rebelo (1996) and Lubke (1996) the Kammanassie Mountain falls into the Fynbos and Thicket biomes. Very small pockets of the Forest Biome are found in kloofs on the southern slopes of the Kammanassie Nature Reserve (Cleaver 2002).

The Fynbos Biome is characterised by its high richness in plant species (over 8000 species) and its high endemicity (Low & Rebelo 1996). The main physiognomic features of the vegetation are the prevalent sclerophyllous shrub form, the scarcity of trees and the relatively minor importance of grasses and evergreen succulent shrubs (Kruger 1979). Low & Rebelo (1996) recognises five major vegetation types within the Fynbos Biome of which only the Mountain Fynbos, is found in the Kammanassie Nature Reserve.

The Subtropical Thicket biome comprises closed shrubland to low forest dominated by evergreen, sclerophyllous or succulent trees, shrubs and vines. Lubke (1996) recognises five major vegetation types within this biome of which only the Spekboom Succulent Thicket is found on the Kammanassie Mountain.

The canopy cover of forests is continuous, comprising mostly evergreen trees, and beneath it the vegetation is multi-layered. The ground layer is almost absent due to the dense shade. Lubke & Mckenzie (1996) recognise three major vegetation types of which only Afromontane Forest is found on the Kammanassie Mountain.

Climate

The reserve receives rain throughout the year with an average annual rainfall of approximately 450 mm (Fig. 2). The highest annual rainfall of 1216 mm and lowest of 242 mm were recorded in 1981 and 1984 respectively. The hottest months on the Kammanassie Nature Reserve are from December to February with average maximum temperatures of 35 °C and the coldest months are June and July with average minimum temperatures of -2 °C (Cleaver *et al.* 2003)

Geology

The Kammanassie Mountain is one of the prominent east-west trending ranges comprising the southern branch of the Cape Fold Belt. It was formed as a result of north-south oriented compressive stress during the Cape Orogeny 123-200 million years ago. The Kammanassie Nature Reserve is an eroded remnant of the Kammanassie mega-anticline (Halbich & Greef 1995). The Kammanassie Mountain range comprises almost exclusively the resistant quartz arenites of the Table Mountain Group, overlain on the lower slopes by the shale of the Bokkeveld Group (Kotze 2001). A very important shale marker horizon, the Cedarberg Formation (varying between 50 and 120 metres thick) occurs within the Table Mountain Group, separating formations of the Peninsula Formation from the lithologies comprising the Nardouw (Kotze 2001).

According to Kotze (2001) the Peninsula Formation is a highly competent succession

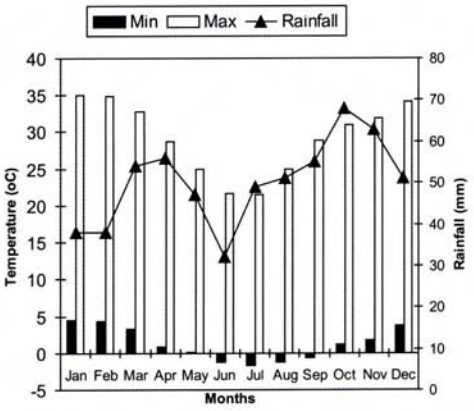

Fig. 2. The average monthly rainfall and the mean average minimum and maximum temperatures for the Kammanassie Nature Reserve (1977-2001).

of medium to coarse-grained, thickly bedded, grey sandstone. The Nardouw weathers more brownish, and thin shale intercalations are more common than in the Peninsula Formation. The Nardouw Formation is more ductile as a result (Kotze 2001). Recent deposits occur in the floor of the steep-sided Vermaaks River Valley where talus/scree accumulations, up to 20 m thick, are encountered. These deposits comprise large angular quartzite fragments, in some cases metres in diameter, set in an unconsolidated silty matrix (Kotze 2001).

Soils generally form a thin (<1 m) veneer of silty sands/sandy silts as a result of the steep slopes of the Kammanassie Mountain and predominantly quartzitic rocks. Locally clayey soils occur in association with weathered shale horizons, and in particular the Cedarberg Formation (Cleaver *et al.* 2003).

Methods

In order to distribute sample plots efficiently and effectively so that all relevant variation in vegetation would be sampled, the research area was stratified into physiognomic-physiographic units, by using 1:50 000 stereo aerial photographs and 1:30 000 non-stereo aerial photographs. These physiognomic-physiographic units were then verified in the field and the necessary changes effected to ensure that all variations in the vegetation were considered and sampled. A total of 92 relevés were randomly located within these units at the Vermaaks Valley, eighteen at the Marnewicks Valley and nineteen at the Buffelsklip Valley. Plot size was calculated using the nested plot method and determined to be 400 m².

The cover-abundance of each species was assessed according to the Braun-Blanquet cover-abundance scale (Mueller-Dombois & Ellenberg 1974). Fieldwork was carried out between May to August 2000, and May to July 2001. Plant taxon names mostly conform to those given by Goldblatt & Manning (2000). These names may, therefore, differ from the plant species list used by the TURBOVEG database (Hennekens 1996a), which is based on the PRECIS database of the South African National Biodiversity Institute (SANBI) in Pretoria, as on date 1997.

The percentage cover of grasses and herbaceous plants, shrubs (woody species varying in height between >0–3 m) and trees (woody species higher than 3 m) were also estimated. The locality of each plot was determined using a Global Positioning System. Environmental data recorded included aspect, altitude, slope, geology, soil type, percentage rock cover and rock size (small: <10 mm; small/medium: >10–50 mm; medium: >50–200 mm; medium/large: >200– 00 mm; and large: >300 mm).

The floristic data was analysed according to Braun-Blanquet procedures using TURBOVEG (Hennekens 1996a). A first approximation of the main plant communities was derived by applying the two-way indicator species analysis (TWINSPAN) (Hill 1979a) to the floristic data. Further refinement of the classification was achieved by Braun-Blanquet procedures (Bredenkamp *et al.* 1989; Kooij *et al.* 1990; Bezuidenhout 1993; Eckhart 1993; Brown & Bredenkamp 1994). Results are presented in a phytosociological table (Table 1) using MEGATAB (Hennekens 1996b) and the identified plant communities are indicated on a vegetation map (Fig. 3).

An ordination technique, DECORANA (Hill 1979b), was also applied to the floristic data to illustrate floristic relationships between plant communities, to detect possible gradients associated in and between communities and to detect possible habitat gradients associated with vegetation gradients.

Results

Classification

The analysis resulted in the following 21 plant communities, which can be grouped into 13 major community types being identified. The results are presented in a phytosociological table (Table 1) and are indicated on a vegetation map (Fig. 3). In the descriptions of the different plant communities, all species groups refer to Table 1, therefore no repeated reference will be made to Table 1.

DODONAEA ANGUSTIFOLIA-RHUS PALLENS VEGETATION TYPE

A: *Gymnosporia buxifolia-Osyris compressa* Bush

1. *Elegia capensis-Miscanthus capensis* Scrub
2. *Calopsis paniculata-Cliffortia strobilifera* Scrub
3. *Calpurnia intrusa-Rhus pallens* Woodland
   - 3.1. *Calpurnia intrusa-Acacia karroo* Woodland
     - 3.1.1. *Heteromorpha arborescens* Variant
     - 3.1.2. Typical variant
   - 3.2. *Calpurnia intrusa-Diospyros dichrophylla* Woodland

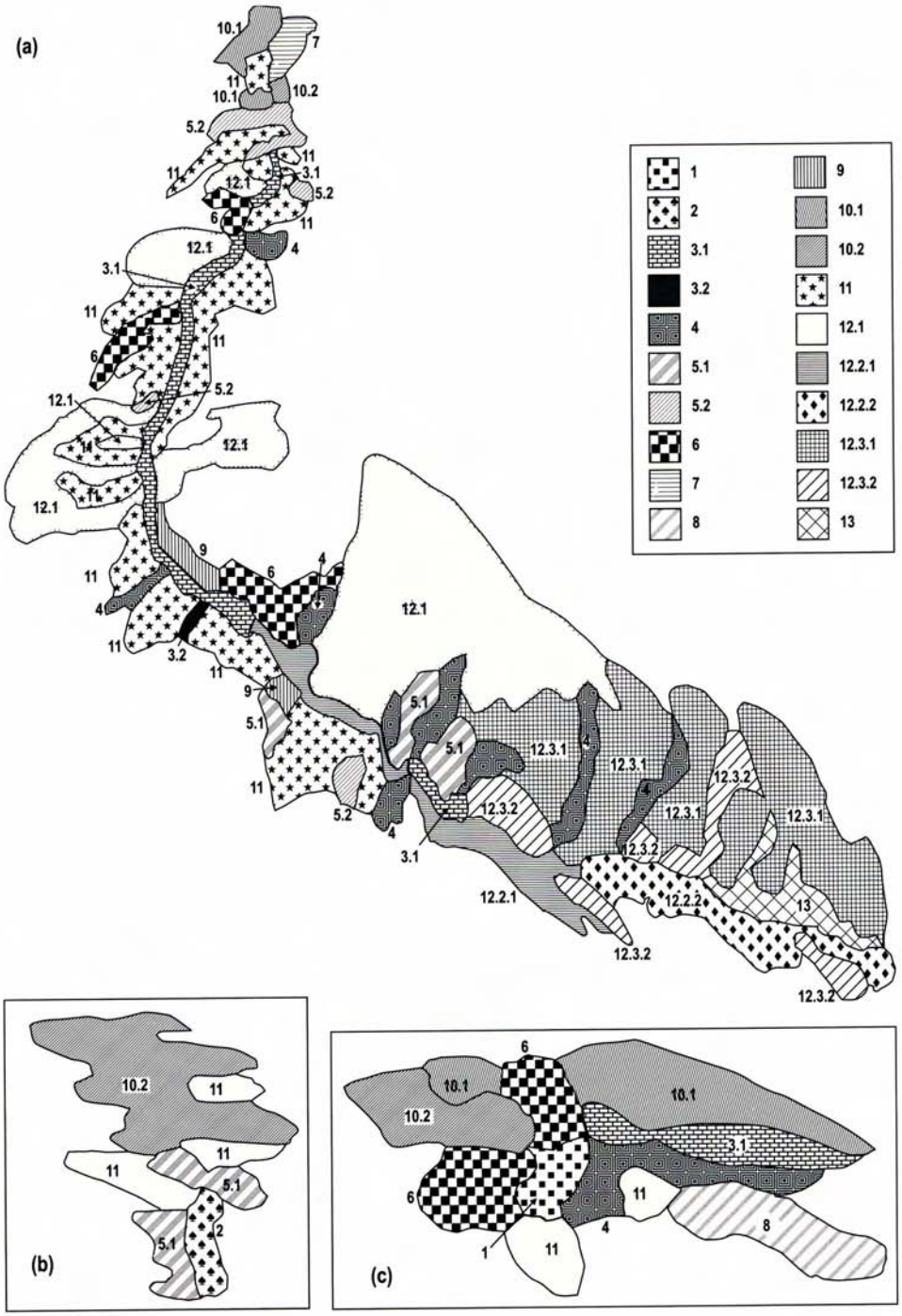

Fig. 3. (a) Vegetation Map of the Vermaaks, Marnewicks and Buffelsklip valleys on the Kammanassie Nature Reserve; (b) The plant communities of the Marnewick valley of the Kammanassie Nature Reserve; (c) The plant communities of the Buffelsklip valley of the Kammanassie Nature Reserve

4. *Tarchonanthus camphoratus-Osyris compressa* Bush
5. *Ficus burtt-davyi-Euclea polyandra* Woodland
   5.1. *Diospyros lycioides-Ficus burtt-davyi* Woodland
   5.2. *Lachnostylos bilocularis-Ficus burtt-davyi* Woodland
6. *Clutia alaternoides-Euclea polyandra* Woodland
7. *Carissa haematocarpa-Acacia karroo* Woodland
8. *Pentaschistis malouinensis-Rhus pallens* Scrub
9. *Osyris compressa-Rhus pallens* Bush

B: *Euclea undulata-Portulacaria afra* Succulent Scrub

10. *Pteronia incana-Portulacaria afra* Scrub
    10.1. *Euclea undulata-Portulacaria afra* Scrub
    10.2. *Passerina obtusifolia-Portulacaria afra* Scrub

C: *Pteronia incana-Eriocephalus africanus* Karroid Scrub
11. *Pteronia incana-Eriocephalus africanus* Scrub

D: *Ischyrolepis ocreata-Elytropappus adpressus* Scrub

12. *Ischyrolepis ocreata-Protea nitida* Scrub
    12.1. *Elytropappus adpressus-Protea nitida* Scrub
    12.2. *Pentaschistis tortuosa-Dodonaea angustifolia* Scrub
        12.2.1. Typical variant
        12.2.2. *Pentaschistis tortuosa* Variant
    12.3. *Metalasia pungens-Leucadendron salignum* Scrub
        12.3.1. *Phylica imberbis* Variant
        12.3.2. *Chironia baccifera* Variant
13. *Eragrostis plana-Ehrharta erecta* Grassland

Description of the plant communities

The vegetation of the whole area is classified as the *Dodonaea angustifolia-Rhus pallens* vegetation type is characterised by the presence of species from species group CC. The vegetation is totally dominated by the tall shrub *Rhus pallens* (species group CC) with the tall shrubs *Nymania capensis*, *Dodonaea angustifolia*, the karroid shrub *Elytropappus adpressus*, and the grass *Chrysocoma ciliata* (species group CC) being co-dominant or very prominent in the whole study area. These species will therefore not necessarily be mentioned in the descriptions of the various plant communities.

A: *Gymnosporia buxifolia-Osyris compressa* Bush

1. *Elegia capensis-Miscanthus capensis* Scrub

This vegetation is found in patches in the streambed of the Buffelsklip River.

This wet stream scrub is restricted to the streambed of the Buffelsklip River at altitudes ranging from 698–732 m above sea level (asl). The slope is between 4–15° with a western aspect. The alluvial soil is sandy with a 10 % rock cover. Upstream of these relevés all flow of the river is channelled into a furrow causing the water at this site to flow only after heavy rains.

The total cover of this vegetation is 80 %, of which the tree layer covers 0 %, the shrub layer 5 % and the herbaceous layer 70 %.

The diagnostic species of the *Elegia capensis-Miscanthus capensis* stream scrub is listed in species group A. The diagnostic restio *Elegia capensis* and grass *Miscanthus capensis* (species group A) together with the restio *Ischyrolepis ocreata* (species group U) dominate the vegetation. The shrub *Cliffortia ilicifolia* (species group Y) is also prominent.

2. *Calopsis paniculata-Cliffortia strobilifera* Scrub

This sub-community occurs in the streambed of the Marnewicks River. Water flows permanently through these relevés.

The altitude varies between 548–568 m asl on a very gentle north to south-western slope. Rock cover is between 5–10 % (small-to-medium). Soil in the river is sandy-loam.

Tree cover is 20 %, shrub cover is 40 % and the herbaceous layer is 30 %.

Diagnostic species for the *Calopsis paniculata-Cliffortia strobilifera* wet streambank scrub include (species group B) the shrubs *Cliffortia strobilifera*, *Pelargonium pseudoglutinosum*, *Morella serrata*, *Helichrysum ordoratissimum*, *Pelargonium hispidum*,

Lobostemon glaucophyllus, *Athanasia tomentosa*, the resio *Calopsis paniculata*, rush-like *Juncus lomatophyllus* and the fern *Thelypteris confluens*.

The shrubs *Cliffortia ilicifolia* (species group Y), *Osyris compressa* and *Gymnosporia buxifolia* (species group O), *Rhus pallens*, *Dodonaea angustifolia* and *Elytropappus adpressus* (species group CC) dominate this community. The forb *Pelargonium scabrum* (species group CC) are also prominent while the the sedge *Mariscus thunbergii* is locally dominant with a cover of 50–70 %.

3. *Calpurnia intrusa-Rhus pallens* Woodland

This woodland is found on dry-to-moist streambanks scattered along the Vermaaks River. The tree *Calpurnia intrusa*, the shrub *Buddleja salviifolia*, the grass *Dipogon lignosus*, the forbs *Solanum linneanum*, *Nemesia fruticans*, *Senecio panduratus* and *Stachys aethiopica* and the fern *Pteridium aquilinum* (species group C) are diagnostic for this community.

3.1. *Calpurnia intrusa-Acacia karroo* Woodland

This sub-community occurs on the streambanks of the Vermaaks River Valley, at altitudes between 543-675 m asl. Aspects of north-east and west with gentle slopes of 3° are dominant.

Soil is sandy-loamy on the alluvial streambank. Small-to-medium rocks occur at a cover of 5–40 %.

Vegetation cover varies between 10–50 %.

The presence of the tree *Acacia karroo*, the woody vine *Clematis brachiata* and the dwarf shrub *Salvia africana-lutea* (species group D) are diagnostic for this sub-community.

3.1.1. *Heteromorpha arborescens* Variant

This variant is found only in the Vermaaks River Valley, in the dry streambed in alluvial soils.

The variant is predominantly found on westerly slopes with a gradient of between 1–16°, at an altitude of 543–668 m asl. Rock cover (small-to-medium) varies from less than 5 % to 40 % with sandy soils dominant.

Trees and shrubs dominate the *Heteromorpha arborescens* Variant, with 40 % cover for each. The herbaceous layer has a cover of 10 %.

The presence of the tree *Heteromorpha arborescens*, the shrub *Lycium afrum*, the grass *Cynodon dactylon*, the creepers *Falckia repens* and *Rumex lativalvis*, the forbs *Laportea peduncularis*, *Spergularia rubra*, *Aizoon canariense*, *Tetragonia portulacoides* and *Pelargonium grossularioides*, the fern *Histiopteris incisa*, the invasive plants *Gomphocarpus fruticosus*, *Solanum guineense* and the weed *Arctotheca prostrata* (species group F), is diagnostic for this variant.

This variant is dominated by the trees *Acacia karroo* (species group D), *Gymnosporia buxifolia* (species group O), and the shrub *Pelargonium zonale* (species group O). Other species also prominent include the trees *Calpurnia intrusa* (species group C), *Heteromorpa arborescens* (species group F), the shrub *Conyza scabrida* (species group E), the woody vine *Clematis brachiata*, the ferns *Pteridium aquilinum* (species group C) and *Histiopteris incise* (species group F). The aromatic forbs *Mentha longifolia*, *Mentha aquatica* (species group E), and the grasses *Ehrharta erecta*, *Ehrharta ramosa* (species group CC) and *Pentaschistis tortuosa* (species group V) are also present within this variant.

3.1.2. Typical variant

This variant occurs in the river valley of the Vermaaks River and is found on north-east facing gentle slopes of 0–3°. The altitude varies between 577–583 m asl. Soil is sandy in the alluvium streambed. The rock coverage, comprising small rocks, is estimated at 10 %.

Tree and shrub cover is between 30–50 %, with a herbaceous layer of 10–20 %.

This variant is characterised by the absence of species from species group F. Dominant species for this variant include the tree *Gymnosporia buxifolia* and large shrub *Osyris compressa* (species group O), the large shrubs *Rhus pallens* and *Nymania capensis* and the succulent *Euphorbia maurianica* (species group CC).

Other prominent species include the trees *Acacia karroo* and *Clematis brachiata* (species group D), *Hetromorpha arborescens* (species group F), *Lachnostylis bilocularis* (species group J), the shrubs *Pelargonium pseudoglutinosum*, *Morella serrata* (species group B), the grasses *Pentaschistis tortuosa* (species group V), *Ehrharta erecta* (species group CC) and the forbs *Senecio panduratus* (species group C) and *Oxalis polyphylla* (species group BB) are prominent species for this variant.

3.2. *Calpurnia intrusa-Diospyros dichrophylla* Woodland

The *Calpurnia intrusa-Diospryos dichrophylla* Woodland sub-community occurs in the river valley of the Vermaaks River.

This woodland is found at altitudes between 678–810 m asl. Slope varies from gentle (2–3°) to moderate (10–16°) on predominantly north north-westerly slopes. This sub-community occurs in sandy alluvial soils of the streambed. Rock cover varies from either 20–40 % medium-to-large or small-to-medium size, or 5 % small rocks.

All relevés have 70 % tree coverage, 25 % shrubby layer and 5 % herbaceous layer present.

Diagnostic species include all species listed in species group H, namely the large shrubs *Diospyros dichrophylla*, *Pterocelastrus tricuspidatus*, the dwarf shrubs *Felicia aethiopica*, *Peucedanum capense*, the forb *Cineraria lobata* and the grass *Pentaschistis* species.

The vegetation is totally dominated by the trees *Gymnosporia buxifoila*, *Osyris compressa*, and the forb *Pelargonium zonale*, (species group O). The trees *Tarchonanthus camphoratus*, *Myrsine africana*, *Cussonia paniculata* and *Maytenus oleoides* (species group G) together with the shrubs *Diospyros dichrophylla* (species group H), *Diospyros lycioides* (species group O) and *Calpurnia intrusa* (species group C) are co-dominant within this community.

4. *Tarchonanthus camphoratus-Osyris compressa* Bush

This community occurs in the Vermaaks and Buffelsklip River valleys.

This streambank bush occurs at altitudes of 572–901 m asl. Aspect varies greatly but is dominant on western slopes. The gradient varies from gentle slopes (1–2°), moderate (8–15°) to steep (26–31°). A high rock coverage of 20–60 % occurs with mostly medium-to-large rocks present. Sandy soil occurs in all relevés.

This plant community has a tree cover of 50 %, shrub cover of 30 % and a herbaceous cover of 10 %.

The presence of the trees *Tarchonanthus camphoratus*, *Maytenus oleiodes*, *Cussonia paniculata*, the shrubs *Myrsine africana*, *Euclea crispa*, *Feylinia densiflora*, the forb *Cineraria alchemilloides* and the climber *Kedrostis nana* (species group G) and the absence of species from species group H are diagnostic for this plant community.

The vegetation is dominated by the trees *Rhus pallens* (species group CC) and *Osyris compressa* (species group O), while the trees *Tarchonanthus camphoratus* (species group G), *Euclea polyandra* (species group L), and the shrub *Euclea crispa* (species group G) are very prominent. Other species also prominent include the shrub *Chrysanthemoides monolifera* (species group U) the grassses *Themeda triandra* (species group T), *Cymbopogon pospischilii* (species group BB) and the forb *Pelargonium zonale* (species group O).

5. *Ficus burtt-davyi-Euclea polyandra* Woodland

The *Euclea polyandra-Ficus burtt-davyi* woodland is confined to the valley and kloof

areas in the western part of the Kammanassie Mountain on scree under steep cliff faces.

Diagnostic species of this sub-community include the trees *Ficus burtt-davyi*, the shrubs *Withania somnifera*, the invasive shrub *Solanum tomentosum*, the succulent *Cotyledon woodii*, the forb *Pelargonium trifidum* and the creeper *Kedrostis capensis* (species group I).

5.1. *Diospyros lycioides-Ficus burtt-davyi* Woodland

This sub-community is found on scree in the Vermaaks and Marnewicks Valleys.

Areas belonging to this kloof woodland are relatively steep with a gradient that varies between 8-35°. Altitude varies between 515–770 m asl on predominantly north-west and north-east slopes. Soils are sandy with small-to-large rocks, with coverage of 10–90 %.

Tree cover is between 50–70 %, shrub coverage is 10–40 % and the herbaceous cover varies between 10–20 %.

This sub-community is characterized by the absence of species from species group J and the presence of species listed in Group I.

The trees *Ficus burtt-davyi* (species group I), *Euclea polyandra* (species group L), the shrub *Diospyros lycoides* (species group O) and the succulent *Tylecodon paniculatus* (species group S) dominate the vegetation. The grasses *Digitaria eriantha* (species group S), *Ehrharta erecta* and *Ehrharta ramosa* (species group CC) are prominent locally.

5.2. *Lachnostylos bilocularis-Ficus burtt-davyi* Woodland

This valley woodland sub-community is found on scree in the Vermaaks Valley.

The altitude varies between 504–772 m asl on steep slopes (17–42°), and aspect varies greatly. Soil is sandy and rock cover is high, 30–50 % (medium-large), found on scree, under cliff faces.

Tree coverage is 60–80 %, with shrub cover between 5–25 % and herbaceous cover between 5–15 %.

The tree *Lachnostylos bilocularis*, the shrubs *Euclea schimperi*, *Melianthus comosus*, *Euclea natalensis*, the bulb *Haemathus albiflos*, the succulent *Crassula capitella* and the forb *Centella eriantha* (species group J) are diagnostic species for this sub-community.

The vegetation is dominated by the trees *Lachnostylos bilocularis* (species group J) and *Euclea polyandra* (species group L). Other species also prominent include the tree *Ficus burtt-davyi* (species group I), the shrub *Pelargonium zonale* (species group O), the grass *Digitaria eriantha* (species group S), and the succulent *Tylecodon paniculatus* (species group S).

6. *Clutia alaternoides-Euclea polyandra* Woodland

The *Clutia alaternoides-Euclea polyandra* Woodland is located on the kloof/cliff areas of the Vermaaks Valley.

Altitude varies between 534–621 m asl, on east to south-west slopes of between 3–34°. Soil is sandy and rock cover of 30 % is found on these scree slopes with medium-to-large rocks present.

Tree cover is 70 %, with shrub cover of 15–25 % and herbaceous cover of between 5–10 %. Succulents dominate the herbaceous layer.

Diagnostic species for this plant community are given in species group K, and include the shrubs *Clutia alaternoides*, *Morella humilis*, the forb *Oxalis* species and the succulent *Crassula atropurpurea*.

The vegetation is dominated by the shrub *Clutia alaternoides* (species group K) and the tree *Euclea polyandra* (species group L). The tree *Gymnosporia buxifolia* (species group O), shrub *Morella humilis* (species group K), and the succulents *Adromischus caryophyllaceus*, *Aloe comptonii*, *Tylecodon paniculatus* (species group S) (species group S) are also prominent locally.

7. *Carissa haematocarpa-Acacia karroo* Woodland

This community is found in the river valley of the Vermaaks Valley.

The altitude varies between 497–513 m asl, on south south-east and east slopes of 2–10°. Soil is sandy with small-to-medium rocks covering less than 5–10 % of the soil surface.

Tree cover varies between 20–70 %, shrub coverage between 25–60 % and the herbaceous layer between 5–20 %.

Diagnostic species for the *Carissa haemetocarpa-Acacia karroo* river valley woodland include the shrubs *Galenia papulosa*, *Lineum telephoides*, the creepers *Drosanthemum* cf. *delicatulum*, *Drosanthemum hispidum* and the grass *Sporobolus africanus* (species group M).

The trees *Acacia karroo* (species group D), *Diospyros lycoides* (species group O), and the shrub *Carissa haematocarpa* (species group P) dominate the vegetation. Prominent species include the trees *Gymnosporia buxifolia* (species group O), the shrub *Grewia robusta* (species group Q), and the grasses *Sporobolus africanus* (species group M) and *Eragrostis plana* (species group BB).

The shrubs *Osyris compressa* (species group O) and *Elytropappus adpressus* (species group CC) are locally conspicuous.

8. *Pentaschistis malouinensis-Rhus pallens* Scrub

This plant community is located on the open slopes of the Buffelsklip Valley.

Steep slopes between 21–30° on south to south-western slopes vary in altitude between 709 –721 m asl. Soil is sandy with medium-to-large rocks covering 30–40 % of the soil surface.

The tree layer is 10 %, shrub coverage is 40 % and the herbaceous cover is 20 %.

The ferns *Cheilanthes hastata* and *Cheilanthes capensis*, the forb *Polyxena ensifolia*, the bulb *Spiloxene trifurcillata* and grass *Pentaschistis maloulnensis* (species group N) are the diagnostic species for this plant community.

The vegetation is dominated by the shrub *Osyris compressa* (species group O), while the shrubs *Passerina obtusifolia* (species group Q), *Oedera squarrosa*, *Anthospermum aethiopicum* (species group T), *Eriocephalus africanus* (species group CC) are locally prominent.

9. *Osyris compressa-Rhus pallens* Bush

This community is located in the Vermaaks and Buffelsklip valleys and comprises dense valley bush.

Altitude varies between 650–775 m asl, on north, north-east and north-western aspects on slopes between 1–31°. Soil is sandy with rock cover 10–80 % and less than 5 % present at certain localities.

Shrubs have a cover of between 40–70 % and the herbaceous layer has a cover of 10–20 %.

The presence of the tree *Gymnosporia buxifolia*, the shrubs *Pelargonium zonale*, *Osyris compressa*, *Leonotis ocymifolia*, *Diospyros lycoides* and the forb *Oxais pes-caprae* (species group O) and the absence of species from species groups A–N is characteristic for this community.

Although the vegetation is dominated by the shrubs *Clutia alatemoides* (species group K), *Osyris compressa* and *Gymnosporia buxifolia* (species group O), the vegetation comprises a mixture of other co-dominants such as the shrub *Diospyros lycioides* (species group O), *Euclea undulata* (species group CC) and the grass *Themeda triandra* (species group T).

The shrubs *Dodonaea angustifolia*, *Eriocephalus africanus* (species group CC) and the grass *Cynodon dactylon* (species group F) are conspicuous locally.

B: *Euclea undulata-Portulacaria afra* Succulent Scrub

10. *Pteronia incana-Portulacaria afra* Scrub

This community is found on steep shale slopes in the Vermaaks, Marnewicks and Buffelsklip valleys.

Diagnostic species for this community include the shrubs *Portulacaria afra*, *Carissa haematocarpa*, *Chaetacanthus setiger*, *Asparagus striatus*, *Putterlickia pyracantha* and the succulent *Pachypodium bispinosum* (species group P).

10.1. *Euclea undulata-Portulacaria afra* Scrub

This sub-community is located on the higher-lying slopes of the Vermaaks and Buffelskip valleys.

This succulent dominated sub-community is found on steep slopes (23–34°), at altitudes between 524–782 m asl. Aspect varies greatly between north-east, north, west and south slopes and is found on shale bands. Soil is sandy with small-to-medium rocks with a coverage of 25–40 %.

Tree coverage is 10 %, shrub cover is 20–60 % and the herbaceous layer is 10–40 %.

This sub-community is characterized by the presence of species from species groups P and R and the absence of species from species group Q.

The vegetation is dominated by the trees *Portulacaria affra* (species group P) with the shrub *Pteronia incana* (species group R) locally dominant. Other species also prominent include the shrubs *Pteronia incana*, *Eriocephalus africanus* (species group CC) and the succulents *Adromischus caryophyllaceus*, *Aloe comptonii* (species group S), *Crassula rupestris*, *Cotyledon orbiculare*, (species group CC). The succulent *Crassula atropurpurea* (species group K) is present locally.

10.2. *Passerina obtusifolia-Portulacaria afra* Scrub

The *Passerina obtusifolia-Portulacaria afra* sub community is characteristic of the lower slopes found predominantly in the Marnewicks Valley, but also in the Vermaaks and Buffelsklip valleys.

Altitude varies between 494–808 m asl, on slopes between 1–30°. Aspect varies greatly. Soils are sandy with small-to-medium rock size, with a rock coverage of 10–30 %.

Tree coverage is 10 %, shrubs cover is between 40–60 % and the herbaceous cover is between 10–20 %.

Diagnostic species for this sub-community include the tree *Grewia robusta*, the shrubs *Passerina obtusifolia*, *Polygala myrtifolia*, *Rushia multiflora* and the forb *Pollichia campestris* (species group Q).

The vegetation is dominated by the tree *Portulacaria affra* (species group P) and the shrubs *Pteronia incana* and *Passerina obtusifolia* (species group R). Prominent species are the shrubs *Carissa haematocarpa* (species group P), *Polygala myrtifolia*, *Ruschia multiflora*, *Grewia robusta* (species group Q), and *Helichrysum zeyheri* (species group R).

C: *Pteronia incana-Eriocephalus africanus* Karroid Scrub

11. *Pteronia incana-Eriocephalus africanus* Scrub

This karroid shrub community, which is the dominant plant community in the study area, is located in the Vermaaks, Marnewicks and Buffelsklip valleys.

Altitude varies between 385–776 m asl on dry slopes of 16–33°. Aspect varies greatly. Soils are sandy with rock cover varying between 10–60 % (small-medium-large).

The shrub cover is 50–70 %, dominated by *Eriocephalus africanus* and the herbaceous coverage is 20–40 %.

This community is characterized by the presence of species from species groups R, S and T. The vegetation is dominated by the shrub *Pteronia incana* (species group R) and the grasses *Digitaria eriantha* (species group S) and *Themeda triandra* (species group T).

The shrubs *Felicia filifolia*, *Rushia lineolata* (species group T), and the succulents *Tylecodon paniculatus*, *Adromischus caryophyllaceus* (species group S) are prominent within this community.

D: *Ischyrolepis ocreata-Elytropappus adpressus* Scrub

12. *Ischyrolepis ocreata-Protea nitida* Scrub

The open scrubby fynbos *Ischyrolepis ocreata-Protea nitida* community is situated in the Vermaaks River. This plant community is divided into three sub-communities.

Species diagnostic for this community include the tree *Protea nitida*, the shrubs *Chrysanthemoides monilifera*, *Montinia caryophyllacea*, *Hibiscus aethiopicus*, *Aspalathus laricifolia*, *Muraltia dispersa*, *Eriospermum capense*, *Helichrysum teretifolium*, the fern *Ceterach cordatum* and the restio *Ischyrolepis ocreata* (species group U).

12.1. *Elytropappus adpressus-Protea nitida* Scrub

This open scrub fynbos sub-community is found in the Vermaaks River.

Altitude varies between 571–721 m asl on moderate to steep slopes (8–32°). Aspect varies greatly. Soil is sandy with a rock coverage of 5–20 %, small-to-medium in size.

Tree coverage is 5–10 %, shrubs cover 60–70 % and the herbaceous layer has a coverage of 10–30 %.

This community is characterised by the absence of species groups V–AA. Dominant species include shrubs *Protea nitida* (species group U), *Elytropappus adpressus* (species group CC) and the grass *Ehrharta erecta* (species group CC). Prominent shrubs include *Aspalathus laricifolia* (species group U), *Eriocephalus africanus*, *Dodonaea angustifolia* and *Senecio juniperinus* (species group CC).

12.2. *Pentaschistis tortuosa-Dodonaea angustifolia* Scrub

The *Pentaschistis tortuosa-Dodonaea angustifolia* sub-community comprises open scrubby fynbos and is found in the Vermaaks River.

The shrubs *Muraltia ericaefolia*, *Metalasia massonii*, *Polygala microlopha*, *Metalasia pallida*, *Aspalathus hystrix*, *Hermannia holosericea*, the forb *Pelargonium pulverulentum* and the grass *Pentaschistis tortuosa* (species group V) are diagnostic for this sub-community.

12.2.1. Typical variant

This variant occurs on dry steep slopes of 18–28°, at altitudes between 708–954 m asl. Aspect varies greatly but south and north north-west slopes are dominant. Soil is sandy with rock coverage ranging between 5–30 % (small-medium-large).

Shrubs cover is 30–40 % with herbaceous cover of 40–60 %, with grasses dominating the herbaceous layer.

The absence of species from species group X is characteristic of this community. The vegetation is dominated by the shrubs *Chrysanthemoides monilifera* (species group U), *Oedera squarrosa*, and the grass *Themeda triandra* (species group T). Other species also prominent include the shrubs *Protea nitida* (species group U), *Muraltia ericaefolia*, (species group V), *Asparagus africanus*, *Dodonaea angustifoli*, *Eriocephalus africanus* and *Elytropappus adpressus* (species group CC).

12.2.2. *Pentaschistis tortuosa* Variant

This variant occurs on north, north-east and north north-west dry steep slopes (11–25°), at high altitudes between 918–1004 m asl. Soils are sandy with a rock coverage of 15–30 %, comprising small, medium and large rocks.

Shrub coverage is 40–70 % and the herbaceous cover is 10–30 %.

Diagnostic species for this variant includes the shrubs *Pentzia elegans*, *Lobostemon fruticosus*, the fern *Pellaea calomelanos*, the forb *Pelargonium auritum* and the grass *Tribolium uniolae* (species group X). The vege-

tation is dominated by the tree *Dodonaea angustifolia*, the shrubs *Pentaschistis tortuosa* (species group V), *Asparagus africanus*, *Elytropappus adpressus* (species group CC) and the grass *Themeda triandra* (species group T).

Other prominent shrubs include the shrubs *Ruschia lineolata* (species group T), *Montinia caryophyllacea* (species group U) and *Aspalathus histrix* (species group V). The shrubs *Osyris compressa* (species group O), *Rhus pallens* (species group CC) and the grasses *Eragrostis plana* and *Cymbopogon plurinodis* (species group BB) are present locally.

12.3. *Metalasia pungens-Leucadendron salignum* Scrub

This fynbos sub-community is found in the Vermaaks Valley.

The *Metalasia pungens-Leucadendron salignum* scrubby fynbos diagnostic species include the shrubs *Clutia polifolia*, *Metalasia pungens*, *Cliffortia falcata*, *Erica curvifolia*, *Agathosma affinis*, *Hermannia cunefolia*, *Leucadendron salignum*, *Protea repens*, *Pteronia stricta*, *Elytropappus gnaphaloides*, *Cliffortia ilicifolia*, *Zygophyllum flexuosum*, *Agathosma ovata*, the bulb *Androcymbium capense*, the herb *Othonna auriculifolia*, the forb *Scabiosa columbaria*, the fern *Mohria caffrorum*, the restios *Rhodocoma arida*, *Restio fourcadei* and the grass *Aristea pusilla* (species group Y)

12.3.1. *Phylica imberbis* Variant

Altitude varies between 901–1004 m asl, on south, south south-west and south south-east slopes of 13–29°. Soil is sandy with a rock cover of 10–30 % of medium-to-large in size.

Tree coverage is 10 %, with the shrub layer coverage 65 % and the herbaceous cover 10–30 %.

Diagnostic species for the *Phylica imberbis* Variant (species group Z) include the shrubs *Phyica imberbis*, *Muraltia leptorhiza*, *Leucadendron rubrum*, *Pelargonium laevigatum*, the forbs *Oxalis obtusa*, *Chamarea capensis* and the restio *Cannomois scirpoides*.

The shrubs *Phylica imberbis* (species group Z) and *Metalasia pungens* (species group Y) dominate the vegetation, while the shrubs *Muraltia leptorhiza* (species group Z), *Agathosma affinis* (species group Y), the forb *Scabiosa columbaria*, and the restio *Cannomois scirpoides* (species group Z) are locally prominent.

12.3.2. *Chironia baccifera* Variant

Altitude varies between 858–1114 m asl, on moderate to steep slopes (10–25°), on south, south south-east and south south-west slopes. Soil is sandy with a low rock coverage of 5–10 %.

Tree cover is 25 % with shrub cover varying between 20–60 % and herbaceous cover of 20–60 %.

The shrubs *Polygala fruticosa*, *Indigofera heterophylla*, *Plecostachys polifolia*, *Selago glomerata*, *Sutera denudata*, *Chironia baccifera*, the forbs *Disa bracteata*, *Pritzia polifolia*, *Pelargonium myrrhifolioum* and the bulbous herb *Corymbium africanum* (species group AA) are diagnostic species for the *Chironia baccifera* Variant.

The vegetation is dominated by the shrubs *Cliffortia falcata* and *Erica curvifolia* (species group Y). The shrubs *Ischyrolepis ocreata*, *Chrysanthemum monolifera* (species group U), *Printzia polifolia* (species group AA) together with the grass *Themeda triandra* (species group T) are prominent locally.

13. *Eragrostis plana-Ehrharta erecta* Grassland

This karroid grassland occurs in the upper reaches of the Vermaaks River Valley.

Altitude varies between 926–990 m asl and is found on south south-west to west dry slopes of 1–2°. Soil is sandy with no rocks present.

Shrub coverage is 40–60 % and the herbaceous cover, dominated by *Ehrharta erecta* is between 40–60 %.

Diagnostic species for this community include the shrubs *Athanasia trifurcata*, *Hermannia flammea*, the forbs *Oxalis polyphylla*, *Selago dregei*, the bulb *Babania sambucina* and the grasses *Eragrostis plana*, *Cymbopogon plurinodis*, *Aristida diffusa* and *Aristida junciformis* (species group BB).

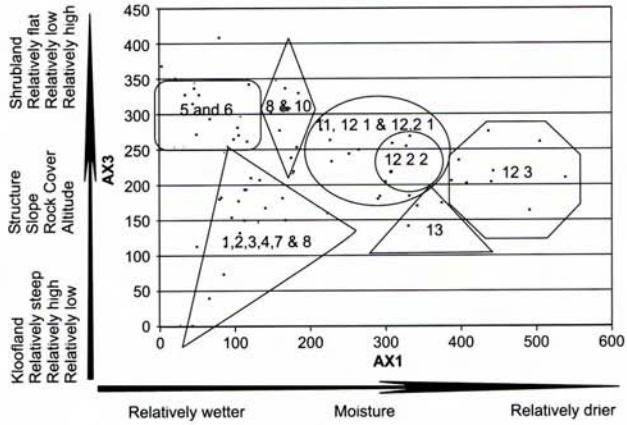

Fig. 4. Ordination.

This grassland is dominated by the grasses *Eragrostis plana* (species group BB) and *Ehrharta erecta* (species group CC). The shrubs *Chrysocoma ciliata*, *Elytropappus adpressus*, *Aspalatus suaveolens* (species group CC), *Pentaschistis tortuosa* (species group V), and the grass *Aristida diffusa* (species group BB) are prominent locally.

Ordination

The distribution of the plant communities along the first and third axes of the DECORANA ordination (Hill 1979a) is given in a scatter diagram (Fig. 4).

The third axis illustrates a gradient, which can be related to slope, rock cover and altitude (Fig. 4). Along this axis the plant community shifts from River Valley Woodland plant communities (1, 2, 3, 4, 7 and 9) to woodland plant communities (5 and 6), found on scree (top left corner of the graph). The first axis represents the moisture gradient, with the left being wetter and right drier.

Discussion

The plot size determined to be necessary for phytosociological vegetation surveys on the Kammanassie Mountain comprising predominantly mountain and arid fynbos was determined to be 400 m². Brown and Bezuidenhout (2000) used the same plot size when working in the Mountain Zebra National Park with predominantly Grassland and Nama-karoo biomes. McDonald (1993) however determined plot size for fynbos shrubland communities in the Southern Langeberg to be 50 m². The larger plot size necessary on the Kammanassie Nature Reserve could be attributed to the wide variety of plant communities surveyed, which included grassy proteoid vegetation in the Vermaaks Valley, valley and kloof shrubland, dense valley bush, succulent scrub, karroid grassland and open scrubby fynbos.

Plant communities 1 (wet stream scrub), 2, 3 (wet streambank scrub), 4 (streambank bush), 7 (river valley woodland) and 9 (dense valley bush) could be grouped together in the ordination (Fig. 4). Plant communities 5 and 6, valley and kloof woodland plant communities were found mainly on scree at high altitudes, very steep slopes (35–42°) and extremely rocky areas. They are found in the valleys, surrounded with steep cliffs on either side of the alluvium basin. These areas are situated under steep cliffs with moist soils as a result of being shaded most

of the day. Plant communities 8 (open slope scrub) and 10 (succulent scrub), dominated by *Portulacaria afra*, are found at high-medium altitudes on steep dry slopes with a high percentage of rock cover.

From the 21 different plant communities identified and described in this study a total number of 12 occur only in the Vermaaks Valley, two in the Buffelsklip Valley, and only one in the Marnewicks Valley. Three plant communities occur in both the Buffelsklip and Vermaaks valleys, while only a single community is found in both the Marnewicks and Vermaaks valleys. Only two plant communities (communities 10.2 & 11) occur in all three valleys. Eighty six percent of all the plant communities are therefore present in the Vermaaks Valley. The Buffelsklip and Marnewicks valleys comprise 33 % and 19 % respectively of all the plant communities identified.

This study also resulted in a total of 481 plant species being identified in the study area. A total of 441 plant species (92 % of all the species) were found in the Vermaaks Valley comprising 229 genera and 76 families while a total of 189 plant species (48 % of all the species) comprising 120 genera and 57 families were found in the Marnewicks Valley, and a total of 171 species (36 % of all the species) comprising 118 genera and 55 families were identified in the Buffelsklip Valley. A new *Erica* species was also discovered as a result of this survey (still to be named by Prof TE Oliver).

Conclusion

No similar vegetation descriptions have previously been completed on the vegetation of the valleys of the Kammanassie Mountain and this research therefore provides valuable data on these ecosystems. The data obtained from this study will be incorporated into the management plan (Cleaver 2002) for the Kammanassie Nature Reserve.

The large number of plant communities and plant species identified in the Vermaaks Valley can be contributed to the larger area studied, but is also an indication of the high conservation value of this valley with a vast number of habitats and species contributing to biodiversity. The presence of two and one unique plant communities in the Buffelsklip and Marnewicks valleys respectively, also makes them important from a conservation point of view.

The description of plant communities, together with the vegetation map can now serve as a basis to formulate a management programme for the Vermaaks, Marnewicks and Buffelsklip valleys in the Kammanassie Nature Reserve. An understanding of the plant communities and their associated habitats are of fundamental importance for compiling sound management and conservation strategies.

These vegetation surveys and descriptions provide baseline information on the plant species and communities present in the study area. Future monitoring data can be compared with this study to determine if changes/shifts in plant communities and species have occurred, especially in respect to the large-scale groundwater abstraction taking place in the Vermaaks Valley.

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