FIREWOOD AND MINING TIMBER IN THE EASTERN GOLDFIELDS

by

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I, Alan James Williamson, declare that except where acknowledged, this thesis is an account of my own research.

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ABSTRACT

An estimated 30 million tonnes of mining timber and fuelwood was removed from 4 million hectares of woodland of the Eastern Goldfields for the goldmining industry between 1890 and 1960. This thesis describes a pilot project to study the effect on the vegetation of the removal of so much timber. There is no recorded work that describes the effect of this large-scale removal of trees on the vegetation of the Eastern Goldfields. Nowhere else in the world in areas of such low rainfall do trees grow as tall as they do in the woodlands of the Eastern Goldfields. Rainfall records confirm that heavy summer storms are not uncommon and this summer rain could be a major reason for the survival of the eucalypt regeneration observed in this study and elsewhere in the Eastern Goldfields.

Two study areas were investigated. One was a Eucalyptus salmonophloia woodland near Kambalda, and the other was a E.salubris var glauca woodland near the St. Ives mine south-east of Lake Lefroy. At both areas releves were measured in cut and uncut sites. Each releve was 10 m × 10 m, and for each species present its cover abundance was measured on the Braun-Blanquet scale. Analysis of the data was carried out by a computer program, VEGCLASS, that caters for both classification and ordination. At the Kambalda study area the vegetation on the cut and uncut releves was similar enough to be generally grouped together by the analysis. The same applied at the St. Ives study area. However when the vegetation at the Kambalda and

St. Ives study areas was compared, the analysis showed that the vegetation belonged to two different units.

This pilot study suggests that many more releves should be measured so that future work can attempt to answer the three basic questions needed to unravel this extensive environmental puzzle:

Are there any differences in vegetation between cut and uncut sites?

If there are differences, what are they due to?

If there are differences, how important are they to the future management of the area?

Should a similar operation involving timber removal in the Eastern Goldfields be proposed in the future, the answers to these questions will help provide a sound basis for future environmental management.

INTRODUCTION

The discovery of gold in the Eastern Goldfields in 1887 was accompanied by an immediate demand for timber. Initially the demand was for tent poles, domestic firewood, posts and poles for sheds and stockyards, firewood for water condensing plants, and pit props for the mines. Later, industrial firewood was needed to generate power. Six of the eight pumping stations along the Mundaring to Kalgoorlie water pipe line were kept working for 55 years with wood from nearby timbered areas. From about 1890 to 1960 an estimated 30 million tonnes of mining timber and fuelwood was removed from inland forests for the goldmining industry in the Eastern Goldfields (Forests Department 1969). This cutting has now virtually ceased. However in its heyday it removed a similar amount of timber each year to the chiplog component of the timber industry in the Manjimup region in 1980 (over 500,000 cubic metres). Cutting eventually covered over 4 million hectares, or twice the present area of state forest in the south west of Western Australia. (Appendix 1)

Nearly all *Eucalyptus* species that grew large enough to produce a pit prop or a piece of firewood were used. Even the mallees were used for light firewood. In the north-east of the area *Acacia aneura* (mulga) was also used. The main species used for mining timber were:

Eucalyptus brockwayii
Eucalyptus dundasii
Eucalyptus flocktoniae
Eucalyptus griffithsii
Eucalyptus longicornis
Eucalyptus salmonophloia
Eucalyptus salubris

Because of the high demand for wood in the goldfields from 1890 to 1960, the removal of these trees could be considered equivalent to clear felling in todays terms. Regeneration that is now present is therefore the result of that clear felling.

No other region in the world has a vegetation dominated by trees as tall, in such a semi arid climate. Milewski (1981) has indicated that this may be due to the occasional cyclonic summer storms that reach well inland with deeply penetrating falls useful for tree survival and growth and thus help space out the annual rainfall.

Pastoral leases in the Eastern Goldfields were first issued about 1890 and they now cover roughly half of the area cut over for mining timber. Because of clearing restrictions on pastoral leases there is little danger to the existing trees from pastoral operations. However grazing by sheep or cattle could change the composition of the shrub and herb layers of the vegetation, and it does prevent regeneration of most species of trees, shrubs and herbs from developing. Most of the *Eucalyptus* regeneration is from lignotubers but even this will be removed by repeated grazing and trampling by stock.

There is always the possibility that the large amount of cellulose and energy in this woodland will prove attractive to a future commercial venture. Before any land use changes are contemplated we should know what the effect of past timber removal has been and how grazing has affected the vegetation in this area. Such information may help provide a sound basis for deciding whether it would be possible to carry out future forestry operations in the Eastern Goldfields and if so, what conditions and controls need to be applied.

This thesis will indicate a method of studying the effect of the vegetation of the Eastern Goldfields of the past man made alterations due to timber removal and grazing. The area studied and samples taken form a pilot project which provides guidelines for further work in this vast area.

VEGETATION SCIENCE: LITERATURE REVIEW

The present study deals in part with the composition, development, geographic distribution, and environmental relationships of plant communities. This is known by various names such as phytosociology, vegetation ecology, plant sociology, phytocoenology, sociologic geobotany, and vegetation science. I prefer the simple, all-embracing term vegetation science. How this relates to other branches of field botany is shown in table 1, after Mueller-Dombois and Ellenberg (1974).

There have been many approaches to a general description of vegetation. Early workers accepted that plants formed distinct communities, and Grisebach (1838) introduced the concept of the plant formation as a distinct plant community with a definite physiognomic character and structure. This contrasted with the later work of Warming (1895, 1909) who defined the plant formation as a community of associated species that have adapted to the climatic or edaphic character of the environment which they occupy. As will be seen later, this concept of species association forms the logical basis for the indirect gradient analysis approach of Whittaker (1967). Vegetation was viewed on a broader scale in the work of Clements (1916, 1928), Tansley (1920), and Braun-Blanquet (1928, 1932, 1964), and this led to the development of community analogies. Clements compared the process of succession in a plant community with that of the growth of a living organism. He considered that a climax community could reproduce itself by repeating the development of the stages of the succession.

TABLE 1 AREAS OF SPECIALIZATION WITHIN THE FIELD OF GEOBOTANY; THEIR SYNONYMS AND ANGLO-AMERICAN EQUIVALENTS.

Area of Specialization (and Synonyms, European Terms)	*Subject Matter*	*Anglo-American Equivalents, (and Synonyms)*
Floristic geobotany	Study of geographic distribution of plant taxa and their evolutionary relationships	Plant geography (phytogeography)
Sociologic geobotany[a] (vegetation science, plant sobiology, phytosociology, phytocoenology)	Study of composition, development, geographic distribution, and environmental relationships of plant communities	Synecology[a] (community ecology, plant ecology in part)
Ecological geobotany (plant ecology)		
Autecology (ecophysiology)	Study of physiological functions of individual organisms in field environments and communities; life history studies of species or ecotype	Autecology (physiological ecology, population ecology in part)

Table 1 cont.

Area of Specialization (and Synonyms, European Terms)	*Subject Matter*	*Anglo-American Equivalents, (and Synonyms)*
Demecology (population ecology)	Study of structure and function of populations	Population ecology
	Study of genetic variation in populations	Genecology
Synecology (habitat science; ecosystem research)	Study of habitat factors and the physiological response of species and species groups to these factors; study of community functioning, and niche functions of plant populations in an ecosystem context	Ecosystem ecology (community process ecology, functional ecology, systems ecology)
Historical geobotany	Study of historical origin and development of populations and communities	Paleobotany (paleoecology)

a Equivalent to the term vegetation ecology.

Tansley modified this idea by showing that certain stages of the succession were dependent on particular factors for their establishment into previously existing communities, while other stages were not nearly so dependent. Braun-Blanquet (1928), on the other hand, viewed communities in much the same way as organisms, and proposed a taxonomic classification which related "narrow" vegetation types to "broad" ones in an hierarchical way. He introduced the term phytosociology for his approach. He classified plant communities using floristic attributes, and considered the plant association to be the fundamental unit of vegetation. He defined an association to consist of samples of vegetation, all of which had a similar combination of species. However, Braun-Blanquet overlooked, in his taxonomic analogy, that individual organisms of a species are members of genetically related populations, whereas the individual plant association is not genetically related to other similar associations that may be grouped into higher units although they may be dynamically related. Whittaker emphasised a different feature when he defined an association as a class of communities defined by the dominance of one or more species. A number of associations may be grouped into an alliance on the basis of shared characteristic species. Alliances may be grouped into orders, and orders into classes on the same basis. Braun-Blanquet considered that plant communities had a definite floristic composition by which they could be recognised and which expressed their relationships with each other and to the environment far more accurately than could any other characteristic. Amongst these species some express a given relationship more sensitively than others and these species are the most effective indicators of a particular plant community. They are called diagnostic species and they are the basis for this floristic approach to vegetation classification. Character species, differential species and companion species are the three types of diagnostic species. Character species are those (in Braun-Blanquet's terms) restricted to a definite plant community and they serve to identify all associations and some higher units. Differential species are those which are used to distinguish units of lower rank than association. Companion species are those species that occur in most samples (releves) and are added to the character species to help describe associations and higher groupings. Beard (1981) used a combination of the floristic character, the physiognomy of the ecologically dominant and generally biomass dominant stratum, and the density of the various layers to describe the vegetation of Western Australia. Specht (1970) used a similar approach but based his classification on the tallest stratum, which is not necessarily the ecologically dominant stratum. The other major Australian approach has been that of Beadle and Costin (1952). They regard the association as the basic unit for floristic classification, and associations are grouped into alliances. The association is defined as a community in which the dominant stratum exhibits uniform floristic composition, the community usually exhibiting uniform structure. The number of dominant species is often one, sometimes two or three, and rarely several. These are all useful approaches for preliminary surveys of a very large and little known area. However when a more detailed study is required, such as that needed for management of a nature reserve or a forest, or for monitoring purposes, a quantitative approach to vegetation science is required. There are two main strategies for the quantitative study of vegetation: classification and ordination.

Classification has as a major feature the concept of plant communities with which a fairly consistent group of species are associated. However classification on the basis of physiognomy and dominant species has a number of limitations. Species chosen on the basis of how conspicuous they are do not necessarily indicate a full spectrum of environmental relationships and may result in the definition of types having little homogeneity. The approach is highly subjective, requiring decisions to be made about the species to be considered as dominants, the combination of dominant species to be accepted as dominant types, and where boundaries between intergrading dominance types are to be placed. Classification may now better be considered as an arrangement of sample units by group values (Mueller-Dombois and Ellenberg (1974)), and this approach follows logically from the work of Grisebach, Warming, Clements, Tansley and Braun-Blanquet referred to above.

One of the many approaches to classification, and one usually applied when detailed analysis is carried out over a small area, is the Zurich-Montpellier (Z -M) system of phytosociology based on floristics. This is frequently incorrectly referred to as the "Braun-Blanquet" approach. Although Braun-Blanquet played a major role in the development of this system many others contributed, and the term Z -M indicates a less pedagogic approach.

The system features community types, defined by diagnostic species clearly showing the relationships of communities to one another and the continuous variation of species combinations and proportions. Whittaker (1962) considers that "to those who are familiar with the system and the vegetation, such classifications embody a wealth of information on species relations, community types, and habitat relations such as can hardly be conveyed with equal efficiency by any other system". However the system does have shortcomings. While it is objective in the manipulation of releves, it is subjective in the establishment of lower units, and in the choice of samples. Since classification is achieved using floristics, results will be determined by the level to which taxonomy has progressed. To ensure that the subsequent analysis is correct, it is necessary to be able to recognise a new species when it occurs in a releve, and also to ensure that those species that have already occurred are not recorded as new species. This takes considerable care, involving much time and effort, and the Z - M method is generally only undertaken for the detailed analysis of a small area.

Ordination consists of arranging sample stands or species along axes that represent environmental gradients, according to the values of the environmental factors being studied on those individual sample stands. Developing from Gleason's (1926, 1939) work, ordination has, as its major feature, the concept of a continuum. Gleason emphasised that the environmental factors that determine the composition of a plant community are themselves always changing with time and with locality. Therefore, distinct plant communities having a clearly recurring pattern of species are rare. Instead of plant species forming a community they are continuously changing according to the changing environmental factors, forming a continuum (Curtis and McIntosh (1951), McIntosh (1967)). The Wisconsin school under Curtis and Whittaker developed new approaches that were needed to cope with the continuum concept. Techniques were developed to study the continuous variation of vegetation in relation to environmental factors. These range from the relatively simple ones of reference set types (Anderson, 1971) and gradient analysis, to the more mathematically complex ones of principal component analysis (PCA), factor analysis, and canonical analysis.

With direct gradient analysis (Whittaker, 1973), the gradient of an environmental factor is first recognised, then sampling is carried out along it to study trends in species importance along the gradient. For example elevation might be used to represent other environmental factors such as temperature and exposure. The values of the environmental factors sampled by each unit (species or releves) is arranged on axes such that the similarity between units as well as the overall variation is expressed. Direct gradient analysis is suited to the study of vegetation in which the distribution of species is determined largely by one or two environmental gradients.

Indirect gradient analysis (Whittaker, 1973) is the result of analysing a set of sample data and then deducing the gradient of an environmental factor. The axis of an ordination figure is interpreted on the basis of known or supposed physical attributes. Indirect gradient analysis is used where species populations are not distributed in relation to any predominant gradients. In this case abstract axes derived from measurements of similarity between units may be used. Individual units are visualised as points in space with their attribute scores as coordinates. Summarization is achieved by projection of the points into a space which has less dimensions than the original. The result will be an arrangement distorted from one that would be given by using all dimensions. To reduce this distortion, the first axis coincides with the direction of maximum variation between releves, the second axis coincides with the next most important direction of variation and so on. Once the ordination figure is produced, vegetation units equivalent to phytosociological units may be recognised, thus aiding an understanding of the vegetation being studied. This is true of all ordination approaches, but is especially useful when indirect gradient analysis is used.

Reference set ordination attempts to select releves from either end of the first ordination axis and to locate the other releves between them, with their exact position being determined by their similarity to the reference releves. The same is done for subsequent axes. The reference set technique that has been used the most is known as Bray and Curtis ordination, and was developed by Bray and Curtis (1957) as an early product of the Wisconsin school (Whittaker, 1973). It is a simple method but suffers from two problems. Firstly, the axes of ordination may not always be perpendicular. This means that the second most important gradient is not distinguishable from the first (Busby (1973), Austin and Orloci (1966)). Orloci (1966) developed a position vectors technique to overcome this problem. Secondly there are problems with selection of the reference releves. To obtain an accurate ordination, releves should be chosen for each axis that forms the ends of each of the major gradients, and not just those that are the most dissimilar. Such releves are "outliers" that are the result of sampling a very different vegetation type originating from historical or environmental conditions not typical of the vegetation being studied. Bray and Curtis ordination does not ensure that this is done, (Austin and Orloci (1966), Anderson (1971)). This led ven der Maarel (1969) to develop his Principal Axes ordination (PAO) in which he introduced an index called negative correlation tendency. This is used to select reference releves that represent the extremes of gradient, and not just the extremes of the total vegetation sample.

Principal component analysis (PCA) was considered by Austin and Orloci (1966) as a superior method of vegetation analysis to reference set techniques. They stated that principal component analysis "probably represents the most successful ordination technique currently employed in studies of vegetation". Orloci (1966), van der Maarel (1969), and Greig-Smith (1964) indicated that reference set techniques can give comparable results to principal component analysis, and since principal component analysis has a much greater computational load, van der Maarel (1969) suggested that reference set techniques may be used where a computer is not available. More recent work (Beals, 1973) also indicated that reference set ordination can give much the same ecological information as PCA for less computation. PCA has two main shortcomings and they are important ones. Firstly it is assumed that a random sample of the sample space has been taken, but this may not be the case. If a certain vegetation type predominates over an area, then random sampling will cause it to be over sampled, and the calculated centroid will deviate from the centre of the hyper-ellipsoid (Austin, 1968). Random sampling may also result in outlier stands being included and this affects the efficiency of the ordination in the same way that reference set ordination does. Secondly, and more importantly, it is assumed that there is a linear relationship between the axes and the original species variable. In nature the non linear relationship between species and environmental gradients results in distortion when analysis is carried out by principal component analysis with its assumption of a linear relationship. A further problem arises with principal component analysis because the axes resulting from indirect ordinations are usually orthogonal by definition, whereas the effects of environmental factors on populations are often not independent, but are correlated (Noy-Meir and Whittaker, 1977).

Vegetation gradients that exhibit a high degree of beta diversity (degree of change in species composition) in the samples taken along a coenocline (community gradient), also inflict curvilinear distortion on both polar (reference set) ordinations, and non polar (principal component analysis) indirect ordinations (Swan

(1970), Noy-Meir and Austin (1970), Gauch and Whittaker (1972)). Non polar distortions are often unimodal, but are sometimes bimodal with two or more reversals of slope. Often the extracted axes are devoid of ecological meaning and the ordination can't serve as an heuristic technique for revealing directions of community variation. With high beta diversity "principal components can produce from a coenocline a multi-dimensional doodle" (Whittaker and Gauch, 1972). However with "reference set" techniques such as principal axes ordination, the poles of the first axis are anchored by specific end point samples. Thus the arrangement of the co-ordinates may not be ecologically meaningless, and only the inter unit distances can be misleading. Because of this, and because reference set ordination can give much the same ecological information as principal component analysis for less computation, a reference set technique, principal axes ordination, was used in this pilot study.

PREVIOUS WORK

There is no recorded work that studies the effect of the large scale removal of trees on the vegetation of the Eastern Goldfields. The rangelands management section of the Department of Agriculture is known to have carried out studies on the effect of grazing on the vegetation of the Eastern Goldfields areas. Burbidge (1941) published notes on the vegetation of the north Eastern Goldfields based on 14 transects. She pointed out that very little work had been published previously on the vegetation of this area. While her work referred to Glenorn Station about 180 kilometres north of Kalgoorlie, many of the same species occurred there as in this present study, and genera such as *Acacia*, *Atriplex*, *Eremophila*, *Cassia*, *Maireana* (*Kochea* in her paper), *Rhagodia*, and *Santalum* were reported for both studies.

There have been several attempts at general descriptions of the vegetation of the Eastern Goldfields, usually as part of a general study of the vegetation of Western Australia. The most recent of these is by Beard (1972 - 1980) in both his 1 : 1 000 000 and 1 : 250 000 scale series of maps. His work follows that of the then Woods and Forests Department (1902), Diels (1906), Jutson (1914), and Gardner (1928). These were, however, little more than sketch maps, whereas Beard's work was based on interpretation of aerial photos.

A detailed biological study of system 11, which includes the Eastern Goldfields, of the Conservation Through Reserves

Committee is currently being carried out by several government instrumentalities. When published, this study will no doubt add greatly to our knowledge of the vegetation and general biology of the Eastern Goldfields.

Milewski (1981) has published an interesting paper on the reasons for taller trees being present in semi arid areas of Western Australia compared to areas of similar latitude, altitude and distance from the sea in South Africa. He pointed out that not only is the rainfall slightly greater in the semi arid areas of Western Australia, but more importantly much of it comes from January to March as heavy falls from storms derived from tropical cyclones. The resulting deep moistening of the soil allows trees to become established. As they get older similar heavy falls of rain keep them established and growing. Areas in South Africa of similar latitude, altitude, and distance from the sea have no such storms and the vegetation has much shorter trees than in Western Australia. Milewski's ideas seem to fit observable facts. Rainfall records confirm the past occurrence of these heavy storms and they could be a major reason for the successful survival of the eucalypt regeneration, which is mainly from lignotubers, observed in this study and elsewhere in the Eastern Goldfields.

DESCRIPTION OF STUDY AREAS

The vegetation of four study areas A, D, L, and G, was measured using small plots or releves each 10 m × 10 m (Appendix 3.1). Study areas A and D are south west of Kambalda, while areas L and G are south east of Lake Lefroy (Appendix 2). Each locality had one set of releves in an uncut or control area, and another set in an area in which the trees had been cut for mining timber or firewood. Cutting in the Kambalda set was 70 years old. Cutting in the Lake Lefroy set was 36 years old. Table 2 shows the allocation of releves to study areas.

TABLE 2 ALLOCATION OF RELEVES TO STUDY AREAS

	Locality	*Releve Numbers*	*Vegetation*	*Age of Cutting*
A	11.3 km from Kambalda	1 - 10	Woodland with E.salmonophloia	70 years
D	8.1 km from Kambalda	11 - 21	Woodland with E.salmonophloia	uncut control
L	south east of Lake Lefroy 40 km from Kambalda	22 - 26	Woodland with E.salubris var glauca	36 years
G	south east of Lake Lefroy 43.5 km from Kambalda	27 - 31	Woodland with E.salubris var glauca	uncut control

Beard's 1981 map of the vegetation of Western Australia at a scale of 1 : 3 000 000 confirms the field observation that E.salmonophloia woodland is one of the major vegetation types in the Eastern Goldfields. It would have been the main vegetation type from which mining timber and firewood were removed. The two Kambalda sites, A cut and D control, were chosen to represent this E.salmonophloia woodland.

The eucalypts in the area studied are E.salmonophloia, E.lesouefii, E.gracilis, E.celastroides, and E.stricklandii. The major shrub genera are Eremophila, Cassia, and Scaevola. Santalum acuminatum and S.spicatum also occur.

Forests Department records show that cutting occurred in 1910 in the Kambalda area. A ring count on one of the regrowth stems of E.lesouefii from locality A confirmed that it is approximately 70 years old. These sites are therefore very valuable because they contain some of the oldest regrowth resulting from past cutting in the Eastern Goldfields.

To follow any trend in vegetation change after cutting it would have been desirable to study a site having the same vegetation type, E.salmonophloia woodland, as locality A, but cut over more recently than it. However, this was not available close to locality A. Instead locality L south east of Lake Lefroy was chosen in a E.salubris var glauca woodland vegetation type. Locality L had been cut over approximately 36 years before.

Locality G is the uncut control and on both localities L and G, E.salubris var glauca is the only eucalypt present. The major shrub genera are Eremophila, Atriplex, and Scaevola. Santalum acuminatum is also present as a large shrub or small tree. Forests Department records show that cutting occurred in locality L from 1945 to 1951. A ring count on one of the regrowth stems of E.salubris var glauca from locality L showed that the stem was approximately 36 years old. If regeneration took place in the same year as cutting, the area was cut over approximately 1946, and this confirms the accuracy of the records.

The soil types for the E.salmonophloia woodland of localities A and D are very similar to those for the E.salubris var glauca woodland of localities L and G. Both are fine red sandy loams with patches of yellow sand and quartz particles scattered throughout. There is also a scattering of ironstone pebbles. However localities L and G appear to be in water gaining sites, and this is confirmed by the presence of Halosarcia species, whereas localities A and D do not appear to be water gaining sites.

There are no temperature or rainfall data recorded specifically for the sites. However Kalgoorlie is only about 50 kilometres away from them and, in the absence of topographic or other features likely to cause a change in climate, provides a good idea of the conditions at the sites. Kalgoorlie's mean monthly temperature and rainfall data for 41 years give a clear indication of the semi arid nature of the area (Table 3). Note especially the effect of summer storms as shown in the "highest one day" rainfall figures for January and February. It is also interesting to see that although the rainfall is not considered to be reliable, the mean figure for each month falls within a fairly narrow range of 12 mm to 33 mm.

TABLE 3 TEMPERATURE AND RAINFALL DATA FOR KALGOORLIE (from Bartlett (1981))

	Temperature (°C)		*Rainfall (mm)*	
	Mean maximum	*Mean minimum*	*Mean*	*Highest one day*
January	33.6	18.3	23	154
February	32.0	17.7	32	178
March	29.5	15.8	23	70
April	25.2	12.3	23	70
May	21.0	8.3	26	45
June	17.8	6.7	33	57
July	16.5	4.8	27	28
August	18.2	5.1	20	40
September	21.7	7.3	15	44
October	26.1	11.0	14	26
November	29.4	14.0	15	65
December	32.0	16.5	12	25
Annual			263	

METHOD

The basis for studying the vegetation of the cut and uncut sites was to compare the presence and cover abundance of all plant species present on a number of plots or releves. A meaningful comparison of sites can only be made if the sites are homogeneous. It is assumed that the characteristics of a plant community need a minimum area for their homogeneous expression. For efficiency the size of the releve used to record the species and cover abundance should be approximately that of the minimum area for that plant community. It has been determined that minimal areas generally vary between 25 square metres to 100 square metres for sedgelands, grasslands and low scrub, up to 200 square metres to 400 square metres for forests (Bridgewater and Morales, 1981). For this study a minimal area of 100 square metres has been assumed to be appropriate. Accordingly each releve measured was 10 metres by 10 metres.

The cover abundance scale used for all releves was the Braun-Blanquet (1964) scale as follows:

+ = occasional, cover less than 5%

1 = common, cover less than 5%

2 = very common, cover less than 5% OR any number of individuals, cover 5 - 20%

3 = any number of individuals, cover 20 - 50%

4 = any number of individuals, cover 50 - 75%

5 = any number of individuals, cover 75 - 100%

The releves were laid out in a linear manner as shown in appendices 3.1, 3.2, 3.3, 3.4. Herbarium specimens were collected from all species whose identity was not known to the author in the field. These are now part of the author's collection and most have been named subsequently.

The age of the regrowth on each of the cut sites was verified by taking a section of a regrowth eucalypt stem and counting the annual rings. This indicates the likely age of cutting as regeneration is most likely to have taken place soon after cutting occurred.

The presence and cover abundance data for each releve were recorded during May 1982. The data were then analysed using the computer program VEGCLASS designed by Bridgewater and Morales (1981) for the classification and ordination of vegetation (Appendix 6).

DISCUSSION

Appendix 5 presents the releve, species, and cover abundance data collected for each releve at both the Kambalda and St. Ives sites.

Appendices 7.1 to 7.8 show the ordination diagrams resulting from the analysis of these data by the program VEGCLASS. In all these ordinations the Sørensen quantitative coefficient of similarity and a 10% error factor was used. The analyses were carried out originally using error factors of 0%, 5%, 10%, 15%, 20%. However the final presentation and discussion is based on the ordinations with a 10% error factor as these give the clearest separation of releve groups.

In some cases an understanding of the closeness of the groupings has been obtained by looking at several analyses. For instance in the St. Ives set, appendix 7.4, releves 28, 29, both cut over, were grouped together and releves 23, 24, 25, not cut over, formed another group. These five releves were in the same group when all 31 releves were analysed, appendix 7.1 This indicates that the five releves are more alike than the St. Ives analysis suggested.

Appendices 7.3, 7.5, 7.6, 7.7, 7.8, show the effect of omitting one or all of four releves (1, 19, 20, 21) that appear to be very different from the others in appendix 7.1. In general the groupings of releves remain the same, although the relationship of their component releves is sometimes, but not always, clearer.

Discussion of Kambalda Releves

Kambalda releves occur in the ordination diagrams of appendices 7.1, 7.2, 7.3, 7.5, 7.6, 7.7, 7.8. Appendix 7.2 is the ordination diagram for all the Kambalda releves without any of the St. Ives releves. Of the five groups of releves in it, one contains only cut over releves (two releves), two contain only uncut releves (seven releves), two contain both cut and uncut releves (eight releves). There are four releves not grouped, three of these are cut over, and one is uncut.

Releve 1 is cut over and is never grouped with any other releve in any of the analyses with a 10% error factor. It has the highest cover abundance of Eucalyptus lesoeufii and has only one other species on it (Number 2 - a low prickly shrub).

Releves 8 and 9 are not grouped with other releves until releves 19, 20, 21, are omitted (appendix 7.3). Releve 9 is then grouped with releve 12. While 9 is cut, 12 is not. However both have a fairly high cover abundance of Eucalyptus salmonophloia.

Releve 11 is not grouped with any other releve. It is open, has no tree cover, and only four low shrub species. It is the only releve with species 17, an un-named species 1 metre tall.

Releves 19, 20, 21, are always grouped together, and are uncut. They each contain Eremophila oppositifolia. Releve 18 is the only other releve to have this species. Releves 19, 20, 21, are different enough from the other releves to warrant excluding them from further analysis (see appendix 7.3).

The other group of uncut releves consists of releves 12, 14, 16, 17. When releves 19, 20, 21, are omitted, releve 12 goes with releve 9, leaving 14, 16, 17 as one group. This indicates that releve 12 does not have such strong affinities with releves 14, 16, 17, as the first analysis suggests.

The biggest group of releves contains numbers 4, 5, 6, 10, 18 and is a mixture of cut and uncut. When releve 1 alone, or 1 and 19, 20, 21 are omitted, releve 18 leaves the big group. This is logical as 18 is the only releve of the group to contain Enchylaena tomentosa, Santalum spicatum, and Eremophila oppositifolia.

The other cut and uncut group contains releves 7, 13, and 15. Releve 13 seems the odd one as it is the only one of all 31 releves to contain Eucalyptus celastroides. In fact when releve 1, 19, 20, 21 are omitted from the analysis, 13 is not grouped with any other releve. Releves 7 (cut) and 15 (uncut) continue to be grouped together.

In the Kambalda area there are some cut and uncut releves grouped together strongly enough to suggest that their different treatments have not caused a large difference in their vegetation. At least in some situations it appears as if cutting has not caused any large change in vegetation. However many more releves would have to be analysed in the manner indicated in this project before it would be possible to define the factors controlling the relationship between cutting and vegetation development.

Discussion of St. Ives Releves

St. Ives releves occur in the ordination diagrams of appendices 7.1, 7.4, 7.5, 7.7, 7.8. Appendix 7.4 is the ordination diagram for all the St. Ives releves without any of the Kambalda releves. Of the three groups of releves in it, one contains only cut over releves (two releves), one contains only uncut releves (three releves), and one contains both cut and uncut releves (four releves). One releve, number 31, is not grouped.

Releve 31 is never grouped with any other releves and is the only one that contains Chenopodium and a Scaevola species (AJW 39). It does not contain Eucalyptus salubris var glauca. It has a slightly greater cover abundance of Atriplex vesicaria than the other St. Ives releves.

Releves 28 and 29, both cut, are always in the same group, even though 29 contains Eucalyptus salubris var glauca and 28 doesn't. Releves 23, 24, 25, are always in the same group. When St. Ives releves are analysed with Kambalda releves, 23, 24, 25, (uncut), are always combined with 28 and 29 (cut). Therefore the indication is that these cut and uncut releves are similar.

Releves 22, 26 (uncut) and 27, 30 (cut) form the third group of

St. Ives releves and always remain as one group even when Kambalda releves are analysed with them. Therefore the indication is that these cut and uncut releves are similar.

In the St. Ives area there are several groupings of cut and uncut releves, including four with Eucalyptus salubris var glauca. This is strong evidence that cutting does not appear to have caused a major change in the composition of the vegetation on these sites.

Of the 45 species encountered in the Kambalda and St. Ives releves, eight occur in both areas. They are:

Atriplex nummularia	Maireana georgei
Atriplex vesicaria	Maireana sedifolia
Enchylaena tomentosa	Santalum acuminatum
Eremophila (AJW 3)	Scaevola spinescens

While this might indicate some similarity between the sites, the fact that releves from the two areas are never in the same group is clear evidence that the Kambalda and St. Ives sites are different. This could be due to differences in soil, climate, fire history, other catastrophic events, or previous land use.

The soil types, as mentioned in the section describing the study areas, are very similar at each site. A slight difference could be due to the St. Ives sites being water gaining, whereas the Kambalda sites are not.

There is no reason to suspect a marked difference in the climate of each site. They are less than 50 kilometres apart and in this relatively flat and semi arid region, there is no reason to expect any difference in climate due to topography. However the St. Ives sites, being water gaining, show evidence of more moisture than the Kambalda sites. Field observations reveal that summer storms are often quite localized. It is therefore possible that by chance the St. Ives sites have received more summer storm rainfall than the Kambalda sites. In the absence of adequate records there is no direct way of knowing if this is so. One recent and potentially significant climatic event in the Eastern Goldfields was the drought from 1973 - 1978. Again, in the absence of records there is no direct way of knowing whether each of the sites was affected equally.

These sites were not burnt in the 1974 - 1976 fires in the Eastern Goldfields, which were over 50 kilometres to the north. While their older fire history is not known, fires would have been a very rare event in this semi arid region before grazing began. The ungrazed native vegetation is not generally dense enough to provide sufficient fuel to allow a fire to run. The situation changed in certain parts of the Eastern Goldfields north of Kalgoorlie where, before 1974 there were several seasons with above average rainfall. Grazing had removed the competition from certain native grasses, mainly Stipa species, that grew much better than usual after the higher rainfall. When the drought followed in 1974 - 1976 those areas affected in this way had enough fuel to allow fires to run.

There are no records of any other catastrophic natural events in the area with the potential to alter the vegetation, such as windstorms, earthquakes and disease.

The two major land uses in the area have been timber removal and grazing. Documentation of timber removal is confined to dates of cutting, although observation of stumps and regeneration indicates which species have been removed and the intensity of the cut. The *Eucalyptus* stumps and regeneration at each cut site indicate the operation was a clear felling.

The intensity and duration of grazing has not been well documented. Observations of the effect of present-day grazing intensities and general knowledge of grazing intensities in past decades can give some indication of the likely effect of grazing on these sites. Hacker (pers. comm.) has observed that if the study sites are more than 1 - 2 kilometres from a watering point it is unlikely that grazing will have caused a marked change in the composition of the vegetation. No watering points were observed within 2 kilometres of the study sites.

If it is accepted that differences in the vegetation do occur between the sites, it must also be recognized that there are not sufficient records to provide direct evidence of the cause of those differences.

Of the 45 species recorded on the sites, 19 occurred only on the uncut and 11 occurred only on the cut sites. More releves must be measured in both cut and uncut sites to establish whether this is a chance or a causal situation.

Future work should focus on three questions:

1. Are there any differences in vegetation between the cut and uncut sites?

2. If there are differences, what are they due to?

3. If there are differences, how important are they to the future management of the area?

This study has established that there are small differences between cut and uncut sites but has not been able to find out how important they are, nor what they are due to.

The minimum number of releves needed at each site to provide adequate measurements should be studied. This study has indicated that at least 10 releves should be measured at each site. The appropriate size of releves should also be studied. This can be achieved efficiently by an appropriate design.

To eliminate the effect of grazing, cut and uncut sites should be chosen that have not been grazed. To study the effect of grazing, sites should also be chosen that have a grazing history whose intensity and duration are known.

Salmon gum woodland is the major vegetation type in the Eastern Goldfields and was the type most widely involved in past cutting. Future work should be concentrated in that type. Other vegetation types can be studied at a later date.

A more detailed documentation of the catastrophic natural events, the climate, and the soil at each site is needed, as well as the kind, intensity, and duration of timber removal and grazing. Additional methods of vegetation analysis may also be helpful. A combination of approaches are needed in future work to help unravel this intriguing, extensive and important environmental puzzle.

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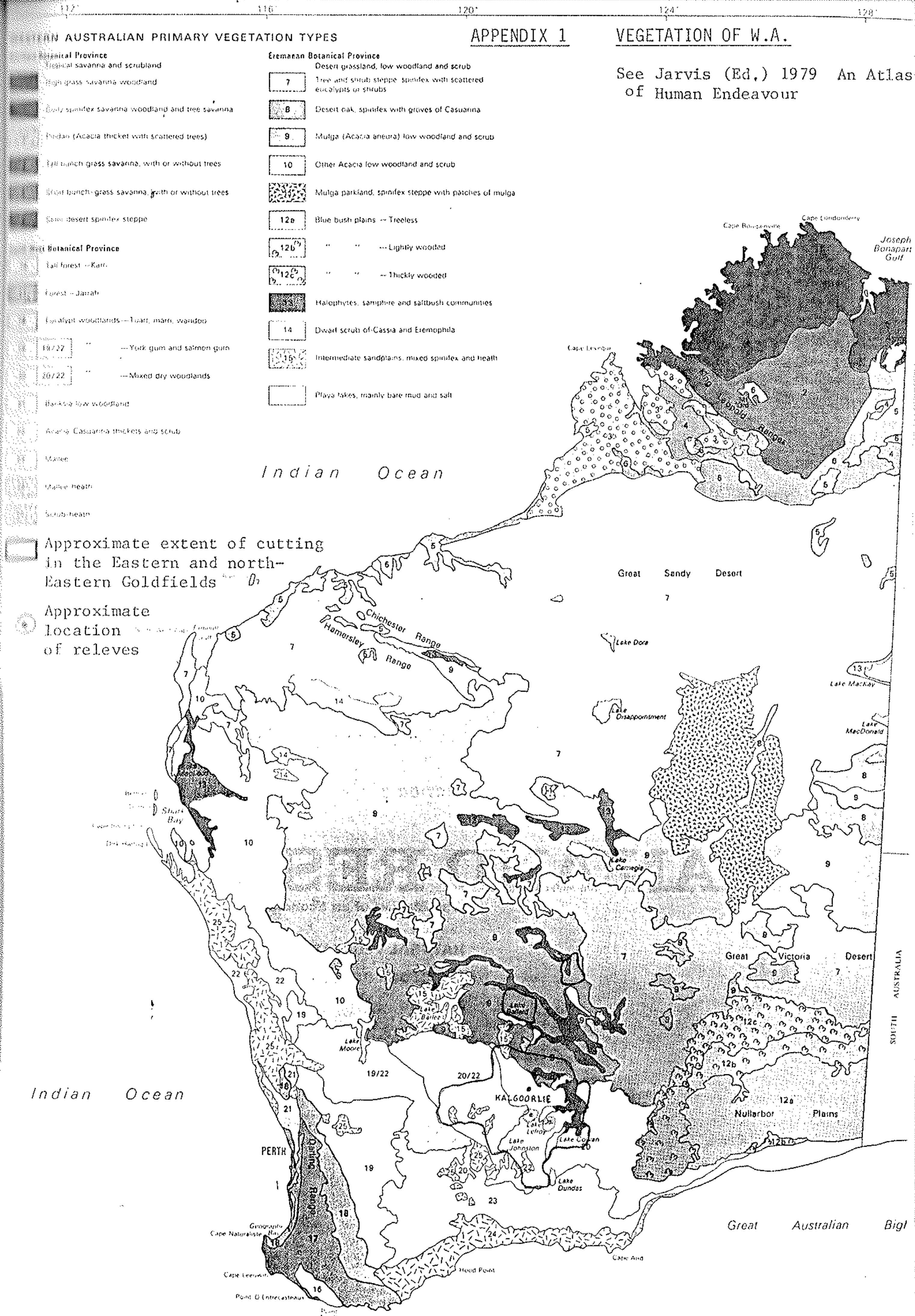
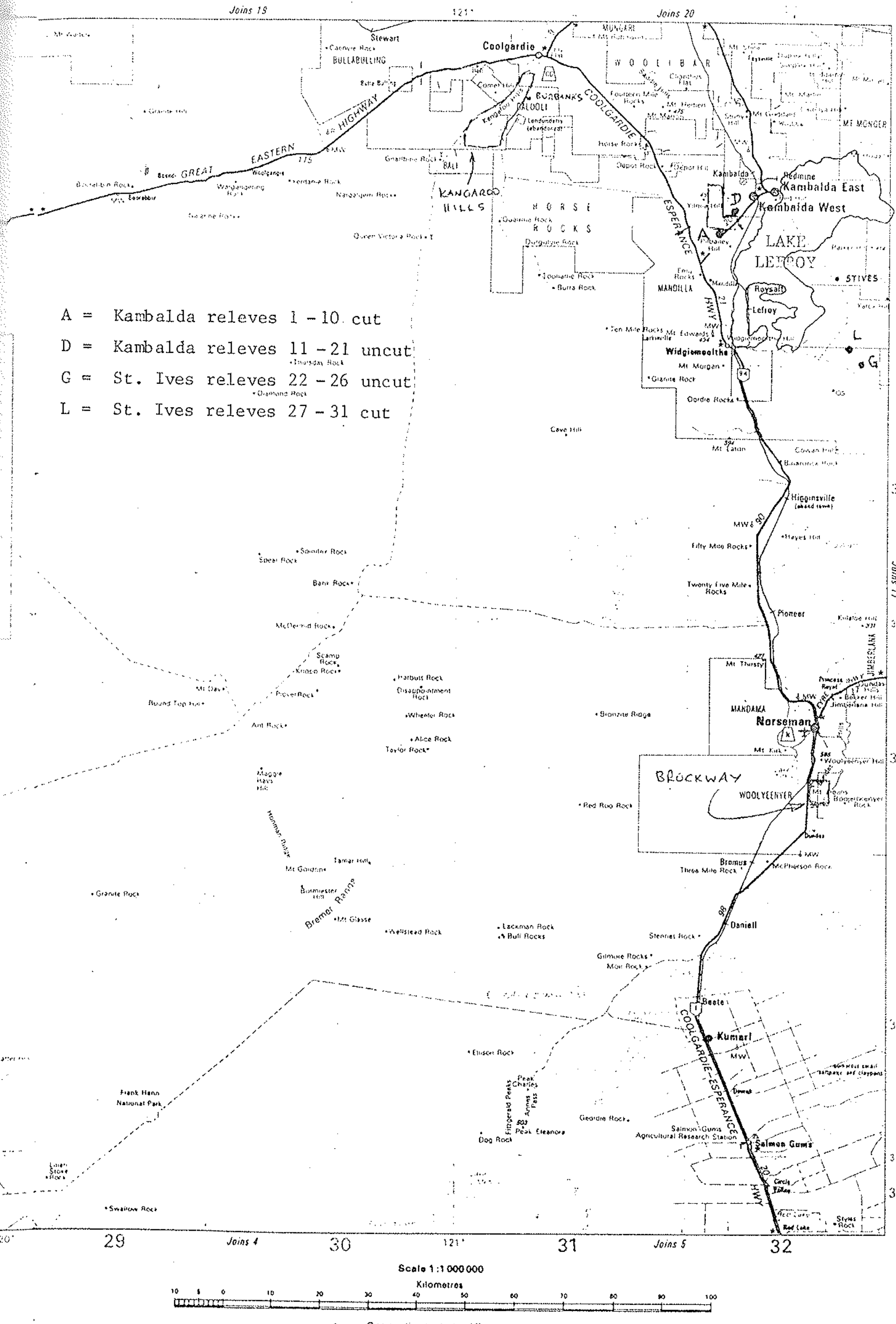
APPENDIX 1 VEGETATION OF W.A.

See Jarvis (Ed.) 1979 An Atlas of Human Endeavour



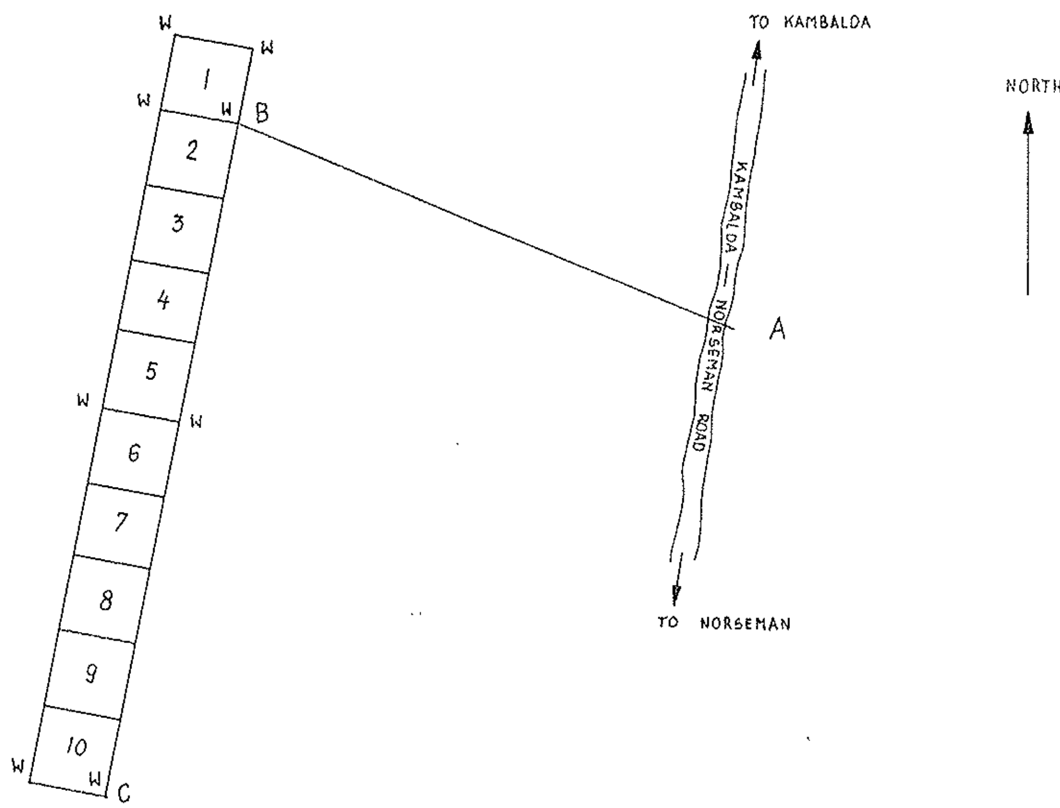
Scale 1 : 10 000 000

APPENDIX 2 LOCALITY MAP



APPENDIX 3.1

Tie sketch for Kambalda releves 1 - 10, locality A, cut 1912.



Notes

1. Not to scale.

2. A = road sign [N 120] 11.3 km south of the Kambalda-Kalgoorlie road junction on the Kambalda to Norseman road. [N 120] means 120 km from Norseman.

3. W = position of small wooden pegs at several releve corners.

4. B = corner between releves 1 and 2.

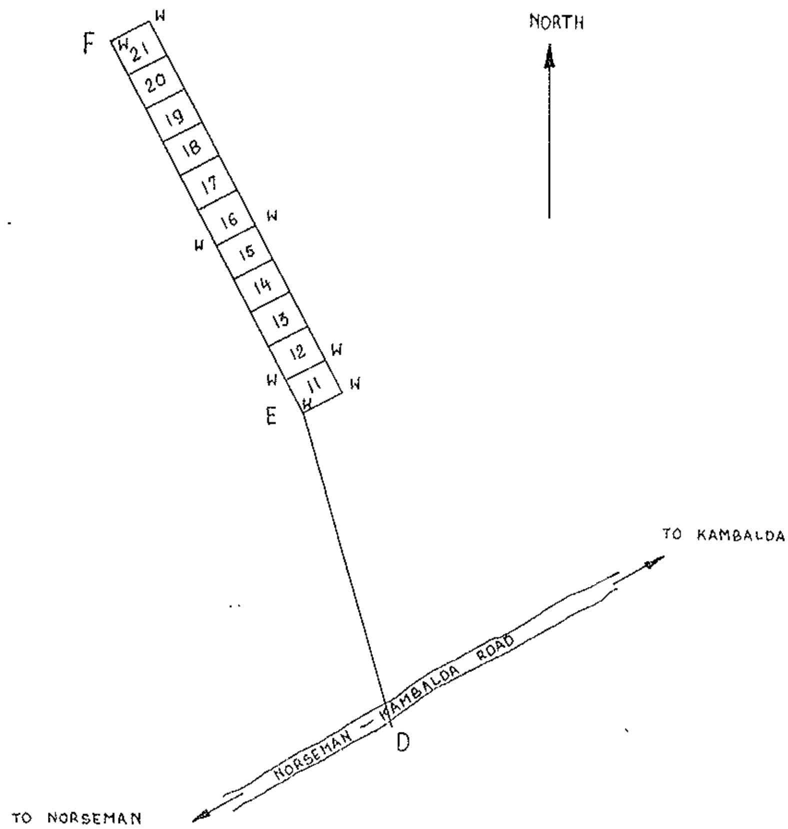
5. A - B distance = 145 m
   bearing = 293 degrees compass

6. B - C distance = 90 m
   bearing = 190 degrees compass

7. 1, 2, ... 10 = releve numbers. Each releve measures 10 m × 10 m.

APPENDIX 3.2

Tie sketch for Kambalda releves 11 - 21, locality D, uncut.

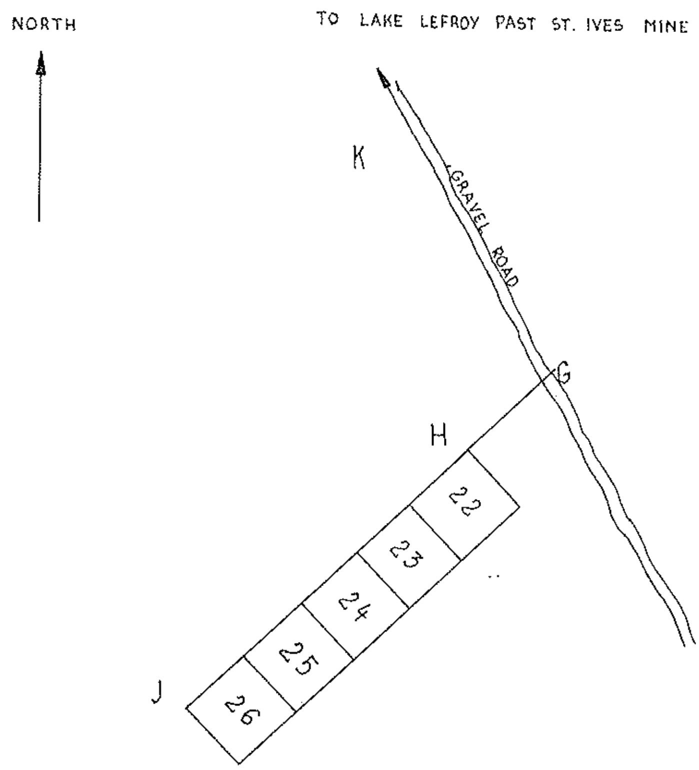


Notes

1. Not to scale.
2. D = GRID sign on the Kambalda - Norseman road, 8.1 km south-west of the Kambalda - Kalgoorlie road junction.
3. W = position of small wooden pegs at several releve corners.
4. E = corner post of releve 11
5. D - E distance = 126 km
   bearing = 341 degrees compass
6. E - F bearing = 330 degrees compass
7. 11, 12, ... 21 = releve numbers. Each releve measures 10 m × 10 m.

APPENDIX 3.3

Tie sketch for St. Ives releves 22 -26, locality G, uncut.

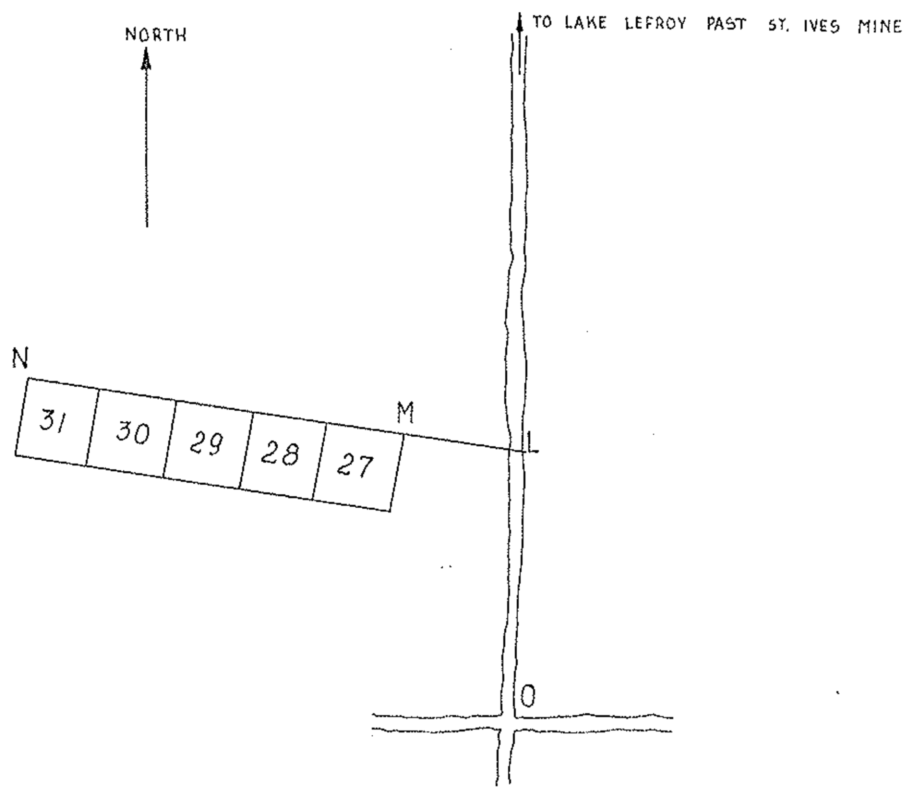


Notes

1. Not to scale.
2. G = point on road 27.1 km south of Lake Lefroy on road going past St. Ives mine.
3. G - H distance = 10 m
   bearing = 225 degrees compass
4. H - J bearing = 225 degrees compass
5. 22, 23, ... 26 = releve numbers. Each releve measures 10 m × 10 m
6. K = benchmark SI 11 (bronze and cement) on west side of road.
7. G - K distance = 183 km
   bearing = 334 degrees compass

APPENDIX 3.4

Tie sketch for St. Ives releves 27 - 31, locality L, cut 1946.



Notes

1. Not to scale.
2. L = point on road 23.7 km south of Lake Lefroy on the road going past St. Ives mine.
3. M = corner of releve 27
4. L - M distance = 14 m
   bearing = 279 degrees compass
5. M - N bearing = 279 degrees compass
6. 27, 28, ... 31 = releve numbers. Each releve measures 10 m × 10 m.
7. O = cross roads
8. L - O distance = 43 m

Near releve 1 Kambalda cut

Eucalyptus lesouefii regrowth. Tree with booking board is 16 cm dbhob and 12 m high. Note stump on right. Cutting was in 1912.

Near releve 8 Kambalda cut

Eucalyptus salmonophloia 32.3 cm dbhob and 13 m high. Note Maireana Georgei (Bluebush), bare ground, and Eucalyptus lesouefii regeneration in background.

Near releve 16 Kambalda uncut

Looking towards releve 20. This is uncut Salmon Gum woodland. Note Eremophila and bare ground. The Eucalypts are E.salmonophloia. E.lesouefii, E.stricklandii, E.transcontinentalis.

Near releve 21 Kambalda uncut

Looking towards releves 20, 19. E.stricklandii on right. E.salmonophloia in background. Also present are Acacia acuminata, Eremophila, Santalum spicatum and bare ground.

Near releve 23 St. Ives uncut

This is uncut Gimlet woodland. Note Bluebush (Maireana), Scaveola, Eremophila and bare ground. The Eucalypt is E.salubris var glauca.

Near releve 24 St. Ives uncut

Looking towards releves 25, 26. Note Bluebush (Maireana), Atriplex vesicaria, dead Samphire and bare ground. The Eucalypt in the background is E.salubris var glauca.

Near releve 27 St. Ives cut

The yellow ribbon is on Quandong (Santalum Acuminatum). The young regeneration in the background is E.salubris var glauca. Eremophila is growing beneath this regeneration. The booking board is alongside Atriplex nummularia. Older E.salubris regeneration is at the right of the photo.

Near releve 28 St. Ives cut

The regeneration in the background is E.salubris. Note Atriplex nummularia (Old Man Saltbush), Atriplex vesicaria, bare ground, samphire (Halosarcia). The booking board is alongside Rhagodia drummondii.

APPENDIX 4.5

Near releve 30, St. Ives cut 1946.

The regeneration is E.salubris var glauca.

The stump is 13 cm diameter.

The central shrub is a Quandong (Santalum acuminatum).

The road in the background leads left to the St. Ives mine and Lake Lefroy.

APPENDIX 5 RELEVES, SPECIES, COVER ABUNDANCE

No.	Species	001	002	003	004	005	006	007	008	009	010	011	012	013	014	015	016	017	018	019	020	021	022	023	024	025	026	027	028	029	030	031
		KAMBALDA																					ST. IVES									
		CUT 1912										UNCUT											UNCUT					CUT 1946				
1	Eucalyptus lesouefii	5	1	2																												
2		+		+																												
3	Eremophila		+	2	1	1	+	+	+	+	1	2	2	1	1	+	2	1	+				+			2	2	1	1			+
4	Scaevola		+	1	1		1		+	+	+							+	+													
5	Eremophila parvifolia		+	+	+	+																										
6	Atriplex nummularia			+	+	1	1				+	+							+									2	1	1		
7	Acacia acuminata			+															+	1	+											
8	Cassia nemophila			+		+		+						+	+	+	+	+														
9	Acacia pachypoda				+		+		+																							
10	Scaevola spinescens			+	1	1	1	+	1	1	+				+	+	+	1	1	+			2					1			1	+
11					+																											
12	Eucalyptus salmonophloia								+	3			3					+														
13	Eucalyptus gracilis									1	+																					
14	Myoporum platycarpum									1																						
15	Santalum acuminatum									1	+												1		+	+	+	1				1
16	Maireana georgei										+													+	+	+						
17												+																				
18	Eremophila interstans												+																		+	
19	Enchylaena tomentosa												+	+	+		+	+	+								+	+			+	+
20	Acacia												+				+					+										
21	Maireana glomerifolia												+																			
22	Maireana sedifolia											+		+	1								1	1	+							
23	Eucalyptus celastroides													2																		
24	Exocarpus cupressiformis													+		1					+											
25															+			+		+		+										
26	Rhagodia crassifolia														+																	
27	Eucalyptus salubris var glauca																						3			+	4	3		1	5	
28																							+				+					
29	Solanum nummularium																						+			+						
30	Artiplex vesicaria													+		+								+	1	1		1	1	1	1	2
31	Sclerolaena diacantha																							+								
32																																
33	Halosarcia doleiformis																							+	+	+			1	+		2
34																																
35																																
36	Sclerolaena drummondii																									+			1	1		
37	Rhagodia drummondii																												+			
38																													1			
39	Scaevola																															+
40	Chenopodium																															+
41	Melaleuca pauperiflora															+																
42	Santalum spicatum																+		+													
43	Olearia axillaris var eremicola																+															
44																																
45	Eremophila oppositifolia																		+	1	+	+										
46																																
47	Dodonaea lobulata																			+		+										
48	Eucalyptus stricklandii																					1										
49	Alyxia buxifolius																					+										
50	Eremophila saligna																					+										

Cover abundance codes:

+ = Occasional, cover less than 5%
1 = Common, cover less than 5%
2 = Very common, cover less than 5%
OR 2 = Any number of individuals, cover 5 - 20%
3 = Any number of individuals, cover 20 - 50%
4 = Any number of individuals, cover 50 - 75%
5 = Any number of individuals, cover 75 - 100%

APPENDIX 6

VEGCLASS

The reference set technique used in this study is embodied in an interactive computer program VEGCLASS (Bridgewater and Morales, 1981) for classifying and ordinating data. It is based on the Zurich-Montpellier (Z -M) method of ranking vegetation samples. The Zurich-Montpellier method assumes that every species has a preference for particular habitats and that every species has a potentially wider distribution than it is now in. Its distribution is narrowed by competition with other species. Survival generally occurs on habitats that are nearly optimal (Ellenberg, 1952). Plant species require certain habitats for their persistence and show preference for association with certain other species. These species are of diagnostic value for describing a plant community and are called "differential species" (Whittaker, 1962).

Constancy or presence is another feature of this approach. If a species occurs in a large percentage of sample plots, it will show a high presence (constancy) value for the plant community represented by the plots. On the other hand some species are restricted to certain sub-units of a plant community. These are the character species referred to in section 2, and are useful in classifying associations and higher units.

The ordination method used in VEGCLASS is a computer modified version of the principal axes ordination method of van der Maarel (1969).

There are three similarity coefficients available for use in VEGCLASS. The Jaccard coefficient, based on qualitative (presence/absence) data; the Sørensen (qualitative) coefficient based on presence/absence data, and the Sørensen (quantitative) coefficient based on cover abundance data. As this study measured cover abundance data, the Sørensen quantitative coefficient was used in the analysis, as quantitative changes may have been important in the dynamics of vegetation change associated with clear felling. The Sørensen similarity coefficients are calculated as follows:

$$S.C. = \frac{400a}{(2a + b + c)} - 100$$

where S.C. = the Sørensen similarity coefficient.

For the Sørensen qualitative coefficient using only presence/absence data:

a = number of species in common.
b = number of species confined to releve 1
c = number of species confined to releve 2

For the Sørensen quantitative coefficient using cover abundance values:

a = the number of the lowest cover abundance values for species in common.

b = the total cover abundance values "left over" for all species in releve 1.

c = the total cover abundance values "left over" for all species in releve 2.

A hypothetical example will clarify the way the two Sørensen coefficients are calculated.

	Releve No.1 cover abundance value	*Releve No.2 cover abundance value*	*Least value of cover abundance for species in common*
Species A	2	1	1
Species B	3	3	3
Species C	4	0	0
Species D	1	3	1

For the qualitative coefficient: a = 3, b = 1, c = 0.

For the quantitative coefficient: a refers to the sum of the lowest cover abundance (CA) values for the species common to both releves. For species A, the CA value in releve 1 is 2, in releve 2 it is 1. The least value in common is therefore 1. For species B, the least value in common is 3. As species C does not occur in releve 2 its least value in common is 0. For species D, the least value in common is 1. a therefore equals 5(1 + 3 + 0 + 1).

b refers to the species in releve 1 whose CA values in releve 1 are greater than their CA values in releve 2. It is the sum of the excess of CA value in releve 1 to releve 2. For species A, the CA value in releve 1 is 2, and in releve 2 it is 1. Therefore the excess is 1(2 - 1). For species B, the excess is 0(3 - 3). For species C the excess is 4(4 - 0). For species D there is no excess as the CA value of 1 in releve 1 is less than the CA value of 3 in releve 2. b therefore equals 5(2-1 + 3-3 + 4-0 + 0).

c refers to the species in releve 2 whose CA values in releve 2 are greater than their CA values in releve 1. It is the sum of the excess of CA value in releve 2 to releve 1. For species A the CA value of 1 in releve 2 is less than the CA value in releve 1, and there is therefore no excess. For species B the excess is 0(3 - 3). For species C there is no excess. For species D the excess is 2(3 - 1). c therefore equals 2(0 + 3-3 + 0 + 3-1).

The Sørensen qualitative SC

$$= \frac{400 * 3}{(2 * 3 + 1 + 0)} - 100 = + 71.4$$

The Sørensen quantitative SC

$$= \frac{400 * 5}{(2 \times 5 + 5 + 2)} - 100 = + 17.6$$

In this example the qualitative coefficient shows a much stronger similarity between releves (+ 71.4) than the quantitative coefficient (+ 17.6) does. This demonstrates the value of using a quantitative coefficient and in general the fewer the species the more useful is the quantitative coefficient.

The SC coefficient produces values ranging from +100 to -100. The distance (D) between the samples for ordination purposes can be calculated as:

$$D = 100 - SC$$

The pair of samples with the lowest SC value is selected as the X axis reference stands. Negative correlation tendency (NCT) values are calculated by summing the differences between the columns, ignoring signs. The X axis releves are selected from the two releves with the highest NCT and lowest similarity values. The position of a stand (J) on the X axis is calculated using:

$$XJ = \frac{(DAJ + DBJ) \quad (DAJ - DBJ)}{2\ DAB}$$

where DAJ = the distance of releve J from reference releve A

DBJ = the distance of releve J from reference releve B

DAB = the distance between reference releves A and B.

All other stands can be located in a similar way.

The Y axis reference releves are now calculated using the following procedure:

1. Releves with a value between +20 and -20 on the X axis are compared, and the pair with the highest NCT value are selected as the Y axis reference stands.

2. Values of the Y axis are calculated with the formula used for the X axis stands.

Function PAO calculates a matrix of similarity values (SC) and a matrix of NCT values. Function PORD uses these matrices and generates a list of X and Y coordinates, from which an ordination diagram can be plotted. Function CCLST (Carlson Cluster Analysis) is based on the work of Carlson (1972). It creates groups of releves using the similarity matrix produced by function PAO. Clusters are initiated by selecting the releves with the highest similarity value and these form the nucleus of the first cluster. The releve pair with the next highest similarity value is selected and a check is made to determine if either of these is already in the first cluster. If not, then they form the nucleus of the second cluster. If, however, one is in the first cluster then the second is added to the cluster if:

- its similarity to all (minus the percentage deviations allowed, specified at the beginning of the process) members in the cluster is greater than the selected index.

- its similarity to all (minus the percentage deviations allowed) non-members of the cluster is less than the selected index.

The releve pair with the next highest similarity is selected and the process is repeated until no more releves can be found that meet these criteria.

Up to five percentage deviation values can be used in the program. In practice, 20% is considered to be the maximum useful deviation when analysing sets of vegetation data.

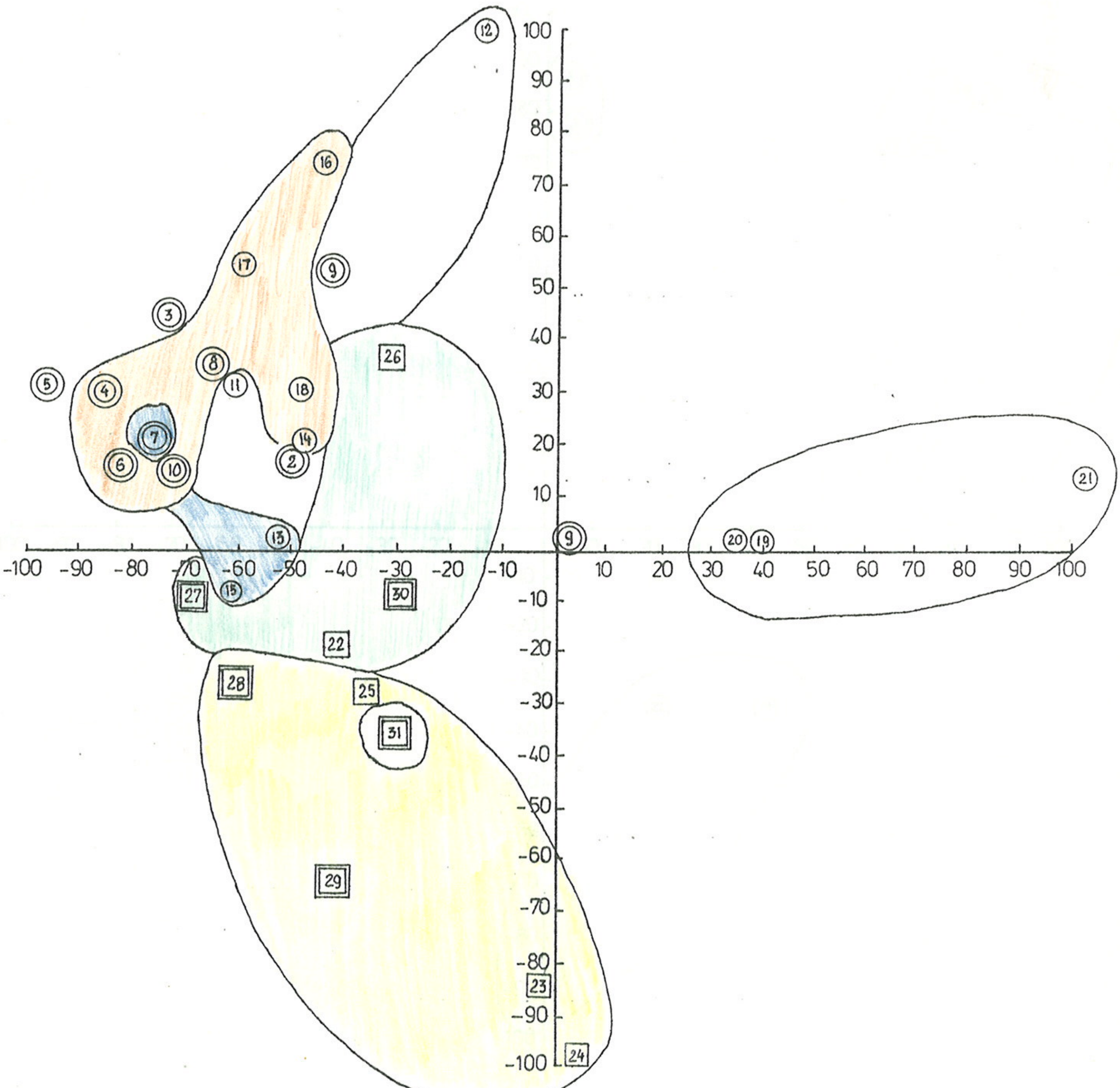
The advantage of VEGCLASS is that it allows leads indicated by one analysis to be followed up quickly and inexpensively. In this study it was very easy to exclude releves 1, 19, 20, 21 and then re-analyse the remaining releves.

APPENDIX 7.1

Ordination Diagram

Releves 1 - 10 Kambalda cut
11 - 21 Kambalda uncut
22 - 26 St. Ives uncut
27 - 31 St. Ives cut

10% error factor; Sørensen quantitative coefficient used.



Appendices 7.1 to 7.8 which follow are the ordination diagrams for the releve data produced by VEGCLASS. The colours show more clearly the releves grouped together by VEGCLASS using the Sørensen quantitative coefficient and a 10% error factor.

APPENDIX 7.2

<u>Ordination Diagram</u>

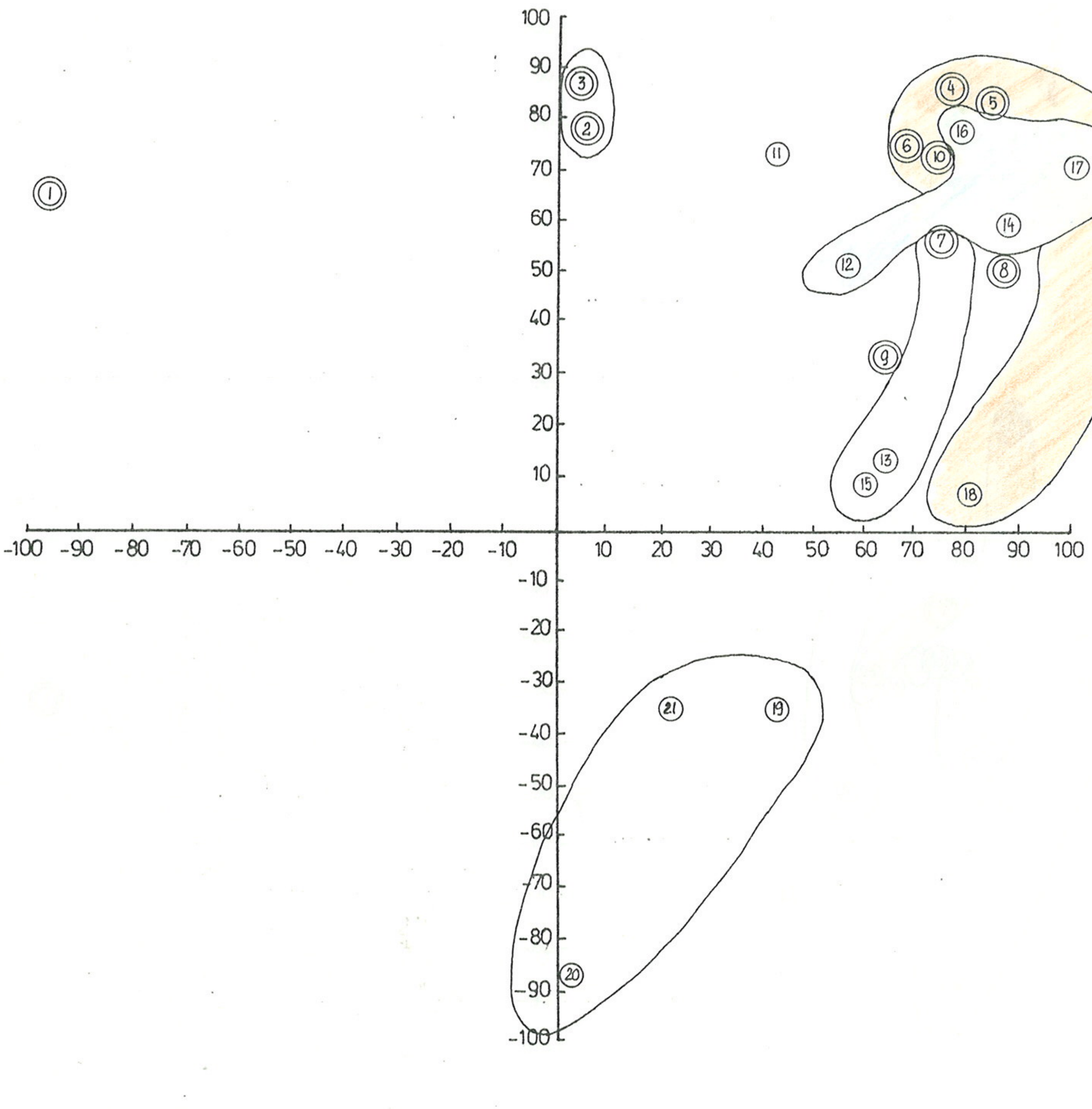
Kambalda only

Releves 1 - 10 cut

Releves 11 - 21 uncut

10% error factor

Sørensen quantitative coefficient used.



APPENDIX 7.3

Ordination Diagram

Kambalda only

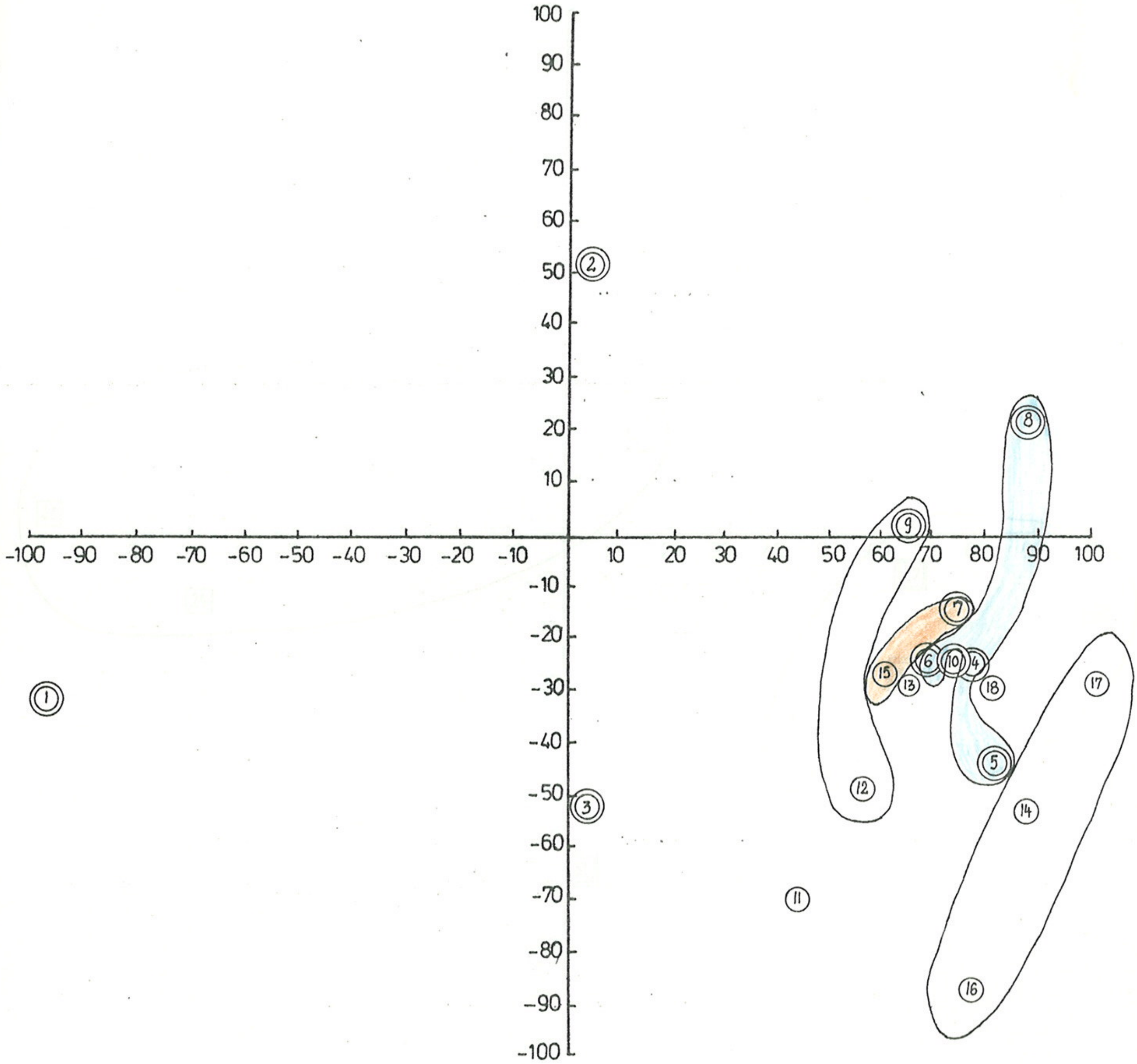
Releves 19, 20, 21 omitted

Releves 1 - 10 cut ◎

Releves 11 - 18 uncut ○

10% error factor

Sørensen quantitative coefficient used.



APPENDIX 7.4

Ordination Diagram

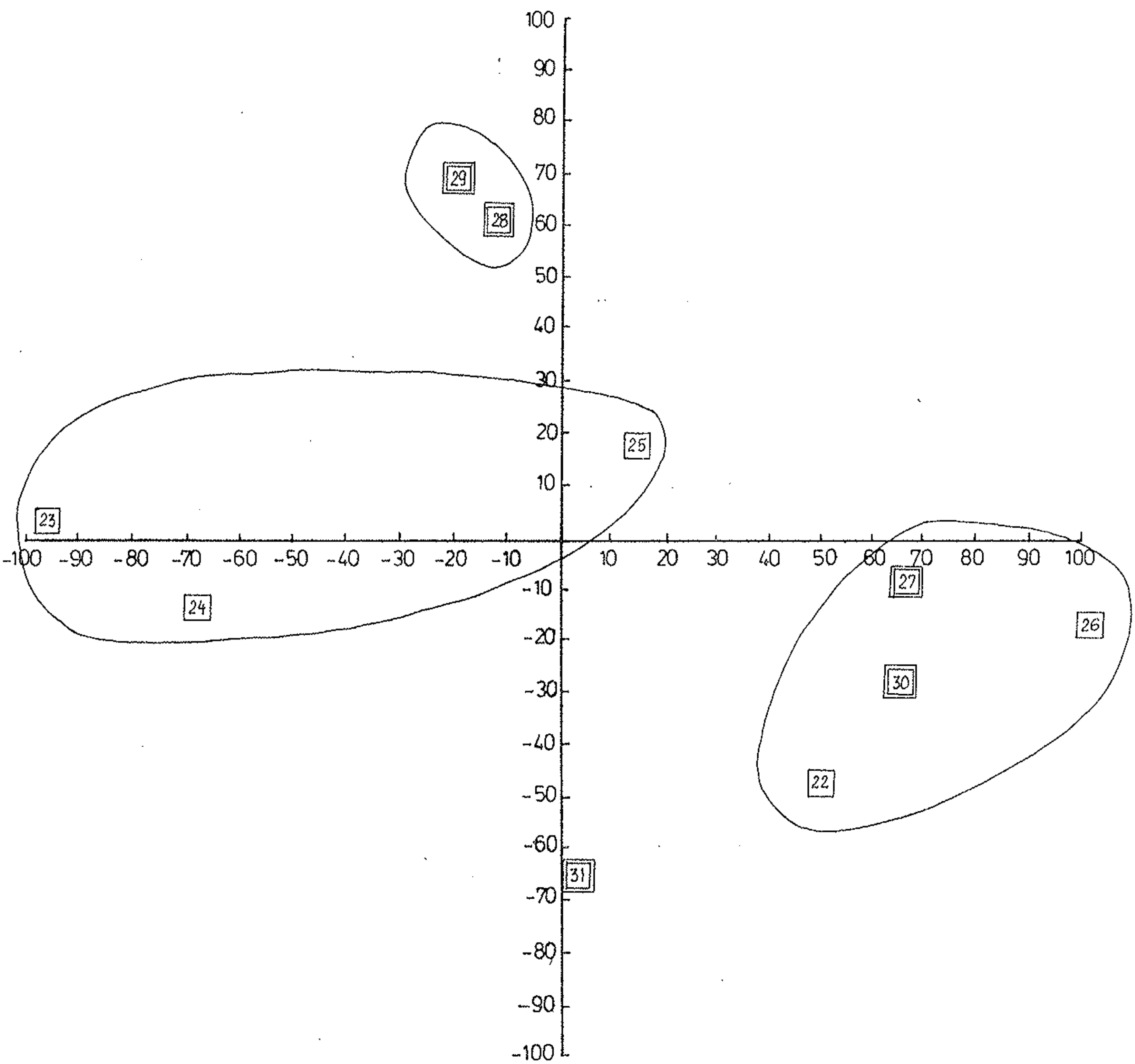
St. Ives only

Releves 22 - 26 uncut ☐

Releves 27 - 31 cut ☐

10% error factor

Sørensen quantitative coefficient used.



APPENDIX 7.5

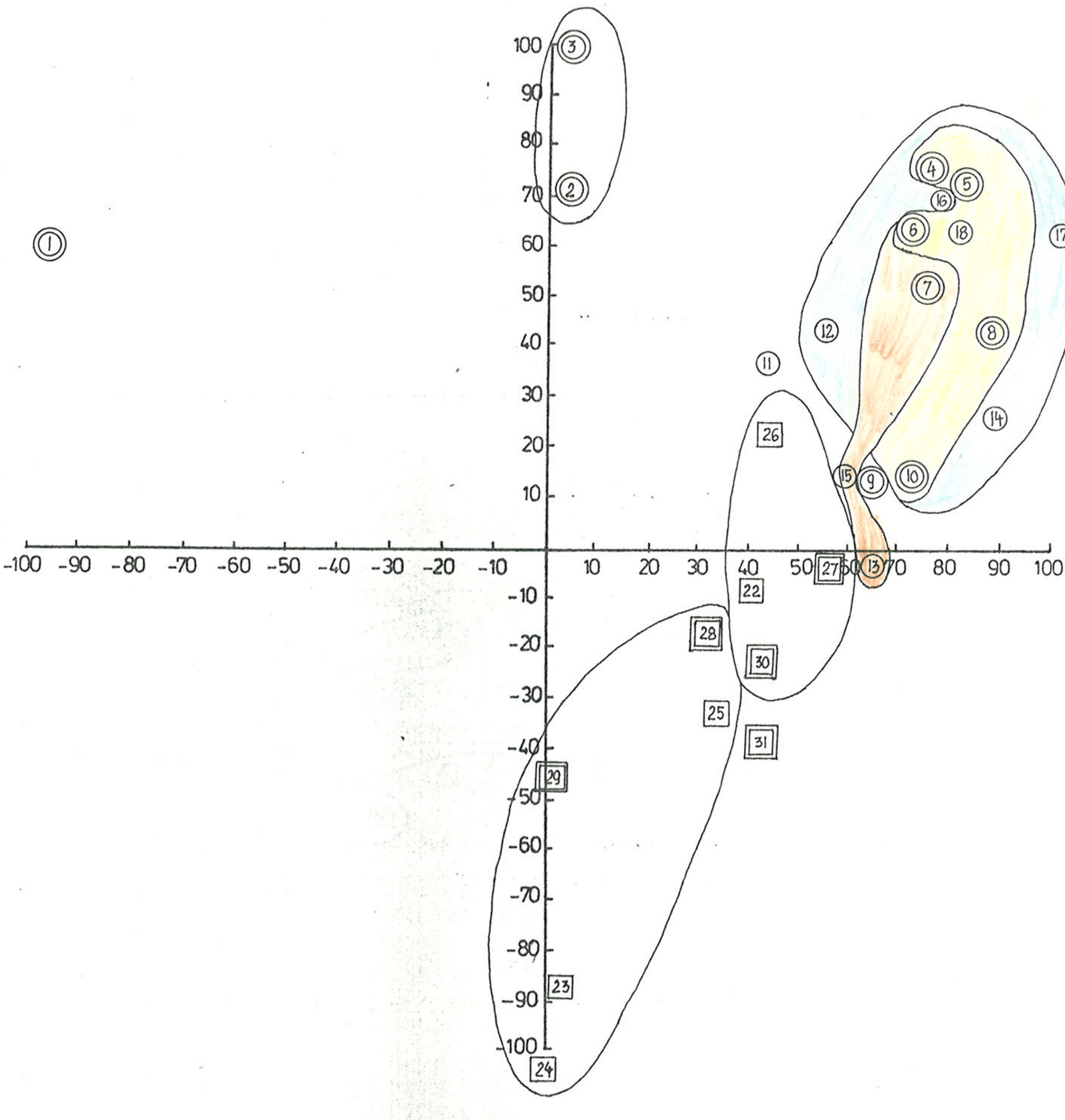
Ordination Diagram

Kambalda and St. Ives

Releves 19, 20, 21 omitted

Releves	1 - 10	Kambalda cut	◎
	11 - 18	Kambalda uncut	○
	22 - 26	St. Ives uncut	□
	27 - 31	St. Ives cut	⧈

10% error factor; Sørensen quantitative coefficient used.



APPENDIX 7.6

Ordination Diagram

Kambalda only

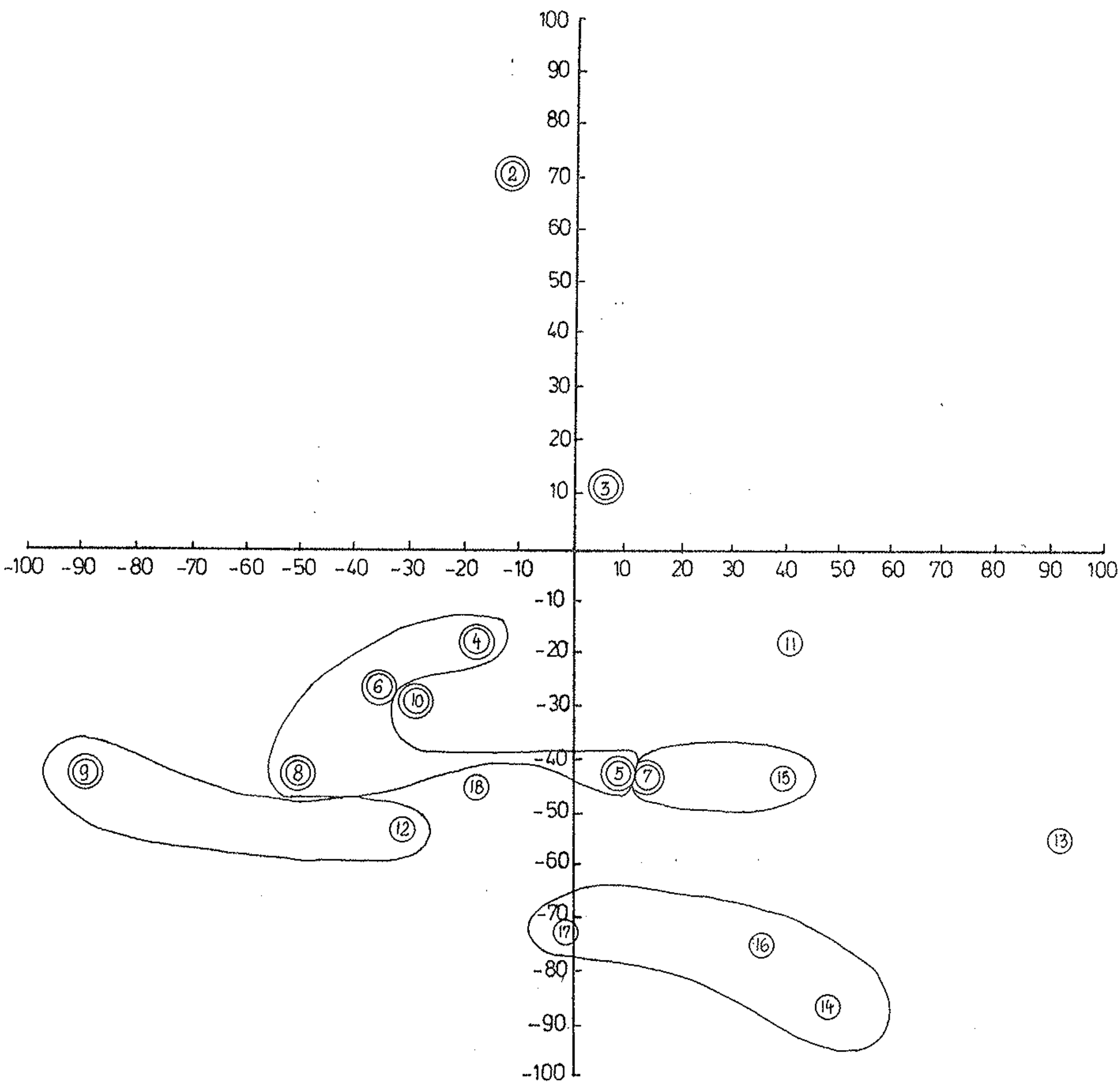
Releves 1, 19, 20, 21 omitted

Releves 2 - 10 cut ◎

Releves 11 - 18 uncut ○

10% error factor

Sørensen quantitative coefficient used.



APPENDIX 7.7

Ordination Diagram

Kambalda and St. Ives

Releves 1, 19, 20, 21 omitted

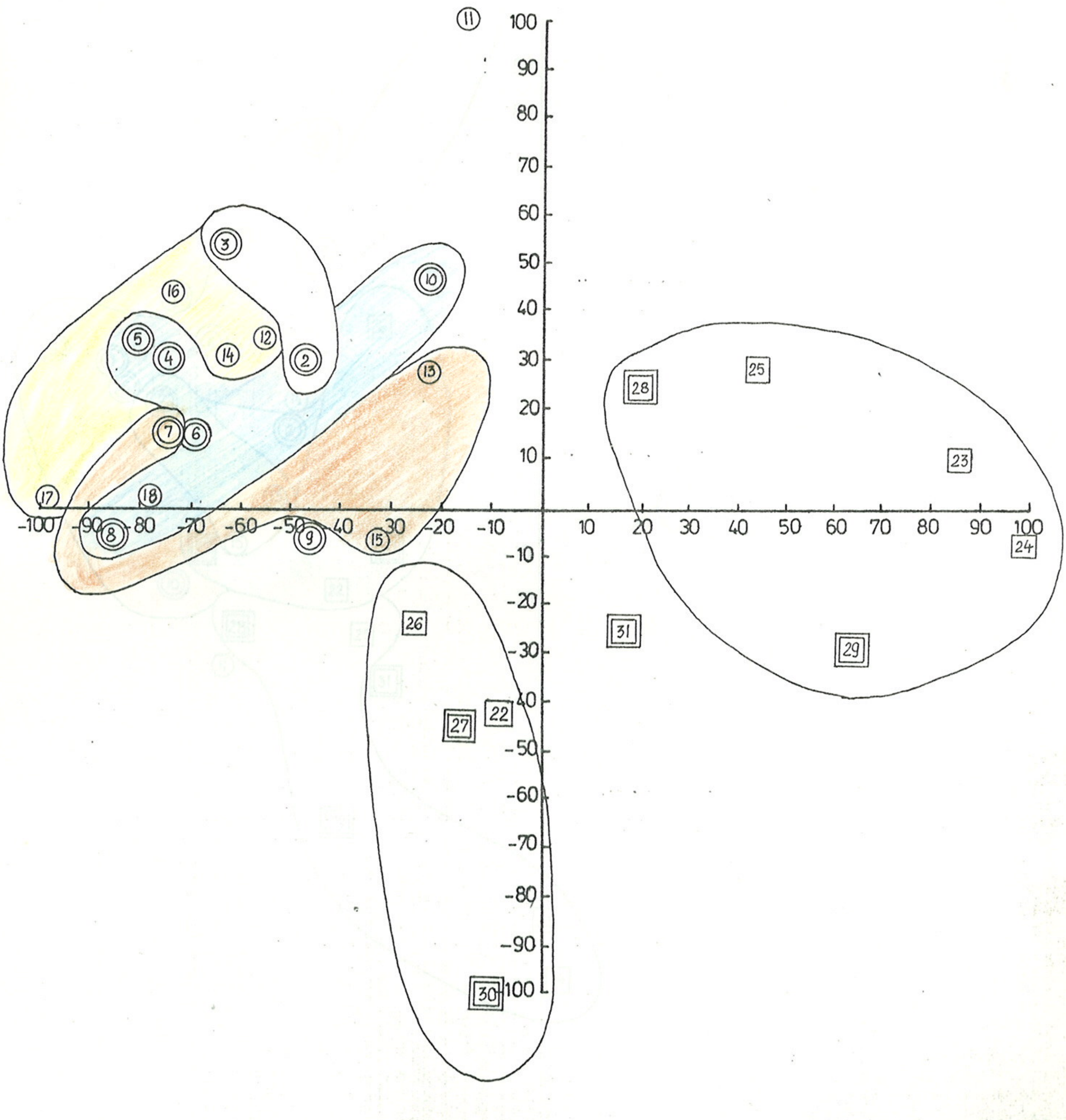
Releves 2 - 10 Kambalda cut ◎

11 - 18 Kambalda uncut ○

22 - 26 St. Ives uncut □

27 - 31 St. Ives cut ⧈

10% error factor; Sørensen quantitative coefficient used.



APPENDIX 7.8

Ordination Diagram

Kambalda, St. Ives

Releve 1 omitted

Releves 2 - 10 Kambalda cut

11 - 21 Kambalda uncut

22 - 26 St. Ives uncut

27 - 31 St. Ives cut

10% error factor

Sørensen quantitative coefficient used.