THE PHYSIOGRAPHY AND PLANT COMMUNITIES
OF THE JAKKALSRIVIER CATCHMENT

By
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(Forestry) at the University of Stellenbosch.

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FRONTISPIECE. Panoramic view of the Jakkalsrivier catchment. The peak is the highest point on the watershed. In the foreground is the main meteorological station.
ACKNOWLEDGEMENTS

The Secretary for Forestry kindly gave me the opportunity of doing this work and allowed me to use the data for thesis purposes.

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ABSTRACT

The Jakkalsrivier catchment is one of several mountain drainage basins selected for research on the effects of treatment on vegetation, stream flow and erosion in the fynbos ecosystems of the south-western Cape Province of South Africa.

This study comprises a report on the physiography and plant communities there.

Jakkalsrivier is situated on poor sandstones and quartzites, and soils are characterized by acidity, low base status and wide variation in moisture (seasonal and spatial) and organic content. The land is steep, gently dissected and faces south. The climate may be described as of the moist transitional Mediterranean type.

The catchment, which receives about 1000mm of rain per annum and where ambient temperature averages 13.6°C, is cooler, moister and windier than the surrounding lowlands. Altitudinal gradients are marked by increasing precipitation (at a rate of 50 mm per 100 m) and decreasing solar radiation with increasing elevation.

Community classification is based on association-analysis and group analysis of a qualitative floristic data set collected from a systematic sample of 367 fifteen-square-metre quadrats. Eleven communities are distinguished, most of which are essentially of the microphyllous evergreen dwarf scrub formation class,
with some microphyllous and some sclerophyll evergreen scrub. Community variation is associated chiefly with major soil type differences and gradients of relative solar insolation and of soil moisture.

The sampling system used is felt to be inefficient. A well-designed suite of computer programmes would greatly assist work of this nature.
INTRODUCTION

One of the striking features of the vegetation-environment complex in the Western Cape is the frequent recurrence of extensive wild-fires in the dry season. Equally striking, though rarely remarked, is the fact that though communities with a post-burn age greater than 20 years are rare, the vegetation has largely retained its character. The observer does not usually realise that the attractive vigorous vegetation adjacent to recently burnt and apparently desolate land had, a short time previously, appeared the same.

Opinions as to the more long-lasting effects of veldfire on the Cape Fynbos have varied and are still conflicting. Speakers at a symposium on veld-burning in 1924 (Levyns, 1924; Marloth, 1924; and Pillans, 1924) stressed its destructive effects. Wicht (1945) summarised the scanty and contradictory data available at that date, and, inter alia, proposed that controlled burning could play an important and vital role in practical land use and catchment management.

The Department of Forestry is by far the largest single controller of mountain land under natural vegetation in the Republic. In the Western Cape it owns approximately 267 000 hectares of unafforested mountain land, much of which constitutes important catchment areas.
Management of these unafforested watersheds has consisted almost exclusively of attempts - mostly unsuccessful - to protect them completely from fire. This practice, though considered necessary at the time of its adoption, is (in the light of the past history of Southern Africa) somewhat arbitrary and artificial. It has proved detrimental to the flora in some cases at least; examples are the virtual disappearance of *Serruria florida* and *Orathamnus zeyheri* plants in their natural habitats, as a result of complete protection from fire. There is also a growing body of opinion that judicious burning in specific cases would be beneficial to water supplies (Wicht and Banks, 1963; le Roux, 1966; Malherbe, 1968; van der Zel and Kruger, in press). It therefore became increasingly apparent that a more realistic approach was required, consonant with a national policy for water and vegetation conservation and a growing awareness of the value of amenity (Möhr, 1966; and le Roux, 1966). In 1972 the Department of Forestry accordingly adopted a policy of controlled burning (Garnett, 1973). A basis for this was to be found through veld-burning experiments, statistically designed and evaluated, in the region concerned.

On the 17th January, 1962, a sub-committee (also known as the Inter-departmental Committee of Investigation into Mountain Catchments of the Winter-rainfall Region) met in Pretoria to inaugurate work in this field. It was resolved that "...a series of experiments would be established to determine the effects of veld-burning on water discharge, erosion and vegetation, in comparison with protected veld and pine plantations in mountain..."
catchments of the winter rain region ...." (Wicht: typed report, 22.2.1965). As a result of these deliberations, and subsequent investigations in the field by a reconnaissance party, two areas in the Western Cape were chosen for the first series of experiments. These are the Jakkalsrivier and Zachariashoek catchments.

The primary aim of these studies is to investigate the relationship between vegetation and habitat-factors, with the emphasis on the effect of controlled burning of different frequencies at different seasons on the dynamics and composition of the vegetation, and through this, on soils and the hydrologic cycle.

The Cape Fynbos is a fire-type vegetation, as defined by Sweeney (1967), i.e. a vegetation in which component species are adapted to survive the recurrent fires characteristic of a fire-type climate. He describes a fire-type climate as "..... characterised by the coincidence of low temperature with high moisture, and, conversely, high temperatures with low moisture ....". Daubenmire (1968) states the idea as follows: "Wherever plants grow close enough together to carry a conflagration, fire can be a significant component of biotic environment, yet recognition of the ubiquity and importance of burning in determining the distribution and form of many plants, as well as the composition of vegetation, has been slow to develop." Henkel (in Wicht, 1945) it seems, was the first to make largely the same observation of the Cape fynbos.

The interrelationship between vegetation and the environmental complex in a fire environment may be schematically repre-
sented as follows (adapted from Jackson, 1968):

![Diagram showing the relationship between Man's influence, climatic variables, soil features, soil moisture, vegetation, fire frequency and season, stream flow, and erosion rates, with animals and man interconnecting.]

Broadly, it is this complex system which is to be investigated. Implicit in the diagram is the following hypothesis, which these investigations aim to refine or discard:

a change in fire frequency, season, or both induces a change in vegetation structure and dynamics, which in turn effects a change in soil characteristics, including the soil moisture regime, water discharge and erosion rates.

Information on the interaction between vegetation and fire in the Cape fynbos is scarce.

West (1965) has comprehensively reviewed the results of
veld-burning experience and research in Southern Africa, but has taken little cognisance of the limited data available for the Western Cape.

As early as the eighteenth century, Sparrman (Sparrman, 1775 in Muir, 1929) pointed out that injudicious vegetation management, including the use of fire, was having a marked effect on the vegetation of the Riversdale district.

Bolus (1905) was apparently the first botanist to note that "..... the prevalence of bush fires in exercising a marked influence on the (Cape) flora, in a manner not yet fully understood, but probably has as one of its effects the diminution in the number of species."

Levyns (1924, 1929, 1935, (nee) Michell, 1922) provided the first descriptive account of the regeneration and growth of fynbos species after fire. Adamson (1935), working on the slopes of Table Mountain, described the regeneration after fire of the plant communities there. Both postulated successional development after a burn.

Jordaan (1949), after studying the life-history and phenology of *Protea repens*, theorised that fire at different times of the year would have different effects on the regeneration of this species. Later (1965) he determined that a winter burn had had a detrimental effect on certain species populations.

Van der Merwe (1966), studying communities after a fire, determined that a late summer burn had had no effect on their
species composition, and attempted a prediction of the effect of a similar burn.

The first serious attempt at a rigorous statistical study of the problem, however, was that made by Wicht (1948). He used a randomised block design to test the effect of different burning treatments. Unfortunately, only the preliminary results were published, but the experiment did emphasize the importance of a statistical approach to such vegetation studies.

Since 1948 there had been a dearth of experiments in this field and only recently, as a result of intensive development in the spheres of agriculture, forestry and botany, has it received fresh stimulus.

At this stage, the hypothetical interrelationships may be outlined in general terms, on the basis of observations, measurements and experiments reported in the literature quoted above. The vegetation includes components which are adapted to recurrent fires, and which may be subdivided in two groups: those which propagate vegetatively, and those which reproduce by seed. Fires occurring at intervals of about three to six years, will eliminate the latter component, because such species require a minimum period after fire to grow to maturity and produce seed. (A further increase in fire frequency is considered generally impossible because vegetation with a post-burn age of about 4 years and less does not provide sufficient fuel for a burn.) If fires recur at between 8 and forty year intervals, a more or less dense scrub develops, in which the seed-regenerating species dominate and the phytomass of those species which propagate vegetatively declines.
Where fire frequency decreases to 40–100 years, forest may develop where soil and other factors are favourable.

The season of firing controls the vegetation type because of interspecific differences in phenological behaviour and regeneration characteristics. Thus, burning at different seasons will result chiefly in changes in the relative abundance particularly of the seed-regenerating species, and may even result in a change in structure and physiognomy.

These changes may be regarded as beneficial or detrimental, depending on the point of view of the observer.

Great controversy exists on the effect of fire on soil characteristics and the hydrological cycle. Generally, however, it is agreed that increased fire frequencies, resulting in reduced phytomass, will increase total streamflow, the size and frequency of spate-flow, the amount of summer base-flow and the rate of erosion.

The consensus of opinion has it that recurrent fires retard the development of the soil profile through removal of organic wastes. The more frequent the fire, the more immature the profile.

The study reported here is a preliminary one in the Jakkalsrivier project, aimed chiefly at obtaining a community classification to serve as a frame of reference, and as a record in broad terms of the existing communities for future comparison. Other projects comprise detailed measurements of vegetation parameters to determine the influence of burning and protection.
CHAPTER 1

SITE DESCRIPTION - PHYSICAL

1.1. LOCATION

The Jakkalsrivier catchment, 157.5 ha in extent, is situated at 34°09' south latitude and 19°09' east longitude, on the Lebanon State Forest. It lies on the southern slopes of the Groenlandberg range, about 12 kilometers east of Grabouw. The shortest distance from the centre of the catchment to the Atlantic Ocean is 24 kilometers on a south by south-east bearing. A low range of hills with elevations to about 500 m occurs on the coast on this line, but a higher coastal range (to 1200 m elevation) is situated to the south-east. These shield the catchment to a limited extent from maritime influences. About 17 kilometers west by north-west lies the Hottentots-Holland range, aligned north-east to south-west, which constitutes a major climatic divide.

Fig. 1 shows the location of the catchment relative to communications and major centres.

![Fig. 1. Location of Jakkalsrivier. Shaded areas denote land above 610 m (2000 ft.) elevation.](image-url)
1.2. TOPOGRAPHY

Fig. 2 shows the topography of the basin. The catchment has a high relief - elevation rises 536 m in the short distance of 1,847 kilometers. However, the predominant land-surface is somewhat undulating. The valley bottom is narrow and flood-plains almost non-existent. The catchment is gently rather than sharply dissected, and only one small ravine occurs.

Fig. 2. Topography of Jakkalsrivier. Contour intervals are 20 ft. The network of environmental data acquisition stations is also shown.
1.2.1. **Topographic Analysis**

(i) **Slope and aspect.** Slope and aspect were determined from the contour map, using the method described by Lee (1963). Summarised data from a systematic sample of 200 points are depicted in fig. 3.

![Diagram](image)

**Fig. 3.**

- **a.** Frequency of slope azimuth for 200 points
- **b.** Frequency of percentage slope inclination classes for 200 points
- **c.** Frequency of altitude classes (in m x 10^2) for the same sample
The average slope of the whole catchment is 46% (24°40'), and general aspect south. Generally, slope increases with altitude, except on small subsummit plateaus and rather extensive necks. Steepest slopes (over 70%) are confined to upper-middle zones of the scarp faces. Level sites occur chiefly on subsummit plateaus and necks.

(ii) Basin characteristics and the drainage network

Data for the topographic analysis were obtained from a 1:7 200 sheet specially commissioned from the Trigonometrical Survey Office. Results are therefore not comparable to those obtainable from the standard topographic sheets used in South Africa (1:50 000).

The drainage network was analysed using methods developed by Horton (1945) and Strahler (1969, 1964), using the latter's definitions.

TABLE I. STATISTICS OF CATCHMENT CHARACTERISTICS AND THE DRAINAGE NETWORK

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<thead>
<tr>
<th>Catchment Area (A)</th>
<th>= 1,575 km²</th>
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<tbody>
<tr>
<td>Total stream length</td>
<td>= 13,391 km</td>
</tr>
<tr>
<td>Stream density (D)</td>
<td>= 8,5022 km/sq. km</td>
</tr>
<tr>
<td>Order of mainstream</td>
<td>= 3</td>
</tr>
<tr>
<td>Bifurcation ratio:</td>
<td></td>
</tr>
<tr>
<td>Stream Order u</td>
<td>Frequency N_u</td>
</tr>
<tr>
<td>1</td>
<td>49</td>
</tr>
<tr>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>

....../12
Bifurcation ratio (from regression) \( R_b = 9.95 \)

Stream length ratio:

<table>
<thead>
<tr>
<th>Stream Order</th>
<th>Mean length ( l_u ) (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.1970</td>
</tr>
<tr>
<td>2</td>
<td>0.2516</td>
</tr>
<tr>
<td>3</td>
<td>1.2240</td>
</tr>
</tbody>
</table>

Stream length ratio (from regression) \( R_1 = 3.13 \)
Stream frequency \( (F) = 38.93/km^2 \)
Mean length of overland flow (corrected) = 87.0 m

Data from Plathe and van der Zel (1969) are:
Mean elevation : 874 m
Mean slope : 40%
Form factor (Gravelius) : 0.50
Compactness (Gravelius) : 1.20

They calculated mean slope using Horton's formula (mean slope = \( \frac{\Sigma a e}{A} \), where \( a \) = area between pairs of contour lines, \( e \) = mean elevation of \( a \), and \( A \) = total area of Catchment). There is fairly good agreement between their results and those obtained here (46%), but Lee's method (Lee, 1963) is quicker and provides more useful data.

Strahler (1964) states that bifurcation ratios range between 3.0 and 5.0 "..... for watersheds in which the geologic structures do not distort the drainage pattern". The high bifurcation ratio here therefore indicates strong geological influences on the drainage pattern, though these are not as marked as may be found in other parts of the Cape fold mountains.

The stream density of 8.5 km per square km indicates good
drainage, though the drainage texture is rather coarse. (This figure is, however, much higher than would be obtained from, for example, a standard 1 : 50 000 topographic sheet). The relatively high stream-length ratio reflects the occurrence of comparatively long first-order streams.

The third-order stream therefore has a low to moderate drainage intensity. In spite of the geologic control reflected in a high bifurcation ratio, the drainage follows a dendritic pattern.

1.3. GEOLOGY AND GEOMORPHOLOGY

Information on the geological formations and geomorphology is available from de Villiers et al (1964), King (1967), and, in more detail, Wilson (1964).

The underlying rocks consist almost entirely of white, coarse-grained quartzites and sandstone, typical of the Table Mountain Series east of the Hottentots-Holland divide, and are extremely poor in minerals other than silica. They weather slowly, often forming striking gendarmes and gargoyles. Most soils thus derived are coarse white or grey sands.

A band of siliceous shale is exposed for a short distance on the north-eastern side of the small ravine in the centre of the basin, between the 2700' (823m) and 2800' (853m) contours. This, with isolated shale lenses and the iron-rich reddish-brown quartzite to the north-east, gives rise to soils very different from those on the rest of the area.
The catchment is situated on a major east-west local fault scarp (de Villiers et al., 1964). This controls the overall nature of the site, particularly slope and general aspect. The northern boundary lies on the crest of the massif, and the catchment lies on the scarp face.

The basin formation is attributable to a major and several minor faults, while the main stream trends south, roughly on the course of the major local fault-line transverse to the scarp.

In spite of the steep slopes, most of the chief drainage channels have a moderate grade, owing to greater or lesser barriers at regular intervals. Long segments are fairly well graded. There is, for example, a 20 m cascade in the ravine mentioned above.

Streams seldom transport material larger than coarse sand.

The slopes are covered chiefly by a mantle of talus debris but colluvial fans are small. Though the upper slopes are steep, there are only two very old mass wastage scars. Talus creep is hardly detectable over most of the catchment. The upper steep slopes (> 70% slope inclination) are covered by a shallow, dark, humic soil. This is no doubt owing to the very stable vegetation which develops on these cool moist aspects, coupled with the anchoring effect of the hard rock strata which dip about 25° north-west on an east-north-east strike.

Tributaries on the upper scarp have not eroded significant
basins, so that these perched streams have poorly defined channels. At their lower reaches, they enter small colluvial fans, often disappearing completely, and selection of stream-gauging sites has therefore been difficult.

Alluvial deposits are limited and sporadic in the immediate vicinity of streams.

Fairly deep (to about 1.0m) deposits of sand occur on the slightly graded saddles. These are subject to moderate deflation.

The dip-slopes of local faults are moderate with a northerly aspect. Here, very rocky, skeletal soils occur.

In places on the lower moderate slopes, where drainage lines are indefinite and soils shallow, seepage steps occur, where the high water table is associated with organic accumulations.

1.4. SOILS

Mr. J.H. Neethling, soil scientist of the Department of Forestry, completed a preliminary investigation of soil chemistry in December 1969 and a reconnaissance survey of soil types in June 1972. This account is based on his data.

1.4.1. Classification

Soils are classified on profile descriptions using the new standard South African national soil classification system (as developed from earlier classifications systems, e.g. Orchard, 1969). This is essentially a two-category system. Soil forms are recognised and subdivided into series on the basis of defined diagnostic horizons. "The diagnostic horizons and the
particular combinations in which they occur have distinct genetic meaning and reflect factors and processes of formation" (Neethling, 1970). Certain variations within a series are acceptable, but a series may be subdivided into phases, when one or more of these variations are stressed.

The criteria used are: diagnostic topsoil horizons, which include organic O, black vertic Al, melanic Al, humic Al and orthic Al horizons; diagnostic subsoil horizons, such as gleyed, uniformly chromatic, plinthic and cutanic horizons, and diagnostic materials such as regic sands and young stratified alluvia.

The diagnostic horizons and materials present in the soils at Jakkalsrivier are defined below.

Organic O: horizon has sufficient organic carbon to ensure an average content of at least 10% throughout a vertical distance of 30 cm, or in a shallow profile overlying rock.

Orthic Al: horizon does not qualify as an organic, vertic, melanic or humic topsoil horizon although it has been darkened by organic matter.

Red apedal B2: a uniformly chromatic subsoil horizon, with hue 5 YR, values 3 - 4 and chroma 4 - 6, which is apedal and occurs directly below a diagnostic topsoil horizon.

Yellow-brown apedal B2: a uniformly chromatic subsoil horizon with hue 7.5 YR, a value of 4 and chroma of 4, or a value of 5 or more with a chroma of 8, which is apedal and which occurs directly below a diagnostic topsoil horizon.

Perched gley P: a horizon directly below a diagnostic topsoil horizon, with grey matrix colours, mottles and underlain by hard rock.
Young stratified alluvium: unconsolidated material containing fine stratifications of alluvia which occurs directly below a diagnostic topsoil horizon.

The soil types distinguished are described below (subdivision in series was not always possible as data were inadequate).

i. DUNDEE FORM:

The soil consists of an orthic A horizon on young stratified alluvium. It occurs on most drainage channels where relatively thick layers of sandstone and shale alluvium have accumulated.

ii. HUTTON FORM:

The soil consists of an orthic A on a red apedal B horizon on saprolite or hard rock. The type is limited to the shale band and shale-derived talus on the slopes below upper isolated shale lenses.

iii. CLOVELLY FORM:

The soil consists of an orthic A on a yellow-brown apedal B on saprolite or hard rock. It is rare and occurs in association with the Huttons.

iv. CARTREF FORM:

The soil comprises an orthic A on a perched gley P on saprolite or hard rock. The type occurs on relatively gentle slopes on necks in the catchment area. It is restricted to sandstone and sandstone talus and is extensive in Jakkalsrivier.

v. MISPAH FORM:

The soil consists of an orthic A on hard rock. This is the most common soil type and occurs on sandstone on all the steep slopes where material removal is rapid. On cool slopes much humus has accumulated and the A horizon is turfy.
vi. MISPAH-CARTREF INTERPHASE:

This has characteristics of forms iv & v and occurs on lower slopes as a transition from the Mispah to Cartref and in pockets of deeper soil on the steep Mispah slopes.

vii. CHAMPAGNE FORM:

The soil comprises an organic O on hard rock. The type is restricted to very wet sites where drainage is impeded by impenetrable sandstone layers.

viii. ROCKY LAND-CLASS:

On much of the area sandstone outcrops are so abundant that soils are patchy and restricted to hollows among the rocks. Many of the hot moderately steep north-east and west slopes fall in this category.

This is a tentative classification, based on few data. There is evidence that turfy Mispahs on the steep upper slopes with southerly aspects should be classified as Champagne forms as they contain a great deal of organic carbon. A humic phase of the Mispah form may also be recognised, and soils of the Fernwood form could be present on the necks.

1.4.2. SOIL CHEMISTRY

Samples for chemical analysis were obtained from subjectively located points distributed to represent the crest, midslope and footslope elements of the landscape. The data are to indicate soil conditions and statistically valid measures are not required.

Soil cores were obtained by augering at 43 points selected as described above.
Material was collected from the upper 7.5 cm of soil and from 7.5 cm to 20 cm depth where possible.

Raw soil samples were used to determine pH and resistance electrometrically in saturated soil-water pastes. Samples were then leached in a NH₄Ac solution, and the following chemical characteristics were determined:

i. Percentage content of oxidizable organic carbon, C% (W alkely-Black)

ii. cation exchange capacity, CEC (modified Metson)

iii. total exchangeable cations, S (Ca and Mg by Jackson's methods, Na and K by flame photometry).

Variation in these characteristics as measured in the top horizon was examined in some detail.

Soil acidity is the least variable of the factors measured, with pH ranging from 3.5 to 5.0, averaging 4.07, with standard deviation 0.33. Soil resistance is high, ranging from about 1200 ohms to 8000 ohms but most values lie between 1500 and 4000 ohms.

Organic carbon content, CEC and S are highly variable, ranging from a trace to 16.4% (mean 6.82, standard deviation 4.25), from 0.5 to 44.0 me/100gm (mean 14.32, standard deviation 8.92), and from 0.2 to 7.9 me/100gm (mean 2.94, standard deviation 2.04), respectively.

Except in Hutton and Clovelly soils, clay content is seldom more than 5%. It is clear that the ratio of S (in me per 100 gm) to each 1% clay content is very low, and soils may be described as dystrophic.
The interrelation between soil chemical factors (excluding resistance) and some topographic factors was examined by means of step-wise multiple regression, using the University of California Fortran programme BMD O2R (Dixon, 1968).

The correlation matrix is presented in Table 2.

<table>
<thead>
<tr>
<th>Variable</th>
<th>pH</th>
<th>C%</th>
<th>CEC</th>
<th>S</th>
<th>Altitude</th>
<th>Aspect</th>
<th>Slope</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>1,00</td>
<td>-0,077</td>
<td>-0,102</td>
<td>0,285</td>
<td>-0,044</td>
<td>0,000</td>
<td>0,055</td>
</tr>
<tr>
<td>C(%)</td>
<td>1,00</td>
<td>0,890</td>
<td>0,766</td>
<td>0,358</td>
<td>0,190</td>
<td>0,391</td>
<td></td>
</tr>
<tr>
<td>CEC</td>
<td>1,00</td>
<td>0,774</td>
<td>0,378</td>
<td>0,017</td>
<td>0,239</td>
<td>0,330</td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>1,00</td>
<td>0,197</td>
<td>0,050</td>
<td>0,294</td>
<td>0,050</td>
<td>0,294</td>
<td></td>
</tr>
<tr>
<td>Altitude</td>
<td>1,00</td>
<td>0,262</td>
<td>0,305</td>
<td>1,00</td>
<td>0,484</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aspect</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slope</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

This exercise did not reveal marked topographic gradients in soil chemical factors. The moderate positive correlations between altitude, slope and aspect with organic carbon content, CEC and, to a lesser extent, with exchangeable cations, reflects the general phenomenon of high humus content in soils in the upper steep south-facing slopes. This is most probably obscured by the presence of Champagne and humic Mispah soils on moist and wet sites scattered throughout the catchment. Only 20% of the variation in C% is accounted for by altitude and slope (C% = -4,142 + 0,003 (Altitude) + 0,074 (Slope), multiple R = 0,46, SE = 3,86).

The high correlation between organic carbon content and CEC and S is natural in these poor, highly leached soils.

Seventy-nine percent of the variation in CEC is associated
with variation in C%, and 70% of S variation is accounted for by variation in C% and pH (59% by the former). The appropriate relations are as follows:

\[
\begin{align*}
\text{CEC} &= 1,580 + 1,870 (C\%), \ r = 0,89 \\
S &= 0,434 + 0,368 (C\%), \ r = 0,77 \\
S &= -8,423 + 2,152 (\text{pH}) + 0,381 (C\%), \ R = 0,84
\end{align*}
\]

In this catchment fertility therefore depends largely on the amount of plant remains in the soil, though this is probably not entirely true for the Hutton and Clovelly soils.
2.1. REGIONAL CLIMATE

According to published maps, the Jakkalsrivier research area falls within Weather Bureau climatic region M, rather close to region A (Schulze, 1965), or within the Köppen Zone Csb (Swart, 1956). Plathe and Van der Zel (1969) describe the climate as Mediterranean or Etesian, and closest to Köppen's Erica-climate (Csb), but suggest that it tends towards the Cfb type (i.e. rain through the year); they indicate further that it is humid-meso-thermic, according to Thornthwaite (1931) and Walter (1962). The following description of the regional climate of the South-Western Cape Province is based chiefly on the report by Schulze (1965).

In the Western Cape, Weather Bureau region M lies within latitudes which are markedly affected by atmospheric circulation patterns. The sub-tropical high-pressure belt straddles the zone in summer, but moves three to four degrees north in winter, when the region is influenced by the mid-latitude westerlies.

The average total solar radiation is about 450 - 500 cal. cm\(^{-2}\) day\(^{-1}\) (700 - 750 cal. cm\(^{-2}\) day\(^{-1}\) in December, 200 - 250 cal. cm\(^{-2}\) day\(^{-1}\) in June) which is about 60 - 70% of the solar radiation rate at the top of the atmosphere. The average annual duration of bright sunshine amounts to 60 - 70% of the possible (i.e. about 6 - 8 hours per day). Maximum cloud cover occurs in the winter half-year, but peak values occur in spring and autumn. The zone is enclosed chiefly by the real isotherms of 15°C and
17.5°C, though the equivalent isotherms, with values adjusted to mean sea-level temperatures, are about 16°C and 18°C respectively. The mean annual temperature may be up to 2°C higher than the expected mean sea-level temperature for these latitudes. Maximum screen temperatures occur in January (mean 20.0 - 22.5°C) and minima in July (10.0 - 12.5°C).

The annual range in mean monthly temperature in region M is relatively low, about 7.5 - 10.0°C. Absolute maxima reach 40°C or slightly higher, but absolute minima are generally not much below freezing point. On the average, 5 - 10 days per year have maximum temperatures exceeding 35°C, and frost days are rare (fewer than 5 days per year) except in montane areas.

The annual mean relative humidity at 1400 hours is about 60 - 70%, 40 - 60% in January and 60 - 80% in July. The annual mean vapour pressure at the same hour is about 14 - 16 mb., 14 - 18 in January and 10 - 12 in July, while annual mean vapour pressures are around 10 mb. (10 - 15 mb. in January and 5 - 10 in July).

Average annual evaporation, measured in a Symons tank, is about 1250 - 1500 mm, and that measured in class A pans ranges from 1750 - 2250 mm.

Precipitation is mainly in the form of rain; snowfalls are restricted to mountain peaks, generally above the 1000 m contour, and occur about 5 times a year, while hail falls about as frequently. With a Mediterranean-type climate, most rain falls in winter (i.e. by definition, more than 60% of rain falls in the winter...
months April to September). Jakkalsrivier falls in Weather Bureau rainfall district four, which receives on the average 67% of its rain in winter - less than in the case of the other winter rainfall districts.

Rain occurs chiefly during the passage of frontal depressions which accompany anticyclones moving over the land from the west. There is a pronounced orographic effect. Schulze (1965) calculated a rainfall gradient of 50 mm per 300 m increase in altitude (on an average annual basis), though Wicht et al (1969) showed that local factors can have an influence. In the mountains precipitation generally varies from 1000 mm to 2000 mm per annum, and may frequently exceed 3000 mm.

Summer is characterized by rather strong persistent winds from the south, especially south-east. North-west winds predominate in winter but are intermittent and southerly winds are quite frequent.

2.2. ANALYSIS AND DESCRIPTION OF LOCAL CLIMATE

Meteorological data are available from two stations within the catchment. The main station is situated at the mouth of the valley at an altitude of 655 m (2150 feet), and a subsidiary is placed more or less in the centre of the basin at about 870 m (2810 feet).

The following instruments are used to measure climatic variables at the main station:
### Instruments

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Variable measured</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 Gunn-Bellani radiometers (standard pattern; distilled water)</td>
<td>Daily total hemispherical solar radiation: total incoming and reflected radiation</td>
</tr>
<tr>
<td>1 Campbell-Stokes pattern sunshine recorder</td>
<td>Daily duration of bright sunshine</td>
</tr>
<tr>
<td>1 Symon's tank</td>
<td>Daily values of open water evaporation</td>
</tr>
<tr>
<td>1 Casella recording raingauge (128.5mm orifice, elevated 1.2 m above ground)</td>
<td>Daily records of depth, intensity and duration of rain</td>
</tr>
<tr>
<td>1 Snowdon raingauge, with Nipher shield (127 mm orifice, elevated 1.2 m above ground)</td>
<td>Daily rainfall totals</td>
</tr>
<tr>
<td>In Stevenson screens:</td>
<td></td>
</tr>
<tr>
<td>3 Mercury in glass thermometers</td>
<td>Daily maximum air temperature; wet and dry bulb temperatures</td>
</tr>
<tr>
<td>1 Alcohol in glass thermometer</td>
<td>Daily minimum air temperature</td>
</tr>
<tr>
<td>2 Piché evaporimeters</td>
<td>Daily index of the drying power of the air</td>
</tr>
<tr>
<td>1 Thermohydrograph (mercury in steel)</td>
<td>Continuous record of wet and dry bulb temperatures</td>
</tr>
<tr>
<td>1 Barograph</td>
<td>Continuous record of atmospheric pressure</td>
</tr>
<tr>
<td>1 Thermograph (mercury in steel)</td>
<td>Continuous record of soil temperatures at 20 and 30 cm depths</td>
</tr>
<tr>
<td>2 Piché evaporimeters</td>
<td>Daily index of vapour losses</td>
</tr>
<tr>
<td>1 Snowdon raingauge, unshielded (127 mm orifice, elevated 22.9 cm above ground)</td>
<td>Daily rainfall totals, for correction of Symon's tank readings</td>
</tr>
</tbody>
</table>

The meterological station has been established according to the South African Weather Bureau standards. It is situated on a slight slope (c 10%) which has been levelled and grassed. Aspect is south. The station is visited daily at 0800 hours.

The following instruments are used at the subsidiary station:
### Instruments

<table>
<thead>
<tr>
<th>In Stevenson screen:</th>
<th>Variable measured</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 Mercury in glass thermometers</td>
<td>Maximum and wet and dry bulb temperatures: check on thermohygrograph</td>
</tr>
<tr>
<td>1 Alcohol in glass thermometer</td>
<td>Minimum temperature: check on thermohygrograph</td>
</tr>
<tr>
<td>1 Thermohygrograph (bimetal thermometer and hair hygrometer)</td>
<td>Continuous weekly records of temperature and relative humidity</td>
</tr>
<tr>
<td>1 Class A pan, with water level recorder</td>
<td>Continuous weekly records of open water evaporation</td>
</tr>
<tr>
<td>1 Casella recording raingauge (128.5mm orifice, elevated 1.2 m above ground.)</td>
<td>Continuous weekly records of rainfall amount, duration and intensity</td>
</tr>
<tr>
<td>1 Snowdon raingauge, with mist precipitator (127 mm orifice elevated 1.2 m above ground)</td>
<td>Index of mist precipitation</td>
</tr>
</tbody>
</table>

This station, situated on a break in the slope and inclined about 20% to the south-west, is visited weekly except when mist occurs. Readings are taken at about 0900 hours.

There is in addition a network of six Snowdon raingauges distributed about the catchment. Each is equipped with a Nipher screen and is installed normal to the average slope at the gauging point (i.e. with the plane of the orifice parallel with the slope) and with the orifice elevated 1.2 m above ground level. These gauges are emptied weekly.

This network and the positions of stream-gauging points are shown on Fig. 2.

Climatic analysis is based on data from this meteorological network.
In the interest of increased sensitivity, and to facilitate statistical treatment (see Slatyer, 1960), pentades and fortnights should be used as units of time. As far as possible, the conventional "hydrological year" for the Western Cape has been used for data presentation. This year begins on April 1st with the 19th pentade. It is however logical to subdivide the year on the basis of the progress of the sun from winter to summer solstice, and the seasons thus defined are as follows:

<table>
<thead>
<tr>
<th>Season</th>
<th>Pentade numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spring</td>
<td>45 - 62</td>
</tr>
<tr>
<td>Summer</td>
<td>63 - 7</td>
</tr>
<tr>
<td>Autumn</td>
<td>8 - 25</td>
</tr>
<tr>
<td>Winter</td>
<td>26 - 44</td>
</tr>
<tr>
<td>Winter half-year</td>
<td>17 - 53</td>
</tr>
<tr>
<td>Summer half-year</td>
<td>54 - 16</td>
</tr>
</tbody>
</table>

(In this subdivision, the winter quarter of half-year includes one extra pentade).

Where pentades are used, the year will begin with the 17th pentade (March 22nd). Where fortnights are used, Slatyer's (1969) convention will be followed, with the year beginning at the start of the 7th fortnight (March 26th).

However, it has not always been feasible to follow this system: in such cases, monthly values have been used, adjusted to a 30-day month.

2.2.1. SOLAR RADIATION, SUNSHINE AND DAY LENGTH

(a) METHODS

The Gunn-Bellani radiometers are used to estimate total in-
coming solar radiation, but these instruments have not yet been calibrated. Correlation between solar radiation measurements and sunshine duration records at a nearby station (say, Elgin Experimental Farm) could possibly be used to derive estimates for this site. Walter (1969) has shown that solar radiation may be correlated with the integral of the periodic mean diurnal air temperature curve.

The solar climate has, however, been derived from sunshine duration records and estimates of relative insolation.

Sunshine duration records for four years are available (from February 1968). These have been used to illustrate the annual march of average daily sunshine. These results were compared with the maximum possible at the main meteorological station and with that at the subsidiary. Published tables were used to derive the necessary figures for a free horizon.

A graphical technique was used to measure loss of sunshine due to the mountain skyline, as illustrated in Geiger (1959: 526). The elevation of the skyline at all points of the compass, as seen from both stations, was measured by means of a theodolite. The horizon was then graphically represented as a circle of given radius, whose centre represented the zenith. This radius represents an angular elevation of 90°. The mountain skyline is depicted by converting the angular elevation of given points to the appropriate linear scale (if the radius of the circle = r, then 1° = r/90 linear units) and plotting them on the diagram, on the appropriate bearings. The path of the sun on various dates is projected on this circle, using data on the bearing and elevation of the sun at sunrise, sunset and noon. These projections
may be used to determine the elevation of the sun at the skyline on given dates (see fig. 4).

The time at which the sun reaches these elevation on the given date, may be derived from a nomogram published by Roelofs (1950), given the latitude of the site and the declination of the sun on this date. The possible loss of sunshine hours due to the skyline was determined in this way.

Dates chosen for measurement were those when the sun had the same declination in the equinoctial halves of the year (see Frank et al, 1966). Declinations of the sun on those dates were obtained from the Smithsonian Tables (List, 1966). Times are given as Local Apparent Time.

No provision was made for differences in elevation between the two stations, as errors are insignificant at this latitude (Lee, 1963: 24).

Further information on the solar climate of the area may be derived from relative insolation of different land facets with given slope and aspect, using methods and tables described by Lee (1963) and Frank et al (1966).

"Solar radiation values computed from the solar constant, an atmospheric attenuation constant (turbidity factor), and the geometry of a site with respect to the sun's rays, provide remarkably good long-term means" (Frank et al, 1966). These workers
derived a theoretical parameter, the 'potential solar beam irradiation', by ignoring the atmospheric turbidity factor and using fairly straightforward equations to calculate the amount of radiation received by a surface of any slope or orientation at any latitude, for a given instant or period. Radiation intensity is proportional to the cosine of the angle of incidence of the sun's rays, and this may be derived from the well-known earth-sun relationships. Frank et al (1966) published tables which list total potential insolation on different latitudes in the northern hemisphere. Also listed are radiation indices, defined as the ratios '.... of the total annual potential insolation to the maximum potential insolation at the site.' These tables are easily adapted for the southern hemisphere.

Slope and aspect figures obtained from the topographic analysis were used to calculate radiation indices and to map the radiation climate of the catchment. The effect of topographic shading was ignored.

b. RESULTS

The projected mountain skylines at the main station and the subsidiary appear in fig. 4. Fig. 5 shows the annual march of sunrise and sunset times for the free horizon, and for the actual skyline. The annual march of day length, maximum daily sunshine duration and actual average sunshine duration at the main station are depicted in Fig. 6.
Fig. 4. A. Projection of the skyline observed at the Main meteorological station.

B. The skyline at the subsidiary station.

Arrows indicate the projected course of the sun at the equinoxes and solstices.

Because of the catchment's latitude of 34°09' S and the observed horizon, sunrise time varies from 0453 hrs to 0708 hrs and sunset from 1907 to 1652 hrs; day-length varies from 9.74 hours to 14.24 hours. The maximum possible midwinter sunshine duration is 5.95 hours, midsummer duration is 12.80 hours, and annual average 9.34 hours per day. Annual average actual sunshine duration is 5.53 hours per day, 45.4 per cent of the mean day-length and 59.0 per cent of the average maximum duration, as calculated. Mean winter, summer, spring and autumn daily durations are 3.74 - 7.48 - 5.28 and 5.64 hours (i.e. 37.3 - 53.5 - 44.0 and 47.0 percent of the day length, and 59.4 - 59.8 - 56.2 and 60.0 per cent of maximum sunshine duration, respectively).
Fig. 5. Sunrise and sunset times

The solar climate at the subsidiary station is not markedly different from that at the lower. Annual mean maximum sunshine duration at the main station is 78.2% of the mean day length, and 75.3% in the former at the subsidiary (i.e. 9.09 hrs per day). In winter somewhat more sunshine is lost because of topography at the main station than at the other, while the situation in summer is the reverse. However, more sunshine hours are lost in the morning at the subsidiary than at the main station (an annual average of 2.19 hours as opposed to 1.61 hours), due to peculiarities in topography, shown in fig. 4. This similarity is, however, obscured by a greater frequency of cloud cover at the upper station (of which, unfortunately, there is no record).

Zones of equal insolation (radiation index), as mapped, are shown in fig. 7. The catchment has an average slope of 46%, and average aspect is south (mean slope azimuth = 186.80), so that
the radiation index for the entire catchment is 35%.

Fig. 6. Day length and sunshine duration at the main meteorological station. (Points represent observed three-pentade means).

If we use a solar constant of 2,00 gm cal/cm²/mm, total annual incoming solar radiation at this latitude on a horizontal surface, without attenuation by the atmosphere, is very nearly 271 525 gm cal cm⁻² (743 per day) that is, about 52% of the solar radiation received by a surface normal to the sun's rays, at the mean distance from the earth to the sun. Total annual potential insolation on the catchment is therefore about 183 960 gm cal cm⁻² (504 per day) and varies from about 130 000 gm cal cm⁻² to 300 000 gm cal cm⁻² on different slope facets.
Fig. 7. Insolation map of Jakkalsrivier catchment, with choropleths of equal relative insolation, expressed as a percentage.

If a linear relationship between annual mean sunshine duration and total solar radiation on the ground is assumed, a horizontal surface at Jakkalsrivier would receive about 116 000 gm cal cm$^{-2}$ year$^{-1}$, while the catchment would receive, on the average, about 77 700 gm cal cm$^{-2}$ year$^{-1}$ (based on figures for
Cape Town - Wingfield - which receives about 173 400 gm cal cm$^{-2}$ year$^{-1}$, with annual mean sunshine duration of 8.2 hours - Schulze, 1965). These figures are approximate, and probably underestimated, as loss of direct radiation because of cloud cover is likely to be compensated to a greater extent by diffuse radiation from clouds.

The annual march of potential insolation (daily rates) on the catchment is shown in fig. 8. The extreme variation in seasonal values is remarkable.

Fig. 8. Daily potential insolation at Jakkalsrivier. The lower curve represents insolation on a surface with 46% slope and a south aspect.
Scrubutiny of published tables reveals that seasonal variation in potential insolation on slopes with a northerly aspect is much less. A north slope with 30% inclination, for example, has a minimum potential insolation of 650 gm cal cm$^{-2}$ day$^{-1}$ in mid-winter and maximum of 950 in midsummer.

2.2.2. PRECIPITATION

Precipitation in this catchment is clearly influenced by its location high on a mountain mass. Average annual rainfall is about 35% higher than that recorded at the Lebanon State Forest offices, 6 km SE at 245 m elevation. However, the orographic influence is not as strong as might be expected, because mean annual rainfall measured at the Elgin State Forest offices, 10.5 km to the west and at 270 m elevation, is a little higher (1053 mm compared with 956.5 mm) than that measured at Jakkalsrivier.

Rainfall is the predominant type of precipitation, and occurs chiefly in winter as cyclonic rains with a strong orographic component (i.e. of the type described by Barry & Chorley, 1968: 93), and in summer as orographic precipitation associated with easterly trade winds. Table 3 summarises the available rainfall totals (mean rainfall for the catchment was calculated using Thiessen weights). Mean rainfall at the Lebanon office during 1967 - 1971 was close to the 47-year mean of 654 mm, and the mean of about 960 mm for the catchment should approximate the long-term mean closely. Brook and Mametse (1970) have shown that this part of the Cape has experienced a positive rainfall trend during the past 70 years, amounting to an average increase of 126 mm. They also confirmed the existence of short-term trends.
direction of future trends cannot be predicted. For these reasons, the rainfall during the initial stages of this experiment cannot be accepted as being indicative of that of even the near future.

There is an obvious but inconsistent relation between total rainfall and elevation. The gradient between the office and Snowdon A (at the main catchment meteorological station) amounts to some 50 mm per 100 m altitude increase. This is about equal to that indicated by the mean rainfall records for gauges A and 2 - 5 (see table 3). On the other hand, the rainfall recorded at the highest station (Snowdon 6) is close to the median for the set of gauges. Gauges B (at the subsidiary meteorological station), 1, and 3 lie at the same altitude, yet the mean rainfall differs by as much as 140 mm, and this despite gauges B and 3 being a mere 300 m apart. This could be due to observer and instrument errors, but some of the difference (at least between gauges 1 and 3 - gauge B is a weekly recorder without Nipher shield) must be real. In addition, the ratio between catches recorded by different gauges varies, not only between storms, but also with years. The altitudinal gradient is therefore strongly obscured by other topographic influences and by variables associated with different storms.

Mean monthly rainfall for Snowdon gauge A is shown in fig. 10. The brief period of record produces a rather irregular distribution, but the peak rainfall period is June to August, with a suggestion of a minor peak in January and February, following the December low. Thirty-five per cent of the annual fall occurs
<table>
<thead>
<tr>
<th>Raingauge</th>
<th>Elev (m)</th>
<th>Rainfall</th>
<th></th>
<th></th>
<th></th>
<th>Three-year mean</th>
<th>Five-year mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Snowdon 1</td>
<td>853</td>
<td>956,8</td>
<td>881,5</td>
<td>754,5</td>
<td>787,4</td>
<td>986,9</td>
<td>842,9</td>
</tr>
<tr>
<td>2</td>
<td>795</td>
<td>1028,7</td>
<td>967,3</td>
<td>820,2</td>
<td>867,9</td>
<td>1046,6</td>
<td>911,6</td>
</tr>
<tr>
<td>3</td>
<td>853</td>
<td>1096,3</td>
<td>1059,7</td>
<td>878,7</td>
<td>911,2</td>
<td>1090,2</td>
<td>960,0</td>
</tr>
<tr>
<td>4</td>
<td>954</td>
<td>1074,6</td>
<td>1046,1</td>
<td>898,7</td>
<td>900,8</td>
<td>1099,7</td>
<td>966,4</td>
</tr>
<tr>
<td>5</td>
<td>780</td>
<td>1019,2</td>
<td>974,6</td>
<td>841,8</td>
<td>884,4</td>
<td>1047,3</td>
<td>924,5</td>
</tr>
<tr>
<td>6</td>
<td>1076</td>
<td>-</td>
<td>-</td>
<td>854,8</td>
<td>886,0</td>
<td>970,7</td>
<td>903,8</td>
</tr>
<tr>
<td>Snowdon A</td>
<td>666</td>
<td>935,4</td>
<td>863,2</td>
<td>718,2</td>
<td>802,5</td>
<td>980,0</td>
<td>833,6</td>
</tr>
<tr>
<td>Casella B</td>
<td>853</td>
<td>-</td>
<td>873,3</td>
<td>767,7</td>
<td>734,0</td>
<td>951,6</td>
<td>817,8</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>1037,4</td>
<td>987,1</td>
<td>814,8</td>
<td>842,3</td>
<td>1021,9</td>
<td>893,0</td>
</tr>
</tbody>
</table>

TABLE 3: RECORDS OF TOTAL ANNUAL RAINFALL
in summer (as opposed to 26% and 27% at Elgin and Lebanon respectively) and the catchment therefore experiences a winter rainfall climate as defined by the Weather Bureau while the relatively high proportion of summer rain places it in rainfall district 4 (Anon, 1949).

Rainfall intensities at Jakkalsrivier appear to be very low, but reliable rainfall records from a Casella gauge with daily clock at the main meteorological station (Casella A) are available only for the 3 years 1969/70 to 1971/72 and this period is too short for a good frequency analysis of rainfall. The short return period rains (36 months and less) are interesting. The maximum intensity for each rain during the period 1969 to 1971/72 was determined by inspection. Total catch and duration for all rains were also recorded. Rains usually consist of a succession of showers, however, and the Casella recorder is insensitive at very low intensities so that the start and end of rainstorms are often obscure. Therefore, successive showers separated by a period of six hours during which no precipitation was recorded on the chart were distinguished as individual storms. Return periods for storms of different maximum intensities (for 15- and 60-minute intervals) are illustrated in fig. 9. High-intensity storms are rare; slightly more than 50% of the storms recorded had maximum intensities less than 4 mm per hour and 90% had maximum 15-minute intensities of 12 mm per hour and less. Half the rain that fell during the three years came from storms with maximum 15-minute intensities of about 10 mm per hour and less. Over half (56%) of the storms had a depth of less than 5 mm; about half the total
rain fell as storms of depths less than 15 mm. Storms frequently endure for more than 12 hours (the longest persisted for about 54 hours); 22.8% lasted for more than 12 hours, and provided just over half the total rainfall.

Further information on rainfall intensity, depth and duration is presented in table 4.

Precipitation as mist or fog is a major but indefinable component of the water balance. In winter, during passage of anticyclones, part or all of the catchment projects into the cloud zone. Orographic cloud associated with the south-east trades in summer often does not produce rain, but mist precipi-
## Table 4: Rainfall Jaakkalsrivier, Gauge A. Intensity/Depth/Duration Analysis.

### Max I<sub>15</sub> mm/hr

<table>
<thead>
<tr>
<th>Duration (Hrs)</th>
<th>0-6</th>
<th>6-12</th>
<th>12-18</th>
<th>18-24</th>
<th>24-30</th>
<th>30-36</th>
<th>36-42</th>
<th>42-48</th>
<th>48-54</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 3.9</td>
<td>116</td>
<td>23</td>
<td>13</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>156</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.0 - 7.9</td>
<td>33</td>
<td>17</td>
<td>9</td>
<td>6</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>71</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.0 - 11.9</td>
<td>12</td>
<td>12</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>0</td>
<td>39</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12.0 - 15.9</td>
<td>5</td>
<td>5</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>0</td>
<td>1</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16.0 - 19.9</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20.0 - 23.9</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24.0 - 27.9</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>168</td>
<td>58</td>
<td>29</td>
<td>15</td>
<td>11</td>
<td>7</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>293</td>
</tr>
</tbody>
</table>

### Max I<sub>15</sub> mm/hr

<table>
<thead>
<tr>
<th>Depth</th>
<th>0-5</th>
<th>5-10</th>
<th>10-15</th>
<th>15-20</th>
<th>20-25</th>
<th>25-30</th>
<th>30-35</th>
<th>35-40</th>
<th>40-45</th>
<th>45-50</th>
<th>50-55</th>
<th>55-60</th>
<th>60-65</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 3.9</td>
<td>144</td>
<td>12</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>159</td>
</tr>
<tr>
<td>4.0 - 7.9</td>
<td>27</td>
<td>20</td>
<td>15</td>
<td>5</td>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td>71</td>
</tr>
<tr>
<td>8.0 - 11.9</td>
<td>4</td>
<td>11</td>
<td>11</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td>39</td>
</tr>
<tr>
<td>12.0 - 15.9</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
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<td></td>
<td></td>
<td>20</td>
</tr>
<tr>
<td>16.0 - 19.9</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>20.0 - 23.9</td>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>24.0 - 27.9</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>176</td>
<td>45</td>
<td>34</td>
<td>14</td>
<td>4</td>
<td>10</td>
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<td>3</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>296</td>
</tr>
</tbody>
</table>

### Depth

<table>
<thead>
<tr>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-1</td>
</tr>
<tr>
<td>0 - 5</td>
</tr>
<tr>
<td>5 -10</td>
</tr>
<tr>
<td>10 -15</td>
</tr>
<tr>
<td>15 -20</td>
</tr>
<tr>
<td>20 -25</td>
</tr>
<tr>
<td>25 -30</td>
</tr>
<tr>
<td>30 -35</td>
</tr>
<tr>
<td>35 -40</td>
</tr>
<tr>
<td>40 -45</td>
</tr>
<tr>
<td>45 -50</td>
</tr>
<tr>
<td>50 -55</td>
</tr>
<tr>
<td>55 -60</td>
</tr>
<tr>
<td>60 -65</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>
A Grunow fog gauge, which consists of a gauze cylinder with surface area equal to that of the orifice of the raingauge, i.e. 127 cm$^2$, (Nagel, 1955), was mounted on a Snowdon raingauge in 1968 (and later on a Casella recording gauge) at the subsidiary meteorological station. Nagel (1962) derived an empiric formula to calculate quantities of mist precipitation from rainfall, fog catch and wind-run data, but such an analysis has not been attempted because there is no wind recorder at the subsidiary station. Nevertheless, certain interesting features are revealed by the records. Mist precipitation in the absence of rainfall occurred on about 20 - 36 days per year, and 70 - 75% of such events occurred in summer. About 50 - 60 raindays were recorded in summer; the record of days with precipitation in this season is increased by about 30 - 50% by the addition of days with mist precipitation. Furthermore, 40 - 50% of the total catch, i.e. precipitated mist, intercepted rain and direct rain, is recorded in summer. Also, mist precipitation relative to rainfall is higher in summer than in winter. Regressions of mist on rain data in the winter and the summer of 1971/72 were compared, and the difference between co-efficients proved highly significant ($t = 3.96$ with 149 degrees of freedom; constants in the equation $y = a + bx$, where $y =$ mist catch and $x =$ rainfall, are 3.80 and 1.47 and 2.43 and 2.11 for winter and summer respectively). Clearly, mist precipitation plays a strong role in reducing moisture stress in summer.

Of the other forms of precipitation, snow is probably most
important. Falls occurred once or twice a year, four times in 1969/70. Snow accumulates at elevations down to 850 m, such falls being recorded on 16.8.67, 18.7.71 and 31.7.72. The falls may persist on the ground for 12 - 48 hours, but not longer.

Dew is generally prevented by air drainage, and occurs rarely, about two to four times per year, as does frost.

2.2.3 TEMPERATURE

Continuous records could not be used in this analysis because, frequently, clocks stopped and ink dried up. In addition, no suitable programme for processing digital records extracted automatically from analogue temperature charts was available. The analysis is therefore based largely on maximum temperatures recorded with conventional thermometers.

The main features of the air temperature regime at the main meteorological station are shown in fig. 10 (data are for the period 1968/69 to 1971/72). Fig. 10 A is a Deasy-diagram prepared in the standard manner (Deasy, 1941). Short-period fluctuations are probably mainly the result of the few years of record, but the general trend probably reflects annual fluctuations adequately.

Some indicative figures derived from these data are presented in table 5. ET and \( T_d \) are derived from Bailey's formulae (Stucken-berg, 1969). Effective temperature, in degrees Celsius, is derived as follows:

\[ \text{Effective Temperature (ET)} = \frac{T + T_d}{2} \]
ET = \( \frac{(8T + 14AR)}{(AR + 8)} \),

where \( T \) = mean annual temperature
and \( AR \) = mean annual range of temperature

\( T_d \) is the duration of time in a year in which mean temperatures are warmer than \( ET \), that is, a measure of the duration of the warm season, and is derived as follows:

\[ T_d = 182,600 + 2,032 \times \sin x \]

where \( \sin x = \frac{(ET - 14)}{4} \)

The length of the thermal summer (see Schultze, 1965) is the duration of the period when mean temperature exceeds the temperature halfway between that of the coldest period, and that of the warmest.

Values for the subsidiary station were estimated from regression.

The short record does not warrant a detailed analysis of the thermal climate at Jakkalsrivier, but broad conclusions are possible.

Screen temperatures are considerably lower than those generally recorded in climatic region M. Grabouw, known as an area with a mild climate, is warmer than Jakkalsrivier (data for Grabouw are from the Elgin Experimental Farm - see Anon, 1972). Jonkershoek experiences a thermal climate of a different class.
Fig. 10  Climatic diagrams, Jakkalsrivier

A. Deasy diagram  B. Walter diagram  C. Thornthwaite's annual moisture budget: precipitation and potential evapotranspiration. Vertical hatching indicates the period of moisture surplus, preceded by the period of soil moisture repletion, and succeeded by that of depletion (transverse hatching); the stippled area indicates the period of soil moisture deficit.
TABLE 5: TEMPERATURE DATA FROM JAKKALSRIVIER AND OTHER STATIONS IN THE WESTERN CAPE

<table>
<thead>
<tr>
<th>Station</th>
<th>Jakkalsriver (main)</th>
<th>Jakkalsrivier (subsidiary)</th>
<th>Grabouw (Elgin)</th>
<th>Jonkershoek (Manor House)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>34°09'S, 19°09'E</td>
<td>34°08'S, 19°02'E</td>
<td>33°58'S, 18°57'E</td>
<td></td>
</tr>
<tr>
<td>Altitude (m)</td>
<td>655</td>
<td>870</td>
<td>305</td>
<td>244</td>
</tr>
<tr>
<td>Years of record</td>
<td>4</td>
<td>8</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Mean temperature</td>
<td>13.6</td>
<td>12.9</td>
<td>15.0</td>
<td>16.1</td>
</tr>
<tr>
<td>Mean, warmest period</td>
<td>18.4</td>
<td>17.5</td>
<td>19.3</td>
<td>21.0</td>
</tr>
<tr>
<td>Mean, coolest period</td>
<td>8.4</td>
<td>7.7</td>
<td>10.4</td>
<td>11.5</td>
</tr>
<tr>
<td>Mean maximum</td>
<td>18.4</td>
<td>17.9</td>
<td>20.9</td>
<td>22.3</td>
</tr>
<tr>
<td>Mean maximum, warmest period</td>
<td>24.2</td>
<td>23.7</td>
<td>25.4</td>
<td>28.1</td>
</tr>
<tr>
<td>Mean maximum, coolest period</td>
<td>12.2</td>
<td>11.6</td>
<td>16.0</td>
<td>16.8</td>
</tr>
<tr>
<td>Mean minimum</td>
<td>8.7</td>
<td>7.9</td>
<td>9.0</td>
<td>9.9</td>
</tr>
<tr>
<td>Mean minimum, warmest period</td>
<td>13.1</td>
<td>12.1</td>
<td>13.3</td>
<td>14.0</td>
</tr>
<tr>
<td>Mean minimum, coolest period</td>
<td>4.3</td>
<td>3.7</td>
<td>4.8</td>
<td>6.1</td>
</tr>
<tr>
<td>ET</td>
<td>13.8</td>
<td>13.5</td>
<td>14.5</td>
<td>15.0</td>
</tr>
<tr>
<td>T_d (days)</td>
<td>176.8</td>
<td>170.7</td>
<td>196.3</td>
<td>215.7</td>
</tr>
<tr>
<td>Length of thermal summer (days)</td>
<td>183.0</td>
<td>-</td>
<td>186.0</td>
<td>181.0</td>
</tr>
</tbody>
</table>
Observations over a longer period may change the picture, but it is nevertheless striking that the lowest temperature recorded is $-1.2^\circ C$ because lower records would be expected in such montane areas.

Tropical days (maxima equal to or exceeding $30^\circ C$) occurred about 8 times annually, mainly during January to March. Summer days, with maxima equal to or exceeding $25^\circ C$, occurred on the average 45 times annually and are most frequent in the same period, but may be expected from September to April. Cold days (maxima equal to or less than $10^\circ C$) are frequent from June to October, and were experienced about 27 times annually. The lowest maximum recorded was $4.4^\circ C$ – an indication of the miserable conditions which prevail during passage of cold fronts in the winter half-year. Frost days (minimum at or below $0^\circ C$) are rare, occurring about once a year.

Temperature records from the subsidiary station are discontinuous and useful averages can therefore not be computed but temperatures differ from those at the main station.

A thermohygrograph was placed in a Stevenson screen at the main station and records obtained for 38 days before the instrument was moved to the subsidiary station. Differences between stations were assessed by examining regressions, details of which are presented in table 6 (statistical significance was not tested as data do not conform to the criteria required for statistical analysis). The second thermohygrograph was moved to the subsidi-
ary station on 20.3.70; relations between temperatures recorded by the two instruments subsequently changed.

As the data from chart recorders are not sufficiently accurate for comparison between stations over a short period the available maximum and minimum thermometer data were used to determine the size of temperature differences. Data from months where records were available for every or nearly every day, were used to construct linear regressions for maximum and for minimum temperatures. These are as follows

\[ y_1 = -0.47 + 0.96x_1 \quad (r = 0.91) \]
\[ y_2 = -0.60 + 1.01x_2 \quad (r = 0.98) \]

where \( y_1 \) = minimum temperature at the subsidiary station
\( x_1 \) = minimum temperature at the main station
\( y_2 \) = maximum temperature at the subsidiary station
\( x_2 \) = maximum temperature at the main station

These relations were used to estimate mean temperatures for the subsidiary station, details of which appear in table 5. Differences between temperatures at the two stations are small. The lapse rate for the mean temperatures is less than the dry-adiabatic lapse rate for the Standard Atmosphere (which, at 0.67°C per 100 m would be 1.44°C for 215 m altitude difference between the stations.)

\[ ^{2.2.4} \text{EVAPORATION} \]

Mean daily Symons Pan evaporation figures for the period 1968/69 are shown in fig. 11. The four-year average is 3.59 mm
### Table 6: Comparison Between Temperatures Recorded on Thermo-Hygrometers at the Main and Subsidiary Meteorological Stations, Jakkalsrivier.

<table>
<thead>
<tr>
<th>PERIOD</th>
<th>DAILY MAXIMUM TEMPERATURES</th>
<th>DAILY MINIMUM TEMPERATURES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean, Main St.</td>
<td>Mean, Subs.</td>
</tr>
<tr>
<td>10 02 70 - 19 03 70</td>
<td>23,0</td>
<td>24,2</td>
</tr>
<tr>
<td>25 03 70 - 01 05 70</td>
<td>19.9</td>
<td>18.7</td>
</tr>
<tr>
<td>10 02 71 - 20 03 71</td>
<td>22.6</td>
<td>21.3</td>
</tr>
</tbody>
</table>

Note: The table shows the comparison between temperatures recorded on thermo-hygrometers at the main and subsidiary meteorological stations. The columns for each period list the mean temperatures, their differences (a), the correlation coefficient (r), and the standard deviation.
per day; maximum evaporation is recorded from December to February (5.85, 6.13 and 5.20 mm per day, for each month) and minima in June, July and August (1.80, 1.67 and 1.86 mm per day, respectively.) Total annual evaporation averages 1310 mm.

Fig. 11 Seasonal variation in daily evaporation rates as measured in a Symons tank.
TABLE 7: REGRESSION AND CORRELATION PARAMETERS FOR EVAPORATION DATA: LINEAR REGRESSION
WITH DAILY EVAPORATION TOTALS FROM SYMONS TANK AS INDEPENDENT VARIABLE.

<table>
<thead>
<tr>
<th></th>
<th>a</th>
<th>b</th>
<th>r</th>
<th>Calculated F Value</th>
<th>Proportion of A-pan variation attributable to variation in Symons tank readings</th>
</tr>
</thead>
<tbody>
<tr>
<td>1969/70</td>
<td>0.41</td>
<td>1.05</td>
<td>0.87</td>
<td>1066.1</td>
<td>75%</td>
</tr>
<tr>
<td>1970/71</td>
<td>0.89</td>
<td>0.88</td>
<td>0.70</td>
<td>349.9</td>
<td>49%</td>
</tr>
<tr>
<td>1971/72</td>
<td>0.74</td>
<td>0.94</td>
<td>0.79</td>
<td>573.2</td>
<td>62%</td>
</tr>
</tbody>
</table>
The ratio between the evaporation from class A pans and Symons tanks varies appreciably from place to place and with seasons (Kriel, 1963; Roberts, 1961). In the south-western Cape the annual pan ratio varies from about 1.30 to 1.35 and from about 1.4 in winter to 1.2 in summer (Kriel, l.c.) Eighteen months' observations from a class A pan, adjacent the Symons tank at Jakkalsrivier, are available; this period is too short for reliable calculation of pan ratios. These varied from 0.97 to 1.64 (averages for each month) with a mean of 1.16, during a full hydrological year.

Using Kriel's ratios to compare the Jakkalsrivier data with the 1965 - 1971 average A-pan evaporation at Elgin Experimental Farm shows that evaporation is somewhat higher at Jakkalsrivier (actual figures at Elgin are 4.1 mm average, with a monthly maximum of 6.8 mm and minimum of 1.9 mm: converted, these are equivalent to 3.2, 5.6 and 1.4 mm per day, respectively).

Linear regressions were fitted to the A-pan and Symons tank data for three successive years. The relevant parameters are presented in table 7.

The relation between data from adjacent tanks is poor (many inconsistencies were apparent in the figures), and the correlation naturally declined after the A-pan was moved to the subsidiary station at the beginning of 1970/71. (Regressions were also applied to daily data from each month: parameters showed even more inconsistent relations between readings from the tanks, before and after the A-pan was moved).
As the relation between readings from the tanks is poor, and the data from the subsidiary station few, the amount of evaporation at the latter station has not been estimated. The regressions indicate that evaporation is lower than at the main station. This was investigated further by examining the relation between pan ratios and mean daily Symons tank evaporation. Curves of the form \( y = ax^b \) were fitted to annual data: parameters are presented in Table 8.

<table>
<thead>
<tr>
<th>Year</th>
<th>a</th>
<th>b</th>
<th>Linear Correlation</th>
<th>Exp. Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1969/70</td>
<td>1.53</td>
<td>-0.20</td>
<td>0.62</td>
<td>0.63</td>
</tr>
<tr>
<td>1970/71</td>
<td>1.93</td>
<td>-0.42</td>
<td>0.78</td>
<td>0.84</td>
</tr>
<tr>
<td>1971/72</td>
<td>1.82</td>
<td>-0.35</td>
<td>0.88</td>
<td>0.92</td>
</tr>
</tbody>
</table>

These data indicate that the ratios when evaporation is low are higher at the subsidiary station than those recorded when the A-pan was adjacent to the Symons tank; conversely, ratios are lower when evaporation rates are high. This suggests that summer evaporation at the subsidiary station is lower than at the main station, and the converse in winter.

2.2.5 SURFACE WIND

Surface wind was measured by means of a cup-and-vane anemometer mounted with the cups 2m above the surface of the ground. The instrument records a trace on waxed chart by means of a spiral...
ridge on a steel drum: the drum is driven through a single revolution during approximately 10 km wind-run (precise wind-run figures are obtained from calibration data). Oscillations in wind direction are recorded in the same way. The chart advances at 2 cm per hour.

Wind data were extracted from the charts by converting analogue records to digital data on Hollerith punch-cards by means of an encoder, the D-Mac Pencil Follower. For the wind records co-ordinates were transcribed at the points where the trace crossed the 0800 hr. lines, and at the end of each 10 km wind-run. A code for direction (or calm) was punched with each pair of co-ordinates; the code assigned to a run was that for the direction which prevailed during the period of observation. These data were then processed by computer. The programmes used incorporated routines for rotation of the chart axes, as described by Meyburgh et al (1970), correction of measured wind-run according to calibration, and determination of total wind-run, wind-speeds and wind frequencies for different periods from eight compass bearings. In addition, standard parameters descriptive of wind characteristics were computed using the formulae presented by Conrad and Pollack (1962).

Resultant run of wind is calculated with Lambert's formulae, where total run from north to south,

\[ C_N = N - S + (NW + NE - SW - SE) \cos 45^\circ, \]

and total run from west to east,

\[ C_W = W - E + (NW + SW - NE - SE) \cos 45^\circ, \]

where \( N \) is the total wind-run from the north, \( S \) is the total wind-run from the south, and so on.
Resultant run (the vector of total wind-run from the two directions), \( \rho \), equals \( \sqrt{C_N^2 + C_W^2} \).

The average resultant wind velocity \( \bar{V} \) is the ratio of the resultant run of wind to the total number of hours in a given period. The azimuth of wind direction (clockwise from north) \( \alpha \), is calculated from the angle \( \alpha' \) between the resultant run of wind and the west direction, where \( \tan \alpha' = \frac{C_N}{C_W} \). Steadiness of the wind \( S \) is the proportion in percent of resultant run to total run for a given period.

Calculations of this kind are usually based on hourly values. The raw data are, however, the intervals between events, i.e. 10 km runs of wind, and are therefore biased relative to conventional observations in that higher mean speeds are sometimes measured (though the instrument is not capable of measuring the instantaneous speeds that may be recorded on a Dynes atmometer, for example). Certain editing errors occur. Frequency of calms has been overestimated by 50 - 100% due to editing errors. Codes have been assigned for eight directions only; inspections of charts show that strong winds blow from a NNE bearing, and that most editors assign a NE code to these observations. The resultant wind directions calculated are probably somewhat east of the true value.

Summaries of the data are presented in tables 9 and 10 and illustrated in fig. 12.

Clearly, wind is a dominant factor at Jakkalsrivier. Of the 25 Western Cape weather stations manned by the Food and Fruit Technology Institute, Stellenbosch, the one with the highest record of wind is at the Worcester Veld Reserve.
Fig. 12 Characteristics of surface wind at Jakkalsrivier. A, B and C: wind-roses for the year and for the winter and summer half-years, respectively. D: Seasonal variation in mean daily wind-run (km) E: Seasonal variations in wind-speed (km/hr) frequencies for Jakkalsrivier.
### TABLE 9: SUMMARY OF MONTHLY WIND PARAMETERS

<table>
<thead>
<tr>
<th>MONTH</th>
<th>MEAN WIND-RUN, km/day</th>
<th>a (degrees)</th>
<th>S%</th>
<th>C</th>
<th>N</th>
<th>NE</th>
<th>E</th>
<th>SE</th>
<th>S</th>
<th>SW</th>
<th>W</th>
<th>NW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apr</td>
<td>331,3</td>
<td>31,5</td>
<td>8,2</td>
<td>59,6</td>
<td>7,4</td>
<td>28,3</td>
<td>29,9</td>
<td>5,5</td>
<td>5,6</td>
<td>6,3</td>
<td>9,7</td>
<td>3,0</td>
</tr>
<tr>
<td>May</td>
<td>317,1</td>
<td>14,6</td>
<td>8,8</td>
<td>66,6</td>
<td>8,3</td>
<td>40,1</td>
<td>23,1</td>
<td>1,4</td>
<td>2,2</td>
<td>4,9</td>
<td>8,7</td>
<td>4,1</td>
</tr>
<tr>
<td>June</td>
<td>345,6</td>
<td>8,9</td>
<td>10,4</td>
<td>72,0</td>
<td>7,2</td>
<td>45,9</td>
<td>19,9</td>
<td>1,5</td>
<td>1,2</td>
<td>5,1</td>
<td>7,8</td>
<td>3,1</td>
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<tr>
<td>July</td>
<td>313,4</td>
<td>8,0</td>
<td>9,2</td>
<td>70,4</td>
<td>9,4</td>
<td>45,9</td>
<td>18,5</td>
<td>1,4</td>
<td>1,7</td>
<td>3,7</td>
<td>8,3</td>
<td>2,2</td>
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<tr>
<td>Aug</td>
<td>311,7</td>
<td>5,6</td>
<td>7,7</td>
<td>58,9</td>
<td>8,9</td>
<td>40,3</td>
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<td>2,3</td>
<td>6,3</td>
<td>11,7</td>
<td>4,5</td>
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<tr>
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<td>294,7</td>
<td>15,7</td>
<td>5,6</td>
<td>45,4</td>
<td>8,9</td>
<td>30,3</td>
<td>18,8</td>
<td>2,3</td>
<td>4,6</td>
<td>7,4</td>
<td>17,2</td>
<td>4,2</td>
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<tr>
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<td>316,3</td>
<td>28,0</td>
<td>5,6</td>
<td>42,7</td>
<td>8,9</td>
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<td>7,5</td>
<td>18,7</td>
<td>4,6</td>
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<tr>
<td>Nov</td>
<td>316,9</td>
<td>48,4</td>
<td>4,5</td>
<td>33,8</td>
<td>9,1</td>
<td>14,0</td>
<td>25,8</td>
<td>5,9</td>
<td>5,7</td>
<td>10,2</td>
<td>22,3</td>
<td>3,7</td>
</tr>
<tr>
<td>Dec</td>
<td>303,1</td>
<td>32,1</td>
<td>3,2</td>
<td>25,0</td>
<td>9,3</td>
<td>16,5</td>
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<td>3,4</td>
<td>6,1</td>
<td>9,8</td>
<td>24,9</td>
<td>4,0</td>
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<td>299,2</td>
<td>35,3</td>
<td>3,0</td>
<td>24,4</td>
<td>9,2</td>
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<td>3,6</td>
<td>6,2</td>
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<td>45,1</td>
<td>6,7</td>
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<td>8,0</td>
<td>8,8</td>
<td>10,2</td>
<td>15,4</td>
<td>3,6</td>
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<tr>
<td>Mar</td>
<td>331,2</td>
<td>34,1</td>
<td>7,2</td>
<td>52,0</td>
<td>7,8</td>
<td>21,7</td>
<td>30,2</td>
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<td>3,4</td>
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<td>Year</td>
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<td>25,72</td>
<td>6,6</td>
<td>49,3</td>
<td>8,4</td>
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<td>3,7</td>
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<tr>
<td>MONTH</td>
<td>N</td>
<td>NE</td>
<td>E</td>
<td>SE</td>
<td>S</td>
<td>SW</td>
<td>N</td>
<td>NW</td>
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<tr>
<td>April</td>
<td>14.6</td>
<td>19.6</td>
<td>14.7</td>
<td>10.3</td>
<td>9.3</td>
<td>7.8</td>
<td>8.5</td>
<td>8.9</td>
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<tr>
<td>May</td>
<td>14.7</td>
<td>19.4</td>
<td>11.3</td>
<td>8.3</td>
<td>9.0</td>
<td>7.1</td>
<td>8.0</td>
<td>9.2</td>
<td></td>
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<tr>
<td>June</td>
<td>17.5</td>
<td>18.3</td>
<td>12.4</td>
<td>10.2</td>
<td>8.3</td>
<td>7.8</td>
<td>7.2</td>
<td>9.7</td>
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<tr>
<td>July</td>
<td>15.3</td>
<td>17.8</td>
<td>9.5</td>
<td>8.3</td>
<td>8.7</td>
<td>7.6</td>
<td>8.4</td>
<td>9.9</td>
<td></td>
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<tr>
<td>August</td>
<td>15.6</td>
<td>18.8</td>
<td>11.3</td>
<td>10.0</td>
<td>9.6</td>
<td>8.0</td>
<td>9.0</td>
<td>10.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>September</td>
<td>14.3</td>
<td>20.1</td>
<td>11.9</td>
<td>10.7</td>
<td>8.9</td>
<td>8.2</td>
<td>8.9</td>
<td>8.7</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>October</td>
<td>14.9</td>
<td>20.9</td>
<td>14.9</td>
<td>11.6</td>
<td>10.0</td>
<td>8.6</td>
<td>8.9</td>
<td>8.9</td>
<td></td>
<td></td>
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<tr>
<td>November</td>
<td>12.7</td>
<td>22.1</td>
<td>14.2</td>
<td>12.6</td>
<td>11.0</td>
<td>8.9</td>
<td>10.7</td>
<td>9.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>December</td>
<td>15.2</td>
<td>19.9</td>
<td>12.0</td>
<td>11.9</td>
<td>10.2</td>
<td>9.6</td>
<td>10.0</td>
<td>9.6</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>January</td>
<td>14.5</td>
<td>20.1</td>
<td>12.8</td>
<td>11.3</td>
<td>10.1</td>
<td>9.5</td>
<td>10.2</td>
<td>8.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>February</td>
<td>14.6</td>
<td>21.2</td>
<td>15.0</td>
<td>11.1</td>
<td>10.7</td>
<td>9.2</td>
<td>9.5</td>
<td>7.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>March</td>
<td>14.4</td>
<td>20.9</td>
<td>13.7</td>
<td>11.0</td>
<td>9.8</td>
<td>8.4</td>
<td>9.2</td>
<td>8.9</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Year</td>
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<td>20.0</td>
<td>13.2</td>
<td>10.8</td>
<td>9.7</td>
<td>8.4</td>
<td>9.0</td>
<td>9.2</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
The average run there is 270 km per day (Anon, 1972) and the average at Jakkalsrivier is 318 km per day. There is little variation in average daily wind-run through the year (see fig. 12d). Slight peaks occur in winter and in summer. It is interesting to note a clear seasonal cycle in wind-run west of the Hottentots-Holland divide with a definite summer peak (the data for Bien Donne are an example) whereas the slight fluctuation recorded east of the range is a mirror image of the former.

Most wind (67 per cent of the annual run) blows from the north and north-east. This is pronounced in winter and somewhat less so in summer (see table 11).

TABLE 11 : SEASONAL WIND-RUN FROM N AND NE (IN KILOMETERS)

<table>
<thead>
<tr>
<th>PERIOD</th>
<th>WIND-RUN FROM</th>
<th>PERCENTAGE OF TOTAL</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>NE</td>
<td>N</td>
</tr>
<tr>
<td>Apr-June</td>
<td>12 528</td>
<td>9 784</td>
<td>43,4</td>
</tr>
<tr>
<td>July-Sept</td>
<td>12 902</td>
<td>7 301</td>
<td>46,1</td>
</tr>
<tr>
<td>Oct-Dec</td>
<td>7 149</td>
<td>10 831</td>
<td>25,2</td>
</tr>
<tr>
<td>Jan-Mar</td>
<td>5 235</td>
<td>12 211</td>
<td>18,3</td>
</tr>
<tr>
<td>Year</td>
<td>36 429</td>
<td>40 127</td>
<td>33,3</td>
</tr>
</tbody>
</table>

Wind from the north predominates in winter and that from the north-east in summer.

The strongest winds blow from the north and north-east (see table 12) and though the former are more frequent, north-east winds have a higher average speed. There is little variation.
in wind-speed through the year (see fig. 12d).

### TABLE 12: MEAN SPEEDS OF WINDS FROM DIFFERENT BEARINGS (IN KM PER HOUR)

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>NE</th>
<th>E</th>
<th>SE</th>
<th>S</th>
<th>SW</th>
<th>W</th>
<th>NW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apr - June</td>
<td>15.7</td>
<td>19.2</td>
<td>13.7</td>
<td>9.8</td>
<td>9.0</td>
<td>7.6</td>
<td>7.9</td>
<td>9.4</td>
</tr>
<tr>
<td>July - Sept</td>
<td>15.2</td>
<td>18.9</td>
<td>11.1</td>
<td>10.0</td>
<td>9.1</td>
<td>8.0</td>
<td>8.8</td>
<td>9.7</td>
</tr>
<tr>
<td>Oct - Dec</td>
<td>14.4</td>
<td>21.0</td>
<td>13.8</td>
<td>12.1</td>
<td>10.4</td>
<td>9.1</td>
<td>9.8</td>
<td>9.3</td>
</tr>
<tr>
<td>Jan - Mar</td>
<td>14.5</td>
<td>20.8</td>
<td>14.1</td>
<td>11.1</td>
<td>10.2</td>
<td>9.1</td>
<td>9.7</td>
<td>8.6</td>
</tr>
<tr>
<td>Year</td>
<td>15.0</td>
<td>20.0</td>
<td>13.2</td>
<td>10.8</td>
<td>9.7</td>
<td>8.4</td>
<td>9.0</td>
<td>9.2</td>
</tr>
</tbody>
</table>

Fig. 12 e emphasises the relatively constant speed frequencies through the year, and the rarity of calms.

There is a clear but small fluctuation in the bearing of wind through the seasons. The resultant wind direction is closest north in winter and veers to the east in summer (see fig. 13), but is never west of north and only slightly east of NE in summer. The most important seasonal difference is the prevalence of light SW winds in summer (fig. 12 c).

The wind pattern which prevails in the South-western Cape is much distorted here and the usual strong north-west and south-east components have been almost completely masked. This is owing to the situation of the station at the mouth of a valley whose main axis is at right angles to a major scarp running about north-west to south-east. The valley therefore lies more or less at right angles to the direction of geostrophic winds; a possible explanation for the extreme modification of normal air flow is
that the mountain mass, particularly local topographic features, modifies strong geostrophic winds so that the valley normally lies in their lee and thermodynamic downwash (Munn, 1966) prevails. As wind-speeds are high, it is unlikely that the wind bearings recorded are a reflection of mountain and valley (i.e. anabatic and katabatic) winds; this is confirmed by the small southerly component. Anabatic and katabatic effects are observed during light geostrophic winds, but their effect on the record though perhaps reflected in the high frequency of light south-west winds in summer is masked by the prevalence of high winds.

![Graph](attachment:27083_28255_00005.pdf)

Fig. 13 Annual march of resultant wind direction, expressed as eastward deviation from north.
2.2.6 SYNTHESIS

Thornthwaite's (1955) moisture budget was calculated as a final step in the description of the local climate. A Fortran IIID programme developed by Black (1966) was modified for use in the southern hemisphere and the figures were calculated on an IBM 360 computer. Precipitation and temperature records used were those from the main meteorological station, for the years 1968/69 to 1971/72.

As the mean temperature falls between 0°C and 26.5°C, unadjusted potential evapotranspiration was calculated as follows

$$\log E^1_t = 0.01 - 0.0245 I + (0.46745 + 0.01702 I) \log T$$

where $T$ = mean monthly temperature, degrees Celsius

$I$ = annual heat index = $Z_i$,

$$i = (T/\gamma)^{1.514}$$

Monthly $E^1_t$ values were multiplied by a correction factor for day-length, where the factor

$$= a + b\theta + c\theta^2,$$

where $\theta$ = latitude (34°)

and $a$, $b$, and $c$ are constants which differ for each month.

Soil moisture storage capacity was assumed to be 100 mm.

The relevant data are presented in table 13 and the annual march in potential evapotranspiration (with the hydrological seasons) is illustrated in fig. 10 c.
<table>
<thead>
<tr>
<th>COMPONENT</th>
<th>Precip.</th>
<th>Temp. °C</th>
<th>Heat index, i</th>
<th>E_t</th>
<th>P - E_t</th>
<th>Acc.pot. waterloss</th>
<th>Soil storage</th>
<th>Actual evapotr.</th>
<th>Deficit</th>
<th>Surplus</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Jul</td>
<td>Aug</td>
<td>Sep</td>
<td>Oct</td>
<td>Nov</td>
<td>Dec</td>
<td>Jan</td>
<td>Feb</td>
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<td>Apr</td>
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<tr>
<td></td>
<td>120,4</td>
<td>122,0</td>
<td>56,4</td>
<td>81,7</td>
<td>46,0</td>
<td>37,7</td>
<td>47,0</td>
<td>56,4</td>
<td>37,6</td>
<td>48,9</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>73,3</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>118,4</td>
</tr>
<tr>
<td>TOTAL YEAR</td>
<td>845,6</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>154,0</td>
</tr>
</tbody>
</table>

(Data contain small rounding-off errors)
The following indices were calculated:

Moisture index \( I_m \) (Thornthwaite and Mather, 1955)
\[ I_m = \frac{(S - D)}{E_t} \]
where \( S \) = water surplus
\( D \) = deficit
\[ = \frac{(271 - 116)}{691} = 0.224 \]

Index of aridity = \( 100 \cdot \frac{D}{PE} = 16.8 \)

\( E_2 \), percentage proportion of the deficit occurring in the three summer months = 41.4.

A Walter (Walter, 1955) diagramme is presented in fig. 10b.

In the Bailey classification of the world in zones of warmth (Stuckenberg, 1969), the boundary between cool and mild zones is given as 13.4°C, effective temperature. The xerothermal index (indice xérothermique - Gaussen, 1967), i.e. the number of days per annum where mean monthly temperature exceeds twice the monthly rainfall, is zero.

This information was used to classify the climate at Jakkalsrivier according to Bailey (Bailey, 1960), Thornthwaite (Thornthwaite & Mather, 1955), Köppen (in Houtzagers, 1956), Gaussen (1967) and Walter (1955). Details are presented in Table 14.

The climate here does not fit comfortably in all the types listed above. The best illustration is the Walter diagram, where the precipitation curve does not fall below the curve of mean monthly temperature and there is therefore by definition no dry period. This reflects the moderating influence of altitude and aspect on air temperature.
TABLE 14 : CLASSIFICATION OF THE CLIMATE AT JAKKALSRIJVER

<table>
<thead>
<tr>
<th>CLASSIFICATION</th>
<th>TYPE</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bailey</td>
<td></td>
<td>Mild (to cool)</td>
</tr>
<tr>
<td>Köppen</td>
<td>Csb</td>
<td>Moist (P 2t)</td>
</tr>
<tr>
<td>Gaussen</td>
<td>I Cd</td>
<td>Submediterranean transition (subméditerranéen, transition)</td>
</tr>
<tr>
<td>Thornthwaite</td>
<td>B_{2s}B_{1a}</td>
<td>Maritime humid mesothermal, very moist, very mildly warm with a moderate summer moisture deficit.</td>
</tr>
<tr>
<td>Walter</td>
<td>(IV)</td>
<td>(Etesian climate of the eastern Mediterranean type).</td>
</tr>
</tbody>
</table>

In most of these systems the results are deceptive, based as they are on temperature and rainfall only, and on empiric relations between evaporation or total vapour losses and temperature which may hold in the regions where they were derived, but cannot be expected to have validity everywhere. In this case, the failings are clearly indicated by the fact that evaporation at Elgin, with higher temperatures, is apparently lower or at least very similar to that at Jakkalsrivier. This is possible owing to the much higher wind-run recorded at the latter station.

A soil moisture surplus prevails from about the beginning of June until the end of October. This is depleted until a deficit becomes apparent from about the middle of January; repletion begins in the middle of April.

On the whole, the local climate is cooler, has a higher precipitation, and is moister but more windy than the regional climate. Summer moisture stress is probably much moderated by mist conden...
sation from orographic cloud.

Gradients within the catchment are not clear in most cases, chiefly as they cannot be examined critically with the few data available. Clearest trends evident now are the positive relation between rainfall and altitude and decline in insolation with altitude. The latter is probably a primary local controlling factor.
CHAPTER 3.

THE VEGETATION

3.1 INTRODUCTION

Taylor (1969) has emphasized imperfections in our knowledge of the community relations in the Cape fynbos and of its dynamics and reaction to ecological factors. Acocks' (1953) vegetation map delineates the boundaries of the fynbos (Cape Macchia - Type 69) as a whole but he does not attempt further sub-division on structural or physiognomic grounds or on the basis of floristic associations.

Adamson's Cape Bush (Sclerophyll) (cf. Adamson, 1938) vegetation is equivalent to the fynbos referred to here. Three types are found at Jakkalsrivier. Sclerophyll Bush predominates, with Leucadendron xanthoconus (L. salignum) the most widespread component of the upper stratum, though Leucadendron gandogeri (L. decorum) and Aulax pinifolia are locally characteristic, ousting to a lesser or greater extent the former species. The top height of this type varies from 1 m to 3 m, depending to a certain extent on the post-burn age of the vegetation. An interesting local variant is the community dominated by tall (4 - 5m) Protea lacticolor, which is prominent along a small scarp north of the ravine in the centre of the catchment. Most of the tall scrub was burnt in 1947, while around its perimeters is a younger, lower form, which is still developing rapidly. Another striking form is that dominated by Priestleya myrtifolia, a tall (to 3 - 4m) tree-like shrub which is abundant over a restricted area.
Wet Sclerophyll Bush occurs along streams, at seepage zones and pediment marshes. This community, 1.5 - 3 m high, is generally dominated by one or two species. Composition varies with habitat. Prominent species are Leucadendron salicifolium (L. strictum), Berzelia lanuginosa, Brunia alopecuroides, and Berzelia squarrosa (B. arachnoidea). This form of Wet Sclerophyll Bush is highly characteristic of the wet Table Mountain Sandstone sites on the area east of the Hottentots-Holland divide, as far as the Swartberg at Caledon.

Adamson's Mountain Bush predominates on the steep, cool slopes, generally at elevations above 920 metres, but also in equivalent habitats at lower altitudes. Generally a low, dense shrub (0.25 - 0.5m), this type is dominated largely by Ericaceae, particularly Erica hispidula.

Some types occur which are not included in Adamson's classification. A striking example is the locally fairly extensive tussock graminoid vegetation, where Tetraria flexuosa dominates.

The vegetation has a rich flora, and while some 500 Pteridophytes and Angiosperms have been recognised (see Appendix A), it is estimated that about 600 will be found to occur here once collection is complete.

Forest Department records indicate that the whole catchment was burnt in December 1939, February 1947 and again in December 1958. The last two dates were confirmed by node-counts on the Proteaceae and ring-counts on species such as Penaea mucronata.
and *Mimetes capitulatus*, local patches, notably the tall *Protea mundii* scrub, have survived since the 1947 fire. A small area on the south-western boundary was burnt accidentally in January 1967, and another on the northern boundary in March 1966. A double fire-break, last burnt in 1963 and 1961, runs through a portion of the south-eastern part of the area.

Light infestations of *Pinus pinaster* occur throughout Jakkalsrivier. A small portion of the vegetation has been heavily disturbed by a dense stand, which was felled in 1965. The south-eastern portion includes part of a *P. pinaster* compartment. Populations of this exotic were controlled by recurrent fires in the past, but are now cut out regularly.

Roads are limited, while existing footpaths are narrow and affect only an extremely small portion of the vegetation. The area has been disturbed in places in the search for suitable stream-gauging sites and the installation of flumes and weirs, and tracers have been cut on the divides of the sub-catchments.

Severe deflation occurs on the fire-break (mentioned above) where it crosses deep sand.

As a whole, the area has escaped major human influences.

3.2 LITERATURE

Vegetation study i.e. the classification, description and analysis of plant communities has had a reasonably long history in South Africa (for example, Fourcade, 1889; Sim, 1907; Marloth, 1908; Bews, 1925; et al). However, it is only comparatively recently that South African vegetation and its component units have been
studied in detail (see Philips, 1931; Muir, 1929; Story, 1952; Acocks, 1953; Taylor, 1955; Killick, 1953; Scheepers, 1966; and Edwards, 1967).

In the Cape Floral Region, Adamson, (1927 et seq.) studied the vegetation, particularly the life forms, on Table Mountain for an extended period. Duthie (1929) distinguished community types on a limited area around Stellenbosch on the basis of physiognomy and floristic composition. Muir (1929) and Jordaan (1949) described extensive regions. In intensive studies of restricted sites, Rycroft (1950), Grobler (1964) and van der Merwe (1966) distinguished communities subjectively, but analysed them on a more or less rigorous quantitative basis.

In most of these investigations, communities were distinguished subjectively. It is largely within the present decade that workers have begun using techniques where communities are objectively identified and described. Most of these workers have used association analysis (van der Walt, 1962; Miller, 1966; Roberts, 1966; (in Roberts, 1967;) Grunow, 1965; Downing, 1966; Scheepers, 1970; Taylor, 1969). Moll (1969) has used an ordination technique to examine forest types, while Grunow and Morris (1969) have used a basically similar method to order species and stands. Hall (1967, 1970) has developed and tested new classification procedures for taxonomy and phytosociology.

3.3 PHYTOSOCIOLOGICAL PRINCIPLES

Becking (1957) defines phytosociology as follows:
"Phytosociology, plant sociology or phytocenology is the science of vegetation, studying all characteristics of plant communities ..., i.e. their physiognomy, floristic composition, community morphology and structure, community development and change, the multilateral relations of plants to one another and to environment, and the classification of communities. The last two are aspects of phytosociology as a whole".

Lambert and Dale (1964) discuss the concept and one meaning they present is " ... the study of sets of species forming communities under natural or semi-natural conditions", but point out that it is often " ... equated solely with attempts to classify such communities into a generalized scheme".

Phytosociology, as used here, includes the concepts of plant ecology as normally used by Anglo-American ecologists and is roughly equivalent to the concept of synecology. It usually denotes the classification and analysis of plant communities.

Phytosociological terminology is confusing. The subject has been adequately reviewed by Whittaker (1962) and Shimwell (1971) has used this work as a basis for his thorough analysis. Extensive discussion of the subject is not appropriate here. However, the confusion has increased recently with the application of modern numerical techniques which have brought statistical and mathematical terms into the phytosociologist's vocabulary. In the statistical sense, a phytosociological survey comprises a sample of a number of sample units, which are designated variously as plots, quadrats or sites, each of which is placed in a (uniform) stand of vegetation. Certain records of vegetation parameters or states
are recorded with respect to that portion of the stand encompassed by the sample unit: these are the attributes of the site. Frequently, the minimum data-set collected for a given sample unit is a list of species present and this is a qualitative record (two-state or binary data). More elaborate records are usual, and these may be semi-quantitative, comprising, for example, discontinuous data representing abundance, cover-abundance or similar ratings for each species present, according to a fixed scale. Quantitative measures embody continuous records (i.e. where any value of a given variable is possible) of abundance, cover, mass, etc. for individual species, or other vegetation parameters. These measures or ratings are often called "importance values" (Whittaker, 1970). The phytosociological record from a given sample unit may be called a stand, or site - in the language of numerical taxonomy, this is usually referred to as an "individual" with certain "attributes".

Records are usually supplemented with measurements, ratings or descriptions of a number of environmental factors.

The most elaborate standard record of this kind is that used by Zurich-Montpellier phytosociologists. It consists of a list of species present with their cover-abundance ratings, estimates of height and cover for each stratum, estimates of total cover, and a standard set of environmental descriptions, ratings and measures: this is called a relevé.

The sample of phytosociological records is, usually, employed to detect homogeneous subsets of stands each of which may then be referred to as a group and is taken to represent a possible com-
munity. A subset (or a single stand) which is taken to be typical of a putative community of any rank is often called a nodum.

I have used the term "community" to denote any vegetation category or type with constant characteristic features and with no definite rank, that is, neither a type which includes any subsidiary categories, nor one of the subsidiary categories. The term "abstract community" is conceptual and refers to the set of selected information used to define a category of vegetation; it is a "community-type".

3.3.1 GENERAL DISCUSSION

The aim of the phytosociological study on the limited Jakkalsrivier area is to subdivide the vegetation complex into communities, to define these communities by their distinct recognisable features, and to produce a map showing their distribution. The results should provide a useful framework within which various phenomena and the effects of treatment may be interpreted. The communities defined should be such that they may be related to similar types elsewhere, to provide a basis for inductive reasoning. The communities and the map should be useful in planning quantitative investigations in the area.

These aims can be attained if certain initial assumptions and decisions are made, and these depend on consideration of various theories of vegetation and phytosociology.

The first important question is that of the nature of community pattern and variation in vegetation. All phytosociologists
agree that vegetation exhibits discernible patterns; the basic controversy is between proponents of the continuum and of the community concept. From Gleason's (1926, in Kormondy, 1965) individualistic concept of vegetation, which holds that every stand of vegetation is unique and intergrades imperceptibly with the next (except at environmental discontinuities), arose the concept of vegetation as a continuum of populations. McIntosh (1967) defines this as follows: "vegetation changes continuously and is not differentiated, except arbitrarily, into sociological entities". He contrasts this with the community concept: vegetation is composed of "... well-defined discrete, integrated units which can be combined to form abstract classes or types reflective of natural entities in the "real world"." In the latter view, transition zones occur, but form only a negligible proportion of the total area in any large tract of vegetation. It is convenient to use a hypothetical mathematical model to illustrate this discussion (Goodall, 1963; Pielou, 1969). Where stands of vegetation are represented by points whose position in s-dimensional space are defined by their co-ordinates on any of s axes (each axis representing the presence or absence, or some quantitative measure of the occurrence of a species in a stand) various patterns are possible. If the points form a single hypersphere, then the vegetation may be regarded as homogeneous. If the points are clustered in two or more hyperspheres, there are as many natural classes as there are clusters, but if the population forms a single non-isodiametrical cluster such as a hyperellipse, then the vegetation is neither homogeneous nor naturally divisible, but continuously variable (Pielou, 1969). However, Pielou goes on
to say that even this model allows for argument either way. Whittaker (1962) points out that both continuity and relative discontinuity have been observed, but that gradation between communities is the rule. Poore (1962) disagrees, saying that "It is the common experience of plant ecologists ... that plants are associated in communities, which have a definite structure and often a regular specific composition", while Becking (1957) and Küchler (1967) are more emphatic in their support of the hypothesis that "Given species are consistently grouped together in plant communities which can be clearly identified" (Küchler, 1967: 17). On the other hand Whittaker (1962) cites his own research and that of the Wisconsin school as examples of work that gives strong support to the continuity hypothesis. Some more recent studies appear to confirm this (e.g. Webb et al., 1970) while Becking (1968) has suggested that data may indicate continuity or otherwise, depending on the sampling techniques used to obtain them.

This controversy raises certain basic questions about the validity of vegetation classifications. Many question whether a natural classification is possible or desirable (Whittaker, 1962: 78 et seq.). Whittaker (1970) argues that, because species do not share the same niches within the habitat, communities recognisable by concurrent species are rare, that continuous variation along environmental gradients is the rule, and that vegetation patterns should therefore be studied by means of ordination. However, as community types are considered characteristic of the habitat, and as the habitat includes many niches, it seems reasonable to expect some species in different niches to be confined
to the same habitat, and thus characteristic of the community. Whittaker's studies and those he refers to are normally based on measurement of the importance values of trees and large shrubs. Species of smaller shrubs and herbs and rarer trees may prove to have mutually exclusive distributions, and thus serve to characterize communities.

Ordination (which includes gradient analysis) consists of the ordering of stands along one or more axes, according to their attributes (Lambert and Dale, 1964). Pielou (l.c.) presents a succinct discussion of the approach. Where the $s$-dimensional vegetation model, representing $N$ stands, does not comprise a group of fairly compact clusters, a natural classification is not appropriate. The problem of applying a classification to a hyperspace of diffuse clusters may be avoided by applying ordination. This "...consists in plotting the $N$ points in a space of fewer than $s$ dimensions in such a way that none of the original $s$-dimensional patterns is lost". Ideally, the vegetation should be represented in two or three dimensions, for easy visualisation. As a method of summarizing the results of a survey, ordination has two great advantages over classification; it obviates the need for setting up arbitrary criteria for defining the classes and there is no need to assume that distinct classes (if there are any) are hierarchically related. Greig-Smith (1964) argues that classification tends to emphasise discontinuity, whereas ordination will reveal any real relationships and differences between communities and is therefore to be preferred as an initial approach.

In contrast, Poore (1962) presents further argument in
favour of classification. He states that "... no inductive generalisations are possible without classification. This need for classification is quite independent of subject matter ...". The real problem is that some phenomena are easier to classify than others. Lambert and Dale (l.c.) argue that either approach is valid: "... continuous systems can be efficiently classified if classification is desired, while "discontinuous" ... groups can be ordinated if ordination is thought more useful for the immediate purpose in hand". Greig-Smith (l.c.) in his discussion of the subject, concludes that the practising ecologist cannot wait for clarification of theoretical concepts and that classification is often approximate but useful. It is true that in Europe, where plant communities have been most thoroughly investigated, classification has led to a very good understanding of vegetation patterns (Whittaker, 1962). At Jakkalsrivier, a classification is most likely to meet the aims of the study.

It is necessary to consider what type of vegetation data is required for classification. Fosberg (1967) lists seven categories of information which may be used. These are (a) physiognomy: the "... appearance, especially the external appearance, of the vegetation ..."; (b) structure: "... the arrangement in space of the components ..."; (c) function: a term which " ... includes features that seem to suggest special adaption to environmental situations ... periodicity ..., life forms (in the Raunkiaer sense), growth forms, protective mechanisms" and others; (d) floristic composition, either quantitative or qualitative; (e) dynamics and successional phenomena; (f) habitat or environmental relations; and (g) history. Webb et al (1970) maintain that the distinction between the first three terms is obscure, and prefer to
consider only two categories, floristic features as opposed to non-floral ('structural-physiognomic') features. Greig-Smith (1964: 135) lists seven criteria: the species present, measure of abundance of species, performance of individuals of species, growth and life form, physiognomy, pattern of the constituent species, and various mathematical constants. He emphasises that these are interrelated. For the purpose of this study, however, a critical examination of the following broad types of criteria is required:

(a) floristic composition;
(b) dynamics and succession: syngenetics;
(c) growth and life form, and physiognomy;
(d) habitat or environmental relations.

Poore (1955a) quotes the arguments prevalent among European phytosociologists against the use of habitat or environmental relations ('ecologic' criteria) in classification. These factors are difficult to measure and to relate to the occurrence or performance of communities, and historical factors, particularly plant geography, may have a considerable influence. Also, in the Jakkalsrivier study as in many others, the aim is partly to use the plant communities distinguished as indicators of the habitat, and not vice versa.

Webb et al (1970) and Lambert and Dale (1964) discuss these questions in greater detail. Whittaker (1962: 55 et seg.) reviews some of the classifications based on habitat features such as climate, topography and soils, or on "multifactoral or landscape units" (as applied by Jeffrey et al, 1968). This leads ......./81
on to a classification of ecosystems which is not pertinent to this study, and would require a great deal more information to succeed in such a detailed investigation. What is required here is a classification of plant communities which may then be related to habitat factors or used as aids in the study of such factors.

The use of syngenetics in vegetation classification is widely applied (Whittaker, 1962). The most formal application is represented by the so-called Clementsian approach. Here, the formation - the climax community of a particular climatic region - is recognised as consisting of a number of subordinate communities - associations and their constituent consociations and societies - and all other subclimax or seral communities are related to these in a hierarchical series of successional types. This and related approaches, modified according to prevailing theories and conditions, has been of great influence in the Anglo-Saxon world. A number of more or less formal approaches have evolved, but these are varied, and a universal system has not developed. Braun-Blanquet (in Poore, 1955a) has criticised the approach on the grounds that the climax is largely hypothetical and the number of man-influenced communities, which cannot be grouped into a true series, is rapidly increasing.

Fosberg (1967) argues that this kind of information is too complex for general application, and "... much of the evidence for dynamic status is inferential, derived from other data, hence its introduction into classification may give double weight to
certain features. Such information does not appear to be of much immediate value in a vegetation type like fynbos where fire has an overriding influence and stands in all stages of development may be encountered. Dynamics have been little studied here, and the existence and nature of climax communities are controversial.

Classifications based on such non-floral criteria as physiognomy, structure, and life and growth-form have been successfully applied, though generally on a broad scale (Webb et al., 1970). Recent studies, using such information for detailed classifications, hold promise and are worth closer examination (Webb et al., 1970) and Knight and Loucks, 1969). In the Australian study (Webb et al., 1970), investigators attempted to solve problems of phytosociology with few trained observers to collect floristic data in rich, little known floras. A carefully chosen check-list of twenty-four physiognomic characters, including height, stratification, habit, leaf-size, bark character and so on, was drawn up and submitted to various independent field workers for completion in selected stands of Australian rain-forest. One of the authors also listed species for each stand. Both sets of data were then used to construct classifications, using various modern numerical techniques. The results indicated that physiognomic-structural classification can prove as useful as a floristic, and that it can, with refinement, be applied at a level practical in land-use planning.

Knight and Loucks (1969) had data on floristic composition of a number of stands from coniferous and broad-leaved upland forest in Wisconsin available. They scored each species in terms
of a limited list of structural and functional characters and then applied a technique of gradient analysis to obtain an ordination of the data. The results indicated that "Quantitative analysis on the basis of structural-functional features has been shown again to provide a means by which the ecology of a community can be investigated directly instead of indirectly through plant names." It should be noted, however, that this study was based primarily on available floristic data and also depended on much existing autecological information. This work suggests strongly that non-floristic data of this nature can be profitably employed in fairly detailed phytosociological studies. However, both studies were based on a thorough knowledge of the vegetation and the prior accumulation of data, which is not so in the Jakkalsrivier study. In addition, the influence of fire may obscure real differences between communities because in the early stages of development after a burn different communities are essentially similar in physiognomy. The physiognomic approach is therefore not relevant in this case.

Floristic criteria are used to a lesser or greater extent in many classifications, but there is room for argument as to their utility and relevance. "A difficulty in floristic studies is that in those areas where survey is most needed the flora is both at its richest and least known; trained observers are needed to collect the data, and identification of the species concerned becomes a major task" (Webb et al., 1970); this comment is certainly valid in the case of the Jakkalsrivier study. However, floristic criteria have been widely used for classification because plant species serve as more or less sensitive indi-
cators of certain habitat, syngenetic and historical or geographical factors (Braun-Blanquet, 1932: 362). Fosberg (1967) rates floristic composition as the most significant kind of information on vegetation, and though he prefers other criteria he concedes that the former would be most useful at the lower levels of most classifications. Lambert and Dale (1964) approve of the general use of floristics, accepting "... the species concept as an economical method of characterising plant material by a number of properties simultaneously at a generally convenient level of abstraction". They therefore agree with Braun-Blanquet (1932). They emphasise also that the species best communicates the greatest spectrum of information on the vegetation and that (because they consider multivariate classification essential) floristic information ensures records of sufficient variables to reveal significant differences between communities. A floristic list is generally a more precise characterisation of a stand than, for example, a list of structural-functional characters.

Where floristic composition is used, qualitative or quantitative data must be chosen. Greig-Smith (1964: 136) thinks that a simple list of species present is a "... crude and insensitive mode of characterisation .."; "... the important difference between stands lies in the amount of different species ..." (p. 160). Presence and absence data, in his opinion, will separate stands which are very different in composition and serve merely to confirm the self-evident. Because communities are characterised by differences in continuous variables, they should be classified on the same basis. Lambert and Dale (1964) claim that presence and absence records form 'a self-contained logical system', whereas,
for quantitative data, recording abundance of each species present only does not, because the absence of another is not measurable. Whatever the philosophical arguments, there are practical problems in the use of quantitative data; it is often difficult to distinguish individual plants (Greig-Smith, 1964: 5) and the work is time-consuming. Quantitative data may, however, be useful where a classification is required for a certain purpose (as in forest management), or at the lowest levels of classification. Certainly, qualitative data have been successfully used by the Zürich-Montpellier School, and in recent numerical studies.

Practical considerations determine finally what approach is best. Poore (1962) concludes "... that classification of communities within one relatively uniform floristic region should be based on floristic comparison, but that classification on a larger scale should be based on physiognomic-ecological criteria". Conditions in Jakkalsrivier favour the first approach, and a further advantage is that recording floristics is a straightforward procedure, yielding unambiguous data. In his phytosociological study of an essentially similar vegetation, Taylor (1969) used floristics to define and describe Communities at lower levels of the hierarchy, but physiognomy and habitat were used to describe the higher levels.

3.3.2 CLASSIFICATION SYSTEMS

Pielou (1969) reviews modes and techniques of primary vegetation classification. Initially, certain choices must be made: (a) whether to employ a hierarchical or a reticulate classification; (b) whether a divisive or agglomerative approach is
Hierarchical classification is exclusively employed in taxonomic work, and used widely in phytosociology. The approach is simple and familiar, and this is probably the main reason why it is preferred to a reticulate system, where classes are defined separately and each is related to the others by a logical network. Lambert and Dale (1964) emphasise the advantage of hierarchy in that the routes by which classes are obtained may be displayed, and suggest that the system is more natural. Reticulate systems are generally impractical.

In divisive classificatory techniques the vegetation is successively subdivided in progressively more homogeneous groups, until further subdivision is unnecessary. Agglomerative techniques require successive combination of the most similar units, starting at the lowest level. "Subdivisive methods thus concentrate essentially on differences, while agglomerative methods seek similarity" (Lambert and Dale, 1964). For the former, less computation is usually employed because the process may be halted at any convenient level and certainly before individual stands appear. The agglomerative approach requires the whole procedure to be completed before the relations at the top of the hierarchy are revealed. Pielou (1969) suggests that, because agglomerative techniques start with individual units (i.e. sample units or relevés), where chance anomalies are most likely to obscure true similarities, the approach is prone to produce bad combinations at the start. Generally, subdivision is preferable.
Group formation in polythetic methods is based on overall similarity of the groups, as expressed by a combination of characters, while in monothetic methods a single character is used for each division. With a monothetic approach, only subdivision may be used, whereas subdivision and agglomeration are possible in the polythetic method (Lambert and Dale, 1964), though subdivision is not practical (Pielou, 1969). The monothetic method may be wasteful of information and produce bad classifications on the basis of ecologically meaningless attributes. Theoretically the polythetic method should produce better and more informative classifications. However, monothetic methods usually employ much less computation.

Lambert and Dale (1964) discuss other factors governing the choice of classificatory technique, but practical considerations play a strong role. One of the most important considerations is the computation time required (and availability of computation aids). Subdivisive monothetic techniques are consequently more popular.

Pielou (1969) describes and discusses various numerical classification techniques, which will not be examined here. However, the Zürich-Montpellier system merits close consideration. The approach has been described and discussed by Becking (l.c.), Poore (1955a) Whittaker (1962) and Shimwell (1971). Küchler (1967) and Shimwell (1971) describe the appropriate techniques in some detail, while Taylor (1969) and Werger et al (1972) have used it in the Cape fynbos. Certain salient features of the approach should be noted.

The Zürich-Montpellier system classifies vegetation on
floristic characters. Communities are recognised and described by diagnostic species. The basic vegetation unit is the association, an abstract plant community of definite floristic composition, of uniform habitat conditions and of uniform physiognomy, which is recognised and described primarily by its character species, that is, species which tend to occur exclusively in the community. Vegetation units are related in a hierarchical system, based on diagnostic species, and each unit receives a Latinised name derived from its diagnostic species. The hierarchy and names are universally applied, and each worker relates the types he deals with to the published system.

Classification is based on thorough field work. The worker samples stands which are postulated to represent community-types and locates a number of plots in each hypothetical community-type, each placed in a chosen homogeneous stand. He applies the concept of minimal area in determining the size of the plot (it should be large enough to include all the species of the community) and plot size is not necessarily constant. He then completes an accurate description of the stand - the relevé.

The data are tabulated in the laboratory, with the columns showing the species content of each relevé. Manipulation of the table by shifting rows and columns reveals groups of relevés similar in composition. He then seeks species with high constancy (those present in all or most relevés of the group) and fidelity (those confined entirely or nearly so to the group) to characterize his groups (which represent abstract communities). These are the character species of the groups of relevés, which now

....../89
represent communities. Plot samples are selected and presented in composite tables as representative of the communities distinguished, and published.

Taylor (l.c.) applied the technique to data obtained from fynbos at Cape Point. Though a systematic sampling strategy placed many plots in ecotones, the results provided a more natural classification than the numerical technique he had tested. He recommended the approach as valuable in at least the primary survey of unknown vegetation. Werger et al (1972) agreed. Nevertheless, this technique was rejected in the Jakkalsrivier study. First, and most important, successful application requires a skilled and experienced worker. Second, the subjective selection of sample units does not necessarily accord with the requirements of detailed experimental investigations.

Though the considerations discussed above were examined, the choice of phytosociological approach to the Jakkalsrivier study was dictated by practical considerations as much as any other. The kind of phytosociological record required, sample size and plot size and shape are discussed in section 3.4. The choice of classification method, however, was determined chiefly by the fact that one, association-analysis, was then under trial in many parts of South Africa (see references below) as an objective method which could supplant the earlier descriptive and subjective approaches. Preliminary results had been promising (Grunow, 1965 and Scheepers, 1969), the technique was tried on a large tract in the fynbos (Taylor, 1969) and it was felt appropriate that it should be applied on a small one. Furthermore, technical support in this
field was then confined mainly to this technique. The features and relative merits of the various numerical classification techniques will therefore not be discussed here.

3.3.3 ASSOCIATION-ANALYSIS

Association-analysis is a monothetic subdivisive classificatory technique devised by Williams et al (1969) for the study of qualitative floristic data (presence and absence of species). It was developed from Goodall's (1953) earlier attempt at distinguishing vegetation units on an objective basis. The derivation and application of the method are described in detail by Williams and Lambert (1959, 1960). Greig-Smith (1964) discusses the technique thoroughly, while Grunow (1965) presents a comprehensive analysis of the requisite computation procedures. The method is economical only if moderately powerful electronic computers are available.

The technique has been applied by various workers in a number of South African veld types, such as the Cymbopogon-Themeda veld (Acocks' type 48a), the Highland and Sourveld (type 44a), the Sourish Mixed Bushveld (type 19) and the Cape fynbos (type 69) (Grunow, 1965; Downing, 1966; Roberts, 1967; and Taylor, 1969; and Boucher, 1971).

Plot lists of the presence and absence of species are the raw data required. The technique computes the association between species from this information. The total assemblage of stands (plots) is divided into successively more homogeneous (in statistical terms) subsets on the basis of those species showing the
Association between all possible pairs of species in the whole set of stands is determined by calculating the chi-square (generally with Yates' correction) for the relevant 2 x 2 contingency tables. The subsequent step is to subdivide the set of stands in such a way that the level of association in the resulting groups is reduced i.e. the subsets must contain progressively fewer pairs of associated species. Several alternative ways of achieving this are possible, and Williams and Lambert therefore introduced "... the concept of efficient subdivision, i.e. subdivision based on that species which produces the smallest total number of significant associations in the two sub-classes" (Greig-Smith, 1964). The parameter I, chosen as a practical measure of association, is conventionally either the chi-square for the relevant species, or some derivative of chi-square. They found $X^2/N$ ($N =$ total number of stands in the data-set) most satisfactory; "Williams and Lambert show that, on theoretical grounds, division on the species with maximum $I$ will tend to reduce the residual $I$ in the resulting subclasses to a minimum."

(Greig-Smith, l.c.). The first subdivision of the stands results therefore in two groups, one containing the species with maximum $I$ and the other without.

This procedure is repeated for both groups, and these and all succeeding groups are further subdivided in the same way until the highest individual chi-square in the relevant groups is smaller than 3.84 (the highest value indicating significant association corresponding to $P = 0.05$), or until an arbitrary chi-square level
is reached (Williams and Lambert suggest $X^2 = N \cdot 2^{-5}$). The result is a hierarchical series of subdivisions, in which the successive division steps may be traced, and which is readily illustrated by means of a dendrogram.

In such a hierarchy, subdivisions of the same order might differ in degree of heterogeneity; Williams and Lambert therefore selected the highest individual chi-square in a group as a measure of heterogeneity, and subdivisions are ranked accordingly.

Association-analysis therefore provides a hierarchy with a number of final groups of stands ("communities"), which the authors claim have ecological relevance and which are eminently suitable for vegetation mapping.

3.4. SAMPLE STRATEGY AND DATA ACQUISITION

An unbiased sampling procedure is essential to objective methods of vegetation study. In the case of probabilistic statistics, a random or stratified random sampling technique is generally necessary, but this is not a requirement in the non-parametric methods applied at Jakkalsrivier. (This matter was referred to Mr. A. Schoeman of the Department of Statistics, Faculty of Commerce, University of Stellenbosch, who confirmed that this is the case for both classification and the ordination techniques.) Most workers using association-analysis have used systematic sampling procedures. This limits additional statistical analysis, but the advantages outweigh this drawback. Units are easier to locate in the field, coverage of the research area is more efficient, and mapping is facilitated. At Jakkalsrivier, therefore, sampling units were located at the intersections of a grid overlay.
From the literature it would appear that sampling intensity has been very much an arbitrary choice in statistical phytosociology. Williams and Lambert (1959) used an espacement of 5m x 5m, while Grunow (1965) distributed his sample units at 200 yd. intervals. No standardised procedure has been adopted, but certain general principles provide guides. The number of sampling units required will be governed largely by the scale of the operation, the complexity of the vegetation, and the amount of detail required. On economic grounds, a combination of large area and numerous plots is to be avoided if possible. On the other hand, where a detailed map is required, close espacement may be necessary to cater for barely perceptible differences between vegetation units. The amount of field work and concomitant calculations must be kept within practical bounds, without sacrificing essential information.

A basic requirement is an adequate sample of each of the communities present. This, of course, is not possible, as the communities and their distribution are presumably unknown. Workers of the Zürich-Montpellier School circumvent this by sampling intuitively recognised communities until they are satisfied that sufficient data on most are available. Even in objective studies, workers no doubt often base their choice of sampling intensity on an intuitive assessment of the communities present and the sample-size required for each.

In the Jakkalsrivier study, to ensure that most of the unpredictable changes in the vegetation will be detected after treatment, rather a large number of sample units was required. However, as the survey was to be repeated at fairly short inter-
vals, the recurrent costs should be restricted to a reasonable minimum. With this in mind, it was decided to use an espacement of 70m x 70m - a convenient density of about 2.5 plots per hectare.

3.4.1 SIZE AND SHAPE OF SAMPLE UNITS

In some of the examples cited above, square metre plots were adopted. Taylor (1969) used 5m x 10m plots. The choice again largely depends on what is required, the environment and the scale of survey. According to Greig-Smith (l.c.), sample units should be "... sufficiently large to eliminate features due to pattern within communities". The Zürich-Montpellier School bases its choice of plot size on the hypothetical minimal area of the relevant community. The plot should be at least equal to the minimal area; the size and shape should be such as to include only those elements typical of a homogeneous unit of vegetation (Becking, 1957).

A concept similar to that of minimal area is efficient plot size (Taylor, 1969). With the proviso that the plot should be at least large enough to include the important species in the vegetation stand sampled, final choice of size rests on economic considerations. The relationship between number of species and area is semi-logarithmic. Consequently, an increase in plot area beyond a certain size does not produce a proportionate increase in the number of species encountered. Therefore, the plot size adopted is one which includes most species, and the work involved with further expansion is not justified by the small addition to one's
species list.

A preliminary test, using three nested plots and 32 randomly distributed plots of various sizes, was run at Jakkalsrivier. The data are not comprehensive, but some results are tabulated below:

<table>
<thead>
<tr>
<th>Area (m²)</th>
<th>% of Total Number of Species Recorded</th>
<th>Nested Plots</th>
<th>Multiple-size Plots</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td></td>
<td>23</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>24</td>
<td>33</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>35</td>
<td>43</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>42</td>
<td>50</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>46</td>
<td>57</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>50</td>
<td>60</td>
</tr>
<tr>
<td>10</td>
<td></td>
<td>62</td>
<td>70</td>
</tr>
<tr>
<td>15</td>
<td></td>
<td>68</td>
<td>77</td>
</tr>
<tr>
<td>20</td>
<td></td>
<td>74</td>
<td>80</td>
</tr>
<tr>
<td>25</td>
<td></td>
<td>77</td>
<td>83</td>
</tr>
<tr>
<td>30</td>
<td></td>
<td>80</td>
<td>87</td>
</tr>
<tr>
<td>40</td>
<td></td>
<td>85</td>
<td>93</td>
</tr>
<tr>
<td>50</td>
<td></td>
<td>89</td>
<td>97</td>
</tr>
<tr>
<td>60</td>
<td></td>
<td>92</td>
<td>97</td>
</tr>
</tbody>
</table>

(These figures were obtained by plotting percentage of total number of species recorded on 64m² over plot size on semi-logarithmic paper i.e. from a curve of the form \( y = a + b \log x \)).

From these data an "efficient" plot size of 15m² was adopted. To give a greater coverage of variation, a rectangular design, 5m x 3m, was chosen.
3.4.2 FIELD PROCEDURE

Plots were located by pacing on a compass bearing; the long axis of each plot was oriented north-south, and the short axis located east of the 70-metre mark.

The vegetation at Jakkalsrivier is such that quantitative parameters cannot be simply and efficiently recorded on the plots. The graminoid species are mainly tufted or clumped, making it very difficult to distinguish individuals. The vegetation is generally extremely dense and very often matted. These factors, together with very high species richness make it impractical to measure individual species density, cover, etc., or even to make estimates such as the Braun-Blanquet cover-abundance measures. For these reasons, only presence or absence of species were recorded.

Each plant species rooted within the perimeter of the plot was recorded. Geophytes, annuals and any perennials whose above-ground parts die back seasonally to render identification difficult, if not impossible, were excluded. Due to inexperience, a number of species were excluded which might profitably have been listed.

In addition, the site was assessed by recording ratings of various features. Surface soil texture was estimated by feel and recorded in one of nine classes (coarse sand to clay). Surface stones, of five different classes, from gravel to boulders, were recorded as rare, frequent or abundant. The geological
formation was noted, while the active erosion agents (i.e. wind or water) and the degree of erosion were recorded, the latter according to the following classes:

(a) None apparent
(b) Slight - slight loss of top soil and / or some slight dissection by run-off channels.
(c) Moderate - moderate loss of top soil and / or marked dissection by run-off channels.
(d) Severe - high percentage loss of top soil and / or marked dissection by run-off channels or gullies.

Slope and aspect were measured. The prevailing soil moisture regime was rated as follows:

1. Very wet. The soil is more or less permanently saturated; the water table is at or near the surface for most of the year; e.g. swamp, very wet vleis, etc.
2. Wet. Usually saturated during wet seasons; soil wetness is a distinct limiting factor to most plants.
3. Moist. The availability of soil moisture is not a limiting factor; in normal years plants suffer from neither an excess nor a deficiency of soil moisture, Soil moisture balance is at an optimum.
4. Dry. The seasonal availability of soil moisture is below optimum; periodic dryness is a distinct limiting factor.
5. Very dry. The availability of soil moisture is a severe limiting factor.

Exposure was classified as follows:

(a) Wind.
(1) Very exposed. Hardly sheltered from prevailing winds. Flat land, top of ridges and koppies; no shelter from configuration of the land.
(2) **Exposed.** Sheltered from one of the prevailing winds; receives some shelter because of the configuration of the land.

(3) **Sheltered.** Sheltered from both prevailing seasonal winds and receives a fair amount of topographic shelter.

(4) **Very sheltered.** Wind due almost entirely to air drainage; e.g. kloofs.

(b) **Insolation.**

(1) **Very hot.** Completely exposed to sun. Plateau, north slopes.

(2) **Hot.** Little or no topographic shading; gentle slopes, partly orientated towards sun.

(3) **Warm.** Some topographic shading and reduction in insolation due to slope and orientation.

(4) **Cool.** Topographic shading through most of the day. Deep kloofs, steep south slopes.

Humus in the surface horizon was rated rich, moderate or poor. Topographic position was indicated, and a diagram used to show the nature of the terrain.

The density, habit and height of emergent species and the dominant species (and height) in the canopy were recorded together with an estimate of total plant cover (in four equal classes).

Each plot was photographed.

The printed survey form (Appendix B) provides for more information which, however, is not relevant here.
3.5 RESULTS OF SURVEY

Floristic lists were obtained from 367 sites. Two hundred and sixty-nine species occurred in the sample, but species with a presence of 3 and fewer were excluded, and 196 remained in the data for analysis. The analysis was executed with a Fortran programme (AANAL) by Mr. J.W. Morris of the Botanical Research Institute (Morris, 1968). The parameter used for subdivision was $\chi^2/N$ (without Yates' correction) and subdivision was terminated when the maximum chi-square (with Yates' correction) between two species in a group was less than 3.84, or when a group contained 7 or fewer plots.

Association-analysis provided 85 final groups. This number is a little cumbersome for illustration, and the subdivision to the short-division groups (maximum chi-square = 11.47) is illustrated by means of a dendrogram in fig. 15. This figure indicates the level of heterogeneity at each subdivision (i.e. the maximum chi-square for each group produced). (The species given in the diagram as Anthoxanthum sp. is Ehrharta dodii, and Metalasia cymbifolia is, in fact, M. muricata).

3.5.1. ECOLOGICAL INTERPRETATION OF ASSOCIATION-ANALYSIS

It is useful, as a first step, to examine the correlation between the association-analysis groups and factors of the environment, to assist the interpretation of results.

In this terrain the overriding factors which determine vegetation pattern are likely to be those associated with the altitudi-
nal complex gradient, relative insolation and soil moisture. The emphasis in this ecological interpretation will therefore be placed on altitude, calculated relative insolation, and soil climate ratings, though other factors must be considered.

Altitude was determined from the topographic map. Relative insolation was calculated from the slope and aspect measured at each plot, using published tables (Frank & Lee, 1966), but topographic shading was disregarded. Soil climate ratings assigned to each plot in the field were used as indices of soil moisture status. Other factors were assessed on the observations and ratings noted on the survey forms, or by examining the distribution of plots within any group on the topographic map.

Selected ecological characteristics of each short-division group are presented in condensed form in Table 14a. Median, first and third quartile values were calculated for all relative insolation, altitude and slope data from the 367 plots. Frequencies of these values in each category for each group illustrate deviations from the median for the catchment. Brief descriptions of the groups in terms of ecological characteristics appear in Appendix B. These descriptions are superficial but sufficient at this stage to make a broad assessment of the efficacy of association-analysis in detecting ecologically meaningful groups.

The results obtained here are somewhat confused, but certain features are clear. The positively defined group produced by the first partition of the data (defined by the presence of Thamnochor-tus spp., and including short-division groups XV - XXVII) consists
<table>
<thead>
<tr>
<th>GROUP NO.</th>
<th>RELATIVE INSOLATION (%)</th>
<th>ALTITUDE</th>
<th>SLOPE</th>
<th>ASPECT</th>
<th>SOIL CLIMATE RATING</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>0.455</td>
<td>817.9</td>
<td>125.5</td>
<td>E-SW: 57% SW</td>
<td>0</td>
</tr>
<tr>
<td>II</td>
<td>0.280</td>
<td>800.0</td>
<td>105.0</td>
<td>Both SW</td>
<td>1</td>
</tr>
<tr>
<td>III</td>
<td>0.466</td>
<td>757.1</td>
<td>34.3</td>
<td>Variable, NE-W</td>
<td>1</td>
</tr>
<tr>
<td>IV</td>
<td>0.425</td>
<td>985.0</td>
<td>3</td>
<td>75% SE-S</td>
<td>5</td>
</tr>
<tr>
<td>V</td>
<td>0.485</td>
<td>750.0</td>
<td>25.0</td>
<td>E &amp; SW</td>
<td>1</td>
</tr>
<tr>
<td>VI</td>
<td>0.404</td>
<td>855.0</td>
<td>49.0</td>
<td>All SW</td>
<td>2</td>
</tr>
<tr>
<td>VII</td>
<td>0.501</td>
<td>783.3</td>
<td>11.7</td>
<td>Variable, SW-NE</td>
<td>4</td>
</tr>
<tr>
<td>VIII</td>
<td>0.419</td>
<td>845.6</td>
<td>45.6</td>
<td>S-W: 88% SW</td>
<td>3</td>
</tr>
<tr>
<td>IX</td>
<td>0.335</td>
<td>958.3</td>
<td>61.7</td>
<td>SE-W: 87% S-SW</td>
<td>3</td>
</tr>
<tr>
<td>X</td>
<td>0.408</td>
<td>933.3</td>
<td>42.2</td>
<td>NE-SW: 67% SE-S</td>
<td>6</td>
</tr>
<tr>
<td>XI</td>
<td>0.306</td>
<td>1035.0</td>
<td>64.0</td>
<td>SE-S: 80% S</td>
<td>1</td>
</tr>
<tr>
<td>XII</td>
<td>0.329</td>
<td>1025.0</td>
<td>61.7</td>
<td>SE-SW: 80% S-SW</td>
<td>6</td>
</tr>
<tr>
<td>XIII</td>
<td>0.338</td>
<td>1025.0</td>
<td>55.8</td>
<td>85% S</td>
<td>6</td>
</tr>
<tr>
<td>XIV</td>
<td>0.460</td>
<td>825.0</td>
<td>33.3</td>
<td>67% SW-W</td>
<td>1</td>
</tr>
<tr>
<td>XV</td>
<td>0.504</td>
<td>833.0</td>
<td>20.0</td>
<td>Variable: 58% N &amp; E</td>
<td>3</td>
</tr>
<tr>
<td>XVI</td>
<td>0.445</td>
<td>800.0</td>
<td>25.8</td>
<td>Variable, NW-SW: 75% E-SW</td>
<td>14</td>
</tr>
<tr>
<td>XVII</td>
<td>0.387</td>
<td>691.7</td>
<td>41.7</td>
<td>All SW</td>
<td>2</td>
</tr>
<tr>
<td>XVIII</td>
<td>0.472</td>
<td>875.0</td>
<td>23.9</td>
<td>All but one SW</td>
<td>5</td>
</tr>
<tr>
<td>XIX</td>
<td>0.372</td>
<td>930.0</td>
<td>50.3</td>
<td>All but one SE-SW</td>
<td>7</td>
</tr>
<tr>
<td>XX</td>
<td>0.356</td>
<td>815.0</td>
<td>49.0</td>
<td>All but one S</td>
<td>3</td>
</tr>
<tr>
<td>XXI</td>
<td>0.432</td>
<td>815.0</td>
<td>45.0</td>
<td>SE-W</td>
<td>2</td>
</tr>
<tr>
<td>XXII</td>
<td>0.462</td>
<td>882.5</td>
<td>33.0</td>
<td>All aspects: 65% E &amp; SW-W</td>
<td>4</td>
</tr>
<tr>
<td>XXIII</td>
<td>0.519</td>
<td>805.0</td>
<td>31.5</td>
<td>Variable, 65% NE-E</td>
<td>7</td>
</tr>
<tr>
<td>XXIV</td>
<td>0.424</td>
<td>808.3</td>
<td>46.4</td>
<td>All aspects: 87% E-SW</td>
<td>1</td>
</tr>
<tr>
<td>XXV</td>
<td>0.471</td>
<td>744.1</td>
<td>34.5</td>
<td>All aspects: 81% E-SW &amp; SW-W</td>
<td>7</td>
</tr>
<tr>
<td>XXVI</td>
<td>0.518</td>
<td>859.8</td>
<td>34.6</td>
<td>All aspects, 65% NW and S</td>
<td>14</td>
</tr>
<tr>
<td>XXVII</td>
<td>0.432</td>
<td>804.0</td>
<td>40.3</td>
<td>Variable: 95% SE &amp; SW-W</td>
<td>4</td>
</tr>
</tbody>
</table>

**Summary of Selected Site Factors for Short Division Association Analysis Groups.**
primarily of more or less arid, hot sites in the lower portion of the catchment. The negatively defined group is more heterogeneous, but the next subdivision is revealing. This partition produces a positively defined group (defined by the presence of Chondropetalum deustum: groups X - XIV) which consists primarily of plots from cool sites at high altitudes. The negatively defined group (without C. deustum) consists again of two main types: first, plots from riparian zones on streams or seepage areas which are often boggy in winter, and second, plots from the slopes north-east of the middle section of the main stream, on Hutton and Clovelly soils.

The group of 215 plots defined by the presence of Thamnochortus spp. produces on subdivision a set defined by the presence of Danthonia macrantha*(groups XXIII - XXVII) which is characterised by hot, arid, rocky sites, but the negatively defined group is highly heterogeneous.

Patterns are further illustrated in fig. 15a. In the upper diagram, the relative positions of short division groups are plotted against altitude and insolation gradients, using mean elevation and mean relative insolation as co-ordinates. In the lower, groups are plotted against altitude and moisture gradients, where the latter is based on a hypothetical "moisture index". This "index" was obtained by assigning arbitrary values ranging from 1 to 5 to soil climate ratings, from "very dry" to "very wet". The arithmetic means of these values were then used to fix the position of each group on the soil moisture gradient.

* D. macrantha is now Pentameris macrantha
Fig. 15  Dendogram of association-analysis hierarchy. Nodes are drawn at a level corresponding to the maximum chi-square in the relevant group. Boxes represent short-division groups. Roman numerals are the group numbers and Arabic, the number of plots in the group. Centre line of the box is at a level corresponding to the maximum chi-square for the group.
Fig. 15: Ordination of association-analysis short-division groups along three environmental gradients. (explanation in text)
The upper diagram in fig. 15 is a basically an expression of the physiography of this terrain; there is a broad negative correlation between altitude and relative insolation, and sites at higher elevations are therefore also cool (and vice versa). Nevertheless, the results agree largely with this trend. If this had not been so, and each group had consisted of plots from all altitudes, with variable insolation rates, all would have appeared in the centre of the diagram. The position of groups XI, XII and XIII are particularly striking. These are separated completely from the rest, and may therefore be considered well-defined in terms of altitude and insolation. Groups IV, IX, X and XIX are intermediate. The remainder, however, are not well-defined in this respect and tend to form an indefinite cluster on the graph. Nevertheless, the lower diagram contributes further to the interpretation. Once again, this illustrates the general pattern of conditions here (sites at higher altitudes are moist, those at lower elevations tend to be drier), but the diagram demonstrates also that results of association-analysis are fairly consistent in this respect. In addition, the illustration shows that other factors determine the character of the amorphous group in the centre of the upper diagram. Groups I and III consist of plots from wet, though generally warm or hot, sites at middle and lower elevations, while group IV represents wetter sites than the average on cool areas at high elevations. On the other hand, group XXVI contains plots which are, on the average, a good deal more arid than all others.

At first sight it is striking that group XXIII should contain chiefly plots representing recently burnt vegetation. However,
a closer examination of the data revealed that the group represented sites of fairly diverse character, including those of rock outcrops, fairly level pediment, and of moist sands.

This brief and necessarily crude assessment shows that association-analysis produces groups of plots with characters which correlate broadly with recognisable ecological factors. Nevertheless, the results are not entirely consistent. An effective classification should produce groups at all levels of the hierarchy which are relatively homogeneous in their habitat characteristics. This is not so here. The set produced by the first subdivision, defined by the absence of Thamnochortus spp., contains a number of groups representing arid, rocky sites of lower elevations (such as groups VII and XIII) which should ideally have fallen in the "positive" leg of the hierarchy. Similarly, group XIX should presumably be included in the "negative" leg.

A detailed analysis of the ecological validity of the results is, however, not appropriate at this stage. The technique is based on floristics, and its success or otherwise should be assessed in these terms.

3.5.2. FLORISTIC INTERPRETATION OF ASSOCIATION-ANALYSIS

The mean size of the 85 final groups obtained in the association-analysis is 4.3 quadrats. The largest group contained eight quadrats: this was the only final group with maximum chi-square less than 3.84. Sixty-five (77 per cent) of the final groups contained five quadrats or less, and these accounted for 237 (65 per cent) of the 367 quadrats in the total data set. This
suggests either that communities are very ill-defined here, or that the measure of homogeneity is too sensitive to small differences in composition among quadrats.

There was therefore little point in assessing the results on the basis of the final groups and the preliminary study was limited to the short-division groups.

If the groups produced by association-analysis represent communities, then they should exhibit some distinctive floristic composition. I therefore attempted to detect distinctive composition in the groups by assessing the fidelity of the constant species, i.e. those which tend to occur in all or most of the quadrats in a given group. The concepts of the Zürich-Montpellier school are useful in this approach. Firstly, I have used the association as the fundamental abstract vegetation unit. This is defined as an abstract plant community "... identified by its characteristics species composition (or assemblage) including one or more (local) character or differentiating species" (Meijer-Drees, 1954 in Becking, 1957). Faithful species, that is, species which are restricted or nearly so to the set of quadrats representing a community (a simplified version of the concept, but sufficient for this study) are used to characterize the abstract community. The Zürich-Montpellier school recognizes five qualitative fidelity classes (Becking, 1957), namely:

(a) CHARACTER SPECIES (Kennarten, espèces caractéristiques)

Ⅴ. plant species exclusively or almost exclusively restricted to certain communities (Exclusives; treue Arten; espèces exclusives).

Ⅳ. plant species with a strong preference for a specific community but also occurring in others; however, these then occur sparingly, infrequently or rarely (Selectives; feste
Arten; espèces élector).

III. plant species often occurring in other communities but with their optimum definitely in one community (preferents; holde Arten; espèces préférents).

(b) COMPANIONS (Begleiter) (Companions)

II. plant species without any definite preference for certain communities (Indifferents; vage Arten; espèces indifferents).

(c) STRANGERS

I. plant species rare or accidental in the studied community with their definite optimum outside the given community (Strangères; fremde Arten; espèces étrangères).

Fidelity may also be determined statistically (Goodall, in Greig-Smith, 1964 and Grunow, 1965). Goodall points out that "... testing fidelity of a species to a particular community ... is essentially the same as testing the association between two species in a set of samples." If a species is believed to be faithful to a community A, and community B is the one in which it occurs next most commonly, we have a contingency table

<table>
<thead>
<tr>
<th></th>
<th>Community A</th>
<th>Community B</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Species present</td>
<td>a</td>
<td>b</td>
<td>a + b</td>
</tr>
<tr>
<td>Species absent</td>
<td>c</td>
<td>d</td>
<td>c + d</td>
</tr>
<tr>
<td>Total</td>
<td>a + c</td>
<td>b + d</td>
<td>a + b + c + d = N</td>
</tr>
</tbody>
</table>

which may be tested for departure from random expectation, and which gives an unbiased indication whether or not a species does tend to occur more commonly in community A than in community B" (Greig-Smith, l.c.). Chi-square may be obtained from the table using:

\[ \chi^2 = \frac{(N|ad - bc| - N/2)^2}{(a + c)(b + d)(a + b)(c + d)} \]
Goodall suggested a simpler index of fidelity, the 'indicator value', which he defined as follows:

\[ I.V. = \frac{(a - 0.5)/(a + c) - (b + 0.5)/(b + d)}{(b + 0.5)}/(b + d) \]

\[ = \frac{(a - 0.5)(b + d)}{(b + 0.5)(a + c)} - 1 \]

(This includes Yates' correction for continuity).

The measure is essentially the difference in frequency of the species in the two communities, expressed as a proportion of the lesser value.

The indicator value was used here to assess the floristic discreteness of the association-analysis groups except that the presence of a species in a group was not compared with its presence in the group in which it was next most common, but rather with its presence in the remainder of the data set. Further, the ratio of a species presence in a given group to its presence in the total data set was used as an additional measure of fidelity.

Species in the first three constancy classes in a given group were examined in this way. The constancy classes are defined as follows, in terms of percentage presence: class V, presence of 80 – 100, class IV, 60 – 80, III, 40 – 60, II, 20 – 40, and class I, 0 – 20.

It was immediately apparent that most groups lacked identity. Of groups I – XIV, i.e. those defined by the absence of Thamnochortus spp. aff similis, only groups XII and XIII
contained relatively constant species with fidelity greater than 0.50, and, of the remainder, only group XXIII was thus distinguished.

On the other hand, it was also clear that the association-analysis partition did follow some floristic pattern. The positively defined branch of the hierarchy, i.e. groups XV to XXVII, contained several faithful species in the higher constancy classes (see table 15), though the negatively defined branch had none. Further examination of branches at lower levels of the hierarchy revealed other possibly distinct groups, but as the computation of indicator and chi-square values was extremely laborious, I sought a different approach to the problem.

A two-way table was constructed with species presence listed for each of the short-division final groups in the columns. Species which tended to occur optimally in certain groups or sets of groups were identified and the table redrafted with those species and groups adjacent each other, much as Zurch-Montpellier phytosociologists manipulate their data matrices. The table showed certain sets of groups which included exclusive and selective species and I therefore applied the same procedure to the 85 final groups. The exercise revealed several species associations characteristic of communities on wet and on cool sites, but a number of groups remained in which no good floristic patterns could be detected, though they were obviously different from those already identified. (These were mostly the groups defined by the presence of Thamnochortus spp. aff. similis i.e. those on hotter, drier sites.) As it was clear from field
experience that various communities existed in drier habitats, I decided to seek further information by applying group analysis.

Group analysis is a rapid monothetic divisive classificatory technique, developed by Crawford and Wishart (1967).

**TABLE 15: FAITHFUL SPECIES IN THE POSITIVELY-DEFINED FIRST-DIVISION GROUP (215 PLOTS) PRODUCED BY ASSOCIATION-ANALYSIS**

<table>
<thead>
<tr>
<th>SPECIES</th>
<th>PRES.</th>
<th>FID.</th>
<th>I.V.</th>
<th>FIDELITY CLASS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constancy class V</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pentaschistis spp.</td>
<td>201</td>
<td>0.63</td>
<td>20.88</td>
<td>III Preferent</td>
</tr>
<tr>
<td>Tetraria flexuosa</td>
<td>173</td>
<td>0.69</td>
<td>36.50</td>
<td>III</td>
</tr>
<tr>
<td>Restio nr. dispar</td>
<td>191</td>
<td>0.70</td>
<td>56.82</td>
<td>III</td>
</tr>
<tr>
<td>Thamnochortus spp.</td>
<td>215</td>
<td>1.00</td>
<td>362.96</td>
<td>V Exclusive</td>
</tr>
<tr>
<td>Constancy class IV</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypodiscus aristatus</td>
<td>153</td>
<td>0.80</td>
<td>72.11</td>
<td>IV Selective</td>
</tr>
<tr>
<td>Corymbium glabrum</td>
<td>159</td>
<td>0.79</td>
<td>72.28</td>
<td>IV</td>
</tr>
<tr>
<td>Constancy class III</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anthospermum prostratum</td>
<td>126</td>
<td>0.76</td>
<td>37.74</td>
<td>IV Selective</td>
</tr>
<tr>
<td>Schizea pectinata</td>
<td>125</td>
<td>0.67</td>
<td>10.84</td>
<td>III Preferent</td>
</tr>
<tr>
<td>Tetraria fasciata</td>
<td>123</td>
<td>0.81</td>
<td>53.70</td>
<td>IV Selective</td>
</tr>
<tr>
<td>Danthonia macrantha</td>
<td>113</td>
<td>0.89</td>
<td>72.03</td>
<td>IV</td>
</tr>
<tr>
<td>Tetraria microstachys</td>
<td>108</td>
<td>0.87</td>
<td>60.99</td>
<td>IV</td>
</tr>
<tr>
<td>Metalasia muricata</td>
<td>98</td>
<td>0.92</td>
<td>68.53</td>
<td>V Exclusive</td>
</tr>
<tr>
<td>Tetraria crassa</td>
<td>94</td>
<td>0.82</td>
<td>35.64</td>
<td>IV Selective</td>
</tr>
<tr>
<td>Sympieza articulata</td>
<td>90</td>
<td>0.87</td>
<td>47.30</td>
<td>IV</td>
</tr>
</tbody>
</table>

....../109.
The technique differs from association-analysis '....in that it is an attempt to distinguish the major groups of coincident species and thus searches for gregariousness rather than homogeneity. The method aims, firstly, at being rapid even when the survey is large and secondly, at obtaining an absolute value for the group significance of any intermediate or final set of quadrats.....Thirdly, the method attempts to measure the significance of each species in forming any final grouping and of each quadrat in belonging to any such group.' In addition, '.....it is not only the floristic similarity of the quadrats that is assessed but also their floristic richness.'

Crawford and Wishart maintain that there are two factors which determine the likelihood of a species being contained in a group, the probability of occurrence and the number of species with which it occurs. For a species X the probability of occurrence, and the mean sample density, i.e. the mean number of species present in those quadrats that contain X, are defined respectively as follows:

\[ P_X = \frac{f_X}{N} \]
\[ V_X = \frac{M_X}{f_X} \]

where \( f_X \) = the number of occurrences of species X, i.e. its
\[ M_X = \text{the total number of species occurrences in those quadrats that contain the species X.} \]

Species which occur frequently with a high mean sample density are held to determine an ecological group and the authors used the product of the two factors, i.e.
as a measure of the significance of a species contributing to a group, and termed it group element potential (GEP) of the species. They used $S'_J$, the sum of all GEP values for a given quadrat $J$, as a measure of the group attributes of that plot, i.e. the higher the value of $S'_J$, the more likely will the quadrat $J$ be to include species characteristic of a group. The maximum value $S'_{J_{\text{max}}}$ is obtained when a quadrat contains all the species in the set. Values are rendered absolute for the given group and the set element potential defined as follows

$$S'_J = S'_J / S'_{J_{\text{max}}}, \quad 0 \leq S'_J \leq 1$$

$W'_X$ is redefined so as to obtain an absolute coefficient as follows:

$$W'_X = \frac{P_X.V_X}{\bar{V}}, \quad 0 \leq W'_X \leq 1$$

where $\bar{V} = \text{mean sample density for all the quadrats in the data set.}$

The non-set element potential $\overline{S'_J}$ was defined so that

$$S'_J + \overline{S'_J} = 1$$

Crawford and Wishart then developed '...a measure of the interaction between species and group potential....' which may be used to determine the best species for subdivision of a given group. The following 2 x 2 array may be constructed for a given set of quadrats:

$$\begin{array}{cc}
A & B \\
C & D \\
N - f_X & f_X \\
\end{array}$$

....../111
where $A$ is the sum of non-set element potentials for all the quadrats without species $X$, $B$ is that for those containing $X$, and $C$ and $D$ are the sums of the SEP values for the two subsets. The sum of squared cell deviations from expectation is used as a measure of interaction, and the group is subdivided on the species with the highest value. The measure is calculated as follows:

$$
\mu'^2 = \sum (o_i - e_i)^2 \\
= (A - e_A)^2 + (B - e_B)^2 + (C - e_C)^2 + (D - e_D)^2
$$

where for example, $e_D = fx.\bar{Z}S/N$

This reduces to

$$
\mu'^2 = 4(D.N - f_x\bar{Z}S)^2/N^2 \\
= 4(D - p_x\bar{Z}S)^2
$$

or, after division

$$
= (D - p_x\bar{Z}S)^2
$$

The 'group coefficient' is defined thus:

$$
C = \bar{Z}S/N
$$

Subdivision is halted when $C$ exceeds an arbitrary limit $\phi$.

Group analysis requires about one per cent of the processing time required by association-analysis and provides a classification as good and better (Crawford and Wishart, 1967). I therefore obtained a programme listing from the authors and modified it for a Fortran IV compiler of the IBM 360/50 used by the University of Stellenbosch, (the original programme was written in Fortran IID for an IBM 1620 system). The programme was run
using limits of $\phi = 0.5$ and a minimum subset size of eight quadrats. Presence of species in the final groups was written onto disc for later use.

This run produced 42 final groups - the dendogram is shown in fig. 16. The mean group size was 8.7, but 58 per cent of the quadrats were included in groups of eight or larger. These larger groups represented 19 per cent of the 42 obtained. Thirty-three groups were rated as significant (i.e. had group coefficients exceeding 0.5) and these included 86 per cent of the quadrats in the survey.

The classification corresponded broadly with that obtained by association-analysis. For example, 53 of the quadrats in groups X - XIV (62 quadrats) of the association-analysis formed a subset of the 90 quadrats in groups 15 - 28 of group analysis. All 63 quadrats in groups XXV, XXVI and XXVII formed a subset of group 42 (78 quadrats). The chi-square measure of association between the sets was 12.07 in the first case and 13.34 in the latter. Nevertheless, the correspondence between groups distinguished by the two methods was smaller in other cases and it was evident that the classifications differed in detail.

A computer programme was written to print reordered constancy tables according to lists of the species and quadrats in sequence as I required them. This programme saved much tedious labour. It was used to read off and tabulate the group analysis sets stored on disc, and the subsequent manipulations showed
Fig. 16. Dendogram of group analysis hierarchy. Nodes are drawn at a level corresponding to the group coefficient of a given group. Boxes represent final groups; the upper figure is the group number and lower, the number of plots in the group. Centre line of the box corresponds to the group coefficient value.
that group analysis accounted fairly satisfactorily for the community patterns thought to obtain at Jakkalsrivier.

In order to examine and refine the classification further I subjected the sets of presence data to computer manipulation by means of a programme written by Ceska and Roemer (1971) which is a computer simulation of the Braun-Blanquet table manipulation technique. A version for manipulation of constancy tables was used. The groups were first reduced in average size by raising \( \rho \) to 0.7, as constancy tables cannot be satisfactorily manipulated when there are large disparities in group size (Ceska and Roemer, 1971). The programme was run using the 67 groups thus obtained and the final groups of association-analysis. The results tended to confirm those obtained by prior manipulations but provided useful additional information which I used to draw up a final constancy table for the 42 groups obtained in the first analysis (Table 16). This was used as a basis for the description of communities.

I have used the approaches described above as a means of detecting noda, i.e. groups or sets of groups that contain faithful species (species which fall into fidelity classes III - V, and which have a relatively high constancy). The final table illustrates the combinations of groups and species which define the noda: these noda have been taken as representing abstract communities and the communities have been described on this basis, with reference to the original quadrat data for further floristic, structural and habitat information. Table 16 does not contain a full list of species, for reasons of economy.
and because I felt the data are not sufficiently sound to warrant it (see further discussion below); the table cannot therefore be regarded as an objective presentation of community composition as are those normally published by the Zurich-Montpellier school but it will suffice for this study.

Table 17 shows species constancies of the association-analysis short-division groups with the species arranged as in Table 16.
<table>
<thead>
<tr>
<th>SET NUMBER</th>
<th>3 1 9 6 13 23</th>
<th>2 7 10 9 8 12</th>
<th>13 16 17 18 17 16 25 14 18</th>
<th>21 20 18 24 19 25</th>
<th>42 30 35 18 33 34 37 40 16 29 39 32 15 31</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO. OF SPECIES IN SET</td>
<td>3 4 3 2 3 3</td>
<td>3 3 5 6 4 3</td>
<td>3 3 4 4 3 3</td>
<td>3 3 2 3 3 3</td>
<td>3 4 4 6 7 8 9</td>
</tr>
</tbody>
</table>

| Species characteristic of the *Bacillus* | | | | | |
|-----------------------------------------| | | | | |

| Specie characteristic of the *Corynebacterium* | | | | | |
|-----------------------------------------------| | | | | |

| Species characteristic of the *Streptomyces* | | | | | |
|-----------------------------------------------| | | | | |

| Species characteristic of the *Sarcina* | | | | | |
|-----------------------------------------| | | | | |

| Species characteristic of the *Rhiobacterium* | | | | | |
|-----------------------------------------------| | | | | |

| Species characteristic of the *Propionibacterium* | | | | | |
|--------------------------------------------------| | | | | |

| Species characteristic of the *Aerobacter* | | | | | |
|-------------------------------------------| | | | | |

| Species characteristic of the *Achromobacter* | | | | | |
|-----------------------------------------------| | | | | |

| Species characteristic of the *Acinetobacter* | | | | | |
|-----------------------------------------------| | | | | |

| Species characteristic of the *Proteus* | | | | | |
|----------------------------------------| | | | | |

| Species characteristic of the *Klebsiella* | | | | | |
|-------------------------------------------| | | | | |

| Species characteristic of the *Salmonella* | | | | | |
|-------------------------------------------| | | | | |

| Species characteristic of the *Shewanella* | | | | | |
|-------------------------------------------| | | | | |

| Species characteristic of the *Pseudomonas* | | | | | |
|--------------------------------------------| | | | | |

| Species characteristic of the *Staphylococcus* | | | | | |
|-----------------------------------------------| | | | | |

| Species characteristic of the *Streptococcus* | | | | | |
|-----------------------------------------------| | | | | |

| Species characteristic of the *Streptococcus* | | | | | |
|-----------------------------------------------| | | | | |

| Species characteristic of the *Lactobacillus* | | | | | |
|-----------------------------------------------| | | | | |

| Species characteristic of the *Lactococcus* | | | | | |
|--------------------------------------------| | | | | |

| Species characteristic of the *Lactobacillus* | | | | | |
|-----------------------------------------------| | | | | |

| Species characteristic of the *Lactococcus* | | | | | |
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| Species characteristic of the *Clostridium* | | | | | |
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| Species characteristic of the *Clostridium* | | | | | |
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| Species characteristic of the *Clostridium* | | | | | |
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| Species characteristic of the *Clostridium* | | | | | |
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| Species characteristic of the *Clostridium* | | | | | |
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| Species characteristic of the *Clostridium* | | | | | |
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| Species characteristic of the *Clostridium* | | | | | |
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<p>| Species characteristic of the <em>Clostridium</em> | | | | | |
|--------------------------------------------| | | | | |</p>
<table>
<thead>
<tr>
<th>GROUP NUMBER</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
<th>19</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of species in group</td>
<td>21</td>
<td>2</td>
<td>8</td>
<td>2</td>
<td>5</td>
<td>6</td>
<td>17</td>
<td>15</td>
<td>18</td>
<td>10</td>
<td>15</td>
<td>6</td>
<td>12</td>
<td>24</td>
<td>3</td>
<td>9</td>
<td>15</td>
<td>10</td>
<td>20</td>
</tr>
</tbody>
</table>

### Table 1: Constant Table for Short-Division Association-Analysis Groups

<table>
<thead>
<tr>
<th>Species characteristics of the <strong>Aegopodium</strong></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
<th>19</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. hirsutum</strong></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
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<td>12</td>
<td>13</td>
<td>14</td>
<td>15</td>
<td>16</td>
<td>17</td>
<td>18</td>
<td>19</td>
</tr>
<tr>
<td><strong>A. maritimum</strong></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
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<td>13</td>
<td>14</td>
<td>15</td>
<td>16</td>
<td>17</td>
<td>18</td>
<td>19</td>
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</tbody>
</table>

### Table 2: Specht Characters of the **Aegopodium**

<table>
<thead>
<tr>
<th>Species characteristics of the <strong>Aegopodium</strong></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
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<th>18</th>
<th>19</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. hirsutum</strong></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
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<td>13</td>
<td>14</td>
<td>15</td>
<td>16</td>
<td>17</td>
<td>18</td>
<td>19</td>
</tr>
<tr>
<td><strong>A. maritimum</strong></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
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<td>15</td>
<td>16</td>
<td>17</td>
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<td>19</td>
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</table>

### Table 3: Specht Characters of the **Aegopodium**

<table>
<thead>
<tr>
<th>Species characteristics of the <strong>Aegopodium</strong></th>
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<th>5</th>
<th>6</th>
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<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
<th>19</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. hirsutum</strong></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
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<td>6</td>
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<td>15</td>
<td>16</td>
<td>17</td>
<td>18</td>
<td>19</td>
</tr>
<tr>
<td><strong>A. maritimum</strong></td>
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<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
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<td>19</td>
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</tbody>
</table>

### Table 4: Specht Characters of the **Aegopodium**

<table>
<thead>
<tr>
<th>Species characteristics of the <strong>Aegopodium</strong></th>
<th>1</th>
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<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
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<th>11</th>
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<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
<th>19</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. hirsutum</strong></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
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<td>10</td>
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<td>13</td>
<td>14</td>
<td>15</td>
<td>16</td>
<td>17</td>
<td>18</td>
<td>19</td>
</tr>
<tr>
<td><strong>A. maritimum</strong></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
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<td>9</td>
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### Table 5: Specht Characters of the **Aegopodium**

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3.6 PLANT COMMUNITIES

The communities detected have also been classified according to Fosberg (1967) and formation categories are included in the community descriptions.

(a) PHREATIC COMMUNITIES

Phreatic communities occur along streams and drainage lines and on seepage steps where the configuration of the underlying rock strata causes the water table to lie at or near the soil surface. These habitats occur throughout the catchment though they do not cover much of the area. Soils are generally of the Champagne form but these communities may occur on transitions to the Dundee form which are nevertheless moist or wet and very humic.

Character species are as follows:

- *Elegia thyrsifera*
- *Restio purpurascens*
- *Episcoenus quadrangularis*
- *Carpacoce spermacocea*
- *Centella eriantha*
- *Hypolaena crinalis*
- *Cliffortia graminea*

Other faithful but not constant, and then normally preferential, species are those such as *Chironia decumbens*, *Villarsia capensis* and *Erica curviflora*. The powerful metallic odour exuded by *C. spermacocea* when crushed is characteristic of this vegetation. These communities are designated...
Eleqia thyrsifera - Restio purpurascens communities.

1. Berzelia lanuginosa - Leucadendron salicifolium community.

Subformation category: 1Bl 8(a) Green microphyllus evergreen scrub.

Character species are as follows:

- Berzelia lanuginosa
- Leucadendron salicifolium
- Restio perplexus
- Erica parviflora

B. lanuginosa and L. salicifolium are normally prominent in the shrub stratum which is usually about two to three metres tall, but other shrubs such as Psoralea aphylla often accompany them. Eleqia thyrsifera and, when present, Restio purpurascens also penetrate this stratum.

The ground layer, 30 - 50 cms high, is normally a tangled mass of shrubs and restioid plants, often dominated by Erica parviflora, Cliffortia graminea or both.

This community is found on riparian sites with Champagne or Dundee soils.

2. Brunia alopecuroides - Restio bifidus community.

Subformation category: 1Bl 8(a) Green microphyllus evergreen scrub.

Character species are as follows:

- Brunia alopecuroides
- Restio bifidus
- Restio ambiguus

....../119.
Tetraria punctoria
Ursinia caledonica
Chrysithrix capensis

The shrub stratum, usually 1.0 - 1.5 m tall (though much taller in older stands) is normally dominated by B. alopecuroides but a few stands were sampled where Berzelia squarrosa dominates. This stratum is commonly penetrated by E. thyrsifera and R. purpurascens and sometimes by Chondropetalum mucronatum. The slender erect subshrub Ursinia caledonica is also present here. The ground layer is often a dense tangled mass of ericoid shrubs and graminoid or restioid plants, but tussocks and hummocks (Tetraria spp., Epischoenus quadrangularis and, especially, R. ambiguus in the former case and Hypolaena crinalis in the latter) are normally prominent.

The community is found on seepage steps, usually on fairly level sites, where Champagne soils are typical.

Fig. 17. A stand in the Brunia alopecuroides - Restio bifidus community. The erect shrubs with slender branches are B. alopecuroides; the tall stout reed-like plants are Chondropetalum mucronatum
The *Elegia thyrsifera - Restio purpurascens* communities resemble others reported in the literature. The *Berzelia lanuginosa - Osmitopsis asteriscoides* community described by Werger et al (1972) has character species common to the Jakkalsrivier communities and include *Elegia thyrsifera, Cliffortia graminea, Berzelia lanuginosa, Leucadendron salicifolium* and *Neesenbeckia (Tetraria) punctoria*. The Jakkalsrivier communities also have affinities with the *Restio - Chondropetalum* Tussock Marshes distinguished by Boucher (1972) in the Kogelberg, which include as typical species *Restio purpurascens* and *Villarsia capensis*. Boucher's *Berzelia - Pseudobaekcia* Tall Fynbos of rocky streams has affinities (*Berzelia lanuginosa, Leucadendron salicifolium* and *R. purpurascens* are among the typical species.)

The *Berzelia - Osmitopsis* Seepage Scrub described by Taylor (1969) on similar habitats at Cape Point has few floristic features in common with the communities at Jakkalsrivier.

(b) COMMUNITIES OF THE UPPER COOL, STEEP SLOPES

A distinct set of communities occur on the steep south-facing slopes with low insolation ratios. In spite of the steep slopes the soils are fairly stable due to the anchoring effect of the dense root mat and the configuration of the underlying rock strata (which are close to the surface - debris horizons are normally non-existent). Soils are turfy Mispahs, and are generally moist. Character species are *Willdenowia sulcata* and *Protea cynaroides*. No communities described in the literature correspond to these.

Subformation category: 1C1 2(a) Microphyllus evergreen dwarf scrub.

Character species are as follows:

- *Thamnochorus pulcher*
- *Erica lutea*
- *Corymbium latifolium*
- *Thesium ericaefolium*
- *Aspalathus ciliaris*

This community comprises very short vegetation, only 20 - 30cm high from which emerge occasional ericoid or sclerophyll plants such as *Erica lutea* and *Leucadendron gandogeri*, which in these eight-year-old stands reach a height of some 60 - 80 cm. *Hypodiscus aristatus* is also sometimes prominent, attaining about the same height.

The canopy is a mixture of ericoid shrubs, chiefly *Erica hispidula*, and graminoid and restoid species among which *Tetraria fasciata*, *Pentaschistis colorata*, *Chondropetalum deustum* and *Thamnochorus pulcher* are prominent. *Berzelia abrotanoides* is conspicuously absent from these stands.

The community is confined to the debris slopes at the foot of the steep scarps; southerly aspects prevail and the sites are relatively cool. Soils are somewhat turfy but comparatively dry Mispahs, slightly terraced, and littered with small white quartzite chips.
Fig. 18. *Willdenowia sulcata* - *Erica brevifolia* community.

The taller shrubs with dark foliage are *Protea neriifolia*, those with lighter foliage, *Leucadendron xanthoconus*.
the canopy to a height of between one and two metres. *Elegia racemosa*, 75 - 90 cm tall, is very abundant. The canopy, 40 - 50 cm high, is often dominated by *Erica hispidula* but is intermingled with the graminoid / restoid layer, where *Pentaschistis colorata* predominates.

The community is found on the steep scarp on turfy Mispahs where some seepage prevails.

It has strong floristic affinities with the *Willdenowia sulcata* - *Erica brevifolia* community. Species common to both communities are *Erica coccinea*, *E. transparens*, *Leucadendron spissifolium*, *Erica calycina* var. *periplocaeflora*, *Phylica* sp. cf *P. diffusa* and *Myrica diversifolia*.

The *Willdenowia sulcata* communities emerged as a rather heterogeneous group. However this habitat is characterized by small but abrupt variations in slope, aspect and soil moisture conditions, special microhabitats occur on and in the vicinity of boulders and rock faces and these factors contribute to subtle floristic variations which must have affected the classification.

The information in the constancy table suggests the existence of another community characterized by *Phylica* sp. of *P. diffusa*, *Anemone capensis*, and *Ficinia ramosissima*, but the evidence is too sparse to justify its description.
The Willdenowia sulcata – Klattia partita community shares some of the character species of the Elegia thyrsifera communities and this is no doubt a reflection of similarities in their habitats.

The canopy of the 10-year-old Willdenowia sulcata communities is a mixture of ericoid dwarf shrubs and graminoid / restioïd components. However, a few stands were found that had survived the 1958 fire (and apparently dated from 1949) and in these the dwarf shrubs had formed a closed canopy, dominating the herb layer. There was nevertheless little difference between the canopy heights of the young and old stands.

(c) COMMUNITIES ON SHALE SOILS

6. Tetraria bromoides – Erica plukeneti community.
Subformation category: 1B1 4(a) Mesophyllous evergreen broad sclerophyll scrub.

A community which differs rather strongly from all others here is found on the Hutton and Clovelly soils derived from shales. Character species are as follows:

Tetraria bromoides
Erica plukeneti
Elegia juncea
Hypodiscus albo-aristatus
Peucedanum ferulaceum
Aster reflexus
Protea neriifolia
Gnidia viridis

Others, not evident in the table, include Cliffortia
eriocephalina, Protea lacticolor, Tetraria fimbriolata, Aspalathus millefolia, Tharninophyllum multiflorum, Lachnospernum umbellatum and Gerbera asplenifolia.

This community has a rather well-developed structure with a shrub stratum about 1,0 - 1,5 m tall (but up to 4 - 5 m in older vegetation) dominated by sclerophyll shrubs, typically Leucadendron xanthoconus. An intermediate ericoid shrub layer about 60 - 80 cm tall is often present, with Erica longifolia prominent. The dwarf shrub stratum intermingles with the graminoid/restioid layer and together these form a dense stratum 40 - 60 cm tall. Ericoid shrubs such as Erica hispidula are prominent or dominant but usually the graminoid/restioid element is equally so.

A striking phase of this community is that where Protea lacticolor dominates. The shrub canopy in the stands which had survived since the 1949 fire reached a height of 5 m in places.

Fig. 19 shows a stand in this community.

The Tetraria bromoides - Erica plukeneti community has rather marked affinities to the Protea lepidocarpodendron Tall Fynbos Association described by Taylor (1971), sharing such character species as Tetraria bromoides, Tetraria fimbriolata, Eleqia juncea and Hypodiscus albo-aristatus. There is also some resemblance to the Protea - Gerbera Dry Short Fynbos in the Kogelberg (Boucher, 1972), which is dominated by Leucadendron xanthoconus and typically contains Tetraria bromoides; the
Berzelia - Leucadendron Tall Moist Fynbos is also similar in some respects but the 'characteristic' species listed for these two communities correspond little with those at Jakkalsrivier.

(d) COMMUNITIES OF HOT DRY SITES

The remainder of the area is covered by vegetation of communities on warm to hot sites with dry Cartref or Mispah soils, or on the rocky land-class. Slope is variable as is aspect, but aspects in the southerly sector are rare.

Character species of this group are as follows:

Metalasia muricata
Danthonia macrantha
Erica pulchella
Tetraria microstachys
Helichrysum vestitum
Hypodiscus aristatus

Other species which are typical but occur also in the Tetraria bromoides - Erica plukeneti community are:

Erica longifolia
Ficinia filiformis
Corymbium glabrum
Anthospermum prostratum
Thesium euphrasioides
Tetraria fasciata
Chrysithrix junciformis
Agathelpis dubia

Thamnochortus spp. aff. T. similis (i.e. T. gracilis and
rarely, *T. similis, T. dichotomus* and *T. guthriae*) are also restricted largely to this group of communities.

*Tetraria thermalis*, though not constant in the table, is conspicuous in these communities and if not present in a quadrat is normally to be found close by. I have therefore designated these the *Tetraria thermalis* - *Hypodiscus aristatus* communities.

This group has a rather uniform structure with a canopy of ericoid shrubs more or less intermingled with the graminoid / restioid component. It is a short vegetation dull green-brown in colour except when the abundant pink Ericas are in flower, characteristic of the dry mountain slopes at medium altitudes in the Caledon district.

The *Tetraria thermalis* - *Hypodiscus* community seems to have fairly marked affinities to the Upland Mixed Fynbos Association at Cape Point (Taylor, 1969), which contains exclusives such as *Tetraria thermalis, Corymbium glabrum, Lobelia pinifolia, Erica corifolia*, and selectives such as *Danthonia macrantha* and *Erica pulchella* - species characteristic of the Jakkalsrivier communities. They are also superficially similar to the *Thamnochortus gracilis* - *Hypodiscus aristatus* community described by Werger et al (1972) which, in common with the Jakkalsrivier communities, contains the character species *Thamnochortus gracilis, Hypodiscus aristatus* and *Staberoha cernua*.
7. **Staberoha cernua - Restio tenuissimus community.**
Formation category: lHl 3 Open evergreen microphyllous dwarf scrub.
Character species are *Restio tenuissimus* and *Tetraria compar*.

This community is distinguished chiefly by the abundance of graminoid species in the canopy, which is dominated by *Staberoha cernua* and *Tetraria* spp. about 25 - 40 cm high. Dwarf shrubs such as *Erica hispidula*, *E. pulchella* and *Blaeria dumosa* may be prominent but never dominate. The community is restricted to Cartref soils on gently sloping land.

This community is illustrated in fig. 20. It bears little resemblance to the *R. tenuissimus* community described by Werger et al (1972).

8. **Staberoha cernua - Phylica lasiocarpa community.**
Subformation category: lCl 2(c) Microphyllous evergreen dwarf scrub.
Character species are *Staberoha cernua*, *Phylica lasiocarpa* and *Mimetes cucullatus*.

This community has a rather variable structure. The shrub stratum, generally about 1 m high, may be strongly developed when such sclerophyll species as *Leucadendron gandogerii* and *L. xanthoconus* dominate, but it is often sparse. *Berzelia abrotanoides* and *Mimetes cucullatus* occur regularly but sparsely in this layer. Once again, the dwarf shrub and graminoid/restioid strata are intermingled to form a canopy about 30 to 45 cm high. *Blaeria dumosa* and *Erica hispidula* are usually prominent and may
Fig. 20. *Staberoha cernua* - *Restio tenuissimus* community. The prominent herb with white inflorescences is *Helichrysum vestitum*.

Fig. 21. *Erica corifolia* - *Restio egregius* community. The robust sprawling sedge before and beyond the figure is *Tetraria thermalis*; dark erect shrubs are *Erica longifolia* and the slender erect reed-like plants are chiefly *Restio* sp. nr. *R.dispar* and *R.egregius*. 
sometimes dominate. Restio sp. aff. dispar is common but the graminoid/restioid component is dominated by tufted plants such as Staberoha cernua, Chondropetalum deustum, Pentaschistis colorata and Tetraria spp. Cartref soils and slightly lower potential insolation rates are characteristic of the sites occupied by this community; slopes are moderate and rock scattered or absent.

Subformation category: lCl 2(c)Microphyllous evergreen dwarf scrub.
Character species are as follows:

Erica corifolia
Restio egregius
Chondropetalum hookerianum
Erica sessiliflora
Sympieza articulata
Helichrysum sesamoides
Agathelpis dubia
Lobelia pinifolia

The community has a simple structure where ericoid dwarf shrubs and graminoid/restioid components intermingle to form a canopy about 40 to 60 cm high. This canopy is dominated by ericoid dwarf shrubs, especially Sympieza articulata though Erica hispida, E. pulchella and Philippia leeana may also at times be prominent. Hypodiscus aristatus, Restio egregius, Restio sp. aff. R. dispar, Thamnochortus spp., Pentaschistis spp. and Danthonia macrantha are prominent graminoid/restioid species. The Restionaceae tend to emerge from the canopy to a height of
about one metre and give the vegetation a characteristic reed-like appearance.

On very hot, dry, rocky sites, *Erica longifolia*, which reaches a height of about one metre, may dominate.

This community is the most extensive in the catchment. It is confined to hot dry rocky sites with moderate slopes. Soils are skeletal Mispahs. A typical stand is illustrated in fig. 21.

Formation category: 1Ml 3 Evergreen orthophyll short tussock grass.
Character species are as follows:

- *Leontonyx spathulatus*
- *Roella incurva*
- *Willdenowia humilis*
- *Indigofera glomerata*
- *Centella difformis*

This is a rather ill-defined community with a variable structure but with the canopy normally dominated by tufted graminoid and restioid plants. Ericoid shrubs are absent or sparse. The prevalence of *Tetraria compar* indicates floristic relations with the *Staberoha cernua* - *Restio tenuissimus* community. It occupies sandy sites with rocks absent or varying from sparse to abundant. It is characteristic of disturbed sites. Many of the quadrats from the recent burn are included here as are others where deflation between the tufts is evident.

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11. Rochea coccinea - Prismatocarpus schlechteri community

Formation category: not classifiable (microphyllous dwarf scrub, or sclerophyll grass).

Character species are Rochea coccinea, Prismatocarpus schlechteri and Cliffortia atrata.

This is a loosely defined community found on hot, rocky ridges and amongst large boulders on exposed sites. The outcrops and boulders ensure a wide variety of habitats which gives the community its peculiar composition. The rock surfaces are covered in lichens: an Umbillicaria sp. is characteristic. Shallow crevices are often occupied by such specialized species as Bryomorphe lycopodioides, Erica petrophila and Teedia lucida. Other species which are found in clefts and crevices (and which are preferentials in this community) are Asparagus compactus, Rumohra adiantiformis, Myrsine africana, Liparia splendens subsp comantha and various species of the Mesembreanthemae. Olea capensis subsp. capensis and Raspalia microphylla occur at Jakkalsrivier only in this community and then rarely. Species atypical of this habitat, such as Blechnum punctulatum and Asparagus scandens, occur under sheltered overhangs where water run-off from the rocks ensures adequate moisture.

Other selective or preferential species are Ficinia elongata, Selago serrata, Clutia alaternoides, Diospyros glabra and Pentameris macrocalycina.

The community has a variable structure depending on exposure and the disposition of rocks and boulders.
3.7 EVALUATION

The four major community types have been mapped and are shown in fig. 22. Comparison between this and the insolation map in fig. 9 shows the clear influence of relative insolation on the distribution of communities, with the influences of geology and soil moisture superimposed. The communities as described agree well with what was seen in the field, though not all have been identified and not every one has been clearly described.

The performance of the approach I used was, however, not satisfactory chiefly because of the great amount of work required to achieve the results. This is partly a result of lack of training and experience but also of the faults inherent in the method. The procedure must therefore be assessed in detail.

3.7.1 SAMPLING AND SAMPLE UNITS

The disadvantages of a rigid systematic sampling procedure were soon apparent. Plots frequently straddled ecotones and where transitions between phytocoenoses are sharp, as, for example, between the Brunia alopeceuroides - Restio bifidus and Erica corifolia - Restio bifidus communities, the floristic content of the plots was obviously heterogeneous. Problems also occurred when plots chanced to occur on large boulders, on disturbed ground or on other sites subject to extreme local habitat variation which induce an atypical or a mixed complement
Fig. 22. Diagrammatic presentation of distribution of major communities at Jakkalsrivier. Dots represent stands of the *Tetraria thermalis* - *Hypodiscus aristatus* communities, circles, those of the *Willdenowia sulcata* communities, triangles, the *Tetraria bromoides* - *Erica plukeneti* communities, and squares, the *Elegia thyrsifera* - *Restio purpurascens* communities.
of species. These anomalies probably account for a large proportion of the problems encountered during interpretation of the results of the classifications, and for the rather large number of poorly characterized groups obtained.

The popular solution to the difficulties outlined above is to reject obviously transitional or atypical sample units and to replace them with others selected by some objective procedure (Scheepers, 1969 and Boucher 1972). However, this introduces an element of subjectivity which tends to subvert the arguments for an objective sampling procedure. This method is usually coupled with stratified sampling where the strata are mapped physiographic, structural and photographic tone-textural classes. However, in fynbos ecosystems variation within such strata is wide and local extreme habitat differences remain problematic, particularly on rocky landscape facets (which are prevalent).

The advantages of objective sampling strategies in floristic classifications seem few, the chief being that they ensure that the study area is thoroughly traversed, and correlations between variables may be determined by normal probabilistic statistics. Nevertheless, the approach represents an unnecessary application of the principles of probabilistic statistics. The classificatory procedures do not require a statistically unbiased sample and the results are dependent entirely on the information content of the individual sample units. The phytosociologist who has chosen classification (as opposed to ordination) is less concerned with variation within and between communities than with distinguishing and characterizing the communities in the first place.

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Thus selection of sample stands that are good examples of the vegetation types under study will serve his goals more efficiently than would a set of units which by, the very nature of the sampling strategy (an unbiased sampling procedure is a priori aimed at covering most of the variation in the sample universe), is a confusing representation of the categories he seeks to delimit. It may be argued that an objective sample serves dual objectives, but it is clear from this and other studies (e.g. Taylor, 1969) that this leads to inefficiency. It would be more efficient to determine, describe and map the communities by means of a selected sample and thereupon investigate quantitatively the variation of habitat and vegetation parameters within and between communities with objective samples, stratified on the basis of the classification. This is not to say that the phytosociologist should not avoid bias in his sample. He should do so by rigorous discipline, rather than through mechanical probabilistic procedures. The implication is that a floristic classification is one of the primary steps in the study of vegetation which should precede rigorous quantitative studies.

The sample size was also too large. The classification and description of these communities is based chiefly on the information content of the sample units rather than on the means and dispersion of a set of continuous variables. The community need be represented only by a limited number of sample units - about four to ten would probably be sufficient. Here, the Erica corifolia - Restio egregius community is represented by about 80 plots. The procedure was thus obviously inefficient and a strategy which does not allocate sample units in proportion
to the area of a community would be preferable.

In this kind of study, interpretation of results depends heavily on scrutiny of the information contained in individual sample units or in sets of units and a large sample considerably increases the labour involved. It is practically impossible to verify the information by subsequent checks in the field.

It is now conventional to use rather large plots commonly 50 to 100 square metres in area (Taylor, 1969, Werger et al, 1972; Boucher, 1972) in phytosociological surveys of the fynbos. There is little clear evidence that the units used here were too small. A larger unit would have increased the frequency of quadrats with a mixed complement of species, but aside from this comment nothing concrete can be added towards a resolution of the problem of plot size.

In most cases the plot dimensions appeared satisfactory except where elongate stands were sampled (as in the phreatic communities) where narrower plots would have served to avoid inclusion of fragments of adjoining communities.

The information recorded for each sample unit was adequate, but the record could have been improved considerably in several ways. The greatest problem was that of species identification, partly because one cannot always identify each species positively, but also because it is impossible to have unknown species identified promptly and several unidentifiable or indefinite taxa occurred. These problems are likely to persist for some time. Some species
were omitted from the lists used in the computer analyses for the above reasons but also because I thought initially that some would not be recognized in certain seasons. Subsequent experience showed that many, such as *Watsonia*, *Drosera* and inconspicuous species of Compositae could profitably have been included in the lists.

Estimates of abundance, though not required in the computer procedures used, could have contributed immensely to subsequent interpretation and permitted further refinement of the classification. Even inexperienced observers should allocate cover-abundance estimates to the species listed in quadrats.

3.7.2 CLASSIFICATION PROCEDURES

Neither of the classificatory procedures used here produced immediately intelligible results, nor could either be used without further manipulation to refine the classification and to identify the communities distinguished. The hierarchies produced by both methods did correspond to the natural order in a broad way: the first division (identical in both cases) separated a group which corresponded closely to the set of *Tetraria thermalis* - *Hypodiscus aristatus* (quadrats in the positively defined branch) from a heterogeneous group which was then partitioned into a subset representing chiefly the *Willdenowia sulcata* - *Protea cynaroides* communities, and another corresponding well to the *Elegia thyrsifera* communities. At lower levels, however, the partition is confused by misclassi-
fications, both of groups and of individual quadrats, as shown by examination of table 17. This partly due to the monothetic system used, which causes groups or quadrats to be widely separated in the terminal branches of the dendogram as a result of chance occurrence of a dividing species in quadrats, and partly because the dividing species has no phytosociological significance. Thus, though the monothetic systems used provide an effective primary partition of the data set, the results can only be regarded as a preliminary step in the classification and description of the vegetation. Identification of groups of diagnostic species and then of noda must follow. This would correspond to application of inverse association-analysis and nodal analysis (Williams and Lambert, 1961; Lambert and Williams, 1962), though other procedures could be followed. The Williams and Lambert procedures were not used in this study as operative programs were not available and the methods are costly to use.

Ideally, interpretation of objective classifications should proceed by determination of similarity between groups or between quadrats or both. These data should then be used to ordinate the groups. An analogous procedure should be followed for detection of similar groups of species. This information should then be used to set up constancy tables which illustrate the composition of groups and the differences and similarities between groups. Characterization and description of groups may then be based on these tables. I achieved this in my study by the manipulation of constancy tables rather than by computer routines chiefly because of the lack of suitable computer programmes and of expert advice. A programme was written for
calculation of similarity between groups by different measures but did not operate successfully in time for completion of this report. There is no doubt that skilful use of appropriate electronic data processing routines would considerably hasten progress in studies such as this.

The classificatory procedures used here produced similar results but differed in efficiency. Whereas, for example, group analysis produced one group of 78 quadrats (group no. 42) which corresponded to the *Erica corifolia* – *Restio egregius* community, association-analysis partitioned a similar set into thirteen final groups (derived from short division groups nos. XXV, XXVI and XXVII). The latter method tended to over-classify and group analysis is to be preferred for this reason and also because it requires far less processing time.
3.7.3 CONCLUSION

Several improvements in the approach to classification of fynbos communities applied in this study are suggested by experience during the survey and the results obtained.

Firstly, objectivity in sampling must be obtained by means other than the random or mechanical allocation of sample units. Randomness is certainly not necessary as unbiased estimates of sampling errors are not a primary requirement in this kind of study, and the classificatory procedures are not based on any mathematical model of the population of stands or phytocenoses which comprise the communities. The need for an objective sample is two-fold: (a) the different communities in the study area should be adequately represented, and (b) the sample units should be typical examples of the phytocenoses in the communities present. The practice of first draughting a map of physiographic, physiognomic and tone-texture classes from air photographs goes a long way toward the first requirement, but presupposes availability of suitable photographs. One of the greatest drawbacks in this survey was the fact that the available air photographs were totally inadequate to the needs; good photographs would speed work considerably and, where suitable photographs are not available, surveys of this kind should be preceded by special air photography flights.

Objectivity could be further ensured by plotting sample units on the map at locations selected to represent the various categories detected on the photographs and located on sites.
apparently uniform with respect to the features observed on the image. However, the system devised in the office must not be followed rigidly in the field. The surveyor must be free to reject units which are atypical or visibly heterogeneous in habitat, structure and floristics and replace these with quadrats in homogeneous stands representative of the category demarcated on the map. If the map category is seen to contain more than one type of vegetation, the sample should be supplemented with additional units until it adequately represents the types distinguished. Sampling is dependent to a large degree on the training and experience of the observer and it is unfortunately true that the strategies normally applied in statistical studies are no substitute.

The only rule applicable to the question of sample size is that of flexibility but it would be governed by the number of (putative) communities encountered during a survey and therefore, indirectly, by the number of categories demarcated on the map. The average worker may find it difficult to handle a sample of more than 50 to 100 units in a given study, but this figure could be much increased by improved data handling techniques.

The normal floristic data set as recorded for sample units by the Zurich-Montpellier phytosociologists is simple to collect, amenable to fairly refined classifications in the fynbos (Werger et al, 1972) and may be used in computer systems where semi-quantitative (discontinuous) data are required (Coetzee and Werger, 1973). Though the inexperienced worker may have

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difficulty in assigning cover-abundance ratings (and these will very likely differ quite strongly from those of a trained observer), I have found that one soon becomes accustomed to making such decisions. This record contains so much more useful information than a bare list of species that it should always be used as the minimum data set for a survey. Species identification remains an intractable problem best solved (and then only partially) by quickly assembling a good reference collection.

The question of the habitat record requires closer analysis. The data assembled here cannot be expected to reveal the subtle relations between vegetation and site but obvious relations may be more securely established if a good representation of the critical factors is recorded. Probably the most comprehensive checksheet of habitat features to be scored, classified or measured at the sample site is that used by Emberger and his associates at Montpellier (Godron, 1968). A modification of this form would probably serve admirably for use in the fynbos.

Rapid progress depends as much on an effective data handling system as on a sound data-gathering system. All floristic and site data should be digitally coded as soon as possible after completion of fieldwork to eliminate manual data handling and computation at the earliest stage in the task - most of the time in these studies is wasted on laborious hand computation and manipulation. The coded records
should then be filed on computer magnetic tape or disc. Routines must be written which allow easy modification of the records and extraction of sets of records by quadrat set or by floristic category. If the results of this study are a good guide, it appears that it is immaterial what classification routine is used, as the techniques serve only for a preliminary reduction of the total data set into more or less homogeneous subsets whose character and relations must still be identified. It is important however that the programmes used should be modified and expanded so that the suite includes provision for the following:

(a) a routine to read the data from the files and transpose the records for the main programme, if necessary,
(b) calculate such synthetic characters as species constancy, fidelity and indicator value for each group,
(c) summarize habitat data for each group, preferably in terms of simple statistical parameters such as the range and median, and histogram data,
(d) write these and data on the composition of the groups (species presence) onto new files on disc or tape,
(e) calculate and print a table of similarities between groups and execute a simple ordination of groups, by principle components analysis or the simpler principle axis ordination used by van der Maarel (1969).
Groups of possible diagnostic species should then be detected perhaps by such techniques as inverse association-analysis or by hierarchiacal syndrome analysis, which has been successfully applied to fynbos data (Coetzee and Werger, 1973).

This information may then be used by the phytosociologist for interpretation and description on the basis of releve or constancy tables, ordered according to the ordination of the groups detected and the sets of diagnostic species. For this purpose he must be supplied with a programme which enables him to use the computer as a rapid sorting and printing machine.

His information back-up could be further supplemented by subjecting the floristic records to the computer simulations of the Braun-Blanquet table method developed by Ceska and Roemer (1971) and Spatz and Siegmund (1970).

It would benefit the phytosociologist immensely if he were to become familiar with the elements of computer programming as this would permit more flexible application of his suite of programmes, but he must have access to an expert programmer to whom he can refer problems outside his sphere of competence. He would also benefit if he had access to an interactive processing system, preferably using BASIC, so that on-line control over his manipulations is possible.
CHAPTER 4
CONCLUSION

The Jakkalsrivier catchment experiment has unique value, not primarily because the interactions between land-use and catchment resources are studied, but because this is the only site in the country where a natural montane fynbos ecosystem is monitored in detail. The project therefore has intrinsic value in that information will be forthcoming which will contribute to a better understanding of such ecosystems in general. It is therefore important to define the ecosystem as accurately and closely as possible to permit valid extrapolation to others that are similar. This study represents a first step in such a definition.

The mountain ecosystems of the Cape folded belt are recognized as unique but have never been adequately characterized and an attempt at such a description is beyond the scope of this study. However, a superficial description is necessary to place the results in perspective.

The landscape reflects the dominant influences of the orogenic folding and faulting processes and the subsequent action of geomorphic processes on resistant rock formations. The hillslope elements (crest, scarp, talus slope and pediment) prevail, though pediments are usually small. Alluvial or colluvial fans and cones are frequently conspicuous. Stream depositional features such as river terraces and floodplains are minor features or absent and wind erosion is seldom notable;
where it does occur it is normally restricted to local deflation. The landscape is usually dominated by the influence of differential weathering and mass-wastage, typically shown in steep talus slopes with active talus and rock creep. Rills and gullies are usually rare. Periodic catastrophic combinations of water erosion and the force of gravity give rise to large fans on the pediments or to rock-streams or -glaciers.

These geological and geomorphic factors combine with the Mediterranean-type climate to control other subordinate ecological factors.

Soils are predominantly skeletal lithosols, though fairly well-developed profiles may be found where material accumulates on plateaus, necks and pediments. The characteristically low pH, nutrient and clay levels resulting from the nature of the parent material and leaching by high moisture fluxes during winter frequently give rise to poor, dystrophic soils. Dystrophic organic soils, though never extensive, are often characteristic in that they occur scattered throughout the landscape.

The profile is usually very porous but drainage and variations in depth to bedrock cause wide fluctuations in soil moisture.

Soil factors and mesoclimate, which is governed largely by the interaction between geology and macroclimate, are the major influences governing distribution of plant communities in a
given area. The altitudinal complex gradient (where the primary variables are temperature, with a lapse rate of 6.7°C per 1000 m in the International Standard Atmosphere, and precipitation, which increases approximately 150 mm per 1000 m rise in altitude) is a principle factor determining variations in local climate but is confounded by the insolation gradient, which is negative on uniformly concave slopes but variable or even positive on concavo-convex or broken slopes, by variations in slope and aspect and by the shading and sheltering influences of scarps and defiles.

Superimposed on this pattern of controlling and dependent factors (terms as used by Jenny, 1961) is the influence of fire which in many ways tends to obscure their effects.

It is symptomatic of the state of knowledge about the fynbos that vegetation patterns have not yet been related to ecological gradients in a general way. Marloth (1908), Adamson (1938) and Taylor (1963) have discerned various fynbos types and described them briefly as functions of ecological factors, but these attempts are based on observation and not on careful study. The Cape mountains are not high (maximum elevation about 2330 m and maximum relief about 1700 m) so that zonation (in the sense of discernable vegetation change along the altitudinal gradient) is not distinct and is not associated with major changes in community structure. Such zonation can be seen. On the Langeberg and coastal ranges of the Southern Cape, for example, a tall proteoid fynbos, usually dominated by Leucadendron
eucalyptifolium (equivalent to Adamson's Sclerophyll Bush or Phillip's Hygrophyllous Macchia) occurs at lower altitudes on the seaward slopes and is succeeded at higher elevations by short ericoid fynbos (like Adamson's Mountain Bush). The sequence is repeated at higher elevations on the northern slopes of the same ranges and on the southern slopes of inland mountains. However, true vegetation zones or formations, i.e. altitudinal belts ('plant communities that are associated with altitudinal changes in climate and which correspond, in a general sense, to the zonal vegetation of level areas...'), the zonal vegetation being the vegetation characteristic of a given climatic zone and corresponds closely with the concept of formation - Walter 1971), are not present as they are to be found on tropical mountains (e.g. Hedberg 1951) or even like those in the Natal Drakensberg (Killick, 1963). This absence of altitudinal belts is probably one of the major reasons why no thorough descriptive account of fynbos vegetation has yet appeared.

Two major categories of Cape mountain fynbos ecosystems may be recognized. The first is warmer, less humid and with a more pronounced contrast between winter and summer climate. Land forms are dominated by high cliffs and large bouldery fans deposited by mass wastage. Talus and soil creep is very active on the debris slopes; soils are often more fertile and are brown or reddish rather than grey in colour. Protea arborea and Leucadendron salignum are often prominent elements of the vegetation. The mountain ranges of the north and west and inland of the coastal ranges are typically of this kind. The
second category is characterized by a cooler humid climate. Slopes are steep but cliffs are not prominent and the debris mantle more stable; colluvial fans are rare or small. Black, grey or even white soils predominate; they are normally dystrophic. Waters of streams and rivers are stained brown by humic acids and aquatic ecosystems are also dystrophic. Jakkalsrivier is an example of this latter type, and the vegetation shows zonation arising from the important ecological gradients.

However, it seems that at this stage no more can be said. The Kogelberg mountain ecosystem described by Boucher (1972) is similar in a general way to that here, yet it has not been possible to relate the communities closely to those he describes. Climatic data from Table Mountain summit indicate that the climate there is cooler (with effective temperature of 12.5°C - Stuckenberg, 1969) and more humid (see climatic diagram in Walter, 1971) than that at Jakkalsrivier. There are no other data from similar stations that show which of the range of mountain climates in the Cape, Jakkalsrivier represents. A proper perspective must await a general survey of the Cape fynbos and establishment of further mountain meteorological stations.

However, it is true that this study does present information of value in the further investigation of mountain fynbos and, in addition, the results must contribute to improvements in the necessary research techniques.


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APPENDIX A: PROVISIONAL LIST OF THE FLORA AT JAKKALSRIVIER.

The flora at Jakkalsrivier has been collected as far as possible. Specimens are stored in the Jonkershoek Forest Research Station herbarium (JF) but have been duplicated as far as possible in the National Herbarium at the Botanical Research Unit, Stellenbosch (STE).

Specimens were identified at the National Herbaria, Stellenbosch and Pretoria, the Bolus Herbarium, University of Cape Town, and the Compton Herbarium, National Botanic Gardens, Kirstenbosch. I have followed the nomenclature used by these institutions.

Pteridophyta have been arranged according to Schelpe (1969). Genera of the Gynnospermae and Angiospermae are arranged and numbered according to the Englerian system as used by De Dalla Torre and Harms (1958). Only pteridophytes and spermatophytes are included in the list.

Exotic species are marked with an asterisk.

PTERIDOPHYTA

LYCOPODIACEAE

Lycopodium carolinianum L.

L. complanatum L. subsp. zanchophyllum (Wilce) Schelpe

OSMUNDACEAE

Todea barbara (L.) Moore

SCHIZAEACEAE

Schizaea pectinata (L.) Smith

S. tenella Kaulf.

GLEICHENIACEAE

Gleichenia polypodioides Smith
HYMENOPHYLLACEAE

Hymenophyllum capense Schrad.
H. tunbridgense (L.) Smith

DENNSTAEDTIACEAE

Pteridium aquilinum (L.) Kuhn

ASPIDIACEAE

Ruhmohra adiantiformis (Forst.) Ching

POLYPODIACEAE

Polypodium vulgare L.

ASPLENIACEAE

Asplenium aethiopicum (Burm.) Becherer

LOMARIOPSIDACEAE

Elaphoglossum acrostichoides (Hook.) Schelpe

BLECHNACEAE

Blechnum capense (L.) Schlechtd.
B. punctulatum Sw.
B. tabulare (Thunb.) Kuhn

SPERMATOPHYTA

GYMNOSPERMAE

CUPRESSACEAE

Widdringtonia cupressoides (L.) Endl.

ANGIOSPERMAE - MONOCOTYLEDONAE.

GRAMINEAE

175 Pennisetum macrourum Trin.
201 Ehrharta capensis Thunb.

E. dodii Stapf.
E. ramosa Thunb. var. aphylla (Schrad.) Gluckman
E. rehmannii Stapf. var. filiformis Stapf.
E. setacea Nees
GRAMINAEE (cont.)

201 Ehrharta tricostata Stapf
265 Aira cupaniana Juss.
280b Pentaschistis aroides (Nees) Stapf
   P. aristidoides (Thunb.) Stapf
   P. colorata Stapf
   P. curvifolia (Schrad.) Stapf
   P. heptamera (Nees) Stapf
   P. steudelii (Nees) McClean
   P. viscidula (Nees) Stapf
   P. imperfecta Stapf
   P. sp. nov. (Haynes 873)
280c Pentameris macrocalycina (Steud.) Schweickerdt
   P. macrantha (Schraeder) Conert
280d Merxmuelleria rufa (Nees) Conert
   M. lupulina (Thunb.) Conert
   M. stricta (Schrad.) Conert
*367 Briza maxima L.
368 Plagiochloa uniolae (L.F.) Adams. & Sprague
*372 Dactylis glomerata L.
385 Festuca scabra Vahl.

CYPERACEAE

456a Asterochaete glomerata (Thunb.) Nees
459 Cyperus tenellus L.f.
465 Ficinia bergiana Kunth
   F. bracteata Boeck.
   F. capillifolia (Schrad.) C.B. Cl.
   F. deusta (Berg.) Nees
   F. elongata Boeck.
   F. indica (Lam.) Pfeiffer
Cyperaceae (cont.)

465 Ficinia involuta Nees
   F. minutiflora C.B. Cl.
   F. monticola Nees
   F. tenuifolia Kunth
   F. trichodes (Schrad.) Benth & Hook.
   F. zeyheri Boeck
   F. sp. cf. F. filiformis Schrad.
   F. sp. cf. F. indica (Lam.) Pfeiffer

468 Scirpus digitatus Boeck.
   S. ludwigii (Steud.) Boeck.
   S. setaceus L.

477a Epischoenus adnatus Levyns
   E. complanatus Levyns
   E. quadrangularis C.B. Cl.
   E. villosus Levyns

494 Tetraria bolusii C.B. Cl.
   T. brevicaulis C.B. Cl.
   T. bromoides (Lam.) Pfeiffer
   T. brevicaulis C.B. Cl.
   T. capillacea (Thunb.) C.B. Cl.
   T. compacta Levyns
   T. compar (L.) Lestib.
   T. crassa Levyns
   T. cuspidata C.B. Cl.
   T. exilis Levyns
   T. fasciata (Rittb.) C.B. Cl.
   T. fimbriolata C.B. Cl.
   T. flexuosa (Thunb.) C.B. Cl.
   T. microstachys (Vahl.) Pfeiffer
   T. variabilis Levyns
494a Macrochaetium dregei Steud.

494b Neesenbeckia punctoria (Vahl.) Levyns.

500 Chrysithrix capensis L.
   C. capensis L. var subteres C.B. Cl.
   C. dodii C.B. Cl.

RESTIONACEAE

804 Restio ambiguus Mast.
   R. bifidus Thunb.
   R. cuspidatus Thunb.
   R. egregius Hochst.
   R. filiformis Poir.
   R. pedicellatus Mast.
   R. perplexus Kunth.
   R. purpurascens Nees
   R. quadratus Mast.
   R. sieberi Kunth.
   R. strictus N.E. Br.
   R. tenuissimus Kunth.
   R. triticeus Rottb.
   R. sp. nr. R. dispar Mast.

805 Chondropetalum deustum Rottb.
   C. hookerianum Pillans
   C. mucronatum Pillans

804 Elegia asperiflora Kunth
   E. juncea L.
   E. neesii Mast.
   E. racemosa Pers.
   E. spathacea Mast.
   E. thrysifera Pers.
   E. vaginulata Mast.
Leptocarpus distichus Pillans
L. esterhuyseniae Pillans
L. membranaceus Pillans
L. paniculatus (Mast.) Pillans
Thamnochortus gracilis Mast.
T. guthriae Pillans
T. pulcher Pillans
T. similis Pillans
Staberoha aemula Pillans
S. cernua Dur. & Schinz.
Hypolaena crinalis Pillans
Hypodiscus albo-aristatus (Nees) Mast.
H. aristatus (Thunb.) Nees
Cannomois virgata (Rottb.) Steud.
Willdenowia argentea Hiern.
W. humilis Mast.
W. sulcata Mast.

JUNCACEAE
Prionium serratum Drege
Juncus dregeanus Kunth var. sphaerocephalus Adamson.
J. lomatophyllus Spreng.

LILIACEAE
Dipidax punctata (L.) Hutch.
Bulbinella triqueta Kunth.
Bulbine favosa Roem. & Schult.
Bulbine sp. nr. B. foleyi Phillips
Albuca canadensis (L.) Leighton
Ornithogalum nanodes Leighton
Asparagus compactus Salter
A. scandens Thunb.
A. thunbergianus Schult.
**HAEMODORACEAE**

1160  *Dilatris viscosa* L.

1162  *Wachendorfia paniculata* Burm.

**AMARYLLIDACEAE**

1191  *Cyrtanthus angustifolius* (L.f.) Ait.

C. *ventricosus* (Jacq.) Willd.

1230a  *Spiloxene capensis* (L.) Garside

S. *curculigoides* (Bol.) Garside

S. *monophylla* (Scltr.) Garside

**IRIDACEAE**

1265  *Moraea angusta* (Thunb.) Ker

M. *anomala* Lewis

M. *ramosissima* (L.f.) Druce

M. *teruis* Ker

M. *tripetala* Ker var. jacquiniana Scltr.

1277  *Homeria ochroleuca* Salisb.

1384  *Bobartia gladiata* (L.f.) Ker

1295  *Aristea racemosa* Bak.

A. *spiralis* (L.f.) Ker

1296  *Witsenia maura* Thunb.

1298  *Klattia partita* Bak. var. *flava* Lewis

1300  *Geissorrhiza humilis* (Thunb.) Ker. var. *bicolor* Bak.

G. *ovata* (Burm.) Asch. & Groeb.

G. *ramosa* Ker

1302  *Ixia trinervata* (Bak.) Lewis

1311  *Gladiolus brevifolius* Jacq.

G. *brevitubus* Lewis

G. *carneus* de la Roche

G. *debilis* Ker.

G. *punctulatus* Schrank.

1311b  *Tritoniopsis lata* (L. Bol.) Lewis

T. *pulchella* Lewis
IRIDACEAE  (cont.)

1311b Tritonia ramosa (Eckl. ex Klatt.) Lewis
1312f Anapalina pulchra (Bak.) N.E. Br.
1315 Watsonia fulgens (Andr.) L. Bol.
    W. pyramidata (Andr.) Stapf
1315 Thereianthus bracteolatus (Lam.) Lewis
    T. juncifolius (Bak.) Lewis
    T. spicatus (L.) Lewis

ORCHIDACEAE

1408 Holothrix cernua (Burm. f.) Schelpe
    H. condensata Sond.
    H. squamulosa Lindl.
    H. villosa Lindl.
1426 Pachites bodkinii Bolus
1430 Satyrium bicallosum Thunb.
    S. humile Lindl.
1430a Satyridium rostratum Lindl.
1432 Schizodium inflexum Lindl.
    S. obliquum Lindl.
1434 Disa cornuta Swartz
    D. ferruginea (Thunb.) Swartz
    D. maculata L.f.
    D. obtusa Lindl.
    D. racemosa L.f.
    D. tenuicornis Bolus
    D. tripetaloides N.E. Br.
    D. uncinata Bolus
    D. vaginata Harvey
**ORCHIDACEAE** (cont.)

1434a *Orthopenthea bivalvata* (L.f.) Rolfe
   O. *fasciata* (Lindl.) Rolfe
   O. *rosea* (Lindl.) Rolfe

1434c *Penthea patens* (L.f.) Swartz

1435 *Herschelia graminifolia* (Ker.) Dur. & Sch.

1436 *Monadenia micrantha* Lindl.
   M. *ophrydea* Lindl.
   M. *pygmaea* Dur. & Sch.

1437 *Disperis capensis* (L.f.) Swartz

1438 *Pterygodium acutifolium* Lindl.
   P. *catholicum* (L.) Swartz

1440 *Corycium carnosum* (Lindl.) Rolfe

1556 *Liparis capensis* (L.f.) Swartz

1561 *Acrolophia lamellata* (Lindl.) Schltr. ex Bolus

1648 *Eulophia tabularis* (L.f.) Bolus

**ANGIOSPERMAE - DICOTYLEDONAE**

**MYRICACEAE**

1874 *Myrica diversifolia* Adams

**PROTEACEAE**

2029 *Paranomus sceptrum-gustavianus* Hylander

2030 *Serruria elongata* R.Br.
   Serruria sp. (Kruger 314)

2031 *Mimetes capitulatus* R.Br.
   M. *cucullatus* (L.) R.Br.

2031b *Diastella serpyllifolia* Knight

2032 *Spatalla curvifolia* Salisb. ex Knight
   S. *mollis* R.Br.

2035 *Protea acaulos* (L.) R.ichard
   P. *cynaroides* L.
PROTEACEAE (cont.)

2035 Protea lacticolor Salisb.
   P. neriifolia R.Br.
   P. scabra R.Br.
   P. speciosa L.

2036 Leucospermum oleifolium (Berg.) R.Br.

2037 Leucadendron gandogerii Schinz ex Gandoger
   L. salicifolium Williams
   L. spissifolium (Salisb. ex Knight) Williams
   L. xanthoconus (O. Kuntze) K. Schum.

2038 Aulax cancellata (L.) Druce

SANTALACEAE

2108 Colpoon compressum Berg.

2117 Thesidium fruticulosum A.W. Hill

2118 Thesium carinatum A. DC.
   T. ericaefolium A. DC.
   T. euphorbioides Berg.
   T. euphrasiodes A. DC.
   T. paniculatum L.
   T. sp. nr. T. spinosum L.f.
   T. sp. cf. T. bathyschistum Schltr.

GRUBBIACEAE

2121 Grubbia rosmarinifolia Berg.
   G. tomentosa (Thunb.) Harms

Balanophoraceae

2155 Mystropetalon thomii Harv.

Polygonaceae

*R2195 Rumex angicarpus Murb.

Ranunculaceae

2541 Anemone capensis L.
CRUCIFERAE
2875 Heliophila crithmifolia Willd.

DROSERACEAE
3136 Drosera aliciae Hamet
   D. cistiflora L.
   D. curviscapa Salter
   D. hilaris Cham & Schlecht.d.
   D. ramentacea Burch ex D.C.

RORIDULACEAE
3138 Roridula gorgonias Planch.

CRASSULACEAE
3168 Crassula capensis (L.) Baill.
3171 Rochea coccinea (L.) DC.
   R. odoratissima DC.
   R. subulata (L.) Adams.

BRUNIACEAE
3286 Lonchostoma monogynus (Vahl.) Pillans
3288 Raspalia microphylla Brongn.
3289 Nebelia fragarioides O. Kuntze
   N. paleacea Sweet
3290 Staavia radiata Thunb.
3291 Pseudobaeckia cordata Niedenzu
   P. cordata Niedenzu var. monostyla Pillans
3292 Brunia alopecurioides Thunb.
   B. nodiflora L.
3294 Berzelia abrotanoides L.
   B. lanuginosa Brongn.
   B. squarrosa (Thunb.) Sonder
ROSACEAE

3388  Cliffortia atrata Weim.
      C. eriocephalina Cham.
      C. exilifolia Weim.
      C. graminea L.f.
      C. polygonifolia L.
      C. subsetacea Eckl. & Zeyh.

LEGUMINOSAE

3620  Cyclopia genistoides (L.) R.Br.
      C. genistoides (L.) R.Br. var. ovalifolia Kies.
      C. meyeriana Walp.
3621  Podalyria biflora (L.) Willd.
      P. calyprata Willd.
      P. cordata R.Br. ex Ait. fil.
3642  Liparia splendens (Burm. f.) Bos & de Wit subsp. comantha
      (Eckl. & Zeyh.) Bos & de Wit
3643  Priestleya latifolia Benth.
      P. myrtifolia DC.
3644  Amphithalea bodkinii Duemmer
3660  Lebeckia inflata Bolus
      L. wrightii (Harv.) Bolus
3662  Aspalathus ciliaris L.
      A. marginata Harv.
      A. millefolia R. Dahlgr.
3673  Argyrolobium filiforme Eckl. & Zeyh.
      A. lanceolatum Eckl. & Zeyh.
3673(4) Chrysoscias leucoscias Benth. var. augustifolia Harv.
3702  Indigofera glomerata E. Mey.
      I. gracilis Spreng.
      I. ovata Thunb.
LEGUMINOSAE (cont.)
3703 Psorlea aphylla L.
  P. pinnata L.
  P. restioides Eckl. & Zey.
  P. sp. (Kruger 518)
  P. sp. (Haynes 324)

GERANIACEAE
3928 Pelargonium angulosum Ait.

OXALIDACEAE
3936 Oxalis heterophylla DC.
  O. polyphylla Jacq.
  O. purpurea L.
  O. truncatula Jacq.
  O. sp. cf. O. commutata Sond.
  O. sp. cf. O. melanostricta Sond.

RUTACEAE
4037 Agathosma bifida Bartl. & Wendl.
4038 Adenandra acuta Schltr.
4041 Diosma oppositifolia L.

POLYGALACEAE
4273 Polygala bracteolata L.
  P. pappeana Eckl. & Zeyh.
4278 Muraltia concava Levyns.
  M. hyssopifolia Chodat

EUPHORBACEAE
4448 Clutia alaternoides L.
  C. polygonoides L.
  C. polifolia Jacq.
  C. pterogona Mull. Arg.
ANACARDIACEAE
4594 Rhus africana Mill.
R. tomentosa L.

CELASTRACEAE
4627 Maytenus oleoides (Lam.) Loes
4645 Hartogia schinoides C.A. Smith

RHAMNACEAE
4886 Phylica gracilis D. Dietr.
P. lasiocarpa Sond.
P. sp. cf. P. diffusa Pillans

PENAEACEAE
5425 Penaea mucronata L.

THYMELARACEAE
5435 Gnidia humilis Meisn.
G. linearifolia (Wikstr.) Peterson
5435 Gnidia oppositifolia L.
G. pinifolia L.
G. viridis Berg.
5436 Struthiola ciliata (L.) Lam.
S. myrsinites Lam.
S. sp. cf. S. eckloniana Meisn.
5435c Pseudognidia anomala (Meisn.) Phillips
5459 Cryptadenia breviflora Meisn.

UMBELLIFERAE
5894 Centella difformis (E & Z) Adamson
C. eriantha (A. Rich.) Druce
5917 Hermas capitata L.f.
H. ciliata L.f.
H. gigantea L.f.
H. quinquedentata L.f.
UMBELLIFERAE (cont.)

6020 Chamarea capensis (Thunb.) Eckl. & Zeyh.
6046a Thunbergiella filiformis (Lam.) Wolff
6116 Peucedanum ferulaceum Thunb.

ERICACEAE

6237 Erica azalaefolia Salisb.
   E. banksia Andr.
   E. brevifolia Soland
   E. calycina L.
   E. calycina L. var. periplocaeflora Bolus
   E. carduifolia Salisb.
   E. cerinthoides L.
   E. coccinea L.
   E. corifolia L.
   E. corydalis Salisb.
   E. cumuliflora Salisb.
   E. curviflora L.
   E. curvirostris Salisb.
   E. fascicularis L.f.
   E. fastigiata L.
   E. glutinosa Berg.
   E. gnaphaloides L.
   E. hispidula L.
   E. imbricata L.
   E. intervallaris Salisb.
   E. krugeri E.G.H. Oliver
   E. lateralis Willd.
   E. longifolia Ait.
   E. lutea Berg.
ERICACEAE (cont.)

6237  Erica massoni L.f.
   E. obliqua Thunb.
   E. obtusata Kl. ex Benth.
   E. odorata Andr.
   E. parviflora L.
   E. pavettaeflora Salisb.
   E. petrophila L. Bolus
   E. placentaeeflora Salisb.
   E. parvula Guthrie & Bolus
   E. plukeneti L.
   E. pulchella Houtt.
   E. savilea Andr.
   E. sessiliflora L.f.
   E. spumosa L.
   E. taxifolia Ait.
   E. tegulaefolia Salisb.
   E. tenuifolia L.
   E. transparens Berg.

6242  Blaeria dumosa Wendt.
   B. ericoides L.
   B. equisetifolia (Salisb.) G. Don.
   B. revoluta Bartl.

6242  Philippia leeana Kl.

6243  Aniserica gracilis (Bartl.) N.E. Br.

6243c  Acrostemon stokoei L. Guthrie var. confusus E.G.H. Oliver

6245  Sympieza articulata (Thunb.) N.E. Br.

6246  Scyphogyne muscosa (Ait.) Stend.

6248b  Nagelocarpus serratus (Thunb.) Bullock
PRIMULACEAE

* 6338 Anagallis arvensis L.

EBENACEAE

6406 Diospyros glabra (L.) de Winter

OLEACEAE

6434 Olea capensis L. subsp. capensis

GENTIANACEAE

6481 Sebaea exacoides (L.) Schinz.

6503 Chironia decumbens Levyns

C. linoides L. subsp. nana Verdoorn

6544 Villarsia capensis (Houtt.) Merrill

CONVOLVULACEAE

6968 Cuscuta angulata Engelm.

VERBENACEAE

7134 Stilbe albiflora E. Mey.

S. mucronata (E. Mey.) N.E. Br.

SOLANACEAE

7407 Solanum retroflexum Dümmer

SCROPHULARIACEAE

7476 Nemesia diffusa Benth.

7493 Halleria lucida L.

7494 Teedia lucida Rudol.

7522 Polycarena glutinosa (Schltr.) Levyns

7568 Selago burmannii Choisy

S. serrata Berg.

S. verbenacea Thb.

S. sp. (Kruger 552)

7571 Agathelpis dubia (L.) Hutch.
7627 Harveya capensis Hook.

LENTIBULARIACEAE
7901 Utricularia capensis Spreng.

RUBIACEAE
8438 Anthospermum aethipium L.
   A. prostratum Sond.
8443 Carpacoce spermacoea Sond.
   C. vaginellata Salter

CAMPANULACEAE
8661 Merciera tenuifolia (L.f.) A.DC. var. azurea Adamson
8662 Roella incurva Banks ex A.DC.
   R. psammophila Schltr.
8663 Prismatocarpus schlechteri Adamson Ms.
8668 Wahlenbergia cernua (Thunb.) A.DC.
   W. obovata Van Buhm.
   W. sp. (Kruger 311)
8670 Lightfootia parvifolia (Berg.) Adamson
   L. rubioides (L.) DC.
8681 Cyphia bulbosa (L.) Berg.
   C. digitata (Thunb.) Willd.
   C. volubilis (Thunb.) Willd.
8694 Lobelia capillifolia (Presl.) A.DC.
   L. coronopifolia L.
   L. erinus L.
   L. linearis Thunb.
   L. pinifolia L.
   L. sp. cf. L. laurentioides Schltr.
8694 Monopsis lutea (L.) Urb.

COMPOSITAE
8764 Corymbium congestum E. Mey.
COMPOSITAE (cont.)

C. latifolium Harv.
C. glabrum L.
C. scabrum L. forma filiforme
C. scabrum L. forma scabrum

8883 Mairia crenata (Thunb.) Nees
     M. taxifolia (L.) DC.

8900 Aster reflexus L.
*8901 Erigeron canadense L.

8930 Chrysocoma tenuifolia Berg.

8936 Brachylaena neriifolia (L.) R.Br.

8992 Gnaphalium candidissimum Lam.
     G. undulatum L.

8997 Phaenocoma prolifera (L.) D. Don

9000 Helipterum gnaphaloides (L.) DC.
     H. speciosissimum (L.) DC.

9006 Helichrysum crispum (L.) D. Don
     H. cymosum (L.) D. Don
     H. felinum (Thunb.) Less.
     H. foetidum (L.) Moench.
     H. humile (DC) Andr.
     H. sesamoides (L.) Willd.
     H. vestitum (L.) Schrank.

9008 Leontonyx spathulatus Less.
     L. squarrosus (L.) DC.

9037 Stoebe cinerea Thunb.
     S. incana Thunb.
     S. plumosa Thunb.

9039 Disparago ericoides Gaertn.
Elytropappus longifolius (DC.) Levyns
Metalasia muricata R.Br.
Lachnospermum umbellatum (D.Don.) Pilland
Bryomorphe lycopodioides (Sch. Bip.) Levyns
Athrixia heterophylla Less.
Osmotopsis africana (L.) Bremer
Athanasia parviflora L.
Thaminophyllum multiflorum Harv.
Cotula ceniaefolia DC.
Hippia pilosa (Berg.) Druce
Senecio burchellii DC.
  S. cordifolius L.f.
  S. cymbalariaefolius (L.) Less.
  S. erubescens Ait. forma
  S. paniculatus Berg.
  S. pinifolius L.
  S. pubigerus L.
  S. rigidus L.
  S. speciosus Willd.
  S. triqueter DC.
  S. umbellatus L.
  S. sp. cf. S. consanguineus DC.
Euryops abrotanifolius (L.) DC.
Othonna parviflora L.
Osteospermum caulescens Harv.
9431  Ursinia caledonica Phill.
      U. crithmoides (Berg.) Poir.
      U. dentata (L.) Poir.
      U. eckloniana (Sond.) Phill.
      U. nudicaulis (Thunb.) N.E. Br.

9432b  Haplocarpha lanata Less.

9528  Gerbera asplenifolia Spreng.
      G. tomentosa DC.

*9572  Hypochoeris radicata L.
APPENDIX B: EXAMPLE OF FIELD SHEET

<table>
<thead>
<tr>
<th>LOCALITY</th>
<th>DATE</th>
<th>SURVEY</th>
<th>PLOT NO</th>
<th>Plot Size</th>
<th>NAME</th>
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</table>

<table>
<thead>
<tr>
<th>Soil Moisture</th>
<th>2 Soil Texture</th>
<th>3 Stones</th>
<th>4 Soil Climate</th>
<th>5 Erosion</th>
<th>6 Geology</th>
<th>7 Slope</th>
<th>8 Aspect</th>
<th>9 Mists</th>
<th>10 Exposure</th>
<th>11 Litter</th>
<th>12 Erosion Hazard</th>
<th>13 Humus</th>
<th>14 Land Form</th>
<th>15 Altitude</th>
</tr>
</thead>
</table>

VEGETATION

a) EMERGENTS: (i) SPECIES
   (ii) DENSITY
   (iii) HABIT
   (iv) HEIGHT

b) CANOPY: (i) SPECIES (DOMINANT)
   (ii) DENSITY
   (iii) HABIT
   (iv) HEIGHT

c) COVER

d) AGE

e) REMARKS
APPENDIX C. ECOLOGICAL CHARACTERS OF SHORT-DIVISION GROUPS.

GROUP I: This group includes plots at middle to low altitudes which tend to occur on warm and hot sites. The aspect of the sites is fairly variable, but does not deviate much from the general for the terrain. Most sites have slight or moderate slopes, though a few steep sites are included. Most plots occurred on sites rated wet and very wet, or moist. Surface rocks are absent. This group is concentrated about the centre of the area and most plots are on or near streams, in the riparian zone or on its fringe. Marked accumulations of peat-like humus occur. Many sites are boggy in the wet season. Most sites are exposed to the weather.

GROUP II: Both plots occur at lower altitudes on very cool steep sites with south-west aspect. One site was rated wet, the other moist. The former occurs on an open slope near a drainage line, the other in the central gorge.

GROUP III: This group is concentrated at lower altitudes with a few plots at median elevations. Sites are mostly warm to hot with north-eastern to western aspects (thus deviating fairly markedly from the norm) and slight to moderate slopes; plots on steep ground are exceptional. Most sites were rated wet and very wet, or moist. Surface rocks are largely absent. Peat-like humus accumulations are found on most plots, and most are boggy in the wet season. Most sites are exposed to the weather. Plots are scattered from lower to mid-slopes and are mostly associated with seepage zones.

GROUP IV: Plots occur chiefly at upper and upper-middle elevations, mostly on warm sites but some on cool. South-east to south aspects predominate, and slopes are slight to moderate, except in the case of two plots on steep slopes. Sites were rated moist or wet. Surface rocks are absent, and peat-like humus/..............
humus was found on most plots; these are boggy in the wet season. Sites are exposed to the weather. Most plots occur in the gentle basin of the north-western portion of the area, with a few on the upper scarp. Riparian zones or high water tables due to other influences characterise the group.

**GROUP V:** Both plots occur at lower altitudes on warm and hot sites with slight to moderate slopes, one facing east and the other south-west. One was rated wet and the other moist, though both are situated on stream-banks.

**GROUP VI:** Sites at upper-middle altitudes, both warm and cool, are represented here. All have a southwesterly aspect and were rated dry or moist. Surface rocks are rare or absent. Some plots occur on the sandstone-shale band. Both slightly sloping and steep sites were represented. All sites are exposed to the weather. The group represents the slopes and pediment immediately north-east of the central gorge.

**GROUP VII:** This group represents hot sites concentrated at lower altitudes rated dry or occasionally moist, with mainly slight slopes (though two are steep). Aspects vary from south-west to north-east but deviate from the mode. Surface rocks and stones are frequent or abundant. Plots occur scattered about the lower portion of the catchment, mainly on the colluvial slopes of the hill in the south-eastern corner of the catchment (hill 2998).

**GROUP VIII:** Plots included here represent warm and hot sites at middle, chiefly lower-middle, altitudes, with very variable slopes, from gentle to steep. Most face south-west and were rated moist, with some dry. Most plots occur on the scarp and hillslopes east of the middle section of the main stream, from
the stream almost to the crest of the divide. Plots often fell on shale-derived soils, or soil derived from sandstone rich in iron, i.e. those of the Clovelly and Hutton series. Surface rocks are often abundant or frequent, sometimes rare. Most sites are exposed to the weather, but some are at least slightly sheltered.

GROUP IX: This group includes plots from cool sites at upper and occasionally upper-middle elevations of mainly steep and sometimes moderately steep slopes, most facing south and south-west. Sites were rated moist or occasionally moist, wet or dry. The soil surface is often turfy and rich in humus. Surface rocks are largely absent. Most are exposed to the weather, but many are at least slightly sheltered. Plots are restricted to the middle zone of the upper scarp; many occur in or near shallow depressions or gullies.

GROUP X: Warm and hot, and occasionally cool sites chiefly from upper and upper-middle elevations with variable but predominantly south-east and south aspects are included here. Slope varies from slight to very steep, though it is mostly moderate. Most sites were rated moist, and a large proportion dry. Surface rocks are mainly rare or absent, but occasionally abundant or frequent; the surface soil is often turfy and rich in humus. Plots occur on exposed sites on the lower slopes of the upper scarp and the south slopes of hill 3033, though some are situated on the upper east slopes of the crest peak. Some sites were described as slightly terraced.

GROUP XI: This group includes plots restricted to upper elevations (none below 950m) on cool, steep sites with predominantly southerly aspect. Almost all were rated moist, surface rocks are/.............
are rare or absent, and the soil surface is turfy and rich in humus. Most plots fall within the upper basin of catchment Ib. Most sites are exposed, but almost as many are sheltered. Slightly terraced sites are present.

**GROUP XII:** All plots occur above the 950m contour on cool, mostly steep, sites with predominantly southerly and southwesterly aspects. Most were rated moist, but many appeared dry. Though rocks are largely absent, some sites have a stony surface. On most sites the soil surface is turfy and rich in humus. Plots occur scattered about the upper zones of catchment Ib and the northern slopes of Catchment Ia. Some occur on the summit crests. One of the plots represents vegetation burnt in March 1966. Slightly terraced sites are present.

**GROUP XIII:** All plots in this group occur above the 950m contour on cool steep sites with predominantly southerly aspect. Sites were rated either moist or dry and surface rocks are generally abundant. The soil surface is somewhat turfy, and slight terracing is a common feature. Plots are concentrated mainly on the northerly slopes of catchment Ia on slightly warmer sites and at somewhat lower altitudes than those of Groups XI and XII.

**GROUP XIV:** This group includes plots on warm sites, chiefly at lower-middle altitudes with slight or moderate slopes and largely south-westerly and westerly aspects. Most were rated dry, some moist, and surface rocks are abundant or frequent. Plots are scattered about the mid-slopes and hillcrests.

**GROUP XV:** Mainly hot, and some warm sites at upper-middle to low altitudes, on predominantly gentle slopes are included here.

Aspect/.............
Aspect varies, but many sites face north and east. Most plots were rated dry and some very dry; surface rocks are abundant or frequent at most sites. Most plots occur at mid-slope and on the hillcrests; the majority occur on and near the hill on the western boundary of the catchment (hill 3033).

GROUP XVI: Plots included here occur on warm and hot sites chiefly at lower altitudes (with a small proportion at upper-middle and upper elevations) with gentle and moderate slopes. Aspect varies from north-west to south-west, most plots facing east to south-west. Most sites were rated dry, but a large proportion appeared moist and a few wet. Rock cover is highly variable: some sites have frequent and occasionally abundant surface rocks, whereas others were stony or gravelly with rocks rare or absent. Plots are scattered about the lower south-western portion of the catchment, chiefly around hill 2998. Many occur on the gentle slopes of broad necks.

GROUP XVII: All plots occur at lower altitudes on sites with south-west aspects. Two fall on cool steep sites, the other on a hot level area, but all were rated wet. Rocks are frequent or rare.

GROUP XVIII: Warm and hot sites from chiefly upper-middle and upper elevations are represented in this group. Slopes are predominantly gentle, though some are moderate; all sites but one face south-west, and were rated dry or moist. Rocks were rated abundant or frequent on some plots, but are rare or absent on others. Most plots are distributed much as those of groups VIII and IX, many occurring on Clovelly-type soils derived from shale or iron-rich sandstone.

GROUP XIX/......
GROUP XIX: Cool or moderately warm sites, mainly from upper-middle and upper altitudes, are represented here. Slopes are moderate and steep and all sites but one face south-east or south-west. Most were rated moist, but many dry. Rocks are often rare or absent, but were occasionally rated frequent or abundant, and a few stony sites are represented. Many sites are slightly terraced. Two plots represent vegetation burnt in March 1966. Plots occur predominantly towards the upper summit crest on the eastern boundary of the area.

GROUP XX: This group includes plots on cool and moderately warm sites from lower to middle altitudes. Slopes are largely moderate, and aspect chiefly southerly. Sites were rated dry or moist and surface rocks were absent or rare. Three plots are grouped on the lower south slopes of hill 3033, the rest scattered elsewhere.

GROUP XXI: Plots included here represent sites at median, chiefly lower-middle altitudes, which are warm and vary in slope from slightly sloping to steep. Aspect varies from south-east to west. Most sites were rated moist, but some appeared dry or very dry. Surface rocks are frequent or abundant, but stony and rock-free sites are also represented. Plots are scattered about the mid-slopes, chiefly on hill 2998, and represent sites exposed to the weather.

GROUP XXII: This group includes plots from chiefly upper-middle and upper elevations from mainly warm and hot sites, though most sites have a moderate or moderately steep inclination. All aspects are represented, but most sites face east and south-west to west. Most sites were rated dry, some very dry, and in most cases surface rocks are abundant or frequent. Many sites had been/ ..................
been subject to biotic influences of some sort (occurring on firebreaks, tracers, or near Procavia colonies), or are associated with rock outcrops or large boulders, but this is not generally the case. Plots are scattered about the area and are not associated with any morphological patterns.

**GROUP XXIII:** Plots in this group occur chiefly at lower altitudes, with a few at middle and upper elevations. They occur largely on hot sites of variable slope, though no steep sites are included. Aspect is also variable, but sites which face north-east and east predominate. Most were rated dry or very dry, and rocks are generally abundant or frequent. Plots are concentrated chiefly in the south-western portion of the area. The most striking feature of this group, however, is that it includes all plots representing vegetation burnt in January 1967 and three from the area burnt in March 1966. On the other hand, it also contains four plots in old vegetation.

**GROUP XXIV:** Sites represented here are chiefly cool or warm, but some hot areas are included. Most are from middle and lower elevations and though sites of all aspects are found, most face east and south-west. Slopes are variable, though many plots occur on steep ground. Most sites were rated dry, though a large proportion appeared moist. Rocks are often abundant at the surface but rare or absent in some cases. These plots are scattered over the whole area except the upper scarp.

**GROUP XXV:** Plots in this group occur chiefly at lower elevations on warm and hot sites with variable but chiefly slight or moderate slopes. All aspects are represented but most sites face east and south-east, or south-west or west. Most sites were rated dry, but a large proportion was considered moist. Rocks are sometimes frequent, but generally abundant and often covered 40 - 50%
of the surface of the plot (occasionally up to 80%). Sites represented tend to be those of the lower hill-slopes.

**GROUP XXVI:** Hot sites at middle altitudes predominate in this group. Slopes are moderate and north-west and east aspects are most common, though all are represented. Most sites were rated very dry, and a large proportion dry. Rocks are always abundant and in most cases cover at least 50% of the surface of the plot, often about 75%. Plots occur on the crest and north-west slopes of hill 2998 and the east slopes of hill 3033.

**GROUP XXVII:** This group includes plots from warm sites at lower and middle altitudes on moderate slopes. Most were rated dry and rocks are largely abundant, generally covering about half the soil surface. Most sites have south-east and south-west or west aspects. Plots are scattered about the lower portion of the catchment, and occur at all positions from valley-bottom to hill-crest.