PHYTOSOCIOLOGY OF THE NAMIB DESERT PARK, SOUTH WEST AFRICA

by

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I HEREBY DECLARE THAT, EXCEPT WHERE OTHERWISE STATED, ALL MATERIAL PRESENTED HEREUNDER IS ORIGINAL AND HAS NOT PREVIOUSLY BEEN SUBMITTED FOR PUBLICATION OR ANY OTHER PURPOSE.

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SUMMARY.

The geology, topography, soils and climate of the Namib Desert Park south of 23° S. Lat. are described briefly.

The vegetation was investigated using the techniques of the Zürich - Montpellier school of phytosociology. Floristic and other site data were collected from 472 sites in the standard Braun - Blanquet manner and the techniques are described in some detail. These data are presented by means of phytosociological tables and detailed descriptions of each community. A total of 34 noda, communities and sub-communities, were delimited in the study area and the floristic and ecological relationships of these are discussed. Only a few of the communities can be assigned to syntaxa from other parts of the world or southern Africa because most of the Namib Desert communities seemed too different to be compared to associations from North Africa, the Middle East, South America or Australia on more than a superficial, structural basis. Very few data from other arid or semi-arid areas in southern Africa have received formal phytosociological treatment and there is therefore insufficient material to draw meaningful comparisons.

The "foam structure" described by Volk & Geyger (1970) was found to be widely distributed in soils of the plains of the Namib Desert, and it was shown to have a profound influence on water penetration. The effects on vegetation development are discussed.

The study generated a number of questions about the vegetation and ecosystems of the Namib Desert and some recommendations are made concerning future synecological and autecological studies.

A list of species and synonyms of the names of all higher plants recorded in the study area are given in Appendix I.

It is concluded that the Braun - Blanquet method is efficient in terms of time required to collect data which can be used for a number of purposes, but that a classification of vegetation should be followed up by autecological and detailed synecological

studies of species (particularly those which characterize communities) and individual communities to determine the controlling factors more precisely and to enable more accurate predictions concerning the effects of management programmes to be made.

Chapter 1. INTRODUCTION

The vegetation of the central Namib Desert of South West Africa, despite the interest evinced by plants such as *Welwitschia mirabilis* and the remarkable interplay of factors resulting in the fog zone, has received relatively little study in the past. It is possible that the inhospitable aspect and inaccessability were the major factors that discouraged plant ecologists from carrying out general surveys. On the other hand, the sparseness of plants over much of the area, the absence of striking annuals as are found in Namaqualand or a rich succulent flora as found in the winter rainfall area of the southern Namib Desert (see 3.1 below) may also have been contributory factors. Early travellers were impressed by endemic plants such as *Welwitschia mirabilis* and *Acanthosicyos horrida* (for example, Pearson wrote, in 1907, of "....several highly peculiar endemic forms (of plants).") but passed much of the vegetation over with a few words, remarking on the barrenness of large areas (Pearson, 1907; 1911). Even I.B. Pole Evans remarked that, "Below this (the Escarpment) the vast gravel plains are for miles almost destitute of vegetation or support a more or less scanty growth of Vogelstruisgras (*Eragrostis spinosa*). In some places the only plant on these plains is an annual *Mesembryanthemum*, on others nothing but a lichen growth covers the small pebbles " (Evans, 1920, p 32). Small wonder, then that synecologists took little interest in the Namib Desert with its problems of accessability and water supply but instead concentrated on the richer vegetation of the remainder of southern Africa.

In 1936 Walter published an account of the ecology of an area of the Namib Desert in the vicinity of Swakopmund in which he concentrated mainly upon the fog zone and the anatomy and autecology of some species growing there. Subsequent to this work, interest seemed to have lapsed except for somewhat restricted studies on botanically interesting plants, such as Vogel's (1955) study of the "window plants" of the fog zone and Rodin's (1958) study of the leaf anatomy of the unique *W. mirabilis*. A rather general description of the vegetation as a whole was given by Logan (1960) in his work on the geography of the central Namib Desert.

As Koch's * studies on desert insects continued it became apparent that the tenebrionid beetles of the Namib region have undergone a tremendous degree of speciation. This observation generated considerable interest in the Namib Desert ecosystem as a whole (see Koch, 1961 for a discussion of the fauna and flora in the Namib Desert) and led to the establishment of the Namib Desert Research Station in 1963 (Levinson, 1972). However, even with the realization that the vegetation, sparse though it might be, was of great importance to all parts of the system, including the dune-dwelling insects (Koch, 1961), botanical studies remained either superficial (for example, Giess, 1964 and 1971) or directed to the unique components of the flora (for example, Kers, 1967 and Bornman et al, 1973). There remained therefore an urgent need for a plant ecological survey of the Namib Desert, and this need stimulated the present study.

Without general plant ecological information the investigation of the ecology of individual species or of groups of species remain isolated studies and cannot be integrated to assist in understanding the ecosystem as a whole. For such a survey to be useful, it, in turn, should not be a study in isolation . It must yield information in a form that can be compared directly with other botanical studies while still being descriptive enough to provide for the needs of other interested workers such as zoologists, ethnologists or nature conservationists. To achieve these aims standard methods should be used wherever possible.

* Dr. Charles Koch was an Austrian entomologist specializing in the study of desert tenebrionidae (beetles). In 1948 he visited the Namib Desert with the California University expedition to South West Africa. He was so interested in the fauna and flora of the Namib Desert that he stayed on to study it further, first on a grant from the Council for Scientific and Industrial Research and then as an employee of the Transvaal Museum. He died in 1970 in South West Africa (Levinson, 1972).

In southern Africa a number of techniques (for example, Story, 1952; Acocks, 1953; Killick, 1963; Grunow, 1965; Edwards, 1967; Leistner, 1967 and Leser, 1971) have been used to study the vegetation of large tracts of country. Because these studies were carried out using different methods it is difficult to draw comparisons between the results. More recently, stimulated by Werger, who showed the applicability of the methods of the Zürich-Montpellier School of phytosociology to African conditions, emphasis has been placed on phytosociological studies using these methods (for example, Volk & Leippert, 1971; Werger, Kruger & Taylor, 1972; Werger, 1973a and 1973b; Leistner & Werger, 1973 and Bredenkamp, 1975) which has introduced some degree of standardization to botanical surveys. Outside southern Africa the Zürich-Montpellier syntaxonomic system is probably the most widely used phytosociological classification procedure (see Whittaker, 1962; Braun-Blanquet, 1968; and Tüxen, 1969 and 1970 for documentation of the acceptance of the method in Europe and the rest of the world).

For these and other reasons dealt with below, it was decided that a classification of the vegetation would best meet the aims of the project, and that the Braun-Blanquet technique would be the most effecient and appropriate for the purpose.

Accordingly, a phytosociological and synecological study of the plant communities of the Namib Desert Park was commenced in 1972 and carried out during the period 1972 - 1975, while the author was resident at the Namib Desert Research Station, Gobabeb.

Doubtless the fact that many of the surviving specimens collected in the erstwhile German colony were housed in the Munich Herbarium and because there was a real need for a flora dealing with South West Africa, Dr. H. Merxmueller instigated and edited the "Prodromus einer Flora von Südwestafrika", the last instalment of which appeared in 1972. As this is the only complete and up-to-date taxonomic treatment of the flora of the region it was decided that it would be preferable to follow the nomenclature therein despite the differences between this and the systems more generally used by South African herbaria. However, to enable rapid comparisons to be made between this and other studies and to avoid confusion regarding specific names, a list of species recorded and their synonyms was required. Species that could not be positively identified are housed in the Windhoek Herbarium of the Botanical Research Institute.

Chapter 2. METHODS

2.1 Introduction : Why apply a classification procedure ?

The aim of the present study was to produce a multi-purpose grouping of stands of vegetation into units (taxa) on the basis of similarities between the stands, judged upon as wide a variety of characteristics of the vegetation and habitat as possible : the study was not intended as a test as to whether the Namib Desert vegetation consisted of a vegetational continuum (in the sense of Curtis and McIntosh, 1951) or of a series of "well-defined, discrete, integrated units which can be combined to form abstract classes of types reflective of the 'real world' " (McIntosh, 1967).

A grouping of stands (classification) which was based on a large number of characters of the stands would enable comparisons to be made between the groups and would have considerable predictive value if the groups were ecologically distinct (see below).

The opposing concepts of the continuum and the community-unit are excellently summarized and discussed in papers by Whittaker (1962), and McIntosh (1967), while Anderson (1965) and Shimwell (1971) point out that there is no real need for there to be a controversy over the concepts. A review of the literature concerning the pro's and con's of the association (community-unit) and continuum will, therefore, not be given here.

Whether vegetation consists of a continuum of intergrading species populations or not, it seems generally accepted that classification for specific purposes is useful and, in many instances, possibly essential (see Lambert and Dale, 1964; Williams et al., 1966; McIntosh, 1967; Daubenmire, 1968; and Shimwell, 1971, for example). In addition, classification does not necessarily preclude the use of ordination procedures to elucidate inter- and intra-community relationships as has been shown by van der Maarel (1969) and Werger (1973a) and others. For these reasons it was decided that a classification of the vegetation into discrete, ecologically meaningful and reasonably easily identified units would best satisfy the aims (see Introduction above) while retaining the ability to be used for many purposes.

2.2 Classification of the vegetation.

2.2.1 Choice of the Braun-Blanquet method.

The Zürich-Montpellier School of vegetation classification, which is based largely upon principles expressed by Braun-Blanquet (1928, 1932) and which has been theoretically developed by many followers, has been widely applied in Europe and elsewhere (Werger, 1973a) for vegetation study at all scales. It was chosen for the present study for the following reasons:

(i) It aims specifically to be versatile, and according to Westhoff (1967, p. 495), the Braun-Blanquet system "is the most widely used and uniform system of vegetation classification, enabling us to compare plant communities over an area as large as (e.g.) Europe, and therefore also presenting a basis for such items as geographical comparison of habitats, vegetation mapping of large areas, or the analysis of geographical differences in the autecological behaviour of taxa." In addition, the School "wants to construct an abstract taxonomy of vegetation units of general applicability, from which ecological inferences may be drawn" (Ivimey-Cook & Proctor, 1966). This means that data collected in a study area can be compared directly with data from other studies, both in Africa and elsewhere.

For a comprehensive review of the history of the Zürich-Montpellier School and the similarities and differences between this and other approaches to vegetation classification, the reader is referred to Poore (1955), Becking (1957), Shimwell (1971) and Werger (1973a). The two latter authors give particularly lucid and accurate descriptions of the system.

(ii) The Braun-Blanquet approach has been evaluated as the best method for surveys which are to produce the most widely applicable (that is, multi-purpose) classification and which will yield a maximum of understanding of the relationships between vegetation and environmental factors for a minimum of time input (Moore et al., 1970; Werger, 1973a).

(iii) As pointed out by Coetzee and Werger (1975a), ecologically interpretable vegetation types are usually differentiated by several species rather than by a single species. Because few stands of vegetation are ever identical, they should be identified on the basis of "family resemblance." For this reason a polythetic approach is preferable to a monothetic one, such as association analysis, when classifying vegetation. The Braun-Blanquet method, using as it does, total species composition is such a polythetic approach (Coetzee and Werger, 1975a). The use of floristic data rather than physiognomic data (as was used by Fosberg, 1967; Kuchler, 1969 and Phillips, 1970) was preferred because the assemblage of species comprising a phytocoenosis reflects the environmental conditions better than do growth form or habit. In addition, as further data become available about the major species the predictive value of the classification will increase. It must be stressed, however, that species lists alone (without environmental data for the individual stands) have little predictive value (Grieg-Smith, 1964).

(iv) The hierarchical nature of the classification, depending as it does upon character and differential species (Braun-Blanquet, 1932; Poore, 1955; Werger, 1973a) allows new relevés to be incorporated without re-classification of the entire data set (cf. Grieg-Smith, 1964), and should not upset the classification. Since this is not the case with classifications produced by association analysis (Grunow, 1965), it was an important consideration in the choice of method in the present study, where only a part of the Namib Desert could be sampled (see 3.1 below). New data can be incorporated as it is collected, and the vegetation can be classified and re-classified until, by a process of "successive approximation" (Poore, 1962), an overall classification can be produced from which ecological inferences may be drawn with successively increasing precision.

2.2.2 Application of the method.

2.2.2.1 Collection of the field data.

With a modification to the cover-abundance scale (see below), the Braun-Blanquet system as described by Braun-Blanquet (1932), Poore (1955), Becking (1957) and later Werger (1973a) was adopted. The method can be divided into two sections, namely, sampling and synthesis.

Representative homogenous phytocoenoses (stands) of the vegetation were sampled subjectively. Subjective sampling was chosen because of the sparse and scattered nature of the vegetation and in order to avoid obvious heterogeneity in habitat and vegetation structure in plots (Ellenberg, 1956; Becking, 1957; Daubenmire, 1968). As pointed out by Ivimey-Cook and Proctor (1966), Daubenmire (1968) and Werger (1973a), the argument against subjective sampling seems to have been over-emphasized, and in the Namib Desert it proved to be more efficient in obtaining data than stratified random objective sampling.

Representativeness

Stands which were representative of the floristic and structural composition of the vegetation were sampled and each plot was chosen to represent a single entity of vegetation (Ellenberg, 1956; Braun-Blanquet, 1964). Hence in open tree or shrub vegetation, for example, plots were located so that the relative importance of the tree or shrub component was comparable to the surrounding vegetation.

Clearly, representativeness of a plot is closely related to homogeneity. In the Zürich-Montpellier School floristic, structural and environmental homogeneity are assessed visually. It is of great importance that plots are homogeneous as information from only one unit of vegetation and not a mixture of units is required (Ellenberg, 1956; Braun-Blanquet, 1964; Daubenmire, 1968; Shimwell, 1971). The questions of homogeneity and whether any stand of vegetation is ever truly homogeneous, have received considerable attention (for example, Dahl and Hadac, 1949; Goodall, 1954; Daubenmire, 1968). For the purposes of this study the pragmatic approach suggested by Daubenmire was followed and a homogeneous stand was defined as "one in which variations are attributable to chance rather than to intrinsic habitat factors" (Daubenmire, 1968, p. 26).

Another important point regarding sampling is the size of plot to be used. The minimal area has been defined as the area at which the species-area curve becomes more or less horizontal (Braun-Blanquet, 1932 and 1964), and this is the smallest area in which a phytocoenosis can fully represent itself (Grieg-Smith, 1964; Werger, 1973a). For this survey the minimum area was arbitrarily determined as that size of sample plot in which at least two-thirds

TABLE 2.1. COVER-ABUNDANCE RATINGS ACCORDING TO THE DOMIN AND BRAUN-BLANQUET SCALES (AFTER KERSHAW, 1964 AND MUELLER-DOMBOIS AND ELLENBERG, 1974).

	DOMIN	BRAUN-BLANQUET
Any number, cover about 100%	10	5
Any number, cover 75% but not complete	9	
Any number, cover 50 - 75%	8	4
Any number, cover 33 - 50%	7	3
Any number, cover 25 - 33%	6	
Any number, cover 10 -25%	5	2
Any number, cover 5 - 10%	4	
Scattered, cover under 5%	3	1
Very scattered, cover small	2	
Seldom, cover insignificant	1	+
Solitary, cover insignificant	+	r

of the species comprising the stand occurred as it was felt that this would account for most of the characteristic species of the stand. Data, collected from homogeneous stands of different vegetation types (tree, shrub, dwarf shrub, and grassland) using plot sizes ranging between 1m^2 and 100 m^2, indicated that plots of 50 m^2 adequately represented the phytocoenoses in all but the riverine forest, where the espacement of vegetation was such that plots of 200 m^2 were occasionally required before most of the species were recorded. Accordingly, relevés of 5 x 10 m were used for most phytocoenoses, but in the open woodlands of washes and along the Kuiseb River, the plots were either 5 x 20 m or 10 x 20 m in extent. As the survey prodeeded and more experience was gained, it became a simple matter to visually assess the plot size required in any stand.

All species of vascular plants present at the time of the survey were listed and the presence of lichens, fungi, hepatics and algae was noted within each sample plot. Features such as stratification of the vegetation and life forms of the species were noted, but other analytic characters such as phenology, local frequency, sociability, vitality, or yield of vegetation within the quadrat (Werger, 1973a) were not recorded because of the variability of rainfall, the scarcity of records in the area and the widespread distribution of most communities which resulted in very great variability.

Cover-abundance Scale

Each species was assigned a cover-abundance rating according to the Domin scale (q.v.). Cover-abundance is a measure of the relative importance of a species to the stand, and is based partly on aerial cover and partly on numerical abundance (Braun-Blanquet, 1932; Ellenberg, 1956; Poore, 1955; Becking, 1957; Werger, 1973a). It is estimated, not measured. The Domin scale was chosen because it was felt that this allowed finer distinction at the lower levels, as it is a 10-point scale (cf. the Braun-Blanquet scale, Table 2.1). Since many desert plants are short-lived it was thought worthwhile to record dead plants as well as living plants. In cases where individuals of a species were dead, but remained rooted in the sample plot, the cover-abundance value was listed in parentheses in the phytosociological table.

Life Form

The life form of each species was noted following the Raunkiaer (1934) system as modified by Ellenberg (1956), and these are given in the descriptions of the communities. Definitions of the life-form classes used are given in Appendix II.

Habitat Data

Apart from the plant data, habitat characteristics were noted for each site in the following manner:

(a) The geological nature of the substrate was identified wherever possible.

(b) Notes were made concerning the geomorphology of the quadrat area as well as its location with respect to the landscape.

(c) Slope angle and direction (slope aspect) were determined, using a level and compass respectively.

(d) Exposure to direct solar radiation, prevailing winds etc. were noted.

(e) On salt marshes the degree to which the plot was subjected to tidal flooding was ascertained as accurately as possible by direct observation and inference (Plate 8).

(f) Biotic influences such as trampling, grazing and activity of burrowing animals were recorded.

(g) Soil texture and dry consistence of the upper 0,1 m were determined and rockiness or the presence of cemented crusts were noted.

(h) Soil depth to 0,5 m was measured, and when deeper soil was encountered the depth was estimated by driving a sharpened metal rod 1 m long into the ground.

(i) Soil profiles were recorded from pits placed within the sample area. The United States Department of Agriculture (1962) system of description was applied.

These habitat characteristics were entered at the head of the phytosociological tables and their significance in vegetation development discussed in the habitat descriptions of each community. These habitat data were given in abbreviated form in the phytosociological tables and a key to the abbreviations follows:

Key to habitat description abbreviations as used in the phytosociological tables..

Slope of sites:

0	0°	6	2°01' - 5°00'
1	0°01' - 0°15'	7	5°01' - 10°00'
2	0°16' - 0°30'	8	10°01' - 15°00'
3	0°31' - 0°45'	9	15°01' - 20°00'
4	0°46' - 1°00'	10	> 20°.
5	1°01' - 2°00'		

Geological substrate:

P	Pegmatite	Q	Quartzite
G	Granite	C	Calcrete
Sc	Schist	Co	Conglomerate
Dr	Dolerite	Sst	Sandstone
Ig	Unidentified igneous rock	C/G	Calcrete overlying granite
Do	Dolomite	G/Sc	Granite intruded through schist
M	Marble	P/Sc	Pegmatite intruded through schist.

Soil:

Soil consistence and texture were classified following the United States Department of Agriculture (1962) system.

A. Soil consistence (when soil is dry):

0	Loose	3	Hard
1	Soft	4	Very hard
2	Slightly hard	5	Extremely hard

B. Soil texture:

1	Coarse textured soils	A	Coarse sand
		B	Medium sand
		C	Fine sand
		D	Very fine sand
		E	Coarse loamy sand
		F	Loamy sand

		G	Fine loamy sand
		H	Very fine loamy sand
2	Moderately coarse textured soils	A	Coarse sandy loam
		B	Sandy loam
		C	Fine sandy loam
		D	Very fine sandy loam
3	Medium textured soils	A	Loam
		B	Silty loam
		C	Silt
4	Moderately fine textured soils	A	Sandy clay loam
		B	Clay loam
		C	Silty clay loam
5	Fine textured soils	A	Sandy clay
		B	Silty clay
		C	Clay

C. Coarse fragments in the soil:
Rounded to sub-rounded fragments less than 7,5 cm in diameter were classified as gravel, abbreviated to G, and used as a prefix to the textural class symbol. (For example, G2C is a fine sandy loam soil with some gravel).

D. Cementing substances:

C	Calcrete
G	Gypcrete
S	Salt

E. Soil depth:

0	Very little soil (only in cracks)	5	21 - 30 cm
		6	31 - 40 cm
1	1 - 5 cm	7	41 - 50 cm
2	6 - 10 cm	8	51 - 70 cm
3	11 - 15 cm	9	> 70 cm
4	16 - 20 cm		

F. Degree of flooding (applies only in Table I):

0 Site never flooded

1 Site may be flooded by extremely high seas (during storms or spring high tides)

2 Site flooded by every high tide.

The completed site record of species, their relative abundance, other analytic characters of flora and vegetation, as well as habitat data is called a relevè (Werger, 1973a). In the present study a total of 472 relevés were taken in an area of about 7 500 km^2, yielding a sampling intensity of approximately 1 relevé per 16 km^2.

2.2.2.2. Synthesis of the data.

When the field data had been collected, they were synthesised and interpreted ecologically. Detailed procedures for tabulation and synthesis are given by Ellenberg (1956), Kuchler (1967), Shimwell (1971), Müller et al. (1972) and Werger (1973a) and no description will, therefore, be given here. Within each group of species, or nodum (Poore, 1955), individual relevés were arranged in a specific sequence. Except where a relevé was transitional between two noda, the most westerly relevé was plotted in the left hand side of the nodum in the phytosociological table (Tables II, III, IV and VI). This sequence was followed because of the marked influence of the east-west environmental gradient (see chapters 3, 4 and 5.6.2 below). The salt marsh (Table I) and pan (Table V) communities did not vary with the east-west gradient; in these cases the controlling environmental gradients were the degree of tidal flooding and height above the pan floor respectively, and the relevés were not ordered as in the other tables. In these instances, most frequently flooded or lowest relevés were plotted on the left and least frequently flooded or highest relevés were plotted in the right of the noda.

The ecological significance of the noda in the phytosociological tables was determined from the habitat notes for each relevé and were confirmed in the field. Coincidence between the pattern in the phytosociological table and specific habitat conditions was taken to indicate the delineation of a basic vegetation unit (a community). This is in agreement of the view of Werger (1973a) that species which are indicators of particular environmental conditions and which characterize a community will, therefore indicate the typical habitat of that community.

Although no classification into higher syntaxa was attempted (see 5.1 below), a Roman (or constancy) table (Werger, 1973a) was constructed (Table VII) to simplify assessment of the community relationships. This table was drawn up in the following way (Werger, 1973a p. 101): The percentage of relevés of each community in which a species was recorded as being present was calculated, rated on a five-point scale and the value entered in the appropriate column of Table VII. The following are the class intervals:

I	Species present in 1 - 20% of the relevés of a community;
II	Species present in 21 - 40% of the relevés of a community;
III	Species present in 41 - 60% of the relevés of a community;
IV	Species present in 61 - 80% of the relevés of a community;
V	Species present in 81 - 100% of the relevés of a community.

Each community was therefore reduced to a single column in the Roman table.

Community structure

Initial application of the physiognomic classifications of Phillips (1970) and later Fosberg (1967) showed that both these systems lead to a classification of two relevés of the same community (defined on floristic criteria) as belonging to two different formations because the systems were too rigid. Such a conclusion has also been arrived at elsewhere (Leistner and Werger, 1973). It was therefore decided that no physiognomic classification would be applied to the data, although the physiognomy of each community is described.

2.3 Measurement of the time taken for water to infiltrate into soil on the plains east of Mirabib.

Preliminary observations suggested that water soaked into soil in which dense patches of vegetation occurred far more rapidly than into the surrounding, sparsely covered areas (see also 3.4.3 and 5.5.2.3). This was tested in the following way:

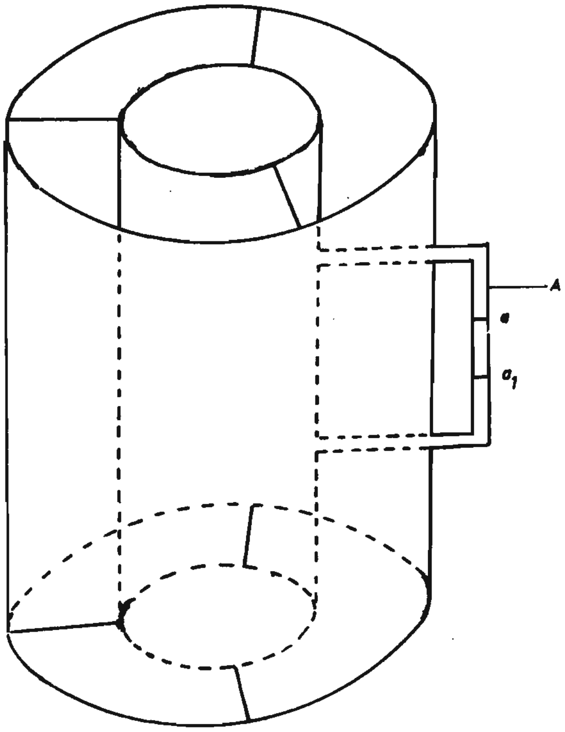


Fig. 2.1 Apparatus used to measure rates of water infiltration into soils of the plains (After Astapov & Dolgov, 1959).

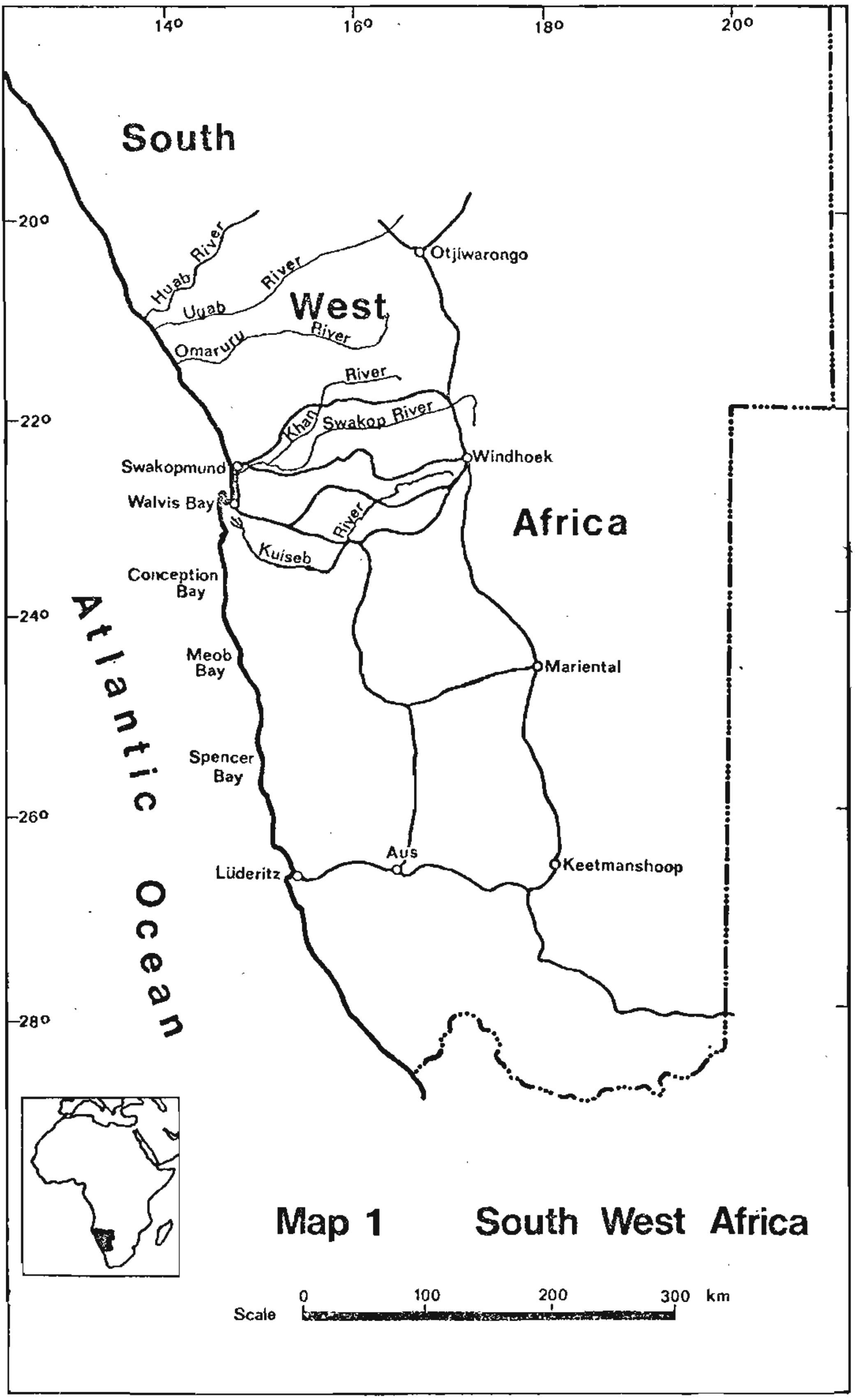
The apparatus used consisted of galvanised iron pipes of different diameters, the smaller one (7,5 cm diameter) being fixed inside the larger one (which was of 22,5 cm diameter) as shown (Fig. 2.1). A length of glass tubing (A) was connected to the inner pipe via a thin brass tube, thus permitting the fall of the water level in the inner pipe to be measured.

The theoretical basis for this measurement is that by placing water around the central (gauging) tube lateral water movement is reduced because the "experimental" area is surrounded by saturated soil. In this way the rate of downward movement into the soil is measured (Astapov & Dolgov, 1959). Results from bare areas and patches of dense plant cover were compared (see below).

In practice this method worked satisfactorily in most cases. In very coarse grained soil, however, infiltration rate was too rapid for the tubes to be filled, while in situations where a desert pavement of stones and pebbles covered the soil surface it was very difficult to prevent water leaking under the sides and thus making measurement of infiltration impossible.

Sites of visibly patchy grassland vegetation were located along the Gobabeb - Mirabib road and the Gobabeb - Zebra Pan road (Map 2). A square 1 metre quadrat was randomly located within the dense patch. Total plant density was recorded and the time taken for a fixed quantity of water to soak into the uppermost layers of the soil was determined. This was achieved in the following way: The apparatus was carefully placed on the soil surface, avoiding distrubance as far as possible. Water was carefully poured into the outer and inner tubes until the level reached 'a' in the glass tube. The time taken for the level to drop 1 cm (i.e. from a to a_1; Fig. 2.1) was then recorded. Three replicates were carried out within the dense patch, except where desert pavement or stones caused difficulty in obtaining measurements in a restricted area.

The quadrat was then placed in a bare area as close as possible to the dense patch (quadrats were never more than five metres apart) and the procedure repeated. The results are given below (3.4.3).



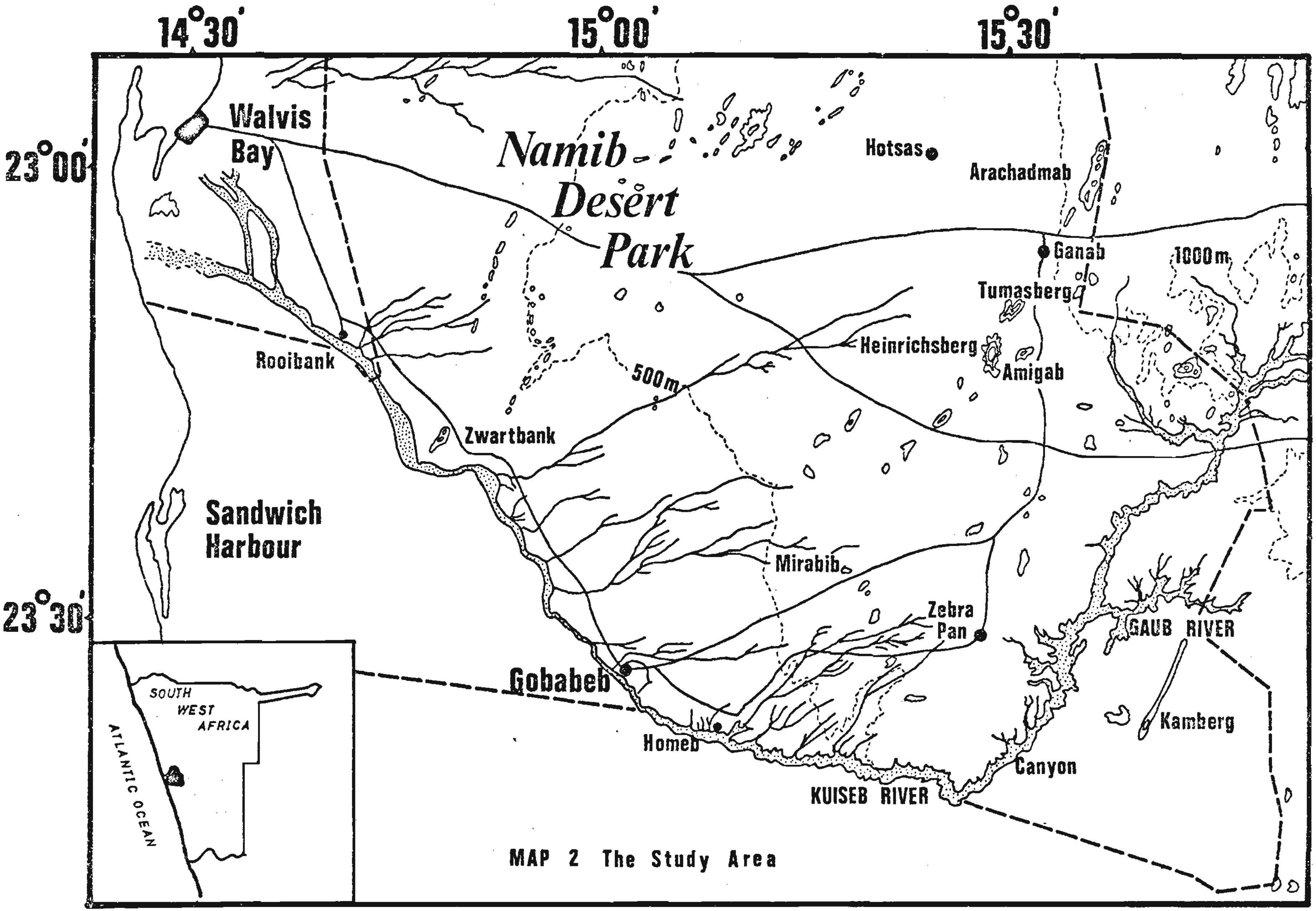
Map 1 South West Africa

Chapter 3. THE STUDY AREA.

3.1 Introduction

The Namib Desert (the word "Namib" is the Hottentot name for the coastal desert of South West Africa - H. Martin in Mertens, 1971), extends some 1 500 km along the west coast of Africa from the Olifants River in the Cape Province to about 80 km north of Mossamedes in Angola, and is about 90 - 120 km broad (Martin, 1965). Along this stretch of coast the sea is cold because of the presence of the Benguela Current and associated upwellings of cold water, and at Walvis Bay mean annual sea temperature is 15,1°C (Wellington, 1955). The Benguela Current, an offshoot of the West (or Westerly) Wind Drift Current, flows northwards from about 33° S. Lat. to the equator where it merges into the South Equatorial Current. Along the western margin of the Benguela Current surface water "fans out" into the Atlantic Ocean and is replaced by upwellings of cold bottom water derived from the Antarctic Intermediate Current (Wellington, 1955). The presence of cold water offshore has a very marked influence on the climate of the entire west coast of Africa, and the study area in particular (Jackson, 1951 and see 4.1.2 below).

Between the coast and the western boundary of the African Plateau two or three zones, running parallel to the coast, may be distinguished. Walter (1936, 1962) and Logan (1960) recognised two zones, the Nebelwüste (fog desert) of the Outer Namib, which is the zone closest to the sea, and the Inner Namib, which extends from about 40 km inland to the foot of the escarpment. Kaiser (1926) and Wellington (1955), on the other hand, divide the Namib Desert into three zones - the coastal strip where fog is frequent, a strip of about 35 - 40 km wide at Walvis Bay, the extremely arid zone, about 50 km wide, and the variable inner zone, where the desert merges into the arid steppe or bushveld. This latter zone has also been referred to as the 'normal arid' or 'semi-arid' (Kaiser, 1926) or the pro-Namib (Vornamib - Giess, 1971) zone. On the basis of the plant communities described here (Chapter 5 below), it seems that the sub-divisions proposed by Kaiser and Wellington (that is, to divide the area into three zones) are the most satisfactory.



MAP 2 The Study Area

The Namib Desert may be further divided into Southern, Central, and Northern sub-regions. The Southern Namib extends northwards as far as Lüderitz Bay and is predominantly a winter-rainfall area, while the Northern Namib is a summer-rainfall area. There is some disagreement as to the southern boundary of the latter sub-region, since Wellington (1955) considers it to be that portion from the Swakop River northwards, whereas Giess (1971) gives the southern boundary as the Huab River (Map 1). The study area is located in the Central Namib Desert, which is the area between the Northern and Southern sub-regions. The Central Namib sub-region thus stretches from a geological formation known as the Lüderitz-Aus horst, which is a spur of the plateau gneiss extending west through Aus to Lüderitz, to the Swakop River (Wellington, 1955 and see Map 1). The Central and Northern Namib sub-regions fall within the summer-rainfall area and therefore do not possess as rich a succulent flora as does the Southern sub-region (Geiss, 1971). The Namib Desert Park extends from south of Sandwich Harbour (23°30' S.Lat.) to the Swakop River (22°40' S.Lat.) and inland to a maximum distance of 130 km, but excluding the coastal strip (10 - 25 km wide) from Walvis Bay northwards (South West Africa 1:1 000 000; Map 2). This game reserve of about 14 174 km^2 (1 312 500 hectares) in extent includes all the biotypes of the Central Namib Desert (pers. obs.).

However desirable it may be to study the vegetation of the entire Namib Desert Park, financial and time restrictions made it essential to limit the study area. Accordingly, it was decided to restrict the study to an area of about 7 500 km^2 stretching from the southern boundary of the Namib Desert Park to the 23° S.Lat. line (Map 2). This area was selected because it included a wide range of biotypes: the Sandwich Harbour salt marshes; an area of shifting sand dunes; the coastal fog zone; the extremely arid and semi-arid plains; the washes dissecting these plains; the Kuiseb River and outcrops of granite and schist. In addition, the road from Walvis Bay to Windhoek roughly coincides with the northern boundary (Map 2), facilitating location in the field.

3.2 Geology.

The study area is underlain by rocks of the Damara System and the Nosib Formation. These overlie the Precambrian Abbabis Formation

(Martin, 1965 and Smith, 1965). In certain areas, notably the shifting sand dune region south of the Kuiseb River, aeolian sand or calcrete of Tertiary to Recent origin are deposited over these formations.

Stratigraphically oldest are the gneisses, schists, amphibolites and other rocks of the Abbabis Formation, but in the study area these rocks comprise only a small part of the total area of rock outcrops (Smith, 1965). All the rock types of the Abbabis Formation have been invaded by granite and pegmatite of the Damara System and these form dykes and sills.

Above this formation lies the Nosib Formation (formerly called the Quartzite Series of the Damara System by Gevers (1929), Martin (1965) and Smith (1965)). This consists of conglomerate, quartzite, amphibolite and calc-granulite facies (Smith, 1965).

The Damara System overlies the Nosib Formation, and it is divided into two series. The lowermost (the Hakos Series) consists of marble, tillite and dolomitic marbles with chert bands and schist intercalations (Martin, 1965). The marbles of the Lower Stage of the Hakos Series form Zwartbank and the marble ridges north of this. The uppermost, and most prominent, series is the Khomas Series, consisting of great thicknesses of alternating bands of biotite schist and biotite-quartz-schist striking in a northeast - southwest direction (Martin, 1965). The alternation of harder, more arenaceous bands with softer, more easily weathered ones produce the schistose ridges so characteristic of the eastern parts of the Namib Desert Park.

Granite gneisses, pegmatites and granites are found throughout the rocks. Some of these, such as the Salem granite (a grey or reddish, porphyritic alkali granite (Wellington, 1955)), and the medium grained red or grey granite formed below the marbles of the Hakos Series were derived from the schistose rocks of the Khomas Series and rocks of the Nosib Formation respectively. Other of the rocks, for example, some of the pegmatites, are believed to have been intruded from below (Martin, 1965). These rock types form such inselbergs, "island mountains" (King, 1963) as Mirabib (Plate 3) and Tumasberg (Map 2) and form striking dykes (Plate 24).

Geology has direct effects on the vegetation so that some communities appear to be restricted to particular substrates (Petalidium variabile and Commiphora glaucescens communities - Chapter 5 below), but the indirect influence is more significant. This is because various rock types weather in characteristic ways and thus produce different landscapes and habitats (see 3.3.6 below).

3.3 Topography

Six landscape units may be distinguished within the study area. A landscape unit is defined here as a topographic element (hill, river-bed or drainage line, marsh, etc.) which may be distinguished by having a particular geological or geomorphological origin, and which provides an unique habitat. Because these units provide different habitats (for example, the Kuiseb River has a bed with deep, loose soil and abundant groundwater, while the shallow drainage lines of the plains often have shallow soil and less groundwater), they are of great importance in determining the occurrence of different plant communities.

3.3.1 Lagoons and salt marshes

The northward flowing Benguella Current carries sand and deposits it on the leeward sides of headlands, producing sand spits (Plate 1). As these lengthen they form sand bars enclosing expanses of water (bays). When the opening of these bays is small or completely closed, the enclosed area, here referred to as a lagoon despite the lack of rivers entering it, is sheltered enough to receive mud and/or sand deposited by the sea and wind. In this way salt marshes are formed. Even when the sand spit enclosing the lagoon is completely closed (that is, there is no direct inlet for sea water), water seeps through the sand bar (King, 1963, p. 112). These processes have produced Spencer, Meob and Conception Bays along the Namib Desert coast, Sandwich Harbour (Plate 1) in the study area and Walvis Bay (Map 2).

Sandwich Harbour, an important harbour until 1889 when the sand bar closed completely for the first time (Mertens, 1971), is now a lagoon about 8 km long and 1 km wide with a narrow opening to the sea. It has no supply of surface water from inland and is

Plate 1

Portion of the Central Namib Desert photographed from Gemini 5. (From a transparency released by the Carl Zeiss Optical Works).

Bays such as Walvis Bay (A), Sandwich Harbour (B) and Conception Bay (C) are formed by sand bars. Linear (seif) dunes are a conspicuous feature of the dune area (D). The Kuiseb River (E) separates the dunes from the gravel plains (F), except along the coast, where a narrow belt of dunes (G) extends northwards to the Swakop River (H).

Plate 2

Sand dunes of the Central Namib Desert as seen from the Namib Desert Research Station at Gobabeb (photographed during November 1974). On the upper slopes the sand is moved by even gentle winds (A), and the direction of the crest-lines changes with seasonal changes in predominant wind direction. For the previous few days the area had experienced east wind conditions, and the west-facing slopes are therefore the steepest (B). Forest grows in the valley of the Kuiseb River (C).

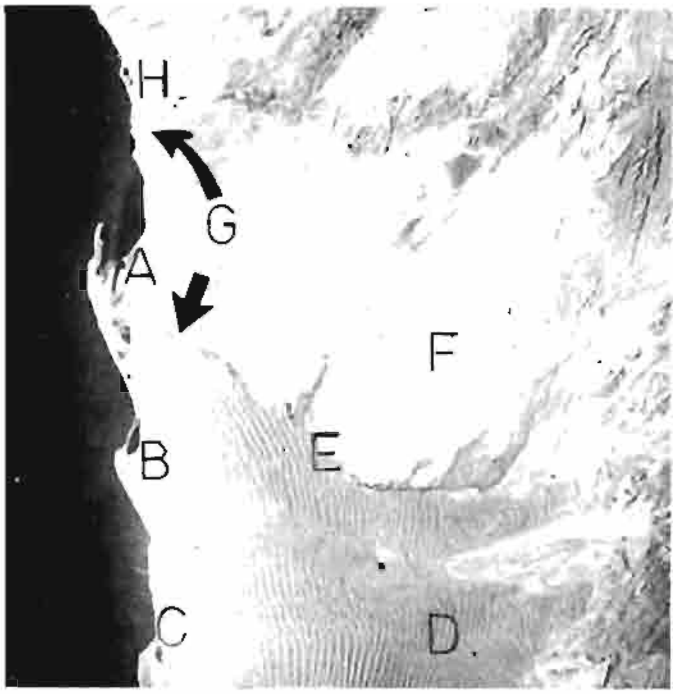


Plate 1

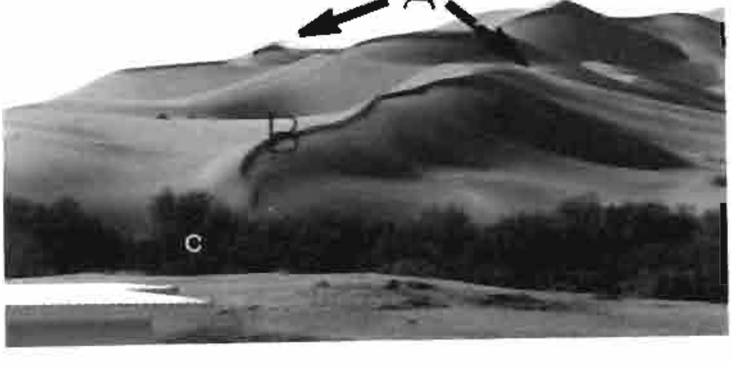


Plate 2

therefore not an estuary in the generally accepted terminology. However, it still receives material of land origin by wind action, which carries sand from the high dunes on the landward side. A subsurface flow of fresh water enters the lagoons at the northern end of the system and this is very significant to the vegetation of the marshes. This water apparently flows beneath the dunes from the Kuiseb River (Hellwig* pers. comm.) and reduces the salinity of the water in some of the creeks (Berry* pers. comm.).

The material deposited by wind and the sea has resulted in areas of salt marsh being intersected by broad, tidal creeks and pools (Plate 5). The oldest part of the system appears to be at the southern end, in accordance with Chapman's (1960, p.22) statement that "...the oldest and highest marshes (are) nearest the proximal end (of the system) and the youngest near the distal end." Because much of the substrate is fine grained, the creeks tend to branch and form long parallel arms, with occasional pans becoming isolated as the overall level rises (Chapman, 1960), presumably because of the way in which such material is eroded by water.

At the southern end of Sandwich Harbour a series of brackish pools are found in the inter-dune valleys at between 10 m and 30 m above sea level. Around these occur plant communities similar to those on the dryer part of the marshes.

3.3.2 The sand dunes

Aptly named the "dune sea" of the Namib Desert (Barnard, 1965), the sand dune area of the Central Namib Desert extends from near Lüderitz Bay to the Kuiseb River, with a maximum width of nearly 120 km (Map 1 and Plate 1). The northward extension is prevented by the Kuiseb River which runs from east to west (that is, across the line of advance of the dunes), and acts as a sand trap. Irregular floods scour most of the length of the riverbed clear of sand, but 15 km from the coast the gradient is small (1:400 - Stengel, 1964) and the riverbed is wide so that floods are less violent than further upstream. The volume of water carried by the river is insufficient at this point to produce a strong surface flow. These factors have reduced the scouring action to the point where sand is not removed as fast as it is deposited, and a narrow belt

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of dunes now extends as far north as the Swakop River (Plate 1).

It seems reasonable to suppose that should the river fail to flow for a number of consecutive years then dune sand would bury the river bed and prevent any further flow. This would allow the dune area to extend northwards over what at present are the gravel plains. This process appears to have taken place south of the study area, where the Tsondab River has become cut off from the sea and dammed to form the large Tsondab Vlei (Seely & Sandelowsky, 1974).

Barnard (1965) recognises three regions within the dune area - a coastal dune belt a few kilometres wide, the longitudinal (linear or seif) dunes of the central region which are all orientated in the same direction and a region of complex, multi-faceted dunes forming a narrow belt near the escarpment. From the vegetation point of view, the first two provide very similar conditions - linear dunes which are aligned roughly north - south with moderately stable lower slopes and crests which shift with the prevailing wind direction (Plate 2). These are separated by sandy or gravelly "streets" ('Straats"; King, 1963, p. 76) of varying width. The dunes may be up to 100 m from crest to trough and consist of reddish coloured, medium to coarse sand which is very loose (see Chapter 5 below). The streets on the other hand may be pebbly or even have a layer of surface limestone (calcrete).

The dunes at the eastern edge of the study area differ from the others in being much smaller (only about 10 - 30 m from crest to trough), and less regular in orientation. The lack of strong directional orientation may be due to irregularities in wind direction which is expected close to the mountainous escarpment region, while the small size may be due to lower wind velocities and because the area is somewhat isolated from the main dune area (Maps 1 and 2 and Plate 1). In addition, the sand is finer grained than at Gobabeb or the coast. Barnard (pers. comm.) believes that this sand may be of inland origin, while that of the dune sea is derived from the mouth of the Orange River.

3.3.3 The plains north of the Kuiseb River

Topographically all the plains of the study area are very similar; broad peneplains with very low relief, interrupted by shallow drainage lines, shallow washes, ridges of resistant rock or isolated inselbergs. As Logan (1960) indicates, there are differences in geomorphology and substrate between the coastal and inland plains, but these are of less significance to vegetation than the climatic differences (Chapter 4 below).

Despite the general flatness, the small changes of relief (as little as 10 cm) that do occur are extremely important in controlling run-off water and thus play a very significant part in plant growth (Chapter 5 below). Surface run-off is high throughout the study area, and is aggravated by the occurrence of impermeable "foam soil" or "Schaumboden" (Volk and Geyger, 1970) at or just beneath the surface (3.4 below).

3.3.4 Drainage and associated landscape units

Drainage in most of the Namib Desert is endoreic (drainage of the rivers does not reach the sea). The rivers rising in the escarpment area or on larger inselbergs disappear into the plains because rainfall is insufficient to maintain surface flow in the sandy riverbeds and the evaporation is high (4.9 below). The Kuiseb River is the only large river in the study area and even this flows only for short spells (see below). Nevertheless, the watercourses are extremely important in the development of many of the perennial communities in the Namib Desert.

The Kuiseb River rises in the Khomas Highlands near Windhoek and flows south-west for about 230 km to the bottom of the escarpment, where the Canyon begins (Map 2), and for the next 130 km it flows between steep, high schist walls. From about 20 km upstream of Gobabeb the river widens and the southern bank is formed by the sand dunes (Plate 1). Downstream from Gobabeb the bed widens still further and the river meanders between the dunes on the southern side and the low rocky banks on the north so that at Rooibank (Map 2) the bed is some 200 m wide. A rock outcrop 27 km from the coast causes the river to divide into two branches forming a delta with mouths nearly 25 km apart. The northern course used to enter the sea near Walvis Bay, but it has been closed by a 7,3 km long dam to prevent flooding of the town (Stengel, 1964). The southern course presumably used to traverse the area now covered by the dunes, to reach the sea north of Sandwich Harbour (Map 2).

Flow is infrequent and floods are insufficiently violent to maintain an open outlet to the sea. It is only during exceptionally heavy floods that the river overflows into the sea. Even during years of heavy rain, for example 1963 and 1974, the water remained dammed up; Stengel (1964) calculates that some 100 000 000 m^3 of water collected behind the coastal sand barrier during the 1963 flood. Since 1837 the river has reached the sea only 15 times (Stengel 1964; Seely, pers. comm.), even though flow is recorded at Gobabeb for periods of a few days to several months (three in 1974) in most years. These surface floods scour sand from the river bed, preventing the dunes from advancing northwards, and also restricting colonization of the river bed by perennials.

Much of the water in the Kuiseb River is beneath the surface (Stengel, 1968, in Scholz, 1972), and this supply maintains the fringing forest of *Acacia albida* and other species, supplies Walvis Bay and Swakopmund with drinking water and replenishes the freshwater supplies of the Sandwich Harbour lagoons.

Water courses on the plains vary from narrow drainage lines, noticeable only because of the plant communities occupying them, to 50 m wide washes filled with deep, loose sand. Where gradients are steep (for example the washes leading to the Kuiseb Canyon) the beds may be deeply incised, forming miniature canyons. but on the plains they are rarely more than 1 m below the general surface level. Surface flow occurs only after rain and lasts for no more than a few hours, although the suddenness of the showers and the high run-off turn gullies into raging torrents in a few minutes.

Plate 3

Plate 4

Plate 3

The Mirabib inselberg, composed of Salem granite. Notice the general flatness of the plains and the concentration of shrubs (primarily *Acacia reficiens*) in the drainage lines.

Plate 4

A saline wash on the plains north of Gobabeb. A salt crust (A) lines the watercourse, and drying of the salt and clay complex in the soil produces doming of the surface crust (B).

3.3.5 Pans

Several areas of restricted drainage occur in the Namib Desert Park. Generally they are very shallow depressions on the plains and may cover a small area or a few hectares. Most pans develop on clayey soil, but a few in the study area were underlain by calcrete. The pans clearly have a profound influence on the plant communities, and in a number of cases supported communities which were similar to those of riverine and rocky habitats.

3.3.6 Inselbergs and other rock outcrops

One of the most striking features of the study area are granite plutons which form spectacular "island mountains" (inselbergs) rising from the flat plains like mountains from the sea (Plate 3). They are frequently steeply rounded and rise 100 m or more above the plain. Many dykes, composed of rock of different hardness, traverse the granites of the Post - Damara granitic intrusive rocks (Du Toit, 1956), and thus the inselbergs are dissected by numerous small gullies and plateaux, providing sites in which plants establish themsleves.

The Damara System also forms hills and mountains, but these are more frequently in the form of ridges. A major feature of the schist inselbergs and ridges is the way in which the stratified rocks are inclined due to faulting. As noted previously (3.1), the predominant strike direction is northeast - southwest, which means that the north-facing slopes are relatively smooth with unbroken sheets of rock being exposed, while south-facing slopes are extremely broken and frequently more steeply sloping. Dolomites, quartzites and marble, on the other hand, are more resistant to weathering and are of more uniform composition than schists or granite, and therefore outcrops of these rocks present a less dissected appearance. However, here too are found intrusions of igneous rock (Plate 24) which weather leaving rigdes and gullies.

The numerous cracks and crevices on the rock outcrops, together with the collection of run-off water provide relatively mesic micro-habitats (see Channing, 1975, for example) where a characteristic species composition was often noted, while some of the most species-rich communities were found on inselbergs in the eastern part of the study area.

Frequently the accumulation of water at the foot of inselbergs supports communities of trees and shrubs which bear close resemblance to more widespread wash communities.

3.4 Soils

The soils of the study area have been little investigated and the only papers dealing specifically with the Namib Desert Park are those of Logan (1960) and Scholz (1972). In the present study even immature or unconsolidated material (gravel, sand or rocky substrate) is treated as soil (cf. Zohary, 1973, p. 39).

In the area of the Namib Desert covered by this study the physical properties of the soil (for example, particle size and consistence - the hardness or softness - and whether cementing substances such as calcrete or gypsum were present) were of great importance to the vegetation. This is particularly well demonstrated by the communities of Zebra Pan (see Chapter 5 below), where soil consistence differs quite noticeably between communities. Because of the scarcity of water the main influence of soil on vegetation is its effect on water supply, which is controlled to a greater degree by the physical rather than the chemical factors of the soil. Similar findings are reported for the Sonoran Desert in North America (Shreve, 1951), arid areas in the Near East (Zohary, 1961) and the Sudan (Obeid and Mahmoud, 1971).

Following Scholz (1972), the soils can be divided into the following types: Soils of the dune areas; Syrosems; Limestone soils; Gypsum crust soils; Silt or Flood-plain loam; Gravels of water-courses; and Saline soils.

3.4.1 Soils of the dune areas

In the dunes continual movement of the particles prevents differentiation into horizons. Chemical weathering does, however, occur, especially near the coast where conditions are moister.

The situation is aggravated by the arid climate which acts both to reduce the amount of organic matter available for decomposition and subsequent incorporation into the soil, as well as to reduce almost completely the rate of litter decomposition.

The size and specific gravity of the sand particles varies; the smaller and lighter grains are more easily transported by wind so that heavier and larger particles accumulate on the windward slopes. These are frequently dark coloured (dark grey-black in the case of magnetite and reddish if the mineral is garnet) resulting in the dark and light patches on the dunes.

In the interdune valleys the sand grains are frequently cemented by limestone or gypsum, and limestone concretions are common. The cemented layer, which is of considerable importance for water percolation, is found at varying depths beneath the surface, while the concretions may take a number of forms and have various origins. Scholz (1972) discusses this aspect in some detail, but it is of negligable importance to plants, and is not treated here.

3.4.2 Syrosems

These are accumulations of rock fragments produced by mechanical weathering (Scholz, 1972). They occur widely in the study area, both on rock outcrops (usually as pediments), and on the plains. Progressing further from the point of origin of the syrosems, the degree of chemical weathering increases until the particles are small and, in humid regions, true soils are formed.

Syrosems are equivalent to the "Regs" of the North African deserts (Scholz, 1972).

3.4.3 Limestone soils

Following Scholz's (1972) terminology, these are soils that have developed on calcrete. Calcrete, also called "caliche" or "surface limestone" (Logan, 1960), occurs very widely throughout the Namib Desert and other arid areas of southern Africa (King, 1963). It is formed when water containing large quantities of calcium

TABLE 3.1. TIMES TAKEN BY A FIXED VOLUME OF WATER TO INFILTRATE INTO SOIL IN DENSELY VEGETATED PATCHES AND ADJACENT BARE AREAS ON THE GRAVEL PLAINS EAST OF GOBABEB. THREE REPLICATE DETERMINATIONS WERE OBTAINED AT EACH SITE.

SITE	PLANT DENSITY IN $1m^2$		INFILTRATION TIME (Secs)			
	BARE AREA	VEGETATED AREA	BARE AREA	mean	VEGETATED AREA	mean
1	0	51	133		45	
			332	260,0	48	48,7
			315		53	
2	0	56	567		21	
			670	606,2	30	27,7
			600		32	
3	1	72	257		39	
			140	207,3	52	46,7
			226		49	
4	0	116	1040		80	
			1260	960,0	47	63,7
			580		64	
5	0	169	85		35	
			147	139,3	41	35,0
			186		29	
6	0	65	360		40	
			453	472,0	39	42,0
			603		47	
7	0	110	503		35	
			987	536,7	68	48,3
			120		42	
8 *	15	140	430		36	
					62	45,3
					38	
9	2	33	201		123	
			445	302,7	30	66,7
			262		47	
10 *	15	74	133		29	32,0
			76	97,3	37	
			83			
11	16	142	270		13	
			327	252,3	53	38,3
			161		49	
12 *	2	87	734		30	
					38	28,3
					17	
13 *	6	63	1060		35	
					38	34,7
					31	

* In these samples the surface was covered by a pebble layer which made it impossible to obtain 3 measurements within a small area.

Both the plant density and water infiltration rates were significantly greater in the densely vegetated patches than in the bare areas. These differences were significant at the 1% level of F.

carbonate or bicarbonate evaporates. In the Namib Desert Park the limestone crusts are believed to have formed in two ways; the uppermost layers, "must have formed at the surface on the evaporation of rain water saturated with calcium hydro-carbonate," while the lower layers were formed when "ground water dissolves the calcium carbonate from the bedrock and sub-soil, rises to the surface through capillary action and deposits the dissolved $CaCO_3$ on evaporation" (Scholz, 1972 p. 35). Logan (1960) believes that the calcretes were formed during periods of higher rainfall than is experienced at present, and Martin (in Scholz, 1972, p. 35) agrees that they are fossil deposits which have been exposed by erosion.

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Soils developing on cl~~a~~crete are usually dark coloured (ochre-brown to grey), show a calcium-rich horizon and are often covered with a layer of pebbles resulting from wind deflation. Limestone soils occur over large areas of the plains, and are therefore of considerable importance to the vegetation of the Namib Desert Park.

The "foam structure" described by Volk and Geyger (1970) is found in these soils in the study area. Observations suggested that patchiness of vegetation on the plains (5.5.2.2 (d) and Plate 35 below) might be due to differences in the rates of water infiltration (Table 3.1). Both these factors are related to the presence of a "foam structure" in the soil. This is a layer consisting of an accumulation of spherical vesicles (bubbles) within a fine-grained matrix and the formation is explained as follows by Volk and Geyger (1970): Where fine fractions, clay or silt, occur in sandy soils in regions where rainfall is low, water penetrates only a small depth before the soil dries out again. Bubbles of air are trapped in the mud formed when the fine fraction is wetted, and when the soil dries out before the bubbles can work their way to the surface, a cemented, vesicular structure results. The cementation and trapped air reduce water penetration, thus increasing run-off, and consequently have a profound influence on the vegetation. This hypothesis was tested by measuring the times taken for a fixed volume of water to soak into the soil at 13 sites on the plains east of Gobabeb (Table 3.1).

At each site infiltration was measured in bare areas where the foam structure was evident and in densely vegetated patches where foam soil was not found. The large variability in infiltration times recorded (Table 3.1) can be explained by the variability of sites with regard to amount of superficial coarse material, depth of the foam layer beneath the surface and its thickmess and hardness. An analysis of variance was performed on the data, and it indicated that the vegetated sites were significantly more densely covered than bare areas, the difference being estimated as 86,23 ± 14,76 plants per m^2, significant at the 1% level of F. This was related to more rapid infiltration of water into soil in the vegetated areas, the difference in favour of the vegetated areas over bare patches being estimated as 426,18 ± 107,82 seconds which is also significant at the 1% level of F. This difference in rate at which water enters the soil is important as it influences the amount of water which will soak in during brief showers and may also affect water retention time, both of which have a profound effect on the establishment and survival of plants.

3.4.4 Soils of gypsum crusts.

Gypsum crusts are found in soil to a distance of about 80 km inland, with the quantity of gypsum steadily increasing towards the coast. Martin (1964) beleives the gypsum to be produced from the reaction of hydrogen sulfide (derived from gaseous eruption offshore, which is then carried inland by the sea-breeze and condensed out with the fog), with carbonate in the soil. Scholz (1972) supports this hypothesis, and points out that the gypsum soils first occur at approximately the inland border of the fog zone and that the greatest deposits are where maximum condensation of fog takes place.

These soils are found throughout the fog zone of the study area. Their direct effects on the vegetation are unknown. Since their development is related to fog and fog precipitation any correlation between soil and vegetation may be purely coincidental, for example, representing a response to some undetermined factor such as moisture.

3.4.5 Silts and flood-loam soils.

Most of the suspended solid material carried by the Kuiseb River is fine grained micaceous material and sand. Silts and flood loams are deposited wherever the current slows down and form marginal terraces. These soils comprise most of the substrate of the Kuiseb River banks, but it seems as though the availability of water is the controlling factor in the Kuiseb River valley and not the soils, except in so much as they influence this factor. Availability of water throughout the year is largely determined by the occurrence of rock barriers which form underground dams thereby keeping the groundwater level close to the surface (pers. obs. and see Stengel, 1968 in Scholz, 1972).

At a number of points along the river fossil flood-loams form terraces at up to 15 m above the present riverbed (Scholz, 1972 p 40) which may be taken as evidence that the Kuiseb River was dammed up in the past (Goudie, 1973). These fossil soils are sometimes of considerable depth; at Homeb (Map 2) they are over 5 m in depth. The main difference between the fossil flood-loams and the recently deposited silts is that the former are sometimes very hard (presumably as a result of greater compaction), and this, together with their height above the river and consequent greater distance above the groundwater source makes them a less favourable habitat for plants.

At Zebra Pan (Map 2) and some other localities clay soils were encountered. These had obviously developed during periods of flooding following rains by a process of elluviation when fine material was washed from the surrounding plains and settled in the pans. Clay serves to both improve water retention and base exchange capacity, and it is not surprising therefore that these soils supported distinct assemblages of plants (see 5.4 below).

3.4.6 Gravels of the watercourses.

Many of the larger washes are filled with coarser substrate than is found on the surrounding plains. This varies from coarse feldspar and quartz gravel to medium sand and, where the wash flowed through schist, fine, micaceous material. In all cases in was uncompacted. The soil may show some degree of layering, with coarse gravels being separated by layers of finer material, probably due to deposition under different conditions (more and less violent floods respectively).

Water infiltrates rapidly into the gravels of the water-courses, which means that most water entering a wash will soak into the substrate, provided the gravel is not too shallow or the rain too heavy. Once water has soaked into gravel or sand it does not evaporate very rapidly (Leistner & Werger, 1973), and therefore the washes retain water for a considerable time. This is reflected in the vegetation occupying these habitats - it is composed of more perennial species than the vegetation of the plains, and trees and shrubs often grow in larger washes.

3.4.7 Saline soils

Saline soils are occasionally encountered between the coast and the inland boundary of the study area. As might be expected, some of these are extremely hard, with the surface being broken into irregular polygons. This is because the surface crust is pushed up by swelling of the salt - clay complex on wetting (Scholz, 1972). On drying a hard, irregular surface is produced having cavities beneath it. The under-surface of the upthrust crust are frequently coated with blue-green algae, but apart from these, few plants colonize the substrate and their cover is low (see 5.3.2.5 below).

3.5 Conclusion

Frome the brief review of the literature relating to soils of the study area, it is clear that in certain instances the soil has direct effect on vegetation (for example, clayey and saline soils) but that, in most cases, the development of communities is an indirect response, reacting to water availability in the soil.

Chapter 4. CLIMATE

4.1 Introduction.

4.1.1 Description of the climate of the Namib Desert.

The concepts of "desert" and "arid" are frequently somewhat confused and definitions are numerous and varied (for discussion of the definitions that have been applied, see Walton, 1969 p 8 et seq.; Yaron, Danfors and Vaadia, 1973, Ch 1; and, Zohary, 1973 p 407 et seq.). The entire Namib Desert region has low and highly variable rainfall (4.6 below), evaporation exceeds precipitation (4.9 below) and vegetation is sparse and plants are drought-avoiding, drought-tolerant, drought-resistant or succulent. It therefore seems to qualify for the term "desert" no matter which definition is preferred.

Climate in the Namib Desert region is strongly influenced by the Benguela Current (3.1 above) and its associated upwellings of cold water (Jackson, 1951). This cold water offshore is one of the major factors leading to the aridity of the west coast of southern Africa (4.1.2 below).

Temperatures on the coast are moderately cool, but increase with distance from the sea (4.4.1 below). Coastal temperatures are low because of the cold sea and the frequent occurrence of fog and low cloud (below and 4.7.2), but occassionally very high temperatures are experienced (Table 4.6). Diurnal variation on the coast is lower than inland, although even here it is only during the cool season that low night temperatures are common. Frost has not been recorded for the Central Namib Desert of South West Africa (Weather Bureau, 1954; 4.4.1 below).

As a result of the low plant cover and high insolation, soil temperatures may be high and surface temperatures of over 60° C are common (4.4.2 below). This has both direct effects on plant growth (soil and air temperatures immediately above the soil are very high), and indirect effects (such as increasing evaporation and transpiration).

Fog and low cloud, called 'Cacimbo' in the Angolan area, is common and extends about 50 km inland (Meteorological Services of the Royal Navy and South African Air Force, undated; Jackson, 1951; pers. obs.). It is produced by interaction between warm air derived from the high-pressure anticyclone over the Atlantic Ocean (q.v.) and air cooled by the sea. At the point where cold and warm air meet condensation of moisture occurs. At the coast this takes place close to sea level, producing fog. Further inland condensation occurs at higher altitudes, as the plane of inversion of temperature rises, to form stratus cloud (Walton, 1969). Relative humidity is high along the coast (except during Berg wind conditions, q.v.) and both diurnal and annual variation is small (4.8 below). Inland, relative humidity decreases rapidly with increasing distance from the sea, so the air over the greater part of the Namib Desert is very dry during the day. At night moist air tends to move further inland (particularly up the deep river valleys such as the Kuiseb, Swakop and Kunene Rivers (pers. obs.)), raising the humidity.

Winds are of two main types; land- and sea-breezes (the latter may be strong and penetrate at least 60 km inland in the Central Namib Desert (Schulze, 1969; also 4.5 below)), and the Berg winds from the plateau. The high insolation results in local low-pressure cells over the land during the day, producing the sea-breezes. At night the situation is reversed, the sparse plant cover and cloudless skies allow the land to cool rapidly and land-breezes predominate (Jackson, 1951; Wellington, 1955; Schulze, 1965 and 1969; Walton, 1969). The sea-breeze does not blow directly onshore because of the combined effects of the high-pressure anticyclone over the Atlantic Ocean and the Coriolis force, which is the force produced by the revolution of the earth, (Walton, 1969.) . Berg winds move from the warm anticyclone situated on the plateau towards the coast. Adiabatic heating occurs as the air mass descends to lower altitudes (as a result of increased atmosperic pressure) and these winds are extremely hot and dry(Wellington,1955; 4.5 below). Wind has direct and indirect effects on plant growth and vegetation developement and these are discussed in 4.5 below.

4.1.2 Factors responsible for the existence of the Namib Desert.

The major factors responsible for the existence of a desert along the west coast of southern Africa are the presence of a cold ocean current and the coincidence of the eastern edge of the oceanic high-pressure cell (the Atlantic Ocean anticyclone) with the coast of Africa (Wellington, 1955, maps p 317; Schulze, 1965; Walton, 1969 p 21). Interaction between these results in low precipitation in the following ways:

Upper air temperatures are higher than those at the earth's surface as a result of subsidence of air in the anticyclone (the sinking air is heated because of the compression due to increasing atmospheric pressure, which in turn heats the surrounding air). The surface air is cooled by the cold Benguela Current and associated upwellings (Jackson, 1951). This produces a strong temperature inversion; cold air close to the ground and warm air at higher altitude, and marked atmospheric stability (Walton, 1969). Circulation of the air around the anticyclone leads to a flow of air parallel to the coast (Schulze, 1965, maps; Walton, 1969). When such cool winds off a cold sea approach the warm land the water holding capacity of the air increases, because warm air can carry a greater amount of water vapour per unit volume than cold air, and therefore precipitation cannot occur. As the air mass moves inland the higher temperatures lead to evaporation of any water droplets which may have formed, so rain does not even fall on the escarpment (Walton, 1969).

Where the temperature inversion is weakened by raised sea temperatures, precipitation will occur. This happens north of Mossamedes where the Benguela Current is deflected away from the coast by the shape of the coastline. Between the deflected cold current and the shore is warmer "stagnant" water, and here rainfall is higher (Jackson, 1951; Walton, 1969).

In summary: The Namib Desert is therefore caused by the presence of a temperature inversion in the atmosphere near the coast which increases the water carrying capacity of air moving towards the land. The temperature inversion results from interaction between the anticyclonic high-pressure area (and its associated air movements) over the Atlantic Ocean and the low temperature air above the cold Benguela Current.

4.1.3 The climate of the study area.

Climatic data are available from Gobabeb (407 m a.s.l. and 60 km inland - Map 2) for the period 1962 - 1972 and most data discussed below are derived or quoted from Schulze (1969) and Seely and Stuart (1976). Unfortunately the data from the automatic recording weather stations which have been set up along a transect from sea level to 1 000 m a.s.l. are still unreduced, and thus data for the eastern and western parts are scanty. There is no permanent weather station at either Walvis Bay or Swakopmund (Map 1) although data have been collected at various times and are given in "Weather on the coasts of southern Africa : From River Congo to Cape Delgardo. Vol. 2 Part 1" (Meteorological Services of the Royal Navy and South African Air Force, undated) and, "Climate of South Africa. Part 1; Climate Statistics" (Weather Bureau Publ. 19, 1954). The majority of data for the coastal area are derived from these publications. Data from the weather station at Windhoek are not used as they are unlikely to be applicable to the study area. Windhoek is at an higher altitude (1728 m a.s.l.), is situated in a deep valley on the interior plateau (King, 1963 p 240) and is a considerable distance from the sea (Map 1).

An overall picture of the climate of Gobabeb is given by a climate diagram in the form proposed by Walter (1955) in Fig 4.1). Although this method of representation is confusing to those unfamiliar with it, the climate diagram allows rapid comparison of climates of different areas. It is included here primarily for comparative purposes between this and other phytosociological works.

The major climatic factors are considered briefly in the following sections in order to present a more detailed picture of the climate of the study area.

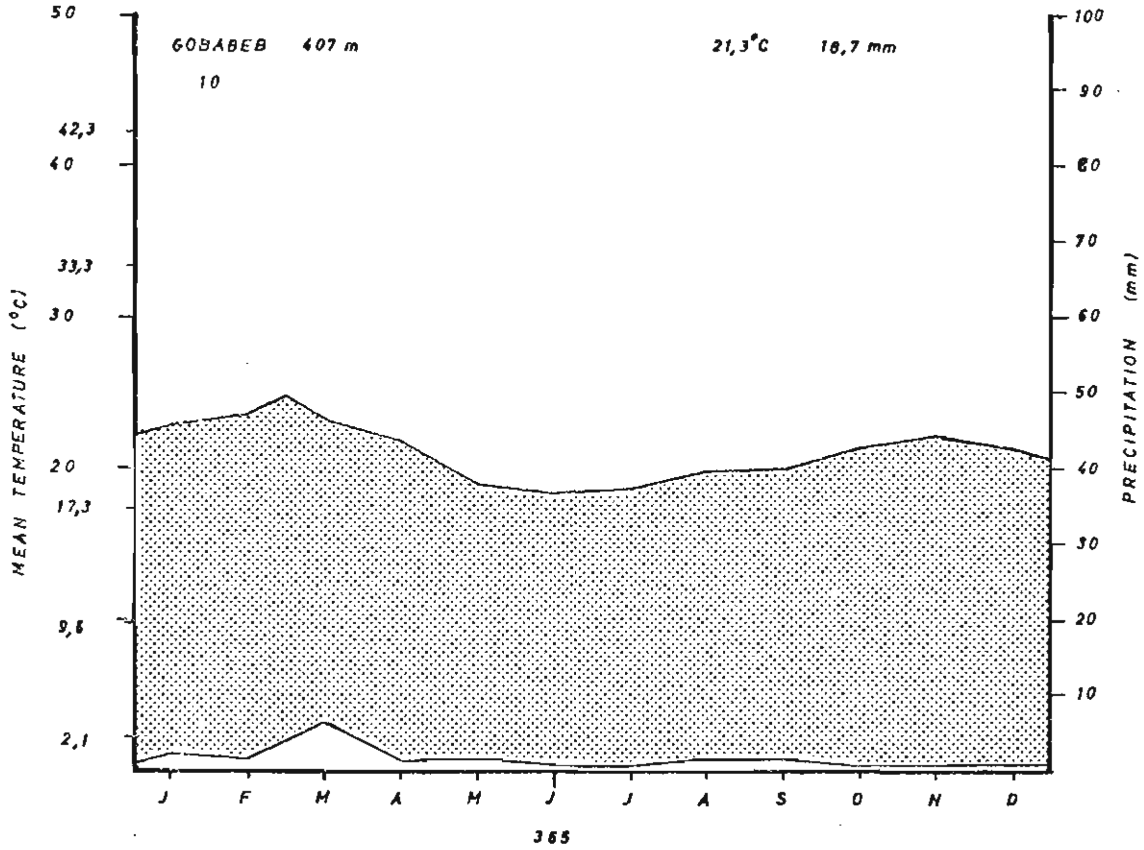


Fig. 4.1 Climate diagram for Gobabeb.

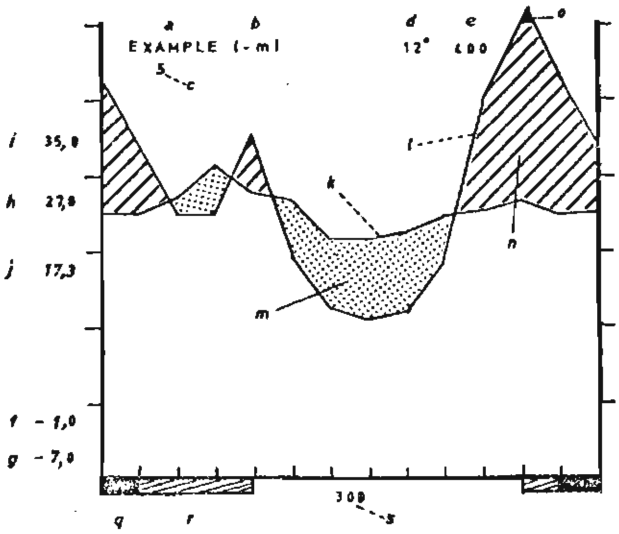


Fig. 4.1 (a) Explanatory example of a generalized climate diagram.

KEY TO Fig. 4.1 (a) EXPLANATORY EXAMPLE OF A GENERALIZED CLIMATE DIAGRAM.

a. Name of the station;
b. Altitude;
c. Number of years of observation
d. Mean annual temperature (^{o}C);
e. Mean annual precipitation (mm);
f. Mean daily minimum temperature of the coldest month (^{o}C);
g. Absolute minimum temperature (^{o}C);
h. Mean daily maximum daily temperature of the hottest month (^{o}C);
i. Absolute maximum temperature (^{o}C);
j. Mean range of temperature (^{o}C);
k. Curve of mean monthly temperature (1 unit = 10^{o}C);
l. Curve of mean monthly precipitation (1 unit = 20mm);
m. Dry season;
n. Wet season;
o. Mean monthly precipitation in excess of 100mm (reduced to 1/10);
q. Months with mean daily temperature under 0^{o}C;
r. Months with absolute daily minimum temperature under 0^{o}C;
s. Mean duration of frost free period (days).

(After Walter, 1955).

4.2 Cloudiness.

Cloud cover is rated on an eight-point scale for the purposes of daily weather reports to the Weather Bureau and is recorded thrice daily (08h00, 14h00 and 20h00) at Gobabeb (Table 4.1).

TABLE 4.1. AVERAGE CLOUD COVER (OCTAS) AT GOBABEB AVERAGED OVER A 10 YEAR PERIOD (1962 - 1972).

	MONTH	J	F	M	A	M	J	J	A	S	O	N	D	YEAR
CLOUD COVER	08h00	5,4	5,0	3,7	2,0	1,6	1,7	1,7	2,4	3,2	4,2	4,0	4,8	3,3
	14h00	1,9	1,8	2,0	1,3	1,1	0,7	0,8	0,7	o,8	1,5	1,6	1,3	1,3
	20h00	2,3	2,1	2,2	1,2	0,9	0,8	0,6	0,8	0,8	1,5	1,5	1,5	1,4

From these data it is possible to draw the following general conclusions: Throughout the year, cloud cover is greatest at 08h00 and decreases towards midday. At least a part of the morning cloud is derived from fog which frequently forms low stratus cloud as it disperses (4.1 above). Maximum cloudiness occurs from about October through to February which coincides with the maximum incidence of fog and the "rainy period". For the greater part of the year, cloud covers less than half of the sky.

Along the coast low stratus cloud is more common than at Gobabeb and it occurs on most mornings (Met. Services of the Royal Navy and South African Air Force, undated). It is greatest in the morning throughout the year, and only in May, June and July does it cover less than half the sky at 08h30 (Table 4.2). However, by afternoon there is little difference between the coastal and inland areas.

The low cloud cover over the inland parts of the study area probably has a minimal effect upon the plants. On the coast, however, cloud cover is probably sufficiently high to influence factors such as insolation (4.3 below), and evaporation (4.9 below), and therefore plant growth.

TABLE 4.2. CLOUD COVER AT WALVIS BAY (OCTAS). (From "Weather on the coasts of southern Africa" - Met. Services of the Royal Navy and South African Air Force, undated) Data are means for a period of 25 years.

	MONTH	J	F	M	A	M	J	J	A	S	O	N	D	YEAR
CLOUD COVER	08h30	6	6	6	5	3	3	4	6	6	6	6	6	6
	15h00	2	2	2	1	1	1	2	2	2	2	3	3	2

4.3 Insolation.

At the present time there are insufficient data on insolation (the heating of the surface of the earth by direct sunshine) to be meaningful. However, insolation is related to sunshine duration, although these are not the same, as measures of sunshine duration only indicate that the sun's rays actually reach ground level. Data for the sunshine duration are available for Gobabeb and Walvis Bay (Table 4.3 and Table 4.4).

As a result of the generally cloudless conditions, the average annual duration of bright sunshine is high inland (10,3 hours per day, or 86% of the possible duration), and it is only in January that sunshine duration falls below 80% (Table 4.3).

Sunshine duration is inversely correlated with rainfall, but even during the period when rain may be expected (January to May and August and September, Table 4.13), the mean number of sunshine hours is still in the region of 80% of the possible duration. This, together with the high temperature, greatly reduces the effectiveness of the scanty rainfall.

Insolation is markedly reduced along the coastal strip by fog and cloud as is evident in the data for Walvis Bay (Table 4.4), where the annual average of sunshine hours is reduced to 7,2 per day (or 60% of the possible duration) and there are 7,4 days without sunshine each year.

TABLE 4.3. SUNSHINE DURATION AT GOBABEB AVERAGED OVER A 10 YEAR PERIOD (1962 - 1972).

MONTH	DAILY AVERAGE SUNSHINE DURATION (HOURS)	% OF POSSIBLE DURATION	NUMBER OF DAYS WITH :-					
			NO SUNSHINE	1-10% OF POSSIBLE DURATION	11-49% OF POSSIBLE DURATION	50-89% OF POSSIBLE DURATION	90-100% OF POSSIBLE DURATION	
J	10,6	79	0,1	0,0	1,5	20,9	8,1	
F	10,7	83	0,0	0,2	1,2	14,3	12,0	
M	10,3	84	0,3	0,1	1,0	12,8	16,9	
A	10,3	89	0,2	0,3	0,6	6,4	22,5	
M	10,2	93	0,0	0,0	0,4	4,6	25,7	
J	9,3	92	0,2	0,0	0,6	4,7	24,2	
J	9,9	91	0,1	0,0	0,3	5,1	25,3	
A	10,0	89	0,0	0,2	0,0	9,1	21,5	
S	10,2	85	0,2	0,0	1,1	11,0	17,8	
O	10,4	82	0,0	0,4	1,4	14,4	14,9	
N	11,1	84	0,0	0,1	1,4	13,8	14,2	
D	11,1	82	0,0	0,0	0,9	19,3	10,9	
AVERAGE	10,3	86						
TOTAL			1,1	1,3	10,4	136,4	214,0	= 363,2

Please Note: The average number of days per annum for which data are available is less than 365 as a result of mishaps during the period 1967 - 1972 (M.K. Seely, pers. comm.).

TABLE 4.4. SUNSHINE DURATION AT WALVIS BAY AVERAGED OVER A 5 YEAR PERIOD (Data from Schulze, 1965).

MONTH	DAILY AVERAGE SUNSHINE DURATION (HOURS)	% OF POSSIBLE DURATION	NUMBER OF DAYS WITH : –					
			NO SUNSHINE	1 – 10% OF POSSIBLE DURATION	11 – 49% OF POSSIBLE DURATION	50 – 80% OF POSSIBLE DURATION	90 – 100% OF POSSIBLE DURATION	
J	7,5	56	0,4	1,6	8,5	18,8	1,7	
F	6,7	52	0,8	1,8	8,8	15,7	1,7	
M	6,8	56	0,6	2,2	7,6	19,2	1,4	
A	7,9	68	0,0	0,4	4,2	20,0	5,4	
M	8,1	75	0,4	0,4	3,6	16,9	9,7	
J	7,7	72	1,6	2,2	1,6	11,8	12,8	
J	7,6	70	1,2	1,6	3,0	14,0	11,2	
A	7,1	62	0,8	1,6	5,3	19,6	3,7	
S	6,3	53	0,8	2,0	10,2	15,4	1,6	
O	7,3	57	0,0	1,2	8,0	19,4	2,4	
N	7,0	53	0,8	1,6	8,8	17,2	1,6	
D	6,9	51	0,0	1,6	12,1	16,9	0,4	
AVERAGE	7,2	60						
TOTAL			7,4	18,2	81,7	204,9	52,9	= 365,1

Comparison of the data in Tables 4.4 and 4.17 shows the influence of fog on sunshine duration and thus insolation. Minimum sunshine duration coincides with maximum fog incidence, and thus minimum insolation is experienced from August until January on the coast (compare with Table 4.3 above).

Reduction in insolation and the extra moisture derived from the fog (4.7.3 below) are important for the vegetation in the 'fog desert' zone because the effectiveness of the moisture that is precipitated is increased.

4.4 Temperature.

4.4.1 Air Temperature.

Over much of the study area the high insolation during the day and clear skies at night result in hot days and moderately cool nights (Table 4.5 and Fig. 4.2).

During the ten years for which records are available, the absolute maximum temperature at Gobabeb has been 42,3° C and the absolute minimum temperature 2,1° C. Mean daily maxima for the summer months, January to April, are about 32° C and for the winter months, June, July and August, about 27° C. Mean daily minima for the same periods are 14° C and 10° C respectively. The aperiodic range (maximum - minimum temperatures) of the temperature remains fairly constant at between 15,7° C and 19,0° C throughout the year.

March and April are the hottest months in terms of both absolute temperatures and number of days when air temperature exceeds 35° C (Table 4.5). Even during the coldest months (June to September), temperatures of less than 5° C are only rarely recorded, and minimum temperatures of less than this may occur, on the average, on three days in July and less frequently between May and September ; Table 4.5). Notwithstanding the general pattern of cooling off in the evening (Fig 4.2), minimum temperatures of greater than 20° C may occur in all months except January, June and July and are most frequent in February, March, April and May.

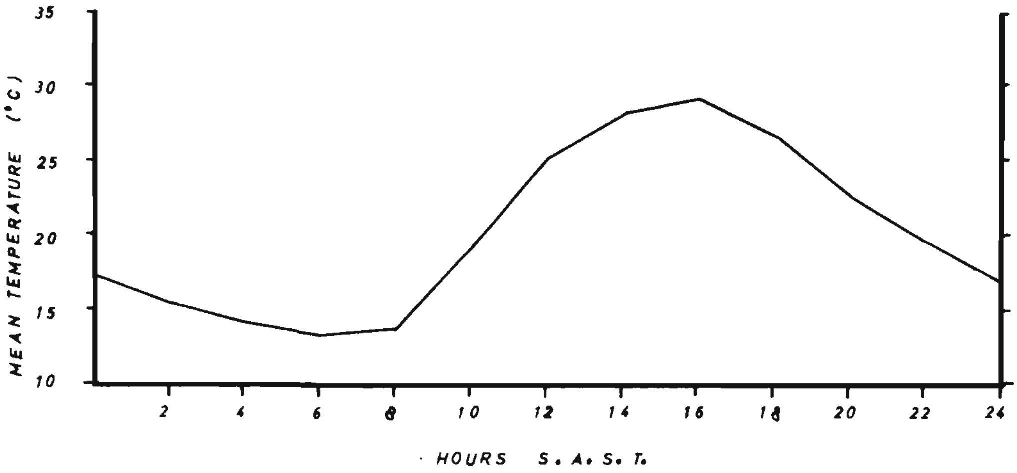


Fig. 4.2 Mean annual diurnal variation of air temperature at Gobabeb for the period 1962 - 1972.

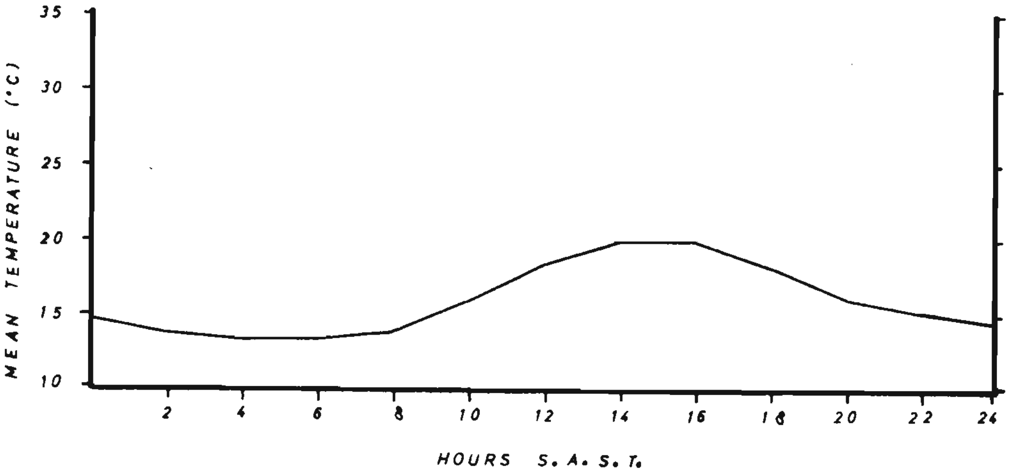


Fig. 4.3 Mean annual diurnal variation of air temperature at Walvis Bay for 1942.

TABLE 4.5. AIR TEMPERATURE AT GOBABEB AVERAGED OVER A PERIOD OF 10 YEARS (1962 - 1972).

MONTH	AVERAGE DAILY MAX. TEMP. (°C)	AVERAGE DAILY MIN. TEMP. (°C)	MEAN TEMP. (°C)	APERIODIC RANGE OF TEMP. (°C)	ABSOLUTE MAXIMUM TEMP. (°C)	ABSOLUTE MINIMUM TEMP. (°C)	LOWEST DAILY MAX. TEMP. (°C)	HIGHEST DAILY MIN. TEMP. (°C)	NUMBER OF DAYS WITH MAXIMUM TEMP. OF :-				NUMBER OF DAYS WITH MINIMUM TEMP. OF :-		
									> 35°	> 30°	< 17,5°	< 10°	< 0°	< 5°	> 20°
J	31,4	15,3	22,9	16,5	40,4	10,4	21,6	24,1	3,3	20,6	0,0	0	0	0,0	0,0
F	31,9	15,2	23,5	16,7	39,7	9,4	21,5	23,6	4,8	20,4	0,0	0	0	0,0	1,3
M	33,3	16,2	24,8	17,2	42,3	9,9	25,4	25,9	9,9	25,4	0,0	0	0	0,0	5,1
A	31,8	14,6	23,2	17,2	39,4	5,1	19,5	24,3	7,2	20,6	0,0	0	0	0,0	4,9
M	30,1	13,6	21,8	16,5	37,0	5,2	18,6	21,4	5,0	18,3	0,0	0	0	0,2	1,6
J	26,6	10,9	18,8	15,7	33,5	2,2	14,8	20,0	0,1	8,6	1,0	0	0	1,6	0,0
J	26,8	10,0	18,4	16,7	34,8	2,1	15,4	19,1	0,1	10,5	1,1	0	0	3,5	0,0
A	27,4	9,8	18,6	17,6	37,4	3,0	14,5	18,8	1,4	11,0	0,6	0	0	2,6	0,1
S	29,3	10,3	19,8	19,0	40,3	3,6	16,9	23,0	6,6	12,8	0,1	0	0	1,0	0,7
O	29,1	10,9	19,9	18,4	40,6	5,4	18,0	18,7	2,7	11,6	0,0	0	0	0,0	0,7
N	30,7	12,4	21,5	18,4	39,6	4,8	23,9	22,2	3,0	17,5	0,0	0	0	0,1	0,9
D	30,9	13,2	22,0	17,7	41,9	8,6	24,2	19,8	3,3	18,0	0,0	0	0	0,0	0,2
YEAR	30,0	12,7	21,3	17,3	42,3	2,1	14,5	25,9	47,2	195,5	2,8	0	0	9,0	16,5

TABLE 4.6. AIR TEMPERATURE AT WALVIS BAY AVERAGED OVER A 25 YEAR PERIOD (1916 - 1941). (Data from Weather Bureau Publ. 19, 1954).

MONTH	AVERAGE DAILY MAX. TEMP. (°C)	AVERAGE DAILY MIN. TEMP. (°C)	MEAN TEMP. (°C)	APERIODIC RANGE OF TEMP. (°C)	ABSOLUTE MAXIMUM TEMP. (°C)	ABSOLUTE MINIMUM TEMP. (°C)
J	23,0	15,1	19,1	7,9	37,8	7,2
F	23,4	15,6	19,5	7,8	36,1	7,2
M	23,1	14,8	18,9	8,3	36,1	7,2
A	23,9	12,9	18,4	11,0	39,4	6,1
M	23,4	10,9	17,2	12,5	40,0	1,7
J	23,2	9,1	16,1	14,1	34,1	1,7
J	21,0	8,4	14,7	12,6	36,7	-3,9
A	19,7	8,0	13,8	11,7	37,2	1,1
S	19,0	8,9	13,9	10,1	37,8	0,0
O	19,6	10,7	15,2	8,9	36,1	0,0
N	21,4	12,1	16,7	9,3	34,8	5,1
D	22,3	13,9	18,1	8,4	32,8	7,2
YEAR	21,9	11,7	16,8	10,2	40,0	-3,9

Frost has not been recorded at Gobabeb. If, however, a minimum temperature of less than 3^{0} C within the Stevenson screen is taken as the criterion for the occurrence of light frost (Schulze, 1965), then Gobabeb experiences frost-temperatures in June and July.

No data are available for the weather station in the eastern part of the study area, situated at Ganab (1 000 m a.s.l.; Map 2). In view of the higher altitude and greater distance from the sea, it is to be expected that minimum temperatures in winter will be lower than at Gobabeb. Conversely, the summer maxima may be expected to be higher because the cooling influence of the Benguela Current probably does not extend this far inland.

In the coastal region temperatures are somewhat lower than at Gobabeb. The mean daily maximum and minimum temperatures are $21{,}9^{0}$ C and $11{,}7^{0}$ C respectively, with absolute values of $40{,}0^{0}$ C (maximum daily temperature) and $-3{,}9^{0}$ C (minimum daily temperature) at Walvis Bay. The range is also smaller than inland, being between $7{,}8^{0}$ C and $14{,}1^{0}$ C (Table 4.6). Diurnal variation in air temperature follows the same pattern as at Gobabeb (Fig. 4.3), but the annual variation is slightly different, with the hottest month being April (Table 4.6). Although July, September and October have minimum temperatures of 0^{0} C or less, and between May and September minimum temperatures are less than 3^{0} C, frost has not been recorded at Walvis Bay during the period covered by the data (Weather Bureau, 1954).

The major influence of air temperature is probably its effect on evaporation and transpiration. Even during the cool season the low temperatures along the coast are unlikely to be as significant to plant growth as water availability. It is possible, however, that air temperature may be significant in delimiting plant-geographical units in the Namib Desert, as is the case in the Middle East (Zohary, 1973), but this hypothesis requires closer investigation.

TABLE 4.7. MEAN MONTHLY SOIL TEMPERATURES AT GOBABEB AVERAGED OVER A 10 YEAR PERIOD (1962 - 1972). (NB Surface temperatures were only recorded for the period 1967 - 1972).

MONTH	08h00 S.A.S.T.						14h00 S.A.S.T.						20h00 S.A.S.T.					
	0cm	10cm	20cm	30cm	60cm	120cm	0cm	10cm	20cm	30cm	60cm	120cm	0cm	10cm	20cm	30cm	60cm	120cm
J	19,7	26,3	30,9	31,2	30,6	28,7	60,9	33,0	30,4	31,0	30,6	28,7	28,3	37,9	33,1	32,1	30,3	28,7
F	19,6	26,7	31,2	31,5	30,9	29,2	61,9	33,0	30,6	31,3	30,9	29,2	29,2	38,2	33,3	32,3	30,9	29,2
M	19,0	26,7	30,8	31,3	30,9	29,4	59,5	33,2	30,4	31,1	31,0	29,4	28,6	37,1	33,1	32,1	30,8	29,4
A	14,9	23,7	27,6	28,6	29,2	29,0	54,4	29,7	27,4	28,5	29,2	29,0	24,2	33,3	30,0	29,4	29,1	29,0
M	12,0	20,8	24,7	25,6	26,8	27,8	45,8	25,8	24,3	25,5	26,8	27,8	21,4	29,1	26,3	26,2	26,7	27,7
J	10,4	17,9	21,3	22,3	24,1	26,2	39,5	21,5	20,9	22,2	24,1	26,2	18,3	25,0	22,7	22,8	24,1	26,1
J	9,3	17,6	20,7	21,4	23,0	24,9	40,3	20,8	20,2	21,5	23,0	35,0	17,9	24,9	22,0	22,0	22,5	25,0
A	9,4	18,1	21,5	22,1	23,2	24,5	44,5	22,6	21,2	22,1	23,2	24,5	19,3	26,4	23,2	23,0	23,2	24,5
S	12,5	20,7	24,3	24,7	25,0	25,0	50,3	26,2	24,0	24,7	25,0	25,0	22,5	30,2	26,6	25,7	25,0	25,0
O	15,8	21,9	26,0	26,5	26,4	25,8	55,2	28,9	25,7	26,4	26,4	25,8	22,5	32,5	28,5	27,5	26,5	25,8
N	20,6	24,2	28,6	29,1	28,4	27,0	60,3	32,1	28,4	28,6	28,5	27,0	26,1	35,9	31,2	30,1	28,4	27,0
D	20,1	25,2	30,0	30,2	29,6	27,9	62,6	32,7	29,6	30.2	29,7	27,9	27,1	37,2	32,1	31,2	29,6	27,9
YEAR	15,2	22,5	26,5	27,0	27,3	27,1	52,9	28,3	26,1	26,9	27,4	27,1	23,7	32,3	28,5	27,9	27,3	27,1
Range	11,3	9,1	10,5	10,1	7,9	4,9	23,1	12,4	10,4	9,8	8,0	4,9	11,3	13,3	11,3	10,3	8,4	4,9

4.4.2 Soil Temperature.

At Gobabeb soil temperatures have been recorded at depths of 10, 20, 30, 60 and 120 cm beneath bare soil for ten years, and for five years (1967 - 1972) at the surface (Table 4.7). Average monthly surface temperatures are predictably high and temperatures of 60° C or greater occur from November until February. The mean monthly minimum surface temperatures vary from about 9°C in July and August to just over 20° C in November and December. Lowest surface temperatures are recorded at 08h00 throughout the year. Below 30 cm the soil temperature fluctuates little either diurnally or seasonally (Table 4.7).

Comparison between the data in Tables 4.1, 4.3, 4.5 and 4.7 show the relationships between cloud cover, insolation (or sunshine duration), air temperature and soil temperature. Soil temperatures are most closely related to mean air temperature and number of hours of sunshine duration and, to a lesser extent, to cloud cover. It is interesting to note that surface temperature of the soil is more closely related to sunshine duration than to air temperature, while soil temperature at greater depths is more closely related to the air temperature.

High incident radiation produces rapid heating of the surface soil, and summer temperatures are high; even when sunshine duration is lowest the surface heats up quite considerably during the daylight hours (see temperatures at 14h00, Table 4.7). However, the dry air and lack of plant cover allows rapid re-radiation, and by 08h00 surface temperature is not very much higher than the minimum air temperature. At greater depths the temperature fluctuates less because loss of heat by conduction is a slow process by comparison to radiation. Not only does soil at depths of greater than 30 cm lose heat more slowly during the night than at the surface, but heat is also retained during the cool season : as sunshine duration decreases temperature at depth does not decrease greatly. In fact, except during the hottest part of the day temperature at depth in the soil is higher than at the surface.

In view of the low aerial cover of many of the plant communities for much of the year, the temperatures recorded at the

TABLE 4.8. MONTHLY WIND DIRECTION FREQUENCY (%) AND MEAN VELOCITY (V ; km/hr) FOR EACH OF EIGHT DIRECTIONS AT GOBABEB, AVERAGED OVER A 5 YEAR PERIOD (1962 - 1967). (Data from Schulze, 1969)

MONTH	N		NE		E		SE		S		SW		W		NW		CALM
	%	V	%	V	%	V	%	V	%	V	%	V	%	V	%	V	%
J	31	14	2	10	1	8	1	7	2	9	15	17	14	14	24	13	10
F	24	12	2	8	1	8	1	9	4	12	16	16	16	13	22	12	14
M	18	11	3	10	2	17	5	10	8	13	14	17	13	13	13	12	24
A	8	11	3	13	7	14	10	9	10	12	15	15	10	12	8	11	29
M	7	13	7	17	12	17	27	10	10	12	10	15	6	11	5	11	16
J	6	14	8	19	14	21	25	12	11	13	10	13	5	10	6	12	15
J	7	14	6	21	13	20	29	11	9	11	10	13	4	10	5	11	17
A	11	12	4	14	7	17	19	11	10	13	14	14	8	10	7	11	20
S	14	11	3	9	4	16	9	13	10	15	18	16	10	11	11	11	21
O	13	11	2	10	3	17	3	9	13	14	22	17	12	12	12	11	20
N	19	12	2	7	1	14	2	12	7	13	20	18	14	13	16	12	19
D	26	13	2	7	1	16	1	7	3	12	15	17	16	13	22	13	14
YEAR	15	12	4	12	5	15	11	10	8	12	15	16	11	12	13	12	18

Research Station's weather station (Table 4.7) may be taken as representative for much of the study area. Soil temperatures of this magnitude must have some influence upon the vegetation, if only because evaporation from the surface soil will be increased. Most rain falls at the period when soil temperatures are highest (Tables 4.1 and 4.7), and any rain, especially from light showers, which falls during the warmer part of the day is likely to be lost by evaporation. Further data are required before the effects of the high soil temperatures on seeds, seedlings and mature plants can be determined.

4.5 Wind.

Schulze (1969) gives data on direction frequency, velocity and diurnal variation of wind speed at Gobabeb for the period 1962 - 1967 (Tables 4.8 and 4.9 and Figs. 4.4 and 4.5 to 4.16). Less comprehensive data are given for Walvis Bay by the Meteorological Services of the Royal Navy and South African Air Force (Tables 4.10, and 4.11 and Figs. 4.17 to 4.21).

It can be seen from these that the inland parts of the study area receive winds mainly from the north, north-west, west and south-west at mean velocities to 18 km per hour during the summer months. In winter, however, the predominant direction is east or south-east, and wind speeds are, on the average, higher (the mean maximum velocity is 21 km per hour). As noted earlier (4.1.1 above), diurnal variation of direction is marked, and at Gobabeb greatest diurnal variation occurs during the summer months. In summer the wind blows from the north (that is, it is a land-breeze) until about 10h00. By this time the land is heated sufficiently to reduce air pressure to below that over the sea and the wind backs to west-south-west (the sea-breeze) till 19h00, before veering back to north as the land cools off at night. During winter, direction is south-east until about 10h00, then it backs all around the compass to become south east again at about midnight. This winter pattern of wind direction is probably because the sea-breeze is weaker (even at the coast) in winter, and does not penetrate so far inland (Table 4.11).

At the coast the situation is essentially the same as inland (Jackson, 1951 p 34; and Table 4.11), except that the alternation

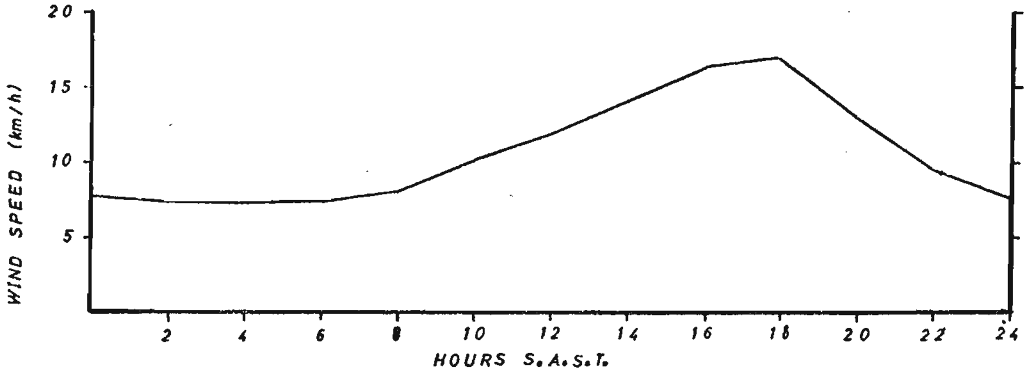
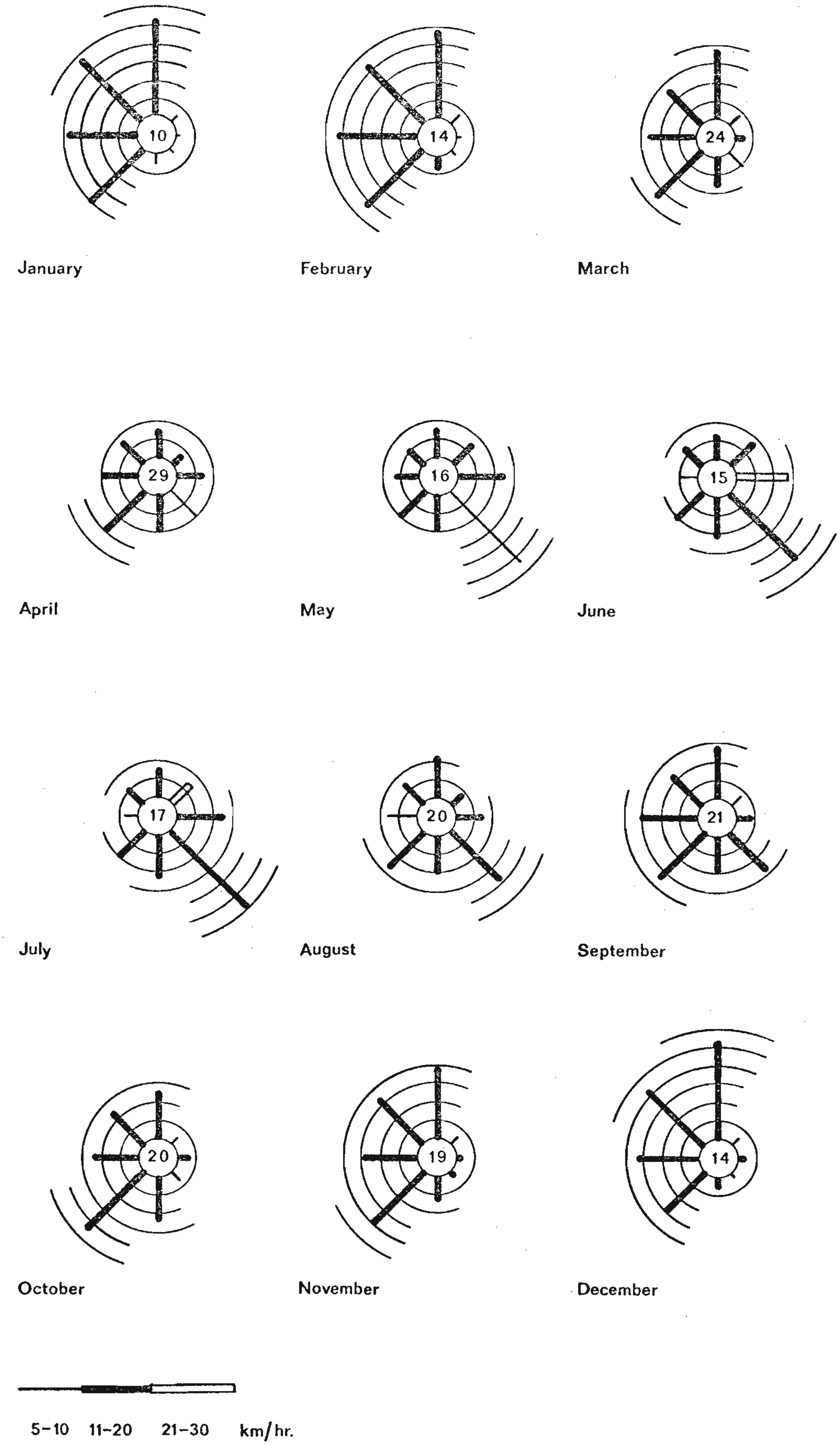


Fig. 4.4 Mean annual diurnal variation of wind velocity at Gobabeb averaged over a period of 5 years (1962 - 1967). (Data from Schulze, 1968).

TABLE 4.9. MEAN MONTHLY DIURNAL VARIATION OF WIND VELOCITY (km/hr) AT GOBABEB AVERAGED OVER A 5 YEAR PERIOD (1962 - 1967). (Data from schulze, 1969).

MONTH	HOURS, S.A.S.T.												
	02	04	06	08	10	12	14	16	18	20	22	24	MEAN
J	10,0	9,1	8,6	8,6	9,5	12,1	15,2	19,3	18,6	14,6	11,9	10,4	12,3
F	8,5	7,1	5,9	6,4	8,2	11,3	14,5	18,0	18,1	14,6	10,5	9,3	11,0
M	6,0	5,7	4,7	6,9	6,2	11,2	12,9	17,1	18,8	14,7	9,4	6,7	10,0
A	4,3	4,4	5,0	5,1	7,2	9,0	11,7	14,4	17,4	12,7	7,5	5,1	8,6
M	6,9	9,5	10,1	11,0	13,1	13,8	12,4	12,5	13,6	10,2	7,2	6,1	10,5
J	10,0	10,5	11,6	11,9	16,6	17,0	14,2	13,3	12,7	10,5	9,4	9,0	12,2
J	8,2	9,4	11,4	12,2	13,4	16,0	14,7	12,2	13,1	10,1	8,4	6,9	11,3
A	6,7	7,5	8,1	8,1	9,9	12,6	12,2	13,5	15,1	11,7	8,5	6,0	10,0
S	6,3	6,0	6,7	7,2	8,2	10,7	13,3	17,1	17,1	12,4	9,3	7,3	10,1
O	6,7	4,7	4,4	5,3	8,8	12,2	15,0	18,8	19,3	14,0	10,5	7,9	10,6
N	6,2	5,3	4,6	6,3	9,2	12,7	16,2	19,8	20,4	15,1	10,3	7,6	11,1
D	6,3	6,9	5,9	7,5	9,2	13,5	16,1	19,0	18,5	15,1	10,9	8,8	11,6
YEAR	7,3	7,2	7,3	8,0	10,0	12,7	14,0	16,3	16,9	13,0	9,5	7,6	10,8



January February March

April May June

July August September

October November December

Figs. 4.5 - 4.16. Wind roses, showing the direction frequency of winds of different velocities at Gobabeb. Concentric circles represent 5% frequency intervals, with the central circle representing a frequency of 5%. Numbers within the circles indicate the number of hours of calm.

TABLE 4.10. MONTHLY WIND DIRECTION FREQUENCY (%) FOR EACH OF EIGHT DIRECTIONS AT WALVIS BAY, RECORDED TWICE DAILY. FREQUENCY AT 08h30 AVERAGED OVER A 10 YEAR PERIOD AND AT 15h00 AVERAGED OVER A 5 YEAR PERIOD. (Data from "Weather on the coasts of southern Africa" - Met. Services of the Royal Navy and South African Air Force, undated).

TIME RECORDED	MONTH	N	NE	E	SE	S	SW	W	NW	CALM
08h30	J	21	6	2	0	4	2	1	5	58
	F	16	5	1	1	3	3	2	4	66
	M	14	5	0	0	3	1	1	2	73
	A	7	5	3	2	3	2	1	0	77
	M	3	3	7	3	2	2	1	0	79
	J	3	7	16	5	3	1	0	1	65
	J	2	6	11	4	4	2	1	0	71
	A	5	3	5	6	4	1	0	1	74
	S	9	7	4	4	5	1	0	1	68
	O	10	8	3	3	5	4	2	2	63
	N	15	8	2	3	3	2	1	4	62
	D	21	6	0	0	4	3	2	7	57
	YEAR	10	6	4	3	4	2	1	2	68
15h00	J	2	0	0	0	6	50	29	14	0
	F	0	0	0	0	5	62	23	6	4
	M	0	0	0	0	9	59	23	7	2
	A	0	0	0	0	11	61	10	3	14
	M	1	1	0	0	18	63	8	5	4
	J	3	0	1	0	18	46	14	9	10
	J	3	1	1	0	17	53	8	9	8
	A	2	1	0	1	23	54	5	8	6
	S	0	0	1	0	18	54	10	7	11
	O	0	0	0	0	19	56	9	5	10
	N	2	0	0	0	15	63	10	5	5
	D	1	0	0	0	9	59	16	7	8
	YEAR	1	0	0	0	14	54	14	7	7

Figs. 4.17 - 4.20. Wind roses, showing the direction frequency of winds of different velocities at Walvis Bay. Concentric circles represent 5% frequency intervals, with the central circle representing a frequency of 5%. Numbers within the circles indicate the number of hours of calm.

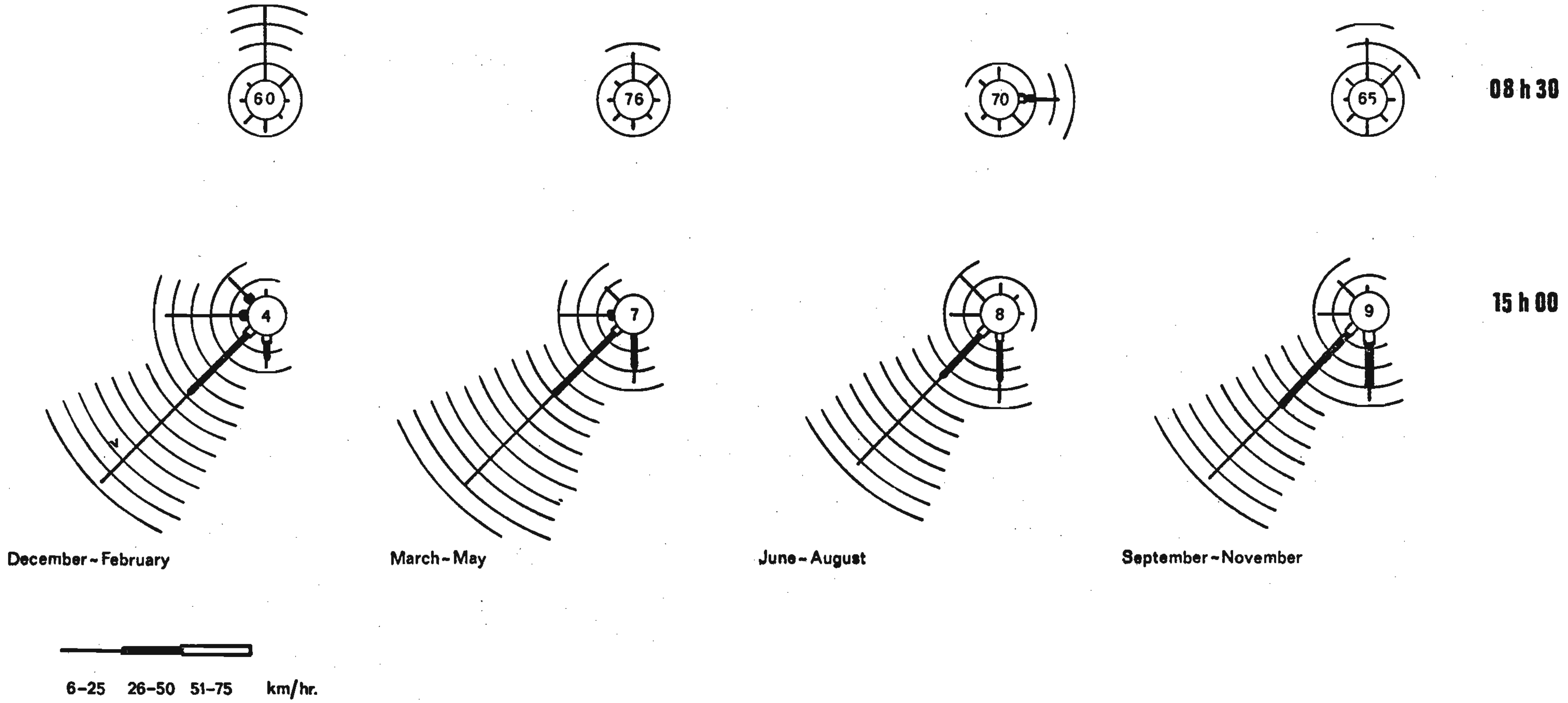


TABLE 4.11. WIND DIRECTION FREQUENCY (%) IN EACH OF THREE VELOCITY CLASSES AT WALVIS BAY, RECORDED TWICE DAILY. DATA AT 08h30 AVERAGED OVER A 10 YEAR PERIOD AND AT 15h00 AVERAGED OVER A 5 YEAR PERIOD. (Data from "Weather on the coasts of southern Africa" - Met. Services of the Royal Navy and South African Air Force, undated).

TIME RECORDED	MONTHS	VELOCITY (km/hr)	% FREQUENCY FROM :								
			N	NE	E	SE	S	SW	W	NW	CALM
08h30	DEC	6 - 25	19	5	1	1	4	3	1	6	60
	to	26 - 50	-	-	-	-	-	-	-	-	-
	FEB	51 - 75	-	-	-	-	-	-	-	-	-
	MAR	6 - 25	8	4	3	2	3	2	1	1	76
	to	26 - 50	-	-	-	-	-	-	-	-	-
	MAY	51 - 75	-	-	-	-	-	-	-	-	-
	JUN	6 - 25	3	5	7	5	3	1	-	1	70
	to	26 - 50	-	-	2	-	-	-	-	-	-
	AUG	51 - 75	-	-	2	-	-	-	-	-	-
	SEP	6 - 25	11	7	3	3	5	3	1	2	65
	to	26 - 50	-	-	-	-	-	-	-	-	-
	NOV	51 - 75	-	-	-	-	-	-	-	-	-
15h00	DEC	6 - 25	1	-	-	-	1	34	21	8	4
	to	26 - 50	-	-	-	-	5	22	1	1	-
	FEB	51 - 75	-	-	-	-	1	1	-	-	-
	MAR	6 - 25	-	-	-	-	4	36	13	5	7
	to	26 - 50	-	-	-	-	9	24	1	-	-
	MAY	51 - 75	-	-	-	-	-	1	-	-	-
	JUN	6 - 25	3	1	1	-	7	33	8	9	8
	to	26 - 50	-	-	-	-	11	17	-	-	-
	AUG	51 - 75	-	-	-	-	1	1	-	-	-
	SEP	6 - 25	1	-	-	-	3	27	9	6	9
	to	26 - 50	-	-	-	-	12	28	-	-	-
	NOV	51 - 75	-	-	-	-	3	2	-	-	-

of land- and sea-breezes is more pronounced.

Inland and at the coast south-east and east winds occur during the winter months (Figs. 4.5 to 4.16 and Figs. 4.17 to 4.20). These are the Berg winds (4.1.1 above), and some of the hottest and driest conditions occur during "east wind weather"; in 1972 an air temperature of 46^0 C and relative humidity of less than 10% at 13h00 was noted when a Berg wind was blowing (pers. obs.). The effects of these winds frequently extend to the coast (Meteorological Services of the Royal Navy and South African Air Force, undated).

In contrast to the dryness of the Berg winds, the westerly winds often carry fog as far inland as Gobabeb, and even Mirabib (Map 2).

Wind is an important ecological factor in the study area because of a number of diverse effects : It influences climatic factors such as evaporation, fog incidence and temperature, which in turn influence the vegetation. It also affects the habitat directly in that sand movement is caused by wind (Plate 2). Wind also acts as an agent of seed dispersal, as was observed during strong east wind conditions in May 1972. Clouds of Stipagrostis ciliata seeds were noted being carried by the wind and accumulating against obstructions in the vicinity of Zwartbank (Map 2). At the time the only known populations of this species large enough to produce such quantities of seed occupied the plains in the vicinity of Mirabib, some 70 km distant (Map 2).

4.6 Sandstorms.

Considering the sparse vegetation cover over much of the area north of the Kuiseb River and the vast areas of shifting sand dunes south of the River, sandstorms are only to be expected. At Gobabeb these occur throughout the year, except in March (Table 4.12). Since the incidence of such storms is low, it is difficult to discern any trends, but they appear to be more common between May and November. No correlation between sandstorms and the available wind data (Table 4.8) is evident.

TABLE 4. 12. MEAN MONTHLY INCIDENCE OF SANDSTORMS AT GOBABEB AVERAGED OVER A 10 YEAR PERIOD (1962 - 1972).

MONTH	J	F	M	A	M	J	J	A	S	O	N	D	YEAR
No. OF DAYS	0,5	0,5	0,0	0,4	0,8	1,0	0,5	0,8	1,0	0,8	0,9	0,5	7,7

Sand movement may be important to the growth of plants in the dune areas, as it may either bury the plants or expose the root systems. It is this instability of substrate that restricts Stipagrostis sabulicola to the lower slopes of the dunes or to sheltered sites where wind action is not so severe (Plates 13a and 15). Where wind-blown sand is trapped by plants such as Acanthosicyos horrida or Salsola nollothensis large hummocks are formed (Plates 13a and 30). Wind-blown sand has contributed to the development of the Sandwich Harbour salt marshes (3.3.1 above) and to raising the level of the marshes by continued deposition of sand. This process will cause further changes in the future, and will thus alter the vegetation in time.

4.7 Precipitation.

4.7.1 Kinds of precipitation.

In the study area precipitation occurs in three ways : As rain, usually falling as light showers, although heavy falls do occur, they are frequently very localised and may be of short duration (pers. obs.); In the form of condensation of moisture from fog; As hail, although this was not observed at all during the present study.

4.7.2 Rain.

Over the ten years for which data are available, rainfall at Gobabeb has averaged 18,7 mm per annum, with a maximum for a 24 - hour period of 16,5 mm (Table 4.13). Although trends cannot be accurately assessed over such a short period, it is evident that most rain falls during summer (January to March) and there is a minor "rainy period" in spring (August and September). The summer maximum

TABLE 4.14. **MEAN MONTHLY AND ANNUAL PRECIPITATION AT WALVIS BAY.** (Data from "Weather on the coasts of southern Africa" - Met. Services of the Royal Navy and South African Air Force, undated).

MONTH	AVERAGE PPT. (mm)	MAXIMUM PPT. IN A 24 hr PERIOD (mm)	NUMBER OF DAYS WITH PRECIPITATION
J	0,0	2,5	0
F	0,0	7,6	1
M	2,5	26,1	1
A	2,5	7,6	1
M	0,0	0,0	0
J	0,0	0,0	0
J	0,0	0,0	0
A	0,0	0,0	0
S	0,0	0,0	0
O	0,0	0,2	0
N	0,0	0,0	0
D	0,0	0,0	0
YEAR	7,6	26,1	3
No. OF YEARS OF OBSERVATION	25	9	25

is related to the predominant wind direction, as most of the rain in the Central Namib Desert seems to be derived from moist air moving from the north over South West Africa.

TABLE 4.13. MEAN MONTHLY AND ANNUAL PRECIPITATION AT GOBABEB AVERAGED OVER A 10 YEAR PERIOD (1962 - 1972).

MONTH	AVERAGE PPT. (mm)	MAXIMUM PPT. IN A 24hr PERIOD (mm)	NUMBER OF DAYS WITH PRECIPITATION IN VARIOUS CLASSES			
			≥ 0,1 mm	≥ 1,0 mm	≥ 10,0 mm	≥ 25,0 mm
J	2,2	5,4	1,5	0,5	0,0	0,0
F	1,8	2,8	0,9	0,3	0,0	0,0
M	5,6	16,5	1,6	1,2	0,2	0,0
A	1,2	5,0	0,8	0,2	0,0	0,0
M	1,6	5,5	0,6	0,3	0,0	0,0
J	0,4	2,4	0,4	0,1	0,0	0,0
J	0,3	1,9	0,3	0,1	0,0	0,0
A	1,6	12,0	0,5	0,3	0,1	0,0
S	1,6	11,7	0,6	0,4	0,1	0,0
O	0,7	3,6	0,3	0,2	0,0	0,4
N	0,9	2,0	0,7	0,4	0,0	0,0
D	1,0	3,3	0,5	0,2	0,0	0,0
YEAR	18,9	16,5	8,7	4,2	0,4	0,4

Rainfall is lowest at the coast and increases inland. At Walvis Bay average rainfall is approximately 7,6 mm, falling in January, February and March (Table 4.14 opposite), while Swakopmund receives about 15 mm per annum (Werger and Colaris, 1975). The eastern edge of the study area, on the other hand, receives about 100 mm per annum (Walter, 1936).

Over the entire Namib Desert rainfall is very erratic. According to Schulze (1965) the relative variability (that is, variability from one year to the next) of annual rainfall is 80% on the coast, and about 60% at the eastern edge. An example of this was the very wet season of 1933/34 when the coastal region near Swakopmund received between 100 mm and 200 mm (Walter, 1936). This unreliability of rainfall is probably the main reason for the large contribution of annual species to the flora, and also the great variability observed in the vegetation (Ch 5 below). The low rainfall at the coast (Table 4.14) must be an important factor leading to the sparse vegetation here.

Rainfall is frequently of the convectional type, particularly over the escarpment zone, which presumably explains the records of thunder being heard. This occurs on an average of 13 days per year, mainly in January, February and March (Table 4.15).

TABLE 4.15 MEAN ANNAUL INCIDENCE OF THUNDER AT GOBABEB AVERAGED OVER A 10 YEAR PERIOD (1962 - 1972).

MONTH	J	F	M	A	M	J	J	A	S	O	N	D	YEAR
NUMBER OF DAYS	2,4	2,4	2,2	0,7	0,3	0,2	0,1	0,2	0,6	1,1	1,3	1,5	13,0

4.7.3 Fog.

In the study area, the 'fog desert' extends 30 to 40 km inland, although fog may occassionally reach Mirabib and Zebra Pan (Map 2 ; pers. obs.). Incidence of fog decreases eastwards; Swakopmund on the coast has more than 200 days with fog each year, most of the 'fog desert' has about 180 days with fog conditions (Walter, 1936), while Gobabeb has only 39 days with fog (Table 4.16).

TABLE 4.16. INCIDENCE OF FOG AT GOBABEB AVERAGED OVER A 10 YEAR PERIOD (1962 - 1972).

MONTH	J	F	M	A	M	J	J	A	S	O	N	D	YEAR
NUMBER OF DAYS WITH FOG AT 08h00	2,3	3,9	2,9	3,1	1,8	1,5	2,3	2,8	4,5	6,0	3,7	3,9	38,7

In contrast to the high frequency of fog occurrence quoted above and observed during the study period, it appears as though fog incidence may vary considerably along the coast, as some data for Walvis Bay indicates that fog was only recorded on 60 days per year during the three years of observation (Table 4.17).

TABLE 4.17. INCIDENCE OF FOG AT WALVIS BAY AVERAGED OVER A 3 YEAR PERIOD. (Data from "Weather on the coasts of southern Africa" - Meteorological Services of the Royal Navy and South Africa Air Force, undated).

MONTH	J	F	M	A	M	J	J	A	S	O	N	D	YEAR
NUMBER OF DAYS WITH FOG	2	1	4	5	8	11	8	8	5	1	5	2	60

Although these data are very much lower than those quoted for Swakopmund, no details are given for them. It is possible that they are not comparable with regard to site, time and even nature (that is, whether the observations refer to specific times or to the whole day) of observation.

At Gobabeb fog can occur during any month, but it is most frequent from September to February (with a maximum in October - Table 4.16). This demonstrates the significance of the south-westerly winds to the climate : From September until February these winds are most frequent, with a maximum during October (Figs. 4.5 to 4.16 above). South-westerly winds carry moist air inland, and this correlation is therefore to be expected.

In contrast to the situation at Gobabeb, maximum incidence of fog at Walvis Bay is from March to September, with October having no recorded fog (Table 4.18). It is difficult to suggest possible explanations for these observations, but they may be as a result of the calm conditions during the morning from March to August whereas from September to February North or north-east (that is, offshore) winds are more frequent (Figs. 4.17 to 4.20).

TABLE 4.18. MONTHLY FREQUENCY OF FOG AT WALVIS BAY AVERAGED OVER A 5 YEAR PERIOD. (Data from "Weather on the coasts of southern Africa" - Meteorological Services of the Royal Navy and South African Air Force, undated).

MONTH	J	F	M	A	M	J	J	A	S	O	N	D
08h00	1	1	3	4	5	8	6	6	2	-	2	1
12h00	-	-	-	-	1	1	1	2	1	-	1	1
20h00	-	-	-	-	-	1	-	1	1	-	1	-

As these data show, fog may persist throughout the day in June, August, September and November.

The quantity of water derived from fog is difficult to measure, but Walter (1936) recorded annual precipitation of 40 - 50 mm and a maximum of 0,7 mm for one day at Swakopmund. These values are similar to those recorded in the Peruvian Desert, where between 5 mm and 43 mm (depending upon the site) were recorded (Ellenberg, 1959). Although Walter (1936 and 1962) maintains that this amount of precipitation is not very significant for plants as it only penetrates 1 - 2 cm into the soil and therefore dries out rapidly, this is only so on the flat plains or exposed rock surfaces. Where the moisture is concentrated, for example, in cracks and crevices on rock outcrops or around stems and under canopies of plants or where the soil surface is protected from direct sunshine thus reducing temperature and evaporation, it is of ecological significance. This may be inferred from the distribution of plants along cracks and at the bases of boulders. A clear example of this phenomenon, albeit rather artificial, is the concentration of plants along the drip-line of roofs of buildings at Saddle Hill in the Southern Namib Desert (Robinson and Giess, 1974). <u>Welwitschia mirabilis</u> has been shown to obtain moisture directly from fog through the stomata (Bornman et al, 1973), while the correlation of the distribution of some species with the fog belt (see Ch 5 below) provides further evidence that fog is indeed a significant source of water.

Measurements presently being made at Gobabeb indicate that the amount of moisture precipitated depends to a large extent upon the characteristics such as aspect, slope and probably wind velocity at each site (pers. obs.). The effects of different kinds of substrate have not been tested yet, but they too may be expected to play a role in the amount of moisture which is obtained by plants from the fog. Ellenberg (pers. comm.) emphasised that significant amounts of water will only be derived from fog if gentle winds (blowing at speeds of about 8 km per hour) blow against rising ground. Under such conditions moist air is continually coming into contact with rising ground, being forced upward rapidly and cooling, and the water condenses and is deposited. In the Peruvian Desert it is only above 200 m a.s.l. on the seaward slopes of the mountain ranges that fog precipitation reaches appreciable proportions (Ellenberg, 1959; Werger and Colaris, 1975).

In the study area fog may also have indirect effects on the biological components of the system. Louw (1972) has shown that dry Stipagrostis sp. grass absorbs moisture when relative humidity increases. This moisture is then available to animals which feed on the grass .

In conclusion, it appears as though fog is a significant source of moisture, at least for the maintenance of plant and animal life, even if it does not provide sufficient water for the germination and establishment of new plants. It is probably effective for a distance of about 35 km inland in the study area and is of most importance on Zwartbank and other mountains in the fog belt, where optimum conditions for condensation of moisture are to be found.

4.7.4 Hail.

Hail is uncommon as a form of precipitation, although it has been recorded during March and September (Table 4.19). It is probably too infrequent to be of any real significance.

TABLE 4.19. INCIDENCE OF HAIL AT GOBABEB AVERAGED OVER A 10 YEAR PERIOD (1962 - 1972).

MONTH	J	F	M	A	M	J	J	A	S	O	N	D	YEAR
NUMBER OF DAYS WITH HAIL	0	0	0	0	0,1	0	0	0	0,1	0	0	0	0,2

TABLE 4.20. MEAN MONTHLY DIURNAL VARIATION OF RELATIVE HUMIDITY AT GOBABEB (%) AVERAGED OVER A FIVE YEAR PERIOD (1962 - 1967). (Data from Schulze, 1969).

MONTH	HOURS, S.A.S.T.												
	02	04	06	08	10	12	14	16	18	20	22	24	MEAN
J	78	84	86	82	63	43	33	31	35	44	57	69	59
F	81	86	86	84	64	43	33	33	35	45	57	70	60
M	67	74	77	76	56	37	28	28	31	38	47	56	51
A	60	64	67	67	53	34	25	25	30	40	46	53	47
M	46	47	48	49	38	25	20	19	24	33	37	42	36
J	52	54	54	53	43	30	22	21	26	37	43	49	40
J	52	54	54	54	43	28	21	21	27	38	45	50	41
A	57	60	62	62	49	34	26	24	29	40	49	54	45
S	66	69	71	70	53	39	27	25	30	38	52	60	50
O	73	77	78	73	52	34	26	25	29	39	52	64	52
N	75	80	82	74	53	34	26	25	28	39	55	66	53
D	79	82	84	78	58	38	30	29	32	42	57	70	57
YEAR	65	69	71	69	52	35	26	25	30	39	50	59	49

4.8 Relative humidity.

Over most of the study area the air is generally rather dry, with monthly mean values of relative humidity of about 60% in summer and 36% in winter (Data for Gobabeb, Table 4.20). During fog conditions relative humidity may be as high as 100% (although it decreases rapidly after the fog disperses), while on individual days values of as low as 5% have been recorded (Schulze, 1969) .

Humidity at the coast is higher and fluctuates less during the day and through the year. At Walvis Bay the maximum is about 95% and the minimum about 48% (Table 4.21).

Over the entire area maximum relative humidity is recorded between 04h00 and 08h00 and lowest values are noted at between 14h00 and 16h00 (Figs. 4.21 and 4.22).

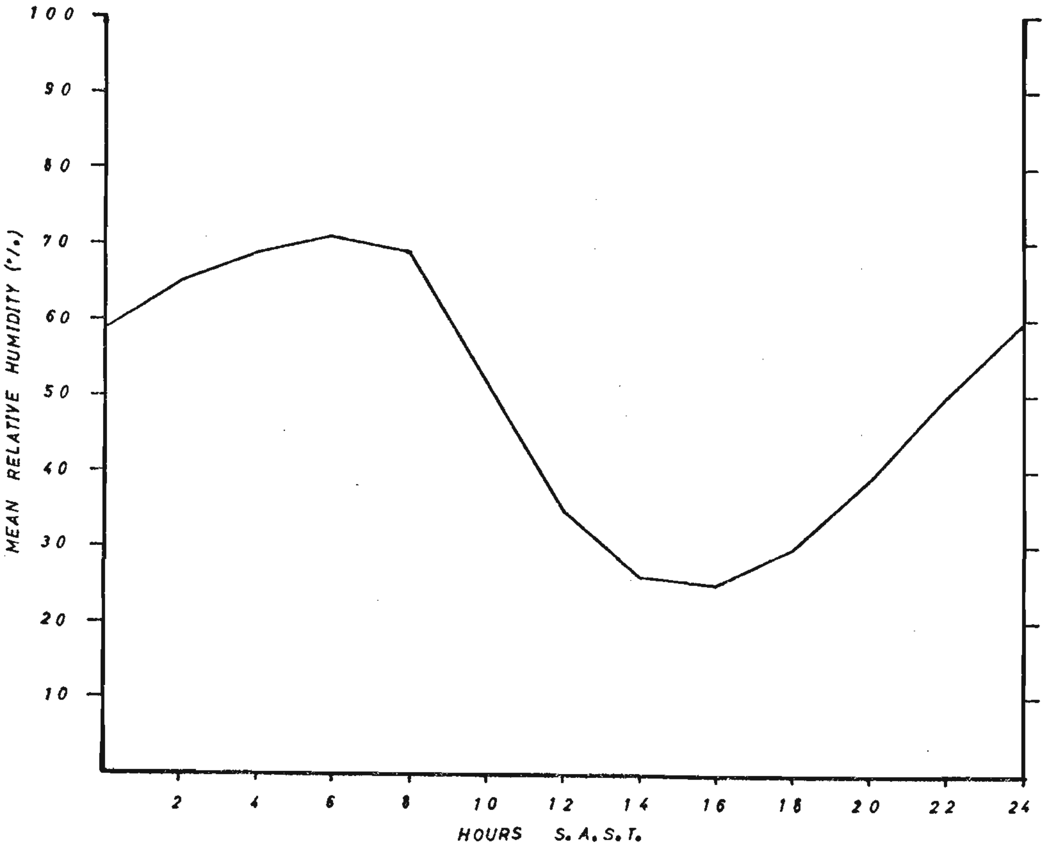


Fig. 4.21 Mean annual diurnal variation of relative humidity at Gobabeb.

TABLE 4.21. MEAN MONTHLY DIURNAL VARIATION OF RELATIVE HUMIDITY AT WALVIS BAY (%) AVERAGED OVER A ONE YEAR PERIOD (1942). (Data from Weather Bureau, Publ. 19, 1954).

MONTH	HOURS, S.A.S.T.												
	02	04	06	08	10	12	14	16	18	20	22	24	MEAN
J	87	88	89	89	83	77	71	72	75	82	86	87	82
F	89	90	90	90	86	79	74	73	77	84	87	88	84
M	90	90	91	91	88	79	72	72	77	85	87	88	84
A	88	88	89	90	86	76	69	66	70	78	82	85	81
M	75	75	76	76	69	59	54	54	59	69	71	74	68
J	74	75	78	77	74	71	61	60	66	74	78	76	72
J	77	76	73	73	66	58	48	51	57	69	75	78	67
A	88	89	90	90	87	77	71	70	77	81	85	87	83
S	91	93	93	93	90	83	78	78	83	89	90	92	88
O	91	92	93	91	89	81	77	78	86	90	84	88	87
N	94	95	94	93	89	80	77	75	82	91	93	93	88
D	90	92	91	91	86	79	76	76	79	86	87	93	85
YEAR	86	87	87	87	83	75	69	69	74	81	84	89	81

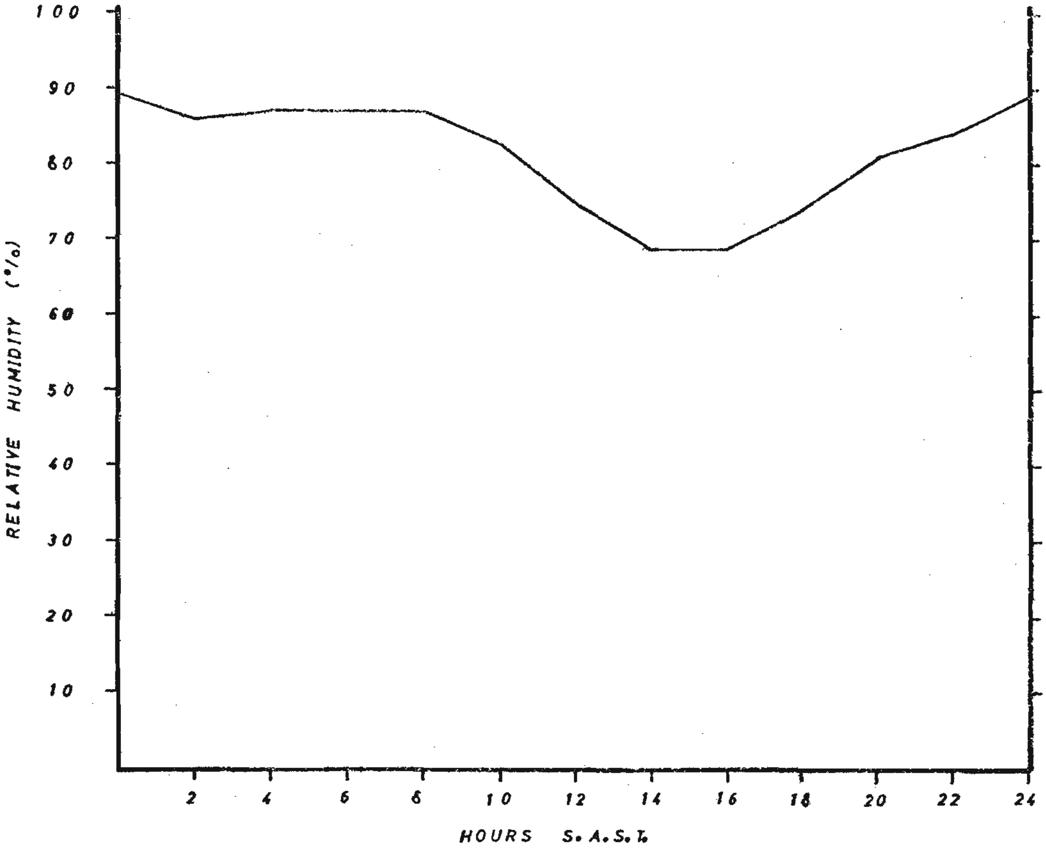


Fig. 4.22 Mean annual diurnal variation of relative humidity at Walvis Bay.

Plant growth may be assisted by the higher relative humidity during the growing season as this will reduce transpiration rate slightly, but it is only during fog that humidity is really high. At the coast the evaporation rate is likely to be considerably reduced, partly as a result of high relative humidity, making fog precipitation more effective.

4.9 Evaporation.

Evaporation is high over most of the Namib Desert, but may be expected to be most severe inland and to decrease towards the coast in response to lower insolation (4.3 above), temperature (4.4.1 above) and higher humidity (4.8 above). The only available data on evaporation are for Gobabeb. Clearly, evaporation is greatest in

November, December and January (Table 4.22), and is considerably in excess of precipitation (cf. Table 4.14 above).

TABLE 4.22. MEAN MONTHLY EVAPORATION FROM AN A - CLASS EVAPORATION PAN AT GOBABEB AVERAGED OVER A 10 YEAR PERIOD (1962 - 1972).

MONTH	J	F	M	A	M	J	J	A	S	O	N	D	YEAR
EVAP.(mm)	346	306	325	281	265	219	230	240	282	307	344	357	3502

Such high evaporation rates as these mean that any water which does not soak into the soil very soon after falling will be lost . It is obvious that evaporation is significant in vegetation development but there are insufficient data available to determine whether the area may be meaningfully divided into different zones of evaporation .

Chapter 5. RESULTS AND DISCUSSION

Introduction

The basic natural community of the Braun-Blanquet system is the association (Braun-Blanquet, 1932, 1964) and was defined by Schröter and Flahault, in 1910, as "a plant community of a definite floristic composition, presenting a uniform physiognomy and growing in uniform habitat conditions. The association is the fundamental unit of synecology," (Braun-Blanquet, 1932, 1964; Werger, 1973a). Therefore, in any study where the Braun-Blanquet system of classification is followed, the lowest syntaxon is the association, and it is named after one or two taxa occurring in it, with the suffix -etum following the generic name(s).

In this work, however, the species groups are simply termed communities. This approach is followed because the area covered by the survey did not extend over the distribution area of the majority of the species, which should be sampled before any hierarchical system is delineated (Werger, 1973a, pp. 102 and 113; 1973b), and therefore it is not desirable to indicate the rank of the vegetation units. A similar approach was used by Poore (1955), who simply termed the species groups "noda", and Schmidt, 1975, who also used the term "community" when dealing with only a part of the distribution range of east African grassland species. It is anticipated, however, that most communities will be shown to be of at least association rank, in which case the names of the communities will be used with the appropriate suffixes. Because no community is assigned a particular syntaxonomic rank the species used to differentiate it are termed simply "differential species" (See Chapter 2 above). Further work is required before it can be decided which of the species are true character species and which are strictly only differential species (see Chapter 2 and Werger, 1973a for further discussion and definitions of these terms).

In the following sections the plant communities are placed into six groups (Tables I - VI). This is largely on the basis of physiography and floristic similarities. Thus communities of similar landscape units (see 3.3 above) and species composition are grouped together. Within a community group in the Tables relevès are arranged with the westernmost plots at the left of the group. This arrangement is followed because of the climatic and altitudinal gradient from west to east (Chapters 3 and 4, and Map 2). Exceptions are for relevés of clearly transitional nature, in which case they are plotted according to species composition, irrespective of geographical location. Data from heterogenous, transitional or fragmentary relevés may be valuable when further data become available since minor communities may only be recognised at this stage (Westhoff and Den Held, 1969; Werger, 1973a), therefore all relevés were used in compiling the Tables. This approach should be compared with that of Tüxen, whereby such relevés are not used in constructing the phytosociological table because they obscure the association boundaries (See Werger 1973a, p. 96).

5.1 The salt marsh system

5.1.1 General

Sandwich Harbour (Map 2 and 3.3.1 above) was the only site in the study area where salt marshes were found, and here the marshes were about 5 km^2 in extent. Elsewhere in the Namib Desert, communities similar to those described from Sandwich Harbour were found at Anichab Pan (north of Lüderitz Bay), Spencer Bay, Conception Bay, Meob Bay, at Wortel (a marshy area just south of Walvis Bay), between the Khan and Swakop Rivers (Map 1) and in the lower courses of the rivers of the Northern Namib Desert (Giess, 1969; Robinson and Giess, 1974; Seely, pers. comm; pers. obs.). With the exceptions of Anichab Pan and the site between the Khan and Swakop Rivers in the Namib Desert Park, all these areas were at or close to the sea.

5.1.2 The salt marsh communities (Table I)

5.1.2.1 The *Typha latifolia* community (Table I)

Differential species. *Typha latifolia*; geophyte; differential against all communities.

Slope of sites : Average 0°55'; Range 0° to 3°00; S.D.1°09'.
Aspect : Variable.
Number of vegetation strata : 2, occasionally 1.
Aerial cover : Average 72%; Range 45% to 100%; S.D. 23%.
Number of species : Average 2; Range 1 to 3; S.D. 1,03.

Plate 5

Plate 6

Plate 5

Sandwich Harbour, October 1973; salt marsh habitat in the Namib Desert. The foot slopes of the dunes (A) were colonized by *Eragrostis cyperoides*, while the *Phragmites australis* sub-community (B) occured on the edges of pans (D). C represents the former site of a stand of the *Typha latifolia* community. In September 1972 this was a dense stand of *Typha* clones, but by the time the photograph was taken not a living plant remained.

Plate 6

Sandwich Harbour, October 1973. A healthy stand of *Typha latifolia* at the northern end of the lagoon system. The slope of the bank is evident, and many of the clones were rooted in permanently flooded soil (A). Egyptian geese, White-backed Pelicans and Red-knobbed Coots can be seen in the background.

Description of the community:

Habitat. (1) General.

This community occured on sloping banks of creeks (relevés 189 and 192, Table I) where substrate was permenently flooded (Plate 6) and around pools with very gently sloping banks where flooding occurred twice a day, at high tide, and where the soil remained wet during the period when it was not flooded.

(2) Substrate.

Soil was a mixture of fine sand and mud rich in organic material and may be exemplified by the following profile descriptions:

(a) Relevé 409, situated on the low-lying edge of a tidal creek. Most of the plot was permanently submerged, the rest being flooded by the high tides. *Typha latifolia* was in excellent condition (no leaves were chlorotic and many clones were reproducing vegetatively) at the time of the survey (October, 1973). Slope was moderate for the community ($0^{\circ}20'$).

0 – 0,05 m	light brown sandy soil with dark mottles of organic material.
0,05 – 0,25 m	dark grey-brown loamy sand.
0,25 – 0,50 m	light brown loamy sand.

(b) Relevé 411, situated at the edge of a pan on the marsh. Flooded twice daily, but none of the plot was permanently submerged. Many of the *Typha latifolia* clones were dead in October 1973 and even the rhizomes were rotting. The site was flat.

0 – 0,05 m	orange-brown loamy fine sand.
0,05 – 0,25 m	black organic mud with numerous undecomposed stems and leaves. When the sediment was disturbed hydrogen sulfide was released, suggesting anaerobic conditions. This was not evident in relevé 409.
0,25 – ? m	grey sandy soil. The water level prevented sampling below 0,35 m.

Physiognomy.

A community of tall (approximately 2,5 m) monocotyledonous plants with a ground layer (up to 0,20 m tall) of grass and succulent forbs, covering up to 50% of the plot on tidal sites. In one relevé (185, Table I) the sedge, *Scirpus dioicus* formed an intermediate stratum of between 0,30 and 0,50 m tall and covered 5% of the area.

Distribution.

In the study area this community occurred at Sandwich Harbour.

Accompanying species.

Geophyte:

Scirpus dioicus

Hemicryptophytes:

Arthrocnemum affine - most common on flat sites where the water table was high and the soil showed what appeared to be an anaerobic layer.

Scirpus littoralis

Sporobolus virginicus - especially on the more steeply sloping sites where the water drained away rapidly after flooding.

Notes.

This community was formerly more widespread than at present (Seely, pers. comm.; Berry, pers. comm.), and in the period 1972 to 1974 the area covered continued to decrease (pers. obs.). At the time of the study it occurred around only a few creeks and pools, and the most healthy stands (that is, those in which the clones were producing new shoots and with no signs of necrosis on the leaves), occupied creek arms where freshwater from the Kuiseb River entered the lagoon 3.3.4 above). Since all relevés were taken in the same season (spring; August 1972 or October 1973), the observed differences could not be ascribed to seasonal differences, in spite of the plant being a cryptophyte.

5.1.2.2 The *Arthrocnemum affine* community (Table I).

Differential species: *Arthrocnemum affine*, a leafless, succulent Hemicryptophyte; differential against all other communities.

Slope of sites: Flat (only relevé 208 had measurable slope, of $0^{0}16'$).

Aspect : Not applicable.

Number of vegetation strata: Usually 1, but in relevés 412, 413 and 174 there were 3 strata.

Aerial cover : Average 84%; Range 50% to 100%; S.D. 20,5%.
Number of species : Average 2; Range 1 to 4; S.D. 1,11.

Description of the community:

Habitat. (1) General.
The community occurred on flat sites which were submerged daily by the high tide (relevés 412, 415 and 200) or when above this level, they were very wet (Plate 8); groundwater level being 0,10 m or less below the surface (relevés 174, 208 and 176). One relevé was taken from a phytocoenosis of intermediate habitat, being flooded only by the high spring tides.

(2) Substrate.
Soil varied between a mixture of sand and mud which was very similar to that of the *Typha latifolia* community (relevés 412 and 413) and a sandy soil such as supported the *Sporobolus virginicus* community (relevé 415). On the wetter sites soil was rich in organic matter, probably a result of the associated anaerobic conditions which reduce the rate of decomposition. Evidence of the anaerobic conditions was found in the evolution of hydrogen sulfide on disturbance. Two profiles are described to show the extremes of substrate recorded.

(a) Relevé 413, situated in a very slight depression some 40 m from a lagoon channel and about 0,30 m above mean sea level, was flooded only by spring high tides and during storms (pers. obs.). Dead clones of *Typha latifolia* occurred in the stand (Plate 5) at the time of the survey (October 1973), and no signs of regeneration were found on subsequent visits in April, September and December 1974, which indicated that this was not a seasonal die-back but represented a response to some unknown adverse conditions. The occurrence of crystalline salt on the surface (see below) suggests that die-back may have been associated with increased salinity.

0 - 0,05 m	light coloured sand with salt on the surface.
0,05 - 0,10 m	dark brown loamy sand.
0,10 - 0,20 m	dark brown to black mud and fine sand; extremely wet -water oozed from the sides of the pit.
0,20 - 0,50 m	grey sandy/loamy soil (about 70%sand, 30% loam). Drier than the dark layer above it.

(b) Relevé 415, situated on the edge of a tidal creek, this site was flooded to a depth of at least 0,05 m every high tide. The only species was *Arthrocnemum affine*.

0 – 0,15 m light brown sandy loam, with many living plant roots.
0,15 – 0,50 m grey-brown sandy to loamy sandy soil.

Physiognomy.

This was a single layered community of succulent forbs and grass attaining a height of 0,20 m (Plates 7 & 8). Cover was generally high (100%) although in relevés which were transitional between this and either the *Typha* or *Sporobolus* communities it was lower, with a minimum of 50% aerial cover being recorded. A taller stratum of graminoids, grasslike plants (Whittaker, 1971) about 0,60 m tall and covering between 1% and 30% occurred (see above).

Distribution.

Widespread on the salt marshes of Sandwich Harbour, where it occurred around most pools and creeks, as well as near the brackish pools behind the first series of shore dunes.

Accompanying species.

Sporobolus virginicus
Typha latifolia
Scirpus littoralis
Juncellus laevigatus

Notes.

The position of relevés 412 and 413 require clarification. In terms of species composition they appeared to be more closely related to the *Sporobolus virginicus* community than that of *Typha latifolia*, because *S. virginicus* had higher cover-abundance values than *T. latifolia* (Table I), and in both relevés many clones of the latter species were dead. However, the substrate was unlike soil supporting the *S. virginicus* community: in both relevés the soil was plastic to slightly plastic (a rod could be formed from the moist soil), indicating a fine fraction (Soil Survey Manual, p. 212), and an apparently anaerobic layer occurred. (Compare with soils of the *S. virginicus* community, below). This supported the hypothesis that there had been some change, for example in salinity, which has been responsible for the death of *Typha latifolia*.

Relevé 208 was also atypical. It was situated on the edge of a pool of brackish water in an interdune valley about 10 m a.s.l. The substrate was a mixture of dune sand and loam which may explain the

Plate 7

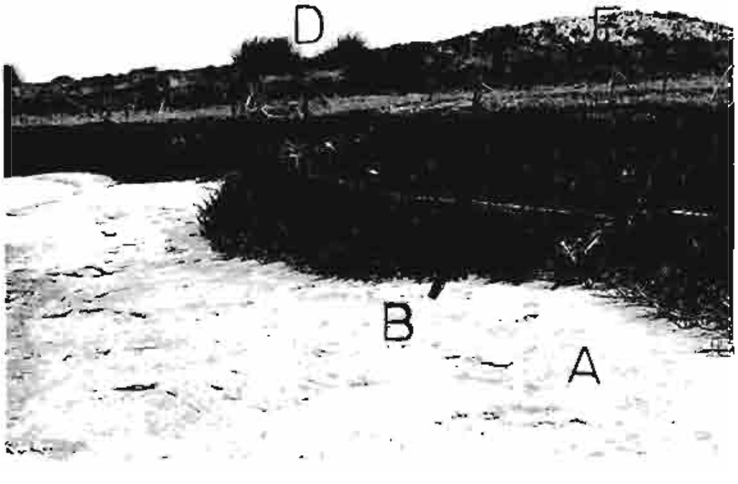


Plate 8

Plate 7

Flat salt marshes at Sandwich Harbour. The Arthrocnemum affine community (A) occupied sites which were inundated by every high tide as the water level in the creeks (arrowed) rose. At slightly higher levels was found the Sporobolus virginicus community (B).

Plate 8

Sandwich Harbour; a tidal pan at low tide. A is the muddy substrate which was submerged to about 0,20 m at high tide. Flotsam, left by the high tides when they receeded (B) gave an idea of the depth to which Arthrocnemum affine stands were submerged. A few dead stems of Typha latifolia remained (C) as the only indication of a formerly healthy stand. Slight depressions at the upper level of the marsh were occupied by Scirpus dioicus (D), while the low dunes (E) were colonized by Odyssea paucinervis.

occurrence of Juncellus laevigatus because this species was also found on sandy substrates colonized by Phragmites australis or Odyssea paucinervis (Table I).

5.1.2.3 The Sporobolus virginicus community (Table I)

Differential species : Sporobolus virginicus; Hemicryptophyte;
Differential against all other communities.

In the area studied, this community could be subdivided on floristic and habitat characters into three sub-communities:

(a) Typical sub-community, with Sporobolus virginicus (Hemicryptophyte) alone.

(b) The Scirpus dioicus sub-community, in which S. dioicus, a Hemicryptophyte, was differential against the other sub-communities.

(c) The Phragmites australis sub-community, where P. australis (Hemicryptophyte), as dominant, and Heliotropium curassavicum (Chamaephyte) were differential against the other two sub-communities.

Details of the differences in habitat are given below.

5.1.2.3 (a) Typical sub-community.

Slope of sites : Average $0^{\circ}04'$; Range 0° to $0^{\circ}20'$; S.D. $0^{\circ}07'$.

Aspect : Variable.

Number of vegetation strata : 1, very rarely 2.

Aerial cover : Average 97%; Range 75% to 100%; S.D. 8,3%.

Number of species : Average 2; Range 1 to 3; S.D. 0,6.

Description of the community:

Habitat. (1) General.

Very similar to the habitat of the Arthrocnemum affine community, except that it was less frequently flooded because of slightly greater elevation as the stands occurred further from the lagoon arms or on raised areas.

(2) Substrate.

The soil was sandier than that of the typical sites of the Arthrocnemum affine community. This resulted in better drainage and aeration so that the organic material was more rapidly decomposed, which accounted for the lighter color, absence of anaerobic conditions and also probably in part for the non-plastic nature (see below). Two profiles are described to show the variation in substrate.

(a) Relevé 414, situated about 30 m from a creek, and 0,30 m above mean sea level, was flooded occasionally by exceptionally high tides. The site was flat.

0 – 0,15 m light yellowish-brown, fine grained loamy sand. This was very slightly plastic.

0,15 – 0,50 m whitish-grey coarse grained sandy soil which was not at all plastic. Water was encountered at 0,22 m below the surface at low tide.

(b) Relevé 416 lay between two creeks, and was about 0,40 m above mean sea level. The site was flat.

0 – 0,05 m sandy loam and stems, leaves and living plant roots.

0,05 – 0,15 m light brown loamy sand with a high concentration of partly decomposed organic material.

0,15 – 0,50 m dark grey-brown sandy to loamy soil which was very slightly plastic. Water table was at 0,15 m at low tide.

Physiognomy.

A very dense, single layered community dominated by perennial grass, that attained a uniform height of about 0,15 m and with few species (Plate 7). In one relevé (181) a shrub layer 1,0 m in height covered 3% of the plot.

Distribution.

The typical sub-community was widely distributed at Sandwich Harbour, being especially well developed on the broad, flat salt marshes of the northern and central parts of the lagoon system. Beyond the boundaries of the study area the community was noted at Spencer Bay (Robinson and Giess, 1974) and near river mouths and brackish pools in the northern Namib Desert (pers. obs.).

Accompanying species.

Hemicryptophyte:

Arthrocnemum affine

Chamaephyte:

Heliotropium curassavicum

Nanophanerophyte:

Lycium tetrandrum

Plate 9

Plate 10

Plate 9

Sandwich Harbour, at the northern end of the marsh system. A is the *Scirpus dioicus* community in the typical habitat - a shallow hollow with coarse substrate. B is a slightly lower-lying bare area of oyster-shell shingle which may have indicated the former course of a lagoon channel.

Plate 10

Sandwich Harbour. *Odyssea paucinervis* formed a dense community on hummocks at the upper levels of the marshes where flooding never occurred, and the plant also colonized the lowest slopes of the dunes (B).

5.1.2.3 (b) The Scirpus dioicus sub-community.

Slope of sites : Average 0°23'; Range 0° to 2°00'; S.D. 0°45'.

Aspect : Variable.

Number of vegetation strata : Usually 2, occasionally 3.

Aerial cover : Average 86%; Range 30% to 100%; S.D. 25,6%.

Number of species : Average 3; Range 2 to 5; S.D. 1,15.

Description of the community.

Habitat. (1) General.

The typical sites of this sub-community were situated at higher levels (1,0 m to 1,80 m above mean sea level) than the Arthrocnemum affine community or the typical sub-community of the Sporobolus virginicus community. They were never flooded and the coarse grained substrate improved drainage. Sites were flat or gently sloping.

(2) Substrate.

The typical stands, attaining 500 m^2 in extent, were found on soil with a thin upper layer of fine grained material over coarse sand in which many shells and little organic matter were found. The water table varied from 0,50 m (relevé 528) to 0,70 m beneath the surface (relevé 527). One profile (typical for the community) is described.

Releve 527, raised area between creeks, about 1,30 m above mean sea level. Site was flat.

0 - 0,10 m	whitish brown, fine grained loamy sand/sand with some litter on the surface.
0,10 - 0,80 m	light coloured, very coarse sea sand with numerous shells and shell fragments. Water was encountered at 0,80 m below the surface.

Physiognomy.

This community was usually two-layered; a stratum of tall (1,5 m) graminoids covering from 60% to 98%, and a ground layer, composed of graminoids and forbs less than 0,20 m (Plate 9), covering between 2% and 100%. It was a community with few species, only 6 having been recorded during the survey. In two relevés (165 and 212), which were recorded in a dune valley at the southern end of the lagoon system, a third stratum of Phragmites australis (2,5 m tall) covered 5% and 25% of the area respectively.

Distribution.

In the study area, the Scirpus dioicus sub-community was only found at Sandwich Harbour, with the best developed stands at the northern end of the system. It occupied 1 - 2% of the total area of the salt marsh. It has also been noted at Anichab Pan, near Lüderitz Bay and at Wortel, near Walvis Bay (pers. obs.).

Accompanying species.

Hemicryptophytes:

Arthrocnemum affine	Phragmites australis
Odyssea paucinervis	Sporobolus virginicus

Chamaephyte:

Heliotropium curassavicum

Notes.

Most of the larger stands at Sandwich Harbour occured in slight depressions, and this, together with the abundance of shells suggested that these stands colonized the central positions of dried up lagoon channels. At Anichab Pan, the Scirpus dioicus stands were in moister habitat in a large area of Eragrostis cyperoides, which strengthened the impression that the sub-community develops on the drier parts of the marshes (see also 5.1.2.4 below).

5.1.2.3 (c) The Phragmites australis sub-community.

Slope of sites : Average $3^{0}02'$; Range 0^{0} to 24^{0}; S.D. $5^{0}24'$.

Aspect : Variable.

Number of vegetation strata : Usually 2, occasionally 1 or 3.

Aerial cover : Average 63%; Range 10% to 100%; S.D. 32,0%.

Number of species : Average 3; Range 1 to 4; S.D. 1,08.

Description of the community:

Habitat. (1) General.

At Sandwich Harbour this sub-community occured in two habitats: The flat or moderately sloping ($0^{0}15'$ to $2^{0}00'$), sandy areas on the duneward side of the pans (Plate 5), and around the brackish pools in the dunes, where the stoloniferous growth habit enabled Phragmites australis to colonize steep (to 24^{0}) dune slopes.

(2) Substrate.

On the dune slopes soil was medium grained sand with very little fine material. On the flatter sites, however, the soil was fine to medium grained loamy sand. In all cases the substrate was loose, well drained and aerated.

Physiognomy.

Typically a 2 layered community with tall (0,50 m to 4,0 m) graminoids as the dominant stratum, covering 25% to 100%. The ground layer (to 0,20 m tall) was composed of grass and forbs covering between 2% and 100%. In some relevés only 1 stratum occurred (relevés 211, 167 and 210), composed of Phragmites australis alone, while in other relevés (171, 188, 169, 207 and 209) an intermediate stratum between 0,20 m to 0,60 m and covering 5% to 80% was recorded. In two of these relevés (188 and 169) the tall stratum was absent. The Phragmites australis sub-community was floristically the richest in the salt marsh system, having eight species (Table I), but in spite of this, no relevé contained more than four species.

Distribution.

In terms of area occupied, this sub-community was best developed at the southern end of Sandwich Harbour, although a few stands also occured elsewhere on the marshes. Stands of the Phragmites australis sub-community were observed at Wortel (near Walvis Bay), at the Walvis Bay sewage oxidation ponds, at a pool of brackish water near the confluence of the Swakop and Khan Rivers (Map 1) and in the lower reaches of many rivers in the northern Namib Desert (Giess, 1969; Robinson, 1974, unpublished report).

Accompanying species.

Geophyte:

Scirpus dioicus

Hemicryptophytes:

Arthrocnemum affine	Sporobolus virginicus
Juncellus laevigatus	

Chamaephytes:

Acanthosicyos horrida	Lycium tetrandrum

Notes.

Two relevés (188 and 169) were included in the sub-community, despite the absence of Phragmites australis, because the other differential species, Heliotropium curassavicum, was present and covered an appreciable area (Table I).

5.1.2.4 The *Odyssea paucinervis* community. (Table I).

Differential species. *Odyssea paucinervis*; Hemicryptophyte; differential against all other communities when dominant.

Slope of sites : Averate $0^{o}19'$; Range 0^{o} to $1^{o}00'$.

Aspect : Variable.

Number of vegetation strata : 1, rarely 2.

Aerial cover : Average 67,2%; Range 35% to 100%; S.D. 29,2%.

Number of species : Average 1,3; Range 1 to 2; S.D. 0,52.

Description of the community.

Habitat. (1) General.

Dry hummocks or the foot-slopes of the sand dunes between 1 m and 4 m above mean sea level, where flooding never occurred (Plate 10). On flat sites, where cover was highest, a humus layer occurred with the plants emerging through the mulch.

(2) Substrate.

This is exemplified by the profile recorded from relevé 417, which was on a gently sloping ($0^{o}30'$) terrace about 1 m above mean sea level.

0 - 0,25 m	whitish-brown, fine to medium grain sand and undecomposed grass stems and leaves; loose consistence.
0,25 - 0,70 m	brown, medium grain loamy sand; loose to seft consistence. Water encountered at 0,50 m.

Physiognomy.

This community was dense (Plate 10), with aerial cover exceeding 50%, composed of a single grass stratum, about 0,30 m tall, with flower culms attaining more than 0,40 m. Only occasionally were there more than two species per relevé (Table I).

Distribution.

It was only recorded at the northern end of Sandwich Harbour, but see below.

Accompanying species.

Hemicryptophyte:

Juncellus laevigatus

Chamaephyte:

Heliotropium curassavicum

Notes.

It was extremely difficult to distinguish between *Odyssea paucinervis* and *Sporobolus virginicus* in the vegetative state. Consequently it is possible that *Odyssea paucinervis* was overlooked during expeditions to other parts of the Namib Desert and also at Sandwich Harbour. The community may therefore have been more widespread than indicated by the present study.

5.1.3 Discussion of the relationships of the salt marsh communities.

Floristic relationships.

As shown (Table VII, communities 1 - 4) the differential species were most frequent in specific communities even though there was considerable floristic overlap between communities (Table I). In an attempt to quantify floristic similarities, Sørenson's coefficient of similarity, calculated as

$$\frac{2c}{a + b} \times 100\%$$

where the two communities contain a and b species respectively and there are c species common to both (Grieg-Smith, 1964), was calculated for all pairs of communities.

The Sørenson coefficient of similarity, which is the same as Czekanowski's coefficient of similarity (Curtis, 1959; Grieg-Smith, 1964) was chosen because: It was easy to compute; the sampling technique employed to collect the data was not suitable for the application of statistical tests which require objective sampling because stands were selected for homogeneity and as being representative of the vegetation type under consideration (Werger, 1973a); due to chance variation between samples, species lists from small samples of a large population were unlikely to be identical (Grieg-Smith, 1964; Rayner, 1967), rendering the added computation required for more involved coefficients unrewarding (compare with Daubenmire, 1969, p. 77 who expressed similar doubts).

A complication that affected the magnitude of the similarity coefficient was that samples were of unequal size since communities were not all represented by the same number of relevés. This made it unlikely that any pair of communities could have similarity coefficients of 100% (Grieg-Smith, 1964). The total number of species and the number in each stand also influence the value of the coefficient as an indicator of similarity between communities (Grieg-Smith, 1964, p. 178), since if the total number of species is small, even a few species common to both communities will produce high coefficients of similarity.

For these reasons, coefficients of similarity are used only as indicators of floristic similarity between communities. As such, they give a measure of the number of species common to pairs of communities, which is a measure of the uniqueness of the community, while also taking some account of the number of species in each community.

Communities of the salt marshes which had high floristic similarity, defined here as a coefficient of similarity of 50% or higher, were the Typha latifolia and Arthrocnemum affine communities (80,0%), the Scirpus dioicus and Phragmites australis sub-communities (71,4%), the Sporobolus virginicus (typical) and Phragmites australis sub-communities (50,0%). These may all be explained simply. Three of the pairs belong to a single community, the Sporobolus virginicus community (Table I and 5.1.2.3), where floristic similarity is fully expected. The high similarity between the Typha latifolia and Arthrocnemum affine communities is due to sampling and the fact that the latter community follows the former in the course of succession (see below). Sampling influenced the species composition because some relevés were taken where Typha latifolia was dying out and the area was being invaded by Arthrocnemum affine (relevés 410 and 411). This was not recognised until the communities were delimited in the tables.

Ecological relationships.

The communities described here are possible seral stages in plant succession on the salt marshes and are represented diagramatically in Fig. 5.1. Ecological relationships are clearly reflected by the floristic relationships, serving to verify the delimitation of the communities.

The sere occupying the wettest habitat was the Typha latifolia community (sea-weed communities were not found during the survey), which frequently occupied permanently submerged soil. Even where it grew on more exposed situations, the sites were always flooded regularly. Where the land level has risen, partly by deposition of mud from the sea and partly by sand which is carried

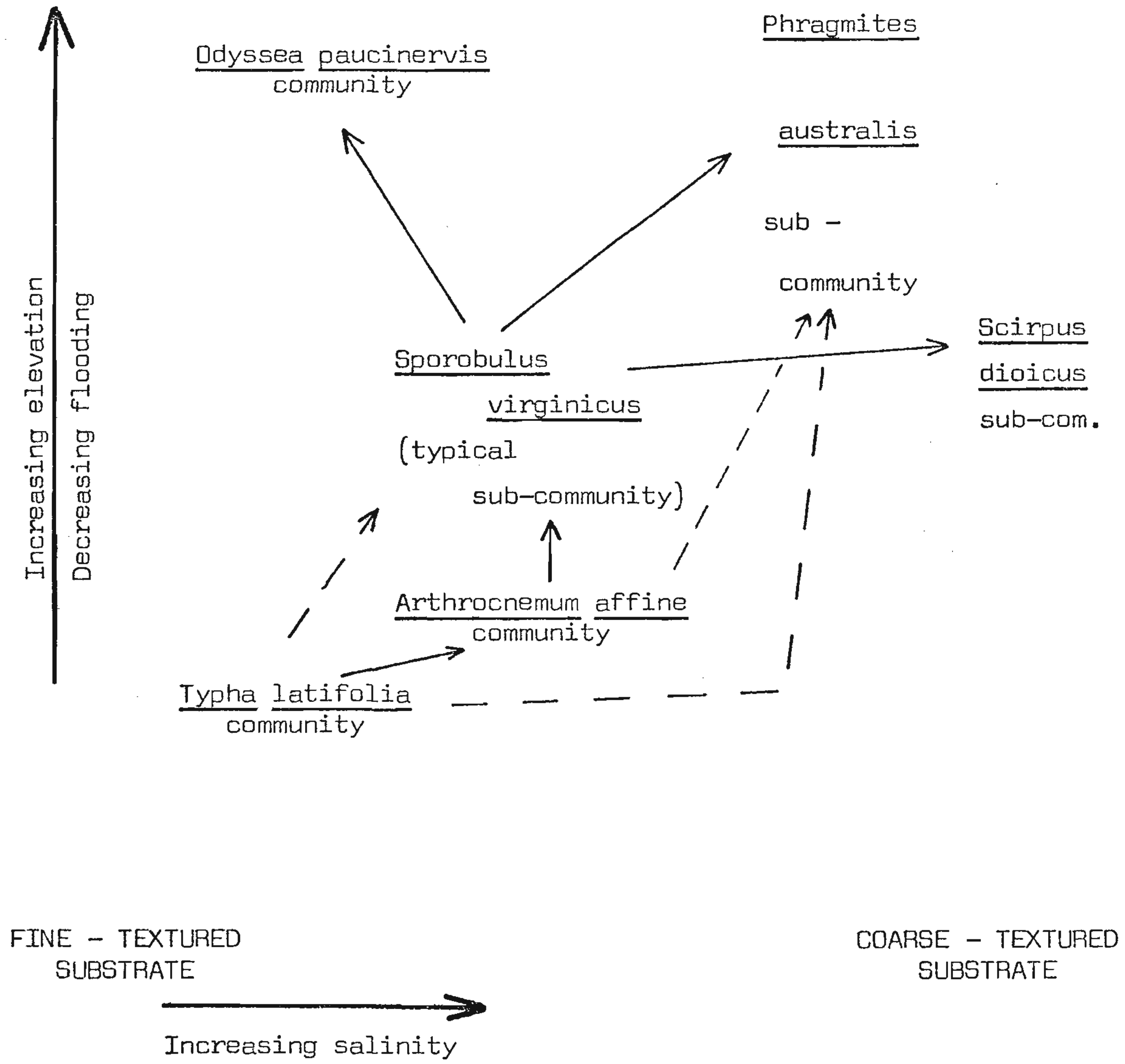


Fig. 5.1 Ecological relationships of the salt marsh communities. (Broken arrows indicate the less frequently observed courses of vegetation development).

from the dunes by wind, Arthrocnemum affine replaced Typha latifolia. Exceptions were found where either the land rose steeply on creek banks, for example, so that there was no zone of intermediate flooding, where the Sporobolus virginicus (typical) sub-community followed directly; or on coarse grained, unstable substrates where the succession led directly to the Phragmites australis sub-community (Plate 5). From the Arthrocnemum affine sere the course of succession is strongly influenced by site and kind of substrate. On flat or gently sloping sites with moderately fine-grained, stable substrate the Sporobolus virginicus (typical) sub-community followed. However, on coarser and unstable substrate (as was often found on steep dune slopes) and sites where tidal flooding did not occur (although the water table may be high), the Phragmites australis sub-community developed. On sites with a sub-surface coarse soil, which will lead to rapid drainage and fluctuation of groundwater levels, the typical Sporobolus virginicus sub-community gave place to the Scirpus dioicus sub-community at higher elevations (Plate 8).

Elsewhere, Odyssea paucinervis formed the final stage of succession on the salt marshes, although it graded into the Eragrostis cyperoides community on the lower slopes of the dunes (Plate 10). The Eragrostis cyperoides community was confined to the foot slopes of dunes, and is therefore not considered as part of the salt marsh system. Where substrate was unstable, the typical sub-community of the Sporobolus virginicus nodum may be followed by the Phragmites australis sub-community rather than the Odyssea paucinervis community.

5.1.4 Syntaxonomic position of the salt marsh communities

(a) Classification into higher taxa

The Typha latifolia and Arthrocnemum affine syntaxa of the Sandwich Harbour marshes can be formally classified at this stage. The classification followed is that of Chapman (1960) whereby syntaxa which are believed to be seral are differentiated from climax ones by use of the prefix "Eco-", while the prefix "Coeno-" is used for naming communities which are dominated by different species of the same genus and occupy similar niches in the succession. In these terms the classification of the Typha latifolia and Arthrocnemum affine communities is:

Order	Phragmitetalia; communities dominated by *Phragmites australis*, *Scirpus* spp., *Typha* spp., and others.
Alliance	Eco-Phragmition; comprises associations with *Scirpus* spp., *Typha* spp., and *Phragmites australis* as the Character Species.
Association	Halo-Typhetum; *Typha latifolia* is the Character Species.

(See below for a discussion concerning the *Phragmites australis* and *Scirpus dioicus* sub-communities).

Order	Coeno-Salicornetalia; communities dominated by *Salicornia* spp., *Suadea* spp., and *Arthrocnemum* spp.
Alliance	Fruti Salicornion; comprises associations with *Arthrocnemum*, *Salicornia*, *Sesuvium*, and other genera as the Chatacter Taxa.
Association	Eco-Arthrocnemetum; *Arthrocnemum affine* is the Character Species.

Until the syntaxonomic position of *Sporobolus virginicus* is clarified, the various sub-communities comprising the *Sporobolus virginicus* community of Sandwich Harbour cannot be classified into higher taxa. Because little other data are available from other sources, and the study does not cover the whole range of *Sporobolus virginicus* it cannot be established whether this species is only a local, regional or absolute character species, and thus the rank of the syntaxon it characterizes cannot be determined (Werger, 1973a).

(b) Comparisons with other salt marsh areas

MacNae (1957) described salt marshes from the Zwartkops River estuary in the Cape Province. Here, two communities are comparable with communities at Sandwich Harbour. At the Zwartkops River estuary an Arthrocnemetum australaci follows the *Spartina maritima* community which is the first terrestrial community and is followed by a Limonietum (dominated by *Limonium tinifolium*) followed, on muddy substrates, by another *Arthrocnemum* community. In sandy areas the last *Arthrocnemum* community is replaced by *Sporobolus virginicus*. Ecologically, both *Arthrocnemum* communities seem equivalent to the Arthrocnemetum of Sandwich Harbour and the *Sporobolus virginicus* communities are directly comparable.

Kassas (1957) describes an Arthrocnemetum occupying the same ecological position as the Arthrocnemum affine community from the Red Sea coast, but here the dominant species was A. glaucum.

In Uruguay (South America), an association characterised by Juncus maritimus contains Heliotropium curassavicum and Phragmites australis as well as species which do not occur in South West Africa (Chapman, 1960). Too few details are given to determine the affinities between this and the Phragmites sub-community of the Namib, but it does suggest that this nodum may not belong to the Phragmitetalia.

Salt marsh communities similar to the Arthrocnemum and Sporobolus communities of the Namib Desert have been described from South Australia (Chapman, 1960 p 231).

The salt marsh communities of the study area do not seem to fit into any of Chapman's (1960) major salt marsh seres. There are affinities with the Mediterranean sere (the Arthrocnemum nodum), but Limonium (a genus typical for the sere) and the sere climax, dominated by Juncus acutus are absent. At the same time there is some relationship between the Sandwich Harbour communities and communities of Australian salt marshes (see above).

5.2 The sand dune system.

5.2.1 Introduction.

The dune habitat of the central Namib Desert (3.3.2 above) poses serious problems for plants. With the exception of the easternmost edge, precipitation is very low (4.7 above), added to which, soil temperatures and insolation are high which result in high evaporation (4.10 above). In addition, the substrate is unstable, the sand grains being set in motion by winds of as little as 18 km per hour (Dury, 1966). To survive in such habitats plants of the Namib Desert dune communities show a variety of adaptations. The majority of perennial species show xeromorphy : rolled, hard leaves to reduce the exposed surface area and resist wilting (for example, Stipagrostis sabulicola and S. lutescens); leaves reduced to scales, or spines or absent to reduce water loss (for example, Acanthosicyos horrida, Eragrostis spinescens and E. cyperoides); water storing leaves as in Trianthema hereroensis. Species such as Acanthosicyos horrida show xeromorphic features and also have very deep root systems which reach groundwater. Other plants may be termed "opportunists" (cf Walter, 1962 and Zohary, 1973) since they grow, set seed and die in a short period following rains, for example *Stipagrostis gonatostachys*, an annual grass and *Albuca sp.*, a geophyte, grow in the "streets" between the dunes after rain showers.

To cope with the ever moving sand, plants either grow faster than sand is deposited and in this way form large sand hummocks (for example, *Acanthosicyos horrida* and *Stipagrostis sabulicola* (Plates 12 and 13a)), or occupy habitats where sand movement is less severe (*Stipagrostis gonatostachys*, *Hermannia gariepina* and *Limeum fenestratum* for example).

Five communities have been identified in the dunes and may be described as follows:

5.2.2 The sand dune communities (Tables II and III)

5.2.2.1 The *Eragrostis cyperoides* community (Table II)

Differential species : *Eragrostis cyperoides*; Geophyte; differential against all other communities.
Slope of sites : Average $2^{\circ}18'$; Range 0° to $5^{\circ}00'$; S.D. $1^{\circ}53'$.
Aspect : Variable.
Number of vegetation strata : Usually 1, occasionally 2.
Aerial cover : Average 61%; Range 25% to 95%; S.D. 23,6%.
Number of species : Average 2; Range 1 to 4; S.D. 1,05.

Description of the community:

Habitat. (1) General.
This community occurred in sandy habitats near the coast. In the study area it was found on the foot slopes of the dunes at Sandwich Harbour (Plate 11), while in the coastal region north of Lüderitz Bay it occured on the slopes of dunes leading to pans and sand pediments of mountains (Robinson & Giess, 1974). Sites were gently sloping or flat and wind action resulted in considerable substrate movement. At Sandwich Harbour sites were between 2,5 m to 20 m above mean sea level and were never flooded.

(2) Substrate.
Soil was medium grain sand with a small proportion of fine (loam) material. It had a loose consistence and there was no differentiation into strata or horizons. At all sites soil depth was considerably

Plate 11

Plate 12

Plate 11

Sandwich Harbour. This photograph shows a typical stand of the *Eragrostis cyperoides* community on medium grain sand of the dunes.

Plate 12

Dunes forming the southern bank of the Kuiseb River upstream from Homeb. On these dunes *Stipagrostis sabulicola* trapped windblown sand and small hummocks formed around the plants.

greater than 1,0 m, while roots and stolons were found down to a depth of 0,30 m beneath the surface.

Physiognomy.

A community of one stratum of perennial, hard-leaved grass covering between 25% and 95%, and from 0,30 m to 0,50 m tall (Plate 11). Occassionally the scandent, broad-leaved evergreen shrub *Capparis hereroensis* was present in this stratum. A ground layer of *Heliotropium curassavicum* or *Odyssea paucinervis*, reaching a height of 0,15 m and covering 3% to 10% was sometimes found in some stands. In two stands (relevés 173 and 418), a taller layer (1,0 , to 1,5 m) was recorded.

Distribution.

Within the study area the *Eragrostis cyperoides* community was well developed only at Sandwich Harbour (Map 2), although it occured from Anichab Pan near Lüderitz Bay (Robinson & Giess, 1974) to the northern Namib Desert.

Accompanying species.

Hemicryptophytes:
- *Odyssea paucinervis*
- *Phragmites australis*

Chamaephytes:
- *Acanthosicyos horrida*
- *Capparis hereroensis*
- *Heliotropium curassavicum*

Nanophanerophyte:
- *Lycium tetrandrum*

Notes.

Acocks (1971) considered that grazing has resulted in the replacement of *Ehrharta villosa* by *Eragrostis cyperoides* on the west coast of South Africa, and thus the *Eragrostis cyperoides* community would be an "artificial" one, maintained by grazing pressure. This replacement was because *Ehrharta villosa* was palatable to livestock while *Eragrostis cyperoides* was "ungrazable" (Acocks, 1971), resulting in preferential consumption. In South West Africa *Ehrharta villosa* only occured as far north as Lüderitz Bay (Merxmueller, 1966-1972). This, together with the fact that there were few grazing animals at Sandwich Harbour (Stuart, 1975) was evidence that the *Eragrostis cyperoides* community was a natural and not an induced community in the Central Namib Desert.

It seemed to be a climax community occupying sandy substrate close to the coast.

3.2.2.2 The Stipagrostis sabulicola community (Table III)

Differential species. Stipagrostis sabulicola; Chamaephyte/Nanophanerophyte; differential against all communities.

Slope of sites : Average $11^{0}26'$; Range $0^{0}30'$ to 30^{0}; S.D. $9^{0}44'$.

Aspect : Most commonly westerly, but all directions except south were recorded.

Number of vegetation strata : 1, seldom 2.

Aerial cover : Average 7%; Range 1% to 20%; S.D. 5,9%.

Number of species : Average 1; Range 1 to 3; S.D. 0,50.

Description of the community.

Habitat. (1) General.

It occurred on the lower slopes of the dunes, or wherever the tufts could grow faster than wind-blown sand buried them. The plants formed hummocks of up to 2 m in height by trapping sand and continuing to grow through it (Plates 12 and 15).

(2) Substrate.

Medium-grain dune sand which was always of loose consistence. Often of great depth, from about 1 m near the Kuiseb River, where granite outcrops, to more than 50 m (estimated from the height of the dunes) on the dunes. Beneath larger tufts there was frequently a certain amount of organic matter in the form of grass leaves and fragments of stems. Fine material, consisting of mica grains, was frequently distributed through the soil at sites close to the Kuiseb River. The fine material was derived from the mica schists of the Damara system (3.2 above) and was carried from the river bed by wind action and trapped by the tufts of grass.

Physiognomy.

This was an extremely open community of widely spaced tufts of perennial grass, up to 1,5 m tall, covering much less than 1% of the dunes. On the hummocks it was up to 2,0 m high and 50 m^2 in area; here aerial cover of up to 20% was recorded. The leaf-succulent, Trianthema hereroensis was frequently noted between the grass tufts and formed small shrublets up to 0,40 m high.

Distribution.

(The location of relevés is illustrated in Map 3). In the study area, the Stipagrostis sabulicola community was found north of the Kuiseb River, and extended from a few kilometres inland to about 120 km from the coast.

Outside the study area it was found on the dunes between Walvis Bay and Swakopmund and the distribution extended as far south as Lüderitz Bay (Robinson & Giess, 1974).

Accompanying species.

Chamaephyte:

Trianthema hereroensis

Notes.

Over large areas of the dunes south of the Kuiseb River the botanical component of the ecosystem was the Stipagrostis sabulicola community, which provided the only cover for small animals.

It is interesting to note that this community closely resembled the Aristida pungens and Calligonum comosum community described by Quèzel (1965) from the Sahara Desert. Both communities occupies similar habitats (areas of shifting sand dunes), the grass species formed hummocks from wind-blown sand, and the communities were physiognomically very similar.

Relevé 288 is included in this community despite its floristic poverty because Trianthema hereroensis was a common companion species in this community and infrequent in others (Table III).

5.2.2.3 The Acanthosicyos horrida community (Table III).

Differential species. Acanthosicyos horrida; Chamaephyte; differential against all communities.

Slope : Average 10°26'; Range 5° to 30°; S.D. 9°58'.

Aspect : Not significant; relevés were taken on hummocks.

Number of vegetation strata : 1.

Aerial cover : Average 40%; Range 8% to 75%; S.D. 21,2%.

Number of species : Average 1; Range 1 to 3; S.D. 0,73.

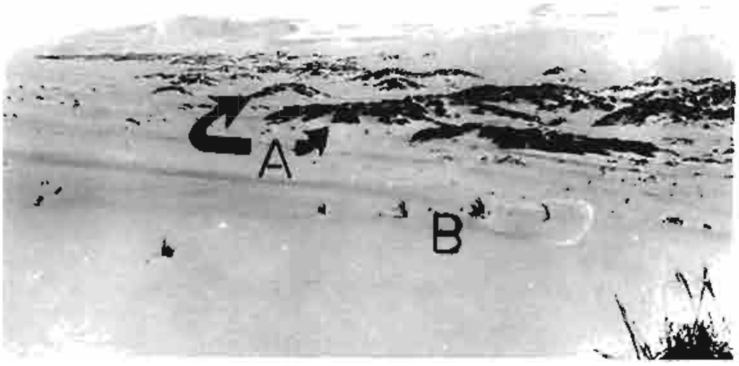


Plate 13(a)

Plate 13(b)

Plate 13(a)

The *Acanthosicyos horrida* community in an interdune valley approximately 16 km downstream from Gobabeb. The hummocks which had formed around the plants (A) were 3 m high. On the lower slopes of the dunes (B) *Stipagrostis sabulicola* tufts formed the perennial vegetation.

Plate 13(b)

Acanthosicyos horrida is a leafless, lax shrub armed with sharp spines. Occassionally branches were flattened and expanded as shown here.

Description of the community.

Habitat. (1) General.

This community occupied areas of unstable sand, but only where sub-surface water was to be found, or where run-off water was collected by rock outcrops. Observations in the northern Namib Desert suggested that the community may also utilize fog moisture since Acanthosicyos horrida only occurred to about 40 km inland on the sand dunes (that is, in the belt where fog is frequent, 4.7.3 above). In this area access to groundwater was unlikely as the dunes were 150 to 200 m above the level of the Kunene River and there was no geological evidence to suggest the presence of basins or aquifers. Further circumstantial evidence supporting this hypothesis was the absence of large woody plants, such as Acacia giraffae or Euclea psuedebenus which frequently indicated the presence of water.

The instability of the substrate made it impossible to determine the depth to which stems and roots penetrate or the depth of the water table.

(2) Substrate.

The substrate consisted of medium to fine grained, reddish coloured sand, the fine fraction often being composed of mica at sites along the Kuiseb River course. It was always loose, and organic material was frequently present, apparently introduced into the soil by the large number of nocturnal animals which inhabit the clumps of Acanthosicyos horrida (Koch, 1961; Scholz, 1972). It usually exceeded 3 m in depth, except where rock occurred close to the surface (for example, relevé 442).

Physiognomy.

A community of scattered, lax, leafless shrubs up to 1,5 m tall which occupied sand hummocks that may exceed 500 m^2 in extent with cover reaching 75% (Plates 13a and 13b). There was rarely more than one species present in a stand.

Distribution.

(The location of relevés is illustrated in Map 3). It occurred from the coast eastwards to Gobabeb, mainly south of the Kuiseb River, although some stands were found in sandy areas a few kilometres north of the river.

Elsewhere the community has been found as far south as Anichab Pan, about 40 km north of Lüderitz Bay (Robinson & Giess, 1974), and as far north as the Kunene River in the northern Namib Desert (Robinson, 1974, unpublished report).

Accompanying species.

Hemicryptophyte:

Odyssea paucinervis (in 1 relevé from the coastal area)

Chamaephytes:

Stipagrostis lutescens	*Trianthema hereroensis*
S. sabulicola	

5.2.2.4 The *Stipagrostis gonatostachys* community (Table III)

Differential species. *Stipagrostis gonatostachys*; Therophyte; differential against all other communities.

Slope of sites : Average $0^{\circ}22'$; Range 0° to $6^{\circ}30'$; S.D. $0^{\circ}59'$.

Aspect : Variable.

Number of vegetation strata : 1.

Aerial cover : Average 5%; Range 1% to 15%; S.D. 4,3%.

Number of species : Average 1; Range 1 to 2; S.D. 0,45.

Description of the community.

Habitat. (1) General.

The community was found on the flat sites in the streets between the dunes (Plate 14a), where the substrate was more stable because sites were less exposed to wind action. A superficial layer of coarse material, which protected finer material from the wind, was often present.

(2) Substrate.

Unlike the sand dune communities previously described, this community frequently developed on shallow soil, as little as 0,08 m deep (Fig. 5.2), overlying calcrete or conglomerate. (See also 3.4.2 above). The profile description of relevé 33, which was situated in a flat interdune valley 10 km south of Gobabeb is representative.

0 – 0,02 m	whitish-red medium grain sand, with a superficial layer of pebbles (from 2 mm to 8 mm in diameter).
0,02 – 0,15 m	grey-brown, fine grained micaceous sand with pebbles and rocks.
0,15 m	surface of a solid calcrete layer.

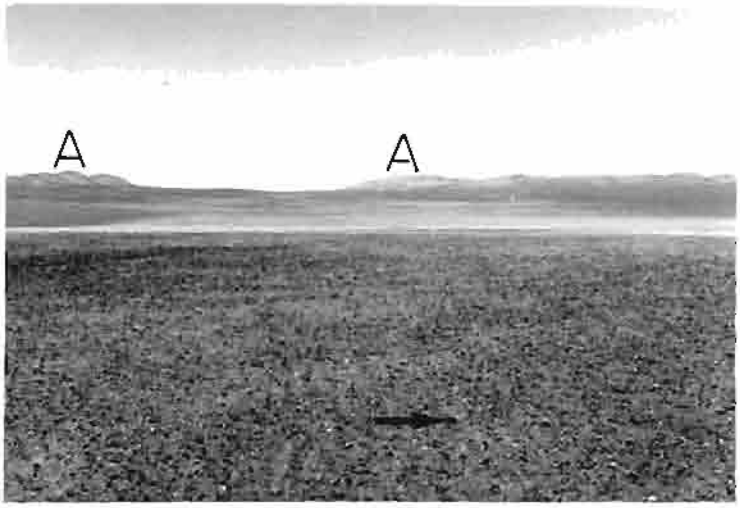


Plate 14(a)

Plate 14(b)

Plate 14(a)

A wide interdune valley about 40 km south of the Kuiseb River. The parallel seif dunes (A) were some 50 m high at this point. In such "streets" between the dunes the *Stipagrostis gonatostachys* community developed following rain showers. The site of Plate 14(b) is indicated by the arrow.

Plate 14(b)

Plants of *Stipagrostis gonatostachys* were less than 10 cm tall, including the flower culm. Notice the large numbers of stones and pebbles on the surface of the shallow sandy substrate. The dark coloured stones, mainly dolomite, clearly showed "desert varnish" (a coating of mineral salts deposited when dew evaporated). Most of the whitish pebbles were quartz.

Physiognomy.

A single layered community composed almost entirely of the annual grass, Stipagrostis gonatostachys. It was short (about 0,05 m tall), and covered less than 20% (Plate 14b). The seeds germinated rapidly following rain showers of only a few millimetres and the plants flower and set seed within a week or two, and then die (Pers. obs.). Most of the organic material was rapidly blown away. Despite the low cover, density may be quite high, for example, in relevé 34 aerial cover of only 4% was recorded (Table III), but there were between 120 and 150 individual plants per m^2.

Distribution.

(The location of relevés is illustrated in Map 3). During the study period this community was recorded from interdune valleys south of the Kuiseb River from about 18 km west to 16 km east of Gobabeb. However, because the community is both short-lived and dependent upon localised rainshowers, stands were frequently missed. It seemed likely that it may have occurred anywhere in the dunes of the study area following rain.

Accompanying species.

Geophyte:

Albuca sp. (only recorded in two relevés in 1972)

Chamaephyte:

Salsola tuberculata (recorded in only one relevé)

Therophyte:

Stipagrostis ciliata

Notes.

Although two of the accompanying species are perennials (Albuca sp. and Salsola tuberculata) they occurred so infrequently as to be of no assistance in mapping the distribution limits of the community.

In sandy areas from Lüderitz Bay to at least Spencer Bay 140 km north, the Stipagrostis gonatostachys community seemed to be replaced by a physiognomically similar one dominated by Stipagrostis hermanni and Monsonia ignorata (Robinson & Geiss, 1974 and Robinson, 1974, unpublished data). Further study is therefore required before the limits of these ephemeral communities can be stated with certainty.

5.2.2.5 The Stipagrostis lutescens community (Table III)

Differential species. Stipagrostis lutescens; Chamaephyte; differential against all other communities.

On the basis of geographical distribution, habitat and species composition two sub-communities were distinguished:

(a) Typcial sub-community. Differentiated by Stipagrostis lutescens alone.

(b) Limeum fenestratum - Hermannia gariepina sub-community.
Differential species : Limeum fenestratum and Hermannia gariepina; Chamaephytes; differential against the typical sub-community and communities of the Kuiseb River where Eragrostis spinosa occurs (Table IV).
: Eragrostis spinosa; Hemicryptophyte; differential against the typical sub-community.

5.2.2.5 (a) Typical sub-community

Slope of sites : Average 3°11'; Range 0°10' to 15°; S.D. 4°45'.
Aspect : Generally N.
Number of vegetation strata : 1, occassionally 2.
Aerial cover : Average 8%; Range 1% to 25%; S.D. 5,4%.
Number of species : Average 2; Range 1 to 4; S.D. 0,78.

Description of the sub-community.

Habitat. (1) General.

The typical sub-community was found on both sides of the Kuiseb River, most commonly on the foot-slopes of dunes, in sheltered sandy areas (Plate 15) (for example, in washes leading to the Kuiseb River and on sand-talus slopes of rock outcrops). It occurred where water probably collected after rainshowers or during fog and was likely to remain available throughout the year. The community attained optimal development, indicated by larger numbers of species in the stands, greater plant cover and maximum plant vigour, in the eastern section of the study area where rainfall was highest.

Sites varied from flat (Plate 15) to quite steeply sloping. The predominance of north-facing relevés may have been because rain showers appeared to move over the dune area from a northerly direction, at least at Gobabeb (Pers. obs.), and thus the north-facing slopes may intercept more precipitation. The data presently available are insufficiently detailed for this hypothesis to be more than tentative.

(2) Substrate.

Soil supporting this sub-community consisted of reddish, medium grain, loose dune sand of variable depth, from 0,10 m to considerably more than 1 m deep (Fig. 5.2), overlying a variety of rocks such as granite, schist and conglomerate (Table III). In some cases (relevé 441 for example), a coarse, superficial layer of pebbles was found.

Physiognomy.

The typical sub-community of the Stipagrostis lutescens community had aerial cover of between 1% and 25% and may be described as open to very open. There was usually a single stratum composed of graminoids between 0,25 and 0,50 m tall (Plate 15). Where a ground layer occurred, it had low aerial cover (1%) and was very short, usually less than 0,05 m tall. All the species were perennial, and most had perennating buds borne close to the ground so that they die back during the unfavorable periods, a property which may serve to conserve water.

Distribution.

(The location of relevés is illustrated in Map 3). This sub-community was found from Zwartbank (Map 2) in the west to 20 km east of Gobabeb. This coincided with the region where fog precipitation was low and rainfall low and irregular, that is, in the "extreme-arid" region (3.1 above).

Accompanying species.

Hemicryptophytes:

Asthenatherum glaucum	Eragrostis spinosa

Chamaephytes:

Salsola tuberculata	Trianthema hereroensis
Tephrosia dregeana	

Notes.

The small number of species, low cover and occurrence of a single differential species suggest that this sub-community is, in the nomenclature of Westhoff and Den Held (1969), an "inops" sub-association, with the Limeum fenestratum - Hermannia gariepina sub-community as

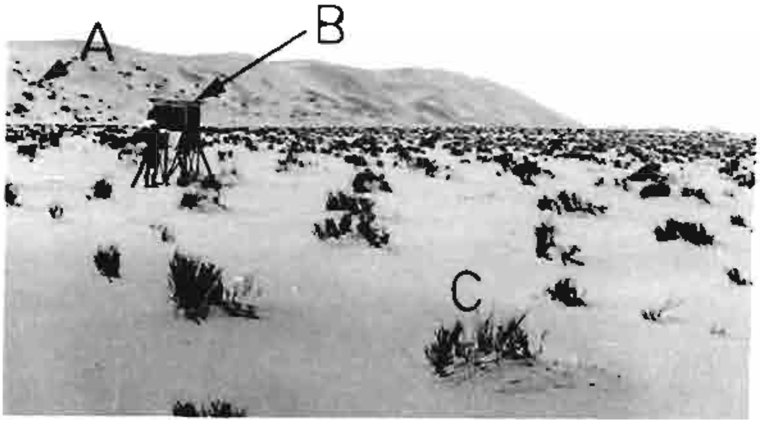


Plate 15

Plate 16

Plate 15.

South of the Kuiseb River at Homeb, where a large area was occupied by the typical sub-community of the Stipagrostis lutescens community. On the sand dunes Stipagrostis sabulicola formed large tufts (A), while Stipagrostis lutescens (C) formed solitary tufts in the valley. B represents the Stevenson screen housing weather recording instruments. This site was one of the five automatic-recording stations set up by the Namib Desert Research Unit.

Plate 16

The south-eastern part of the Namib Desert Park, showing a stand of the Limeum fenestratum - Hermannia gariepina sub-community, which has colonized low dunes. The photograph was taken in the late afternoon, hence the dark colour of the sand. The major plants were: Stipagrostis lutescens (arrowed), Eragrostis spinosa (A), Limeum fenestratum (B) and Helichrysum argyrosphaerum (C). Stipagrostis ciliata flourished in the valleys between the dunes (D).

the "typicum" sub-association. However, until the syntaxonomic classification is completed (see 5.1 above) it is preferable to order the communities from simple to complex, which also seems to follow the east to west environmental gradient found in the study area. This is why the "inops" form is discussed before the "typicum."

5.2.2.5 (b) Limeum fenestratum - Hermannia gariepina sub-community
Slope of sites : Average $7^{0}03'$; Range 2^{0} to $10^{0}15'$; S.D. $2^{0}59'$.
Aspect : Variable.
Number of vegetation strata : Usually 2, occassionally 1, 3 or 4.
Aerial cover : Average 25%; Range 11% to 45%; S.D. 11,2%.
Number of species : Average 7; Range 4 to 9; S.D. 1,72.

Description of the sub-community.

Habitat. (1) General.

The habitat was the small dunes of the southeastern part of the study area (Plate 1), where, at an altitude of 850 m above sea level and 130 km inland, rainfall was higher (4,7,2 above) and more dependable than in sites occupied by the typical sub-community. Well developed stands were found where sand movement was restricted, and therefore the smaller dunes up to 7 m high and the lower slopes of larger dunes up to about 15 m high provided the most favourable sites. The crests of the larger dunes were only occupied by Eragrostis spinosa and Stipagrostis sabulicola. Slope at all sites was moderate (2^{0} to 10^{0}).

(2) Substrate.

In this sub-community soil consisted of reddish coloured, medium or fine grained loose sand of considerable (for the study area) depth, reaching 0,7 m (Fig. 5.2).

Physiognomy.

This community was composed mainly of perennial species usually forming two strata, a ground layer to 0,15 m tall and a taller stratum of tall grass and small shrubs of between 0,30 and 1,0 m tall (Plate 16), covering between 11% and 45%. The taller stratum was usually the dominant, covering between 8% and 15% while the ground layer covered from 2% to 45% (relevé 478). In some relevés as many as four strata were recorded, for example relevé 471, where there were tree, shrub, tall grass/small shrub and ground layers. The Limeum fenestratum -

Hermannia gariepina sub-community, with 15 species recorded, was floristically the richest community of the sand dunes in the study area, probably as a result of higher rainfall.

Distribution.

(The location of relevés is illustrated in Map 3). In the study area this sub-community only occurred in the dune belt of the eastern (or semi-arid, see 3.1 above) region of the Namib Desert.

Further afield, it was recorded from the dunes of the sime-arid region west of Mariental (Map 1) and near Tsondab vlei, 22°55' S. Lat., 15°20' E. Long. (Pers. obs.).

Accompanying species.

Therophytes:
- *Gisekia africana*
- *Sesamum capense*
- *Stipagrostis ciliata*

Geophyte:
- *Hexacyrtis dickiana*

Hemicryptophytes:
- *Asthenatherum glaucum*
- *Brachiaria glomerata*
- *Helichrysum leptolepis*

Chamaephytes:
- *Kohautia lasiocarpa*
- *Tribulocarpus dimorphanthus*

Microphanerophytes:
- *Acacia giraffae*
- *Parkinsonia africana*

Notes.

Physiognomically and floristically this sub-community seemed very similar to the *Eragrostis lehmanniana* - *Asthenatherum glaucum* community described from near Douglas, northern Cape Province (Werger, 1973a). It is also physiognomically similar to the *Stipagrostis amabilis* community of the low dunes of the southern Kalahari (Leistner and Werger, 1973).

Dune crests prolong favourable moisture conditions for plant growth because moisture is absorbed rapidly and deep dessication is prevented by the mulching effect of the large air spaces between the coarse sand grains (Leistner, 1967; Leser, 1971 and Leistner and Werger, 1973). This is of considerable importance in the eastern Namib Desert where fairly large amounts of rain may fall during showers of short duration. The improvement in the moisture conditions provides a less harsh environment and allows an increase in the numbers of species. This accounts for the occurrence of the comparatively floristically rich and dense Limeum fenestratum - Hermannia gariepina sub-community in a sand dune habitat, which is apparently so harsh.

5.2.3 Discussion of the dune communities

5.2.3.1 Floristic relationships (Table VII)

All the differential species except Eragrostis spinosa were virtually restricted to the communities they characterised (Table VII). The other species of the communities were also rather restricted and the only communities with Sørenson coefficients of floristic similarity greater than 50% were the Stipagrostis sabulicola and Acanthosicyos horrida communities where it was 66,7%. The most similar comunity outside the dune system group of communities was the Calicorema capitata (typical sub-community) community which shared two species with the Stipagrostis gonatostachys community giving a coefficient of similarity of 40,0%.

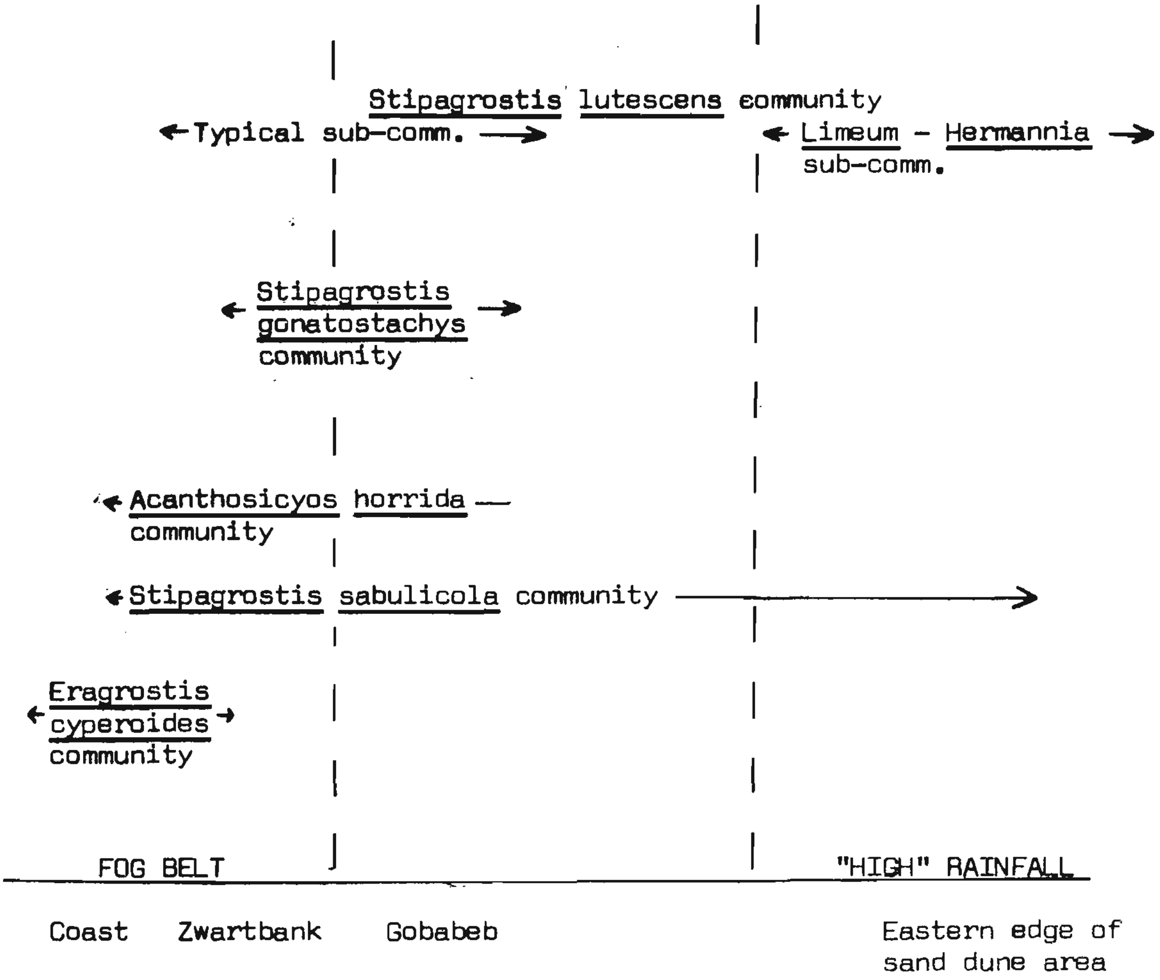
These communities were therefore floristically and ecologically distinct.

5.2.3.2 Ecological relationships

With the possible exception of the Stipagrostis lutescens sub-communities, the dune communities did not appear to be successionally related. Each community occupied a specific habitat, they were floristically distinct and there was no evidence that communities graded into or invaded one another. It is reasonable to suppose that Stipagrostis gonatostachys might occur on flat sites with Stipagrostis lutescens following rain showers because the habitats are so similar, but this has not been observed.

The communities may be ordered relative to the west - east climatic gradient of the study area (4.1 above and Fig. 5.3), in which the primary factor seems to be the amount and nature of precipitation as modified by substrate and availability of ground-water (5.2.2, i - v above). Environmental factors which differentiate the habitats from one another may be summarized as follows:

Fig. 5.3 Distribution of the sand dune communities along the west - east climatic gradient of the study area. Arrows indicate extent of distribution.



The communities of the fog zone and shifting sand habitats (Eragrostis cyperoides, Stipagrostis sabulicola and Acanthosicyos horrida communities) were composed of perennial species. However, the communities which occurred in the "high" rainfall area (or only occurred where rainshowers fall) showed an increase in the number of annuals which were found, although even in the Limeum fenestratum - Hermannia gariepina sub-community there were a number of perennials. This indicated that at both ends of the gradient there was sufficient moisture throughout the year to support evergreen perennials. The only community composed solely of ephemerals was the Stipagrostis gonatostachys nodum which occurred where water supply was least dependable.

The *Eragrostis cyperoides* community (5.2.2.1 above)

- on the lower slopes of coastal dunes;
- substrate was moderately stable;
- fog was frequent, and accounted for most of the precipitation.

The *Stipagrostis sabulicola* community (5.2.2.2 above)

- on the most exposed, unstable sites of the dunes;
- water supply ranged from fog-precipitation to rain-precipitation.

The *Acanthosicyos horrida* community (5.2.2.3 above)

- on sites where ground-water was available or run-off water collected.

The *Stipagrostis gonatostachys* community (5.2.2.4 above)

- on more stable sites where substrate was protected from wind action;
- substrate may be shallow and apparently concentrated water near the surface;
- wholly dependent upon rain showers.

The *Stipagrostis lutescens* community (5.2.2.5 above)

Typical sub-community (5.2.2.5 (a) above)

- apparently occupied the most moist sites in the dunes;
- substrate was unstable, but sites were usually protected from wind action;
- moisture derived from fog and rain.

Limeum fenestratum - *Hermannia gariepina* sub-community (5.2.2.5 (b) above)

- only occurred where the rainfall was higher and more reliable than that noted for the typical sub-community.

5.2.3.3 Syntaxonomic position of the communities

With the exception of the *Stipagrostis sabulicola* and *Limeum fenestratum* - *Hermannia gariepina* syntaxa (dealt with in 5.2.2.2, p 71 and 5.2.2.5 (b), p 78)the communities of the sand dune region of the study area seem to be unrelated to syntaxa described from comparable regions, such as the Kalahari (Leistner and Werger, 1973), the Sahara Desert (Quezel, 1965), or the Middle-East (Zohary, 1973).

5.3 Communities of the washes, Kuiseb River and rock outcrops (Table IV)

5.3.1 Introduction: (i) Reasons for grouping these habitats

The low plant cover, together with the nature of the soil results in high run-off so that much of the precipitation in the Namib Desert collects in gullies, drainage lines or washes. Many of the washes are sand filled (see 5.2.2.5 above) and therefore serve as water reservoirs retaining moisture for some time after the rains. Rock outcrops, by contrast, provide numerous cracks and erosion lines where water collects and remains for some while (3.3.6 above and Channing, 1975). As a result, rock outcrops and washes are rather similar in terms of water availability, and are relatively moist habitats in the Namib Desert environment (Walter, 1962). Water is the primary limiting factor in desert environments, and many other environmental factors influence vegetation through their influence on water availability (Shreve, 1951; Walter, 1962; Obeid and Mahmoud, 1971 and Zohary, 1973 to mention only a few authors), and it is not surprising therefore that communities of washes and rock ourcrops showed structural and floristic similarities (Tables IV and VII).

This is in contrast to the communities of the dunes and salt marshes which occupied distinct and rigorous habitats and therefore had little floristic affinity with any other communities in the study area. Consequently, whereas the dunes and marshes communities could be discussed with little or no reference to the rest of the Namib Desert system, the communities dealt with in 5.3 cannot be treated thus. For these reasons a discussion of their relationships is best delayed until after all the communities have been described.

(ii) Status of the *Pechuel-Loeschea leubnitziae* and *Zygophyllum stapfii* communities

Both these communities occupy washes but are placed with the communities of Table VI because they were floristically more similar to the communities of this group than to those of the washes and rock outcrops (Table IV). However, in view of the ecological similarities these two communities will be described immediately following the *Datura spp.* - *Argemone ochroleuca* community instead of with the communities of Table VI.

5.3.2 Communities of the washes and rock outcrops

5.3.2.1 The *Asclepias buchenaviana* community (Table IV)

Differential species. *Asclepias buchenaviana*; Nanophanerophyte; differential against all other communities.
Slope of site : Average $0^{\circ}13'$; Range 0° to $1^{\circ}00'$; S.D. $0^{\circ}18'$.
Aspect : Generally NW or SW.
Number of vegetation strata : 2.
Aerial cover : Average 4%; Range 2% to 6%; S.D. 1,4%.
Number of species : Average 4; Range 2 to 6; S.D. 1,42.

Description of the community.

Habitat. (1) General.
Shallow erosion lines, usually running westwards towards the coast and seldom more than 0,20 m deep. The underlying rock type, which frequently was exposed, was most often plutonic in origin (granite or pegmatite) although schist, dolomite or calcrete were found. In relevé 420 a gypcrete crust was reported.

(2) Substrate.
Soil was frequently shallow, having an average depth of about 0,20 m (Fig. 5.2), undifferentiated, and generally with a soft consistence; only relevé 279 had slightly hard soil. The following is a typical profile:
Relevé 119. A very shallow drainage line on a flat plain. Although no slope could be accurately recorded it was sufficient to collect significant amounts of water.

0 – 0,02 m	light brown medium grain sandy soil with a coarse gravel fraction.
0,02 – 0,20 m	light brown medium sandy soil, of soft consistence. From 0,08 m numerous flakes, up to 3 cm in length, of bedrock were found
0,20 m	upper surface of the mica schist bedrock.

Physiognomy.
This was a very open community of perennial, needle-leaved, evergreen shrubs attaining a height of 2,0 m, and with a sparse ground layer of between 0,10 m and 0,50 m tall. The dominant plant, *Asclepias buchenaviana*, appeared to bear flowers and fruits throughout the year, indicating that it must be rooted where moisture was continually

available. The shrubs were widely spaced and cover was low, possibly a result of competition for water, although no data were obtained to determine whether root competition actually occurred. The ground layer can cover 4% although it may be absent altogether.

Distribution.
(The location of relevés is illustrated in Map 4). Within the study area, the community occurred from just east of Zwartbank (Map 2) to about 90 km inland, on the gravel plains north of the Kuiseb River. This was the transition zone between the fog desert and the pro-Namib regions (see 3.1 above), where precipitation was very low (4.7.2 above).

Accompanying species.

Therophytes:

- *Stipagrostis ciliata* (May also occur as a perennial; Werger 1973a and pers. obs.).
- *S. hirtigluma*
- *S. obtusa*
- *Zygophyllum simplex*

Chamaephytes:

- *Blepharis bossii*
- *Dyerophytum africanum*
- *Galenia africana*
- *Kohautia ramosissima*
- *Salsola tuberculata*
- *Tephrosia dregeana*
- *Zygophyllum cylindrifolium*

Nanophanerophytes:

- *Acacia giraffae*
- *Pecuel-Loeschea leubnitziae*

5.3.2.2 The *Acacia giraffae* community (Table IV)

Differential species. *Acacia giraffae*; Macrophanerophyte; with high constancy and fairly high cover-abundance values this species was differential against all other communities.

On floristic and ecological grounds two sub-communities were recognised:

(a) Typical sub-community; *Acacia giraffae*, forming a scattered tree stratum, was differential against other sub-communities.

(b) *Acacia albida* sub-community; *A. albida*, *Tamarix usneoides*, *Euclea psuedebenus*, *Salvadora persica* (Macrophanerophytes), *Nicotiana*

Plate 17

Plate 18

Plate 17

The eastern boundary of the Namib Desert Park north of Ganab. On granite mountains a community of shrubs has developed (A), while the typical sub-community of the *Acacia giraffae* community (B) occupied sand washes throughout the study area. Notice the large, perennial tufts of *Stipagrostis ciliata* and *S. hochstetterana* (C) growing in the wash bed where water was more plentiful.

Plate 18

A wash near Heinrichsberg showing the typical sub-community of the *Acacia giraffae* community from ground level. The trees were widely spaced, there were few saplings and the ground cover consisted of tufts of grass and herbs.

glauca (Nanophanerophyte) and Chenopodium ambrosioides (Therophyte) were differential against the typical sub-community. The tree species were differential against the ephemeral Datura spp. - Argemone ochroleuca community (5.3.2.3 below).

5.3.2.2 (a) The typical sub-community

Slope of sites : Average $0^{0}27'$; Range 0^{0} to $2^{0}30'$; S.D. $0^{0}49'$.
Aspect : Variable.
Number of vegetation strata : 2 or 3, occassionally 1 or 4.
Aerial cover : Average 30%; Range 1% to 85%; S.D. 21,73%.
Number of species : Average 9; Range 2 to 26; S.D. 6,51.

Description of the community.

Habitat. (1) General.

The typical sub-community was found in a number of situations: dry watercourses on the plains, sand-filled basins on inselbergs and the upper terraces along the Kuiseb River. In all situations either run-off water accumulated or permanent water was available (Plates 17 and 19).

(2) Substrate.

The soil was usually sandy, consisting of loose, medium, coarse or gravelly sand. Depth varied from 0,05 m to greater than 0,70 m, with an average of just over 0,50 , (Fig. 5.2), and the bedrock was frequently exposed at the surface. None of the profiles examined showed significant differentiation between the surface and deeper layers, which is in agreement with Scholz (1972) who, considering substrate of the smaller desert valleys, stated that, "No soil has developed in this young alluvium."

Physiognomy.

This was an open woodland formation (Phillips, 1970) with trees forming the dominant stratum, although shrubs and dwarf shrubs sometimes comprised a large part of the cover. In the sand washes of the plains a ground layer of grasses and forbs was usually present between the widely spaced trees (Plate 18). There were usually three strata: a tree layer, 3 to 5 m tall, with up to 40% cover; a dwarf shrub layer (to 0,50 m tall) covering from 1% to 20%; and a ground layer of variable cover (1% to 60%) and a number of species, which was less than 0,30 m tall. In some relevés (427 and 262, Table IV) a shrub layer, 0,80 to 2,5 m tall and covering 10% to 15% occurred. The typical sub-community was fairly rich in species, 80 having been recorded, and a maximum of 26 in a single relevé.

Distribution.

(The location of relevés is illustrated in Map 5). The typical sub-community of the *Acacia giraffae* community was found from 30 km inland to the eastern boundary of the Namib Desert Park and occurred wherever there were suitable habitats.

More generally, this sub-community seemed to be found throughout the pro-Namib area.

Accompanying species.

Thallo-epiphyte:

1 species of lichen

Therophytes:

Amaranthus thunbergii
Anticharis linearis
Aristida
Blepharis grossa
Celosia argenteiformis
Cleome diandra
Citrullus ecirrhosus
Dicoma capensis
Eragrostis annulata
Euphorbia glanduligera
E. phylloclada
Geigeria alata
Gisekia africana
Heliotropium ovalifolium
H. tubulosum
Hermannia modesta
Limeum argute-coronatum
L. sulcatum
Lotononis platycarpa
Mollugo cerviana
Monsonia umbellata
Ondetia linearis
Polygala pallida
Schmidtia kalahariensis
Sesamum capense
Setaria verticillata
Stipagrostis gonatostachys
S. hirtigluma
S. uniplumis
Tribulus terrestris
T. zeyheri
Zygophyllum simplex

Geophytes:

Ammocharis tinneana
Pentarrhinum insipidum
Pergularia daemia
Ornithoglossum viride

Hemicryptophytes:

(a) Those which frequently do not survive the dry season

Brachiaria glomerata
Crotalaria podocarpa
Stipagrostis ciliata
S. hochstetterana
S. obtusa

(b) Those which are always perennial

Aptosimum angustifolium
Asthenatherum glaucum
Cleome luederitziana
C. suffruticosa
Eragrostis spinosa
Gazania jurineifolia
Geigeria ornativa
Indigofera auricoma
Osteospermum microcarpum

Chamaephytes:

Blepharis bossii
Dyerophytum africanum
Galenia africana
Kohautia lasiocarpa
K. ramosissima
Monechma arenicola
M. genistifolium
Orthanthera albida
Otoptera burchellii
Petalidium setosum
P. variabile
Psoralea obtusifolia
Ptycholobium biflorum
Salsola tuberculata
Stipagrostis namaquensis
Sutera maxii
Tephrosia dregeana
Welwitschia mirabilis
Zygophyllum stapfii

Nanophanerophytes:

Acacia mellifera
Acanthosicyos horrida
Adenolobus pechuelii
Boscia foetida
Pechuel-Loeschea leubnitziae
Phaeoptilum spinosum

Macrophanerophytes:

Boscia albitrunca
Parkinsonia africana
Ziziphus mucronata

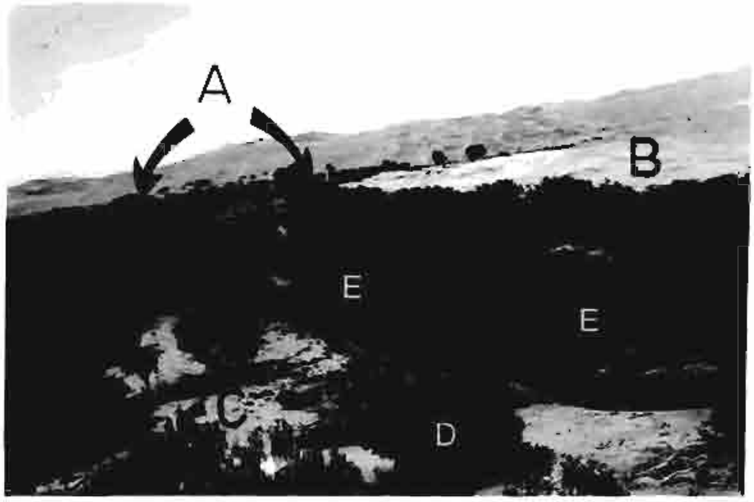
5.3.2.2 (b) The *Acacia albida* sub-community

Slope of sites : Average 2°00'; Range 0° to 30°; S.D. 6°03'.
Aspect : Variable.
Number of vegetation strata : Usually 3, sometimes 2,4 or 5.
Aerial cover : Average 59%; Range 11% to 95%; S.D. 26,20%.
Number of species : Average 11; Range 2 to 26; S.D. 8,10.

Description of the sub-community.

Habitat. (1) General.

In the study area this sub-community only occurred along the Kuiseb River, being found mainly on the first terrace above the river although in places, where floodwaters were unable to up-root the trees, it colonized the river-bed as well (Plates 19 & 20). Stengel, in an unpublished report in 1968 stated, "The Kuiseb is blocked at certain



<u>Plate 19</u>

<u>Plate 20</u>

Plate 19

The Kuiseb River about 12 km downstream from Gobabeb, photographed from the air in February, 1974. *Acacia albida* formed a forest fringing the banks (A), and if trees became well established in the riverbed they could withstand the floods (E). The gravel plains north of the river (B) were almost devoid of vegetation and contrast strongly with the linear oasis produced by the river. Also identifiable in the photograph are clumps of *Tamarix usneoides* (C) and *Acacia giraffae* trees (D).

Plate 20

The Kuiseb River near Homeb, October, 1972. For the greater part of the year the riverbed may be used as a road, with an avenue of tall trees on each side. The *Datura spp.* - *Argemone ochroleuca* community (A) occupied the riverbed for as long as water was sufficiently close to the surface for roots to reach it.

depths by granite rock, forming a groundwater sill with an immense storage basin of groundwater." Since in such places the water level is only a few feet below riverbed level, it seems likely that this community develops where water is continuously available.

(2) Substrate.

The soil was classified by Scholz (1972) as a young flood-loam (3.4.5 above). It was usually loose to soft, but on the terraces a crust, varying in consistence from slightly hard to hard occurred quite often. The texture was always fine and there was a great deal of mica present. Soil depth varied between 0,30 m and considerably more than 0,70 m (Fig. 5.2). In the dense stands (for example, relevés 432, 468, 438, 452, 347, 341, 444, 445, 357, 484, 448, 447, 450 and 462, Table IV) undecomposed litter and sand formed a superficial layer between 0,05 and 0,10 m thick.

Physiognomy.

Acacia albida together with the other tree species formed the only woodland formation (Phillips, 1970) found in the study area. In most cases it consisted of three strata: a tree layer 4 m to 16 m in height covering 10% to 95%; a shrub layer 1,5 m to 4,5 m in height and covering less than 20%, although dense stands of the scandent shrub Salvadora persica sometimes formed thickets raising cover to 70%; the ground layer 0,6 m to 1,5 m tall was usually insignificant with less than 10% cover except where the tree and shrub canopy was open (Plate 21).

The ground layer was rich in species of the river-bed community (5.3.2.3 below), and was best developed near the river's edge where water was presumably more abundant. In a few sites (for example, relevés 436, 484 and 467) four strata were found, the addition being a dwarf shrub stratum 0,30 m to 1,0 m tall that covered between 3% and 20% of the area. This layer often took the place of the shrub layer (for example, in relevés 433 and 434), in which case the community consisted of tree, dwarf shrub and ground strata.

Distribution.

(The location of relevés is illustrated in Map 5). This sub-community was only recorded from the Kuiseb and Gaub Rivers (Map 2). Elsewhere, however, it occurred in many of the larger rivers, such as the Tsondab, Swakop and Khan of the Central Namib Desert (pers. obs.).

Accompanying species.

Thallo-epiphyte:

1 species of lichen

Therophytes:

Argemone ochroleuca
Blumea caffra
B. gariepina
Calostephane marlothiana
Cenchrus ciliaris
Chenopodium pumilio
Chloris virgata
Conyza bonariensis
Datura innoxia
D. stramonium
Flaveria bidentis
Geigeria plumosa
Helichrysum argyrosphaerum
Heliotropium ovalifolium
Hermannia modesta
Kissenia capensis
Nemesia lilacina
Nicolasia stenoptera
Nidorella resedifolia
Polygonum plebeium
Selago sp.
Setaria verticillata
Stipagrostis hirtigluma
S. uniplumis
Sutera canescens
S. lyperioides
Tagetes minuta

Geophytes:

Cyperus marginatus
Pentarrhinum insipidum
Pergularia daemia

Hemicryptophytes:

Aspilia eenii
Brachiaria glomerata
Coronopus integrifolius
Cynodon dactylon
Enneapogon brachystachyus
Eragrostis spinosa
E. trichophora
Forsskaolea hereroensis
Indigofera auricoma
Lobelia nuda
Osteospermum microcarpum
Vahlia capensis
Wahlenbergia androsacea

Chamaephytes:

Galenia africana
Hermannia affinis
Psoralea obtusifolia
Solanum nigrum
Sporobolus consimilis
Stipagrostis namaquensis
Sutera maxii

Nanophanerophytes:

Pechuel-Loeschea leubnitziae
Phaeoptilum spinosum
Ricinus communis
Ruellia diversifolia
Suadea plumosa

Macrophanerophyte:

Ficus sycomorus

Notes.

Large numbers of seedlings of Acacia albida germinated in the riverbed after the floods subsided. Saplings that were not uprooted by subsequent floods became established in the riverbed, forming dense stands. This process was observed near Gobabeb where trees attained a height of 3 or 4 m between 1972 and 1975.

Numerous Tamarix usneoides seeds germinated in the Kuiseb River bed after the heavy floods of early 1974, during which the river flowed for 3 months (pers. obs.). During the previous years (1972 and 1973) no seedlings of this species were noted, despite frequent observations being carried out on the riverine vegetation. Whether the abnormally high germination was a result of the plentiful supply of soil moisture, or because Tamarix seeds require a long imbibition period, or of some less obvious factor was not determined.

The leaves and pods of Acacia albida were an important source of food for animals such as gemsbok (Oryx gazella), steenbok (Raphicerus campestris) and the goats belonging to the Topnaar Hottetots who dwell along the river bank. In the dry months the lower branches of the trees were heavily browsed, and a large part of the seed crop was eaten (Seely, Hamilton, Dixon and Stuart pers. comm. and pers. obs.). Acacia giraffae seed pods were also eaten but to a lesser extent (pers. obs.). Since many of the seeds ingested with the pods were not digested (pers. obs.) this·can, as has been observed in the Kalahari area (Leistner, 1959) serve as an effective dispersal mechanism. It would be particularly valuable to Acacia giraffae as this species has a wider range of possible habitats than A. albida and will therefore benefit most from widespread distribution.

Water also serves as a dispersal agent for Acacia albida, the pods and seeds being carried by flood-waters to new sites where the seeds germinated within a short time of the floods subsiding (pers. obs.).

5.3.2.3 The Datura spp. - Argemone ochroleuca community (Table IV)

Differential species. Datura innoxia, D. stramonium, Argemone ochroleuca, Nidorella resedifolia, Therophytes; Eragrostis trichophora, Hemicryptophyte, but behaves as a Therophyte; and Nicotiana glauca,

Plate 21

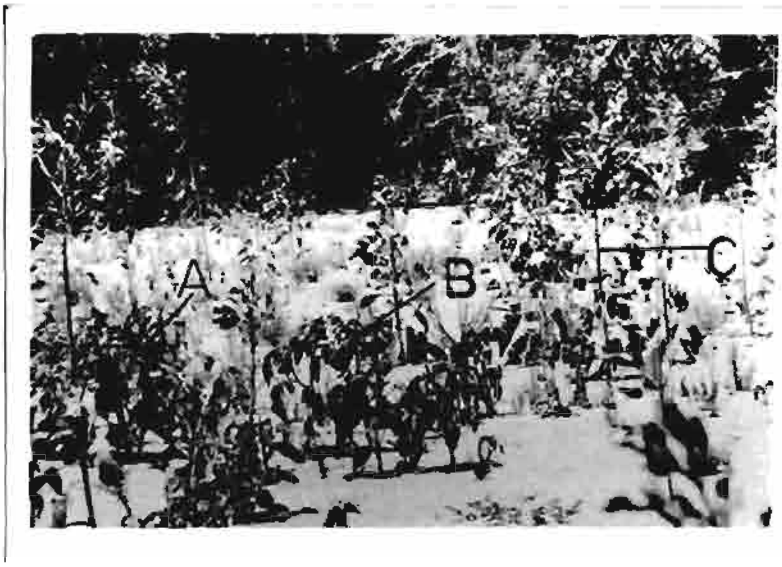


Plate 22

Plate 21

A well developed stand of the riverine forest at Homeb. Here the trees attained a height of 15 m and formed a closed canopy in many places. The shading resulted in a sparse ground layer.

Plate 22

The Kuiseb River at Gobabeb, June, 1973, showing the *Datura spp.* - *Argemone ochroleuca* community. A - *Datura innoxia*; B - *D. stramonium*; C - *Nicotiana glauca*.

Nanophanerophyte, but usually not surviving for more than one year; were differential against all other communities. The absence of Acacia giraffae and A. albida served to distinguish this community further.

Slope of sites : Average $0^{0}14'$; Range 0^{0} to $0^{0}30'$; S.D. $0^{0}10'$.

Aspect : Most frequently westerly because of the direction of flow of the river.

Number of vegetation strata : 2, occassionally 1.

Aerial cover : Average 33%; Range 5% to 90%; S.D. 25,98%.

Number of species : Average 14; Range 5 to 20; S.D. 6,60.

Description of the community.

Habitat. (1) General.

This was an ephemeral community that developed in the bed of the Kuiseb River during the dry season (Plates 20 and 22) and on the terraces closest to the river, where both light intensity was very much higher than beneath the canopy of the riverine woodland, and water was always available because of the presence of rock sills (5.3.2.2 (b) above). When the river flowed most stands were destroyed.

(2) Substrate.

The underlying rock and soil of this community were very similar to those of the Acacia albida sub-community, except that there was seldom a crust on the surface, and leaf litter was never present because it was washed away by floods and blown away by wind.

Physiognomy.

As the lists of differential (above) and accompanying (below) species illustrate, the Datura spp. – Argemone ochroleuca community was composed largely of annuals (Therophytes), and it was therefore not surprising that the cover and species composition of stands varied considerably (Table IV). The community usually consisted of two strata, although a third was not exceptional. The upper stratum, composed of shrubs, was between 1,5 m and 4,0 m tall and covered between 3% and 25%, while the ground layer, which was always present, was less than 0,20 m tall and covered between 5% to 25%. A dwarf shrub stratum (0,5 to 1,5 m tall, covering 5% to 90%) occassionally occurred with or in place of the shrub layer.

Distribution.

The community was only found in the Kuiseb and Gaub Rivers in the study area, but farther afield it occupied most river beds in the Namib Desert and the pro-Namib regions.

Accompanying species.

Therophytes:

- *Blumea caffra*
- *Cenchrus ciliaris*
- *Chenopodium ambrosioides*
- *Chloris virgata*
- *Conyza bonariensis*
- *Eragrostis annulata*
- *Flaveria bidentis*
- *Geigeria alata*
- *Gnaphalium luteo-album*
- *Helichrysum argyrosphaerum*
- *Heliotropium ovalifolium*
- *Hermannia modesta*
- *Launaea intybacea*
- *Mollugo cerviana*
- *Polygonum plebeium*
- *Schmidtia kalahariensis*
- *Selago* sp.
- *Setaria verticillata*
- *Sutera canescens*
- *Tagetes minuta*
- *Tribulus zeyheri*
- *Zygophyllum simplex*

Geophytes:

- *Cyperus* cf. *compressus*
- *Cyperus marginatus*

Hemicryptophytes:

- *Cynodon dactylon*
- *Eragrostis echinochloidea*
- *E. macrochlamys*
- *E. spinosa*
- *Hypertelis salsoloides*
- *Launaea intybacea*
- *Senecio marlothianus*
- *Vahlia capensis*

Chamaephytes:

- *Petalidium setosum*
- *Psoralea obtusifolia*
- *Solanum nigrum*
- *Sporobolus consimilis*
- *Stipagrostis namaquensis*
- *Sutera maxii*

Nanophanerophytes:

- *Nicotiana glauca*
- *Pechuel-Loeschea leubnitziae*
- *Suaeda plumosa*

Nanophanerophytes/Macrophanerophytes:

- *Salvadora persica*
- *Tamarix usneoides*

Macrophanerophytes: (As seedlings or saplings)

- *Acacia albida*
- *A. giraffae*

Notes.

The *Datura* spp - *Argemone ochroleuca* community, maintained by the regular floods, was the initial or pioneer sere in the riverbed, and in Clements' (1916) terms it is a flood preclimax community.

The species lists (above and in Table IV) reflect the degree to which the desert flora may be influenced by plants which are carried into the Namib Desert from beyond the boundaries of the desert zone. Examples are *Datura innoxia*, *D. stramonium*, *Argemone ochroleuca*, *Conyza bonariensis*, *Tagetes minuta*, *Flaveria bidentis*, *Ricinus communis* (all exotics), *Eragrostis echinochloidea*, *E. macrochlamys*, *Hypertelis salsoloides*, and *Vahlia capensis* to mention only some. These species are transported from the inland areas by wind, water, and animals. Seeds of *Ricinus communis* and *Datura spp.*, for example, are eaten by Laughing Doves (*Stigmatopelia senegalensis*) (pers. obs.), and become established in moist places in the riverbed; in this way the Kuiseb River and the other Namib Desert rivers form invasion corridors through the true desert for species requiring more mesic environments.

As might be expected of a community of annuals growing in a riverbed, the species composition varies considerably from year to year (Seely, pers. comm.; pers. obs.). Thus, following the three month floods of 1974, *Senecio eenii* and *Mesembryanthemum guerichianum*, which had not been recorded from Gobabeb at all during 1972 or 1973, occurred in large numbers in the river at the Research Station. Thus the species list presented in Table IV is probably incomplete and only presents those which could be expected in most years in the riverbed.

Nicotiana glauca did not appear to tolerate flooding of its roots. Evidence for this observation was that plants growing in the riverbed or close to the edge of the first terrace above the river died off within a few weeks of the floods, even though they suffered no visible damage.

5.3.2.4 The *Pechuel-Loeschea leubnitziae* community (Table VI)

Differential species. *Pechuel-Loeschea leubnitziae*; Nanophanerophyte; this species was differential against all other communities.

Slope of sites : Average 1°16'; Range 0° to 7°; S.D. 2°23'.

Aspect : Mainly westerly, since most washes run towards the sea.

Number of vegetation strata : 2.

Aerial cover : Average 11%; Range 3% to 20%; S.D. 6,56%.

Number of species : Average 7,5; Range 2 to 19; S.D. 5,83.

Description of the community.

Habitat. (1) General.

This community occupied shallow, sandy drainage lines on the plains. The habitat was rather similar to that of the Asclepias buchenaviana community (5.3.2.1 above), except that the washes were broader and the substrate considerably more sandy.

(2) Substrate.

Soil depth was very variable, from 0,06 m to more than 0,70 m with an average depth of 0,45 m (Fig. 5.2). It overlay a variety of rock types (granite, schist and marble, Table VI). Calcrete occurred quite frequently (37,5% of the relevés - Table VI) as a superficial deposit. It was possible to distinguish different layers, and the following profile was typical for the community:

Relevé 134, situated in a broad, shallow wash on the plains NNE of Gobabeb.

0 - 0,02 m	light brown, gravelly soil with quartzite pebbles, and stones of schist, calcrete and quartzite.
0,02 - 0,50 m	light brown, medium to coarse grain sand, of loose consistence.
0,50 m	stones and pebbles forming a solid layer.

(In June, when the profile was examined, the soil was moist from a depth of 0,15 m. Unfortunately no rainfall data were available for the site and therefore it was impossible to determine for how long the soil remained wet following rain).

Physiognomy.

This was an open community of scattered evergreen shrubs (Plate 23). Two strata were usually present: the shrub layer of 0,50 m to 1,5 m in height and covering 2% to 16%; and the ground layer (less than 0,30 m tall) covering 1% to 8%. Dwarf shrubs occurred in some stands, but did not constitute a stratum as they were too few in number.

Distribution.

(The location of relevés is illustrated in Map 4). The Pechuel-Loeschea leubnitziae community occurred from about 250 m above sea level at Zwartbank to an altitude of nearly 750 m above sea level at Mirabib (Map 2), that is, in the "extreme arid" region (3.1 above) between the fog desert and the pro-Namib regions.

Accompanying species.

Therophytes:

Aristida parvula
Euphorbia phylloclada
Gisekia africana
Heliotropium oliveranum
Heliotropium tubulosum
Lotononis sp. (R 102)
Stipagrostis gonatostachys
Zygophyllum simplex

Geophytes:

Ammocharis tinneana
Hexacyrtis dickiana

Hemicryptophytes:

(a) Thsoe which frequently behaved as Therophytes

Brachiaria glomerata
Helichrysum herniaroides
H. leptolepis
Indigofera auricoma
Stipagrostis ciliata
S. hochstetterana
S. obtusa

(b) Thsoe which were nearly always perennial.

Gazania jurineifolia
Geigeria ornativa

Chamaephytes:

Galenia africana
Kohautia ramosissima
Monechma arenicola
Pentzia hereroensis
Petalidium setosum
Orthanthera albida
Psilocaulon salicornioides
Stipagrostis lutescens
Sutera maxii
Tephrosia dregeana
Zygophyllum cylindrifolium
Z. stapfii

Nanophanerophytes:

Acanthosicyos horrida
Asclepias buchenaviana

Notes.

This community occupied habitats which were very similar to those of the *Acacia giraffae* (typical sub-community) community (p 86 above). The communities were floristically distinguishable (Table VII), but the only recorded abiotic differences between sites supporting the communities was soil depth (Fig 5.2).

The *Acacia giraffae* community was found on deeper soils, although there was considerable overlap between the communities (Fig 5.2). It seems reasonable to suggest that *Acacia giraffae* has a deep root system which reaches groundwater, while *Pechuel-Loeschea leubnitziae*, being a smaller plant, does not have such a deep root system. In the shallower soils supporting the shrub community *Acacia* giraffae may be forced to develop a shallow root system, and the trees may then not be able to withstand the very dry periods

Plate 23.

Plate 24.

Plate 23

A shallow wash on the plains north of Mirabib. In the *Pechuel-Loeschea leubnitziae* community an open shrub layer was formed by the nominate species (A), while *Stipagrostis ciliata* tufts accounted for much of the cover of the ground layer (B).

Plate 24

A saline wash north of Hotsas, showing a stand of the *Zygophyllum stapfii* community. The surface of the soil was covered by a hard crust composed of salts and fine material (loam) (A), and sites were frequently stoney; here a number of quartz stones could be seen (B). The succulent-leaved, dwarf shrub (C) was *Zygophyllum stapfii* which formed an open community to about 1,0 m tall.

The schists of the Damara system are much intruded by igneous rock, and here (D) a quartz dyke is most conspicuous.

as well as the microphyllous shrub can. The same sort of situation has been described for Prosopis spp. and Artemesia tridentata in the American deserts by Carter (1964) and Robertson (1972), and may be the ecological explanation for the existence of the Pechuel-Loeschea leubnitziae and Acacia giraffae communities as distinct entities.

Relevé 158 (Table VI) was clearly heterogenous since species of the Stipagrostis obtusa, Petalidium setosum, Petalidium variabile and Commiphora glaucescens - Anthephora pubescens noda were all present. However, it was plotted with the Pechuel-Loeschea leubnitziae community because of the higher cover and abundance of this species. The data give no clue as to the cause or significance of the floristic heterogeneity.

5.3.2.5 The Zygophyllum stapfii community (Table VI).

Differential species. Zygophyllum stapfii; a leaf - succulent Chamaephyte Alone this species was differential against all other species - compare with the Zygophyllum stapfii sub-community of the Salsola tuberculata community, 5.4.2.2 (a) below.

Slope of sites : Average 1°13' ; Range 0° to 3° ; S.D. 0°54'.
Aspect : Not significant as stands were almost flat.
Number of vegetation strata : 1 or 2.
Aerial cover : Average 13%; Range 2% to 60%; S.D. 16,4%.
Number of species : Average 3; Range 1 to 10; S.D. 2,53.

Description of the community.

Habitat. (1) General.

The community colonized drainage lines on rock outcrops and inland saline washes eroded through schists. At many sites salt crystals were found on the soil surface or along the water channels (Plate 24). Slope of the sites was usually very slight (Table VI) and water tended to collect in the wash bottoms.

(2) Substrate.

Soils supporting this community were frequently saline, with salt or gypsum, and usually quite deep (average, 0,53 m, but varying from 0,10 m to 0,70 m, Fig 5.2). In some stands a hard salt/clay crust was formed, but in most cases the dry consistence was soft. The extreme types of soil supporting stands of the Zygophyllum stapfii community are described below.

(a) Relevé 27. Situated in a sandy wash between schist ridges where there was no crust or sub-surface salt layer, although a pool of saline water occurred about 1 km further down the wash. There was no vegetation near this pool.

0 - 0,02 m surface layer of whitish quartz pebbles.
0,02 - 0,15 m whitish brown, medium grain sand.
0,15 - 0,50 m whitish brown coarse sand with numerous quartz pebbles and stones.

When this site was examined (May, 1972) the soil was visibly moist from 0,10 m beneath the surface. Rain had fallen about three weeks previously.

(b) Relevé 96. This site was in a deep, broad wash. A salt-water spring emerged about 30 m from the site. The soil was extremely saline (crystals of salt lined cracks and edges of the water courses) and the surface was extremely hard when dry (see also 3.4.7 above).

0 - 0,02 m irregular, brownish crust of hard soil.
0,02 - 0,50 m fine grained loamy mica sand with many quartzite pebbles.

The hard crust reduced evaporation so that the sub-surface soil remained moist, providing a suitable habitat for plants which could tolerate the saline conditions. Blue-green algae colonized the under-surfaces of the up-thrust blocks of the crust.

Physiognomy.

This was a community of succulent-leaved dwarf shrubs occupying the most saline sites supporting vegetation. In such inhospitable habitats there were too few plants to constitute layers in most stands. Where the cover was sufficiently high for strata to be distinguished, the dwarf shrubs, 0,20 m to 0,50 m tall, covered between 2% and 20% while the ground layer, less than 0,20 m high, covered between 1% and 10%.

Distribution.

(The location of relevés is illustrated in Map 4). From Zwartbank in the west to the longitude of Mirabib in the east (Map 2). The differential species, Zygophyllum stapfii, was common north of the Swakop River, and particularly plentiful on the Welwitschia Flats between the Khan and Swakop Rivers (Map 1). However, being outside the study area, the stands in these areas were not sampled and their syntaxonomic relationship with the *Zygophyllum stapfii* nodum described here cannot be determined at this stage.

Accompanying species.

Therophytes:

Cleome diandra
Eragrostis annulata
Euphorbia phylloclada
Mollugo cerviana
Zygophyllum simplex

Hemicryptophytes:

(a) Those which frequently behaved as Therophytes.

Brachiaria glomerata
Stipagrostis ciliata

(b) Those which were almost always perennial.

Cleome luederitziana
C. suffruticosa
Grielum sinuatum
Osteospermum microcarpum
Sesuvium sesuvioides

Chamaephytes:

Galenia africana
Psilocaulon kuntzei
Stipagrostis lutescens
Tephrosia dregeana

Nanophanerophytes:

Acanthosicyos horrida
Pechuel-Loeschea luebnitziae

Notes.

The study area appears to be at the southern limit of the geographical distribution of the syntaxon to which the *Zygophyllum stapfii* community belongs as the species occurred widely outside the study area and in different habitats (pers. obs.). It will only be possible to decide whether *Zygophyllum stapfii* is characteristc of a community, association or higher syntaxon after more relevés, covering most of the range of the species, have been taken.

5.3.2.6 The *Adenolobus pechuelii* - *Acacia reficiens* community (Table IV).

Differential species. *Adenolobus pechuelii*; Chamaephyte and *Acacia reficiens*; Nanophanerophyte were differential against communities of deep sand habitats, while *Asthenatherum glaucum*; Hemicryptophyte was differential against communities of rocky habitats.

Slope of sites : Average $1^{\circ}27'$; Range 0° to $11^{\circ}15'$; S.D. $2^{\circ}26'$.

Aspect : Variable.

Number of vegetation strata : 2 or 3.
Aerial cover : Average 20%; Range 3% to 85%; S.D. 18,65%.
Number of species : Average 10; Range 2 to 31; S.D. 6,40.

Description of the community.

Habitat. (1) General.

This community was found in sandy washes, water courses on rock outcrops and occasionally in areas of impeded drainage such as pans. Most sites were gently sloping, slthough some were quite steep (relevé 231, with a slope of 11°15'; Table IV).

(2) Substrate.

The underlying rock type appeared not to be significant in the development of the community since sites were found on granite, schist, and quartzite. The soils were sandy, with a loose consistence, frequently having a gravel layer in the profile, and of variable depth (from 0,08 m to greater tnan 0,70 m, averaging 0,38 m - Fig. 5.2). The following profile description from relevé 76, situated in a watercourse between ridges of schist, was fairly representative.

0 - 0,05 m	greyish coloured, medium grain, loose sand with a high proportion of coarse quartz gravel.
0,05 - 0,25 m	grey-brown, medium grain, loose sandy soil.
0,25 m	decomposing schist of the bedrock.

Physiognomy.

The *Adenolobus pechuelii* - *Acacia reficiens* community was a two- or three-layered community of shrubs, dwarf shrubs and a ground layer. The dwarf shrub stratum (0,20 m to 0,80 m tall) was almost always present (Plate 26) and in most relevés contributed the greatest aerial cover (1% to 25%). When present, the shrub layer (from 1 m to 4,5 m in height) seldom covered more than 15% (Plate 25). The ground layer of grass, usually perennial tufts, and forbs attained a height of 0,15 m to 0,30 m and cover of 1% to 20%.

Distribution.

(The location of relevés is illustrated in Map 5). The best developed stands (that is, those with highest cover) of this community in the study area occurred in washes near Hope Mine and Mirabib (Map 2) at between 500 m and 700 m above sea level, where rainfall seemed to be slightly higher than at Gobabeb. The westernmost stand recorded was about 55 km inland, on the edge of the fog desert zone (Map 5).

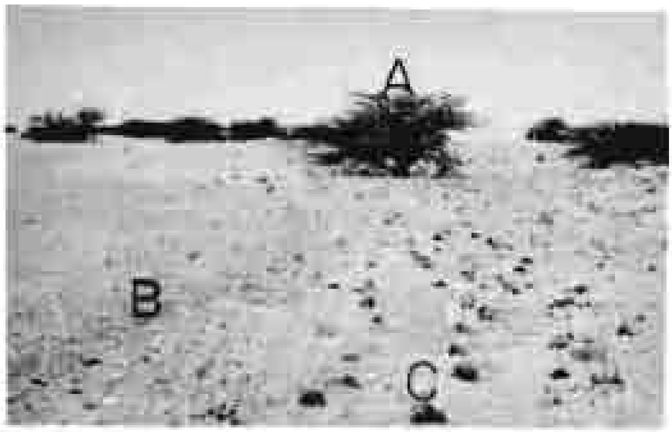


Plate 25.

Plate 26.

Plate 25

A wash 15 km north-east of Mirabib occupied by the Adenolobus pechuelii - Acacia reficiens community. In this photograph only Acacia reficiens appears, forming a shrub stratum (A). Notice that only annual plants of Stipagrostis ciliata occurred on the banks of the wash (B), while perennial tufts grew in the wash bed (C). Soil was considerably deeper than at the site shown in Plate 26.

Plate 26

Hope Mine area; a stand of the Adenolobus pechuelii - Acacia reficiens community. Dwarf shrubs, up to 0,30 m tall (A) of Adenolobus pechuelii occupied the shallow soil of the watercourse. Notice the exposed rock (arrowed). A common accompanying species in this habitat and locality was Welwitschia mirabilis (B). The schist ridges flanking the washes (C) were the habitat of the Sesuvium sesuvioides - Stipagrostis obtusa community.

Accompanying species.

Therophytes:

Amaranthus thunbergii
Aristida parvula
Celosia argenteiformis
Celome diandra
Citrullus lanatus
Enneapogon brachystachyus
Eragrostis annulata
Euphorbia glanduligera
E. inaequilatera
E. phylloclada
Geigeria alata
Gisekia africana
Grielum sinuatum
Hermannia modesta
Kissenia capensis
Limeum argute-coronatum
L. sulcatum
Lotononis platycarpa
Mollugo cerviana
Monechma desertorum
Monsonia umbellata
Pegolettia senegalensis
Sesamum capense
Stipagrostis hirtigluma
S. uniplumis var. *intermedia*
Tribulus terrestris
Zygophyllum simplex

Geophytes:

Dipcadi bakeranum
Hexacyrtis dickiana
Ornithogalum stapfii

Hemicryptophytes:

(a) Those which frequently behaved as Therophytes

Brachiaria glomerata
Crotalaria podocarpa
Helichrysum leptolepis
Indigofera auricoma
Stipagrostis ciliata
S. hochstetterana
S. obtusa

(b) Thsoe which were almost always perennial

Aptosimum angustifolium
Cleome luederitziana
Sesuvium sesuvioides

Chamaephytes:

Aptosimum spinescens
Asparagus denudatus
Blepharis obmitrata
Chascanum gariepense
Galenia africana
Hermannia complicata
Kohautia lasiocarpa
K. ramosissima
Monechma arenicola
M. genistifolium
Orthanthera albida
Petalidium setosum
Psilocaulon salicornioides
Salsola tuberculata
Sutera maxii
Tephrosia dregeana
Welwitschia mirabilis
Zygophyllum cylindrifolium
Z. stapfii

Nanophanerophytes:

- *Boscia foetida*
- *Catophractes alexandrii*
- *Commiphora saxicola*
- *Pechuel-Loeschea leubnitzae*
- *Phaeoptilum spinosum*
- *Sarcocaulon mossamedense*

Nano-Macrophanerophytes:

- *Cordia gharaf*
- *Maytenus heterophylla*
- *Tamarix usneoides*

Macrophanerophytes:

- *Boscia albitrunca*
- *Euclea psuedebenus*
- *Maerua schinzii*
- *Moringa ovalifolia*
- *Parkinsonia africana*

Notes.

Where the underlying bedrock was exposed, pools of water frequently collected following rains, and many of these were saline. This, together with the occurrence of *Zygophyllum stapfii*, which is salt tolerant (5.3.2.5 above), suggests that the *Adenolobus pechuelii* - *Acacia reficiens* community may be able to develop in sites where the soil is too saline for the establishment of *Acacia giraffae*.

Welwitschia mirabilis, which occurred in the vicinity of Hope Mine and in a wash leading to the Kuiseb River near Homeb (Map 2), was recorded for a few relevés of the *Adenolobus pechuelii* - *Acacia reficiens* community (Table IV). The plants were established both in the fairly deep (0,50 m to 0,80 m) sand and in crevices in the schists flanking the washes. The two habitats were geologically, geomorphologically, and pedologically very similar to one another, but differed significantly in amount of rain received: The Hope Mine site received rain in 1972, 1973 and 1974, while at the second site only a few millimetres fell during 1973 and nothing was recorded for 1972 or 1974 (pers. obs.). This difference in rainfall seemed to be relfected by the *Welwitschia* populations. The Hope Mine population was healthy, the plants produced large quantities of seed each season, leaves of the plants showed no signs of chlorosis and seedlings with leaves between 25 cm and 50 cm broad at the cambium were quite numerous. In contrast to this, the population in the wash leading to the Kuiseb River at Homeb was less vigorous, produced fewer cones, had many members showing chlorosis, and lacked young (small) plants altogether (pers. obs.). These observations suggest that *Welwitschia mirabilia* requires rainfall (or significant amounts of precipitation) for reproduction to be successful. Furthermore, the populations found in the study area confirm the views of Kers (1967) that fog is not essential for the occurrence of the species, since fog is infrequent at the sites (see 4.7 above).

5.3.2.7 The Mesembryanthemum guerichianum - Sporobolus nebulosus community (Table IV)

Differential species. Sporobolus nebulosus, Therophyte; Mesembryanthemum guerichianum, leaf-succulent Chamaephyte; Schmidtia kalahariensis, Therophyte; and Galenia papulosa, Chamaephyte; were differential against other communities.

Slope of sites : Average 0°03'; Range 0° to 0°10'; S.D. 0°04'.
Aspect : Not significant on such flat sites.
Number of vegetation strata : 1 or 2 usually.
Aerial cover : Average 29%; Range 12% to 60%; S.D. 21,50%.
Number of species : Average 15; Range 9 to 19; S.D. 4,20.

Description of the community.

Habitat. (1) General.

A steep-walled tributary leading to the upper Kuiseb Canyon (Map 2), with numerous pools of saline water, most of which remained for a few months after the rains. Deposits of crystalline salt formed on rocks and the soil surface when the pools dried up.

(2) Substrate.

Soil was loose, fine grained, greyish coloured sandy loam with stones throughout the profile (relevés 456 and 457) or loose, grey-brown, coarse sand (relevé 461) or light brown, soft, silt over coarse, stony gravel and sand (relevé 459). Depth varied from 0,10 m to greater than 0,60 m (Fig. 5.2), and the schist bedrock was frequently exposed at the surface. With the data available, it therefore appears that the physical nature of the substrate had little influence upon the community, whereas the chemical composition, in particular the salt content, exerted a marked effect on the development of the community.

Physiognomy.

Total aerial cover, produced by two or three strata, was between 12% and 60%. An evergreen and deciduous shrub layer, 1,5 m to 2,5 m tall, covered 4% to 20%; a dwarf shrub layer of tall annuals and evergreen perennials, 0,30 m to 0,60m tall and covering 7% to 30% was usually present, although in relevé 459 (Table IV) it was absent; the ground layer, less than 0,20 m tall, covering 6% to 15% and composed largely of annuals was always present.

Distribution.

This community was only found at a single locality, a ravine leading to the Kuiseb River, in the eastern part of the study area. The location of relevés is illustrated in Map 5.

Accompanying species.

Therophytes:

Chloris virgata
Eragrostis annulata
Enneapogon brachystachyus
Euphorbia glanduligera
Heliotropium tubulosum
Kissenia capensis
Stipagrostis hirtigluma
S. uniplumis var. *intermedia*
Tribulus zeyheri
Zygophyllum simplex

Hemicryptophytes:

Cleome luederitziana
Forsskaolea candida
Osteospermum microcarpum
Stipagrostis ciliata
S. hochstetterana
S. obtusa
Trichodesma africanum
Vahlia capensis

Chamaephytes:

Chascanum gariepense
Petalidium setosum
Psoralea obtusifolia
Sporobolus consimilis
Sutera maxii

Nanophanerophytes/Macrophanerophytes:

Acacia reficiens
Salvadora persica
Tamarix usneoides

Notes.

This group of relevés was floristically distinct in respect of both differential species (Table VII) and accomapnying species. The closest affinity was with the *Petalidium setosum* community (Table IV), and even here the Sørenson coefficient of similarity was only 36,8%. The *Mesembryanthemum guerichianum* – *Sporobolus nebulosus* community was therefore a distinct syntaxon. However, following the 1974 floods, *Galenia papulosa* and *Mesembryanthemum guerichianum* were frequently recorded from stands of the *Datura* spp. – *Argemone ochroleuca* community (p 91 above). This, considered in conjunction with the very restricted range of the *Mesembryanthemum guerichianum* – *Sporobolus nebulosus* community, emphasised the need for further sampling to assess whether this nodum warrants association status, or whether the relevés merely represented a facies of some other community.

5.3.2.8 The *Petalidium setosum* community (Table IV)

Differential species. *Petalidium setosum*, Chamaephyte; *Tribulus terrestris*, *Monechma desertorum* and *Trianthema triquetra* ssp. *parviflora*, Therophytes; were differential against the other communities of the study area.

Slope of sites : Average 0°22'; Range 0° to 1°20'; S.D. 0°36'.

Aspect : Mainly westerly, that is, towards the sea, but probably not significant.

Number of vegetation strata : 2.

Aerial cover : Average 24,5%; Range 10% to 45%; S.D. 9,74%.

Number of species : Average 14; Range 5 to 23; S.D. 4,16.

Description of the community.

Habitat. (1) General.

The *Petalidium setosum* community developed in very shallow almost flat drainage lines on the plains of the pro-Namib region (Plate 27(a)), where the water flowed slowly down the wash and tended to soak into the soil, and drainage lines on granite plutons. Very occasionally the community was found in sand washes or on flat clacrete plains.

(2) Substrate.

The soils were generally loose and sandy, with texture varying from medium to coarse grain, although finer textured, soft or slightly hard sandy loam occurred occasionally (relevés 465, 470, 468, and 235, Table IV). Soil was usually shallow with an average depth of 0,18 m, and ranging between 0,04 m and 0,40 m (Fig. 5.2), and frequently overlying calcrete (46,4%, Table IV). The rock, calcrete, granite or schist was often exposed at the surface. Stratification of the soil was not evident at most sites, but where layers could be distinguished (relevés 65, 71, 72 and 89) the following type of profile was typical:

0 – 0,02 m	greyish-brown, coarse grained sand with numerous stones and pebbles.
0,02 – 0,20 m	brown, medium to coarse grained sandy soil with few stones.
0,20 m	bedrock (schist).

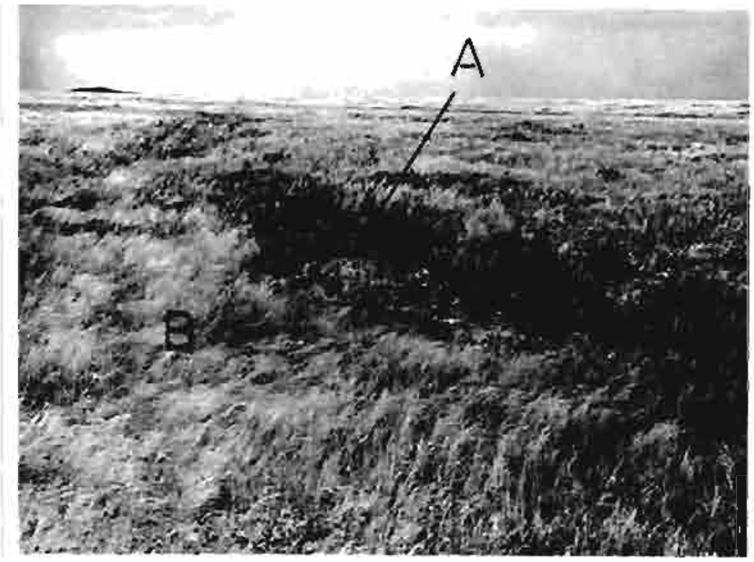


Plate 27(a)

Plate 27(b)

Plate 27(a)

Broad, almost flat plains north-east of Ganab. The *Petalidium setosum* community (A) occupied very shallow drainage lines. Following the rains, *Stipagrostis ciliata* colonized the deeper soil, and the community formed relatively dense stands (B).

Plate 27(b)

Broad, almost flat plains north-east of Ganab. In this close-up view the low growing, evergreen dwarf shrub, *Petalidium setosum* (A) and some *Stipagrostis ciliata* individuals (B) could be seen. The shallowness of the soil was indicated by the outcrops of bedrock (C).

The soil was of loose consistence throughout.

Physiognomy.

The *Petalidium setosum* community was generally composed of two strata, although a third (shrub) stratum was recorded for relevés 263, 257, 150 and 260 (TableVI). The dwarf shrub layer, between 0,10 m and 0,30 m tall, covered 1% to 30%, while the ground layer, less than 0,10 m in height (although flower culms of the grasses attained a height of 0,30 m) covered 4% t0 40% (Plate 27(b)). When a shrub layer occurred it was between 1,5 m and 2,0 m tall and covered 10% to 45% of the area.

Distribution.

(The location of relevés is illustrated in Map 4). This community was only recorded east of the longitude of Mirabib, that is, in the pro-Namib region of the study area.

Accompanying species.

Therophytes:

- *Anticharis linearis*
- *Aristida parvula*
- *Blepharis grossa*
- *Citrullus ecirrhosus*
- *Cleome diandra*
- *Dicoma capensis*
- *Enneapogon brachystachyus*
- *Eragrostis annulata*
- *Euphorbia glanduligera*
- *E. inaequilatera*
- *E. phylloclada*
- *Geigeria alata*
- *Gisekia africana*
- *Grielum sinuatum*
- *Heliotropium tubulosum*
- *Hermannia modesta*
- *Kissenia capensis*
- *Limeum argute-coronatum*
- *L. sulcatum*
- *Lotononis platycarpa*
- *Mollugo cerviana*
- *Monsonia umbellata*
- *Pegolettia senegalensis*
- *Sesamum capense*
- *Schmidtia kalahariensis*
- *Sporobolus nebulosus*
- *Stipagrostis hirtigluma*
- *S. uniplumis* var. *intermedia*
- *Tribulus zeyheri*
- *Triraphis pumilio*
- *Zygophyllum simplex*

Geophyte:

- *Raphionacme* sp.(S_R 10)

Hemicryptophytes:

(a) Those which frequently behaved as Therophytes

- *Asthenatherum glaucum*
- *Brachiaria glomerata*
- *Crotalaria podocarpa*
- *Helichrysum herniaroides*

Indigofera auricoma
I. damarana
Senecio marlothianus
Stipagrostis ciliata
S. hochstetterana
S. obtusa

(b) Those which were almost always perennial

Aptosimum angustifolium
Cleome luederitziana
C. suffruticosa
Forsskaolea candida
Geigeria ornativa
Osteospermum microcarpum
Stipagrostis uniplumis var. *uniplumis*
Trichodesma africanum
Triraphis ramosissima

Chamaephytes:

Adenolobus pechuelii
Aptosimum spinescens
Asparagus denudatus
Blepharis obmitrata
Chascanum gariepense
Dyerophytum africanum
Fagonia minutistipula
Hermannia complicata
Hibiscus elliottiana
Hoodia currorii
Kohautia lasiocarpa
K. ramosissima
Monechma arenicola
M. genistifolium
Orthanthera albida
Otoptera burchelli
Pavonia rehmannii
Petalidium variabile
Polygala guerichiana
Ptycholobium biflorum
Psoralea obtusifolia
Ruellia diversifolia
Salsola tuberculata
Stipagrostis namaquensis
Sutera maxii
Tephrosia dregeana
Zygophyllum cylindrifolium

Nanophanerophytes:

Acacia mellifera
A. reficiens
Commiphora saxicola
Phaeoptilum spinosum
Rhus marlothii

Nanophanerophyte/Macrophanerophyte:

Parkinsonia africana

Macrophanerophytes:

Acacia giraffae
Moringa ovalifolia

Notes.

Relevés 217, 71 and 72 are plotted in the *Petalidium setosum* community, despite the presence of the differential species of the *Adenolobus pechuelii* – *Acacia reficiens* community (Table IV), because the differential species of the *Petalidium setosum* community were dominant (Relevé 217) or were all present (Relevés 71 and 72, Table IV).

This community, in spite of covering only a small area of the Namib Desert (Plate 27a), appeared to be an important component of the desert system because the perennial dwarf shrubs provide cover for small animals throughout the year, and some of the plant species present (Cleome diandra, C. luederitziana, C. suffruticosa and Tephrosia dregeana) are eaten by Namaqua Sandgrouse during the breeding season (Dixon, pers. comm.; pers. obs.).

5.3.2.9 The Sesuvium sesuvioides - Stipagrostis obutsa community (Table IV)

Differential species. Sesuvium sesuvioides, succulent Hemicryptophyte; Cleome diandra and Euphorbia phylloclada, Therophytes; were differential against all other communities when they attained high cover and abundance.

As a result of its abundance in other communities (Tables IV and VI) and since it served as a differential species for the Stipagrostis obtusa sub-community (Table VI), Stipagrostis obtusa was not used as a differential species. It was, however, used to name the community because of the high cover-abundance values and constancy which were recorded.

Slope of sites : Average 7°43'; Range 0° to 30°; S.D. 7°31'.

Aspect : Slight preponderance of northern aspects, but variable.

Number of vegetation strata : Usually 2, sometimes 1 or 3.

Aerial cover : Average 14%; Range 4% to 40%; S.D. 9,23%.

Number of species : Average 9; Range 5 to 17; S.D. 3,40.

Description of the community:

Habitat. (1) General.

The Sesuvium sesuvioides - Stipagrostis obtusa community occurred in rocky habitats, particularly on ridges formed by exposure of bedrock (Plate 26). Most stands were on steeply sloping sites, but occassionally the community developed on flat sites where granite plutons outcropped on the plains.

(2) Substrate.

The soil in which the community was found may be defined as a syrosem, that is, a raw mineral soil (3.4.2 above). It was loose to slightly hard in consistence and of shallow depth, being between 0,05 m and

0,39 m with an average of 0,17 m (Fig. 5.2). The texture varied from fine to medium grained and a coarse fraction of pebbles was often present. Texture was closely related to underlying rock type: fine material overlay schists, while coarsest material seemed to be derived from granites and quartz dykes. In many stands the only place where soil was accumulated was in crevices in the bedrock. Many sites were underlain by metamorphic rocks (Table IV), which was more likely a reflection of the abundance of metamorphic rocks in the Namib Desert than a causal habitat factor.

Physiognomy.

This was a two-layered community of herbaceous species with the ground layer less than 0,10 m tall and covering 1% to 40%. The intermediate stratum which covered less than 15%, was between 0,20 m and 0,40 m tall. In this layer dwarf shrubs sometimes grew (Table IV) but because of the wide spacing and small size (a maximum cover of 6% was recorded) these did not form a stratum.

Distribution.

(The location of relevés is illustrated in Map 6). The Sesuvium Sesuvioides - Stipagrostis obtusa was confined to the region where rain was the major source of water, thus it occurred between 50 km and 115 km from the coast (400 m to 1000 m above sea level), on the plains north of the Kuiseb River.

Accompanying species.

Therophytes:

Aizoanthemum dinteri
Amaranthus thunbergii
Aristida parvula
Dicoma capensis
Enneapogon brachystachyus
Euphorbia glanduligera
Geigeria alata
Gisekia africana
Hermannia modesta
Lotononis platycarpa
Mollugo cerviana
Monsonia umbellata
Stipagrostis uniplumis
    var. intermedia
Zygophyllum simplex

Geophytes:

Dipcadi bakeranum
Ornithogalum stapfii

Hemicryptophytes:

(a) Those which frequently behaved as Therophytes

Brachiaria glomerata
Helichrysum hernarioides
Indigofera auricoma
Stipagrostis ciliata
S. obtusa

(b) Those which were almost always perennial

Cleome luedertiziana
Osteospermum microcarpum
Stipagrostis uniplumis var. *uniplumis*

Chamaephytes:

Adenolobus pechuelii
Blepharis bossii
B. obmitrata
Chascanum gariepense
Dyerophytum africanum
Salsola tuberculata
Tephrosia dregeana
Welwitschia mirabilis
Zygophyllum cylindrifolium
Z. stapfii

Nanophanerophytes:

Boscia foetida
Commiphora saxicola
Euphorbia virosa
Sarcocaulon mossamedense

Macrophanerophytes:

Euclea psuedebenus
Maerua schinzii

Notes.

The *Sesuvium sesuvioides* – *Stipagrostis obtusa* community occupied habitats similar to those of the following syntaxon (the *Monechma genistifolium* community, 5.2.3.10 and Table IV), and the relationships between the communities are discussed after the description of the *Monechma genistifolium* community.

5.3.2.10 The *Monechma genistifolium* community (Table IV)

Differential species. *Monechma genistifolium*, *Sutera maxii*, *Adenia pechuelii*, Chamaephytes; *Gisekia africana*, Therophyte; were differential against the other communities, while the absence of *Petalidium variabile* differentiated between this community and the *Petalidium variabile* community.

Slope of sites : Average $2^{\circ}25'$; Range 0° to $10^{\circ}15'$; S.D. $3^{\circ}09'$.

Aspect : Variable.

Number of vegetation strata : Usually 2, sometimes 3.

Aerial cover : Average 15%; Range 4% to 28%; S.D. 2.45%.

Number of species : Average 13; Range 5 to 20; S.D. 4,50.

Description of the community.

Habitat. (1) General.

This was also a community of ridges and other areas of exposed rock. The only differences between this and the Sesuvium sesuvioides - Stipagrostis obtusa community were soil depth and slope. The Monechma genistifolium community generally occupied flatter sites (Table IV) where run-off was presumably slower and more water soaked into the soil than in the previous community. If this were the case, then the Monechma genistifolium community would occupy moister sites than the Sesuvium sesuvioides - Stipagrostis obtusa community. The species list below supported this, as there were more perennial species in the former community (35 species were recorded) than in the latter community where only 17 species occurred (5.3.2.2 above).

(2) Substrate.

Soil structure was virtually identical with that in the Sesuvium sesuvioides - Stipagrostis obtusa community, except that it was even shallower, the average depth being 0,10 m (Fig. 5.2). The soil was a syrosem (3.4.2 above) and although texture depended upon the parent rock type (5.3.2.9 above), it seemed to have little other influence, since schist, granite and dolerite all supported stands of the Monechma genistifolium community.

Physiognomy.

Two strata were usually present, a dwarf shrub layer between 0,20 m and 0,50 m tall, covering 3% to 15%, and a ground layer less than 0,20 m tall and covering 1% to 20%. A woody layer, 2,0 m tall and covering up to 14%, of deciduous and evergreen plants was sometimes present (relevés 265, 75, 303, 146 and 73, Table IV).

Distribution.

(For location of relevés of the community, see Map 6). The community was restricted to the pro-Namib, where the altitude exceeded 500 m above sea level and precipitation occurred mainly as rainshowers.

Accompanying species.

Therophytes:

- *Aristida parvula*
- *Blepharis grossa*
- *Calostephane marlothiana*
- *Cucumis sagittatus*
- *Enneapogon brachystachyus*
- *Eragrostis annulata*
- *Euphorbia glanduligera*
- *E. inaequilatera*
- *Geigeria alata*
- *Hermannia modesta*
- *Limeum argute-coronatum*
- *Mollugo cerviana*
- *Monsonia umbellata*
- *Pentzia schinziana*
- *Senecio flavus*
- *Stipagrostis hirtigluma*
- *S. subacaulis*
- *S. uniplumis* var. *intermedia*
- *Trianthema triquetra* ssp. *parviflora*
- *Tribulus zeyheri*
- *Zygophyllum simplex*

Geophytes:

- *Dipcadi bakeranum*
- *Ornithoglossum viride*

Hemicryptophytes:

(a) Those which frequently behaved as Therophytes.

- *Brachiaria glomerata*
- *Indigofera auricoma*
- *Stipagrostis ciliata*
- *Stipagrostis hochstetterana*
- *S. obtusa*

(b) Those which were almost always perennial.

- *Aptosimum angustifolium*
- *Asparagus denudatus*
- *Cleome luederitziana*
- *Eragrostis nindensis*
- *Forsskaolea candida*
- *Osteospermum microcarpum*
- *Stipagrostis uniplumis* var. *uniplumis*

Chamaephytes:

- *Adenolobus pechuelii*
- *Barleria merxmuelleri*
- *Blepharis obmitrata*
- *Calicorema capitata*
- *Commicarpus squarrosus*
- *Curroria decidua*
- *Hermannia complicata*
- *Kohautia lasiocarpa*
- *K. ramosissima*
- *Monechma arenicola*
- *Nolletia gariepina*
- *Petalidium setosum*
- *Salsola tuberculata*
- *Senecio alliarifolius*
- *Solanum rigescentoides*
- *Sutera maxii*
- *Tephrosia dregeana*
- *Zygophyllum cylindrifolium*

Nanophanerophytes:

- *Boscia foetida*
- *Commiphora saxicola*
- *Euphorbia virosa*
- *Montinia caryophyllacea*
- *Sarcocaulon mossamedense*

Macrophanerophytes:

- *Maerua schinzii*
- *Moringa ovalifolia*

A number of species were common to other communities of rocky habitats and these are listed on p 121.

Notes.

The *Monechma genistifolium* community showed moderately high floristic similarity with other rock outcrop communities, some wash communities and communities of the surrounding plains: the *Petalidium variabile* community (Table IV) was the most similar and had a Sørenson coefficient of similarity of 58,4%. Relationships between the communities are entered below in decreasing order of floristic similarity (table numbers and Sørenson coefficients of similarity are given in parentheses):

Adenolobus pechuelii - *Acacia reficiens* community (Table IV; 56,3%)
Petalidium setosum community (Table IV; 55,0%)
Stipagrostis ciliata community (Table VI; 54,4%)
Stipagrostis obtusa sub-community (Table VI; 53,3%)
Commiphora glaucescens - *Anthephora pubescens* community (Table IV, 53,2%)
Sesuvium sesuvioides - *Stipagrostis obtusa* community (Table IV; 49,5%)
Aristida adscensionis - *Eragrostis annulata* community (Table V; 39,3%).

Clearly, the *Monechma genistifolium* community bore close floristic relationship (Sørenson coefficient of similarity of 50% or greater) with communities of varied habitat. In desert environments the difficulties of adequate water supply are frequently overcome by adopting an ephemeral existence. It would not be surprising, therefore, to find annuals to be very widespread (the "desert wides" of Zohary, 1973) in arid environments, except where other factors such as moving sand (dune communities) or saline soils (*Zygophyllum stapfii* community) occur. Consequently, the high floristic similarities may have been biased to some extent by the preponderance of annual species (for example, *Stipagrostis ciliata*, *S. obtusa*, *Zygophyllum simplex*, *Enneapogon brachystachyus*, *Euphorbia glanduligera* and others - Tables IV, V and VI). In some cases, however, floristic affinities reflected obvious similarities in habitat. For instance, the similarities between the *Monechma genistifolium* community and the other communities of rock outcrops or communities of shallow drainage lines probably reflected the underlying similarities in habitat, in particular the relatively large quantities of water derived from

Plate 28

Plate 29

Plate 28

Schist ridge east of Mirabib, showing the *Petalidium variabile* community in typical habitat. *Commiphora virgata* (A) formed an open shrub stratum to 1,5 m tall. This deciduous species, which bore leaves for only a short period following rain, also occurred on granite outcrops. The dwarf shrub layer was composed mainly of *Petalidium variabile* (B), an evergreen with leathery, greyish coloured leaves, while *Stipagrostis uniplumis* var. *uniplumis* (D) was important in the ground stratum.

Exposed bedrock covered a large proportion of the ground (C). This site was on the north-west facing slope, where the rock strata were approximately parallel with the surface, producing smoother slopes than on the south-east facing slopes.

Plate 29

A typical site of the *Commiphora glaucescens* - *Anthephora pubescens* community; Tumasberg in the eastern part of the study area.

Euphorbia virosa (A), a stem succulent shrub, and *Aloe dichotoma*, a tree-aloe (D) were frequently found on rock outcrops in the wastern part of the Namib Desert Park. *Commiphora glaucescens* (B), an evergreen or partly deciduous tree attaining a height of 2,5 m grew in cracks or where sand and water collected. Notice that over much of the area of the pluton the exfoliating granite was bare of soil (C).

run-off which remained for some time in cracks and crevices. In other instances, however, floristic relationships were not supported by obvious similarities in habitat, and such was the case of the relationship between this community and the *Adenolobus pechuelii* – *Acacia reficiens* community.

Further data are required before it will be possible to determine whether the *Monechma genistifolium* community as delimited here is a valid syntaxon or whether the relevés obtained from the study area are only fragments of other communities.

5.3.2.11 The *Petalidium variabile* community (Table IV)

Differential species. *Petalidium variabile*, Chamaephyte; was differential against all other communities; *Indigofera auricoma* (forma), Hemicryptophyte; this erect growth form of *Indigofera auricoma* was differential against all communities except the *Commiphora glaucescens* – *Anthephora pubescens* community (5.3.2.12 below), in which it sometimes occurred (Table IV).

Slope of sites : Average 8°42'; Range 0° to 26°10'; S.D. 6°23'.
Aspect : Most frequently on northerly or easterly slopes.
Number of vegetation strata : 2 or 3.
Aerial cover : Average 20%; Range 7% to 40%; S.D. 7,94%.
Number of species : Average 14; Range 7 to 26; S.D. 4,78.

Description of the community.

Habitat. (1) General.

This community occupied schist outcrops (two relevés were from sites over other rock types; relevé 261, pegmatite; and relevé 249 with calcrete as the basement). With only two exceptions (relevés 261 and 249) sites were sloping (Table IV), and aspect seemed to have no influence on the cover or total number of species recorded (Table IV).

(2) Substrate.

The soils were very shallow syrosems (see 5.3.2.9 above), varying in depth between 0,0 m and 0,20 m (average depth, 0,10 m – Fig. 5.2) and occurred in depressions and crevides. It comprised a mixture of stones, pebbles and fine micaceous sand which was not differentiated into strata.

Physiognomy.

A mixed evergreen and deciduous dwarf shrub community (Plate 28), with a dominant dwarf shrub stratum, 0,30 m to 1,0 m tall, which covered 3% to 15%. A ground layer, less than 0,20 m tall and covering 3% to 15% was invariably present, while in many stands, for example relevés 239, 261, 465, 258, 259, 249, 240, 241, 235, 236 and 237 (Table IV), deciduous and evergreen shrubs formed an open layer 1 m to 4,5 m tall and with aerial cover of between 1% and 20%.

Distribution.

(The location of relevés is illustrated in Map 6). The *Petalidium variabile* community covered large areas of the eastern part (from some 80 km inland) of the Namib Desert Park, occupying schist ridges and the plateaux of the pro-Namib region.

Accompanying species.

Therophytes:

Amaranthus thunbergii
Anticharis linearis
Aristida adscencionis
A. parvula
Blepharis grossa
Calostephane marlothiana
Cleome diandra
Dicoma capensis
Enneapogon brachystachyus
Entoplocamia aristulata
Eragrostis annulata
Euphorbia glanduligera
Geigeria alata
Gisekia africana
Heliotropium gibbosum
Hermannia modesta
Hirpicium gazanioides
Kissenia capensis
Limeum argute-coronatum
Mollugo cerviana
Monsonia umbellata
Monsonia sp.
Pegolettia senegalensis
Pentzia schinziana
Polygala pallida
Rogeria longiflora
Selago sp.
Senecio flavus
Sericorema sericea
Sesamum capense
S. triphyllum
Stipagrostis hirtigluma
S. uniplumis var. *intermedia*
Sutera canescens
Tribulus zeyheri
Tricholaena monachne
Triraphis purpurea
Zygophyllum simplex

Geophytes:

Dipcadi glaucum

Eriospermum cf. *roseum*

Talinum arnotii

Hemicryptophytes:

(a) Those which frequently behaved as Therophytes

Brachiaria glomerata

Crotalaria podocarpa

Helichrysum hernarioides

Indigofera auricoma

Rhynchelytrum villosum

Stipagrostis ciliata

S. hochstetterana

S. obtusa

(b) Those which were almost always perennial

Aptosimum angustifolium

Asparagus denudatus

Cleome luedertiziana

C. suffruticosa

Corallocarpus welwitschii

Crotalaria damaranensis

Eragrostis nindensis

Forsskaolea candida

Geigeria ornativa

Limeum aethiopicum

Osteospermum microcarpum

Senecio marlothianus

Stipagrostis uniplumis var. *uniplumis*

Triraphis ramosissima

Chamaephytes:

Adenolobus pechuelii

Aptosimum spinescens

Barleria merxmuelleri

Blepharis obmitrata

Calicorema capitata

Chascanum gariepense

Commicarpus squarrosus

Commiphora saxicola

Curroria decidua

Fagonia minutistipula

Hermannia complicata

Hibiscus elliottiana

Kohautia lasiocarpa

K. ramosissima

Monechma arenicola

M. genistifolium

Orthanthera albida

Otoptera burchelli

Ptycholobium biflorum

Ruellia diversifolia

Solanum rigescentoides

Tephrosia dregeana

T. monophylla

Zygophyllum cylindrifolium

Nanophanerophytes:

Commiphora glaucescens

C. virgata

Euphorbia virosa

Grewia tenax

Maytenus senegalensis

Phaeoptilum spinosum

Macrophanerophutes:

Aloe dichotoma

Commiphora tenuipetiolata

Euclea psuedebenus
Maerua schinzii
Sterculia africana

Notes.

As noted in the section dealing with the geology (3.2 above), the schists of the Khomas series strike in a northerly direction, resulting in the north slopes of the ridges being much smoother than the south-facing slopes (the former are formed by the surfaces of the parallel strata). It would therefore be expected that run-off would be greatest on the north-facing slopes, and that the rough south-facing slopes would provide most crevices for water seepage. If this was the case it did not seem to produce an obvious difference in the development of the *Petalidium variabile* community as the data show no difference between stands on north- or south-facing slopes.

5.3.2.12 The *Commiphora glaucescens* - *Anthephora pubescens* community (Table IV)

Differential species. *Commiphora glaucescens*, usually a Nanophanerophyte, sometimes as a Macorphanerophyte; *Rhus marlothii*, Nanophanerophyte; *Ruellia diversifolia*, *Helichrysum tomentulosum*, Chamaephytes; *Codon schenkii*, *Anthephora pubescens*, *Enneapogon scoparius*, *Panicum arbusculum* and *Triraphis ramosissima*, Hemicryptophytes; *Senecio flavus*, Therophyte.

The groups of species which occur predominantly in the communities of rocky habitats, the *Monechma genistifolium*, *Petalidium variabile* and *Commiphora glaucescens* - *Anthephora pubescens* communities are dealt with under Notes, below.

Slope of sites : Average 12°09'; Range 0° to 34°; S.D. 8° 46'.

Aspect : Variable.

Number of vegetation strata : 3.

Aerial cover : Average 29%; Range 8% to 60%; S.D. 15,90%.

Number of species : Average 21; Range 11 to 28; S.D. 5,88.

Description of the community.

Habitat. (1) General.

The *Commiphora glaucescens* – *Anthephora pubescens* community occupied inselbergs and ridges, usually of granite or granite intrusions. Exceptions were the stands where relevés 253, 254 and 244 were taken, where the community occupied banks flanking washes eroded into calcrete and conglomerate (Table IV). In these habitats there were numerous cracks and crevices in the weathered rock that produced moist microhabitats (Channing, 1975 and 3.3.6 above) allowing colonization by perennial species (for example *Barleria merxmuelleri*, *Commicarpus squarrosus*, *Curroria decidua*, *Berkheya spinosissima*, *Marcelliopsis denudata*, *Aloe dichotoma*, *Anthephora pubescens*, *Panicum arbusculum* and *Triraphis ramosissima*).

(2) Substrate.

As in the other communities of similar habitats, the *Sesuvium sesuvioides* – *Stipagrostis obtusa*, *Monechma genistifolium* and *Petalidium variabile* noda (5.3.2.9 to 5.3.2.11 above), the soil was shallow (average depth was only 0,11 m, Fig. 5.2). Because granite formed the bedrock, the soil was medium or coarse grained sand, with a loose or soft consistence (Table IV and 5.3.2.9 above). Rock was always exposed, and bare rock often accounted for as much as 95% of the surface area of a plot (Plate 29). This contributed to the variability of the plant cover.

Physiognomy.

A three-layered community: the tree/shrub stratum, 1,5 m to 5,0 m tall, covered from 3% to 50%; the dwarf shrub layer, covering 1% to 4% was 0,20 m to 1,0 m tall and was composed of many species; the ground layer was more variable, and was less than 0,20 m tall and covered between 10% and 20%.

Distribution:

(The location of the relevés is illustrated in Map 6). The *Commiphora glaucescens* – *Anthephora pubescens* community was confined to the inselbergs from Mirabib eastwards, in the wetter parts of the study area. The best developed stands, that is those with densest cover and most species, occurred on the higher granite inselbergs such as

Tumasberg, Heinrichsberg and the ranges along the eastern boundary of the Namib Desert Park (Map 2).

Elsewhere, communities with a tree/shrub stratum of *Commiphora glaucescens* and some other species of this community (*Anthephora pubescens*, *Triraphis ramosissima* and *Panicum arbusculum*) occurred on many granite inselbergs of the pro-Namib (pers. obs.) but until relevés are taken it is impossible to decide whether they belong to the community described here, or to a closely related one.

Accompanying species.

Therophytes:

Amaranthus thunbergii
Anticharis linearis
Aristida adscencionis
A. parvula
Blepharis grossa
Calostephane marlothiana
Codon schenckii
Enneapogon brachystachyus
Eragrostis annulata
E. porosa
Euphorbia glanduligera
Geigeria alata
Gnaphalium luteo-album
Helichrysum roseo-niveum
Hermannia modesta
Hybanthus densifolius
Launaea intybacea
Lotononis platycarpa
Mollugo cerviana
Monsonia umbellata
Pentzia schinziana
Polygala pallida
Seidelia firmula
Sporobolus nebulosus
Stipagrostis hirtigluma
S. uniplumis var. *intermedia*
Sutera lyperioides
Zygophyllum simplex

Geophytes:

Ammocharis tinneana
Dipcadi bakeranum
Pergularia daemia
Pentarrhinum insipidum

Hemicryptophytes:

(a) Those which frequently behaved as Therophytes.

Brachiaria glomerata
Cucumella aspera
Geigeria ornativa
Indigofera auricoma
Senecio marlothianus
Stipagrostis ciliata
S. hochstetterana
S. obtusa

(b) Those which were almost always perennial.

Aptosimum angustifolium
Barleria lancifolia
Berkheya spinosissima
Microloma hereroensis
Xerophyta viscosa

Chamaephyte : (often behaving as a Therophyte in this habitat)

Mesembryanthemum guerichianum

Chamaephytes:

- *Abutilon pycnodon*
- *Adenolobus pechuelii*
- *Aloe asperifolia*
- *Amphiasma divaricatum*
- *Barleria merxmuelleri*
- *Calicorema capitata*
- *Chascanum gariepense*
- *Commicarpus squarrosus*
- *Dyerophytum africanum*
- *Fagonia minutistipula*
- *Hermannia complicata*
- *Hoodia currorii*
- *Kohautia cynanchica*
- *K. ramosissima*
- *Leucosphaera bainesii*
- *Marcelliopsis denudata*
- *Monechma genistifolium*
- *Nolletia gariepina*
- *Orthanthera albida*
- *Otoptera burchelli*
- *Polygala guerichiana*
- *Ruellia diversifolia*
- *Tephrosia dregeana*
- *Zygophyllum cylindrifolium*

Nanophanerophytes:

- *Boscia foetida*
- *Commiphora saxicola*
- *Cordia gharaf*
- *Euclea undulata*
- *Maytenus heterophylla*
- *Rhus marlothii*
- *Sarcocaulon mossamedense*

Macrophanerophytes:

- *Acacia giraffae*
- *Aloe dichotoma*
- *Boscia albitrunca*
- *Commiphora tenuipetiolata*
- *Euclea psuedebenus*
- *Sterculia africana*

Notes.

In addition to the differential species of the *Monechma genistifolium*, *Petalidium variabile* and *Commiphora glaucescens* – *Anthephora pubescens* noda, other species were restricted to rocky habitats. These species formed two natural groups (Table VI), one consisting of species common to all three communities, while the species of the other group were common to the *Petalidium variabile* and *Commiphora glaucescens* – *Anthephora pubescens* communities but did not regularly inhabit the *Monechma genistifolium* community (Table VI and listed below).

Species common to the *Petalidium variabile* and *Commiphora glaucescens* – *Anthephora pubescens* communities but which were infrequently found in other communities of the study area are :

Therophytes:

Hirpicium gazanioides
Pegolettia senegalensis

Chamaephytes:

Blepharis obmitrata
Monechma arenicola

Nanophanerophytes:

Commiphora virgata
Euphorbia virosa

Species common to the *Monechma genistifolium*, *Petalidium variabile* and *Commiphora glaucescens* - *Anthephora pubescens* communities and which were infrequently recorded from other communities of the study area (Table IV) are:

Therophyte:

Tribulus zeyheri

Hemicryptophytes:

Asparagus denudatus
Eragrostis nindensis
Osteospermum microcarpum
Trichodesma africana
Stipagrostis uniplumis var. *uniplumis*
Forsskaolea candida

Chamaephytes:

Curroria decidua
Solanum rigescentoides

These floristic similarities united the communities of the rock outcrops of the zone where most precipitation occurred as rain (4.7 above), and show that availability of water was more important in community development than rock type. Rocky habitats provided numerous sites (such as small gullies, basins from which water could not escape, and crevides between boulders or rock strata) where water collects and remains for some time after the rains. These places become filled with organic and mineral material which reduces evaporation and provides a suitable substrate for plants to become established.

As discussed previously (see the *Limeum fenestratum* - *Hermannia gariepina* sub-community, p 79 above) sand absorbs and retains water relatively well, and this together with the moist micro-environments in the cracks (Channing, 1975) ensured an ample (by desert standards) water supply for plants (Walter, 1971).

5.3.3 Relationships between the communities

Although there were obvious similarities between the communities of rock outcrops and washes, the discussion of their affinities will be dealt with after the communities of pans and the plains have been described because they all showed degrees of similarity.

5.4 Communities of the larger pans

5.4.1 Introduction

Although pans are not as striking a feature of the Central Namib Desert as of the Kalahari Desert (cf Leistner and Werger, 1973), a few do occur. Floristically, there were three communities restricted to pans of the study area, while the Acacia giraffae (typical sub-community) and Adenolobus pechuelii - Acacia reficiens communities also colonized pans.

5.4.2 The Platycarpha carlinoides community (Table V)

Differential species. Platycarpha carlinoides; Hemicryptophyte; differential against all communities of the study area.

Slope of sites : Average 0^{0}.

Aspect : Not applicable since sites were absolutely flat.

Number of vegetation strata : 1.

Aerial cover : Average 10%; Range 6% to 20%; S.D. 6,68%.

Number of species : Average 2; Range 2 to 3; S.D. 0,50.

Description of the community.

Habitat. (1) General

The Platycarpha carlinoides community occupied the low-lying part of Zebra Pan (Map 2), a shallow, large (about 10 ha) pan which was subject to occassional flooding (once during the study period, pers. obs.) and heavy utilization by antelope (Springbok, Antidorcas marsupialis (Zimmerman) and Gemsbok, Oryx gazella (L.)), which trample and graze the entire pan very heavily (pers. obs.).

(2) Substrate.

The soil was alluvial, fine grained and greatly compacted (Table V). The depth of the clayey layer was not determined because of the hardness, but the upper 0,20 m at least consisted of light brown coloured sandy clay.

Physiognomy.

This was an extremely short (less than 0,05 m tall), sparse, single layered community of cushion hemicryptophytes with aerial cover between 6% and 20%.

Distribution.

Within the study area both the community and its differential species were recorded only from Zebra Pan (Map 2).

Accompanying species.

Hemicryptophytes:

Geigeria ornativa
Psoralea obtusifolia (Hemicryptophyte here; see Notes below)

Notes.

The distinctive structure, floristic composition and habitat justify the classification of this nodum as a distinct community despite the very restricted distribution and small numbers of species.

Platycarpha carlinoides and Psoralea obtisifolia occurred as dwarfed plants in the pan habitats (see also 5.4.3 below). Platycarpha carlinoides (a rosette forming Compositae with sessile inflorescences), grows to a diameter of 20 to 30 cm in the high rainfall area of the highlands between Windhoek and the coast (pers. obs.), whilst at Zebra Pan plants were only about 5 cm in diameter. Psoralea obtusifolia was even more strikingly dwarfed: whereas in the Kuiseb River, where groundwater is available and the substrate is loose, it grew as a Chamaephyte to 0,30 m tall with leaves 5 cm or more in length, in the pans it occurred as a prostrate Hemicryptophyte with leaves not much more than 5 mm in length. No experimental data are available to determine whether the plants in the pans are ecotypes of Platycarpha carlinoides and Psoralea obtusifolia, but in any event it seems that they were near the limits of their ranges and that soil and moisture conditions in the pans lead to the dwarfed growth habit.

5.4.3 The Calicorema capitata community (Table V)

Differential species. Calicorema capitata; Chamaephyte, with moderately high cover-abundance values, this species was differential against all other communities.

Two sub-communities were distinguished on the basis of floristic composition:

(a) The Aptosimum spinescens sub-community in which this Chamaephyte, when dominant, was differential against all other noda.

(b) The typical sub-community, differentiated by the dominance of Calicorema capitata (a Chamaephyte) and absence or low importance of Aptosimum spinescens.

5.4.3 (a) The Aptosimum spinescens sub-community.

Slope of sites : Average $0^{0}27'$; Range 0^{0} to $0^{0}45'$; S.D. $0^{0}17'$.
Aspect : Variable since sites surrounded the pan.
Number of vegetation strata : 2.
Aerial cover : Average 20%; Range 10% to 45%; S.D. 12,7%.
Number of species : Average 6; Range 5 to 7; S.D. 0,98.

Description of the sub-community.

Habitat. (1) General.

The sub-community was found in areas where the drainage was impeded by clayey soils, and therefore frequently occurred around pans. A calcrete layer was occasionally found (relevés 366 and 373, Table V) which further reduced water penetration.

(2) Substrate.

Apart from a superficial layer of gravel (up to 0,05 m thick), the soil was uniform to a depth of 0,30 m, consisting of light yellow-brown coloured, hard, fine soil (silty loam or loam). At depths greater than 0,30 m the soil was too hard for samples to be taken.

Physiognomy.

This was a two-layered community dominated by microphyllous dwarf shrubs between 0,15 m and 0,60 m tall that covered from 1% to 15% of the area, whilst the ground layer, less than 0,10 m tall, covered 1% to 40%. There were few species in either stratum.

Distribution.

The *Aptosimum spinescens* sub-community was best developed, having greatest cover and aeral extent, at Zebra Pan, but it also occurred at two other pans in the study area. One of these was 8 km southeast of Zebra Pan and the other in the extreme southeast corner of the Namib Desert Park (Map 2).

Accompanying species.

Therophyte:

Stipagrostis uniplumis var. *intermedia*

Hemicryptophytes: (all these often behaved as Therophytes here).

Geigeria ornativa
Indigofera auricoma
Stipagrostis ciliata
S. obtusa

Chamaephytes:

Petalidium setosum
Psoralea obtusifolia *
Salsola tuberculata
Zygophyllum cylindrifolium

Notes.

Although all species of this sub-community were recorded in other communities (Tables IV, V and VI), the high cover-abundance and constancy (Table VII) indicated that this was a valid syntaxon, a conclusion which was supported by the distinctive habitat.

5.4.3 (b) The typical sub-community

Slope of sites : Average 0°55'; Range 0° to 1°30'; S.D. 0°38'.
Aspect : Variable since stands surrounded the pans.
Number of vegetation strata : 2.
Aerial cover : Average 11%; Range 8% to 15%; S.D. 2,94%.
Number of species : Average 4; 4 species were recorded for each relevé.

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* See p 130 below for a discussion of the stunting of this species.

Description of the sub-community.

Habitat. (1) General.

This sub-community was found furthest from the centre of the pans, and was therefore highest above the bottoms of these. No sites were submerged and run-off was more rapid than in the Aptosimum spinescens sub-community, because the sites occupied by the typical sub-community were more steeply sloping, and therefore surface water remained for only a short while after rain ceased.

(2) Substrate.

The soil was coarser grained than in the Aptosimum spinescens sub-community, being a sandy loam with considerable micaceous material and pebbles throughout the profile. Is was of moderately hard to hard consistence (Table V) and was light brown in colour.

Physiognomy.

This was an open community of dwarf shrubs, 0,30 m to 0,50 m tall which covered 1% to 11%, with the plants between 3 m and 20 m apart. The ground layer was sparse, 1% to 10% of cover, and consisted of species from the Stipagrostis ciliata community that occupied the surrounding plains.

Distribution.

Although relevés were only taken at Zebra Pan, where the largest stands were found, the sub-community also occurred about 15 km south-east of Tumasberg on an area of clayey soil where drainage was impeded by a layer of calcrete close to the surface.

Accompanying species.

Therophyte:

Stipagrostis uniplumis var. intermedia

Hemicryptophytes:

(a) Those which frequently behaved as Therophytes

Stipagrostis ciliata

S. obtusa

(b) One which was always perennial

Geigeria ornativa

Chamaephyte:

Salsola tuberculata

Notes.

The small number of species in the typical sub-community described here suggested that it may have been an "inops" form while the *Aptosimum spinescens* sub-community was the "typicum" form of the *Calicorema capitata* community (refer to the *Stipagrostis lutescens* community, 5.2.2.5 above, for a discussion of the classification into "inops" and "typicum" forms of an association).

At Zebra Pan clear zonation of vegetation resulted from the distribution of the *Platycarpha carlinoides*, *Aptosimum spinescens* and *Calicorema capitata* noda along the environmental gradient from the centre of the pan to the flat peneplains surrounding it. This gradient was well represented by the soil types: the finer textured soils were found in the lowest part of the pan and texture became progressively coarser up the slope where submergence did not occur. This soil texture gradient reflected groundwater level, degree of winnowing, and expecially important, elluviation. However, the precise nature of the factor that resulted in the vegetation zonation is unclear. It may result from factors such as differences in level or duration of submergence, pH or ion exchange capacity that influence vegetation directly or from the indirect effects of variations in water holding capacity or infiltration rate.

Whatever the causal factor or factors, there was a group of species (see Notes following the *Aristida adscencionis* – *Eragrostis annulata* community below) which either indicated clay soils or responded to the factors leading to the formation of such soils.

5.4.4 The *Aristida adscencionis* – *Eragrostis annulata* community (Table V)

Differential species. *Aristida adscencionis*, *Eragrostis annulata*, *Geigeria alata*, *Hermannia modesta* and *Euphorbia inaequilatera*, all Therophytes; were differential against the communities of the pan habitats. *Psoralea obtusifolia* Chamaephyte, and *Geigeria ornativa*, Hemicryptophyte, served to differentiate between this community and communities of other habitats when they occurred with moderate to high cover-abundance (Tables IV, V and VI).

Slope of sites : Virtually flat; slopes always less than $0^{o}15'$ (Table V).

Aspect : Not applicable on such flat sites.

Number of vegetation strata : Usually 1, occasionally 4.

Aerial cover : Average 56%; Range 20% to 70%; S.D. 25,07%.

Number of species : Average 11; Range 4 to 23; S.D. 7,03.

Description of the community.

Habitat. (1) General.

This community was found in pans or slight depressions where water collected following rains.

(2) Substrate.

Soil depth was variable, although the average (0,22 m, Fig. 5.2) could be regarded as moderately deep. The texture was moderate to fine (Table V), and coarse material, which would give good drainage, was never recorded. With the exception of relevé 358 (where the underlying rock type was schist) all stands were underlain by schist with a clacrete layer over it. This served to prevent water draining away and, because of the bowl-like topography of the sites, ponding occurred.

Physiognomy.

The stands were too variable to permit a generalized description. Two stands, one represented by relevés 359, 361 and 362, the other by relevé 90, had only a ground stratum which was less than 0,15 m tall with aerial cover of between 40% and 70%. In relevé 358 a second stratum was formed by dwarf shrubs up to 0,30 m tall and covering 10%. The ground layer was sparse and covered only 10%. Two strata also occurred in the stand described by relevé 85 but the uppermost layer here was composed of shrubs between 1,0 m and 2,0 m tall with aerial cover of 20%, while the ground layer was denser and covered 30%. The stand from which relevé 85 was taken comprised a tree stratum up to 3,5 m tall and covering 84%, a shrub layer 1,5 m in height which covered 3% and the ground layer with aerial cover of 55%.

Distribution.

The five stands comprising this nodum all occurred in the pro-Namib Region at altitudes greater than 750 m above sea level. There was no correlation between structural complexity and geographical position of the site.

Accompanying species.

Therophytes:

Amaranthus thunbergii
Anticharis linearis
Chloris virgata
Enneapogon brachystachyus
Eragrostis porosa
Euphorbia glanduligera
Hybanthus densifolius
Launaea intybacea
Limeum argute-coronatum
Mollugo cerviana
Monsonia umbellata
Phyllanthus dinteri
Setaria verticillata
Stipagrostis uniplumis var. *intermedia*
Tragus berteronianus
Tribulus terrestris
T. zeyheri
Zygophyllum simplex

Hemicryptophytes:

(a) Those which frequently behaved as Therophytes

Crotalaria podocarpa
Eragrostis trichophora
Indigofera auricoma
Stipagrostis ciliata

(b) Those which were almost always perennial

Aristida congesta
Cleome luederitziana
Forsskaolea candida
Trichodesma africana

Chamaephytes:

Aptosimum spinescens
Kohautia lasiocarpa
Kohautia ramosissima

Nanophanerophytes:

Boscia foetida
Grewia flavescens
Maytenus heterophylla
Pechuel-Loeschea leubnitziae

Macrophanerophytes:

Boscia albitrunca
Euclea psuedebenus
Ziziphus mucronata

Notes.

The relevés of this nodum showed considerable floristic diversity (Tables V and VII) and of the differential species, only *Aristida* adscencionis had a fairly restricted distribution, being virtually confined to this nodum.

As noted above, Psoralea obtusifolia and Geigeria ornativa were characteristic on sites with fine grained soil which was often of hard consistence, and were thus found on clay soils. The data do not indicate whether these species truly indicate clay soils or whether they are favored by the conditions which result in the formation of clay soils.

The great variation in physiognomy (see above) may be due to differences in the habitats provided by various pans (amount of water received, depth of soil, variations in soil, etc.) or may indicate that relevés are atypical fragments of other communities, but the data do not allow this question to be answered unequivocably (see below).

The nodum had affinities with communities of the plains and washes: the floristically most similar communities were the Stipagrostis obtusa sub-community, with a Sørenson coefficient of 48,8%; the Acacia giraffae (typical) sub-community, 45,2%; the Adenolobus pechuelii - Acacia reficiens community, 44,8%; and the Stipagrostis ciliata community with 42,9% similarity.

These floristic similarities supported the intuitive expectation that pans provided habitats which were intermediate between, and therefore not necessarily similar with, those of the washes and the plains. The hard, impervious soils of the pans were not as readily colonized as were the loose wash soils, but water was more plentiful than on the plains, at least for a while. As with the question of structural variability (see above), the data were insufficiently detailed to determine whether the stands were simply intermediates between various riverine and plains communities or whether they truly represent communities. It will be necessary to carry out observations over a number of years to determine whether the individual pans always support the same assemblage of plants or if different species-groups develop each season. This is particularly important in the case of the Aristida adscencionis - Eragrostis annulata nodum described above because stands were both very restricted in extent and differentiated from other communities by annual species alone.

In some pans the drying up of ground-water strikingly influenced the phenology of the vegetation. Concentric zones of plants (of the same species) at the same phenophase marked the stages of drying out of the soil; plants at the outer edge of the pan flowered and set seed before those at the centre of the pan began to flower. This suggested that many of the species could not tolerate inundation and acted as opportunists, colonizing the substrate where soil moisture conditions were most suitable for the species.

5.4.5 Relationships of the communities of the pans to the desert vegetation

Because of the intermediate position of the pans (between the riverine and plains communities - see above) the discussion of the floristic and ecological relationships will be deferred until the plant communities of the plains have been described.

5.5 Communities of the "Namib fog desert" and the inland plains.

5.5.1 Introduction.

The flat or very gently undulating peneplains of the Namib Desert extend from close to the coast to the foot of the Great Escarpment, and therefore stretch from the relatively wet pro-Namib through the extremely arid region where rain and fog are infrequent to the coastal area where almost all moisture is derived from the fog. These climatic zones are sufficiently well marked to produce a gradient of vegetation types form west to east, and a number of different communities were found on the almost flat plains.

5.5.2 Description of the communities.

5.5.2.1 The Salsola nollothensis community (Table VI).

Differential species. Salsola nollothensis; Chamaephyte or Nanophanerophyte; differential against all other communities.

Slope of sites : Average 0°18'; Range 0° to 5°00'; S.D. 0°31'.
Aspect : Variable; stands covered entire hummocks, thus there is no meaningful aspect.
Number of vegetation strata : 1.
Aerial cover : Average 19%; Range 10% to 30%; S.D. 7,42%.
Number of species : Only 1 species was recorded.

Description of the community.

Habitat (1) General.

The Salsola nollothensis community was found only on sandy areas close to the coast. The plants trapped wind-blown sand and in this way produced large hummocks or sand ridges (Plate 30). Wind action was severe, particularly on the seaward sides of the hummocks, and seemed to reduce the height of the plants; on the sheltered landward side plants were taller and of less uniform height than on the windward side. The sand between the plants was very unstable and easily moved by even gentle winds.

(2) Substrate.

It consisted of unstable sand which varied from fine grained, with considerable mica and organic material, on the larger hummocks with large plants (relevés 295, 296 and 297, Table VI) to medium grained dune sand on smaller hummocks with smaller (younger) plants (relevés 197 and 105, Table VI). The dry consistence was loose to soft.

Physiognomy.

This was a community of dwarf shrubs, up to about 1,0 m tall, occupying hummocks which were from 0,20 m to 5 m in height (Plate 30). In addition to the plants being smaller, cover was also lower on hummocks close to the sea than on those further inland where wind action and wind-borne sea spray were less severe .

Distribution.

(The location of relevés is illustrated in Map 7). In the study area the Salsola nollothensis community occurred in a 10 km wide strip along the coast from Sandwich Harbour to just south of Walvis Bay. It was particularly well developed, that is, consisting of large plants and covering extensive areas, in the hummocks and small dunes near the southern arm of the Kuiseb River (Map 2).

The community also occurred at Wortel (a few kilometres south of Walvis Bay), where it occupied an area of a number of square kilometres; in the dune belt between Walvis Bay and Swakopmund and in the southern and northern Namib Desert (pers. obs., Robinson & Giess, 1974 and Giess, 1969).

Accompanying species.

No other species were recorded from the sample sites (Table VI).

Notes.

The community was very well developed where groundwater was available,

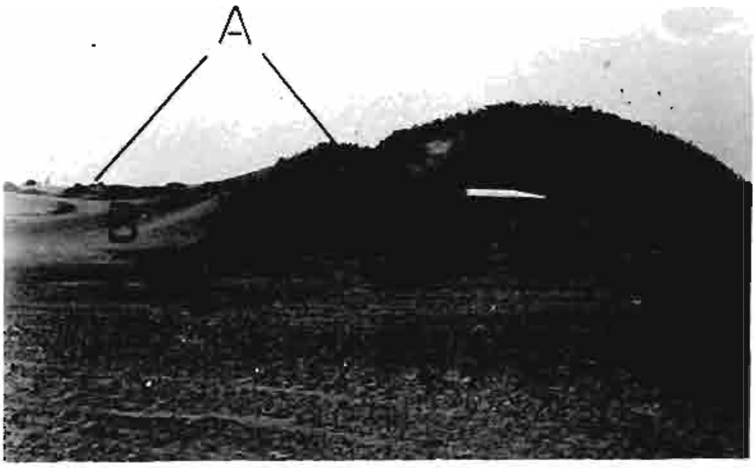


Plate 30

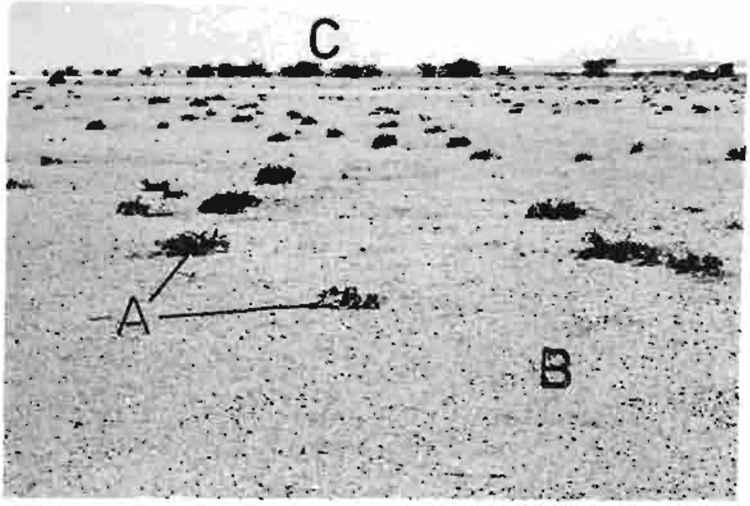


Plate 31

Plate 30

Approximately 10 km from the coast between Walvis Bay and Sandwich Harbour. Salsola nollothensis plants have trapped wind-borne sand (B) to form large hummocks (A). The soil of the coastal salt pan (C) is covered by a crust which may become very hard.

Plate 31

Approximately 15 km east of Mirabib. This photograph illustrates the typical sub-community of the Salsola tuberculata community. Here, the dwarf shrubs (A), Salsola tuberculata were growing in gypsum-rich soil which was overlain by a coarse fraction of quartz pebbles (B). In the distance (C) an Adenolobus pechuelii - Acacia reficiens community occupied a wash.

that is, in the lower Kuiseb River. However, its widespread distribution in the fog zone suggested that the most important criterion is the reliability of the water supply rather than its source.

Although no other species were recorded from stands in the study area, a number of species were found in the same habitat as Salsola nollothensis in the southern Namib Desert (Robinson & Giess, 1974) . In the dunes between Wortel and Walvis Bay the hemicryptophyte, Crotalaria schultzei was a frequent accompanying species (pers. obs.).

It seemed likely that the distinctiveness of the community was probably due to the harsh environment - the substrate was unstable and many sites were exposed to strong wind action and sea spray. Although the source of water is not known for certain, it seems likely that fog provides a reliable source of moisture for most of the year, but measurements are required to determine the quantity of moisture which a shrub could trap (see 4.7.3 above for a discussion of the quantity of fog received and its significance).

5.5.2.2 The Salsola tuberculata community (Table VI).

Differential species. Salsola tuberculata; Chamaephyte. With high constancy (Table VII) this species was differential against other communities of the area.

Four sub-communities were recognised :

(a) The typical sub-community in which Salsola tuberculata alone was differential against the other sub-communities.

(b) The Zygophyllum stapfii sub-community where Zygophyllum stapfii and Aloe asperifolia, leaf-succulent Chamaephytes and Dyerophytum africanum , Chamaephyte were differential against other sub-communities.

(c) The Arthraerua leubnitziae sub-community where Arthraerua leubnitziae, Chamaephyte was differential against the other sub-communities.

(d) The Stipagrostis obtusa sub-community, having Stipagrostis obtusa, Hemicryptophyte/Therophyte, that is, in the lower Kuiseb River. However, its widespread distribution in the fog zone suggested that the most important criterion is the reliability of the water supply rather than its source.

Although no other species were recorded from stands in the study area, a number of species were found in the same habitat as *Salsola nollothensis* in the southern Namib Desert (Robinson & Giess, 1974) . In the dunes between Wortel and Walvis Bay the hemicryptophyte, *Crotalaria schultzei* was a frequent accompanying species (pers. obs.).

It seemed likely that the distinctiveness of the community was probably due to the harsh environment - the substrate was unstable and many sites were exposed to strong wind action and sea spray. Although the source of water is not known for certain, it seems likely that fog provides a reliable source of moisture for most of the year, but measurements are required to determine the quantity of moisture which a shrub could trap (see 4.7.3 above for a discussion of the quantity of fog received and its significance).

5.5.2.2 The *Salsola tuberculata* community (Table VI).

Differential species. *Salsola tuberculata*; Chamaephyte. With high constancy (Table VII) this species was differential against other communities of the area.

Four sub-communities were recognised :

(a) The typical sub-community in which *Salsola tuberculata* alone was differential against the other sub-communities.

(b) The *Zygophyllum stapfii* sub-community where *Zygophyllum stapfii* and *Aloe asperifolia*, leaf-succulent Chamaephytes and *Dyerophytum africanum* , Chamaephyte were differential against other sub-communities.

(c) The *Arthraerua leubnitziae* sub-community where *Arthraerua leubnitziae*, Chamaephyte was differential against the other sub-communities.

(d) The *Stipagrostis obtusa* sub-community, having *Stipagrostis obtusa*, Hemicryptophyte/Therophyte, Enneapogon brachystachyus, Euphorbia glanduligera, Stipagrostis uniplumis var. intermedia and Trianthema triquetra ssp. parvifolia ; Therophytes and Zygophyllum cylindrifolium;Chamaephyte, were differential against the other sub-communities. Salsola tuberculata served to differentiate between this sub-community and the floristically similar Sesuvium sesuvioides - Stipagrostis obtusa and Petalidium setosum communities (5.3.2.9 and 5.3.2.8 above).

Description of the sub-communities.

5.5.2.2 (a) The typical sub-community.

Slope of sites : Average 3°50'; Range 0° to 25°00'; S.D. 8°47'
Aspect : Variable.
Number of vegetation strata : 1 or 2 of higher plants; lichens.
Aerial cover : Average 13%; Range 2% to 60% ; S.D. 16,44%.
Number of species : Average 3; Range 1 to 10; S.D. 2,53.

Habitat (1) General.

Virtually flat plains or very shallow drainage lines were the commonest habitats, with only a few stands occupying other sites; relevé 122 was taken from a wash, relevé 316 from a talus slope and relevé 93 was taken in a stand colonizing a saline wash. The sub-community occurred in the zone where fog and rain were infrequent (see Distribution, below).

(2) Substrate.

Geologically, the substrate was variable, with sandstone, schist and granite all supporting stands of the community. There was usually a sub-surface layer of calcrete or gypcrete, while in relevé 93 this layer was formed by salt (Table VI). Such a sub-surface layer must influence run-off and drainage through the profile and may also adversely affect establishment of plants because of the effects on root growth.

Two main types of soil were recognisable depending whether the soil was derived from calcrete or gypcrete (3.4.3 and 3.4.4 above). The soil depth varied considerably, form 0,10 m to greater than 0,70 m, but was usually shallow (Fig 5.2).

The profile for relevé 125 was typical of a site underlain by calcrete :

0 - 0,05 m	softly cemented layer of calcrete with numerous pebbles.
0,05 - 0,20 m	light brown, fine to very fine sandy soil with calcrete concretions.
0,20 m	layer of solid calcrete which could not be broken with a spade.

The gypsum crust (gypcrete) soils were essentially the same as those described from sites of the Arthraerua leubnitziae sub-community and are dealt with below (5.5.2.2 (c)) because they were typical of that sub-community. The saline soil of relevé 93 was identical with soils of the Zygophyllum stapfii community (5.3.2.5 above).

Physiognomy.

The typical sub-community consisted of widely spaced, microphyllous, evergreen dwarf shrubs and some herbs (Plate 31). The dwarf shrub stratum was usually less than 0,30 m tall, but reached 1,0 m in some washe. It covered between 5% and 25% af the area in most stands. The ground layer herbs were few in number (Table VI) and covered less than 5% of the stand.

Distribution.

(The location of relevés is illustrated in Map 7). Sites occupied by the Salsola tuberculata (typical) sub-community occurred from Zwartbank eastwards to about 90 km inland (Map 2). It was therefore found in the area where fog incidence was low, and rainfall both low and erratic (4.7 above).

Accompanying species.

Thallo-Chamaephytes :

Three species of crustose lichens occurred on boulders.

Therophytes:

Aristida parvula
Enneapogon brachystachyus
Eragrostis annulata
Euphorbia inaequilatera
Euphorbia phylloclada
Limeum argute-coronatum
Tribulus terrestris
Zygophyllum simplex

Hemicryptophytes: (all these often behaved as Therophytes).

Indigofera auricoma	Stipagrostis hochstetterana
Osteospermum microcarpum	S. obtusa
Stipagrostis ciliata	

Chamaephytes:

Psilocaulon salicornioides	Zygophyllum cylindrifolium
Tephrosia dregeana	

Nanophanerophyte :

Pechuel-Loeschea leubnitziae

Notes.

As Table VI and the species list indicate, Stipagrostis ciliata and other grassland species occurred in some stands. These "invading" species were always found on disturbed microhabitats near animal burrows or where the soil had been disturbed by animal activities. It is possible that seeds were carried there by animals, but their germination and survival seemed more likely to be associated with soil factors. In this disturbed soil water soaked in more rapidly than in the surrounding areas (pers. obs.), and this presumably provided more suitable microenvironments for seedlings. This hypothesis was supported by the increase in number of species in the easterly sites (relevés 125 and 57), where rainfall was higher. Increased rainfall and the associated greater availability of water enabled a greater variety of species to grow and increased seedling survival resulted in denser stands of vegetation.

Lichens occurred in the most westerly sites (relevés 321, 322 and 316, Table VI). This was certainly in response to increased relative humidity and reduced eveporation resulting from the fog, as lichens are known to absorb water vapour from moist air and lose water under conditions of rapid evaporation (Hale, 1967). It is to be expected, therefore, that lichens would be favoured by conditions of high relative humidity and low evaporation rates.

5.5.2.2 (b) The Zygophyllum stapfii sub-community.

Slope of sites :Average $8^{o}39'$; Range 0^{o} to 23^{o}; S.D. $10^{o}00'$.
Aspect :Westerly.
Number of vegetation strata : 2 of higher plants plus lichens.
Aerial cover :Average 8%; Range 2% to 45%
Number of species :Average 7; Range 2 to 17; S.D. 4,46.

Habitat (1) General.

Stands of this sub-community developed on sloping sites on rock outcrops (Plate 32) in the fog zone (Map 7). One stand, represented by relevés 92, 94 and 95 (Table VI) was found in a saline wash (see Notes below).

(2) Substrate.

The soil was mostly sandy or gravelly and of loose consistence, although the soil of relevé 422 was loamy mica sand, and relevés 92, 94 and 95 had saline soils with a hard salt-clay crust similar to those described above and illustrated in Plate 4. On the more steeply sloping sites soil was only found in crevices in the rock and average soil depth was only 0,09 m (Table VI and Fig 5.2). Bare rock frequently occupied much of the area of a stand, and this presented a large surface area on which fog could condense before collecting in cracks (Plate 32).

No profile description is given because the soil was not differentiated into layers except in the saline wash (relevés 92, 94 and 95, Table VI), and these soils were described in the *Zygophyllum stapfii* community (5.3.2.5 above).

Physiognomy.

The *Zygophyllum stapfii* sub-community was composed of two strata of higher plants and in the western parts of the community's distribution range lichens formed a layer on the soil surface. The dwarf shrub stratum, 0,20 m to 0,50 m tall and covering 2% to 10% was the most prominent. The ground layer was less than 0,10 m tall and covered between 1% and 5% of the area.

Distribution.

This nodum was found along the hills and mountains north of Gobabeb, extending from Zwartbank in the west to Mirabib in the east (Map 2). It therefore stretched from the edge of the fog zone through the extremely arid area to the edge of the rain zone. In terms of numbers of species, the sub-community was best developed in those stands which occupied the mountain ranges at the edge of the fog zone (relevés 384, 385, 388 and 389, Table VI).

Accompanying species.

Thallo-Chamaephytes:

Three species of crustose lichens.

Therophytes:

Aristida parvula
Calostephane marlothiana
Enneapogon brachystachyus
Euphorbia phylloclada
Lotononis platycarpa
Mollugo cerviana
Monsonia umbellata
Senecio engleranus
Stipagrostis subacaulis
S. *uniplumis* var. *intermedia*
Triraphis pumilio
Zygophyllum simplex

Geophytes:

Albuca sp. (R87311)

Hemicryptophytes:

(a) Those which frequently behaved as Therophytes.

Brachiaria glomerata
Helichrysum leptolepis
Indigofera auricoma
Stipagrostis ciliata
S. obtusa

(b) Those which were almost always perennial.

Asparagus denudatus
Enneapogon scaber
Gazania jurineifolia
Geigeria ornativa
Osteospermum microcarpum
Sesuvium sesuvioides
Trichodesma africanum

Chamaephytes:

Arthraerua leubnitziae
Blepharis bossii
Calicorema capitata
Chascanum gariepense
Euphorbia lignosa
Galenia africana
Kleinia longiflora
Mesembryanthemum guerichianum
Orthanthera albida
Petalidium setosum
Stipagrostis lutescens
Tephrosia dregeana

Nanophanerophytes:

Commiphora saxicola
Pechuel-Loeschea leubnitziae

Macrophanerophyte:

Euclea psuedebenus

Notes.

Relevés 92, 94 and 95 (Table VI) were taken in a broad saline wash where stands of the *Zygophyllum stapfii* community (p 97 above) were also established. Although these relevés were included in the *Salsola* tuberculata community on the basis of the presence of *Salsola*, they

Plate 32.

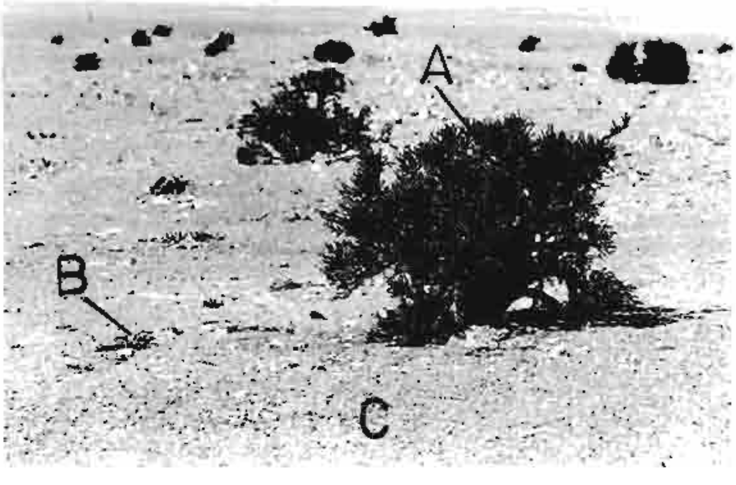


Plate 33.

Plate 32

Zwartbank mountain, showing a stand of the *Zygophyllum stapfii* sub-community of the *Salsola tuberculata* community. Zwartbank is a marble outcrop (A) which is dissected by dykes of dolerite (B). *Aloe asperifolia* (C) and *Zygophyllum stapfii* (D) were prominent characteristic species of the sub-community.

Plate 33

A stand of the *Arthraerua leubnitziae* sub-community near Zwartbank. *Arthraerua leubnitziae* (A) was a leafless dwarf shrub with photosynthetic stems. Although *Salsola tuberculata* (B) was present in most stands, it covered an insignificant area. The soil which developed on a gypsum crust frequently had a superficial layer of pebbles (C).

were clearly transitional between the *Zygophyllum stapfii* sub-community and the *Z. stapfii* community. This is indicated by the absence of most differential species of the *Z. stapfii* sub-community, (Table VI), the habitat (which is atypical for the sub-community) and geographical location (Table VI and Map 7).

From the data (Table VI) it seems that two faciations (if they are climax communities - Phillips, 1970) were present. These were; a western form with *Aloe asperifolia*, *Euphorbia lignosa*, *Senecio engleranus* and crustose lichens which colonized outcrops of metamorphic rock in the fog zone; and, an eastern form, which occurred beyond the zone of frequent fog occurrence, without these species.

5.5.2.2 (c) The *Arthraerua leubnitziae* community.

Slope of sites : Average 0°58'; Range 0° to 5°00'; S.D. 1°36'.
Aspect : Westerly or northerly.
Number of vegetation strata : Usually 1, rarely 2 of higher plants plus lichens.
Aerial cover : Average 6%; Range 2% to 15%; S.D. 4,43%.
Number of species : Average 3; Range 1 to 5; S.D. 1,27.

Habitat (1) General.

This sub-community occurred on flat or gently undulating plains and rounded outcrops of granite or dolomite. Most stands developed on sites with a westerly aspect because of the increased moisture derived from fog-bearing winds striking these slopes as they move from the sea.

(2) Substrate.

In the habitats occupied by this sub-communiy the soil was shallow, never exceeding 0,30 m with an average depth of 0,11 m (Fig 5.2), and a gypcrete crust occurred frequently (relevés 426, 318, 424, 324, 323, 423 and 420, Table VI). The profile from relevé 424, situated about 40 km inland and at 300 m a.s.l., is described as an example.

0 - 0,02 m	brown coloured loamy sand having a slightly hard consistence and with quartz pebbles.
0,02 - 0,15 m	light brown, soft loamy sand.
0,15 - 0,20 m	greyish-brown gypsum crust.
0,20 m	bedrock granite.

Physiognomy.

The community was composed of dwarf shrubs having leaves reduced to scales (photosynthesis being carried out by the green stems) from 0,15 m to 0,50 m in height with aerial cover of 2% to 12%. The dwarf shrubs were often so widely spaced that they barely constituted a stratum (Plate 33, relevé 323). The ground layer was extremely sparse and relevé was taken from the only stand where this stratum attained appreciable cover (4%), although lichens often covered the rocks and even grew on the soil surface.

Distribution.

(The location of relevés is illustrated in Map 7). This sub-community only occurred in a belt from 20 km to 50 km inland and between about 150 m and 300 m a.s.l., north of the Kuiseb River, and was apparently restricted to the fog zone.

Accompanying species.

Thallo-Chamaephytes:

Four species of lichens.

Therophytes:

Celosia spathulifolia	Stipagrostis ciliata

Chamaephytes:

Kleinia longiflora	Zygophyllum stapfii
Trichocaulon clavatum	

Notes.

Within the study area, the Arthraerua leubnitziae sub-community was restricted to the area of gypsum soils (see Scholz, 1972 and 3.4.4 above). It is not clear from the data whether the community developed in response to factors associated with the soils, the incidence of fog or other unidentified factors. It seems probable, however, that the lichen component was only able to become established because of the incidence of fog.

Walter (1971, p 351) noted that in the area near Swakopmund Arthraerua leubnitziae formed sand hummocks by trapping wind-blown sand. This did not occur in the study area because the substrate was stable and not prone to wind erosion. Closer to the coast, along the road between Walvis Bay and Rooibank (Map 2) where sand movement was more marked small deposits were found piling up on the leeward sides of the bushes.

5.5.2.2 (d) The Stipagrostis obtusa sub-community.

Slope of sites : Average $0^{0}39'$; Range 0^{0} to $4^{0}00'$; S.D. $1^{0}01'$.
Aspect : Variable, frequently easterly or southerly.
Number of vegetation strata : 1 or 2.
Aerial cover : Average 17%; Range 5% to 45%; S.D. 8,49%.
Number of species : Average 9; Range 2 to 18; S.D. 4,15.

Habitat (1) General.
Flat or gently sloping plains, ridges, very frequently on the toe-slopes of pediments or shallow drainage lines. Sheet flow run-off was a feature of most sites, and was even noted after only 3 – 5 mm of rain had fallen.

(2) Substrate.
The substrate seemed to be of considerable importance in determining the establishment and development of this sub-community.

Soil was generally shallow although considerable variation did occur. The depth was usually less than 0,26 m, with an average of 0,15 m (Fig 5.2) and the texture was coarse to moderately coarse (sandy loam or loamy sand), usually with a superficial pebble layer. A calcrete layer was present at most sites (Table VI), which had a marked influence on percolation into the soil. Small scale variation in soil consistence was very important in determining the floristic composition of stands (see Notes below).

The profile from relevé 84 provided a good example of the soil from the sub-community.

0 – 0,02 m	superficial layer of pebbles forming a "desert pavement" which protected the underlying soil from wind erosion.
0,02 – 0,10 m	light brown, fine grained sandy loam soil with many calcrete concretions.
0,10 m	solid layer of calcrete which could not be broken with a spade.

Plate 34.

Plate 35.

Plate 34

Plains east of Heinrichberg, where the *Stipagrostis obtusa* sub-community of the *Salsola tuberculata* community was well developed. *Salsola tuberculata* (A), *Stipagrostis obtusa* (B) and *Enneapogon brachystachyus* (C) dominated the site.

The soil was shallow, overlying calcrete in most places, and had a superficial layer of pebbles (D).

Plate 35

The *Stipagrostis ciliata* community on the plains between Mirabib and Hope Mine, photographed following rain in March 1974.

Dense patches of *Stipagrostis ciliata*, with many plants forming perennial tufts, occurred where water soaked into the soil rapidly (A). Where a foam structure underlay the surface layer water soaked in much more slowly, allowing greater run-off and cover of the grass was markedly lower (B).

Physiognomy.

The *Stipagrostis obtusa* sub-community was a grassland formation with scattered dwarf shrubs. Physiognomically, the herb layer, between 0,10 m and 0,15 m tall, with aerial cover of 5% to 30% and composed of tuft forming grass (Plate 34) was the most important stratum. The dwarf shrubs and short or medium height grass often formed an open stratum covering a maximum of 12% of the area and 0,20 m to 0,45 m in height.

Distribution.

(The location of relevés is shown in Map 3). Distributed on the pro-Namib plains where soil was shallow and especially where calcrete was present.

Accompanying species.

Therophytes:

Aizoanthemum dinteri
Amaranthus thunbergii
Anticharis inflata
A. linearis
Aristida parvula
Cleome diandra
Euphorbia inaequilatera
E. phylloclada
Geigeria alata
Hermannia modesta
Limeum argute-coronatum
Limeum sulcatum
Lotononis platycarpa
Mollugo cerviana
Monechma desertorum
Monsonia umbellata
Pegolettia senegalensis
Polygala pallida
Schmidtia kalahariensis
Tribulus terrestris
T. zeyheri
Zygophyllum simplex

Hemicryptophytes:

(a) Those which often behaved as Therophytes

Crotalaria podocarpa
Indigofera auricoma
Stipagrostis ciliata
S. hochstetterana

(b) Those which were almost always perennial

Aptosimum angustifolium
Cleome luederitziana
Eragrostis nindensis
Geigeria ornativa

Chamaephytes:

Adenolobus pechuelii	Petalidium setosum
Blepharis obmitrata	Psoralea obtusifolia
Kohautia lasiocarpa	Tephrosia dregeana
K. virgata	

Notes.

As noted earlier, variation in substrate produced marked changes in species composition over small distances. For example, in relevé 228 (Table VI) the soil was generally between 0,10 m and 0,15 m deep, and was described as a fine to very fine grained, light brown sandy loam with slightly hard consistence. However, there were patches of one to two metres in diameter within the 10 X 5 m sample plot where the soil was deeper (about 0,25 m deep) and markedly less compact (the dry consistence was loose). In these soft patches, cover and density were as much as tenfold higher than outside; tufts of Stipagrostis ciliata and Stipagrostis hochstetterana occurred and Monechma desertorum plants were numerous, while only isolated Stipagrostis obtusa and Enneapogon brachystachyus plants were noted. Conversely, on the harder soil Stipagrostis obtusa was dominant, Stipagrostis hochstetterana was absent and only first year (that is, plants that had germinated after the previous rainy period) Stipagrostis ciliata plants were found. The reasons for this are not certain at this stage, but it may have beeen because less water penetrated the hard soil than the soft patches (3.4.3 above), which restricted germination and/or seedling survival.

The soft patches may have been produced by animals digging or scratching and in this way breaking the hard surface crust or they may have been a result of the dense plant cover: If a seedling becomes established in a bare area the roots will penetrate the soil and the plant will tend to reduce run-off. This increased water supply together with the mechanical effects of root growth could break the surface crust or foam soil layers which in turn favour the establishment of more plants, further increasing the area of softened soil. The data obtained to date give no indication as to which hypothesis is most tenable or whether both may be valid in different situations.

In other areas where the soil was disturbed, for example, relevé 225 (Table VI), patches of up to several hundred square metres were occupied solely by Zygophyllum simplex. This succulent leaved Therophyte occurred widely in the study area and invaded disturbed soil such as ground squirrel (Xerus inauris Zimmerman) colonies, dust bath patches produced by large animals and areas of heavy trampling (pers. obs.). The most likely explanation is that soil is softer, facilitating root growth and water penetration. However, other factors such as selective grazing of the grasses or transport of Zygophyllum simplex seeds probably play a role.

Relevés 68, 145 and 228, with high cover-abundance of Stipagrostis ciliata (Table VI) were intermediate between the S. obtusa and S. ciliata noda, but have been included in the former because of the overall species composition.

The Stipagrostis obtusa sub-community covered a large part of the pro-Namib plains and was exceeded in areal extent only by the Stipagrostis ciliata community. The nomonate species of both these noda are palatable and able to invade arid areas rapidly because of their wind-borne seeds (Acocks, 1970). These species were therefore a significant food source of the grazing animals of the Namib Desert Park. The communities covered large areas because the seeds were sufficiently widely distributed to be able to take advantage of favourable conditions whenever and wherever they occurred.

The syntaxonomic position of the Stipagrostis obtusa nodum could not be determined with the data available, but it appeared to belong to the Alliance Stipagrostion prov. of Werger (1973a). It must be emphasised, however, that the area covered by the "white desert grasses" (Acocks, 1953), that is the grasses of the genus Stipagrostis, is very extensive throughout southern Africa, and the present sample of 25 relevés, from a relatively small area, is not representative enough for the construction of a scientifically sound syntaxonomic hierarchy (refer to the introduction to Ch 5 for further discussion of this point).

5.5.2.3 The *Stipagrostis ciliata* community (Table VI).

Introductory note.

This widespread grassland community posed problems of classification because it was characterized floristically by the absence of differential species of any other community, and the dominant, *Stipagrostis ciliata*, occurred in virtually every other nodum in the area (Table VII). As a result, the structure (a one or two layered community of herbs) had to be used as an additional diagnostic feature. Westhoff (1967) has discussed the use of structure for the purpose of characterizing syntaxa in the Braun-Blanquet system, and concluded that structure was a significant diagnostic feature of an association.

Differential species : *Stipagrostis ciliata*; Hemicryptophyte, but one which frequently behaved as a Therophyte. As sole dominant of a grassland community this species was differential against other noda.

Slope of sites : Average 1°08'; Range 0° to 14°30'; S.D. 2°40'.
Aspect : Variable.
Number of vegetation strata : Usually 1, sometimes 3.
Aerial cover : Average 13%; Range 1% to 35%; S.D. 9,97%.
Number of species : Average 5; Range 1 to 15; S.D. 3,03.

Description of the community.

Habitat (1) General.

This community occupied flat plains, gently sloping pediments, drainage lines and slopes of ridges. Although the slope was usually small, run-off was high and aggravated by soil structure and the local environment was therefore usually very dry.

(2) Substrate.

The wide variety of soil types that supported this community, the large areal extent (Map 3) and the close relationship between rainfall and development of stands (see Notes below) implied that the community developed in response to climatic rather than edaphic conditions.

The soil varied from gravel sands in relevés 120, 121, 15, 135, 142, 149 and 70 through to fine grained soils in relevés 13 and 123 (Table VI) . A prominent and highly significant feature was the formation of an impervious layer of "foam soil" at various depths. The foam soils, which were not uniformly developed over the area occupied by the *Stipagrostis ciliata* community, played a major role in determining the water status of the soil. It restricted infiltration and consequently increased run-off, which in turn reduced the amount of water in the soil and thus plant growth (see 3.4.3 above). The following profile descriptions illustrated the range of soil conditions in the areas colonized by the *Stipagrostis ciliata* community.

(a) Relevé 100. Situated on a smooth plain 11 km east of Gobabeb.

0 - 0,02 m	brown, fine grained sandy soil covered by a layer of quartz pebbles.
0,02 - 0,20 m	brown, fine grained, soft sandy soil.
0,20 - 0,40 m	light grey-brown, very fine grained hard soil. This was the foam layer.
0,40 - 0,65 m	brown, fine, soft sandy soil and pebbles.

(b) Relevé 117. NNE of Gobabeb, approximately 75 km inland.

0 - 0,05 m	greyish-brown, fine grained, hard soil with a coarse superficial layer of pebbles.
0,05 - 0,15 m	greyish-brown, fine grained, soft soil with no pebbles. The soil was markedly softer where patches of vegetation grew.
0,15 m	Upper surface of impenetrable calcrete layer.

(c) Relevé 315. Situated on the flat plains east of Amigab (Map 2), at about 1 000 m above sea level.

0 - 0,05 m	quartzite gravel, up to 5,0 mm in diameter, and light brown, fine grained, soft soil.
0,05 - 0,20 m	light brown, fine grained, soft loamy soil.
0,20 - 0,50 m	as in the previous stratum, but the consistence was hard to very hard.

In this community soil was generally deeper than in the *Stipagrostis obtusa* sub-community (5.3.2.2 (d) above), the average depth being 0,40 m (Fig 5.2). Underlying calcrete occurred at some sites (relevés 98, 102, 103, 136, 120, 121, 135, 144, 69 and 63, Table VI).

Physiognomy.

This was a grassland community with one or two strata. The ground layer was less than 0,10 m tall and covered 1% to 30% of the area. Sometimes a taller stratum of tall grasses, forbs and occassional dwarf shrubs between 0,20 m and 0,40 m tall and with aerial cover up to 25% occurred above the ground layer.

Stipagrostis ciliata, the nominate species, occurred as both perennial and annual individuals. The perennial tufts grew most commonly in drainage lines and animal dust-bath patches where water soaked into the ground most rapidly. In many cases it was these older plants that formed the taller stratum.

Distribution.

(The location of relevés is illustrated in Map 3). During the study period Stipagrostis ciliata grassland was observed between about 60 km inland, at 500 m a.s.l., and the eastern boundary of the Namib Desert Park at 1 000 m a.s.l. (Map 2). It therefore extended through the entire pro-Namib in suitable habitats into the extremely arid area, where the community developed after rain. In the latter part of its range the species behaved almost exclusively as an annual.

Accompanying species.

Therophytes:

Aizoanthemum dinterii
Anticharis linearis
Aristida parvula
Enneapogon brachystachyus
Eragrostis annulata
Euphorbia glanduligera
E. inaequilatera
E. phylloclada
Geigeria alata
Heliotropium oliveranum
Hermannia modesta
Limeum argute-coronatum

Lotononis platycarpa
Mollugo cerviana
Monechma desertorum
Stipagrostis hirtigluma
S. subacaulis
S. uniplumis var. uniplumis
Trianthema triquetra
ssp. parvifolia
Tribulus terrestris
Triraphis pumilio
Zygophyllum simplex

Geophytes:

Dipcadi bakeranum
Eriospermum roseum
Hexacyrtis dickiana
Ornithogalum stapfii
Ornithoglossum viride
Raphionacme sp. (S-R 10)
Trachyandra laxa

Hemicryptophytes:

(a) Those which frequently behaved as Therophytes.

Asthenatherum glaucum
Brachiaria glomerata
Indigofera auricoma
Stipagrostis hochstetterana
S. obtusa

(b) Those which were almost always perennial.

Cleome luederitziana
Eragrostis nindensis
Geigeria ornativa

Chamaephytes:

Hermannia complicata
Kohautia lasiocarpa
K. ramosissima
Monechma arenicola
Salsola tuberculata
Tephrosia dregeana

Nanophanerophytes:

Boscia foetida
Commiphora saxicola
Sarcocaulon mossamedense

Macrophanerophyte:

Moringa ovalifolia

Notes.

The distribution was closely correlated with the occurrence of rain showers. For example, the westernmost site recorded during the study period was a small area (approximately 100 ha in extent) where a light shower of rain fell in April 1973, and by May a sparse stand of *Stipagrostis ciliata* had developed. This was the only stand of grass, or any annual plants, in a radius of 10 km.

The occurrence of "foam soils" (3.4.3 above) contributed to the marked patchiness of cover within the community (Plate 35) on the plains east of Gobabeb.

Microtopographic features such as extremely shallow runnels exerted a striking influence on the development of this community: after rains in 1972, a sparse cover of the community colonized the runnels on the plains east of Miarbib. The rains in 1973 allowed the cover to increase in the runnels and isolated plants colonized the intervening plains; good rains in 1974 resulted in thickening up of the stands in runnels until aerial cover was about 50%, formed by perennial tufts. The plains were also relatively well covered (25%), but by annual plants. In addition, plants in the runnels flowered earlier than those on the plains.

5.6 Discussion of results and notes on the inter-relationships of the communities of the river, washes, pans, plains and rock outcrops

5.6.1 Slope and aspect

Slope, or in many cases the absence of any slope, was extremely important in many of the communities (5.3 to 5.5 above), because of its influence upon drainage. Many wash communities (the Adenolobus pechuelii - Acacia reficiens, Petalidium setosum, Asclepias buchenaviana and typical Acacia giraffae subcommunity noda) colonized areas where there were very slight slopes such as those formed at the lower levels of the gently undulating plains or on pediments of hills. Because of the gentle slopes, these washes collected quantities of run-off water that were of considerable significance in vegetation development. Very often, therefore, it is the slope outside the community that is most important since it channels water to a collection point. Once there the most important factor was the duration of the supply rather than the amount. Where the substrate favoured water retention vegetation development was favoured. The communities (Sesuvium sesuvioides - Stipagrostis obtusa, Petalidium variabile and Commiphora glaucescens - Anthephora pubescens) of rock outcrops, on the other hand, were often found on steeply sloping sites, but once again, it was not the slope that was significant: in this habitat the water that fell on bare rock would soon evaporate if it were not accumulated in drainage lines. For this reason, steep slopes that were not associated with distinct erosion lines or plateaux did not provide suitable conditions for the development of vegetation. In the fog zone, the slope was especially important on rock outcrops, because most precipitation occurred when moist air blew against a rising surface where it condensed (see 4.7.3).

In the southern hemisphere south-facing slopes receive less insolation than do north-facing slopes (Oosting, 1956, pp. 89 - 91 and also Schulze, 1970) and thus the former may be expected to be cooler and moister than the latter. In the study area, however, development of most communities was independent of aspect (5.3 to 5.5). This was probably because the extreme aridity and high air temperature of the entire area exerted an over-riding influence on water relations.

5.6.2 Environmental gradients which seem significant to the development of vegetation (Fig. 5.4 and Maps 3 to 7)

Most of the variability of the vegetation can be explained in terms of three environmental gradients, namely from dry to moist, deep to shallow substrate and fresh to saline groundwater (Fig. 5.4).
It would be instructive to carry out a formal ordination of the data to determine more precisely the relative positions of the communities with regard to these as well as less obvious gradients, but this is not the aim of this study, and will not be attempted here.

As may be expected in an arid environment, the most important gradient was increasing water supply. This was influenced by such factors as type of substrate, its depth, presence of impervious layers and quantity of run-off which is collected. As noted in the section dealing with climatic factors, there were two zones of comparatively (for the Namib Desert) high precipitation, namely the fog zone and the eastern portion where rainfall increased. These two forms of precipitation differed in two important respects, namely, quantity and reliability. Fog provided relatively small quantities of moisture (according to Walter (1971) it wets only the top 1 to 3,5 cm) but is very reliable and of long duration (see 4.7.3 above) at least on the coast. Rain, on the other hand, provided large volumes of water (frequently in the form of heavy showers in which case much water was lost by run-off and caused considerable erosion (pers. obs.)), but even on the eastern edge of the Namib Desert it was highly unreliable (see 4.7.2 above). It therefore appeared that fog was a dependable source of small quantities of water for a large portion of the year, whereas rain was unreliable, a considerable proportion of the water was lost by run-off unless it was trapped, and occurrence was restricted to a few days per year. This seemed to be reflected in the life forms of communities in these zones, as Therophytes (which behaved as

TABLE 5.1. LIFE-FORM SPECTRA FOR COMMUNITIES OF THE RIVER, WASHES, PANS, PLAINS AND ROCK OUTCROPS OF THE STUDY AREA.

COMMUNITY	TOTAL No. OF SPP.	T %	G %	H %	Ch %	N %	M %
Asclepias buchenaviana	14	28,6			50,0	21,4	
Acacia giraffae							
(a) Typical sub-com.	79	40,5	5,1	17,7	24,0	7,6	5,1
(b) *A. albida* sub-com.	62	45,1	5,1	20,9	11,3	9,6	8,0
Datura spp.-*Argemone ochroleuca*	45	48,8	4,4	22,2	8,9	8,9	6,7
Adenolobus-*Acacia reficiens*	72	37,5	4,2	12,5	25,0	12,5	8,4
Mesembryanthemum – *Sporobolus nebulosus*	25	48,0		20,0	20,0	12,0	
Petalidium setosum	86	36,0	1,2	20,9	32,6	7,0	2,4
Sesuvium-*Stipagrostis obtusa*	43	37,2	4,7	20,9	23,2	9,3	4,7
Monechma genistifolium	69	29,0	2,9	23,2	34,8	7,3	2,9
Petalidium variabile	109	33,0	2,7	26,6	25,7	7,3	4,6
Commiphora – *Anthephora pubescens*	101	27,7	3,0	23,8	30,7	8,9	5,9
Platycarpha carlinoides	3			100			
Calicorema capitata							
(a) *Aptosimum* sub-com.	8	25,0		37,5	37,5		
(b) Typical sub-com.	6	16,7		50,0	33,3		
Aristida – *Eragrostis annulata*	43	53,5		20,9	9,3	9,3	7,0
Salsola nollothensis	1				100		
Pechuel-Loeschea	31	22,6	6,5	25,8	35,5	9,7	
Zygophyllum stapfii	18	33,3		27,8	27,8	11,1	
Salsola tuberculata							
(a) Typical sub-com.	17	47,1		23,5	23,5	5,8	
(b) *Zygophyllum stapfii* sub-com.	44	27,2	2,3	27,2	36,3	4,5	2,3
(c) *Arthraerua* sub-com.	8	25,0		12,5	62,5		
(d) *Stipagrostis obtusa* sub-com.	45	60,0		20,0	20,0		
Stipagrostis ciliata	46	47,8	15,2	15,2	13,0	6,5	2,2

opportunists) were more numerous in communities of the rain zone than in the fog zone (see below).

This moisture gradient was also illustrated by the number of species per relevé, with an increase in average number from the drier habitats to the wetter habitats. The communities of the driest habitats (the *Stipagrostis ciliata* community, *S. obtusa* sub-community, and the *Asclepias buchenaviana* community) had less than five species per relevé on average, while those of the wetter habitats (the *Petalidium setosum* community, *Adenolobus pechuelii* - *Acacia reficiens* community, *Acacia giraffae* (typical) sub-community, *Acacia albida* sub-community, *Datura spp.* - *Argemone ochroleuca* community, *Petalidium variabile* community and *Commiphora glaucescens* - *Anthephora pubescens* community) averaged between 9 and 21 species per relevé (Tables IV, V and VI). Exceptions to this trend were found in the cases of communities developing in specific habitats, for example, the *Zygophyllum stapfii* (3 species), *Arthraerua leubnitziae* (3 species) and *Platycarpha carlinoides* (1 species) noda where only a few species can survive the extremes experienced.

The number of vegetation strata also tended to increase from a single stratum on the plains to three on the rock outcrops and four in the river. However, even in the driest habitats there were a number of chamaephytes (Table 5.1), and thus this trend was only significant in the wetter habitats.

Two noda, the *Zygophyllum stapfii* and *Mesembryanthemum guerichianum* - *Sporobolus nebulosus* communities, colonized saline soil where ground-water was available, while the *Adenolobus pechuelii* - *Acacia reficiens* community seemed to be able to tolerate slightly saline conditions. The remaining communities appeared to favour fresh ground-water.

The geographical distribution of some communities supported the hypothesis that fog and rainfall zones were important in the development of the various communities. For example, the *Arthraerua leubnitziae* sub-community was restricted to the fog zone (Map 7) while the *Petalidium setosum*, *Commiphora glaucescens* - *Anthephora pubescens*, *Petalidium variabile* and *Stipagrostis obtusa* noda occurred only in the eastern part of the Desert (Maps 4 and 6) where rainfall was higher and more reliable.

Soil depth seemed to be of considerable importance (Fig. 5.2), although there was notable variation in the depth of substrate within any community. There was a clear sequence of increasing depth from the Zygophyllum stapfii sub-community and Petalidium variabile community to the Datura spp. - Argemone ochroleuca community. This may well have been an indirect effect in that the plants were responding to the increased water storage and duration of supply that would be associated with greater soil depth. Although other authors (for example, Shreve, 1951; Zohary, 1961; and Obeid and Mahmoud, 1971) found similar effects of increased soil depth in arid areas no further explanation has been proposed.

5.6.3 Life forms

It was evident from Table 5.1 that most communities included a component of perennials, while in a few, the Stipagrostis obtusa, Aristida adscencionis - Eragrostis annulata, Datura spp. - Argemone ochroleuca, Mesembryanthemum guerichianum - Sporobolus nebulosus, Stipagrostis ciliata, Salsola tuberculata (typical) and Acacia albida noda, therophytes accounted for a large proportion of the species.

The ubiquity of chamaephytes is in accordance with Zohary's (1973) hypothesis that desert vegetation consists of a matrix of chamaephytes and an unstable part contributed by annuals. In the Namib Desert many species were dwarf shrubs (Table 5.1) and these either formed distinct strata or occurred as widely scattered individuals.

As in the Middle East deserts, the communities of the study area were not closed. In years with good rains annual species (and forms of perennial species) appeared between the perennials suggesting that the only factor preventing their always being present was lack of water. Many species can thus be regarded as "opportunists", taking advantage of favourable conditions wherever these occurred. It was for this reason that species such as Stipagrostis ciliata, Zygophyllum simplex, Indigofera auricoma, Tephrosia dregeana and Tribulus terrestris to name but a few, were recorded from almost all communities; wherever there was sufficient moisture these "desert wides" as Zohary (1973) terms them, appeared.

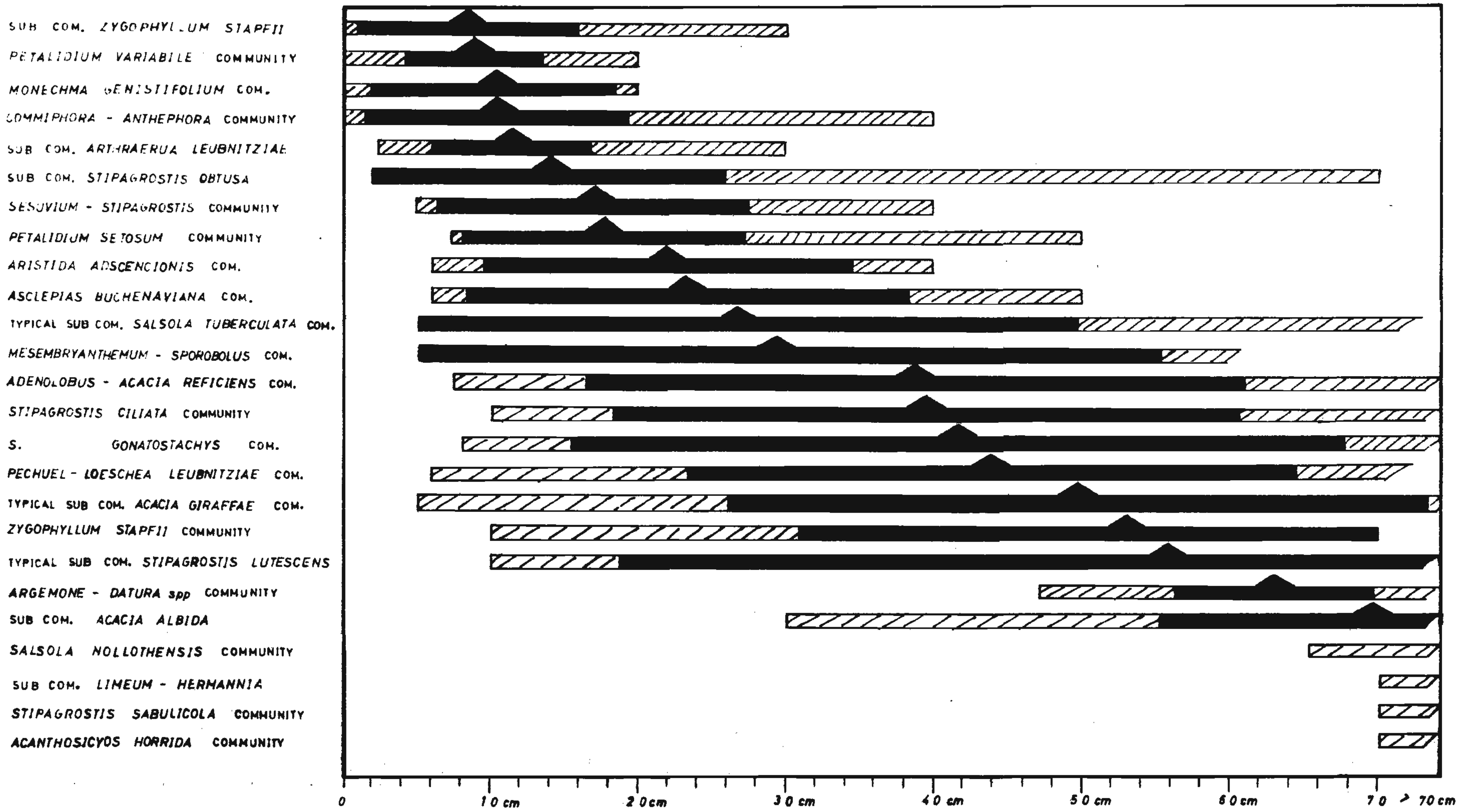


Fig. 5.2 Soil depth in the various communities of the study area. Triangles represent mean soil depth, solid shading indicates 1 S.D. from the mean, and cross-hatching inicates the observed range of soil depth.

The communities which were most dependent upon rainshowers for their water supply (for example, the communities of plains and interdune valleys) had the highest proportions of annual species, and this was probably as a result of the unreliability and short duration of rainfall. Where water was stored in the soil or fog was a regular feature perennials became more numerous.

5.6.4 Relationships between the communities

Communities which occupied the driest habitats were the *Stipagrostis ciliata*, *Salsola tuberculata* (typical) and *Stipagrostis obtusa* sub-communities. Of these, the *Salsola tuberculata* nodum extended furthest west (Map 7), while the *Stipagrostis obtusa* sub-community did not extend beyond the zone where rainfall was (relatively) regular. The *Stipagrostis spp.* noda consisted predominantly of therophytes (see above), although both *S. ciliata* and *S. obtusa* have been classed as hemicryptophytes by Werger (1973a). In the Namib Desert, these species behaved as perennials in moist habitats; on the drier plains the seeds germinated, the plants flowered, set seed and died all within a space of a few weeks following rains. Should a series of wet years occur (as happened in 1972, 1973 and 1974 on the plains near Mirabib) tufts of both species survived in the slightest depression and behaved as hemicryptophytes.

Where fog precipitation was high, three communities were found: the *Salsola nollothensis* community on sandy sites close to the coast (see also below); the *Arthraerua leubnitziae* nodum of gypsum plains; and the *Zygophyllum stapfii* sub-community of shallow soils on rock outcrops. All of these communities were dominated by chamaephytes (Table 5.1). In the first two, the growth form probably facilitated the trapping of fog moisture, while on the rock outcrops the predominance of woody perennials probably reflected the ability of these plants to shed branches and leaves in unfavourable seasons, and of rapidly taking advantage of any rain which does fall, as has been observed by Zohary (1973). The large number of species in the *Zygophyllum stapfii* sub-community (44), together with the observation made in 4,7,3 above concerning fog precipitation and the high proportion of the species which were perennial (70,9%, Table 5.1) could be taken as evidence that moisture was comparatively readily available. The greater the availability and the longer that water was available the larger the plants that could be supported, and hence the larger growth forms were found in habitats where water remained available for the longest periods.

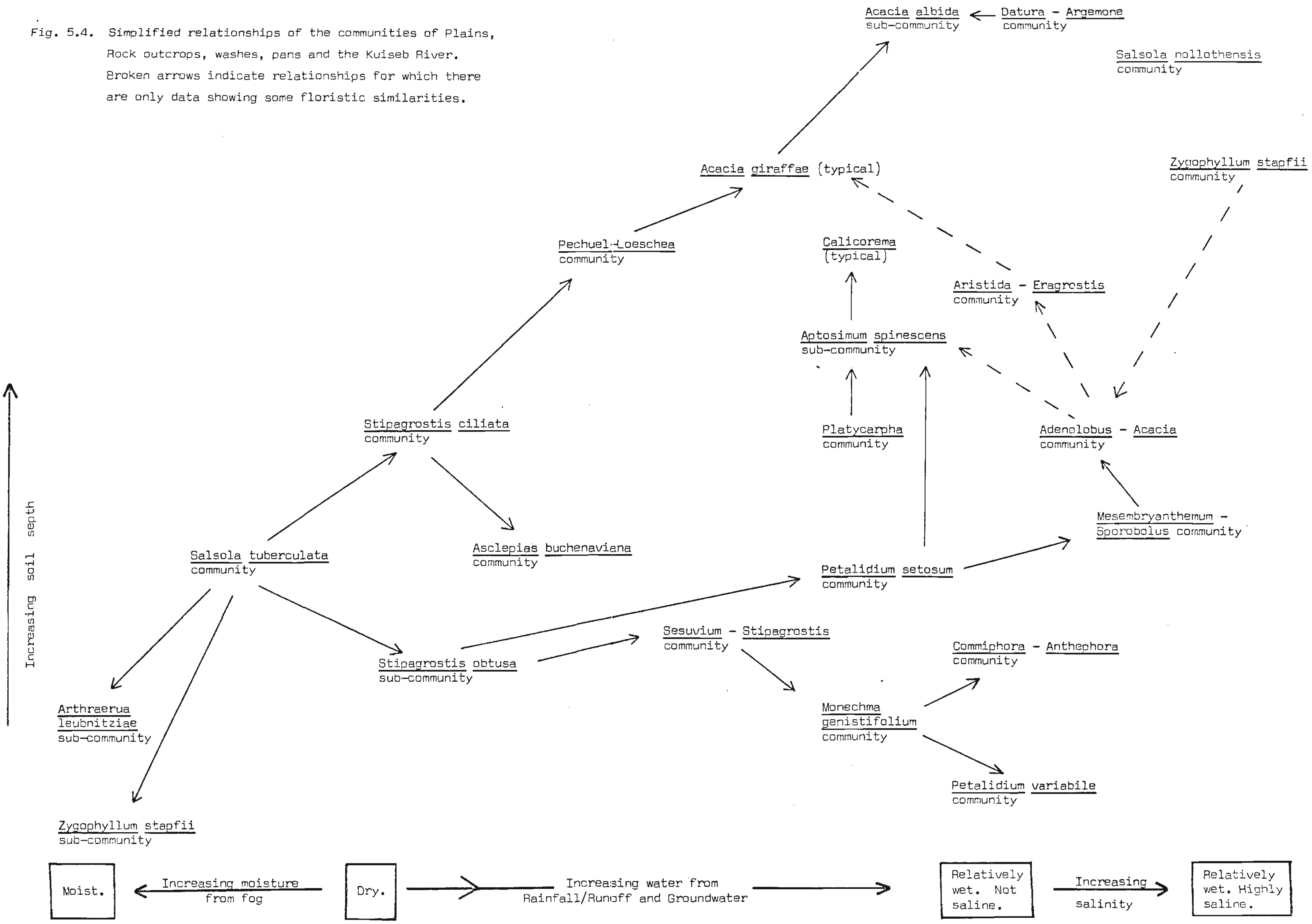
In the extremely arid zone, from Zwartbank to Mirabib (Map 2), the *Asclepias buchenaviana* community occupied washes, most often where granite intrusions were close to the surface or exposed in the wash bed. These probably either dammed ground-water in the wash, in the same way as similar formations dammed water in the Kuiseb River bed (Stengel, 1968), or they may have served as aquifers bringing subterranean water closer to the surface, as has been reported for other arid regions (Yaron, Danfors and Vaadia, 1973). The *Pechuel-Loeschea leubnitziae* community occupied essentially similar habitats, but was best developed from about 500 m above sea level, where rainfall was higher and run-off from the plains was consequently greater.

On deep substrates the *Acacia giraffae* community developed. The typical sub-community was closely related to the *Pechuel-Loeschea leubnitziae* community (p 96) and colonized a variety of sites. In the Kuiseb River the typical sub-community was replaced by the *Acacia albida* sub-community, and this was only found where ground-water was permanently available. Both sub-communities were dominated by trees and both had numerous species of therophytes in the ground layer, no doubt because of the availability of moisture.

The first sere of higher plants in the Kuiseb River was the *Datura spp.* - *Argemone ochroleuca* community. As may be expected in the bed of a river that flowed irregularly, the habitat was very changeable; varying from a flowing river up to 1 m deep to an expanse of very hot, dry sand with the only water a number of metres beneath the surface (pers. obs.). It was therefore only to be expected that the community conisited primarily of therophytes.

The *Petalidium setosum* community occupied the shallowest washes, but only in the "high" rainfall region of the eastern part of the study area. It was presumed to have developed from the floristically related *Stipagrostis obtusa* sub-community.

Fig. 5.4. Simplified relationships of the communities of Plains, Rock outcrops, washes, pans and the Kuiseb River. Broken arrows indicate relationships for which there are only data showing some floristic similarities.



Also closely related to the Stipagrostis obtusa nodum was the Sesuvium sesuvioides – Stipagrostis obtusa community of low rock outcrops. On the shallower soil, but with a more easterly distribution (Map 6), the Monechma genistifolium community developed. These communities seemed to form a link between the plains and the rock outcrops, with the Sesuvium sesuvioides – Stipagrostis obtusa nodum being the drier, and having more therophytes and geophytes, while the Monechma genistifolium community occurred where rainfall was higher and reliable, and was dominated by chamaephytes.

The floristically richest communities were found on the shallowest soils, but only at sites where run-off water could collect and where rainfall was highest. In these habitats evaporation was very greatly reduced beneath the rocks and in cracks (see Channing, 1975, for some data on relative humidity in crevices on plutons in the Namib Desert environment). The increased quantity of water and longer period for which the soil remained moist supported communities of larger plants, allowed a denser cover to develop and also enabled species of the moister inland region to colonize the rock outcrops. The communities occupying these habitats were the Petalidium variabile and Commiphora glaucescens – Anthephora pubescens communities of the rock outcrops from Mirabib eastwards. Both showed floristic relationships with the Monechma genistifolium community (Fig. 5.3), but they occurred on different substrates: the Petalidium variabile community was found on schist outcrops, while the Commiphora – Anthephora community colonized granite plutons. Both these communities, although also containing a number of therophytes, were clearly characterised and dominated by perennial woody vegetation (Table 5.1).

With the information available at this stage, the relationships of the pan communities are not clear. The Aristida adscencionis – Eragrostis annulata community was floristically related to the Acacia giraffae (typical), Stipagrostis ciliata, S. obtusa and Adenolobus pechuelii – Acacia reficiens noda. It may have been derived from elements of all these, because a pan may be expected to provide moisture conditions which were intermediate between plains and washes. Both washes and pans are collection points for run-off water, but in the pans this water remains on the surface where evaporation rates are high while in washes it percolates rapidly into the sandy substrate where evaporation is negligible. Thus in the pans there will be an excess of surface water immediately after rain falls, but only the small amount which soaks into the impervious soil will remain after this has evaporated. In contrast, the soil in washes absorbs water rapidly and almost all water entering the wash is stored. It is this wide range of moisture conditions that leads to the development of the unique vegetation found in pans of the Namib Desert.

Only the *Aptosimum spinescens* sub-community had apparent affinities with other communities (Fig. 5.3 and p 218) The *Calicorema capitata* (typical) sub-community seemed to be successionally related to the *Aptosimum spinescens* sub-community, replacing it on lighter soils or where ground-water level was presemed to be lower (it occurred at a higher level above the pan floor than the typical sub-community). The *Platycarpha carlinoides* community had no apparent affinities with any other communities (p 123) and it seemed unique, occupying a single site in the study area.

The *Adenolobus pechuelii* – *Acacia reficiens* community of washes and some pans appeared to occupy an intermediate position between the *Acacia giraffae* (typical) community and communities of saline areas. The ground-water in at least some sites was slightly saline, and the community showed some affinities with the *Acacia giraffae* (typical), *Sesuvium sesuvioides* – *Stipagrostis obtusa*, *Monechma genistifolium* and *Petalidium variabile* noda (p 218), in other words, with communities of washes, plains and rock outcrops. In even more saline soils the *Mesembryanthemum guerichianum* – *Sporobolus nebulosus* community developed. This was more distinct floristically than the *Adenolobus* – *Acacia* community (p 104), but was only identified from a single locality. The origins of both these communities therefore are uncertain at this stage.

On deep, saline substrate where water seemed readily available (5.3.2.5 above), *Zygophyllum stapfii* formed a community of succulent leaved, dwarf shrubs. With the data available it was difficult to decide the community from which it was derived, although it showed some affinities with the *Salsola tuberculata* (typical) and *Pechuel-Loeschea leubnitziae* communities (pp 135 & 94). However, the generally low floristic similarity between this community and all others of the study area (p 218) does not allow conclusion to be drawn concerning its relationships with other communities.

The *Salsola nollothensis* community was found close to the coast where substrate was deep, where there was a reliable source of water (the fog) and where water could be expected to be fairly saline as a result of sea spray which the wind carried inland. In view of the latter habitat feature it was plotted close to the *Zygophyllum stapfii* community (Fig. 5.4). It was not related to any community in floristic composition (p 134), and seemed unique in the study area.

Chapter 6. GENERAL DISCUSSION AND CONCLUSIONS.

6.1 DISCUSSION.

As was pointed out in the Introduction, this was the first phytosociological treatment of the Namib Desert vegetation. The area covered was reasonably large (some 7 500 km^2) and compares favourably with other studies of semi-arid vegetation in South Africa (Werger, 1973a and Leistner & Werger, 1973). Elsewhere in southern Africa the Braun - Blanquet approach has been successfully applied to a number of diverse vegetation types, from the macchia in the south-western Cape (Werger, Kruger & Taylor, 1972) to the high mountain flora of Lesotho (van Zinderen Bakker & Werger, 1973); from the highveld grassland (Bredenkamp, 1975) to the Kalahari scrub (Leistner & Werger, 1973). The approach proved as satisfactory for dealing with the extremely sparse vegetation of the Namib Desert as it had the vegetation types mentioned above. Zohary (1973) discussed the problems of defining associations in the Middle East desert vegetation, and concluded that phytosociological studies of desert areas required approaches different to those applicable in less harsh environments. Possibly because there is no attempt to group the vegetation units hierarchically, the difficulties noted by Zohary were not encountered in the present study.

The advantages of the Braun - Blanquet approach were that:

(1) It allowed rapid and efficient (in terms of time and effort expended) description of the vegetation in a manner which produces a clear overall picture of the composition, structure and habitat and can be used by workers in any discipline;

(2) The phytocoenoses sampled in the field were readily grouped into units (called communities or noda here) on a floristic and ecologically sound basis. These may be compared with vegetation of other areas, provided that this has also been sampled in a like manner;

(3) The units delimited could be analysed to elucidate the distribution of either species or units relative to environmental factors.

The major disadvantage relates to the imprecision of measurement of habitat factors. This is unavoidable in the survey of large areas, and is common to all techniques used for such studies. A minor disadvantage is the labour involved in the construction of the phytosociological tables, since all species have to be included in the matrix (at least in the early stages). This can be overcome by the use of a computer programme as has been developed at the Botanical Research Institute, Pretoria (Morris pers. comm.). In the present study, however, the small number of species recorded (272) made it possible to construct the Tables manually without too great trouble.

The system was easy to apply in the field as the vegetation was open and it was possible to assess the cover-abundance with ease, primarily because cover was generally sufficiently low for the number of plants and their contribution to the total cover of the stand to be assessed rapidly. The only practical difficulty experienced was that the classification required complete species lists from each site (Braun - Blanquet, 1932; Poore, 1955; Becking, 1957; Shimwell, 1971 and Werger, 1973a). In the arid environment of the Namib Desert, it was impossible to meet this requirement because the geophytes and annuals depended upon the irregular rainshowers for growth, and therefore in dry years certain species would not appear at all. This was particularly well illustrated in the Sesuvium sesuvioides - Stipagrostis obtusa community where geophytes were numerous and covered appreciable areas in some stands following rains in 1972, but were wholly absent from the same sites in 1973 because the area had received no rain (pers. obs.). Fortunately the period during which the study was carried out coincided with a relatively wet spell (Dixon, pers comm.; Seely pers. comm.; pers. obs.) and a full range of stands, from those which were poorly developed due to lack of water to well developed ones were sampled for most communities. Furthermore, as the permanently recognisable species constituted a relatively large portion of the flora (Tables I to VI and 5.1) this possible ommission was not felt to be of significance. Werger (1973a) arrived at the same conclusion in the northern Cape Province. It seemed sufficient, therefore, to be able to identify communities largely by the "stable" component of the vegetation.

Of the other Braun - Blanquet studies which have been completed in southern Africa (see above), only two deal with truly semi - arid or arid vegetation, namely Werger (1973a) and Leistner

& Werger (1973) who dealt with vegetation along the upper Orange River Valley and the southern Kalahari respectively. Even in these areas rainfall is appreciably higher than in the Namib Desert and fog does not occur. Volk & Leippert's (1971) study dealt only with the communities of the highlands of South West Africa and thus comprised savanna types. The transect carried out by Coetzee & Werger (1975) lay within the winter rainfall region of South West Africa, so was also not really similar. There were therefore no studies which dealt with areas which were climatically comparable to the central Namib Desert, and close similarities of communities are not to be expected. This explains why terrestrial communities of the study area cannot be readily assigned to syntaxa of the classifications of Werger (1973a) or Leistner & Werger (1973). In spite of this, some communities showed similarities with associations described by these workers. Communities of this category are the *Stipagrostis ciliata* community which seems to show floristic affinities with the Stipagrostion prov Alliance of Leistner & Werger (1973), and the *Limeum fenestratum* – *Hermannia gariepina* sub-community which showed floristic affinities and ecological similarities with Werger's (1973a) *Eragrostis lehmanniana* – *Asthenatherum glaucum* community. These similarities are significant as they indicate the ability of the technique used to produce ecologically meaningful units which can be compared with units from widely separated regions. More tenuous similarities (based of structure) could be noted between the communities of the study area and the North African and Middle East deserts studied by Kassas (1957), Vesey-FitzGerald (1957), Quezel (1965) and Zohary (1973), but since such similarities are to be expected from similar environments there is little point in describing them in detail.

By contrast with the terrestrial communities, some of the salt marsh communities can readily be assigned to syntaxa described from Africa and Australia, or show marked similarity of seral status and habitat (see 5.1 above). This is doubtless because the salt marsh habitat is rather similar throughout the world.

The study has emphasised the need for further botanical studies in the central Namib Desert. The salt marshes of Sandwich

Harbour are clearly undergoing changes (5.1 above; Seely, pers. comm.; Berry, pers. comm.). These changes seem to be related to some factor which is detrimental to _Typha latifolia_, and may be related to changes in the inflow of freshwater. However, the natural process of succession cannot be overlooked, as considerable quantities of sand are carried from the dunes onto the salt marshes, raising the overall level. Measurements should be made to determine whether salinity or some other factor has exceeded the toleration limit of _Typha_ in the areas where die-back has occurred, and some attempt should be made to determine the rate of deposition of sand. Corings taken around the edges of the pools may be useful for determining whether there have been cyclical changes in the vegetation in the past - marked die-back of _Typha_ seems to be accompanied by the accumulation of a stratum of organic ooze which is not present under conditions of favourable growth of the different communities (51. above).

Many of the gradients of environmental factors which seem important in the development of the inland communities (Fig. 5.3 and Section 5.6 above) are complex-gradients to use Whittaker's (1971) terminology. That is, a number of environmental factors change together along the gradient, and all may have some influence upon vegetation, but the effects of the individual factors cannot be isolated. Further studies of the synecology of the central Namib Desert should attempt to measure the habitat factors in greater detail, especially those related to water availability. Correlated with such studies should be autecological studies to determine the tolerance ranges of the differential species, thus lending greater precision to predictions based on the vegetation units these species characterize, and synecological studies of the same species, to determine the niches occupied.

Fog has been shown to be of ecological significance to certain communities, but detailed data on quantities of water derived, influence of site features and behaviour of the fog zone plants are required to elucidate the causal factors leading to the observed correlations.

The riverine communities are of considerable importance to the Namib Desert biome since they provide shelter and food for many species of animals, particularly during the unfavourable season (Hamilton, pers. comm.), and because they are likely to be affected by the utilization of ground-water reserves in the Kuiseb River by Walvis Bay and Swakopmund and the Rössing mine.

The entire question of water availability and the reliability of supply seems of paramount importance to the vegetation. The present study highlights this, but does no more than pose questions. Studies should be initiated to obtain some idea of the water balances of some of the communities which have been shown to be closely related to different kinds of water supply. As a start, details on the root morphology, quantities of water received at the root zone and the time the soil remains moist as well as water relations of the plants under different conditions (east wind, fog, day or night and so on) would go a long way to confirming or disproving the hypotheses put forward in this work.

6.2. CONCLUSION.

In this study 27 plant communities, each with distinctive floristic composition and habitat were identified from the southern section of the Namib Desert Park. These communities can be recognised on the basis of characteristic species and habitat features.

In contrast to the experience of Zohary in the Middle East deserts (Zohary, 1973) the Braun-Blanquet approach proved efficient in delimiting communities in the Namib Desert. However, because the area covered by this study is considerably less than the geographical range of many of the species, no formal syntaxonomic classification is attempted, and the noda are simply termed communities. The system proved successful in meeting the requirements of the study.

To make maximum use of the data collected during the survey, further Braun-Blanquet surveys should be carried out elsewhere in the Namib Desert to enable a detailed classification of the entire region to be produced.

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APPENDIX I. Species which occurred in one or more relevés.

All species recorded from relevés are listed below. The taxonomic system followed is that of Merxmueller (1966 - 1970) and, with the exceptions noted below, all names are those used in "Prodromus Einer Flora von Südwestafrika". This work was used because it was, and is, the only modern treatment of the entire flora of South West Africa.

A few names do not follow Merxmueller's Prodromus and these are :

Talinum arnotii, which was named following the revision by Tölken (1970);
Stipagrostis uniplumis, in which two infra-specific taxa could clearly be recognized in the field. In addition to showing morphological differences, there were ecological differences which made it necessary to distinguish the forms. The taxa are : *Stipagrostis uniplumis* var. *uniplumis* which had an erect growth habit and seemed to be perennial, and the more prostrate, predominantly annual *S. uniplumis* var. *intermedia.*;
Indigofera auricoma forma. Although this form of *Indigofera aricoma* could not be distinguished on taxonomic characters, it was easily recognised in the field because of the erect habit and stiff stems.

ADDENDUM

One species was positively identified only after the species list had been reproduced and was therefore not included. The species concerned is *Xerophyta viscosa* and a list of the synonomous names is given here :

Family 152 VELLOZIACEAE

Xerophyta viscosa Baker
Synonyms : *Vellozia viscosa* (Baker) Baker
Barbacenia hereroensis Schinz
Vellozia hereroensis (Schinz) Baker
Barbacenia jostinia Dinter nom provis
B. viscosa (Baker) Burtt-Davy

Family 13 WELWITSCHIACEAE

Welwitschia mirabilis Hooker fil.

Synonyms : *Tumboa bainesii* Hooker fil.
T. strobilifera Welw. ex Hook. fil.
Welwitschia bainesii (Hooker fil.) Carriére

Family 16 MORACEAE

Ficus cordata Thunb.

Synonyms : *F. rupium* Dinter

F. sycomorus L.

Synonyms : *F. gnaphalocarpa* (Miq.) A. Richard
F. damarensis Engler

Family 17 URTICACEAE

Forsskaolea candida L. fil.

Synonyms : *F. candida* var. *virescens* Wedd.

F. hereroensis Schinz

Family 23 POLYGONACEAE

Polygonum plebeium R.Br.

Synonyms : *P. roxburghii* Meisner

Family 25 NYCTAGINACEAE

Commicarpus squarrosus (Heim.) Standley

Synonyms : *Boehavia squarrosa* Heim.
Commicarpus fruticosus Pohnert

Phaeoptilum spinosum Radlk.

Synonyms : Nachtigalia protectoratus Schinz ex Engler

Phaeoptilum heimerli Engler

Amphoranthus spinosus S. Moore

Family 26 MOLLUGINACEAE

Gisekia africana (Lour.) O. Kuntze

Synonyms : Miltus africanus Lour.

Gisekia miltus Fenzyl.

G. pentadecandra Moq.

Hypertelis salsoloides (Burch.) Adamson

Synonyms : Pharnaceum salsoloides Burch.

P. verrucosum Ecklon & Zeyher

Hypertelis verrucosa (Eckl. & Zey.) Fenzyl

Limeum aethiopicum Burm. fil.

ssp. namaense Friedr.

Synonyms : L. aethiopicum var. glabrum Moq.

L. suffruticosum Schellenb.

L. capense auct. non. Thunb. : Dinter

L. argute-carinatum Wawra & Peyr.

Synonyms : L. linifolium var. polygonoides Welw. ex Oliver

L. kwebense N.E.Br.

L. africanum auct.non. L : Dinter

L. argute-carinatum var. kwebense (N.E.Br.) Friedr.

L. fenestratum (Fenzyl.) Heimerl

Synonyms : Semonvillea fenestrata Fenzyl.

Limeum glaberrimum Pax ex O. Kuntze

L. fenestratum var. perenne Schinz ex Dinter

Semonvillea sol H. Walter

Limeum frutescens Dinter

L. fenestratum var. frutescens (Dinter) Friedr.

L. sulcatum (Klotzsch) Hutch.

Synonyms : L. linifolium (Presl.) Fenzyl.

Acanthocarpea sulcata Klotzsch.

Limeum echinatum H. Walter

L. diffusum auct.non. Schinz : Range

L. sulcatum var. gracile Friedr.

L. sulcatum var. robustum Friedr.

Mollugo cerviana (L.) Ser. ex DC.

Synonym : Pharnaceum cerviana L.

Family 27 AIZOACEAE

Aizoanthemum dinteri (Schinz) Friedr.

Synonyms : Aizoon dinteri Schinz

Aizoanthemum stellatum Dinter ex Friedr.

A. bossii Dinter ex Friedr.

A. sphingis Dinter ex Friedr.

Galenia africana L.

Synonyms : G. linearis Thunb.

G. africana var. secundata Adamson

G. namaensis auct.non. Schinz : Adamson

G. papulosa (Ecklon & Zeyher) Sonder

Synonyms : Aizoon papulosum Ecklon & Zeyher

A. squamulosum Ecklon & Zeyher

Galenia squamulosa (Ecklon & Zeyher) Fenzl ex Sonder

G. sarcophylla Fenzl ex Sonder

G. papulosa var. *tristyla* O. Kuntze
G. p. var. *microphylla* Adamson

Mesembryanthemum guerichianum Pax

Synonyms : *M. fenchelii* Schinz
M. grandifolium Schinz
M. gariusianum Dinter
Cryophytum guerichianum (Pax) Schwantes
C. fenchelii (Schinz) N.E.Br.
C. grandifolium (Schinz) N.E.Br.
Amoebophyllum guerichianum (Pax) N.E.Br.
Mesembryanthemum crystallinum auct.non.
L. : Range
"*M. grandiflorum* Schinz" ex Range
"*Cryophytum grandiflorum* (Schinz) Dinter &
Schwantes" ex Range

Psilocaulon kuntzei (Schinz) Dinter & Schwantes

Synonyms : *Mesembryanthemum kuntzei* Schinz
M. dinteri Engler
M. schlichtianum auct.non.
Sonder : L. Bolus
Psilocaulon schlichtianum auct.non. (Sonder)
Schwantes : Friedr.
P. salicornioides auct.non. (Pax)
Schwantes

P. salicornioides (Pax) Schwantes

Synonyms : *Mesembryanthemum salicornioides* Pax
M. trothai Engler
Psilocaulon throthai (Engl.) Schwantes
P. woodii L. Bolus

Sesuvium sesuvioides (Fenzl) Verdc

Synonyms : *Diplochonium sesuvioides* Fenzl
Trianthema hydaspica Edgew.
Sesuvium digynum Welw. ex Oliver
Trianthema polysperma Hochst. ex Oliver
Halimum sesuvioides (Fenzl) O. Kuntze
Sesuvium digynum var. *angustifolium* Schinz
S. hoepfnerianum Schinz
S. h. var. *brevifolium* Schinz
Halimum sesuvioides var. *reduplicatum* Welw. ex Hiern.
H. s. var. *welwitschii* Hiern.
H. s. var. *angustifolium* (Schinz) Hiern.
Trianthema dinteri Engler
T. salaria Bremek

Trianthema hereroensis Schinz

T. triquetra Willd. ssp. *parvifolia* (Sonder) Jeffrey

Synonyms : *T. parvifolia* Sonder
T. crystallina var. *rubens* Sonder
T. c. var. *corymbosa* Sonder

Family 28 TETRAGONIACEAE

Tetragonia arbuscula Fenzl ex Sonder

Synonym : *T. spicata* var. *latifolia* auct.non. Sonder : Schinz

Tribulocarpus dimorphanthus (Pax) S. Moore

Synonym : *Tetragonia dimorphantha* Pax

Family 29 PORTULACACEAE

Talinum arnotii Hooker fil.

Synonym : T. cuneifolium auct.non. von Poelnitz : Tolken

Family 32 CHENOPODIACEAE

Arthrocnemum affine Moss ex Adamson

Synonym : A. glaucum auct.non. Del : Schinz

Atriplex suberecta Verdoorn

Synonym : A. muelleri auct.non. Bentham : Aellen

Chenopodium ambrosioides L.

C. pumilio R.Br.

Salsola nollothensis Aellen

Synonyms : S. flexuosa C.A. Smith ex Ulbr.

S. candida auct.non. Fenzl ex Moq.

S. tuberculata (Fenzl ex Moq.) Schinz

Synonyms : Salsola tuberculata Fenzl ex Drege nom.nud.

Caroxylon tuberculatum (Fenzl ex Drege) Moq.

Salsola fuliginosa C.A. Smith ex Ulbr. nom.nud.

S. vermiformis C.A. Smith ex Ulbr. nom.nud.

Suaeda plumosa Aellen

Synonym : S. fruticosa auct.non. (L) Forsk. : Schinz

Family 33 AMARANTHACEAE

Amaranthus thunbergii Moq.

Synonyms : A. tricolor ssp. mangostanus auct.non.

A. mangostanus Jusl. : Suesseng.

Arthraerua leubnitziae (O. Kuntze) Schinz

Synonyms : Aerua leubnitziae O. Kuntze

A. desertorum Engler

Calicorema capitata (Moq.) Hook. fil.

Synonyms : *Sericocoma capitata* Moq.
Aerua pechuelii O. Kuntze

Celosia argenteiformis (Schinz) Schinz

Synonyms : *Hermbstaedtia argenteiformis* Schinz
H. argenteiformis var. *oblongifolio* Schinz
Celosia tönjesii Schinz

C. spathulifolia Engler

Synonyms : *Hermbstaedtia spathulifolia* (Engler) Baker
Celosia intermedia Schinz

Marcelliopsis denudata (Hook. fil.) Schinz

Synonyms : *Sericocoma denudata* Hook. fil.
Marcellia denudata (Hook. fil.) Lopr.
M. dinteri Schinz

Sericorema sericea (Schinz) Lopr.

Synonyms : *Sericocoma sericea* Schinz
Marcellia sericea (Schinz) C.B. Clarke

Family 46 PAPAVERACEAE

Argemone ochroleuca Sweet

Synonyms : *A. mexicana* var. *ochroleuca* (Sweet) Lindley
A. mexicana auct.non. L. : Dinter

Family 47 CAPPARACEAE

Boscia albitrunca (Burch.) Gilg & Benedict

Synonyms : *Capparis albitrunca* Burch.
Boscia pechuelii O. Kuntze
B. pubercula Pax

B. transvaalensis Pestalozzi

B. foetida Schinz

Capparis hereroensis Schinz

Cleome diandra Burch.

Synonyms : *Polanisia dianthera* DC. nom.illeg.
Dianthera petersiana Klotzsch ex Sonder
D. burchelliana Klotzsch ex Sonder
Polanisia petersiana (Klotzsch) Pax
P. diandra (Burch.) Dur. & Schinz

C. linearifolia (Stephens) Dinter

Synonyms : *Polanisia linearifolia* Stephens
Cleome dinteri Pax ex Dinter nom.nud.pro syn
C. semitetrandra Sonder : Kers in Fl. S.Afr. *3*

C. luederitziana Schinz

Synonyms : *Polanisia lutea* var. *polyphylla* Pax
P. lüderitziana (Schinz) Schinz

C. suffruticosa Schinz

Synonym : *Polanisia suffruticosa* (Schinz) Pax

Maerua schinzii Pax

Synonyms : *M. paxii* Schinz
M. arenicola Gilg.
M. angolensis auct.non DC. : Pax

Family 48 BRASSICACEAE

Coronopus integrifolius (DC.) Sprengel

Synonyms : *Senebiera integrifolia* DC.
Coronopus linodes auct.non (Thunb.) O. Kuntze : Schinz

Family 50 MORINGACEAE

Moringa ovalifolia Dinter & Berger

Synonym : *M. ovalifoliolata* Dinter & Berger

Family 53 VAHLIACEAE

Vahlia capensis (L. fil.) Thunberg

Synonyms : *Russelia capensis* L. fil.
Vahlia capensis var. *verbasciflora* Oliver
V. cynodonteti Dinter
V. verbasciflora (Oliver) Mendes
Bistella capensis (L. fil.) Bullock

Family 54 MONTINIACEAE

Montinia caryophyllacea Thunb.

Synonym : *M. acris* L. fil.

Family 56 NEURADACEAE

Grielum sinuatum Licht. ex Burch.

Synonyms : *G. obtusifolium* E. Meyer ex Harvey
G. marlothii Engler
G. humifusum auct.non Thunb. : Range

Family 58 MIMOSACEAE

Acacia albida Del.

Synonym : *Faidherbia albida* (Del.) A. Cheval

A. giraffae Willd.

Synonyms : *A. erioloba* E. Meyer
A. giraffae var. *espinosa* O. Kuntze

A. hebeclada DC. ssp. *hebeclada*

Synonyms : *A. stolonifera* Burch.
A. hebeclada var. *stolonifera* (Burch.) Dinter

A. mellifera (Vahl) Bentham ssp. *detinens* (Burch.) Brenan

Synonyms : *A. detinens* Burch.
A. tenax Marloth

A. reficiens Wawra

Synonyms : *A. lüderitzii* Engler
A. uncinata Engler

Family 59 CAESALPINIACEAE

Adenolobus garipensis (E. Meyer) Torre & Hillc.

Synonym : *Bauhinia garipensis* E. Meyer

A. pechuelii (O. Kuntze) Torre & Hillc.

Synonyms : *Bauhinia pechuelii* O. Kuntze
B. marlothii Engler

Parkinsonia africana Sonder

Family 60 FABACEAE (PAPILIONACEAE)

Crotalaria damarensis Engler

Synonyms : *C. marlothii* Engler
C. fleckii Schinz
C. lindenii Schinz
C. lindneri Schinz
C. diversistipula Harvey

C. podocarpa DC.

Synonyms : *C. belckii* Schinz
C. podocarpa var. *villosa* Schinz

C. hirsutissima Schinz
C. mutabilis Schinz
C. podocarpa ssp. *belckii* (Schinz) Baker fil.
C. damarensis var. *maraisiana* Torre

Indigofera auricoma E. Meyer
Synonyms : *I. auricoma* var. *cuneata* Baker fil.
I. auricoma var. *auricoma* E. Meyer
I.hololeuca Bentham ex Harvey

I. damarana Merxm. & Schreiber
Synonym : *I. wilmaniae* Baker fil. ex Gillett

Lotononis platycarpa (Viv.) Pic. Ser.
Synonyms : *Leobordea platycarpa* Viv.
Lotononis leobordea Benth.
Amphinomia platycarpa (Viv.) Cuf.

Otoptera burchellii DC.
Synonym : *Vigna burchellii* (DC.) Harvey

Psoralea obtusifolia DC.

Ptycholobium biflorum (E. Meyer) Brummitt ssp. *angolense* (Baker) Brummitt
Synonym : *Sylitra angolensis* Baker

Tephrosia dregeana E. Meyer

Family 64 GERANIACEAE

Monsonia senegalensis Guill. & Perr.

M. umbellata Harvey
Synonyms : *M. lüderitziana* Focke & Schinz
M. namaensis Dinter
M. rehmii Suesseng

Sarcocaulon mossamedense (Welw. ex Oliver) Hiern.

Synonyms : Monsonia mossamedensis Welw. ex Oliver
Sarcocaulon marlothii Engler

Family 65 ZYGOPHYLLACEAE

Fagonia minutistipula Engler

Tribulus terrestris L.

Synonyms : T. murex Presl.
T. murex Schlechter ex Dinter nom.illeg., pro parte
T. parviflorus Schlechter ex Engler nom.nud.

T. zeyheri Sonder

Synonyms : T. excrucians Wawra
T. pechuelii O. Kuntze
T. zeyheri var. pechuelii (O. Kuntze) Schinz
T. zeyheri var. hirsutissimus Schinz
T. zeyheri var. hirtus Schinz
T. inermis Engler nom.illeg.
T. erectus Engler
T. terrestris var. zeyheri (Sonder) Schinz
T. zeyheri var. aurantiacus Schlechter ex Dinter
T. murex Schlechter ex Dinter nom.illeg., pro parte

Zygophyllum cylindrifolium Schinz

Z. simplex L.

Synonyms : Z. simplex var. capense Sonder
Z. simplex var. namaense Schinz
Z. namaense Loesener ex Dinter

Z. stapfii Schinz
Synonym : Z. marlothii Engler

Family 67 EUPHORBIACEAE

Euphorbia virosa Willd.
Synonym : E. dinteri Berger

E. glanduligera Pax
Synonyms : E. pfeilii Pax
E. glaucella Pax
E. anomala Pax

E. inaequilatera Sonder
Synonyms : E. parvifolia E. Meyer ex Boiss.
E. sanguinea Hochst.& Steudel ex Boiss.
E. nelsii Pax

E. lignosa Marloth

E. phylloclada Boiss.
Synonym : E. hereroensis Pax

Phyllanthus dinteri Pax

Ricinus communis L.

Seidelia firmula (Prain) Pax & K. Hoffm.
Synonyms : Leidesia firmula Prain
Adenocline aucta auct. non. Baillon : Dinter

Family 70 BURSERACEAE

Commiphora glaucescens Engler
Synonyms : C. pruinosa Engler
C. hereroensis Schinz

C. saxicola Engler
Synonym : C. dulcis Engler

C. tenuipetiolata Engler

C. virgata Engler

Family 73 POLYGALACEAE

Polygala guerichiana Engler

P. pallida E. Meyer ex Harvey

Family 74 ANACARDIACEAE

Rhus marlothii Engler

Synonyms : *R. marlothii* var. *subintegra* Engler
R. m. var. *robustior* Engler
R. upingtoniae Dinter
R. tsemubensis Dinter ex Schonl. nom.nud.
in syn.

Family 77 CELASTRACEAE

Maytenus heterophylla (Ecklon & Zeyher) N. Robson

Synonyms : *Celastrus buxifolius* L.
C. cymosus Solander
C. heterophyllus Ecklon & Zeyher
C. capitatus E. Meyer ex Sonder
Gymnosporia buxifolia (L.) Szyszyl.
G. heterophylla (Eck. & Zey.) Loes.
G. capitata (E.Mey. ex Sond.) Loes.
G. capitata var. *tenuifolia* Loes.
G. acanthophora Loes.
Maytenus cymosa (Solander) Exell
M. angolensis Exell & Mendonca
M. capitatus (E.Mey. ex Sond.) Marais

M. senegalensis (Lam.) Exell

Synonyms : Celastrus senegalensis Lam.
Gymnosporia crenulata Engler
G. senegalensis (Lam.) Loes.
G. dinteri Loes.
G. eremoecusa Loes.

Family 78 SALVADORACEAE

Salvadora persica L.

Synonym : Lauridia ? multiflora Engler

Family 79 RHAMNACEAE

Ziziphus mucronata Willd.

Synonym : Z. mucronata var. glauca

Family 81 TILIACEAE

Grewia flavescens Juss.

Synonyms : ? G. rautanenii Schinz
G. aspera Schinz
G. retinervis Burret

G. tenax (Forsk.) Fiori

Synonyms : Chadara tenax Forsk.
Grewia populifolia Vahl
G. betulaefolia Juss
G. rupestris Dinter & Schinz
G. betulifolia Schinz

Family 82 MALVACEAE

<u>Abutilon pycnodon</u> Hochr.

Synonyms : <u>A. marlothii</u> Ulbr.
<u>A. salmoneum</u> Ulbr.

<u>Hibiscus elliottiae</u> Harvey

Synonyms : <u>H. ebracteatus</u> Mast.
<u>H. ebracteatus</u> var. <u>pechuelii</u> O. Kuntze
<u>H. elliottiae</u> var. <u>pechuelii</u> (O. Kuntze) Hochr.
<u>H. elliottiae</u> var. <u>ebracteatus</u> (Mast.) Hochr.
<u>H. elliottiae</u> var. <u>subciliatus</u> Hochr.

<u>Pavonia rehmannii</u> Szyszyl.

Synonyms : <u>Lüderitzia pentaptera</u> K. Schum.
<u>Pavonia vespertilionacea</u> Hochr.

Family 84 STERCULIACEAE

<u>Hermannia affinis</u> K. Schum.

Synonyms : <u>H. windhukiana</u> Engler
<u>H. complicata</u> Engler
<u>H. arenicola</u> Engler
<u>H. longicornuta</u> Engler
<u>H. spinulosa</u> Engler
<u>H. deserticola</u> Engler
"<u>H. windhoekiana</u> Engler" Dinter
<u>H. squarrosa</u> Dinter ex Range

<u>cf. Hermannia gariepina</u> Ecklon & Zeyher (R117321)

Synonyms : <u>H. exstipulata</u> Meyer ex Harvey

H. truncata Schinz

H. gariepina var. *dentata* Engler

H. gariepina var. *integrifolia* Engler

H. nivea Schinz

Hermannia modesta (Ehrenb.) Mast.

Synonyms : *Trichanthera modesta* Ehrenb.

Hermannia filipes Harvey

H. kirkii Mast.

H. modesta var. *elatior* (K. Schum.)

H. lugardii N.E.Br.

H. modesta var. *elatior* sub.var. *virgatissima* Engler

H. m. var. *e.* sub.var. *brevicornis* Engler

H. m. var. *e.* sub.var. *macropetala* Engler

H. m. var. *e.* sub.var. *mediipetala* Engler

H. modesta var. *tsumebensis* Engler

H. atrosanguinea Dinter

Sterculia africana (Lour.) Fiori

Synonyms : *Triphaca africana* Lour.

Sterculia triphaca R.Br.

S. gürichii K. Schum.

S. triphaca var. *guerichii* (K.Schum.) K.Schum.

S. tomentosa auct.non. Guill & Perr. : Dinter

Family 87 VIOLACEAE

Hybanthus densifolius Engler

Family 89 PASSIFLORACEAE

Adenia pechuelii (Engler) Harms

Synonym : Echinothamnus pechuelii Engler

Family 90 TAMARICACEAE

Tamarix usneoides E. Meyer ex Bunge

Synonyms : T. austro-africana Schinz
T. articulata auct.non. Vahl : Dinter

Family 93 LOASACEAE

Kissenia capensis Endl.

Synonym : K. spathulata R.Br. ex T. Anderson

Family 94 CUCURBITACEAE

Acanthosicyos horrida Welw. ex Bentham & Hooker fil.

Citrullus ecirrhosus Cogn.

Corallocarpus welwitschii (Naudin) Hooker fil.

Synonyms : Rhynchocarpa welwitschii Naudin
Corallocarpus schinzii Cogn.
C. schinzii var. lobatus Cogn.
C. gilgianus Cogn.
C. subhastatus Cogn.
C. scaber Dinter & Gilg nom.nud.

Cucumella aspera (Cogn.) C. Jeffrey

Synonym : Cucumis asper Cogn.

Family 105 PLUMBAGINACEAE

Dyerophytum africanum (Lam.) O. Kuntze

Synonym : *Vogelia africana* Lam.

Family 107 EBENACEAE

Euclea pseudebenus E. Meyer ex A. DC.

E. undulata Thunb.

Synonyms : *E. lancea* auct.non. Thunb. : F. Bolus,
L. Bolus & Glover
E. lanceolata auct.non. E. Meyer ex A. DC.
: Wordsworth, Hutchinson,
F. Bolus & L. Bolus

Family 113 PERIPLOCACEAE

Curroria decidua Planchon ex Hooker fil. & Bentham

Synonym : *Cryptolepis decidua* (Plan. ex Hook. fil. &
Benth.) N.E.Br.

Raphionacme spec. (Seely & Robinson 10)

Family 114 ASCLEPIADACEAE

Asclepias buchenaviana Schinz

Synonyms : *Lagarinthus filiformis* E. Meyer
Gomphocarpus filiformis (E.Meyer) D. Dietr.
Asclepias filiformis (E.Meyer) O. Kuntze

Hoodia currori (Hooker) Decne

Synonyms : *Scytanthus currori* Hooker
Hoodia macrantha Dinter
H. currorii var. *minor* R.A. Dyer

Microloma cf. *Hereroense* Wantrop. (R87328)

Orthanthera albida Schinz

Pentarrhinum insipidum E. Meyer

Pergularia daemia (Forsk.) Chiov.

Synonym : *Asclepias daemia* Forsk.

Trichocaulon clavatum (Willd.) H. Huber

Synonyms : *Stapelia clavata* Willd.

S. cactiformis Hooker

Trichocaulon cactiformis (Hooker) N.E.Br.

T. marlothii N.E.Br.

T. dinteri Berger

T. meloforme Marloth

T. engleri Dinter

T. keetmanshoopensis Dinter

T. sinus-lüderitzii Dinter

T. sociarum White & Sloane

Family 115 RUBIACEAE

Amphiasma divaricatum (Engler) Bremek.

Synonyms : *Oldenlandia divaricata* Engler

O. trichotoma Schinz

Houstonia trichotoma (Schinz) J. Bär.

Kohautia cynanchica DC.

Synonyms : *K. longiflora* DC.

Oldenlandia cynanchica (DC.) K. Schum. ex O. Kuntze

O. neglecta Schinz

O. calcitrapifolia Pearson ex Bremek.

"*O. stricta* K. Schum." apud Wordsworth, Hutch., F.Bol., & L.Bol..

Hedyotis cynanchica (DC.) Steudel

K. lasiocarpa Klotzsch

Synonyms : *Hedyotis thymifolia* Presl.
Oldenlandia lasiocarpa (Klotzsch) Hiern.
O. thymifolia (Presl.) O. Kuntze comb.illeg.
O. papillosa K. Schum.
O. subverticillata K. Schum.
O. sordida Krause
Kohautia lasiocarpa var. *thymifolia* Bremek.
K. lasiocarpa var. *subverticillata* (K. Schum.) Bremek.

K. ramosissima Bremek.

Synonyms : *Oldenlandia ramosissima* Dinter ex Bremek. nom.nud. in syn.
Kohautia aphylla Bremek
Oldenlandia heynii auct.non. G. Don : Dinter

K. virgata (Willd.) Bremek.

Synonyms : *Hedyotis virgata* Willd.
Oldenlandia virgata (Willd.) DC.
O. caffra Ecklon & Zeyher

Family 118 HYDROPHYLLACEAE

Codon schenckii Schinz

Synonym : *C. luteum* Marloth & Engler

Family 119 HELIOTROPIACEAE

Cordia gharaf (Forsk.) Ehrenb. ex Ascherson

Synonyms : *Cornus gharaf* Forsk.

C. sanguinea Forsk. nom.illeg. non L.
Cordia rothii Roemer & Schultes
C.subopposita DC.
C. ovalis auct.an. R.Br. : Dinter

Heliotropium curassavicum L.
H. gibbosum M. Friedrich
Synonyms : *Tournefortia tuberculosa* Cham.
Heliotropium tuberculosum (Cham.) Gürke
Tournefortia argentea auct.non L. fil. : Dinter
H. oliveranum Schinz
H. ovalifolium Forsk.
H. tubulosum E. Meyer ex DC.

Family 120 BORAGINACEAE

Trichodesma africanum (L.) Lehm.
Synonym : *Borago africana* L.

Family 122 VERBENACEAE

Chascanum garipense E. Meyer
Synonyms : *Bouchea garipensis* (E. Meyer) Schauer
B. garipensis var. *microphylla* O. Kuntze
B. glandulifera Pearson
Chascanum glanduliferum (Pearson) Moldenke

Family 124 SOLANACEAE

Datura innoxia Miller

D. stramonium L.

Lycium tetrandrum L. fil.

Nicotiana glauca R. Graham

Solanum nigrum L.

S. rigescentoides Hutch.

Synonym : S. denudatum Bitter

Family 126 SCROPHULARIACEAE

Anticharis inflata Marloth & Engler

A. linearis (Benth.) Hochst. ex Ascherson

Synonyms : Doratanthera linearis Bentham

Anticharis longifolia Marloth & Engler

A. aschersoniana Schinz

A. linearis var. azurea Dinter ex Schinz

Aptosimum angustifolium Weber & Schinz

A. spinescens (Thunb.) Weber

Synonyms : Ruellia spinescens Thunb.

Aptosimum abietinum Burch.

A. scaberrimum Schinz

A. steingroeveri Engler

A. steingroeveri var. glabrum Weber & Schinz

A. scaberrimum var. tenuifolium Weber

A. laricinum Dinter

A. laricinum var. spinosior Dinter

Nemesia lilacina N.E.Br.

Synonym : N. linearis var. denticulata O. Kuntze

Sutera canescens (Bentham) Hiern

Synonyms : Lyperia canescens Bentham
Chaenostoma canescens (Benth.) Wettst. ex Diels
Lyperia seineri Pilger
L. confusa Dinter
L. pilgeriana Dinter
Sutera dioritica Dinter
S. canescens var. laevior Dinter

S. lyperioides (Engler) Engler ex Range

Synonym : Chaenostoma lyperioides Engler

S. maxii Hiern

Family 127 SELAGINACEAE

Selago sp. R107334

Family 128 BIGNONIACEAE

Catophractes alexandri D. Don

Synonym : C. welwitschii Seem.

Family 130 ACANTHACEAE

Barleria merxmuelleri P.G. Meyer

Blepharis bossii Oberm.

B. grossa (Nees) T. Anderson

Synonyms : Acanthodium grossum Nees
Blepharis dichotoma Engler
B. linariaefolia auct.non Pers. : C.B. Cl.

B. obmitrata C.B. Clarke

Synonyms : *B. naegelsbachii* Oberm.
Acanthopsis carduifolia auct.non (L. fil.) Schinz : Dinter
? Blepharis edulis auct.non (Forsk.) Pers. : Engler
B. capensis auct.non Pers. : Dinter

Monechma arenicola (Engler) C.B. Clarke

Synonyms : *Justicia arenicola* Engler
J. steingröveri Schinz ex Lindau

M. desertorum (Engler) C.B. Clarke

Synonym : *Justicia desertorum* Engler

M. genistifolium (Engler) C.B. Clarke

Synonyms : *Justicia genistifolia* Engler
J. hereroensis Engler
Monechma hereroense (Engler) C.B. Cl.

Petalidium setosum C.B. Clarke ex Schinz

P. variabile (Engler) C.B. Clarke

Synonyms : *Pseudobarleria variabilis* Engler
P. variabilis var. *viridescens* Engler
P. variabilis var. *incana* Engler
P. glutinosa Engler
Petalidium glutinosum (Engler) C.B. Cl.
P. damarense S. Moore
P. incanum (Engler) Mildbr.
P. ovatum auct.non (Schinz) C.B. Cl. : C.B. Cl.

Ruellia diversifolia S. Moore

Synonyms : *R. marlothii* Engler
Dinteracanthus marlothii (Engler) Schinz
D. velutinus Schinz
Ruellia velutina (Schinz) Phillips

Family 131 PEDALIACEAE

Rogeria longiflora (Royen) J. Gay ex DC.

Synonyms : *Martynia longiflora* Royen
Rogeria longiflora var. *triloba* Engler
R. rangeana Engler nom.nud. : Dinter

Sesamum capense Burm. fil.

S. triphyllum Welw. ex Ascherson

Family 136 CAMPANULACEAE

Wahlenbergia androsacea A. DC.

Synonyms : *W. nudicaulis* A. DC.
W. arenaria A. DC.
Cephalostigma fockeanum Schinz
Wahlenbergia nudicaulis Engler nom.nud.
W. perennis Brehmer
W. androsacea var. *multicaulis* Brehmer
W. rosulata Brehmer
W. androsacea var. *rosulata* (Brehmer) Markgraf
W. riparia auct.non A. DC. : Brehmer

Family 137 LOBELIACEAE

Lobelia nuda Hemsley

Synonyms : *L. pubescens* var. *simplex* O. Kuntze
L. rosulata S. Moore
L. pubescens auct.non Dryander : Dinter

Family 139 ASTERACEAE

Aspilia eenii S. Moore

Synonym : *A. atrivittata* Merxm.

Berkheya spinosissima (Thunb.) Willd.

Synonyms : *Rohria spinosissima* Thunb.
Berkheya schenckii O. Hoffm.
B. horrida Muschler
B. oppositifolia auct.non DC. : Range

Blumea cafra (DC.) O. Hoffm.

Synonyms : *Conyza cafra* DC.
C. natalensis Schultz-Bip. ex Walpers
Vernonia pechuelii O. Kuntze

B. gariepina DC.

Calostephane marlothiana O. Hoffm.

Conyza bonariensis (L.) Cronq.

Synonyms : *Erigeron bonariense* L.
E. crispus Pourret

Dicoma capensis Less.

Flaveria bidentis (L.) O. Kuntze

Synonym : *Ethulia bidentis* L.

Gazania jurineifolia DC. ssp. *scabra* (DC.) Roessler

Synonyms : *G. scabra* DC.
Meridiana namaensis S. Moore
Gazania violacea Muschler ex Engler
G. venusta Taylor
G. varians auct.non DC. : Dinter

Geigeria alata (DC.) Bentham & Hooker fil. ex Oliver & Hiern.

G. ornativa O. Hoffm.

Synonyms : *Zeyheria acaulis* Sprengel
non *Geigeria acaulis* Oliver & Hiern
Geigeria africana Griess. nom.illeg.
Dizonium longifolium Willd. ex Griess in syn.
Polychaetia passerinoides auct.non *Relhania passerinoides* L'Her. : DC.
Geigeria passerinoides auct.non *Relhania passerinoides* L'Her. : Harvey
G. luederitziana O. Hoffm.
G. eenii S. Moore
G. appendiculata O. Hoffm. & Muschler
G. nonikamensis Heering
G. africana ssp. *ornativa* (O. Hoffm.) Merxm.

G. plumosa Muschler

Synonyms : *G. dinteri* Muschler
G. foliosa O. Hoffm. & Muschler
G. foermeriana Muschler

Gnaphalium luteoalbum L.

Helichrysum argyrosphaerum DC.

H. herniarioides DC.

Synonym : Gnaphalium indicum auct.non L. : Dinter

H. leptolepis DC.

Synonyms : H. damarense O. Hoffm.

H. leptolepis var. intermedia S. Moore

H. leptolepis var. latifolia S. Moore

H. roseo-niveum Marloth & O. Hoffm.

H. tomentosulum (Klatt) Merxm. ssp. aromaticum (Dinter) Merxm.

Synonym : Helichrysum aromaticum Dinter

Hirpicium gazanioides (Harvey) Roessler

Synonyms : Berkheya gazanioides Harvey

Gazania pechuelii O. Kuntze

Berkheya pechuelii (O. Kuntze) O. Hoffm.

Berkheyopsis pechuelii (O. Kuntze) O. Hoffm.

B. pechuelii var. glabrescens Thell.

Kleinia longiflora DC.

Synonym : Senecio longiflorus (DC.) Schultz-Bip.

Nicolasia stenoptera (O. Hoffm.) Merxm. ssp. stenoptera

Synonym : Laggera stenoptera O. Hoffm.

Nidorella resedifolia DC. ssp. resedifolia

Synonyms : N. hirta auct.non. DC. : Dinter

N. foetida auct.non. DC. : Range

Nolletia gariepina (DC.) Mattf.

Synonyms : Nidorella ? gariepina DC.

Felicia gariepina (DC.) L. Bolus

Ondetia linearis Bentham

Osteospermum microcarpum (Harvey) T. Norl. ssp. septentrionale (T. Norl.) T. Norl.

Synonym : O. microcarpum var. septentrionale T. Norl.

Pechuel-Loeschea leubnitziae (O. Kuntze) O. Hoffm.

Synonyms : *Piptocarpha* (vel *Vernonia*) *leubnitziae* O. Kuntze

Pluchea leubnitziae (O. Kuntze) N.E.Br.

Pegolettia senegalensis Cass.

Pentzia hereroensis O. Hoffm.

Synonyms : *P. namibensis* Dinter ex Merxm. & Eberle

P. galpinii Hutch.

? P. dinteri Muschler ex Dinter nom.nud.

P. schinziana (Thell.) Merxm. & Eberle

Synonym : *Matricaria schinziana* Thell.

Platycarpha carlinoides Oliver & Hiern.

Senecio alliariifolius O. Hoffm.

S. engleranus O. Hoffm.

S. flavus (Decne) Schultz-Bip.

Synonyms : *Crassocephalum flavum* Decne

S. brevilimbus S. Moore

S. marlothianus O. Hoffm.

Synonyms : *Othonna glauca* Klatt

Emilia albocostata Hiern.

S. marlothianus var. *minor* S. Moore

S. viridiflorus Hutch.

Tagetes minuta L.

Family 140 CICHORIACEAE

Launaea intybacea (Jacq.) Beauverd

Synonyms : *Lactuca intybacea* Jacq.

Sonchus goraeensis Lam.

Launaea goraeensis (Lam.) O. Hoffm.

"Lactuca sp.fl. sulphureis" Dinter

Family 147 LILIACEAE

Albuca sp. R87311

Aloe asperifolia A. Berger

A. dichotoma Masson

Synonyms : A. montana Schinz

A. dichotoma var. montana (Schinz) Berger

Asparagus denudatus (Kunth) Baker

Synonyms : Asparagopsis denudata Kunth

Asparagus namaensis Schinz

A. pearsonii Kies

A. abyssinicus auct.non. Hochstt. ex A.Richard, H.Bolus, L.Bolus & Glover

Dipcadi bakeranum Bolus

Synonyms : D. brevipes Baker

D. rautaneni Baker

D. gonocarpum Suesseng

D. glaucum (Burch. ex Ker.-Gawler) Baker

Synonyms : Uropetalon glaucum Burch. ex Ker.-Gawler

Dipcadi longibracteatum Schinz

D. magnum Baker

Urginea lorata Baker

Dipcadi gracilipes Krause

Eriospermum roseum Schinz

Synonym : E. majanthemifolium Krause & Dinter

Eriospermum cf. roseum (R531)

Hexacyrtis dickiana Dinter

Ornithogalum stapfii Schinz

Synonyms : *O. spirale* Schinz

O. dinteri Baker

O. juttae Krause

O.karasbergense Glover

O. schinzii Poelln.

O. melanopus Dinter ex Sölch

Ornithoglossum viride (L. fil.) Aiton

Synonyms : *Melanthium viride* L. fil.

Ornithoglossum glaucum Salisb.

O. glaucum var. *grandiflorum* Baker

O. glaucum var. *undulatum* Baker

O. dinteri Krause

Trachyandra laxa (N.E.Br.) Oberm.

Synonyms : *Anthericum laxum* N.E.Br.

A. glutinosum Dinter

A. pachyrrhizum Dinter

A. nigrobracteatum Dinter

A. glutinosum Dinter nom.illeg.

A. dinteri Poelln.

A. buchubergense Poelln.

A. brunneoviride Dinter ex Poelln.

A. elongatum auct.non. Willd. : Poelln.

Family 150 AMARYLLIDACEAE

Ammocharis tinneana (Kotschy & Peyr.) Milne-Redh. & Schweick.

Synonyms : *Crinum tinneanum* Kotschy & Peyr.

C. bainesii Baker

C. belkianum Schinz

Family 160 GRAMINEAE

Anthephora pubescens Nees

Synonym : *A. hochstetteri* auct.non. Nees : Hackel

Aristida adscensionis L.

Synonyms : *Chaetaria curvata* Nees

Aristida curvata (Nees) Trin. & Rupr.

A. pygmaea Trin. & Rupr.

A. confusa Trin. & Rupr.

A. strictiflora Trin. & Rupr.

A. guineensis Trin. & Rupr.

A. pusilla Trin. & Rupr.

A. adscensionis var. *pygmaea* (Trin. & Rupr.) Dur. & Schinz

A. adscensionis var. *strictiflora* (Trin. & Rupr.) Dur. & Schinz

A. adscensionis ssp. *guineensis* (Trin. & Rupr.) Henrard

A. congesta Roemer & Schultes

Synonyms : *Chaetaria congesta* (Roemer & Schultes) Nees

Aristida alopecuroides Hackel

A. rangei Pilger

A. congesta var. *megalostachya* Henrard

A. parvula (Nees) De Winter

Synonym : *Stipa parvula* Nees

Asthenatherum glaucum (Nees) Nevski
Synonyms : *Danthonia glauca* Nees
D. suffrutescens Stapf.
D. glauca var. *lasiophylla* Pilger
Asthenatherum glaucum var. *lasiophyllum* (Pilger) Conert

Brachiaria glomerata (Hackel) A. Camus
Synonyms : *Panicum glomeratum* Hackel
Leucophrys glomerata (Hackel) Stapf.

Cenchrus ciliaris L.
Synonyms : *Pennisetum cenchroides* Pers.
Panicum vulpinum Willd.
Setaria vulpina (Willd.) Beauv.
Pennisetum ciliare (L.) Link
P. rangei Mez

Chloris virgata Swartz

Cynodon dactylon (L.) Pers.
Synonym : *Panicum dactylon* L.

Enneapogon brachystachyus (Jaub. & Spach) Stapf.
Synonym : *Pappophorum brachystachyum* Jaub. & Spach

E. scaber Lehm.
Synonym : *Pappophorum scabrum* (Lehm.) Kunth

E. scoparius Stapf.
Synonyms : *Pappophorum scoparium* (Stapf.) Chiov.
P. filifolium Pilger
Enneapogon filifolium (Pilger) Stapf. ex Garabedian

Entoplocamia aristulata (Hackel & Rendle) Stapf.
Synonym : *Tetrachne aristulata* Hackel & Rendle

Eragrostis annulata Rendle

Synonym : E. ramosa Hackel

E. cyperoides (Thunb.) Beauv.

Synonyms : Poa cyperoides Thunb.

Eragrostis enodis Hackel

E. echinochloidea Stapf.

Synonym : E. auriculata Hackel

E. macrochlamys Pilger

Included : E. macrochlamus var. wilmaniae (C.E. Hubbard & Schweickerdt) De Winter

Syn: E. wilmaniae C.E. Hubbard & Schweickerdt

E. nindensis Fic. & Hiern.

Synonyms : E. denudata Hackel

E. buchananii K. Schum.

E. andongensis Rendle

E. quingensis Rendle

E. vanderysti De Wild.

E. acutissima Jedwabnick

E. porosa Nees

Synonyms : E. emarginata Hackel

E. hereroensis Hackel

E. spinosa (L. fil.) Trin.

Synonym : Festuca spinosa L. fil.

E. trichophora Coss. & Dur.

Synonyms : E. atherstonei Stapf

E. leptocalymma Pilger

E. henrardii P. Jansen

Odyssea paucinervis (Nees) Stapf.

Synonyms : *Dactylis paucinervis* Nees

Diplachne paucinervis (Nees) Stapf. ex Rendle

Panicum arbusculum Mez

Phragmites australis (Cav.) Steudel

Synonyms : *Arundo phragmites* L.

A. australis Cav.

Phragmites communis Trin.

Rhynchelytrum villosum (Parl. ex Hooker) Chiov.

Synonyms : *Monachyron villosum* Parl. ex Hooker

Tricholaena monachyron Oliver

Melinis rangei Mez

M. bertligii Mez

M. pulchra Mez

M. affinis Mez

M. mutica Mez

Schmidtia kalahariensis Stent

Setaria verticillata (L.) Beauv.

Synonym : *Panicum verticillatum* L.

Sporobolus consimilis Fresen.

Synonyms : *Vilfa consimilis* (Fresen.) Steudel

Sporobolus robustus auct.non. Kunth : Chippindall

S. nebulosus Hackel

Synonyms : *S. densissimus* Pilger

S.minutiflorus auct.non. Link : Dinter

Stipagrostis ciliata (Desf.) De Winter

Synonyms : *Aristida ciliata* Desf.

A. ciliata var. *capensis* Trin. & Rupr.

A. ciliata var. *villosa* Hackel
A. ciliata var. *tricholaena* Hackel
A. ciliata var. *pectinata* Henrard
Stipagrostis ciliata var. *capensis* (Trin. & Rupr.) De Winter

S. gonatostachys (Pilger) De Winter
Synonym : *Aristida gonatostachys*

S. hirtigluma (Steudel ex Trin. & Rupr.) De Winter
ssp. *hirtigluma*
Synonyms : *Aristida hirtigluma* Steudel ex Trin. & Rupr.
A. gracilior var. *pearsonii* Henrard
Stipagrostis hirtigluma ssp. *pearsonii* (Henrard) De Winter

S. hochstetterana (Beck ex Hackel) De Winter
Synonyms : *Aristida hochstetteriana* Beck ex Hackel
A. secalina Henrard
Stipagrostis hochstetteriana var. *secalina* (Henrard) De Winter

S. lutescens (Nees) De Winter var. *marlothii* (Hackel) De Winter
Synonyms : *Aristida marlothii* Hackel
Arthratherum lutescens Nees
Aristida lutescens (Nees) Trin. & Rupr.
A. corythroides J. Karl

S. namaquensis (Nees) De Winter
Synonyms : *Arthratherum namaquense* Nees
Aristida namaquensis (Nees) Trin. & Rupr.

S. obtusa (Delile) Nees ex Kunth
Synonyms : *Aristida obtusa* Delile
Stipagrostis capensis Nees

Arthratherum obtusum (Delile) Nees

Aristida bifida J. Karl

S. sabulicola (Pilger) De Winter

Synonym : *Aristida sabulicola* Pilger

S. subacaulis (Nees) De Winter

Synonyms : *Arthratherum subacaulis* Nees

Aristida subacaulis (Nees) Steudel

S. uniplumis (Licht. ex Roemer & Schultes) De Winter

(a) var. *uniplumis*

Synonyms : *Aristida uniplumis* Licht. ex Roemer & Schultes

Arthratherum uniplume (Licht. ex Roemer & Schultes) Nees

Aristida uniplumis var. *pearsonii* Henrard

(b) var. *intermedia* (Schweickerdt) De Winter

Synonym : *Aristida gracilior* var. *intermedia* Schweick.

Tragus berteronianus Schultes

Synonym : *T. racemosus* ssp. *biflorus* var. *berteronianus* (Schultes) Hackel

Tricholaena monachne (Trin.) Stapf. & Hubbard var. *annua* J.G.Anderson

Triraphis pumilio R.Br.

Synonyms : *Diplachne nana* Nees

Triraphis nana (Nees) Hackel

T. nana var. *conspicua* Hackel

T. ramosissima Hackel

Synonym : *T. elliotii* Rendle

Family 164 TYPHACEAE

Typha latifolia L. ssp. capensis Rohrb.

Synonyms : T. capensis (Rohrb.) N.E.Br.

T. australis auct.non. Schum. & Thonn. : Dinter

Family 165 CYPERACEAE

Cyperus compressus L.

C. marginatus Thunb.

Synonyms : Cyperus blandus Kunth

C. marginatus var. blandus (Kunth) Kükenthal

Juncellus laevigatus (L.) C.B. Clarke

Synonyms : Cyperus laevigatus L.

C. subaphyllus Boeck.

C. laevigatus var. subaphyllus (Boeck.) Kükenthal

Juncellus laevigatus var. subaphyllus (Boeck.) Podl.

Scirpus dioicus (Kunth) Boeck.

Synonym : Isolepis dioica Kunth

S. littoralis Schrader

APPENDIX II. Life-Form classes

In the descriptions of the communities above, the life-form system of Raunkiaer (1934) as modified by Ellenberg (1956) is used to describe the life forms of the species. The modified system is used because of its precision of definition and because it uses standard Raunkiaer terminology. Only the relevant classes, that is, those used above, are defined here. The complete system is given by Ellenberg (1956) and Shimwell (1971), and readers are referred to either of these works for details.

I. RADIKANTE (rooted plants)

A. Macrophanerophytes (M) : trees or tree-like plants with buds more than 2 m above ground.

B. Nanophanerophytes (N) : shrubs; buds between 0,25 and 2 m above ground.

C. Chamaephytes (Ch) : buds lower than 0,25 m, but not at ground level. This class includes dwarf shrubs, semi-shrubs, low perennial climbers, low succulents and large hard grasses.

D. Hemicryptophytes (H) : buds close to the ground, and often protected by a layer of dead leaves.

E. Geophytes (or cryptophytes) (G) : plants with buds beneath the soil surface. This class includes plants with bulbs, corms, root tubers and rhizomes.

F. Therophytes (T) : annual plants.

II. ADNATE (attached plants)

A. Thallo-epiphytes : lichens living on other plants

B. Thallo-chamaephytes : foliose and fruticose lichens.

C. Thallo-hemicryptophytes : crustose lichens.

APPENDIX III. Floristic affinities between the communities

The communities described from the study area are listed in classes of decreasing floristic similarity (measured in terms of Sørenson's coefficient of similarity; see 5.1 for discussion of the use of this).

I. Floristic similarity 76% - 80%

Aptosimum spinescens / *Calicorem capitata* (typical) sub-communities

II. Floristic similarity 71% - 75%

Stipagrostis obtusa sub-community / *Stipagrostis ciliata* community

III. Floristic similarity 66% - 70%

Acacia albida sub-community / *Datura* spp. - *Argemone ochroleuca* community

IV. Floristic similarity 61% - 65%

Acacia giraffae (typical) / *Adenolobus pechuelii* - *Acacia reficiens* communities

Petalidium setosum / *Petalidium variabile* communities

Acacia giraffae (typical) / Petalidium variabile communities

Adenolobus - *Acacia reficiens* / *Sesuvium sesuvioides* - *Stipagrostis obtusa* communities

V. Floristic similarity 56% - 60%

Adenolobus - *Acacia reficiens* community / *Stipagrostis obtusa* sub-community

Petalidium setosum community / *Stipagrostis obtusa* sub-community

Monechma genistifolium / *Petalidium variabile* communities

Petalidium variabile / *Commiphora* - *Anthephora pubescens* communities

Adenolobus - *Acacia reficiens* / *Monechma genistifolium* communities

VI. Floristic similarity 51% - 55%

Petalidium setosum / *Monechma genistifolium* communities

Sesuvium - *Stipagrostis obtusa* community / *Stipagrostis obtusa* sub-community

Monechma genistifolium / *Stipagrostis ciliata* communities

Adenolobus - *Acacia reficiens* / *Petalidium variabile* communities

Monechma genistifolium community / *Stipagrostis obtusa* sub-community
Monechma genistifolium / *Commiphora* - *Anthephora pubescens* communities
Petalidium setosum / *Stipagrostis ciliata* communities
Adenolobus - *Acacia reficiens* / *Petalidium variabile* communities

VII. Floristic similarity 46% to 50%

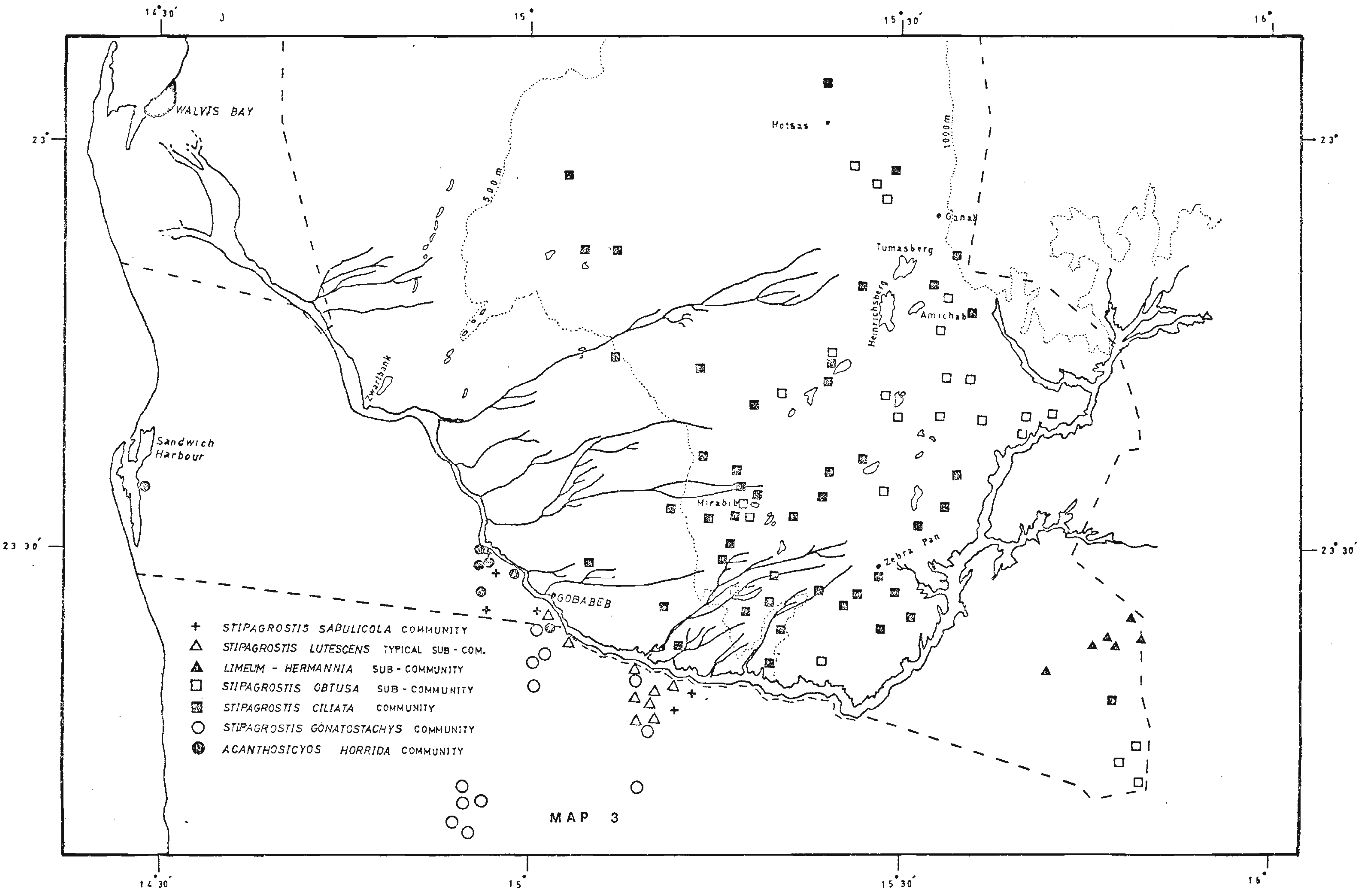
Petalidium setosum / *Commiphora* - *Anthephora pubescens* communities
Acacia giraffae (typical) / *Petalidium variabile* communities
Sesuvium - *Stipagrostis obtusa* / *Monechma genistifolium* communities
Sesuvium - *Stipagrostis obtusa* community / *Zygophyllum stapfii* sub-community
Acacia giraffae (typical) community / *Stipagrostis obtusa* sub-community
Sesuvium - *Stipagrostis obtusa* / *Stipagrostis ciliata* communities
Aristida - *Eragrostis annulata* community / *Stipagrostis obtusa* sub-community
Pechuel-Loeschea leubnitziae / *Zygophyllum stapfii* communities
Pechuel-Loeschea leubnitziae community / *Salsola tuberculata* (typical) sub-community
Salsola tuberculata (typical) / *Stipagrostis obtusa* sub-communities
Zygophyllum stapfii sub-community / *Stipagrostis ciliata* community
Acacia giraffae (typical) / *Sesuvium* - *Stipagrostis obtusa* communities

VIII. Floristic similarity 41% - 45 %

Acacia giraffae (typical) / *Aristida* - *Eragrostis annulata* communities
Adenolobus - *Acacia reficiens* / *Aristida* - *Eragrostis annulata* communities
Acacia giraffae (typical) / *Stipagrostis ciliata* communities
Salsola tuberculata (typical) / *Stipagrostis ciliata* communities
Acacia giraffae (typical) / *Monechma genistifolium* communities
Zygophyllum stapfii community / *Salsola tuberculata* (typical) sub-community
Petalidium setosum / *Sesuvium* - *Stipagrostis obtusa* communities
Sesuvium - *Stipagrostis obtusa* / *Petalidium variabile* communities
Petalidium variabile community / *Stipagrostis obtusa* sub-community
Aristida - *Eragrostis annulata* / *Stipagrostis ciliata* communities
Pechuel-Loeschea leubnitziae / *Asclepias buchenaviana* communities
Zygophyllum stapfii community / *Zygophyllum stapfii* sub-community
Pechuel-Loeschea leubnitziae community / *Zygophyllum stapfii* sub-community

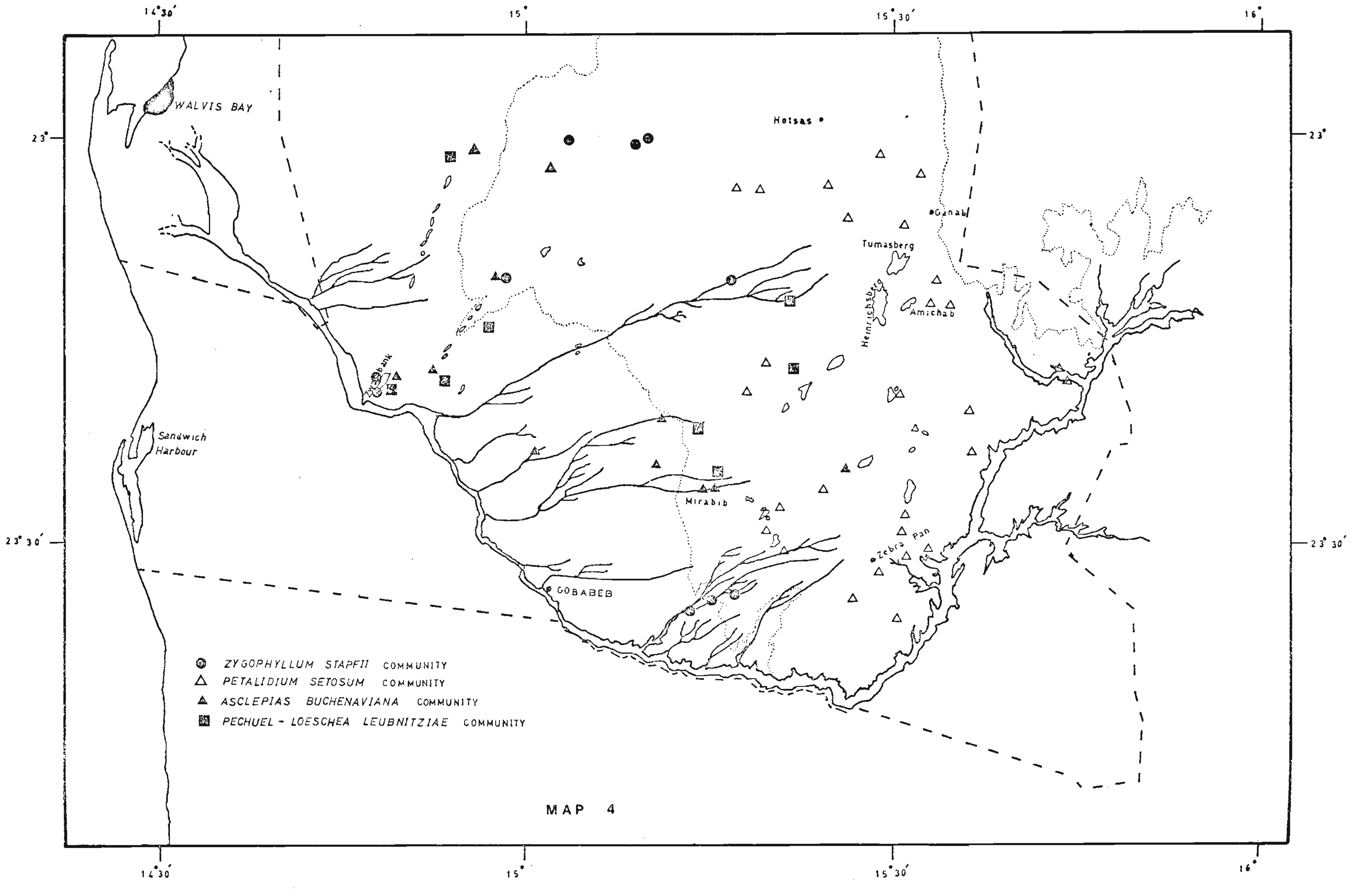
Pechuel-Loeschea leubnitziae / *Stipagrostis ciliata* communities.

Maps 3 - 7. These show the distribution of relevés of various communities in the study area. Where two or more relevés of a community were taken close together (less than 0,5 km apart) the position of only one is shown.

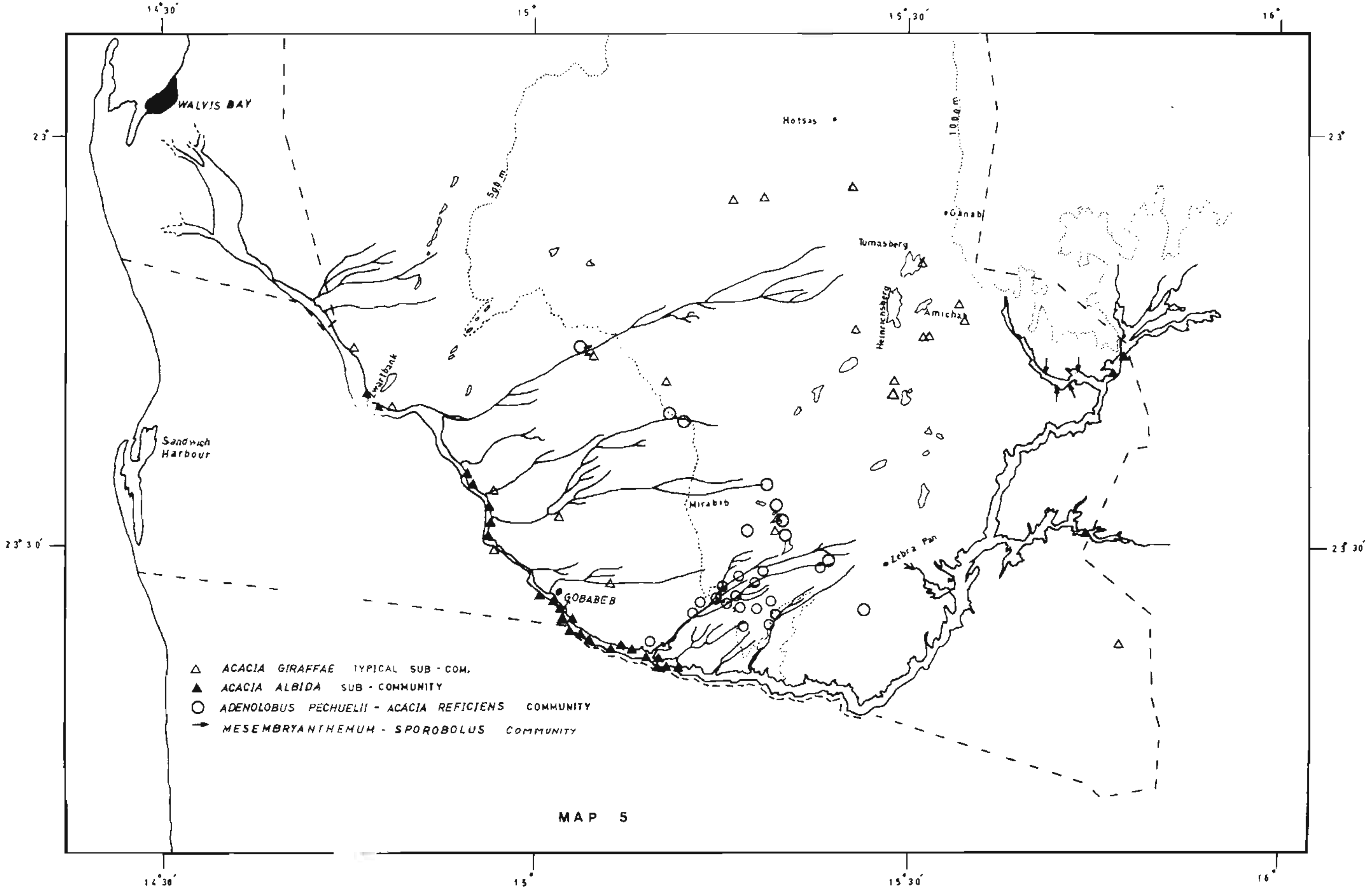


MAP 3

14°30′
15°
15°30′
16°
23°
23°30′
WALVIS BAY
Sandwich Harbour
Zwartbank
500 m
1000 m
Hotsas
Ganab
Tumasberg
Heinrichsberg
Amichab
Mirabib
Zebra Pan
GOBABEB
+ STIPAGROSTIS SABULICOLA COMMUNITY
△ STIPAGROSTIS LUTESCENS TYPICAL SUB-COM.
▲ LIMEUM - HERMANNIA SUB-COMMUNITY
□ STIPAGROSTIS OBTUSA SUB-COMMUNITY
▨ STIPAGROSTIS CILIATA COMMUNITY
○ STIPAGROSTIS GONATOSTACHYS COMMUNITY
● ACANTHOSICYOS HORRIDA COMMUNITY

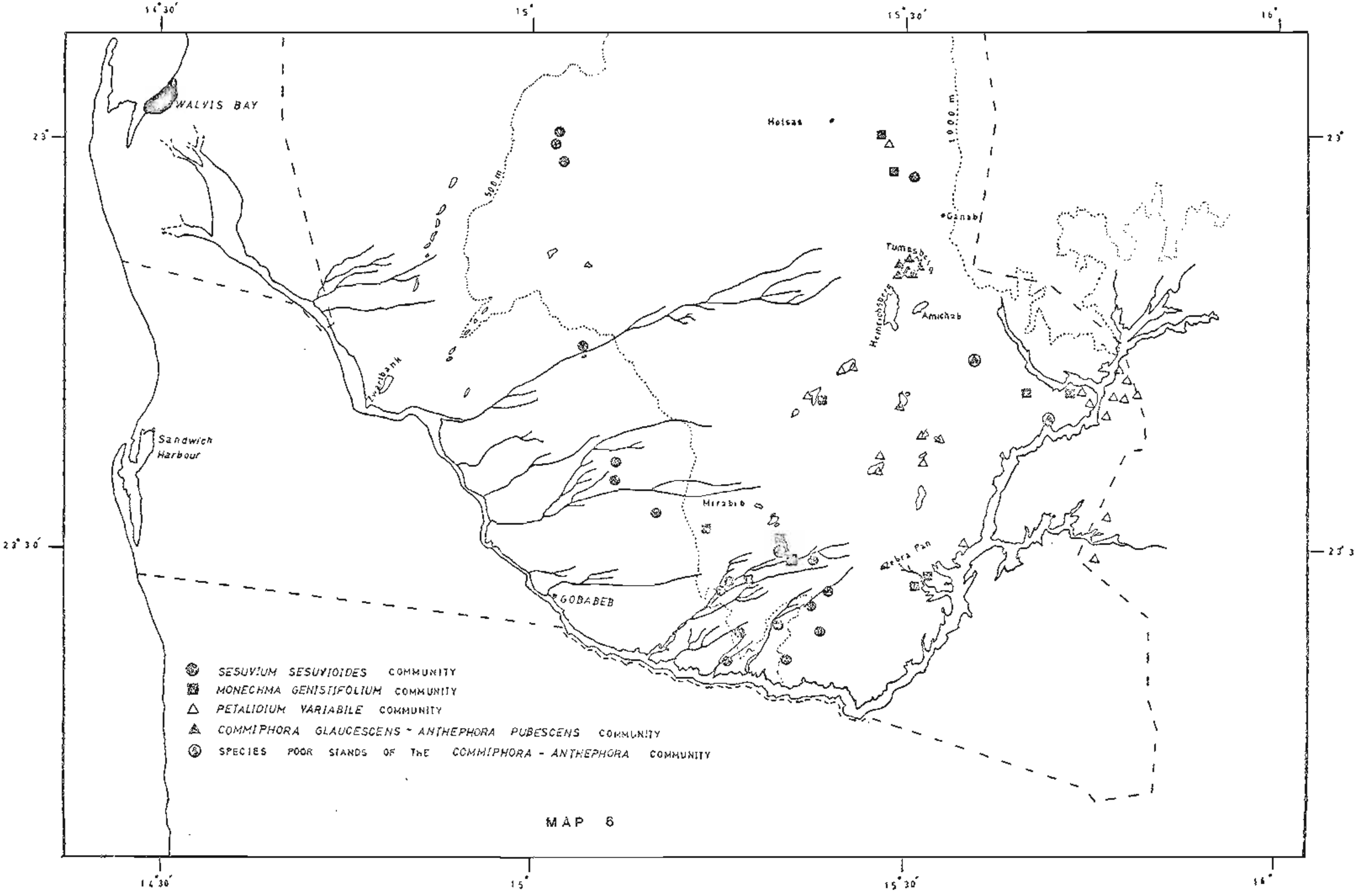

14°30'
15°
15°30'
16°
23°
23°30'
WALVIS BAY
Sandwich Harbour
Hotsas
Ganab
Tumasberg
Heinrichsberg
Amichab
Mirabib
Zebra Pan
GOBABEB
ZYGOPHYLLUM STAPFII COMMUNITY
PETALIDIUM SETOSUM COMMUNITY
ASCLEPIAS BUCHENAVIANA COMMUNITY
PECHUEL - LOESCHEA LEUBNITZIAE COMMUNITY

MAP 4

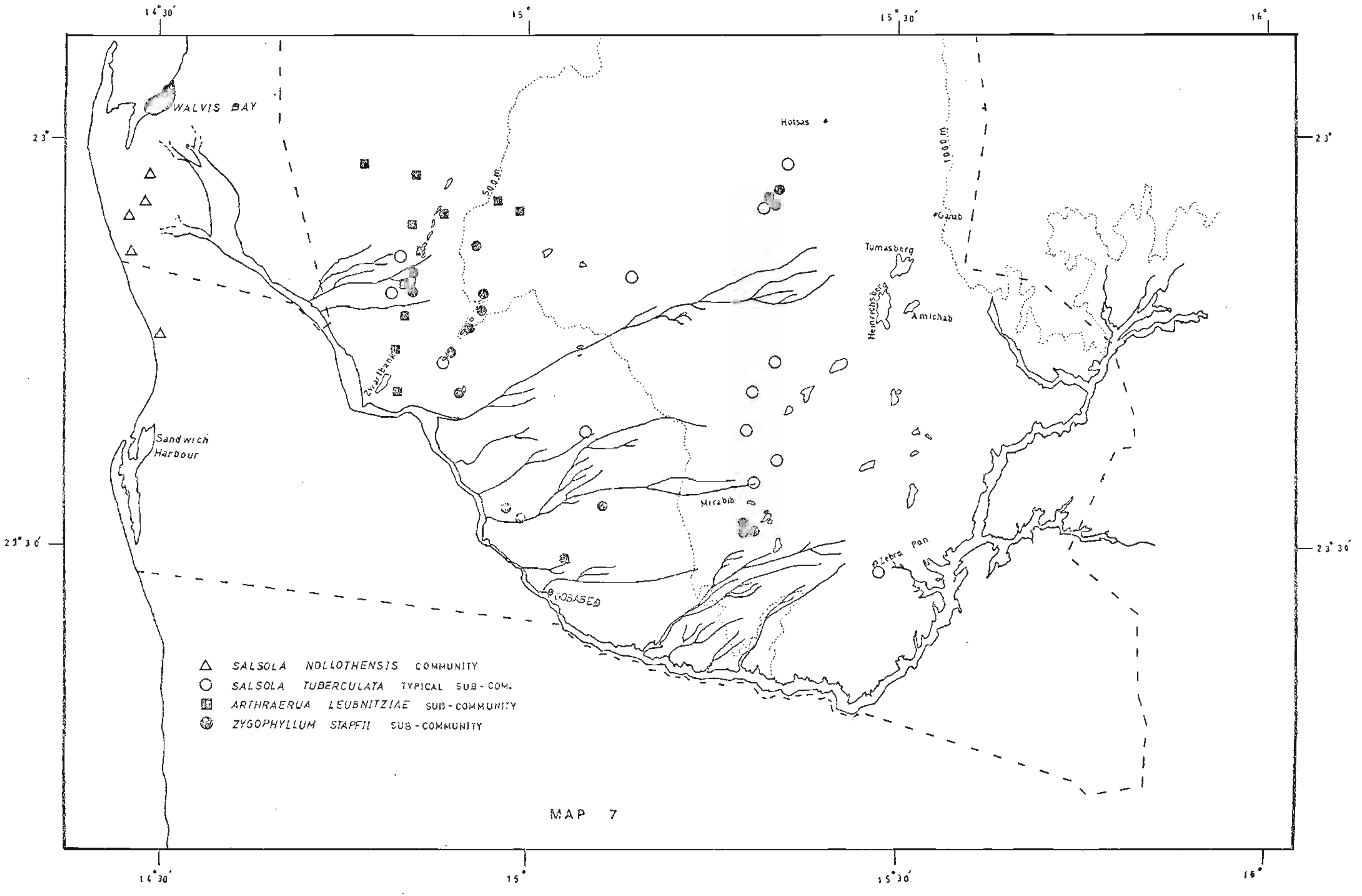


MAP 5

14°30′
15°
15°30′
16°
23°
23°30′
WALVIS BAY
Sandwich Harbour
Zwartbank
500 m
1000 m
Hotsas
Gânab
Tumasberg
Heinrichsberg
Amichab
Mirabib
Zebra Pan
GOBABEB
△ ACACIA GIRAFFAE TYPICAL SUB - COM.
▲ ACACIA ALBIDA SUB - COMMUNITY
○ ADENOLOBUS PECHUELII - ACACIA REFICIENS COMMUNITY
→ MESEMBRYANTHEMUM - SPOROBOLUS COMMUNITY


14°30′
15°
15°30′
16°
23°
23°30′
WALVIS BAY
Holsas
1000 m
500 m
Ganab
Tumasberg
Heinrichsberg
Amichab
Zwartbank
Sandwich Harbour
Mirabib
Zebra Pan
GOBABEB
SESUVIUM SESUVIOIDES COMMUNITY
MONECHMA GENISTIFOLIUM COMMUNITY
PETALIDIUM VARIABILE COMMUNITY
COMMIPHORA GLAUCESCENS - ANTHEPHORA PUBESCENS COMMUNITY
SPECIES POOR STANDS OF THE COMMIPHORA - ANTHEPHORA COMMUNITY

MAP 6



14°30′
15°
15°30′
16°
23°
23°30′
WALVIS BAY
Sandwich Harbour
Hotsas
500 m
1000 m
Ganab
Tumasberg
Heinrichsberg
Amichab
Zwartbank
Mirabib
Zebra Pan
GOBABEB
△ SALSOLA NOLLOTHENSIS COMMUNITY
○ SALSOLA TUBERCULATA TYPICAL SUB-COM.
▨ ARTHRAERUA LEUBNITZIAE SUB-COMMUNITY
● ZYGOPHYLLUM STAPFII SUB-COMMUNITY

MAP 7

	Typha latifolia COMMUNITY						*Arthrocnemum affine* COMMUNITY							*Sporobolus virginicus* COMMUNITY																												*Odyssea paucinervis* COMMUNITY					
														a) TYPICAL									b) *Scirpus dioicus*							c) *Phragmites australis*																	
RELEVE N°	409	192	185	189	410	411	412	413	174	415	200	208	176	414	195	175	177	180	416	203	181	202	201	187	198	527	528	165	212	171	178	179	211	188	163	164	167	169	207	209	210	199	184	186	417	196	213
TOTAL COVER %	95	70	50	100	45	70	90	50	98	100	100	60	90	100	100	100	100	100	100	100	100	75	100	98	95	98	100	80	30	90	100	90	100	60	50	80	60	10	40	95	15	35	98	80	50	100	40
ASPECT	N	NW	NW	S	S	–	–	–	–	–	–	NE	–	–	–	–	–	–	–	NW	N	–	N	–	–	–	–	–	W	–	–	–	–	–	SE	N	SE	N	SE	SE	W	NW	–	–	SW	–	S
SLOPE	2	6	2	5	1	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2	2	0	5	0	0	0	0	0	3	0	0	0	0	0	10	6	7	5	4	5	3	2	0	0	3	0	4
SOIL TEXTURE	1G	1G	1G	1G	1G2A	1G	1G	1G	1G	1G	3A	1F	3B	1G	2A	2A	1G	1G	2B	2B	1F	2B	1F	1C	1F	1C	1C	1B	1B	1F	1F	1F	1F	1C	1B	1B	1C	1A	1F	1F	1B	1C	1B	1C	1F	1C	1C
DEGREE OF FLOODING	2	2	1	2	2	2	2	1	0	2	2	0	0	1	1	1	1	1	1	1	1	1	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL N° OF SPECIES	1	1	3	3	3	3	3	3	4	1	1	2	2	2	2	2	2	2	1	1	3	2	3	2	2	3	2	5	4	4	3	3	1	3	4	4	2	3	4	3	1	1	1	2	2	1	1
DIFFERENTIAL SPECIES OF *Typha* COMMUNITY																																															
Typha latifolia	9	6	10	8	5	6	1	(6)	+																																						
DIFFERENTIAL SPECIES OF *Arthrocnemum* COMMUNITY																																															
Arthrocnemum affine					5	7	6	6	8	10	10	8	10	1	5	2	1	1				5	6					4	4		4/5	4/5			3	7			4	9							
DIFFERENTIAL SPECIES OF *Sporobolus* COMMUNITY																																															
Sporobolus virginicus			4/5	4	4	1	5	3	5				4	10	10	10	10	10	10	10	10	7	8	8	6	3	2	5	4	4/5	10	9		6	3	7		+	4								
DIFFERENTIAL SPECIES OF *Scirpus* SUB-COMMUNITY																																															
Scirpus dioicus			4/5																				7	6	8	9	10	9	5	1				1													
DIFFERENTIAL SPECIES OF *Phragmites* SUB-COMMUNITY																																															
Phragmites australis																												3	4/5	9	5	8	10		7	8	7		6	10	5						
Heliotropium curassavicum																					2							2		1				5	3	2		3						4/5			
DIFFERENTIAL SPECIES OF *Odyssea* COMMUNITY																																															
Odyssea paucinervis																										1																7	9	8	7	10	7
COMPANION AND INFREQUENT SPECIES																																															
Juncellus laevigatus												5																											4	4					4	2	
Scirpus littoralis				3					3																																						
Lycium tetrandrum																					3																	4/5									
Acanthosicyos horrida																																					(+)										

Table I: SALT MARSH COMMUNITIES

	Stipagrostis sabulicola COMMUNITY									*Acanthosicyos horrida* COMMUNITY									*Stipagrostis gonatostachys* COMMUNITY												*Stipagrostis lutescens* COMMUNITY														
																															a) TYPICAL									b) *Limeum fenestratum* *Hermannia gariepina* SUB-COMMUNITY					
RELEVE N°	480	481	288	326	38	252	40	443	430	183	194	206	331	332	333	334	335	442	191	192	193	249	33	34	35	36	37	39	339	431	327	328	329	441	337	338	340	330	429	471	472	473	477	478	479
TOTAL COVER %	6	9	2	4	5	1	5	20	12	75	60	55	20	35	60	50	50	8	7	10	15	10	2	4	5	2	4	1	2	3	1	15	10	1	6	12	8	5	25	25	11	20	22	45	25
ASPECT	W	SW	NW	W	W	E	SW	N	E	N	N	SW	SE	E	N	S	NE	NE	S	-	-	-	-	-	-	E	E	W	NW	SE	E	N	N	N	N	SW	N	N	E	NE	W	W	SE	SE	NW
SLOPE	8	6	2	6	7	10	8	10	6	5	5	7	7	7	9	8	6	10	1	0	0	0	0	0	0	1	3	7	1	1	6	5	5	8	1	1	1	6	2	6	6	6	7	7	7
SOIL TEXTURE	1B	2B	1B	1B	1B	1B	1B	1B	1A	1B	1B	1B	2B	1B	1B	1B	1B	1B	G1B	1B	1B	G1B	G1B	G1B	G1B	1A	2B	1B	G1B	1B	1B	1B	1B	1B	G1B	1A	1B	1B	1B	1C	1C	1C	1C	1B	1C
SOIL CONSISTENCE (DRY)	0	0	0	0	0	0	0	0	0	0	0	0	0/1	0	0	0	0	0	0	0	0	0	0	0/1	0	0	0	0	0	0	0	0/1	0/1	0	0	0	0	0	0	0/1	0/1	0/1	0/1	0	0/1
GEOLOGY	G	G	G	-	-	G	G	G/Sc	Sc	-	-	-	G	G	G	G	G	G/Sc	-	-	-	-	C	C	C	C	C	G	Co	Co	G	G	G	G/Sc	Co	Co	Co	Sc	Sc	C	C	-	-	-	Sc
SOIL DEPTH	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	3	7	4	4	4	9	2-7	2-3	0-7	9	9	0-3	2	8	8	9	9	9	9	9	9	9	9
TOTAL N° OF SPECIES	2	2	1	2	1	1	1	1	1	1	2	1	3	2	1	1	1	1	1	1	1	1	2	1	1	1	1	1	2	2	2	2	1	2	2	2	2	4	2	7	4	8	9	7	8
DIFFERENTIAL SPECIES OF *Stipagrostis sabulicola* COMMUNITY																																													
Stipagrostis sabulicola	3	2		2	4	2	4	5	4/5				3/4																																
DIFFERENTIAL SPECIES OF *Acanthosicyos horrida* COMMUNITY																																													
Acanthosicyos horrida										7	7	8	4/5	6	8	7	7	4/5																											
DIFFERENTIAL SPECIES OF *Stipagrostis gonatostachys* COMMUNITY																																													
Stipagrostis gonatostachys																			4	4/5	5	4/5	3	3/4	4	2	3/4	2	3	3															
DIFFERENTIAL SPECIES OF *Stipagrostis lutescens* COMMUNITY																																													
Stipagrostis lutescens														(4)																	1	4/5	4/5	2	3	4/5	4	2	4/5	3/4	4	4/5	3		4
DIFFERENTIAL SPECIES OF *Limeum fenestratum* — *Hermannia gariepina* SUB-COMMUNITY																																													
Limeum fenestratum																																								2	3/4	3/4	3	2	3/4
Hermannia gariepina																																								1		3/4	3	3	1
Eragrostis spinosa																																						(4)		3	3	4	4/5		
COMPANION AND INFREQUENT SPECIES																																													
Asthenatherum glaucum																																3					3	1	1			2	3		3/4
Trianthema hereroensis	4	4/5	1	2									2																									(2)							
Stipagrostis ciliata																													2													2	3/4	6	3
Brachiaria glomerata																																								2	3/4	3/4		3	
Sesamum capense																																										3	3	1	3
Salsola tuberculata																														1				2	4	4									
Acacia giraffae																																								4/5					4/5
Helichrysum leptolepis																																											4	4/5	
Tephrosia dregeana																															2														
Parkinsonia africana																																								4/5					
Kohautia lasiocarpa																																											+		
Gisekia africana																																												2	
Tribulocarpus dimorphanthus																																													2
Odyssea paucinervis											6																																		

Table II: COMMUNITIES OF THE SAND DUNES

②

	Platycarpha COMMUNITY				*Calicorema capitata* COMMUNITY										*Aristida adscensionis-Eragrostis annulata* COMMUNITY						
					a) *Aptosimum* SUB-COMM.						b) TYPICAL										
RELEVE Nº	367	368	374	375	366	369	371	372	373	376	364	365	370	377	359	361	362	85	90	358	243
TOTAL COVER %	7	6	20	7	45	15	10	12	18	20	8	10	11	15	40	70	50	40	80	20	90
ASPECT	–	–	–	–	SW	NE	NE	NE	–	SW	S	SW	–	SW	S	S	–	–	–	E	–
SLOPE	0	0	0	0	3	3	1	3	0	2	4	5	0	5	1	1	0	0	0	1	0
SOIL TEXTURE	5A	5A	5A	5C	3B	3B	3A	4A	4A	3C	2C	3A	2B	2B	5A	5B	5B	4A	2C	2G	4A
SOIL CONSISTENCE	4	4	4	4	3	3	3	3	3	3	3	3/4	3	3	3	5	5	4	3	2	3
GEOLOGY	–	–	–	–	C/Sc	Sc	Sc	Sc	C/Sc	Sc	C/Sc	C/Sc	Sc	C/Sc	C/Sc	C/Sc	C/Sc	C/Sc	C/Sc	Sc	C/Sc
SOIL DEPTH	–	–	–	–	–	–	–	–	–	–	4	–	–	–	2	3	3	4	4	5	6
TOTAL Nº OF SPECIES	2	2	3	2	7	6	5	5	7	5	4	4	4	4	12	8	5	23	4	8	18
DIFFERENTIAL SPECIES OF *Platycarpha carlinoides* COMMUNITY																					
Platycarpha carlinoides	1	3	3	3/4																	
DIFFERENTIAL SPECIES OF *Calicorema capitata* COMMUNITY																					
Calicorema capitata					3	2	4	3/4	4/5	4/5	4	4/5	2	4/5							
DIFFERENTIAL SPECIES OF *Aptosimum spinescens* SUB-COMMUNITY																					
Aptosimum spinescens					3	1	1	3/4	3	3					2					4/5	
DIFFERENTIAL SPECIES OF *Aristida adscensionis–Eragrostis annulata* COMM.																					
Aristida adscensionis															6	3	2				2
Eragrostis annulata																		4	7	4	7
Geigeria alata																1		1	8		4
Hermannia modesta															3	1		2			2
Euphorbia inaequilatera															1	3		1			1
SPECIES OF CLAYEY SOILS																					
Psoralea obtusifolia	4	4	5	4	2	(3/4)	(2)	(3/4)		(4)					3	8	6	1	4	+	
Geigeria ornativa			1		7(2)	(5)2	1	3	2				2		3	4	+	1			
COMPANION AND INFREQUENT SPECIES																					
Stipagrostis ciliata						3	(3)		(1)	(3)		2	4/5							1	
Stipagrostis uniplumis						3					2	2		3	3	2				3	
Stipagrostis obtusa					+				+		+	2	2								
Salsola tuberculata					+			2		2	3			3							
Kohautia lasiocarpa															3/4	1	+				
Indigofera auricoma					+															1	2
Anticharis linearis															2					1	
Kohautia ramosissima																			4	+	
Enneapogon brachystachyus															2						1
Euphorbia glanduligera																		1			+
Tribulus terrestris																		1			1
Mollugo cerviana																		+			5
Zygophyllum cylindrifolium									3					3							
Petalidium setosum									3												
Boscia albitrunca																					5
Boscia foetida																		4			
Grewia flavescens																					7
Pechuel-Loeschea leubnitziae																					3
Amaranthus thunbergii																					1
Eragrostis porosa																					2
Tragus berteronianus																					3
Crotalaria podocarpa																					2
Zygophyllum simplex																					1
Ziziphus mucronata																		4/5			
Maytenus heterophylla																		4			
Euclea psuedebenus																		4			
Phyllanthus dinteri																		3			
Launaea intybacea																		2			
Chloris virgata																		4			
Hybanthus densifolius																		+			
Eragrostis trichophora																		2			
Trichodesma africana																		1			
Monsonia umbellata																		+			
Tribulus zeyheri																		1			
Forsskaolea candida																		1			
Setaria verticillata																		1			
Limeum argute-coronatum															2						
Cleome luederitziana															3						
Aristida congesta																	6				

Table V: COMMUNITIES OF THE PANS

	Eragrostis cyperoides COMMUNITY								
RELEVE N°	172	173	182	190	193	205	168	418	166
TOTAL COVER %	25	70	95	40	75	35	85	60	65
ASPECT	NE	N	N	NW	NW	SW	N	SW	NW
SLOPE	6	0	4	6	3	6	0	6	6
SOIL TEXTURE	1B	1B/3A	1B/3A	1B	1B	1B	1B	1B	1B
SOIL CONSISTENCE (DRY)	0	0	0	0	0	0	0	0	0
GEOLOGY	–	–	–	–	–	–	–	–	–
SOIL DEPTH	9	9	9	9	9	9	9	9	9
TOTAL N° OF SPECIES	2	3	2	1	1	1	2	3	4
DIFFERENTIAL SPECIES OF *Eragrostis cyperoides* COMMUNITY									
Eragrostis cyperoides	5	5	9	7	8	7	4/5	5	7
COMPANION AND INFREQUENT SPECIES									
Heliotropium curassavicum	1	4	1						
Capparis hereroensis							9		4/5
Odyssea paucinervis								3	1
Acanthosicyos horrida									+
Phragmites australis								1	
Lycium tetrandrum		6							

Table II: *Eragrostis cyperoides* COMMUNITY

	Salsola nollothensis COMMUNITY					*Pechuel-Loeschea leubnitziae* COMMUNITY								*Zygophyllum stapfii* COMMUNITY										
RELEVE Nº	197	105	295	296	297	307	421	336	288	153	133	134	158	308	378	287	419	91	96	162	27	161	26	28
TOTAL COVER %	30	15	20	10	20	6	20	8	3	7	15	20	8	10	5	6	30	3	20	7	20	7	11	12
ASPECT	SE	-	-	NE	-	SE	W	W	SW	E	NW	W	W	S	E	NW	SE	NW	SE	W	E	E	E	E
SLOPE	5	0	0	6	0	7	5	5	1	0	2	0	0	6	4	5	4	1	0	2	5	3	5	2
SOIL TEXTURE	1F	1F	1G	1G	1G	1B	1A	1B	G1C	G1B	G1B	G1B	G1B	1B	1B	G2C	2F	2B	1B	2C	G1B	2B	1B	2A
SOIL CONSISTENCE (DRY)	1	1	1/2	1	2	0	1	1	1	0	1	1	0	1/2	0	3	2	3	1/3	0	1	1	1	1/2
GEOLOGY	-	-	-	-	-	M	G	G	Sc	G	C/Sc	C/Sc	C/G	Do	Do	Sc	Sc	Sc	Sc	Sc	Sc	G/Sc	Sc	Sc
SOIL DEPTH	8	8	8	8	8	8	6	2/5	3/5	8	8	7	4	3/8	8	7	2	4	4	0/6	8	8	9	8
CEMENTING SUBSTANCE								G	S		C	C	C	G				S	S	G		G		
TOTAL Nº OF SPECIES	1	1	1	1	1	4	13	19	2	2	7	7	6	4	2	1	10	2	1	1	7	2	2	2
DIFFERENTIAL SPECIES OF *Salsola nollothensis* COMMUNITY																								
Salsola nollothensis	6	4/5	5	4/5	5																			
DIFFERENTIAL SPECIES OF *Pechuel-Loeschea leubnitziae* COMMUNITY																								
Pechuel-Loeschea leubnitziae						2	4/5	2	1	4	4/5	4/5	3				4							
DIFFERENTIAL SPECIES OF *Zygophyllum stapfii* COMMUNITY																								
Zygophyllum stapfii						1	2							1	1	4	5	1	5		5	2	4/5	4/5
DIFFERENTIAL SPECIES OF *Salsola tuberculata* COMMUNITY																								
Salsola tuberculata																								
DIFFERENTIAL SPECIES OF *Arthraerua leubnitziae* SUB-COMMUNITY																								
Arthraerua leubnitziae																								
DIFFERENTIAL SPECIES OF *Zygophyllum stapfii* SUB-COMMUNITY																								
Aloe asperifolia																								
Dyerophytum africanum																								
DIFFERENTIAL SPECIES OF *Stipagrostis obtusa* SUB-COMMUNITY																								
Stipagrostis obtusa												2												
Euphorbia glanduligera																								
Zygophyllum cylindrifolium													2											
Enneapogon brachystachyus																								
Stipagrostis uniplumis																								
Trianthema triquetra																								
DIFFERENTIAL SPECIES OF *Stipagrostis ciliata* COMMUNITY																								
Stipagrostis ciliata							3	4		(1)	3	4	2				2				2	4		2
COMPANION AND INFREQUENT SPECIES OCCURRING IN TWO OR MORE RELEVES																								
Zygophyllum simplex							+	+									4/5	3			1		+	
Tephrosia dregeana							2	2									2							
Euphorbia phylloclada							1	1									+							
Monechma desertorum																								
Indigofera auricoma								1																
Geigeria alata																								
Geigeria ornativa							1																	
Tribulus terrestris																								
Mollugo cerviana																					2			
Kohautia lasiocarpa																								
Lotononis platycarpa																								
Aristida parvula											3/4	3												
Brachiaria glomerata											+	2									2			
Hermannia modesta																								
Stipagrostis hochstetterana											4	4	(4)											
Eragrostis annulata																					+			
Galenia africana							4/5	2						1										
Cleome luederitziana																	+							
Monsonia umbellata																								
Stipagrostis hirtigluma																								
Eragrostis nindenis																								
Limeum argute-coronatum																								
Trichocaulon clavatum																								
Kleinia longiflora																								
Stipagrostis lutescens						3								4	4									
Monechma arenicola											+		3											
Anticharis linearis																								
Petalidium setosum													2											
Osteospermum microcarpum																	2							
Aizoanthemum dinteri																								
Stipagrostis subacaulis																								
Sesuvium sesuvioides																	3/4				1			
Cleome diandra																	+							
Raphionacme (S-R 10)																								
Euphorbia inaequilatera																								
Psilocaulon salicornioides									2								(3/4)			4				
Blepharis obmitrata																								
Commiphora saxicola																								
Calostephane marlothiana																								
Triraphis pumilio																								
Asparagus denudatus																								
Crotalaria podocarpa																								
Helichrysum herniaroides							+	+																
Aptosimum angustifolium																								
Helichrysum leptolepis								3																
Heliotropium oliveranum								1																
Kohautia ramosissima								+																
Acanthosicyos horrida						3								4										
Lotononis sp (R 102)							+					+												
Gazania jurineifolia								3																
Pegolettia senegalensis																								
Boscia foetida																								
Senecio engleranus																								
Mesembryanthemum guerichianum																								
Euphorbia lignosa																								
Blepharis bossii																								
Chascanum gariepense																								
Celosia spathulifolia																								
Amaranthus thunbergii																								
Tribulus zeyheri																								
Moringa ovalifolia																								
Lichens																								

	Salsola tuberculata COMMUNITY																														
	a) TYPICAL												b) *Zygophyllum stapfii* SUB-COMMUNITY																		
RELEVE Nº	321	322	316	283	93	106	152	154	155	122	125	57	384	385	422	383	386	388	389	350	387	379	276	278	230	231	232	281	92	94	95
TOTAL COVER %	3	8	5	10	20	4	8	5	25	4	60	2	4	3	7	3	8	5	10	4	3	8	2	3	12	12	7	6	8	10	45
ASPECT	W	N	N	NE	SW	NE	S	W	E	S	S	NW	SW	NW	W	S	SW	SE	S	SW	N	N	W	SW	N	SE	W	-	E	S	-
SLOPE	0	0	10	0	0	0	4	0	0	9	0	0	6	8	4	6	10	9	10	7	6	8	1	1	6	8	7	0	6	6	0
SOIL TEXTURE	1B	1B	G2B	1C	1B	G1C	G1C	2C	G1A	G1B	1C	1B	G1A	G1B	G1B	G	1B	S1B	G	G1B	1B	1C	G	G	G	1C	G1B	G	G1A	1B	1B
SOIL CONSISTENCE (DRY)	3	3/4	0	3	4/5	3	2/3	2	2	3	2/4	1	1	1	0	0	1	0	0	0	0	0	1	0	0	0	0	0	2/3	4	4
GEOLOGY	-	G/G	Q	G/G	Sc	C/Sc	C/G	C/G	G	C/G	G	Sc	Do	Do	G	Sst	Sst	Sst	DSst	G	G	Q	G	G	G/Sc	G	G/Sc	G	Sc	Sc	Sc
SOIL DEPTH	5	8	0/3	3	5	2	4	2/7	9	4	4	8	0/2	0/2	5	0/1	0/2	0/2	0/1	0/1	0/4	0/1	0/3	4	0/2	0/4	0/1	0/2	2	2	2
CEMENTING SUBSTANCE		G		G	S	C	C	C		C	C																		G	S	S
TOTAL Nº OF SPECIES	1	2	5	2	1	1	3	3	3	3	5	10	10	5	5	5	13	9	15	4	4	10	6	5	10	17	10	4	2	2	2
DIFFERENTIAL SPECIES OF *Salsola nollothensis* COMMUNITY																															
Salsola nollothensis																															
DIFFERENTIAL SPECIES OF *Pechuel-Loeschea leubnitziae* COMMUNITY																															
Pechuel-Loeschea leubnitziae									3/4						2																
DIFFERENTIAL SPECIES OF *Zygophyllum stapfii* COMMUNITY																															
Zygophyllum stapfii													2	3	4		3	1	4	+	3	4	2			4	3	2	3	1	5
DIFFERENTIAL SPECIES OF *Salsola tuberculata* COMMUNITY																															
Salsola tuberculata	3	4/5	3/4	4/5	5	3/4	2	3	6	1	4	2	3	2	2	3		1	3	+	2	3/4	1	1					4	6	7
DIFFERENTIAL SPECIES OF *Arthraerua leubnitziae* SUB-COMMUNITY																															
Arthraerua leubnitziae													2	2																	
DIFFERENTIAL SPECIES OF *Zygophyllum stapfii* SUB-COMMUNITY																															
Aloe asperifolia													+				3	3/4	4												
Dyerophytum africanum						+										2	+	1	3					3	2			3/4			
DIFFERENTIAL SPECIES OF *Stipagrostis obtusa* SUB-COMMUNITY																															
Stipagrostis obtusa										+																2					
Euphorbia glanduligera																															
Zygophyllum cylindrifolium											2																				
Enneapogon brachystachyus											2														2	2	1				
Stipagrostis uniplumis																									3	3	3/4				
Trianthema triquetra																															
DIFFERENTIAL SPECIES OF *Stipagrostis ciliata* COMMUNITY																															
Stipagrostis ciliata		(2)	3	(3)			4	2			3/4	1	3	2	3	2	1		1		(1)	2				3		3			
COMPANION AND INFREQUENT SPECIES OCCURRING IN TWO OR MORE RELEVES																															
Zygophyllum simplex											1	1						+	2				+		4	1	2				
Tephrosia dregeana												1				2			1		+		(3)	2							
Euphorbia phylloclada			3										+				2		2			+			3	3	2				
Monechma desertorum																															
Indigofera auricoma												2													3	3	1				
Geigeria alata																															
Geigeria ornativa																								3							
Tribulus terrestris												2																			
Mollugo cerviana																									1	1					
Kohautia lasiocarpa																															
Lotononis platycarpa																															
Aristida parvula			2																					+							
Brachiaria glomerata																										3					
Hermannia modesta																															
Stipagrostis hochstetterana							(3)	1																							
Eragrostis annulata												1																			
Galenia africana													+		2	3						3									
Cleome luederitziana																															
Monsonia umbellata																										3	+				
Stipagrostis hirtigluma																															
Eragrostis nindenis																															
Limeum argute-coronatum												1																			
Trichocaulon clavatum													2				+		+			2									
Kleinia longiflora																	2		3			+									
Stipagrostis lutescens																				+											
Monechma arenicola																															
Anticharis linearis																															
Petalidium setosum																											2				
Osteospermum microcarpum			3														2		2												
Aizoanthemum dinteri																															
Stipagrostis subacaulis																	3										+				
Sesuvium sesuvioides																										+	3				
Cleome diandra																															
Raphionacme (S-R 10)																															
Euphorbia inaequilatera												+																			
Psilocaulon salicornioides									1																						
Blepharis obmitrata																															
Commiphora saxicola																									3/4	4					
Calostephane marlothiana																	2		1			+									
Triraphis pumilio																	+		1												
Asparagus denudatus			+															+	+				+								
Crotalaria podocarpa																															
Helichrysum herniaroides																															
Aptosimum angustifolium																															
Helichrysum leptolepis																									+						
Heliotropium oliveranum																															
Kohautia ramosissima																															
Acanthosicyos horrida																															
Lotononis sp (R 102)																															
Gazania jurineifolia																			3												
Pegolettia senegalensis																															
Boscia foetida										3																					
Senecio engleranus																	3	3													
Mesembryanthemum guerichianum																	1									2					
Euphorbia lignosa																		1				2									
Blepharis bossii																				3/4							3(2)				
Chascanum gariepense																									1	1					
Celosia spathulifolia																															
Amaranthus thunbergii																															
Tribulus zeyheri																															
Moringa ovalifolia																															
Lichens	3	3	2										2	2		2	2	3/4	3			1									

	Salsola tuberculata COMMUNITY																																			
	c) *Arthraerua leubnitziae* SUB-COMM.											d) *Stipagrostis obtusa* SUB-COMMUNITY																								
RELEVE Nº	425	426	317	318	424	319	324	325	323	423	320	225	88	266	269	272	145	147	215	228	127	137	148	88	86	245	247	248	250	252	256	274	84	469	476	475
TOTAL COVER %	12	2	15	5	7	3	3	8	2	2	3	8	5	15	25	26	15	6	18	18	15	18	8	45	20	20	20	15	25	18	10	10	15	20	20	5
ASPECT	NW	NW	N	W	NE	-	W	N	W	NW	NW	E	NE	E	S	-	SW	-	SE	E	-	E	S	S	-	-	-	-	W	N	-	-	E	N	N	W
SLOPE	1	1	5	1	2	0	1	6	6	1	1	1	2	1	2	0	3	0	1	5	0	5	5	2	0	0	0	0	1	1	0	0	5	2	5	6
SOIL TEXTURE	1F	1F	G1B	1B	1F	1B	1C	1B	1F	1F	1B	1C	G1B	1F	G1F	2B	1F	G2B	1B	2B	2B	1B	G1B	G1B	2C	1F	1F	1F	1F	1F	1B	G1C	G1F	G1F	2A	G1G
SOIL CONSISTENCE (DRY)	1	3	1	2	1/2	0	1	0	1	2	2	0	2	3	1	3	2/3	2	3	2	2/3	1	2	2	2	3	2	2	1	1	2	3	3	1	1	1
GEOLOGY	G	G/Q	M	Do	G	Do	Do	Do	Do	G/G	-	Sc	Sc	C/G	C	C/G	C	C	C/Sc	P/Sc	C/Sc	G	C/Sc	C/Sc	C/Sc	C	C/Sc	C/Sc	C/Sc	C/Sc	C	C/Sc	C/Sc	C	C	C
SOIL DEPTH	4	1/5	0/4	4	3	0/3	0/2	0/3	1/4	0/2	2	0/3	8	1/5	0/1	1	1/2	1/3	2	2/4	1	4	0/2	4	3	4	2	1/3	8	3/4	1/3	2	2	1	2	2
CEMENTING SUBSTANCE		G		G	G		G		G	G	G		C	C	C	C	C	C	C		C	C	C	C	C	C	C	C		C	C	C	C	C	C	C
TOTAL Nº OF SPECIES	2	2	3	1	3	5	2	5	2	3	2	9	2	12	16	14	6	3	6	9	11	6	5	9	18	11	12	11	9	6	8	6	12	5	3	4
DIFFERENTIAL SPECIES OF *Salsola nollothensis* COMMUNITY																																				
Salsola nollothensis																																				
DIFFERENTIAL SPECIES OF *Pechuel-Loeschea leubnitziae* COMMUNITY																																				
Pechuel-Loeschea leubnitziae																																				
DIFFERENTIAL SPECIES OF *Zygophyllum stapfii* COMMUNITY																																				
Zygophyllum stapfii			3			2		2																												
DIFFERENTIAL SPECIES OF *Salsola tuberculata* COMMUNITY																																				
Salsola tuberculata	4/5		2		4	2	2	3	1		2	3		4	2	4		3			4	2		2	2										3	4
DIFFERENTIAL SPECIES OF *Arthraerua leubnitziae* SUB-COMMUNITY																																				
Arthraerua leubnitziae	1	3	4/5	4	3/4	1	3	3/4	2	2	2																									
DIFFERENTIAL SPECIES OF *Zygophyllum stapfii* SUB-COMMUNITY																																				
Aloe asperifolia																																				
Dyerophytum africanum																																				
DIFFERENTIAL SPECIES OF *Stipagrostis obtusa* SUB-COMMUNITY																																				
Stipagrostis obtusa												2	4	1	4/5	5	2	4	5	3	4	2	4/5		1		3/4	3/4	3/4	3/4	4/5	2	1	5	5	2
Euphorbia glanduligera																									1	1	1	+	+				+	+		
Zygophyllum cylindrifolium														3	1	+	4	3	+			+	2	2	+	2	4/5	4			+	3/4				
Enneapogon brachystachyus												+		2	4	3			3	2	+		3	4/5	1	1	4	3		3	3/4	3/4	4	3		
Stipagrostis uniplumis														2	3/4	3/4			3	4	3			+		4/5	4	3/4	3			3/4	4/5			
Trianthema triquetra																2								+	1		1	1				1	2			
DIFFERENTIAL SPECIES OF *Stipagrostis ciliata* COMMUNITY																																				
Stipagrostis ciliata						2		3/4		2		3	2		4	3	4			4	3	3	3/4	6						3/4				1	3/4	
COMPANION AND INFREQUENT SPECIES OCCURRING IN TWO OR MORE RELEVES																																				
Zygophyllum simplex												4			3	2	2			3	4		3	3	4/5	4	3/4	2	+		1	3	3	3		
Tephrosia dregeana															1	1			1		1				+	2			1							
Euphorbia phylloclada															+						1															
Monechma desertorum														2						3	2					2			5	3						
Indigofera auricoma																										1										
Geigeria alata														1	+	2				3					+											
Geigeria ornativa																											3	+			+		+		(2)	
Tribulus terrestris																								+				+			+		2			
Mollugo cerviana												1																								
Kohautia lasiocarpa												+			+						1				1	2								+		
Lotononis platycarpa															2					2																
Aristida parvula														3							4															
Brachiaria glomerata																																				
Hermannia modesta																	1								+				+							
Stipagrostis hochstetterana																				3/4		4														
Eragrostis annulata																									1		1	+					3			
Galenia africana																																				
Cleome luederitziana										(2)		3				+																				
Monsonia umbellata														1											1						+		2			
Stipagrostis hirtigluma																	3					2														
Eragrostis nindenis														+	2	1																	1			
Limeum argute-coronatum														1																						
Trichocaulon clavatum								1																												
Kleinia longiflora						2																														
Stipagrostis lutescens																																				
Monechma arenicola																																				
Anticharis linearis															+										+											
Petalidium setosum																															+					
Osteospermum microcarpum																																				
Aizoanthemum dinteri												+																								
Stipagrostis subacaulis																																				
Sesuvium sesuvioides																																				
Cleome diandra														1										+												
Raphionacme (S-R 10)																																				
Euphorbia inaequilatera																									+											
Psilocaulon salicornioides																																				
Blepharis obmitrata																											1	1	+							
Commiphora saxicola																																				
Calostephane marlothiana																																				
Triraphis pumilio																																				
Asparagus denudatus																																				
Crotalaria podocarpa																			+											1						
Helichrysum herniaroides																																				
Aptosimum angustifolium																									+		+									
Helichrysum leptolepis																																				
Heliotropium oliveranum																																				
Kohautia ramosissima																																				
Acanthosicyos horrida																																				
Lotononis sp (R 102)																																				
Gazania jurineifolia																																				
Pegolettia senegalensis																													1					+		
Boscia foetida																																				
Senecio engleranus																																				
Mesembryanthemum guerichianum																																				
Euphorbia lignosa																																				
Blepharis bossii																																				
Chascanum gariepense																																				
Celosia spathulifolia		2			3																															
Amaranthus thunbergii																1									+											
Tribulus zeyheri																									2		+									
Moringa ovalifolia																																				
Lichens				2					3	+	+																									

	Stipagrostis ciliata COMMUNITY																																														
RELEVE Nº	290	289	314	273	98	100	102	103	107	109	110	117	20	30	108	136	118	120	121	224	6	13	15	16	19	268	156	222	66	123	135	139	142	143	144	58	59	60	69	149	316	315	129	140	63	70	474
TOTAL COVER %	6	7	18	30	1	1	1	2	4	6	1	3	15	5	5	12	4	3	10	15	1	20	5	30	30	7	5	20	7	6	22	15	15	12	7	2	35	10	18	18	30	30	25	12	20	10	30
ASPECT	SE	SW	-	SE	-	-	-	W	-	-	S	-	-	N	-	-	NE	W	N	N	-	N	-	E	E	-	NE	-	NW	SW	-	-	W	W	SW	-	-	-	-	-	-	-	N	-	S	-	W
SLOPE	8	2	0	5	0	0	0	1	0	0	5	0	0	6	0	0	6	4	5	4	0	7	0	1	1	0	1	0	6	3	0	0	5	4	4	0	0	0	0	0	0	0	2	0	1	0	6
SOIL TEXTURE	1C	G1C	G1C	G1C	1C	1C	1C	G1C	1B	1C	1C	G1F	1F	1B	1F	1F	1B	G1B	G1B	1B	1B	2C	G1B	1G	1B	1G	G	1A	1A	G2B	G1B	1B	G1B	G1B	1C	1G	1G	1G	1B	G1B	1A	G1F	1F	1B	1B	G1B	1G
SOIL CONSISTENCE (DRY)	1	1	1	2	2	1/3	1	1	1	1/2	1/2	1/3	2	2	2	2	1	1	1	2	1	1	0	0	0	2	0	1/2	1	1	0	1	0	0	1	1/2	2	2/3	2/4	2	1	2/4	2	1/2	2	2/4	2
GEOLOGY	Sc	Ig	G/Sc	-	G/Sc	Sc	Sc	C/G	G	G	G	G	Sc	Sc	G	C	P/Sc	C	C/G	Sc	Sc	Sc	Sc	Sc	Sc	C	C/Sc	Sc	C/Dr	P	C/Sc	G	C/G	Sc	C	Sc	Sc	Sc	Sc	Sc	-	G	C/Sc	G	Sc	Sc	C
SOIL DEPTH	1/7	7	1/3	9	3	9	3	4	5	7	1	3	3	7	9	5	5	4	5	6	8	3	7	6	3	2/6	2	6	8	4	6	8	8	0/4	0/5	7	5	5	7	4	8	8	4	2/8	4	7	3
CEMENTING SUBSTANCE					C		C	C	G			G				C		C	C												C				C				C						C		
TOTAL Nº OF SPECIES	3	1	8	4	1	1	1	1	2	2	3	5	4	9	7	2	3	1	2	4	4	4	5	10	8	6	3	5	4	4	2	5	5	5	4	4	3	7	15	6	10	12	5	5	8	3	4
DIFFERENTIAL SPECIES OF *Salsola nollothensis* COMMUNITY																																															
Salsola nollothensis																																															
DIFFERENTIAL SPECIES OF *Pechuel-Loeschea leubnitziae* COMMUNITY																																															
Pechuel-Loeschea leubnitziae																																															
DIFFERENTIAL SPECIES OF *Zygophyllum stapfii* COMMUNITY																																															
Zygophyllum stapfii																																															
DIFFERENTIAL SPECIES OF *Salsola tuberculata* COMMUNITY																																															
Salsola tuberculata														1	2															2								1				+					
DIFFERENTIAL SPECIES OF *Arthraerua leubnitziae* SUB-COMMUNITY																																															
Arthraerua leubnitziae																																															
DIFFERENTIAL SPECIES OF *Zygophyllum stapfii* SUB-COMMUNITY																																															
Aloe asperifolia																																															
Dyerophytum africanum																																															
DIFFERENTIAL SPECIES OF *Stipagrostis obtusa* SUB-COMMUNITY																																															
Stipagrostis obtusa	1										1				+							4/5		+	2				1	2		1	1							3/4							2
Euphorbia glanduligera																																									1						
Zygophyllum cylindrifolium																																															
Enneapogon brachystachyus				4								3			1											3		3							1	+	4		5	3/4		3				1	
Stipagrostis uniplumis																																									5	5					
Trianthema triquetra																																							1			1				1	
DIFFERENTIAL SPECIES OF *Stipagrostis ciliata* COMMUNITY																																															
Stipagrostis ciliata	4	4	3/4	6	1	2	1	3	3	3	2	2	4/5	3	3	4/5	2	3	4/5	4/5	1	4/5	4	6	5	4	3/4	5	2	2	2	4/5	4/5	4	3/4	2	6	4/5	4	4/5	1	3/4	4/5	4/5	5	4/5	6
COMPANION AND INFREQUENT SPECIES OCCURRING IN TWO OR MORE RELEVES																																															
Zygophyllum simplex											1						3		+	3				3	3/4	1	1	1				1			2	1		2	2	1		1	1	1	2	1	
Tephrosia dregeana			2																					1														1	1		1				1		
Euphorbia phylloclada														+									1	1	+																						
Monechma desertorum													1										3	3	3/4														1		1		2	1	1		
Indigofera auricoma			3											+														1						+											2		
Geigeria alata																										+		+									1		+				+				
Geigeria ornativa															2																									+							
Tribulus terrestris																																						2	2						1		
Mollugo cerviana												+		+	+																								1								
Kohautia lasiocarpa																								2																	1			2			
Lotononis platycarpa			2	1																2																					+	3					
Aristida parvula																															5												4/5				
Brachiaria glomerata														+												+															2						
Hermannia modesta																																							1		+	+					1
Stipagrostis hochstetterana																											(3)													+	1	2					
Eragrostis annulata																																										1					
Galenia africana																																															
Cleome luederitziana																																							+								1
Monsonia umbellata																																															
Stipagrostis hirtigluma			4/5																														1	2	3												
Eragrostis nindenis				3																																											
Limeum argute-coronatum																																				1		1	1								
Trichocaulon clavatum																																															
Kleinia longiflora																																															
Stipagrostis lutescens																																															
Monechma arenicola																																	1														
Anticharis linearis																																										+					
Petalidium setosum																																															
Osteospermum microcarpum																																															
Aizoanthemum dinteri																								+															+					+			
Stipagrostis subacaulis												3								2																											
Sesuvium sesuvioides																																															
Cleome diandra																																															
Raphionacme (S-R 10)														2							+				+				3																		
Euphorbia inaequilatera																																						1	1								
Psilocaulon salicornioides																																															
Blepharis obmitrata																																															
Commiphora saxicola																																		4													
Calostephane marlothiana																																															
Triraphis pumilio																								1																							
Asparagus denudatus																																								+							
Crotalaria podocarpa																																															
Helichrysum herniaroides																																															
Aptosimum angustifolium																																															
Helichrysum leptolepis																																															
Heliotropium oliveranum			3																																												
Kohautia ramosissima			2																																												
Acanthosicyos horrida																																															
Lotononis sp (R 102)																																															
Gazania jurineifolia																																															
Pegolettia senegalensis																																															
Boscia foetida																																3/4															
Senecio engleranus																																															
Mesembryanthemum guerichianum																																															
Euphorbia lignosa																																															
Blepharis bossii																																															
Chascanum gariepense																																															
Celosia spathulifolia																																															
Amaranthus thunbergii																																															
Tribulus zeyheri																																															
Moringa ovalifolia																																															
Lichens																														3			3/4														

Table VI: OTHER COMMUNITIES

TABLE VII. FREQUENCY OF OCCURRENCE OF DIFFERENTIAL SPECIES IN ALL COMMUNITIES.

SPECIES	COMMUNITY																																		
	1	2	3			4	5	6	7	8	9		10	11		12	13	14	15	16	17	18	19	20	21		22	23	24	25	26				27
			a	b	c						a	b		a	b										a	b					a	b	c	d	
Typha latifolia	V	II																																	
Arthrocnemum affine	II	V	IV	III	III																														
Sporobolus virginicus	IV	III	V	V	IV																														
Scirpus dioicus	I			V	I																														
Phragmites australis				II	V		I																												
Heliotropium curassavicum			I	I	III	I	II																												
Odyssea paucinervis				I		V	II		I																										
Eragrostis cyperoides							V																												
Stipagrostis sabulicola								V	I					I																					
Acanthosicyos horrida					I		I		V					I																					
Stipagrostis gonatostachys										V																			I						
Stipagrostis lutescens									I		V	V																	I	I		I			
Limeum fenestratum												V																							
Hermannia gariepinna												V																							
Eragrostis spinosa											I	IV		I	II	IV																			
Asclepias buchenaviana													V																I						
Acacia giraffae												II	I	V	IV	II			I																
Acacia albida															IV	II																			
Tamarix usneoides															III	II	I	IV																	
Euclea psuedebenus														I	IV		I			I		I	I			I									
Nicotiana glauca														I	III	III																			
Salvadora persica															II	II		II																	
Chenopodium ambrosioides															II	III																			
Datura innoxia															II	V																			
Datura stramonium															I	IV																			
Argemone ochroleuca															II	IV																			
Ricinus communis															I	III																			
Eragrostis trichophora															I	III											I								
Nidorella resedifolia															II	IV																			
Adenolobus pechueli														I			IV		I	II	II	I													
Acacia reficiens																	III	I	I																
Asthenatherum glaucum											III	III		I			II		I																
Mesembryanthemum guerichianum																		V					I									I			
Sporobolus nebulosus																		V	I				I												
Galenia papulosa																		IV																	
Schmidtia kalahariensis														I		I		V	I																
Petalidium setosum														I			I	I	V		I				I				I			I		I	
Tribulus terrestris														I			I		II								I				I			I	I
Monechma desertorum																	I		II	I														II	I
Trianthema triquetra																			II		I													II	I
Sesuvium sesuvioides																	II			III										I		I			
Euphorbia phylloclada														I			II		I	III									I	I	I	II		I	I
Cleome diandra														I			I		I	III		I								I				I	
Monechma genistifolium														I			I		I		II	I	I												
Adenia pechuelii																					I														
Sutera maxii														I	II	I	I	II	I		I									I					
Gisekia africana														I			I		I	I	II	II					I								
Petalidium variabile														I					I			V													
Indigofera auricoma *forma erecta*																						II	I												
Commiphora glaucescens																						I	IV												
Anthephora pubescens																							IV												
Ruellia diversifolia															I				I			I	III												
Triraphis ramosissima																			I			I	II												
Rhus marlothii																			I				II												
Enneapogon scoparius																							II												
Codon schenckii																							II												
Helichrysum tomentulosum																							II												
Panicum arbusculum																							II												
Senecio flavus																					I		II												
Platycarpha carlinoides																								V											
Calicorema capitata																					I	I	I		V	V									
Aptosimum spinescens																	I					I			V		II								
Aristida adscencionis																						I	I				III								
Eragrostis annulata														I	I	I	I	IV	II		II	I	I				III			I	I			I	I
Geigeria alata														I		I	I		II	I	II	I	I				III							I	I
Hermannia modesta														I	I	II	I		II	I	II	I	I				III							I	I
Euphorbia inaequilatera																	I		II		I						III					I		I	I
Salsola nollothensis																												V							
Pechuel-Loeschea leubnitziae													I	I	II	I	I										I		V	I	I	I			
Zygophyllum stapfii														I			I			I									I	V		V	II		
Salsola tuberculata										I	II		III	I			I		I	I	I				III	III					V	IV	IV	III	I
Arthraerua leubnitziae																																I		V	
Aloe asperifolia																							I									II			
Dyerophytum africanum													I	I					I	I			II									II			
Stipagrostis obtusa													I	I			I	II	III	IV	II	III	I		II	IV			I		I	I		V	II
Euphorbia glanduligera														I			I	II	II	I	III	II	III				II							II	I
Zygophyllum cylindrifolium													I				I		II	I	II	II	II		I	II			I		I			IV	
Enneapogon brachystachyus																	I	II	IV	II	IV	III	IV				II				I	I		IV	II
Stipagrostis uniplumis *var.* intermedia														II	I		II	II	III	I	IV	IV	IV		I	IV	III					I		III	I
Stipagrostis ciliata										I		IV	IV	IV			IV	II	V	V	V	II	III		IV	III	I		IV	II	III	III	II	III	V
Euphorbia virosa																				I	I	I	III												
Commiphora virgata																						III	III												
Blepharis obmitrata																	I		I	I	I	III												I	
Monechma arenicola														I					II		II	III	IV						II						I
Hirpicium gazanioides																						I	II												
Pegolettia senegalensis																	I		I			I	II											I	
Tribulus zeyheri														I		II		II	I		II	IV	II				I							I	
Stipagrostis uniplumis *var.* uniplumis																			I	I	I	III	III												
Eragrostis nindensis																					I	II	IV											I	I
Curroria decidua																					II	I	I												
Solanum rigescentoides																					II	I	II												
Osteospermum microcarpum														I	I			II	I	I	I	I	II							I	I	I			
Forsskaolea candida																		III	I		I	I	II				I								
Trichodesma africana																		II	I		II	I	III				I								
Asparagus denudatus																	I		I		I	I	III									I			

KEY TO THE NUMBERS USED TO IDENTIFY THE COMMUNITIES

1 Typha latifolia COMM.
2 Arthrocnemum affine COMM.
3 Sporobolus virginicus COMM.
 a Typical SUB - COMM.
 b Scirpus dioicus SUB - COMM.
 c Phragmites australis SUB - COMM.
4 Odyssea paucinervis COMM.
5 Eragrostis cyperoides COMM.
6 Stipagrostis sabulicola COMM.
7 Acanthosicyos horrida COMM.
8 Stipagrostis gonatostachys COMM.
9 S. lutescens COMM.
 a Typical SUB - COMM.
 b Limeum - Hermannia SUB - COMM.
10 Asclepias buchenaviana COMM.
11 Acacia giraffae COMM.
 a Typical SUB - COMM.
 b A. albida SUB - COMM.
12 Datura *spp* - Argemone COMM.
13 Adenolubus - Acacia reficiens COMM.
14 Mesembryanthemum - Sporobolus COMM.
15 Petalidium setosum COMM.
16 Sesuvium - Stipagrostis obtusa COMM.
17 Monechma genistifolium COMM.
18 Petalidium variabile COMM.
19 Commiphora - Anthephora COMM.
20 Platycarpha carlinoides COMM.
21 Calicorema capitata COMM.
 a Aptosimum SUB - COMM.
 b Typical SUB - COMM.
22 Aristida - Eragrostis COMM.
23 Salsola nollothensis COMM.
24 Pechuel - Loeschea leubnitziae COMM.
25 Zygophyllum stapfii COMM.
26 Salsola tuberculata COMM.
 a Typical SUB - COMM.
26b Zygophyllum SUB - COMM.
 c Arthraerua SUB - COMM.
 d Stipagrostis obtusa SUB - COMM.
27 Stipagrostis ciliata COMM.

KEY TO FREQUENCY SYMBOLS

I = 1% - 20 %
II = 21% - 40 %
III = 41% - 60 %
IV = 61% - 80 %
V = 81% - 100 %

	Asclepias buchenaviana COMMUNITY									
RELEVE No	306	420	303	279	291	285	282	119	104	157
TOTAL COVER %	4	5	2	3	5	3	5	6	5	6
ASPECT	NW	NE	-	S	SW	SW	SW	-	NW	NW
SLOPE	1	1	0	1	4	1	1	0	1	2
SOIL TEXTURE	G1C	1G	G1B	G1B	1C	1B	1B	1B	1B	G1B
SOIL CONSISTENCE	1	1	0	2	1	1	1	0/1	1	0/1
GEOLOGY	Do	G	G	G	P/Sc	G	G	Sc	Sc	G
SOIL DEPTH	3	3	6	3	4	6	2	6	7	6
CEMENTING SUBSTANCE		G					C			C
TOTAL No OF SPECIES	3	3	5	5	5	2	2	3	3	6

Asclepias buchenaviana COMMUNITY

Acacia giraffae COMMUNITY: a) TYPICAL; b) *Acacia albida* SUB-COMMUNITY

Datura – spp. *Argemone ochroleuca* COMMUNITY

Adenolobus pechuelii – *Acacia reticiens* COMMUNITY

Mesembryanthemum guerichianum – *Sporobolus nebulosus* COMMUNITY

Petalidium setosum COMMUNITY

Sesuvium sesuvioides – *Stipagrostis obtusa* COMMUNITY

Monechma genistifolium COMMUNITY

Petalidium variabile COMMUNITY

Commiphora glaucescens – *Anthephora pubescens* COMMUNITY

RELEVE No
TOTAL COVER %
ASPECT
SLOPE
SOIL TEXTURE
SOIL CONSISTENCE
GEOLOGY
SOIL DEPTH
CEMENTING SUBSTANCE
TOTAL No OF SPECIES

DIFFERENTIAL SPECIES OF *Asclepias buchenaviana* COMMUNITY
Asclepias buchenaviana
Salsola tuberculata

DIFFERENTIAL SPECIES OF *Acacia giraffae* COMMUNITY
Acacia giraffae

DIFFERENTIAL SPECIES OF *Acacia albida* SUB-COMMUNITY
Acacia albida
Tamarix usneoides
Euclea pseudebenus
Nicotiana glauca
Salvadora persica
Chenopodium ambrosioides

DIFFERENTIAL SPECIES OF *Datura* spp – *Argemone ochroleuca* COMMUNITY
Datura innoxia
Datura stramonium
Argemone ochroleuca
Ricinus communis
Eragrostis trichophora
Nidorella resedifolia

DIFFERENTIAL SPECIES OF *Adenolobus pechuelii* – *Acacia reficiens* COMMUNITY
Adenolobus pechuelii
Acacia reficiens
Asthenatherum glaucum

DIFFERENTIAL SPECIES OF *Mesembryanthemum guerichianum* – *Sporobolus nebulosus* COMMUNITY
Mesembryanthemum guerichianum
Sporobolus nebulosus
Galenia papulosa
Schmidtia kalahariensis

DIFFERENTIAL SPECIES OF *Petalidium setosum* COMMUNITY
Petalidium setosum
Tribulus terrestris
Monechma desertorum
Trianthema triquetra

DIFFERENTIAL SPECIES OF *Sesuvium sesuvioides* – *Stipagrostis obtusa* COMM
Sesuvium sesuvioides
Euphorbia phylloclada
Cleome diandra

DIFFERENTIAL SPECIES OF *Monechma genistifolium* COMMUNITY
Monechma genistifolium
Adenia pechuelii
Sutera maxii
Gisekia africana

DIFFERENTIAL SPECIES OF *Petalidium variabile* COMMUNITY
Petalidium variabile
Indigofera auricoma

DIFFERENTIAL SPECIES OF *Commiphora glaucescens* – *Anthephora pubescens* COMMUNITY
Commiphora glaucescens
Anthephora pubescens
Ruellia diversifolia
Tirachis ramosissima
Rhus marlothii
Enneapogon scoparius
Codon schenckii
Helichrysum tomentulosum
Panicum arbusculum
Senecio flavus

SPECIES COMMON TO *Petalidium variabile* AND *Commiphora glaucescens* – *Anthephora pubescens* COMMUNITIES
Euphorbia virosa
Commiphora virgata
Blepharis obmitrata
Monechma arenicola
Hirpicium gazanioides
Pegolettia senegalensis

SPECIES COMMON TO *Petalidium variabile*, *Commiphora glaucescens* – *Anthephora pubescens* and *Monechma genistifolia* COMMS.
Tribulus zeyheri
Stipagrostis uniplumis uniplumis
Eragrostis nindensis
Curroria decidua
Solanum rigescentoides
Osteospermum microcarpum
Forsskaolea candida
Trichodesma africana
Asparagus denudatus

COMPANION AND INFREQUENT SPECIES OCCURRING IN 3 OR MORE RELEVES
Stipagrostis ciliata
Zygophyllum simplex
Stipagrostis uniplumis intermedia
Enneapogon brachystachyus
Tephrosia dregeana
Indigofera auricoma
Stipagrostis obtusa
Euphorbia glanduligera
Zygophyllum cylindrifolium
Mollugo cerviana
Brachiaria glomerata
Stipagrostis hochstetterana
Commiphora saxicola
Geigeria alata
Cleome luederitziana
Hermannia modesta
Eragrostis annulata
Stipagrostis hirtigluma
Pechuel-loeschea leubnitziae
Eragrostis spinosa
Monsonia umbellata
Aptosimum angustifolium
Amaranthus thunbergii
Aristida parvula
Hermannia complicata
Cyperus marginatus
Sarcocaulon mossamedense
Sutera canescens
Geigeria ornativa
Kohautia ramosissima
Limeum argute-carinatum
Solanum nigrum
Kohautia lasiocarpa
Dyerophytum africanum
Crotalaria podocarpa
Kissenia capensis
Psoralea obtusifolia
Flaveria bidentis
Chloris virgata
Sesamum capense
Euphorbia inaequilatera
Dicoma capensis
Zygophyllum stapfii
Heliotropium ovalifolium
Cynodon dactylon
Antichoris linearis
Chascanum garipense
Senecio marlothianus
Boscia foetida
Lotononis platycarpa
Conyza bonariensis
Tagetes minuta
Suaeda plumosa
Commicarpus squarrosus
Orthanthera albida
Ptycholobium biflorum
Maerua schinzii
Cenchrus ciliaris
Celosia argenteiformis
Vahlia capensis
Aloe dichotoma
Pentzia schinziana
Sutera hypericoides
Blepharis grossa
Dipterygium burchellii
Monsonia sp.
Helichrysum argyrosphaerum
Stipagrostis namaquensis
Heliotropium tubulosum
Phaeoptilum spinosum
Sporobolus consimilis
Barleria merxmuelleri
Abutilon pycnodon
Euclea undulata
Aristida adscensionis
Marcelliopsis denudatus
Pergularia daemia
Calostephane marlothiana
Fagonia minutistipula
Moringa ovalifolia
Parkinsonia africana
Citrullus ecirrhosus
Raphionacme sp.
Polygonum plebeium
Setaria verticillata
Helichrysum roseoniveum
Commiphora tenuipetiolata
Lichens
Nicolasia stenoptera
Cucumella aspera
Nolletia gariepina
Cleome suffruticosa
Hoodia currorii
Pentarrhinum insipidum
Cordia gharaf
Polygala pallida
Welwitschia mirabilis
Galenia africana
Blepharis bossii
Acanthosicyos horrida
Limeum sulcatum
Selago sp.
Forsskaolea hereroensis
Blumea gariepina
Blumea cafra
Gnaphalium luteo-album
Launaea intybacea
Microloma hereroense

Table IV. COMMUNITIES OF THE WASHES AND ROCK OUTCROPS.