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Cover photograph
Late afternoon in the southern jarrah forest.
Mature forest near Yanmah, north-west of Manjimup.

Back cover photograph
A Spring display of indicator species in flower in the southern jarrah forest - Clematis pubescens *(white),* Hovea elliptica *(purple),* Acacia urophylla *(yellow).*

Photography - Ashley de Prazer.

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Abstract

THIS paper describes an ecological survey of the southern jarrah forest of Western Australia and provides an analysis of the data to determine site-vegetation types for use in stratification of the forest for management.

The study area is described and compared with the northern jarrah forest where a similar site classification system is used for management. The methods and data analysis are outlined. Analysis was based on principal component analysis and correlation coefficients.

The environmental conditions determining the site-vegetation types were interpreted using this analysis. Site moisture relations and drainage, and soil structure, development and fertility were the major influences determining site types. Their influence on forest structure and growth, dieback and regeneration are discussed.

Seventeen site types delineated from the ordination are described in Appendix III. Particular reference is made to regeneration, dieback and site productivity in the management of these site types.

Introduction

JARRAH (*Eucalyptus marginata* Donn ex Sm.) is unique to the south-west of Western Australia. Today the area of jarrah forest is restricted to approximately 1.5 million hectares from its original distribution of possibly three million hectares. There are pressures for further reductions in this area from alienation, mining and service facilities, and for increased usage of the remaining forest areas. To deal with these increasing pressures more intensive management is required. This in turn requires a better understanding of the forest, and information on which to base management decisions.

The jarrah forest covers four degrees of latitude and a variety of sites, climatic zones and geology over its range (Wilde and Walker 1984). Although it does occur in almost pure stands, it is generally found with other species such as marri (*E. calophylla* R. Br.), blackbutt (*E. patens* Benth.), wandoo (*E. wandoo* Blakely) in the east, and karri (*E. diversicolor* F. Muell.) in the south. This variation makes dealing with the forest as one unit very difficult. By classifying the forest, managers can better identify units which need to be managed differently. Earlier classifications based on forest structure were too broad for detailed management and subject to changes with time.

Work by McArthur and Clifton (1975) on soils and geomorphology of the Pemberton area was similarly prompted by the need for a classification in which land use and management problems could be dealt with. They considered that the agricultural production potential of the area was not being realised and that future conflict for agricultural land use with other uses such as forests, was likely to increase.

It was their intention that their report would provide basic information for long-term resource management in the area. Their survey provided a useful stratification for the planning of this study also, but more detail was needed to make the important decisions facing land managers. Their classification was too broad to fit the units relevant to current forest land management.

The classification of site types or site-vegetation types is based on the relationships of soils, geomorphology, climate and vegetation. Vegetation is seen as the integrator of all the site characteristics such as fertility, moisture and drainage (Havel 1975a). This style of classification is versatile and robust in resisting the vagaries of time or disturbance and revealing the characteristics of the site which will affect how it should be managed. Because the vegetation changes in response to very minor changes in site conditions it can be used to delineate any specific unit of management.

This site type classification work has been carried out in parts of the jarrah forest by Havel (1975a, b) and McCutcheon (1978, 1980), and in relation to fauna habitats by Christensen (1980), but the bulk of the southern jarrah forest areas remain unclassified.

It was postulated, therefore, that this same type of classification could be used in the southern jarrah forest (Fig. 1) to aid management. The objective in this study was to analyse the site variation within the forest based on vegetation, and delineate classes of similar sites to which information such as stand structure, regeneration and soils could be correlated. The correlated information can then be used to describe those classes. The description of each class and how they respond provides a basis to make management decisions for each site class.

How a site type will respond, for instance to dieback (*Phytophthora cinnamomi*), can be either inferred from site characteristics such as drainage and fertility, assessed by a survey correlating site and dieback impact, or researched using specific trials. The information on site behaviour can then be used to prescribe management for that situation on a particular site.

Already in the northern jarrah forest the site classification by Havel (1975a) is being used to make decisions on land use priorities, management of the jarrah dieback disease problem, logging and regeneration requirements and fauna and flora management. It was obvious to managers that this information was essential for the southern forest areas also. A particular concern was regeneration requirements of different sites, and this aspect has been emphasised in this study.

As the following discussions show, the study area in the southern jarrah forest differs considerably from that of the north as described by Havel (1975a), particularly in the greater variability and mosaic of soils and geology. The early work of Diels (1906) recognised, apart from the more obvious east-west trend, a north-south trend in species distribution within the jarrah forest and in the structure and composition of the forest. McArthur and Clifton (1975) commented that the area they studied contains soils and soil-landscape units which have been recognised for many years as unusual in Western Australia and this was one of the reasons for their survey. Both McArthur and Clifton (1975) and Havel (1975a) recognised soils and landscape position as important factors, along with climate, in influencing vegetation upon which recent site classification studies have been based.

Climate, though it differed significantly, showed a gradation from the coast to the north-east similar to the northern forest's west to east trend. Because of climatic differences and the significant changes in soils and geology, however, it was obvious that the site classification for the north could not be overlaid on the southern forest areas.

A separate classification system was necessary. This study set out to provide such a system. One which could be used to categorise, describe and identify units of land relevant to the management decisions to be made with whatever detail was required. The area classified must relate to the management issues such as dieback, silviculture and regeneration, and respond in predictable ways to the management prescribed.

This paper describes the study area (Fig. 1) in comparison with the northern jarrah forest, the procedures used to assess and analyse the differences within the southern forest, and the results obtained. The results include the description of site types defined from the survey.

Description of the Study Area

Location

The area to which this study applies covers most of the main jarrah forest area around Manjimup, Pemberton, Northcliffe and southwards towards Walpole in the extreme south-west of Western Australia. The area covered, of approximately 7 000 km^2, is shown in Figure 1. It extends from the area north of Manjimup south to the vicinity of Mount Chudalup, inland from the southern coast at Pt. D'Entrecasteaux and west to east from the line of the Darling Scarp to Lake Muir.

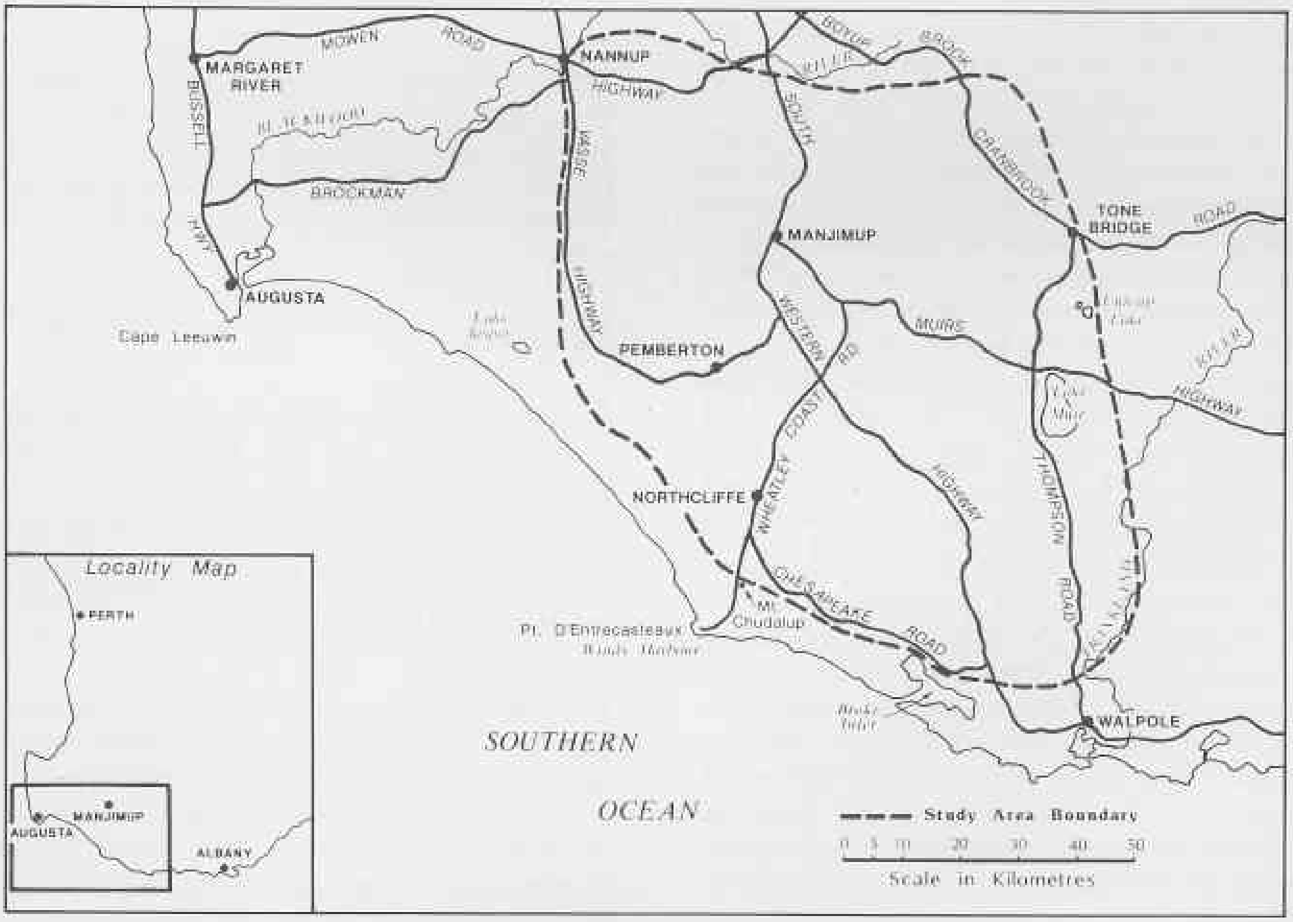

Figure 1
Map of the southern jarrah forest area of the south-west of W.A.

Geology, Topography And Drainage Features

These features have been described in detail by McArthur and Clifton (1975) for the majority of the study area, but a brief description is provided here. The study area is the southern extremity of the Great Plateau (Jutson 1934), and has a basement of Precambrian gneissic rocks (McArthur and Clifton 1975). The gneiss varies in composition, the rock types consisting of acid to basic banded gneisses and granulites which are predominantly metamorphic. Cope (1975) has subdivided the Plateau along a hingeline, the Jarrahwood axis, in the vicinity of Manjimup. To the north is the Darling Plateau, an ancient erosional surface with an average height in that vicinity of 300 m above sea level with much laterisation occurring during the Tertiary period. The Darling Plateau extends north through the northern jarrah forests. The area to the south, covering much of the study area, is known as the Ravensthorpe Ramp.

The Ramp is characterised by the gently sloping nature of the dissected lateritic surface. The remnants of the lateritic duricrust are common in the northern sector at 280 m above sea level around Manjimup, and decreasing in occurrence to the south and in altitude to almost merge with the lateritic remnants of the Blackwood Plateau as the Darling Fault to the west of the area loses definition. The lateritic remnants are much less common than on the Darling Scarp to the north. The remnants appear to pass below the sandy coastal plain at Mt Chudalup at the southern edge of the study area. These basic differences in geology and geomorphology between northern and southern jarrah forest result in differences in proportion and distribution of similar sites, and to some extent in the nature of sites between north and south.

The two major drainage systems in the area are the Warren-Tone and the Frankland Rivers. The latter only drains parts of the eastern extremities of the study area around Lake Muir. Both drainage systems tap the broad Tertiary alluvial flats which extend onto the Ravensthorpe Ramp from the north-east (Wild and Walker 1984). This gives these streams the characteristic sequence of valley forms of the major northern rivers, with broad sluggish drainage in their upper reaches through to more deeply incised valleys of rejuvenated channels in the Pemberton landform (McArthur and Clifton 1975). They become sluggish and swampy again as they pass through the coastal sands and estuarine deposits. Drainage is generally south-westerly but is apparently influenced by the underlying geology and perhaps earlier Tertiary drainage patterns, causing many right-angled turns and horseshoe bends.

The Gardner drainage system rises in the steeply dissected Pemberton landform north-west of Northcliffe, and is much shorter than the two former systems. It does not extend back to tap the earlier drainage deposits of the Darling Plateau, and is a younger stream. It also flows generally south-westerly and becomes very sluggish through the coastal belt. The mouth has been deflected eastwards by sand accumulations as have many of the other streams. The Shannon and Deep drainage systems are of intermediate size rising in the flatter less dissected landscape of the Nyamup and Balbarup landforms (McArthur and Clifton 1975), with swampy headwaters. Only the northern portions of their basins are in the study area.

There are also two very small streams, the Meerup and Doggerup Creeks, entirely within the coastal belt. They run in very broad poorly defined channels through swampy sands and estuarine deposits. Like the major streams they run south-westerly to the coast.

Climate

The climate of the area has been generally described as mediterranean, but with strong oceanic and topographical influences. The distribution of many of the climatic features follows the coastline as it swings eastward along the south-coast creating a north-east to south-west pattern rather than the west to east trends of the northern forest.

The small changes in latitude cause marked differences in some features. The growing season opens mid February in the extreme south, but not until the end of March at Manjimup or mid April in the Armadale area in the north. The length of growing season ranges from ten months to seven and a half months to six months respectively (Bureau of Meteorology 1965).

Rainfall decreases from around 1 400 mm/annum near the coast to around 800 mm/annum in the north-east. This is similar to the range in the northern jarrah forest, though the maxima are concentrated farther from the coast on the western edge of the plateau in the north. The main climatic difference between northern and southern forests is the rainfall distribution through the year. In the north, except for a small cell around Dwellingup, summer rainfall (November-March inclusive) is in the range of 25 to 30 mm/month. In the south, however, it ranges from just over 25 mm/month in the north-east to 65 mm/month south-west of Pemberton.

Temperature is probably the next most important climatic factor influencing vegetation and soil development. The minimum and maximum temperatures are much lower than in the north (Bureau of Meteorology 1975). Summer temperatures are cooler nearer the coast, with temperatures greater than 32°C occurring on average, ten days/annum for Pemberton and twenty days/annum for Manjimup. Winter temperature trends are reversed.

The number of minima of 2°C or less average fifteen days/annum at Manjimup and five days/annum at Pemberton. The number of frosts per annum show similar trends and their high frequency in the inland areas may have a significant influence on the vegetation (Diels 1906).

Vegetation And Soils

The vegetation in the study area has only been described in general terms (Smith 1972; Specht 1970). The soil associations were described in detail for small areas by McArthur and Clifton (1975), and were used to stratify the preliminary sampling. During the course of this study further work was undertaken on soils and landform and may be available soon (Churchward *et al.*, 1988).

Generally, soils higher in the landscape consist of laterites with lateritic gravels and associated podzols. Leached grey sands with deep pallid zones often occur on or near the drainage divides. The laterites give way south of Manjimup to red earths, often with gravelly horizons. The podzols grade into podzolised sands and then to the undifferentiated calcareous sands of the coastal belt.

Lower in the landscape soils may be brown sands and sometimes orange earths. The lower slopes below laterites often consist of gravelly red earths or red podzols. As the laterites become less common and there is more dissection on minor streams, these red earths extend to the midslopes and ridges.

In the eastern parts of this study area there is less dissection, and drainage lines are filled with sandy deposits creating large flats. In the south-east the pattern becomes one of islands of gravelly red earth and podzolic soils emerging from sandy humus podzols in drainage lines. Bradshaw and Lush (1981) present an interesting picture of these features in relation to karri distribution.

The vegetation of the area has not been described in detail, but only in relation to structure and formations which do not really reflect the great diversity in a continuum of species and structural changes. When compared with the site classification work by Havel (1975) in the northern forest the occurrence of species and their site preference was markedly different. This is due no doubt to movement along this continuum from northern to southern forest in the major determining factors such as soils and climate.

Some vegetation information is available for the study area in that Smith (1972) has produced a map covering the study area, based on the classification proposed by Specht (1970). This classification uses floristics and structure in general terms of major species and height and density of the tallest stratum.

The system thus identifies formations such as open forest, open woodland, closed scrub, tall open shrubland and sedgeland, but there are many divisions based on variations in density and major species. For each category Smith describes the typical species and occurrence. Similar to broad soil associations, Smith has also grouped these plant associations into vegetation systems where the associations combine in a sequence or pattern of occurrences and proportions linked to topographic or edaphic factors. These systems are described as follows:

1. The Mooralup system is the main karri forest zone with its admixtures of jarrah, marri and the tingles (*E. jacksonii*, *E. guilfoylei*, *E. brevistylis*). It includes some low closed scrub or forest in

gullies, and the stunted jarrah and paperbark and sedgelands of the broader drainage lines in the south.

2. The Darling system is the jarrah area of dissected country east of the escarpment and its associations with marri, W.A. blackbutt (*E. patens*) and W.A. flooded gum (*E. rudis*). There are also flats with paperbarks (*Melaleuca* sp.) and banksias (*Banksia* sp.).

3. The Jingalup system occurs in the north-east where wandoo appears in the valleys and lower slopes. In wetter areas swamp yate (*E. occidentalis*) occurs and flooded gum is found along the main streams. Jarrah is still dominant on the lateritic ridges.

4. The Scott River system is the extensive area of seasonally wet flats south of the karri forest. Here there is a mixture of low jarrah woodland, stunted jarrah, paperbarks, banksias and sedgelands in the wetter flats. There are also many swamps and small lakes. There are small rises of open jarrah forest, but more commonly occurring are narrow sandy ridges of banksia low woodland.

5. Along the coast is the Boranup system. On the inland side of stabilised dunes occur stands of karri, jarrah, marri, yate and bullich. Much of the dunes are covered with peppermint (*Agonis flexuosa*). On the foredunes and recent dunes are heaths, shrublands and grasslands. There are also extensive areas of unstabilised dunes.

Management of the southern forest for recreation planning, logging, dieback disease and fire management is already at a more detailed level than these vegetation units would allow. They cover too many vegetation complexes and do not provide any detail of the character of the units to assist with a system of management. The aim of this study was to classify the vegetation into associations which could provide useful indications of site characteristics such as productivity, regeneration capacity and dieback susceptibility, for units of sufficient detail to be useful for current management needs. By the methods used it was also intended to determine the environmental and edaphic factors which affect the distribution and abundance of species and determines their site preferences. This would provide the clues to a site's characteristics such as soil development, drainage, moisture and fertility, to assist in decision making for that site's management.

Methods

Preliminary Species Selection

Havel (1975a) discusses various methods used in site classification work and concludes that the use of vegetation as the basis of the survey procedure is the best option. This is favoured because of the lack of soil survey data at the detail required. McArthur and Clifton's (1975) work was neither detailed nor extensive enough.

A later project by Churchward *et al.* (1988) may have been suitable for a combined soils and vegetation approach but was not available at the time this study was commenced and covers only part of the area. McCutcheon (1980) used this approach in the Sunklands jarrah forest.

The successful application of a vegetation-based classification by Havel (1975a) and Christensen (1980) also favoured its use. It was evident from these studies that selection of species for the survey was critical to the success of the classification.

Consequently, a reconnaissance was first carried out to identify plant species likely to occur in the sampling, which might be useful indicators of site characteristics, and hence could be used to identify site classes.

To be a useful indicator a species had to be readily identifiable at any time, since classification would need to be carried out throughout the year. Thus species which were distinguishable only by floral parts were not considered, nor were species which were not identifiable throughout the year, such as annuals and orchids. Rare species, whose distribution was too restricted or occurrence too infrequent to be of use as indicators, were also excluded.

The resultant species list contained 211 individual species (see Appendix I). A large proportion of these were not encountered often enough in the survey to be useful. However, all species were considered in sampling in order to retain the continuity of the results. This will ensure any future work in new areas where some of these species become significant will be comparable. As described later, the number of species used in the data processing was reduced to 100.

Selection Of Sampling Sites

Over 400 sample sites were assessed in this survey. The sampling was carried out in two stages, firstly to obtain a broad coverage of the study area, and then to concentrate on areas of regeneration and dieback (*Phytophthora cinnamomi*) to highlight these management concerns.

To obtain a broad coverage by systematic sampling in such a large area was not feasible. A stratification based on the detailed soil surveys of McArthur and Clifton (1975) was used, plus some additional units which did not appear to be covered in their survey. Within the main soil types, sampling units were subjectively located. Because of the low incidence of dieback and small variation in regeneration treatment in the southern jarrah forest, samples in these areas were also subjectively located to take best advantage of the areas available. Since soils were described at each plot, these sites could also be compared with units described by McArthur and Clifton (1975) and Churchward *et al.* (1988).

Within a sample area plots were located systematically along a transect, the number of plots depending on the size and variability of the area.

Field Measurements and Observations

After selection of the sample points in the office they were located by compass and chain in the field. Circular plots were established around the point. The plots were tied in to a relocatable point and marked with a centre peg for easy relocation.

At each plot the following details were recorded:

Vegetation

The abundance of each indicator species present was estimated using a five-point cover rating (Havel 1975a) within a 20 m radius. Tree species abundance was considered over a larger radius within the site type.

Structure

Structural measurements were taken to relate to types, to aid in the description of site characteristics and in the formation of management guidelines.

Numbers of each tree species were tallied throughout the 20 m radius by sapling, pole and tree size classes and the basal area of each species was measured using a wedge prism.

Cutting history was recorded by assessing stump numbers and size, estimating age, and later checking office records. This was also used to give some indication of whether there had been adequate time for replacement.

The codominant height, percentage canopy cover and scrub height were measured and an estimate of percentage scrub cover was made.

Regeneration

A detailed assessment of regeneration was required to identify problem sites and correlate regeneration potential with other site characteristics. With jarrah it is important to specify what class of regeneration is concerned because of the long development times involved. Five classes of regeneration were tallied over 60 m^2 by species.

The classes were:

seedling - generally less than 1-year-old with no lignotuber as yet and often with cotyledons remaining.

lignotuberous seedling - an established seedling, still retaining the original shoot and the lignotuber present.

lignotuberous coppice - generally older regeneration which has recoppiced from the lignotuber after damage such as fire, or insect attack and may have a few shoots.

incipient lignotuber - a well established lignotuber with multiple stems, but generally less than 1 m tall with no specific leader and likely to remain dormant.

dynamic lignotuber - generally greater than 1 m tall and having developed a main leader, indicating that it will grow on to the sapling stage.

Site Records and Descriptions

The aspect, topographical position, slope and litter depth were recorded for each plot. Time since the last burn was estimated and later checked against office records. The average annual rainfall for the area was also noted from meteorological maps. The number of fauna habitable tree hollows was also noted to assist with fauna studies in relation to site type.

The occurrence and impact of dieback disease was rated after an extended version of that described by Brandis (1983), viz:

(0) nil dieback
(1) isolated Indicator Species Deaths (ISD's), low probability of dieback association.
(2) scattered ISD's.
(3) groups or clusters of ISD's.
(4) Multiple ISD's - a number of species involved, high probability of dieback association.
(5) gap development - paucity of susceptible species in large gap with some ISD pattern around edge.
(6) overstorey expression - low, 1-2 deaths per hectare
(7) overstorey expression - moderate, <5 deaths per hectare.

(8) overstorey expression - high, >5 deaths per hectare.
(9) overstorey expression - graveyard dieback site.

Site Notes

There was also provision for comments about dieback expression or other diseases, insect damage, hydrology and drainage features, occurrence of rock, and comments on the forest soils or other features, such as disturbance, which might be unusual or affect the species composition.

Soils

At each plot a sample of the soil from the surface horizons was taken for analysis to relate site characteristics and indicator species. These were analysed for gravel content, acidity, per cent total soluble salts, per cent organic carbon, per cent total nitrogen, phosphorus in ppm (HCL), potassium me% (HCL), exchangeable calcium me%, exchangeable magnesium me%, and cation exchange capacity me%. At the majority of plots, to ensure adequate representation of sites, a soil profile description was also made based on the system of Northcote (1974).

Results

Data Analysis

This section provides an outline of the techniques used to analyse and interpret the data, and discusses the interpretation of species and plot distribution in terms of the environmental trends revealed by the analysis.

The methods used to analyse vegetation associations have been reviewed and described by Havel (1975a). Some of these techniques as well as more recent developments, as described below, were used in the data analysis for this study. Principal component analysis (PCA) provided the basis for the definition of the site types but other techniques provided additional assistance and information. Although, as Havel describes, there are some discrete associations of species to be found, the changes in species composition form a continuum and thus ordination is the only alternative to provide an integrated picture of the relationships and by which the factors governing those changes can be interpreted. The ordination of species places them in a matrix showing each species in relation to others. This linking is the basis for understanding which environmental factors control the species distribution.

Havel mentions the ordination technique has disadvantages, for example, the ordination does not provide discrete site type categories. However, the ordination matrix can be subjectively subdivided to give useful classes. The advantage is that this can be done to provide classes which represent suitable management units. The units can then be adjusted or redivided for new management interests or increased management intensity if necessary.

The second difficulty is in extending the survey and including new samples. However, recent correlation techniques allow association of new samples to the existing data where they best fit.

Preliminary Analysis

1. The first step in the data analysis used 'Condescriptive' and 'Frequencies' programs of the SPSS system which provide simple statistics such as means, minima and maxima. This helped in checking for errors in the data and was also used to reduce the number of species by excluding rare and very common species.

   Such species tend to make processing and interpretation more complicated because they can give high correlations but are often poor site indicators. Some species, like jarrah, can be significant in their absence, so commonness is not necessarily an indication of a poor indicator species. Some familiarity with the species concerned is therefore necessary in species selection.

2. The program RECAV, a form of Reciprocal Averaging as described by Hill (1958), was used initially to ordinate the data. However, it did not give a very good separation of the species. Nearly all species were clustered at one end of each axis with only a few at the other extreme. This made it difficult to interpret the relationships and subdivide the framework into groups. The poor results using RECAV may have been due in part to some loss of resolution when species records were pooled for plots in what appeared to be similar sites. This was necessary to reduce the data base to a more manageable size required for the program.

Because of the results with RECAV it was decided to do some further preliminary analysis before the PCA to gain a better understanding of species inter-relationships and site preferences, otherwise it would be difficult to interpret the PCA ordination.

3. A locally developed program called MAYHAP which derives a matrix of V-coefficients (Krebs 1972) was used to look at associations and dissociations between species. When compared with well understood species (through field experience) the correlations between species helped in the interpretation of site preferences of species which were less familiar. It helped form notions of the underlying environmental factors governing species distribution and natural associations of species.

   This analysis also assisted in a further reduction in the indicator species to 100 as a more manageable data base to use in the PCA. A number of species were found which nearly always occurred together and it was therefore necessary to include only one. These tended to be in extreme habitats which were easily identifiable.

   The ultimate reduction to 100 species was made through considered decisions based on field experience and knowledge of the species, such as: which were considered to be better indicators, how many other indicators of that site/characteristic were included, how often the species occurred.

4. MAYHAP was also used to cluster the plots based on the similarities of their species composition. The associations were used in the later interpretation of the PCA to assist in associating outlying or marginal plots with groups in the PCA framework.

   The MAYHAP V-coefficients were not used to classify the plots because they give no indication of the relationships between such groupings and thus no interpretation of how they fit into the continuum of site vegetation types, nor what factors determine the changes. Nor is an overview possible to assist in making the arbitrary cutoffs between groups. And it would be a tedious task to sort out all the clustered plots from a 400 x 400 correlation matrix.

5. The Czekanowski coefficient (Goodall 1973) was used to provide a better association estimate for this type of data as it compares the abundance scores of indicator species rather than just presence or absence. If it were possible to weight each coefficient in some way it would greatly improve this technique since some indicators are more reliable and constrained than others. This consideration was not relevant in PCA as the technique merely positions plots in space dependent on their overall similarity. The judgment of whether they are similar enough to combine is then up to the interpreter.

   The Czekanowski coefficient must be run at a number of probability levels before all plots can be incorporated. Only a few plots will associate at the highest level of 0.8 or 0.9 and so the remaining plots must be progressively attributed to groups. This information can be used, however, to establish the loci of groups in the PCA framework.

   The Czekanowksi coefficient also has the limitation of not providing an insight into the relationships between groups and the environment parameters determining the variation - that is, how they fit along the continuum.

   A listing of the 'Best Associates' from the Czekanowski coefficient was useful to help establish cutoffs between groups and allocate marginal plots.

Distribution of Species

The PCA program from the SPSS system (R type, PA1 with Varimax Rotation) was used to ordinate the species data. This provided a good framework to examine relationships between species and to begin to explore the environmental gradients influencing the variation within the co-ordinate framework (see Plate 1, Species Model).

Various manipulations of the data matrix were attempted to give a more easily interpretable species model. The main differences were achieved with square root and fourth root transformations. Because the matrix congested on the positive end of the second component axis, the square root transformation helped to disperse these points and draw in the points on the negative end. The fourth root transformation made the distribution too segmented but did help to identify the -C2 group which was separated out in some analyses to further disperse the array on the +C2 axis.

The grouping of species confirmed some associations observed in the field and revealed new perceptions as well. Species preferring gravelly or sandy soils, fertile or infertile soils, dry or moist sites and so forth could be identified. Relative positions of species and their site preferences could be seen from the model and the closeness of their associations was shown in the correlation matrix. Strong negative correlations were also useful in the interpretation of site preferences.

The plots of species on the components are shown in Figures 2 and 3. The distribution of species on axis 1 and 2 (Fig. 2) of the framework shows the main extensions on the +C1 and -C2. These correspond to species of the gravelly sites and the low rainfall eastern sites respectively. At the intersection of the axes are the species preferring sandy sites and outside these in -C1/+C2 quadrant are the species of the more fertile loams.

The distribution of species on C3 and C4 (Fig.3) has an elliptical shape with an apex on the +C4 representing species on sandy sites. On the C3 the drier and wetter sites are at the +C3 and -C3 respectively. These interpretations are based on knowledge gained in the field, of species occurences crystalised by examining species correlations and distribution on the axes, together with data from Havel's analysis (Havel 1975a) where species were similar.

Relationships of species distribution with environmental gradients were not easily interpreted, particularly on the C3 and C4 axes, and there appeared to be a mixture of factors influencing the distribution on these axes which made interpretation difficult. These first four components accounted for only 25 per cent of the total variation in the data.

A limitation of the species ordination was that a species is represented only by a point in the matrix so there is no indication of how widely it occurs in the matrix or how reliably it occurs. To overcome this limitation an ordination of the plots was used.

Distribution of Plots

To ordinate the plots the program FACVA (Havel 1975a) was used. This uses the same ordination matrix and derives plot co-ordinates from the combined species co-ordinates and their relative abundance value on each plot. Thus the plots are positioned in the component space based on their similarities or dissimilarities with each other. Since the object of the study was to define biologically similar sites, ordination of the plots enables definition of site types based on similar groups of sites rather than species.

A plot model (Plate 2) was constructed using these co-ordinates, for use as a visual aid in the identification of groups of plots, or types. Component 4 was used as the third dimension in the model as component 3 tended to separate out one group of plots with little differentiation in the rest. A range of colours was used to segment the C3 scores on the model as a fourth dimension. Using the model it was possible to see the position of plots and their grouping and relate this to features of the model observed in the field. This gave a better appreciation of the environmental influences determining the distribution of the plots.

However, the interpretation of the model was not straight forward, and C3 and C4 still did not show a clear separation of environmental factors which could not be recognised. There is always the prospect of the PCA analysis deriving abstract axes, and this may be why environmental relationships are difficult to establish. There are some aberrations of the method (Austin and Noy-Meir 1971) which can make interpretation of the data more difficult with complex models.

Because the survey covered such a wide range of sites and environmental conditions and used a large number of indicators it would have been difficult to derive a simple model. This creates some difficulties in understanding the features of the continuum along an axis but the grouping of plots is still distinct. The features of the types can still be identified.

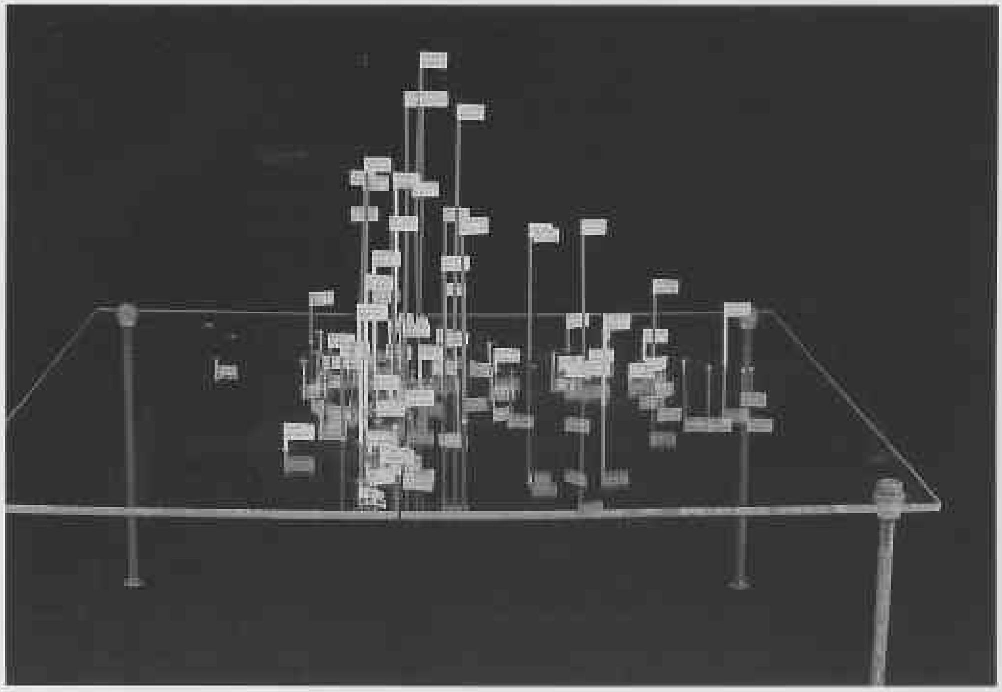

Plate 1
Four dimensional model of species relationships

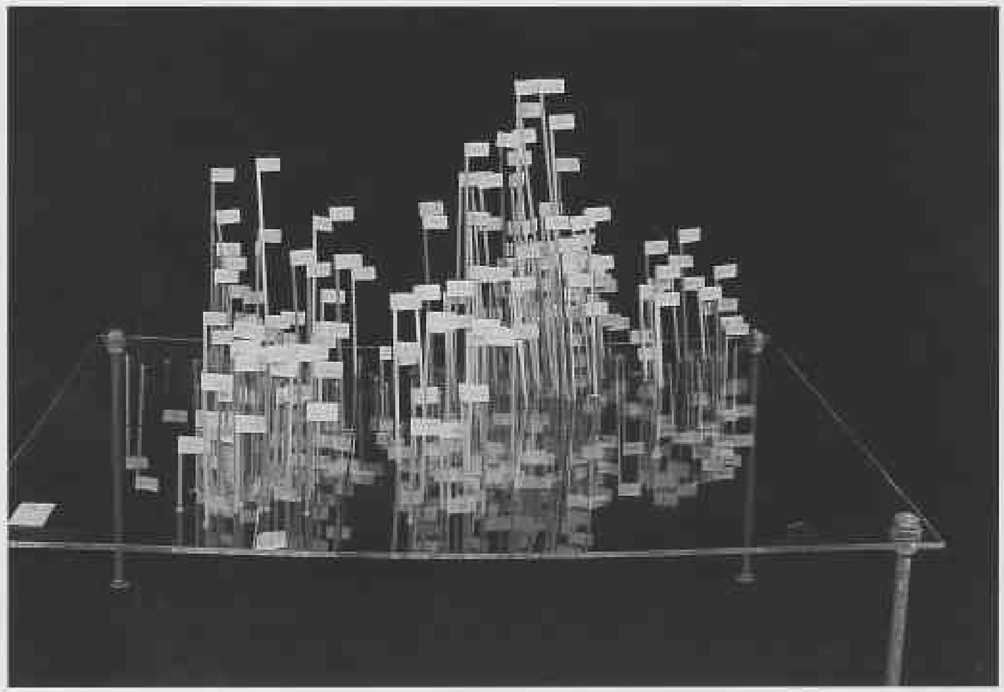

Plate 2
Four dimensional model of plot relationships

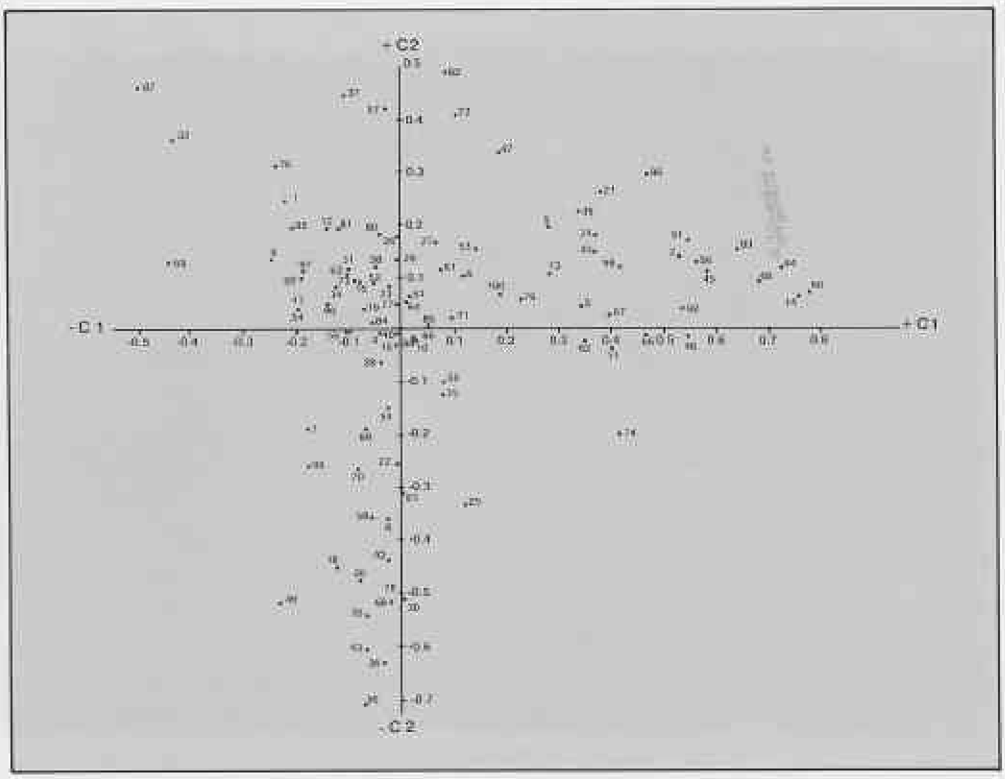

Figure 2

Distribution of indicator species within the component space derived by principal component analysis - axes C1 and C2

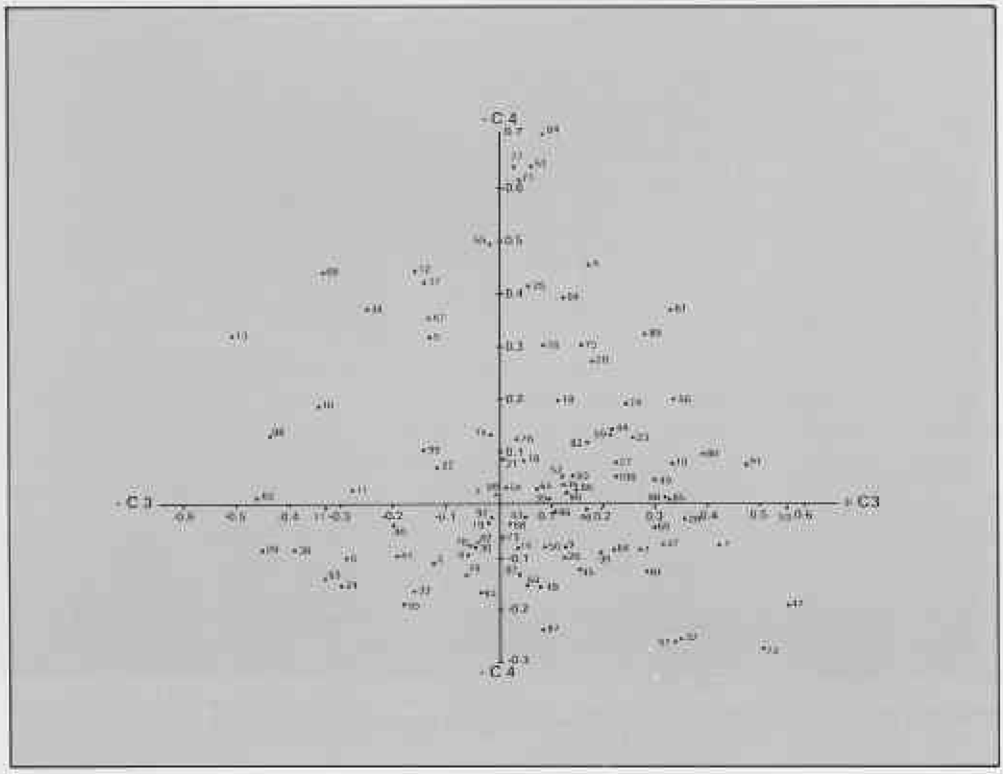

Figure 3

Distribution of indicator species within the component space derived by principal component analysis - axes C3 and C4

Species List (refer Figs 2 and 3)

1. *Acacia alata*
2. *Acacia browniana*
3. *Acacia drummondii*
4. *Acacia extensa*
5. *Acacia myrtifolia*
6. *Acacia pentadenia*
7. *Acacia pulchella*
8. *Acacia saligna*
9. *Acacia urophylla*
10. *Adenanthos barbigerus*
11. *Adenanthos obovatus*
12. *Agonis flexuosa*
13. *Agonis hypericifolia*
14. *Agonis parviceps*
15. *Allocasuarina decussata*
16. *Allocasuarina humilis*
17. *Anarthria prolifera*
18. *Anarthria scabra*
19. *Anigozanthos flavidus*
20. *Astroloma ciliatum*
21. *Astroloma epacridis*
22. *Astroloma pallidum*
23. *Banksia grandis*
24. *Banksia littoralis*
25. *Billardiera floribunda*
26. *Boronia gracilipes*
27. *Boronia spathulata*
28. *Bossiaea laidlawiana*
29. *Bossiaea linophylla*
30. *Bossiaea ornata*
31. *Chorizema ilicifolium*
32. *Clematis pubescens*
33. *Crowea angustifolia*
34. *Dasypogon bromeliifolius*
35. *Dryandra bipinnatifida*
36. *Dryandra nivea*
37. *Eucalyptus calophylla*
38. *Eucalyptus diversicolor*
39. *Eucalyptus marginata*
40. *Eucalyptus megacarpa*
41. *Eucalyptus patens*
42. *Eucalyptus rudis*
43. *Eucalyptus wandoo*
44. *Gompholobium ovatum*
45. *Grevillea breviscuspis*
46. *Grevilea quercifolia*
47. *Hakea amplexicaulis*
48. *Hakea lasianthoides*
49. *Hakea lissocarpha*
50. *Hakea oleifolia*
51. *Hakea ruscifolia*
52. *Hardenbergia comptoniana*
53. *Hibbertia amplexicaulis*
54. *Hibbertia cuneiformis*
55. *Hibbertia glaberrima*
56. *Hovea chorizemifolia*
57. *Hovea elliptica*
58. *Hypocalymma angustifolium*
59. *Hypocalymma robustum*
60. *Isopogon sphaerocephalus*
61. *Johnsonia lupulina*
62. *Kingia australis*
63. *Lasiopetalum floribundum*
64. *Lepidosperma angustatum*
65. *Leptomeria cunninghamii*
66. *Leucopogon australis*
67. *Leucopogon concinnus*
68. *Leucopogon pendulus*
69. *Leucopogon propinquus*
70. *Leucopogon pulchellus*
71. *Leucopogon obovatus*
72. *Leucopogon verticillatus*
73. *Logania vaginalis*
74. *Loxocarya fasciculata*
75. *Loxocarya flexuosa*
76. *Macrozamia riedlei*
77. *Melaleuca thymoides*
78. *Melaleuca viminea*
79. *Mirbelia dilatata*
80. *Opercularia hispidula*
81. *Patersonia umbrosa*
82. *Persoonia longifolia*
83. *Petrophile diversifolia*
84. *Petrophile longifolia*
85. *Platytheca galioides*
86. *Podocarpus drouynianus*
87. *Pteridium esculentum*
88. *Pultenaea reticulata*
89. *Scaevola striata*
90. *Sollya heterophylla*
91. *Sphaerolobium medium*
92. *Strangea stenocarpoides*
93. *Styphelia tenuiflora*
94. *Thomasia grandiflora*
95. *Tremandra stelligera*
96. *Trymalium ledifolium*
97. *Trymalium floribundum*
98. *Xanthorrhoea gracilis*
99. *Xanthorrhoea preissii*
100. *Xanthosia atkinsoniana*

The distribution of plots in the component space confirmed the same observations made with the species ordinations, but provided additional detail because of the plot information available. This information is presented in the summary of component axes in the next section.

Interpretation of Ecological Trends

To be able to identify and describe the groups or clusters of plots as types, it was necessary to better understand both the environmental factors involved and the site preferences of the indicator species. The CORD program developed by Havel (1975a) was used for this purpose.

This program divides the plot co-ordinate matrix into a specified array size for each combination of component axes. The species scores, or any other parameter recorded on the plots, can then be allocated to the array using their scaled component scores and the average value calculated for each position in the array. Figure 4 shows an example of the type of output produced.

The CORD illustration of a species distribution helps to refine the interpretation of a species' site preference and the environmental relationships are revealed.

Widely occurring species with little site preference would show records over much of the CORD array while a site specific indicator will be restricted to a small segment of the array. A species may be confined on one component axis but dispersed on others. This would help determine the environmental relationships influencing that component from knowledge of the species' occurrence in the field. This interpretation of components is reinforced by comparing a number of species with limited distribution at each end of each component axes.

The average score of the species indicates how abundant it is on a site and also the reliability of its occurrence is evident by the uniformity of the scores. Thus CORD shows how good (reliable and site specific) a particular species is as an indicator. This then determines which species are used to identify site conditions or types. Appendix II shows the

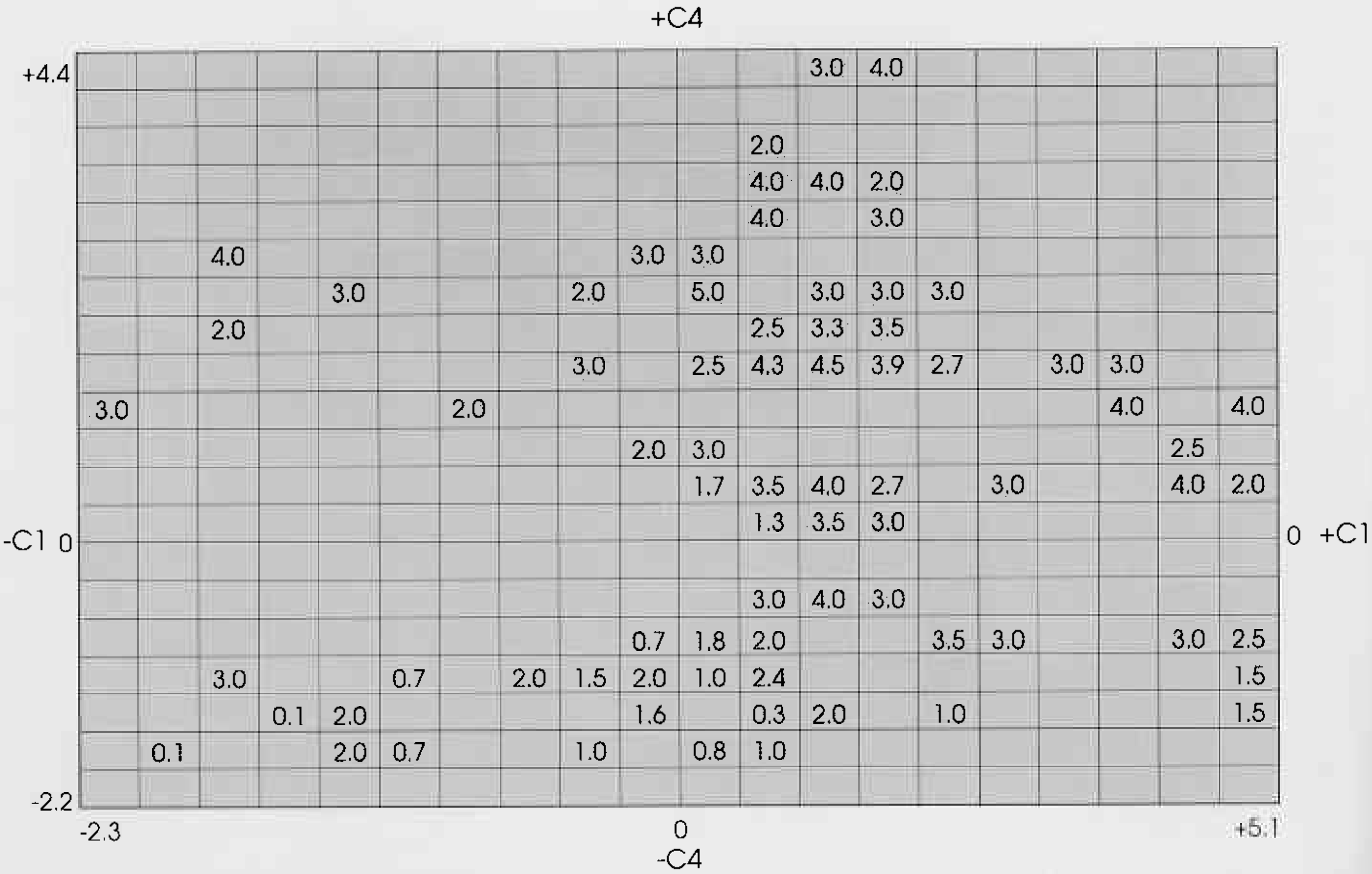

Figure 4
Example of CORD species output - showing distribution of abundance scores for *Agonis parviceps*

distribution of species on different component axes from CORD.

By the same procedure using CORD, all other data recorded on the plot can be examined. This survey included soil analysis data and site and vegetation physical data. From this data it was possible to get direct information on environmental relationships of the component axes. For instance the nutrient content showed which axes have a fertility factor involved. These features were incorporated in the site type descriptions.

Description of Component Axes

The results of the above procedures can be summarised as follows for each axes.

Component 1

This gradient has a soil structure and fertility relationship but is partly complicated by the influence of species showing overlapping moisture responses.

Plots from more uniform or gradational soil profiles with loamy textures and higher fertility occur at the negative end (-C1). The soils of these plots also tend to be less acid (nearly neutral) and on more dissected landscape. These are the younger soils and hence are inherently more fertile. This was evident for all the nutrients analysed (N, P, K, Ca, Mg) and these sites also showed a high cation exchange capacity (C.E.C.) and organic carbon content.

Plots at the positive end of C1 had gravelly soils of sandy and sandy loam textures and a duplex profile development. These plots also had lower fertility and organic carbon content.

Component 2

A climatic trend is shown on this component in rainfall and in the landscape dissection.

Plots on the +C2 are from the high rainfall well dissected areas and plots on the -C2 are from the low rainfall areas of little dissection.

Some plots from lower rainfall areas which were in moister water-gaining sites occurred more towards the +C2. So again moisture response of some species overlaps with other determining factors.

Component 3

This component gave a good separation of plots related to a combined moisture and soil texture influence. Plots on the -C3 are on moist sandy soils and sands over clay in the high rainfall areas, whereas the +C3 plots were more loamy textured soils, better drained and from lower rainfall areas. Plots on heavier soil and poorly drained sites were more central. The -C3 plots also had low gravel content (30 per cent) and lower P and K values.

Component 4

There is some overlap in this component with C1 as fertility shows some relationships with plot distribution but soil drainage is more significant.

Plots on the +C4 are on soils with impeded drainage, sometimes waterlogged. These plots are also more acid, which may be related to the poor drainage.

Plots on the -C4 are well drained and these are also the more fertile plots but most differentiation is in the -C1 quadrant. Organic carbon is also high in this sector, which indicates better nutrient retention ability.

The trends described above are not always well defined as continua along the component axes, but the description of the plot groups is more easily defined for most factors. Appendix III shows these site descriptions.

As discussed by Havel (1975a) the component scores cannot be simply expressed in terms of environmental parameters which only explain a portion of the total variation in component scores (25 per cent in this case). Only some of the environmental parameters could be measured in any case.

Definition of Types

The purpose of this survey was to identify management units. For management purposes they are generally related to the structural and physical parameters measured, because they determine which sites need to be managed differently for silvicultural or dieback hygiene requirements for example.

Using species to identify sites, it would have been possible to delineate many sites which differed in some characteristic. But then it would make using the system too complicated and the delineations would not have been relevant for management. From the experience of previous classifications in Western Australian forests, the features of the plot ordination model itself, and the clustering and correlation analysis carried out, it appeared that about twenty types could be defined.

The features of the model (Plate 2) provided some convenient segregation of the continuum but generally some breakup of the large clusters was necessary. Preliminary segmentation was accomplished by eye from the model, and then groups which were too large and heterogeneous were examined in more detail, using CORD and possible differences in management significance determined from species indications. This was assisted by using the clustering results to identify the loci of high correlation clusters. A Discriminant Analysis (SPSS system program) was also run which, based on species correlators, indicated that 89 per cent of samples had been allocated to the appropriate group. Those which were different were checked in more detail to decide on the best allocation.

Once the model had been segmented the characteristics of each group were listed. These descriptions included features of topography, moisture and drainage, soil, stand structure, fertility and others. They were used as the basis of discussions on the significance for management and ease of recognition and mapping. In comparing some of these groups it was decided that some divisions were too fine and the distinctions were not relevant to management needs. These groups were thus combined and a total of seventeen site classes were described. These descriptions are presented in Appendix III. There are some similarities of some sites with those of Havel (1975a), and those of Christensen (1980) are also related in less detail, but the classification is essentially different.

Site Factors

The principal outcome of this study was the understanding of environmental influences on the forest as discussed under Data Analysis. The derivation of site types and the results in this aspect are detailed in Appendix III as type descriptions presented in a user oriented format. However, other more specific results can also be extracted from the survey data.

The sample point physical data of the survey were analysed using CORD, in the same way as the vegetation, to explore trends within the plot array. These were also checked using the Spearman correlation results (component axes compared with parameter values). Since the samples were not statistically representative for any site type or management influences (such as burning and logging), the values recorded can only be considered as indications. In general the results refer to trends observed and the high or low values are relevant only to the range of samples taken.

Dieback

Where plots were specifically selected in dieback areas there were some severe impact ratings recorded and as would be expected, there was a relatively high incidence of dieback. In plots from the rest of the survey, however, both the incidence and impact of dieback were very low (impact ratings generally only 1 or 2, see Methods).

The most serious impact of dieback was recorded on plots which occurred in types P and S. Other lower levels of impact were recorded in plots which occurred in types K, T, V and G. (see Appendix III).

The main occurrence of dieback was in the +C1, +C2 and +C4 areas of the ordination which are the less fertile, higher rainfall and more poorly drained sites.

Regeneration

Low numbers of seedlings were recorded in the high rainfall areas (Fig. 5) except on the wet sandy soils on -C3 plots (Fig. 6).

Numbers of lignotuberous seedlings were evenly spread, without the higher numbers in the -C3, but slightly higher in types V and U and lower in Q, X, N, B, F and K.

Trends in numbers of the lignotuberous coppice stage were not evident. They were only recorded at low numbers with little variation.

The incipient coppice numbers from the plot averages by types showed the highest numbers were in types T, Q, and N (2300 - 1700 stems per ha [s.p.ha]) while the lowest values were in types M (with a wandoo component), X, F, and B (0-300 s.p.ha).

Numbers recorded for dynamic regeneration showed minor trends (Fig. 7) with higher numbers in the -C4 and lower in the +C4. Highest numbers were in types T, Q, P and K (1800 - 900 s.p.ha) and lowest in F, M, A, R, Z, and X (0-125 s.p.ha).

Marri regeneration in the seedling, lignotuberous seedling and seedling coppice stages were lower only where marri was uncommon (+C1, central C2) but in the incipient and dynamic stages a preference emerged for -C4 (Fig. 8) where higher numbers occurred. In both types A and T numbers averaged about 4 000 s.p.ha and 2 000 s.p.ha for incipient and dynamic regeneration respectively.

Regeneration on heavily cut over plots averaged higher numbers for jarrah seedling, lignotuberous seedling and lignotuberous coppice stages but lower for jarrah incipient and dynamic lignotubers and for marri regeneration generally.

Regeneration for other species was not recorded frequently enough to consider trends.

Stand Structure

Lower numbers of both saplings and poles of jarrah were on the -C3 (Figs 9 and 10) while high numbers were on the -C4 well drained sites (Figs 11 and 12). Highest jarrah tree numbers were on the +C1 gravels and low in the -C1/+C4 quadrant. Similar trends were evident for jarrah basal area (Fig. 13). Jarrah basal area was highest on types S, T, P, N and I with average values between 20 m^2/ha and 17 m^2/ha.

Marri stocking of saplings, poles and trees and their basal area showed a consistent trend to higher numbers in the well drained -C4 though less so on gravelly soils of the +C1 and lower in the -C3 regions of the component framework. Higher values for trees and basal area also occurred on plots in the -C1/+C4 quadrant (Fig. 14). Basal area values were highest on types V, T, U, Q, X and K (15 m^2/ha to 10 m^2/ha).

Other tree species less often encountered were blackbutt (*E. patens*) on types Q, U (good quality) and also on R and B (poor quality); karri (*E. diversicolor*) on types Q, N, T, S, P and K; wandoo (*E. wandoo*) occurred on type M, and flooded gum (*E. rudis*) on type A.

Canopy cover and codominant height of stands showed similar trends. Highest values were in the fertile and well drained -C1/-C4 quadrant (Figs. 15 and 16) with values of 32 m to 36 m codominant height and 40 to 45 per cent canopy cover. Canopy cover percentage was also higher in the +C2 higher rainfall plots (Fig. 17). Low rainfall and poorer quality plots recorded canopy covers of around 20 to 30 per cent. Canopy cover was highest on types S, R, Q and K and lowest on F (nil), B, A, M, Z and X. Codominant height was highest for types K, Q, T, and M and lowest for F (nil), M, Z, B and A.

Results of cutting age and intensity were not very revealing though cutting was possibly more prevalent in the more fertile (-C1) and well drained sites (-C4). Types Q, U, V and T had the highest average stump sectional area.

Site Characteristics

Scrub height was highest in the high rainfall sites (+C2) and in the -C3 sites (Fig. 18). Scrub density was lowest in the low rainfall -C2 plots.

Few trends were evident from slope, topographic position and aspect records. Ratings of topographic position indicated milder topography on the +C2 axis of the low rainfall less dissected sites, and less steep slopes occur on the +C4 axis sites with poorer drainage (Fig. 19). Steepest slopes of 5^o-12^o occurred in the more fertile -C1/+C2 quadrant while other areas generally ranged from 0^o-6^o.

No significant trends were interpreted from the burn age or season and litter depth records.

Rainfall values were lower in the -C1 and -C2. The number of fauna hollows generally showed little variation and no trends were evident.

Recordings of drainage features, rock outcrops and insect damage were not encountered often enough to discern trends.

Soil Analysis

The fertile sites, -C1/+C2 quadrant, tended to be less acid, generally pH 5.5 to 6.8, and the +C4 more poorly drained sites were more acid, generally less than pH 5.5 (Figs 20 and 21). The most acid soils of pH 4 to 4.7 were types R, I, S and A. Heavily cut over plots of the same site type tended to be more acidic. The more fertile types Q, K and T have less acid (nearly neutral) soils.

Sites on the -C3 axes showed the strongest trend in gravel content, with little or no gravel (Fig. 22). Of the +C3-axes sites, types Z, S and T generally had gravel content in excess of 50 per cent.

The organic carbon analysis values were higher in the fertile types, the -C1/-C2 half of the array (Fig. 23) and particularly the -C1/-C4 quadrant (Fig. 24), with values generally of 2.0 per cent or more. Types I, S and X, which are probably the least fertile, had the lowest organic carbon contents of around 1.2 per cent.

Levels of nitrogen were generally lower (less than 0.1 per cent total) in the +C1/+C2 sandy gravels (Fig. 25). Higher values occurred in the fertile well drained loams of the -C1/-C4 quadrant (Fig. 26) and also in the heavier soils of the more eastern plots on the -C2.

Plots in the -C1/-C4 fertile soils and also plots in the -C1/+C3 had the highest levels of phosphorus, generally above 40 ppm (Fig. 27). These same trends were also evident for potassium (Fig. 28).

Results for cation exchange capacity, magnesium and calcium were not available for all plots but the trends were toward higher values in the -C1/-C4 quadrant and for the more eastern sites with heavier soils.

All values for total soluble salts were very low, mostly below the 0.01 per cent level of resolution of the analysis so that no trends were evident.

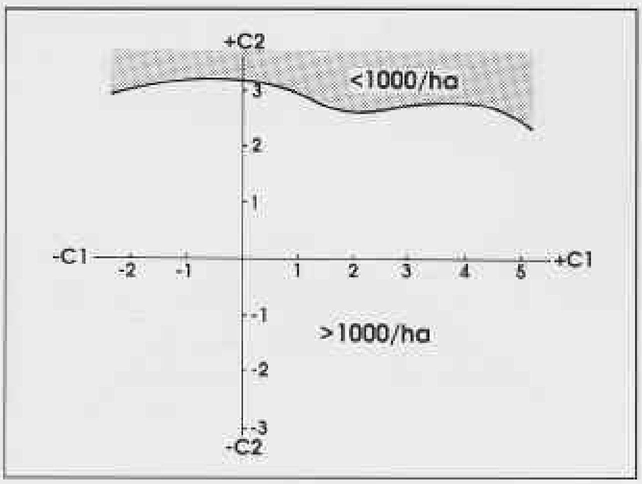

Figure 5
CORD output of jarrah seedling regeneration on axes C1 and C2

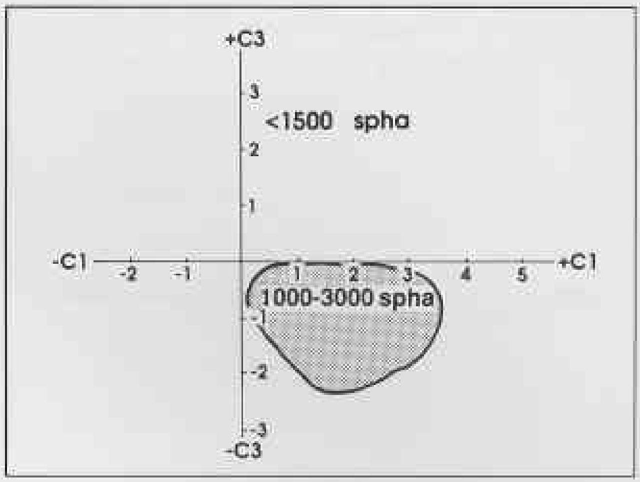

Figure 6
CORD output of jarrah seedling regeneration on axes C1 and C3

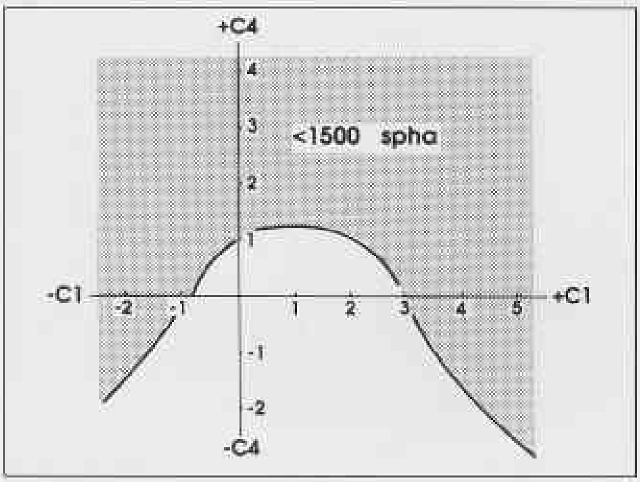

Figure 7
CORD output of jarrah dynamic regeneration on axes C1 and C4

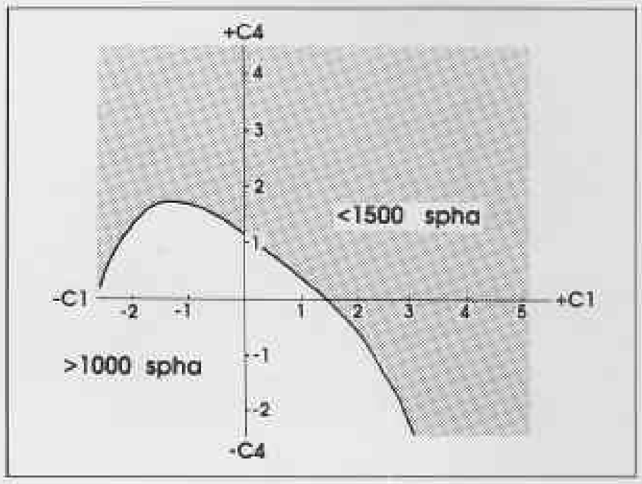

Figure 8
CORD output of marri dynamic regeneration on axes C1 and C4

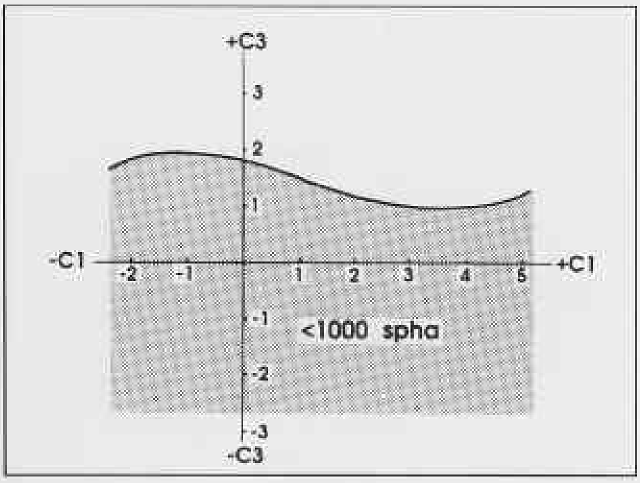

Figure 9
CORD output of jarrah saplings on axes C1 and C3

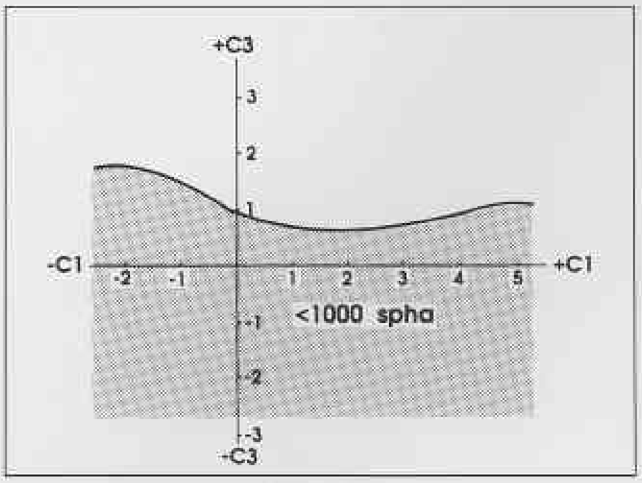

Figure 10
CORD output of jarrah poles on axes C1 and C3

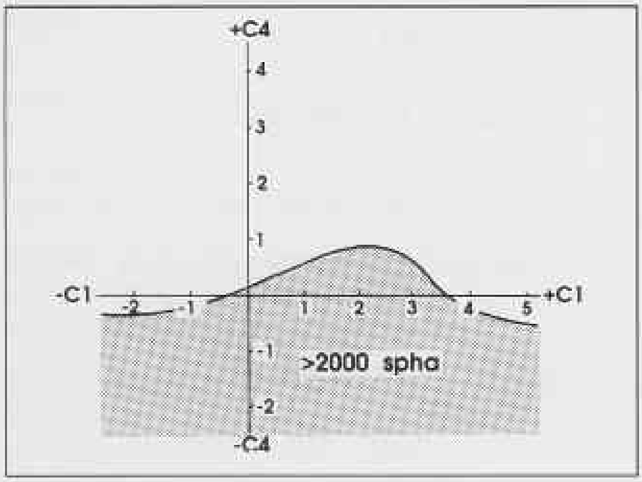

Figure 11
CORD output of jarrah saplings on axes C1 and C4

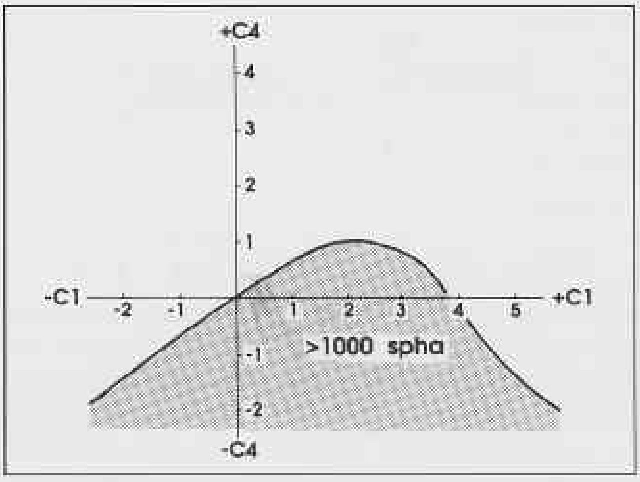

Figure 12
CORD output of jarrah poles on axes C1 and C4

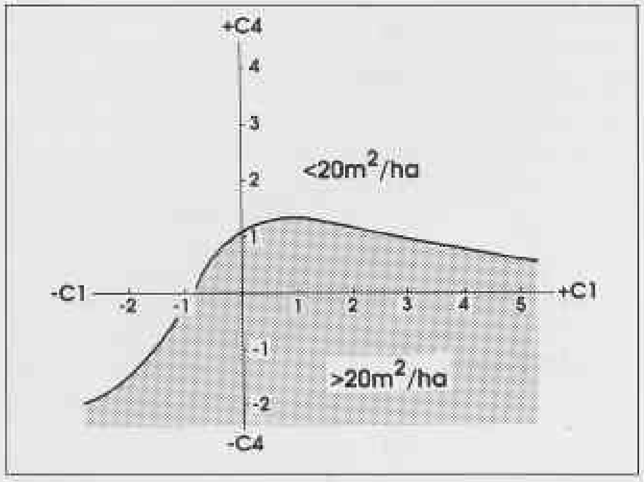

Figure 13
CORD output of jarrah basal area on axes C1 and C4

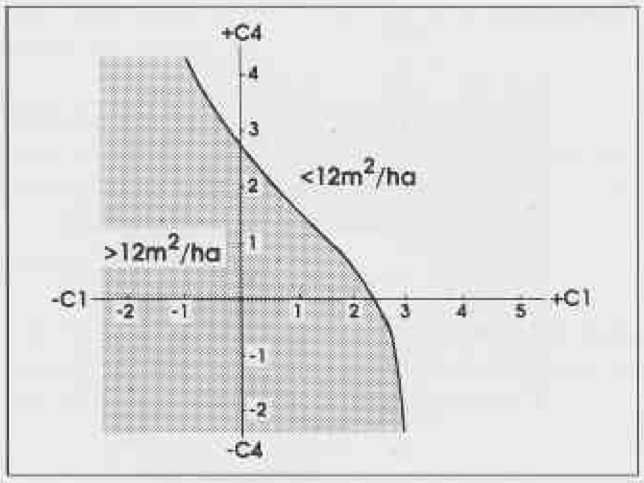

Figure 14
CORD output of marri basal area on axes C1 and C4

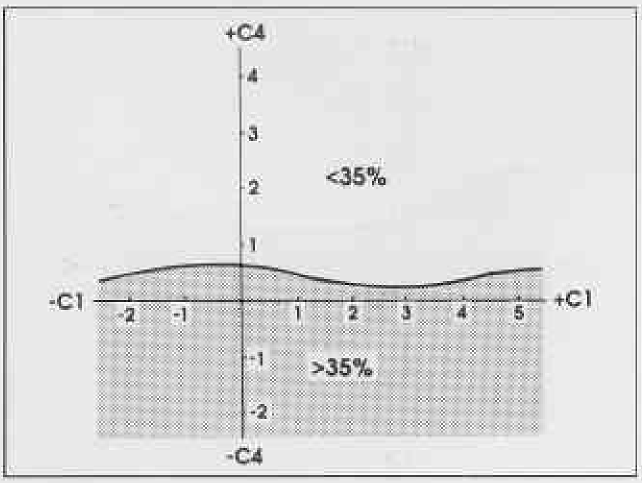

Figure 15
CORD output of canopy cover on axes C1 and C4

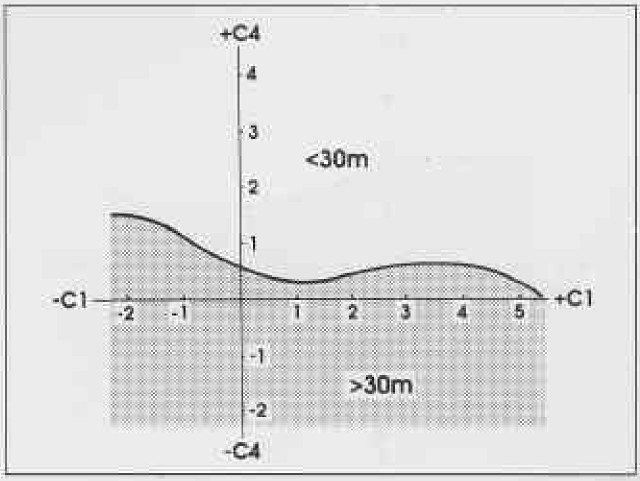

Figure 16
CORD output of codominant height on axes C1 and C4

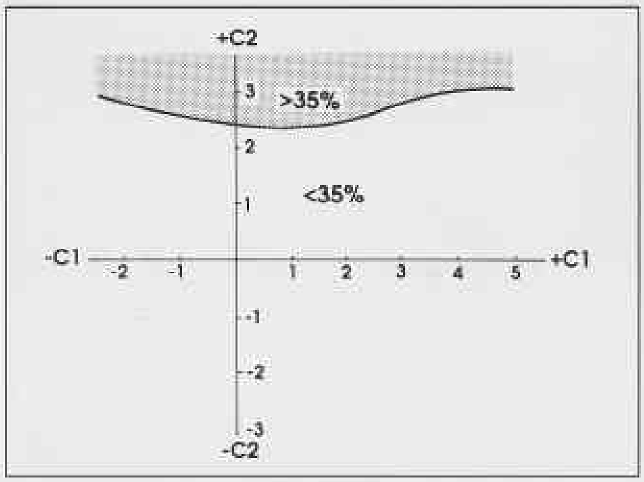

Figure 17
CORD output of canopy cover on axes C1 and C2

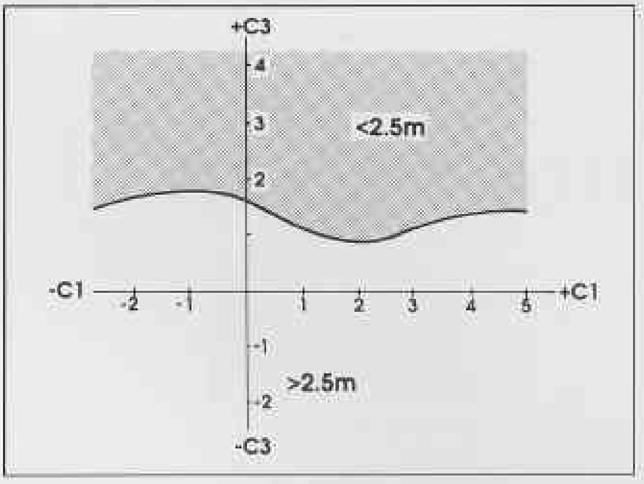

Figure 18
CORD output of scrub height on axes C1 and C3

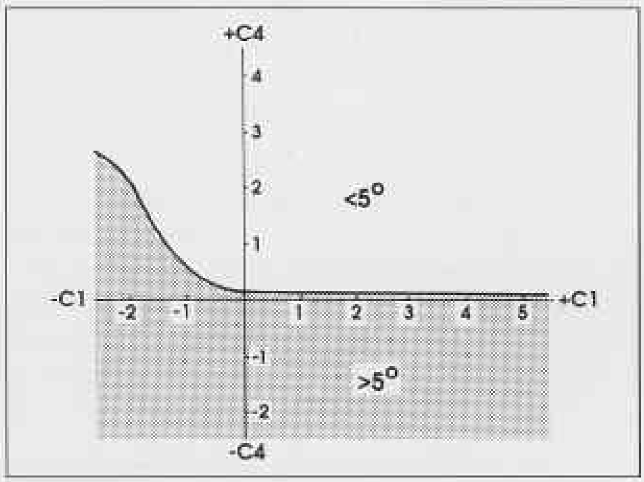

Figure 19
CORD output of slope (degrees) on axes C1 and C4

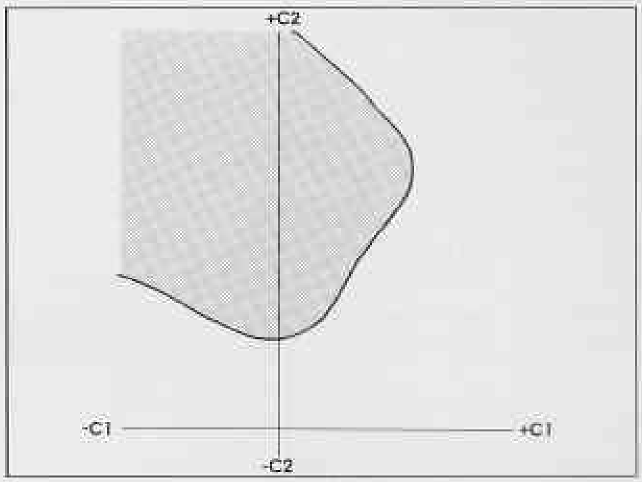

Figure 20
CORD output of acidity (pH) on axes C1 and C2

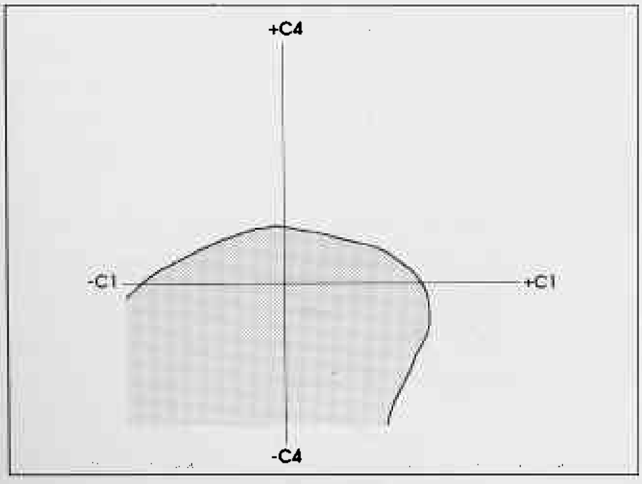

Figure 21
CORD output of acidity (pH) on axes C1 and C4

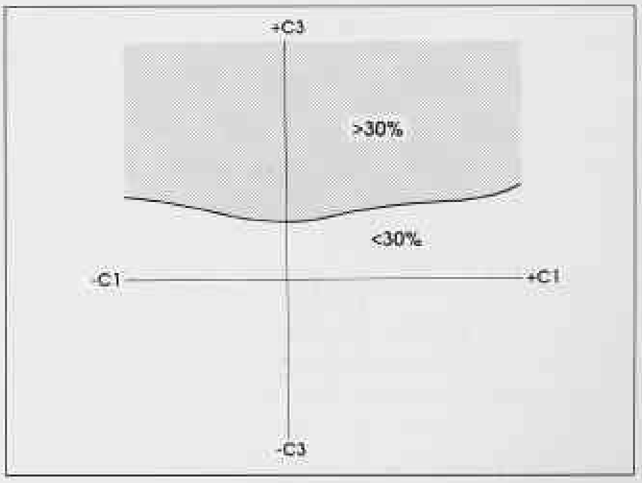

Figure 22
CORD output of percentage gravel on axes C1 and C3

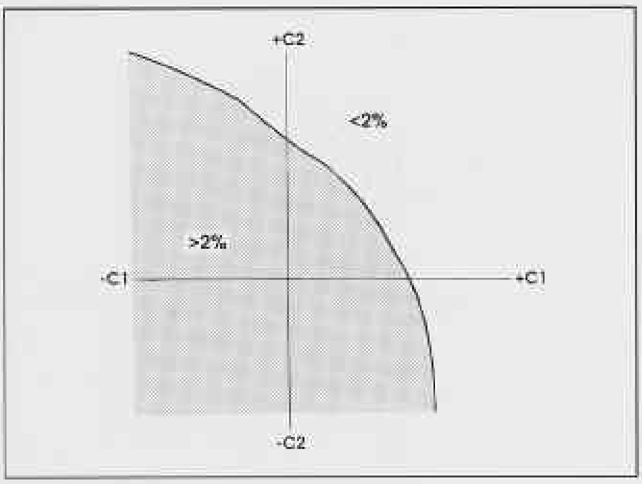

Figure 23
CORD output of organic carbon content on axes C1 and C2

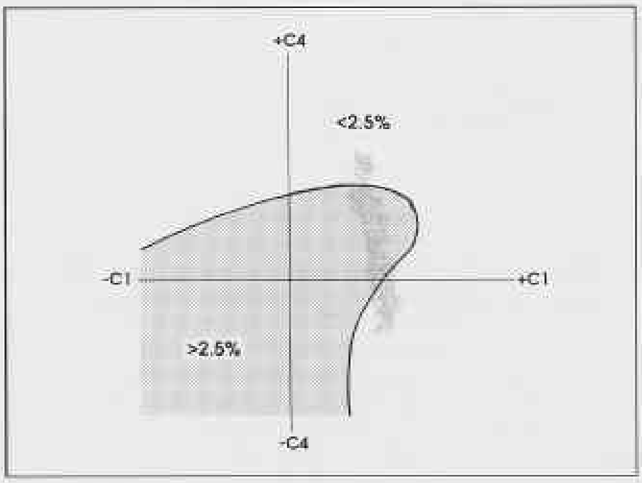

Figure 24
CORD output of organic carbon content on axes C1 and C4

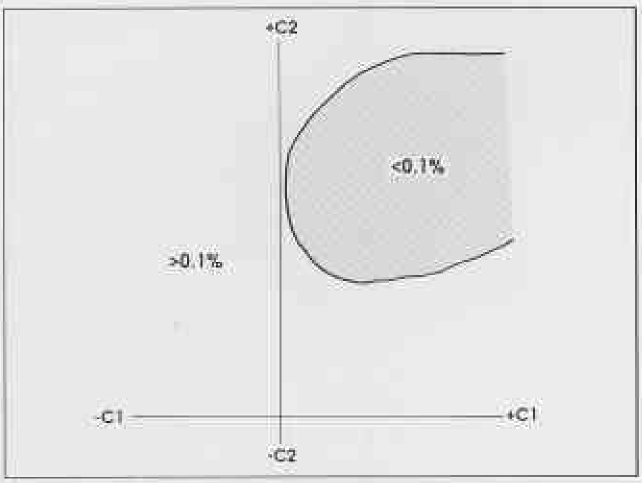

Figure 25
CORD output of total nitrogen on axes C1 and C2

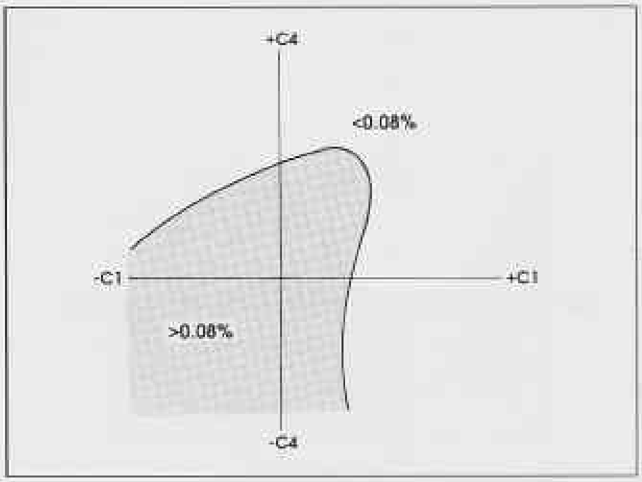

Figure 26
CORD output of total nitrogen on axes C1 and C4

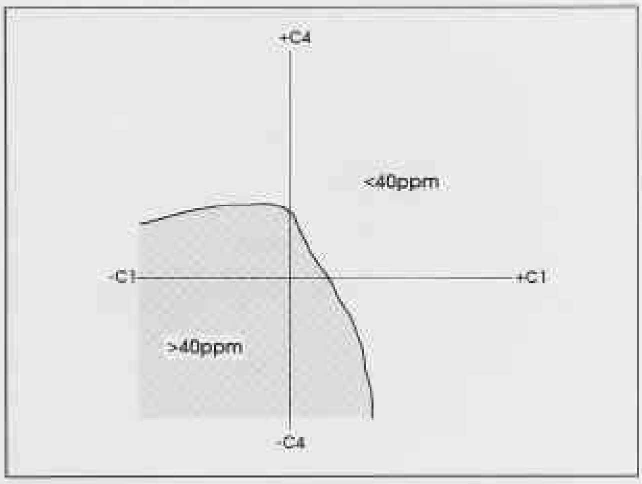

Figure 27
CORD output of phosphorus content on axes C1 and C4

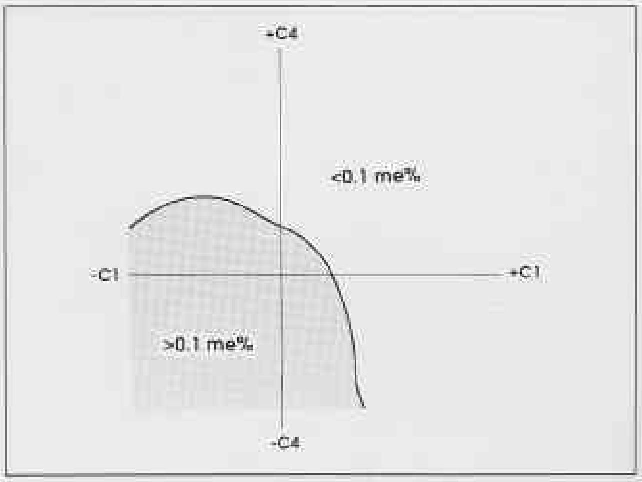

Figure 28
CORD output of potassium content on axes C1 and C4

Discussion

SOME discussion of site types is worthwhile for an overview of the types in respect of some specific aspects of the site record results.

Dieback

Expression of dieback disease in the south is limited by the occurrence of susceptible sites, climatic influences and vegetational influences (Havel 1979).

It is generally considered that there is a lower incidence of dieback in the southern forest than in the northern forest. This impression may be influenced to some extent by the lack of striking examples of high or very high impact in the south compared with the north.

Schuster (1978) found there was a low proportion of sites showing overstorey impact. Those which did exhibit high impact were mostly on laterite and sandy soils and these have a restricted occurrence in the southern forest (McArthur and Clifton 1975).

Lower levels of activity in management operations such as logging, mining and roading in the southern forests in the past may be part of the reason for the lower incidence of disease. Batini (1973) and Havel (1975b) found that the incidence of disease was greater than expected in sites related to activities such as roading.

Climatic differences between northern and southern areas (see Description of Study Area) result in shorter periods of suitable soil temperature and soil moisture overlap necessary for activity of the dieback fungus (Christensen 1975).

There is a greater incidence of leguminous vegetation in the southern forest (Shea *et al.* 1979) which has an inhibiting effect on the fungus (Shea 1975; Malajczuk and McComb 1977; Shea, Malajczuk and Kitt 1976) and a corresponding lower incidence of susceptible species which aid in survival and spread of the fungus (Shea 1975). The greater density of vegetation cover also reduces soil temperature and moisture withdrawal thus further reducing the temperature/moisture overlap.

Because of this low occurrence of dieback on the sample sites there were insufficient records to absolutely define impacts for some types. Therefore the references to likely dieback impact in the type descriptions are based on these observations which were made, deductions of the effect of site conditions on pathogenicity (Shea 1975) and judgements on the possible effects of disturbance (Shea 1979; Havel 1979; West and Vithanage 1979).

The observations showed clearly that type P can have a very high impact of the classical northern jarrah forest graveyard site. This would occur only on sites at one end of the type P range: those with very infertile shallow soils over an impeding layer, similar to conditions found by Weste and Ruppin (1977) to be associated with disease severity. Other P sites with less extreme conditions may only reach moderate or high impact.

Schuster (1978) in a survey of dieback sites in the southern jarrah forest found similar variation in impacts on sites which were equivalent to types P, R and S.

Types R and S were observed with moderate impact, though site conditions in these types tend to favour the dieback fungus and it is expected that infections could progress to the high impact category. Similar results were found by Schuster (1978).

Conditions in these types become seasonally favourable with higher moisture content than other types, as the relationships of site and soil moisture which favour activity of the fungus are improved (Shea 1975). In type S these conditions are more localised and patchy, being related to minor topography, drainage and geological features, which Schuster (1978) also concluded to be significant. The pathogen may then spread from these loci of infection to the less favourable surrounds assisted by its modification of site conditions or disturbance.

Christensen (1975) in a study of southern forest types found that these lateritic soils, typical of type S, have an extended period of susceptibility which include short periods during the winter. Due to lower percentage vegetation cover, logging and indeed the impact of the pathogen itself, soil temperatures increase more rapidly while soil moisture remains above field capacity (Shea 1975).

Another important component of the pathogenicity and impact on these sites of types R and S is their infertility. Incidence of dieback has been noted occurring at lower than expected levels on more fertile soils by Batini (1973) and Havel (1975b) in the northern jarrah forest. Higher levels of nutrients and of the cation exchange capacity (C.E.C.) of the soil help the host to resist attack, and incidence of the pathogen is reduced (Heather 1979). Types R and S were relatively low in nutrition and C.E.C. Similar results were found by McArthur and Clifton (1975) for these soils. Bellamy *et al.* (1971), and Boughton *et al.* (1978), related calcium in particular to the hindrance of the pathogens activity.

The region of the plot ordination where most dieback occurred was the +C1/+C2/+C4 which are the less fertile, high rainfall, poorly drained sites where types P, R and S occur. Other types which had only low or nil dieback impact and also occur in this segment of the ordination matrix are types N, I and B. These have been suggested in the type descriptions as likely to show moderate impact.

Types V and F are marginal to this region of the ordination and may also develop moderate dieback impact in some instances because of the susceptible site conditions. Types of the lower rainfall segments, -C2 which may also develop moderate impact are types Y and A since they are moisture gaining sites low in the topography, also correlated by Schuster (1978) with dieback impact.

In any dieback risk situation the influence of disturbance must also be considered. Batini (1973) and Havel (1975b) noted an increased incidence of dieback associated with disturbance, but as discussed by Schuster (1978) the influence of logging and other treatments (Shea 1979) can make a site more susceptible to the pathogen (Christensen 1975) and hence alter the impact class. Major disturbances such as mining and roading which affect hydrology have a more marked effect.

Dieback incidence and levels of impact may increase in southern forests as management becomes more intensive (particularly in the low to moderate impact categories since they occur on the larger portion of the forest). Schuster (1978) also noted the occurrence of dieback on karri soil types which can act as inoculum sources for spread of the disease into more susceptible jarrah types. The same situation applies for types A, B and F, which have a low component of jarrah, where impact may only be exhibited as low. These latent infection reservoirs have important relevance for hygiene management in the southern forest.

A more thorough investigation of dieback in relation to site types similar to that done by Schuster (1978) is necessary to clarify these relationships. This should include reference to understorey species which may affect a sites susceptibility or resistance to disease (Shea and Malajczuk 1977) and can be considered in management of the site (Shea 1979; Shea *et al.* 1979).

Regeneration

To discuss the regeneration of jarrah, the various stages of development must be considered (see Methods), since they have different potentials for growth (Abbott and Loneragan 1984) and significance for management (Bradshaw 1986). Although in some situations seedfall may be an important source of regeneration the bulk of replacement growing stock for recruitment into the overstorey comes from the lignotuberous pool (Schuster 1980).

Seedling numbers were very variable both on the survey plots and within types. The lower numbers of subsequent regeneration stages indicates a high mortality, noted also by Stoate and Helms (1938) and Abbott and Loneragan (1984). Perhaps the variability is due more to chance than pattern and may reflect the season of assessment rather than site relationships. There were generally lower numbers in the high rainfall areas, due most likely to the competition from denser scrub on these sites. The exception was on wet sandy sites, perhaps because the sands provide a good seedbed and moist conditions for a longer period.

The losses of seedlings, for example through drought, competition and burning are high, and this class of regeneration without the development of the lignotuber is not a reliable regeneration pool. For example, the higher numbers on the wet sandy soils were not maintained into the next stage of development, the lignotuberous seedlings stage, since these sites have dense scrub which would inhibit seedling establishment.

When total regeneration is inadequate, as was found on some sites such as types A, B, F, R and X, then seedling regeneration becomes very important for the future of the stand and a means of enhancing seedling establishment must be defined. Some data available (Strelein, unpublished) indicate some hope of regenerating difficult sites with dense scrub, by natural or artificial means.

In some situations seedlings will produce vigorous regeneration. This is commonly observed in cut over areas on ashbeds. There was insufficient data in this survey to identify what conditions promote dynamic growth. There was a slight trend to higher numbers in the heavily cut over sites indicating that disturbance and reduction of competition will increase the number of seeds establishing. Further research is underway to establish the precise requirements since the circumstances in the southern jarrah forest seem to differ from those described by Abbott and Loneragan (1984) for the northern jarrah forest (Bradshaw 1986).

The numbers of lignotuberous seedlings recorded on similar sample sites were also variable. This is possibly related to management differences. For example, slightly higher counts were recorded in heavily cut over stands. Thus site disturbance or reduction in overstorey or scrub competition may influence establishment.

With development of the lignotuber this stage is a more reliable source of regeneration but still has difficulty surviving in the denser scrub types where numbers were somewhat lower.

Lignotuberous coppice was the least common stage of regeneration. This stage has demonstrated its ability to survive hardships such as burning but often appeared weak and may reflect a stressed condition if this stage persists.

Further long term studies are needed to determine the fate of different regeneration stages so that their significance in stand management may be fully appreciated. These latter two stages, for instance, usually have only small lignotubers in the duff layers or close to the surface and may not survive hotter regeneration burns. Mild burning, however, may allow the lignotuber to develop further by reducing competition.

Lower numbers of incipient and dynamic lignotubers in heavy scrub types highlight again the difficulties in regenerating these sites. Trends in these stages are very difficult to reconcile. Lignotuber numbers were lower in heavily cut stands and in virgin stands. Mechanical disturbance, such as occurs during logging, can reduce numbers (Strelein, unpublished) but there is probably also a proportion progressing into the sapling stages. The virgin stands would be expected to have lower counts (Stoate and Helms 1938). These were sites which also had dense scrub (types I, N and S).

The relationships between stand structure and competition which affect development on various site types require long term studies to more accurately determine the fate of these different regeneration stages, to appreciate the significance of these relationships in stand management. Disturbance and opening up the stand appear to enhance establishment and development but the impact of burning was not adequately addressed in this survey. Regeneration assessments must take such factors into account.

Marri regeneration showed less evidence of the stages of development applying to jarrah and appeared to progress more quickly into a sapling stage. The counts for all stages were lower on the heavily cut over sites, possibly because they are more susceptible to burning, but also the faster progression from the seedling stage to sapling.

Site Characteristics

The results indicated that type P, (and to a lesser extent I) which represent poorly drained podzols, was generally well stocked with high basal areas. This indicates that their potential productivity is good but considering the site conditions the growth rates are probably slower than better quality site types with similar values.

These better sites, type Q, U, and K, were also more heavily cut over. Thus the basal areas for these types as well as types V, T, N and X which had higher marri and karri components, would be somewhat understated when just comparing jarrah basal area on type P.

Unfortunately, there were very few permanent inventory plots which could provide growth data to obtain representative figures for types. Consequently comments regarding growth potential have been inferred from other factors such as soil nutrients, texture and drainage.

Although type P is also dieback susceptible it does represent a significant portion of the forest and is therefore an important resource which must receive consideration in research of silvicultural techniques to improve growth potential in timber production areas.

The best development of jarrah was on the gravelly soils but perhaps only because of its replacement by karri and marri on more fertile loamier soils. Blackbutt showed its dual character, replacing jarrah at both ends of the site quality range.

Soil

The bimodal distribution of blackbutt appears to have some explanation in the analysis of soil nutrients. The organic carbon content seems to hold the key.

Carbon content is lowest in the infertile types I and X and highest in the fertile types Q, U, T and K. However, there are also high values in type B sites, the poor blackbutt flats. The high organic carbon content of these soils helps in nutrient retention on these sites. The better quality sites have inherently fertile soils and high levels of all nutrients examined whereas the poorly drained infertile sands of type B did have relatively high levels of nitrogen. This possibly arises from the fixing capacity of the legume *Pultenaea reticulata* which is abundant on type B.

The carbon content may be high on type B because of lower frequency of burning and faster decomposition and leaching rates in the moist conditions.

Clay can also act as colloidal material in aiding nutrient retention and the clayey soils in Type A also show high nitrogen contents. On some of these sites blackbutt may also occur.

It appears therefore that nitrogen levels may be the important discriminator of blackbutt distribution and other soil nutrient and drainage features determine the quality of the stand.

Nutrient levels generally were relatively high in the more eastern types. Other factors such as rainfall must therefore be limiting productivity on these sites. Eastern types in the northern jarrah also are generally considered to be of lower productivity (Abbott and Loneragan 1983).

Variable carbon values were probably related to both burning and cutting history. Sites which were heavily cut over had carbon values up to twice that of similar uncut sites. Cutting provides a boost of nutrient rich litter unlike normal senescent litter.

Thus the relationships between litter fall, accumulation, cutting and burning are important considerations for managing nutrient conservation (Hingston *et al.* 1979).

Conclusions

THE results of the survey have enabled a number of generalisations to be made relevant to management of site types, mainly in relation to dieback and regeneration. The low incidence of dieback necessitates specific survey work to better clarify site type susceptibility and impact for more accurate predictions and decision making on dieback management. Variation in regeneration was too high to provide detailed knowledge but the identification of types likely to pose problems now provides a basis for future work. The results did, however, indicate the influence of stand history on regeneration overlain on site type, which must be taken into consideration in the stratification of any survey of regeneration or stand structure in general.

With such variation within sites, due perhaps to treatment history, it becomes important to assess each area when regeneration is a consideration of the proposed management. Strelein (unpublished) discusses the various techniques used in Western Australian forests for regeneration and stocking counts.

The lack of silvicultural and growth information for the southern jarrah made it necessary to infer much of the site type characteristics. Some confirmation of these aspects would allow more confident consideration of land use and the subsequent management prescriptions.

This classification of types has application at both these levels. The initial land use decision will be influenced by the mosaic of types. Unfortunately, as has been found in the northern jarrah types, they are not reliably mapped from aerial photography as some important distinctions are made on understorey composition and soils not evident on aerial photographs. This limitation applies to a greater extent in the south. Some relationship is consistent with landform and when landform mapping is available for the southern forest (Churchward *et al.* [1988] covers the south coast) this will be useful in land use planning and the forward planning of operations where site types are relevant.

For more detailed planning and development of prescriptions it is likely that types will need to be determined in the field or at least operations prescribed by types and applied as they are encountered.

Much of the impact of management on each site type still requires clarification. This survey focussed on regeneration and dieback but other attributes such as litter accumulation rates or soil erodability could be related to types where they are thought to influence management decisions.

Since all attributes and indeed all areas of the southern jarrah forest were not included in this survey, some types may not be adequately covered. However, new data can still be included to see where sites fit in the existing data base. By using a correlation coefficient, such as the Czekanowski coefficient described, any new data can be positioned with its best associates in the existing plot matrix. A subjective decision is then required to allocate it to the same type or create a new type if it is significantly different. Similarly, Discriminant Analysis can be used to allocate plots to most similar groups with stated probabilities.

The successful application of this site classification system is dependent on the user developing skills in species identification and appreciation of site characteristics and species' site preferences. This is necessary to be able to describe variations in types, since this system represents point types in an ever changing forest continuum.

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Appendix I

Survey Species List

List of indicator species used in the survey and described in this publication. At each sample point an area of twenty metres radius was searched for each species and its relative abundance recorded. An asterisk denotes those used in the analysis as described in the text.

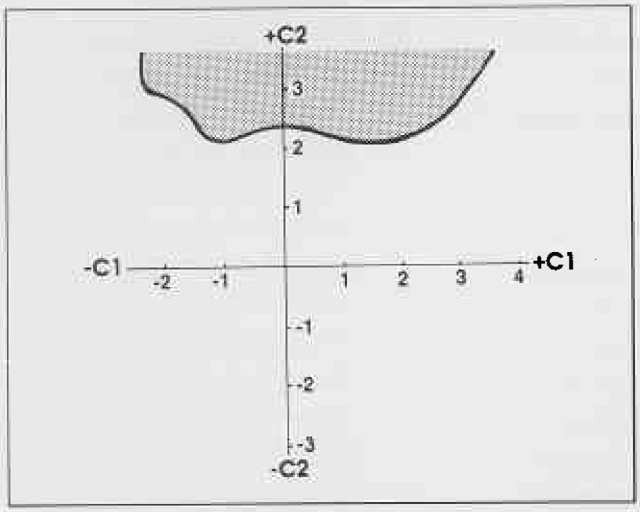
* *Acacia alata*
* *Acacia browniana*
Acacia divergens
* *Acacia drummondii*
* *Acacia extensa*
* *Acacia myrtifolia*
Acacia nervosa
* *Acacia pentadenia*
* *Acacia pulchella*
* *Acacia saligna*
Acacia stenoptera
* *Acacia urophylla*
* *Adenanthos barbigerus*
Adenanthos cuneatus
Adenanthos meisneri
* *Adenanthos obovatus*
* *Agonis flexuosa*
* *Agonis hypericifolia*
Agonis linearifolia
* *Agonis parviceps*
* *Allocasuarina decussata* (Syn Casuarina)
Allocasuarina fraseriana (Syn Casuarina)
* *Allocasuarina humilis* (Syn Casuarina)
* *Anarthria prolifera*
* *Anarthria scabra*
* *Anigozanthos flavidus*
Astartea fascicularis
* *Astroloma ciliatum*
* *Astroloma epacridis*
* *Astroloma pallidum*
Baeckea camphorosmae
Banksia attenuata
* *Banksia grandis*
Banksia ilicifolia
* *Banksia littoralis*
Banksia quercifolia
Banksia sphaerocarpa
Beaufortia decussata
Beaufortia sparsa
* *Billardiera floribunda*
Boronia crenulata
Boronia denticulata
* *Boronia gracilipes*
* *Boronia spathulata*
Bossiaea eriocarpa
* *Bossiaea laidlawiana*
* *Bossiaea linophylla*
* *Bossiaea ornata*
Bossiaea webbii
Brachysema latifolium
Brachysema praemorsum
Burtonia scabra
Callistemon speciosus
Calothamnus lateralis
Chorilaena quercifolia
* *Chorizema ilicifolium*
* *Clematis pubescens*
Conospermum caeruleum
Conospermum flexuosum
* *Crowea angustifolia*
Cyathochaeta avenacea
Dampiera alata
* *Dasypogon bromeliifolius*
Dasypogon hookeri
Darwinia citriodora
Darwinia oederoides
Darwinia vestita
Daviesia alternifolia
Daviesia cordata
Dianella revoluta
Dodonaea ceratocarpa
Dodonaea viscosa (Syn D. attenuata)
Drosera gigantea
Dryandra armata
* *Dryandra bipinnatifida*
Dryandra carduacea
Dryandra formosa
* *Dryandra nivea*
Dryandra sessilis
Eriostemon spicatus

* *Eucalyptus calophylla*
Eucalyptus cornuta
Eucalyptus decipiens
* *Eucalyptus diversicolor*
Eucalyptus guilfoylei
Eucalyptus jacksonii
* *Eucalyptus marginata*
* *Eucalyptus megacarpa*
Eucalyptus occidentalis
* *Eucalyptus patens*
* *Eucalyptus rudis*
Eucalyptus staeri
* *Eucalyptus wandoo*
Gahnia trifida
Gastrolobium bilobum
Gastrolobium forrestii
Gastrolobium spinosum
Glischrocaryon aureum
(Syn Loudonia)
* *Gompholobium ovatum*
Gompholobium polymorphum
* *Grevillea brevicuspis*
Grevillea brownii
Grevillea occidentalis
Grevillea pulchella
* *Grevillea quercifolia*
Hakea ambigua
* *Hakea amplexicaulis*
Hakea ceratophylla
Hakea cyclocarpa
Hakea elliptica
Hakea florida
* *Hakea lasianthoides*
* *Hakea lissocarpha*
* *Hakea oleifolia*
Hakea prostrata
* *Hakea ruscifolia*
Hakea trifurcata
Hakea undulata
Hakea varia
* *Hardenbergia comptoniana*
Hemiandra pungens
* *Hibbertia amplexicaulis*
* *Hibbertia cuneiformis*
* *Hibbertia glaberrima*
Hibbertia pulchra
Homalospermum firmum
* *Hovea chorizemifolia*
* *Hovea elliptica*
* *Hypocalymma angustifolium*
* *Hypocalymma robustum*
Hypocalymma strictum
Isopogon attenuatus
Isopogon formosus
* *Isopogon sphaerocephalus*
Jacksonia furcellata
* *Johnsonia lupulina*
Kennedia coccinea
Kennedia prostrata
* *Kingia australis*
Kunzea ericifolia
(Syn K. vestita)
Kunzea recurva
Labichea punctata
* *Lasiopetalum floribundum*
Lechenaultia biloba
* *Lepidosperma angustatum*
Lepidosperma effusum
Lepidosperma tetraquetrum
* *Leptomeria cunninghamii*
Leptospermum erubescens
* *Leucopogon australis*
Leucopogon capitellatus
* *Leucopogon concinnus*
* *Leucopogon obovatus*
(Syn L. revolutus)
Leucopogon oxycedrus
* *Leucopogon pendulus*
* *Leucopogon propinquus*
* *Leucopogon pulchellus*
* *Leucopogon verticillatus*
* *Logania vaginalis*
* *Loxocarya fasciculata*
* *Loxocarya flexuosa*
* *Macrozamia riedlei*
Melaleuca incana
Melaleuca preissiana
Melaleuca scabra
* *Melaleuca thymoides*
* *Melaleuca viminea*
Mesomelaena tetragona
* *Mirbelia dilatata*
Olax benthamiana
* *Opercularia hispidula*
Orthrosanthus
Oxylobium lanceolatum
* *Patersonia umbrosa*
(Syn P. xanthina)
Pericalymma ellipticum
(Syn Leptospermum ellipticum and L. crassipes)
* *Persoonia longifolia*
Persoonia microcarpa
* *Petrophile diversifolia*
Petrophile linearis
* *Petrophile longifolia*
Petrophile serruriae
Phyllanthus calycinus
* *Platytheca galioides*
(Syn P. verticillata)
* *Podocarpus drouynianus*
* *Pteridium esculentum*
Pultenaea ericifolia
* *Pultenaea reticulata*
Scaevola microphylla
* *Scaevola striata*
* *Sollya heterophylla*
* *Sphaerolobium medium*
Stirlingia latifolia
* *Strangea stenocarpoides*
Stypandra imbricata
* *Styphelia tenuiflora*
Synaphea polymorpha
Tetratheca setigera
* *Thomasia grandiflora*
Thomasia quercifolia
* *Tremandra stelligera*
* *Trymalium ledifolium*
* *Trymalium floribundum*
(Syn T. spathulatum)
Verticordia plumosa
Viminaria juncea
* *Xanthorrhoea gracilis*
* *Xanthorrhoea preissii*
* *Xanthosia atkinsoniana*
Xanthosia rotundifolia
Xylomelum occidentale

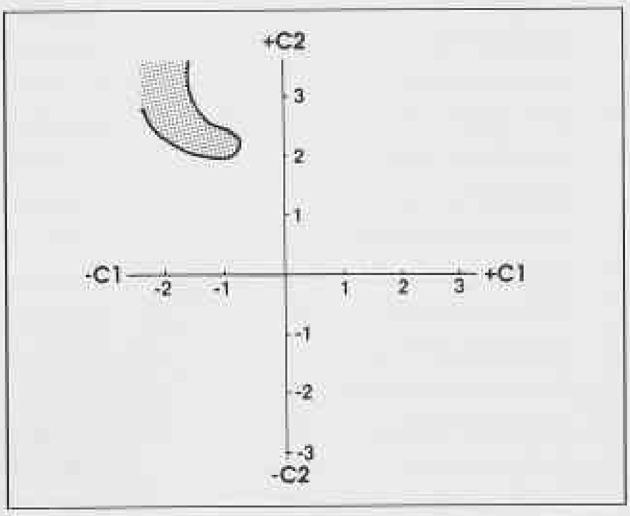
Appendix II

Diagrammatic Representation of Indicator Species

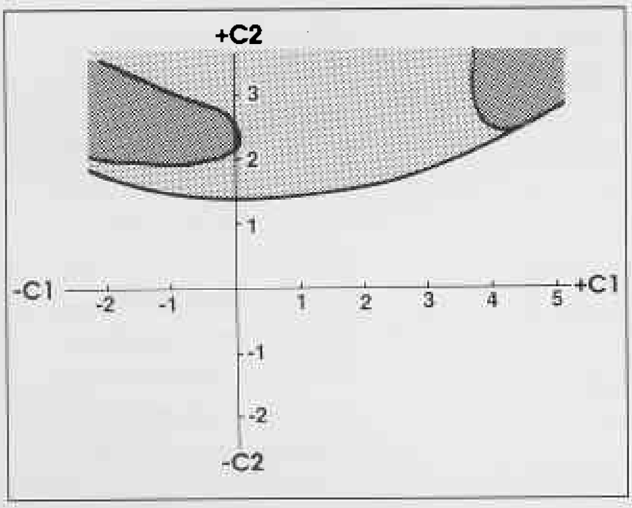
Examples of species which showed a good correlation with component axes. (Listed alphabetically by axes C1 & C2, C1 & C3 and C1 & C4)
These figures provide some selected examples to illustrate the types of distribution of species occurrences in the analysis matrix (see text). They were used to decide which species were good indicators (tight or confined clusters) and determine the factors influencing species distribution along the component axes.



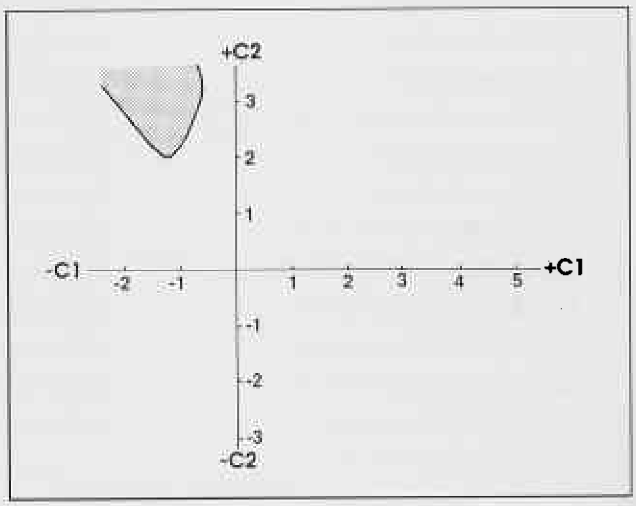
Acacia alata



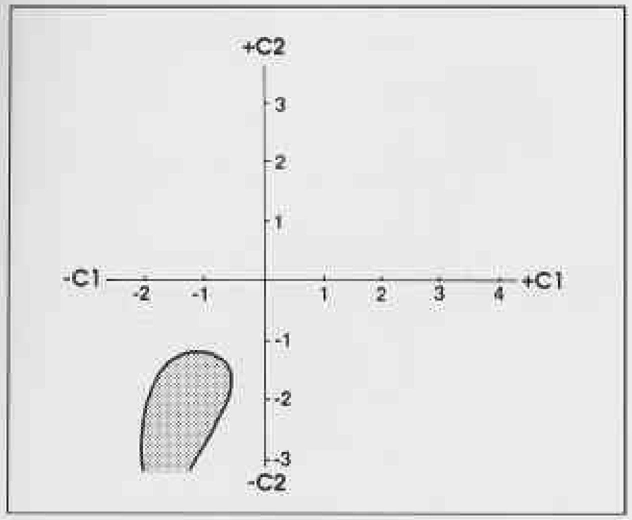
Acacia urophylla



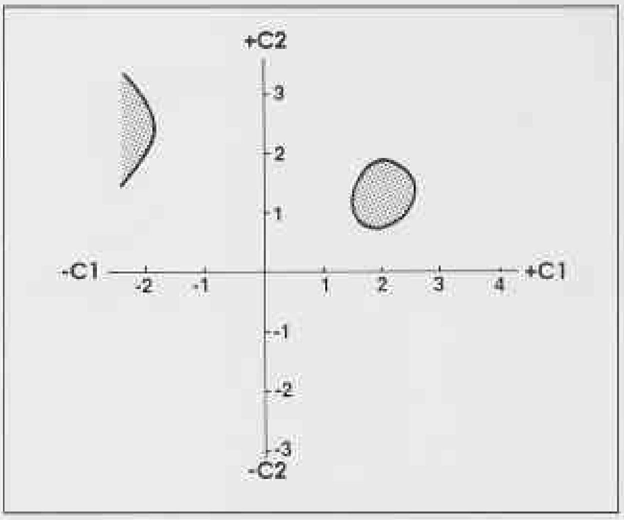
Bossiaea linophylla



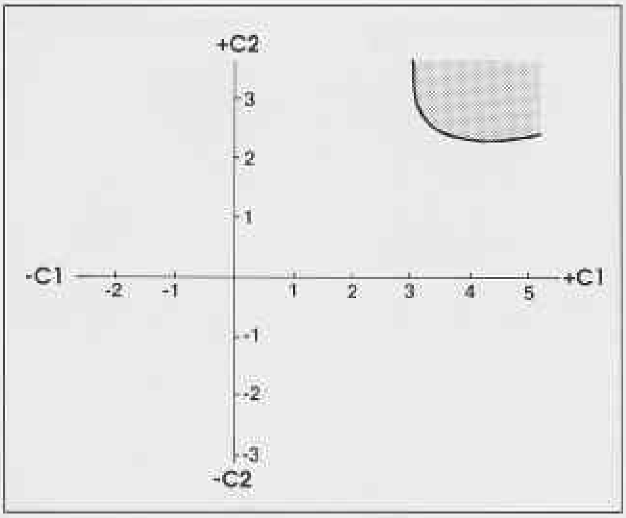
Clematis pubescens



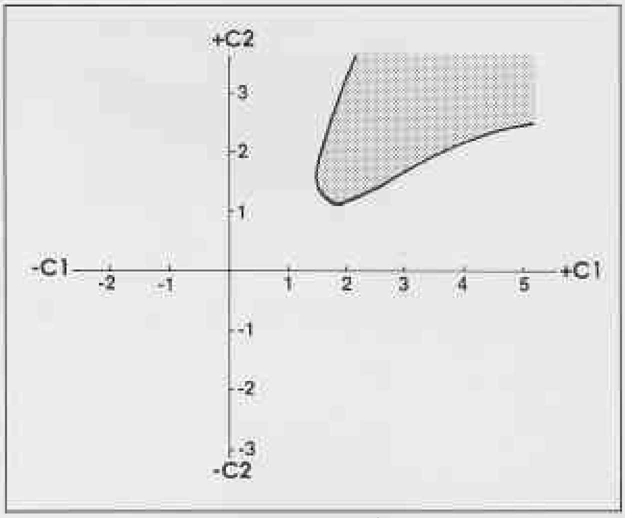
Dryandra nivea



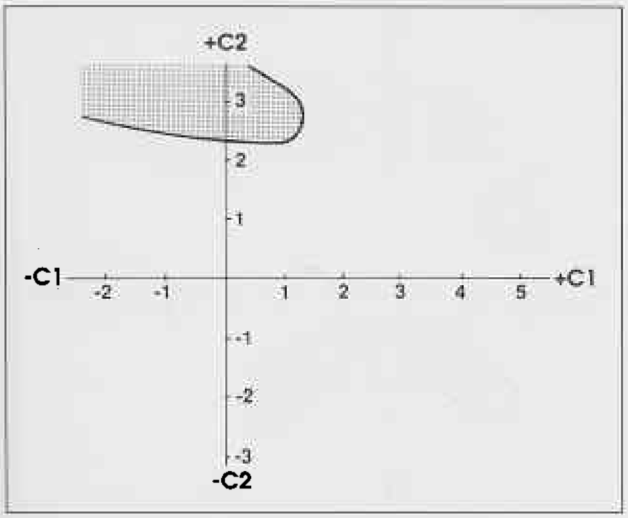
Eucalyptus patens



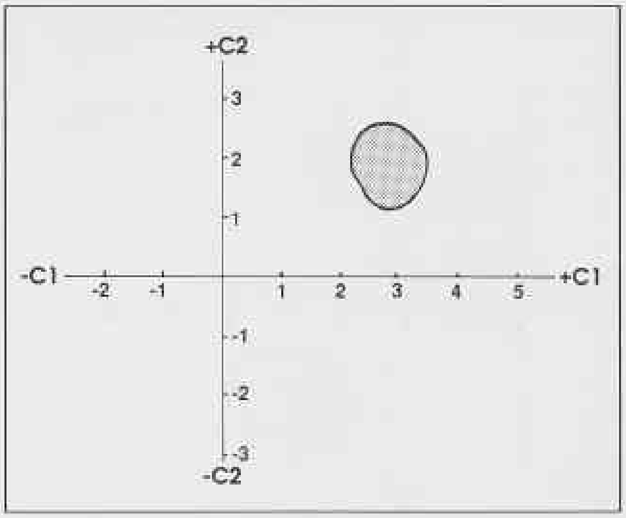
Gompholobium ovatum



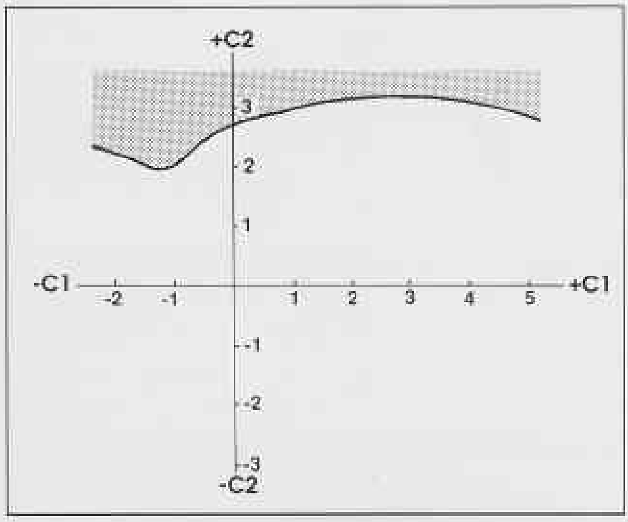
Hovea chorizemifolia



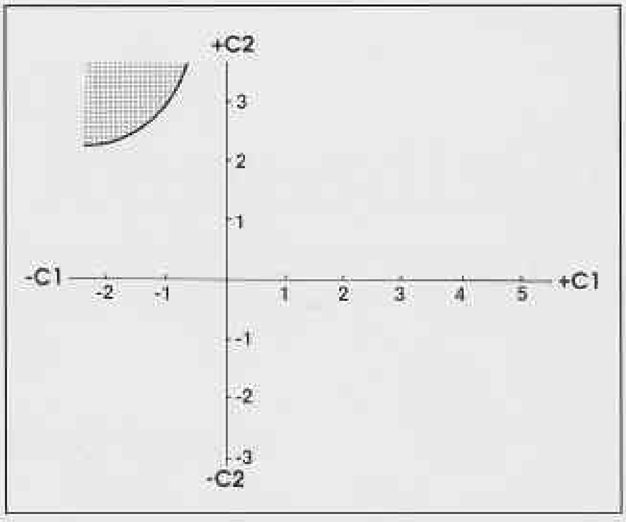
Hovea elliptica



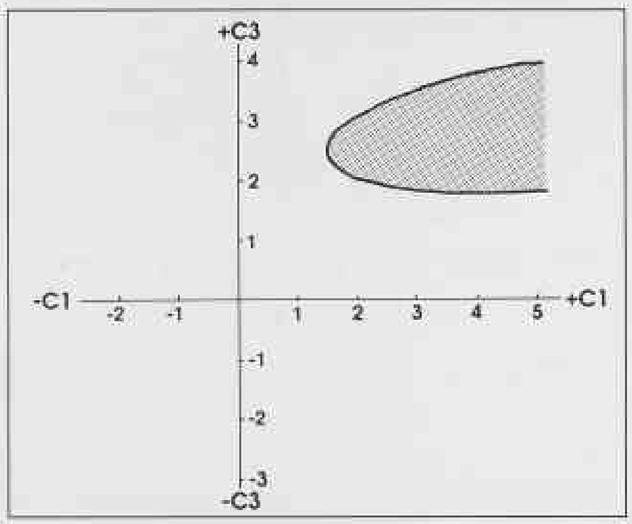
Hypocalymma robustum



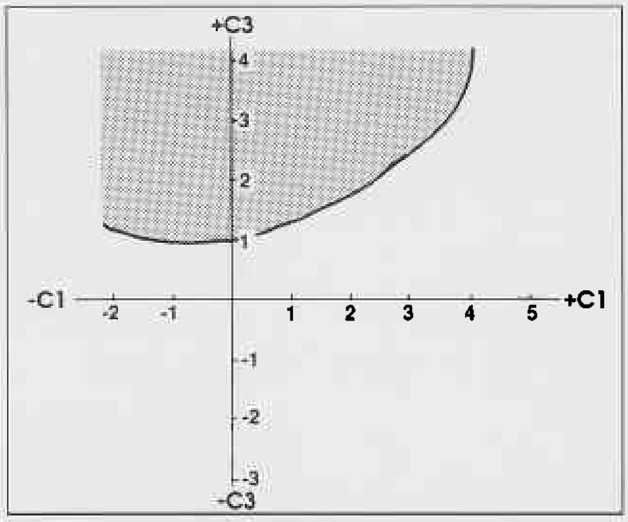
Leucopogon verticillatus



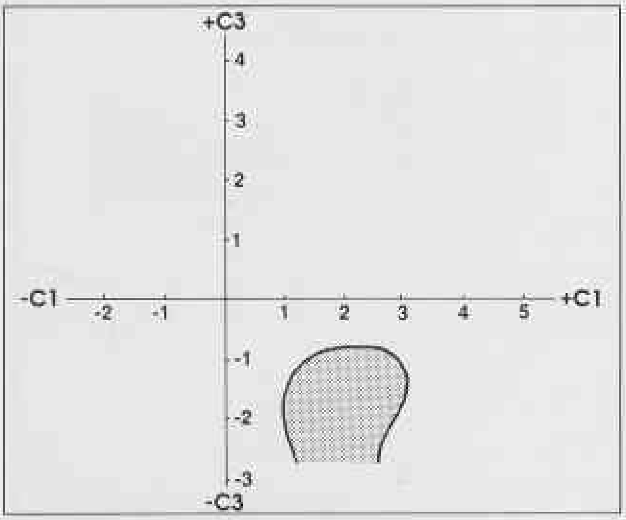
Pteridium esculentum



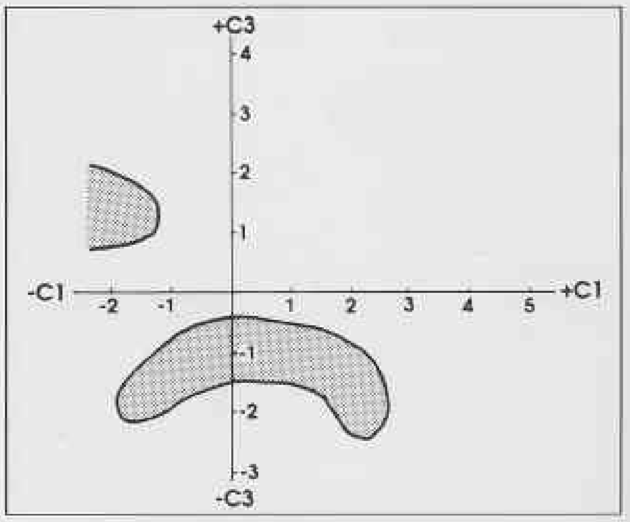
Acacia browniana



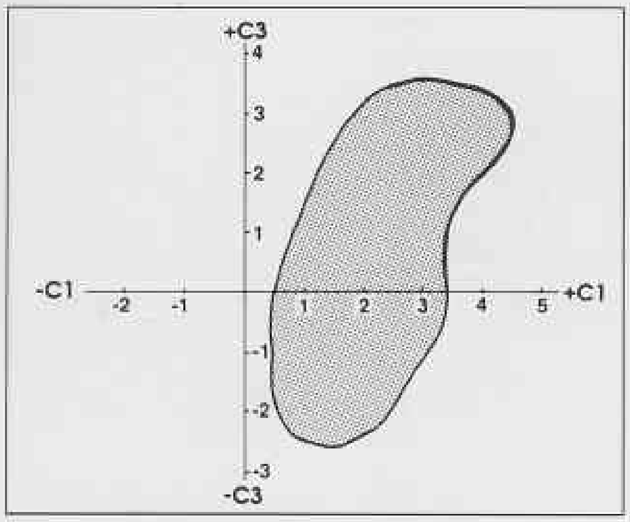
Acacia pulchella



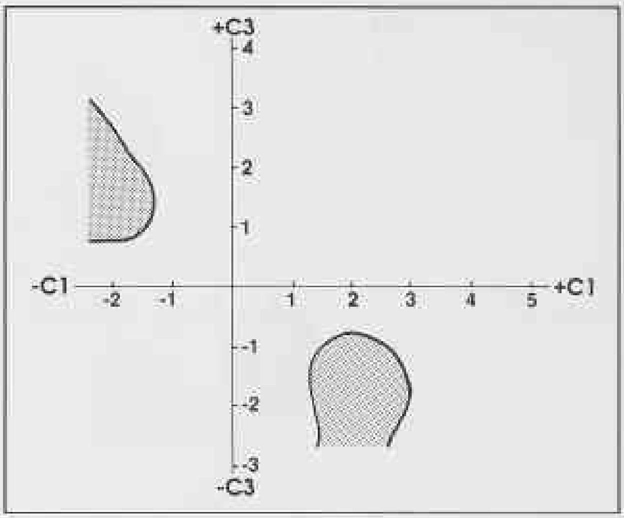
Allocasuarina decussata



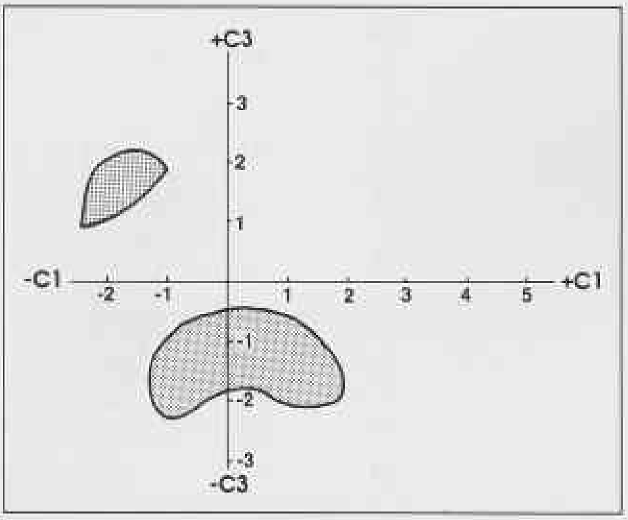
Anigozanthos flavidus



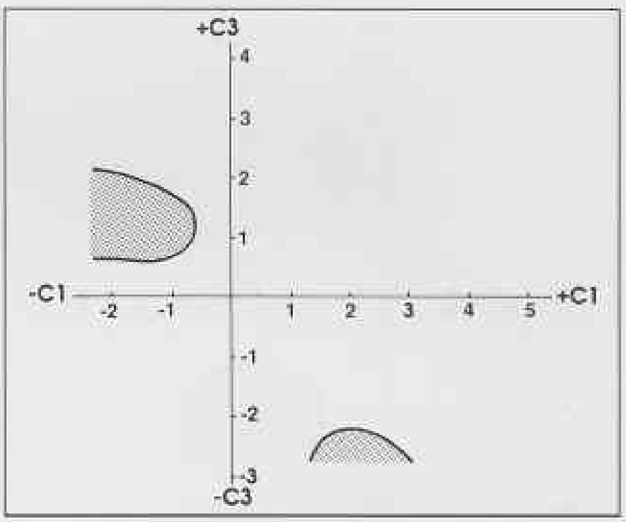
Boronia gracilipes



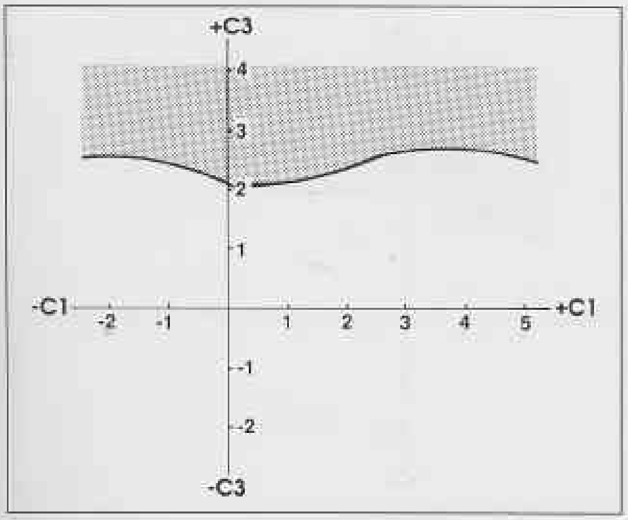
Chorizema ilicifolium



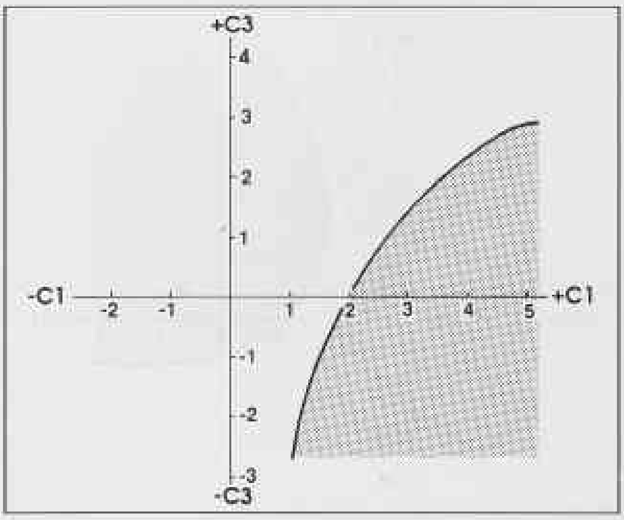
Dasypogon bromeliifolius



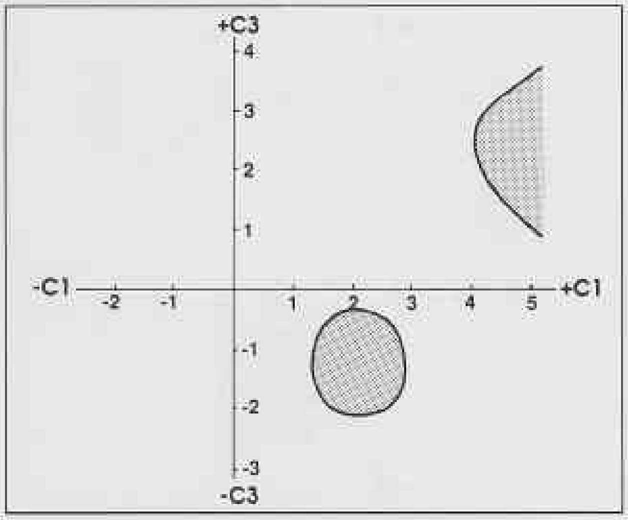
Eucalyptus patens



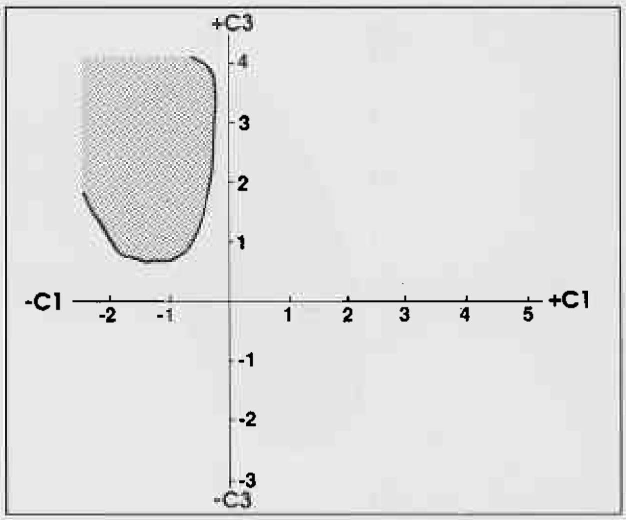
Hakea amplexicaulis



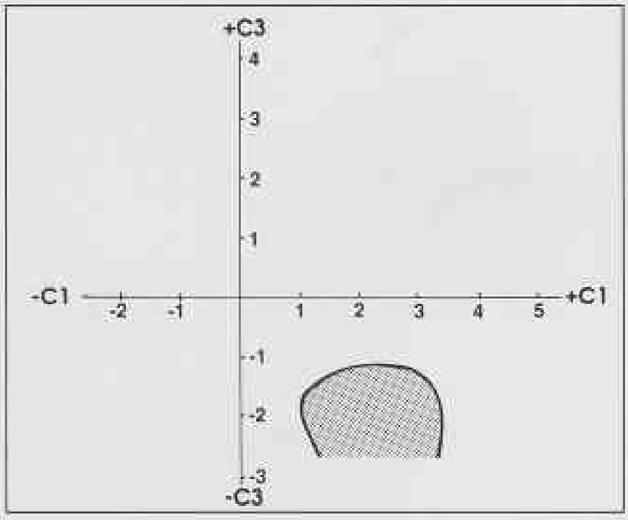
Kingia australis



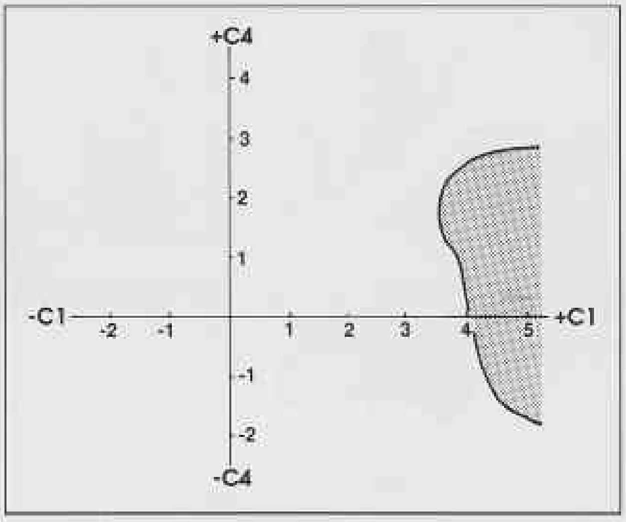
Petrophile diversifolia



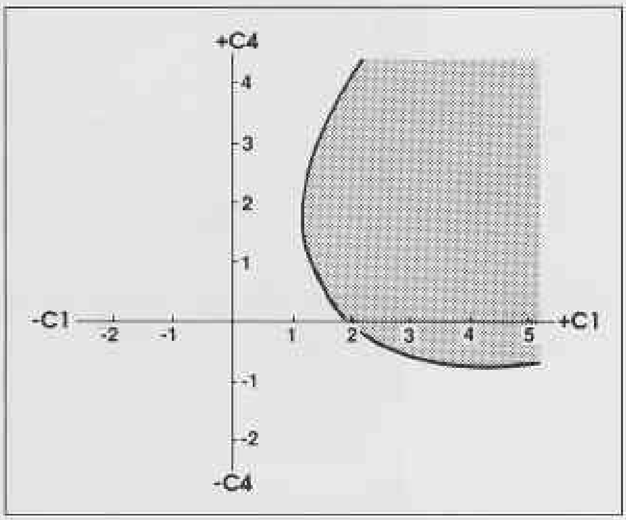
Pteridium esculentum



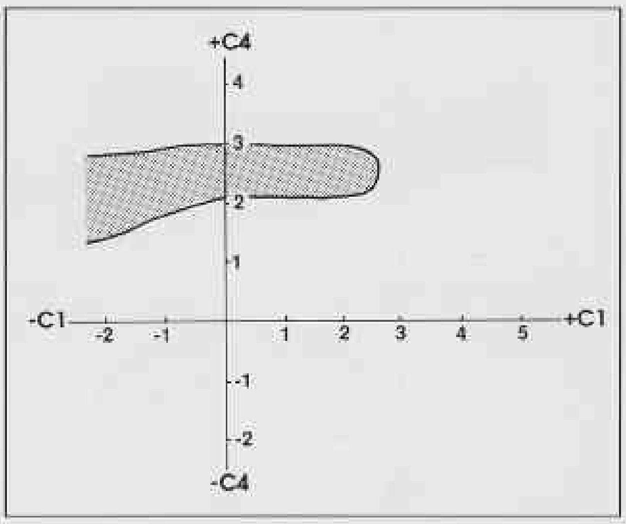
Pultenea reticulata



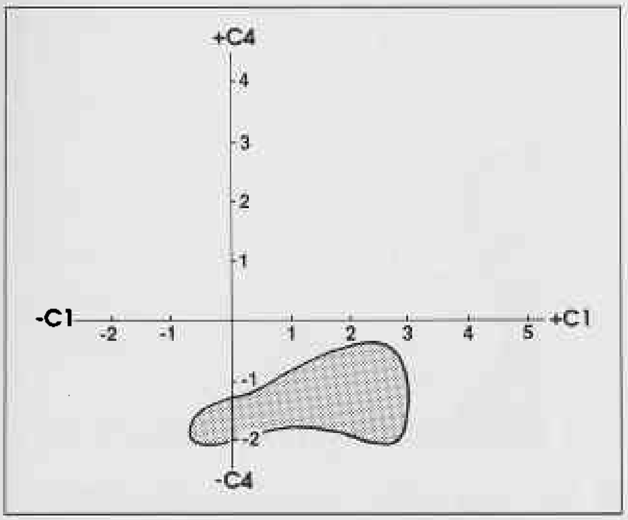
Adenanthos obovatus



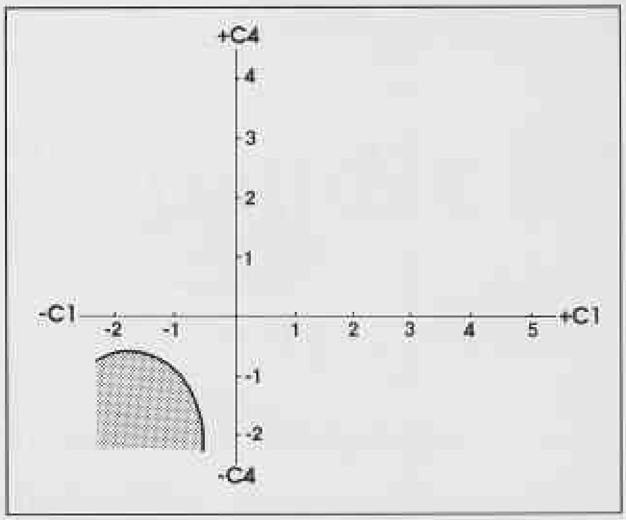
Agonis parviceps



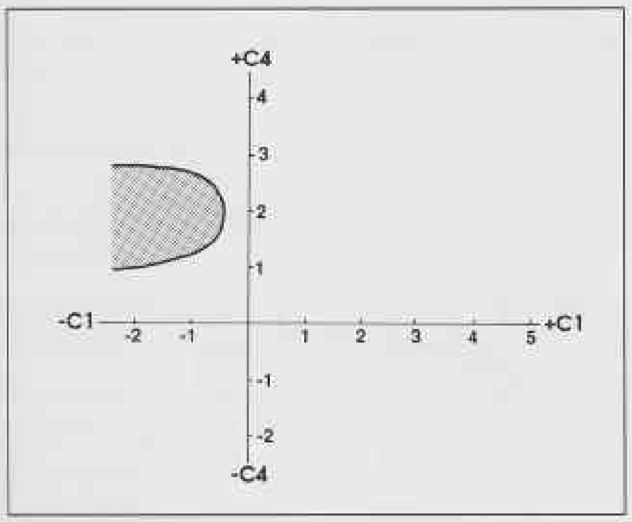
Anigozanthos flavidus



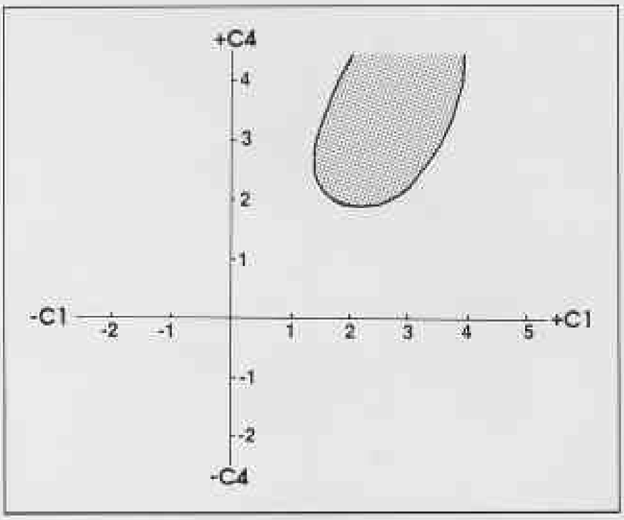
Bossiaea laidlawiana



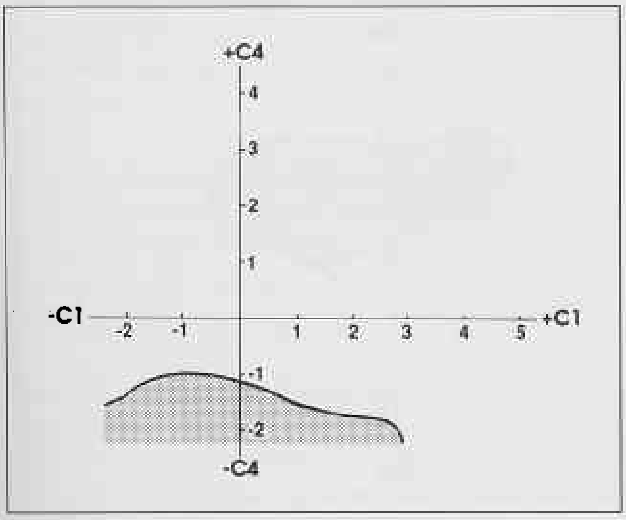
Clematis pubescens



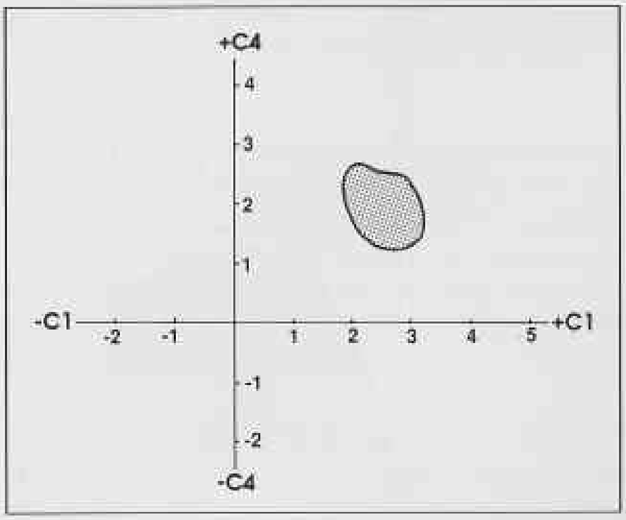
Dasypogon bromeliifolius



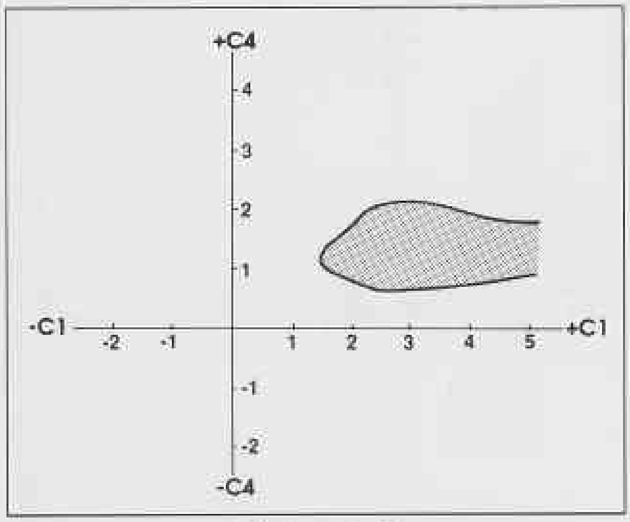
Hakea ruscifolia



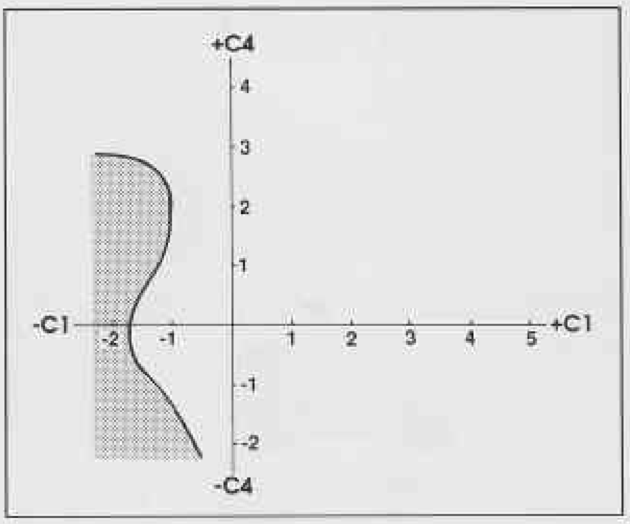
Hovea elliptica



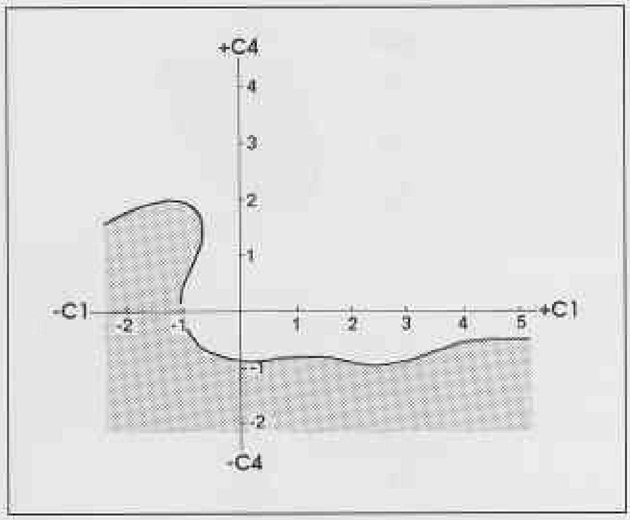
Hypocalymma robustum



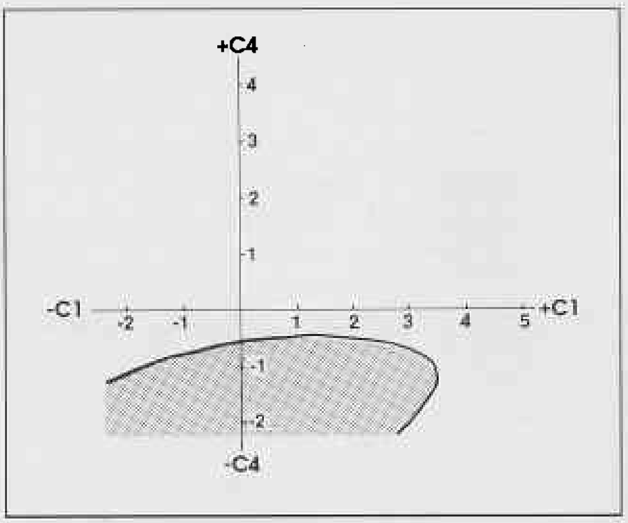
Kingia australis



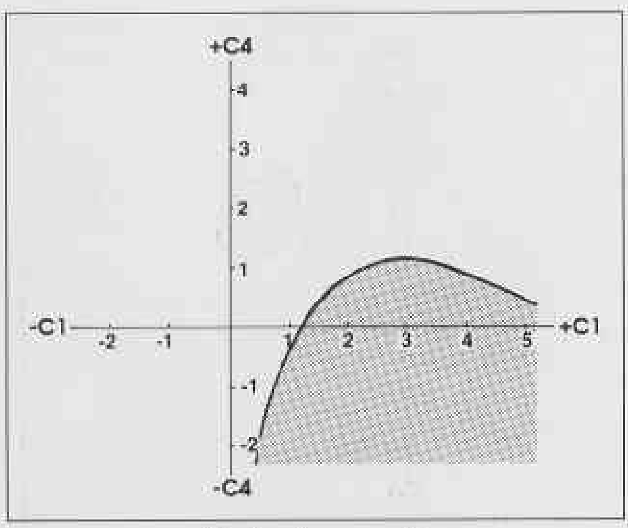
Leucopogon propinquus



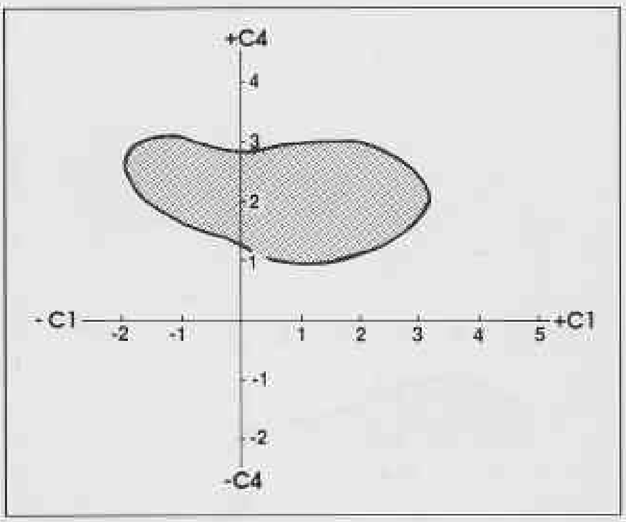
Leucopogon verticillatus



Patersonia umbrosa



Xanthorrhoea gracilis



Xanthorrhoea preissii

Appendix III

Site Type Descriptions used for Identification of Groupings Determined from Analyses of the Survey Data.

This Appendix presents the description of site types in the following format:

The classification criteria for seventeen different site types found in the southern jarrah forest areas based on rainfall, landform, soils and indicator species are outlined and comments for management are given.

Photographs of typical examples for each site type are included.

A summary matrix is provided showing species abundance, dominant soil type and site type.

An outline of the site conditions correlating with the occurrence of indicator species is provided to help in site appreciation.

The order of listing the types reflects a general trend in fertility moisture and drainage. Because of the difficulty in representing a multidimensional system in this way, the listing progresses from the best sites through to the poorly drained and infertile sites with the lower rainfall more easterly types listed last (Fig. IIIa).

As with the northern jarrah classification (Havel 1975) these site types only represent points along a continuum and combinations of types or versions, such as wetter or drier versions, are acceptable means of description.

The alphabetical class names are distinct from the classificaton used in the northern jarrah forest. Where there is some similarity with a northern type the same class name has been used. However, the two systems should not be equated.

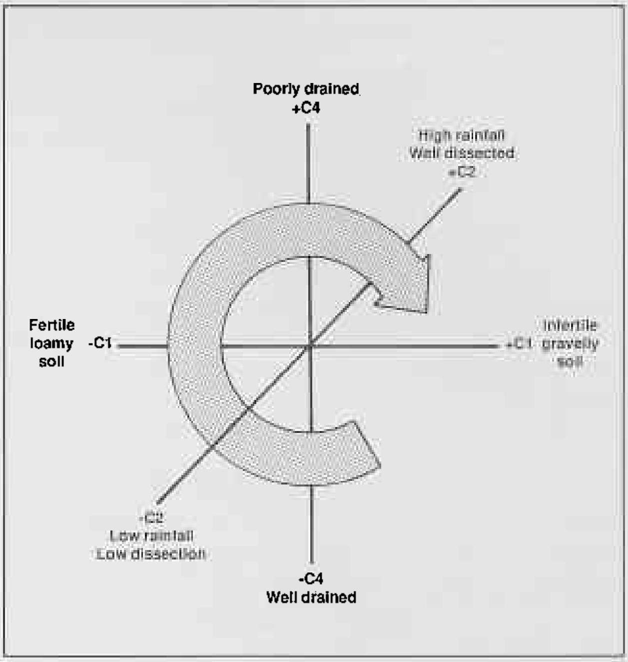


Figure IIIa
Diagrammatic representation of environmental influences for major axes - showing the direction followed in the order of listing the site types.

Landform types referred to are from a preliminary mapping by Churchward *et al*, (1988), but the northern sector of the region is still to be mapped. Familiarity with indicator species site preferences and what they infer about a site will help to identify variations in site types (see indicator species site preferences, App. VI).

Descriptions of site attributes are in terms relative to the range of values encountered in this survey. Reference to the former Forests Department's Aerial Photographic Interpretation (API) types (a system of forest structure classification) are included to enhance the impression of each type (Table IIIa).

Table IIIa
A.P.I. Types

SPECIES		HEIGHT CLASSES	
J	Jarrah	A+	30 m +
M	Marri	A	25-29 m
K	Karri	B+	20 - 24 m
W	Wandoo	B	15 - 19 m
Bbt	Blackbutt	C	<15 m

Southern Jarrah Site Classification

TYPE S

1. General Description - Good to medium quality (API type JMB+), predominantly jarrah forest of lower fertility on gravelly podzols often with much surface laterite rock. These sites are variable in the understorey, stand structure and drainage (Plate III(i), p.52).

2. Occurrence - These sites are generally found in moderately dissected landscape on the uplands and slopes of higher rainfall areas. This type is widespread where lateritic remnants remain. Type S may occur on landform types BEy, CRy, Ky, Ly, MTy, MTb, COy and TRc.

3. Soils - The soils are mostly brownish-yellow loamy sands with about 50 per cent lateritic gravel and some stone in the profile, changing to a brownish-yellow light clay at about 500 mm. Soils can tend to greyish sandier textures in depressions and concave slopes, with less gravel.

4. Indicator Species - *Banksia grandis, Bossiaea linophylla, Boronia gracilipes, Gompholobium ovatum, Grevillea brevicuspis, Hakea amplexicaulis, Hovea chorizemifolia, H. elliptica, Leptomaria cunninghamii, Leucopogon verticillatus, Macrozamia riedlei, Persoonia longifolia, Petrophile diversifolia, Podocarpus drouynianus, Sphaerolobium medium* and *Xanthorrhoea gracilis* are all generally present.

Others which are common on some sites are *Acacia browniana, A. myrtifolia, A. pulchella, Agonis hypericifolia, Bossiaea laidlawiana, B. ornata, Crowea angustifolia, Hakea lasianthoides, Isopogon sphaerocephalus, Lechenaultia biloba, Loxocarya fasciculata, Patersonia umbrosa, Pteridium esculentum* and *Xanthorrhoea preissii.*

In water gaining or wetter sites with impeded drainage, soils will be moister and species such as *Adenanthos obovatus, Agonis parviceps, Kingia australis* and *Leucopogon concinnus* can occur.

5. Management - These sites have moderate growth potential. Regeneration numbers are normally adequate, but may be low on sites with dense scrub. Dieback symptoms occur on these sites and the impact may be more serious in moist situations such as depressions or concave slopes.

TYPE T

1. General description - Good quality forest (API types JMB+/A) with tall undergrowth of medium density on well drained and moderately fertile, gravelly duplex soils (Plate III(ii), p.53).

2. Occurrence - These sites are common and can cover large areas of the uplands and slopes in medium to high rainfall areas of moderate dissection. Type T may occur on landform types BEy, BEb, PP, CRy, Ky, Ly, MTy, MTb, COy, V2, V3, S1 and S2.

3. Soils - The soils have a dark grey-brown sandy loam surface with some gravel changing to a generally yellow or brownish clay at a depth of about 650 mm. There can be considerable laterite rock on some sites.

4. Indicator Species - Species to be found on these sites are *Clematis pubescens, Hakea amplexicaulis, Hovea elliptica, Leucopogon verticillatus, Macrozamia riedlei, Persoonia longifolia, Podocarpus drouynianus* and *Pteridium esculentum*. Others which commonly occur are *Acacia alata, A. browniana, A. pulchella, Banksia grandis, Hovea chorizemifolia, Leucopogon propinquus, Patersonia umbrosa* and *Xanthorrhoea gracilis. Agonis parviceps, Bossiaea laidlawiana, B. linophylla, B. ornata, Leptomaria cunninghamii and Sphaerolobium medium* may occur on some sites.

5. Management - These fertile well drained sites have good growth potential. Regeneration numbers are usually adequate. Dieback symptoms may occur but the impact should be low.

TYPE K

1. General Description - Good quality forest (API type JMB+) on well drained moderately fertile slopes and uplands. Karri (*Eucalyptus diversicolor*) will often extend into these sites in low numbers. There is usually a tall dense understorey (Plate III(iii), p.53).

2. Occurrence - This type becomes more common south of Manjimup in the high rainfall areas in moderate to steeply dissected landscape. Type K may be found on landform types BEb, CRb, Kb, MTb, COb, V1, V2, V3 and S1.

3. Soils - The soils are generally grey sandy to a brown sandy loam surface with up to 50 per cent lateritic gravel and/or quartz grit changing to clay, or sometimes sandy clay, with some grit and gravel, at about 600 mm.

4. Indicator Species - *Agonis parviceps* is often prominent on these sites and *Boronia gracilipes, Macrozamia riedlei* and *Pteridium esculentum* should occur. *Acacia browniana, Allocasuarina decussata, Banksia grandis, Chorizema ilicifolium, Crowea angustifolia, Lasiopetalum floribundum, Leucopogon verticillatus, Persoonia longifolia, Podocarpus drouynianus* and *Tremandra stelligera* are common. *Acacia pentadenia, Leucopogon australis, L. concinnus, L. propinquus* and *Petrophile diversifolia* may also occur.

5. Management - These sites have good to very good growth potential. There may be some dieback expression on these sites, but the impact should be low. Regeneration can be difficult to establish in the denser scrub sites, if adequate advanced growth is not already present. These sites are distinguished from Type N by the deeper loamier soils, better drainage and presence of more karri type elements.

TYPE Q

1. General Description - High quality forest, (API types JM, JBbt, A+) on fertile well drained loams often on steeper slopes and gullies with taller, dense undergrowth. This type contains good blackbutt (*Eucalyptus patens*) and some karri where soils become sandier) Plate III(iv), p.53).

2. Occurrence - Type Q occurs on well dissected landforms in moderate to high rainfall zones on limited areas but is widespread wherever good soils along major streams occur. It may occur on landform types V1, V2, V3, S1 and extend onto adjacent landforms.

3. Soils - Soils have a brownish loamy surface, sometimes with a small amount of gravel. Gravel is more common below the surface but generally less than 50 per cent. This changes gradually to orange or reddish clay at a depth of about 650 mm.

4. Indicator Species - *Acacia alata, Clematis pubescens, Hovea elliptica, Leucopogon propinquus, L. verticillatus, Macrozamia riedlei, Persoonia longifolia* and *Pteridium esculentum* should all be present with *Hovea* and *Pteridium* very abundant. *Bossiaea laidlawiana* or *B. linophylla* and *Hakea amplexicaulis* are common on this type. *Acacia urophylla* occurs on the better sites.

5. Management - This type is very fertile and should have very good growth potential. There is often a good stocking of regeneration on these sites except under dense canopy, though it should not be difficult to establish. These sites are considered to be resistant to dieback. The steeper slopes may need special consideration in some operations to avoid erosion.

TYPE U

1. General Description - Good quality (API types JMA/A+) fairly dense forest, lower in fertility than type Q, on well drained sandy loam soils of slopes and gullies. There is usually a dense understorey (Plate III(v), p.53).

2. Occurrence - This type is generally found in the moderate rainfall areas in well dissected or moderately dissected landscape where there is an accumulation of sand in the profile. These sites are widespread but restricted in area. Type U may occur on landform types BEb, PP, Kb, MTy, MTb, V2, V3 and S1.

3. Soils - Generally the soils are yellow-brown or red-brown sandy loams sometimes gravelly, over reddish-yellow light clays at about 750 mm, with gravel increasing with depth.

4. Indicator Species - These sites have less *Acacia alata, Clematis pubescens, Hovea elliptica* and *Leucopogon propinquus* than type Q, whereas *Acacia pulchella, Bossiaea linophylla, Leucopogon capitellatus, Patersonia umbrosa* and *Tremandra stelligera* become more common. *Pteridium esculentum, Macrozamia riedlei* and *Persoonia longifolia* should also occur.

5. Management - Regeneration is usually adequate on these sites. Dieback symptoms may occur but the impact should normally be very low to low. These sites have very good growth potential. Silvicultural treatments will show good results. Though the areas involved are small and possibly not manageable as separate units, they often merge with other good sites such as Q and T.

TYPE V

1. General Description - good quality forest (API types JMB+/A) on long sandy slopes of moderate fertility but less well drained and therefore moist (Plate III(vi), p.54).

2. Occurrence - Type V is generally on the slopes of moderately dissected country in a wide range of rainfall areas and can occur in large units. This type may occur on landform types BEy, BEb, Ky, Ly, MTy, COy and COb.

3. Soils - The soils have a brown or yellow sandy loam or loamy sand surface often with a small amount of gravel or quartz grit, changing at around 600 mm to brownish-yellow or orange sandy clays and becoming light or medium clay with depth. Variable amounts of gravel and/or quartz material occur, generally increasing with depth.

4. Indicator Species - *Acacia extensa, A. pulchella* and *A. urophylla* can occur on these sites, and also *Agonis flexuosa* where sandier soils occur. *Bossiaea linophylla* and *Clematis pubescens* are generally very common. *Leucopogon propinquus, L. verticillatus, Macrozamia riedlei* and *Persoonia longifolia* should be present. *Hakea lissocarpha, H. ruscifolia, Leucopogon australis* and *Pteridium esculentum* may occur.

5. Management - These sites can be moist and there is risk of dieback infection which may have a low to moderate impact. There is usually adequate regeneration on this type and it has moderate to good growth potential.

TYPE X

1. General Description - Low to moderate quality forest (API type JMB) with dense understorey on deep sands of ridges and slopes of lower fertility (Plate III(vii), p.54).

2. Occurrence - These sites are in the high rainfall coastal areas of low to moderate dissection. They generally occupy small but scattered areas in moist sites. Type X may occur on landform types COy, COp, COd, Q, A and HA.

3. Soils - The deep sandy soils have some organic matter accumulation in the surface which is generally a grey sand and overlying a leached white sand. There may be some quartz grit and rounded pebbles through the profile (800 mm +).

4. Indicator Species - *Acacia myrtifolia, Anigozanthos flavidus, Dasypogon bromeliifolius, Leucopogon propinquus, Macrozamia riedlei, Persoonia longifolia* and *Pteridium esculentum* should all be present. *Agonis flexuosa, Bossiaea linophylla, Hovea elliptica* and *Xanthorrhoea preissii* are generally present also. *Acacia browniana, A. pulchella, Anarthria scabra, Banksia grandis, Clematis pubescens* and *Tremandra stelligera* are common.

5. Management - These infertile sites have low growth potential. The moist, infertile soils may be susceptible to dieback but the impact should be low. Regeneration numbers may be low and can be difficult to establish in these heavy scrub types.

TYPE N

1. General Description - Low to moderate quality forest (API type JMB) with tall dense undergrowth, particularly tea-tree (*Agonis parviceps*), on infertile podzols, generally on wet poorly draining uplands and slopes. Type N includes sites where karri may be present in low numbers (Plate III(viii), P.54).

2. Occurrence - These sites occur mainly in high rainfall moderately dissected country, are common in these areas and can occur in large units. Type N may occur on landform types CRd, Ky, Kp, MTd, COb, COp, COd, A and HA.

3. Soils - The soils are variable but all have a grey sandy surface, either fine or coarse grey sand or sandy loam. There are often small amounts of quartz grit increasing with depth. There is a change to clayey sand or gradually to a sandy clay at about 300 mm with some lateritic gravel, and then to a yellowish clay at about 400 mm. On the poorer sites drainage is more impeded by development of a heavier clay layer or hardpan.

Indicator Species - *Acacia browniana* is common and some sandier types will have *A. myrtifolia*, *A. pentadenia* and *Agonis flexuosa* and karri. *Agonis parviceps* usually dominates and *Banksia grandis*, *Boronia gracilipes*, *Leucopogon australis*, *Macrozamia riedlei* and *Persoonia longifolia* are generally present.

Allocasuarina decussata, *Chorizema ilicifolium*, *Hovea elliptica*, *Leucopogon concinuus*, *L. propinquus*, *Podocarpus drouynianus*, *Petrophile diversifolia*, *Pteridium esculentum* and *Tremandra stelligera* may be present.

On lower slopes and depressions with poorer drainage and sandier soil *E. megacarpa*, *E. patens* and *Anarthria scabra* occur and *Acacia myrtifolia*, *Kingia australis* and *Xanthorrhoea preissii* become more common.

5. Management - The growth potential of these sites is low to moderate. Dieback symptoms occur but generally with a low impact. However, with disturbance and opening up of the stand the impact may become more serious. Regeneration in these scrub types is often sparse and can be difficult to establish.

TYPE P

1. General Description - Low to medium quality forest (API type JMB) on the uplands and slopes with denser, often tea-tree scrub. Soils have a shallow sandy surface over clay with impeded drainage (Plate III(ix), p.54).

2. Occurrence - This is a common type in the jarrah forest of moderate to high rainfall areas and moderate dissection, but occurs less frequently north-east of Manjumup. Type P may occur on landform types CRd, Kp, Lp, MTp, MTd, COy, COp, COd,A, HA and TRc.

3. Soils - Generally soils consist of brown or grey sands or sandy loams with varying quantities of fine to medium lateritic gravel over yellowish medium clay or concreted laterite at about 500 mm.

4. Indicator Species - *Acacia browniana* is most common on these sites but *Acacia extensa* may occur. *Agonis parviceps* is usually prominent. *Banksia grandis*, *Bossiaea ornata*, *Hakea amplexicaulis*, *Hovea chorizemifolia*, *Leucopogon propinquus*, *L. verticellatus*, *Macrozamia riedlei*, *Persoonia longifolia* and *Podocarpus drouynianus* should all be present. *Loxocarya fascicularis*, *Patersonia umbrosa*, *Sphaerolobium medium*, *Xanthorrhoea gracilis* and *Xanthorrhoea preissii* often occur. *Allocasuarina fraseriana* may occur on some sandy gravel sites.

5. Management - Generally these are poorer sites with moderate growth potential but there can be quite good forest on sites where the sandy loam surface is deeper. Regeneration numbers can be inadequate on some sites, and difficult to establish if advanced growth is not already present. Dieback symptoms can be serious with overstorey impact likely. The feature which distinguishes these sites is the poor drainage.

TYPE R

1. General Description - Generally open low quality forest (API type JMC), on grey sands and quartz sands in upland depressions, saddles, broad valley heads and drainage lines in moderately dissected gravelly uplands. This type covers a wide range of sites but all with similar characteristics. Generally they have dense scrub and are seasonally wet but dry out very quickly in summer (Plate III(x), p55).

2. Occurrence - These sites are mostly restricted in area but widespread throughout the jarrah forest on many landform types and all rainfall zones. Type R may occur on landform types Kp, Ks, Lp, Ls, MTp, MTd, COp,COd, CA, PI, BU, MO, Q, A, HA, QN, TRs and F.

3. Soils - The soils are generally a dark grey or grey sand, sometimes loamy sand, overlying sand, often brownish yellow, becoming paler with depth, often with quartz grit and rubble. Frequently it becomes a sandy clay at about 1000 mm which may be overlain by a gravel layer or an organic stained hardpan.

4. Indicator Species - *Agonis parviceps* is generally prominent on these sites. *Acacia extensa, Leucopogon australis, Macrozamia riedlei,* and *Persoonia longifolia* should be present. *Bossiaea linophylla, Banksia grandis, Hakea ruscifolia, Loxocarya fasciculata, L. flexuosa* and *Podocarpus drouynianus* commonly occur.

This type covers a range of similar sites which may occur in different situations and species such as *Acacia myrtifolia, Adenanthos obovatus, Anarthria prolifera, A. scabra, Agonis flexuosa, Allocasuarina fraseriana, Anigozanthos flavidus, Banksia ilicifolia, Boronia spathulata, Dasypogon bromeliifolius, Kingia australis, Lepidosperma angustatum, Leucopogon concinuus, Melaleuca thymoides, Pultenea reticulata, Scaevola striata, Thomasia grandiflora, Xanthorrhoea preissii,* and *Xylomelum occidentale* may occur.

5. Management - These infertile sites have low growth potential. Because of the infertile soils they may be affected by dieback and the impact can be moderate to high. Regeneration numbers on this type are often low and would be difficult to establish.

TYPE I

1. General Description - Low to medium quality forest (API type JMB) on moist poorly drained sites with gravelly duplex soils in high rainfall areas (Plate III(xi), p.55)

2. Occurrence - Type I is more common in the southern high rainfall areas in moderately dissected landscape than it is elsewhere. It generally occurs on lower slopes but also on uplands where drainage is impeded. Type I may occur on landform types CRy, CRd, Kp, Lp, MTp, COy, COp, COd, and TRc.

3. Soils - There is generally a shallow sandy surface over a clayey sand (sometimes sandy loam) with some quartz grit and small amounts of gravel increasing with depth to about 50 per cent. This changes to a sandy clay or clay at about 300 mm or less with about 30 per cent lateritic gravel.

4. Indicator Species - *Acacia browniana* and *Agonis parviceps* dominate, *Banksia grandis, Kingia australis, Leucopogon australis, L. concinnus, Macrozamia riedlei, Petrophile diversifolia* and *Podocarpus drouynianus* should be present. *Agonis hypericifolia, Bossiaea linophylla, Gompholobium ovatum, Hakea amplexicaulis, H. lasianthoides, Hovea chorizemifolia, H.elliptica, Leptomaria cunninghamii, Leucopogon verticillatus, Loxocarya fasciculata, Persoonia longifolia* and *Xanthorrhoea gracilis* are common.

5. Management - These sites may carry good timber volumes but have only low to moderate growth potential. The sites are similar to Type P but moister. Dieback symptoms are likely to occur and the impact may be low to moderate or possibly worse with opening up of the stands and disturbance. Some sites may lack adequate regeneration.

TYPE B

1. General Description - Poor quality blackbutt and jarrah forest (API type JBbtC) on seasonally wet infertile sands on flats and along drainage lines. Marri is not common on these sites and there is usually a heavy scrub layer. Drainage is very poor (Plate III(xii), p.55).

2. Occurrence - This type does not occupy large areas but is common in the moderate to high rainfall areas of low to moderate dissection. Type B may occur on landform types COd, CM,CA, HA, S3 and S4.

3. Soils - These soils consist of coarse grey sands, often with quartz material, sometimes over a light clay or more often deeper sands with an organic hardpan.

4. Indicator Species - *Agonis parviceps* dominates, *Pultenea reticulata* and *Kingia australis* should be present. *Adenanthos obovatus, Leptomaria cunninghamii* and *Xanthorrhoea preissii* are common. *Acacia browniana, A. pentadenia, Leucopogon australis, L. concinnus, Persoonia longifolia* and *Podocarpus drouynianus may also occur.*

5. Management - These poor sites have low growth potential, regeneration numbers are often low and would be difficult to establish in this scrub type. There is some occurrence of dieback symptoms and the impact may be low to moderate.

TYPE F

1. General Description - Southern treeless flats and swamps with dense low vegetation and sometimes with scattered stunted jarrah. These sites are poorly drained and waterlogged in winter (Plate III(xiii), p.55).

2. Occurrence - There may be only small areas but these may become larger and more common in the south. These sites are in the high rainfall areas of low to moderate dissection. Type F may occur on landform types LS, SC, CA, PI, and F.

3. Soils - The soils are humic podzols with a thick surface root mat in fine grey sand with some surface quartz material, over a deep fine sand becoming darker with depth (to 800 mm+) which overlays clay.

4. Indicator Species - *Beaufortia sparsa* , *Dasypogon bromeliifolius*, *Evandra aristata* and *Homalospermum firmum* should occur and species such as *Adenanthos obovatus*, *Agonis parviceps*, *Anarthria prolifera* and *Leucopogon australis* are common.

5. Management - Dieback is likely to be a problem because, although the impact may only be classified as low (understorey only), it is very noticeable on these open flats. The impact may be high in the jarrah fringes associated with these flats.

TYPE Z

1. General Description - Low to moderate quality (API type JMB) dry eastern jarrah slopes and uplands on gravelly, heavier soils, with more open understorey (Plate III(xiv), p.56).

2. Occurrence - These sites are widespread in the drier low rainfall areas of low dissection. Type Z may occur on landform types BEy, PP, Ly, COy, and S2.

3. Soils - Soils are generally a brownish sandy loam to sandy clay loam with varying amounts of gravel. This changes to a clay or sandy clay loam at about 300 mm. There may be a layer of heavy lateritic gravel at about 400 mm.

4. Indicator Species - Species which should be found on these sites include *Astroloma pallidum*, *Bossiaea ornata*, *Dryandra bipinnatifida*, *Hakea lissocarpha*, *Loxocarya fasciculata*, *Macrozamia riedlei*, *Trymalium ledifolium* and *Xanthorrhoea preissii*. *Acacia pulchella* and sometimes *A. extensa*, *Astroloma ciliatum*, *Leptomaria cunninghamii*, *Leucopogon verticillatus*, *Persoonia longifolia* and *Styphelia tenuiflora* are common.

5. Management - These sites have a low to moderate growth potential. Regeneration numbers are normally adequate on these sites. Dieback symptoms occur but generally with only a low impact.

TYPE M

1. General Description - Moderate quality eastern wandoo and jarrah forest (API type JWB) on slopes with clayey soils. This type merges with the jarrah upper slopes and ridges or low wandoo ridges further east. Marri is less common on these sites than type Z for instance, occurring where the soils are sandier (Plate III(xv), p.56).

2. Occurrence - This type is widespread to the north-east of Manjimup in areas of low rainfall and low dissection. Type M may occur on landform types BEy,BEb, PP, MTb, COy and S2.

3. Soils - The soils are brown or yellowish-brown sandy loams or loamy sands with varying amounts of lateritic gravel, overlying at about 400 mm yellowish-brown or yellowish-red clays, sometimes with lateritic gravel.

4. Indicator Species - *Acacia pulchella*, *Dryandra nivea*, *Hakea lissocarpha*, *Leucopogon propinquus*, and *Trymalium ledifolium* should all be present. *Astroloma ciliatum*, *A. pallidum*, *Loxocarya fasciculata*, *L. flexuosa*, and *Macrozamia riedlei* are also common.

Boronia spathulata, Dryandra bipinnatifida and *Xanthorrhoea preissii* may occur and *Hypocalymma angustifolium* may occur in moister sites such as below rock outcrops.

5. Management - These sites have low to moderate growth potential. Regeneration numbers are generally adequate on this type, and dieback disease expression is uncommon.

TYPE Y

1. General Description - Moderate quality forest (API type JMB) in the eastern broad flat drainage lines on sandy soils. Drainage is impeded and these sites can become very wet in winter due to the low dissection of the landscape (Plate III(xvi), p.56).

2. Occurrence - These sites are widespread in the low rainfall eastern forests but cover restricted areas. Type Y may occur on landform types BEy, PP, Ly, Lp, MTp, CM and S2.

3. Soils - Soils are a black or dark grey clayey sand in the upper profile. At about 500 mm there is generally a heavy layer of lateritic gravel in a yellowish or pale brown coarse sandy clay.

4. Indicator Species - *Bossiaea linophylla, B. ornata, Hakea lissocarpha, Hypocalymma angustifolium, Leucopogon propinquus* and *Loxocarya fasciculata* should be present. *Acacia extensa, Astroloma ciliatum, Boronia spathulata, Macrozamia riedlei* and *Trymalium ledifolium* may also occur.

5. Management - This type has a low growth potential and regeneration may be inadequate on some sites. This type may be susceptible to dieback because of the moister soils, but the impact should be low.

TYPE A

1. General Description - Flats and broad drainage lines, with *Eucalyptus rudis* on shallow soils with impeded drainage. Some jarrah occurs on the fringes and *E. decipiens* may occur on low gravelly rises. Some blackbutt may also occur on better sites (Plate III(xvii), p.56).

Occurrence - These sites cover small areas scattered throughout the north-eastern low rainfall parts of the study area with low dissection. They also include the associated open swampy areas. Type A may occur on landform types Ls, CM, CA, S2, and S3.

3. Soils - There is a yellowish-brown sandy clay loam surface, generally with little or no gravel, changing gradually to a light brown fine sandy clay loam, often gravelly, over a shallow laterite or clay impeding layer.

4. Indicator Species - *Acacia saligna, Allocasuarina humilis, Astroloma ciliatum, Loxocarya fasciculata, Melaleuca preissiana* and *M. viminea* should be present. *Banksia littoralis, Boronia spathulata* and *Xanthorrhoea preissii* may occur.

5. Management - This type has a low growth potential and regeneration is usually sparse. These sites are wet and sticky in winter and may be potential dieback inoculum sources. The impact of dieback on these sites would be low.

Plate III(i)
Type S

Plate III(ii)
Type T

Plate III(iii)
Type K

Plate III(iv)
Type Q

Plate III(v)
Type U

Plate III(vi)
Type V

Plate III(vii)
Type X

Plate III(viii)
Type N

Plate III(ix)
Type P

Plate III(x)
Type R

Plate III(xi)
Type I

Plate III(xii)
Type B

Plate III(xiii)
Type F

Plate III(xiv)
Type Z

Plate III(xv)
Type M

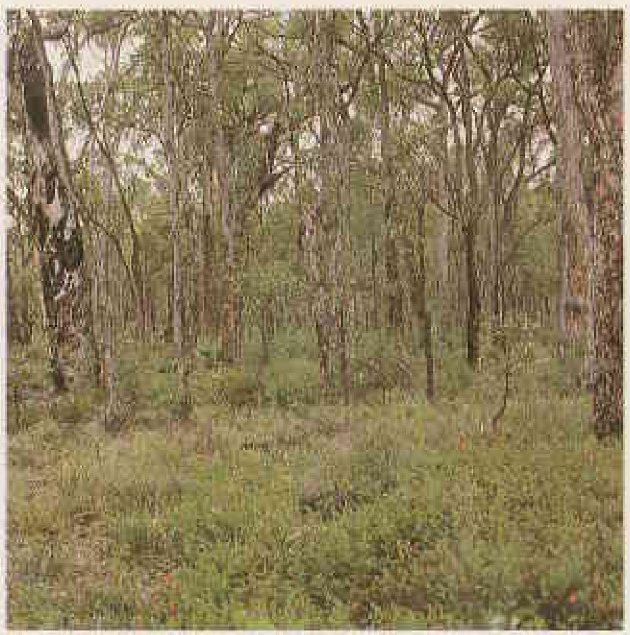


Plate III(xvi)
Type Y

Plate III(xvii)
Type A

Appendix IV

Site/Vegetation Summary Matrix

The following four pages are a summary of the site type attributes which can be used as a quick reference checklist for site typing. It illustrates the relationship between species adundance and site types and shows the dominant soils of each site type.

LEGEND

Soils	Species Abundance
Loam or S/L gravelly	**Blank** .... species generally absent
Laterites/gravelly podzols	**Zero/score** ... species may be present
Sandy podzols	**Score 1 - 5** .... species generally present
Impeded podzols	**1** .... low abundance
Deep sands	**5** .... high abundance

Site Types / Soils

INDICATOR SPECIES	S	T	K	Q	U	V	X	N	P	R	I	B	F	Z	M	Y	A
Acacia alata		2/0		3	2/0				2/0	2/0							
Acacia browniana	4	0/3	2/0				2/0	2/0	2		3						
Acacia extensa						3/0				2						2/0	
Acacia myrtifolia	2/0						3	0/2		2/0	0/2						
Acacia pentadenia			0/2					0/2				2/0					
Acacia pulchella	2/0	2/0			2/0		2/0							3/0	3		
Acacia saligna																	

Site Types / Soils

INDICATOR SPECIES	S	T	K	Q	U	V	X	N	P	R	I	B	F	Z	M	Y	A
Acacia urophylla				2	1	0/2											
Adenanthos obovatus	0/2									2/0	0/2	2					
Agonis flexuosa						3/0	2	0/2		2/0							
Agonis hypericifolia	2										0/2						
Agonis parviceps	0/2		3					5	3	3	3	4	2/0				
Allocasuarina decussata			0/2					0/2									
Allocasuarina humilis																	2
Anarthria prolifera										0/2			2/0				
Anarthria scabra							0/3	1									
Anigozanthos flavidus							3			2/0							
Astroloma ciliatum														2/0	2	2	2
Astroloma pallidum														2	2		
Banksia grandis	2	2/0	2/0	2/0			1	2	2	2/0	2						
Banksia littoralis																	2/0
Beaufortia sparsa													3				
Boronia gracilipes	2/0		2					2			2/0						
Bossiaea laidlawiana	2/0	2/0							2/0								
Bossiaea linophylla	2	2/0		2/0	2/0	3	2		0/2	2/0	2					2	
Bossiaea ornata	2/0	2/0							2/0					3		2	
Chorizema ilicifolium			0/2					0/2									
Clematis pubescens		2		3	2	2											
Crowea angustifolia	2/0		2/0														

Site Types / Soils

INDICATOR SPECIES	S	T	K	Q	U	V	X	N	P	R	I	B	F	Z	M	Y	A
Dasypogon bromeliifolius							3			2/0			2				
Dryandra bipinnatifida														2	2/0		
Dryandra nivea															3		
Eucalyptus calophylla	2	3	2	2	3	3	3	2	2	2	2			2	2/0	2	
Eucalyptus diversicolor			1/0					0/1									
Eucalyptus marginata	4	3	2	3	2	3	3	3	3	2	3	2		3	3	3	2/0
Eucalyptus patens				2/0								2					
Eucalyptus rudis																	2
Eucalyptus wandoo															3		
Gompholobium ovatum	2									2/0	0/2						
Hakea amplexicaulis	2	2		2	2	1			2		0/2						
Hakea lasianthoides	3										0/2						
Hakea lissocarpha						2			0/2					3	3	3	2/0
Hakea ruscifolia						0/2				2/0							
Homalospermum firmum													2				
Hovea chorizemifolia	2	2/0							2	2/0	0/2						
Hovea elliptica	2	3		4	3	2/0	2	2/0			2/0						
Hypocalymma angustifolium															0/3	4	
Kingia australis	0/2							2/0		2/0	2	2					
Lasiopetalum floribundum			2														
Lepidosperma angustatum										2/0							
Leptomeria cunninghamii	2	2/0							2/0		0/2	2/0		3/0			

Site Types / Soils

INDICATOR SPECIES	S	T	K	Q	U	V	X	N	P	R	I	B	F	Z	M	Y	A
Leucopogon australis						2/0		2	0/2	2	2	2/0	2/0			2/0	
Leucopogon concinnus	0/2									2/0	0/3	2/0					
Leucopogon propinquus		2/0		3	2	2	2		1	1/0				2/0	2	2/0	
Leucopogon verticillatus	2	2	2/0	3	2	3			3	2/0	0/2			2/0			
Loxocarya fasciculata	2								2	2	2/0			2	2/0	2	2
Loxocarya flexuosa									2/0	2/0					2/0		
Macrozamia riedlei	2	2	2	3	2	2	3	2	2	2	1	2/0		2	2	1	
Melaleuca preissiana																	2
Melaleuca thymoides										2/0							
Melaleuca viminea																	3
Patersonia umbrosa	2/0	3/0		2/0	3/0	1			2/0								
Persoonia longifolia	2	2	2/0	2	2	2	2	2	2	2	2	1/0		2/0			
Petrophile diversifolia	3		2/0								2						
Podocarpus drouynianus	2	2	2/0					2/0	2	2	3	2/0					
Pteridium esculentum	2/0	2	2	4	3	2/0	3	0/2									
Pultenea reticulata										2/0		2					
Sphaerolobium medium	2								2/0		0/2						
Thomasia grandiflora										2/0							
Tremandra stelligera			2	2/0	3/0			2/0									
Trymalium ledifolium														3/0	3	2	
Xanthorrhoea gracilis	2	2/0							2/0	2/0	0/2						
Xanthorrhoea preissii				2/0			2	2/0	0/2	2/0	2/0	2		3	3/0		2/0

Appendix V

Landform Types
Referred To In Site Type Description (App.III),
Legend From Churchward *et al.* (1988)[1],
Landform Mapping In The Study Area.

LEGEND
Units developed in granitic rocks and associated unconsolidated sediments

PLATEAU ELEMENTS

BEVAN. Gently undulating terrain; includes minor valleys.

BE	BEy	Gravelly or sandy yellow duplex soils; J-M forest.
	BEb	Brown gravelly duplex soils and red earths; M-K forest.

PERILLUP. Plain of low relief often slightly lower than Bevan.

PP	Yellow duplex soils on long slopes; J-M forest.
	Podzols on drainage floors; Mel low woodland.
	Yellow solonetzic soils in swamps; Ys thickets.

CROWEA. Crests and upper slopes of spurs and ridges.

CR	CRb	Brown gravelly duplex soils and red earths; K-M forest.
	CRy	Gravelly yellow duplex soils; J-M forest.
	CRd	Sandy yellow duplex soils; M-J forest.

HILLS AND HILLY TERRAIN

KEYSTONE. Hills and ridges. >60 m relief; smooth crests and slopes; occasional ravines; some prominent granite domes.

K	Kg	Granite outcrop.
	Kb	Brown gravelly duplex soils and red or yellow earths; much laterite. M-K-Tr-Ty forest.
	Ky	Gravelly yellow duplex soils; J M-Ty forest.
	Kp	Shallow gritty yellow duplex soils; J-Bu woodland.
	Ks	Podzols; Tt heath and J woodland.

[1] CHURCHWARD, H.M., McARTHUR, W.M., SEWELL, P.L. and BARTLE, G.A. (1988). Landforms and Soils of the South Coast and Hinterland, W.A. Northcliffe to Many Peaks. Divisional Report 88/1, C.S.I.R.O. Division of Water Resources.

LINDESAY. Hills; >60 m relief, rocky crests, smooth flanks.

L	Lg	Granite outcrop.
	Lp	Shallow gritty yellow duplex soils; J-Bu woodland.
	Ly	Gravelly yellow duplex soils with laterite; J-M forest.
	Ls	Leached sands and podzols; Tt heath and J woodland.

GARDNER. Coastal hills and headlands 60 m relief, steep irregular rocky crests and upper slopes separated by smooth sandy tracts.

G	Gg	Granite outcrop.
	Gs	Leached sands and podzols; mallee-heath.

BARROW. Hills and ridges. >60 m relief, crests of granite, gently sloping flanks.

BA	BAg	Granite outcrop.
	BAf	Yellow duplex soils, sands, gravels; J-M-Yf forest.

MATTABAND. Hills and hilly terrain. 20-60 m relief; scattered granite.

MT	MTy	Gravelly yellow and yellow duplex soils; J-M-Ty forest.
	MTb	Brown gravelly duplex soils; K-M-Ty-J forest.
	MTp	Shallow gritty yellow duplex soils; J woodland.
	MTd	Sandy yellow duplex soils; J-M forest.

PILLENORUP. Hills of granite with a fringe of sedimentary rocks, <60 relief; rounded crests and smooth gentle slopes; some granite.

PN Gravelly yellow duplex soils, sands and laterite; J-M-Y low forest.

COLLIS. Low hills and low hilly terrain. 20 m relief.

CO	COy	Gravelly yellow duplex soils; J-M forest.
	COb	Brown gravelly duplex soils; M-J-K forest.
	COp	Shallow gritty yellow duplex soils; J-Bu woodland.
	COd	Sandy yellow duplex soils; M-J forest.

SWAMPY TERRAIN

CAMBELLUP. Plains with drainage floors, swamps and low rises.

CM Yellow solonetzic soils and podzols on floors; Bb-Ys-Y thickets and Mel woodland.
Shallow solonetzic soils in swamps; myrtaceous heath.
Gravelly yellow duplex soils on rises; M forest; Ha scrub.

SIDCUP. Shallow narrow depressions.

SC Humus podzols; Mel woodland.

CALDYANUP. Plains with drainage floors, and low rises.

CA Yellow solonetzic soils; Ha scrub, Mel woodland.
Humus podzols; Kg sedgelands, Tt heath.
Reddish yellow earths; Ha scrub.
Gravelly yellow duplex soils on rises; M forest, Ha scrub.

PINGERUP. Poorly drained plains and drainage zones, some swamps.

PI Humus and peaty podzols; Kg sedgeland; Tt heath.
Peat in swamps; Wt thickets.

BURNETT. Plains with drainage floors; scattered granite.

BU Podzols and shallow gritty soils; Kg sedgelands,Tt heath.

MORANDE. Lunettes, dunes and hummocks and intervening swamps.

MO Podzols on sands; B Sh woodland.
Yellow solonetzic soils in swamps; Ha scrub, Ys thickets.

QUAGERING. Broadly convex sandy crests and valley divides, occasional swamps.

Q Humus and peaty podzols; Kg sedgeland, Tt heath.

ANGOVE. Gently sloping sandy terrain; slight dissections.

A Humus podzols on broad crests; Kg sedgeland,Tt heath.
Sandy yellow duplex soils in shallow dissections; J woodland.

HAZELVALE. Narrow sandy plains; slight stream incision.

HA Humus podzols on crests of spurs; Tt scrub.
Yellow duplex soils on valley flanks; J-M low forest.
Peaty podzols on minor valley floors; sedges and reeds.

QUINDABELLUP. Shallow, elongate sandy depressions and valley divides.

QN Humus podzols and sandy yellow duplex soils; Mel woodland.

Units Developed In Siltstones And Sandstones

PLATEAU ELEMENTS

REDMOND. Broadly undulating plateau: scattered lakes and depressions.

R Yellow duplex soils and laterite on plains; M-J-Ab forest.
Yellow solonetzic soils in depressions; Mel woodland.

TAKALARUP. Broadly undulating plateau: lakes; depressions; hummocks; scattered siltstone.

TK Gravelly yellow duplex soils on plains; J-M woodland, mallee heath.
Yellow solonetzic soils in depressions; Ys-Mel thickets.
Podzols in sands of hummocks; B woodland.

CHILLINUP. Broadly undulating plateau; scattered small lakes and depressions with lunettes; many sandy hummocks and linear dunes.

CH Yellow duplex soils, laterite on plains; mallee heath.
Yellow solonetzic soils in depressions; Ys-Mel thickets.
Podzols in sands of hummocks and dunes; B woodland.

YELLANUP. Gently sloping terrain fringing higher hills and ridges.

Y Gravelly yellow duplex soils; J-M forest; mallee heath.

DEMPSTER. Ridge crests formed by dissection of plateau units.

D Dc Sands and laterite on elongate crests; J-Ab-M forest.
Ds Sands and gravels on smooth slopes; Ab-Sh low forest.

MITCHELL. Broadly undulating uplands.

MI Gravelly yellow duplex soils and laterite on crests; J-M forest.
Leached sands in depressions; J-Sh woodland.

TRENT. Flat topped hills. <40 m relief, gently sloping flanks.

TR
- TRc Gravelly yellow duplex soils and laterite on crests; J-M forest.
- TRs Leached sands with iron pan on flanks; J-Sh woodland.

SWAMPY TERRAIN

BOULONGUP. Broad, shallow, poorly drained depressions in plateau surface; complex of swamps, lakes, low lateritic rises, lunettes and hummocks.

BO Yellow solonetzic soils in swamps; Ys-Mel thickets, reeds.
Podzols in sands; J-B-Sh woodland.

FERNLEY. Gently undulating sandy terrain.

F Sandy or gravelly yellow duplex soils on rises; J-Bu woodland.
Humus podzols in broad depressions; Kg sedgeland, Tt heath.

Units Developed In Coastal Aeolian And Fluviatile Sediments

SWAMPY TERRAIN

BLACKWATER. Plains with hummocks, linear dunes and swamps.

BW
- BWp Humus podzols on plains; Kg sedgelands, Tt heath.
  Peat in swamps; Wt thickets.
  Podzols on dunes; B woodland.
- BWo Shallow gleyed duplex soils; Mel woodland.
  Podzols on dunes; B-Sh woodland.

OWINGUP. Plains with swamps, lunettes and dunes.

OW Yellow solonetzic soils, organic loams and diatomaceous earths; Wt-Mel thickets.
Tt heath and reeds Podzols on dunes; B-Sh woodland.

KORDABUP. Broad drainage floors in lower reaches of streams.

KO Humus podzols; Tt scrub and Kg sedgeland.

WALPOLE. Flat to gently sloping benches; some shallow dissections.

WA Podzols and deep sands; Tt scrub, Sh woodland and Kg sedgeland.

DUNE SYSTEMS

D'ENTRECASTEAUX. Broad ridges of limestone, often >100 m relief; undulating crests; steep scarps to seaward; much limestone outcrop.

E Podzols and shallow brown sands; Pp-B scrub.

MEERUP. Parabolic dunes.

M
- My Calcareous sand; Pp heath and woodland.
- Mc Calcareous sand with shallow leaching; Pp woodland.
- Mp Podzols over calcareous sand; B-Bu-Y woodland.
- Ms Podzols in siliceous sand; B-Bu-Y-Sh woodland.
- Mu Unstable sand.
- Mf Podzols on interdune plains; B-Bu-Y woodland.
- Mr Beach ridges; Pp heath and B woodland.

Units Associated With Drainage Lines

MAJOR VALLEYS (V)

V1 Valleys in granitic areas; >40 m relief; smooth steep slopes; narrow terrace.
Red earths, yellow duplex soils on slopes; K-M forest. Brown loamy soils on terraces; K-M-Bb-Wt forest.

V2 Valleys in granitic areas; 20-40 m relief; smooth, moderate, slopes; narrow terrace.
Red earths, gravelly yellow duplex soils on slopes; K-M-J forest. Sands, yellow duplex soils on terraces; K-M-Bb-Wt forest.

V3 Valleys in granitic areas; 20 m relief; rocky slopes; terrace.
Yellow duplex soils on slopes; J-M-Ty forest. Deep sands on terrace; Wt-Mel low forest.

V4 Terraces, levees and swampy tracts; <10 m relief.
Sandy and silty alluvial soils; M-Mel-Bb-Wt forest.

V5 Valley of upper Kent River in granitic plateau; about 20 m relief; gentle smooth flanks; broad flat saline floor (st).
Yellow duplex soils on flanks: J-M forest. Yellow solonetzic soils on floors; Mel woodland, halophytes.

V6 Valley of upper Kalgan River in granitic and sedimentary rocks; 20-30 m relief; extensive gently sloping, irregular, often rocky flanks; broad flat saline floor (st).
Yellow duplex soils on flanks; J-M-W low forest. Yellow solonetzic soils on floors; Mel scrub and halophytes.

V7 Valleys in sedimentary rocks; 20-40 m relief; short, steep, irregular slopes, much siltstone, occasional granite outcrop, narrow terrace (t).
Sandy and gravelly yellow duplex soils on slopes; J-M forest. Deep sandy soils on terrace; M forest.

V8 Valleys in sedimentary rocks, 20 m relief; short, gentle flanking slopes; broad flat terrace (t).
Sands, and gravelly duplex soils on flanks; J-M forest. Yellow duplex soils on terraces; J-M-Ys-Bb forest, heath.

MINOR VALLEYS (S)

S1 Valleys in granitic terrain, narrow swampy floor: <20 m relief.
Gravelly yellow duplex soils on smooth flanks; J-M-K forest.
Peaty soils on narrow floor; Wt low forest.

S2 Valleys in granitic terrain: <20 m relief: saline seepages.
Yellow duplex soils on gently sloping flanks; J-M forest. Yellow solonetzic soils on floors; Mel woodland, halophytes.

S3 Shallow valleys in swampy terrain; <10 m relief, gentle slopes.
Sandy yellow duplex soils and podzols on flanks; J-M forest.
Peaty sands on floor; Tt heath and sedges.

S4 Broad swampy drainage zones; <5 m relief.
Podzols and sandy yellow duplex soils; Tt heath; sedgelands.

S5 Narrow, V-shaped valleys in granitic country; 5-10 m relief.
Sandy yellow duplex soils and deep sands; Mel-B woodland.

S6 Narrow V-shaped valleys, in sedimentary rocks; <10 m relief.
Sandy yellow duplex soils on slopes; J-M low forest.
Deep sands on narrow swampy floor; sedges and reeds.

S7 Broad, valleys in sedimentary rocks; 30 m relief; smooth slopes; swampy floor (f).
Deep sands and iron podzols on slopes; Ab-J-Sh woodland.
Podzols and yellow duplex soils on floors; Mel woodland, Tt heath.

S8 Broad, shallow, gently sloping valleys and alcoves.
Deep sands and gravelly sands on slopes; J-Sh low forest.
Humus podzols on floors; Kg sedgeland, Mel woodland.

S9 Valleys in sedimentary rocks; 40 m relief; steep slopes; much siltstone, swampy floor (f).
Shallow sandy soils on slopes; mallee heath Humus podzols on floors; Kg sedgelands, Tt heath.

J	Jarrah	*E. marginata*
M	Marri	*E.calophylla*
K	Karri	*E.diversicolor*
Bb	Blackbutt	*E. patens*
Bu	Bullich	*E. megacarpa*
Y	Yate	*E. cornuta*
Ys	Swamp Yate	*E.occidentalis*
		E. decipiens
Tr	Red Tingle	*E.jacksoni*
Ty	Yellow Tingle	*E.guilfoylei*
Ab	Albany Blackbutt	*E. staeri*
W	Wandoo	*E. wandoo*
Sh	Sheoak	*Allocasuarina fraserana*
Ha	Hakea	*Hakea varia*
		H. ambigua
Pp	Peppermint	*Agonis flexuosa*
Tt	Teatree	*Agonis parviceps*
		A. linearifolia
Wt	Wattle	*Agonis juniperina*
Kg	Kangaroo grass	*Evandra aristata*
		Anarthria scabra
Mel	Paperbarks	*Melaleuca cuticularis*
		M.teretifolia
		M.rhaphiophylla
B	Banksia	*Banksia attenuata*
		B. grandis
		B. illicifolia
		B. quercifolia

Appendix VI

Southern Jarrah Forest Indicator Species Site Preferences

The following listing outlines the site conditions which are observed to correlate with the occurrence of the indicator species used in the site classification survey of the Southern Jarrah Forest. The reference to site characteristics such as fertility, drainage and rainfall are generalised and are relative to the range of situations encountered in the survey.

Acacia alata
Fertile soils with reasonable drainage show best development but it will also take advantage of higher fertility after burns.

Acacia browniana
Moderate to high rainfall, sandy loam duplex soils - higher clay content close to surface.

Acacia divergens
Wet areas, either creek edges, valley bottoms or swamps which do not dry out in summer.

Acacia drummondii
Moderate rainfall, gravelly surface duplex soils.

Acacia extensa
Sandy surfaces, favours moister areas and moderate fertility sites. Also on disturbed sites.

Acacia myrtifolia
Sandy loams or sands, mostly moister areas. Also on disturbed sites.

Acacia pentadenia
Generally higher rainfall areas, sandy loam soils or wet sands.

Acacia pulchella
May be on sand in high rainfall areas, gravelly sandy loams in medium rainfall areas, but mainly heavier soils associated with igneous rock outcrops in drier areas. Also common on burnt areas.

Acacia saligna
Variable, may occur as a thicket in swampy soil in medium rainfall areas or as individuals on gravels or sandy loams. Very wide range of rainfall.

Acacia urophylla
Generally occurs in medium to high rainfall areas on fertile loamy or heavier soils.

Adenanthos barbigerus
Infertile soils, sandy gravel, freer draining than soil where *A. obovatus* grows.

Adenanthos obovatus
Sandy loams, sands and sandy gravels with impeded drainage.

Agonis flexuosa
Sands and sandy loams with good drainage but ample moisture.

Agonis hypericifolia
Sandy gravels or sands in higher rainfall areas with drainage slightly better than A. parviceps sites.

Agonis linearifolia
Creek banks and valley bottoms, generally on loamy soils. Associated with fresh ground water.

Agonis parviceps
Any soil type with impeded drainage but very common on sands over clay or rock or gravelly soils over concreted laterites. Not generally present in low rainfall areas.

Allocasuarina decussata
Sandy or loamy sand surfaced soils in high rainfall areas, frequently seasonally wet.

Allocasuarina fraseriana
Drier sands, frequently with laterite.

Allocasuarina humilis
Lower rainfall areas with shallow soil layer frequently over laterite and often seasonally wet or waterlogged (subject to heavy grazing).

Anarthria prolifera
Open forest on moist sandy soils.

Anarthria scabra
Sands in moderate to high rainfall areas on damp through to wet sites.

Anigozanthos flavidus
Favoured by disturbance, generally on sands or sandy loams in moister situations.

Astroloma ciliatum
Gravelly sandy loams in moderate to low rainfall areas with better fertility.

Astroloma pallidum
Gravelly sandy loams in low to moderate rainfall areas on drier sites.

Banksia attenuata
Deep sands - a species of limited distribution in survey area (more common in coastal areas).

Banksia grandis
Throughout area but lower numbers in karri loams and wandoo sites and higher numbers in gravels or moderate rainfall sandy loams.

Banksia ilicifolia
Damp sands on slopes, and sands in drainage lines but not gravelly soils.

Banksia littoralis
Swampy or poorly drained sites.

Beaufortia sparsa
Damp humic sands.

Billardiera floribunda
Better fertility, sandy loams.

Boronia gracilipes
Higher rainfall areas, sandy loam surface less well drained, duplex soils.

Boronia spathulata
Sandy or sandy loam surface, less well drained sites with shallow clayey subsoil in all rainfall areas.

Bossiaea laidlawiana
Medium to higher rainfall areas on moist sites with sandy loam surface and reasonable drainage and fertility.

Bossiaea linophylla
Widespread in low to medium rainfall areas on sands or gravelly sandy loams with reasonable drainage but lower fertility.

Bossiaea ornata
Common in drier sites on ridges and well drained slopes.

Chorizema ilicifolium
Larger flowered form in karri types on more fertile sandy or sandy loam surfaced soils, sometimes seasonally wet. Jarrah forests form in medium rainfall areas on more fertile gravelly sandy loams.

Clematis pubescens
Not usually found on very dry, infertile or poorly drained sites. Abundance of plants increases with fertility and moisture availability.

Crowea angustifolia
Sandy loam surfaces in higher rainfall areas, generally on duplex soils (poorer karri sites) or on disturbed karri/marri sites.

Dasypogon bromeliifolius
On shallow water gaining, poorly drained soils, seasonally wet clayey soils with sandy surfaces.

Dryandra bipinnatifida
In low rainfall areas on well drained gravelly sites.

Dryandra nivea
In all areas, best developed on open poorly drained sites with heavier textured soils.

Eucalyptus calophylla
Maximum development on duplex soils in high rainfall areas or on loamy sands but virtually absent from driest or wettest sites.

Eucalyptus diversicolor
Sandy loams in high rainfall areas.

Eucalyptus marginata
Best development on less fertile well drained soils in higher and moderate rainfall areas but large numbers in lower rainfall areas also.

Eucalyptus megacarpa
Poorly drained sandy or gravelly surface soils often in heads of gullies. Absent from lower rainfall areas.

Eucalyptus patens
Good trees found in medium rainfall areas on well drained sandy loams with ample moisture. Poorer trees found on coarse gravelly sandy loams. Poor trees found on very wet sandy flats in higher rainfall areas generally with organic hardpans.

Eucalyptus rudis
In swamps in lower rainfall areas or along watercourses particularly on heavy clays.

Eucalyptus wandoo
Low rainfall area valley floors and lower slopes with sandy loam or loam surface over clay. Generally shallow, more fertile soils in the area.

Gompholobium ovatum
Medium rainfall areas on gravelly surface soils.

Grevillea brevicuspis
Medium and high rainfall areas on shallow loamy surfaced soils and loamy gravels.

Grevillea quercifolia
Gravelly slopes in high rainfall areas.

Hakea amplexicaulis
Best development on well drained and more fertile sites.

Hakea lasianthoides
Medium to high rainfall areas, generally on water gathering sites, waterlogged at times with sandy loam surfaces.

Hakea lissocarpha
In most areas but more common in deeper, possibly more fertile, gravelly soils of the drier areas.

Hakea oleifolia
Medium to high rainfall areas on deep well drained sandy loams with ample moisture.

Hakea prostrata
Seasonally wet shallow soils usually over clay or laterite.

Hakea ruscifolia
Low to medium rainfall areas, generally on lower slopes with yellowish sandy soils.

Hakea undulata
Moist seasonally wet sites with heavier textured soils.

Hardenbergia comptoniana
Medium to high rainfall areas on sandy loams with good drainage and ample moisture requirements which limit distribution in lower rainfall areas or on sandy soils.

Hibbertia cuneiformis
Medium to high rainfall areas, not on laterites, heavy gravels or poorly drained sites.

Hibbertia glaberrima
All areas on grey sandy lateritic gravels.

Homalospermum firmum (Syn Leptospermum)
Wet sites often with surface water in winter.

Hovea chorizemifolia
All areas on lateritic gravels.

Hovea elliptica
On all except poorly drained sites in heavy rainfall and not on dry sites in medium rainfall. Best development on fertile well drained soils.

Hypocalymma angustifolium
In medium to low rainfall areas on poorly drained sites with sandy loam surfaces.

Hypocalymma robustum
Scarp area only on moist sandy gravels.

Isopogon sphaerocephalus
Medium to heavy rainfall areas on sandy gravels.

Johnsonia lupulina
Sandy surface soils in medium to high rainfall areas.

Kingia australis
Medium to high rainfall areas on sandy surface poorly drained soils, generally seasonally wet because of shallow clay or hard pan.

Lasiopetalum floribundum
Moist sites in medium to high rainfall areas, generally on sandy soils in the jarrah forest.

Lepidosperma angustatum
Moist upland sandy soils.

Leptomeria cunninghamii
Sandy loam uplands in medium rainfall areas.

Leucopogon australis
Sandy surface watergaining sites, but generally not waterlogged.

Leucopogon concinnus
Sandy loam or loamy surface often seasonally wet or high rainfall areas.

Leucopogon obovatus (Syn. L. revolutus)
Wet sandy soils.

Leucopogon propinquus
Sandy loam with reasonable fertility and moisture.

Leucopogon pulchellus
Sandy or loamy surface in medium to low rainfall areas, shallow soils over granite or clay.

Leucopogon verticillatus
Reasonably fertile and moist soils in all areas, reaches best development in higher rainfall, well drained duplex soils.

Logania vaginalis
Medium and higher rainfall, more fertile types of sandy loam surface soils.

Loxocarya fasciculata
More open sites, often seasonally wet.

Loxocarya flexuosa
More open moister sites.

Macrozamia riedlei
Found throughout, but rare on dry laterites or in heavy undergrowth on fertile, better sites. Maximum numbers on deeper sandy profiles in better rainfall areas.

Melaleuca preissiana
Widespread on swampy clayey soils or swampy sands.

Melaleuca thymoides
On grey sands except flats where sandy surface soil is frequently humic.

Melaleuca viminea
Lower rainfall areas on seasonally swampy shallow soils over laterite.

Mirbelia dilatata
On sandy loam soils in moist sites.

Opercularia hispidula
Medium rainfall areas generally not on grey or yellow sands or dry laterites, generally on duplex type soils.

Patersonia umbrosa (Syn. P. xanthina)
Medium rainfall areas on loamy surface gravelly duplex soils or gradational soils outside karri range. Reasonable moisture and fertility required.

Persoonia longifolia
Best development on better soils in medium rainfall areas.

Petrophile diversifolia
Soils with shallow clay layer subject to seasonal waterlogging, becoming more common in higher rainfall areas.

Platytheca galioides (Syn P. verticillata)
Moist sandy soil sites.

Podocarpus drouynianus
Not on dry laterite sites or better drained fertile sites. More common on sites with poorer drainage and lower fertility. Less abundant in drier low rainfall areas.

Pteridium esculentum
Widespread but not usually occurring on dry laterite, infertile sands or in low rainfall areas except in very fertile moist loams. Best development on moist fertile loams.

Pultenaea reticulata
Mainly on coarse quartzite sands or sometimes on sands over shallow clays, generally lesser numbers on grey sands.

Scaevola striata
Appears to have best development on open sites but can occur on any site.

Sollya heterophylla
Not common but widespread on more fertile soil types.

Sphaerolobium medium
Favoured by open stands in gravelly sandy loams, mainly in medium rainfall areas (subject to heavy grazing).

Strangea stenocarpoides
In medium to high rainfall areas on gravelly surface sandy loam shallow duplex soils.

Styphelia tenuiflora
Uncommon but mainly in low rainfall areas in gravelly soils.

Thomasia grandiflora
Lower slopes of low to medium rainfall areas. Gravelly sandy loams in water gathering situations.

Tremandra stelligera
Medium to high rainfall areas, favoured by disturbance and better fertility and moisture.

Trymalium ledifolium
Best development on well drained soils on lower rainfall areas but not grey sands.

Trymalium floribundum (Syn. T. spathulatum)
Better quality gradational, fertile, well drained soils with adequate moisture and only in valley bottoms or lower slopes as rainfall diminishes.

Xanthorrhoea gracilis
Generally in gravelly well drained soils.

Xanthorrhoea preissii
Generally deeper soils with better moisture availability.

Xanthosia atkinsoniana
In medium to low rainfall areas on better sandy loams, frequently gravelly.