The identification and description of the management units of the Goegap Nature Reserve

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Goegap Nature Reserve, near Springbok, is situated in the floral paradise of Namaqualand. This 15 000 ha reserve falls within the Namaqualand Broken Veld and in the transition zone between this Veld type and the False Succulent Karoo. Otherwise, it could be said that the reserve falls within the Upland Succulent Karoo and the transition zone between this vegetation type and the Bushmanland vegetation type. With the use of stratified aerial photographs of the reserve, random sample plots were placed within each homogeneous physiographic-physionomic unit and 284 relevés were compiled in September 1998. With the use of the BBPC computer program, the resulting TWINSPAN split the data into two tables, one predominantly for the Plains and one for the Rocky Hills. After refining these tables, 13 plant communities were identified. These communities, together with the stratified aerial photographs, land type and habitat information were used to determine ten management units for the reserve. These units will be used in effective management and monitoring on the reserve.

Key words: management units, Namaqualand, plant communities, plains, rocky hills.

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Introduction

Namaqualand is famous for its mass floral displays of many annuals and some perennial species. In spring, after a good rainy season, this arid region is transformed into a land of colour (Rösch 1996). Goegap Nature Reserve is situated in this floral paradise, with numerous tourists visiting the region yearly.

The Hester Malan Nature Reserve was proclaimed in 1966. Later, in 1990, a section of adjoining land was added to the reserve and it was re-proclaimed as the Goegap Nature Reserve. Le Roux (1984) produced a description of the plant communities on the Hester Malan Section of the reserve after completion of the fieldwork in 1975 and 1976. As Le Roux's (1984) study did not include the Goegap Section, it was decided to conduct a botanical study of the entire reserve in 1998, 23 years later.

For this study it was decided to combine factors such as vegetation type and land type together with other habitat characteristics to determine management units according to which the reserve could be managed more effectively.

Study area

Goegap Nature Reserve is situated between 29°34'24"S–29°43'24"S and 17°54'40"E–18°07'20" E in the Namaqualand Rocky Hills near Springbok and covers approximately 15 000 ha. According to Acocks (1988) the reserve is situated in the Namaqualand Broken Veld and the transition zone between this veld type and the False Succulent Karoo. This is substantiated by Low & Rebelo (1996) which indicates that the reserve is situated in the Upland Succulent Karoo and in the transition zone between the Upland Succulent Karoo and the Bushmanland vegetation types.

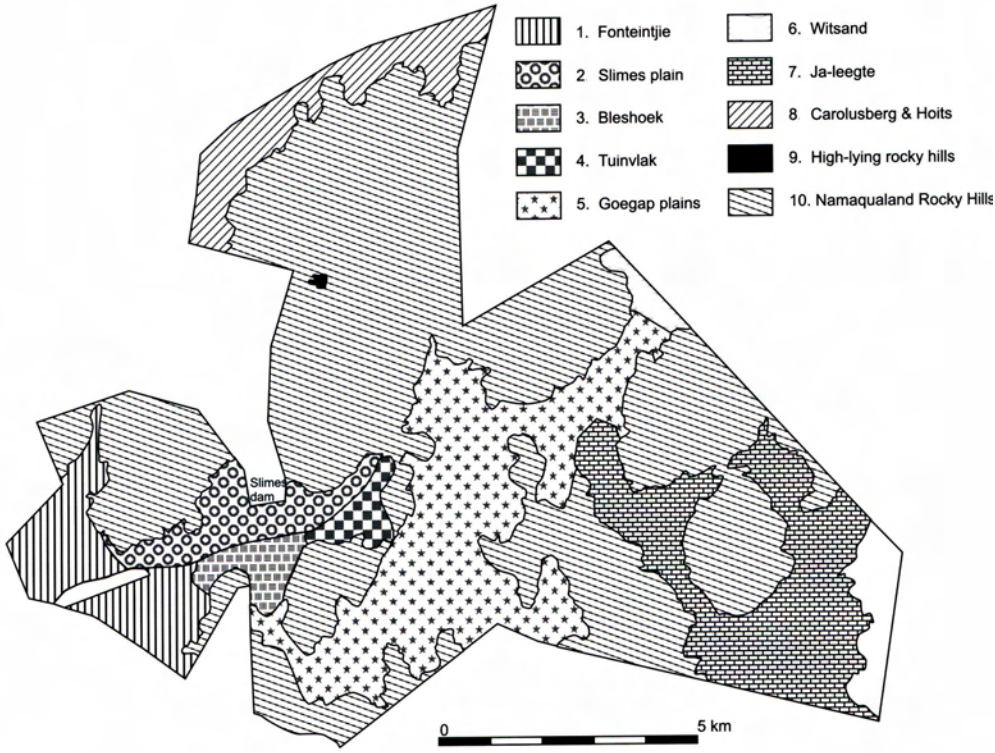

Fig. 1. Management units identified on Goegap Nature Reserve.

The reserve lies mainly in the winter rainfall area and the climate can be described as a warm, dry, desert climate, characterised by sparse, irregular winter rainfall and large daily and seasonal temperature fluctuations (Schulze 1965). The average annual rainfall on the reserve is 149.06 mm (reserve data 1977–1999), falling mainly in the winter months. The average rainfall in the winter season (May - September) is 106.61 mm (reserve data 1977–1999).

Four land types are present on the reserve, namely: Ae80, Ae85, Ib127 and Ib129. Map unit Ae refers to red, high base status soils which are deeper than 300 mm and no dunes are present, while map unit Ib indicates land types with exposed rock (exposed country rock, stones or boulders) covering 60–80 % of the area (Land Type Survey Staff 1987).

Land type Ae80 comprises granites and gneisses of the Okiep Group of the Namaqualand Metamorphic Complex. The Hutton soil form dominates this land type, especially along the footslopes (terrain unit 4) and the valleys (terrain unit 5), which comprises 80 % of the land type (Land Type Survey Staff 1987).

Gneissic granite of the Namaqualand Metamorphic Complex covered with early tertiary to more recent deposits of older sands dominates land type Ae85. This land type is characterised by the deep soils (>1200 mm) of the Hutton soil form (Land Type Survey Staff 1987).

The geology of land type Ib127 is also comprised of gneissic granite of the Namaqualand Metamorphic Complex. Sixty-seven percent of this land type is covered in rock. Granite boulders dominate on the crests and

midslopes (terrain units 1 & 3), with the footslopes and valleys characterised by Hutton soils (Land Type Survey Staff 1987).

Granite boulders also dominate land type Ib129 (69 % of this land type) which is found on the eastern side of the reserve (Land Type Survey Staff 1987). These granites and gneisses of the Okiep Group of the Namaqualand Metamorphic Complex create such large boulders that the reserve boundary fence runs along the foot of the boulders, in effect, excluding them from the reserve.

Materials and methods

Aerial photographs (1:50 000) of Goegap Nature Reserve were stratified into relatively homogeneous physiographic-physionomic units. With the use of maps of the infrastructure on the reserve, Braun-Blanquet (BB) sample plots were randomly placed in each of the units within walking distance of a road. These points were then located in the field and surveyed.

Relevés were compiled from 284 sample plots with a fixed plot size of 50 m^2 (Le Roux 1984). The fieldwork was done in September 1998. Each species present in the plot was noted and a cover-abundance value given according to the Braun-Blanquet cover-abundance scale (Werger 1974). Various topographic characteristics such as aspect, slope, an estimation of rock cover and erosion, soil type and colour were noted at each sampling point.

The floristic data were analysed with the use of BBPC suite (Bezuidenhout *et al.* 1996) and the resulting table was split into two with the help of TWINSPAN. This was done for each table, after which the tables were independently refined using Braun-Blanquet procedures to produce two phytosociological tables for the reserve. No attempt was made to formally fix syntaxa names, as this is normally avoided in detailed local studies (Coetzee 1983; Bezuidenhout 1996).

The collection code (HRSK) and number of some of the species were kept throughout the process as not all the species, especially the Mesembryanthemaceae, were positively identified. These specimens are kept at the Compton Herbarium.

The structural classification used was adapted from that proposed by Edwards (1983). The height class 'low' shrub, grass and herb class of Edwards (1983) was divided into two classes using the terminology of Campbell *et al.* (1981). The 'low' height class of Edwards (1983) becomes the low class from >0.25–0.50 m and the dwarf class from >0.00–0.25 m (Lloyd 1989). These classes conform to those adapted by Le Roux (1984) and Lloyd (1989). Only perennial species visible at all times of the year are used in the structural classification (Lloyd 1989).

A 1:50 000 map of the reserve, on which each sample plot and plant community were indicated was used together with the stratified aerial photographs, land type and habitat information, to determine management units on the reserve. Mosaic soil patterns were also taken into consideration, as these local differences would result in local changes in the vegetation. Thus, isolated plots of different plant communities within management units were ascribed to the mosaic soil pattern and not necessarily an indication of a different overall vegetation type.

Results and discussion

The floristic data analysis resulted in two phytosociological tables, one for the predominantly rocky hills and one for the plains. Nine plant communities were identified in the Plains table (Table 1) and four in the predominantly Rocky Hills table (Table 2). These communities and combinations thereof were used to identify ten management units on Goegap Nature Reserve (Fig. 1).

In semi-arid areas, as in the case of Goegap Nature Reserve, there can be considerable variation in the number of species in each sample plot from season to season and from year to year, because of the strong geophyte and ephemeral component (Lloyd 1989). The survey year was a drought year with an annual average rainfall of 102.2 mm compared to the annual average of 149.06 mm (years 1977–1999). The rainfall amount is not as significant as the distribution in time of the rainfall. The average rainfall in the winter season (May-September) on the reserve is 106.61 mm (years 1977–1999). However, in 1998 only 51.97 mm were recorded over the same period. The vegetation data collected were thus very dependent on the perennial component present in the field at the time of the survey and not the annual component which was very limited due to the low seasonal rainfall.

Description of the vegetation

1. Plant communities of the Plains (Table 1)

1. *Stipagrostis namaquensis* short closed grassland community

The *Stipagrostis namaquensis* short closed grassland community is found along the drainage lines on the plains of land types Ae85 and Ib127 (Table 1). These sandy soils of the low-lying areas, with no rock cover, are dominated by the perennial grass *S. namaquensis*. Other grasses or woody perennial species do not occur in combination with this species although, some annuals are present between the grass tussocks. This plant community differs from the other communities in that the grass, *S. namaquensis*, does not occur in any of the other communities (Table 1).

2. *Ruschia brevibracteata* short sparse shrubland community

The succulent *Ruschia brevibracteata* (Table 1) is dominant in this plant community and occurs in isolated patches throughout the reserve on the gentle midslopes of the Rocky Hills. Although found in the Rocky Hills, no rock cover is present where this community occurs. Various annuals and isolated perennials also occur in combination with the succulent *R. brevibracteata*.

3. *Stipagrostis obtusa* short closed grassland community

The *Stipagrostis obtusa* short closed grassland community is found in randomly distributed patches throughout the reserve (Species group C, Table 1). In all cases this community is present on the midslopes of land type Ib127 or Ae80 with sandy soils and no rock cover evident except, where isolated boulder(s) occur. *Stipagrostis obtusa* (Species group C) occurs in combination with Species group N which includes perennial species such as *Zygophyllum retrofractum*, *Galenia sarcophylla* and *Hypertelis salsoloides,* but *Stipagrostis obtusa* dominates (Table 1). Moles, porcupines and whistling rats frequently inhabit the area.

4. Cf. *Drosanthemum otzenianum* low closed shrubland community

The cf. *Drosanthemum otzenianum* low closed shrubland community occurs throughout Goegap Nature Reserve on the gradual slopes of the Plains and not in the Rocky Hills. This plant community occurs on land types Ae85, Ib127 and Ae80. Species group D occurs in combination with Species group N and O which include succulent perennials such as *Drosanthemum hispidum* and *Psilocaulon absimile* and woody perennials such as *Lycium* species and *Zygophyllum retrofractum* (Table 1). The community is dominated by the shrublike succulent cf. *Drosanthemum otzenianum* which can be distinguished physionomically from the other plant communities. It is assumed that specific local soil differences are responsible for the distinct patchy distribution of this community.

5. *Psilocaulon absimile - Drosanthemum hispidum* low sparse shrubland community

This community is found in the lower lying areas on the plains throughout the reserve. The plant community mainly occurs on land type Ae80 on the midslopes and valleys (terrain units 3 & 5). These sandy areas, with no rock cover, are dominated by the presence of the species groups E, N and O (Table 1). The diagnostic species of this community are *Atriplex lindleyi*, *Aridaria noctiflora*, *Salsola* species (HRSK 21) and the annual *Osteospermum pinnatum* (Species group E, Table 1). *Psilocaulon absimile* and *Drosanthemum hispidum* (Species group O, Table 1) and *Zygophyllum retrofractum* (Species group N, Table 1) are the dominant perennials in this community.

6. *Mesembryanthemum guerichianum* dwarf sparse shrubland community

Plant community 6 is dominated by *Mesembryanthemum guerichianum* (Species group G) and includes various geophytes (Species group M), succulent perennials such as *Drosanthemum hispidum*, *Psilocaulon absimile* (Species group O) and *Galenia sarcophylla* (Species group N), (Table 1). This dwarf shrubland can be divided into two sub-communities:

6.1. *Galenia sarcophylla - Mesembryanthemum guerichianum* dwarf sparse shrubland sub-community

This predominantly annual shrubland is dominated by combinations of annual species such as: *Karoochloa schismoides*, *Senecio arenarius* and *Dimorphotheca sinuata* (Species group F, Table 1). The community occurs on sandy soils (land types Ae80, Ae85 and Ib127) with no rock cover, on historically and/or presently disturbed areas such as the Tuinvlak. A limited perennial species cover is also found in the presence of *Galenia sarcophylla*, *Hypertelis salsoloides* and *Zygophyllum retrofractum* (Species group N) and various geophytes (Species group M), (Table 1).

Historically these areas were subjected to patch selective grazing (Palmer *et al.* 1999) by game and small mammal disturbance, later overgrazing by livestock also occurred. Presently, with the livestock removed, small mammals and game (in the wet season) contribute mainly to the continued disturbance, keeping these plains bare in the dry season and covered in annuals in the rainy season.

6.2. *Drosanthemum hispidum - Mesembryanthemum guerichianum* dwarf sparse shrubland sub-community

This annual sub-community differs from that of sub-community 6.1 in that *Galenia filiformis* and *G. africana* (Species group I, Table 1) are the perennial diagnostic species that occur in sub-community 6.2. The *Drosanthemum hispidum - Mesembryanthemum guerichianum* dwarf sparse shrubland sub-community occurs predominantly on the gentle slopes of land type Ae80. The absence of annuals in Species group F (Table 1) could be as a result of the drought conditions in 1998 and thus the poor establishment of annuals in that year. It is expected that in good rainfall years, the annual component would be more prominent. The pioneer species *Galenia filiformis* and *G. africana* are an indication of the past disturbance of the area. The sandy soils with no rock cover are ideal habitat for small mammals.

7. *Osteospermum sinuatum* short open shrubland community

This plant community is dominated by the perennial woody species *Aptosimum spinescens*, *Osteospermum sinuatum* and *Hermannia trifurca* (Species group L, Table 1) and occurs on the plains, excluding Ja-leegte plains, of Goegap Nature Reserve. Species groups M, N and O occur in combination with Species group L to delimit this plant community (Table 1). This short open shrubland can be divided into four sub-communities:

7.1. *Galenia filiformis - Osteospermum sinuatum* short sparse shrubland sub-community

This sub-community is largely restricted to land type Ae80 i.e. red soils with a high base status and >300 mm deep and occurs in the Fonteintjie region of the reserve. The edaphic factors promote the occurrence of moles, whistling rats, porcupines and mice. There is a close association between this sub-community and the annual sub-community 6.2 with the presence of species in Species group I (Table 1). The presence of the pioneer species *Galenia filiformis* and *G. africana* indicates past disturbance in the area, natural disturbance by game and/or small mammals and/or disturbance due to overgrazing by domestic livestock. The presence of diagnostic species such as *Hermannia disermifolia*, *Ruschia elineata*, *Sphalmanthus* species and *Euphorbia mauritanica* (Species group H, Table 1) and Species group G (Table 1)

distinguish this sub-community from annual sub-community 6.2.

7.2. *Stipagrostis brevifolia - Osteospermum sinuatum* short open shrubland sub-community

The *Stipagrostis brevifolia - Osteospermum sinuatum* short open shrubland sub-community occurs on land type Ib127 on the Goegap plains section of the reserve. According to the land type information (Land Type Survey Staff 1987), this area is dominated by exposed rock covering 60–80 % of the area. The Goegap plains section however, occurs on the less dominant terrain units 4 and 5, footslopes and valleys, of the Hutton soil form with no rock cover present. These soil characteristics are ideal habitat for small mammals which were found in these sample plots. The two diagnostic species in this sub-community are *Stipagrostis brevifolia* and various *Trachyandra* species (Species group J, Table 1). The presence of *Stipagrostis brevifolia* indicates that the Goegap plains occur in the transition zone between the Succulent Karoo biome and the more grassy Nama Karoo biome.

7.3. *Leipoldtia pauciflora - Osteospermum sinuatum* short open shrubland sub-community

This sub-community occurs on all three land types in isolated patches on the plains of the reserve. The diagnostic species are *Leipoldtia pauciflora*, *Gazania heterochaeta* and *Ruschia robusta* (Species group K, Table 1) which are more characteristic of the Rocky Hills, however, in this plant community this species combination occurs on the plains. These species distinguish this sub-community from the other sub-communities in the *Osteospermum sinuatum* short open shrubland community. Small mammals were found in some of the sample plots.

7.4. *Aptosimum spinescens - Osteospermum sinuatum* short open shrubland sub-community

Drosanthemum hispidum (Species group O), *Galenia sarcophylla* and *Hypertelis salsoloides* (Species group N) together with *Aptosimum spinescens* (Species group L) are dominant species in this sub-community (Table 1). This sub-community occurs on the midslopes of land types Ib127 and Ae85 in areas with no rock cover. The sandy soils and absence of rock are ideal habitat for the small mammals found in these areas.

8. *Psilocaulon absimile - Zygophyllum retrofractum* low sparse shrubland community

This community is diagnosed by the presence of species belonging to species groups N and O (Table 1) and occurs on the gentle midslopes of all three land types. No rock cover was noted on these sandy soils. Small mammal disturbance occurs in this community due to the favourable edaphic conditions for their distribution. It is expected that in good rainfall years the annual component, such as *Osteospermum pinnatum*, *Heliophila seselifolia*, *Dimorphotheca sinuata*, will dominate the perennial component e.g., *Psilocaulon absimile*, *Zygophyllum retrofractum* and *Hypertelis salsoloides*, of this plant community.

9. *Psilocaulon absimile* low sparse shrubland community

This community is dominated by the perennial species such as various *Lycium* species, *Drosanthemum hispidum* and *Psilocaulon absimile* (Species group N, Table 1). The *Psilocaulon absimile* low sparse shrubland community occurs only on land type Ae85, with sandy soils and no rock cover. There is also an abundance of small mammal disturbance. It is expected that in wetter years the annual component will be very prominent in these open patches.

2. Plant communities of the Rocky Hills (Table 2)

1. *Helichrysum obtusum* dwarf open shrubland community

This very localised community occurs in a small area in the Rocky Hills. Species group

A (Table 2) indicates the diagnostic species of the *Helichrysum obtusum* dwarf open shrubland community. *Helichrysum obtusum*, *Pentaschistus tomentula* and *Leysera gnaphalodes* (Species group A, Table 2) dominates this community that occurs at high altitudes (>1100-1400 m) on land type Ib127, although land type Ib127 is dominated by rock, this community is present in areas without rock cover. At the time of the survey, game concentrated in this area and contributed to the moderate trampling of the soil.

2. *Rhus undulata* tall sparse shrubland community

Rhus undulata and *Senecio cinerascens* (Species group D, Table 2) distinguishes this plant community from the other communities. This community occurs at high altitudes, on gentle to steep slopes with > 95 % rock cover and can be divided into two sub-communities:

2.1 *Nenax namaquensis - Rhus undulata* tall sparse shrubland sub-community

The *Nenax namaquensis - Rhus undulata* tall sparse shrubland sub-community occurs in the high-lying regions (>1000 m) of land type Ib127 in the Rocky Hills on gentle to steep slopes with a rock cover of 95–99 %. Diagnostic species such as *Nenax namaquensis*, *Arctotis laevis* and *Leipoldtia* species (HRSK 29), (Species group B, Table 2) distinguish this high-lying sub-community 2.1 from sub-community 2.2.

2.2 *Diospyros ramulosa - Rhus undulata* tall sparse shrubland sub-community

Sub-community 2.2 occurs in areas between 800 m and 1100 m high on land type Ae85 with 95–99 % rock cover. The diagnostic species *Diospyros ramulosa* (Species group C, Table 2) distinguishes this sub-community from that of the previous sub-community. Also, this sub-community contains species such as *Eriocephalus ericoides*, *Hermannia disermifolia* and *Pentzia incana* (Species group O, Table 2) not included in the previous sub-communities. Yet, the presence of *Rhus undulata* and *Senecio cinerascens* (Species group D, Table 2) indicates the relationship between the two sub-communities.

3. *Leipoldtia pauciflora* short open shrubland community

This plant community occurs in the Rocky Hills throughout the reserve, on the gentle to steep midslopes or koppies, with little or no rock cover or with an abundance of rock cover. Due to the steepness of the slopes, signs of water flow were evident in many of the sample plots. The *Leipoldtia pauciflora* short open shrubland community can be divided into 6 sub-communities:

3.1 *Dyerophytum africanum - Hermbstaedtia glauca - Leipoldtia pauciflora* short open shrubland sub-community

Dyerophytum africanum and *Hermbstaedtia glauca* (Species group E, Table 2) are the two diagnostic species of sub-community 3.1. This sub-community occurs on level to moderate slopes with 80–99 % rock cover, throughout Goegap Nature Reserve. *Zygophyllum meyeri* and *Othonna arbuscula* (Species group H, Table 2) indicates the shared species with the closely related sub-communities 3.2 and 3.3. *Galenia namaensis* (Species group J), *Euphorbia mauritanica* (Species group L) and *Tetragonia fruticosa* (Species group N) further substantiated the grouping of the larger plant community (Table 2).

3.2 *Pteronia divaricata - Tetragonia microptera - Leipoldtia pauciflora* short open shrubland sub-community

This plant sub-community is closely related to sub-communities 3.1 and 3.3 through the species presence of *Zygophyllum meyeri* and *Othonna arbuscula* (Species group H, Table 2). The diagnostic species of sub-community 3.2 are *Pteronia divaricata* and *Tetragonia microptera* (Species group F, Table 2). This community occurs on level to gentle slopes with < 2 % rock cover.

3.3 *Ruschia* species (HRSK 17) - *Leipoldtia pauciflora* short open shrubland sub-community

Sub-community 3.3 is composed of the following diagnostic species: *Ruschia* sp17, *Berkheya fruticosa*, *Didelta spinosa* and *Montinia caryophyllacea* (Species group G, Table 2). This sub-community occurs predominantly on the gentle to steep midslopes of land type Ib127 with a rock cover of 0-90 %. *Zygophyllum meyeri* and *Othonna arbuscula* (Species group H, Table 2) closely relates this sub-community with the previous two sub-communities.

3.4 *Eriocephalus ericoides* - *Leipoldtia pauciflora* short open shrubland sub-community

The diagnostic species of this sub-community are indicated in Species group I (Table 2). This sub-community occurs mainly on gentle slopes of land type Ib127 with no rock cover, except when single large boulders occur. Other noteworthy species in this sub-community are *Osteospermum sinuatum* (Species group N) and *Euphorbia decussata* (Species group Q), (Table 2).

3.5 *Euphorbia decussata* - *Leipoldtia pauciflora* short open shrubland sub-community

This sub-community occurs only in areas with less than 1 % rock cover, on the gentle midslopes of the various land types. The diagnostic species *Aptosimum spinescens*, *Aridaria noctiflora* and *Salsola tuberculata* (Species group K, Table 2) are species that are usually more salt tolerant and distinguish sub-community 3.5 from sub-community 3.6.

3.6 *Ruschia robusta* - *Leipoldtia pauciflora* short open shrubland sub-community

Species group M (Table 2) contains the diagnostic species of this sub-community. Other dominant species present are *Osteospermum sinuatum*, *Tetragonia fruticosa* (Species group N), *Eriocephalus ericoides* (Species group O), *Euphorbia decussata* and various *Lycium* species (Species group Q), (Table 2). This *Ruschia robusta* - *Leipoldtia pauciflora* short open shrubland sub-community occurs on the gentle midslopes of the various land types on the reserve. Sandy soils with no rock cover dominate this plant sub-community.

4. *Stipagrostis brevifolia* short sparse shrubland community

This community occurs on the Ja-leegte plains of Goegap Nature Reserve, land type Ae85, at 700–1020 m above sea-level with no rock cover. The *Stipagrostis brevifolia* short sparse shrubland is comprised of the diagnostic species *S. brevifolia* and *Sarcocaulon* species (Species group P), (Table 2). The common species of the *Leipoldtia pauciflora* short open shrubland and *S. brevifolia* short sparse shrubland communities are *Ruschia robusta*, *Euphorbia decussata* and various *Lycium* species (Species group Q), (Table 2). The presence of *S. brevifolia* (Species group P, Table 2) indicates the close relationship with the grassy Bushmanland plains. The soil characteristics are favourable for small mammal activity and abundant activity was noted in all of the sample plots, especially the disturbance created by whistling rats.

3. Management units identified on Goegap Nature Reserve (Fig. 1)

Management unit 1 - Fonteintjie

This management unit occurs on land type Ae80 of the Fonteintjie region, west of the reserve (Fig. 1). The dominant terrain unit which comprises 65 % of the landscape is the footslopes (unit 4). The soil has a sandy texture with no rocks present on the soil surface. The *Drosanthemum hispidum* - *Mesembryanthemum guerichianum* dwarf sparse shrubland and the *Galenia filiformis* - *Osteospermum sinuatum* short sparse shrubland sub-communities (Table 1) dominate this management unit. These two sub-communities consist mainly of annual species and are grouped together by the common

occurrence of the pioneer species *Galenia filiformis* and *G. africana* (Species group I, Table 1). However, the difference between the two sub-communities is that the *Galenia filiformis - Osteospermum sinuatum* short sparse shrubland contains the species *Aptosimum spinescens*, *Osteospermum sinuatum* and *Hermannia trifurca* (Species group L, Table 1). The pioneer species present in this management unit indicates the past disturbance—livestock overgrazing—of the area.

Three other communities present in this management unit are the annual *Galenia sarcophylla - Mesembryanthemum guerichianum* dwarf sparse shrubland sub-community (Table 1), the *Psilocaulon absimile - Drosanthemum hispidum* low sparse shrubland community (Table 1) and the locally isolated *Stipagrostis obtusa* short closed grassland community (Table 1). The *Psilocaulon absimile - Drosanthemum hispidum* low sparse shrubland community occurs in the lower lying areas of terrain unit 5, the valleys, and is represented by species such as *Atriplex lindleyi*, *Aridaria noctiflora*, *Osteospermum pinnatum* and *Salsola* species (HRSK 21), (Species group 6, Table 1).

With respect to environmental factors noted in the survey, there is no notable difference between the communities. All these communities occur in valleys or on footslopes. The gravel sand and absence of rock in these areas are ideal for small mammals such as whistling rats, moles, porcupines and mice, and their activity was noted in the majority of sample plots. The large open patches are also ideal for game to accumulate on. They feed on the herbaceous annuals in the wet season and on the dried out rests in the dry season thus, moderate trampling is found in certain areas. Patch selective grazing is a natural component of the African ecosystems utilised by indigenous herbivores, and is an important agent of plant community diversity (Palmer *et al.* 1999). The small mammal and game concentrations on these patches are common on all the plains throughout the reserve.

Management unit 2 - Slimes plain

Management unit 2 occurs in an area South of the Slimes dam (Fig. 1). This valley habitat is present on land type Ae80 and is dominated by the *Psilocaulon absimile - Drosanthemum hispidum* low sparse shrubland community (Table 1). The species in this community are characteristic of the species in the lower lying areas throughout the entire reserve. *Atriplex lindleyi* and *Aridaria noctiflora* are the most dominant species in these regions where there is a higher salt concentration in the soil. Also present in this management unit is the *Galenia sarcophylla - Mesembryanthemum guerichianum* dwarf sparse shrubland sub-community (Table 1) and the more isolated patches of the *Leipoldtia pauciflora - Osteospermum sinuatum* short open shrubland sub-community (Table 1), including species such as *Leipoldtia pauciflora* and *Ruschia robusta* (Species group K, Table 1). The footslopes and valleys are characterised by sandy soils with no rock cover. These habitat conditions are ideal for small mammal activity. Game also accumulates here as a result of the open patches covered in annuals in the wet season. The slimes dam dust also has a great effect on this area and changes in vegetation over time will have to be monitored.

Management unit 3 - Bleshoek

This Management unit occurs on the gentle slopes to the south of the entrance road (Fig. 1). The *Galenia sarcophylla - Mesembryanthemum guerichianum* dwarf sparse shrubland sub-community and the *Psilocaulon absimile - Zygophyllum retrofractum* low sparse shrubland community (Table 1), are present on land type Ae80 in this management unit. This land type is dominated by footslopes and valleys with coarse sandy soils. A combination of perennial species dominates the *Psilocaulon absimile - Zygophyllum retrofractum* low sparse shrubland community. The species include *Lycium* species, *Drosanthemum hispidum* and *Psilocaulon absimile* (Species group O) however, the distinguishing species are *Zygophyllum*

retrofractum, *Galenia sarcophylla* and *Hypertelis salsoloides* (Species group N), (Table 1). These perennial species occur on their own or in combination with annuals, producing the *Galenia sarcophylla - Mesembryanthemum guerichianum* dwarf sparse shrubland sub-community. Isolated patches of *Stipagrostis obtusa* short close grassland community (Table 1), dominated by the grass *Stipagrostis obtusa*, also occur in this management unit.

Management unit 4 - Tuinvlak

On the Tuinvlak, the annual *Galenia sarcophylla - Mesembryanthemum guerichianum* dwarf sparse shrubland sub-community (Table 1, Fig. 1) dominates land type Ae80. This open landscape with its gentle footslopes and 0–3 % rock cover is the ideal habitat for this predominantly annual plant community. These topographic characteristics and vegetation type create the ideal habitat conditions for small mammals. At the base of the Rocky Hills the *Stipagrostis obtusa* short closed grassland community (Community 3, Table 1) is represented on a small scale in this management unit. The present and historical disturbance, be it natural or man-made, of the Tuinvlak has ensured that the annual communities attract the game during the wetter months. Thus maintaining the phenomenon of patch selective grazing (Palmer *et al.* 1999).

Management unit 5 - Goegap plains

The large Goegap plains section occurs on land type Ib127 (Fig. 1). This land type is usually dominated by midslopes, terrain unit 3. Yet, the Goegap plains section of land type Ib127 is dominated by terrain units 4 and 5 namely, footslopes and valleys, with coarse sandy soils and no rock cover. A mosaic of communities occurs in this region. This could be due to the fact that this area lies in the transition zone between Namaqualand (Succulent Karoo biome) and Bushmanland (Nama Karoo biome) with all its climatic transitions from a winter to a summer rainfall area. A list of plant communities found in this management unit are as follows: *Stipagrostis namaquensis* short closed grassland community, *S. obtusa* short closed grassland community, cf. *Drosanthemum otzenianum* low closed shrubland community, *Psilocaulon absimile - Drosanthemum hispidum* low sparse shrubland community, *Galenia sarcophylla - Mesembryanthemum guerichianum* dwarf sparse shrubland sub-community, *Osteospermum sinuatum* short open shrubland community and *Psilocaulon absimile - Zygophyllum retrofractum* low sparse shrubland community (Table 1).

The *Stipagrostis namaquensis* short closed grassland community (Table 1) is present along the drainage lines (washes) in the valleys while the *S. obtusa* short closed grassland community (Table 1) occurs in isolated patches on the midslopes. cf. *Drosanthemum otzenianum* low closed grassland community is characterised by cf. *Drosanthemum otzenianum* and *Drosanthemum* species (HRSK 5), (Species group D, Table 1). This community occurs in isolated patches throughout the reserve where, presumably, soil conditions dictate this species combination. The more saline, lower lying drainage line areas, are dominated by the *Psilocaulon absimile - Drosanthemum hispidum* low sparse shrubland community. The *Galenia sarcophylla - Mesembryanthemum guerichianum* dwarf sparse shrubland sub-community occurs in the previously highly disturbed areas such as old sheep stations or naturally disturbed areas for example, small mammal dominated areas such as old whistling rat warren systems or areas where game concentrate.

The *Osteospermum sinuatum* short open shrubland community with its sub-communities are strongly represented in this management unit. The species *Aptosimum spinescens*, *Osteospermum sinuatum* and *Hermannia trifurca* (Species group L, Table 1) distinguish this plant community with its sub-communities from the other communities found on the plains. As these Goegap plains are in the transition zone between the Namaqualand Rocky Hills and the grassy Bushmanland it is expected that

the grassy species from the Bushmanland would become evident. This grassy component is found in the *Stipagrostis brevifolia - Osteospermum sinuatum* short open shrubland sub-community, where *Stipagrostis brevifolia* (Species group J, Table 1) dominates.

Isolated patches of the *Psilocaulon absimile - Zygophyllum retrofractum* low sparse shrubland community are found in the plains. Species such as *Drosanthemum hispidum*, *Psilocaulon absimile* (Species group N, Table 1) and *Zygophyllum retrofractum* and *Galenia sarcophylla* (Species group O, Table 1) are present within this community.

Management unit 6 - Witsand

Management unit 6, near Witsand (Fig. 1), is similar to Management unit 5 however, it is found on a different land type namely land type Ae85. The dominant terrain form of the area is terrain form 4, consisting of footslopes. The communities are once again present in the Namaqualand-Bushmanland transition zone and thus the similarity between this management unit and Management unit 5. Communities and sub-communities found in this area are: *Psilocaulon absimile - Drosanthemum hispidum* low sparse shrubland community, *Galenia sarcophylla - Mesembryanthemum guerichianum* dwarf sparse shrubland sub-community, *Leipoldtia pauciflora - Osteospermum sinuatum* short open shrubland sub-community and *Aptosimum spinescens - Osteospermum sinuatum* short open shrubland sub-community (Table 1).

The *Psilocaulon absimile - Drosanthemum hispidum* low sparse shrubland community is found along the drainage lines and the predominantly annual *Galenia sarcophylla - Mesembryanthemum guerichianum* dwarf sparse shrubland sub-community on presently and/or historically disturbed areas. Isolated patches of the *Leipoldtia pauciflora - Osteospermum sinuatum* and *Aptosimum spinescens - Osteospermum sinuatum* short open shrubland sub-communities are also found which closely relates this management unit to the Goegap plains, management unit 5.

Management unit 7 - Ja leegte

This management unit includes the Ja-leegte plain (Fig. 1) found on land type Ae85 and is represented by the *Galenia sarcophylla - Mesembryanthemum guerichianum* dwarf shrubland sub-community and the *Psilocaulon absimile* low sparse shrubland community (Table 1) as well as the *Stipagrostis brevifolia* short sparse shrubland community (Table 2). Isolated patches of the *S. namaquensis* short closed grassland community (Table 1) are also found in the drainage lines (washes).

The disturbed areas are represented by the annual *Galenia sarcophylla - Mesembryanthemum guerichianum* dwarf sparse shrubland sub-community (Table 1). These areas were historically overgrazed or used as grazing selected patches by game (Palmer *et al.* 1999) and recovery is slow due to the abundance of small mammals in the area. The *Psilocaulon absimile* low sparse shrubland community is found only in Management unit 7 with the diagnostic species such as various *Lycium* species, *Drosanthemum hispidum* and *Psilocaulon absimile* (Species group O, Table 1). The drought year in which the surveys were done severely limited the annual vegetation which is expected to form a large part of the biomass in a good season.

Bushmanland elements such as *Stipagrostis brevifolia* of the *Stipagrostis brevifolia* short sparse shrubland community indicates the close proximity to this vegetation type. However, *Ruschia robusta*, *Euphorbia decussata* and *Lycium* species (Species group Q, Table 2), are also present in this management unit. These species combinations substantiate the fact that this area is in the transition zone between the Namaqualand Rocky Hills (Succulent Karoo biome) and the Bushmanland (Nama Karoo biome).

Management unit 8 - Carolusberg & Hoits

This area is delimited by land type Ae80 with its coarse sandy soils and gentle footslopes (Fig. 1). The *Drosanthemum hispidum - Mesembryanthemum guerichianum* dwarf sparse shrubland sub-community dominates the area while communities such as the cf. *Drosanthemum otzenianum* low closed shrubland community, *Psilocaulon absimile - Drosanthemum hispidum* low sparse shrubland community and the *Psilocaulon absimile - Zygophyllum retrofractum* low sparse shrubland community also occur in isolated patches. Species such as *Mesembryanthemum guerichianum* (Species group G, Table 1) and pioneer species such as *Galenia africana* indicates the present or past disturbance in the area. The *Psilocaulon absimile - Zygophyllum retrofractum* low sparse shrubland community is also represented in this area with *Drosanthemum hispidum*, *Zygophyllum retrofractum* and *Galenia sarcophylla* (Species group N and O, Table 1) as noteworthy species. These species combinations substantiate the fact that this area lies in the transitional zone between the Namaqualand Rocky Hills and the Bushmanland.

Management unit 9 - High lying rocky hill vegetation

This management unit occurs on land type Ib127 at a height of approximately 1100-1360 m on gentle slopes with no rock cover (Fig. 1). The *Helichrysum obtusum* dwarf open shrubland community (Table 2) dominates the area with the species *H. obtusum*, *Pentaschistus tomentula* and *Leysera gnaphalodes* (Species group A, Table 2). This area of the rocky hills can be indicated on a map due to its height above sea-level as well as vegetation type which is very different from the other vegetation of the Rocky Hills.

Management unit 10 - Namaqualand Rocky Hills

Various sub-communities (Table 2) were identified in the Rocky Hills of land type Ib127. These sub-communities cannot be drawn on a map as local factors determine their position in the heterogeneous landscape (Fig. 1).

The *Rhus undulata* tall sparse shrubland community (Table 2) is subdivided into two sub-communities, with the *Nenax namaquensis - Rhus undulata* tall sparse shrubland sub-community representing areas at a height of >1000 m, 95–99 % rock cover in the form of boulders and a unique species composition (Species group B, Table 2). Similarly, the *Diospyros ramulosa - Rhus undulata* tall sparse shrubland sub-community also occurs in areas with 95–99 % boulder cover, yet a different set of higher-lying species (Species group C, Table 2) are present at these locations. *Rhus undulata* and *Senecio cinerascens* (Species group D, Table 2) are common in both sub-communities and distinguish them from the other communities in the Rocky Hills.

The *Leipoldtia pauciflora* short open shrubland community (Table 2) is subdivided into 6 different sub-communities which represents the majority of the communities found on the Rocky Hills. Topographic differences such as percentage rock cover seems to be a major determinant of the community position in the landscape, however a much more detailed study of these features will have to be made to define the reasons for the location of a various sub-communities.

Dyerophytum africanum and *Hermbstaedtia glauca* (Species group G, Table 2) are represented by the *Dyerophytum africanum - Hermbstaedtia glauca - Leipoldtia pauciflora* short open shrubland sub-community. These communities occur at a height of between 800–1000 m and have a rock cover of 80–99 %, while the *Pteronia divaricata - Tetragonia microptera - Leipoldtia pauciflora* open shrubland sub-community has a rock cover of <2 % and is represented by *Pteronia divaricata* and *Tetragonia microptera* (Species group F, Table 2). The last community in this group is the *Ruschia* species (HRSK 17) - *Leipoldtia pauciflora* short open shrubland sub-community with a highly variable rock cover. The species *Ruschia* species (HRSK 17), *Berkheya fruticosa* and

Didelta spinosa (Species group G, Table 2) distinguishes this sub-community from the previous two sub-communities.

Plant sub-community *Eriocephalus ericoides - Leipoldtia pauciflora* short open shrubland contains a combination of species including *Pteronia* species (HRSK 7) and *Cephalophyllum namaquanum* (Species group I, Table 2). This community occurs mainly on gentle slopes with no rock cover except if single large boulders occur.

The *Euphorbia decussata - Leipoldtia pauciflora* and *Ruschia robusta - Leipoldtia pauciflora* short open shrubland sub-communities occur on gentle slopes with 0–2 % rock cover. The difference between these two sub-communities is expected to be a higher salt content in the soils of the *Euphorbia decussata - Leipoldtia pauciflora* shrubland sub-community. This is proposed as the species present (Species group K, Table 2) in this community are species that usually grow in areas of higher salt concentrations.

Conclusions

Goegap Nature Reserve is situated in the floral paradise of Namaqualand with numerous tourists visiting the region yearly. The effective management of the reserve is of utmost importance. In order to effectively manage the reserve a combination of factors including plant communities and land types were used to produce management units that could form the basis for management and monitoring programs.

The floristic data analysis resulted in two phytosociological tables, one for the predominantly Rocky Hills and one for the Plains. Nine plant communities were identified in the Plains table and four in the predominantly Rocky Hills table. These communities and combinations thereof were used to identify 10 management units on Goegap Nature Reserve. These management units will, later, be used in the determination of grazing capacity of the various units as well as the carrying capacity of the entire reserve and thus have an effect on the management of the reserve.

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