APPLICATIONS OF AIR PHOTO INTERPRETATION TECHNIQUES IN THE LANGEBAAN AREA, S.AFRICA

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Ecology : Major : Project

I. The vegetation of the Langebaan Area, S.Africa. (See attached reprint from Trans.roy.Soc.S.Afr., 42, Part 3, May, 1977.)

II. The photo interpretation of 1:10 000 scale colour aerial photographs in mapping the vegetation of the Langebaan Area, South Africa.

III. A report on an air-photo based determination of the length of shore-line occupied by, and total area covered by various macrophyte species and the length of shore-line and area covered by sand-flats of Langebaan Lagoon, South Africa.

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II. The photo interpretation of 1:10 000 scale colour aerial photographs in mapping the vegetation of the Langebaan Area, South Africa.

1. SUMMARY

A fairly extensive introduction to the theory behind the use of remote sensing products for vegetation survey work is given. This includes the particular benefits of colour air photographs, the relationship between scale of survey and scale of mapping and remote sensing products, and more information about the 'semi-detailed' level of survey operation. The latter is the category of survey which the vegetation survey of the Langebaan Area, South Africa falls into. The importance of the timing of photography in the usefulness of air photographs in vegetation survey work is also emphasised.

The particular example of the semi-detailed survey of the vegetation of the Langebaan Area using colour aerial photographs of Job 195 was then used in describing the Phases of operation involved. Phase I is essentially the planning stage, Phase II the operational stage, divided into 5 separate sections of operation, and Phase III involves the final mapping and report compilation. Reference to the results is given, as is a short discussion on the merits of air photographic techniques, as given

2. INTRODUCTION

The current awareness by planners of the important role that vegetation plays in maintaining a stable environment has created a demand for vegetation mapping and monitoring at various scales. The majority of these surveys have been found to be more efficiently and accurately done with the aid of remote sensing products.

In any vegetation study, the problem, or aims and objectives, must be clearly defined prior to embarking on the study and especially before obtaining any remote sensing products. In defining the aims and objectives of a vegetation inventory, it is very important that the likely reults be considered and, especially, the form the results will take and how they will be presented. An efficient method of presenting plant information, is by means of a vegetation distribution map. If a map is to be used to illustrate the results of a vegetation survey, the amount of information to be gathered by fieldwork and from remote sensing media should be applicable to the final mapping scale. It is therefore essential that botanists and ecologists should understand the relationships between the terms 'scale of survey', 'scale of mapping' and 'scale of remote sensing' (Küchler, 1967; Edwards, 1972a). The scale of remote sensing and mapping is entirely dependent on the scale of survey, which is dictated by the problem which has to be solved and how the results are to be presented.

Vegetation surveys have been grouped into five major classes:

1. General and general-reconnaissance surveys
2. Reconnaissance surveys
3. Regional surveys
4. Semi-detailed surveys
5. Detailed surveys and studies

(after: Edwards, 1972a; Edwards, 1972b; Edwards & Jarman, 1972).

These survey classes, defined by scale of mapping, are designed to give the required results from various trends in fieldwork and in remote sensing product requirements.

It is implicit in air photograph interpretation and mapping of vegetation that a classificatory process is involved. For aerial photographic interpretation work, involving the delineation of units of vegetation, it is essential that the nature of the classificatory process being applied is clearly understood. The nature of the "photo community" or vegetation unit identifiable on the photograph (Howard, 1970) which is to be recognized must be clearly established by using ground control as it is not necessary that a photo community will co-incide with a "real vegetation community". In the first approximation the photo community must be related to the vegetation classification used in survey. If the primary emphasis in the classification of the vegetation is to be laid upon habitat, for instance, then the first delineation of the air photograph will be along habitat boundaries and these will often cut across a physiognomically-homogeneous vegetation type. Such a situation would be unacceptable in a physiognomic ve vegetation study. An example of this would be a forest extending from a river across alluvial flats to residual soils along valley sides. The first photo delineation could be made according to geomorphology and would cut across the physiognomic unit. These problems may occur in particular if a geomorphological approach is used (Verstappen, 1968).

For vegetation survey, the view taken here is that the properties of vegetation should be the primary criteria for its classification. As Whittaker says "... for most purposes it is appropriate to define units for a given aspect by the properties of that aspect - to classify vegetation by the properties of vegetation"

(Whittaker, 1962 p.11). The chief vegetational criteria by which vegetation has been classified, singly or in combinations, are physiognomy and dominance, floristic composition, and successional relationships. Non-vegetational criteria such as habitat and geomorphology are used where vegetation units may not be the prime consideration such as in land-use surveys.

2.1 Colour aerial photography

In South Africa a number of colour experimental jobs have been carried out. In the Northern Transvaal (Lebowa Bantu Homeland) colour photographs at 1:30 000 scale were used, with back-up multispectral photography at 1:30 000 and panchromatic photography at 1:19 500 and 1:30 000. The opinion in this case was that colour photography was superior to panchromatic photography. While the multi-spectral photography has still to be fully evaluated (Loxton, 1972). The vegetation studied was mainly open woodland with a few open grass patches (Ibid.) . In the Eastern Orange Free State, colour photography at a scale of 1:12 000 was used to recognize and map different grass and dwarf shrub community types. This experiment was successful with interpretation from colour photography being more accurate than either black and white monochrome photography or infra red colour transparencies forming part of the same aerial photographic job (Jarman,1977). Another job was flown in the Cathedral Peak area at a scale of 1:5 000 and colour was found to be useful in recognizing vegetation in considerable detail (J.E. Granger, 1974. pers. comm.).

Experimental colour air photographic jobs have also been taken in Rhodesia. Colour photography in the Eldorado area was taken at a scale of 1:25 000. User reaction to this was that it was useful, especially for accentuating grazing pressure and estimating tree density, though a larger scale would have been preferred (Mitchell, 1971). In the South of Rhodesia, colour photography

around Diti at 1:12 500 was taken, but analyzed primarily for geological information (Stagman & Kirkpatrick, 1971), although some vegetational aspects were considered by Kyle (1971). For photo interpretation of the vegetation itself he considers colour an extremely useful tool.

The major advantage of colour lies in assisting interpreters who do not have a wealth of experience, as they are able to recognize patterns on hue as well as textural differences and site factors, and not merely on tonal variations, textural differences and site factors (Duddek,1967). The eye can detect 20 000 different hue variations compared with a mere 2 000 tonal variations (Evans, 1948). The disadvantages of this film type are that flying conditions, due to its inability to penetrate haze, and the processing, are more critical than panchromatic film and the cost is therefore higher.

2.2 Scale of survey and scale of mapping and remote sensing

Küchler (1967) stresses the relationships between the scale at which the survey is planned, the final mapping scale and the scale of the remote sensing product. Different scales of survey will detect different types and sizes of vegetation pattern. The survey scale hence indicates the degree of precision at which the vegetation is studied, recognized and described. Table 1. represents a suggested scheme which incorporates the five major classes of vegetation survey previously referred to and their inherent restictions as to field methods of vegetation analysis and scale of remote sensing products.

Photo scale of remote sensing product is usually larger than the final mapping scale. The remote sensing product actually contains more information than is required on the map. The scale difference is in order to make boundaries as accurate as possible. It does mean however that for mapping, much of the information

TABLE 1. Guidelines to aims, map scales, air photo scales and field work (Edwards & Jarman, 1972)

Scale of Survey	Aim	Map Scale	Photo Scale	Field Work
General and General Reconnaissance	Ascertain major classes of vegetation at regional and sub-regional landscape levels	1:1 000 000 or smaller	1:500 000 - 1:60 000	Non-defined plots usually recognizing physiognomic types
Reconnaissance	To determine the main plant communities	1:500 000 - 1:100 000	1:100 000 - 1:40 000	Non-defined plots physiognomic, floristic and ecological criteria
Semi-detailed	Investigation of physiognomic and floristic structure of community	1:50 000 - 1:10 000	1:20 000 - 1:5 000	Defined plots, Quantitative or semi-quantitative measures taken
Detailed	Study of structure and function of community or part of community	1:5 000 and larger	1:5 000 and larger	Intensive quantitative sampling

on the remote sensing product has to be classified into major types to make the map easily intelligible. The following classing of survey scales has been specifically designed for use in South Africa (Edwards, 1972b).

1. General and general reconnaissance: to ascertain the major classes of vegetation at regional and sub-regional landscape levels, and to ascertain the main climatic, soil and biotic relationships.
2. Reconnaissance surveys: to redefine and confirm more accurately the main classes of vegetation established by the general surveys, but specifically to determine the main communities.
3. Regional surveys: to depict considerable detail over large areas to assist with the planning of the total area.
4. Semi-detailed surveys: to discern, define and investigate vegetation on the basis of the plant community.
5. Detailed surveys: to study in detail the structure and functioning of one or more of a group of closely related plant communities (or ecosystems).

As the main objective of this survey was to provide fairly detailed information as to the existing plant communities, prior to their possible destruction as a result of development of Saldanha Bay as an ore-loading port, this survey fell into the category called "semi-detailed surveys".

2.3 Semi-detailed surveys

The physiognomic and floristic structure of the community and its habitat are determined by analyzing circumscribed plots. Mapping of the plant communities is at scales from 1:10 000 to 1:50 000. These surveys are of major importance in defining, classifying and studying community and habitat relations from quantitative or semi-quantitative data. They provide also the main

classificatory reference framework for ecosystems from which the extrapolations and predictions provided by more detailed studies can be made. They are the type of survey upon which most management procedures of an area are based. Appropriate air photo scales for such surveys are from 1:5 000 to 1:20 000, for upon these scales of photographs the various plant communities can be determined, and measurement of vegetation density and cover can be made with reasonable accuracy appropriate to the scale of survey. This level of survey is ideally suited to colour photography. The emphasis in this scale of survey is on a moderately high plot sample density which records vegetation at a Association level (Shimwell, 1971), and air photos are important in all phases. Stereoscopic coverage is essential to increase accuracy of interpretation and thereby use the imagery to its maximum advantage.

There are a number of classification methods which may be used to group vegetation into classes at this scale. The methods most commonly used are physiognomic/floristic ones.

2.4 Timing of photography

As maximum information on remote sensing imagery is associated with maximum contrast on the ground, remote sensing products should usually be made at the time of maximum vegetal contrast on the ground. This time of contrast varies, depending on climate and structure of the vegetation.

3. METHODS AND MATERIALS

As previously stated the scale of survey most appropriate to the aims and objectives of the study was the "semi-detailed"one. The study area was the total terrestrial area covered by the 1:10 000 scale colour aerial photographs produced by the Department of Land Surveying, University of Natal after a flight over the area on 26th March 1975 - an area approximately 22 km long and 10 km wide.

The quality of the colour aerial photographs was very good and consistent throughout the runs. The scale of the photographs being 1:10 000 was ideal for "semi-detailed" scale of survey. The timing of the photography, being late summer, provided sufficient contrast for ease of identification. The air photograph information was transferred to base map at a scale of 1:25 000, with a photographic reduction to a final mapping scale of 1:50 000. The vegetation communities were floristically defined, with the field sampling procedure being that of the Braun-Blanquet phytosociological method (Werger, 1973).

The air photo interpretation study was divided into three major phases:

3.1 Phase I - planning

The clearest and most efficient way of portraying details of vegetation communities was in the form of a map. It was decided to have a final mapping scale of 1:50 000.

A complete literature survey, including maps, was carried out of the area.

The air photographs were available because of the priority of the area with respect to its overall planning.

The area was visited for orientation and intensive botanical collecting was undertaken.

3.2 Phase II was divided into five main categories:

3.2.1 In the laboratory

The photographs were studied for general orientation - at all stages the photographs were studied stereoscopically. Small areas, called test areas, which were typical of larger areas as far as physiography and physiognomy were concerned, were chosen. These areas were recognized on the photo image by the differences in tone, texture, shape and position on the landscape. These areas and the various boundaries within them were marked, using Rotring pens and ink, and identified using numbers.

3.2.2 In the field

Each of the areas marked on the air photographs was visited and an attempt made to recognize the boundaries

and the differences which cause them. Randomly within this boundary, at a homogeneous site, a Braun-Blanquet sample plot was made, where detailed floristic data was collected, the species present given cover-abundance ratings, and notes made on the physiognomy of the vegetation. Species within the boundary but outside the sample plot were also recorded. Other details such as physiography, slope and aspect, geology, soil type and biotic and animal influences were also recorded.

3.2.3 In the laboratory

The detailed field information was annotated on to the air photographs. There are no standard annotation systems but most follow similar trends. The aim is to describe as much information about a particular site, as possible, in the most concise way. The approach adopted in the interpretation and annotation, is to describe detail from the general level to a more detailed or specific level. An example of the lay-out for annotation is given below:

General detail — (Vegetation features) / Environmental features — Specific detail

or

General — Physiognomy / Geology / Soil / Species most abundant / Biotic Influence — Specific

for example

Ds / L / Mp — PtZmZfSfLp / ex/ridge

Key: Physiognomy Ds = Dwarf Shrubland
Geology L = Limestone
Soil Mp = Mispah Form
Erosion status Ex/ridge = exposed windblown ridge
Species Pt = Pteronia uncinata
Zm = Zygophyllum morgsana
Zf = Zygophyllum flexuosum
Sf = Senecio floribunda
Lp = Limonium perigrinum

(After Edwards 1972b; Poulton, 1970; Herlocker & Dirschl, 1972).

If a mosaic pattern is to be recognized, the same information is recorded, but the total percentage of each type is recorded and annotated as a ratio of one type to the other.

From preliminary table making processes, using the Braun-Blanquet method of table making, a tentative vegetation classification was set up, based on total floristics and the physiognomy of the vegetation.
Check areas, similar to the first test areas were recognized, and in this instance the boundaries were drawn in and the photographs were annotated using the experience gained in the previous study areas to arrive at the annotations.

3.2.4 Checking annotations - in the field

This stage involved checking the annotations of the check area in the field as well as checking the provisional vegetation classification. Not all the classification units will be recognisable on the aerial photographs as some of the communities may have the same dominant shrub type yet have a different understorey due to disturbance factors. Many such 'hidden changes' can be predicted on the basis of variations in aerial cover of the shrubs (coarseness of textural differences), or slight topographic differences. Where these boundaries cannot be recognized by photo interpretation methods, they should be inserted using ground control.
The field checking involved placing of sample plots within the boundaries demarcated on the photographs. This stage was repeated until it was felt that a good degree of accuracy was obtained in annotation predictions.

3.2.5 Extrapolation

The experience gained in the test and check sites enabled the entire area to be annotated. Random field checks were made to check the interpretation accuracy.

3.3 Phase III

In this study the final mapping classification was one which was synthesized from the groupings obtained on

the Braun-Blanquet table (Appendix to the attached reprint). The floristic groupings obtained on this table were backed up by consistent relationships between other site and photograph information such as aspect, slope, altitude, soil series, photo-unit texture, photo-unit colour and position on the landscape.

From the annotated air photographs, information was transferred on to the base-map at a scale of 1:25 000, and this base-map was photographically reduced to a scale of 1:50 000, being the final mapping scale. The annotated units which were classified together for ease of map interpretation (e.g. Coastal shelf communities A. Atriplex-Zygophyllum and B. Pelargonium-Muraltia) were given the same hatching, and further identified by the symbols A, B, C etc.

It is important to stress that the map and Braun-Blanquet Table are inseparable and that they are also all that is necessary for a completely summarised representation of the total vegetation information of the area. The Braun-Blanquet table represents virtually an expanded map legend.

Table 2. Represents a diagrammatic representation of the Phases involved in a semi-detailed vegetation survey.

4. RESULTS

Reference to 'The vegetation of the Langebaan Area, South Africa' by C. Boucher and M.L.Jarman, Trans.Roy Soc.S.Afr. 42(3): 241-272 will give the following

1. Fig.1. page 244. Map of Langebaan area showing sites at which the vegetation was sampled.
2. Fig.2. Map of the vegetation of the Langebaan area. Page 247.
3. Appendix - Braun-Balnquet table showing vegetation communities of the Langebaan area.

TABLE 2. DIAGRAMMATIC REPRESENTATION OF PHASES OF METHOD FOR A SEMI-DETAILED VEGETATION SURVEY After James + Edwards, 1972.

Problem: To make a vegetation map to show the main vegetation communities of the area.
Decide: Scale of survey = semi-detailed
Map scale = 1:50 000
Therefore smallest unit at 3mm by 2mm on the map is equal to 150m by 100m on the ground.

PHASE I

1. Study literature of area and investigate what aerial photographs are available

Available Photographs
1975 Colour
1:10 000

Past management
What has happened

PHASE II

2. a) Study the 1:10 000 photos of the area for orientation
b) Pick out typical areas which are repeated over the area, making a test area
c) Delineate boundaries within a test area and number each one

From the photographic record it is possible to monitor vegetation changes

Delineation of boundaries
Major physiographic, physiognomic, textural and tonal variations of vegetation,
Shape, biotic influences etc.

3. Field
a) Check visually for evidence of boundaries
b) Lay out plots inside annotated boundaries

Record physiognomy, floristics and site information

4. Laboratory
a) From data establish the classification
b) Devise annotation system
c) Annotate test area
d) Find check area to test and annotate

5. Check area
If interpretation and annotation accurate, proceed, if not return to 4(d)

6. Extrapolation
Over entire area and checking

PHASE III

7. Draw map with extensive legend, regarding potential etc.

8. Write report - include effect of past management and proposed management

5. DISCUSSION

Plants are a measure of the conditions under which they grow and act as an index for soil and climate (Clements, 1920). The fact that changes in vegetation occur is visible proof of the dynamic nature of the environment. It is necessary to be able to record and follow the vegetation changes in order to predict and determine and control any changes which could severely upset the balance of nature. The role of vegetation mapping is therefore of major importance.

Remote sensing products are desirable for most surveys at any scale. The advantage of having remote sensing products is that it provides a permanent record of a situation at a particular time. Differences may then be plotted over a number of years if so desired.

There are certain areas which are impossible to reach by normal transport and areas such as these can best be surveyed, using remote sensing techniques. In other areas, although it is possible to work without remote sensing, the rate of progress would be considerably slower and boundaries would not be as accurate as those given by the synoptic view. The time and effort saved in fieldwork offsets the additional coets of photography. This survey was successfully carried out with a total of 150 hours in the field - a very important factor in conserving man-power in work of this nature.

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III. A report on the air-photo based determination of the length of shoreline occupied by, and total area covered by various macrophyte species and the length of shore-line and area covered by sand-flats of Langebaan Lagoon, South Africa.

1. INTRODUCTION
2. METHOD USED
3. RESULTS
4. CONCLUSION

I. INTRODUCTION

A study into the macrophyte productivity of the Lagoon system at Langebaan was being carried out by the Department of Planning. For this study it was desirable to have an estimate of the total surface area occupied by the various macrophyte species, as combining this with the biomass values, the rate of production and calorific values it would be possible to arrive at an approximate value for the Kcals released into the lagoon in the form of detritus for a summer month.
Surface area figures were also required by the Percy Fitzpatrick Bird Unit, in their studies of the extent of various bird habitats in the lagoon system.
This was a very good example of the 'spin-off' obtained from use of one set of photographs by people from many disciplines; and also of the greater efficiency obtained from lack of duplication of this kind of effort.

2. METHOD USED

Colour aerial photographs (Job 195) at a scale of 1:10 000 were investigated. Photo-units were demarcated on the basis of colour signature, pattern and texture using stereoscopic methods. The photo-units were identified

as to the macrophyte species present by means of ground checking of key areas. The image identification was made very much simpler in that the macrophyte species tended to grow in single species platforms. The photo-units were given the dimensions of area by means of superimposing a transparent dot-grid, where the area covered by a single dot at various scales could be looked up on a table. Shore-length determinations were made by measurement.

The information was collated as follows:

1. The lagoon was divided into eleven shore regions and six cross-sectional regions for the macrophyte species Zostera, Arthrocnemum, Spartina, Gracilaria and species of kelp. (See Fig.1.).
2. Separate photo-unit data were compiled for Phragmites, Typha and Juncus species, individual photo-unit values being indicated.
3. The ground surface area covered by individual species was determined.
4. The area of sandflats at various depth classes was calculated using a base-map (1:10 000).

3. RESULTS

Detailed records of individual photographs were kept and running totals maintained. These when compared with the final compiled totals indicated a 5% discrepancy in transfer of information.

TABLE 1. represents the photosynthetic ground surface area of individual species. Table 2. represents the area of sand-flats at various depth classes.

4. CONCLUSION

The air photographs proved invaluable in providing the information required. The time-saved in being able to conduct the bulk of this work in the laboratory instead of laborious field-collecting of data in areas which were difficult to access cannot be measured.

From these measurements it was possible for a valuable piece of research to be rounded off - the three most

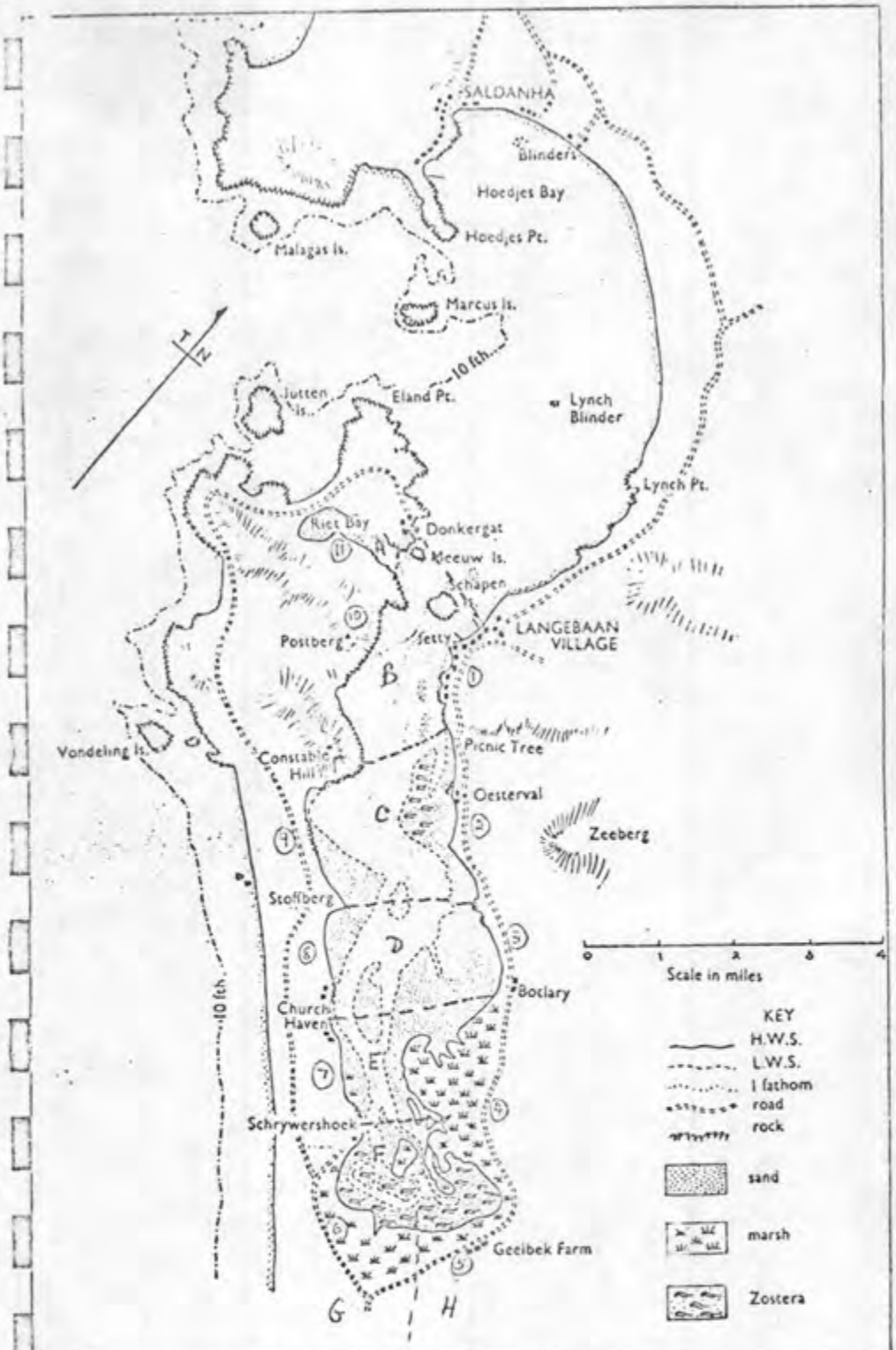

FIGURE 1

Chart of Saldanha Bay—Langebaan lagoon. Modified from Admiralty Chart 1232 (Saldanha Bay) with corrections to 1956.

Fig.1. Showing the eleven shore regions and six cross-sectional regions for the macrophyte species studied.

important plants to the lagoon are Gracilaria ($6,9 \times 10^9$ Kcals), Arthrocnemum ($2,1 \times 10^9$ Kcals) and Zostera ($8,4 \times 10^8$ Kcals). Gracilaria is therefore 3 times more important than Arthrocnemum in releasing energy into the lagoon.

The very valuable contribution of air photography to monitoring of the environment is illustrated here. As a result of the development of the Saldanha Bay system, certain changes appear to have taken place in the Langebaan Lagoon area. One of these is the apparent decrease in Gracilaria prduction. Whether or not it has actually decreased in total biomass or whether its locality has changed can be easily verified by means of a follow-up air photo job. A plant which is contributing this much to the system should not decrease drastically without provoking considerable concern.

TABLE 1. Photosynthetic ground surface area of individual species

Species	Surface Area (Hectare)
ARTHROCNEMUM	925,85
GRACILARIA	343,125
ZOSTERA	262,625
SPARTINA	241,125
JUNCUS	221,125
TYPHA	128,625
PHRAGMITES	28,125
"kelp"	15,5
"reeds"(Unidentified)	6,375
Total	2172,475

TABLE 2. Area of sand-flats at various depth classes

Depth class	Area (Hectare)
0 - 0,5 m	925
0,5 - 1,0 m	830
1,0 - 1,5 m	316
1,5 - 2,0 m	202
Total	2273

THE VEGETATION OF THE LANGEBAAN AREA, SOUTH AFRICA

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Summary

An account, with illustrations, is given of 20 terrestrial plant communities found in the vicinity of Langebaan Lagoon. A map is included which is based on the Braun–Blanquet method of vegetation sampling and data synthesis, and on the photo interpretation of 1:10 000 scale colour aerial photographs. Known rare and endangered plants occurring in the Saldanha–Langebaan area are listed. Recommendations are made for the establishment of a nature reserve which includes the marsh communities around the lagoon and the varied West Coast Strandveld vegetation on the Langebaan Peninsula.

Opsomming

'n Geïllustreerde uiteensetting van 20 terrestriële plantgemeenskappe in die omgewing van die Langebaan-strandmeer word gegee. 'n Plantegroeikaart gebaseer op die Braun–Blanquet-metode van monstering en dataverwerking asook op die foto-interpretasie van 1:10 000-skaal-kleurlugfoto's, word ingesluit. Skaars en bedreigde plante wat in die Saldanha–Langebaan-gebied voorkom, word genoem waar bekend. Aanbevelings vir 'n natuurreservaat wat die moerasgemeenskappe van die strandmeer en die diverse weskusstrandveldplantegroei op die Langebaan-skiereiland sal insluit, word gemaak.

INTRODUCTION

The development of Saldanha Bay as an ore-loading port will result in the destruction of large areas of natural vegetation. Detailed information on this vegetation is not available. This paper presents a map and an account of the vegetation communities in the area around the Langebaan Lagoon.

MATERIALS AND METHODS

Study area

The area selected for study is the total terrestrial area covered by the 1:10 000 scale aerial photographs produced by the Department of Land Surveying, University of Natal, after a flight over the area on 26 March 1975; the area is approximately 22 km long and 10 km wide (Fig. 1). Langebaan is the largest town within this area. The low-tide level at springs was regarded as the limit of the terrestrial environment, and the various islands in the Saldanha Bay–Langebaan Lagoon system were excluded from this study.

The most prominent features of the landscape, other than the lagoon itself, are the granite outcrops, of which Vlaeberg (193 m) and Konstabelkop (189 m), in the Oude Post Private Nature Reserve, are the highest. The geology has been described by Visser & Schoch (1973). The geological features include exposures of the Malmesbury Formation, Hoedjiespunt and Darling Granites, Saldanha Quartz Porphyry and

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Table 1

Soil characteristics at sites sampled for vegetation in the Langebaan area. Soil colour was determined using a Munsell colour chart. Soil texture was assessed subjectively. The presence (+) or absence (−) of $CaCO_3$ was determined by the reaction of the soil to HCl. Classification nomenclature follows that proposed by the South African Soils Classification Working Group.

Relevé number	Sampled horizon	Dry colour Code	Dry colour Description	Wet colour Code	Wet colour Description	Soil depth	Texture	PH H_2O	PH KCl	Resistance (ohms)	mg/ℓ Na^+	mg/ℓ K^+	mg/ℓ Ca^{++}	mg/ℓ Mg^{++}	$CaCO_3$	Heated weight loss (70–600 °C)	Classification Form	Classification Series
260	B	7.5YR3/2	dark brown	5YR2.5/2	dark reddish brown	> 0,5 m	medium sandy loam	7,00	6,35	266	620,0	54,0	77,0	66,6	−	3,2 %	Oakleaf	Levubu
262	A	5YR2.5/2	dark reddish brown	7.5YR2.5/0	black	< 0,1 m	humic coarse sand	7,45	6,90	200	380,0	27,7	200,0	155,0	+	22,6 %	Mispah	Muden
265	A	7.5YR5/2	brown	10YR3/2	very dark greyish brown	> 1,0 m	medium sand	7,95	7,30	1 560	70,0	16,0	61,0	8,7	+	1,3 %	Fernwood	Langebaan (calcareous)
266	A	5YR4/2	dark reddish grey	5YR2.5/2	dark reddish brown	> 1,0 m	medium sand	7,50	6,95	865	85,0	25,2	63,0	11,9	+	4,4 %	Fernwood	Langebaan (humic)
267	A	10YR6/4	light yellowish brown	7.5YR4/4	brown to dark brown	> 1,0 m	medium sand	7,35	6,75	3 200	45,0	22,8	34,0	6,4	−	1,0 %	Fernwood	Langebaan (non-calcareous
268	A	5YR2.5/1	black to dark reddish brown	7.5YR2.5/0	black	0,05 m	humic medium sand	7,50	7,00	325	200,0	54,0	141,0	38,0	+	25,7 %	Mispah	Muden (humic))
269	B	10YR6/4	light yellow brown	7.5YR4/4	brown to dark brown	> 1,0 m	medium sand	6,55	5,95	2 260	45,0	16,5	18,0	5,5	−	1,2 %	Clovelly	Sandspruit
270	A	7.5YR5/2	brown	10YR4/2	dark greyish brown	> 1,0 m	medium sand	7,55	6,95	1 240	52,0	24,5	89,0	7,7	+	2,2 %	Fernwood	Langebaan (calcareous)
277	A	10YR6/2	light brownish grey	10YR5/2	greyish brown	> 1,0 m	medium sand	7,45	7,40	650	88,5	21,5	81,0	16,8	+	1,8 %	Fernwood	Langebaan (calcareous)
286	A	10YR5/3	brown	5YR3/1	very dark brown	< 0,1 m	fine sand	7,10	6,60	680	80,0	23,5	63,0	23,0	+	6,4 %	Mispah	Kalkbank (humic)
290	B	10YR6/4	light yellowish brown	7.5YR5/4	brown	> 1,0 m	medium sand	6,60	5,90	3 370	43,8	33,0	13,0	5,7	−	0,7 %	Clovelly	Sandspruit
297	A	2.5YR2.5/4	dark reddish brown	10R2.5/1	reddish black	< 0,1 m	humic medium sand	6,95	6,55	357	180,0	48,0	180,0	49,0	+	13,7 %	Mispah	Kalkbank (humic)
304	B	5YR3/4	dark reddish brown	5YR3/3	dark reddish brown	> 0,5 m	loamy fine sand	7,15	6,50	550	120,0	20,2	49,0	13,5	−	4,3 %	Hutton	Maitengwe
310	A	2.5YR2.5/2	very dusky red	2,5YR2,5/0	black	< 0,2 m	humic medium sand	5,90	5,55	289	80,0	58,5	162,0	47,0	−	46,9 %	Nomanci	Nomanci
313	B	5YR5/3	reddish brown	5YR3/3	dark greyish brown	> 1,0 m	medium sand	4,65	3,95	357	430,0	51,0	55,0	65,5	−	1,7 %	Hutton	Gaudam
328	A_1	10YR6/2	light brownish grey	10YR5/2	greyish brown	< 0,1 m	medium sand	6,40	6,30	71	1 780,0	120,0	75,0	146,0	+	1,5 %	Fernwood	Soetvlei (saline)
	A_2	10YR5/3	brown	10YR5/2	greyish brown	> 0,1 m	medium sand	7,45	7,05	57	2 450,0	150,0	77,0	173,0	+	1,7 %		
329	O	5Y5/2	olive grey	5Y4/1	dark grey	< 0,4 m	clay	6,80	6,45	19	5 670,0	300,0	215,0	632,0	−	10,5 %	Champagne	Ivanhoe (saline)
	A	2.5Y6/2	light brownish grey	10YR6/2	light brownish grey	0,4–1,2 m	medium sandy loam	6,80	6,20	40	6 050,0	350,0	270,0	790,0	−	1,4 %		
	G	5Y6/2	light olive grey	5Y5/3	olive	> 1,2 m	medium sand	7,50	7,25	21	5 800,0	500,0	310,0	925,0	−	1,0 %		
330	O	—	—	10YR3/4	dark yellowish brown	< 0,3 m	organic medium sand	5,40	5,30	13	10 400,0	400,0	450,0	1 260,0	−	64,1 %	Champagne	Ivanhoe (saline)
	A	10YR6/1	—	5Y4/1	dark grey	0,3–0,4 m	clay	6,25	6,25	18	3 400,0	150,0	170,0	35,3	−	6,8 %		
344	A	10YR6/2	light brownish grey	10YR4/2	dark greyish brown	> 1,0 m	medium sand	7,70	7,25	1 200	59,6	7,5	75,0	8,5	+	2,0 %	Fernwood	Langebaan (calcareous)
345	A	10YR7/2	light grey	10YR5/2	greyish brown	> 1,0 m	fine sand	7,50	6,75	1 470	32,7	13,5	81,0	5,2	+	2,5 %	Fernwood	Langebaan (calcareous)

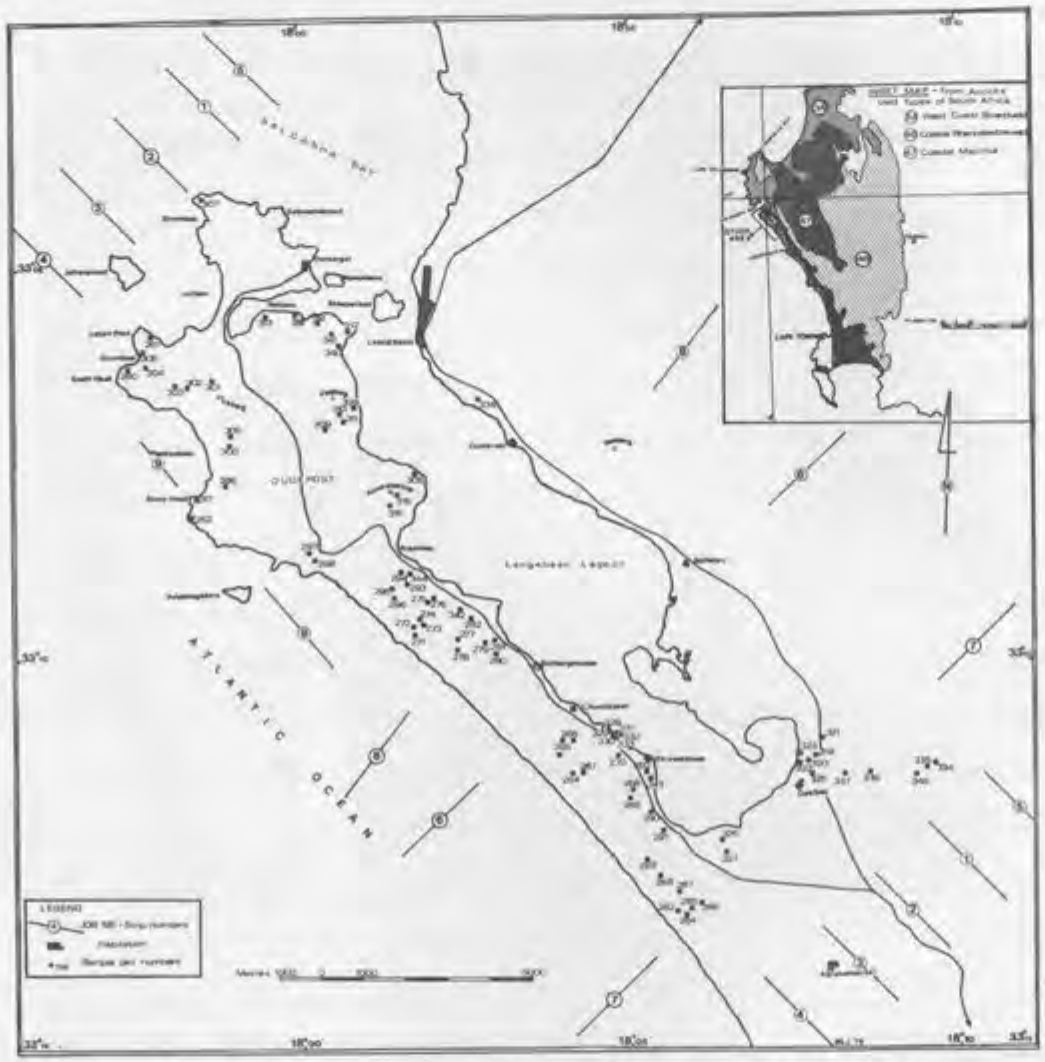

Fig. 1. Map of Langebaan area showing sites at which vegetation was sampled.

consolidated to unconsolidated limestones and lime-rich sands. Soil samples were taken at sites occupied by the plant communities, and were classified (Table 1) using the nomenclature proposed by the South African Soils Classification Working Group (pers. comm. J. J. N. Lambrechts, of the Department of Soil Science, University of Stellenbosch).

The area falls within the Winter Rainfall Region. Average annual rainfall for the farm Geelbek, at the southern end of the lagoon, is 269,9 mm, and for Langebaan village it is 253,1 mm. The average monthly rainfall for the period May–July is 40–45 mm (Table 2). Data on insolation are available for Stompneus Bay, 40 km north of

Table 2

Average monthly and annual rainfall (mm) and number of rain days at Langebaan Police Station (33°05′S 18°02′E) at 5 m altitude for 48 years, and at Geelbek farm (33°12′S 18°08′E) at 4 m altitude for 25 years (data taken from Weather Bureau Report 1965*b*)

	Langebaan		Geelbek	
	Rainfall	Days	Rainfall	Days
Jan.	5,3	1	6,1	1
Feb.	6,3	1	7,6	2
March	6,4	2	8,1	2
April	22,0	4	18,8	4
May	44,3	7	42,7	6
June	42,3	7	45,2	6
July	43,1	7	40,9	7
Aug.	33,2	7	39,6	6
Sept.	22,5	5	30,7	6
Oct.	13,2	3	15,0	4
Nov.	8,8	2	9,1	2
Dec.	5,7	1	6,1	1
Year	253,1	47	269,9	47

Table 3

Average monthly temperature at Cape Columbine (32°50′S 17°15′E) at 60 m for 1970 (data taken from Weather Bureau Report 1972); and average monthly and annual sunshine duration at Stompneus Bay (32°43′S 17°58′E) at 5 m for 5 years (data taken from Weather Bureau Report 1965*a*)

	Cape Columbine			Stompneus Bay	
	Av. max. (TX)	Av. min. (TN)	$\frac{TX + TN}{2}$	Mean daily hours	% of possible duration
Jan.	20,6	13,4	17,0	11,9	85 %
Feb.	21,0	13,2	17,1	10,8	82 %
March	20,7	13,3	17,0	9,3	75 %
April	19,7	11,7	13,7	8,0	71 %
May	16,1	11,2	13,7	5,8	56 %
June	16,0	10,3	13,1	6,6	66 %
July	14,6	8,7	11,7	6,9	68 %
Aug.	14,6	9,3	12,1	7,7	71 %
Sept.	16,5	10,0	13,3	8,7	73 %
Oct.	19,1	11,6	15,3	9,5	74 %
Nov.	18,5	11,1	14,8	10,8	78 %
Dec.	19,5	12,1	15,8	11,0	77 %
Annual				8,9	74 %

Langebaan (Table 3). Temperature data for Cape Columbine, 34 km north of Langebaan, are given in Table 3. Southerly winds predominate throughout the year, but northerly winds are more frequent between May and August (Weather Bureau 1972).

Man has influenced the vegetation in the Saldanha area over a long period. In 1601 Joris van Spilbergen observed fires set by Hottentots near St Helena Bay, about 30 km north of Saldanha Bay. The natives bartered sheep to Jan van Riebeeck, in Saldanha Bay, in 1652 (Burman & Levin 1974). The area around Riet Bay and Salamander Bay has been occupied periodically by Europeans for more than 200 years (E. Axelson pers. comm.). Both veld burning and grazing have affected the state of

the vegetation in the Saldanha Bay–Langebaan Lagoon area.

Adamson (1938) mapped the vegetation of the area as dry sclerophyllous bush. He described it as being open and not distinctly layered; bushes having small, dry, flat leaves; the number of bushes with ericoid leaves being fewer than in the wetter sclerophyllous bush vegetation; succulent plants being often associated with the bushes; geophytes and annuals being common. Adamson states that there is a gradient in the area between the dry and typical sclerophyllous bush with no sharp line of demarcation.

Acocks (1975) indicated on his map that three of his Veld Types occurred in our study area: West Coast Strandveld; Coastal Rhenosterbosveld; and Coastal Macchia (or Coastal Fynbos). Acocks described the Strandveld, which is the most widespread Veld Type on his map in this area, as containing two variations: 'A dense, dwarf, semi-succulent scrub', and, secondly, 'the Strandveld proper, an open semi-succulent scrub of fynbos form and intermediate between the Coastal Fynbos and the Succulent Karoo'. He also mentioned bush clumps on the hillocks or 'heuweltjies'. He described a good example of dense Strandveld scrub at Yzerfontein, 30 km south of Langebaan town, as being 'about 1 m high and very dense, a lilliputian forest', and the Strandveld proper as being 'rather clumpy . . . with species of the dense scrub in the bush clumps and on rocky outcrops, and a variety of smaller bushes, annuals and grasses in the spaces between the larger shrubs'. Acocks commented on the Rhenosterbosveld of the west coast belt as having an admixture of fynbos and grass, but less grass than the south coast Rhenosterbosveld. The west coast belt at 'its lower margin becomes semi-succulent and merges easily into the Strandveld'. He further considered the climax of the Coastal Fynbos, in the drier west coast belt, to be a bush clump veld in grassy fynbos. It 'appears to have lacked the dense thorniness and semi-succulence of the scrub of heavier soils' (Acocks 1975). More than half of the 12 principal species listed in his Coastal Fynbos are found in the Strandveld vegetation, but with *Willdenowia striata* and *Eriocephalus racemosus* being the Fynbos element in the scrub.

Taylor & Boucher (1973), in reporting on the natural vegetation boundaries of the south-western Cape from Land Sat—1 satellite imagery, distinguished West Coast Strandveld along the coastal strip between Cape Columbine and Yzerfontein. This agrees with Acocks's (1975) findings, but they stated that farther south of this, along the west coast 'it becomes difficult to distinguish this Veld Type from Coastal Macchia'. They also pointed out that, where Acocks showed a narrow tongue of Coastal Rhenosterbosveld, extending from the Darling area north-westward to the eastern shores of Langebaan Lagoon 'there was a lack of differentiation on the satellite image' and that it seemed as if Acocks's boundary was faulty there. They did not indicate what the vegetation in this tongue was. In contrast to Acocks, they mapped Coastal Fynbos on less stable recent sand on the eastern side of the lagoon. Cultivated areas were mapped on the granite-derived soils around Saldanha Bay and northwards to St Helena Bay. They noted a 'distinctive lilac colour, in the south-eastern part of the Langebaan Lagoon', on the satellite imagery and identified it as demarcating 'marshes with vegetation of *Phragmites—Senecio halimifolius*, Chenopod—*Juncus* and other halophytic communities'.

Day (1959) described the marine flora of the lagoon system and included a brief

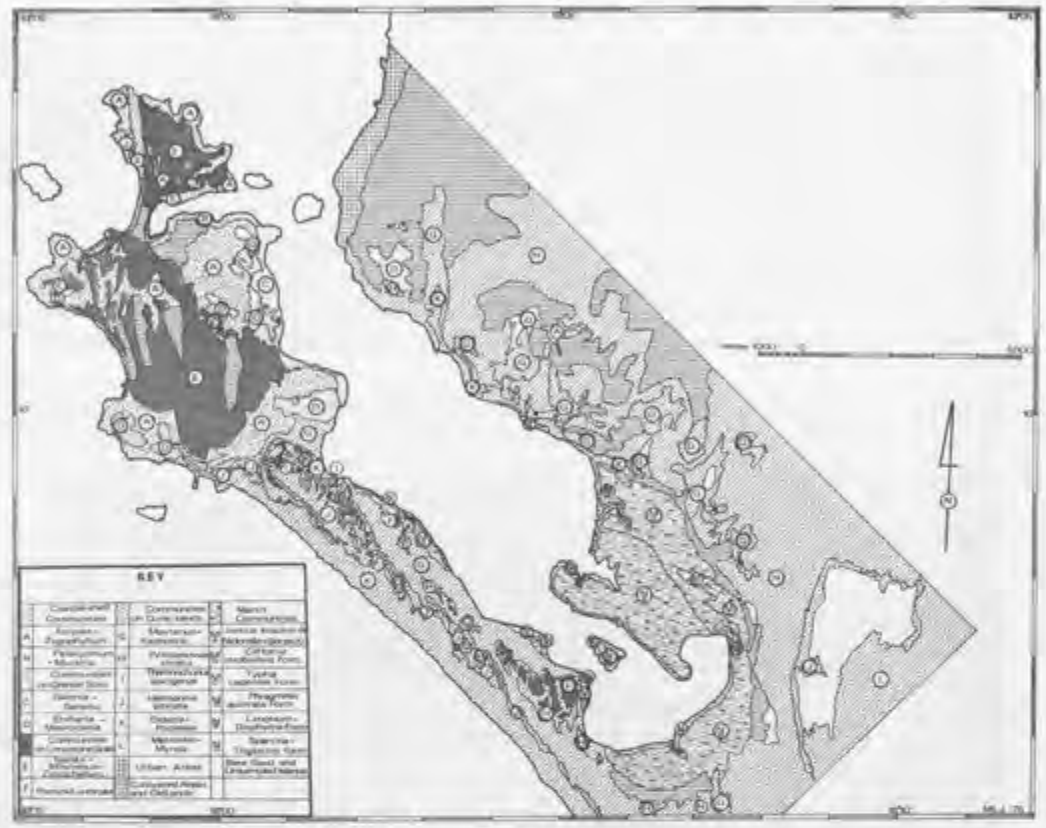

Fig. 2. Vegetation of the Langebaan area.

description of the salt marshes and the vegetation on the dry sandy banks, as well as details of two transects on rocky shores and four transects on sandy shores.

Sampling strategy and synthesis

The Braun–Blanquet method of sampling and synthesis as applied by the Zürich–Montpellier School of phytosociology was used (Werger 1973). Colour air photographs (job 195), at a scale of 1:10 000, were examined, after preliminary visits to the area. The photographs were annotated for likely vegetation units. Quadrats were placed in the field for checking whether the photo-units represented discrete plant communities. A standard quadrat of 10 × 5 m was used, to accord with the quadrat size employed by Taylor (1969) and Boucher (1972).

The formation classes used to describe the plant communities are those defined by D. Edwards of the Botanical Research Institute, Pretoria. The communities were named using differentiating species which are, wherever possible, also conspicuous. The communities were related to outstanding habitat features. The terms 'restioid' and 'ericoid' were used, following the definitions proposed by Taylor (1972*b*).

RESULTS

Vegetation description

The description given below of the vegetation communities is based on a synthesis of relevé data (Appendix). Fig. 2 presents a map of the vegetation of the Langebaan area.

Coastal-shelf communities

Atriplex–Zygophyllum Coastal-shelf Dwarf Shrubland
Relevés: 260, 261, 262, 303, 304, 305, 306, 307, 317.
Community defining species: *Atriplex semibaccata* and *Zygophyllum cordifolium*.
Differential species: *A. semibaccata*, *Pteronia onobromoides* and *Didelta carnosa* var. *carnosa*.
Dominant species: *A. semibaccata*, *Drosanthemum floribundum*, *Zygophyllum morgsana*, *Z. cordifolium*, *Ruschia geminiflora* and *Mesembryanthemum crystallinum*.

Fig. 3. *Atriplex–Zygophyllum* community. Prostrate *Zygophyllum cordifolium* and *Atriplex semibaccata* cover the ground in the centre. The shrub *Asparagus capensis* var. *litoralis* can be seen on the right.

This community (Fig. 3), located on the coastal-boulder shelf extending from the wave-splash line farther inland, is north-westerly in aspect and very exposed to salt spray and on-shore wind. The photographs show a distinctively even background, red-brown photo-unit which is due to the presence of a lower stratum of vegetation and the underlying granite-derived soil. There is a 5–10 cm tall mat-like cover of plants, the chief components of which are the deciduous succulents *Zygophyllum cordifolium*, *Atriplex semibaccata* and *Mesembryanthemum crystallinum*. The coarsely

stippled textural photo-unit pattern is accounted for by the presence of an upper layer of divaricate drought-deciduous succulent shrubs represented by the community dominants *Zygophyllum morgsana* and *Senecio floribunda*. This stratum is 0,5–1,0 m tall. The total-canopy cover ranges between 30 and 85 % depending on the extent of grazing. The shallow soil is gravelly or sandy and sometimes has a high proportion of marine shells. The following soils were recorded: Mispah Form (Muden Series), Oakleaf Form (Levubu Series) and Hutton Form (Maitengwe Series).

Small shallow temporary pans occur along the coastal shelf. *Arthrocnemum littoreum* commonly occurs around the edges of these pans and in the spray zone along the rocky coast. *Heliotropium supinum*, *Mollugo tenella* and *Phalaris minor* can be found growing in the mud when the pools dry up.

Pelargonium–Muraltia Coastal-shelf Dwarf Shrubland
Relevés: 313, 314 and 318.
Community defining species: *Muraltia dumosa*, *Pelargonium hirtum* and *Ficinia nigrescens*.
Differential species: *Muraltia dumosa*, *Pelargonium hirtum*, *Aspalathus heterophylla* subsp. *lagopus*, *Ficinia nigrescens* and *Pentaschistis thunbergii*.
Dominant species: *Diosma hirsuta*. *Muraltia dumosa*, *Ehrharta calycina* and *Ruschia geminiflora*.

Fig. 4. Riet Bay and Donkergat. *Pelargonium–Muraltia* community on the southern shores at the entrance to Riet Bay, flanked by *Atriplex–Zygophyllum* community. *Zygophyllum morgsana* is the common shrub in the foreground.

A predominantly north-easterly aspect and altitude of less than 3 m distinguishes this coastal shelf community from the *Atriplex–Zygophyllum* Coastal-shelf Dwarf Shrubland community. It occurs on Fernwood Form sandy soil which accumulates at the foot of granite outcrops along the southern shores of Riet Bay and the adjacent coastal shelf (Fig. 4). The sandy soil and plant cover of ericoid and restioid elements which occur there produce a pale grey-red brown photo-unit. Apart from the species listed above, *Restio cuspidatus, Thamnochortus dichotomus, Aspalathus cuspidata, Stoebe cinerea* and *S. incana* also occur here. The vegetation cover consists of low prostrate succulents and dwarf shrubs, 15–50 cm tall, and a conspicuous grassy element in which *Ehrharta calycina* is prominent.

Communities on granite soils

Numerous granite outcrops occur throughout the Langebaan–Saldanha area. The rocks on these outcrops support a sparse succulent (Fig. 5) and bulbous flora which is unique and contains a number of endemic species. This flora was not studied in detail, because it is obviously a distinct unit requiring a sampling strategy different from the one used in this survey. The weathering products of the granites form a deep relatively fertile soil, but the low annual rainfall is a factor limiting high biomass production.

The two granite hillside communities which were sampled and mapped have

Fig. 5. Succulent flora on granite rock on the left. The tree-like *Phillipia chamissonis* has its most northerly distribution range here. Kraal Bay and the Atlantic Ocean are visible in the middle distance.

Tetragonia spicata and *Ehrharta erecta* as common species, and are further distinguished by relatively higher cover-abundance values for *Rhus glauca*.

Galenia–Senecio Hillside Closed Dwarf Shrubland
Relevés: 312, 339, 340 and 341.
Community defining species: *Galenia crystallina* and *Senecio floribunda*.
Differential species: *Pelargonium fulgidum, Drosanthemum calycina, Galenia crystallina* and *Aspalathus pinguis*.
Dominant species: *Galenia crystallina, Tetragonia spicata, Rhus glauca, Zygophyllum morgsana, Senecio floribunda* and *Ehrharta calycina*.

Fig. 6. *Galenia–Senecio* community with the darker *Ehrharta–Maurocenia* community extending from the granite outcrop. Langebaan Town is visible in the distance.

This is a community which occupies the steep granitic hillslopes between 3 and 40 m altitude, with a south-easterly aspect (Fig. 6). It stretches from Kraal Bay to Riet Bay on the lagoon side of the Oude Post Private Nature Reserve. It is a two-layered community. A 50 cm tall upper stratum dominated by the shrubs *Rhus glauca, Zygophyllum morgsana* and *Tetragonia spicata* gives the community a closed canopy, and a smooth stippled texture to the photo-units. There is also a grassy element and a low succulent element 15–35 cm tall, with *Ehrharta calycina* being the dominant understorey species. Canopy cover varied between 50 and 75 % during the dry season. The weathering of the parent granite rock in the area has produced soils of the following forms: Cartref Form (Kusasa and Grovedale Series), Estcourt Form (Darling and

Balfour Series), Hutton Form (Gaudam Series) and Fernwood Form (Fernwood Series).

There are several species which occur in common with previously described communities. *Euphorbia hamata*, *Aspalathus hispida*, *Lampranthus amoenus*, *Diosma hirsuta*, *Aspalathus pinguis*, *Drosanthemum calycina*, *Felicia filifolia* subsp. *filifolia*, *Thesium aggregatum* and *Pelargonium fulgidum* occur in both the *Galenia–Senecio* Hillside Closed Dwarf Shrubland and *Pelargonium–Muraltia* Coastal-shelf Dwarf Shrubland. The coastal-shelf communities have the following species in common with the *Galenia–Senecio* Hillside Closed Dwarf Shrubland: *Drosanthemum floribundum*, *Prenia pallens* and *Asparagus capensis* var. *littoralis*.

Ehrharta–Maurocenia Hillside Dense Shrubland
Relevés: 308, 310, 311, 315, 316.
Defining species: *Ehrharta erecta*, *Maurocenia frangularia*.
Differential species: *Maurocenia frangularia*, *Polygala myrtifolia* and *Australina acuminata*.
Dominant species: *Rhus glauca*, *Zygophyllum morgsana* and *Ehrharta erecta*.

Fig. 7. *Ehrharta–Maurocenia* community. Darker clumps of *Maurocenia frangularia* occur between the granite boulders.

This dense shrubland community occupies the south-east to south-west slopes of the granite hillsides, around the bases of granite rock domes, where there is relatively more rainfall run-off (Fig. 6). All sites enjoy protection from the north and north-west

winds. Hutton Form (Gaudam Series) and Nomanci Form (Nomanci Series) soils occur, the latter being a very shallow highly organic soil.

A community exists here which has three strata in its most developed form. Leathery-leaved evergreen gnarled trees, 1,2–4,0 m tall, occur in clumps and have a closed canopy (Fig. 7). The shrub layer consists of a mixture of leathery-leaved evergreen shrubs and drought-deciduous shrubs. Both types of shrubs have a divaricate habit and vary in height between 1,0 and 2,0 m. The herbaceous layer varies in height between 0,25 and 0,5 m. Annuals are prevalent during the wetter period. The tree layer is sometimes absent, probably due to removal by man and grazing by goats, and open patches occur which are bare of vegetation during the dry season. These factors combine to produce a photo-unit texture which varies between being coarsely stippled to almost smooth and even, where the canopy is closed. During autumn the canopy cover is approximately 80 %.

Communities on limestone soils

The communities on limestone soils are distinguished from other communities by the high occurrence of the common dominant species *Clutia daphnoides*, *Zygophyllum morgsana*, *Senecio floribunda*, *Ehrharta calycina* and *Zygophyllum flexuosum*, together with the absence or low occurrence of other common dominant species, such as *Rhus glauca*, *Salvia lanceolata*, *Pterocelastrus tricuspidatus* and *Othonna carnosa*. These communities have species in common with the *Atriplex–Zygophyllum* Coastal-shelf Dwarf Shrubland community, namely: *Mesembryanthemum crystallinum*, *Zygophyllum cordifolium* and *Pelargonium carnosum*.

Nenax–Maytenus–Zygophyllum Limestone Evergreen Shrubland
Relevés: 297, 298, 299, 301, 302, 309, 338.
Defining species: *Nenax hirta* and *Zygophyllum cordifolium*.
Differential species: *Festuca scabra*, *Nenax hirta*, *Limonium linifolium* var. *maritimum*, *Cheiridopsis purpurascens*, *Ficinia trichodes* and *Eriocephauls petrophiloides*.
Dominant species: *Ehrharta calycina*, *Zygophyllum flexuosum*, *Ruschia geminiflora*, *Senecio floribunda*, *Rhus longispina*, *Lasiochloa longifolia* and *Festuca scabra*.

This community occupies a position which is either on exposed limestone ridges or outcrops on hillslopes, which are predominantly south-west, west to north-west, or sea-facing in aspect, and much exposed to on-shore winds. The vegetation has generally been trampled heavily and grazed by both domestic stock and reintroduced indigenous antelope.

The soil is a shallow, dark-brown sand of the Mispah Form (Kalkbank Series) occurring between exposed limestone rocks. The *Nenax–Maytenus–Zygophyllum* community in its best form is composed of two strata. The upper stratum is dominated by *Rhus longispina*, *Senecio floribunda* and *Zygophyllum flexuosum* and varies in height between 0,8 and 1,2 m. The lower stratum, dominated by *Zygophyllum cordifolium* and *Ehrharta calycina*, varies in height between 5 and 25 cm. The shrubs are generally divaricate in habit and evergreen or alternatively are drought-deciduous succulents. These soil and vegetation cover factors result in a photo-unit texture which has a

coarse, but even, 'smudgy' appearance and is grey-green brown in hue.

Annuals are present, especially in the very disturbed areas, during spring. Cosmopolitan grasses, such as *Briza maxima*, occur.

Relevé 338 appears to be intermediate between the *Ehrharta–Maurocenia* Granite-hillside community and the *Nenax–Maytenus–Zygophyllum* Limestone community. *Pharnaceum dichotomum* and *Lasiochloa longifolia* occur in both this limestone community and the *Pelargonium–Muraltia* Coastal-shelf Dwarf Shrubland.

Pteronia uncinata Limestone Evergreen Dwarf Shrubland
Relevés: 268, 292, 342, 343.
Defining species: *Pteronia uncinata*.
Differential species: *Pteronia uncinata* and *Crassula expansa*.
Dominant species: *Pteronia uncinata, Zygophyllum morgsana, Zygophyllum flexuosum, Senecio floribunda* and *Limonium perigrinum*.

Fig. 8. *Pteronia uncinata* community. The common coarse shrub is *Pteronia uncinata*.

The *Pteronia uncinata* community (Fig. 8) occupies a prominent position in the landscape, being confined to exposed limestone ridge crests on low rises on the Langebaan Lagoon side of the Langebaan Peninsula isthmus. The very shallow soil belongs to the Muden Series (Mispah Form). This probably prevents the *Maytenus–Kedrostis* Consolidated-dune Dense Evergreen Shrubland community from occurring on these sites in its complete form, although elements of this community do occur here, wherever there are deeper pockets of soil.

Dominance by *Pteronia uncinata*, a 30–50 cm tall ericoid shrub, is the most important floristic feature of this community. During early autumn, the community is especially conspicuous, because of the yellow flowers of the dominant species which blooms when few other species are in flower.

The exposed limestone sites and growth form of the dominant species combine to give a distinctive pale, grey-green brown photo-unit with a very fine stippled textural pattern. *Mesembryanthemum crystallinum* occurs both in this community and in the *Atriplex–Zygophyllum* Coastal-shelf Dwarf Shrubland.

Communities on consolidated and unconsolidated dune sands

'Most of the isthmus south of Langebaan Lagoon is occupied by coastal dunes of greatly varying elevation and degrees of stabilization by vegetation' (Visser & Schoch 1973). Narrower and more conspicuous dunes occur along some of the smaller bays, such as at Jut Bay and Plankies Bay. Most of the dunes consist of calcareous sand and where they rest on Langebaan Limestone, which is sometimes exposed, the lime content is much higher.

The differential species for this major subdivision of the vegetation are: *Ehrharta villosa, Limonium perigrinum, Euphorbia caput-medusae, Cynanchum obtusifolium, Galium tomentosum, Senecio burchellii, Microloma sagittatum* and *Lebeckia separia*.

Maytenus–Kedrostis Consolidated-dune Dense Evergreen Shrubland
Relevés: 276, 279, 281, 286, 287, 291.

Fig. 9. The *Maytenus–Kedrostis* community generally has a dense stratum of 1,25 m tall spiny shrubs. *Melianthus minor* is the broader-leaved shrub in the foreground.

Defining species: *Maytenus lucida* and *Kedrostis nana*.
Differential species: *Crassula* sp. (Boucher 2955), *Cotyledon paniculata* and *Cotyledon orbiculata*.
Dominant species: *Euphorbia mauretanica*, *Maytenus lucida*, *Salvia lanceolata*, *Clutia daphnoides*, *Putterlickia pyracantha*, *Zygophyllum morgsana*, *Ehrharta villosa*, *Limonium perigrinum*, *Euclea racemosa*, *Senecio floribunda*, *Pentzia pilulifera*, *Ehrharta calycina*, *Zygophyllum flexuosum* and *Tetragonia fruticosa*.

The community generally occupies gullies, lower sides of hillslopes, depressions or slight drainage lines on stable dunes, with a west or south-west aspect, along the isthmus south of Langebaan Lagoon. These undisturbed consolidated dunes generally consist of a brown sand belonging to the Fernwood (Langebaan Series) and Mispah (Kalkbank Series) Soil Forms. The soil varies in depth, on a limestone base.

The *Maytenus–Kedrostis* community generally has a dense single stratum of 1,25 m tall spiny shrubs (Fig. 9). The evergreen and drought-deciduous shrubs are randomly distributed, generally with crowns interlocking, and have a divaricate habit, branching near ground level. This results in a photo-unit colour of deep grey-green brown, and a very even textural pattern. The only discrepancy is a coarser textural pattern where disturbance, such as grazing, results in openings in the canopy, and dwarf shrubs and annuals can be found. The creepers *Kedrostis nana* and *Cynanchum obtusifolium* occur frequently.

Crassula expansa occurs as a species common to this consolidated dune community and the *Pteronia uncinata* Limestone Evergreen Dwarf Shrubland.

Willdenowia striata Consolidated-dune Dense Evergreen Restioid Shrubland
Relevés: 266, 269, 270, 290, 336.
Differential species: *Willdenowia striata*, *Eriocephalus africanus* and *Helichrysum hebelepis*.
Dominant species: *Willdenowia striata*, *Eriocephalus africanus*, *Salvia lanceolata*, *Putterlickia pyracantha*, *Zygophyllum morgsana*, *Euclea racemosa* and *Ehrharta calycina*.

This community occurs on the consolidated dune sands generally inland of the *Maytenus–Kedrostis* community, on undulating hillslopes, in slight drainage lines, or on the junction between exposed calcrete and the fixed-dune formations. A deep Clovelly Form (Sandspruit Series) of soil is general, although Fernwood Form (Langebaan Series) soils also occur. The soil is more acid than that on which the *Maytenus–Kedrostis* community occurs.

The 1,0 m tall randomly scattered clumps (approximately 1,0 m diameter) of *Willdenowia striata* (Fig. 10) give this community a distinctive restioid character, and a very distinctive coarsely stippled deep brown-purple pattern on a yellow background photo-unit hue and texture. This indicates a single stratum of vegetation on a fixed dune sand base. The canopy cover averages about 80 %.

Relevés 269, 270, 290 and 336 are good examples of the community, but Relevé 266 has elements of the *Maytenus–Kedrostis* community present in the form of *Cotyledon orbiculata* and *Crassula expansa*. It lacks the community defining species *Willdenowia striata*, but does contain *Eriocephalus africanus* and *Helichrysum hebelepis*. Its position on the landscape explains these discrepancies, in that it has a western sea-facing aspect, occurs on deeper sand, is slightly moister, and occupies a position intermediate between the two communities.

Fig. 10. *Willdenowia striata* community. *Willdenowia striata* (right foreground) gives this community a distinctive restioid character.

There are a number of species which are common to this *Willdenowia striata* Consolidated-dune community, the *Maytenus–Kedrostis* Consolidated-dune community and to all the limestone and granite soil communities. They are: *Euphorbia mauretanica*, *Rhus glauca*, *Antizoma capensis*, *Maytenus lucida*, *Asparagus aethiopicus*, *Ballota africana*, *Hermannia* sp. (Boucher 2946A), *Pteronia divaricata* and *Crassula muscosa*.

Thamnochortus spicigerus Dune Dense Tall Restioid Herbland
Relevés: 265, 294, 300, 344.
Differential species: *Thamnochortus spicigerus*.
Dominant species: *Thamnochortus spicigerus*, *Limonium perigrinum* and *Ehrharta calycina*.

This community appears to be a depauperate form of the dune communities and occurs in scattered patches (Fig. 11), without any obvious ecological pattern, through

the communities of consolidated dunes that are richer in species. The larger patches have been mapped (Fig. 2), while the smaller patches have been incorporated into the communities in which they occur. These smaller clumps are too small to be sampled as a uniform entity using a relevé size of 5 × 10 m. Relevé 300 would be an example of such a situation. This community occurs on Fernwood Form (Langebaan Series) soils.

The nature of the growth form of *Thamnochortus spicigerus*, which has straight, pencil-thick, erect stems, 1,2–2,0 m tall, and which forms large dense uniform clumps with few other species in association with it, makes it easily recognizable as a photo-unit. It is generally dark green brown in colour, with an even, smooth stippled texture, and clearly defined edges to the community. When it is in flower, *Limonium perigrinum* lends colour to this otherwise drab community.

The community marks the division between the consolidated-dune communities and the littoral-dune communities, and has species in common with the communities so far described. It has a common species with the *Willdenowia striata* Consolidated-dune community, namely, *Colpoon compressum*, and has a species in common with the *Maytenus–Kedrostis* Consolidated-dune community, namely, *Kedrostis nana*. Species common to the communities on limestone soils, the *Ehrharta–Maurocenia* Hillside Dense Shrubland and the *Maytenus–Kedrostis* and *Willdenowia striata* Consolidated-dune communities are: *Salvia lanceolata, Clutia daphnoides, Putterlickia pyracantha, Pelargonium gibbosum, Pterocelastrus tricuspidatus, Solanum guineense, Viscum capense, Asparagus crispus, Lebeckia spinescens, Olea africana* and *Myrsine africana*. Species common to all the communities described so far, namely the coastal-shelf communities, the granite-soil communities, the limestone-soil communities and the consolidated-dune communities, are: *Zygophyllum morgsana, Senecio floribunda, Rhus longispina* and *Lycium ferocissimum*.

Hermannia pinnata Littoral-dune Dwarf Succulent Shrubland
Relevés: 263, 267, 272, 273, 274, 275, 277, 278, 280, 282, 285, 288, 289, 293, 295 and 296.
Defining species: *Hermannia pinnata*.
Differential species: *Hermannia pinnata, Grielum grandiflorum, Nylandtia spinosa, Limeum africanum, Gazania pectinata* and *Polycarena selaginoides*.
Dominant species: *Ehrharta villosa, Limonium perigrinum, Ehrharta calycina* and *Ruschia geminiflora*.

This community is easily distinguishable due to its prominent position on the landscape, being situated in the dune valleys and slacks and on the exposed ridges, of the dune systems running in a south-westerly direction on the sea side of the Langebaan Lagoon (Fig. 11). These are all areas subject to heavy grazing. The soils are deep and sandy (Fernwood Form) and both the calcareous and non-calcareous phases of the Langebaan Series are present. There is a subdivision within the community in that Relevés 273, 277, 289 and 296 are differentiated by the relatively high occurrence of *Eragrostis cyperoides*. These sites represent a minor ecological variation in that they all occupy positions on slight crests and ridges within the dune valleys and slacks.

Fig. 11. *Hermannia pinnata* community in the foreground. A light-grey clump of *Thamnochortus spicigerus* is discernible in the middle distance. The distant ridge supports the *Maytenus–Kedrostis* community.

Two strata are sometimes distinguishable, consisting of a 5–15 cm tall, dwarf succulent shrub layer and a 30–50 cm tall, dwarf shrub and grass layer. This results in an even, finely stippled textural photo-unit pattern, yellow-green brown in colour. The dwarf shrubs are sometimes evergreen or drought-deciduous and succulence is common. The shrubs are randomly spaced with crown diameters of less than 1 m being the general rule. The grasses tend towards clumping. Annuals are common and may dominate the community during spring and early summer. The canopy cover varies from 30 % in the very heavily grazed and/or browsed areas to 95 % in those areas that are undisturbed. The average canopy cover is 60 %.

Species common to the *Hermannia pinnata* Littoral-dune community and the Consolidated-dune communities include: *Ehrharta villosa, Limonium perigrinum, Euphorbia caput-medusae, Cynanchum obtusifolium, Galium tomentosum, Senecio burchellii, Microloma sagittatum* and *Lebeckia sepiaria*. The community has species in common with the Consolidated-dune communities, the Limestone communities and the Granite communities, these being: *Euclea racemosa, Chrysanthemoides monilifera, Othonna carnosa, Pharnaceum lanatum, Wahlenbergia annularis* and *Heliophila linearis*.

Species common to the Consolidated-dune communities, the *Hermannia pinnata* Littoral-dune community, the Limestone communities, Granite communities and the Coastal-shelf communities are: *Bromus japonicus, Thesium spinosum, Argyrolobium lunaris, Pentzia pilulifera, Chaetobromus dregeanus, Senecio repandus, Ehrharta calycina, Ruschia geminiflora, Exomis microphylla* var. *axyrioides, Zygophyllum flexuosum, Tetragonia fruticosa* and *Asparagus capensis* var. *capensis*.

Didelta–Psoralea Littoral-dune Open Grassland
Relevés: 264, 271, 283, 284.
Defining species: *Didelta carnosa* var. *tomentosa* and *Psoralea repens*.
Differential species: *Carpobrotus edulis*, *Didelta carnosa* var. *tomentosa* and *Psoralea repens*.
Dominant species: *Eragrostis cyperoides* and *Senecio elegans*.

Fig. 12. *Didelta–Psoralea* community. The spiky grass, *Eragrostis cyperoides*, can be seen in the foreground. A clump of *Didelta carnosa* var. *tomentosa* is clearly visible on the left.

This community (Fig. 12) occupies the undulating crests of the lines of dunes closest to the sea on the isthmus of the Langebaan Peninsula. The substratum is typically deep undulating sand (Langebaan Series) in fairly close proximity to the western seaboard. Sand dominates the landscape.

The colonizers along the beach, in addition to the community differential species, include *Arctotheca populifolia*, *Myrica cordata*, *Cnidium suffruticosum* and *Senecio maritimus*. Dwarf shrubs and grasses are common in this community, with succulence and hairiness being a common feature. The dwarf shrubs are often prostrate. This produces a low, smooth, even canopy which gives a photo-unit texture which is even, and a photo-unit colour of grey-yellow green brown. This is substantiated by site data which showed the community to be typically open or patchy, but even, in the patches. Ninety-five per cent canopy cover was recorded in 75 cm tall vegetation. A cover of 85 % was recorded in a 50 cm tall patch of artificially established *Ammophila arenaria* on the southern end of the farm Schrywershoek. This species is used to

stabilize sand dunes. It can form a fairly thick litter through which the indigenous vegetation appears to have little difficulty in establishing itself.

The two Littoral-dune communities have several species in common, these being: *Dischisma ciliatum*, *Trachyandra divaricata*, *Amellus asteroides*, *Cnidium suffruticosum*, *Scirpus trachyspermus*, *Manulea tomentosa*, *Psoralea striata*, *Eragrostis cyperoides* and *Senecio scapiflorus*.

Metalasia–Myrica Dune Dense Evergreen Ericoid Shrubland
Relevés: 334, 335, 345.
Defining species: *Metalasia muricata* and *Myrica quercifolia*.
Differential species: *Metalasia muricata*, *Anthospermum aethiopicum*, *Passerina paleacea*, *Carpobrotus acinaciformis*, *Ficinia filiformis*, *Scirpus membranaceus*, *Myrica quercifolia*, *Koeleria cristata*, *Lightfootia tenella*, *Psoralea fruticans* and *Selago stricta*.
Dominant species: *Metalasia muricata*, *Restio eleocharis*, *Myrica quercifolia*, *Anthospermum aethiopicum* and *Passerina paleacea*.

Fig. 13. *Metalasia–Myrica* community. The large bush in the centre foreground is *Metalasia muricata*. The darker bushes in the right background are the introduced *Acacia cyclops*.

The *Metalasia–Myrica* community (Fig. 13) occurs on the unconsolidated to consolidated shifting dunes forming a plume along a north–south axis to the south and east of the Langebaan Lagoon. It occurs on Mispah Form (Kalkbank Series) soils or

on deep regic sands. Limestone is locally exposed. Dune scrub consisting of such species as *Rhus glauca, Euclea racemosa* and *Colpoon compressum* occupies the dune ridges, which is a situation similar to that found on the Cape Flats (Taylor 1972*a*).

The photo colour for the community is a deep purple-grey brown, and the photo-units have a very coarse texture, indicating the presence of two strata of vegetation. The upper stratum is formed mainly by *Metalasia muricata* and *Passerina paleacea*, and varies in height between 1,0 and 1,6 m. These shrubs have ericoid leaves and give the community its characteristic appearance. The lower stratum is formed mainly by *Restio eleocharis, Myrica quercifolia* and *Carpobrotus acinaciformis* and varies in height between 15 and 25 cm. This stratum is formed by a mixture of ericoid-leaved, graminoid, restioid and succulent plants. The canopy cover varies between 65 and 85 %, averaging 75 %.

The species common to this *Metalasia–Myrica* Dense Evergreen Shrubland, and to the other littoral-dune communities, are: *Helichrysum metalasioides, Senecio elegans, Ficinia lateralis, Restio eleocharis, Rhus laevigata* and *Chironia baccifera*.

Marsh communities

Arthrocnemum pillansii var. *pillansii* is the differential species for the marsh communities in which it is also often the dominant species. Marshes are those tracts of soft wet land which are covered wholly or partially with water (Carpenter 1938). Marsh conditions occur around the whole of the Langebaan Lagoon except where a rocky coast occurs. The shallow temporary pans found along the coastal shelf along the western seaboard are described under the *Atriplex–Zygophyllum* community.

Juncus kraussii Dense Sedgelands
Relevés: 319, 320, 321, 322, 324, 325, 326, 327.
Differential species: *Juncus kraussii, Scirpus nodosus, Nidorella foetida, Senecio halimifolius, Conyza pinnatifida, Samolus valerandii, Typha capensis, Cliffortia strobilifera* and *Phragmites australis*.
Dominant species: *Juncus kraussii, Scirpus nodosus, Nidorella foetida, Senecio halimifolius, Typha capensis, Phragmites australis* and *Arthrocnemum pillansii* var. *pillansii*.
Species in common with the *Chenolea–Salicornia* community: *Arthrocnemum pillansii* var. *pillansii*.

The *Juncus kraussii* Sedgelands (Fig. 14) can be further subdivided on the basis of dominance. Floristically, considerable variation occurs within each of these communities and they are therefore considered to be variations of the *Juncus kraussii* Sedgelands.

The high water-table found where this community occurs results in Champagne Form (Champagne Series) soils being prevalent, although Katspruit Form (Killarney Series) soils were also found.

The community is restricted mainly to the south-eastern borders of the lagoon

Juncus kraussii-dominated Form

Juncus kraussii forms fairly extensive dense stands with *Arthrocnemum pillansii* var. *pillansii* as the only accompanying species. These dense (canopy cover 100 %) 60 cm tall spiky stands appear black from a distance during summer, almost as if they have been burnt.

Fig. 14. *Juncus kraussii* Sedgelands. The *Nidorella–Senecio* community in the foreground separates the *Juncus kraussii*-dominated Form in the middle distance from the *Typha capensis*-dominated Form in the left distance and the *Phragmites australis*-dominated Form on the right.

Nidorella–Senecio Mixed Form

This is probably the more typical form of the *Juncus* Sedgelands consisting of a mixture of reeds, sedges and shrubs. The following species are commonly found: *Juncus kraussii, Senecio halimifolius, Nidorella foetida, Conyza pinnatifida, Samolus valerandii, Scirpus nodosus* and *Arthrocnemum pillansii* var. *pillansii*.

Cliffortia strobilifera-dominated Form

This form has a very similar species composition to the *Juncus–Scirpus* Form but differs in the occurrence of and dominance by approximately 3,0 m tall *Cliffortia strobilifera* individuals.

Typha capensis-dominated Form

Most of the species found in the *Juncus–Scirpus* Form occur in this variation, but dense stands of *Typha capensis* individuals reaching 2,0–3,0 m in height dominate the community.

Phragmites australis-dominated Form

Phragmites australis can form dense 3,5 m tall stands with *Scirpus triqueter* as the only accompanying species. These stands usually occur where there is free surface water. In the slightly higher lying areas the species of the *Juncus–Scirpus* Form also occur.

Chenolea–Salicornia Dwarf Succulent Shrubland
Relevés: 328, 329, 330, 331, 332, 333, 323.
Defining species: *Chenolea diffusa* and *Salicornia meyerana*.
Differential species: *Chenolea diffusa*, *Salicornia meyerana*, *Eragrostis* sp. (Boucher 2820), *Disphyma crassifolium*, *Limonium equisetum*, *Triglochin bulbosa* and *Spartina capensis*.
Dominant species: *Arthrocnemum pillansii* var. *pillansii*, *Salicornia capensis* and *Disphyma crassifolium*.
Species in common with *Juncus kraussii* community: *Arthrocnemum pillansii* var. *pillansii*, *Spergularia marginata* and *Lycium tetrandrum*.

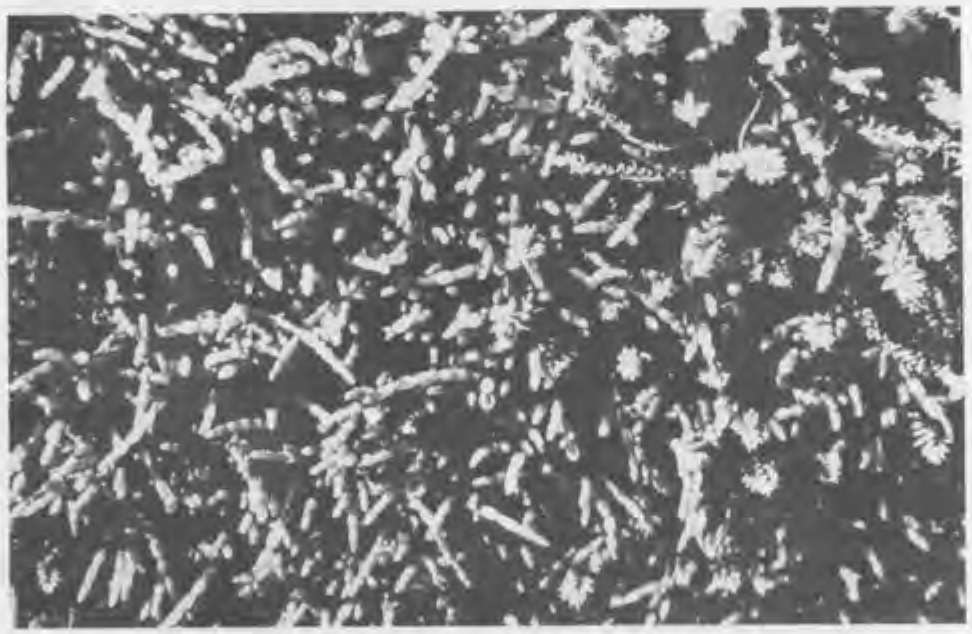

Fig. 15. *Chenolea–Salicornia* community. *Chenolea diffusa* individuals on the left occur amongst a mat of *Salicornia meyerana*.

This community (Fig. 15) appears mainly as a 5–15 cm tall thick mat of scandent divaricate succulents covering 90–100 % of the substrate. The *Spartina–Triglochin* Form is about 25–35 cm tall and in slightly deeper water forms a pure grassland, while in the shallower areas, the shorter succulent mat covering the substrate is formed by

the 5–15 cm tall *Limonium–Disphyma* Form. The following soils were identified where this community was found: Fernwood Form (Soetvlei Series), Champagne Form (Ivanhoe Series) and Katspruit Form (Killarney Series).

Salicornia meyerana is an annual species according to definition, but it has been used to describe this community because it is permanently recognizable. The canopy cover would vary seasonally according to the stage of development of this species.

The *Chenolea–Salicornia* community occurs widely around the Langebaan Lagoon in the zone exposed during low tides and flooded during spring tides. It is composed of a mosaic mainly of the two variations described below.

Limonium–Disphyma Form

This form is characterized by the presence of *Disphyma crassifolium* and *Limonium equisetum*. It occurs on the slightly raised portions on the intertidal salt marshes. The soil was found to belong to the Fernwood Form (Soetvlei Series). *Chenolea diffusa* is particularly prominent in this form. This is the more extensive form of this community.

Spartina–Triglochin Form

This form is characterized by the presence of *Triglochin bulbosa* and *Spartina capensis*. It occurs on the edges of the water channels or along slight drainage lines between the *Limonium–Disphyma* Form. The grass, *Spartina capensis*, forms dense stands on its own, particularly in the lower-lying areas where the regularly spaced erect stems form a uniform field varying in height between 25 and 35 cm.

Alien communities

Alien, exotic or naturalized problem plants can form dense stands, suppressing the indigenous flora. These plants are, therefore, important in a description of the vegetation of an area. *Acacia cyclops* (rooikrans) (Fig. 13) probably presents the greatest threat to the natural indigenous vegetation in the area. This species was originally introduced into South Africa from Australia to stabilize dune sands. It has been used for this purpose south of the Langebaan Lagoon. The Langebaan Peninsula is relatively free of this species, with a few individuals occurring along the roadside. Considerably larger infestations occur in the veld to the south and east of the lagoon, and scattered throughout the Saldanha area. *Populus canescens* (grey poplar) seems to be spreading in a small moist area on Bottelary farm on the eastern side of the lagoon. Scattered *Acacia saligna* (Port Jackson wattle) individuals occur to the south and east of the lagoon.

Rare and endangered species (mainly compiled by A. V. Milewski)

Moraea loubseri Goldblatt is known only from the top of an 80 m hill of Darling Granite near Langebaan village. The site, receiving an annual precipitation of 200–300 mm, bears a disturbed, grassy form of Acocks's (1975) Strandveld proper. This vegetation is 1 m high with 60–70 % total canopy cover, being composed of shrubs (e.g. *Eriocephalus racemosus*, *Pteronia divaricata*, *Matricaria* sp., cf. Schlechter 5293, *Melolobium* sp., cf. *M. aethiopicum*, *Aspalathus acuminata* subsp. *acuminata*, *Lycium*

afrum, *Indigofera* sp. and *Hermannia* sp.), succulents (e.g. *Ruschia langebaanensis*, *Ruschia* sp., cf. *R. tumidula*, *Drosanthemum floribundum*, *Lampranthus aureus*, *Euphorbia burmannii* and *Zygophyllum morgsana*) and a ground stratum of grasses and soft woody plants (e.g. *Ehrharta calycina*, *Tetragonia fruticosa*, *Leyssera* sp., cf. *L. tenella*, *Othonna coronopifolia*, *Lotononis* sp. and *Asparagus* sp.).

Moraea loubseri is probably now extinct in its natural habitat owing to quarrying operations. Already established horticultural populations might make it possible to re-establish the species in the nearest suitable site with a long-term conservation future.

The following additional species are regarded as possibly threatened by man-induced environmental changes in the Langebaan–Saldanha area: *Vanzijlia rostella* L. Bolus; *Hessea chaplinii* Barker; *H. mathewsii* Barker; *Felicia elongata* (Thunb.) O. Hoffm.; *Pauridia longituba* M. F. Thompson (in hollows on granite rocks); *Ferraria langebaanensis* L. Bolus; *Geissorhiza lewisae* Foster (associated with sand); *Gladiolus gracilis* Jacq. var. *latifolius* Lewis (associated with sandy soil); *Ixia purpureorosea* Lewis (associated with limestone or granite); *Romulea elliptica* De Vos (associated with white sandy soil); *R. saldanhensis* De Vos (occurs in temporary pools) (Fig. 16); *Watsonia hysterantha* Mathews (associated with crevices in large granite boulders); *Hyacinthus paucifolius* Barker (appears to be associated with granite hills); *Lachenalia viridiflora* Barker (on granite rocks); *Oxalis subsessilis* L. Bolus; *Oxalis burtoniae* Salter; *Muraltia harveyana* Levyns; *Leucospermum tomentosum* (Thunb.) R. Br.; and *Agathosma thymifolia* Schlechtd.

Research is in progress on the status of these species. Recommendations arising

Fig. 16. *Romulea saldanhensis*, a rare species found in some of the temporary pools on the coastal-shelf.

from the research will need to be put into effect rapidly in view of the major changes planned for the Langebaan–Saldanha area.

DISCUSSION

The *Metalasia–Myrica* Dune community was the only one found during this survey which could be regarded as fitting into Acocks's (1975) category of Coastal Fynbos. It represents an early stage in the development of this Veld Type. The rest of the communities recorded on the consolidated and unconsolidated sands, on granite soils and coastal-shelf locations, and on limestone soils may be regarded as members of the West Coast Strandveld of Acocks. The *Willdenowia striata* Consolidated-dune community, the *Thamnochortus spicigerus* Dune community and certain facets of the *Pelargonium–Muraltia* Coastal-shelf community and the *Galenia–Senecio* Hillside-granite community have affinities with Fynbos as defined by Taylor (1972*b*), but have a preponderance of West Coast Strandveld components. Taylor & Boucher (1973) pointed out that the narrow tongue of Coastal Rhenosterbosveld extending to the eastern shores of the Langebaan Lagoon appeared to be a faulty boundary on Acocks's (1975) map. This study substantiates that finding. They also noted a dark pattern on the Land Sat—1 images, to the east of the Langebaan Lagoon, and identified it as representing Coastal Fynbos. This differed from the boundaries indicated by Acocks (1975) for Coastal Fynbos. This study also supported that finding in so far as the extreme south-east tip of this study area included a portion of that dark pattern, and a Coastal Fynbos community was recorded there. This community appears closely related to Taylor's (1972*a*) *Metalasia* Inland-dune Fynbos. The rest of the area to the east of the lagoon, included within the study area, was mainly found to have West Coast Strandveld communities.

The colonization of the littoral loose dunes in this West Coast Strandveld occurs through the *Didelta–Psoralea* Littoral-dune community to the *Maytenus–Kedrostis* Consolidated-dune community. According to Marloth (1908), the sand dune vegetation north of Table Bay differed from that south of False Bay and he distinguished a Cape hard-leaved formation in the Coastal Fynbos which did not overlap with the Cape Flora proper. He described the Cape hard-leaved formation as containing semi-bushy succulents, such as *Euphorbia mauretanica*, with succulent pelargoniums, such as *Pelargonium gibbosum*, and thick-stemmed members of the family Crassulaceae. This formation agrees in broad definition with the *Maytenus–Kedrostis* community. The *Euclea–Rhus* Inland-dune Scrub and *Pterocelastrus* Coast-dune Scrub on the Cape Flats (Taylor 1972*a*) differ from the *Maytenus–Kedrostis* community in the absence of the succulent shrub components common at Langebaan. Indications of a community similar to Taylor's *Euclea–Rhus* community were found in the *Metalasia–Myrica* community at Langebaan. The succulent shrub components of the communities at Langebaan were found to be drought-deciduous, in contrast to the sclerophyllous woody components such as *Euclea racemosa* and *Rhus glauca*. This results in the vegetation having marked seasonal differences, particularly when the spring annuals are in full bloom.

Adamson (1938) described the taller succulent shrubs as being abundant in his Coastal Succulent Bush extending from St Helena Bay northwards. Acocks (1975) extended this vegetation in a narrow strip southwards along the coast to False Bay and divided what he called the West Coast Strandveld into dense strandveld scrub and strandveld proper. This division is not clear, particularly with regard to habitat differences. The principal species of the dense strandveld scrub are mostly elements of the unconsolidated to consolidated dune communities. Elements of the communities on granite soils in the Langebaan area such as *Maurocenia frangularia*, *Myrsine africana* and *Rhus glauca* are considered by Acocks to belong to a less xerophytic and transitional scrub to dune forests on the Cape Peninsula. Taylor (1969) found a related community, the *Maurocenia–Linociera* Tall Scrub association, to occur on Table Mountain Sandstone slopes and screes in the southern Cape Peninsula. The communities themselves do not appear to be identical, the Langebaan *Ehrharta–Maurocenia* Hillside community having a greater number of succulent components. Acocks (1975) classifies the West Coast Strandveld under his Karoo and Karroid Bushveld Types, which is reasonable considering its general bushy succulence, but the presence of ericoid and restioid elements, albeit in local patches, indicates a tendency towards the sclerophyllous bush types of the Cape Floral Kingdom (Good 1964).

Acocks (1975) noted that *Willdenowia striata* became plentiful near the upper margin of the West Coast Strandveld, providing an easy transition to Arid Fynbos while towards the lower margin an increase in the proportion of mesems caused it to pass easily into Succulent Karoo. During this study *Willdenowia striata* was found to occur in a distinct community inland of the *Maytenus–Kedrostis* community and contained a large number of elements of that community. This could, therefore, be in the upper transition area to Coastal Fynbos but there was not enough Coastal Fynbos in the study area to study the occurrence of *Willdenowia striata* there.

Species of *Typha*, *Scirpus*, *Cyperus* and often *Phragmites* can be regarded as characteristic plants of the marshes of the Cape (Stephens 1929). These genera are all found in the south-eastern corner of the Langebaan Lagoon. Taylor (1969) described a *Helichrysum–Scirpus* Marsh association on the southern Cape Peninsula, and a grass–rush community on the Cape Flats (Taylor 1972*a*) which have a number of species in common with the *Nidorella–Senecio* community at Langebaan. *Cliffortia strobilifera*, which forms a dense stand in the *Juncus kraussii* Sedgeland, is also recorded as forming patches along the Berg River (Harrison 1964). It appears to have a wide distribution in southern Africa, occurring in wet patches at low altitudes near the coast and at high altitudes farther inland (Weimarck 1934).

Salt marshes are cosmopolitan in distribution, and it is therefore not surprising to find the cosmopolitan halophytic genera *Spartina*, *Juncus*, *Salicornia*, *Arthrocnemum* and *Limonium* at Langebaan. However, the genera in the Langebaan halophytic community embrace a number of African endemic species some of which differ from congeners in similar habitats around the South African coast (Millard & Scott 1955; Scott *et al.* 1951; McCallum undated).

European salt marsh communities have been classified (Reimold & Queen 1974) according to the Zürich–Montpellier system as:

(1) Class Salicornietalea
  Order Coeno-Salicornietalia
  Order Coeno-Spartinetalia
  Order Limonietalia

(2) Class Juncetea

(3) Class Phragmitetea

The genera found at Langebaan, e.g. *Salicornia*, *Spartina*, *Limonium*, *Juncus* and *Phragmites*, can all be identified in this classification which could provide a guideline for the ordering of South African halophytic communities. The more detailed analysis of the *Chenolea–Salicornia* community in this paper agrees in principle with Day's (1959) findings. However, the dry sandy banks, with patches of *Sporobolus virginicus*, mentioned by Day were not found to be extensive enough for delimitation at the scale involved in this survey.

The *Chenolea–Salicornia* community has been considerably disturbed by vehicles and domestic animals. Utilization of the natural vegetation by domestic animals such as horses, cattle, sheep, goats and ostriches appears to be governed by the availability of fresh water, despite the vegetation being deficient in proteins, phosphorus, copper, manganese and cobalt (Louw 1969). The marsh communities are heavily utilized during the summer months. However, livestock is normally withdrawn in summer from farms on the southern part of the Langebaan Peninsula which lacks fresh water. This practice probably accounts for the vegetation there being in a relatively undisturbed condition. Disturbance is relatively great around habitations, and exposed limestone often occurs at Churchhaven, Stofbergsfonteyn and Oupos. The Oupos area was grazed by domestic animals for hundreds of years prior to part of it recently being proclaimed as a private nature reserve. A number of sources of fresh or slightly saline water permit utilization of the vegetation throughout the year. At present the Oude Post Nature Reserve is fairly heavily stocked with introduced antelope and dassies (*Procavia capensis*) appear to be abundant, judging from the state of the grazed vegetation and the variety of cosmopolitan annual weeds.

Tilling of the granitic and sandy soils is practised mainly for wheat production. The sandy soils are often strip ploughed to reduce wind erosion. The old fallow lands usually support dense 1 m tall stands of *Exomis microphylla* var. *axyrioides* (Fig. 17) with a 10 cm tall understorey of *Atriplex semibaccata*, *Schismus barbatus* and *Pentzia pilulifera*.

The aggressive alien *Acacia cyclops* (Fig. 13) occurs commonly in the indigenous vegetation on the eastern shores of Langebaan Lagoon. This species spreads readily and suppresses the natural vegetation; it will therefore considerably affect the environment and thereby farming practices in the area unless control measures are implemented soon to combat and eradicate it. The Langebaan Peninsula is relatively free of alien species, although exotic plants do occur sporadically along the main access route, in contrast to most of the West Coast Strandveld to the south of the study area. The relative lack of perennial alien species on the Langebaan Peninsula is a feature which, in itself, strongly suggests that the whole area should be proclaimed as a nature reserve.

Fig. 17. *Exomis microphylla* var. *axyrioides* on fallow lands in the Oude Post Private Nature Reserve.

Additional features recommend this area for conservation: the relatively good state of preservation of the vegetation, particularly in the southern section; the diverse communities which occur because of the variety of habitats present; the scientifically important distribution ranges of a number of species; the presence of remnant tree clumps around the granite boulders; and the limited access to the area.

Only 6 308 ha or 1-5 % of the West Coast Strandveld, which formerly covered 0,5 % of South Africa, is conserved (Edwards 1974). There are four 'conservation' areas for this Veld Type: The Lambert's Bay Nature Reserve of 57 ha, of which a portion has been dammed to form a vlei. Rocher's Pan Nature Reserve of 390 ha, of which large areas are in fact vleis. The Nortier Experimental Farm of 2 930 ha. Formerly this was a nature reserve which is now used for grazing experiments and has been strip ploughed in parts. It is therefore no longer in a natural state. The Oude Post Private Nature Reserve (3 153 ha) which is part of the area which it is here recommended should be encompassed within a larger nature reserve.

The establishment of a viable reserve for the vegetation at Langebaan would require the accession of approximately 2 550 ha, embracing the Donkergat Peninsula, the farms Stofbergsfonteyn and Schrywershoek, and portions of the farms Geelbek and Abrahamskraal to link in the south with property of the Department of Forestry and to include the *Juncus kraussii* marsh communities. This proposed consolidation would result in a 5 700 ha nature reserve.

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APPENDIX

Braun–Blanquet table showing vegetation communities of the Langebaan area.

Key:-

*Soil code:
Champagne form (Ivanhoe series) = 1
Novanci form (Novanci series) = 4
Clovelly form (Sandspruit series) = 44
Hutton form (Gaudam series) = 53
(Waterpoe series) = 54
Oakleaf form (Cavubu series) = 63
Fernwood form (Soetvlei series) = 71
(Langebaan series) = 72
Milpah form (Muden series) = 77
(Kalkbank series) = 78

**Photo-unit Texture:
St = stippled
c = coarse
f = fine
s = smooth
e = even
v = very

***Photo-unit Colour:
(ISCC-NBS colour chips)
Br = Brown
Y = Yellow
G = Green
P = Purple
r = red
p = pale
gy = grey
d = dark
g = green

Cover-abundance symbols according to Kuchler (1967). (+) refers to species noted in releve surroundings.

Aspect refers to uncorrected compass reading. The magnetic declination is 24 degrees west of north.

ROMAN TABLE
(SUMMARY TABLE)

COMMUNITIES
A B C D E F G H I J K L M N