AN ANALYSIS OF THE VEGETATION ON SOME STRANDED COASTAL DUNE RANGES IN THE LOWER SOUTH-EAST, SOUTH AUSTRALIA

by

Michael Welbourn

(M.Sc. Thesis, Adelaide, 1965)

This project was carried out in association with the Botany Department of the University of Adelaide, and the thesis was submitted for the degree of Master of Science in October 1965. The thesis contains no material which has been accepted for the award of any other degree or diploma in any other University, and to the best of the author's knowledge and belief contains no material previously published or written by another person, except where due reference is made.

R.M.E. WELBOURN
B.Sc., Dip.For.

SUMMARY

Dune ranges representing Pleistocene coastlines in the South-East of South Australia are most distinct in County Robe, where they form a chronosequence. Within this area the predominant ecosystem is dry sclerophyll forest containing Eucalyptus baxteri on deep podsolized sands. On the basis of the occurrence of about a hundred species, this vegetation consists of environmentally controlled associations, of which there are about ten depending on the method of analysis employed.

Association-analysis, proposed by Williams and Lambert (1959-1961) for use with an electronic computer, is preferred to the manual interspecific correlation method of Goodall (1953). This is because the former is based on the most strongly associated species, which is more meaningful in detecting local vegetation and habitat differences than is the most frequent species. Furthermore, the latter only produces a limited number of associations, and the analysis is influenced by choice of significance level. Nevertheless results obtained by the two methods are not dissimilar, and accordingly some further comparative studies are suggested.

CONTENTS

Part II. METHOD and RESULTS

Part III. DISCUSSION

TABLES and ILLUSTRATIONS

A. Tables

B. Plates

C. Text Figures

AN ANALYSIS OF THE VEGETATION ON SOME STRANDED COASTAL DUNE RANGES IN THE LOWER SOUTH-EAST, SOUTH AUSTRALIA.

Part I. INTRODUCTION

A. The Problems Studied

The clearing of scrub for land development is considered, by those who would preserve a rational balance between natural and artificial vegetation, to be excessive in many parts of Australia. This is certainly the case in the Lower South-East of South Australia, since the area has a relatively high agricultural potential. The author was stationed as a forester at Penola in the South-East in 1963, and one aspect of this problem which seemed worthy of study was the need for a specific record of the vegetation in its natural state, prior to its ultimate disappearance in many places. In the area studied, the remaining vegetation occupies a series of habitats which is regarded as unique in the world, and thus a record seemed particularly desirable. To this end a survey for the collection of suitable data was the initial object of this research project.

The analysis of the data suggested two further problems for study. The first was the elucidation of species association and the distribution of any homogeneous groups of species in relation to habitat factors. In particular, it was thought that the effect of time on vegetation might be tested, since there were a number of distinct habitats which appeared to be of different ages, namely dune ranges representing various stranded coastlines of the Pleistocene. The second problem was the determination of the best method of analysing the data. Of the numerous methods in the literature, it was decided to compare two contemporary approaches and to briefly examine a third, with particular regard to their validity and their usefulness relative to the resources needed for the analyses. The three specific research objectives are discussed in Section C below.

The area studied is substantially that of County Robe, which together with Counties MacDonnell and Grey make up the Lower South-East, a geographical province within the political boundary of South Australia. This province is part of the Murray and Otway Sedimentary Basins, and as such the country rock is predominantly level-bedded Mid-Tertiary marine limestone, and the topography is flat (Figure 1). The mean annual rainfall of the province, from 21 to 33 inches, is high by South Australian standards. Thus, despite the marked summer drought typical of the

Mediterranean-type climate, the province claims nearly half of the state's top-dressed pastures, and supports beef, dairy, wool, and softwood industries. The ecology and land-use of the province are well covered in the literature.

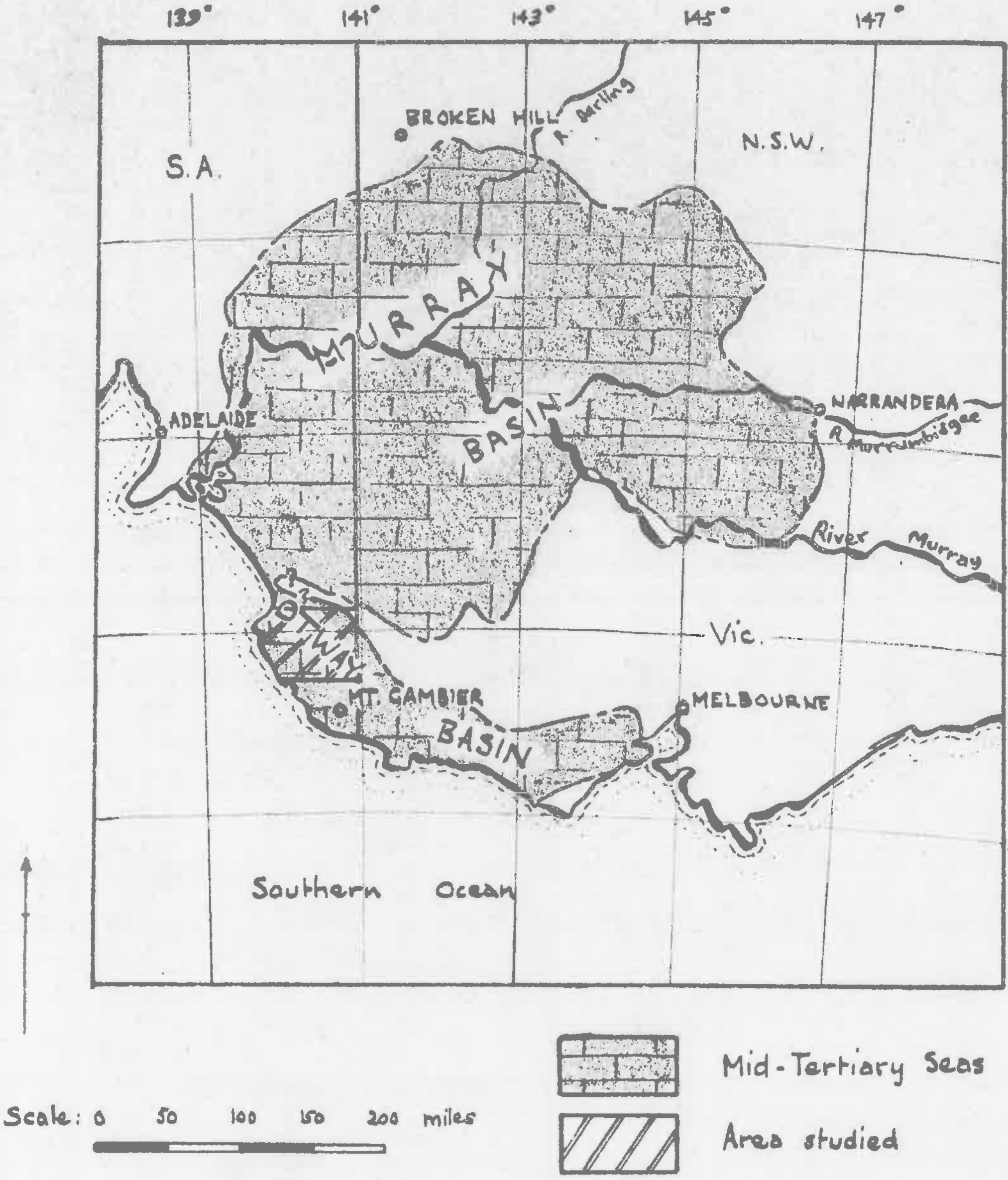


Fig. 1. **THE MURRAVIAN GULF**, showing its maximum extent in the Mid-Tertiary. This area approximates the Murray and Otway sedimentary basins, in which the predominant country rock is the Gambier Limestone or its equivalent, laid in the Mid-Tertiary seas.

B. Literature Review

This review of some fifty publications relating to the ecology of the area studied and the measurement of vegetation has been divided for convenience under three headings: the Lower South-East, the dune ranges, the data and its analysis.

1. The Lower South-East: (a) geography & climate.

This province is defined as the portion of South Australia south of latitude 36 degrees 30 minutes. As such it comprises the three counties mentioned above and covers an area of some 3,746,000 acres. The region known as the South-East is a broader area described by Fenner (1930) as grading into the mallee areas to the north, and distinguished therefrom in terms of climate, ecology, and production. The 18 inch rainfall isohyet might be taken to delimit the South-East and the Murray Mallee.

The topography of the Lower South-East is generally flat becoming undulating towards the coast, and with seven main ridges intersecting the area parallel to the coast (Figure 6). These ridges, although only a hundred feet high and a mile wide, are so prominent in contrast to the low-lying flats between them that they are known as dune ranges. The elevation of the area is slight, the highest point being the extinct volcano Mount Burr 802 feet above sea level. Disregarding the dune ranges, the country slopes gently westward to sea-level from 200 feet at the Victorian border, a maximum distance of some 70 miles (Figure 7), and in addition from Dismal Swamp (250 feet) northwest through Naracoorte (190 feet) to the Murray tidal lakes 200 miles distant, and from Dismal Swamp south through Mount Gambier (140 feet) to Port Macdonnell 40 miles distant. Generally speaking, the dune ranges are distinct in the centre of the area, County Robe, but tend to coalesce in the north-sloping area of County MacDonnell, and in the Mount Burr area of County Grey.

The Lower South-East is an area of poor drainage since the natural flow of rainwaters is impeded by the dune ranges. The heavy winter rainfall, and the emptying of the Morambro, Naracoorte, and Mosquito Creeks into the Naracoorte Plains result in considerable spring flooding, in marked contrast to the late summer drought. This situation is being relieved by a system of deep drains to carry floodwaters through the ranges to the sea, and by the use of supplementary summer irrigation with underground water. Prior to the advent of the drains in 1864 (Williams, 1964), natural drainage was achieved largely by the percolation of water through the country rock or sinkholes and caves therein to coastal and submarine springs. In addition there was a sluggish movement of floodwater northwest along the inter-dune flats to the Coorong area, and southeast from Dismal Swamp to the Glenelg River in Victoria. The system of artificial drains is now extensive, but seasonal flooding inland of each dune range, permanent lakes inland of the Canunda Range, and the seasonal flow of springs are still common features.

Land-use in the Lower South-East has received much attention in literature, and the activities of the various government and other organisations in the area are well documented. A convenient summary is that of Hagerstrom (1965) who presents tables of agricultural production on the three most extensive soil types: rendzina, solonetzic, and podsolic. For example on the (podsolic) deep sands of the ranges there is bore water adequate in quality and quantity at from 30 to over 50 feet, and main production is sheep and beef on lucerne-phalaris pasture top-dressed with superphosphate, potash, and trace elements. Other items on the average 1500 acre farms are oats and pines, and there is some potential for increased production. The area developed for agricultural production in County Robe over a decade,

1953: 1,046,166 acres (84%)
1962: 1,135,971 acres (90%)

adequately represents the rate of development in the province.

The population of the Lower South-East is (1963) about 42,000 most of whom live in County Grey, and most of whom live near the main towns of the province, for example Mount Gambier (15,400), Naracoorte (4,500), and Millicent (3,400). Communications are good although in the area studied access to undeveloped scrub is often difficult by car, especially in spring due to excess surface water. Bitumen roads connect the main towns, and the ubiquitous rough and ready all-weather limestone roads serve most farms. Maps of the South-East are plentiful, ranging from various road and tourist publications, to those of the specialized organisations presenting geography, geology, soils, agriculture, forests, and others; maps showing land subdivisions and aerial photographs are available from the Lands Department.

The climate of the Lower South-East is well known and general descriptions may be found in numerous publications dealing with the Australian environment. Climatic data are available from the Commonwealth Bureau of Meteorology which has a recording station at Mount Gambier, and various data and descriptions are presented in the introductions to Crocker (1944), Sprigg (1952), and Blackburn (1959), (1964). The area is within the temperate zone and is subject to a succession of subtropical anticyclones which largely determine the weather in their passage eastwards across Australia. Since the Lower South-East is entirely within 100 miles of the Southern Ocean, there is some coastal influence on the weather. The net result is hot dry summers with maximum daily temperatures occasionally reaching 100 degrees Fahrenheit, and cold wet winters with numerous frosts. The mean annual rainfall for the area studied is about 25 inches falling mainly in the six winter months following marked opening rains in April (Figure 4), and the growing season in which rainfall is effective is about 8 months. Mean annual temperatures for the province are 56 to 58 degrees; the average daily temperatures for the two main towns are shown:

	Mt. Gambier		Naracoorte	
	Jan.	Jul.	Jan.	Jul.
max.	74	56	82	57
min.	54	42	56	40

The wind roses (Figure 5) indicate southwesterly prevailing winds with prominent winter northwesterlies, which would be expected from the northerly migration in winter of the path of the anticyclones.

1. The Lower South-East: (b) geology.

The Lower South-East coincides geologically with the Gambier Sunklands which may be defined as that portion of the Otway Basin in South Australia. The Sunklands have a similar history of relatively undisturbed marine and terrestrial sedimentation to that of the rest of the Murray and Otway Basins. However they differ in the degree of Mesozoic lacustrine deposition, and in the degree of preservation of stranded Pleistocene coastlines. Sprigg (1952) gives a comprehensive description of the geology of the province.

The stratigraphy of the Lower South-East has been determined largely from bores, due to the absence of outcrops in the province. The predominant country rock is the Mid-Tertiary marine Gambier Limestone, several hundred feet thick, and its equivalents. This is underlain by several thousand feet of terrestrial Mesozoic sediments on the Palaezoic sediments and metasediments which form the floor of the basin. The Gambier Limestone is regarded by Ludbrook (1963) as Middle and Upper Oligocene to Lower Miocene in age, based on a study of planktonic foraminifera; she does however emphasize the uncertainty of the Oligo-Miocene boundary. The formation occurs to a varying degree over the whole of the Murray and Otway Basins, a total extent of some 100,000 square miles, since it was laid in warm shallow seas of the Murravian Gulf (Figure 1). The rock, which consists largely of the hard remains of coraline bryozoa and foraminifera, is thus porous and almost pure calcium carbonate; it is mined for building stone and lime, and carries the groundwater which is a local source of domestic supplies (Ward, 1941). Within the Otway Basin the Gambier Limestone grades in purity, thickness, and depth; it is clayey and less porous, and generally thinner, to the north-east. For example, on the Padthaway Horst dividing the Murray and Otway Basins it is 200 feet thick, at Mount Gambier 600 feet, and at Portland 2300 feet; at Mount Gambier a particularly pure deposit outcrops for about a square mile, and is the source of the familiar building stone.

Overlaying the Gambier Limestone are various volcanic, aeolian, and sedimentary deposits, for example Pliocene basalt in Western Victoria (Symposium, 1964) and shell beds in the Lower South-East (Crocker and Cotton, 1946); Pleistocene dune ranges in the area studied and lagoon and estuarine deposits in the inter-dune flats and elsewhere. Immediately below the limestone the Lower Tertiary Knight Sands and Clays represent paralic conditions preceding the Mid-Tertiary marine transgression, and similar sedimentation in coastal swamps and estuaries with periodic incursions of shallow sea water also obtained in the Cretaceous. Jurrassic argillaceous sandstones 3000 to 5000 feet thick indicate very rapid sedimentation in a deep landlocked fresh water basin. They form the bulk of the sediments in the Otway Basin, especially in the South Australian section - the Gambier Sunklands.

Tectonic activity in Southern Australia may be considered as either Palaeo-Mesozoic or Cainozoic. The first resulted in uplift of the granitic Padthaway Horst, downwarp of the Murray Basin to a depth of 1000 feet, and downthrow of the Gambier Sunklands to a depth of some 4000 feet. Cainozoic activity is reflected in the present topography. There was an earlier period forming Bass Strait and the Older Basalts of eastern Victoria, but the later period was the main one and has been called the Kosiosko Epoch (Fenner, 1930), since the Great Dividing Range resulted. Uplift commenced in Upper Miocene times following stable Lower Tertiary peneplain conditions, and a long period of steady uplift caused the Mid-Tertiary seas to gradually retreat. Activity still continues today, but was emphasised in the Upper Pliocene when the Newer Basalts, 1 to 200 feet thick, were extruded to form the 9000 square mile Basalt Plains of Western Victoria (Symposium, 1964) with which the Burr-

McIntyre vulcanism is associated.

The Lower South-East was relatively unaffected by the Kosiosko Epoch but there was some bedrock block-faulting and regional warping. The block-faulting was Plio-Pleistocene coinciding with the Burr lava flows, with dolomite and springs in County Grey indicating some faulting and folding. The faults are contentious, Hossfeld (1950) calling the structures marine cliffs; probably they are both. Regional warping was Pleistocene-Recent causing the land to tilt downwards from the Cape Banks Axis (Gambier Upwarp) in the Dismal Swamp area. The degree of downwarping is measured in one area by Sprigg (1952), and vindicated in the Murray Lakes area by De Mooy (1959), although Tindale (1959) considers that in the Coorong area downwarping is less than generally supposed, and that progressive shallowing of the Coorong lagoon is due to precipitation of dolomitic limestones. Associated with the warping was Gambier-Schank volcanism occuring about 5000 years ago, and as such producing ash and tuff, since Newer Basalt activity in the last 15,000 years was explosive in nature. The very mild repercussions of the Kosiosko epoch in the Lower South-East resulted in enough progressive uplift of the Gambier Limestone to allow formation of distinct coastal dunes in separate Pleistocene sea-level stages, and to subsequently strand them above sea-level, but not enough to destroy them.

The topography of the province is a result not only of tectonic activity (or lack of it), but also of changes in sea-level in the Cainozoic. Zeuner (1959) quotes various authors who consider that world-wide sea-level has been continuously falling in the Cainozoic to the extent of 1000 feet in all, of which a 220 foot fall has occurred since the Pliocene due to unknown causes but possibly oceanic crustal subsidence. If this is correct, the retreat of Mid-Tertiary seas from the Murravian Gulf was due only in part to regional warping and gentle uplift in the Kosiosko Epoch; i.e. the fall in sea-level was both eustatic and isostatic (Sprigg, 1952). Nevertheless, irrespective of the cause, the sea had retreated to the position of the Naracoorte Range by the start of the Pleistocene and stopped there long enough to form shell beds and sand dunes. At this time the Mount Burr region formed a prominent peninsula in an otherwise sweeping coastline stretching in a NNW direction from Mount Gambier through Naracoorte (Figure 2). Subsequent eustatic fluctuations in sea-level have left a number of other stranded coastline remnants which, associated with siliceous sands (Figure 3), largely determine topography in the area studied.

1. The Lower South-East: (c) soils.

There are abrupt boundaries between the soil types of the province, since they are controlled by parent material and topography rather than climate. There is a number of miscellaneous soils, but the four main types, with their approximate extent in County Robe, are as follows:

dune range soils formed from calcareous beach sands -
podsol (26% of Co. Robe),
terra rossa (7%);

interdune flat soils formed from lacustrine and estuarine deposits - groundwater rendzina (38%),
solodised solonetz & solod (25%).

The former two will be discussed in some detail below, as they are the soils concerned in the vegetation survey, while the latter two are
the latter two are discussed here. Relevant references are the general description of Crocker (1944), the more detailed C.S.I.R.O. investigations of Blackburn (1959 and 1964), and the soils manual of Stephens (1962).

The groundwater rendzina is a shallow heavy-textured black soil over calcareous material on the plains. It is generally flooded in spring, and may set hard and crack in summer. It is the most extensive soil type in the Lower South-East where it supports improved pastures, e.g. on the Naracoorte Plains, and indeed is not known to occur commonly elsewhere in

Australia. There is little profile development, generally about 12 inches of black friable lime-free clay of pH 8.0 over limestone and marl, and less commonly a variable depth of grey limey loam. The rendzina itself, a dark brown well drained soil of similar origin, is not common.

The solonetzic soils are those which have a moderate depth of light-textured grey soil, pH about 6, over a subsoil of compact brown clay with lime at depth, occurring on higher plains than the rendzinas. The solodized solonetz is the less mature form, and is more extensive, especially in the north; its topsoil is shallower and more acid, and lime and soluble salts are more frequent at shallower depths, while the subsoil has a characteristic columnar structure and a veneer of white silica. On the other hand the more mature solod lacks this structure, and has a layer of ironstone gravel above the subsoil. The Kalangadoo Sand in County Grey is termed a meadow podsol by Stephens <u>et al.</u> (1941), but Blackburn (1959) considers it to be a solod on genetic grounds.

A number of locally important minor soils occur in the Lower South-East on a variety of parent materials. The volcanic areas of County Grey have some fertile krasnozems, and some chernozems and black earths containing small amounts of volcanic dust. In the north-east there are grey soils of heavy texture ("gilgae") on the higher plains, and saline soils where drainage is impeded. On limestone rises in the solod area shallow red-brown earths occur which are similar to terra rossas, and are used for wine growing (at Coonawarra) and pastures (at Kongorong). Various swampy soils, including peat, occur irregularly throughout the area, especially inland from the coastal calcareous aeolian sands which are discussed with the soils of the ranges.

1. The Lower South-East : (d) vegetation.

Vegetation boundaries in the province are controlled largely by soils, and as such are abrupt. Nevertheless, Wood (1939) describes ectones between the two main formations in the area studied, dry sclerophyll forest and savannah woodland. A typical sequence shows Eucalyptus baxteri forest on the podsols grading through E. huberiana to E. leucoxylon and Casuarina stricta on the terra rossas, and through E. ovata and heaths to E. camaldulensis woodland on the solods. Wood (1937) has given a general account of the vegetation communities, while Black (1943-1957) and Ewart (1930) have compiled flora, the former in the process of revision by Dr Eichler of the State Herbarium of South Australia. The standard account of Lower South-East ecology is by Crocker (1944), who describes four vegetation categories: dry sclerophyll forest and heath (q.v. vegetation of the dune ranges); savannah communities and other communities.

Savannah communities extend from those on shallow red sandy-loams of the ranges to those on black clays of the flats. Melaleuca pubescens occurs on the terra rossas of the ranges, and similar soils on raised portions of the flats, especially near the coast, e.g. on the Woakwine Range. The community is very open with introduced grasses and clovers or scattered annual and perennial herbs and shrubs such as Bursaria spinosa; Leucopogon parviflorus and Acacia Sophorae are common near the coast, and mallee replaces the dominant tree to the north. Sheoke, yacka and bracken predominate on the deeper soils, such as on Harper's Range inland. The E. camaldulensis community occurs extensively in the province, largely on meadow podsols (i.e. solods of Blackburn, 1959) such as the Kalangadoo Sand. Native grasses with occasional shrubs have now been largely replaced by sub-clover, perrenial rye, cocksfoot, and phalaris, and the soil subjected to cultivation and drainage. A number of transitional types occur: rushes, bladey grasses, and other monocots may replace the normal understory, and Banksia marginata, sheoke, hill gum, or blue gum may replace the dominants. Rendzina soils typically carry the Gahnia trifida - Cladium filum community which is treeless except for B. marginata, and for E. ovata with yacka, on soils grading to meadow podsol.

Other communities in the Lower South East are those of the volcanic hills, swamps, and mallee areas. Volcanic areas are limited to County Grey, and are generally farmed or support open E. ovata, A. melanoxylon and A. mearnsii. Swampy areas of various degrees of soil texture, drainage, and salinity are frequent; they are little studied, but commonly support Melaleuca e.g. M. halmaturorum and M. oraria. Mallee areas are those which contain eucalypt species with a characteristic coppice habit, little understory, and solonized brown soils (Crocker, 1946). Thus the vegetation of the Upper South-East is regarded as transitional between true mallee and sclerophyll forest, since in addition to the eucalypts there is a sclerophyllous understory and the soils are solodized solonetz. The formation is known as mallee-heath (Wood, 1937); it is distributed extensively on the siliceous sands which obscure Pleistocene aeolianite in the Upper South-East (Figure 3), and its importance in the area studied is discussed in the section on vegetation of the dune ranges.

The vegetation of the Lower South-East has affinities with that of Eastern Australia (Crocker, 1944). In contrast, other areas in the state such as the gulf regions have an equal mixture of species from both the east and the south-west, the two areas of species production and dispersal (Wood, 1930). This situation is suggested as being due largely to disjunction of a pan-Australian flora in the Upper Tertiary, and to the pattern of recolonization after a Recent arid period (Crocker and Wood, 1947).

By Mid-Tertiary the Australian element was predominant across southern Australia (Wood In Keast, Crocker, and Christian, 1959). Prior to this a broad-leaf mesic flora containing species of Antarctic and Indo-Melanesian origin such as Nothofagus, Podocarpus, Flindersia, and palms had developed under stable peneplain conditions. These conditions followed a major epoch of folding and the transgression of Cretaceous seas, which marked the biological isolation of Australia from Asia. Mid-Tertiary seas destroyed large areas of vegetation and initiated the disjunction into east and west. Retreat of the seas in the Eucla and Murray Basins coincided with the uplift of the Flinders-Lofty-Olary Range, but the timing of these events was such that for a short time in the Upper Tertiary there was a virgin area from Port Augusta to Portland. This time was the last opportunity for the mixing of east and west before the uplift of the ranges and the corresponding downthrow of the gulfs were completed. Similar migration took place from the east to the area studied while the seas retreated and the Great Divide was uplifted. Vegetation at the close of the Tertiary was similar to that of today, although Proteaceae was more prominent, since Pleistocene fluctuations in temperature and humidity appear to have had little overall effect.

The present composition of the vegetation of the Lower South-East in terms of eastern and western species is thought to be due in large measure to the effects of Mid-Recent aridity. This Great Australian Arid Period or Post-Glacial Thermal Maximum occurred some 4000-6000 years ago, and apparently was contemporaneous with the Anadara (Arca) trapezia beds of the South-East and the Climatic Optimum of the northern hemisphere; see Crocker and Wood (1947), Symposium (1964), Sprigg (1952), Zeuner (1959), Tindale (1933), and other references therein. Widespread destruction occurred because the climate, although only slightly more hot and dry than today, was severe relative to the rainy glacial periods; in addition, the onset of aridity was sudden. However, some plants were able to contract their areas and survive the arid period in refuges such as mountains and large rivers. Such plants were the colonizers of bare areas, upon the return of slightly more humid conditions, mainly by migration along suitable continuous habitats such as the siliceous dunes and sheets of the South-East. As a result the vegetation on the sands of the Lower South-East show affinities with that of Western Victoria; in fact, according to Crocker (1944), two thirds of local species also occur exclusively in the east, none in the west, and a quarter is common to both. It must be emphasised that the above history is based on conjecture rather than fossil evidence, of which, at least in the Quaternary, very little exists (Dr N.M. Wace, pers.comm.).

Bibliographies of the effects of fire on vegetation and soils have been collected by Cooper (1963) and the Society of American Foresters, Forest Fire Division (1963); Mr D.R. Douglas of the S. Aust. Woods and Forests Department also has a comprehensive list of references. Long term effects of fire on vegetation types are discussed by Gilbert (1962), and the course of pyric succession in eucalyptus sclerophyll forest by Wood (1937) and Jarrett and Petrie (1929). Gilbert points out that fire is to be regarded as a major ecological factor in the long term sense, but that existing vegetation regenerates rapidly after fire; however, bracken is induced by frequent burning of E. regnans and E. obliqua forests. Wood, referring to the E. obliqua - E. baxteri association, states that fire affects only the understory, and that return to its original floristic state is accomplished in a very few years, fireweed Ixioda achilleoides being replaced by teatree, Leptospermum myrsinoides, at from three months to three years after fire. Jarrett and Petrie in the E. amygdalina - E. obliqua association in Victoria point out that bracken, Pteridium aquilinum, where present originally, will be a foot or so higher in the spring following a winter fire than the Cassinia which is usually prevalent after fire. They also emphasize the importance of fire in stimulating the growth of other rhizomatous species and of the seedlings of eucalypts and acacias. The normal floristic composition of understory species seems to be re-established in about two or three years. The author's observations on this subject, of some importance in choosing sites for the survey, are discussed in Part II, below.

Figures 2-5.

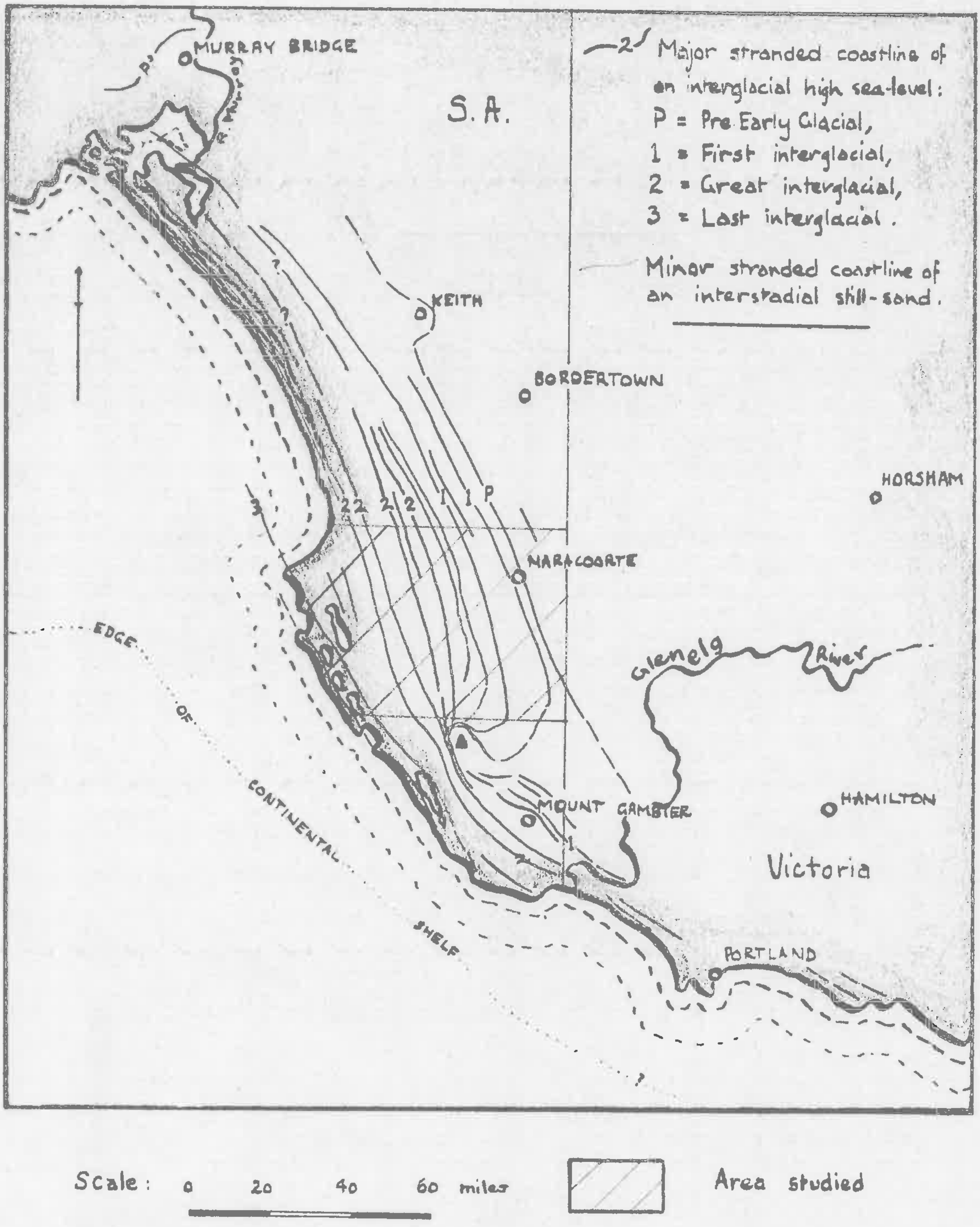
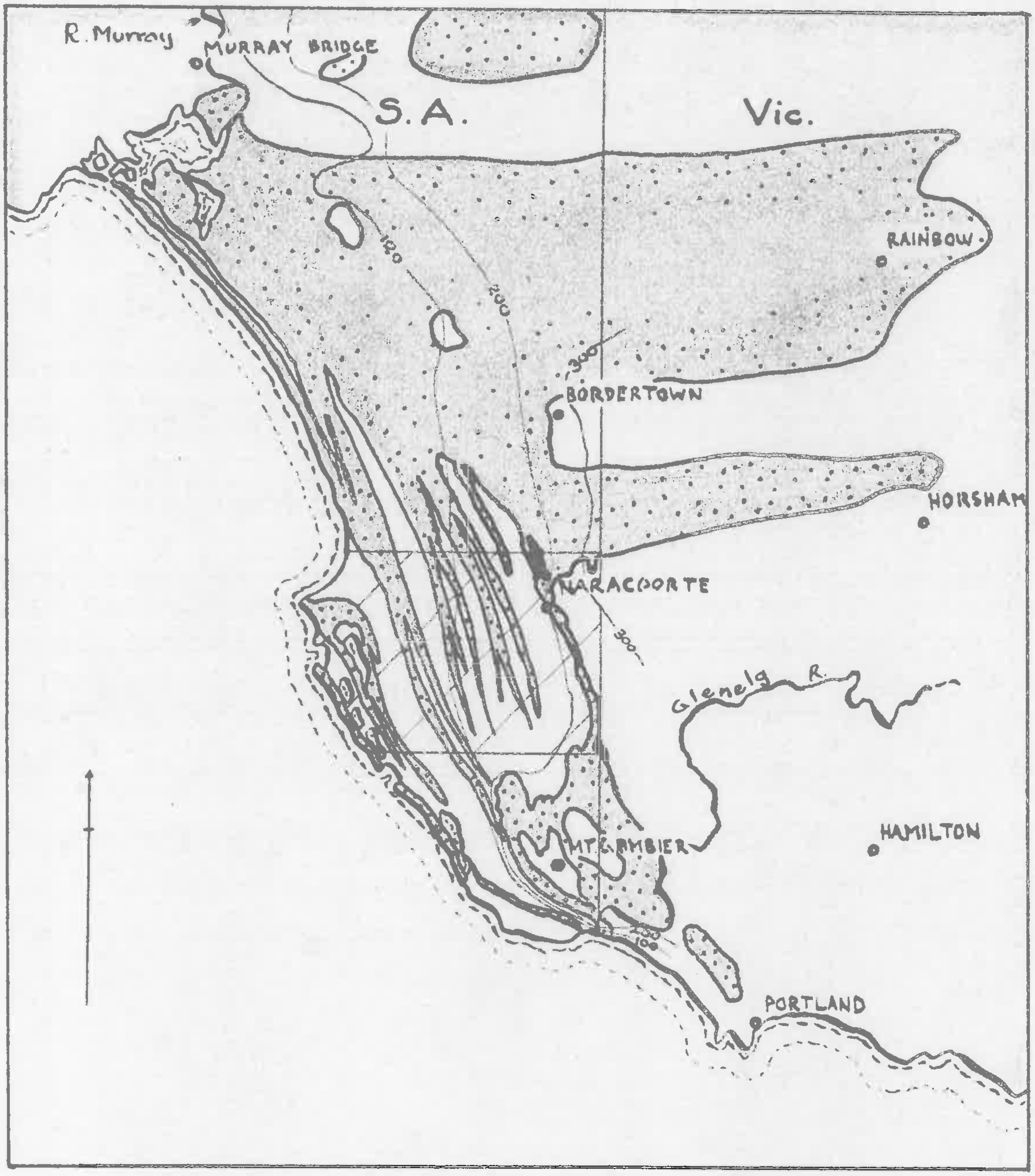


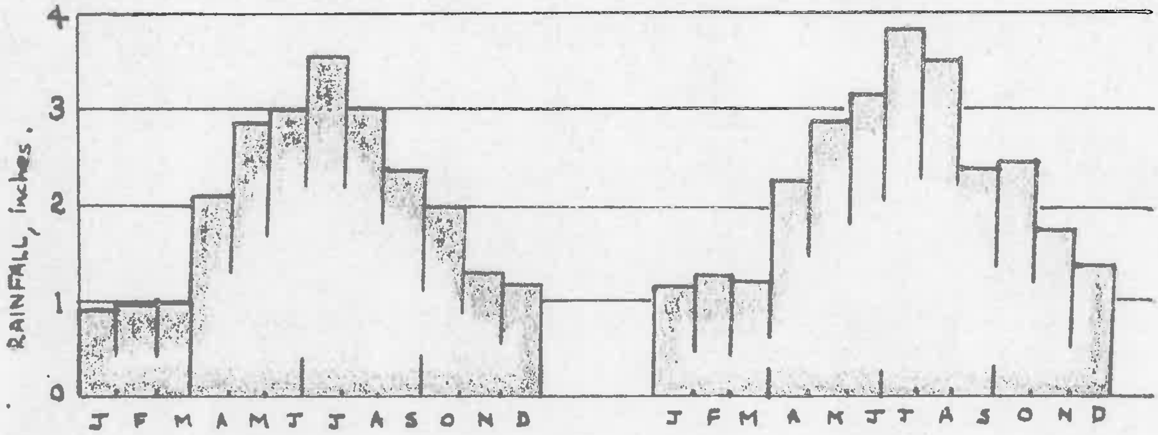
Fig. 2. **STRANDED PLEISTOCENE COASTLINES** are represented by aeolianite, shell beds, and various other beach structures. In the area studied, aeolianite stranded coastal dunes predominate and are the basis of the familiar dune ranges of the Lower South-East.



Scale: 0 20 40 60 miles — Siliceous sands

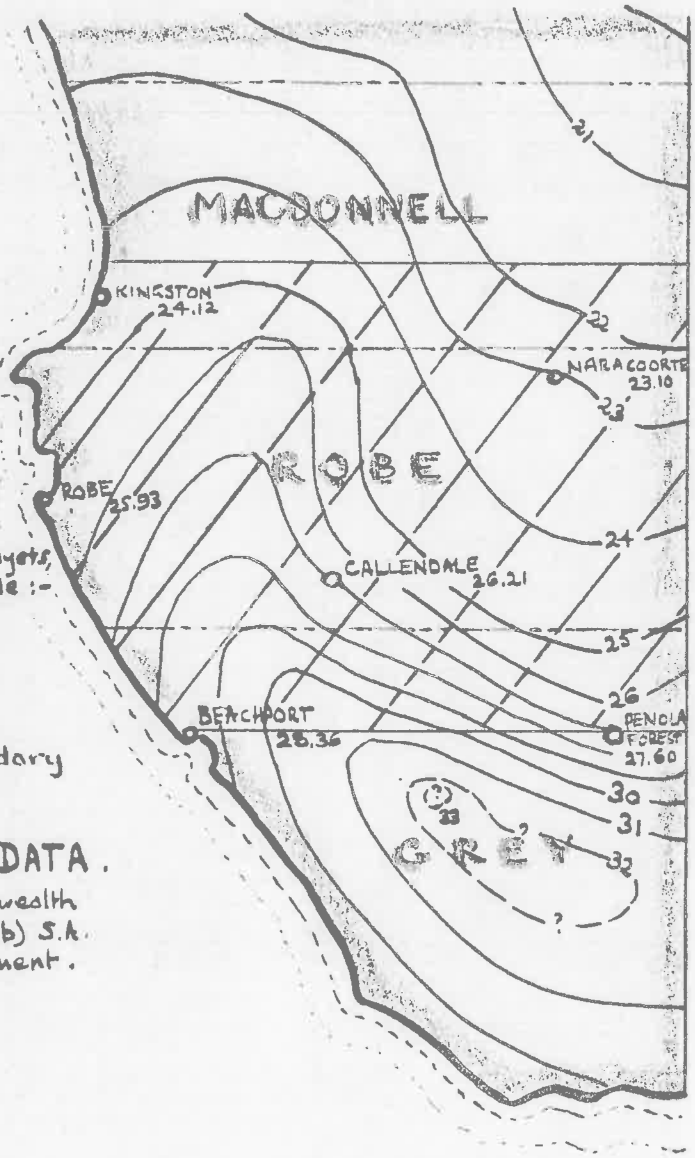
200 Elevation, feet — Area studied

Fig. 3. THE SILICEOUS SANDS accumulated as dunes or sheets in the quaternary. In the area studied these sands are associated with Pleistocene aeolianite, forming the familiar dune ranges of the Lower South-East.



(a) COASTAL station, mean monthly rainfall, 1931 - 1960; Kingston, mean annual rainfall = 24.12".

(b) INLAND station, mean monthly rainfall, 1924 - 1960; Penola Forest, 35 miles from coast, year = 27.60".



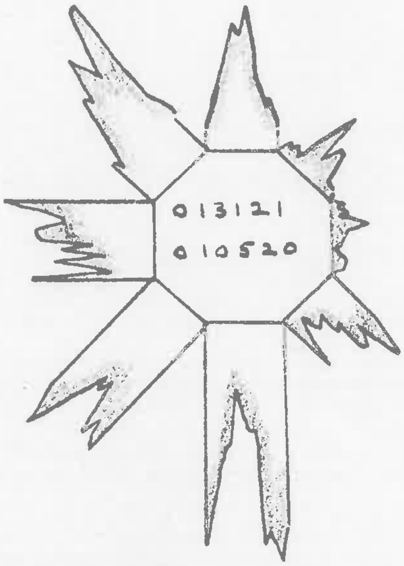
(c) LOWER SOUTH-EAST mean annual rainfall isohyets, 1931 - 1960, inches. Scale :- 1 inch = 20 miles.

Area studied

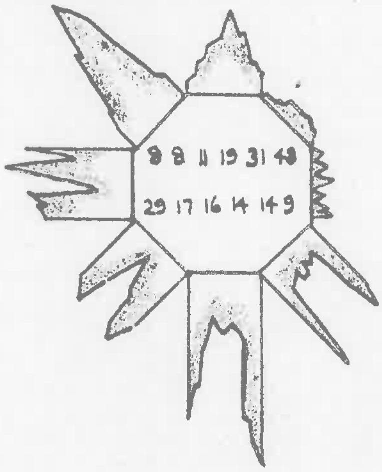
County boundary

Fig. 4. RAINFALL DATA.

Sources: (a), (c) Commonwealth Bureau of Meteorology; (b) S.A. Woods and Forests Department.



(a) Robe, 1943-1947: coastal, altitude ≏ 30 feet.



(b) Mt. Gambier: 15 miles inland, altitude = 150 feet.

Fig. 5. WIND ROSES, simplified, showing monthly frequency distributions of wind directions at 3 p.m. local time to eight points of the compass. At each point, read clockwise from January to December. Relative monthly frequency of calms is shown inside the rose. Sources: (a) Bureau of Meteorology, (b) Woods and Forests.

Scale: 0 10 20 30 40 50 Frequency %

2. The dune ranges: (a) general description.

The stranded coastal dune ranges of the Lower South-East are the most important topographical feature in the area studied. They have been frequently described, from about 1862 by the early geographers and geologists (see Tindale, 1933) to the present, by workers interested in various aspects of the province such as groundwater (Ward, 1941), ecology (Crocker, 1941), and shell fauna (Crocker and Cotton, 1946), and have been variously called stranded sea beaches, beach ridges, ~~and~~ coastal remnants, strandlines, and raised beaches. The most comprehensive accounts are those of Tindale (1947), Hossfeld (1950), and Sprigg (1952).

The nature and disposition of the ranges may be ~~compiled~~ appreciated from Figures 2,3,6,7, and Table 1 which were compiled largely from Sprigg. There are about thirty ranges in all, varying in length from 10 to 100 miles as distinct ranges, and considerably longer as remnants obscured by earth movements ~~are~~ and other processes; e.g. the Alexandrina Range which disappears gradually under that lake (De Mooy, 1959), and the "Tintinara Bay" near Keith caused by the Naracoorte strand being tied to granite outcrops during its formation (Tindale, 1959). The mouths of the Murray and Glenelg ("Mundi") Rivers breached this and other younger strands at various times (Hossfeld, 1950), and subsequent coastal erosion has affected the Woakwine, Canunda, and other postulated offshore ranges. Tindale (1947) describes the ranges in some detail, stating that their length is up to 200 miles, e.g. the Woakwine extends from east of the Glenelg River to Lake Alexandrina. He also stresses the complexity of the Naracoorte Range, suggesting its continuity with the Marmon Jabuk Range east of Murray Bridge - this suggestion is ~~discussed~~ discounted by Blackburn et al. (1965)- and describes the 20 foot Arca (Anadara) beach, suggesting its indication of recent warmer seas. He attributes the Bakers, Ardune, and East Avenue Ranges all to one "terrace", i.e. period of dune formation, and the West Avenue and Reedy Creek to another.

A section of a dune range reveals that it consists of two materials, namely aeolianite limestone and siliceous sands (Figure 7c). The aeolianite is consolidated calcareous beach sand composed of fragments of shells and micro-organisms, stratified and of varying hardness according to age; it is used widely as road metal. It has been also called calcarenite, travertine, dune limestone, and described as cemented, lithified, and indurated by various authors. This rock occurs throughout the world, but is particularly evident on the southern coast of Australia (Symposium, 1964). Kunkar, a hard secondary limestone of illuvial origin, frequently occurs as a veneer on the aeolianite (Blackburn et al., 1965), while fossil soils may be intercalated(Hills, 1939; Crocker, 1946; Symposium, 1964). In the area studied at least, the aeolianite is not to be regarded as a solid deposit: there is, in fact, only a mantle of more or less consolidated rock over unconsolidated calcareous sands, which suggests how the original coastal structure was preserved.

The siliceous sands are also of aeolian origin, but largely not contemporaneous with the aeolianite limestone. The sands have a history of leaching, resorting, and water erosion (Coulson, 1940), and are the parent material of the present podsols, known locally as deep sands, which support the predominant sclerophyll forest vegetation on the dune ranges. The sands constitute the bulk of each range, occurring up to several miles wide, and in the Upper South-East as sheets extending some 200 miles to the Big and Little Deserts of Victoria; thus, north of the area studied, aeolianite is not evident superficially, and typical dune ranges are not formed.

2. The dune ranges: (b) origin.

Despite the contrary suggestion of Hills (1939), it is generally accepted that the dune ranges mark the position of coastlines during various world-wide high sea-levels of the Pleistocene period (Figure 2). This period was one of alternate glaciation and deglaciation, high sea-levels occurring in the interglacial phases, and in warm interstadials within each glacial phase (Zeuner, 1959; Daly, 1934). However, the actual age of the dune ranges, and some aspects of their history, are yet to be agreed upon, in particular of the source of the siliceous sands (Figures 7c,3). But, whatever their origin, the sands are thought to have been considerably winnowed, resorted and redeposited by wind before being fixed and podsolized in their present position. Therefore, the sands of a particular range may not necessarily be associated genetically with that range.

Eustatic sea-levels, due to successive advances and retreats of the sea during the Pleistocene, were suggested as the cause of the ranges by Tindale (1933), and this has been subsequently corroborated by others (Blackburn <u>et al.</u>, 1965; Ward and Jessup, 1965). Other suggestions were: a simple orderly recession in the Recent (pre-Tindale), and intermittent regional uplift (Ward, 1941). By comparing fossil fauna and other characteristics, Tindale tentatively correlates the ranges with interglacial terraces on the south-east coast of America, concluding that the ranges are successively younger toward the coast. Sprigg (1952) and most others agree with this, although Hossfeld (1950) has adduced evidence to the contrary. Sprigg, on the grounds of relative altitude and volume, correlates the ranges with European terraces, which have themselves been attributed to specific phases of the Pleistocene by Zeuner (1959). Zeuner also discusses the actual age of the terraces on the basis of the astronomical theory of Milankovitch, which relates the glacial and inter-glacial phases to fluctuations in the amounts of solar radiation received by the earth, and which provides the best available estimate (Table 1). Tindale (1947) reviews the literature and discusses Pleistocene chronology as it relates to South Australia. Such attempts to correlate local dune ranges with overseas terraces are based on circumstantial evidence, and ignore tectonic effects, according to Blackburn <u>et al.</u> (1965).

There is little reason to suppose that the original coastal dunes, now represented by aeolianite, were very different from modern dunes. Sprigg (1952) considers that they were typical open ocean coastal backshore dunes, similar to those on the Coorong beach today. However, it has been thought that inland migration of submarine offshore bars (Johnson, 1938) is relevant to the South-East (Tindale, 1947). Possible origins of the original calcareous dune material are the River Murray heavily laden with calcareous salts, currents from the west laden with shellfish food, and the grinding action of the open ocean (Tindale, 1933). However Modern South-East beach sands contain 77% calcium carbonate, which due to its relative softness cannot be transported, and which accordingly is largely derived locally (Sprigg, 1952). Therefore if the original coastal sands are to be regarded as similar (Crocker, 1946), the calcareous fraction of aeolianite is derived ultimately from remains of local shellfish populations. These must have been prolific in marine flat conditions, such as obtain today on the wide continental shelf off the Coorong beach.

Initial preservation of the Pleistocene dunes was enhanced by their calcareous nature, which enabled rapid consolidation and thus fixation. This idea was suggested by Tindale (1933), and became the classical leaching theory (Crocker, 1941) which purports to account for the origin not only of aeolianite, but also of the siliceous sands, and of travertine limestone in mallee soils (Crocker, 1946). According to the theory, each dune was partially leached for an indefinite time after its formation, causing the illuviation and redeposition of lime. The results were twofold:

1. a B-horizon of lime cemented sand now known as aeolianite, and whose degree of development reflects its age according to Gill (Symposium, 1964); and 2. a residual A-horizon, becoming progressively more leached, and thus siliceous, throughout the Pleistocene. The question of loess and mallee soils is contentious, and is in any case irrelevant to this thesis, so will not be discussed. Leaching is supposed to have continued until the Great Arid Period, during which the A-horizon was wind-eroded and redeposited as parent material of the present podsols.

The leaching theory is generally accepted in principle, but reservations are expressed with regard to the siliceous sands question. The source, timing, and method of origin of the sands are unproven; and the leaching theory is certainly not entirely correct in this respect (Blackburn et al., 1965). Suggested sources are Palaeozoic granite outcrops or Lower Tertiary paralic sands by (implied) erosion of the continental shelf (Stephens et al., 1941), and Jurassic sediments deposited by the Glenelg River near one of its ancient outlets (Hossfeld, 1950 and pers. comm.). Various times in the Quaternary have been proposed for the deposition of the sands, one feasible suggestion being during arid cycles within otherwise warm-humid interglacials (De Mooy, 1959). Denudation of sand dunes near Portland to a fluviatile plain is reported by Coulson (1940), and similar processes are known to have affected the Nangwarry Sands, but otherwise a deflationary origin for the siliceous sands is not impugned. Sprigg (1959) suggests that aridity as a factor in the erosion and deposition was not as important as the westerly winds greater than 15 knots prevailing in the Pleistocene. He also discounts the importance of leaching in the original dunes, since aeolianite occurs at the Murray Lakes despite a progressive decrease to the north in lime content of modern beach sands. However this decrease appears to have been wrongly deduced, and in any case the modern and Pleistocene situations are not necessarily similar in this respect. Therefore, substantially, the process of leaching and deposition of lime in the original calcareous dunes is vindicated, but the subsequent stripping of a siliceous residue is not.

The uniqueness of the dune ranges of the Lower South-East lies in the fact that they represent a whole series of Pleistocene coastlines, which are quite distinct for considerable distances. The roles of progressive warping in stranding the original dunes, and of partial leaching of lime in their initial preservation have been indicated. Subsequent preservation is due to absence of significant river erosion, since there are no highland catchments and underground drainage largely obviates the need for rivers.

2. The dune ranges: (c) soils.

In the area studied, podsol, terra rossa, and calcareous sands are the three soils associated with the ranges; as such their common parent material is calcareous beach sand. General descriptions are to be found in the references cited above, while more specific investigations are those of Stephens et al. (1941) who present details of the podsols near Penola Forest, and Blackburn et al. (1965) who consider the development of the range soils in detail.

The podsol is the predominant soil of the ranges and occupies about a quarter of the area studied. It is developing on siliceous sands, which are themselves largely the result of Quaternary leaching and aeolian sorting of calcareous beach sands, although Blackburn states that some podsols are residual, i.e. not resorted. The solum is three to ten feet thick, and the parent material of the order of 30 feet; both generally consist of loose infertile acid quartz sand with little watertable influence. The profile details are,

- A: 1-8 feet of loose white or light grey sand or sandy loam pH 6.1, grey with tree roots and organic matter pH 5.8-6.2 at the surface;
- B: a variable iron-organic illuvial horizon, typically 2 feet of compact yellow and brown sand or sandy loam pH 5.9;
- C: deep yellow sand.

Fertility is generally low, for example in the top six inches total nitrogen may be 0.1%, and phosphorus (HCl extract) 0.01%; chemical analyses by the C.S.I.R.O. are presented in articles by Blackburn and by Stephens (see Bibliography). The origin, vegetation, and land-use of the podsol zone are discussed elsewhere.

The groundwater (humus) podsol occurs commonly within the normal podsol zone where land is low-lying or drainage otherwise impeded. Such conditions obtain between dune range and interdune flat, and in the flattened sand deposits in the Hundreds of Nangwarry and Coles. Such areas are known as heathlands because of the typical shrubby treeless vegetation. The soil is a heavily leached white infertile sand, pH 5.3, but is nevertheless waterlogged in winter due to the black or brown iron-organic hardpan at about three feet known as coffee rock. Other variants of the podsol are the transitionals to terra rossa and to solonetz, coinciding respectively with changes in parent material and climate.

The terra rossa and calcareous sand together occupy about 12% of the area studied. The former is developed on kunkar or aeolianite limestone, the latter on unconsolidated coastal calcareous dunes. The calcareous sand is an azonal soil since there is no significant profile development, merely a darkening of the surface with organic matter; although this soil covers the Canunda Range, it was not concerned in the vegetation survey. The terra rossa on the other hand occurs on all the ranges contiguous to the podsol, and is the only soil developed on the actual Pleistocene coastal dune material, viz. aeolianite. The soil is a shallow sand to clay-loam, typically 6-18 inches of sandy loam, red to red-brown depending on drainage which is usually godd. The soil is of low to moderate fertility, pH 7.0-7.2, supporting improved pastures, arable crops, horticulture, and forestry unless very stony. Variants are the red-brown earth mentioned elsewhere, and the terra rossas influenced by aeolian accession of material from the lacustrine-estuarine plains, especially of silt.

2. The dune ranges: (d) vegetation.

Dry sclerophyll forest is the predominant formation on the ranges in the area studied, where its distribution is controlled by soil types. The most important association is that of the stringybark eucalypt E. baxteri on the podsols, and Crocker (1944) recognises two other associations, E. obliqua and E. huberiana, both on shallower soils. Wood (1937) regards all three associations as part of a single climax association, the first two being called "consociations", where one or other dominant is locally preponderant, and the third the E. baxteri - E. huberiana ecotone; his classification is probably more realistic, but not as simple, and will not be followed here.

The E. baxteri association has an open canopy at 40-50 feet; it is usually pure but occurs occasionally in mixed stands with most of the other eight or so eucalypts in the area, notably E. vitrea. A sporadic subcanopy of tall shrubs and trees includes Banksia marginata, Acacia melanoxylon, Exocarpos cupressiformis, and Bursaria spinosa. Over a half of the species of the abundant sclerophyllous understory of small shrubs and undershrubs belong to the five groups Proteaceae, Epacridaceae, Cyperaceae, Myrtaceae tribe Podalyriae, and Acacia section Phyllodineae. About a hundred species are present in this stratum, notably

Leptospermum myrsinoides, Pteridium aquilinum, Xanthorrhoea australis, Acacia myrtifolia, Epacris impressa, Brachyloma ciliatum, Leucopogon virgatus, Calytrix tetragona, and Hibbertia sericea. Variations in density and floristics in this stratum are difficult to characterise and usually reflect soil differences, particularly in drainage. This is the case with Pteridium which requires a light textured soil; this species has become widespread due to the increased light and decreased competition which have followed cutting, burning or clearing operations (see Gilbert, 1962). The sporadic ground stratum consists of annuals e.g. Wahlenbergia, perennials e.g. Hélichrysum, and grasses. The E. baxteri association grades imperceptibly into heath, discussed below, under certain conditions.

E. obliqua is an ash eucalypt but with a somewhat stringy bark. The association is similar in appearence to the above, but with Acacia pycnantha and Ac. mearnsii more prominent, and many sclerophyll shrubs, particularly Leptospermum, rare. It occurs within a restricted climatic and edaphic range, viz. rainfall above 24 inches and surface soil pH higher than 6, which conditions are met on the deeper terra rossas and the shallower volcanic soils. Thus in the area studied the association is transitional between E. baxteri and the savannah associations of Melaleuca pubescens, E. leucoxylon, and *Casuarina stricta*. Another community which grades between *M. pubescens* and *E. baxteri* is that of *E. fasciculosa*, containing *Xanthorrhoea semiplana*, *Hibbertia stricta*, *Tetratheca ciliata*, *Hakea rostrata*, *Olearia*, and *Leucopogon parviflorus*, and occurring extensively on skeletal terra rossas where the rainfall is above 25 inches. The *E. huberiana* association generally occurs as a transition between *E. baxteri* forest on the podsols and *E. camaldulensis* woodland on the solods, and is intermediate in topography, soil type, and appearance between the two formations. This association contains scattered *Ac. pycnantha*, *Ac. melanoxylon*, *Ac. mearnsii*, and *Banksia marginata* over a number of shrubs and undershrubs, particularly bracken.

The treeless heath formation occurs on the humus podsol and to a lesser extent the solodized solonetz. It is likely to occur between the range and the flat in lieu of *E. huberiana* in areas where the siliceous sands have been flattened and spread more than usual. Thus the boundary may not be abrupt between sclerophyll forest with eucalypts and bracken, and heath without either. In some situations *Leptospermum juniperinum* and *Xanthorroea semiplana* will replace *L. myrsinoides* and *X. australis* which are typical of the podsols, before *E. baxteri* disappears; in others a shrubby form of *E. huberiana* occurs at the boundary. The species are very similar to those of the sclerophyll forest, with legumes, epacrids, melaleucas, and hakeas more prominent. Two associations deserve mention, viz. X. australis - Hakea rugosa on sandy rises, with Banksia ornata common where there is a claypan, and E. ovata where the soil becomes solodized; and Melaleuca gibbosa - H. rostrata with Casuarina pusilla in wetter situations. E. baxteri is frequently found on sand flats adjacent to a range.

The mallee-heath formation is represented in the Lower South-East by the E. diversifolia sub-climax association, which grades into the vegetation on the podsols, humus podsols, and terra rossas of the dune ranges in the area studied. Maiden regards this species as a variety of E. baxteri with which it is associated in County MacDonnell, particularly on Reedy Creek, Woolumbool, and Peacock Ranges (Wood, 1930). Here it has grey fibrous bark and large fruits, while the baxteri is extremely stunted, and ground cover is Astroloma humifusum, Darwinia micropetala, Phyllota pleurandroides, Adenanthos terminalis, and Grevillea ilicifolia. By contrast, on the Woakwine Range, at its upper rainfall limit of 25-30 inches, it has smooth bark and small fruits and is associated with E. fasiculosa; the soil is the characteristic shallow terra rossa of that range, and other species are those of the heath and scleroph¥ll forest with native currant Leucopogon parviflorus and coastal wattle Ac. sophorae.

Figures 6-7.

Table 1.

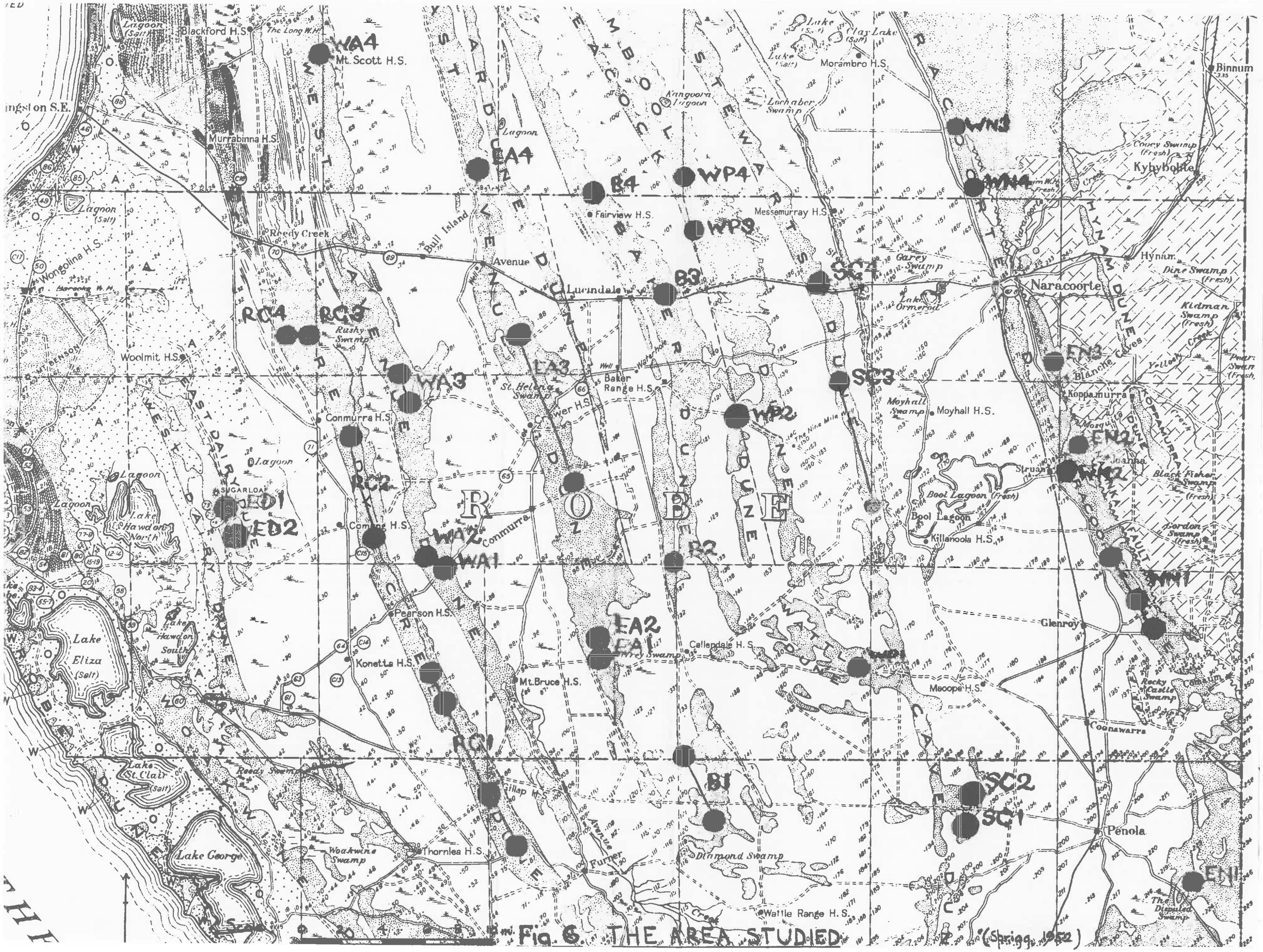
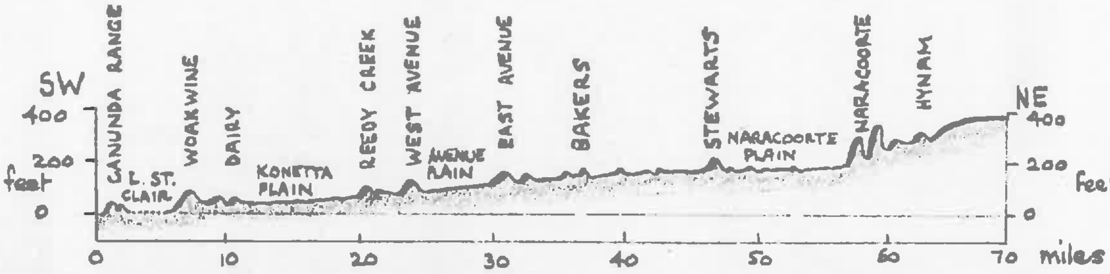
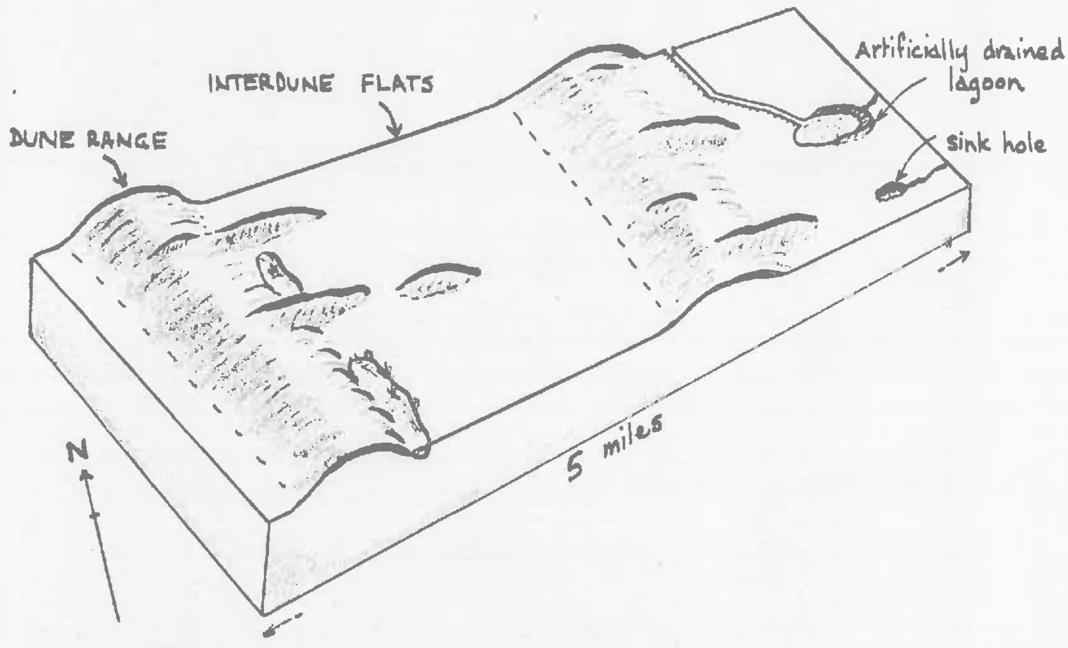


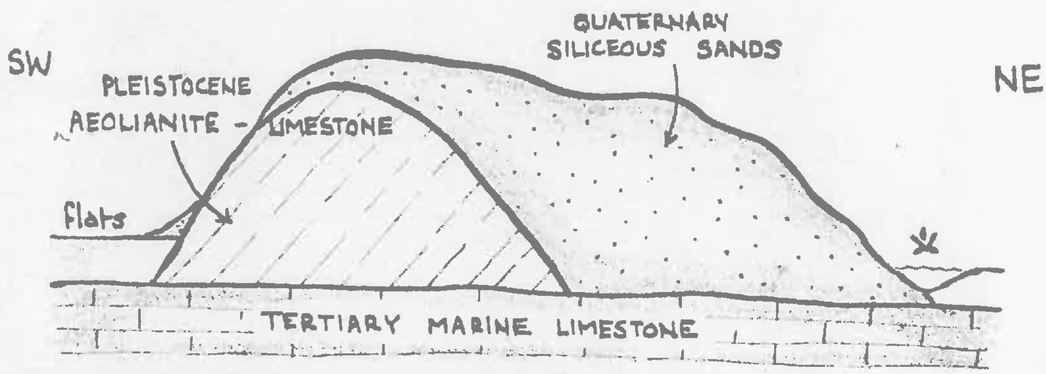
Fig. 6. THE AREA STUDIED (Sprigg, 1952)



(a) section across the area studied, from the coast to the Victorian Border.



(b) perspective diagram showing topography of the area studied.



(c) diagrammatic section of a dune range; height about 100 feet, width one mile.

Fig. 7. THE DUNE RANGES run parallel to the coast in the area studied, preventing the direct surface flow of excess winter rainfall to the coast. Sources: (a),(b) from Blackburn (1964).

Table 1.

SOME STATISTICS OF THE DUNE RANGES

representing stranded Pleistocene coastlines in the Lower South-East. Sources: Sprigg (1952), and Zeuner (1959).

RANGE		SIZE			AGE		REMARKS,
NAME, in area studied.	SYMBOL used in the analysis.	observed length, miles.	altitude of foredune* flats, feet.	average width, miles.	postulated glacial or interglacial phase of coastline.	radiation date thousands of years B.P.	and local names applied to the ranges outside the area studied.
HYNAM	-	2	250	0.5	Pre-Early Glacial (Silician)	?	= Koppamurra [? Pliocene]
EAST NARACOORTE	EN	80+	230	1 ?	"	580	"cliff" beach. (1st glacial ?)
WEST NARACOORTE	WN	90	230	2.0	1st Interglacial (Milazzian)	538	= Dismal
HARPERS	-	9	228	0.4	"	504	= Black
STEWARTS	SC	60	210	1.0	"	483	= Cave = Mingbool
WOOLUMBOOL	WP	50	180	1.0	2nd Glacial (Mindel)	460	= ? Compton = Main Heath = Wattle
PEACOCK		35	145	0.6	"	445	= Glenburnie = West Heath (two ranges appear as one)
BAKERS	B	40	130	1.0	2nd Interglacial (Tyrrhenian)	425	= ? Lucindale
ARDUNE	-	35	105	0.5	"	370	
EAST AVENUE	EA	45	120	1.5	"	330	= Gambier
WEST AVENUE	WA	55	100	1.7	"	294	= Caveton
REEDY CREEK	RC	60+	65	1.5	"	249	= Burleigh = Blackford = ? Neville = ? Alexandrina
EAST DAIRY	ED	10	30	0.5	3rd Glacial (Riss)	210	= ? Kongorong
WEST DAIRY	-	80	45	0.5	"	200	= MacDonnell
WOAKWINE	-	90	20	1.0	3rd Interglacial (Main Monastirian)	175	= Hatherleigh ? (two subsequent truncations)
CANUNDA	-	80	-45	? 1	" (Late ")	44	= Robe. (? Last (Wurm) Glacial ie. Pre-Flandrian)

* in area studied.

3. The data and its analysis: (a) general considerations.

Methods of measuring the behavior of individual plant species are fully discussed in the manual of Cain and Castro (1959). Collection and analysis of data is described pertaining to the problems of pattern, number, and dominance, which are the basic criteria of species behavior. The association of species into groups with common attributes, and detection and characterisation of such association, is discussed by Greig-Smith (1957).

Pattern is departure from random distribution of plants in space. Such departure is the rule in nature, and is due to habitat diversity and reproductive behavior. Pattern in the strict sense refers to individuals within a species, but is nevertheless basic to an understanding of groups of species, since such species being related will tend to be distributed similarly, and thus be associated. Intensity of pattern is the degree of non-randomness, which is usually measured by deviation of a population from the Poisson distribution. The several tests for this all involve frequency, i.e. the proportion of quadrats occupied by a species, and such data is most commonly collected because it is convenient and comprehensive, but it is however liable to misrepresentation under certain conditions, particularly when quadrat size is not suitable. This effect of quadrat size is used to indicate the scale of pattern. Greig-Smith stresses the importance of pattern in describing the occurrence of plants, and the significance of quantitative measures thereof in solving ecological problems.

The importance of a species in a community cannot be adequately expressed without measures of number and dominance. The counted number of individuals per area is the density of a species, and when estimated is called abundance. This index is most meaningful when associated with some indication of height, diameter, or life-form. The term dominance is not specific, and its precise meaning must often be inferred from the context; for example, cover, canopy, volume, biomass, density, height, or crown position may be variously implied. Cover, i.e. the vertical projection of the leaf mosaic onto the ground, is a common index measured by point-quadrat or line-intercept methods or else estimated. The combination of cover and frequency is more valid in detecting pattern and association than frequency alone (Kershaw, 1957, 1960). A physically dominant species does not necessarily exert any ecological control on a community, although such control is usually implied.

Sampling technique, in particular the size, shape, number, and location of quadrats, is discussed in the manual and by Greig-Smith. The stratified random multiple plot method is considered to effect the best compromise between the convenience and precision of systematic layouts, and the measures of dispersion obtainable with random layouts. The importance of using correct quadrat sizes when collecting frequency data is stressed at length. For example, a too large quadrat is likely to overrate rare species with low intensity small scale pattern, and underrate common species with intense large scale pattern. Also, a large quadrat may not detect positive species association, whereas a too small quadrat will show an association as negative.

Selection of correct quadrat size is an arbitrary or trial-and-error matter. However, some degree of objectivity can be achieved by observing the graph of number of species scored x area of quadrat in the situation concerned. Cain (1932) as a result of his experience suggests that each synusia should have separate quadrat sizes as follows:

herbaceous layer	1	square	metre,
shrubs	4	"	" ,
low trees	16	"	" ,
tall trees	100	"	" .

On the other hand, Curtis (1959) considers that the difficulty of not using separate quadrat sizes is offset by difficulty of not using separate quadrat sizes is offset by the similar behavior patterns of trees and ground vegetation. A single quadrat size is considerably more convenient, and has been widely used. For example Goodall (1953) used a 25 sq. metre quadrat in the Victorian mallee, although Greig-Smith (1957) wonders whether this was large enough to include the largest scale of pattern. One may conclude that quadrat size must be determined arbitrarily, but with considerable discretion.

The role of species, not as individuals but as members of a vegetation community, is discussed by Greig-Smith (1957). He states that vegetation is of a continuously variable nature, modified by the much commoner occurrence of certain variants. A number of objective but necessarily arbitrary methods is presented, by which to distinguish the common variants, i.e. communities, from the less common, i.e. ecotones. Curtis (1959) also stresses the continuous nature of vegetation, and that hierarchical associations are for convenience only, and must be delimited on arbitrary bases. Distinction between communities may be based on relative pattern, number, or dominance of the associated species, according to the degree of refinement required. Measurement of differences between potential communities is objective, but the interpretation of such differences in classifying vegetation is subjective. Floristic composition is the obvious initial approach to such classification (Goodall, 1953), but consideration of quantities, e.g. product moment correlation coefficient of densities, is sounder, especially if a set of stands includes a wide range of floristic types. Factor analysis of estimates of cover by the method of principle axes is a most precise but laborious process, described in detail by Greig-Smith.

Having set up communities, they must be suitably described so that further stands may be assigned to them. With a given degree of overlap in the communities as defined, the risk of misclassification of stands can be minimised using appropriate techniques. Physiognomy is the result of relative performance of species of different life-forms; it can be measured, but is of value only in describing communities of a high order such as the formation. Species with a high degree of presence in one community relative to others, are said to have a high fidelity or exclusiveness to that community, and are known as faithful, preferential, characteristic, or indicator species; their use will probably continue in popularity, despite Curtis' (1959) contention that fidelity must be rejected statistically. His data shows that species of high fidelity are usually rare within the community, and contends that therefore sampling is likely to be invalid. Greig-Smith describes several other quantitative methods, for example the continuum analysis of Curtis, which is similar to factor analysis but less precise, less laborious, and of different application; Curtis used a combination of fidelity and importance value, the latter itself a useful index since it is the sum of relative frequency, density, and basal area.

Various tests for the correlation of vegetation and habitat are suggested by Greig-Smith; for example, depending on the type of data and the information required, Chi-squared, analysis of variance, or regression analysis might be used. This thesis is concerned with the effect of the factor time on vegetation with regard to the question of succession (Clements, 1916), so that particular attention was paid to similar studies on sand dunes in New South Wales (Burgess and Drover, 1953), and on volcanic mud flows in California (Dickson and Crocker, 1953). The latter study recorded frequency, cover, and basal area of the five conifer forest types, and changes in mass, carbon/nitrogen ratio, and pH of the forest floor and superficial soil; it was concluded that these characteristics remain relatively stable after about 500 years. Burgess (1960) suggests that similar stability, i.e. climax formations, obtains on the N.S.W. dunes at 240 years, and in African tropical forest at 50 years.

Variation in soils with age of the land surface is shown by terra rossa characteristics such as depth of soil, thickness of kunkar, and occurrence of ferruginous concretions and solution pipes (Blackburn _et al._, 1965). Further variation in the terra rossa may be shown by cutans, which are features of the surface of structural aggregates in certain heavy-textured soils (Brewer, 1960). They are superficial concentrations of the clay minerals and other minerals, and are loosely termed clay skins; their effects on profile development and plant growth may be considerable. Cutans are formed by illuviation and deposition, and there is evidence that, in general, their formation becomes progressively more dominant as soil profiles become older.

Thickness of both A and B horizons appears to increase with age in residual podsols in the South-East (Blackburn _et al._, 1965). However, it is difficult to determine whether a podsol is residual or secondary, and since the precise origin and history of the siliceous sands are not known, few conclusions can be reached. Nevertheless the deduction that podsols are more likely to be residual in elevated situations is probably valid. The age of some mature podsols is thought to be 1200-1500 years under conifers in Sweden, and 4000 years on the N.S.W. dunes (Burgess, 1960).

3. The data and its analysis: (b) interspecific correlation.

Distinction between vegetation communities, by the method of Goodall (1953), is based on association of species with a similar pattern of distribution. The raw data is presence or absence in numerous quadrats, i.e. actual frequency, and subdivision is carried out by consideration of the correlated species with the highest frequency at each step of the process. Quadrat data representing absence of the species is "pooled", i.e. discarded and later combined with other similar data to be further subdivided.

According to Goodall, vegetation may be described as heterogeneous if, subject to considerations of chance, the distribution of individuals in quadrats is not uniform. As discussed earlier, this situation generally is due to habitat diversity, causing two or more species to be associated. Thus interspecific correlation provides an index of heterogeneity; for the sake of simplicity only positive correlations are used, although it is recognised that negative correlations are equally meaningful, and that their omission could render the method less valid. On this basis, a set of quadrat data is considered not uniform if the number of positive interspecific correlations exceeds the number expected by chance. The data is arranged in 2 x 2 contingency tables and correlations tested by chi-squared, a significance level of 0.05, qualified by number of quadrats, being used throughout. If the data is edge-punched onto cards, a visual appreciation of frequency quickly indicates combinations suitable for testing.

Subdivision has as its object the assignment of quadrats into as few as possible groups which are homogeneous, i.e. without internal correlations. The procedure is to eliminate heterogeneity by first taking as a potentially homogeneous group, all quadrats containing one of the two most frequent correlated species (e.g. species A); all other quadrats are discarded temporarily. This potential group is then tested for correlation between A and other species, and further divided on the most frequent correlated species (e.g. B); B-absent quadrats are discarded as above, and pooled with the A-absent. Potential group AB-present is similarly tested and discards pooled. This process continues until a homogeneous group of quadrats is attained, whereupon the entire pool of species-absent quadrats is subjected to the original procedure.

In this manner, a number of homogeneous groups will be erected. However, these groups are regarded as discrete only if they each survive the test of showing significant association upon recombination with every other group, i.e. causing the reappearance of positive interspecific correlation. This stipulation does not of course apply to the group separated last, since this necessarily consists entirely of species-absent quadrats. Potentially homogeneous groups might equally well consist of quadrats containing none, both, or either of the two most frequent correlated species. However, the procedure described is empirically the most efficient.

3. The data and its analysis: (c) association-analysis.

Distinction between communities, by the method of Williams and Lambert (1959-1961), is based on data similar to that used by Goodall. However, subdivision is carried out on the species with the highest index of association, summed chi-squared. Also, absence data is not pooled, but treated as a distinct path of subdivision, and processed in the same way as corresponding presence data.

According to Williams and Lambert, a population is described as a multivariate system if associations between units of the population are not all independent. That species associations constitute a multivariate system is the basis of association-analysis. This method seeks to subdivide the plant population in the most efficient manner, leaving the least amount of significant association. Combinations of all species in pairs are tested for significance, and the algebraic sum of the chi-squared values of a species is deemed the association index of that species. Yates' correction for discontinuity is applied, but for the sake of simplicity the use of Fisher's exact method with small frequencies is not recommended. Species with a frequency less than 2% are ignored, although it is recognised that the omission of species of evén very minor occurrence can have a serious effect on the results. Non-significant and indeterminate chi-squared values are treated as zero; an indeterminate value occurs when either or both species are present or absent in all quadrats. Such species do not manifest pattern within the scope of the quadrats, so are discarded; in practice, species with frequency greater than 98% are regarded as indeterminate. When a large number of species combinations is to be tested, the use of an electronic computer is indicated.

An association index is used to assess the ecological importance of successive orders of subdivision, and of each group of species. Several possible indices are discussed, and in the selection of corrected chi-squared, principle is compromised for the sake of simplicity, since strictly speaking Yates' correction renders this index inappropriate. Furthermore it tends to alter the path of subdivision at lower levels, and to generate ambiguities such as a class with only one non-zero chi-squared value because all others have been treated as zero. On the other hand, uncorrected indices only change the degree of subdivision; also ambiguities are unlikely, and neither important nor irrevocable. Such indices are 1, the quotient of chi-squared on number of quadrats, and 2, the square-root of this quotient. The latter is suggested as being more appropriate, and the results obtained using it are compared with those using chi-squared. Since there is little difference, it is concluded that maximum summed corrected chi-squared has the right properties for the association index, albeit for the wrong reasons.

Subdivision might equally well be effected by a pooling process such as used by Goodall, or by a hierarchical process, i.e. not pooling. Williams and Lambert compared the two processes, and found the latter preferable, because the relative importance of the groups at each step is apparent. By contrast, with pooling the route of subdivision is meaningless, only the groups themselves being available for examination, and in any case the computation is longer. Certainly the final groups are similar to the hierarchical groups, but are not necessarily definable statistically by presence or absence of key species. ~~Term~~

Termination of subdivision is generally by reference to a standard significance level of 0.05, corresponding to a chi-squared of 3.85. However, the major subdivisions are of most importance in situations where association-analysis analysis is appropriate, viz. the elucidation of basic pattern in complex ecological situations. Therefore in order to save resources, Williams and Lambert selected an arbitrary maximum chi-squared (2^{-5}x number of quadrats) at which to terminate subdivision, and this expedient they called "short division".

Recombination of final groups is inherently likely to recreate significant association when an associative parameter is used, therefore recombination testing is usually pointless. However, two special situations may occur when it is not so. First, very small groups may combine indiscriminantly, indicating a significance level too low to detect association. Second, if many of the possible associations are indeterminate, recombination may not recreate association. This second situation is meaningful but rare, and not discussed except to suggest that here the criterion of non-significance has become less important than that of indeterminacy, which is normally not the case.

3. The data and its analysis: (d) cluster analysis.

Classification of variable populations, as outlined by Sneath (1962) and detailed by Sokal and Sneath (1963), is based on overall similarity of numerous characters. The method seeks not subdivision into groups, but merely representation of all species relationships to provide a basis for their subjective interpretation. Various measures of similarity suited to presence-absence data are suggested.

Suitable selection and expression of the population, its taxonomic units, e.g. species, and their taxonomic characters are basic to the validity of the analysis. These aspects are stressed since the method is applicable generally, not only to ecology. There should be as many characters as possible, at least 50, and these should be ascribed equal weight, each contributing one item of additional information about the species, so that no attribute is overemphasized; see also Diver (1940). In this way all knowledge about each species can be assessed, and, if an index of similarity is available, relationships between species can be expressed in a phenetic, i.e. "natural", classification.

Several methods for estimating overall similarity are presented, of which the most useful are thought to be the coefficients of association. One of these, suited to coding of characters in two categories such as plus and minus, is $S = a/(a + b + c)$, where a,b,c are numbers of characters according to the table,

		species A	
		+	−
species B:	+	a	b
	−	c	d

This index for the sake of simplicity ignores negative associations, such as entry "d". S values may be expressed as a percentage in which case 100% indicates complete similarity. The result of testing every combination of species, for which an electronic computer is necessary, is a similarity matrix tabulating the S value of each species pair, to say the nearest per cent.

Cluster analysis itself is the method for identifying from the similarity matrix phenetic groups or "clusters" of species with high mutual similarity. Retabulation of the matrix is the first step, listing species pairs according to their similarity at intervals of say 10%. By inspection of this table, associations between species at each level may be determined.

Such association may be expressed diagrammatically in the form of a "dendrogram", such as Figure 16 of this thesis.

For example, if species A & B associate at S = 90% or higher they form a cluster at that level, given an interval of 10%. Next, suppose C & D form a separate cluster; then these clusters will fuse at any one level at which all four species associate. In practice however, C & D will rarely associate with both A & B at one level, so that a criterion to determine the fusion of clusters - and in the same way the fusion of single species - must be decided. The simplest, although not the most valid, criterion is to allow fusion at the highest similarity of any species pair between clusters. Within a cluster, affinity will be indicated by presenting species in order of their entry to the cluster.

Patterns of association are revealed in the dendrogram, and these must be appraised subjectively according to the the information required from the analysis. If some clusters are thought to be of value, they can be described in terms of constant characters, and diagnostic keys prepared. One important aspect of this numerical type of analysis is that the proportion of character matches to mis-matches between two species should be a specific value, deviation from which is due to experimental error. Consequently separate studies on the same material should produce substantially the same result.

C. Research Objectives

This analysis of the dry sclerophyll forest on dune ranges in and near County Robe had three objectives:

1. TO RECORD disappearing vegetation.

The existence of scattered remnants of hitherto extensive natural vegetation, and the likelihood of its ultimate disappearance, indicated the expediency of making a permanent botanical record for its intrinsic value. With this initial objective in mind, the survey was planned to determine what species were present, and in what quantities, and how they were associated. Such information had not been collected quantitatively before, although several general descriptions were available.

2. TO CORRELATE vegetation and habitat.

The presence of a sequence of distinct habitats of differing ages suggested the second objective which was to correlate any heterogeneity in the vegetation with differences in the environment, particularly with respect to one factor - time. Other factors were to be held constant by careful selection of sampling sites with respect to soil, aspect, and rainfall and thus it was hoped that some evidence bearing on the question of primary plant succession would be found.

3. TO COMPARE analytical methods.

Having decided on the various aspects of sampling and measuring the vegetation, the problem of adequate presentation of a large mass of presence-absence data arose. This situation suggested the third objective; to compare results obtained using the recently proposed association-analysis of Williams and Lambert, with those using the well known positive interspecific correlation method of Goodall. In addition an examination was planned of the cluster analysis method of Sneath. It was intended that these investigations would yield useful information about techniques of vegetation analysis.

Plate 1.

TERTIARY GAMBIER LIMESTONE IS THE COUNTRY ROCK IN THE SOUTH-EAST.

(a) It is near the surface to the south: open-cut building stone quarries near Mount Gambier. (Photo, "Camera Techna").

(b) It is flat-bedded and not penetrated by water-courses: river red gum near Penola encouraged by seasonal flooding.

(c) It relieves flooding by gradually absorbing excess winter rainfall: sink-hole near Caroline.

(d) It carries local ground-water supplies: the lakes, Mount Gambier, looking north-west; also lack of vegetation in this area is apparent. (Photo, J. Pratt).




Plate 2.

AEOLIANITE LIMESTONE REPRESENTS PLEISTOCENE COASTLINES.

(a) Fossilised dune structure: Warrnambool, Victoria.

(b) Mantle of aeolianite over less consolidated calcareous material: Baker's Range near Lucindale.

(c) Terra rossa soil and solution pipes: close-up of (b).

(d) Modern coastal erosion of aeolianite largely reflects sea-level fluctuations: Woakwine Range near Mount Gambier.

Plate 3.

SILICEOUS SANDS ARE ASSOCIATED WITH AEOLIANITE IN THE AREA STUDIED: THEIR ORIGIN IS OBSCURE.

(a) Sands overlie aeolianite to form a dune range: West Naracoorte Range, looking south from Naracoorte. (Photo, J.Pratt).

(b) Deep artificial drains through the ranges relieve seasonal flooding: Drain K, West Avenue Range.

(c) The sands support dry sclerophyll forest: Peacock Range east of Lucindale.

(d) The sands have become podsolised: Bakers Range near Callendale.




Part II. METHOD AND RESULTS

A. Collection of Data

1. The sites: (a) reconnaissance.

County Robe was chosen for study because the dune ranges are most distinct in this area. To the south, the ranges coalesce in the Mount Burr area, and are largely without natural vegetation near Mount Gambier; to the north, they coalesce due to progressive regional downwarping towards the Murray Lakes, and in any case are obscured by siliceous sands supporting mallee-heath vegetation. Thus the study was initially confined to the dune ranges of County Robe, although subsequently extended to include adjacent Hundreds in order to obtain more data.

Initial reconnaissance was undertaken in the winter and spring of 1963. Enquiries of government and tourist agencies produced a number of maps of the area, and information relating to location of and access to the ranges was transposed onto a Lands Department map, and supplemented by weekend excursions by car from Penola Forest and numerous local enquiries. At the same time, and subsequently, a systematic survey was undertaken to determine the nature and extent of vegetation on any ridges which appeared to be part of a dune range ~~was recorded~~, provided that disturbance from earthworks or pastoral activity was not too great. This coarse information was to provide a basis on which to choose sites for quantative sampling.

At first, only scrub which covered an entire range from west to east was considered. However, this requirement was found to be far too stringent since most scrub occurred in patches, or along roadsides, or in strips running north and south. Therefore this idea was abandoned, thereafter any area greater than about an acre being considered. Location was determined from observation, enquiry, and, in the case of Naracoorte Range, from aerial photos. Aerial photos are of course ideal for locating scrub areas, but since they are usually several years old, and since scrub-clearing is so prevalent, they could act only as a guide in this particular survey. Mr G. Blackburn of the C.S.I.R.O. Division of Soils, and Mr D. Raglass of the S.A. Department of Agriculture provided useful help in locating suitable scrub.

Sketches were made of each potential site; location, extent, ownership and history of cutting, grazing and burning being recorded where known. Colour and texture of surface soil were noted and profile depth determined by enquiry; aspect and topography were noted and vegetation type recorded. Species present were noted in detail, particularly Eucalyptus and Pteridium. Number and height of the various eucalypts were thought to give a good indication of the type of site particularly with regard to drainage, and it was thought that this might be important in selecting comparable sites. Whilst the presence or absence of bracken reflects local drainage, its quantity appears to indicate the degree of human interference of the natural vegetation; although largely speculation, this nevertheless proved a good rule-of-thumb.

Two main facts emerged from this reconnaissance. Firstly, although there was an area of perhaps 300 square miles of scrub left on the dune ranges in the area studied, most of this had been interfered with. Deliberate or accidental burning of the understory were evident, although these appeared to have had little lasting effect on the sclerophyll shrub species. On the other hand, sporadic or controlled light grazing, also common, had exerted considerable influence; furthermore, wildlife must surely have been concentrated after clearing into the remaining scrub areas, and this must have had a similar effect. It would appear that bracken is favoured by such activity, particularly after a fire. It seems that the other species are either eaten or trampled, and that once bracken is able to form a canopy the other species cannot become re-established; about two-thirds of the scrub examined was in this category. Secondly, most of the scrub was dry sclerophyll forest on deep sands, with _E. baxteri_ and _Leptospermum myrsinoides_ predominant. The terra rossas were largely cleared and cultivated except on roadsides, although transitional soils carrying _E. fasciculosa_, _E. obliqua_, and _E. leucoxylon_ were not uncommon. Thus the survey was to be restricted to sclerophyll forest, in a more or less unnatural state.

1. The sites: (b) final selection.

Since one object of the survey was to test the effects of time on vegetation, every attempt was made to hold other factors of the environment constant. It was thought that the sands of the ranges might reflect the fact that underlying aeolianite was formed at a specific time. Thus vegetation on these sands might similarly reflect the age of the aeolianite. These considerations, and the availability of natural scrub, determined the comparability of sites. It was not possible to keep climate, soils, parent material, topography, and biota strictly uniform, so that some compromises had to be made in selection of sites.

It was assumed that climate, with the exception of rainfall, was constant over the area studied. This assumption was necessary because of the limitations of this project, although it is probably not correct; for example wind and insolation at Kingston and Penola no doubt differ to some extent. On the other hand, immediate coastal influences were eliminated, since the Woakwine and Canunda Ranges were not surveyed, for reasons discussed elsewhere. Rainfall varies from about 22 to 30 inches, so, where possible, sites were chosen so that each range had sites receiving 23, 25, and 27 inches mean annual rainfall. An examination of Figures 4 and 6 indicates that this was possible only to a limited extent; Ardune and Hynam Ranges were excluded as they are too short. It was also assumed that the pattern of rainfall has remained constant throughout the Quaternary.

Because the remaining scrub occurred mainly on podsolised sands, it was decided for the sake of simplicity to restrict the survey entirely to such habitats. Thus sites with terra rossa and other shallow soils over limestone were not generally acceptable, preference being given to those with yellow and grey sands; However, some of the vegetation on pink sandy terra rossa transitionals was included at some sites. Woakwine, West Dairy, and Harpers Ranges consist largely of limestone with skeletal soils, and accordingly were excluded from the survey; Canunda Range is mostly covered with modern calcareous sands and was similarly excluded. Soil and parent material were thus thought to be reasonably uniform.

Particular attention was paid to uniformity of topography. Blackburn <u>et al.</u> (1965) suggest that if the deep sands do vary with age of land surface, this effect will be most pronounced in the residual podsols. These cannot be readily distinguished, but are likely to occur on the crest of a range, i.e. adjacent to the terra rossas. Thus it was hoped to restrict sampling to the crests.
However, such sites adjoi

However, such sites adjoin the agriculturally more valuable terra rossas which were often clear of vegetation; also roads with their associated vegetation are not usually made on the crest. Therefore it was not possible to restrict sampling to the crests, so instead, vegetation on any sandhill was included, so that at least drainage was uniform.

The biota factor was assumed uniform, except with respect to man's activity. Vegetation which showed the usual signs of grazing was excluded; on the other hand, disturbance due to other than very recent cutting was considered to be unimportant. Areas where bracken was predominant, to the detriment of other species, were excluded from the survey; this was not only because such areas may have been disturbed by man, but also on practical grounds. It seemed pointless to record bracken as the sole understory species with perhaps Hibbertia sericea and Astroloma conostephiodes, since any measurements of frequency would be indeterminate, and the vegetation would not manifest any differences in pattern.

Vegetation recently burnt was excluded from the survey, because the original species, although present again shortly after a fire, do not for some time manifest their previous relative frequencies. In order to obtain an indication of this time, the author examined seven hundred-acre scrub blocks on Penola Forest, Hundred of Nangwarry, Section 28, north of Bocker's Lane. These blocks are periodically - about every four years - burnt as a fire protection measure, and vegetation could be seen 1,2,4,6, and more-than-10 years after burning. As a general statement, at one year bracken and pioneer composites predominate, with little at the soil surface except ash and some bryophytes. By the second year many original species are evident, mainly as coppice shoots or seedlings; scattered composites and much bracken are still present. At four and six years, appearance of the scrub is similar.

The eucalypt stems are still black, but composites are absent, ash occupies only 10% of the ground surface, and the understory appears to have reverted to its original state. The scrub at more than ten years differs from this only in having no charcoal on the eucalypt stems, and no ash on the ground. This information was used as a guide in excluding all scrub which had been burnt within four years.

Initially it was intended to sample vegetation at a number of sites on each range. However, it was found difficult to replicate adequately, since there was not enough scrub left suitably distributed to represent each range. After excluding vegetation unduly disturbed by man, in the ways just described, the number of sites was small. The result (see Figure 6, and Appendix A) was a total of 33 sites on nine ranges.

2. The species: (a) reconnaissance.

While looking for suitable vegetation on the ranges, a collection of plants was made, with the object of compiling a comprehensive list of species likely to occur in the area studied. About a hundred plants were collected at this stage, and sent to the State Herbarium for identification. Since it seemed likely that some species would be missed, due to limited time being available for collection, the advice of four local botanists was sought, and these people provided many specimens. Collections were made in Western Victoria and the Upper South-East, in case species from these areas should occur in the area studied.

In this way, and with the use of Black (1943-1957), Ewart (1930), and Crocker (1944), information on species likely to occur was obtained. A reference herbarium of several hundred species was compiled, and many of these were mounted in a field book with notes for identification, in order to avoid errors during the survey. During the reconnaissance the first recording in South Australia of *Dillwynia cinerascens* * was made.

2. The species: (b) final selection.

The 150 species finally selected for sampling are shown in Tables 2 and 3. Many of these had not been collected during reconnaissance (and subsequently nearly half were found to have a frequency less than one per cent.) but they were included for the sake of completeness. Nevertheless, several common species were overlooked, notably Xanthosia pusilla Bunge., X. dissecta Hook.f., and Pimelêa flava R.Br. Voucher specimens of all except about ten of the species are lodged with the Herbarium.

A considerable amount of time was spent ensuring correct identification from vegetative as well as floral specimens, because circumstances of employment necessitated the survey to be carried out in winter. The various Flora, local advice, and discussion and study at the Herbarium supplemented the author's observations, and resulted in the annotated field reference specimens. Calytrix tetragona and Banksia marginata were both divided into two varieties for the purpose of the survey, q.v. Table 2. These "varieties", particularly of the Banksia, are not to be regarded as such taxonomically, although their habit and habitat differences, seemed to warrant their being treated as statistical entities.

Eastern and western affinities of the species used in this project are suggested by the following appraisal. The information is from Wood (1930).

Occurring in S.A.	and eastern Australia only:	62	species
"	and western Australia only:	2	"
"	and both east and west:	26	"
"	only:	7	"
Not mentioned:		53	"
Total:		150	species

A complete list of species, and the number to which they will be referred in the text, follows as Tables 2 and 3.

Table 2.

SPECIES LIST I

Eighty species scored a frequency of at least one per cent and were used in the analyses. The quadrats occupied by these species are shown in Appendix B.

MYRTACEAE

I Leptospermum juniperinum Sm. syn. L. scoparium var junerinum Ewart.
2 Leptospermum pubescens Lamk. syn. L. lanigerum Sm.
3 Leptospermum myrsinoides Schlecht.
4 Melaleuca craria Black.
5 Eucalyptus baxteri (Benth.) Maiden et Blakely.
6 Eucalyptus obliqua L'Herit.
7 Eucalyptus huberiana Naudin.
approximates E. viminalis Labill. x E. aromaphloia Pryor et Willis.
8 Eucalyptus fasciculosa FvM.
9 Eucalyptus leucoxylon FvM.
IO Calytrix tetragona Labill.
variety "A". Leaves pubescent; flowers generally red, flowering for a limited time.
II Calytrix tetragona Labill.
variety "B". Leaves glabrous or subglabrous; flowers pink or white, flowering most of the year.
I2 Lhotskya alpestris (Lindl.) Druce.
I3 Kunzea pomifera FvM.
I4 Darwinia micropetala (FvM) Benth.

(continued overleaf)

EPACRIDACEAE

15 Epacris impressa Labill.

16 Acrotriche serrulata (Labill.) R.Br. and A. affinis D.C.

17 Astroloma humifusum (Cav.) R.Br.

18 Astroloma humifusum var. denticulatum (R.Br.) Black.

19 Astroloma conostephioides (Sond.)FvM.

20 Leucopogon collinus (Labill.) R.Br.

21 Leucopogon virgatus (Labill.) R.Br.

22 Leucopogon woodsii FvM.

23 Leucopogon ericoides (Sm.) R.Br.

24 Monotoca scoparia (Sm.) R.Br.

25 Brachyloma ciliatum Benth.

26 Brachyloma ericoides (Schldl.) Sond.

27 Styphelia adscendens R.Br.

PROTEACEAE

28 Banksia marginata Cav.
variety "A". Shrub or tree 2-5 m. high; leaves c. 10 mm. broad; spike 10x4 cm;

29 Banksia marginata Cav.
variety "B". Shrub 1-2 m. high or postrate; leaves 5mm. broad; spike 4 x 3 cm.

30 Banksia ornata FvM. ex Meisn.

31 Hakea vittata R.Br.

32 Hakea nodosa R.Br.

33 Hakea rostrata FvM. ex Meissn.

34 Grevillea ilicifolia (R.Br.) R.Br.

35 Persoonia juniperina Labill.

36 Adenanthos terminalis R.Br.

37 Isopogon ceratophyllus R.Br.

38 Conospermum patens Schlecht.

LEGUMINOSAE

39 Acacia spinescens Benth.
40 Acacia myrtifolia (Sm.) Willd.
41 Acacia pycnantha Benth.
42 Acacia melanoxylon R.Br.
43 Acacia verticillata (L'Herit.) Willd.
44 Acacia oxycedrus Sieb.
45 Acacia sophorae (Labill.) R.Br.
46 Acacia mearnsii de Willd. syn.A. mollissima Willd.
47 Acacia suaveolens Willd.
48 Daviesia brevifolia Lindl.
49 Bossiaea cinerea R.Br.
50 Gompholobium ecostatum Kuchel. MS. SYN. G. minus Sm.
51 Pultenaea prostrata Benth.
52 Pultenaea tenuifolia R.Br.
53 Pultenaea acerosa R.Br. includes var. acicularis H.B. Williamson.
54 Phyllota pleurandroides FvM.
55 Dillwynia floribunda Sm.
56 Dillwynia peduncularis Benth.
57 Bossiaea prostrata Benth.
58 Kennedia prostrata R.Br.

OTHER FAMILIES

59 Pittosporaceae : Bursaria spinosa Cav.
60 Casuarinaceae : Casuarina paludosa Sieb. includes var robusta Macklin.
61 " : Casuarina pusilla Macklin.
62 Sapindaceae : Dodonaea viscosa Jacq.
63 Santalaceae : Exocarpos cupressiformis Labill.
64 Thymeleaceae : Pimelea glauca R.Br.

(continued overleaf)

OTHER FAMILIES (contd.)

65 Restionaceae : Hypolaena fastigiata R.Br.

66 Euphorbiaceae : Amperea xiphoclada (Sieb.) Druce.

67 Rutaceae : Boronia coerulescens FvM.

68 " : Correa reflexa (Labill.) Vent. var. reflexa.

69 Rhamnaceae : Spyridium vexilliferum var. latifolium Benth.

70 Phytolaccaceae: Gyrostemon australasicus (Moq.) Heimerl.

71 Dilleniaceae : Hibbertia sericea (R.Br.) Benth. includes varieties with leaf-margins not reaching midrib; leaves silky.

72 " : Hibbertia stricta R.Br. includes varieties with leaf-margins reaching midrib; leaves usually not silky, but glabrous to pubescent; includes H.australis Wakefield.

73 " : Hibbertia virgata R.Br.

74 " : Hibbertia virgata var. crassifolia (Benth) Black.

75 " : Hibbertia fasciculata R.Br. ex DC.

76 Sterculiaceae : Thomasia petalocalyx FvM.

77 Tremendraceae : Tetratheca ciliata Lindl.

78 Liliaceae : Xanthorrhoea quadrangulata FvM.

79 " : Xanthorrhoea semiplana FvM.

80 " : Xanthorrhoea australis R.Br.

Table 3.

SPECIES LIST II

Seventy species either (a) scored a frequency of less than one per cent., the occupied quadrats being shown below, and were not used in the analyses, or (b) did not occupy any quadrats, although known, from observation or information, to occur locally.

MYRTACEAE

Baeckea behrii (Schlecht.) FvM.

Leptospermum laevigatum (Gaertn.) FvM.

Melaleuca wilsonii FvM.

Melaleuca decussata R.Br.

Melaleuca squamea Labill.

Melaleuca lanceolata Otto syn. M. pubescens Schau.

Melaleuca uncinata R.Br.

Melaleuca gibbosa Labill.(occurs site B4 quadrat 3, ED1-I)

Eucalyptus vitrea R.T. Baker.

Eucalyptus diversifolia Bonpl. (RC3-7)

EPACRIDACEAE

Lissanthe strigosa (SM.) R.Br. (SC3-1)

Acrotriche cordata (Labill.) R.Br. (?EN2-2)

Leucopogon clelandii Cheel. (EA2-2)

Leucopogon parviflorus (Andr.) Lindl. (RC1-5)

Leucopogon attenuatus Tate

Leucopogon rufus Lindl.

Styphelia exarrhena FvM.

Sprengelia incarnata Sm.

Brachyloma daphnoides (Sm.) Benth.

PROTEACEAE

Hakea ulicina var latifolia Black (WP3-9)

Hakea rugosa R.Br.

Hakea muelleriana Black

Grevillea lavandulacea Schlecht. (WP3-5, WP3-7)

Conospermum mitchelli Meisn.

LEGUMINOSAE

Acacia armata R.Br. (RC1-5, RC2-2)

Acacia rhetinodes Schlecht. includes var oraria Black

Acacia ligulata A.Cunn.

Acacia farinosa Lindl.

Daviesia ulicina Sm. (RC1-9)

Daviesia ulicina var ruscifolia Benth.

Daviesia corymbosa A. Cunn.

Pultenaea teretifolia H.B. Williamson

Pultenaea stricta Sims

Pultenaea pedunculata Hook.

Pultenaea pubescens H.B. Williamson

Pultenaea humilis Benth.

Pultenaea densifolia FvM.

Pultenaea canaliculata FvM.

Pultenaea graveolens Tate

Dillwynia hispida Lindl. (B2-6, B2-8)

Dillwynia cinerascens R.Br.

Swainsona lessertifolia DC.

Indigofera australis Willd. (WN1-1)

Gompholobium huegelii Benth.

(continued overleaf)

Sphaerolobium vimineum Sm.
Platylobium obtusangulum Hook.
Platylobium triangulare R.Br.
Eutaxia microphylla (R.Br.) Black.
Goodia lotifolia Salisb.
Viminaria juncea (Schrad.) Hoffmgg. syn V.denudata Sm.(WA1-2)

OTHER FAMILIES

Rutaceae	: Boronia pilosa Labill. (EN2-3,EA2-1)
"	: Boronia filifolia FvM.
Sterculiaceae	: Lasiopetalum discolor Hook.
"	: Lasiopetalum behrii FvM.
"	: Lasiopetalum baueri Steez.
"	: Lasiopetalum schulzenii FvM.
Thymeleaceae	: Pimelea spathulata Labill. (EN2-5, RC1-9, ?RC3-7)
"	: Pimelea serpyllifolia R.Br. (B2-6)
"	: Pimelea octophylla R.Br. (RC2-6)
Casuarinaceae	: Casuarina stricta Ait. (EN3-9, RC1-1)
"	: Casuarina muelleriana Miq. (WA4-1)
Euphorbiaceae	: Adriana klotzschii (FvM.) Muell. Arg.
Compositae	: Olearia ramulosa (Labill.) Benth.
Rhamnaceae	: Spyridium parvifolium (HOOK.) FvM.
"	: Spyridium subochreatum laxiusculum Black
Phytolaccaceae	: Didymotheca thesioides Hook. f.
Loganiaceae	: Logania linifolia (WP2-10) Schlecht.

3. The parameters.

The parameter Frequency accounts for most of the data collected in this survey, carried out in winter 1964; this was measured in terms of presence or absence of 150 species in 330 quadrats. Occurrence of the 80 species with a frequency of at least one per cent. is presented in Appendix B, and of the remaining 70 species in Table 3, while total actual and percentage frequency figures for the former species are shown in Table 4 and in Table 6. Density of 16 species was measured in 33 subjectively chosen quadrats, one to represent each site. Choice of these species was arbitrary, with the thought that changes in quantities of related species, e.g. E. baxteri and E. obliqua, might reflect changes in habitat. Cover of these and other species was also measured; details of method and results of cover and density measurements are given in Appendix C.

Soil samples were taken from two subjectively chosen representative quadrats at each site. A wedge of approximately 6 x 3 x 1 inches of the top three inches of soil was dug with a spade, litter and humus having been removed. It was intended that phosphorus and organic carbon contents would be determined, in order to assess differences between sites. However, circumstances did not permit the analyses to be made, and accordingly the 66 samples are stored in plastic bags at the Botany Department, University of Adelaide.

At each of the 33 sites, ten frequency samples were taken. These were located randomly as far as possible, usually stratified within a limited area. In the case of the several roadside sites, the samples cannot be said to be distributed randomly since there was often barely enough vegetation to be sampled. In another sense also, the samples are surely not representative of natural vegetation on the ranges, since scrub-clearing itself is not a random process, and certain areas will have had preference. Sketch maps with estimated position of samples is shown in Appendix A.

Considerations of quadrat number, size, and shape are often somewhat contentious, judging from the literature. It was decided that a large number of quadrats was necessary in order to adequately sample the nine ranges; 330 was the number used. Size and shape were decided after several trial runs had been made, using long rectangular quadrats 22 square yards in area. Circular quadrats of 20 square metres were used for the actual survey, and proved to be most convenient in the field, and satisfactory statistically.

B Analysis of Frequency Data

1. Interspecific correlation: (a) application.

Goodall in 1953 proposed a simple method of detecting association between species which has become well known and which was used in this project. The method requires at each stage of subdivision knowledge of the frequency of each species, and the significance of association between each of several frequent species and a number of others. The prohibitively laborious computation implied is avoided by transferring presence-absence data into a card-sorting system which renders the method practicable manually.

Initially, one quadrat was represented by two cards containing a total of 160 numbered holes to which the 150 species were assigned. The hole relating to a species present in the quadrat was punched out, so that the card would fall during sorting; this punching was done manually, and was itself a quite tedious process of some 100 man-hours. Later it was found that sorting with two cards per quadrat was impracticable, so the data relating to the 80 species present in three or more quadrats were transferred to one card (see Appendix D), that of the remaining 70 species being ignored. Assignment of species to new holes was made according to convenience, and hence their haphazard numbering; this special edge-punched card notation is shown in the second column of Table 4 and in the introduction to Appendix D.

During the transfer an error was made, resulting in omission of Hakea vittata, H. nodosa, H. rostrata, and Grevillea ilicifolia. Total frequency of these species is negligible, except of rostrata which is 22%. However, inspection of Table 4 will show for example, that even though this species occupies 43% of the Group C quadrats, there are many other species which have a greater frequency in that group. Therefore the error is regarded as of little consequence.

Subdivision involved testing a number of species pairs for significant association, then subdividing the quadrats on the most frequent correlated species, according to the distribution of chi-squared with one degree of freedom. Observed actual frequency data were arranged in a contingency table, expected frequencies deduced therefrom by proportion, and chi-squared with Yates' correction derived in the usual way. The probability used was that suggested by Goodall: $P = 0.05/N$, where N is the number of comparisons, i.e. number of quadrats, to be tested; P varied from 0.00015 (330 quadrats, chi-squared = 14.5) to 0.0013 (39,9). Over 50 such tests were made during subdivision, and 60 during recombination of groups.

1. Interspecific correlation: (b) results.

Analysis according to Goodall's method resulted in seven groups, three on three species, three on two species, and one consisting of species-absent quadrats, see Figure 8. Size of the groups varies from 16 to 88 quadrats; for actual and percentage frequency of species in the groups, see Table 4. Significance of the correlations was generally high, for example the least significant comparison tested was that of Group F: chi-squared of 12.75, compared with 11.9 from the distribution. In all of the recombinations significant association reappeared, the least so being B with D (chi-squared 12.4, compare 12.4), and B with E (12.0, compare 11.8). Thus, at the significance level used, all seven groups were deemed discrete.

Characterisation of the groups would enable their swift recognition in the field. Figure 9 suggests some species which may be a useful indication because they occur in some groups to the exclusion of others. For example, Hibbertia and Monotoca present in all of a set of samples would indicate Group A, remembering the limits imposed by chance and sampling. On the other hand, the histograms also illustrate the similarity of Groups B and D which are alike in all respects, excepting for the occurrence of Correa. Using Table 5, a key based on Figure 9, estimated or measured frequency of nine species would enable vegetation to be mapped in terms of the seven groups.

Location of the quadrats representing each group may be determined from Figure 10, which shows the quadrats at each site in order of sampling; Figure 10a is the same information presented to show how individual groups are distributed. It is apparent that smaller groups such as A and E, and loosely characterised groups such as F and G, tend to be restricted in distribution. Approximate, almost arbitrary, division of the sites into north and south sections with annual rainfall respectively less and greater than 25 inches is also shown. Numbers of quadrats relating to each group are presented in Figure 11 for each of six categories; numbers are expressed as a percentage of all quadrats in a particular category. It was thought that separation of quadrats containing eucalypts observed to occur on shallower soils, would tend to eliminate undue variations in the soil factor. Thus a better appreciation of any patterns in the vegetation, as elucidated by the groups, would be possible.

Figures 8-11.

Tables 4-5.

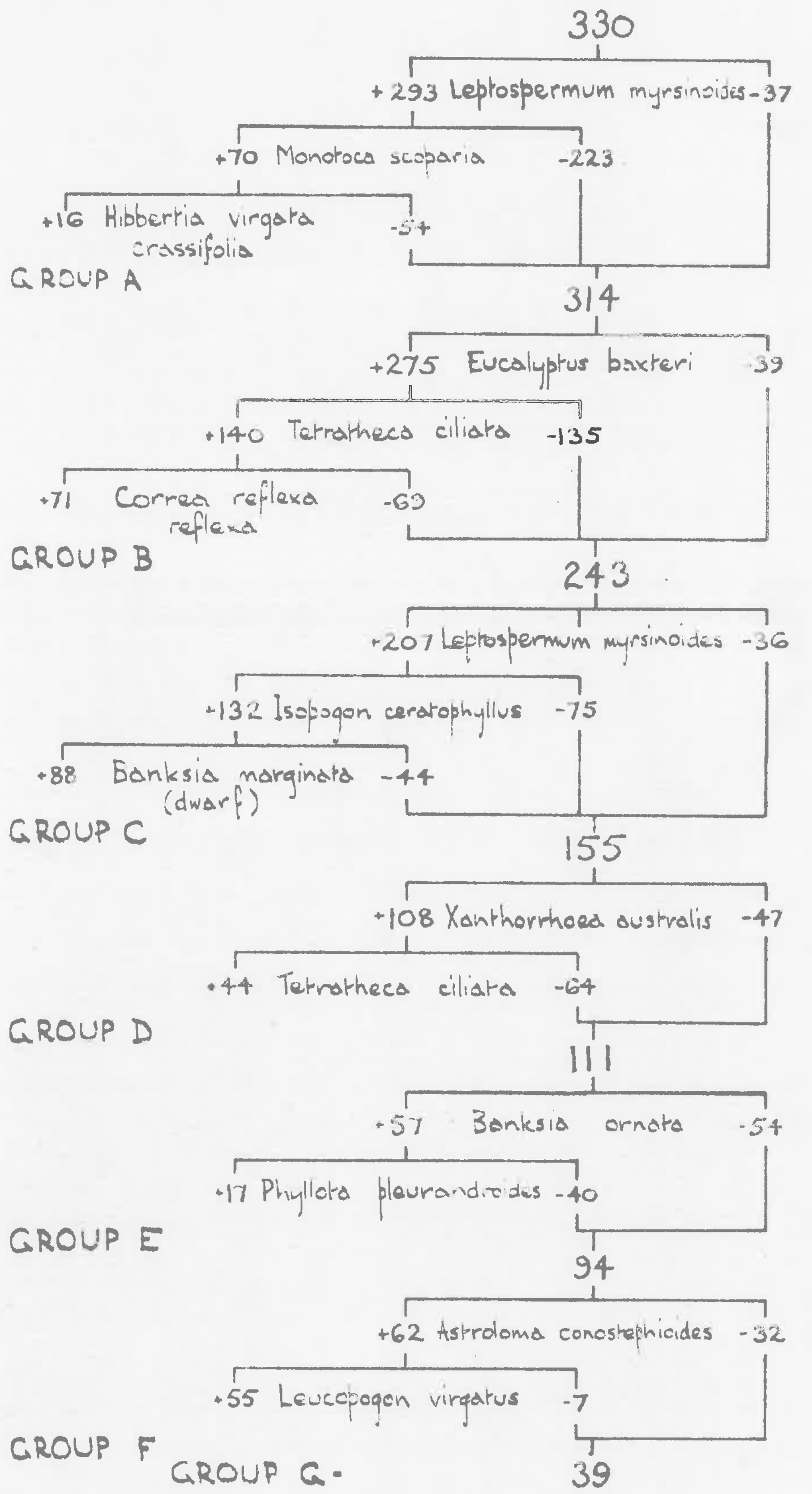


Fig. 8 GOODALL'S ANALYSIS. Subdivision is based on the species with highest frequency.

Table 4

GOODALL GROUPS: SPECIES FREQUENCY

SPECIES q.v. Table 2	punched-card notation	frequency: all groups actual	%	frequency: individual group A (16 quads.)		B (71)	
1	4	28	8	2	12	6	8
2	12	6	2			3	4
3	13	292	89	16	100	69	97
4	2	3	1				
5	14	290	88	16	100	71	100
6	19	40	12			2	3
7	20	17	5			4	6
8	22	48	15	1	6	11	16
9	24	4	1				
10	25	92	28	4	25	29	40
11	26	98	30	14	88	33	47
12	27	23	7			3	4
13	1	22	7	1	6	9	13
14	2	5	2			2	3
15	28	167	51	7	44	29	40
16	3	154	47	6	38	31	44
17	5	112	34			16	23
18	6	102	31	3	19	14	20
19	7	245	74	16	100	60	85
20	8	76	23	1	6	16	23
21	9	265	80	13	81	64	90
22	10	5	2			2	3
23	11	170	52	8	50	43	61
24	15	71	22	16	100	24	34

SPECIES q.v. Table 2	frequency: individual groups.									
	C (88)		D (44)		E (17)		F (55)		G (39)	
1	6	7	2	4			4	7	8	21
2	2	2	1	2						
3	87	100	40	89	16	94	45	82	19	50
4	1	1							2	5
5	66	76	41	91	17	100	48	87	31	79
6	23	26	3	7			6	11	6	15
7	5	5	4	9			3	5	1	3
8	10	12	7	16	5	29	6	11	8	21
9	1	1					3	5		
10	21	24	18	40	10	59	4	7	6	15
11	16	18	11	24	2	12	19	36	3	8
12	6	7	2	4	6	35	6	11		
13	3	3	3	7	5	29	1	2		
14	1	1	1	2					1	3
15	52	60	23	51	6	35	34	62	16	41
16	53	61	27	60	2	12	18	33	17	44
17	25	29	23	51	6	35	22	40	20	52
18	27	31	11	24	6	35	27	49	14	36
19	63	72	36	80	8	47	55	100	7	18
20	33	38	7	16	11	65	5	9	3	8
21	68	78	42	93	6	35	55	100	17	44
22	3	3								
23	23	26	26	58	5	29	43	78	22	57
24	15	17	7	16	2	12	3	5	4	10

SPECIES q.v. Table 2	punched-card notation	frequency: all groups		frequency: individual A (16)		frequency: individual B (71)	
		actual	%				
25	17	207	63	10	60	43	61
26	16	5	2			1	1
27	18	18	5	5	31	3	4
28	29	112	34	5	31	25	35
29	30	161	49	6	38	41	58
30	31	201	61	13	81	45	63
31	37	7	2				
32	38	2	1			2	3
33	42	72	22			8	11
34	43	5	2				
35	45	29	8	3	19	12	17
36	46	4	1			1	1
37	47	189	57	11	69	40	56
38	21	3	1			1	1
39	51	8	2	1	6	1	1
40	52	101	30	6	38	30	42
41	A	24	7			2	3
42	C	15	4			1	1
43	D	20	6	1	6	5	7
44	H	7	2	1	6	5	7
45	I	18	5			1	1
46	M	15	5				
47	Mac	4	1			3	4
48	N	69	21	2	12	15	21
49	O	18	5	5	31	9	13
50	23	54	16	1	6	11	16
51	32	31	9			9	13
52	33	7	2			2	3

SPECIES q.v. Table 2	Frequency: individual groups. C (88)		D (44)		E (17)		F (55)		G (39)	
25	3	3			1	6				
26	55	63	37	82	7	41	26	47	29	74
27			1	2			7	13	2	5
28	10	12	26	58	4	24	25	45	17	44
29	87	100	11	24	2	12	5	9	9	23
30	62	71	24	53	17	100	15	27	25	64
31	3	3			2	12			2	5
32										
33	37	43	12	26	5	29	2	4	8	21
34	4	5					1	2		
35	8	9	1	2	1	6	2	4	2	5
36					3	18				
37	87	100	19	42	10	59	10	18	12	31
38	2	2								
39	4	5	1	2	1	6				
40	30	34	17	38	2	12	9	16	7	18
41	4	5	4	9			9	16	5	13
42	1	1	2	4			4	7	7	18
43	5	6	4	9			1	2	4	10
44			1	2						
45	3	3	4	9			1	2	9	23
46							11	20	4	10
47							1	2		
48	33	38	5	11	2	12	4	7	8	21
49	1	1	2	4					1	3
50	29	33	6	13	2	12	2	4	3	8
51	6	7	6	13			7	13	3	8
52	3	3			2	12				

SPECIES q.v. Table 2	punched-card notation	frequency: all groups actual	%	frequency: individual A (16)		B (71)	
53	34	6	2			3	4
54	35	59	18			7	10
55	36	45	14	6	38	13	18
56	39	52	16	4	25	19	27
57	40	9	3	3	19	2	3
58	41	98	30	5	31	24	34
59	U	16	5	1	6	3	4
60	V	15	5			4	6
61	W	29	8	2	12	11	16
62	X	13	4			1	1
63	Y	5	2			1	1
64	44	27	8			11	16
65	48	198	60	13	81	52	73
66	49	3	1	1	6	2	3
67	50	9	3			4	6
68	53	134	41	9	56	71	100
69	B	5	2			3	4
70	E	3	1			1	1
71	F	277	84	13	81	60	85
72	G	204	62	9	56	41	58
73	I	4	1	1	6	1	1
74	J	17	5	16	100		
75	K	32	10	5	31	9	13
76	P	49	15	1	6	12	17
77	Q	159	48	12	75	71	100
78	R	19	6			1	1
79	T	13	4			6	8
80	S	261	80	12	75	63	89

SPECIES q.v. Table 2	frequency: individual groups.									
	C (88)		D (44)		E (17)		F (55)		G (39)	
53	1	1	1	2					1	3
54	29	33	5	11	17	100	1	2		
55	8	9	5	11	3	18	7	13	3	8
56	17	19	14	39	3	18	6	11	2	5
57	2	2					1	2	1	3
58	34	39	13	29	1	6	9	16	12	31
59			3	7			3	5	6	15
60	7	8	1	2	1	6	1	2	1	3
61	12	14	2	4	1	6	1	2		
62	1	1	3	7			4	7	4	10
63			1	2			2	4	1	3
64	2	2	7	16			4	7	3	8
65	56	64	36	80	15	88	17	31	9	23
66										
67	4	5	1	2						
68	38	44	1	2	1	6	10	18	4	10
69	1	1	1	2						
70	1	1			1	6				
71	75	86	38	84	10	59	49	89	32	82
72	76	87	24	53	13	76	25	45	16	41
73							2	4		
74									1	3
75	6	7	3	7	1	6	8	15		
76	15	17	12	27	2	12	3	5	4	10
77	27	31	44	100	1	6	2	4	1	3
78	11	13	1	2	6	35				
79	3	3			1	6	1	2	2	5
80	77	89	44	100	13	76	20	36	31	79

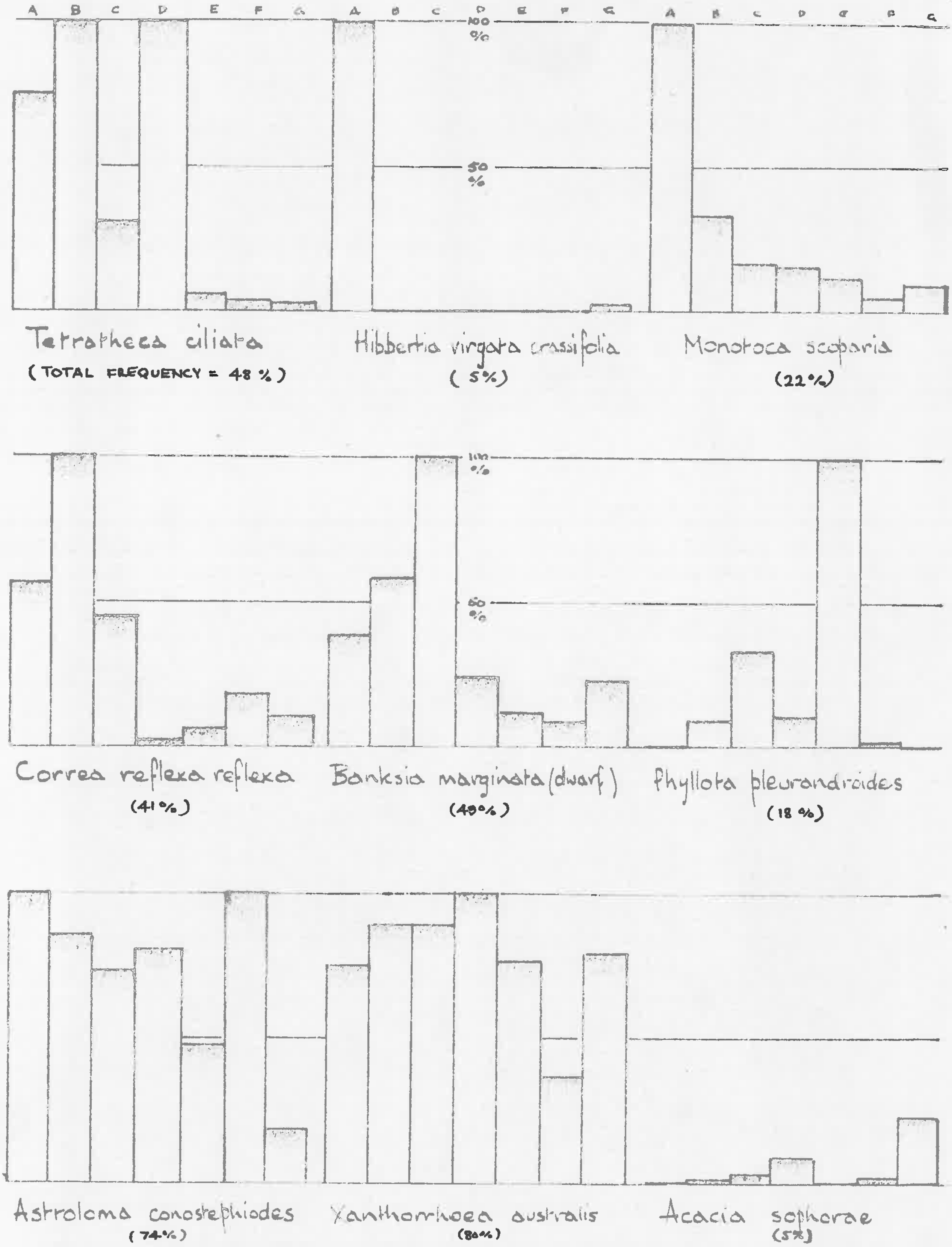


Fig. 9 INDICATOR SPECIES. Relative frequency of some species likely to be characteristic of the Goodall groups A to G.

Table 5

GOODALL GROUPS:

A KEY BASED ON FREQUENCY

of the nine suggested indicator species shown in Figure 9.

Tetratheca ciliata 75 or 100%.

Hibbertia virgata crassifolia 100%(group G: 3%);
Monotoca scoparia 100%(B: 34%, others: 5-17%):- Group A

Hibbertia 0%.
Correa reflexa reflexa 100%:- Group B
Correa 2%:- Group D

Tetratheca 31% or 3-6%.

Banksia marginata (dwarf) 100% (B;58%, A:38%, D:24%);
Tetratheca 31%:- Group C

Banksia 9-23%; Tetratheca 3-6%.
Phyllota pleurandroides 100%(C:33, others:0-11%)Group E
Phyllota 0-11%.
Astroloma conostephiodes 100% (G:18%, others 47-100%); Xanthorrhoea australis 36%(G:79%, others:75-100%):- Group F
Astroloma 18%; Acacia sophorae 23% (D:9%, others:0-3%):- Group G

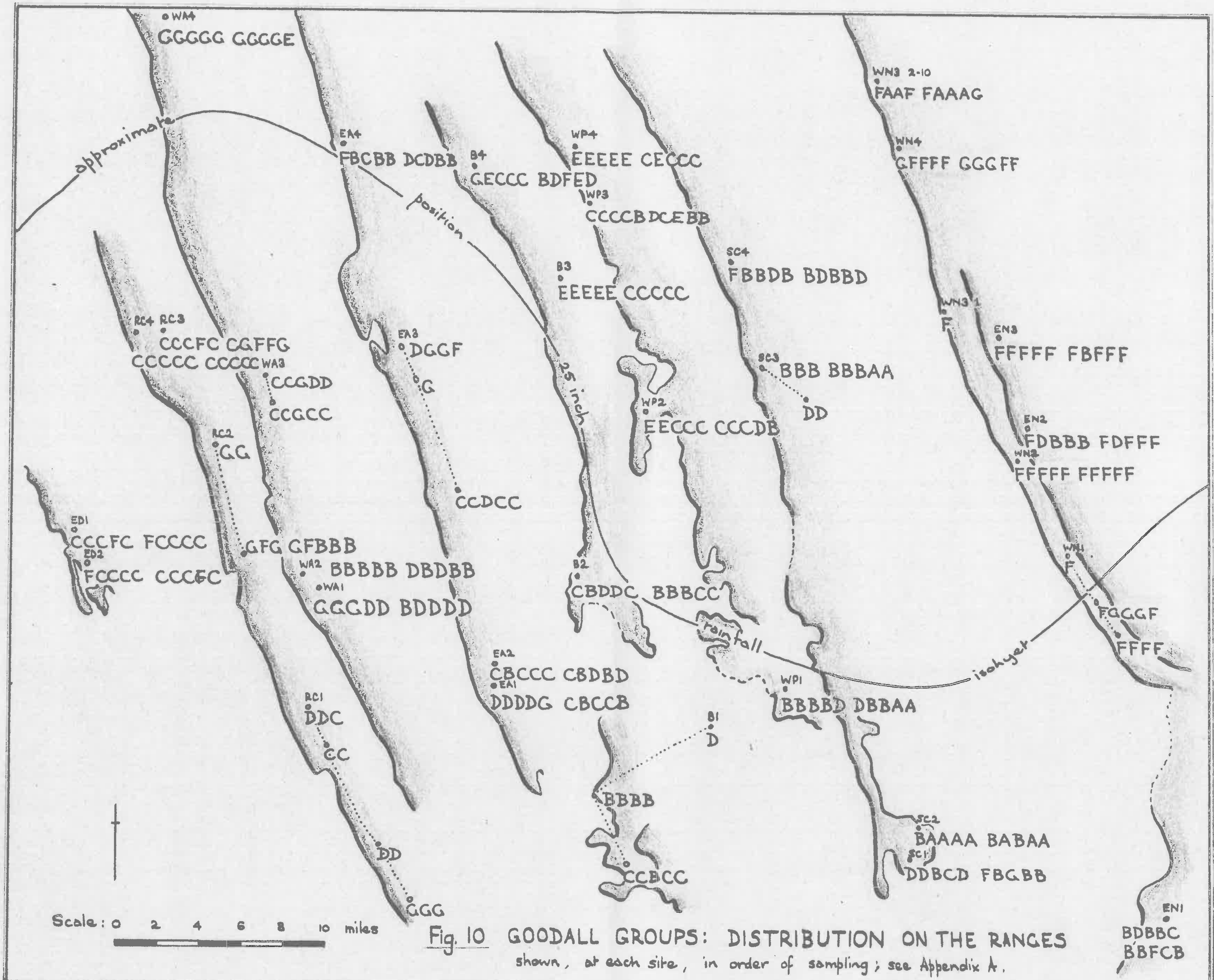


Fig. 10 GOODALL GROUPS: DISTRIBUTION ON THE RANGES
shown, at each site, in order of sampling; see Appendix A.

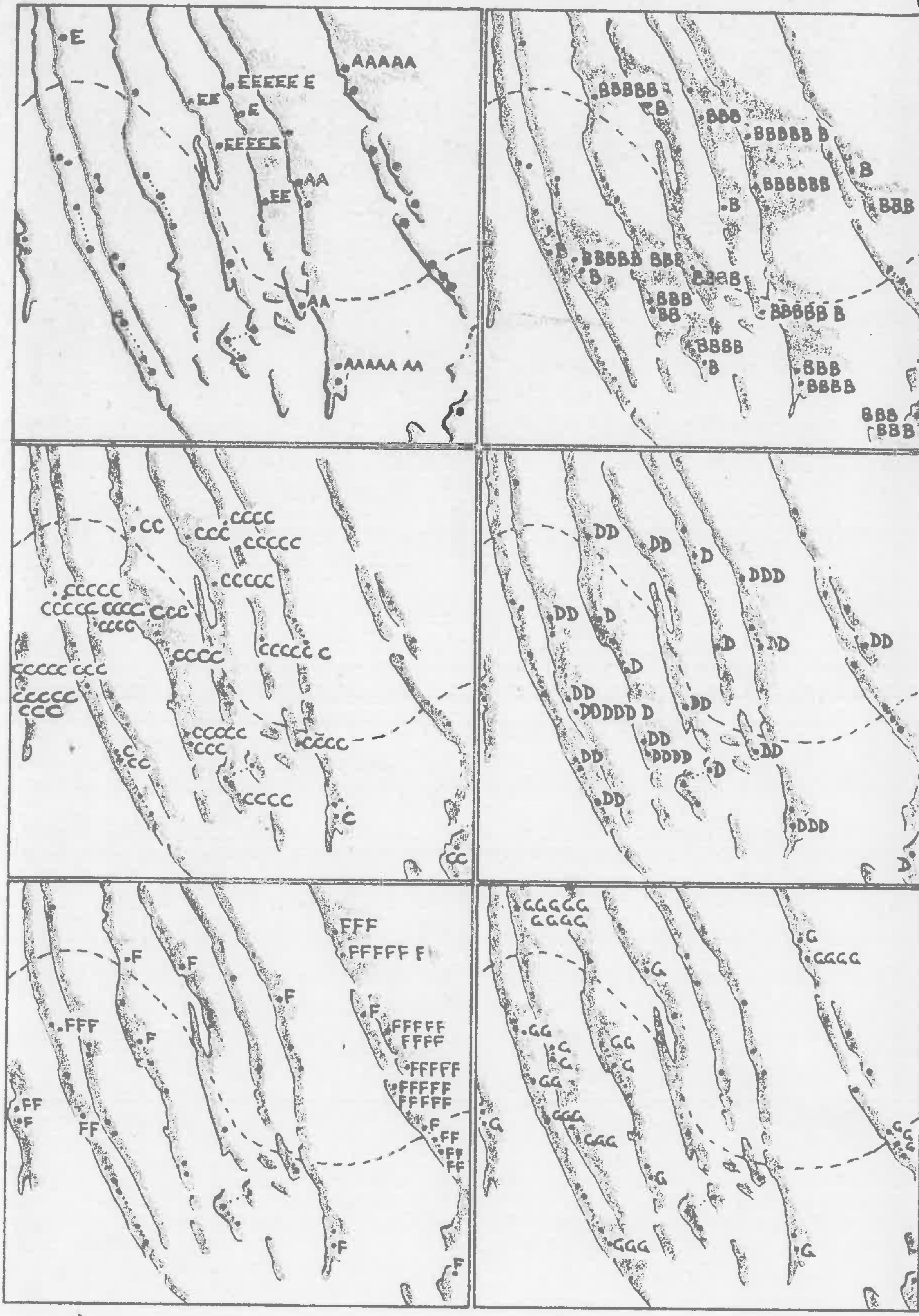


Fig. 10a. DISTRIBUTION of the GROUPS, SHOWN SEPARATELY, not as Figure 10.

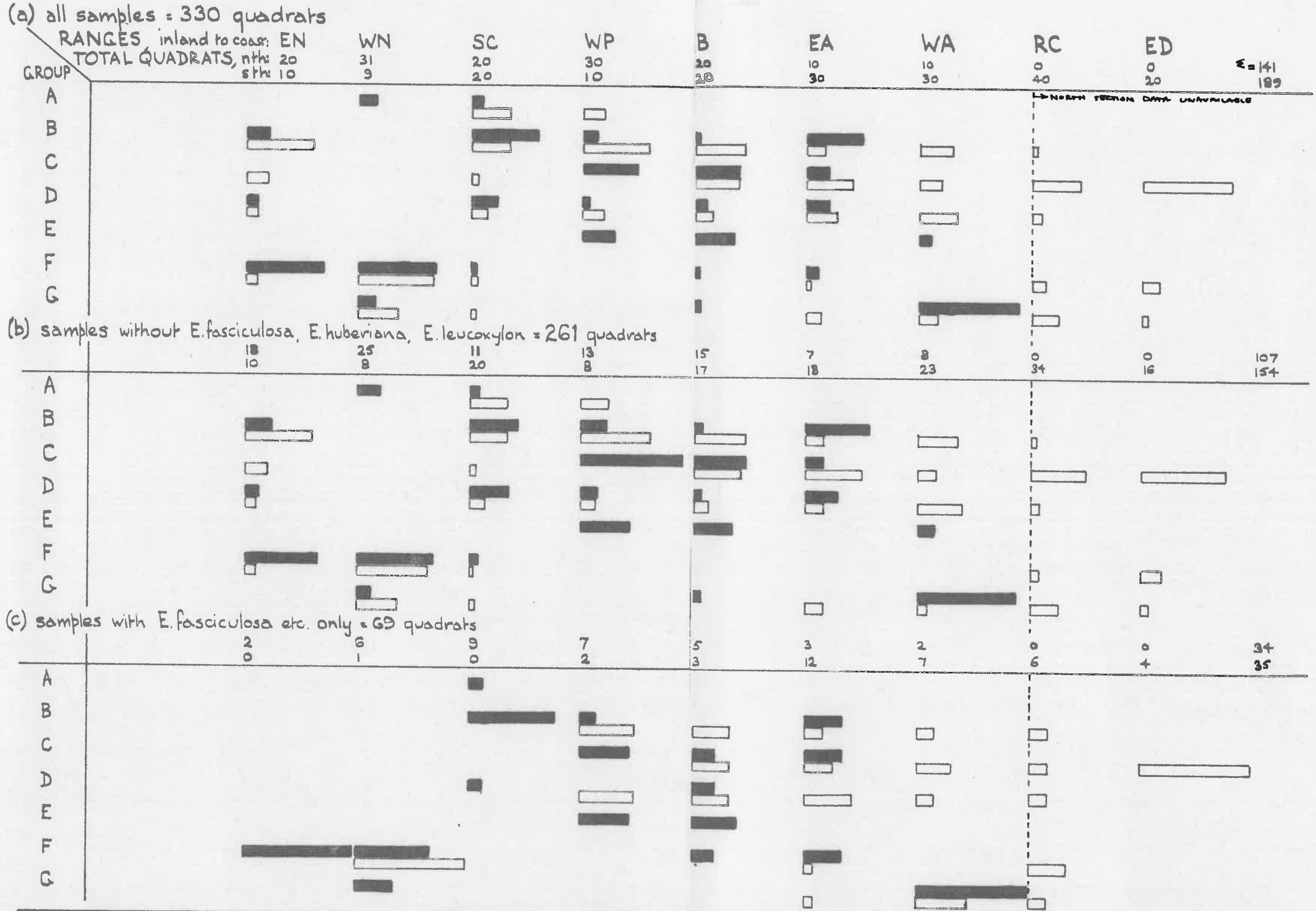


Fig. 11 GOODALL GROUPS: PROPORTION ON EACH RANGE.

Six categories are considered after division of the data (1) on certain eucalypts typical of shallower soils, and (2) north ▬ and south ▭ of the approximate 25 inch rainfall isohyet. The number of quadrats relating to a particular group on a particular section of a range is expressed as a percentage of the total number of quadrats in that section, according to the scale 1 inch: 100 %.

2. Association-analysis: (a) application.

Williams and Lambert in 1959 proposed a method of detecting and characterising association between species, which was used in this project. The method requires at each stage of subdivision knowledge of the significance of association between each species and every other species, and the summation of this significance for each species. Such computation is normally carried out in full by an electronic computer.

Data used for this analysis were presence or absence over all the quadrats of 80 species with a frequency greater than one per cent. These are the same species as those used in Goodall's interspecific correlation analysis and shown in Species List 1 (Table 2) with three minor exceptions, Brachyloma ericoides, Hakea nodosa, and Gyrostemon australasicus, for which Melaleuca gibbosa, Acacia armata, and Pimelea spathulata were inadvertently substituted. In the text, species are numbered as in Table 2, but differently in the printed statement of computations (see Table 6 and introduction to Appendix D).

Processing of the data was done in about five minutes in a CDC3600 electronic digital computer, input being in the usual punched-card form. Chi-squared for each species pair was determined, in the manner suggested by Williams and Lambert, treating as zero all insignificant values according to the chosen standard probability level of 0.05. The highest frequency of any species in this project was 89%, so that none were to be regarded as indeterminate. The computer was programmed to terminate subdivision, not at a particular significance level as suggested by Williams and Lambert, but at a specific number of groups.

2. Association-analysis: (b) results.

Analysis according to Williams' and Lambert's method was continued until 16 groups were evident, which occurred at an association index of about 17, see Figure 12. It may be seen that over a large range of the index, 120 to 60, only four groups were apparent; at 30 there were eight groups, and thereafter considerable fragmentation is to be expected. It was thought that 16 groups was a suitable number with which to elucidate vegetation patterns, and to compare the method with that of Goodall.

Actual and relative frequencies of the species in each of the groups are shown in Table 6, from which 16 possible indicator species are selected, see Figure 13. A few of these species characterize single groups, such as Boronia coerulescens in Group T, but generally the frequencies of combinations of species must be assessed - such as absence of Eucalyptus baxteri with presence of E. obliqua to indicate Groups K plus L. From Table 7, a key to the groups based on Table 6, it may be seen that indicator species alone can generally only be used to key out pairs of similar groups such as P and Q. Frequencies of numerous other species have been invoked to separate individual groups.

Distribution of quadrats representing each of the groups may be seen in Figure 14; quadrats at each site in order of sampling are not shown, but may be determined from Appendices D and A together. A few groups such as Group I are ubiquitous, but many are restricted in distribution and appear to indicate environmental gradation over the area studied. For example, Group H tends to occur inland and Group W towards the coast, while Groups Q and R appear to occur in respectively higher and lower rainfall areas. Proportional representation of the groups in the two rainfall categories on each range is shown in Figure 11. Division of eucalypts typical of shallower soils was not attempted because it was thought that the large number of groups would require unrealistic fragmentation of the data.

Figures 12-15.

Tables 6-7.

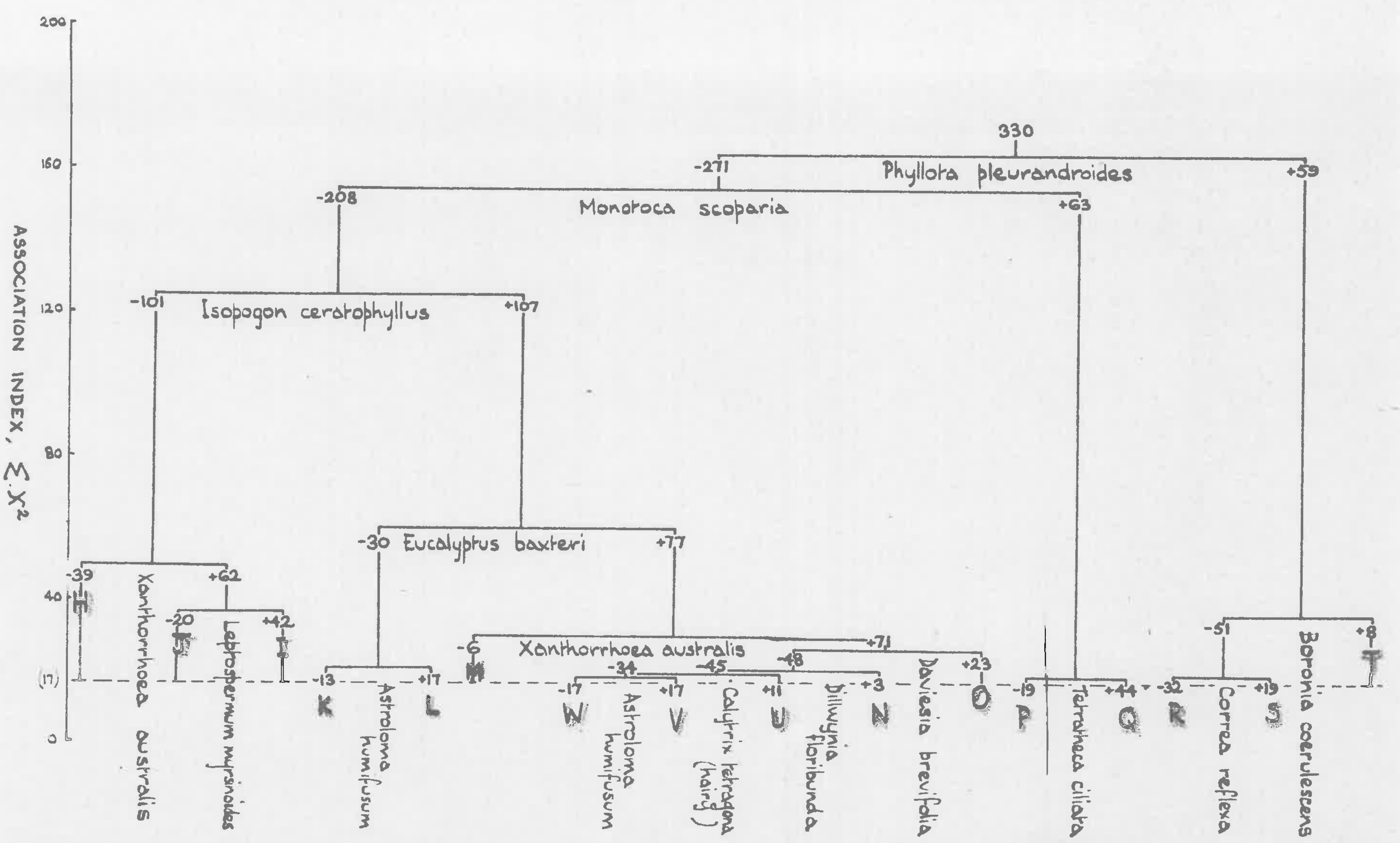


Fig. 12 WILLIAMS & LAMBERT ANALYSIS. Subdivision is based on the species with highest association index.

Table 6 *

WILLIAMS & LAMBERT GROUPS: SPECIES RREQUENCY

(a) actual frequencies.

SPECIES q.v. Table 2	Association -Analysis notation	Frequency - all groups	Frequency - individual groups. H 39a.	I 42	J 20	K 13	L 17	M 6	N 3	O 23	P 19	Q 44	R 32	S 19	T 8	U 11	V 17	W 17
1	3	28	4	3	4	0	5	0	0	4	1	4	1	2	0	0	1	0
2	4	6	0	2	0	0	0	0	0	0	0	0	0	0	0	0	2	0
3	5	292	29	42	0	13	15	5	2	23	19	43	30	19	8	11	17	15
3a	7	2	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
4	14	3	0	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0
5	15	290	38	39	18	0	0	6	3	23	17	44	32	18	6	11	17	17
6	16	40	0	2	2	9	16	0	1	3	1	1	1	2	2	0	1	0
7	18	17	2	2	1	2	0	0	0	2	2	0	0	0	0	1	2	2
8	19	48	4	4	4	0	3	2	0	2	3	3	9	2	2	2	4	3
9	20	4	1	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0
10	22	92	1	14	2	5	1	3	0	5	6	17	21	3	2	11	0	0
11	23	98	8	14	2	6	2	6	1	9	10	25	4	1	4	5	0	1
12	24	23	5	1	0	0	0	1	0	1	0	0	8	0	7	0	0	0
13	75	22	0	6	1	0	0	2	0	11	0	1	5	0	0	3	0	1
14	76	5	0	0	1	0	1	0	0	1	0	0	0	1	0	0	0	0
15	25	167	23	5	5	12	11	4	1	12	10	15	11	14	3	5	7	10
16	77	154	8	27	4	10	15	1	2	11	10	23	5	11	3	4	12	10
17	79	112	16	27	9	0	17	2	1	1	2	6	10	1	0	3	17	0
18	80	102	23	15	6	6	8	0	0	2	8	8	12	7	1	5	2	2
19	81	245	35	32	8	12	11	5	3	19	12	42	20	17	4	9	9	7
20	82	76	0	5	0	9	4	0	2	1	7	12	20	3	6	6	0	1

* (accurate to the nearest one quadrat)

Table 6(a) (continued)

SPECIES		TOTAL	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
21	83	265	35	39	11	10	12	4	2	20	15	39	16	16	4	8	17	15
22	84	5	0	0	0	0	0	0	0	3	0	0	0	0	2	0	0	0
23	85	170	36	30	14	0	7	1	3	7	6	32	8	2	1	5	11	14
24	89	71	0	0	0	0	0	0	0	0	19	44	6	3	1	0	0	0
25	91	207	18	29	19	9	12	0	1	12	8	36	16	9	0	8	15	13
27	92	18	2	2	1	0	0	1	0	1	6	5	0	0	0	0	0	0
28	27	112	19	20	8	3	5	5	2	2	5	15	5	2	0	7	11	2
29	28	161	1	19	5	9	11	0	1	15	10	26	15	15	7	5	8	12
30	29	201	9	22	8	13	8	3	1	14	11	30	27	16	8	6	10	14
31	30	7	0	0	0	1	0	0	0	3	0	0	0	1	0	1	0	1
33	32	72	0	4	3	12	10	0	0	10	2	1	9	5	5	2	6	3
34	36	5	0	1	0	3	0	0	0	0	1	0	0	0	0	0	0	0
35	39	29	0	0	0	0	0	0	0	5	4	9	4	0	6	0	0	0
36	41	4	0	0	0	0	0	0	0	3	0	0	1	0	0	0	0	0
37	42	189	0	0	0	13	17	6	3	23	16	26	24	15	7	11	17	17
38	95	3	0	0	0	0	0	0	0	0	1	0	0	1	1	0	0	0
39	43	8	0	0	0	0	0	0	0	0	1	0	3	2	1	0	0	0
39a	44	3	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
40	48	101	1	8	4	1	4	4	0	4	10	27	14	10	0	2	6	7
41	49	24	8	4	2	0	3	3	0	0	0	1	1	1	0	1	0	1
42	50	15	5	3	3	0	2	0	0	0	0	2	0	0	0	0	1	1
43	52	20	0	3	5	1	3	0	0	2	1	2	0	0	0	0	1	0
44	53	7	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0
45	54	18	0	2	8	0	4	0	0	1	1	1	0	0	0	0	0	1
46	55	15	10	2	2	0	0	0	1	0	0	0	0	0	0	0	0	0
47	56	4	0	0	0	0	0	0	0	0	0	3	0	0	0	0	1	0
48	58	69	0	2	0	2	9	2	0	23	7	5	6	10	3	0	0	0
49	64	18	2	6	0	0	0	0	0	0	0	12	0	0	0	0	1	0
50	97	54	0	2	0	5	3	2	0	7	7	6	7	5	4	0	4	2

Table 6(a) (continued)

SPECIES		TOTAL	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
51	106	31	4	4	0	0	0	1	0	8	0	0	1	1	0	3	0	2
52	107	7	0	0	0	0	0	1	1	0	0	0	5	0	0	0	0	0
53	108	6	0	1	0	0	1	0	0	0	0	0	0	2	2	0	0	0
54	109	59	0	0	0	0	0	0	0	0	0	0	32	19	8	0	0	0
55	110	45	4	5	0	0	1	3	3	2	6	7	4	2	0	0	0	0
56	113	52	0	6	0	2	3	0	1	4	5	22	0	5	0	1	1	3
57	114	9	0	1	1	1	1	0	0	0	1	3	0	0	0	0	0	0
58	115	98	4	14	5	3	13	0	1	11	7	15	3	6	3	2	4	5
59	66	16	1	4	6	0	0	0	1	0	0	3	0	0	0	0	1	0
60	69	15	0	0	0	0	1	1	0	1	1	0	4	2	3	0	1	1
61	70	29	0	1	0	1	3	2	1	6	3	3	1	0	7	1	0	0
62	71	13	4	2	5	0	0	0	0	0	0	0	1	1	0	0	0	0
63	72	5	1	1	1	0	0	0	0	0	1	1	0	0	0	0	0	0
64	118	27	5	3	0	0	3	1	0	1	0	11	0	0	0	1	1	0
64a	119	3	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0
65	122	198	6	26	3	2	3	6	3	20	16	35	29	9	8	9	8	15
66	123	3	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0
67	124	9	0	0	0	0	0	0	000	1	0	0	0	0	8	0	0	0
68	127	134	1	17	0	13	5	4	2	13	7	32	0	19	4	4	4	7
69	129	5	0	0	0	0	0	0	0	0	0	0	1	1	3	0	0	0
71	133	277	33	37	16	13	13	6	3	14	18	36	24	18	5	8	17	14
72	134	204	15	21	4	9	13	3	3	21	16	18	28	14	7	5	10	11
73	136	4	1	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0
74	137	17	0	0	0	0	0	1	0	1	4	12	0	0	0	0	0	0
75	138	32	7	2	0	0	0	0	0	1	0	14	1	2	0	2	2	0
76	144	49	1	10	3	0	5	2	0	0	0	1	8	5	4	4	4	1
77	145	159	10	23	5	0	2	4	2	14	0	44	5	4	6	9	16	12
78	146	19	0	0	0	0	0	0	0	0	0	0	11	2	6	0	0	0
79	148	13	0	1	0	0	1	2	0	2	1	3	1	0	0	0	0	3
80	147	261	0	42	20	13	16	0	3	23	12	41	23	18	4	11	17	17

Table 6

WILLIAMS & LAMBERT GROUPS: SPECIES FREQUENCY

(b) percentage frequencies

SPECIES q.v. Table 2	Association -Analysis notation	Frequency - all groups	Frequency - individual groups H 39q.	I 42	J 20	K 13	L 17	M 6	N 3	O 23	P 19	Q 44	R 32	S 19	T 8	U 11	V 17	W 17
1	3	8	10	7	20	0	29	0	0	17	5	9	3	10	0	0	6	0
2	4	2	0	4	0	0	0	0	0	0	0	0	0	0	0	0	12	0
3	5	89	73	100	0	100	88	83	67	100	100	98	94	100	100	100	100	88
3a	7	1	0	0	0	0	12	0	0	0	0	0	0	0	0	0	0	0
4	14	1	0	0	5	0	12	0	0	0	0	0	0	0	0	0	0	0
5	15	89	97	90	90	0	0	100	100	100	85	100	100	94	75	100	100	100
6	16	12	0	4	10	70	94	0	33	13	5	2	3	10	25	0	6	0
7	18	5	5	4	5	15	0	0	0	9	10	0	0	0	0	9	12	12
8	19	15	10	8	20	0	18	33	0	9	15	7	29	10	25	18	24	18
9	20	1	3	2	0	8	0	16	0	0	0	0	0	0	0	0	0	0
10	22	28	3	32	10	38	6	50	0	22	33	39	66	15	25	100	0	0
11	23	30	20	32	10	0	12	100	33	39	50	58	13	5	50	45	0	6
12	24	7	13	2	0	0	0	16	0	4	0	0	25	0	88	0	0	0
13	75	7	0	12	5	0	0	33	0	48	0	2	16	0	0	27	0	6
14	76	2	0	0	5	0	6	0	0	4	0	0	0	5	0	0	0	0
15	25	51	60	10	25	92	65	67	33	52	54	35	35	74	37	45	42	59
16	77	47	20	64	20	77	88	16	67	48	54	48	16	58	37	36	71	60
17	79	34	40	64	45	0	100	33	33	4	10	14	32	5	0	27	100	0
18	80	31	60	37	30	46	47	0	0	9	42	18	38	36	12	45	12	12
19	81	74	88	75	40	92	65	83	100	22	63	95	63	90	50	81	54	42
20	82	23	0	12	0	70	24	16	67	4	36	28	63	15	75	54	0	6

Table 6(b) (continued)

SPECIES		TOTAL	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
21	83	80	88	90	55	77	71	67	67	80	75	88	50	84	50	72	100	90
22	84	2	0	0	0	0	0	0	0	13	0	0	0	0	25	0	0	0
23	85	52	90	70	70	0	41	16	100	30	32	70	25	10	12	45	65	82
24	89	22	0	0	0	0	0	0	0	0	100	100	19	15	12	9	0	0
25	91	63	45	66	95	70	71	0	33	52	42	85	50	47	0	72	88	76
27	92	5	5	4	5	0	0	16	0	4	32	12	0	0	0	0	0	0
28	27	34	47	50	40	23	29	83	67	9	26	35	16	10	0	63	66	12
29	28	49	3	47	25	70	65	0	33	60	54	59	47	79	88	45	50	72
30	29	61	23	51	40	100	47	50	33	61	58	75	84	84	100	54	60	82
31	30	2	0	0	0	8	0	0	0	13	0	0	0	5	0	9	0	6
33	32	22	0	9	15	92	59	0	0	43	10	2	29	26	62	18	35	18
34	36	2	0	2	0	23	0	0	0	0	5	0	0	0	0	0	0	0
35	39	8	0	0	0	0	0	0	0	22	21	21	14	0	75	0	0	0
36	41	1	0	0	0	0	0	0	0	13	0	0	3	0	0	0	0	0
37	42	57	0	0	0	100	100	100	100	100	80	60	73	79	88	100	100	100
38	95	1	0	0	0	0	0	0	0	0	5	0	0	5	12	0	0	0
39	43	2	0	0	0	0	0	0	0	0	5	0	10	10	12	0	0	0
39a	44	1	0	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0
40	48	30	3	19	20	8	24	67	0	17	54	62	42	53	0	18	35	41
41	49	7	20	10	10	0	18	50	0	0	0	2	3	5	0	9	0	6
42	50	4	13	8	15	0	12	0	0	0	0	4	0	0	0	0	6	6
43	52	6	0	8	25	8	18	0	0	9	5	4	0	0	0	0	6	0
44	53	2	0	0	0	0	0	0	0	0	0	16	0	0	0	0	0	0
45	54	5	0	4	40	0	24	0	0	4	5	2	0	0	0	0	0	6
46	55	5	13	4	10	0	0	0	33	0	0	0	0	0	0	9	0	0
47	56	1	0	0	5	0	0	0	0	0	0	6	0	0	0	0	6	0
48	58	21	0	4	0	15	53	33	0	100	37	12	19	53	37	18	0	0
49	64	5	5	15	0	0	0	0	0	0	0	26	0	0	0	0	6	0
50	97	16	0	4	0	38	18	35	0	30	37	14	22	26	50	0	24	12

Table 6(b) (continued)

SPECIES		TOTAL	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
51	106	9	10	10	0	0	0	16	0	34	0	0	3	5	0	27	0	12
52	107	2	0	0	0	0	0	16	33	0	0	0	16	0	0	0	0	0
53	108	2	0	2	0	0	6	0	0	0	0	0	10	10	25	0	0	0
54	109	18	0	0	0	0	0	0	0	0	0	0	100	100	100	0	0	0
55	110	14	10	19	0	0	6	50	100	9	32	16	13	10	0	0	0	0
56	113	16	0	14	0	15	18	0	33	17	25	48	0	26	0	9	6	18
57	114	3	0	2	5	8	6	0	0	0	5	6	0	0	0	0	0	0
58	115	30	10	35	25	23	76	0	33	48	37	33	10	33	37	18	25	29
59	66	5	3	10	30	0	0	0	33	0	0	6	0	0	0	0	6	0
60	69	5	0	0	0	0	6	16	0	4	5	0	13	11	37	0	6	6
61	70	8	0	2	0	8	18	33	33	26	16	7	3	0	88	9	0	0
62	71	4	10	5	25	0	0	0	0	0	0	0	3	5	0	0	0	0
63	72	2	3	2	5	0	0	0	0	0	5	2	0	0	0	0	0	0
64	118	8	13	7	0	0	18	16	0	4	0	24	0	0	0	9	6	0
64a	119	1	0	0	0	0	12	0	33	0	0	0	0	0	0	0	0	0
65	122	60	15	55	15	15	18	100	67	87	80	72	90	47	100	81	50	88
66	123	1	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0
67	124	3	0	0	0	0	0	0	0	4	0	0	0	0	100	0	0	0
68	127	41	3	38	0	100	28	67	67	56	37	70	0	100	50	36	24	42
69	129	2	0	0	0	0	0	0	0	0	0	0	3	5	37	0	0	0
71	133	84	82	86	80	100	76	100	100	61	90	80	75	94	62	72	100	82
72	134	62	40	49	20	70	76	50	100	87	80	40	88	72	88	40	60	66
73	136	1	3	0	0	0	0	0	0	0	5	4	0	0	0	0	0	0
74	137	5	0	0	0	0	0	16	0	4	21	25	0	0	0	0	0	0
75	138	10	17	4	0	0	0	0	0	4	0	30	3	10	0	18	12	0
76	144	15	3	24	15	0	29	33	0	0	0	2	25	26	50	36	24	6
77	145	48	25	53	25	0	12	67	67	61	0	100	16	20	75	81	94	71
78	146	6	0	0	0	0	0	0	0	0	0	0	35	10	75	0	0	0
79	148	4	0	2	0	0	6	33	0	9	5	6	3	0	0	0	0	18
80	147	80	0	100	100	100	94	0	100	100	60	90	72	94	50	100	100	100

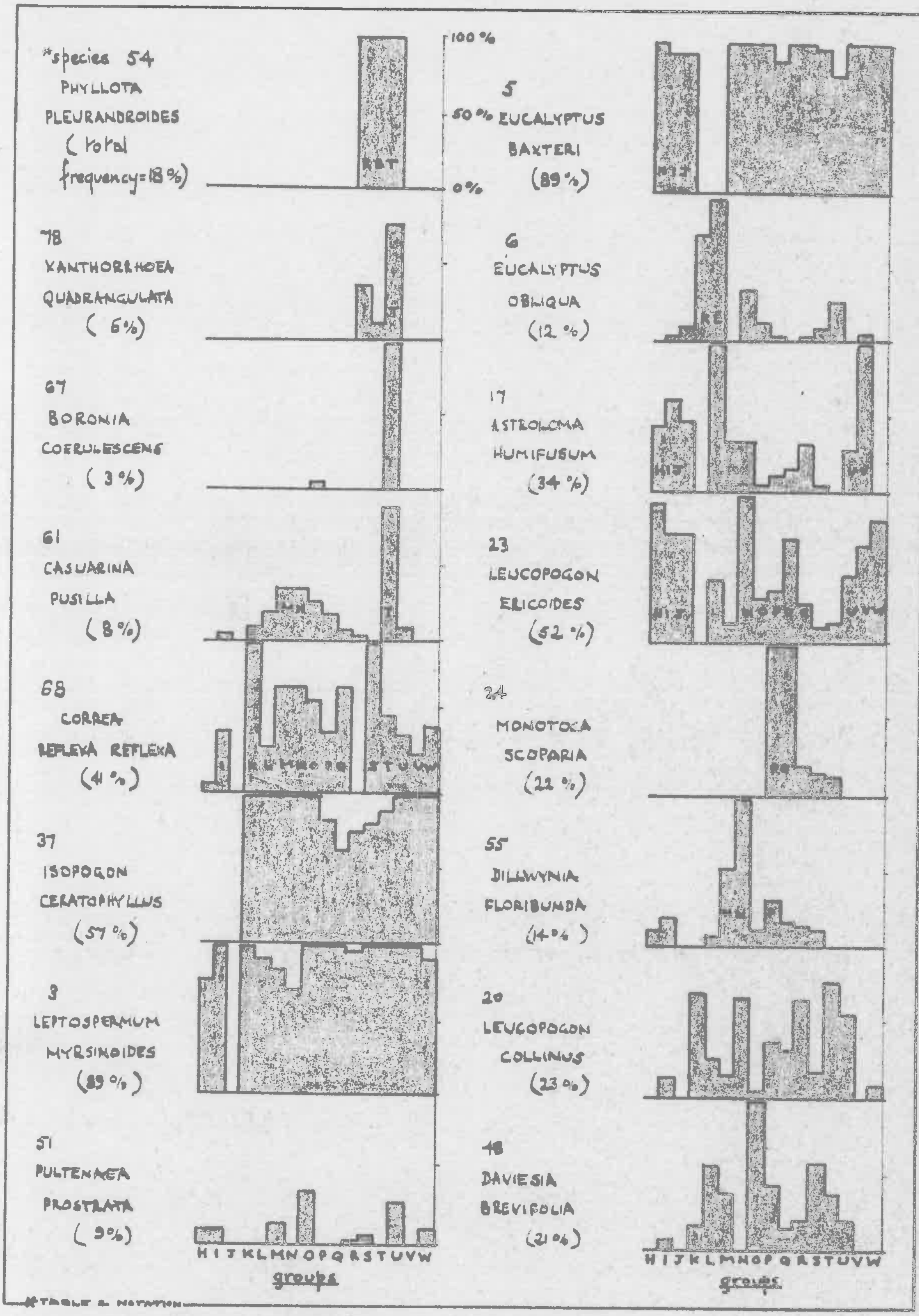


Fig. 13 INDICATOR SPECIES. Relative frequency of some species likely to be characteristic of the Williams & Lambert groups H to W.

Table 7.

A PHYLLOTA abundant (100%), X. QUADRANGULATA present (10-75%).

B BORONIA abundant (100%), CAS. PUSILLA abundant (88%), 22 = 25%, 40 = 0%, 25 = 0% :- **T**

BB BORONIA absent, CAS. PUSILLA rare, 22 = 0%, 40 = 40-53%, 25 = 47-50%.

species:	CORREA	12	56
group S:	100	0	26
.. T:	0	25	0

S R

AA PHYLLOTA absent, X. QUADRANGULATA absent.

B. ISOPOGON absent.

C LEPT. MYRSINOIDES abundant (73-100%), 55 = present (10-100%), 39a = absent.

species:	X. AUSTRALIS	13	33
group H:	0	0	0
.. I:	100	12	9

H I

CC LEPT. MYRSINOIDES absent, 55 = 0%, 39a = present (10%) :- **J**

BB ISOPOGON common (60-100%).

C EUC. BAXTERI absent, EUC. OBLIQUA abundant (70-94%), 65 = rare (15-19%).

species:	A. HUMIFUSUM	L. ERICOIDES	THOMASIA
group K:	0	0	0
.. L:	100	41	29

K L

CC EUC. BAXTERI abundant (88-100%), EUC. OBLIQUA sparse (0-33%), 65 = 50-100%.

D MONOTOCA abundant (100%).

species:	TETRATHECA	75	49	64
group P:	0	0	0	0
.. Q:	100	30	26	24

P Q

DD MONOTOCA absent.

E DILL. FLORIBUNDA rare (5%) or absent, 33 = present (18-43%).

F DAV. BREVIFOLIA abundant (100%), 35 = 22%, 22 = 13%, 36 = 13% :- **O**

FF DAV. BREVIFOLIA rare (0-18%), 35 = 0%, 22 = 0%, 36 = 0%.

G CAL. TETRAGONA 'HAIRY' abundant (100%) :- **U**

GG CAL. TETRAGONA 'HAIRY' absent.

species:	A. HUMIFUSUM	28	51
group V:	100	66	0
.. W:	0	12	12

V W

EE DILL. FLORIBUNDA not rare (50 or 100%), 33 = absent.

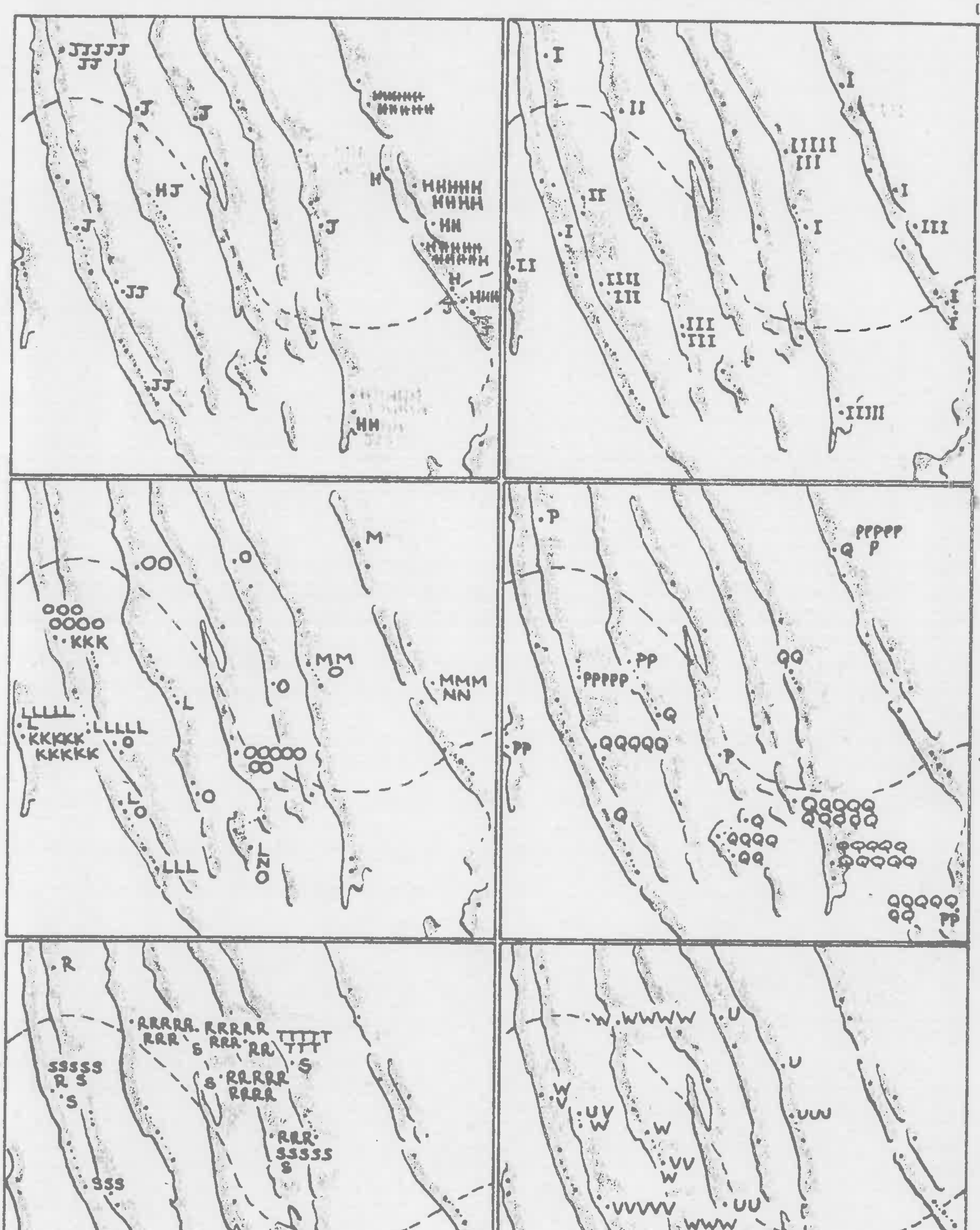
species:	X. AUSTRALIS	23	40
group M:	0	16	67
.. N:	100	100	0

M N

WILLIAMS - LAMBERT GROUPS:

A KEY BASED ON RELATIVE FREQENCIES

of various species, particularly the indicator species of Figure 13.



↑ Fig. 14 WILLIAMS & LAMBERT GROUPS : DISTRIBUTION.

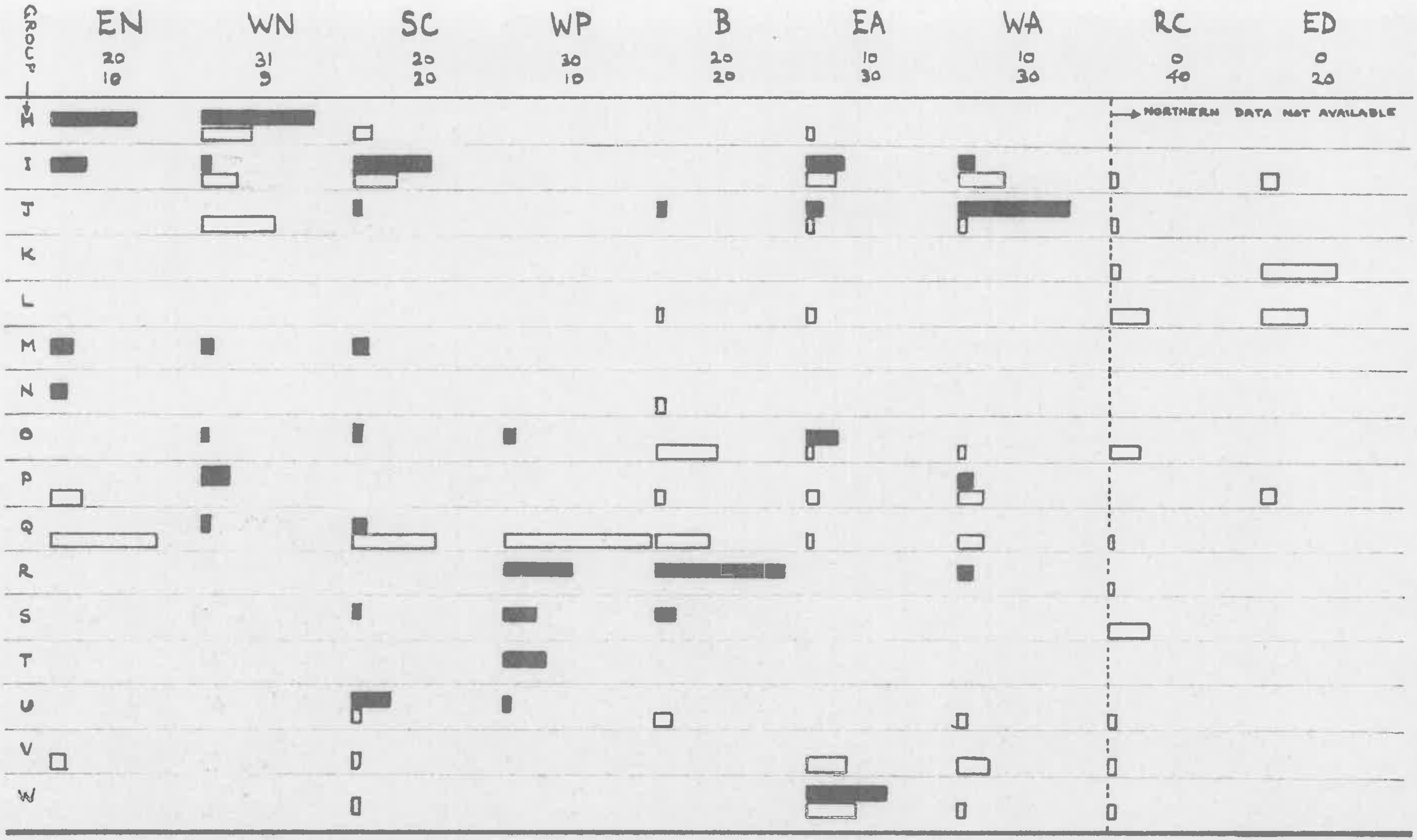


Fig. 15 WILLIAMS & LAMBERT GROUPS: PROPORTION ON EACH RANGE. Two only categories are considered, north ▬ and south ▭, ie. lower and higher rainfall. Otherwise terminology is as for Figure 11; 330 quadrats.

3. Cluster analysis.

Sneath in 1962 invoked the principle that a natural or valid classification of any variable population is one based on overall similarity of numerous equally weighted characters, rather than on a consideration of a few key characters. Sneath discussed the possibilities of developing this principle of numerical taxonomy using electronic computers, and suggested some indices of similarity, and also a way to express clusters of taxonomic units with a high mutual similarity. In this project is presented a brief examination of the principle, in the form of a classification by cluster analysis of species, in terms of their similarity of occurrence in quadrats. Classification of vegetation into groups of quadrats was not attempted, as it would have involved considerably longer computation.

Data used for this analysis were presence or absence of the same 80 species used for Williams' and Lambert's method, although the notation is different (see introduction to Appendix D). In order to test the validity of the method, the quadrat data was randomly split so that two separate classifications ("odds" and "evens") would evolve. For both of these the computer calculated similarity $S = a/(a + b + c)$ to 0.1% for each species pair, and issued a printed statement both of the matrix as such, and the matrix retabulated in classes of 2% (see Appendix D).

Dendrograms were constructed by inspection of the matrix, the criterion for fusion being highest similarity between any species pair; Figures 16 and 17 show dendrograms for odds and evens data at class intervals of 4% and 16% similarity. It will be apparent that the smaller interval presents a detailed picture of relationships between individual species, whereas the larger interval presents that between clusters of species, hence there is closer agreement between odds and evens at the larger interval. It is also noteworthy that the shape of a dendrogram may be more apparent than real at larger intervals; for example, with an interval of 16%, clusters which fuse at ~~17.9%~~ 18.1 will be shown at 18%, whereas clusters which fuse at ~~18.1%~~ 17.9 will be shown at 2%, and thus a large discrepancy between two such dendrograms reflects only a small real difference. This situation is an artefact according to the particular criterion for fusion of clusters, and to class interval.

It is difficult to attach any precise meaning to the numerous clusters which are apparent at even low levels of similarity, other than to say that species in any cluster tend to occur together in the field. But even this is not meaningful in the case of common species, because those which occur in most quadrats must tend to occur together, i.e. they are indeterminate. For example Species 3 Lept. myrsinoides, 5 Euc. baxteri, and 21 Leuc. virgatus have high frequencies and thus a high similarity, and form the basis of the first cluster. Conversely if several less common species are clustered they may well represent a vegetation group; for example the following are typical of Group T (Figures 12,13): Species 54 Phyllota, 78 X. quadrangulata, 67 B. coerulescens and 61 Cas. pusilla, and these cluster with some others at 22-26% similarity. Nevertheless clusters do not correspond with vegetation groups other than in this very general way.

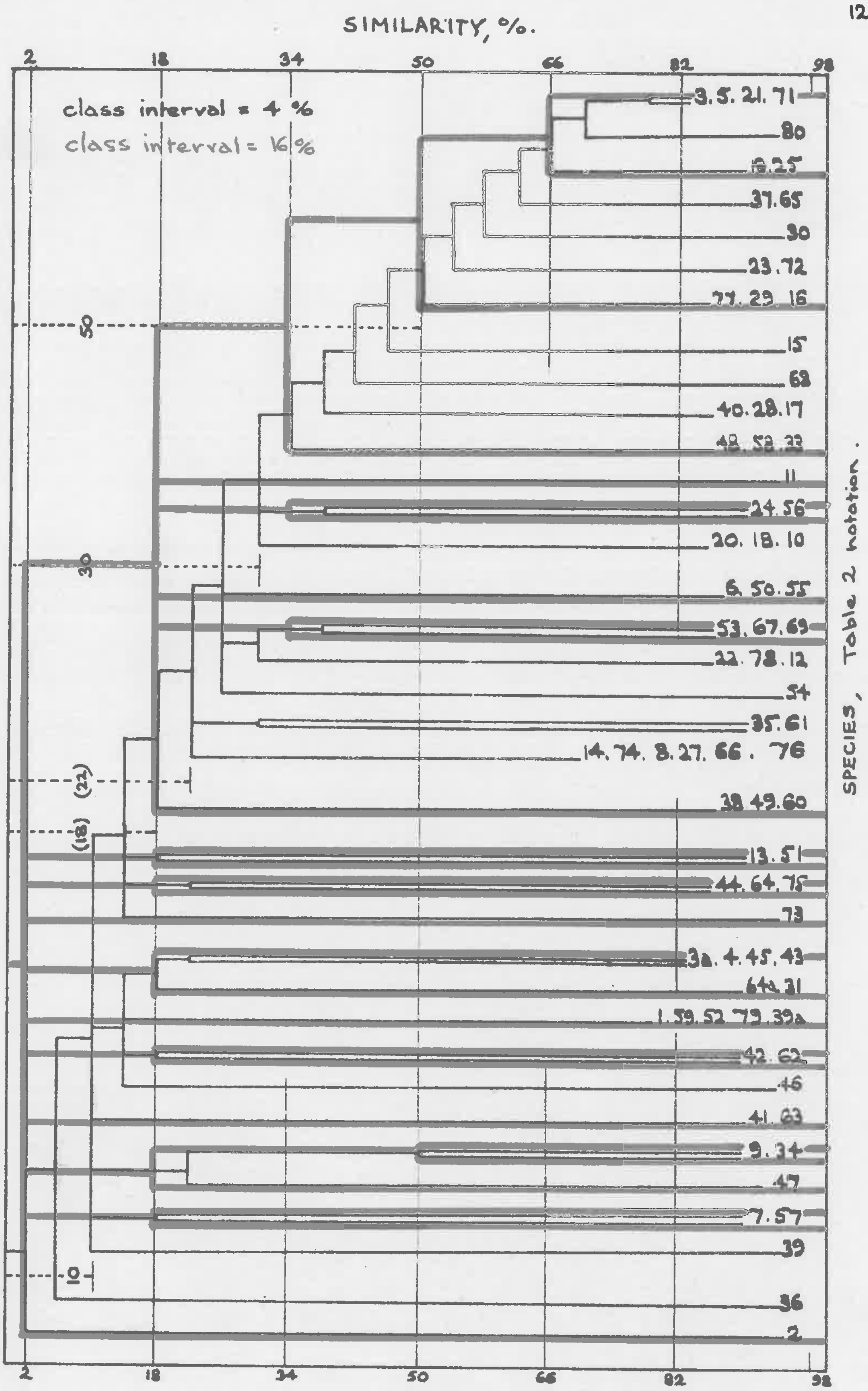


Fig. 16 SNEATH'S ANALYSIS: ODDS. The Dendrogram shows species relationships in 165 quadrats.

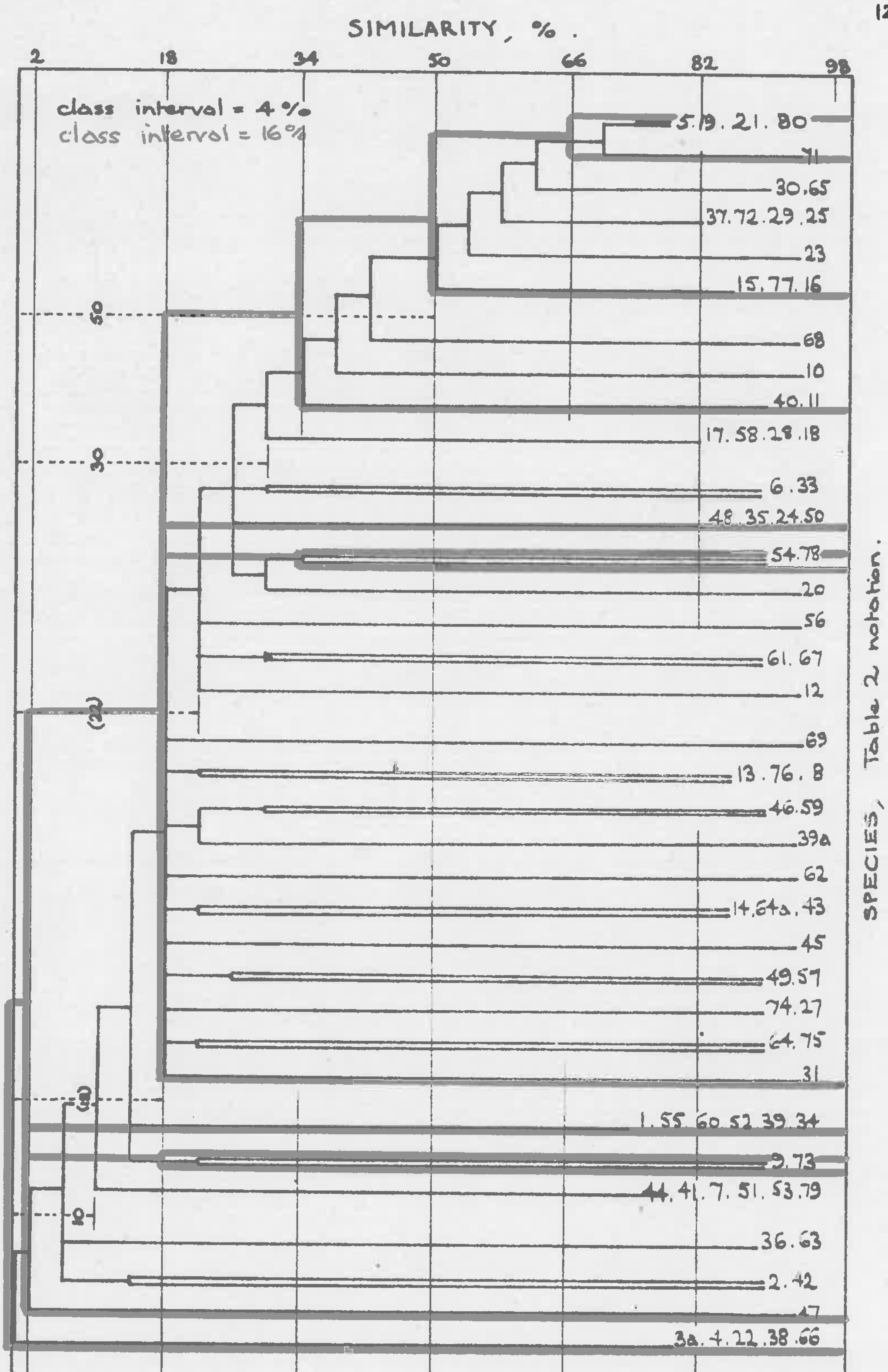


Fig. 17 SNEATH'S ANALYSIS: EVENS. The Dendrogram shows species relationships in 165 quadrats.

Part III. DISCUSSION

A. Vegetation and Habitat

1. A quantitative description of the vegetation studied.

This project has achieved a permanent record of vegetation on some stranded coastal dune ranges in County Robe. The record is largely in terms of presence or otherwise of about a hundred species in numerous small circular sampling quadrats at subjectively chosen sites. In addition, actual amounts of some species in terms of number and coverage per given area have been recorded. Such records complement the general descriptions of Crocker (1944), Wood (1937), and others.

Since measurements were mainly confined to dry sclerophyll forest formation, the main species were anticipated as such. These were Eucalyptus baxteri, Leptospermum myrsinoides, Leucopogon virgatus, Hibbertia sericea and Pteridium aquilinum which were of course almost omnipresent, and thus indeterminate with respect to vegetation patterns. Several less common species were found to be of greater importance than might be expected from superficial examination, for example Isopogon and Correa which each occurred in half the quadrats, and in fact a new recording of one species was made. On the other hand Hakea, *Acacia*, and the legumes generally were not as prominent as expected. Also very few of species thought to be typical of the arid Mallee area and the humid Grampians area were found to occur in County Robe, although vegetation in Western Victoria generally was observed to be similar to that studied. That many of the species occur also in eastern but not western Australia does not detract from the historical sequence proposed by Crocker and Wood (1947).

Taxonomic and geographic variation in several species was observed, at the suggestion of local botanists. No measurements were taken, but it appears that *Correa reflexa*, *Acacia pycnantha*, and *Acrotriche serrulata* all have several races adapted to particular habitats. Furthermore, division of *Calytrix tetragona* into hairy and glabrous varieties, of *Banksia marginata* into erect and dwarf, and of *Astroloma humifusum* into the type and the variety *denticulatum* appears to be vindicated by the fact that these pairs rarely occur at the same site in similar quantities (Appendix C).

Measurements of relative frequency indicate that species do not occur haphazardly in space. On the contrary, some are strongly restricted in their distribution, and furthermore some tend to occur only in association with other particular species. Such association is easily recognized visually on a large scale, especially since coincidental changes in some environmental factor are often readily apparent; for example, an association of stringybark with heath species invariably occurs on upland sites in the area studied. But small scale association is less easily detected recognized, and in this project a number of groups has been detected and characterized by frequency measurements. The nature and size of these groups depends on considerations of sampling technique, criterions of significance, and method of analysis.

2. The meaning of vegetation patterns in terms of habitat.

As a general statement it may be said that the distribution of a plant species is determined by one or more controlling factors in its environment (Wood, 1939), and from this premise may be drawn the inference that the distribution of groups of associated species will be similarly determined. Hence, the distribution pattern of a group will indicate the extent of a particular habitat-type. This information can itself be used for whatever purpose is in hand, reinforced if desired by further description of the habitat. In this project some groups appear to occur indiscriminantly while others are restricted to various parts of the area studied, and the causes of these patterns will now be examined with respect firstly to time and climate, secondly to parent material and topography.

If time is the only controlling factor groups would ideally be restricted largely to one range, and would gradually fall away in importance on successively younger and older ranges. Trends of this kind are evident across the chronosequence of ranges in the area studied; for example, Groups F-E-G (Figure 10a) appear to complement one another, as do H-W-L (Figure 14). Such trends are better illustrated by considering the proportion of quadrats belonging to each group on each range; for example, in the lower and higher rainfall regions respectively, the sequences F-G and B-D-C (Figure 11), H-R-J and Q-O-L (Figure 15). On the other hand density and cover measurements generally vary irregularly, despite the following exceptions:

species	importance	Maximum
20 Leuc. collinus	central	density of 17 at WP3
10 C. tetragona hairy	inland	" 12 at WP4
21 Leuc. virgatus	(two density maxima)	
68 Correa reflexa	(three " ")	
6 Euc. obliqua	coastal	cover of 60% at ED2
20 Leuc. collinus	subcoastal	" 50% " WP3,ED1.

Therefore there is apparently some evidence to suggest that the vegetation reflects the chronosequence of habitats, modified by rainfall differences.

However, this evidence is not fully sustained upon closer examination of three basic assumptions: that successive habitats are successive in age, that the sample represents the population, and that habitat factors other than time are uniform. 1. Age. Most authors agree that the aeolianite cores of the dune ranges are successive in age, but this does not necessarily apply to the mantle of siliceous sands which are the parent material in question (Blackburn et al., 1965). 2. Sampling. The total area of the 330 samples taken - about two acres - cannot adequately express about 300,000 acres of vegetation, and this will cause errors. Furthermore, the location of sampling sites was often a matter of expediency, and this must introduce bias in assessing relative importance of the groups. In addition there may of course be some deficiencies inherent in the methods of analysis. 3. Other factors. Whilst climate and biota may be regarded as uniform, despite reservations expressed in Part II, parent material and topography are certainly not. For example, some sites are eastern slopes bordering swampy flats, while others are stony upland areas; these variables are likely to confuse any vegetation patterns caused by differences in age.

Therefore it is apparent that the chronosequence may not adequately explain patterns in the vegetation, and thus some other explanation must be sought.

Variations in parent material modified by topography can be correlated with the occurrence of many Williams and Lambert groups. Examples follow of three general types of situation: shallow stony pink sands or loamy sands on western slopes (about 10% of all quadrats), deep yellow or white sands on ridges (70%), and shallower sands with some waterable influence on eastern slopes (20%). 1. Stony sites.

Group K has most of its 13 quadrats confined to Site ED1 which is almost flat and has a shallow reddish soil carrying *Eucalyptus obliqua*. 2. Deep sands. Within this situation groups appear to be controlled by minor differences in aspect and profile depth. For example, Group Q (44 quadrats) occurs on flattened crests of sandridges such as Site EN1, R and T (40 quadrats) on south-western crests of wide sandhills such as WP3, and H (39 quadrats) on eastern crests such as WN2. 3. Shallow sands. Examples are Group O (23 quadrats) at B2, and Group L (17 quadrats) at ED2. Thus there is evidence that vegetation patterns reflect the nature and quantity of parent material, modified by topography.

3. Conclusions.

The vegetation in question consists of several hundred species of which but a few are widespread, most being rare. Of 150 species selected for study only 13 were present in more than 50% of the sampling quadrats, whereas over three quarters were present in 10% or less. A few understory species such as Phyllota and Monotoca which are of sparse frequency on the whole, are nevertheless found to be plentiful within certain limited areas. Such species signify measurable associations or societies which tend to be exclusive to a high degree, and of which there are about ten, depending on the criterion of association.

From the literature it is apparent that there is a chronosequence in soils on the dune ranges across the area studied, certainly in terra rossas and probably in residual podsols. However this situation is largely not reflected in the vegetation studied, due in part to difficulty in obtaining enough comparable sampling sites. But even if this difficulty were to be resolved, and in addition soil samples taken, the effects of age would not necessarily be evident since the ranges are probably old enough to have developed a climax vegetation. Nevertheless it is suggested that, although this project has not demonstrated clear evidence for a succession or other effect of time across the ranges, a more complete study might do so.

Non-uniformity of environmental factors other than time provides an explanation for patterns in the vegetation. Parent material is the most important variable factor since samples were located not only on residual podsols as originally intended, but also as a perhaps unwise expedient on secondary podsols, and to some extent on terra rossas and humus podsols. Furthermore, as will be readily appreciated, precise uniformity of topography is difficult to achieve in any study on massive fossil dune systems, although this would certainly be lessened by a larger number of samples. On the other hand climate and biota differences will have had little effect, once rainfall is taken into account. Therefore it is concluded that the cause of vegetation patterns revealed in this study is not age as such but rather recent geological history, i.e. the degree and timing of aeolian processes and the chance placement of siliceous sand, especially with respect to subsequent podsolization and groundwater influence.

B. <u>Analytical Methods</u>

1. A comparison of interspecific correlation with association-analysis.

These two methods differ basically only in the criterion upon which quadrats are divided or associated, and all other differences are unimportant. Certainly the mechanical processes differ: on the one hand Goodall computations must generally be performed manually, i.e. selecting by eye suitable species pairs for testing, then counting or weighing the cards thus sorted, and performing at least a rough chi-squared test; experience will greatly shorten this process, but it is still laborious. On the other hand all Williams and Lambert computations are performed in a few minutes, although at greater cost, and the results stored in the computer or issued as a printed statement or diagram. Also the former ignores negative association, and employs pooling of negative quadrats at each stage of subdivision, the latter recommends the contrary. However, the kind of process used appears to be a more a matter of expediency than principle.

The real difference lies in the nature of the species on which any given set of quadrats is subdivided. Goodall uses the most frequent species, i.e. the one which occurs in most quadrats in the set, provided only that it is significantly associated at an arbitrary probability level with at least one other species, irrespective of the actual degree of association. Williams and Lambert, on the other hand, use the species which shows the highest degree of association with all other species, for which several indices are suggested, irrespective of the frequency of the species. For example, the first division is on Leptospermum myrsinoides (total frequency 89%) using the former method, but on Phyllota pleurandroides (18%) using the latter, which illustrates that abundant species are not necessarily strongly associated, and in fact are likely to be the reverse, since they tend to occur indiscriminantly over a wide range of habitats. Thus an ecologically important species is held by Goodall to be a widespread one, but by Williams and Lambert a restricted one.

Two practical consequences of these contrary viewpoints might be mentioned. 1. Both methods require a significance level to be arbitrarily chosen; in Goodall's method this choice may alter the path of subdivision by determining that a given species does not meet the requiremint of association with at least one other, and may also allow recombination of groups. In the other method, the choice will determine which individual chi-squared values are insignificant and thus to be regarded as zero; this will alter many association index values, and in this way will slightly distort the levels of subdivision, and may possibly - at lower levels - cause different species to be selected. 2. At a given significance level, Goodall must produce a fixed number of groups, since by definition each each stage of subdivision is terminated when no species are associated. Certainly Williams and Lambert also produce a fixed number, but only if subdivision is continued to zero association index, and in practice this can be terminated at any level to produce any desired number of groups.

Despite the disparity in principle between methods, the final groups do correspond to some extent, for example many Group R quadrats coincide with Group E quadrats, J with G, H with F, and so on (Figure 18). Goodall Group C embraces several Williams and Lambert groups, and illustrates the fact that large groups may not indicate patterns in the vegetation; for example, from the distribution of C (Figure 10a), the restriction of some quadrats (Groups K and L, Figure 14) to the west, and others (S and T) to the north-central would not be suspected. But, having taken into account this artefact due to a differing number of groups, the patterns elucidated by the two methods are not dissimilar, and it is suggested that any such similarity exists because the methods arrive at the same destination by different routes. In other words, supposing that division of a set of quadrats indicates two habitat-types, one will be represented by either absence of the species used by Goodall or presence of that used by Williams and Lambert, whilst the other will be represented by the reverse. This suggestion could only be tested if both analyses were performed using the hierarchy process.

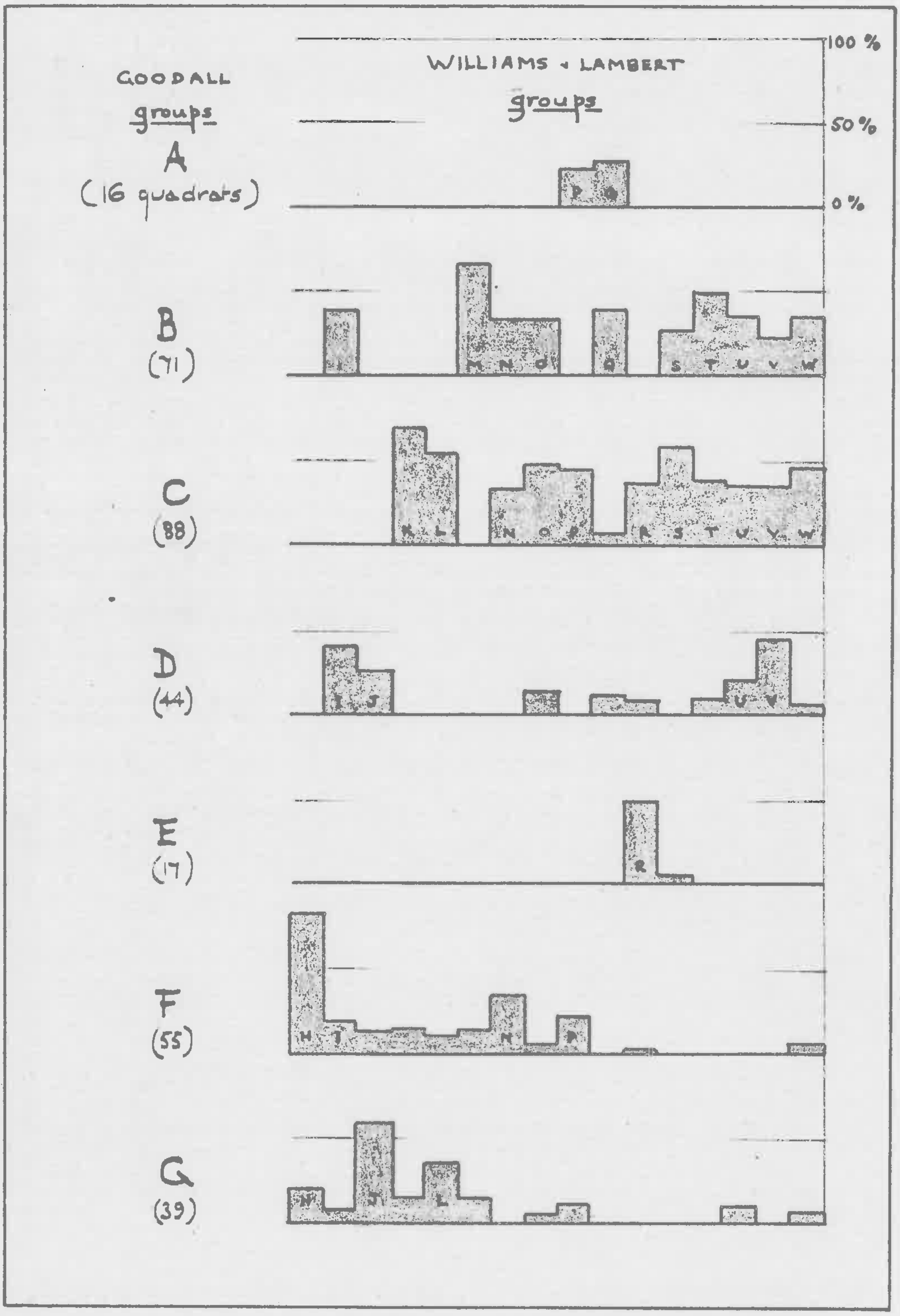


Fig. 18 A COMPARISON OF METHODS showing the proportion of quadrats ascribed to each Williams + Lambert group corresponding to a particular Goodall group.
Scale, one inch = 100 %.

2. A brief examination of cluster analysis.

This method differs in principle from those just discussed in that taxonomic units (i.e. quadrats) are clustered (associated) on presence or absence not of one key character (species), but of many characters (e.g. all 80 species) equally weighted. On the one hand Goodall and Williams and Lambert split the population into groups of quadrats on the principle that two groups are most unlike if the ecologically most important species is entirely present in one, entirely absent in the other. Sneath on the other hand works in the reverse sense to construct the population of quadrats from its individuals; two quadrats are deemed most alike if they have the largest number of species present in both quadrats. It is apparent that Sneath proposes a natural system in which the classes are subjective, flexible, and generally applicable, whilst the others propose artificial systems with objective, rigid, locally applicable classes.

As used in this project, cluster analysis suffers several practical defects. 1. The similarity index does not take negative association into account, which is unfortunate because in ecology such association can be regarded as meaningful. 2. Highest similarity between any species pair is perhaps too crude a criterion for fusion of clusters, since it can be quite misleading. For example, consider two large clusters between which one species pair happens to have a similarity higher than average; fusion will occur at this higher level, ~~but~~ yet this obviously does not represent the real situation. 3. The process of constructing a dendrogram from a similarity matrix is tedious and subject to human error; in fact if the matrix were between all quadrats, and average similarity between clusters was the criterion for fusion, it would be impracticable manually.

3. Conclusions.

In principle the difference between positive inter-specific correlation (Goodall, 1953) and association-analysis (Williams and Lambert, 1959-1961) lies in the choice of key character by which vegetation classes are distinguished. Both use the ecologically most important species to subdivide a population of sampling quadrats into groups, but their definitions of this species differ: Goodall implies by usage that widespread species are most important, Williams and Lambert the reverse. It follows that since restricted species tend to be physiologically confined to a particular habitat, they will indicate environmental variation, which will in turn be reflected in vegetation differences. Thus such species are more useful than widespread ones in distinguishing vegetation classes. Furthermore, Williams' and Lambert's key species is chosen by consideration of association between all species, and is thus likely to be more meaningful than Goodall's key species which need only be associated with one other. Therefore it is concluded that association-analysis is a more valid method of vegetation analysis than interspecific correlation.

In practice the methods are similar. Goodall's main virtue is that it can be processed manually, but it suffers the considerable disadvantage of producing a fixed number of groups; also the path of subdivision depends upon significance level. Williams and Lambert does not suffer these disadvantages, but must be electronically processed; flexibility in number of groups produced makes it the more preferable method, provided that a computer is both available and warranted. It is recommended that data be processed electronically by Goodall's method using a hierarchy process, since in this way, human error would be avoided in selecting the most frequent species, and in selecting correlations to be tested; also a better comparison of the paths and results of subdivision of the two methods would be available, especially if negative association is recognised.

Sneath's method based on overall similarity of equal characters is a natural system, and thus likely to indicate general trends on a regional basis in the sclerophyll forest formation. It is recommended that the method would be enhanced by an index using negative association and based on species quantity as well as frequency. Furthermore, a computer programme which directed clusters of quadrats to be fused at an average similarity level, and which drew the dendrogram, would be a useful refinement.

By contrast, the methods of Goodall and Williams and Lambert are likely to reflect habitat differences within the area studied, since they are artificial systems based on locally important characters. Furthermore, these methods are to some extent local fabrications, because measures of density and dominance are not incorporated to counteract any undue effects of quadrat size on frequency. Nevertheless they could be most suitable for recognizing habitat and land-use types, since, once basic categories had been characterised, typing could become a quick process for use in agricultural and forestry planning.

ACKNOWLEDGEMENTS

Particular thanks are due to Dr R.T. Lange who supervised this project and conceived and organised the electronic computation, and to my wife who provided technical and moral assistance and typed the thesis.

A number of people helped in various ways, especially Miss D. Hunt, and Messrs. G. Blackburn, R. Plank, J. Ross, and K. Stuckey, and Drs. Hj. Eichler, and P. Hossfeld.

The good offices of the University of Adelaide, the State Herbarium of S.A., and the S.A. Woods and Forests Department contributed in large measure towards the success of this project.

APPENDICES

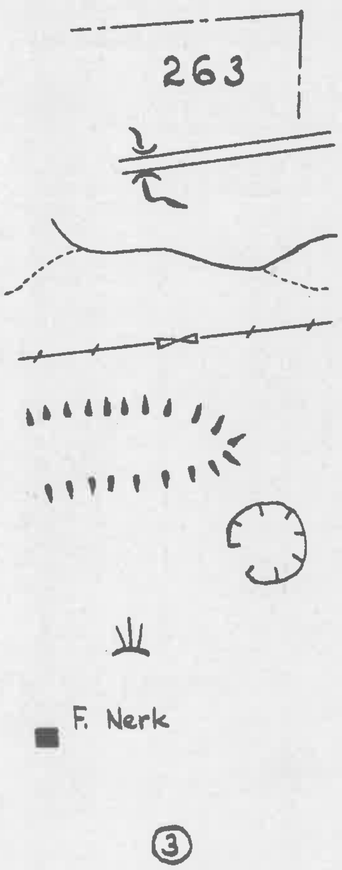
Appendix A.

Appendix A

LOCATION OF QUADRATS

The following maps indicate the approximate location of the 330 quadrats. They are sketches and not to scale. S.A. Lands Department hundred maps should be consulted for the exact scale. Quadrats are in County Robe unless otherwise stated.

Legend



section (§), unless bounded by road or fence

road with bridge

tracks

fence with gate

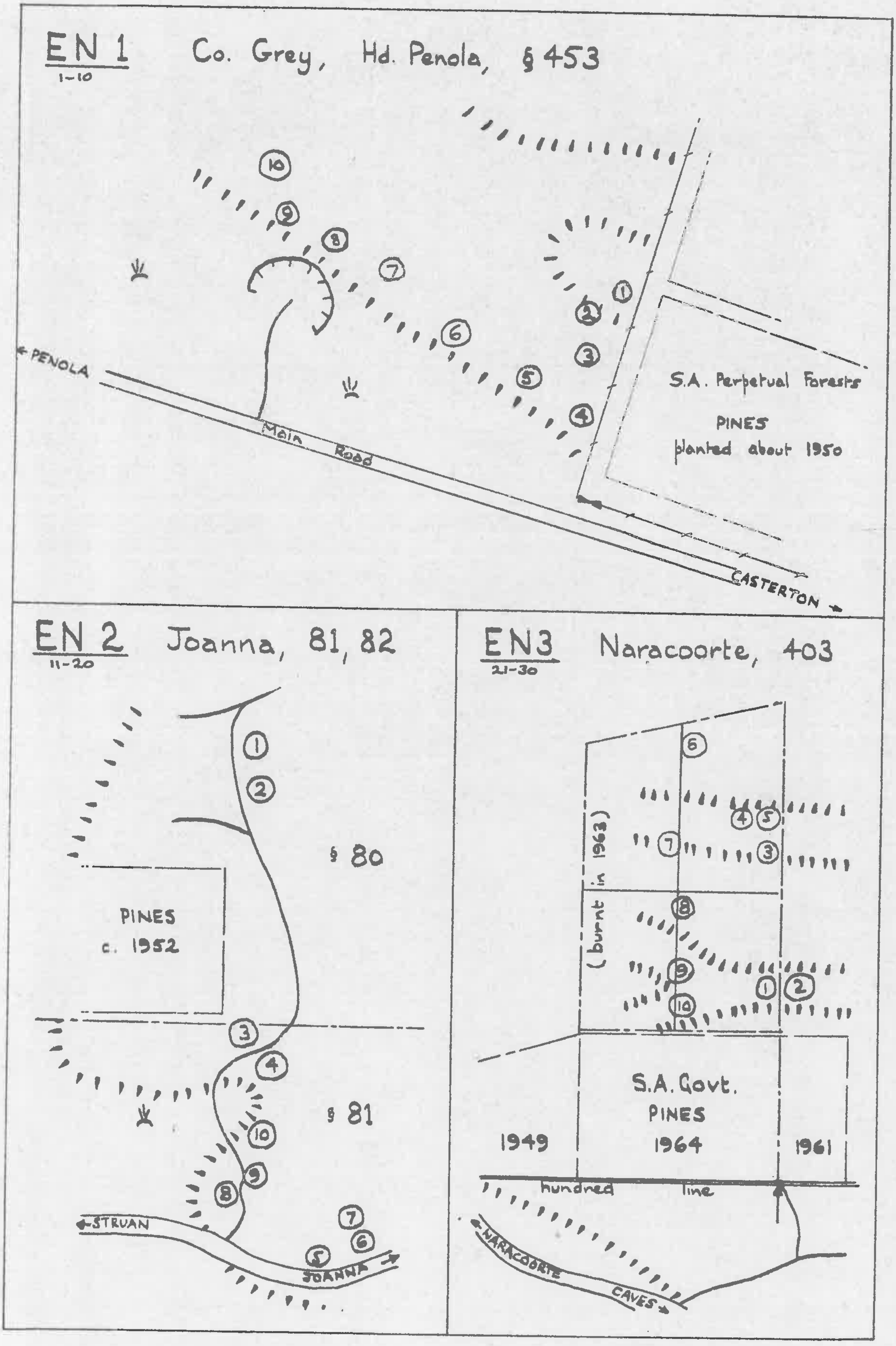
sand ridge

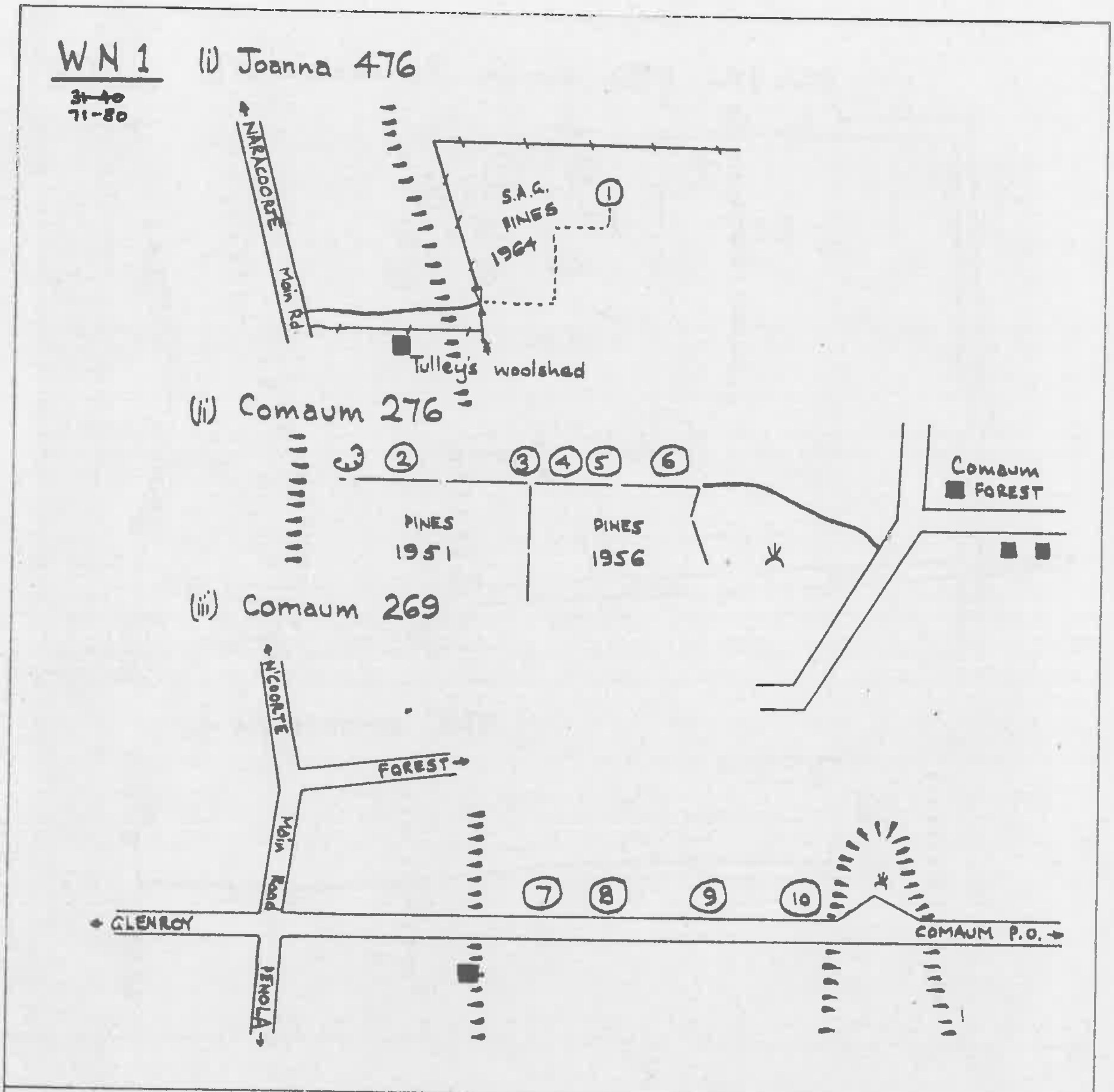
quarry or sand pit

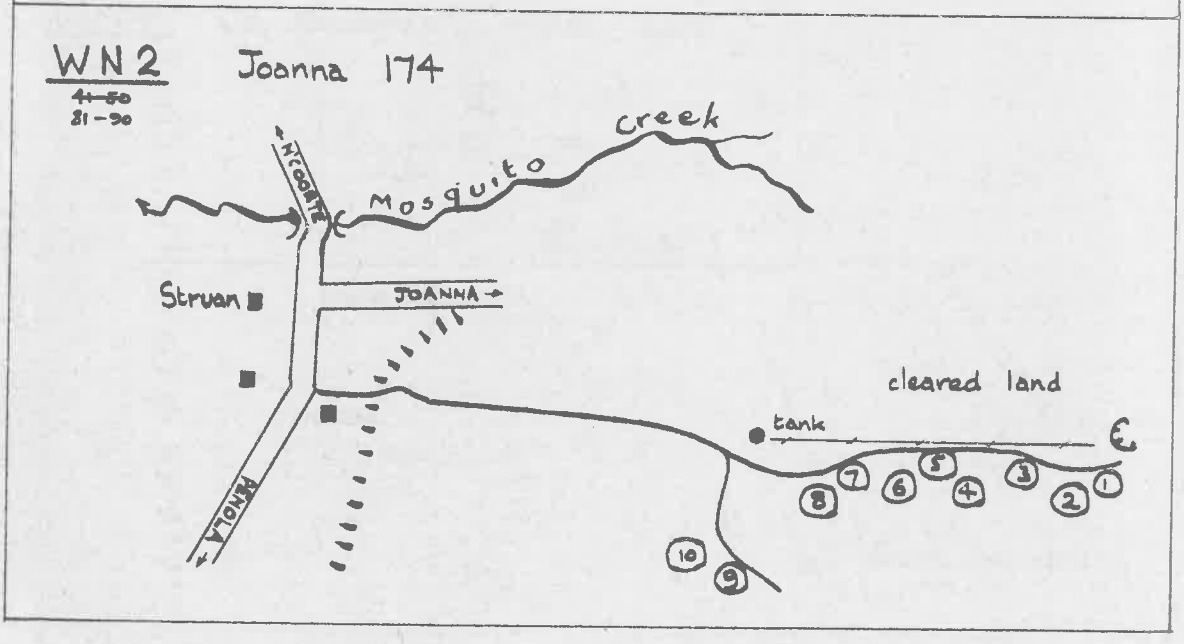
swamp

building with name of owner or location

quadrat


EN 1
1-10
Co. Grey, Hd. Penola, § 453
PENOLA
Main Road
CASTERTON
S.A. Perpetual Forests
PINES
planted about 1950
EN 2
11-20
Joanna, 81, 82
§ 80
PINES
c. 1952
§ 81
STRUAN
JOANNA
EN3
21-30
Naracoorte, 403
(burnt in 1963)
S.A. Govt.
PINES
1949
1964
1961
hundred line
NARACOORTE
CAVES

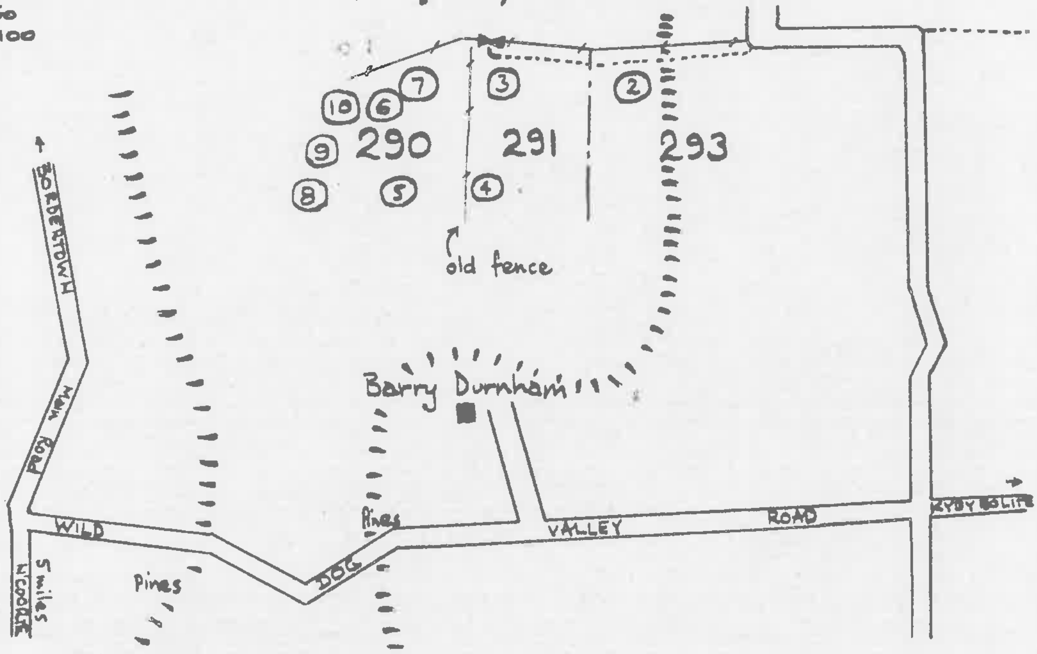

WN 1
~~31-40~~
71-80
(i) Joanna 476
NARACOORTE Main Rd
S.A.G. PINES 1964
Tulley's woolshed
(ii) Comaum 276
PINES 1951
PINES 1956
Comaum FOREST
(iii) Comaum 269
N'COORTE Main Road
FOREST
GLENROY
PENOLA
COMAUM P.O.


WN 2
~~41-50~~
81-90
Joanna 174
N'COORTE
Mosquito creek
Struan
JOANNA
PENOLA
cleared land
tank

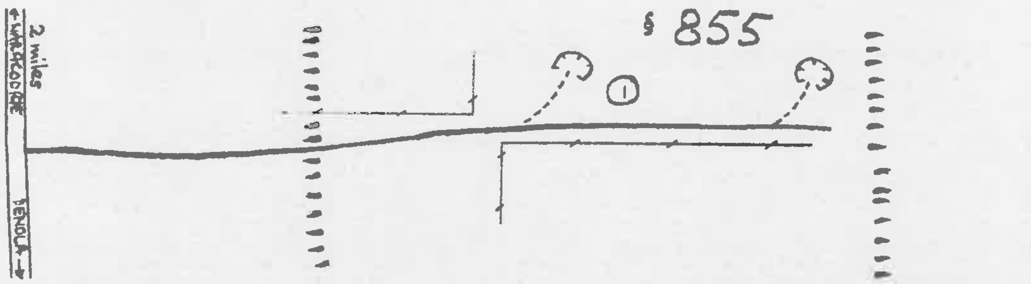
WN3

~~51–60~~
91–100

(i) Co. Macdonnell, Hynam, 290 291 293



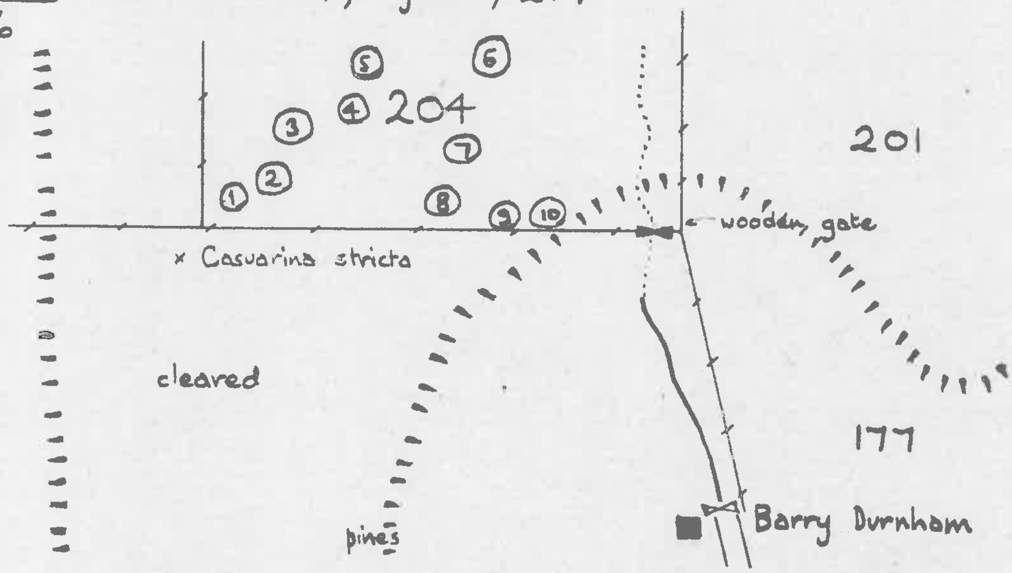
(ii) Naracoorte 855



WN4

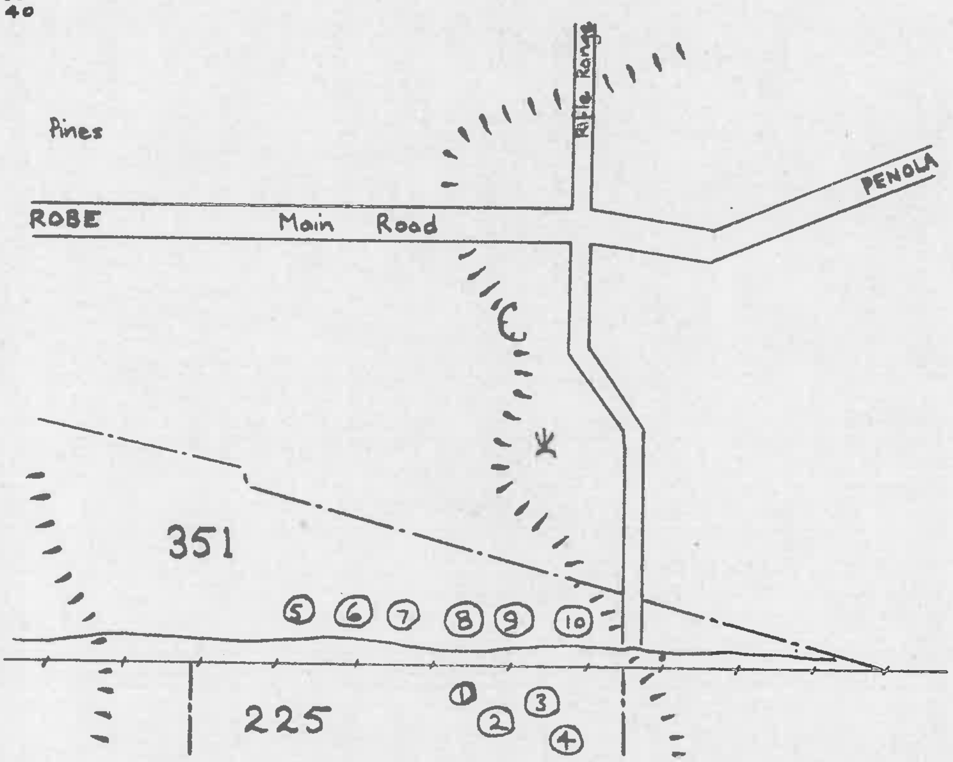
~~61–70~~
101–110

Co. Macdonnell, Hynam, 204



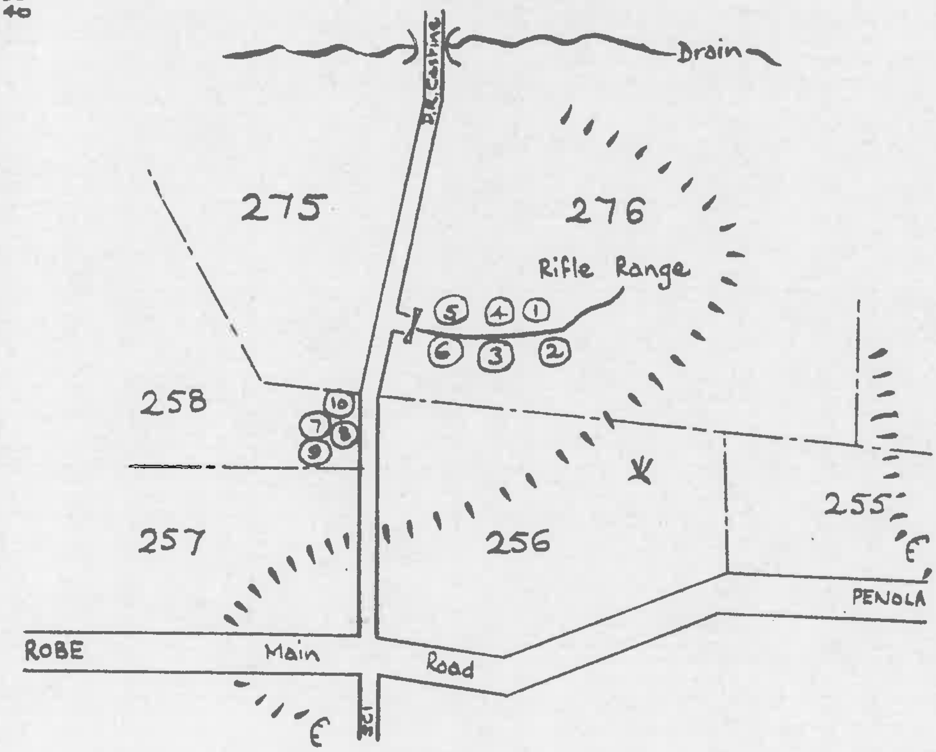
SC 1 Co. Grey, Monbulla, 225, 351

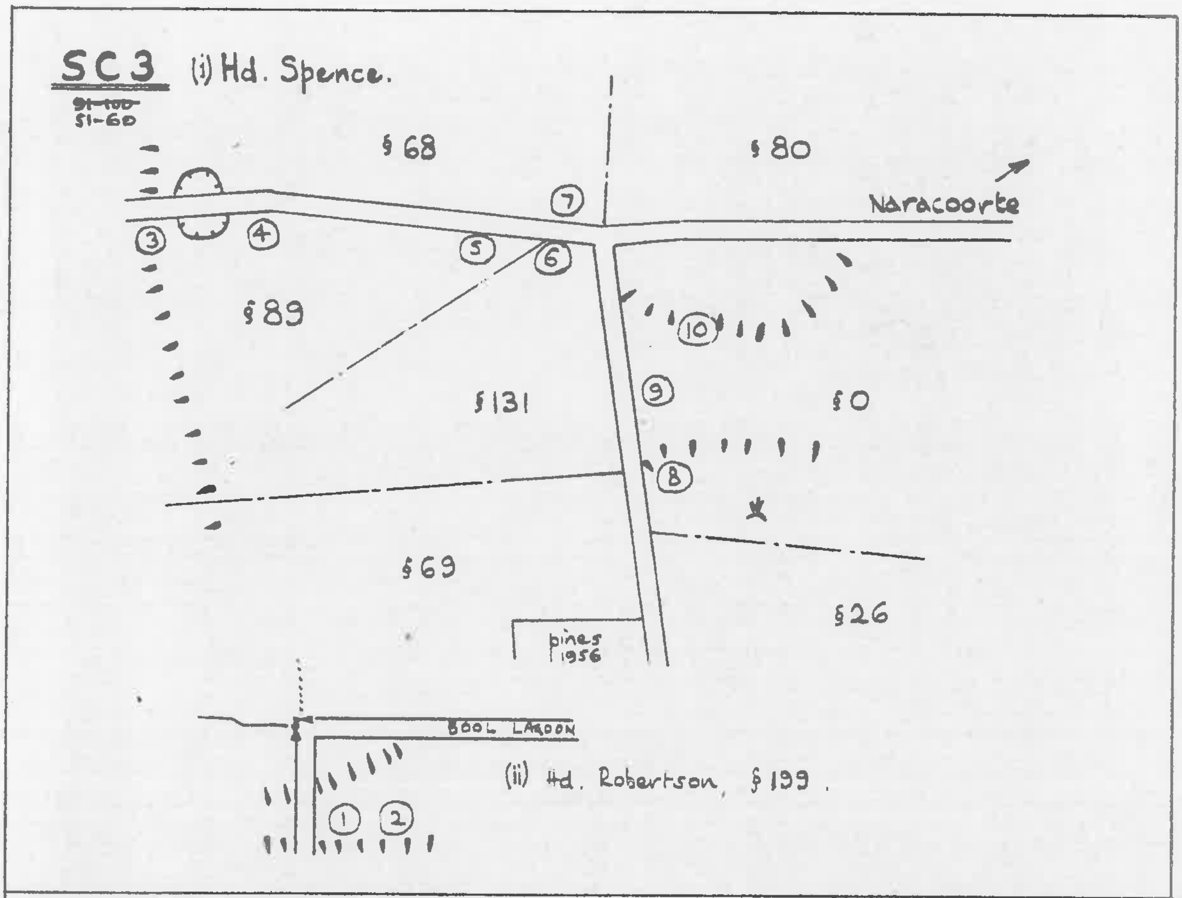
~~71-80~~
31-40

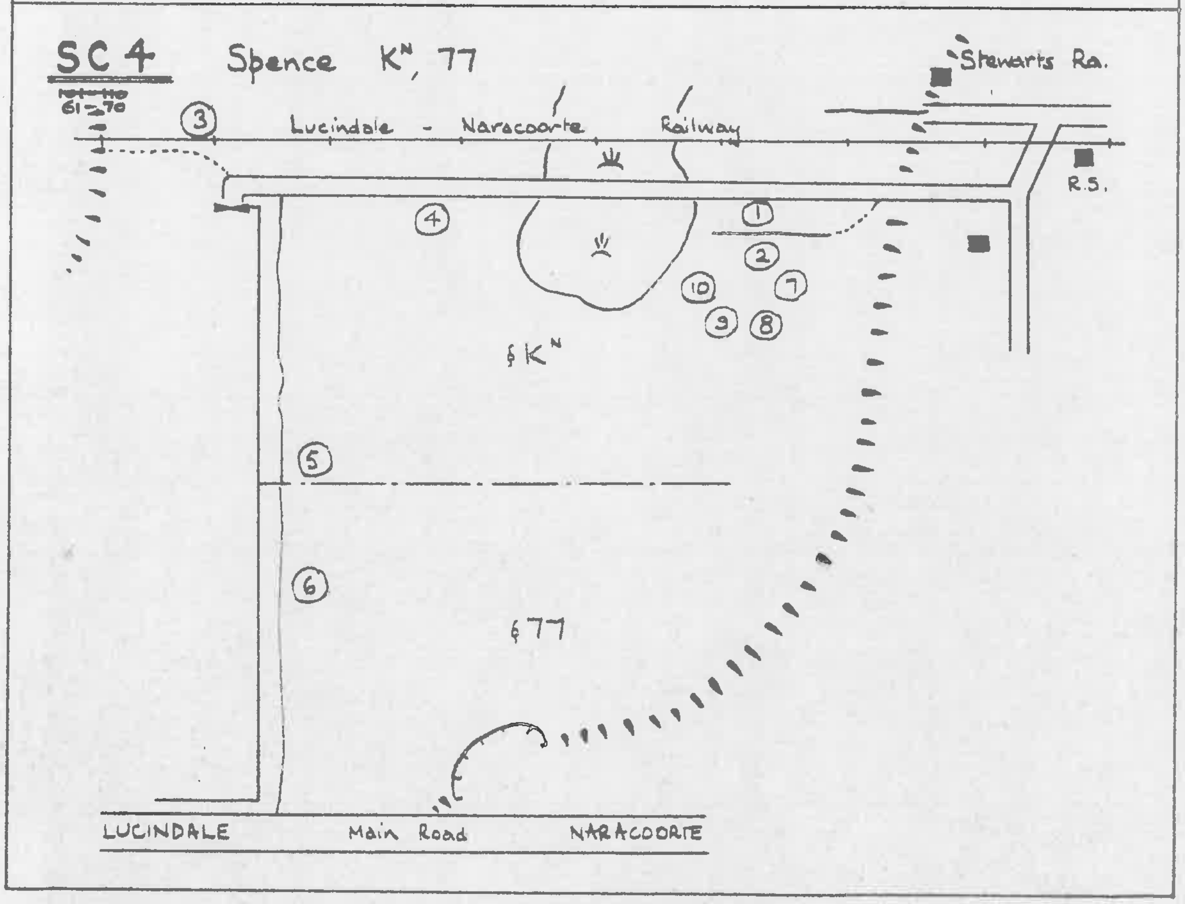


SC 2 Co. Grey, Monbulla, 276, 258

~~81-90~~
31-40

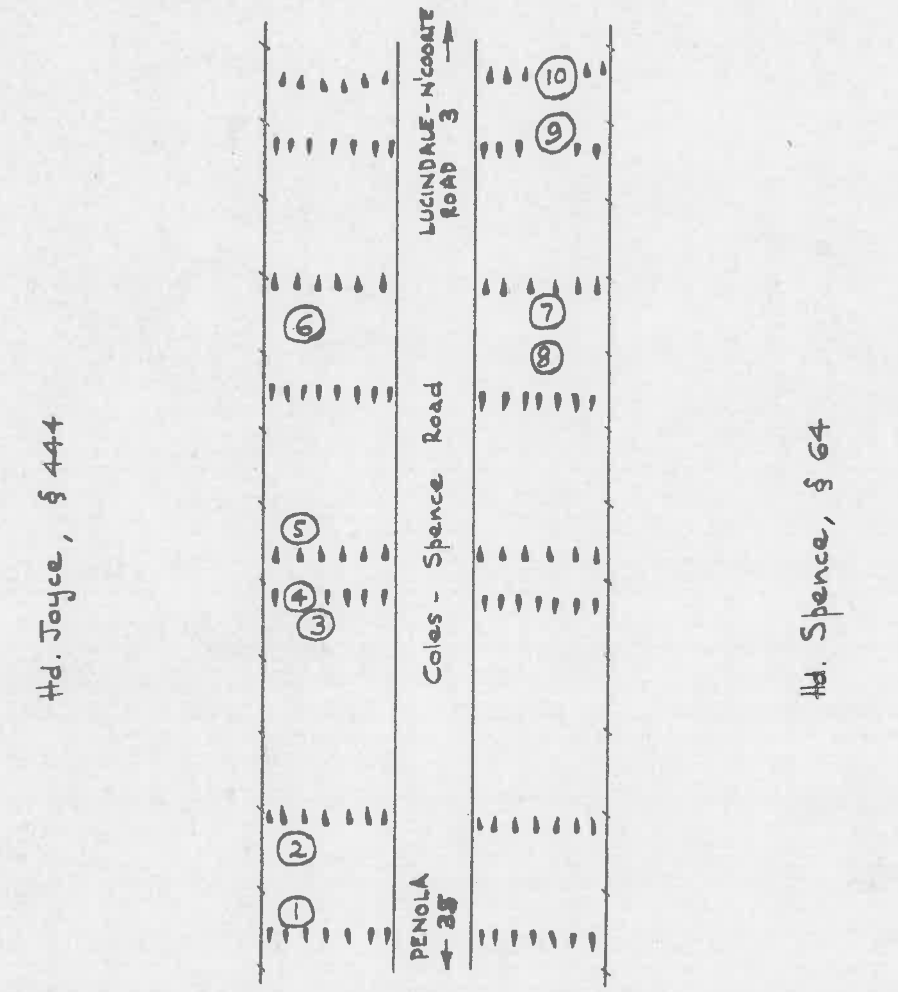



SC3
(i) Hd. Spence.
91-100
51-60
§68
§80
Naracoorte
§89
§131
§0
§69
§26
pines
1956
BOOL LAGOON
(ii) Hd. Robertson, §199.
1
2
3
4
5
6
7
8
9
10


SC4
Spence K^N, 77
101-110
61-70
Stewarts Rd.
Lucindale - Naracoorte Railway
R.S.
§K^N
§77
LUCINDALE
Main Road
NARACOORTE
1
2
3
4
5
6
7
8
9
10

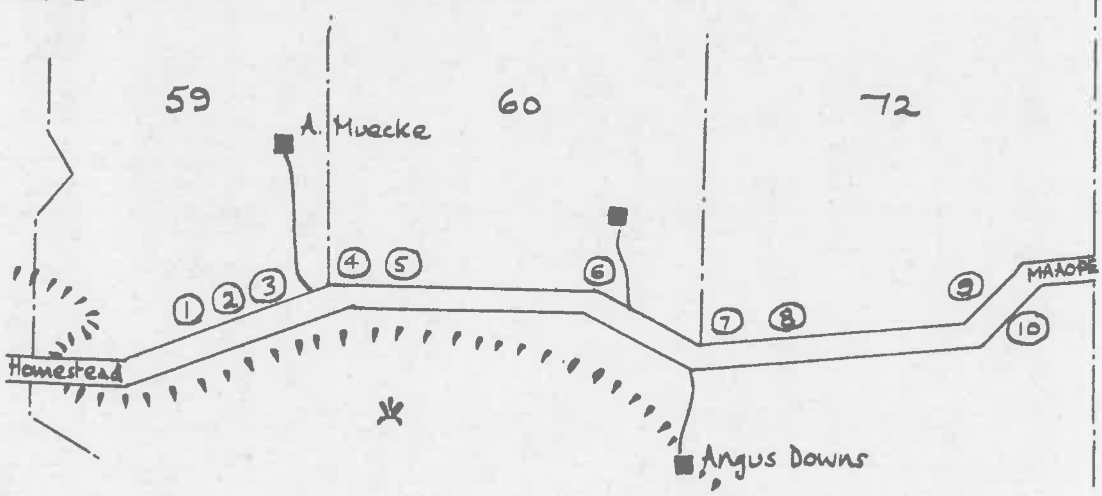
WP 2 Spence 64

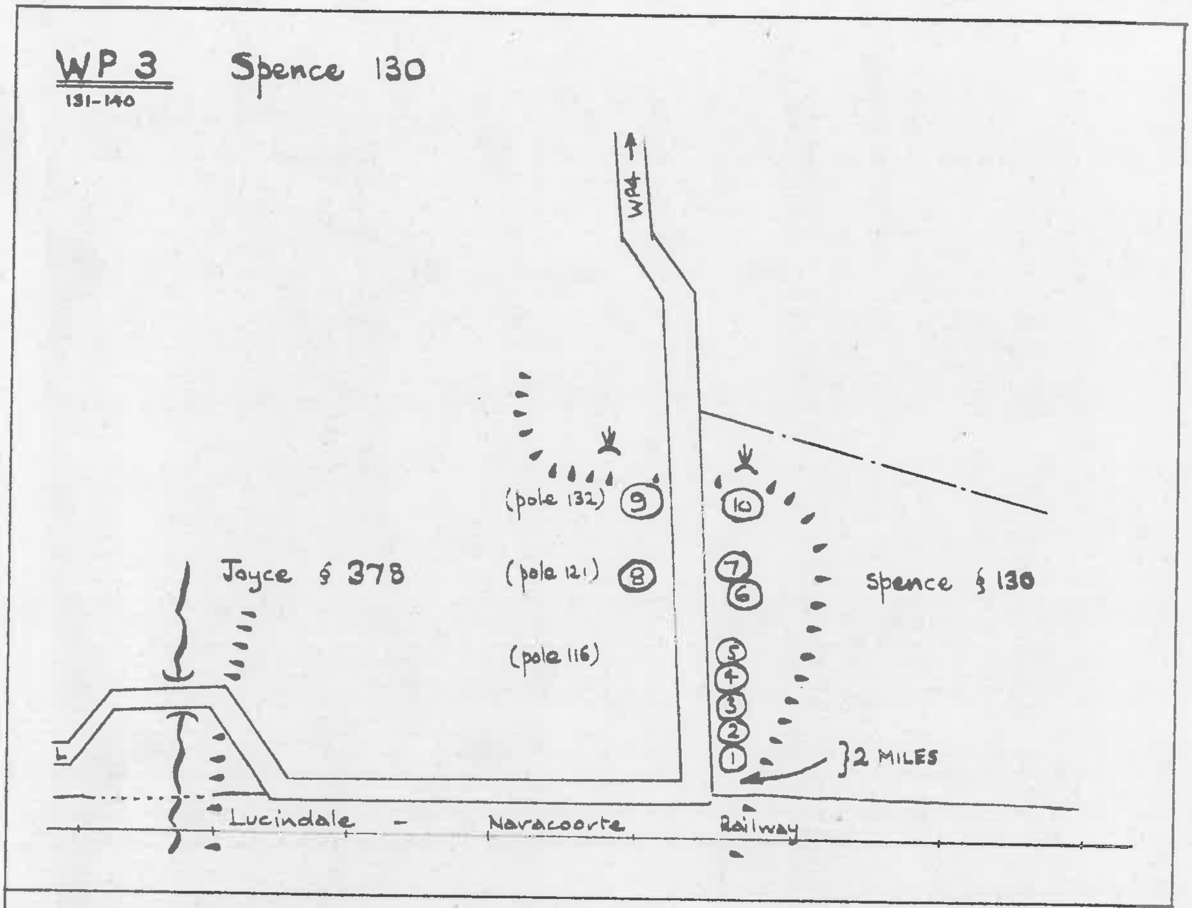
121-130

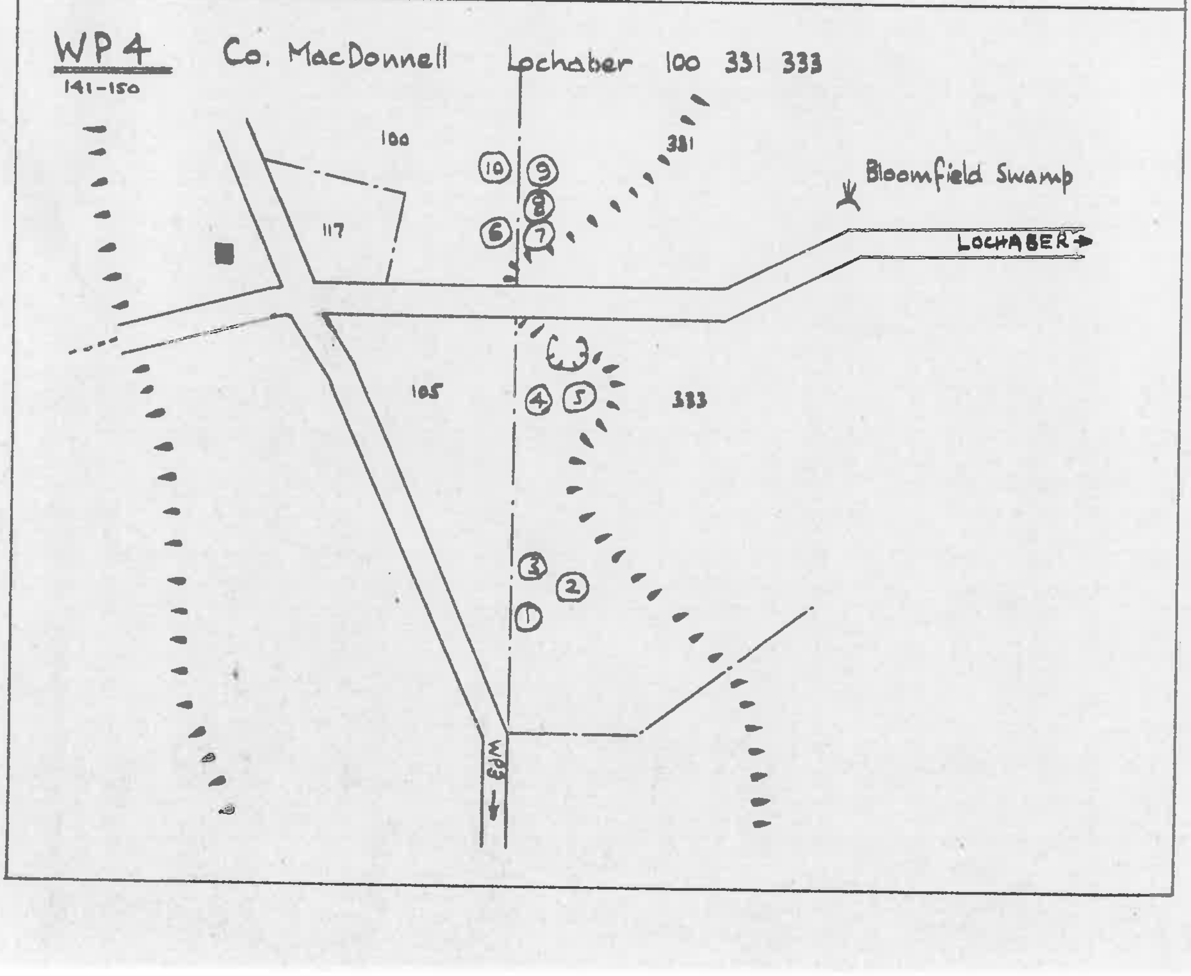


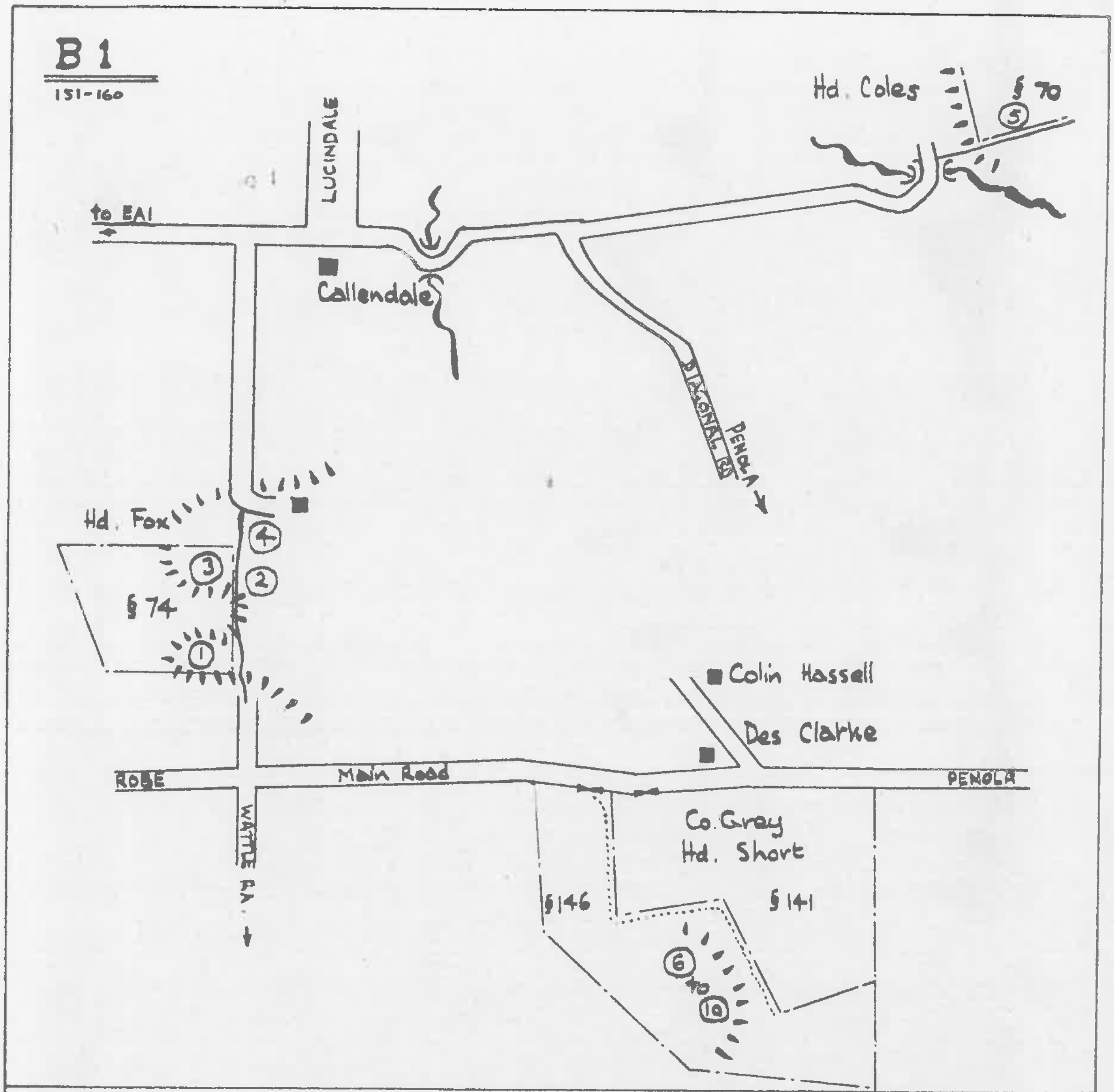
WP 1 Coles 59 60 72

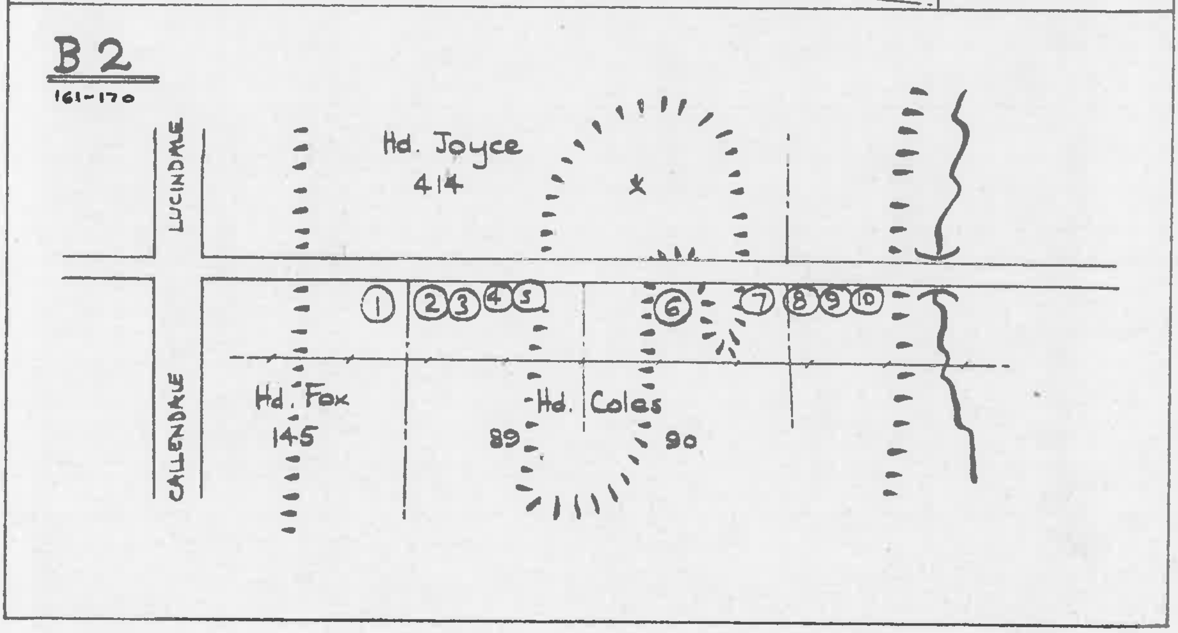
111-120

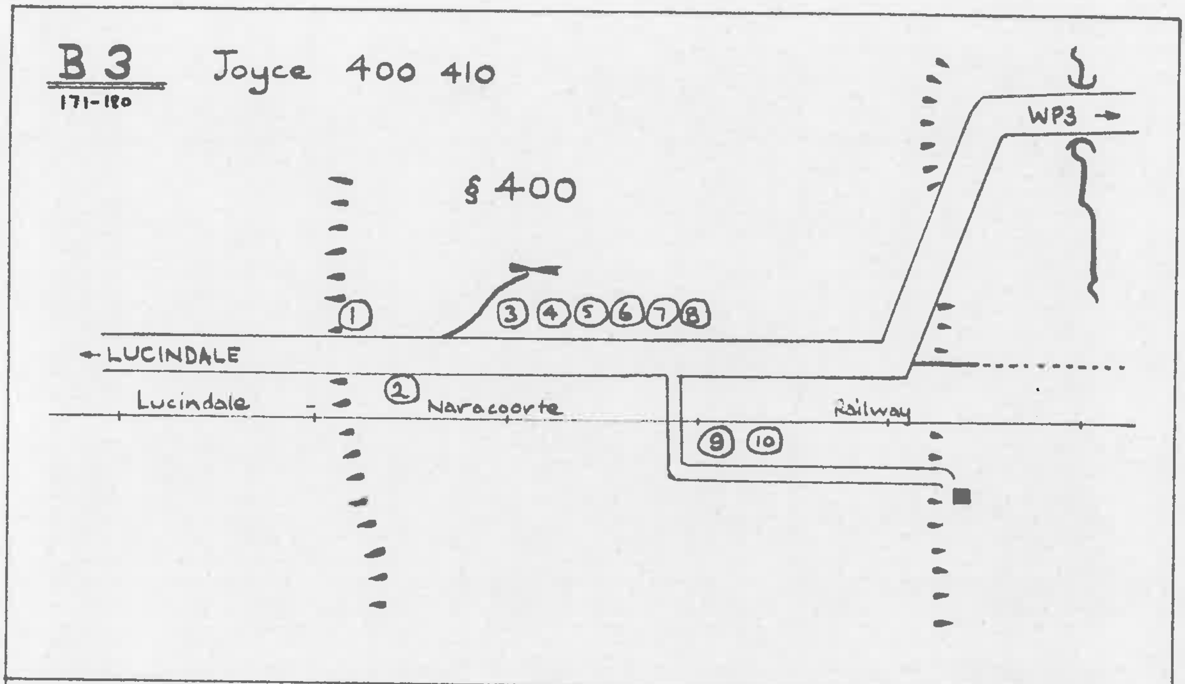


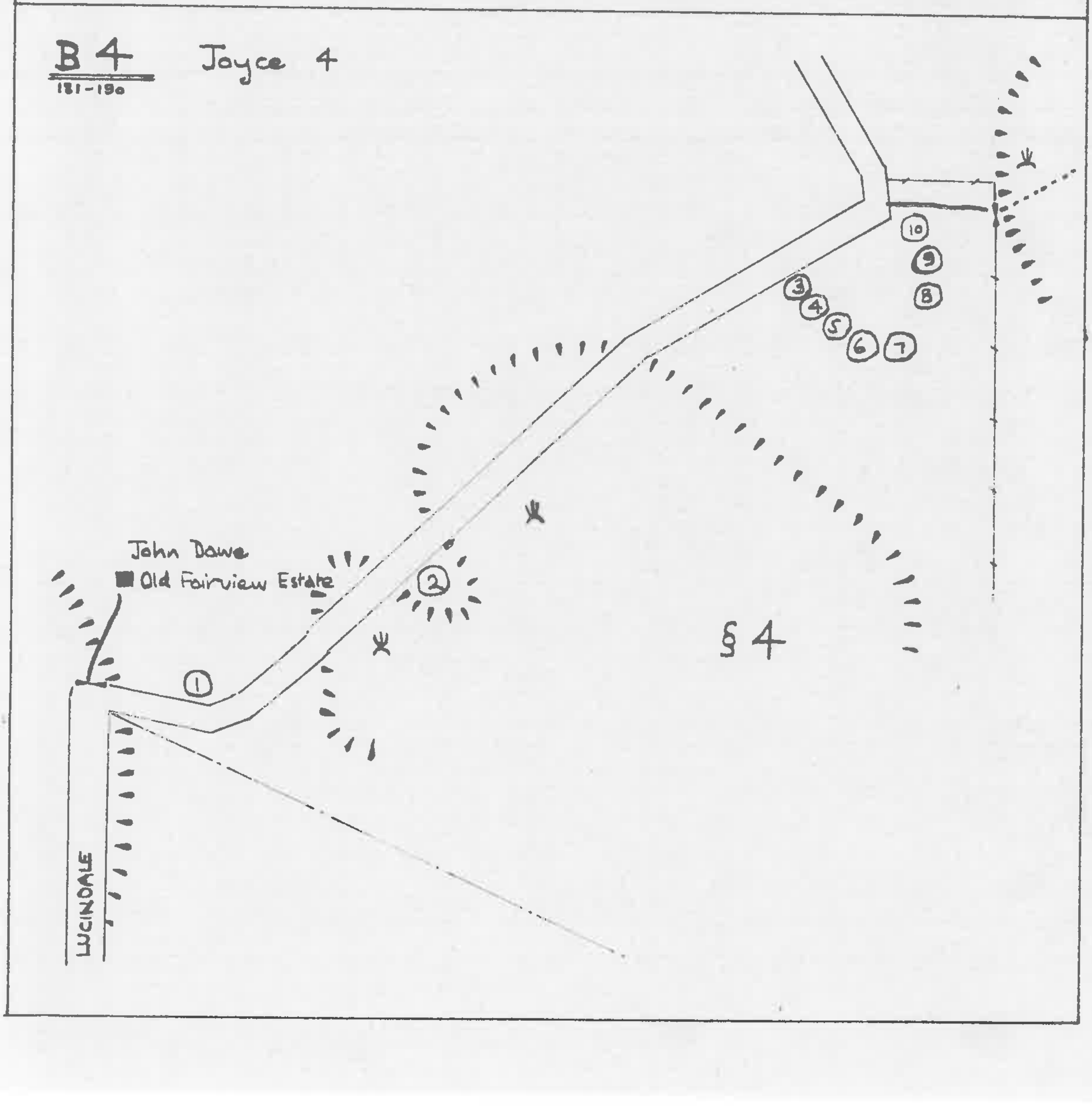

WP 3
131-140
Spence 130
WP4
(pole 132)
(pole 121)
(pole 116)
Joyce § 378
Spence § 130
2 MILES
Lucindale - Naracoorte Railway

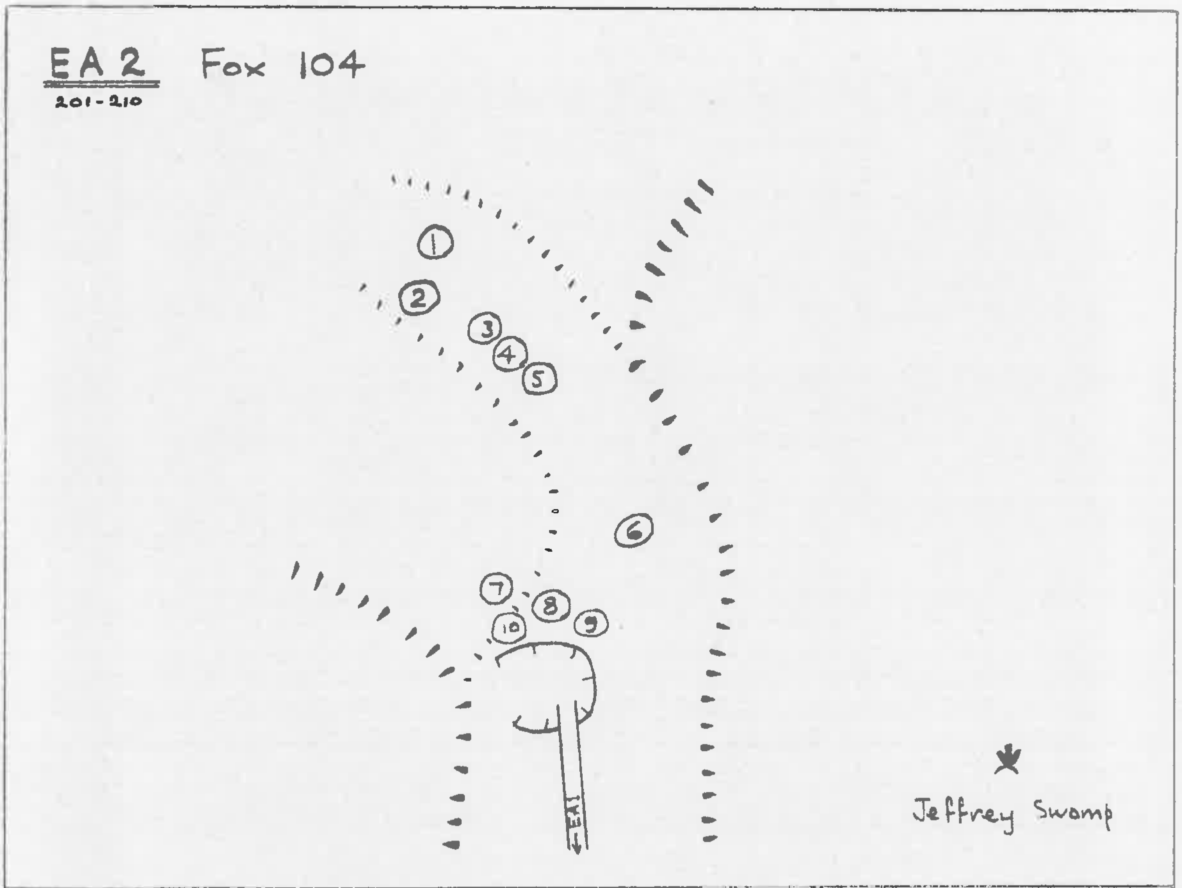

WP 4
141-150
Co. MacDonnell Lochaber 100 331 333
100
331
117
105
333
Bloomfield Swamp
LOCHABER
WP3

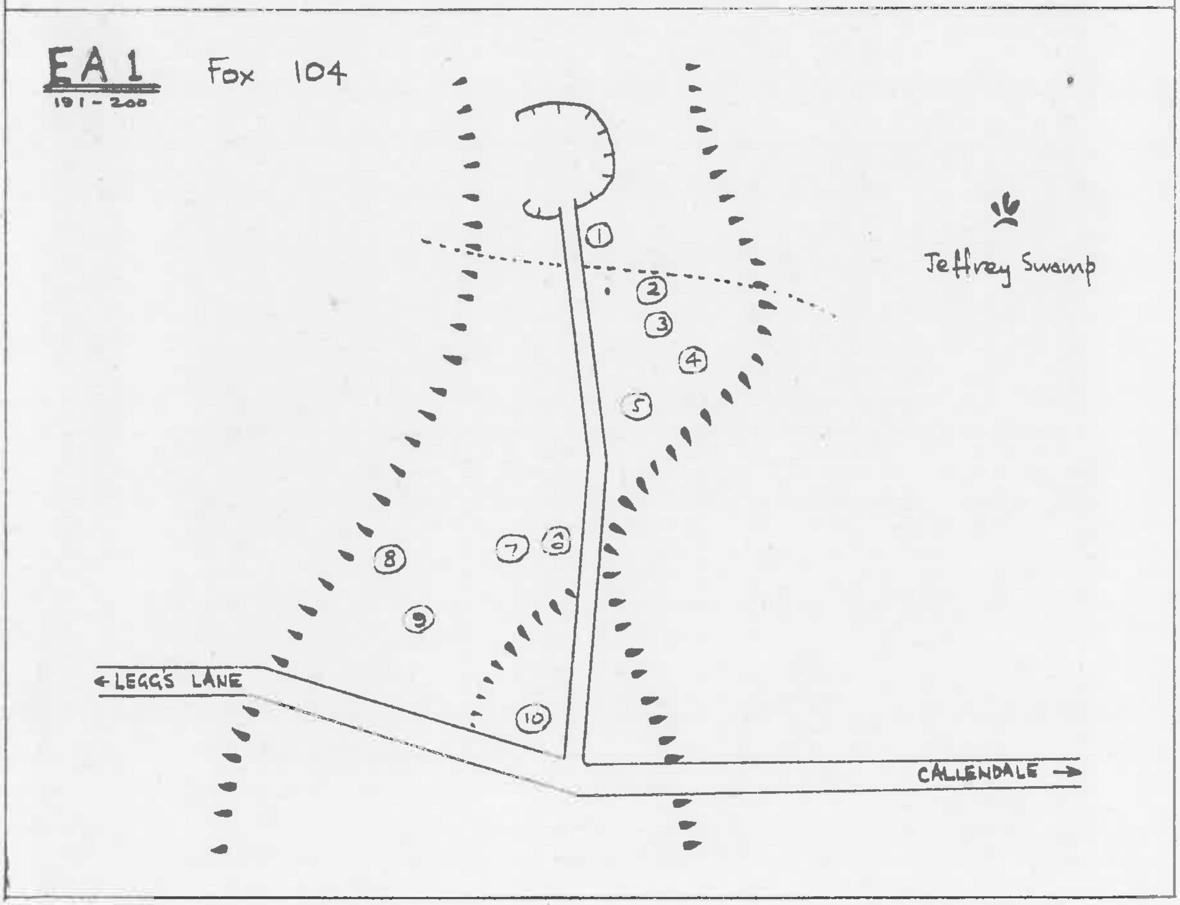

B 1
151-160
LUCINDALE
to EA1
Callendale
Hd. Coles
§ 70
5
DIAGONAL Rd
PENOLA
Hd. Fox
4
3
2
§ 74
1
Colin Hassell
Des Clarke
ROBE
Main Road
PENOLA
WATTLE RA.
Co. Grey
Hd. Short
§146
§141
6
to
10

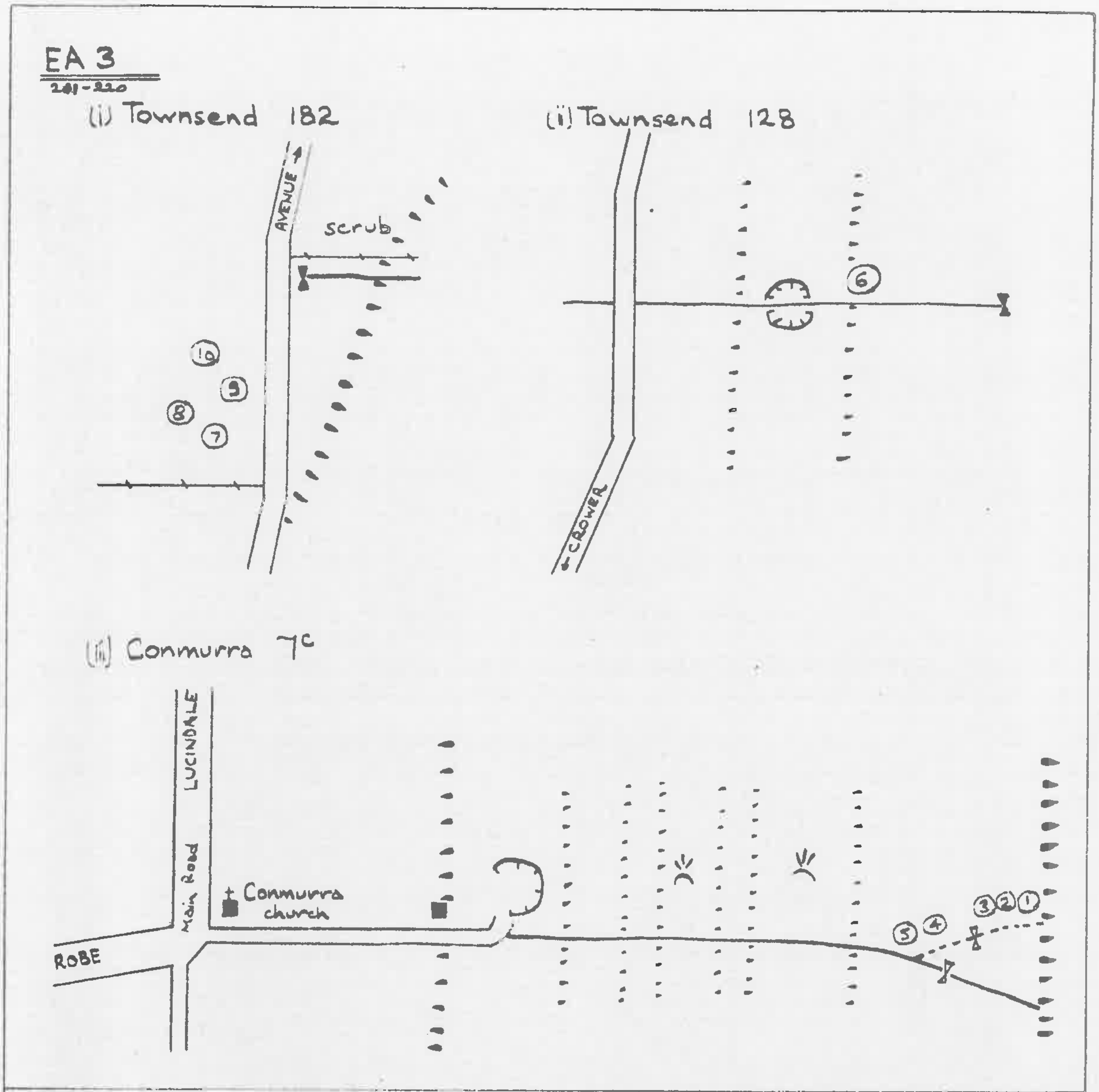

B 2
161-170
LUCINDALE
Hd. Joyce
414
1
2
3
4
5
6
7
8
9
10
CALLENDALE
Hd. Fox
145
Hd. Coles
89
90

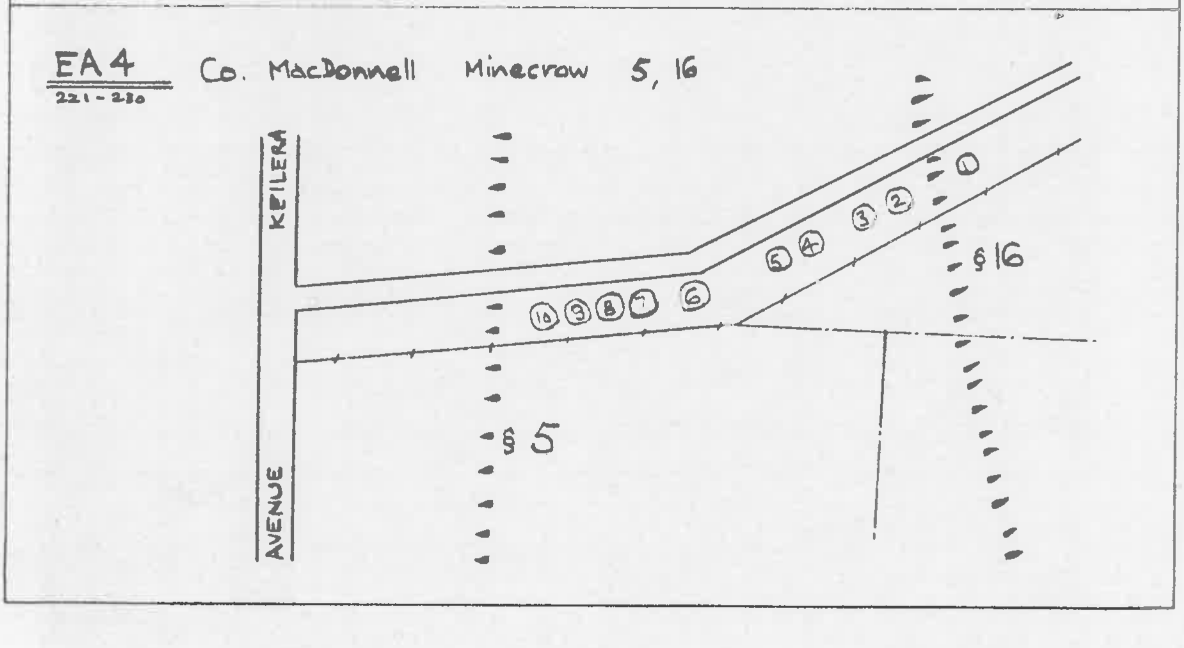

B 3
171-180
Joyce 400 410
§ 400
WP3 →
← LUCINDALE
Lucindale
Naracoorte
Railway
1
2
3
4
5
6
7
8
9
10

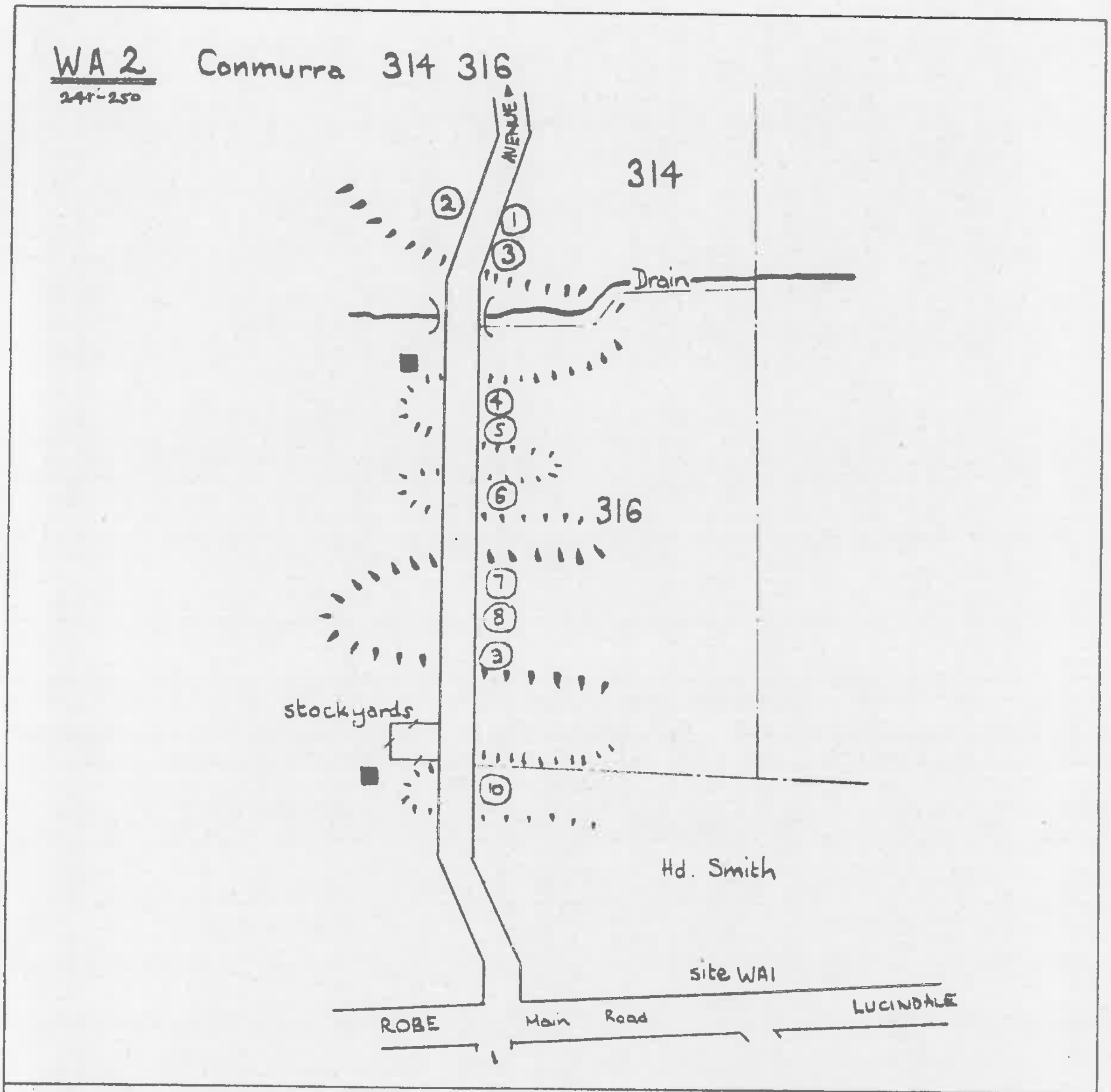

B 4
181-190
Joyce 4
John Dowe
Old Fairview Estate
§ 4
LUCINDALE
1
2
3
4
5
6
7
8
9
10

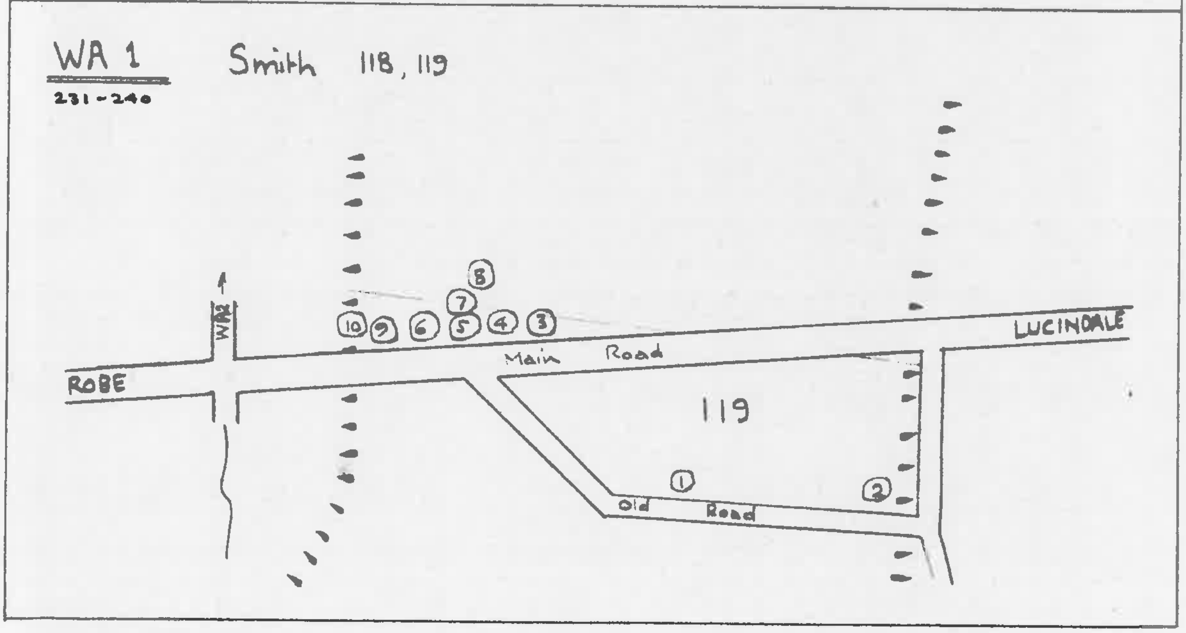

EA 2
201-210
Fox 104
1
2
3
4
5
6
7
8
9
10
EA1
Jeffrey Swamp

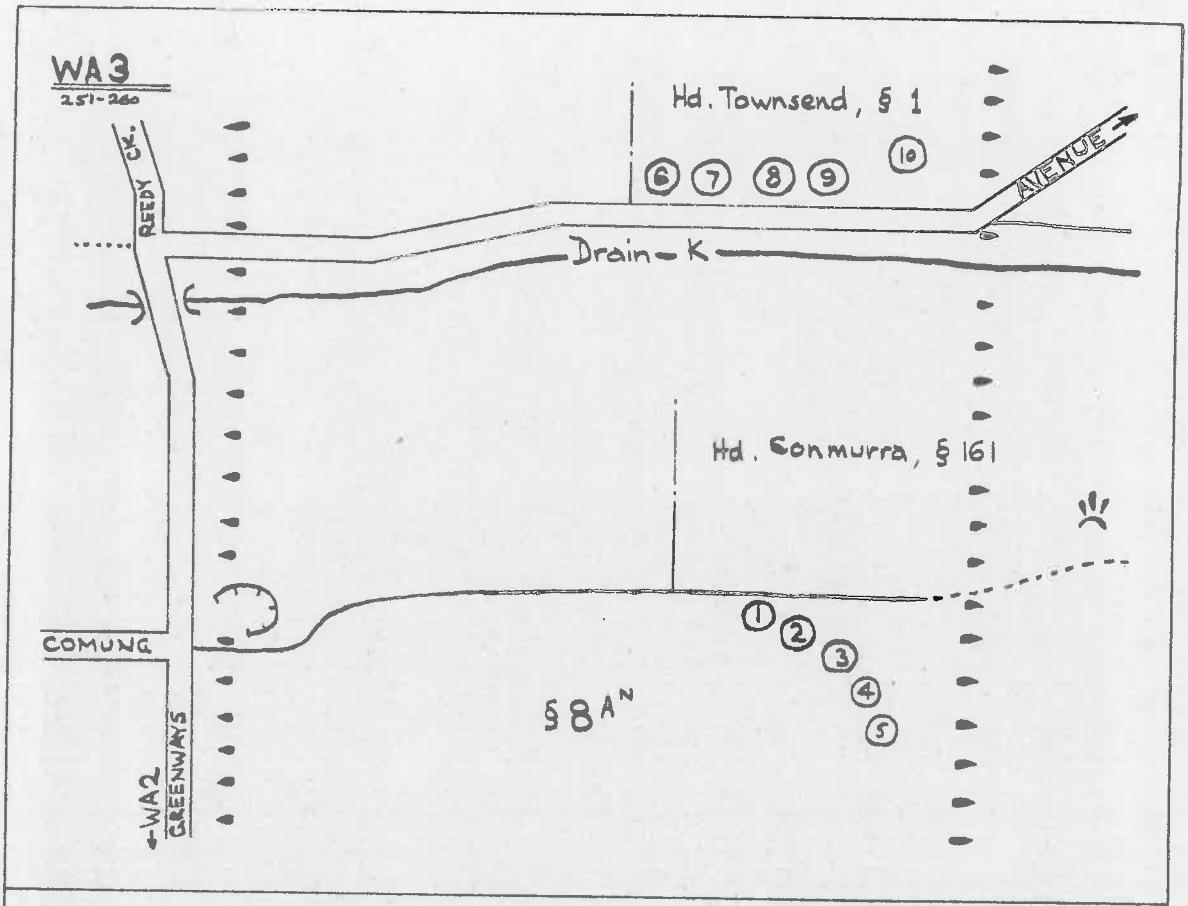

EA 1
191-200
Fox 104
Jeffrey Swamp
1
2
3
4
5
6
7
8
9
10
← LEGG'S LANE
CALLENDALE →

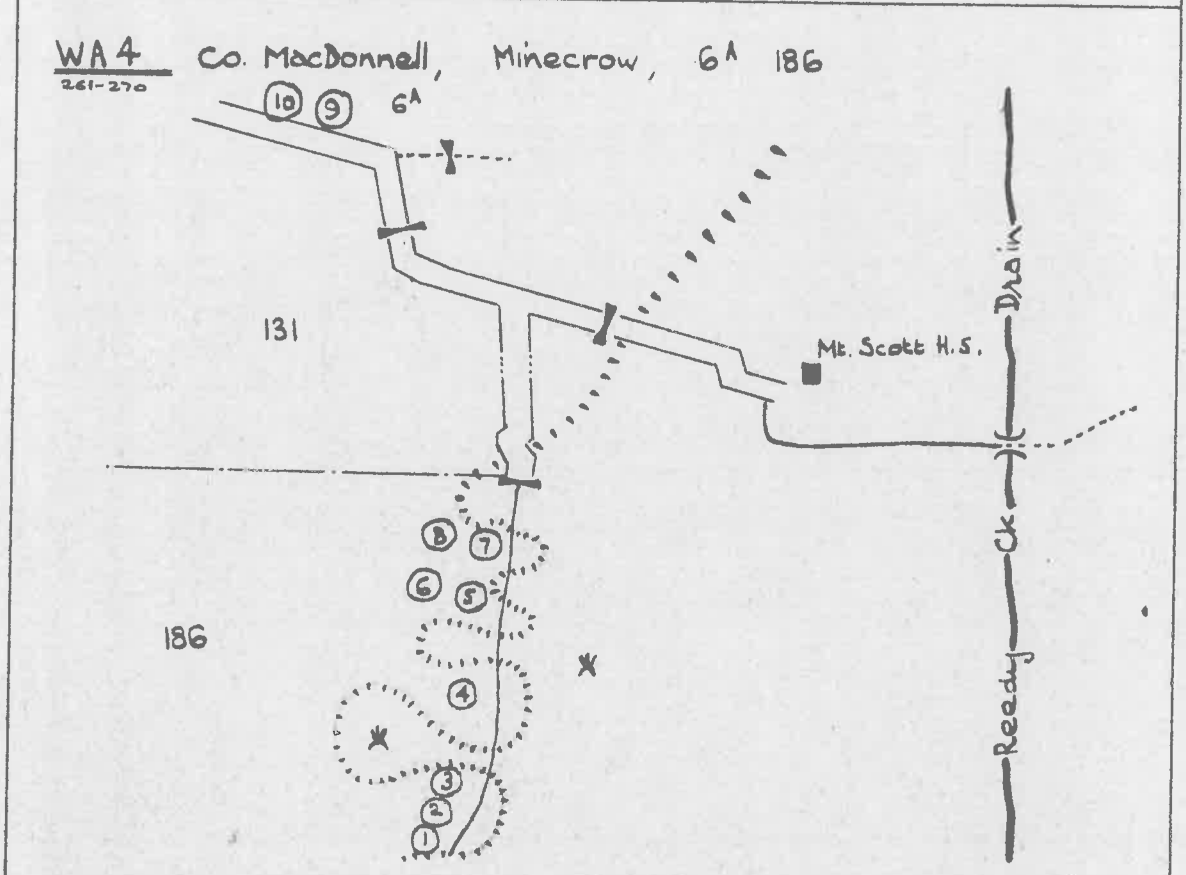

EA 3
201-220
(i) Townsend 182
AVENUE
scrub
10
9
8
7
(ii) Townsend 128
6
CROWER
(iii) Conmurra 7c
LUCINDALE
Main Road
ROBE
Conmurra church
5
4
3
2
1

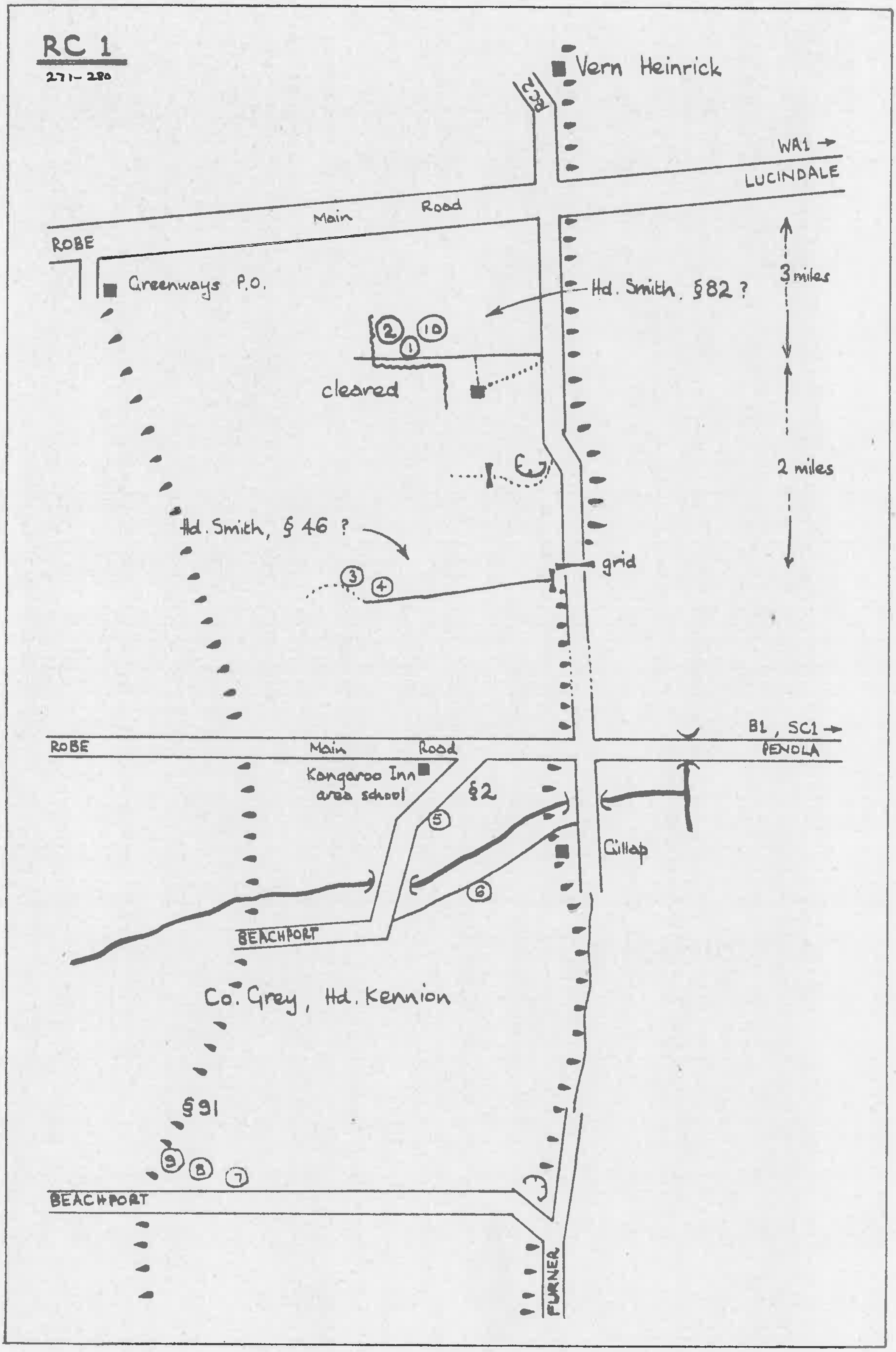

EA 4
221-230
Co. MacDonnell Minecrow 5, 16
KEILERA
AVENUE
10
9
8
7
6
5
4
3
2
1
§ 16
§ 5

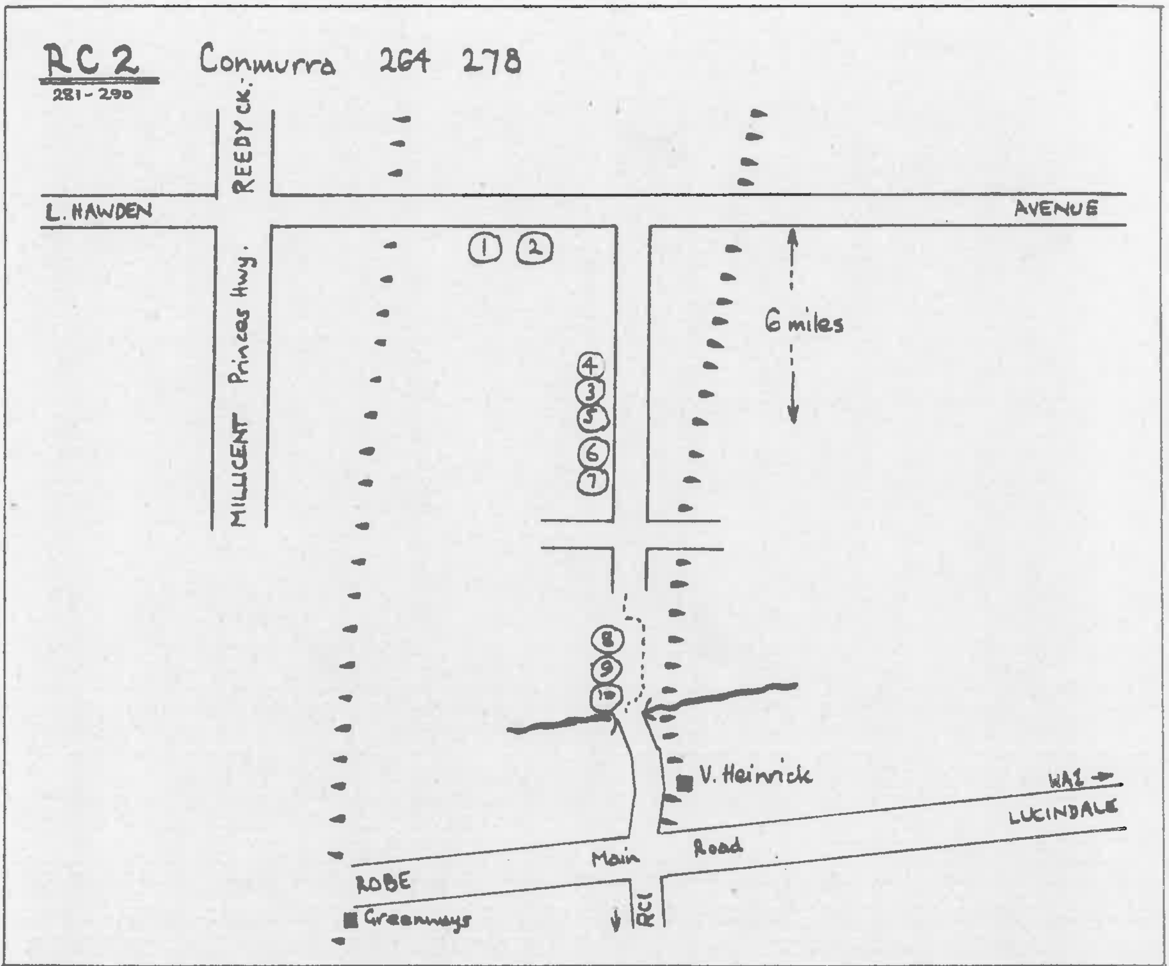

WA 2
241-250
Conmurra 314 316
AVENUE
314
Drain
316
stockyards
Hd. Smith
site WA1
ROBE
Main Road
LUCINDALE

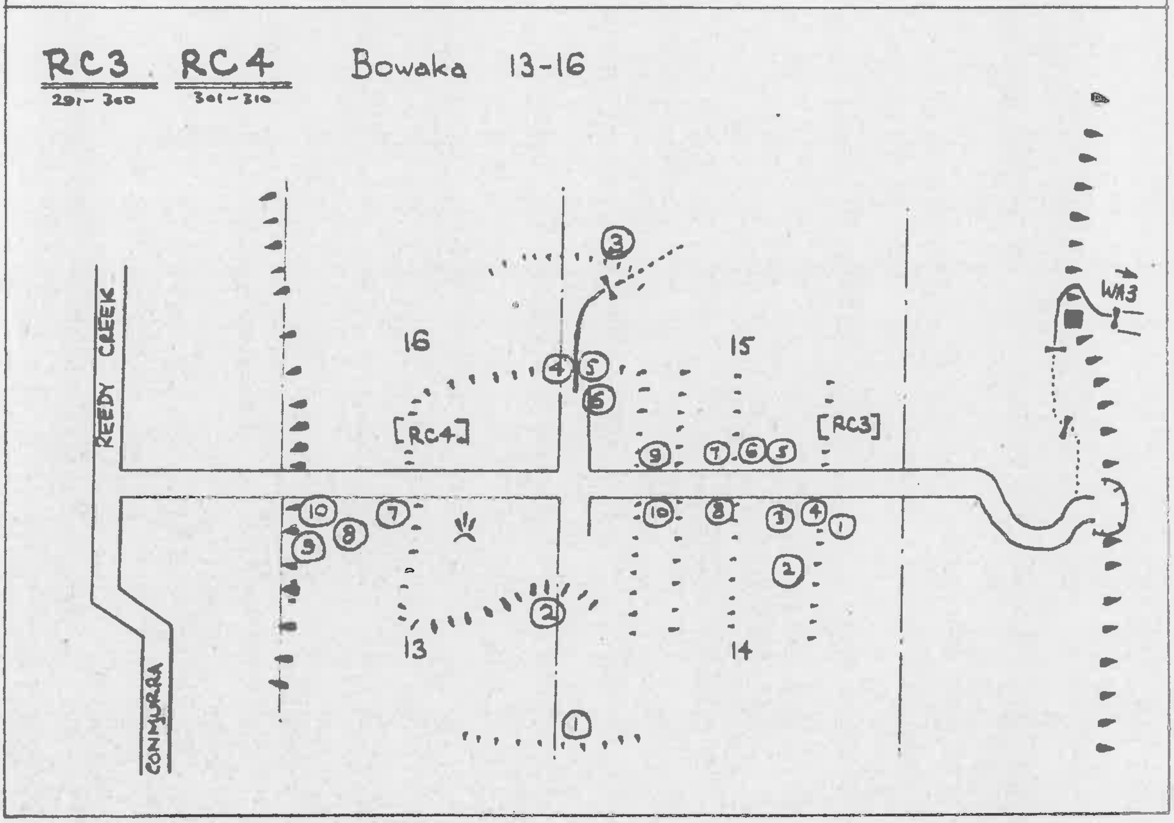

WA 1
231-240
Smith 118, 119
WA2
ROBE
Main Road
LUCINDALE
119
Old Road

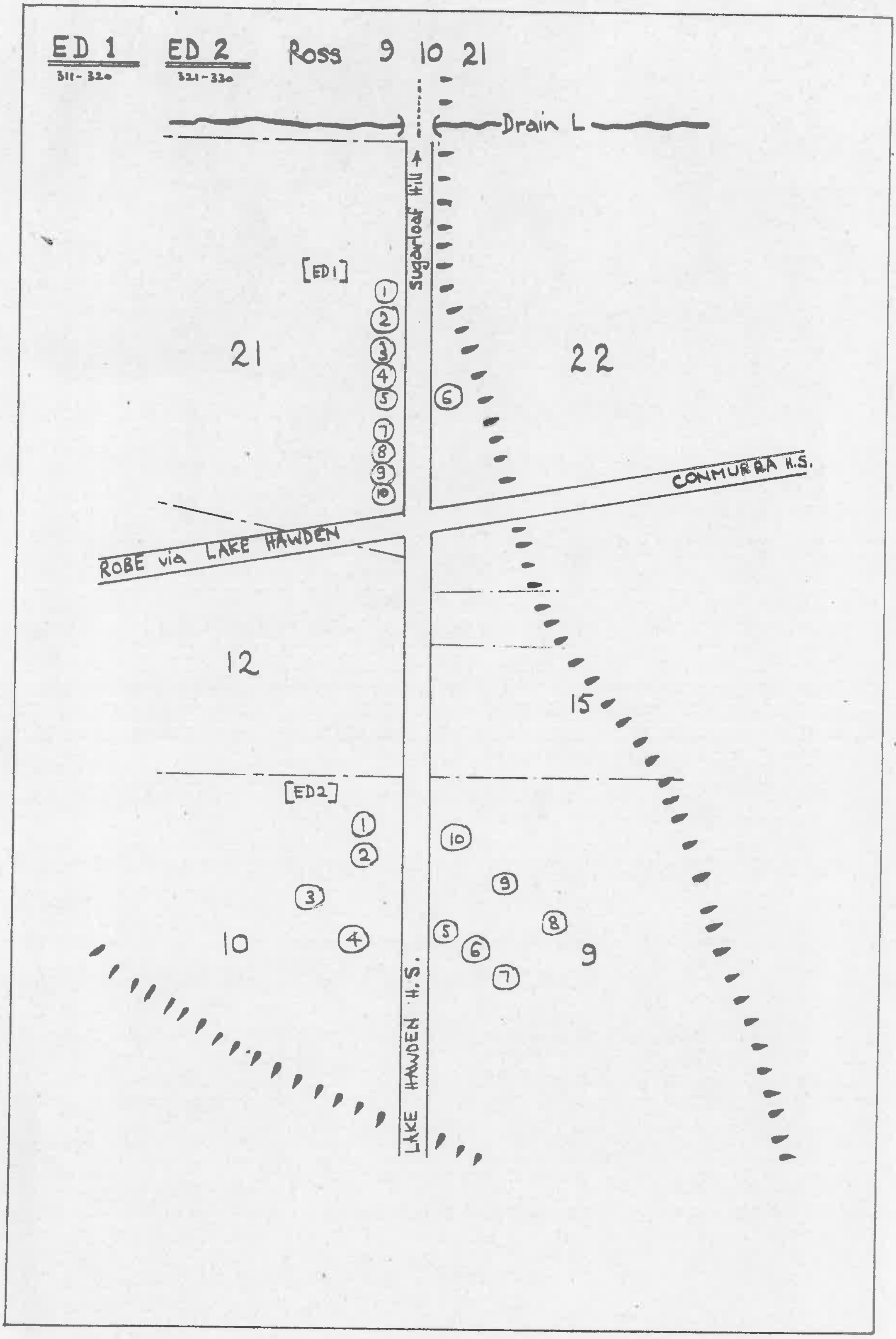

WA3
251-260
Hd. Townsend, § 1
AVENUE
REEDY CK.
Drain — K
Hd. Conmurra, § 161
COMUNG
§ 8 A N
WA2
GREENWAYS
1
2
3
4
5
6
7
8
9
10


WA 4
261-270
Co. MacDonnell, Minecrow, 6 A 186
6 A
131
186
Mt. Scott H.S.
Reedy Ck. Drain
1
2
3
4
5
6
7
8
9
10


RC 1
271–280
Vern Heinrick
RC2
WA1 →
LUCINDALE
Main
Road
ROBE
Greenways P.O.
Hd. Smith, §82 ?
3 miles
cleared
2 miles
Hd. Smith, § 46 ?
grid
B1, SC1 →
PENOLA
ROBE
Main
Road
Kangaroo Inn
area school
§2
Gillap
BEACHPORT
Co. Grey, Hd. Kennion
§91
BEACHPORT
FURNER


RC 2
281-290
Conmurra 264 278
REEDY CK.
L. HAWDEN
AVENUE
MILLICENT Princes Hwy.
6 miles
V. Heinrick
WA2
LUCINDALE
ROBE
Main Road
Greenways
RC1


RC3
291-300
RC4
301-310
Bowaka 13-16
REEDY CREEK
CONMURRA
16
15
13
14
[RC4]
[RC3]
WA3



ED 1
311-320
ED 2
321-330
Ross 9 10 21
Drain L
Sugarloaf Hill
[ED1]
1
2
3
4
5
6
7
8
9
10
21
22
CONMURRA H.S.
ROBE via LAKE HAWDEN
12
15
[ED2]
1
2
3
4
5
6
7
8
9
10
10
9
LAKE HAWDEN H.S.

Appendix B.

Appendix B

PRESENCE-ABSENCE DATA

The eighty species which scored a frequency of at least one per cent., i.e. present in more than two of the 330 quadrats. The species, and the numbers assigned to them, are shown in Species List I, Table 2. The locations of the quadrats are shown in Appendix A.

site	EN1										EN2									
quadrat:-	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
species																				
1																				
2																				
3	x	x	x	x	x		x	x	x	x	x	x	x	x	x		x	x	x	x
4																				
5	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
6																				
7																				
8																				
9																				x
10										x										
11								x		x	x	x	x	x	x			x		x
12												x								x
13																				
14																				
15											x	x		x			x	x	x	x
16	x	x	x	x	x	x	x	x							x		x	x		x
17				x	x		x				x	x	x		x		x	x	x	x
18		x	x	x	x	x	x	x	x											
19	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
20															x	x				

	EN1										EN2									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
21	x	x	x	x	x	x	x	x	x	x	x	x		x		x	x	x	x	x
22																				
23	x	x	x	x	x	x	x	x	x	x		x	x		x	x	x	x	x	
24	x	x	x	x	x	x		x	x	x										
25	x	x	x	x	x	x	x	x	x	x								x		
26																				
27	x	x	x	x																
28	x	x		x		x			x		x	x	x	x	x	x	x	x	x	x
29	x		x	x	x	x	x	x	x	x										
30																				
31																				
32																				
33																				
34																				
35								x	x	x										
36																				
37	x	x	x		x	x	x		x	x			x	x	x	x				x
38									x											
39																				
40	x	x	x	x		x	x	x	x	x			x	x				x		x
41											x	x	x	x			x	x	x	x
42		x	x																	
43																				
44																				
45																				
46																x				
47				x	x	x	x													
48																				
49	x		x		x					x										
50		x							x											

	EN1										EN2									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
51																				
52															x					
53																				
54																				
55											x	x	x		x	x	x			
56					x			x	x	x	x	x								
57																				
58				x															x	
59						x	x									x				
60																				
61																				
62																	x			
63								x				x								
64							x					x		x						
65					x	x	x	x	x	x	x	x	x	x	x	x		x	x	x
66	x		x																	
67																				
68	x		x	x		x	x	x	x	x			x	x	x	x				
69																				
70																				
71	x	x			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
72						x		x					x		x	x	x			
73																				
74																				
75																				
76																				
77	x	x	x	x	x	x	x			x		x	x	x	x		x		x	
78																				
79																				
80	x	x	x		x	x	x	x	x	x	x	x			x	x	x			

	EN3										WN1									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
1		x																		
2																				
3	x	x	x	x	x	x	x	x	x	x	x					x		x		
4																				
5	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
6																				
7												x								
8																				
9						x													x	
10																				
11							x												x	x
12	x	x	x	x	x															
13																				
14																				
15			x	x	x	x								x	x	x				
16			x			x				x				x		x	x			
17												x	x	x		x				x
18	x	x			x	x	x	x	x		x	x	x	x	x		x	x		
19	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x
20																				
21	x	x	x	x	x	x	x	x	x	x	x	x		x		x	x	x	x	x
22																				
23	x	x	x	x	x	x	x	x	x	x	x			x	x	x		x	x	x
24																				
25	x			x				x			x	x	x	x		x	x		x	x
26																				
27						x						x				x			x	
28	x	x	x	x	x	x	x	x	x	x										
29																				
30																				

	EN3										WN1									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
31																				
32																				
33																				
34																				
35																				
36																				
37																				
38																				
39																				
40																				x
41																				
42	x													x			x	x		
43																				
44																				
45																				
46								x			x	x	x		x		x	x		
47																			x	
48																				
49																				
50																				
51		x	x		x	x														
52																				
53																				
54																				
55							x													
56																				
57																x				
58												x			x	x				
59																		x		
60																				

	EN3										WN1									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
61																				
62								x	x			x					x			
63										x										
64														x						
65	x	x																		
66																				
67																				
68							x													
69																				
70																				
71	x	x	x	x		x	x	x	x	x	x	x	x	x		x	x		x	x
72		x						x												
73						x														
74																				
75																x				
76									x											
77							x													
78																				
79																				
80							x								x	x	x	x	x	x

	WN2										WN3									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
1																				
2																				
3	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x
4																				
5	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x
6																				
7										x	x									
8																				
9																				
10														x						x
11			x	x	x	x	x	x			x	x	x	x	x	x	x	x	x	x
12																				
13																				
14																				
15	x	x	x	x	x	x	x	x	x	x		x	x		x		x		x	x
16											x	x								
17	x	x	x		x			x	x	x		x								
18	x	x	x	x	x		x	x	x	x	x	x	x		x					
19	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
20																				
21	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
22																				
23	x	x	x	x	x	x	x	x	x	x	x	x	x		x			x		
24													x	x	x	x	x	x	x	
25	x											x			x		x			
26																				
27												x	x	x	x	x	x	x	x	x
28											x	x		x	x					
29																				
30												x	x	x	x	x	x	x	x	x

	WN2										WN3									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
31																				
32																				
33																				
34																				
35																x		x		
36																				
37													x	x	x	x	x	x	x	x
38																				
39													x							
40														x	x	x	x	x		x
41											x									
42																				
43																				
44																				
45																				
46								x		x	x	x								
47																				
48															x	x	x	x		x
49																				
50												x								x
51																				x
52																				
53																				
54																				
55			x		x		x						x				x	x	x	x
56																				
57																				
58																				
59												x								
60																				

	WN2										WN3									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
61																x	x		x	
62																				
63																				
64	x	x																		
65													x	x	x	x	x	x	x	x
66																				
67																				
68									x											
69																				
70																				
71	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
72		x			x			x	x	x		x	x	x	x	x	x	x	x	x
73															x					
74													x	x			x	x	x	x
75	x	x		x	x	x	x	x												
76																				
77																	x			
78																				
79																				
80												x					x			

	WN4										SC1									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
1				x									x			x		x	x	
2																				
3	x		x	x			x		x		x	x	x	x	x		x	x	x	x
4																				
5	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
6																				
7																				
8	x							x		x										
9																				
10											x									
11											x									
12																				
13																				
14																				
15		x	x	x	x		x				x	x	x	x	x	x	x		x	x
16			x								x		x	x	x		x		x	
17	x	x				x	x				x	x			x		x		x	
18						x	x			x	x									x
19	x	x	x	x	x			x	x	x	x	x	x	x		x	x			
20																				
21		x	x	x	x		x		x	x	x	x	x	x	x	x	x	x	x	
22																				
23		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
24																				
25		x	x	x			x	x	x	x	x	x	x	x	x	x	x	x	x	x
26																				
27																				
28	x	x					x	x	x	x	x						x			
29												x	x	x	x			x	x	x
30	x	x	x	x	x	x	x	x								x			x	

	WN4										SC1									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
31																				
32																				
33																				
34																				
35																				
36																				
37											x			x					x	
38																				
39																				
40																				
41	x				x				x	x								x		
42	x					x										x				
43														x						x
44																				
45																				
46	x		x															x		
47																				
48																				
49												x		x	x		x	x	x	x
50																				
51																				
52																				
53																				
54																				
55										x										
56																				
57																	x	x		x
58							x						x		x	x	x		x	x
59																		x		
60																				

	WN4										SC1									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
61																				
62	x																			
63																				
64			x						x			x								
65											x	x	x	x	x	x	x			
66																				
67																				
68													x				x		x	x
69																				
70																				
71	x	x				x	x	x	x	x	x	x	x	x	x		x		x	x
72		x	x	x		x	x	x	x	x										
73																				
74																				
75												x								
76																				
77											x	x	x	x	x	x	x	x	x	x
78																				
79																				
80											x	x	x	x	x		x		x	x

	SC2										SC3									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
1	x									x									x	
2																				
3	x	x	x	x	x	x	x	x	x	x	x			x	x	x	x	x	x	x
4																				
5	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
6																				
7																				
8												x	x	x		x	x		x	
9																				
10													x	x	x	x	x	x	x	x
11	x	x	x	x		x		x	x	x			x	x		x		x	x	x
12																				
13													x			x	x	x		x
14																		x		
15												x	x					x	x	x
16	x			x	x	x		x	x	x	x	x								x
17											x	x					x	x		
18											x						x	x	x	x
19	x	x	x	xxx		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
20													x		x		x			
21	x		x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
22																				
23	x			x	x	xxx		x						x					x	x
24	x	x	x	x	x	x	x	x	x	x									x	x
25		x	x	x	x	x	x	x	x	x	x	x					x			
26																				
27																				
28					x						x		x	x	x	x	x	x		x
29	x			x	x	x	x	x	x	x									x	
30	x	x	x		x	x		x	x	x			x	x	x	x		x	x	x

	SC2										SC3									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
31																				
32																				
33																				
34																				
35						x														
36																				
37				x					x				x	x	x	x	x	x	x	x
38																				
39																		x		
40				x																
41																				
42																				
43	x									x	x	x					x			
44																				
45																				
46																				
47																				
48													x					x		
49	x	x	x	x			x			x										
50						x							x							
51														x			x			
52													x							
53																				
54																				
55													x							
56	x				x	x	x	x		x										
57				x	x				x											
58		x	x		x				x	x		x								
59					x							x								
60													x							

	SC2										SC3									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
61													x	x		x				
62												x								
63																				
64											x									
65			x		x	x	x	x	x	x	x	x	x	x	x	x			x	
66																				
67																				
68	x	x			x	x	x	x		x			x	x	x	x	x	x	x	x
69																				
70																				
71	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	
72													x				x	x	x	x
73						x														
74		x	x	x	x		x		x	x									x	x
75	x	x			x													x	x	x
76											x	x	x	x		x	x			x
77	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
78																				
79													x			x				
80	x	x	x	x	x	x	x	x	x	x	x	x		x	x		x	x	x	x

	SC4										WP1									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
1																				
2																				
3	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
4																				
5	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
6																				
7						x														
8					x	x					x					x				
9																				
10		x	x	x		x	x	x		x	x	x	x	x	x	x	x			x
11	x	x		x	x			x	x			x	x	x	x			x	x	x
12																				
13	x	x	x	x			x	x	x											
14																				
15		x		x	x	x													x	x
16	x	x		x	x	x	x	x	x							x				x
17	x	x	x		x	x	x		x											
18	x	x	x	x			x	x	x	x										
19	x	x	x	x	x	x		x		x	x	x	x	x	x	x	x	x	x	x
20	x										x	x	x	x			x	x	x	
21	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	
22																				
23	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
24											x	x	x	x	x	x	x	x	x	x
25	x	x	x	x			x	x	x	x			x	x		x	x	x	x	x
26																				
27																				
28			x	x								x					x		x	x
29	x	x			x	x	x	x	x	x	x		x	x	x			x		
30	x	x	x		x	x	x		x	x	x	x	x	x	x	x	x	x		x

	SC4										WP1									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
31																				
32																				
33																				
34																				
35												x		x					x	x
36																				
37				x	x						x						x		x	x
38																				
39																				
40		x	x			x			x		x	x		x	x	x	x	x	x	x
41				x																
42			x																	
43																				
44											x	x			x		x	x	x	
45																				
46																				
47																				
48																				
49													x	x						
50											x						x	x	x	
51	x		x	x	x	x				x										
52																				
53																				
54					x															
55	x										x		x	x	x	x	x	x	x	x
56												x	x	x			x		x	
57																				
58																				
59						x														
60																				

SC4

	1	2	3	4	5	6	7	8	9	10
61										
62										
63										
64										
65				x		x	x		x	x
66										
67										
68	x	x	x		x	x		x	x	
69										
70										
71	x	x	x	x	x	x	x		x	
72	x	x	x			x	x	x		
73										
74										
75										
76		x	x	x			x	x		x
77		x	x	x	x	x	x	x	x	x
78										
79										
80	x	x	x	x	x	x	x	x	x	x

WP1

	1	2	3	4	5	6	7	8	9	10
61										
62										
63										
64	x	x	x	x	x	x	x	x		
65	x	x	x	x	x	x	x	x	x	x
66									x	
67										
68	x	x	x	x			x	x	x	x
69										
70										
71	x	x	x		x	x	x	x	x	x
72			x	x	x	x	x	x	x	x
73										x
74									x	x
75				x	x	x	x	x		x
76										
77	x	x	x	x	x	x	x	x	x	x
78										
79	x									
80	x	x	x	x	x	x	x	x	x	x

	WP2										WP3									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
1					x															
2																				
3	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
4																				
5	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x
6													x	x	x					
7																				
8							x							x				x		x
9																				
10							x	x	x										x	x
11							x		x	x					x		x		x	x
12											x	x	x	x	x	x	x	x	x	
13																				
14					x					x										
15				x	x	x		x			x					x	x			
16	x				x	x	x	x						x					x	
17																				
18				x											x					
19		x	x	x	x	x	x	x	x						x	x	x			x
20				x				x			x	x	x	x	x	x	x	x		
21	x		x			x	x	x	x	x				x	x			x	x	x
22											x						x			
23																x				
24	x					x		x								x		x		
25	x				x		x		x				x		x					
26																				
27																				
28	x	x	x						x											
29			x	x	x	x	x	x		x	x	x	x	x	x		x		x	x
30	x	x	x	x	x	x					x	x	x	x	x	x	x	x	x	x

	WP2										WP3									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
31							x													
32																				
33					x	x			x	x		x		x	x				x	x
34																				
35												x	x	x	x	x	x	x	x	
36																				
37	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
38											x									
39	x													x						
40	x	x		x	x	x	x	x	x				x							
41																				
42																				
43										x										
44																				
45																				
46																				
47																				
48		x			x		x		x	x		x	x	x	x					x
49																				
50					x				x	x	x	x	x			x			x	
51									x	x										
52																				
53															x	x			x	
54	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x
55		x									x			x						
56																				
57																				
58		x	x							x				x	x				x	
59																				
60		x		x					x				x				x		x	x

	WP2 1	2	3	4	5	6	7	8	9	10	WP3 1	2	3	4	5	6	7	8	9	10
61											x	x		x	x	x			x	x
62																				
63																				
64																				
65										x	x	x	x	x	x	x	x	x	x	x
66																				
67											x	x		x	x	x	x		x	x
68	x		x	x	x		x	x		x				x	x				x	x
69					x				x						x				x	x
70										x	x									
71	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x			
72	x	x	x		x	x	x	x	x	x	x	x	x	x	x		x	x	x	x
73																				
74																				
75			x					x		x										
76							x	x						x	x				x	x
77									x	x		x	x		x	x	x	x	x	x
78				x		x		x			x	x		x	x	x	x	x		
79																x	x		x	x
80	x	x	x	x	x	x	x	x	x	x						x	x		x	x

	WP4										Bl4									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
1		x										x								
2																				
3	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
4																				
5	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x
6																x		x	x	x
7																				
8			x				x		x											
9																				
10		x	x	x	x	x	x	x	x	x					x					
11				x	x			x			x	x	x	x		x				
12	x	x		x	x		x													
13					x			x		x										
14																				
15						x	x					x	x	x		x	x	x	x	x
16							x							x	x	x	x	x	x	x
17				x						x				x		x	x	x		
18						x	x	x	x						x	x				
19			x	x		x	x	x		x	x	x	x	x	x	x	x	x	x	x
20	x	x	x	x	x	x			x	x	x	x	x	x	x	x				
21											x	x		x	x	x	x	x	x	x
22																				
23	x	x	x			x	x	x					x		x	x	x	x	x	x
24											x	x	x	x	x		x	x		
25	x	x				x	x		x	x	x	x		x	x	x	x	x	x	x
26																				
27																				
28							x				x	x	x	x						
29						x		x	x	x						x	x	x	x	x
30	x	x	x	x	x	x	x	x	x	x		x	x		x				x	x

	WP4										B1									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
31								x		x										
32																				
33							x	x	x	x					x					
34																				
35											x		x	x					x	
36			x	x	x															
37		x	x			x	x	x	x	x	x			x	x	x	x	x	x	x
38																				
39																				
40						x			x		x	x	x		x					
41																				
42																				
43																x				
44												x								
45																				
46																				
47																				
48								x							x	x	x		x	
49																				
50							x				x					x				
51																				
52	x					x														
53																				
54	x	x	x	x	x	x	x		x											
55	x			x																x
56											x	x	x	x	x	x		x		x
57																				
58											x	x		x		x			x	x
59															x					
60																				

	WP4										B1									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
61											x					x		x	x	x
62																				
63																				
64											x			x		x		x		
65	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
66																				
67																				
68											x	x	x	x				x		
69																				
70																				
71	x	x									x	x	x			x	x	x	x	x
72	x	x	x	x	x	x	x	x	x	x				x	x	x		x	x	x
73																				
74																				
75		x									x		x	x						
76									x	x										
77											x	x	x	x	x	x	x	x	x	x
78																				
79											x	x								
80	x	x	x	x	x	x	x	x	x	x			x	x	x	x	x	x	x	x

	B2										B3									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
1							x	x		x										
2																				
3	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x
4																				
5	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
6																				
7	x	x	x																	
8													x		x		x			
9																				
10	x	x	x	x	x							x		x	x	x	x	x	x	x
11	x	x	x	x		x		x		x									x	
12							x												x	
13											x	x	x		x					
14																				
15													x	x	x					
16	x	x	x	x		x										x	x			x
17											x	x	x	x	x		x		x	
18											x	x	x		x	x	x			
19	x	x		x		x	x		x	x	x	x			x	x		x	x	x
20					x						x	x	x	x				x		x
21	x	x	x	x		x		x	x	x	x				x	x	x	x		x
22							x		x											
23		x		x	x						x					x	x	x		
24	x																			
25	x	x	x	x	x					x									x	x
26																				
27																				
28		x											x				x			
29	x	x		x	x	x	x	x	x	x						x	x	x	x	x
30	x								x	x	x	x	x	x	x			x		x

	B2										B3									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
31																				
32						x														
33			x			x	x								x	x				
34																				
35							x		x											
36																				
37	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x
38																				
39																x			x	x
40					x							x				x	x	x	x	x
41																			x	
42																				
43							x													
44																				
45																				
46																				
47																				
48	x		x	x		x	x	x	x	x					x	x	x	x		
49																				
50			x			x		x							x					
51		x	x						x	x										
52															x			x		x
53																				
54											x	x	x	x	x	x	x	x	x	x
55																				
56								x	x											
57																				
58	x		x			x		x	x	x										
59																				
60																				x

	B2										B3									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
61	x					x	x	x	x	x				x						
62																	x			
63																				
64				x	x															
65	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
66																				
67						x														
68		x				x	x	x								x				
69																				
70																				
71	x	x									x			x	x	x	x	x	x	x
72	x	x	x	x	x	x	x	x	x		x		x		x	x	x			x
73																				
74																				
75					x															
76												x			x	x	x			
77		x	x	x	x	x	x	x	x	x										
78											x	x	x	x	x		x	x	x	x
79						x														
80	x	x	x	x	x	x	x	x	x	x	x	x				x				

	B4										EA1									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
1														x						
2																				
3		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
4																				
5	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x
6																				
7											x	x				x	x			x
8								x		x										
9																				
10		x	x	x	x	x		x												
11																			x	
12																				
13																				
14																				
15		x		x		x			x	x		x	x							
16				x								x	x	x	x	x	x	x		x
17				x	x					x	x	x	x	x		x				
18						x				x										x
19		x		x	x	x	x	x				x		x		x		x		x
20				x		x	x	x	x	x										
21		x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x
22																				
23	x	x										x	x	x	x	x	x	x	x	x
24										x										
25	x	x	x	x	x	x	x		x	x	x	x	x	x	x			x	x	
26																				
27																				
28											x	x	x	x	x	x				
29		x	x	x	x	x		x	x						x	x		x	x	x
30	x	x	x	x	x	x	x		x	x		x			x	x	x	x	x	

	B4										EA1									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
31																				
32																				
33				x			x													
34																				
35			x																	
36																				
37			x	x	x		x				x	x				x	x	x	x	x
38																				
39																				
40			x	x	x							x	x					x	x	
41	x																			
42																				
43												x								
44																				
45																				
46																				
47																				
48																x				
49																				
50				x	x	x	x													
51																				
52																				
53																				
54		x	x	x	x	x	x	x	x	x										
55			x	x		x														
56																		x		
57																				
58				x	x	x						x	x							
59	x																			
60																				
																				x

	E4										EA1									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
61																				
62																				
63	x																			
64																				
65		x	x	x	x	x	x	x	x	x			x	x	x		x	x	x	x
66																				
67																				
68						x											x		x	x
69																				
70																				
71	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
72	x	x	x	x	x	x	x	x	x	x				x		x				
73																				
74																				
75																				
76			x	x	x			x			x	x	x	x						
77			x			x				x	x	x	x	x		x	x	x		x
78																				
79																	x	x		
80	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

	EA2										EA3									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
1																				
2			x	x			x		x											
3	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			x	x	x
4																				
5	x	x	x	x	x	x	x	x	x			x	x	x	x	x	x	x	x	x
6																				
7										x										
8											x	x	x			x	x		x	
9																				
10											x						x	x	x	x
11									x								x			x
12																				
13																	x			
14																				
15	x	x	x																	
16	x	x	x	x		x	x		x	x		x	x	x	x	x	x	x	x	x
17			x	x		x	x	x			x	x	x					x		
18																		x		
19				x	x		x	x		x	x		x				x		x	
20	x	x																		
21	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	
22																				
23	x	x	x	x	x	x							x	x	x				x	x
24															x			x		x
25	x	x	x	x	x	x	x			x	x	x	x	x	x	x	x	x		x
26																				
27																				
28			x		x	x	x	x	x	x			x			x	x	x	x	x
29	x	x	x	x	x	x				x	x	x		x	x					
30	x	x		x				x	x					x	x	x	x	x		x

	EA2										EA3									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
31																				
32																				
33	x						x				x	x				x	x			
34																				
35																				
36																				
37	x	x	x	x	x	x		x			x	x	x	x	x	x				x
38																				
39																				
40													x							
41														x	x		x			
42				x																
43																				
44																				
45																				
46																				
47																				
48																				
49																				
50	x	x	x									x								
51																				
52																				
53																				
54																				
55											x									
56								x						x	x					
57																				
58	x						x		x	x				x	x	x				x
59																				
60											x	x								

	EA2										EA3									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
61																				
62																				
63																				
64																				
65	x	x	x	x	x		x	x		x			x	x	x	x	x	x	x	x
66																				
67																				
68		x	x				x		x											
69																				
70																				
71	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
72	x	x	x		x	x	x	x	x		x	x	x	x		x	x	x		x
73																				
74																				
75			x	x																
76	x							x	x	x	x	x								
77	x	x	x	x	x	x	x	x	x	x			x		x		x			
78																				
79																x		x		
80	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x

	EA4										WA1									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
1	x																			
2																				
3	x	x	x	x	x	x	x		x	x			x	x	x	x	x	x	x	x
4																				
5	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
6																				
7																				
8	x						x		x		x		x			x				x
9																				
10				x				x												
11	x							x												
12																				
13					x		x													
14																				
15	x	x	x	x	x	x	x	x	x	x			x	x	x				x	x
16										x			x	x		x	x		x	x
17											x	x	x	x	x	x	x	x	x	
18																x				
19	x	x	x	x	x	x			x					x		x		x	x	x
20																				
21	x	x	x	x	x	x		x	x	x		x	x	x	x	x	x	x	x	
22																				
23	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x
24																				
25		x		x	x	x	x	x	x		x	x		x	x	x	x	x	x	x
26																				
27																				
28	x										x	x	x	x	x	x	x	x	x	x
29		x	x	x	x		x	x	x	x										
30	x	x	x	x	x	x	x	x	x	x				x	x	x		x		x

	EA4										WA1									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
31																				
32																x				
33													x	x	x	x	x		x	x
34																				
35																				
36																				
37		x	x		x	x	x		x	x					x	x	x	x	x	
38																				
39																				
40		x		x			x	x		x					x		x			
41																				
42												x								
43																				
44																				
45											x	x								x
46																				
47																				
48	x		x		x															
49																				
50																				
51			x		x	x		x		x										
52																				
53																				
54																				
55																				
56	x	x																		
57																				
58																				x
59											x									
60																				

	EA4										WA1									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
61																				x
62											x									
63																				
64																				
65	x	x	x	x	x	x		x	x	x							x	x	x	x
66																				
67																				
68		x		x	x				x	x						x				
69																				
70																				
71	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x
72	x	x	x	x	x	x	x	x	x	x			x			x	x	x		
73																				
74																				
75																				
76																				
77		x	x	x	x	x	x	x	x	x				x	x	x	x	x	x	x
78																				
79																				
80	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

	WA2										WA3									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
1																				
2																				
3	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
4																				
5	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
6																				
7																				
8											x		x			x				
9																				
10	x	x	x	x	x	x	x		x	x		x			x			x	x	x
11	x					x														
12																				
13																				
14																				
15	x		x	x	x	x	x		x		x	x	x	x	x	x	x	x	x	x
16						x		x	x		x	x	x	x			x		x	
17					x	x										x				
18						x					x									
19	x	x	x	x	x	x	x	x		x	x								x	x
20											x	x	x	x	x			x	x	x
21	x	x	x	x	x	x	x	x	x	x			x	x		x	x	x	x	x
22																				
23		x	x		x			x	x	x										
24	x	x	x	x					x		x	x	x	x	x					
25	x	x	x		x	x	x	x	x	x										
26																				
27																				
28																		x	x	
29	x	x			x	x			x		x	x	x	x	x	x	x			x
30	x	x	x	x	x	x	x	x	x	x			x			x	x	x	x	x

	WA2										WA3									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
31																				
32																				
33												x								
34																				
35																				
36																				
37	x	x	x	x			x				x	x	x	x	x	x	x	x		
38																				
39																				
40	x	x	x	x	x	x	x		x		x	x	x		x	x	x	x		x
41																				
42																				
43																				
44																				
45				x													x			
46																				
47																				
48		x	x				x			x		x	x		x					
49																				
50											x	x		x	x	x			x	
51																				
52																				
53																x				
54																				
55			x								x		x	x						
56	x	x						x		x			x	x				x		
57																				
58		x	x	x	x	x	x		x	x		x	x		x	x	x	x		
59																				
60													x							

	WA2										WA3									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
61																				
62																				
63	x																			
64																				
65	x	x	x	x	x	x	x	x		x	x	x	x	x			x	x	x	x
66																				
67																				
68	x	x	x	x	x		x		x	x	x	x			x					
69																				
70																				
71	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x			x
72	x	x		x	x		x	x		x	x	x	x	x		x			x	x
73																				
74																				
75																				
76																				
77	x	x	x	x	x	x	x	x	x	x						x	x		x	x
78																				
79																				
80	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x

	WA4										RC1									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
1				x	x	x	x									x	x	x	x	
2																				
3						x			x	x	x	x	x	x						x
4			x																x	
5	x	x	x	x	x	x	x	x	x	x	x	x	x	x						
6												x			x	x	x	x	x	x
7			x																	
8						x										x			x	
9																				
10									x	x	x	x	x	x						
11											x			x						
12																				
13																				
14																x		x		
15			x		x						x	x	x	x			x	x	x	x
16								x			x	x		x			x		x	x
17	x	x	x	x	x	x	x	x	x	x	x					x	x	x	x	x
18	x		x		x				x	x		x	x	x						
19											x	x	x	x	x	x			x	x
20														x						
21					x	x					x	x	x		x	x		x		x
22																				
23	x	x	x	x	x		x	x												x
24						x					x									
25	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x		x	x	x
26																				
27																				
28				x				x			x	x			x	x			x	
29	x			x	x		x						x	x			x	x		x
30	x		x	x	x	x		x	x	x	x	x	x	x						x

	WA4										RC1									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
31																				
32																				
33								x		x		x	x			x	x	x	x	
34																				
35																				
36																				
37											x	x	x	x			x	x	x	x
38																				
39																				
40		x									x	x								x
41																				
42															x					
43	x	x	x													x		x		
44																				
45		x	x			x	x					x			x	x		x	x	
46																				
47																				
48												x							x	
49																				
50																				
51																				
52																				
53																				
54										x										
55																				
56																				
57																				
58											x	x		x	x	x		x		x
59							x									x				
60																				

	WA4										RC1									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
61																				
62	x								x						x					
63																				
64																	x	x		
65									x	x	x	x	x							x
66																				
67																				
68																				
69																				
70																				
71	x	x	x		x	x	x		x	x	x	x	x	x	x	x	x	x	x	x
72												x	x			x	x	x	x	
73																				
74																				
75													x							
76																x		x	x	
77											x	x	x	x	x	x				x
78																				
79										x										
80	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

	RC2										RC3									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
1																				
2																				
3	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
4																				
5	x	x						x	x	x	x	x	x			x		x	x	x
6			x	x	x	x	x					x	x	x	x	x				
7																				
8							x	x								x			x	
9																				
10														x	x		x			
11															x					
12																				
13																				
14																				
15	x					x	x	x	x	x	x		x	x	x	x		x	x	x
16	x		x	x	x	x	x			x		x	x		x	x	x		x	x
17	x	x	x	x	x	x	x						x							
18		x	x		x			x				x					x			
19				x			x	x	x	x	x		x	x	x	x	x	x	x	
20																				
21	x	x	x	x			x	x	x		x	x	x	x	x	x		x	x	x
22																				
23			x	x	x	x	x													
24																				
25	x	x	x	x	x	x	x				x	x	x	x	x	x	x	x		x
26																				
27																				
28	x	x	x	x	x		x													
29								x			x	x	x		x	x				
30	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x

	RC2										RC3									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
31																	x	x	x	x
32																				
33												x	x	x	x	x		x	x	x
34																				
35																				
36																				
37			x	x	x	x	x		x		x	x	x	x	x	x	x	x	x	x
38									x											
39																				
40		x			x	x	x	x	x	x								x		
41	x			x		x														
42	x		x		x															
43																				
44																				
45		x																		
46																				
47																				
48			x		x	x			x	x	x	x				x			x	x
49																				
50					x						x	x	x	x						x
51									x											
52																				
53						x		x	x											
54								x	x	x		x								
55																				
56							x		x	x				x						
57																				
58		x	x	x	x	x	x	x		x			x					x		
59	x	x																		
60																			x	

	RC2										RC3									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
61																				
62										x										
63																				
64																				
65												x		x	x			x	x	x
66																				
67																				
68						x		x	x	x	x	x	x	x	x	x	x	x	x	x
69																				
70																				
71	x		x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x
72			x					x				x	x		x	x		x	x	x
73																				
74																				
75																				
76		x	x	x				x												
77								x	x	x										
78																				
79																x				
80	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

	RC4										ED1									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
1		x			x						x	x								
2																				
3	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
4											x									
5	x	x	x	x	x	x	x	x	x	x										
6	x										x	x		x	x	x	x	x	x	x
7													x							
8																				
9																				
10																x				
11																x	x	x		
12																				
13																				
14																				
15	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x		x
16		x	x			x	x		x		x	x	x		x	x	x	x	x	x
17							x				x	x		x	x	x	x	x	x	x
18		x						x		x	x	x	x	x	x		x	x		x
19	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x
20											x	x	x	x		x	x	x		
21	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
22																				
23																				
24	x		x										x					x		
25	x		x	x	x	x	x		x									x	x	x
26																				
27																				
28																				
29	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
30	x	x	x	x	x	x	x	x	x	x		x	x				x			

	EC4										ED1									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
31																				
32																				
33					x		x		x	x	x	x			x		x	x	x	x
34																x		x		
35																				
36																				
37	x	x	x	x	x	x	x	x	x	x	x	x	x		x		x	x	x	x
38																				
39																				
40			x		x															
41																			x	
42																				
43											x					x		x		
44																				
45												x				x	x			
46																				
47																				
48	x		x	x	x	x	x		x			x			x		x		x	
49																				
50					x			x	x			x	x					x		
51																				
52																				
53																				
54	x	x	x				x	x	x	x										
55																				
56	x	x	x	x	x							x	x	x						
57												x	x	x						
58						x	x		x		x	x	x	x	x		x	x		x
59																				
60	x																			

	RC4										ED1									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
61																	x		x	
62																				
63																				
64																				
65	x	x	x	x	x	x	x	x	x	x			x		x					
66																				
67																				
68	x	x	x	x	x		x	x	x				x	x	x	x	x	x	x	x
69																				
70																				
71	x	x	x	x		x	x	x	x	x				x	x	x	x	x	x	
72			x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
73																				
74																				
75																				
76							x			x										
77																				
78																				
79											x					x				
80	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x

ED2

	1	2	3	4	5	6	7	8	9	10
1										
2										
3	x	x	x	x	x	x	x	x	x	x
4										
5										
6	x		x	x			x	x	x	x
7		x					x			
8										
9					x					
10			x	x						
11					x	x		x	x	x
12										
13										
14										
15	x	x	x	x	x	x	x	x	x	x
16	x		x	x	x	x	x		x	x
17										
18	x	x	x		x	x				
19	x	x		x	x	x	x	x	x	x
20	x	x	x		x	x	x	x	x	x
21	x	x	x	x	x	x		x		x
22										
23										
24										
25	x	x	x		x		x			x
26										
27										
28	x		x				x			
29		x	x	x	x	x	x	x		x
30	x	x	x	x	x	x	x	x	x	x

ED2

	1	2	3	4	5	6	7	8	9	10
31										
32										
33	x	x	x	x	x	x	x	x	x	x
34		x			x			x		
35										
36										
37	x	x	x	x	x	x	x	x	x	x
38										
39										
40	x									
41										
42										
43			x							
44										
45										
46										
47										
48		x							x	
49										
50		x			x	x		x		
51										
52										
53										
54										
55										
56			x							
57							x			
58			x		x				x	
59										
60										

<u>ED2</u>

	1	2	3	4	5	6	7	8	9	10
61								x		
62										
63										
64										
65										
66										
67										
68	x	x	x	x	x	x	x	x	x	x
69										
70										
71	x	x	x	x	x	x	x	x	x	x
72	x	x	x		x	x		x	x	x
73										
74										
75										
76										
77										
78										
79										
80	x	x	x	x	x	x	x	x	x	x

Appendix C.

Appendix C

DENSITY & COVER DATA

Sixteen common species were arbitrarily selected for density measurements. The number of individual plants rooted inside half of a 20 square metre quadrat was counted, provided that a plant reached a specific height. In the course of scoring presence and absence, the quadrat was subjectively chosen as being representative of the site. Thus density was measured in one in every ten quadrats, i.e. 33 quadrats in all.

Cover of the same species was estimated by eye in and around the same quadrats. This is the total area of ground upon which the vertical projection of the aerial parts of a species would fall, disregarding overlap. This was expressed as a percentage of the total area considered, and the species ascribed to one of the five coverage classes: 1-10, -25, -50, -75, -100%. In addition the cover of twelve further species was estimated for each site from a consideration of all the quadrats, and of the vegetation immediately adjacent.

Scale-

DENSITY, 1 inch: 30 plants/10 sq. metres

COVER, 1 inch: 100%

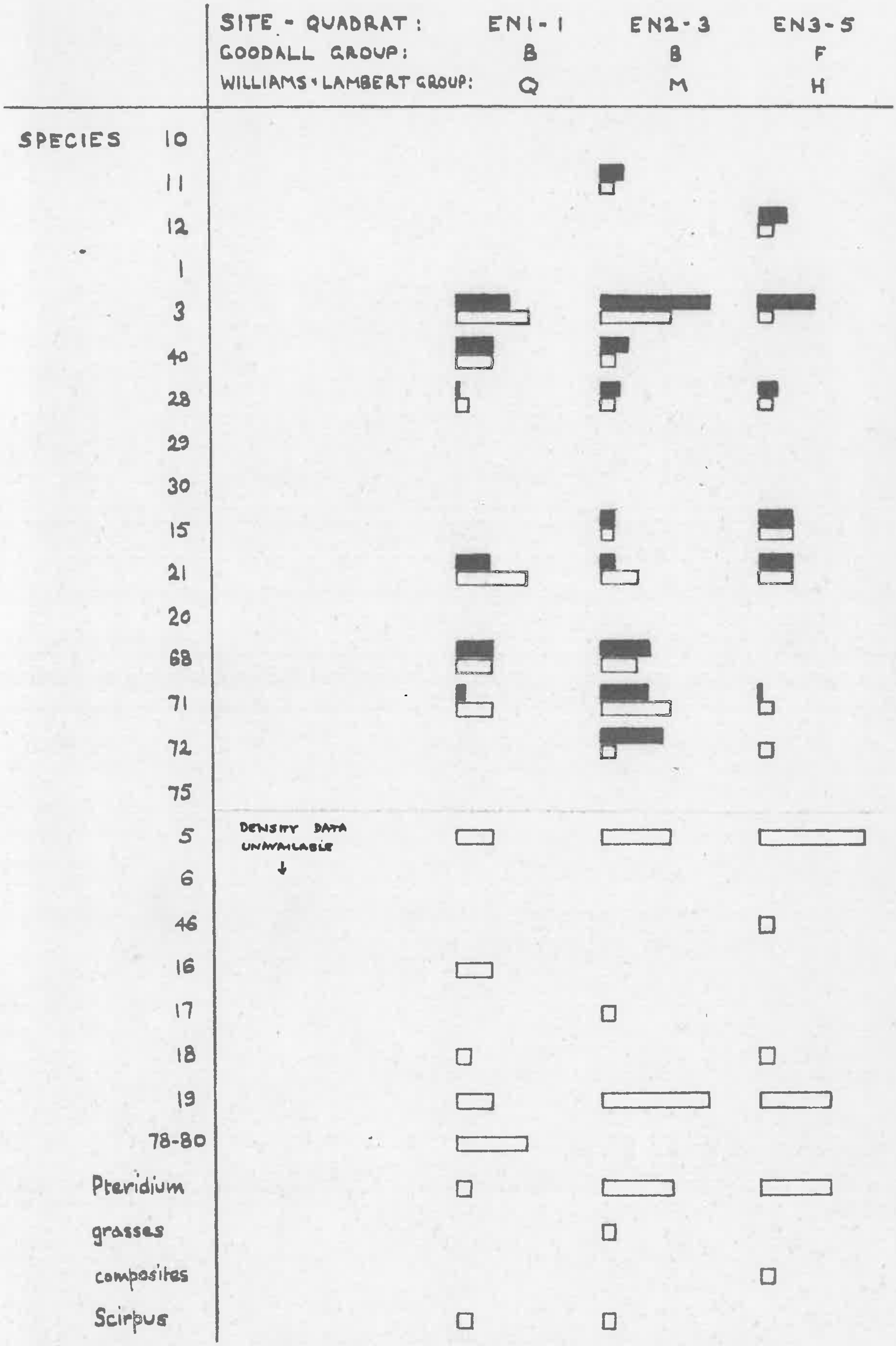
In this Appendix, species are numbered according to the notation of Table 2.

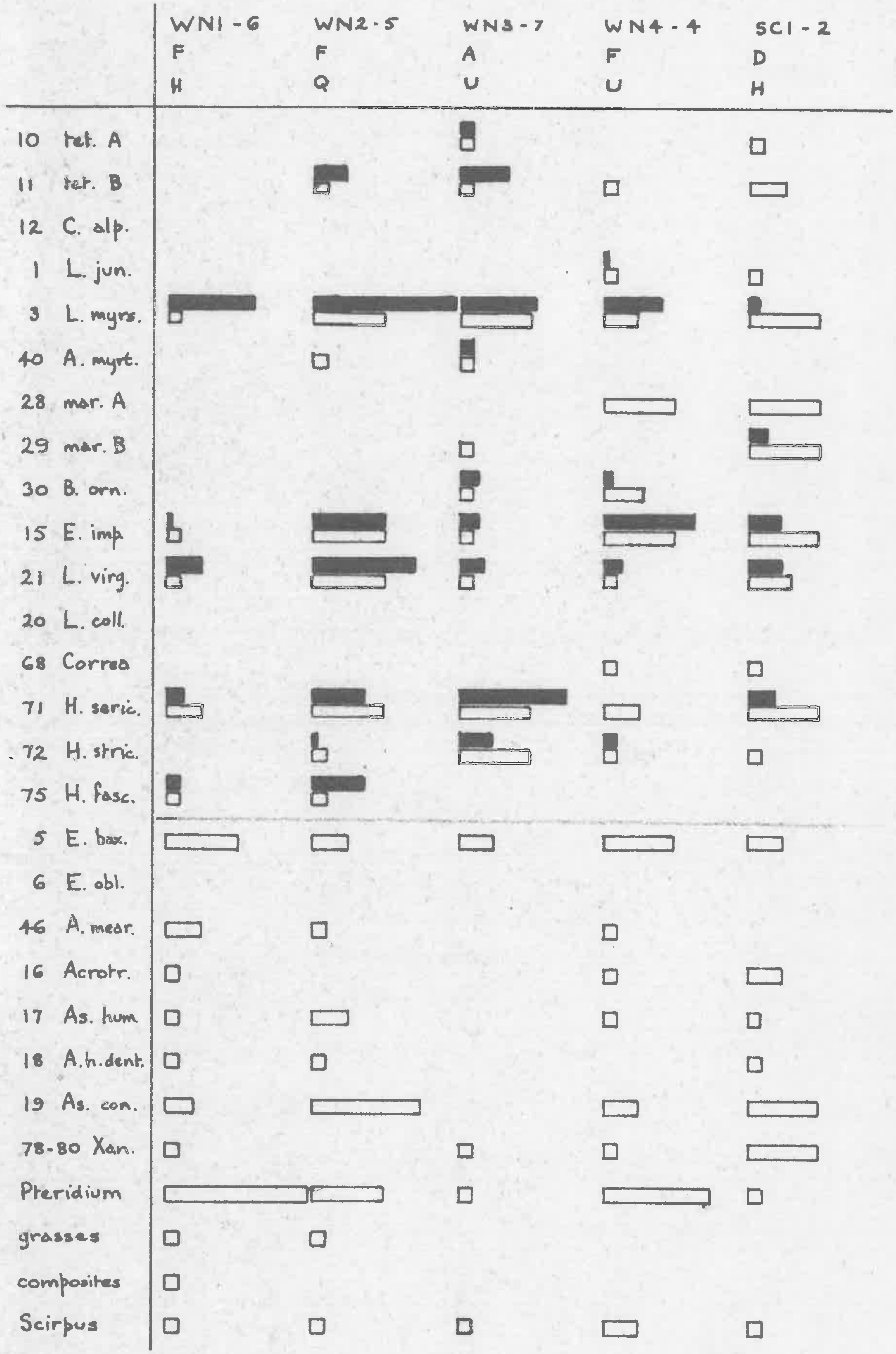
16 SPECIES (density & cover)-

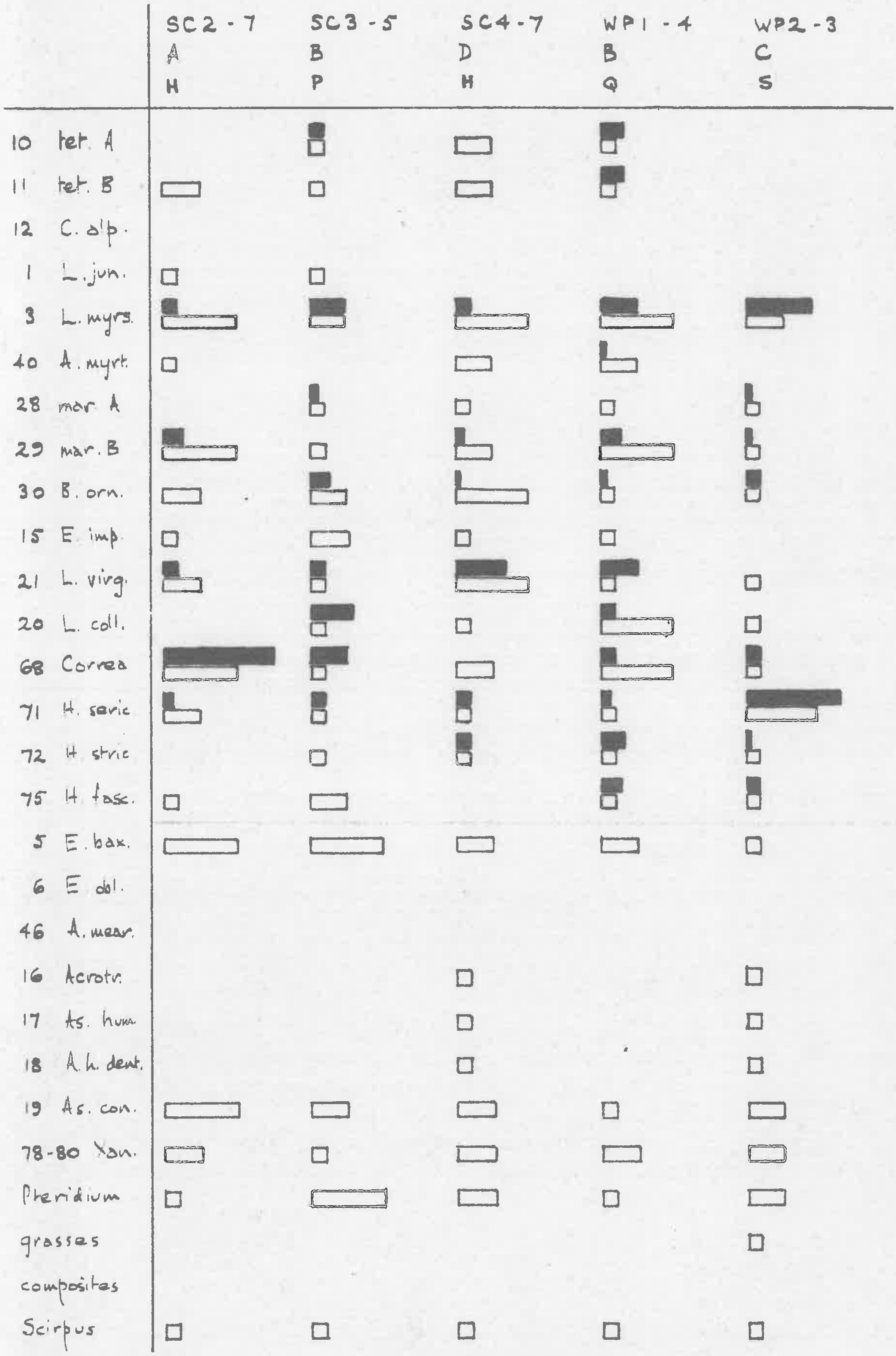
10	Calytrix tetragona A(hairy)	specified height	12 inches
11	Calytrix tetragona B(glabrous)	"	"
12	Calytrix alpestris	"	"
1	Leptospermum juniperinum	"	"
3	Leptospermum myrsinoides	"	"
40	Acacia myrtifolia	"	"
28	Banksia marginata A(erect)	"	4 feet
29	Banksia marginata B(dwarf)	"	6 inches
30	Banksia ornata	"	12 inches
15	Epacris impressa	"	6 inches
21	Leucopogon virgatus	"	"
20	Leucopogon collinus	"	"
68	Correa reflexa reflexa	"	"
71	Hibbertia sericea et var.	"	"
72	Hibbertia stricta et var.	"	"
75	Hibbertia fasciculata	"	"

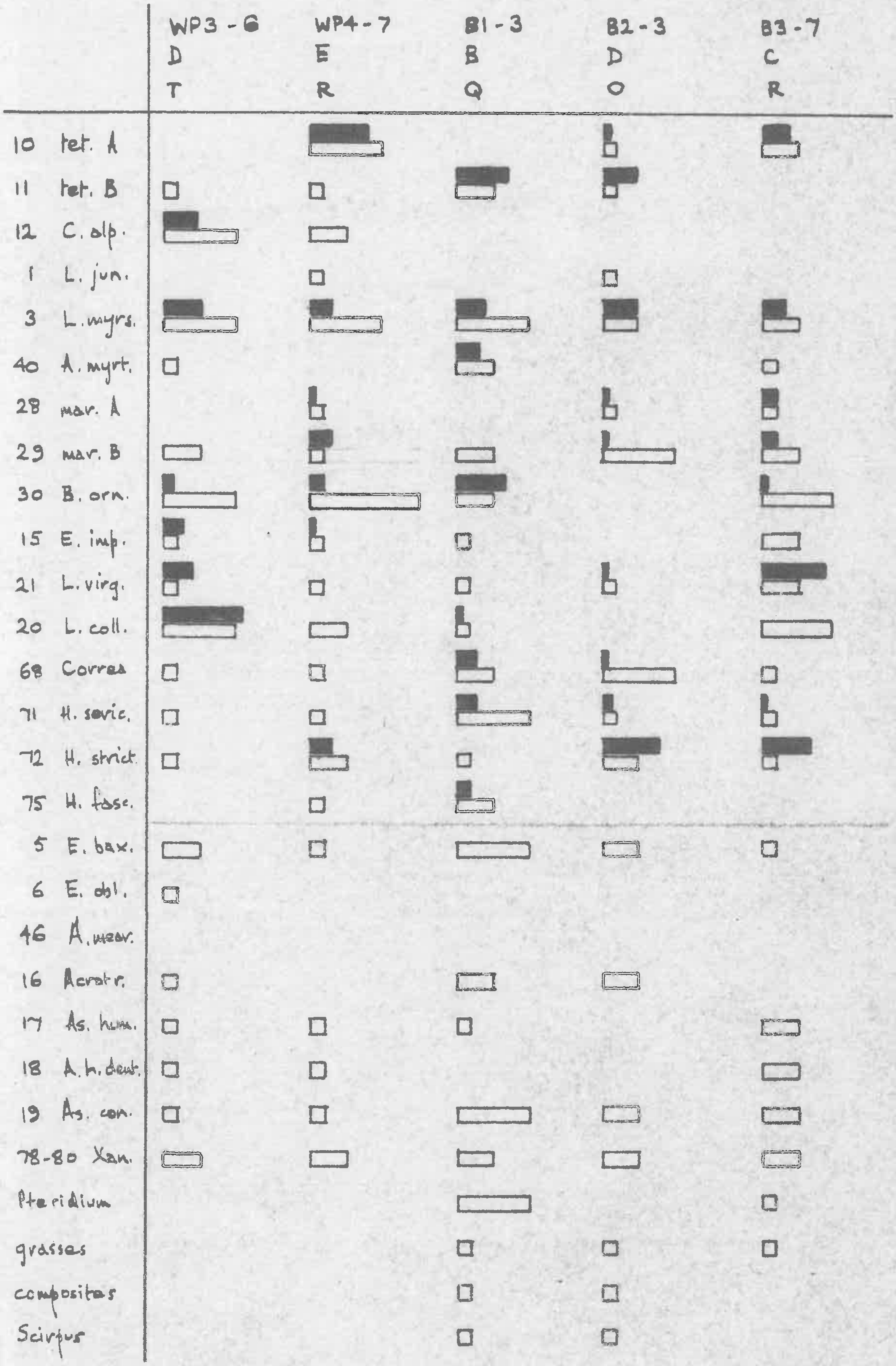
12 SPECIES (cover only)-

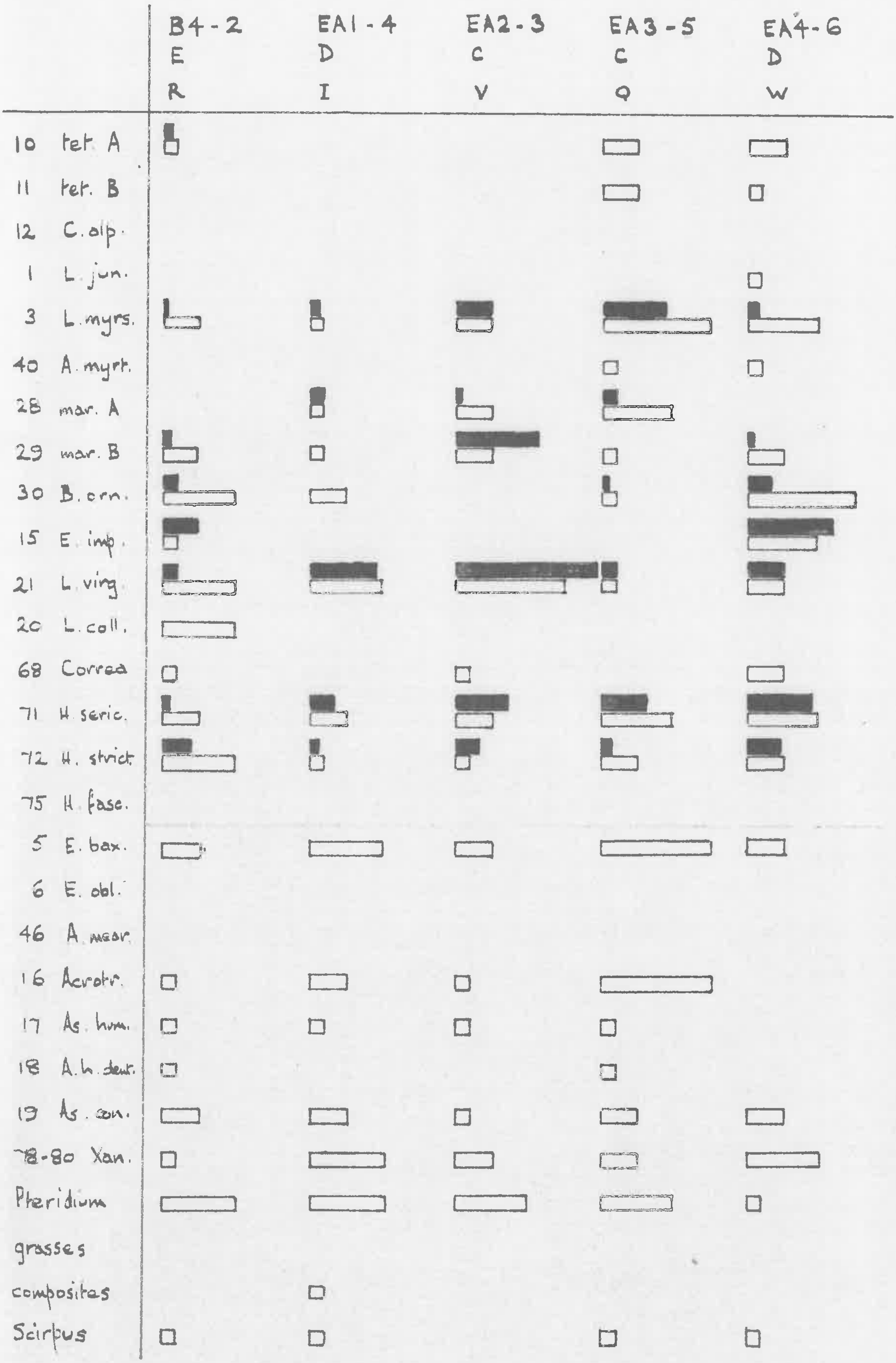
5 Eucalyptus baxteri
6 Eucalyptus obliqua
46 Acacia mearnsii
16 Acrotriche serrulata
17 Astroloma humifusum
18 Astroloma humifusum denticulatum
19 Astroloma conostephiodes
78-80 Xanthorrhoea spp.
Pteridium aquilinum (L.) Kuhn.
grasses
composites
Scirpus nodosus Rottb.

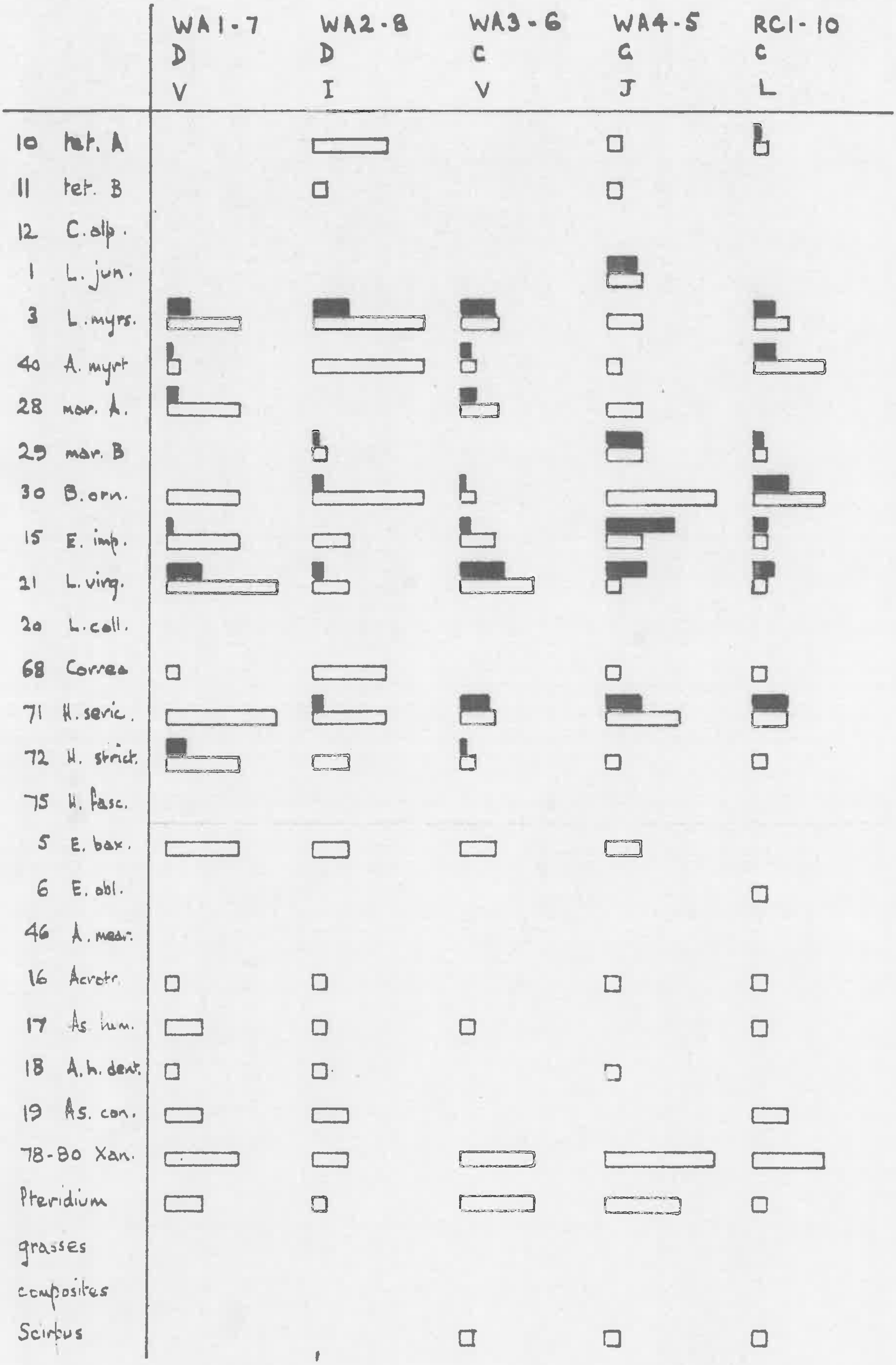

SITE - QUADRAT: EN1-1 EN2-3 EN3-5
GOODALL GROUP: B B F
WILLIAMS + LAMBERT GROUP: Q M H
SPECIES
10
11
12
1
3
40
28
29
30
15
21
20
68
71
72
75
5
6
46
16
17
18
19
78-80
Pteridium
grasses
composites
Scirpus
DENSITY DATA UNAVAILABLE

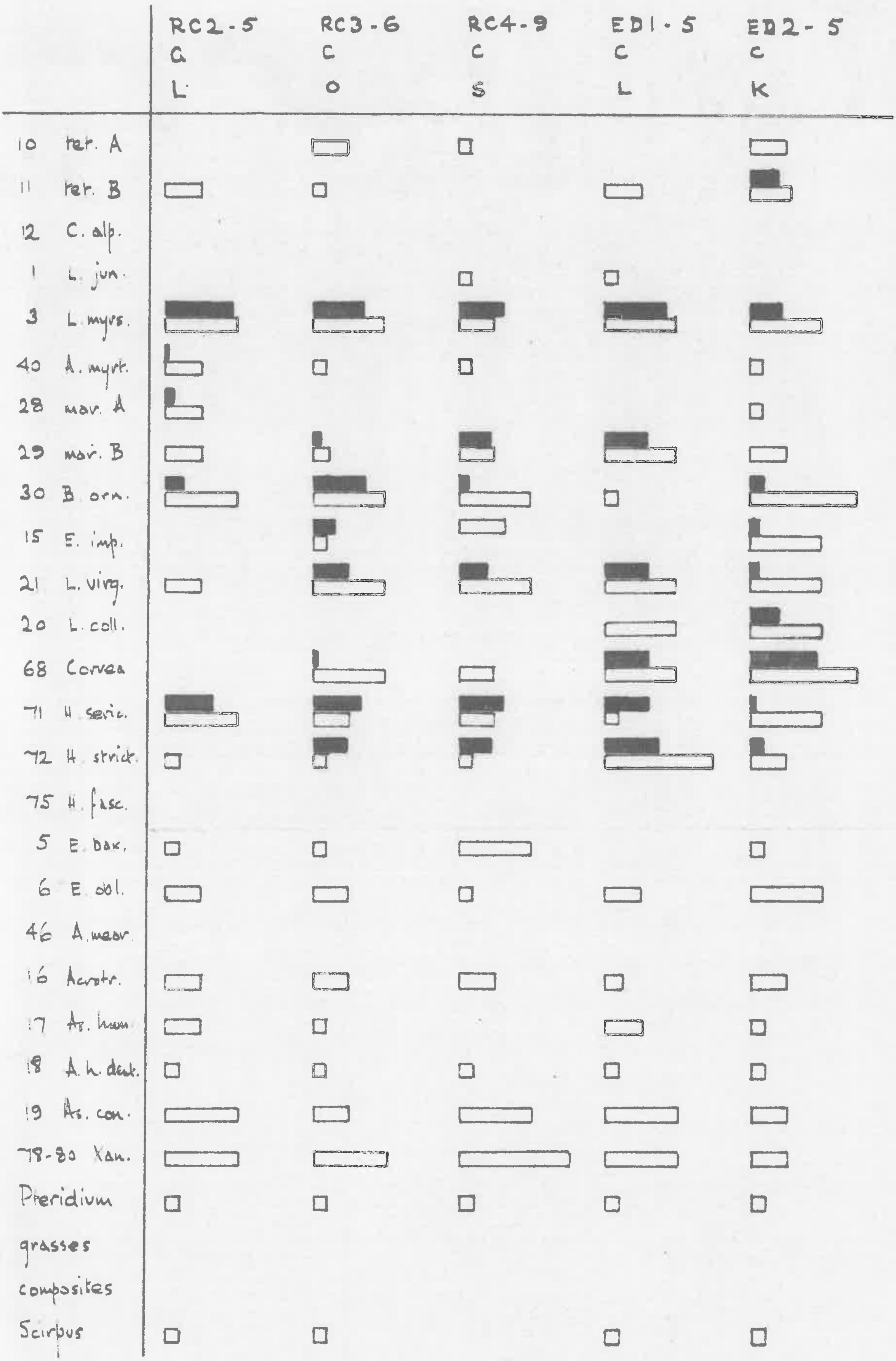

WN1-6 F H
WN2-5 F Q
WN3-7 A U
WN4-4 F U
SC1-2 D H
10 tet. A
11 tet. B
12 C. alp.
1 L. jun.
3 L. myrs.
40 A. myrt.
28 mar. A
29 mar. B
30 B. orn.
15 E. imp.
21 L. virg.
20 L. coll.
68 Correa
71 H. seric.
72 H. stric.
75 H. fasc.
5 E. bax.
6 E. obl.
46 A. mear.
16 Acrotr.
17 As. hum.
18 A.h.dent.
19 As. con.
78-80 Xan.
Pteridium
grasses
composites
Scirpus


SC2-7 A H
SC3-5 B P
SC4-7 D H
WP1-4 B Q
WP2-3 C S
10 tet. A
11 tet. B
12 C. alp.
1 L. jun.
3 L. myrs.
40 A. myrt.
28 mar. A
29 mar. B
30 B. orn.
15 E. imp.
21 L. virg.
20 L. coll.
68 Correa
71 H. seric
72 H. stric
75 H. fasc.
5 E. bax.
6 E. obl.
46 A. mear.
16 Acrotr.
17 As. hum.
18 A. h. dent.
19 As. con.
78-80 Xan.
Pteridium
grasses
composites
Scirpus


WP3 - 6
D
T
WP4 - 7
E
R
B1 - 3
B
Q
B2 - 3
D
O
B3 - 7
C
R
10 tet. A
11 tet. B
12 C. alp.
1 L. jun.
3 L. myrs.
40 A. myrt.
28 mar. A
29 mar. B
30 B. orn.
15 E. imp.
21 L. virg.
20 L. coll.
68 Correa
71 H. seric.
72 H. strict.
75 H. fasc.
5 E. bax.
6 E. obl.
46 A. mear.
16 Acrotr.
17 As. hum.
18 A. h. dent.
19 As. con.
78-80 Xan.
Pteridium
grasses
composites
Scirpus


B4-2 E R
EA1-4 D I
EA2-3 C V
EA3-5 C Q
EA4-6 D W
10 ter. A
11 ter. B
12 C. alp.
1 L. jun.
3 L. myrs.
40 A. myrt.
28 mar. A
29 mar. B
30 B. orn.
15 E. imp.
21 L. virg.
20 L. coll.
68 Correa
71 H. seric.
72 H. strict.
75 H. fasc.
5 E. bax.
6 E. obl.
46 A. mear.
16 Acrotr.
17 As. hum.
18 A. h. dextr.
19 As. con.
78-80 Xan.
Pteridium
grasses
composites
Scirpus


WA1-7
D
V
WA2-8
D
I
WA3-6
C
V
WA4-5
G
J
RC1-10
C
L
10 tet. A
11 tet. B
12 C. alp.
1 L. jun.
3 L. myrs.
40 A. myrt
28 mar. A.
29 mar. B
30 B. orn.
15 E. imp.
21 L. virg.
20 L. coll.
68 Correa
71 H. seric.
72 H. strict.
75 H. fasc.
5 E. bax.
6 E. obl.
46 A. mear.
16 Acrotr.
17 As. hum.
18 A. h. dent.
19 As. con.
78-80 Xan.
Pteridium
grasses
composites
Scirpus


RC2-5 G L
RC3-6 C O
RC4-9 C S
ED1-5 C L
ED2-5 C K
10 ter. A
11 ter. B
12 C. alp.
1 L. jun.
3 L. myrs.
40 A. myrt.
28 mar. A
29 mar. B
30 B orn.
15 E. imp.
21 L. virg.
20 L. coll.
68 Correa
71 H. seric.
72 H. strict.
75 H. fasc.
5 E. bax.
6 E. obl.
46 A. mear
16 Acrotr.
17 As. hum.
18 A. h. dext.
19 As. con.
78-80 Xan.
Pteridium
grasses
composites
Scirpus

Appendix D.

Appendix D

ANALYSES IN DETAIL

The frequency data presented in Appendix B as presence and absence of 80 species were analysed by each of three methods, the results of which are summarised in text Figures 8, 12, and 16 to 17 respectively. These three analyses are presented here in greater detail. 1. Interspecific correlation: an example of the manual edge-punched cards follows; the cards themselves are held at the University of Adelaide. 2. Association-analysis: a copy of a printed statement of the electronic computer sorting of quadrats on the basis of association index follows; the statement itself and the punched cards on which the data were programmed are at the University. 3. Cluster analysis: a copy of the basic and retabulated similarity matrix, electronically processed, follows; statement and cards are at the University.

Quadrats and species are for various reasons designated differently in the three methods. Numbers and letters used in this Appendix are explained in the following tables.

Quadrat notation in the text is generally that used in Appendix B e.g. EN2-4 means East Naracoorte range (see Table 1), site number 2 (Figure 6), quadrat number 4 (Appendix A). However, in the association-analysis statement, quadrats are referred to in the following way:

range	EN,	sites 1-3,	quadrats 1-10	are numbered	1-30
"	~~WN~~ SC	"	1-4	"	31-70
"	~~SC~~ WN	"	"	"	71-110
"	WP	"	"	"	111-150
"	B	"	"	"	151-190
"	EA	"	"	"	191-230
"	WA	"	"	"	231-270
"	RC	"	"	"	271-310
"	ED	"	1-2	"	311-330

Species notation in the text is that shown in Species List I (Table 2), but in this Appendix species are numbered according to the following table. Interspecific correlation notation and Association-analysis notation are more conveniently determined from the second columns of Tables 4 and 6 respectively, but are repeated here for the sake of completeness.

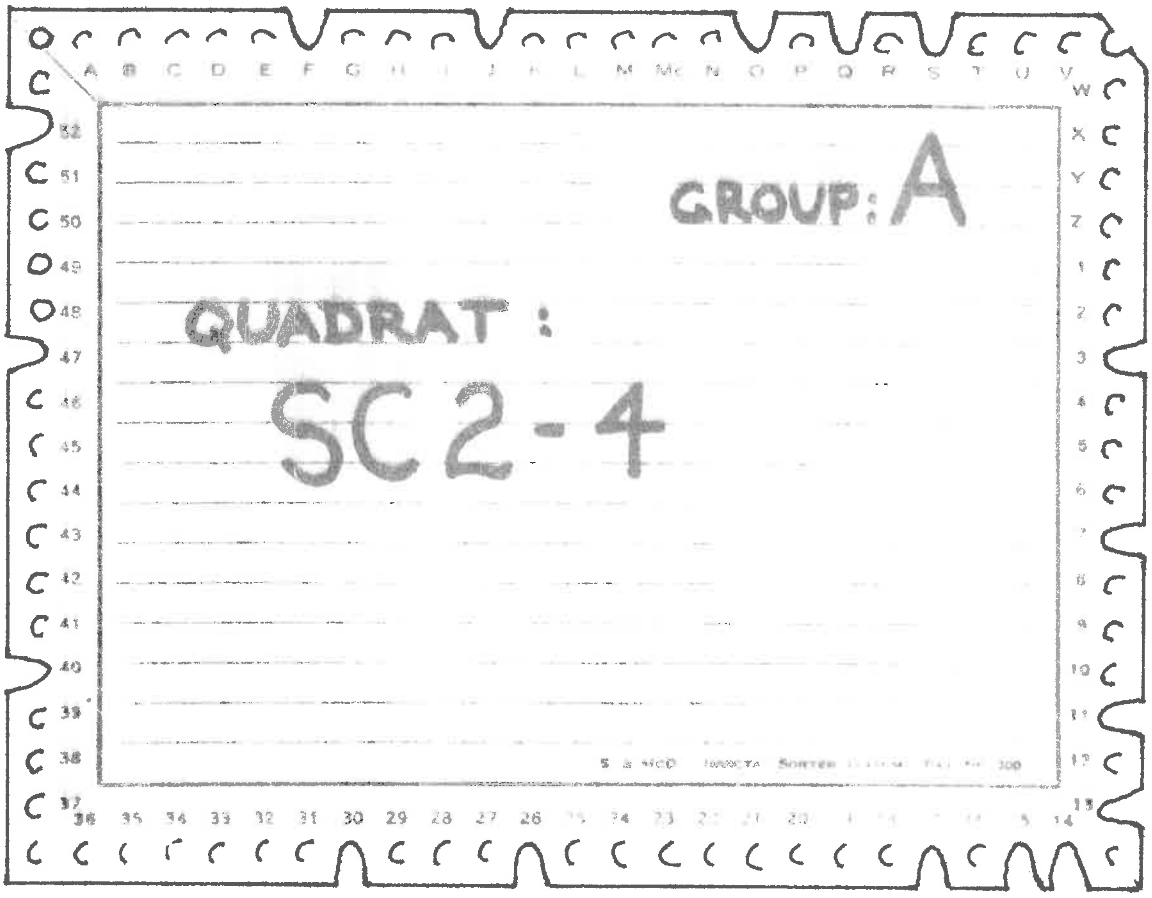
species notation				species name
Interspecific correlation	Association-analysis	Cluster analysis	q.v. TABLE 2	
4	3	1	1	L. juniperinum
12	4	2	2	L. pubescens
13	5	3	3	L. myrsinoides
-	7	4	3a	M. gibbosa
Z	14	5	4	M. oraria
14	15	6	5	E. baxteri
19	16	7	6	E. obliqua
20	18	8	7	E. huberiana
22	19	9	8	E. fasciculosa
24	20	10	9	E. leucoxylon
25	22	11	10	Calytrix hairy
26	23	12	11	Calytrix glabrous
27	24	13	12	Lhotzkya
28	25	14	15	Epacris
29	27	15	28	B. marginata erect
30	28	16	29	" dwarf
31	29	17	30	B. ornata
37	30	18	31	H. vittata
38	-	-	32	H. nodosa
42	32	19	33	H. rostrata
43	36	20	34	G. ilicifolia
45	39	21	35	Persoonia
46	41	22	36	Adenanthos
47	42	23	37	Isopogon
51	43	24	39	Ac. spinescens
-	44	25	39a	Ac. armata
52	48	26	40	Ac. myrtifolia
A	49	27	41	Ac. pycnantha

species notation				
Interspecific correlation	Association-analysis	Cluster analysis	q.v. TABLE 2	species name
C	50	28	42	Ac. melanoxylon
D	52	29	43	Ac. verticillata
H	53	30	44	Ac. oxycedrus
L	54	31	45	Ac. sophorae
M	55	32	46	Ac. mearnsii
Mac	56	33	47	Ac. suaveolens
N	58	34	48	Dav. brevifolia
O	64	35	49	Bossiaea cinerea
U	66	36	59	Bursaria
V	69	37	60	Cas. paludosa
W	70	38	61	Cas. pusilla
X	71	39	62	Dodonaea
Y	72	40	63	Exocarpos
1	75	41	13	Kunzea
2	76	42	14	Darwinia
3	77	43	16	Acrotriche
5	79	44	17	Astro. humifusum
6	80	45	18	Astro. " var.
7	81	46	19	" conostephiodes
8	82	47	20	L. collinus
9	83	48	21	L. virgatus
10	84	49	22	L. woodsii
11	85	50	23	L. ericoides
15	89	51	24	Monotoca
17	91	52	25	Brachy. ciliatum
16	-	-	26	Brachy. ericoides
18	92	53	27	Styphelia
21	95	54	38	Conospermum

species notation				
Interspecific correlation	Association-analysis	Cluster analysis	q.v. TABLE 2	species name
23	97	55	50	Gompholobium
32	106	56	51	P. prostrata
33	107	57	52	P. tenuifolia
34	108	58	53	P. acerosa
35	109	59	54	Phyllota
36	110	60	55	Dill. floribunda
39	113	61	56	Dill. peduncularis
40	114	62	57	Bossiaea prostrata
41	115	63	58	Kennedia
44	118	64	64	Pimelea glauca
-	119	65	64a	P. spathulata
48	122	66	65	Hypoleana
49	123	67	66	Amperea
50	124	68	67	B. coerulescens
53	127	69	68	Correa
B	129	70	69	Spyridium
E	-	-	70	Gyrostemon
F	133	71	71	H. sericea
G	134	72	72	H. stricta
I	136	73	73	H. virgata
J	137	74	74	" var.
K	138	75	75	H. fasciculata
P	144	76	76	Thomasia
Q	145	77	77	Tetratheca
R	146	78	78	X. quadrangulata
S	147	79	80	X. australis
T	148	80	79	X. semiplana

1. Positive interspecific correlation.

The method of Goodall involves manual sorting of edge-punched cards, of which an example is shown here. A hole punched out indicates that a species, e.g. species 3, 7, 11, 13 etc., occurs in the quadrat represented by the card. Calculations of significance of association between species a are not presented.



e.g. species 26 present.

2. Association-analysis.

The method of Williams and Lambert involves electronic computation, and a printed statement of the sorting of quadrats into groups is shown here, preceded by a list of the 80 species ("attributes") used in the analysis, viz. 3-5/7/......../144-148.

The group containing all 330 quadrats ("individuals") is considered:

quadrats 1-330/.

Within this group, two groups may be formed by sorting on attribute 109 (Phyllota) at the association index level of about 165;

group Phyllota - present has 59 individuals:

quadrats 65/121-129/......./307-310/.

This group may be sorted on attribute 124(Boronia);

group Phyllota - absent has 271 individuals:

quadrats 1-64/66-120/......./311-330/.

This group may be sorted on attribute 89 (Monotoca);

and so on, the result being shown diagrammatically in Figure 12.

ATTRIBUTES = 80 Species :

```
3-5/7/14-16/18-20/22-25/27-30/32/36/39/41-44/48-50/52-56/58/64/66/69-72/75-77/79-85/89/91-92/95/97/106-110/113-115/118-119/122-
        124/127/129/133-134/136-138/144-148/,
NO. OF INDIVIDUALS IN THIS GROUP IS  330, ie. QUADRATS.
1-330/,
SORT WILL BE ON ATTRIBUTE 109 IF  165,21637 LEVEL IS REACHED, ie. ≤X², ASSOCIATION ANALYSIS INDEX.


NO. OF INDIVIDUALS IN THIS GROUP IS   59
65/121-129/131-147/149/171-180/182-190/270/288-290/292/301-303/307-310/,
SORT WILL BE ON ATTRIBUTE 124 IF   36,18040 LEVEL IS REACHED,


NO. OF INDIVIDUALS IN THIS GROUP IS  271
1-64/66-120/130/148/150-170/181/191-269/271-287/291/293-300/304-306/311-330/,
SORT WILL BE ON ATTRIBUTE  89 IF  153,77405 LEVEL IS REACHED,


NO. OF INDIVIDUALS IN THIS GROUP IS   63
1-6/8-10/41-50/59-60/93-99/111-120/151-155/157-158/161/215/218/220/241-244/249/251-255/266/271/313/318/,
SORT WILL BE ON ATTRIBUTE 145 IF   18,64070 LEVEL IS REACHED,


NO. OF INDIVIDUALS IN THIS GROUP IS  208
7/11-40/51-58/61-64/66-92/100-110/130/148/150/156/159-160/162-170/181/191-214/216-217/219/221-240/245-248/250/256-265/267-269/
        272-287/291/293-300/304-306/311-312/314-317/319-330/,
SORT WILL BE ON ATTRIBUTE  42 IF  125,64316 LEVEL IS REACHED,


NO. OF INDIVIDUALS IN THIS GROUP IS  107
7/13-16/20/31/34/39/53-58/64/100/130/148/150/156/159-160/162-170/191-192/196-206/208/211-214/216/222-223/225-227/229-230/235-239
        /247/256-258/272-274/277-280/283-287/291/293-300/304-306/311-312/315/317/319-330/,
SORT WILL BE ON ATTRIBUTE  15 IF   59,42564 LEVEL IS REACHED,


NO. OF INDIVIDUALS IN THIS GROUP IS  101
11-12/17-19/21-30/32-33/35-38/40/51-52/61-63/66-92/101-110/181/193-195/207/209-210/217/219/221/224/228/231-234/240/245-246/248/
        250/259-265/267-269/275-276/281-282/314/316/,
SORT WILL BE ON ATTRIBUTE 147 IF   49,58218 LEVEL IS REACHED,


NO. OF INDIVIDUALS IN THIS GROUP IS   77
7/13-16/20/31/34/39/53-58/64/100/130/148/150/159-160/162-170/191-192/196-206/208/212-214/216/222-223/225-227/229-230/235-239/247
        /256-258/272-274/291/293/296/298-300/304-306/,
SORT WILL BE ON ATTRIBUTE 147 IF   30,22773 LEVEL IS REACHED,


NO. OF INDIVIDUALS IN THIS GROUP IS   30
156/211/277-280/283-287/294-295/297/311-312/315/317/319-330/,
SORT WILL BE ON ATTRIBUTE  79 IF   20,45560 LEVEL IS REACHED,


NO. OF INDIVIDUALS IN THIS GROUP IS   62
11-12/17/27/32-33/35/37/40/51-52/61-63/66-70/75-80/92/181/193-195/207/209-210/217/221/224/228/231-234/240/245-246/248/250/259-
        265/267-269/275-276/281-282/314/316/,
SORT WILL BE ON ATTRIBUTE   5 IF   36,39077 LEVEL IS REACHED,


H  NO. OF INDIVIDUALS IN THIS GROUP IS   39
18-19/21-26/28-30/36/38/71-74/81-91/101-110/219/,
SORT WILL BE ON ATTRIBUTE  28 IF   10,02538 LEVEL IS REACHED,
```

```
  NO. OF INDIVIDUALS IN THIS GROUP IS   42
I 11-12/17/27/32-33/35/37/40/51/61-63/66-70/76/78/92/193-195/207/209-210/221/224/233-234/240/245-246/248/250/259-260/269/281/314/
          316/.
  SORT WILL BE ON ATTRIBUTE  16 IF   16.51888 LEVEL IS REACHED.

  NO. OF INDIVIDUALS IN THIS GROUP IS   20
J 52/75/77/79-80/181/217/228/231-232/261-265/267-268/275-276/282/.
  SORT WILL BE ON ATTRIBUTE 145 IF   10.43210 LEVEL IS REACHED.

  NO. OF INDIVIDUALS IN THIS GROUP IS    8
T 131-132/134-137/139-140/.
  SORT WILL BE ON ATTRIBUTE  83 IF    4.50000 LEVEL IS REACHED.

  NO. OF INDIVIDUALS IN THIS GROUP IS   51
  65/121-129/133/138/141-147/149/171-180/182-190/270/288-290/292/301-303/307-310/.
  SORT WILL BE ON ATTRIBUTE 127 IF   19.25221 LEVEL IS REACHED.

  NO. OF INDIVIDUALS IN THIS GROUP IS   71
  7/15-16/31/34/39/54-55/57-58/64/130/148/150/159-160/162-170/191-192/196-206/208/212-214/216/222-223/225-227/229-230/235-239/247/
          256-258/272-274/291/293/296/298-300/304-306/.
  SORT WILL BE ON ATTRIBUTE  58 IF   26.16067 LEVEL IS REACHED.

  NO. OF INDIVIDUALS IN THIS GROUP IS    6
M 13-14/20/53/56/100/.
  SORT WILL BE ON ATTRIBUTE  19 IF    2.66667 LEVEL IS REACHED.

  NO. OF INDIVIDUALS IN THIS GROUP IS   23
O 58/130/148/159/163-164/166-170/196/223/225/247/272/291/296/299-300/304-306/.
  SORT WILL BE ON ATTRIBUTE  25 IF   12.12911 LEVEL IS REACHED.

  NO. OF INDIVIDUALS IN THIS GROUP IS   48
  7/15-16/31/34/39/54-55/57/64/150/160/162/165/191-192/197-206/208/212-214/216/222/226-227/229-230/235-239/256-258/273-274/293/298
          /.
  SORT WILL BE ON ATTRIBUTE 110 IF   21.14685 LEVEL IS REACHED.

  NO. OF INDIVIDUALS IN THIS GROUP IS    3
N 15-16/160/.
  SORT WILL BE ON ATTRIBUTE  16 IF    0.18750 LEVEL IS REACHED.

  NO. OF INDIVIDUALS IN THIS GROUP IS   45
  7/31/34/39/54-55/57/64/150/162/165/191-192/197-206/208/212-214/216/222/226-227/229-230/235-239/256-258/273-274/293/298/.
  SORT WILL BE ON ATTRIBUTE  22 IF   18.36551 LEVEL IS REACHED.

  NO. OF INDIVIDUALS IN THIS GROUP IS   17
L 156/211/277-280/283-287/311-312/315/317/319-320/.
  SORT WILL BE ON ATTRIBUTE  82 IF   13.12209 LEVEL IS REACHED.

  NO. OF INDIVIDUALS IN THIS GROUP IS   13
K 294-295/297/321-330/.
  SORT WILL BE ON ATTRIBUTE  25 IF    5.87031 LEVEL IS REACHED.
```

S
NO. OF INDIVIDUALS IN THIS GROUP IS 19
65/121/123-125/127-128/176/186/288-290/292/301-303/307-309/.
SORT WILL BE ON ATTRIBUTE 145 IF 5,97284 LEVEL IS REACHED.

R
NO. OF INDIVIDUALS IN THIS GROUP IS 32
122/126/129/133/138/141-147/149/171-175/177-180/182-185/187-190/270/310/.
SORT WILL BE ON ATTRIBUTE 48 IF 13,30472 LEVEL IS REACHED.

Q
NO. OF INDIVIDUALS IN THIS GROUP IS 44
1-6/10/41-50/59-60/97/111-120/151-155/157-158/215/241-244/249/271/.
SORT WILL BE ON ATTRIBUTE 77 IF 12,37500 LEVEL IS REACHED.

P
NO. OF INDIVIDUALS IN THIS GROUP IS 19
8-9/93-96/98-99/161/218/220/251-255/266/313/318/.
SORT WILL BE ON ATTRIBUTE 92 IF 11,32765 LEVEL IS REACHED.

U
NO. OF INDIVIDUALS IN THIS GROUP IS 11
31/54-55/57/64/150/162/165/258/273-274/.
SORT WILL BE ON ATTRIBUTE 106 IF 5,30478 LEVEL IS REACHED.

NO. OF INDIVIDUALS IN THIS GROUP IS 34
7/34/39/191-192/197-206/208/212-214/216/222/226-227/229-230/235-239/256-257/293/298/.
SORT WILL BE ON ATTRIBUTE 79 IF 18,33643 LEVEL IS REACHED.

V
NO. OF INDIVIDUALS IN THIS GROUP IS 17
7/39/191-192/203-204/206/208/212-213/235-239/256/293/.
SORT WILL BE ON ATTRIBUTE 28 IF 8,73139 LEVEL IS REACHED.

W
NO. OF INDIVIDUALS IN THIS GROUP IS 17
34/197-202/205/214/216/222/226-227/229-230/257/298/.
END

3. Cluster analysis.

The method of Sneath involves electronic computation, and a printed statement of the retabulated similarity matrix is shown here in the following manner, e.g. "odds" -

similarity	species pairs
80%	3 (Lept. myrsinoides) with 6 (Euc. baxteri);
78%	3 with 48 (Leucopogon virgatus)
	3 with 71 (Hibbertia sericea);

and so on, the result being shown diagrammatically in Figure 16.

The highest similarity of a species is indicated by circling the species when it first appears in the matrix. Fusion of clusters containing more than one species is indicated by underlining the species pair concerned, according to the criterion of highest similarity between any species pair. The "evens" matrix is only presented as far as 20% as an example.

"ODDS"

SPECIES PAIRS

SIMILARITY, %										
80	3, 6									
78	3, 48	3, 71								
76	6, 71									
72	6, 48	48, 71	3, 79							
70	71, 79									
68	3, 46	46, 48	6, 79							
66	48, 79	52, 79								
64	3, 23	6, 66								
62	6, 46	3, 66	46, 71	52, 71						
60	23, 79									
58	3, 17	3, 52	6, 52	48, 52	17, 79					
56	6, 50	3, 73	23, 72	46, 79						
54	6, 17	23, 66	48, 66	23, 71	66, 79					
52	6, 23	23, 46	23, 48	17, 71	6, 77	66, 77	16, 79	72, 79	77, 79	
50	10, 20	16, 23	17, 23	17, 48	48, 50	46, 66	50, 71	66, 71	6, 72	17, 72
50	66, 72	3, 77	48, 77	43, 79						
48	3, 14	3, 16	3, 43	3, 50	23, 52	17, 66	48, 72	71, 72		
46	14, 48	43, 48	17, 52	46, 52	14, 71	46, 72				
44	6, 14	14, 17	16, 17	14, 46	16, 52	52, 66	3, 69	46, 69	16, 71	50, 79
44	69, 79									
42	6, 16	14, 23	17, 46	16, 48	50, 52	16, 66	16, 69	23, 69	43, 71	52, 77
42	71, 77	14, 79								
40	23, 43	46, 50	43, 52	58, 68	48, 69	58, 70	69, 71	14, 72	16, 72	52, 72
40	23, 77	46, 77	50, 77							
38	23, 26	16, 43	51, 61	17, 69	15, 71	44, 71				
36	3, 15	23, 34	6, 43	43, 46	15, 48	50, 66	6, 69	69, 77		
34	6, 15	14, 43	43, 44	16, 46	43, 63	14, 66	43, 69	19, 72	43, 72	16, 77
34	17, 77									
32	14, 16	19, 23	3, 26	17, 43	3, 44	15, 44	12, 46	15, 46	44, 48	14, 50
32	15, 50	17, 50	26, 51	14, 52	26, 52	43, 66	49, 68	52, 69	68, 70	47, 72
32	69, 72	43, 77	72, 77	68, 78						
30	6, 26	21, 38	15, 43	19, 43	6, 44	44, 45	45, 46	43, 50	44, 50	45, 50
30	15, 52	44, 52	48, 63	11, 66	26, 66	13, 68	14, 69	66, 69	11, 72	34, 72
30	15, 77	26, 77	15, 79	44, 79						
28	3, 12	11, 17	7, 19	11, 23	3, 45	44, 46	17, 47	23, 47	12, 48	45, 48
28	16, 50	3, 63	16, 63	17, 63	51, 66	26, 69	26, 71	45, 71	50, 72	26, 79
28	63, 79									
26	3, 11	6, 11	6, 12	12, 17	11, 26	16, 26	17, 26	19, 34	14, 44	23, 44
26	6, 45	26, 48	23, 50	47, 55	13, 59	12, 60	14, 63	23, 63	52, 63	12, 66
26	51, 69	63, 69	12, 71	63, 71	12, 72	59, 72	11, 77	12, 77	14, 77	51, 77
26	63, 77	59, 78	11, 79							
24	4, 5	13, 21	15, 23	5, 31	10, 33	3, 34	14, 34	16, 34	17, 34	34, 46
24	3, 47	11, 48	3, 51	12, 51	16, 51	23, 51	46, 51	48, 51	11, 52	45, 52
24	23, 55	17, 59	23, 59	15, 66	34, 66	47, 66	63, 66	53, 67	12, 69	34, 69
24	47, 69	50, 69	42, 70	15, 72	26, 72	44, 72	51, 74	44, 77	19, 79	
22	9, 11	14, 15	11, 16	3, 19	14, 19	16, 19	12, 23	5, 29	7, 34	26, 34
22	14, 45	17, 45	23, 45	43, 45	11, 46	19, 46	26, 46	34, 48	21, 49	26, 50
22	6, 51	17, 51	19, 52	19, 55	51, 60	6, 63	7, 63	34, 63	46, 63	30, 64
22	44, 66	21, 68	19, 69	34, 71	45, 72	55, 72	63, 72	53, 74	64, 75	11, 76
22	13, 78	12, 79	34, 79	45, 79	51, 79					
20	11, 12	12, 14	15, 17	17, 19	14, 26	15, 26	6, 34	34, 38	28, 39	26, 43
20	34, 43	16, 44	11, 47	16, 47	46, 47	19, 48	13, 49	38, 49	50, 51	34, 52
20	51, 52	26, 55	54, 58	6, 59	16, 59	34, 59	47, 59	55, 59	47, 60	26, 61
20	19, 63	44, 63	5, 65	18, 65	55, 66	59, 66	38, 68	11, 69	15, 69	55, 69
20	61, 69	11, 71	51, 71	9, 72	59, 76	49, 78	47, 79			
18	9, 15	7, 23	9, 23	13, 38	7, 43	12, 43	19, 44	15, 45	16, 45	6, 47
18	12, 47	14, 47	19, 47	45, 47	12, 50	3, 55	11, 55	16, 55	17, 55	34, 55
18	41, 56	3, 59	11, 59	26, 59	8, 62	19, 66	45, 66	61, 66	35, 67	37, 68
18	45, 69	37, 70	19, 71	47, 71	60, 72	9, 76	44, 76	72, 76		
16	6, 9	12, 15	12, 16	11, 19	12, 26	11, 29	31, 36	21, 37	9, 41	11, 43
16	9, 44	17, 44	11, 45	12, 45	9, 46	7, 47	26, 47	11, 51	14, 51	35, 51

16	43, 51	47, 51	12, 52	51, 53	49, 54	6, 55	14, 55	52, 55	9, 59	19, 59
16	3, 60	30, 60	46, 60	50, 60	3, 61	16, 61	17, 61	21, 61	46, 61	47, 61
16	48, 61	15, 63	26, 63	51, 63	55, 63	57, 65	60, 66	30, 67	54, 68	44, 69
16	59, 71	60, 71	62, 74	51, 75	41, 76	47, 77	41, 78	55, 79	59, 79	61, 79
16	4, 80									
14	1, 5	3, 9	7, 14	9, 14	11, 14	11, 15	7, 16	9, 17	6, 19	9, 19
14	25, 31	28, 32	11, 34	12, 34	13, 37	34, 37	12, 38	31, 39	32, 39	11, 41
14	9, 43	7, 44	26, 44	19, 45	9, 47	15, 47	43, 47	47, 48	11, 50	34, 51
14	47, 52	21, 55	43, 55	46, 55	48, 55	51, 55	13, 58	21, 58	38, 58	37, 59
14	46, 59	52, 59	6, 60	14, 60	26, 60	48, 60	6, 61	23, 61	34, 61	11, 63
14	12, 63	47, 63	50, 63	9, 66	7, 69	21, 70	9, 71	55, 71	7, 72	51, 72
14	53, 73	12, 74	61, 75	15, 76	19, 76	23, 76	34, 76	45, 76	48, 76	52, 76
14	34, 77	60, 77	61, 77	9, 79	5, 80					
12	1, 16	7, 17	1, 19	12, 19	15, 19	9, 26	15, 27	7, 31	9, 34	9, 37
12	7, 38	23, 38	36, 40	17, 41	11, 44	12, 44	27, 44	41, 44	7, 45	26, 45
12	41, 45	7, 46	13, 47	21, 47	41, 47	9, 48	9, 50	7, 52	10, 53	35, 53
12	15, 55	37, 55	34, 56	41, 57	14, 59	21, 59	48, 59	11, 60	17, 60	23, 60
12	55, 60	12, 61	14, 61	15, 61	35, 61	50, 61	52, 61	55, 61	38, 63	45, 63
12	61, 63	60, 64	21, 66	59, 68	59, 69	60, 69	13, 70	38, 70	59, 70	7, 71
12	61, 71	38, 72	41, 72	60, 74	12, 75	30, 75	50, 75	3, 76	6, 76	16, 76
12	17, 76	43, 76	63, 76	66, 76	71, 76	19, 77	21, 77	35, 77	55, 77	75, 77
12	76, 77	47, 78	7, 79	60, 79	76, 79	30, 80	38, 80	57, 80	64, 80	
10	1, 7	3, 7	5, 8	1, 14	7, 15	9, 16	7, 21	12, 21	16, 21	21, 23
10	19, 26	21, 26	7, 28	15, 28	25, 28	4, 29	1, 31	27, 32	1, 34	21, 34
10	27, 36	33, 36	16, 38	19, 38	37, 38	25, 39	34, 44	9, 45	28, 45	29, 45
10	34, 45	34, 47	38, 47	7, 48	35, 50	47, 50	15, 51	30, 51	45, 51	12, 53
10	24, 53	33, 53	38, 53	9, 55	12, 55	13, 55	30, 55	38, 55	12, 59	41, 59
10	43, 59	58, 59	9, 60	15, 60	38, 60	44, 60	53, 60	57, 60	43, 61	60, 61
10	11, 64	26, 64	47, 64	51, 64	31, 65	13, 66	38, 66	9, 69	19, 70	55, 70
10	61, 72	35, 74	38, 74	61, 74	46, 75	60, 75	37, 76	55, 76	45, 77	56, 77
10	21, 78	24, 78	38, 78	54, 78	58, 78	76, 78	47, 80	55, 80		
8	5, 7	1, 9	9, 12	3, 13	6, 13	12, 13	13, 16	13, 19	3, 21	6, 21
8	6, 27	12, 27	27, 28	26, 30	15, 34	1, 35	16, 35	33, 35	11, 37	18, 37
8	19, 37	23, 37	3, 38	17, 38	9, 39	15, 39	27, 39	6, 41	12, 41	1, 43
8	35, 43	39, 44	32, 45	39, 45	27, 46	38, 46	37, 47	38, 48	29, 49	37, 49
8	27, 50	34, 50	21, 51	38, 51	9, 52	35, 52	45, 55	3, 56	6, 56	13, 56
8	46, 56	48, 56	37, 57	37, 58	44, 59	45, 59	16, 60	27, 60	37, 60	45, 60
8	1, 61	11, 61	54, 61	36, 62	21, 63	59, 63	62, 63	46, 64	50, 64	52, 64
8	55, 64	61, 64	41, 66	28, 67	51, 67	1, 69	21, 69	35, 69	38, 69	41, 69
8	56, 69	27, 71	1, 72	13, 72	21, 72	37, 72	56, 72	24, 74	30, 74	66, 74
8	67, 74	1, 75	3, 75	6, 75	11, 75	15, 75	16, 75	21, 75	26, 75	45, 75
8	47, 75	48, 75	66, 75	69, 75	71, 75	72, 75	74, 75	21, 76	26, 76	38, 76
8	46, 76	47, 76	57, 76	58, 76	68, 76	69, 76	70, 76	9, 77	38, 77	41, 77
8	59, 77	64, 77	74, 77	9, 78	44, 78	45, 78	57, 78	66, 78	70, 78	1, 79
8	8, 80	29, 80								
6	1, 4	1, 6	7, 12	7, 13	11, 13	15, 16	1, 17	13, 17	9, 18	4, 21
6	17, 21	19, 21	13, 22	1, 23	13, 23	13, 24	7, 26	3, 27	24, 27	7, 29
6	8, 29	16, 29	19, 29	11, 30	21, 30	8, 31	9, 31	28, 31	29, 31	8, 32
6	13, 34	3, 35	6, 35	28, 36	7, 37	12, 37	16, 37	6, 38	14, 38	29, 39
6	36, 39	27, 40	3, 41	15, 41	22, 41	23, 41	34, 41	1, 42	8, 43	27, 43
6	28, 43	28, 44	29, 44	35, 44	13, 45	1, 46	13, 46	21, 46	35, 46	41, 46
6	29, 47	30, 47	44, 47	27, 48	35, 48	41, 48	1, 49	1, 50	36, 50	41, 50
6	9, 51	1, 52	21, 52	27, 52	28, 52	36, 52	41, 52	26, 53	28, 53	13, 54
6	21, 54	38, 54	7, 55	44, 55	50, 55	54, 55	11, 56	12, 56	14, 56	15, 56
6	17, 56	23, 56	45, 56	49, 56	50, 56	54, 56	9, 57	13, 57	38, 57	47, 57
6	55, 57	56, 58	7, 59	15, 59	22, 59	24, 59	38, 59	49, 59	54, 59	56, 59
6	57, 59	34, 60	52, 60	7, 61	9, 61	29, 61	30, 61	36, 61	37, 61	45, 61
6	35, 62	43, 62	51, 62	61, 62	31, 63	35, 63	3, 64	6, 64	16, 64	33, 64
6	48, 64	1, 65	37, 66	64, 66	21, 67	26, 67	12, 68	47, 68	55, 68	64, 69
6	1, 70	12, 70	34, 70	56, 70	1, 71	21, 71	35, 71	38, 71	39, 71	41, 71
6	56, 71	64, 71	64, 72	3, 74	6, 74	17, 74	36, 74	46, 74	48, 74	2, 75
6	14, 75	17, 75	23, 75	52, 75	55, 75	7, 76	12, 76	13, 76	14, 76	28, 76

6	29, 76	39, 76	50, 76	56, 76	60, 76	37, 77	11, 78	16, 78	23, 78	34, 78
6	37, 78	39, 78	72, 78	21, 79	35, 79	41, 79	56, 79	75, 79	9, 80	21, 80
6	37, 80	60, 80								
4	1, 3	4, 7	3, 8	6, 8	7, 9	8, 11	1, 12	8, 12	10, 12	1, 13
4	13, 14	2, 15	8, 15	13, 15	8, 17	11, 18	5, 19	8, 19	1, 21	14, 21
4	15, 21	11, 22	8, 23	12, 24	7, 25	24, 26	8, 27	9, 27	14, 27	17, 27
4	19, 27	3, 28	6, 28	13, 28	17, 28	3, 29	6, 29	11, 29	13, 29	15, 29
4	21, 29	12, 30	14, 31	15, 31	19, 31	6, 32	8, 34	18, 34	28, 34	31, 34
4	12, 35	28, 35	29, 35	1, 36	6, 36	15, 36	3, 37	6, 37	14, 37	17, 37
4	26, 37	1, 38	8, 38	11, 38	29, 38	31, 38	6, 39	11, 39	13, 41	14, 41
4	16, 41	19, 41	28, 41	29, 41	37, 41	38, 41	29, 43	36, 43	38, 43	41, 43
4	1, 44	31, 44	36, 44	1, 45	8, 45	28, 46	29, 46	32, 46	37, 46	39, 46
4	8, 47	22, 47	1, 48	8, 48	21, 48	28, 48	37, 48	16, 49	34, 49	47, 49
4	13, 50	19, 50	21, 50	28, 50	30, 50	32, 50	39, 50	1, 51	8, 51	24, 51
4	36, 51	37, 51	8, 52	13, 52	29, 52	31, 52	38, 52	39, 52	3, 53	6, 53
4	14, 53	23, 53	34, 53	45, 53	46, 53	48, 53	50, 53	52, 53	26, 54	1, 55
4	8, 55	41, 55	8, 56	9, 56	16, 56	19, 56	21, 56	28, 56	29, 56	37, 56
4	38, 56	43, 56	44, 56	47, 56	52, 56	55, 56	11, 57	12, 57	34, 57	7, 58
4	12, 58	19, 58	34, 58	50, 59	51, 59	13, 60	21, 60	41, 60	43, 60	59, 60
4	19, 61	27, 61	38, 61	40, 61	56, 61	59, 61	7, 62	15, 62	16, 62	17, 62
4	46, 62	47, 62	1, 63	2, 63	8, 63	28, 63	58, 63	1, 64	12, 64	15, 64
4	17, 64	21, 64	23, 64	27, 64	29, 64	32, 64	35, 64	36, 64	38, 64	43, 64
4	44, 64	45, 64	7, 65	1, 66	7, 66	27, 66	30, 66	35, 66	49, 66	57, 66
4	62, 66	7, 68	16, 68	17, 68	19, 68	63, 68	66, 68	8, 69	18, 69	29, 69
4	30, 69	37, 69	58, 69	62, 69	67, 69	7, 70	11, 70	26, 70	63, 70	69, 70
4	8, 71	13, 71	28, 71	29, 71	31, 71	36, 71	37, 71	53, 71	27, 72	29, 72
4	49, 72	53, 72	57, 72	68, 72	70, 72	1, 74	14, 74	16, 74	21, 74	23, 74
4	50, 74	52, 74	63, 74	69, 74	71, 74	72, 74	29, 75	35, 75	36, 75	44, 75
4	62, 75	63, 75	2, 76	4, 76	5, 76	18, 76	65, 76	1, 77	7, 77	13, 77
4	27, 77	29, 77	30, 77	3, 78	6, 78	12, 78	14, 78	17, 78	19, 78	27, 78
4	46, 78	55, 78	71, 78	8, 79	13, 79	27, 79	28, 79	29, 79	31, 79	36, 79
4	37, 79	38, 79	39, 79	64, 79	74, 79	1, 80	7, 80	11, 80	12, 80	23, 80
4	41, 80	51, 80	63, 80	66, 80	69, 80	75, 80	77, 80			
2	2, 3	2, 6	6, 7	7, 8	5, 9	4, 11	7, 11	2, 12	9, 13	5, 14
2	8, 14	1, 15	4, 16	8, 16	3, 18	12, 18	2, 19	4, 19	10, 19	18, 19
2	12, 20	19, 20	11, 21	9, 22	12, 22	17, 22	18, 23	3, 24	6, 24	11, 24
2	17, 24	23, 24	1, 26	4, 26	13, 26	18, 26	7, 27	11, 27	13, 27	16, 27
2	23, 27	26, 27	9, 28	23, 28	26, 28	9, 29	14, 29	17, 29	23, 29	3, 30
2	6, 30	9, 30	15, 30	16, 30	17, 30	23, 30	6, 31	16, 31	17, 31	23, 31
2	3, 32	9, 32	14, 32	15, 32	6, 33	12, 33	16, 33	26, 33	5, 34	29, 34
2	14, 35	15, 35	17, 35	23, 35	26, 35	3, 36	9, 36	11, 36	16, 36	17, 36
2	19, 36	26, 36	34, 36	15, 37	9, 38	15, 38	26, 38	27, 38	3, 39	7, 39
2	16, 39	17, 39	34, 39	11, 40	12, 40	17, 40	26, 40	26, 41	27, 41	19, 42
2	26, 42	34, 42	2, 43	5, 43	13, 43	18, 43	21, 43	31, 43	32, 43	33, 43
2	37, 43	39, 43	2, 44	5, 44	32, 44	33, 44	38, 44	5, 45	21, 45	31, 45
2	33, 45	35, 45	36, 45	38, 45	8, 46	18, 46	30, 46	31, 46	33, 46	36, 46
2	1, 47	4, 47	5, 47	10, 47	20, 47	31, 47	35, 47	36, 47	2, 48	13, 48
2	29, 48	30, 48	31, 48	32, 48	33, 48	36, 48	39, 48	3, 49	6, 49	12, 49
2	14, 49	17, 49	19, 49	23, 49	46, 49	7, 50	8, 50	29, 50	31, 50	33, 50
2	27, 51	28, 51	29, 51	33, 51	40, 51	44, 51	32, 52	33, 52	37, 52	15, 53
2	16, 53	17, 53	43, 53	3, 54	6, 54	14, 54	16, 54	17, 54	23, 54	34, 54
2	47, 54	51, 54	2, 55	10, 55	20, 55	28, 55	42, 55	49, 55	26, 56	3, 57
2	6, 57	14, 57	15, 57	17, 57	19, 57	23, 57	44, 57	46, 57	50, 57	3, 58
2	6, 58	11, 58	16, 58	17, 58	23, 58	26, 58	47, 58	48, 58	55, 58	1, 59
2	4, 59	18, 59	27, 59	39, 59	42, 59	4, 60	24, 60	35, 60	39, 60	49, 60
2	54, 60	56, 60	8, 61	33, 61	44, 61	49, 61	58, 61	3, 62	6, 62	12, 62
2	14, 62	19, 62	23, 62	48, 62	50, 62	52, 62	55, 62	4, 63	5, 63	9, 63
2	10, 63	13, 63	20, 63	25, 63	27, 63	29, 63	37, 63	49, 63	56, 63	60, 63
2	7, 64	9, 64	14, 64	19, 64	9, 65	11, 65	12, 65	15, 65	19, 65	23, 65
2	34, 65	43, 65	44, 65	46, 65	47, 65	60, 65	2, 66	8, 66	22, 66	24, 66
2	33, 66	36, 66	53, 66	54, 66	56, 66	58, 66	3, 67	6, 67	12, 67	15, 67
2	16, 67	23, 67	43, 67	46, 67	47, 67	48, 67	50, 67	52, 67	55, 67	60, 67

"EVENS"

SPECIES PAIRS

SIMILARITY, %

80	3, 6									
78	3, 48	3, 71								
76	6, 71									
72	6, 48	48, 71	3, 79							
70	71, 79									
68	3, 46	46, 48	6, 79							
66	48, 79	52, 79								
64	3, 23	6, 66								
62	6, 46	3, 66	46, 71	52, 71						
60	23, 79									
58	3, 17	3, 52	6, 52	48, 52	17, 79					
56	6, 50	3, 72	23, 72	46, 79						
54	6, 17	23, 66	48, 66	23, 71	66, 79					
52	6, 23	23, 46	23, 48	17, 71	6, 77	66, 77	16, 79	72, 79	77, 79	
50	10, 20	16, 23	17, 23	17, 48	48, 50	46, 66	50, 71	66, 71	6, 72	17, 72
50	66, 72	3, 77	48, 77	43, 79						
48	3, 14	3, 16	3, 43	3, 50	23, 52	17, 66	48, 72	71, 72		
46	14, 48	43, 48	17, 52	46, 52	14, 71	46, 72				
44	6, 14	14, 17	16, 17	14, 46	16, 52	52, 66	3, 69	46, 69	16, 71	50, 79
44	69, 79									
42	6, 16	14, 26	17, 46	16, 48	50, 52	16, 66	16, 69	23, 69	43, 71	52, 77
42	71, 77	14, 79								
40	23, 43	46, 50	43, 52	58, 68	48, 69	58, 70	69, 71	14, 72	16, 72	52, 72
40	23, 77	46, 77	50, 77							
38	23, 26	16, 43	51, 61	17, 69	15, 71	44, 71				
36	3, 15	23, 34	6, 43	43, 46	15, 48	50, 66	6, 69	69, 77		
34	6, 15	14, 43	43, 44	16, 46	43, 63	14, 66	43, 69	19, 72	43, 72	16, 77
34	17, 77									
32	14, 16	19, 23	3, 26	17, 43	3, 44	15, 44	12, 46	15, 46	44, 48	14, 50
32	15, 50	17, 50	26, 51	14, 52	26, 52	43, 66	49, 68	52, 69	68, 70	47, 72
32	69, 72	43, 77	72, 77	68, 78						
30	6, 26	21, 38	15, 43	19, 43	6, 44	44, 45	45, 46	43, 50	44, 50	45, 50
30	15, 52	44, 52	48, 63	11, 66	26, 66	13, 68	14, 69	66, 69	11, 72	34, 72
30	15, 77	26, 77	15, 79	44, 79						
28	3, 12	11, 17	7, 19	11, 23	3, 45	44, 46	17, 47	23, 47	12, 48	45, 48
28	16, 50	3, 63	16, 63	17, 63	51, 66	26, 69	26, 71	45, 71	50, 72	26, 79
28	63, 79									
26	3, 11	6, 11	6, 12	12, 17	11, 26	16, 26	17, 26	19, 34	14, 44	23, 44
26	6, 45	26, 48	23, 50	47, 55	13, 59	12, 60	14, 63	23, 63	52, 63	12, 66
26	51, 69	63, 69	12, 71	63, 71	12, 72	59, 72	11, 77	12, 77	14, 77	51, 77
26	63, 77	59, 78	11, 79							
24	4, 5	13, 21	15, 23	5, 31	10, 33	3, 34	14, 34	16, 34	17, 34	34, 46
24	3, 47	11, 48	3, 51	12, 51	16, 51	23, 51	46, 51	48, 51	11, 52	45, 52
24	23, 55	17, 59	23, 59	15, 66	34, 66	47, 66	63, 66	53, 67	12, 69	34, 69
24	47, 69	50, 69	42, 70	15, 72	26, 72	44, 72	51, 74	44, 77	19, 79	
22	9, 11	14, 15	11, 16	3, 19	14, 19	16, 19	12, 23	5, 29	7, 34	26, 34
22	14, 45	17, 45	23, 45	43, 45	11, 46	19, 46	26, 46	34, 48	21, 49	26, 50
22	6, 51	17, 51	19, 52	19, 55	51, 60	6, 63	7, 63	34, 63	46, 63	30, 64
22	44, 66	21, 68	19, 69	34, 71	45, 72	55, 72	63, 72	53, 74	64, 75	11, 76
22	13, 78	12, 79	34, 79	45, 79	51, 79					
20	11, 12	12, 14	15, 17	17, 19	14, 26	15, 26	6, 34	34, 38	28, 39	26, 43
20	34, 43	16, 44	11, 47	16, 47	46, 47	19, 48	13, 49	38, 49	50, 51	34, 52
20	51, 52	26, 55	54, 58	6, 59	16, 59	34, 59	47, 59	55, 59	47, 60	26, 61
20	19, 63	44, 63	5, 65	18, 65	55, 66	59, 66	38, 68	11, 69	15, 69	55, 69
20	61, 69	11, 71	51, 71	9, 72	59, 76	49, 78	47, 79			

Appendix E.

BIBLIOGRAPHY

BLACK, J.M. (1943-1957).- Flora of South Australia. 1010 pp. (Govt. Printer, Adelaide).

BLACKBURN, G. (1959).- The soils of County Grey, South Australia. C.S.I.R.O. Aust. Soils Land Use Ser. No. 33.

BLACKBURN, G. (1964).- The soils of Counties MacDonnell and Robe, South Australia. C.S.I.R.O. Aust. Soils Land Use Ser. No. 45.

BLACKBURN, G., et al. (1965).- Soil development associated with stranded beach ridges in South-East South Australia. C.S.I.R.O. Aust. Soil Pub. No. 22.

BREWER, R. (1960).- Cutans: their definition, recognition, and interpretation. J. Soil Sci. 11: 280-292.

BURBIDGE, Nancy T. (1960).- The phytogeography of the Australian region. Aust. J. Bot. 8: 75-211.

BURGES, N.A. (1960).- Time and size as factors in ecology. J. Ecol. 48: 273-285.

BURGES, N.A., and DROVER, D.P. (1953).- The rate of podsol development in the sands of the Woy Woy district, New South Wales. Aust. J. Bot. 1: 83-94.

CAIN, S.A. (1932).- Concerning certain phytosociological concepts. Ecol. Monog. 2: 475-508.

CAIN, S.A., and CASTRO, G.M. de O. (1959).- Manual of Vegetation Analysis. 325 pp. (Harper, New York).

CLEMENTS, F.E. (1916).- Plant Succession. 512 pp. (Carnegie Institution, Washington).

COOPER, C.F. (1963).- Bibliography of the Effects of Fire on Vegetation. Soil Cons. Authority, Vict.

COULSON, A. (1940).- The sand dunes of the Portland district and their relation to post-Pliocene uplift. Proc. Roy. Soc. Vict. 52: 315-335.

CROCKER, R.L. (1941).- Notes on the geology and physiography of South-East, South Australia, with reference to late climatic history. Trans. Roy. Soc. S. Aust. 65: 103-107.

CROCKER, R.L. (1944).- Soil and vegetation relationships in the Lower South-East of South Australia. A study in ecology. Trans. Roy. Soc. S. Aust. 68: 144-172.

CROCKER, R.L. (1946).- Post-Miocene climatic and geologic history and its significance in relation to the genesis of the major soil types of South Australia. Coun. Sci. Industr. Res. Aust. Bull. No. 193.

CROCKER, R.L., and COTTON, B.C. (1946).- Some raised beaches of the Lower South-East of South Australia and their significance. Trans. Roy. Soc. S. Aust. 70: 64-82.

CROCKER, R.L., and WOOD, J.G. (1947).- Some historical influences on the development of the South Australian vegetation communities and their bearing on concepts and classification in ecology. Trans. Roy. Soc. S. Aust. 71: 91-136.

CURTIS, J.T. (1959).- The Vegetation of Wisconsin. An Ordination of Plant Communities. 657 pp. (Univ. of Wisc. Press).

DALY, R.A. (1934).- The Changing World of the Ice Age. 272 pp. (Yale Univ. Press).

De MOOY, C.J. (1959).- Notes on the geomorphic history of the area surrounding Lakes Alexandrina and Albert, South Australia. Trans. Roy. Soc. S. Aust. 82: 99-118.

DICKSON, B.A., and CROCKER, R.L. (1953).- A chronosequence of soils and vegetation near Mt. Shasta, California. I and II. J. Soil Sci. 4: 123-157.

DIVER, C. (1940).- The problem of closely related species living in the same area. In The New Systematics: 303-328. (Clarendon Press, Oxford).

EWART, A.J. (1930).- Flora of Victoria. (Govt. Printer, Melbourne). 1257 pp.

FENNER, C. (1930).- The major structural and physiographic features of South Australia. Trans. Roy. Soc. S. Aust. 54: 1-36.

GILBERT, J.M. (May, 1962).- Fire as a factor in the development of vegetation types. (Paper to Inst. Foresters Aust., Conference, Melbourne).

GOODALL, D.W. (1953).- Objective methods for the classification of vegetation. I. The use of interspecific correlation. Aust. J. Bot. 1: 39-63.

GREIG-SMITH, P. (1957).- Quantitative Plant Ecology. 198 pp. (Butterworth, London).

HAGERSTROM, R.C. (1965).- Agriculture in South Australia. The Lower South-East. J. Agric., S. Aust. 68 (7): 200-214.

HILLS, E.S. (1939).- The age and physiographic relationships of the Cainozoic volcanic rocks of Victoria. Proc. Roy. Soc. Vict. 51: 112-140.

HOSSFELD, P.S. (1950).- Late Cainozoic history of the South-East of South Australia. Trans. Roy. Soc. S. Aust. 73: 232-279.

JARRETT, Phyllis H., and PETRIE, A.H.K. (1929).- The vegetation of the Black's Spur region. II. Pyric succession. J. Ecol. 17: 249-281.

JOHNSON, D.W. (1938).- Shore Processes and Shoreline Development. (Wiley, New York).

KEAST, A., CROCKER, R.L., and CHRISTIAN, C.S. eds. (1959).- Biogeography and Ecology in Australia. Monographiae Biologicae No. 8. 640 pp. (W. Junk, The Hague).

KERSHAW, K.A. (1957).- The use of cover and frequency in the detection of pattern in plant communities. Ecology 38: 291-299.

KERSHAW, K.A. (1960).- The detection of pattern and association. J. Ecol. 48: 233-242.

LUDBROOK, N.H. (1963).- Correlation of the Tertiary rocks of South Australia. Trans. Roy. Soc. S. Aust. 87: 5-15.

O'DRISCOLL, E.P. (1961).- The hydrology of the Murray Basin province in South Australia. Geol. Surv. S. Aust. Bull. No. 35.

(1) ADDENDUM

SPRIGG, R.C. (1952).- The geology of the South-East Province, South Australia, with special reference to Quaternary coast-line migrations and modern beach developments. Geol. Surv. S. Aust. Bull. No. 29.

SPRIGG, R.C. (1959).- Stranded sea beaches and associated sand accumulations of the Upper South-East. Trans. Roy. Soc. S. Aust. 82: 183-193.

STEPHENS, C.G. (1962).- A Manual of Australian Soils. 61 pp. 3rd Ed. (C.S.I.R.O., Melbourne).

STEPHENS, C.G. *et al.* (1941).- A soil and land use survey of the Hundreds of Riddoch, Hindmarsh, Grey, Young and Nangwarry, County Grey, South Australia. Coun. Sci. Industr. Res. Bull. No. 142.

SYMPOSIUM (1964).- The basalt plains of Western Victoria. *Proc. Roy. Soc. Vict.* **77**: 329-432.

TINDALE, N.B. (1933).- Tantanoola Caves, South-East of South Australia: geological and physiographical notes. *Trans. Roy. Soc. S. Aust.* **57**: 130-142.

TINDALE, N.B. (1947).- Subdivision of Pleistocene time in South Australia. *Rec. S. Aust. Mus.* **8**: 619-652.

TINDALE, N.B. (1959).- Pleistocene strandlines of the Upper South-East of South Australia. *Trans. Roy. Soc. S. Aust.* **82**: 119-120.

WARD, L.K. (1941).- The underground water of the south-eastern part of South Australia. Geol. Surv. S. Aust. Bull. No. 19.

(1) ADDENDUM

WILLIAMS, W.T., and LAMBERT, J.M. (1959-1961).- Multivariate methods in plant ecology. I-III. *J. Ecol.* **47**: 83, **48**: 689, **49**: 717.

WOOD, J.G. (1930).- An analysis of the vegetation of Kangaroo Island and adjacent peninsulas. *Trans. Roy. Soc. S. Aust.* **54**: 105-139.

WOOD, J.G. (1937).- The Vegetation of South Australian. 164 pp. (Govt. Printer, Adelaide).

WOOD, J.G. (1939).- Ecological concepts and nomenclature. Trans. Roy. Soc. S. Aust. 63: 215-223.

ZEUNER, F.E. (1959).- The Pleistocene Period. 447 pp. (Hutchinson, London).

---

(1) ADDENDUM

SNEATH, P.H.A. (1962).-The construction of taxonomic groups. In Microbial Classification. (Cambridge Univ. Press): 289-332.

SOKAL, R.R., and SNEATH, P.H.A. (1963).-~~The~~ Principles of Numerical Taxonomy. 359pp. (Freeman, San Francisco).

WARD, W.T., and JESSUP, R.W. (1965).- Changes of sea-level in Southern Australia. Nature 205 (4973): 791-792.

WILLIAMS, M. (1964).- The historical geography of an artificial drainage system: the lower south east of South Australia. Australian Geographical Studies 2: 87-102.