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THE JARRAH FOREST AVIFAUNA AND ITS RE-ESTABLISHMENT
AFTER BAUXITE MINING

by Dr B.J. Wykes

SCHOOL OF BIOLOGY BULLETIN

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The Jarrah Forest Avifauna and its Re-establishment after Bauxite Mining

Dr Boyd John Wykes*

Abstract

A two-year study of avifaunal ecology in the Jarrah forest of Western Australia was conducted in relatively undisturbed, mature forest and, for one year, in 6-year old vegetation of rehabilitated bauxite mine-pit. Avian community composition and distribution in relationship to vegetation composition was monitored and foraging observations gathered in all seasons. Changes in avian density were also compared with changes in relative abundance of insect and nectar food resources and climatic variables.

The avifauna of the forest was found to be relatively depauperate in species numbers and abundances compared with communities of eastern Australian forests. Suggested reasons included geographic isolation of the S.W. forests, lack of alternative habitat for potentially migratory species during winter food minima, and specific factors such as restricted litter decomposition and absence of eucalypts with decortivating bark. Consequently, the jarrah community is of species that are widespread in southern Australian or S.W. habitats.

Predictions for conservation and management of the avifauna were optimistic - most species are not restricted in distribution and those that favour habitat within the jarrah forest were not of the upland sites where bauxite is mined. The adaptable, opportunistic nature of most species are already apparent from their readiness to colonize young rehabilitation plots, with densities and diversities of species indistinguishable from those of natural forest. However, the young rehabilitation vegetation was more similar to that of the creeks than to adjacent upland forest, as was its avian community. Recommendations were made for further monitoring of rehabilitation plots since they are as yet far from mature or demonstrably viable, and for further research on some potentially endangered bird species, particularly the hollow-nesting, socially complex, frugivorous parrot races and species that are specific to the S.W. region.

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CHAPTER 1. INTRODUCTION

1.1 Introduction

Alcoa of Australia established a bauxite mining lease in 1961 that covered most of Western Australia's northern jarrah Eucalyptus marginata forest. In recent times, much research conducted by the Forest Department, Alcoa and tertiary institutes in W.A. has been directed at describing the flora and fauna of this region, although the findings have been primarily published in local reports (e.g. Christensen and Kimber, 1975; Havel, 1975a & b; Springett, 1979; Heddle et. al. 1980; Kabay and Nichols 1980; Majer, 1980; Nichols and Bunn, 1980; Carati, 1981; Majer et. al., 1983). Some studies have been on the avifauna but have generally only involved comparisons of species' presence in natural jarrah forest and area affected by fire, mining and jarrah dieback (Phytophthora cinnamomi), without additional knowledge of ecologies being obtained (Christensen and Kimber, 1975; Kabay and Nichols, 1980, Nichols et. al., 1981; Curry and Nichols, 1985; Nichols and Watkins, 1984).

The Environmental Research Group of Alcoa financed the present study in recognition that further work was needed on the requirements of the bird species of the jarrah forest and whether these requirements were likely to be met in the mine rehabilitation pits. This was in the form of a two-year fellowship in the Biology Department at WAIT, under the supervision of Dr. Brian Collins.

1.2 The Habitat

Jarrah reaches its optimum development on the deep, well-drained gravel on the slopes of the laterite-capped ridges of the Darling Ranges, south of Perth (Harris, 1966). The ranges are an uplifted region on the western edge of the ancient shield rocks that form the Great Plateau of Western Australia and consist of shallow, infertile soil on concentrations of aluminium and iron oxide, over a bedrock of granite (Alcoa, Dames and Moore, 1978). The climate is typically mediterranean, with annual summer droughts and cool, wet winters. The presence of a tall forest with a diverse associated flora and fauna under conditions of infertile, shallow soil, severe summer drought and a long history of frequent bushfires led Shea (1975) to suggest that the jarrah forest is one of the world's most unique forest ecosystems. The jarrah itself is impressive, attaining a height of up to 56 metres and can provide extremely dense concentrations of merchantable timber in virgin stands (Shea, op. cit.). The claim that the forest is biologically rich is based on studies such as Havel (1975 a & b), in which 20 well-defined plant communities are described for the jarrah forest, and Kimber (1972), who recorded 87 bird species in a 30 mile diameter region of forest, with a density of 4 birds of resident species per hectare.

1.3 Bauxite Mining

The importance of jarrah forest to Western Australians is primarily as water catchment, with timber, biological conservation and recreation close behind (Shea and Herbert, 1977). Its ability to meet these demands in recent years has been

threatened by salt discharge from the soil due to over clearing of private land (Shea and Herbert, op. cit.), spread of jarrah die-back (Shea, 1975), and bauxite mining (I.F.A., 1980). Open-cut mining of bauxite deposits in the Darling Ranges commenced near Jarrahdale in 1963. Mineable quality bauxite is found in less than 5 per cent of the forest region. The bauxite occurs as isolated pods on the flanks and gentle hill slopes. Individual ore bodies range from one to 100 ha. in area, averaging 10 to 20 ha. There are now three major mining areas with annual production equivalent to 4.5 million tonnes of alumina or about 14 million tonnes of bauxite, involving mining of 300 to 400 ha. annually (Nichols et al., 1985).

Rehabilitation of disused pits commenced in 1966 (Alcoa, 1976). The rehabilitation procedure has been continually revised since then, with early attempts being far less satisfactory than procedures being implemented around 1980 (Tacey, 1979). Most improvisations have been concerned with increasing the rapidity with which vegetation re-established on the pits and increasing the structural and floristic diversity of the vegetation in the early stages of regrowth. These procedures both reduce the likelihood that dieback will be spread in water run-off from the mine pits and increase the attractiveness of the habitat for wildlife. The utility of the timber produced by the trees has, at this stage, been of less importance than whether the trees are resistant to jarrah dieback, fire resistant and have roots that can penetrate through the compacted pits to the water-table (Shea and Herbert, 1977). The dieback-susceptible jarrah has generally not been replanted and, instead, eastern Australian species such as red mahogany E. resinifera and Sydney blue gum E. saligna, and the local marri E. calophylla and wandoo E. wandoo have been established (Alcoa, 1976). The long-term success of these species in terms of the afore-mentioned criteria has yet to be determined.

The present rehabilitation procedure (Nichols et al., 1981) is to:

- i. Landscape the pit floor slopes and construct contour banks, where necessary;
- ii. Distribute overburden followed by topsoil, which is taken directly from areas about to be mined, in order to provide litter and fresh seeds for natural regeneration of the local flora;
- iii. Rip the pit floors and banks to a depth of 2m, in the lines 2m apart, to provide a foot-hold for the tree saplings;
- iv. Plant the trees in mixtures of species, with at least 50% indigenous to W.A. and 625 trees/ha;
- v. Add native seed at 1kg per ha, including species that do not readily germinate in returned topsoil, and Acacia species which may suppress die-back fungus (1979) and fix nitrogen in the soil.
- vi. Apply nitrogen/phosphate fertiliser to give plants a

vigorous start.

In contrast, early rehabilitation attempts were of monocultures of pine or eucalypt seedlings in unbroken soil without fresh topsoil or seed mix. Obvious failings included death of saplings in summer drought and uprooting in high winds. Furthermore, from the viewpoint of wildlife conservation, such areas have supported a low diversity of jarrah forest plant species and have attracted low densities and diversities of invertebrates and vertebrates (Kabay and Nichols, 1980; Greenslade and Majer, 1980; Majer et. al., 1981).

1.4 Birds of the Rehabilitation Sites

Kabay and Nichols (1980), in their review of avian monitoring programmes in the rehabilitated mine pits found that the presence of a dense shrub layer in recently revegetated pits attracts a variety of bird species not found in the earlier attempts, but also list many species that are not expected to return until the saplings of the rehabilitated areas mature to form a tree layer. Species of noneyeater, parrot and pigeon were found to recolonise only where the nectar and seed of their diets were provided by the particular plant species concerned. This work was extended by Nichols and Watkins (1984) (summer populations) and Wykes et. al (1980) (winter populations), who used strip transect counting techniques to estimate densities of birds in rehabilitated sites and neighbouring areas of forest. Again, it was found that the dense shrub layer produced by present rehabilitation techniques attracts jarrah forest species that forage in this layer, some in greater densities than in natural habitat, and that species that forage in the tree-canopy, on bark and amongst litter were relatively sparse or absent in the rehabilitated areas. The species thought likely to be deleteriously affected by mining in the long-term unless attracted by specific measures were those that require particular food sources such as nectar and seed, and those that nest in the hollows of ageing tree, such as parrots, pardalotes and treecreepers.

1.5 Aims of the Present Study

The results of the short-term studies already conducted on birds of the rehabilitation sites and neighbouring forest have been very predictable from the nature of the present regrowth vegetation (see above). However, it will be many years before such vegetation matures, during which time its character and dependant avifauna are likely to change markedly. Some predictions are optimistic for the return of species that at present lack suitable foraging and nesting sites (Kabay and Nichols, 1980), but use of non-indigenous eucalypt species for rehabilitation leads others to be more cautious in their predictions for long-term viability of the vegetation (Shea and Herbert, 1977). The present study was primarily directed towards describing the ecology of the forest bird community to:

- i. provide a standard against which the effects of the mining could be accurately compared as the rehabilitated vegetation matures; and,
- ii. provide details of the birds' requirements that could lead

to improvements in the rehabilitation techniques without having to wait for possible deficiencies to become apparent over time.

1.6 The Study Areas

The main study area was in the Serpentine M.P.A. (Management Priority Area) to the east of the Pipehead Dam Catchment, Jarrahdale (Figures 1 & 2). It is in the Dale sub-district of the Darling Botanical district, which represents the jarrah forest north of Collie (Beard, 1979). The site was chosen because it was topographically varied, encompassing a series of lateritic ridges dissected by shallow valleys, including exposed granite outcrops close to the Pipehead Dam. However, it did not include marri-wandoo or Riverain woodlands of deeper valleys (Beard, op. cit.). Some of the vegetation was little disturbed while heavy logging, gravel pitting and dieback contributed to variation within the study area. The most recent fires were Forests Department spring and autumn burns in the eastern side of the site in 1976/77. There was an estimated litter build-up of 6.5 tonnes/ha by 1980. Pegs along Alcoa drilling lines over much of the site provided ready-made transects along which to conduct the biological surveys. Furthermore, the Alcoa Environmental Research Group surveyed flora and fauna in this area during the research period and floristic information was incorporated in the present study, while some of my avian data were used by Alcoa (Nichols et al., 1981).

Research was also conducted in a rehabilitation pit and neighbouring jarrah forest during the second year of the study (Figure 1). This pit, at Scenic Drive in the Alcoa No. 2 minesite, was revegetated with Eucalyptus calophylla in 1975 and had a generally dense understorey regenerated from seed mix and fresh topsoil applied in the rehabilitation procedure.

The main types of information collected were:

- a) Species occurrence, density and distribution of the birds at both study area over all seasons.
- b) Correlation of avian distribution with floristic and structural characteristics of the vegetation in the jarrah forest.
- c) Relative arthropod and nectar food availability to the birds of the jarrah forest over all seasons.
- d) Foraging ecologies and nesting requirements of the bird species.

These were gathered at bi-monthly intervals over two years (1981-82) at the Serpentine study area and over one year (1982) at the Scenic Drive rehabilitated site.

Figure 1. Locations of the study areas.

The localities of the jarrah forest study area in the Serpentine M.P.A., and of the Scenic Drive rehabilitation pit in the Alcoa No.2 Mine Site are shown in relation to Perth, the Alcoa mineral lease and the State forest.

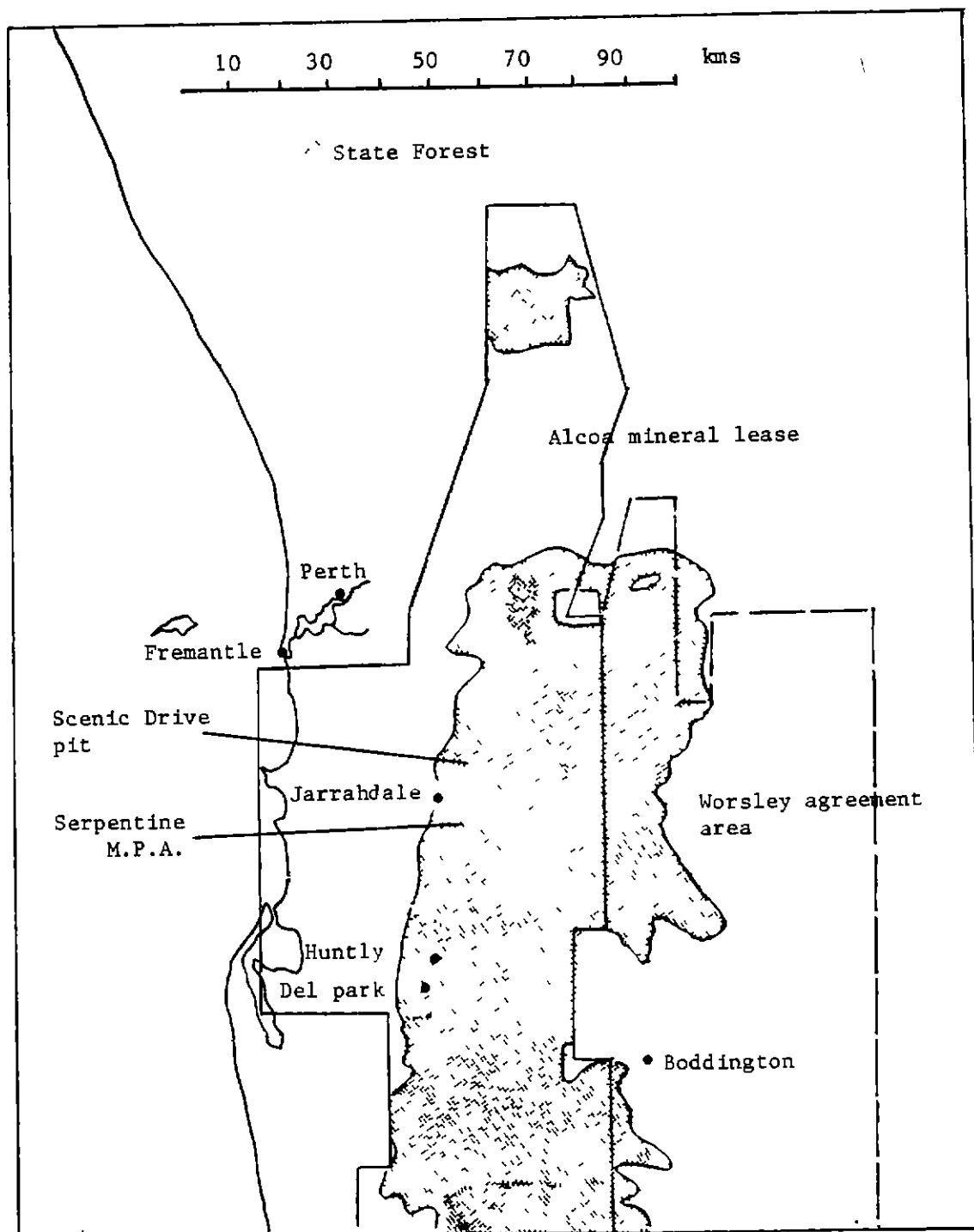
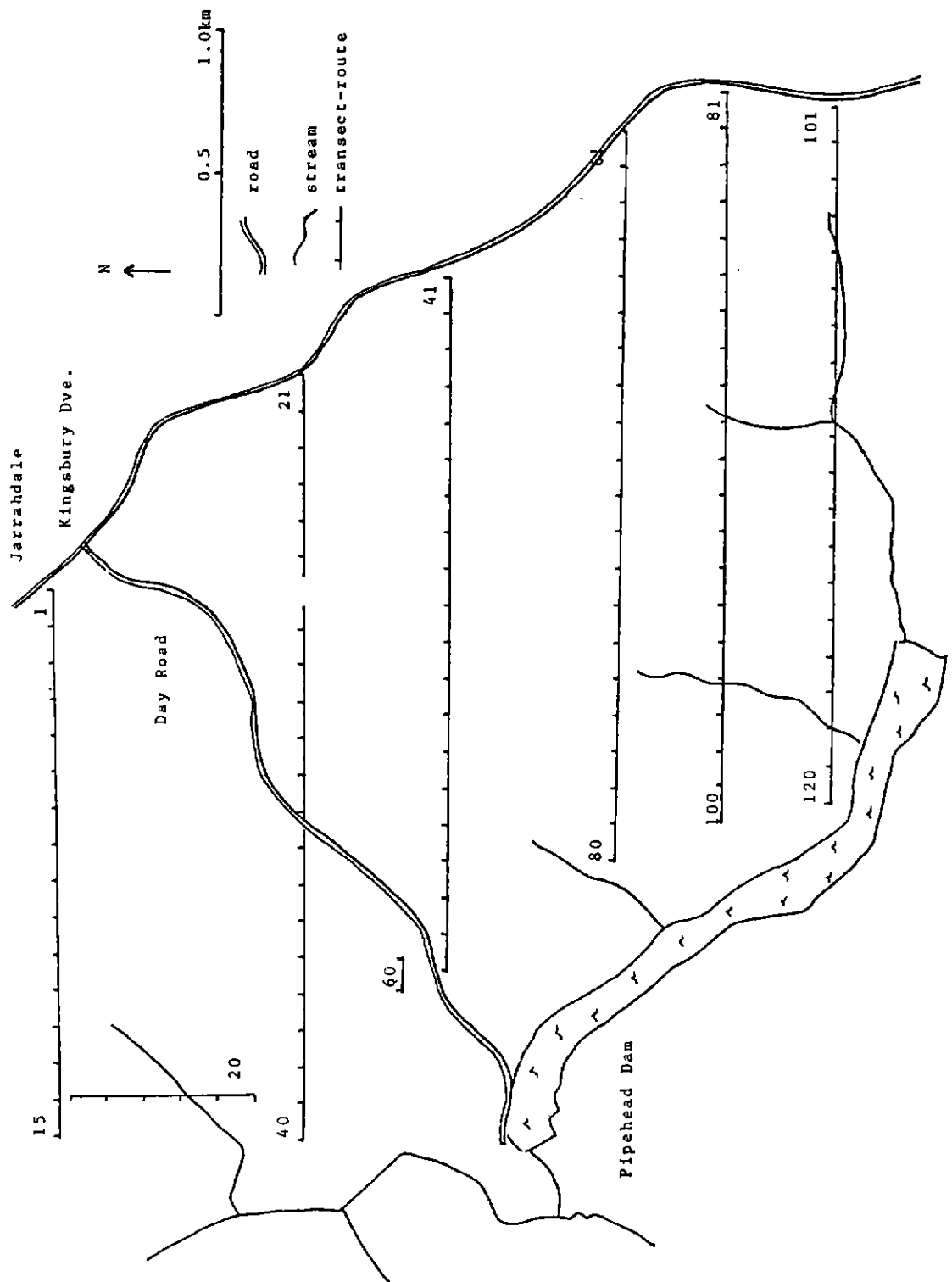


Figure 2 Sketch-map of the Serpentine Study Area.

The lay-out of the 14.6 kilometres of transect-lines is shown within the 7.7 km² study area of Jarrah forest that was part of the Serpentine MPA (management protection area). Each length of the total transect was divided into twenty 400ft sections, as shown. The lines generally ran E-W but were redirected where they met private property, a road, and a gravel pit.



CHAPTER 2. METHODS

2.1 Availability of food to the birds

An understanding of avian communities and their susceptibility to changes of environment depends on a knowledge of the resources that limit the populations of each species and the times of the year in which the limitations act (Fretwell, 1972). It is extremely difficult to prove that food is a limiting resource for avian populations (Lack, 1954) but seasonal abundance curves of food availability can provide circumstantial evidence of limitation if observed changes in avian population dynamics correlate with changes in food supply.

Most of the species of the jarrah forest feed partially or totally on arthropods. All methods of collecting arthropods are biased towards particular groups (Southwood, 1966). Two methods were chosen to compare types and frequencies of arthropods in different sites in the habitat and to provide a composite assessment of overall food availability. These were sweep-netting and stick traps.

Other major food types utilised by jarrah forest birds were likely to be nectar and seeds. Nectar availability was monitored but assessment of seed availability was not attempted.

2.1.1 Sweep-net sampling.

Sweep-net sampling of shrub-layer foliage was used to gather large samples of arthropods from extensive belts of vegetation. The net was of 1.5 mm- mesh, nylon flywire, attached to a 50cm diameter ring on a 135cm long handle. It was swept rapidly through the flexible, outer foliage of whatever shrub or herb layer was present, in a horizontal arc of about 90°. Units of 25 sweeps were taken along 20 of the 400' sections of the avian strip-transect routes (Sections 81-100, Figure 2).

Collecting was confined to the early afternoon of days when there was no rain or strong winds. Two complete samples were collected within each bi-monthly period of observations. The contents of the net were sprayed with household insecticide before the arthropods were removed. Seven of the 9 floristic associations (Chapter 4) were covered by the sweep-net route but arthropod abundances were not compared between associations because of small sample sizes.

2.1.2 Sticky trap sampling

Populations of airborne arthropods amongst tree-layer foliage are likely to show differing compositions and phenologies to those sampled by other methods. Plastic grids of 40 x 40 cm area and 0.5 cm mesh were covered on one face with a coat of 'Tangle trap.' Two traps were placed in separate trees at each of five markers representing a variety of floristic associations and tree species along the avian strip-transect route. The traps were attached by hooks to branches or limbs of the lower canopies of the trees to avoid buffeting by wind (Cuthbert and Peacock, 1975). They were hung for 72 hours per visit, since a lesser time would produce very small catches during some seasons (Wykes,

1982). Rain and strong winds reduce the effectiveness of the traps because of water and debris on the sticky surface, and such weather conditions were avoided. However, this introduces an obvious bias since availability of insects to the birds would be over-estimated during seasons (winter) of frequent adverse conditions. A further difficulty inherent in the sticky-trap technique arises from the exposure of the traps during both day and night, as it was not feasible to handle the traps morning and night for three days of each visit.

The arthropods collected by both the sweep-netting and sticky trap techniques were classified to Order using CSIRO (1970), with species enumerated for calculation of species richness. Arthropod availability as measured by each of the techniques was presented in three ways for each group of arthropods:

- a) Species Richness - the mean number of species indentified per sample for each site and visit.
- b) Abundance - the mean number of individuals (of all species) per sample.
- c) Biomass Index - approximation of biomass by totalling the sizes of the individuals, as measured by dorsal width x length of the bodies. Measurement of biomass or dry weight was not compatible with detailed classification of the items.

2.1.3. Statistical analysis

Variance between arthropod groups comprising the samples was tested for by Kruskal-Wallis analysis of variance. Non-parametric multiple comparison of means (Zar, 1974) was then used to determine the relative importance of the groups where variance was significant. The same procedure was also used to test variance of total food availability over time.

2.1.4. Nectar availability.

Nectar availability was estimated during each visit by counting the number of plants in flower along a line-transect which followed one third (4.9 km) of the avian strip-transect route (Section 1-40, Figure 2). All plants of species known to be visited by birds for nectar that would have been intercepted by a vertical plane along the transect were examined for the presence of flowers. The species and the degree of flowering were recorded for each plant in flower. The total number of plants of each species intercepted by the line-transect was also determined so that the proportion of flowering was known, and the densities of the species in a 4 m wide strip were measured so that absolute flowering densities in the study area could be estimated. The degree of flowering was determined by either counting the number of fresh, open flowers on the plant or, where this was not possible with eucalypts, three classes of floral abundance were defined. These were 'poor' - less than 20% open of flowering structures (i.e., buds, open and spent flowers); 'substantial' - 20-50% open and 'rich' - greater than 50% open.

2.2 Bird population densities and dispersions in the Serpentine Jarrah forest

Estimates of densities and dispersions of the bird species in the study area were necessary in order to establish which species utilise jarrah forest, which microhabitats each uses within the forest, how densities change with season, and how these communities differ in composition from those re-established in rehabilitated bauxite minepits.

Kendeigh (1944) has reviewed census techniques for bird populations and Emlen (1971) presents some refinements. The most accurate estimates are obtained by recapturing or sighting marked individuals but this is time consuming and only practical for small sedentary populations of one or a few species. Similar limitations apply to the widely-used method of spot-mapping sightings of singing males, territorial encounters and nest sites (e.g. Cody, 1974; Recher & Abbott, 1970). Furthermore, this latter technique can be applied only to monogamous, territorial species which lack a large, non-breeding component in the population. Instead, some workers prefer to use simple sampling techniques that estimate relative abundances (e.g. Ford & Paton, 1977), but with these there is difficulty comparing results obtained in differing habitats or by different methods.

A strip-transect method was used to census the avian populations. This simulatenously monitored the densities and distributions of all species with the least possible error introduced by the differences in observability existing between and within the species throughout all seasons of the year. Each transect was subdivided into sections so that records of the dispersions of the sightings were obtained. These data were used to examine habitat preferences of species over the study period (Chapter 2.3).

Emlen (1971) used a similar technique which involved a system of indices based on average density estimates obtained by a variety of methods. These indices were used to compensate for such effects as differing observabilities of species between seasons and habitats when considering the tallies from wide strip transect censuses. The wide strip method is impractical for short-term projects so an attempt was made to count all birds within a narrow strip, whilst traversing extensive routes to cover large total areas.

The transect at Serpentine comprised six parallel lines, running east-west from a major ridge to the Serpentine River and Pipehead Dam (Figure 2). Each of these consisted of twenty, four hundred foot long (121 m) divisions (400' being the drilling interval used by Alcoa). The Alcoa survey lines only occurred for the first half of each strip of 20 sections since surveying was confined to higher areas, and sections 101 to 120 did not follow any survey line since these were within a valley (Figure 2). All sections not surveyed by Alcoa were established by pacing.

A strip width of 40m (20 m either side of the route) was chosen as being one within which I could confidently detect most individuals of all species whilst walking along the route. This was the same width that I have used in previous studies of birds

in temperate forest (Wykes, 1982). Emlen (1971) found that observability of many bird species in open, temperate forest was equally good up to 15 m from the observer for periods of day when birds are active, while Jarvinen (1976), working in Finland, used a main belt of 25 m each side of the observer. Estimation of the 20 m strip-width during counts in the jarrah forest was aided by periodically pacing out the distance and by placing some marker tags at the extremity of the strip.

The total area covered by the strip-transect was 53 ha, with each census conducted over three mornings, covering two of the six strips during each. Emlen (1971) avoided being distracted by obstacles by using existing footpaths for his transect routes but I was able to mark a clear transect line with survey tape directly through the relatively sparse shrub larger than that occurred over much of my study areas. I thus avoided the potential biases inherent in sampling only vegetation types through which tracks passed. Ideal observation conditions were chosen to ensure a standard, high observability of the birds: counts were conducted only on days with no more than light wind and no rain, and were taken during the morning, when birds were most likely to be active. The counts commenced at about one hour after dawn and took 3-4 hours to complete, finishing by 1200 hours. Thus, an average speed of 1-1.5 km/hr was maintained. Birds further than 30 m ahead were ignored. I avoided long stops that might allow either repeated recording of the same individuals or for birds to move into the strip and be illegitimately included in the count.

All avian species sighted within the strip-transect were recorded. Differences in the densities of the species over the study period were tested by analysis of variance, and the mean densities of the species ranked by the Student-Neuman-Keuls test. In addition, all birds recorded immediately outside of the strip in similar vegetation were also noted, to boost sample sizes for analysis of distribution.

2.3 Selection of microhabitats in the Serpentine jarrah forest

The floristic analysis used in this study was developed by botanists to generate phytosociological descriptions of vegetation (e.g. Gullan et al., 1976), and by ecologists studying habitats of small, nocturnal mammals (e.g., Braithwaite and Gullan, 1978; Cockburn, 1978). It has proven more useful than readily obtainable structural measurements for describing habitat preferences of small mammals and has recently been successfully applied to studies of avian communities (Shurcliff, 1980; Wykes, 1982).

Regression of bird species' distributions against variance of some general structural parameters of the vegetation was also performed to compare the relative success of the two approaches in habitat description of the various types of birds.

2.3.1 Floristic Description.

The descriptions of the plant species in the Serpentine block were determined in late 1980 in conjunction with Beverley Glossop, botanist for Alcoa. The analysis followed that of Bridgewater (1971, 1976), based on the Zurich-Montpellier system

of phytosociology. Species lists were compiled for 10 x 10 m quadrats half-way along each 400' section of the strip-transect line. Bridgewater (1976) found that 10 m² was a large enough area to indicate the full community characteristics of similar open forest.

All species that grew within, or projected over, the quadrats were given a positive score. A two-way table of plant species against quadrats was then analysed by a computer sorting programme "Vegclass", an interactive programme written by P. Bridgewater and R. Morales, and offered by the Murdoch University Computer Service Unit. This programme applies the clustering-technique of Carlson (1972) to matrices of similarity values, known as "Jaccard Coefficients" (Gullan, 1978). The clusters of plant species (plant species) and of quadrats (floristic associations) formed by this process contain members that have more similarity to each other than to non-members, based on the presence/absence scores of plant species in the quadrats. The procedure is polythetic (i.e., assesses all characters of the individuals), agglomerative (forms clusters which are then treated as single units), and non-hierarchical.

The clusters were then ordered by hand so that the most dissimilar groups of quadrats (floristic associations) were placed at opposing ends of the horizontal axis of the two-way table. The plant groups that characterized the floristic associations were similarly ordered down the vertical axis so that those groups which were unique to each association were linked by those demonstrating affinities between the associations.

2.3.2 Relationships between avian distributions and floristic associations

The mean number of birds of each species for transect sections which belonged to the same floristic association were calculated for each census. Individuals recorded outside as well as within the strip were included to increase the chance that any relationship between a bird species and an association would be detected by the analysis.

Variance in density of each species amongst the associations was tested by one-way analysis of variance, combined with Student-Neuman-Keuls ranking of the means, where "F" was significant at $P < 0.05$ (Zar, 1974). Non-parametric analysis of variance would have been appropriate for these data but non-parametric ranking of means for groups with unequal sample sizes was not available and parametric analysis is considered to be a "robust" procedure (Zar, *op. cit.*). Species with less than one bird/transect-section in all floristic associations were not included in the analysis but the analysis was performed for these species on the combined records of the ten censuses.

2.3.3 Structural description of the vegetation.

The following variables were measured:

- i. Tree density - the number of trees (plants greater than 2 m in height) present within a 4 m wide strip along each 400 ft

transect section. A circumference tape was used to measure the diameters of the holes at 1.3 m above the ground level, and the scores were noted for a series of diameter classes (see below).

ii. Vertical foliage distribution - twenty point samples were taken along each transect sections at 6 m intervals. A calibrated pole was held vertically at each point and presence/absence of vegetation was scored for a series of height classes (see below), based on whether foliage touched the pole within the interval. Tree-layers were rated as present when an extension of the pole would have passed through the canopy of a tree (heights measured with a "Topcon" distance-measuring unit).

Suspected multicollinearity of the variables within the trunk and foliage stratification classes was confirmed by generation of correlation matrices for the data from 40 transect sections. The problems resulting from entering multicollinear variables in a multiple regression can be avoided by using only one of the variables of each highly intercorrelated set, or, as I have done, by replacing them with composite variable (Nie et al., 1975; Austin, 1971). The PA2 factoring method of SPSS (Nie et al., op cit.) was applied to produce principal components that accounted for most of the total variance. This procedure was used on the data from the first 40 transect sections measured, and produced 6 trunk diameter principal components from the original 21 and 7 foliage stratification classes from 19. Intercorrelated classes in the original data tended to be of consecutive sizes and thus the principal components provided a basis for devising new consecutive size classes that accounted for most of the original variability (see similar procedure by Wilson, 1974). Trunk and foliage scores were obtained for these new classes over the remaining transect lines and calculated by conversion of the scores for the original 40 sections.

2.3.4 Correlations between avian distribution and vegetation structure.

The composite classes were used as the independent variable in the regression analysis of bird distribution against variance in structural characteristics of the vegetation.

All bird species with more than 9 sightings were included in the regression analysis for each census, and combined sightings for the research period were also analysed. The SPSS multiple regression analysis that was used was a forward (step-wise) procedure that entered the independent variables into the equation in the order of greatest to smallest contribution to explained variance. Only variables that added a significant contribution (at $\alpha = 0.05$) were entered (Hull and Nie, 1981).

2.4 Foraging Characteristics

Observations on foraging birds were systematically recorded during censuses where this did not hinder the counting procedure. Further observations were obtained by traversing the site such that all habitats and bird populations were sampled. Each attempt to take a food item such as a peck at a leaf surface or probe into a flower, was classed as one feeding observation. No

more than five observations at a time were recorded per bird, so that any tendency for individuals to feed successfully on the same food items did not greatly bias the samples. Foraging stratum, plant species used, and the site from which food was obtained (foraging station) were recorded.

2.4.1 Utilisation of vegetation strata.

The vegetation was readily divisible into ground, herb, shrub, sub-canopy and tree canopy layers, for the purposes of recording foraging heights. The herb layer was defined as comprising plants with little or no development of woody, upright stems. The shrub layer consisted of plants with woody, upright stems but no definite trunks. Species such as Banksia grandis, Casuarina fraseriana and eucalypt saplings that formed a layer below that of the mature eucalypt canopy were termed the sub-canopy. Aerial and bark-foraging records were included in the strata classes in which they occurred.

2.4.2 Utilisation of plant species

The frequencies at which the birds foraged in the various plant species of the Serpentine study area were recorded in order to determine whether particular species appeared to be of importance in their ecologies. Frequency of usage was compared with the relative frequencies of the species in the vegetation, as estimated by the nectar transect data (see Chapter 2.1.4). Usage of plant species by birds in the rehabilitation vegetation at Scenic Drive was also recorded.

2.4.3 Foraging stations.

Most workers who have studied the feeding habits of arboreal birds have devised novel classifications of feeding sites which reflect characteristics of the vegetation under study (e.g., Gibb, 1954; Snow, 1954; Keast, 1968; Ford & Paton, 1976b). The following classes of foraging stations, based on Snow (1954) were used in this study:

a) Ground

b) Bark

- i. Trunk - the main vertical, supporting structure of a tree, greater than 20 cm diameter;
- ii. Limb - major appendage of a trunk, greater than approximately 10 cm diameter, and including 'trunks' of less than 20 cm diameter;
- iii. Branch - woody structure of 3-10 cm diameter;
- iv. Twig - structure of less than 3 cm diameter.

c) Foliage

- i. Glean;
- ii. Hover - bird airborne, prey on substrate;

- iii. Snatch - active snatching of prey amongst the foliage.
- d) Aerial (hawk) - bird and prey airborne.
- e) Nectar and fruit.

2.5 Diet

The food items taken by birds should obviously be known if a full assessment of their ecological requirements is to be made. At the outset of the research, it was hoped to use emetics to gather samples of food from stomachs of mist-netted birds and to use "neck chokers" to gather items brought to nestlings (Wykes, 1982). However, I found it very difficult to efficiently capture the sparse birds in the jarrah forest, except along the creeks. Furthermore, "neck chokers" were not effective on the small passerines such as Western Thornbills and Wrens because the chicks fled the nest if disturbed at an age when they were strong enough to support the rings of pipe-cleaner. Consequently, the dietary assessments rely purely on field observations, which are comprehensive for nectarivores and frugivores but less satisfactory for small insectivores.

2.6 Nesting characteristics

Information on the breeding habits of the birds was gathered to determine the relationship between food abundances and breeding seasons, and whether availability of nesting resources may have limited densities or distributions of any species either in the jarrah forest or in the rehabilitation vegetation. However, nesting by many species was not well documented because of low densities, and assessment of breeding habits is supplemented by Curry and Nichols (1985).

2.7 Scenic Drive rehabilitation pit

A short strip-transect was used to compare densities of birds in the Scenic Drive rehabilitation pit and the neighbouring jarrah forest remnants. It consisted of two parallel lines running south-east from a hill top to a broad valley, with a total length of 2 km, divided into forty 50 m long sections. Shorter sections than at Serpentine were chosen because habitat frequently altered along the transect. The strip width was 40 m, and the total area covered by the strip was 8.0 ha. The one transect was covered three times for each bi-monthly census over one year period. Counts were conducted during mornings of fine weather.

Great variability in vegetation composition and small sample sizes prevented as detailed an analysis of avian distribution at Scenic Drive as at Serpentine. Transect-sections were classed as either rehabilitation pit, healthy jarrah forest, or severely disturbed jarrah forest. Analysis of variance and ranking of the means was used to compare the densities of the avian species in these habitat types for each census for the research period. Feeding observations were collected in the same way as at Serpentine, both in the rehabilitation pit and the neighbouring jarrah forest.

2.8 Presentation of results

Food availability results are presented in Chapter 3. The general results of the avian density and distribution analysis are presented in Chapter 4 while all results on the ecologies of individual species are presented in Chapter 5.

CHAPTER 3. AVAILABILITY OF FOOD TO THE JARRAH FOREST AVIFAUNA

3.1. Sweep-net sampling of arthropods

The sweep-net samples were collected in 20 units along a transect of the study area during each visit (Chapter 2). Kruskal-Wallis A.O.V. was used to compare overall arthropod catches at the 20 sites over the research period. The result for species richness (number of species per site) was $\chi^2 = 46.8$ ($\chi^2_{0.05,19} = 30.1$, $p < 0.001$), with site 20 having significantly lower catches than elsewhere. Similarly for abundance (no. individuals per site), $\chi^2 = 49.6$ ($\chi^2_{0.05,19} = 30.1$, $p < 0.001$), with site 20 having significantly lower catches. For the biomass index (area of arthropods, estimated as lengths x widths of all individuals), $\chi^2 = 30.10$ ($\chi^2_{0.05, 9} = 30.14$, $p < 0.05$). Thus, similar quantities of arthropods were captured at all sites except site 20 (in the mature forest of wet, western slopes - floristic association 8, Chapter 4.2), and major differences in food availability to birds between habitat types were not found. This analysis supports the use of the site values as replicates for further analysis of catch compositions and phenology.

Table 1 shows the comparative contributions made by the various arthropod taxa to the sweep-net catches for each visit. There were highly significant differences in contributions made by the taxa to all samples. Spiders and flies predominated in most of the samples from all seasons, with flies significantly more abundant than spiders for many spring samples. Bugs (Hemiptera) were the next most common taxon, as measured by both species richness and the biomass index, and were particularly prominent in summer samples. Other highly ranked taxa were beetles, ants, grasshoppers (particularly in summer), and larvae (particularly in winter and spring).

Changes over time in sweep-net catches for total arthropods and the more abundant taxa are shown in Figure 3. Statistical analyses of seasonality are given in Table 2. These show that there was a clearly defined pattern of spring-summer peaks and winter minima in both diversity and biomass of total arthropods sampled by sweep-netting. The fluctuation was very marked, with median biomass ('area' of arthropods per 50 sweeps) varying from under 50 to over 350. Patterns shown by particular taxa included spring-summer peaks for Coleoptera and Lepidoptera, summer peaks for Hemiptera and Orthoptera, and spring peaks for Diptera. All of these taxa had winter minima. The larvae were most common in some spring visits and least in autumn, and ants were also only prominent in some spring visits. Araneida were relatively non-seasonal.

In general, the results indicate a marked poverty in shrub-layer food availability for insectivorous birds in winter. The highest carrying capacity (and likely time for breeding) in the jarrah forest was either spring or summer, depending on the particular arthropod taxa favoured as food.

3.2. Sticky-trap sampling of arthropods

Sticky-trap samples were collected from 10 traps erected along a transect for three days during each site visit. Kruskal-Wallis

Table 1. Compositions of the sweep-net catches

Kruskal-Wallis analysis of variance by ranks was used to determine whether the taxa that comprised the sweep-net catches differed significantly in their relative contributions to the population parameters of species richness (Sp. R.) and biomass (Biom.) for the research period. Results for the analysis of abundance (no. individuals) data differed little to those of biomass (total length x widths of individuals - Chapter 2) and are not presented.

Taxa present in less than half of the site-visits, which were pooled as 'other', were Class Insecta : Orders Odonata, Mecoptera, Isoptera, Thysanoptera, Phasmatodea, Dermaptera, Mantodea, Blattodea, Ephemeroptera, Plecoptera, psyllids and their lerps (Hemiptera), all eggs; Class Arachnida, O. Acarina.

All Kruskal-Wallis H-values (approximated by χ^2 tables - Zar, 1974) were significant at $p < 0.001$ (xxx). The relative importances of the taxa were determined by non-parametric, multiple-range testing. The results are presented as homogenous subsets of arthropod groups whose highest and lowest rankings did not differ by more than the shortest significant ranges for subsets of that size ($\alpha = 0.05$)(smallest to largest - left to right).

Key to arthropod taxa: 1 - Araneida, 2 - Diptera, 3 - Coleoptera, 4 - Hemiptera, 5 - ants, 6 - wasps, 7 - Orthoptera, 8 - Lepidoptera, 9 - Neuroptera, 10 - larvae (Lepidoptera, Coleoptera, Hymenoptera and Diptera), 11 - 'other'.

Visit	Parameter	² x	Sign.	Comparisons of medians							
1. Nov. 1980 Spring	Sp. R.	77.0	xxx	7	<u>6,10,11,9,8</u>	<u>4,5,3,1</u>				2	
	Biom.			7	<u>11, 6,10,8</u>	9 4,5 3	1	2			
2. Nov. Spring	Sp. R.	60.1	xxx		<u>9,7, 6, 8 10,11, 4,5,1 3</u>					2	
	Biom.			7	<u>9, 6, 8</u>	11 10, 5,4,3,1				2	
3. Jan. 1981 Summer	Sp. R.	79.3	xxx		<u>6,9</u>	5 <u>11,10, 3</u> 8 7 1 2 4					
	Biom.				<u>6,9</u>	11, 5,10, 8, 7 3 2 1, 4					
4. Jan. Summer	Sp. R.	97.6	xxx		<u>9,6</u>	11, 8 5 10 3 7 1 2, 4					
	Biom.				<u>9,6,11</u>	8 5 10 7 3 1 2 4					
5. Feb. Summer	Sp. R.	83.8	xxx	9	<u>3, 5, 8, 10,11</u>	6 7 1 2, 4					
	Biom.			9	<u>3,11,10, 8, 5, 6, 7</u>	2 4 1					
6. Mar. Autumn	Sp. R.	47.4	xxx	9	<u>11,10, 3, 8, 6, 5</u>	<u>7,1</u> 4 2					
	Biom.			9	<u>10,11</u> 3, 8, 6, 7,5	<u>4,1</u> 2					
7. May Autumn	Sp. R.	79.8	xxx		<u>9,8</u>	<u>11,7</u> <u>6, 3,10, 5</u> 4 2 1					
	Biom.				<u>9,8</u>	<u>11,7</u> 10, 6, 3, 5 4 2 1					
8. Jun. Winter	Sp. R.	79.0	xxx		<u>9,8</u>	<u>5,11, 3, 7, 10, 6, 4, 2</u>				1	
	Biom.				<u>9,8</u>	<u>5,3,7,11,10,6,4</u> 2 1					
9. Jul. Winter	Sp. R.	101.1	xxx	9 8	<u>6,11,3</u> 7 5, 4 10 2 1						
	Biom.				<u>9,8</u>	<u>6,11, 3,7</u> 10,4,5 2 1					
10. Aug. Winter	Sp. R.	80.1	xxx	9	<u>11,6, 8, 7</u> 4 3 10 5 1 2						
	Biom.				<u>9,11,6,7,8,3,5,10,4</u>	1 2					
11. Sep. Spring	Sp. R.	136.5	xxx	9 11	<u>6,8</u> 7 5,3 10 4 1 2						
	Biom.				<u>9,11</u> <u>6,7,8</u> 5,3,10 4 2 1						
12. Sep. Spring	Sp. R.	142.2	xxx	9	<u>11,6,8,7</u> 5 10,4,3 1 2						
	Biom.				<u>9,11,8,6,7</u> 5 10,3,4 1,2						
13. Nov. Spring	Sp. R.	78.0	xxx	9 6 11	<u>7,10,8</u> 5 <u>3,4</u> 1,2						
	Biom.			9	<u>11,6,7</u> 10 8 5 3 4,2 1						

Visit	Parameter	² x	Sign.	Comparisons of medians									
14. Nov. Spring	Sp. R.	99.2	xxx	<u>9,6</u>	<u>11,7</u>	<u>8</u>	<u>5</u>	<u>3</u>	<u>4,10,1</u>	<u>2</u>			
	Biom.			<u>9,6</u>	<u>11,7</u>	<u>5,8,10,3</u>	<u>4</u>		<u>1,2</u>				
15. Jan. 1982 Summer	Sp. R.	100.0	xxx	9	<u>8,6</u>	<u>10,5,3,11,7</u>			<u>1</u>	<u>2,4</u>			
	Biom.			9	8	<u>6,7,10,5,11</u>	<u>3</u>	1	<u>4,2</u>				
16. Jan. Summer	Sp. R.	109.3	xxx	9	6	8	<u>10,11</u>	<u>3,5</u>	<u>2,1,7</u>	<u>4</u>			
	Biom.			9	6	<u>8,11,5</u>	<u>10</u>	<u>3</u>	<u>7</u>	<u>2</u>	<u>1</u>	<u>4</u>	
17. Mar. Autumn	Sp. R.	99.7	xxx	9	10	<u>3</u>	<u>8</u>	<u>11</u>	<u>5</u>	<u>6,4,7</u>	<u>1,2</u>		
	Biom.			9	10	<u>3,8,11</u>	<u>7,5</u>		<u>6,4</u>	<u>2</u>	<u>1</u>		
18. Apr. Autumn	Sp. R.	80.0	xxx	9	<u>11,10,8,3</u>		<u>6</u>		<u>4,5</u>	<u>7</u>	<u>2</u>	<u>1</u>	
	Biom.			9	<u>11,10,3,8</u>	<u>7,6,5</u>			<u>4</u>	<u>2</u>	<u>1</u>		
19. Jun. Winter	Sp. R.	84.8	xxx	9	8	<u>11</u>	<u>6</u>	<u>3</u>	<u>7,5,4,10,2</u>	<u>1</u>			
	Biom.			<u>9,8</u>	<u>11,6</u>	<u>3</u>	<u>7</u>	<u>5,10</u>	<u>4</u>	<u>2</u>	<u>1</u>		
20. Jun. Winter	Sp. R.	92.1	xxx	9	8	<u>11,5,3,6,7</u>			<u>4,10,2</u>	<u>1</u>			
	Biom.			<u>9,8</u>	<u>5,11,7,3,6</u>	<u>10,4</u>	<u>2</u>				<u>1</u>		

Figure 3 Seasonal changes in arthropod abundances - Sweep-net sampling

Changes in species richness and 'biomass-index' over the research period are shown for total arthropods and the three dominant taxa in the sweep-net catches (Table 1). The median and 95% confidence interval are given for each series of twenty, 25-sweep samples collected along a transect each site-visit.

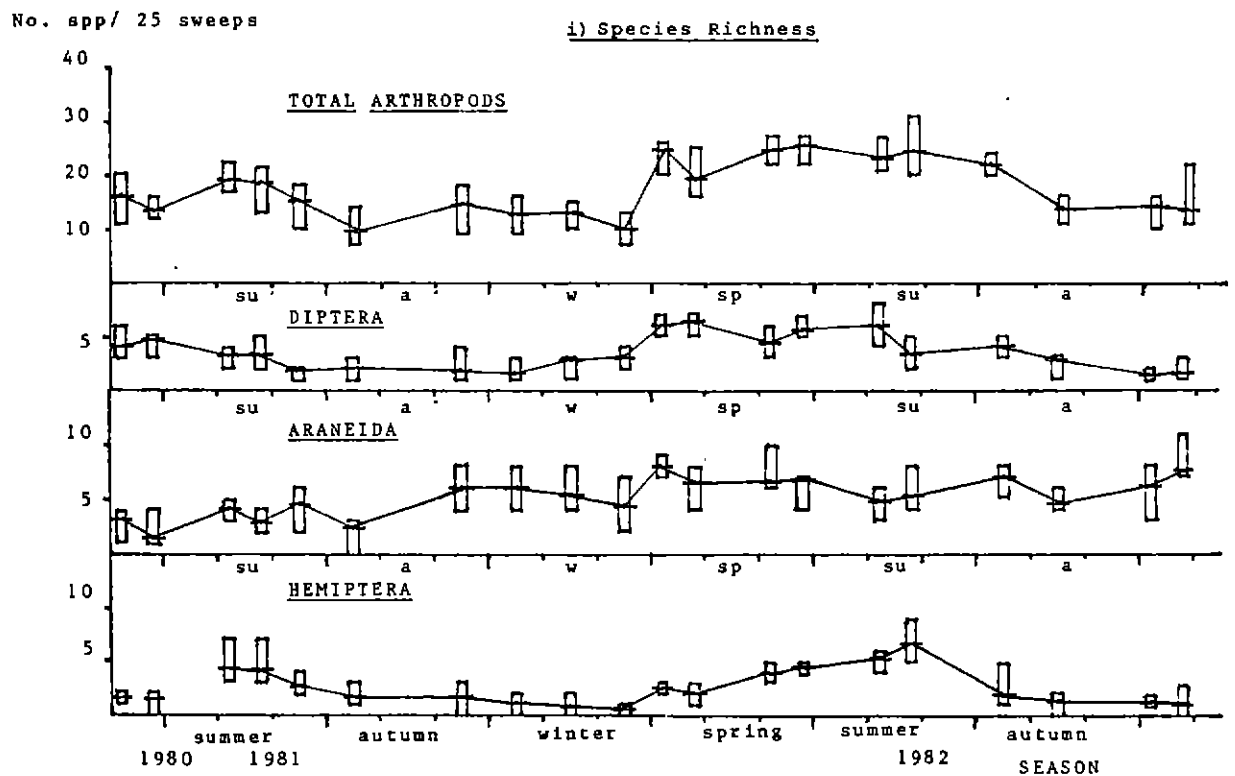


Table 2. Seasonality in sweep-net catches

Kruskal-Wallis A.O.V. was used to test for variance in arthropod availabilities (species richness and the biomass index) over time for the major taxa and total arthropods. Multiple-range testing was then performed to compare values for the visits, summarized as seasons, with smallest to largest presented from left to right. xxx = $p < 0.001$.

Taxon	Parameter	² x	Sign.	Comparison of visit medians
Total	Sp. R.	173	xxx	A W W,W,W,A,Sp,A,Su W Sp Su Sp,Su A Sp,Su,Su,Sp.
	Biom.	243	xxx	W W W,W,W A A,A Sp Su Sp,A Sp Su Su,Sp,Sp,Sp,Su,Su
Diptera	Sp. R.	154	xxx	W W W,Su,A,W,A A W,Su,Su,Su A,Sp,Sp,Sp Sp,Su Sp Sp
	Biom.	246	xxx	W W,W W A,W A A Su A Su,Su Sp Sp Sp,Sp,Su Sp,Sp
Araneida	Sp. R.	118	xxx	A,Sp Su Sp Su Su W,Su,A Su,W,W,Sp,A,Sp,A,Sp Sp,W
	Biom.	89	xxx	A W,Sp,W,A,A,W,Su,Sp,Su W Su Su A Sp,Sp,Su,Sp Sp
Hemiptera	Sp. R.	201	xxx	W W,W,W,Sp,A,Sp,A,A Sp A Su,Sp Sp Su,Su,Sp Su Su
	Biom.	226	xxx	W W W,W,W A,A,Sp,A,Sp,Sp A Sp Su,Sp Sp Su Su,Su,Su
Coleoptera	Sp. R.	120	xxx	A,W,A,W,W,W,W,Su,A,A Sp,Sp,Sp,Su,Su,Su,Su,Sp Sp Sp
	Biom.	110	xxx	W,A,A,W,W,A,Su,W,W,A Sp,Sp,Su,Su,Su,Sp,Su Sp,Sp Sp.
Ants	Sp. R.	59	xxx	all other visits Sp
	Biom.	65	xxx	W,W all other visits Sp Sp
Orthoptera	Sp. R.	84	xxx	Sp,Sp,W,A,Sp,W,W,Sp W,Sp,A,Sp,A,Su Su,Su Su A Su
	Biom.	93	xxx	Sp,W,A,Sp,Sp,W,W,W,Sp Sp A,Sp A Su,Su,Su
Larvae	Sp. R.	68	xxx	A A A W,Sp,A,W,Su,Su,W,W,Sp,Su,Su,Sp,Su,W,Sp Sp Sp
	Biom.	74	xxx	A,A,A W,Sp,W,A,Sp,Su,W,W,Su,W,Su,Su,Su,Sp,Sp Sp Sp
Lepidoptera	Sp. R.	131	xxx	Sp,Sp,W,A,Sp,W,W,Sp W,Sp,A,Sp,A,Su,Su,Su Su A Su
	Biom.	139	xxx	W,W,W,W,A W,Sp A Sp,Sp,A,Su,Su Su Su,A,Sp Su Sp Sp

A.O.V. was used to compare the catches on the traps for the research period. $\chi^2 = 21.9$ ($\chi^2_{0.05, 9} = 16.9$, $p < 0.01$) for species richness. Trap 8, which was placed in Floristic Association 1 in disturbed habitat (Chapter 4.2), had significantly higher catches than the other traps. $\chi^2 = 20.1$ ($\chi^2_{0.05, 9} = 16.9$, $p < 0.05$) for the biomass index. All traps had similar values except for trap 1 (Floristic Association 2) which had significantly smaller catches than the others. As for sweep-netting, there was thus found to be high similarity between sampling sites, and these were used as the replicates in analysis of compositions and phenology.

Table 3 shows the comparative contributions made by arthropod taxa to the sticky-trap catches. There was highly significant variance in the compositions for all visits, as measured by both species richness and the biomass index. Diptera dominated the catches, particularly in winter and spring. Other prominent contributors were Hemiptera (spring, summer visits), wasps and Coleoptera.

Changes in sticky-trap catches over time are shown in Figure 4 and analysed in Table 4. Seasonality was less distinct for the sticky-trap than for the sweep-net species-richness values. The statistical analysis of biomass indices also indicated indistinct seasonality, but this was because the spring-summer peaks were quite sharp (Figure 4). Thus, only some of the spring and summer values for total arthropods and many of the taxa were significantly greater than those from other seasons. The two winter samples were lowest for many taxa. I conclude from these results that insectivorous birds reliant on active arthropods of the tree-canopy have a highly seasonal resource, abundant for a relatively short period in spring or summer. Not surprisingly, such species were generally the migrants (Chapter 5).

3.3. Litter invertebrates

Insectivores that forage in the ground-layer of a forest are likely to prey on different types of arthropods that have differing phenologies to those of the shrub or tree-layers. This fauna was not sampled during the present study, but Carati (1981) did so in similar habitat on the northern side of Jarrahdale, 5 km from my study area, as part of a study on Antechinus flavipes during 1980-81. He found that energy content of diurnal invertebrate fauna of litter (suction-sampling) was low, while larger, active invertebrates of debris (pit-fall sampling) gave high total energy values. The small, litter decomposers were most abundant when soil was warm and moist in spring samples (maximum mean of 3,000 J per sample unit), while abundances were extremely low under hot, dry summer conditions (minimum mean of 200 J per sample unit).

In contrast, the larger, vagile predators caught in pit-fall traps, appeared able to avoid the hot, dry summer extremes. They were most abundant in the humid summer conditions, with a maximum mean of 14,000 J per pit-sample, compared with relatively even values in other seasons, with a minimum mean of 2,000 J in early spring. Comparison with other studies showed these conclusions to be generally true of south-western forest invertebrate communities of litter and debris (Carati, 1981).

Table 3. Compositions of the sticky-trap catches

Kruskal-Wallis analysis of variance by ranks was used to determine whether the taxa that comprised the sticky-trap catches differed significantly in their contributions to species richness (Sp. R.) and biomass (Biom.) for the research period. Taxa present in less than half of the site-visits, which were pooled as 'other', were Class Insecta: Orders Lepidoptera, Mecoptera, Isoptera, Blattodea, Psocoptera, Embioptera, larvae (various orders); Class Arachnida, O. Acarina; Class Collembola.

The relative importances of taxa were determined by non-parametric, multiple-range testing, where the A.O.V. was significant at $\alpha = 0.05$. The results are presented as for Table 2.

Key to taxa:

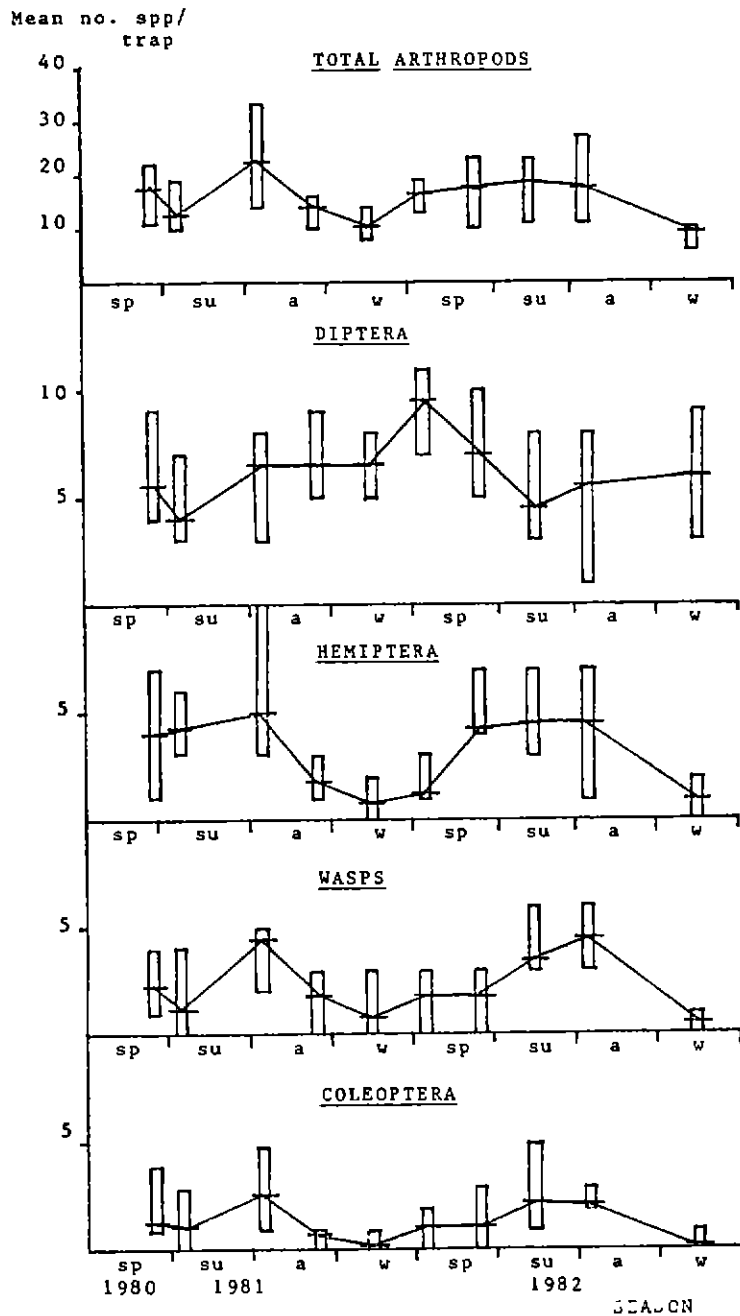
1 - Araneida, 2 - Diptera, 3 - Coleoptera, 4 - Hemiptera, 5 - ants, 6 - wasps, 7 - Neuroptera, 8 - other.

Visit	Parameter	² x	Sign.	Comparisons of medians						
1. Nov. 1980 Spring	Sp. R.	48.5	xxx	<u>5,8,1</u>	7	3	6	4	2	
	Biom.	44.2	xxx	<u>5,8,1</u>	<u>7,6,4,3</u>			2		
2. Dec. Summer	Sp. R.	43.4	xxx	<u>8,5,7,1,3,6</u>			<u>4,2</u>			
	Biom.	34.4	xxx	<u>5,8,1,7,6</u>		3	4	2		
3. Mar. 1981 Autumn	Sp. R.	53.8	xxx	7	5	<u>1,8</u>	3	6	<u>4,2</u>	
	Biom.	35.7	xxx	7	<u>5,1</u>		<u>6,2,3,4,8</u>			
4. May Autumn	Sp. R.	47.8	xxx	7	<u>5,8,3,1,6,4</u>			2		
	Biom.	40.9	xxx	7	<u>8,5,6,1,4,3</u>			2		
5. Jul. Winter	Sp. R.	46.4	xxx	<u>all other taxa</u>						2
	Biom.	40.2	xxx	<u>7,5</u>	<u>8,3,6,1,4</u>			2		
6. Sep. Spring	Sp. R.	49.9	xxx	7	5	<u>8,3,4,6,1</u>			2	
	Biom.	52.3	xxx	<u>7,5</u>	8	<u>4,6,1,3</u>			2	
7. Nov. Spring	Sp. R.	43.9	xxx	<u>8,5,7,1,6,3</u>			4	2		
	Biom.	30.8	xxx	<u>8,5,7,1,6</u>			3	4	2	
8. Jan. 1982 Summer	Sp. R.	62.2	xxx	<u>8,7,5</u>	1	3	<u>6,4,2</u>			
	Biom.	59.2	xxx	<u>8,7,5</u>	1	<u>6,2,3,4</u>				
9. Mar. Autumn	Sp. R.	55.0	xxx	<u>7,5,8</u>	1	3	<u>4,2,6</u>			
	Biom.	47.0	xxx	<u>7,8,5</u>	1	<u>3,2</u>		<u>4,6</u>		
10. Jul. Winter	Sp. R.	47.2	xxx	<u>all other taxa</u>						2
	Biom.	35.5	xxx	<u>all other taxa</u>						2

Figure 4 Seasonal changes in arthropod abundances - Sticky-trap sampling

Changes in species richness and 'biomass index' over the research period are shown for total arthropods and the four dominant taxa in the Sticky-trap samples. The median and 95% confidence interval are given for the samples taken from 10 traps erected for three days of each site-visit.

i) Species Richness



ii) Biomass-index

Mean mm²/
trap

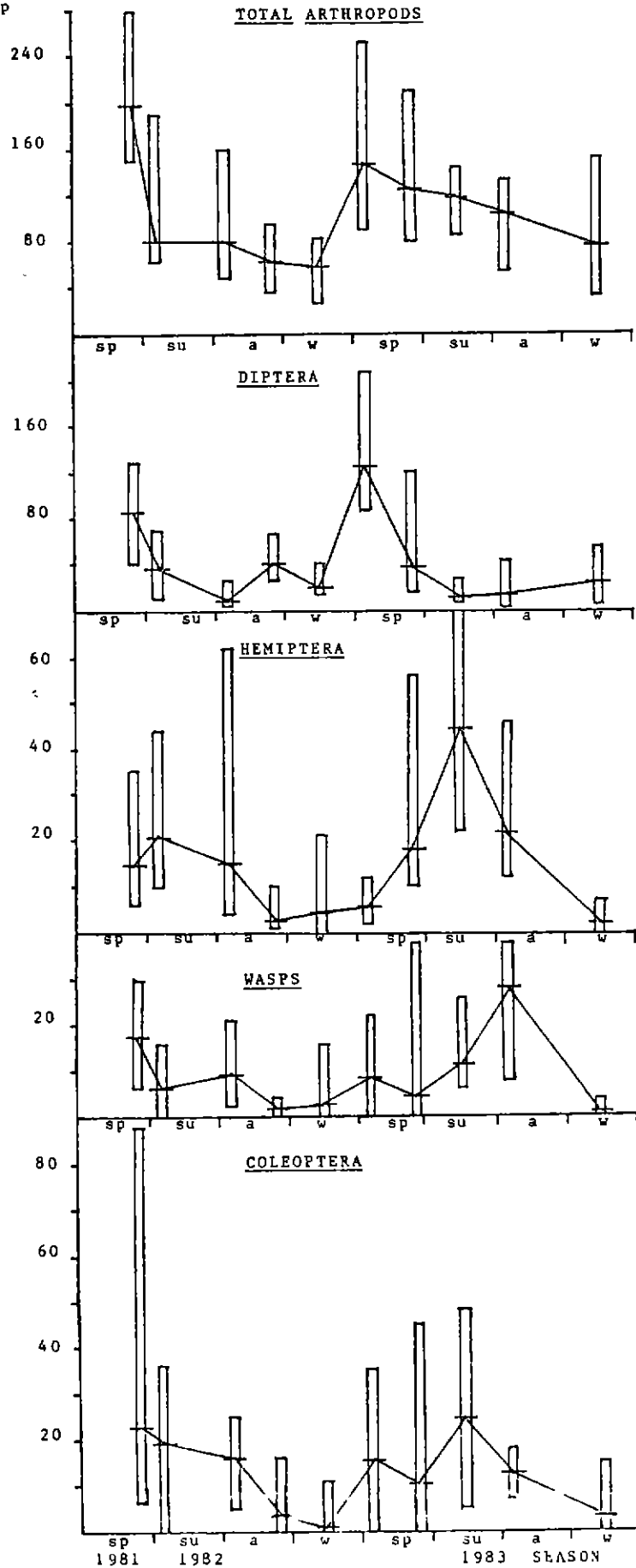


Table 4. Seasonality in sticky-trap catches

Results of Kruskal-Wallis A.O.V. testing of arthropod availabilities (species richness and biomass index) over time for the major taxa and total arthropods in the sticky-trap catches. Multiple-range testing was used to compare values for visits, summarised as seasons, with smallest to largest presented from left to right.

Taxon	Parameter	² X	Sign.	Comparison of visit medians
Total	Sp. R.	34.9	xxx	W W A, Su, Sp, Sp, A, Sp, Su A
	Biom.	37.5	xxx	W A W, A, A, Su, Su Sp Sp Sp
Diptera	Sp. R.	23.7	xxx	all other visits Sp
	Biom.	53.9	xxx	A, Su, A W W, Su, Sp, A Sp Sp
Hemiptera	Sp. R.	48.9	xxx	W, W Sp, A Sp, Su, A, Sp, Su, A
	Biom.			W A, W, Sp Sp, A, Sp, Su, A Su
Araneida	Sp. R.	13.8	N.S.	
	Biom.	13.7	N.S.	
Coleoptera	Sp. R.	41.5	xxx	W, W A Su, Sp, Sp, Sp Su, A, A
	Biom.	24.0	xx	W, W A, A, Su, A, Sp, Sp Sp Su
Ants	Sp. R.	13.4	N.S.	
	Biom.	14.4	N.S.	
Wasps	Sp. R.	44.3	xxx	W, W, Su, Sp, Sp, A, Sp, A, Su, A
	Biom.	33.6	xxx	W, A W, Su, Sp, Sp, A Sp, Su A
Neuroptera	Sp. R.	50.3	xxx	all other visits Sp
	Biom.	49.9	xxx	all other visits Sp
Other	Sp. R.	28.8	xxx	all other visits A
	Biom.	37.5	xxx	W A W, A, A, Su, Su Sp Sp Sp

3.4. Nectar availability

Figure 5 shows the densities of flowering ornithophilous plants in the study area over the research period, while the distributions of these species along the transect are shown in Figure 6.

The two eucalypt species did not flower profusely or for any length of time during the research period. Jarrah (*E. marginata*) was the densest tree species in the study area, with reduced densities primarily in areas of disturbance (Figure 6). It flowered in spring or summer, with a maximum in January 1982 (7.2 plants/ha), when 140 of 410 trees intercepted by the transect were in flower. Marri (*E. calophylla*) was half as abundant as jarrah, with a tendency to increase inversely in density to jarrah (Figure 6). It flowered in early autumn, and was also most prolific in 1982 (5.8 flowering plants/ha), when 86 of the 165 intercepted plants were in bloom.

Adenanthos barbiger, a prostrate shrub, was the most abundant ornithophilous species, with a mean density of 38.8 plants/ha. It was widely distributed, being present in all but stream vegetation (Figure 6), and flowers were present throughout the year (Figure 5). Flowering densities were greatest in winter and spring, with up to 20 flowering plants/ha. However, numbers of flowers per plant were generally low, the perianth is long and narrow, and nectar quantities are low (\bar{x} calories per flower = 13.8, Newland and Wykes, 1981). Thus, only the small Western Spinebill, using specialized foraging behaviour and bill morphology, utilizes this resource in the jarrah forest (Newland and Wykes, *op. cit.*; Chapter 5).

Grevillea wilsonii was another low, shrub species of much lesser importance in the study area than *A. barbiger*. It was limited in distribution (Figure 6) and flowering season (spring), although relatively fecund (Figure 5). Newland and Wykes (1981) found it to produce a mean of 24 calories per flower in jarrah forest east of Perth. Its flowering season was more prolonged at this site.

Banksia grandis was highly seasonal in flowering (Figure 5) but was widely and densely distributed in non-riparian vegetation (mean of 22.5 plants/ha - Figure 6). There were up to 13.5 flowering plants/ha during spring visits. These had means of only around 2.5 flowering cones per plant, but each cone is a large, profuse nectar source. Newland and Wykes (1981) recorded a mean of 9,200 calories standing crop per cone, with each producing nectar over many days.

Dryandra sessilis was a patchily distributed nectar source, confined to some disturbed vegetation of slopes (Figure 6). Densities of up to 3.7 of the 3.8 plants/ha flowered in the autumn to early spring period, with relatively high numbers of flowers per plant - maximum mean of 10.3 for a spring visit. Nectar production per flower-head is also relatively high - mean of 90 calories (Newland and Wykes, 1981).

Kangaroo Paws, *Anigosanthos manglesii*, were also present in the study area, but flowers were so sparsely distributed in the

spring flowering period that no further data were obtained.

To summarize:

A. barbigera provided a widely distributed year-round nectar resource that was only attractive to honeyeaters that can probe the long, tubular perianths of the sparse, low-nectar producing, flowers. B. grandis provided an abundant, widespread nectar source for any honeyeater able to switch from other resources or other regions to exploit it during the short, spring flowering period; and D. sessilis was patchily distributed but flowered abundantly in the wet season when seasonal nectarivores might be present. Neither of the co-dominant eucalypts flowered abundantly during the research period, but flowering did occur in the summer and autumn when other nectar sources were scarce.

Figure 5. Nectar availability

Estimates of nectar availability from plant species utilised by nectarivores are shown for the research period. Counts were made of flowering plants that intercepted a line-transect taken through sections 1-40 of the avian estimates transect (Figure 2). These counts were converted to absolute densities (flowering plants/ha) using counts of total flowering and non-flowering plants along the line-transects and in a 4M-wide strip-transect (see Figure 9). However, eucalypt densities were calculated using counts of trunks in forty 10 x 10 M quadrats taken along the transect by B. Glossop (pers. comm.).

The mean numbers of flowers per flowering plant are noted below the graphs for the shrub species, while ratios of poor:medium:rich blossom (defined in methods, Chapter 2.1) are given for the two eucalypt species.

Flowering plants/ha

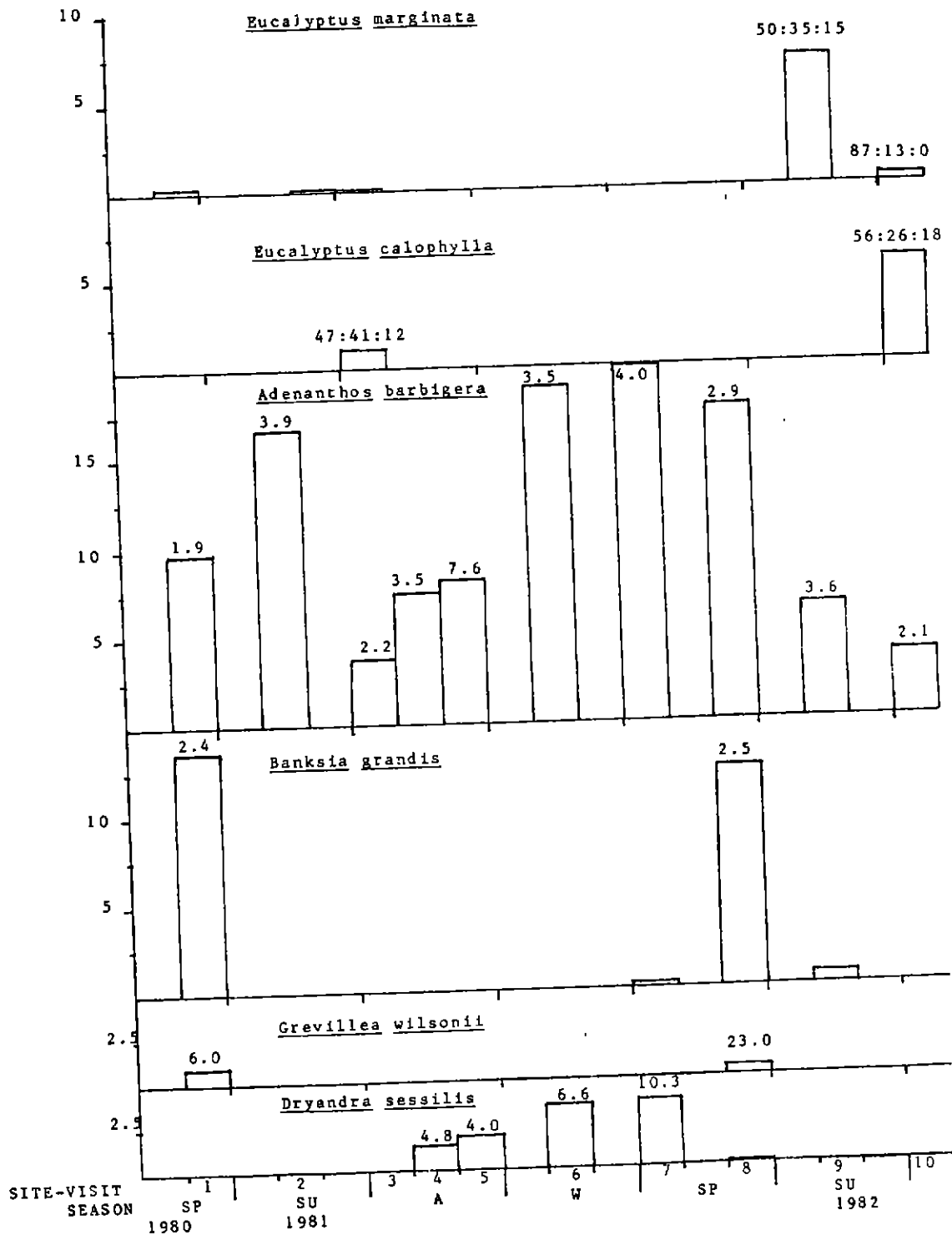
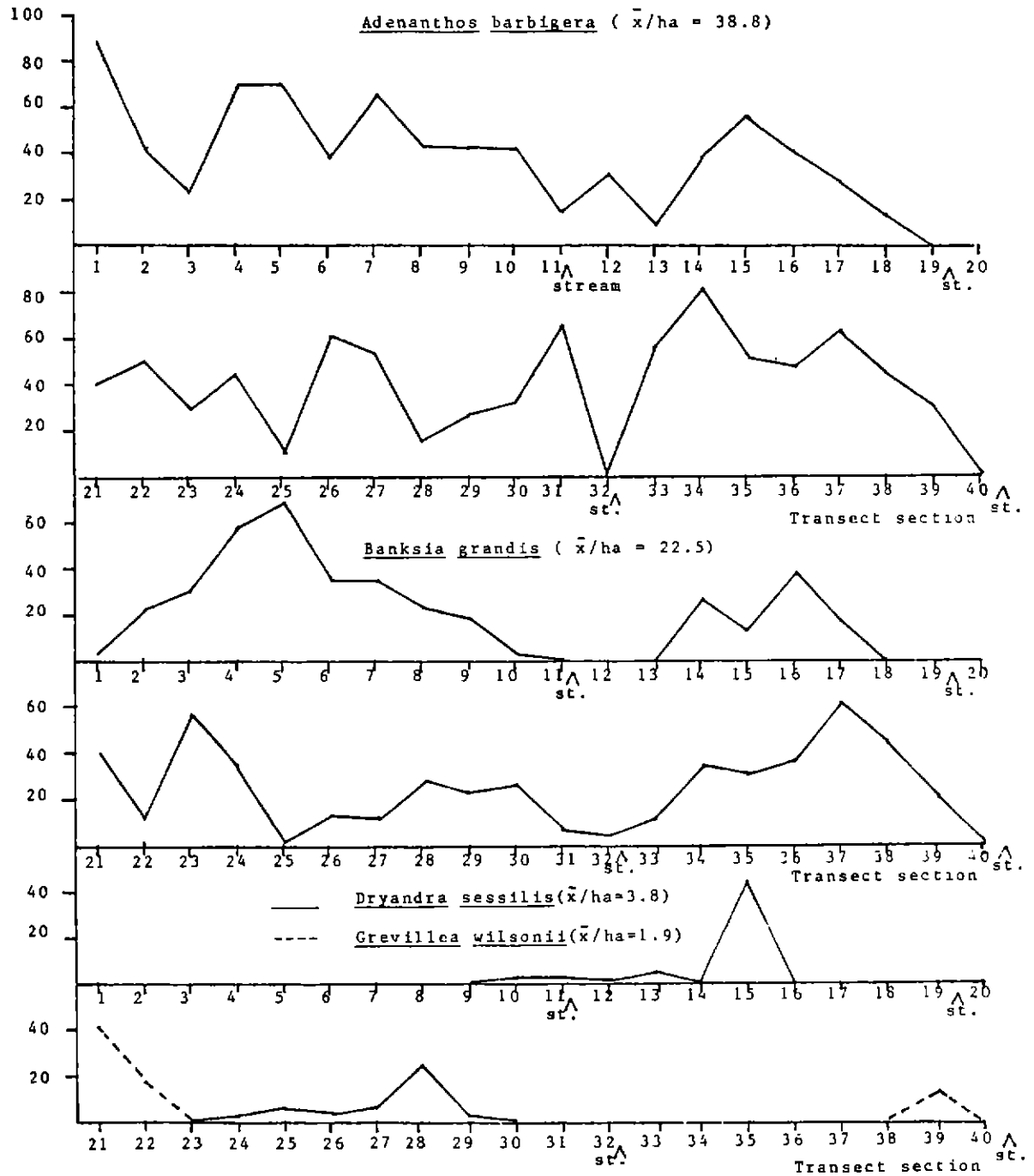


Figure 6. Distributions of ornithophilous plants

Distributions of ornithophilous plant species along sections 1-40 of the avian-estimates transect (Figure 2) are indicated. The total numbers of eucalypts intercepted by a line-transect are given for each 121 M (400 ft) section, while the shrub densities per ha were derived from counts in a 4M-wide strip ($4 \times 121 \text{ M} = 484 \text{ m}^2$). Overall means/ha are also noted for the shrub-species. Means/transect section and means/ha, derived from $10 \times 10 \text{ M}$ counts in quadrats taken in each section (B. Glossop pers. comm.), are given for the eucalypts.

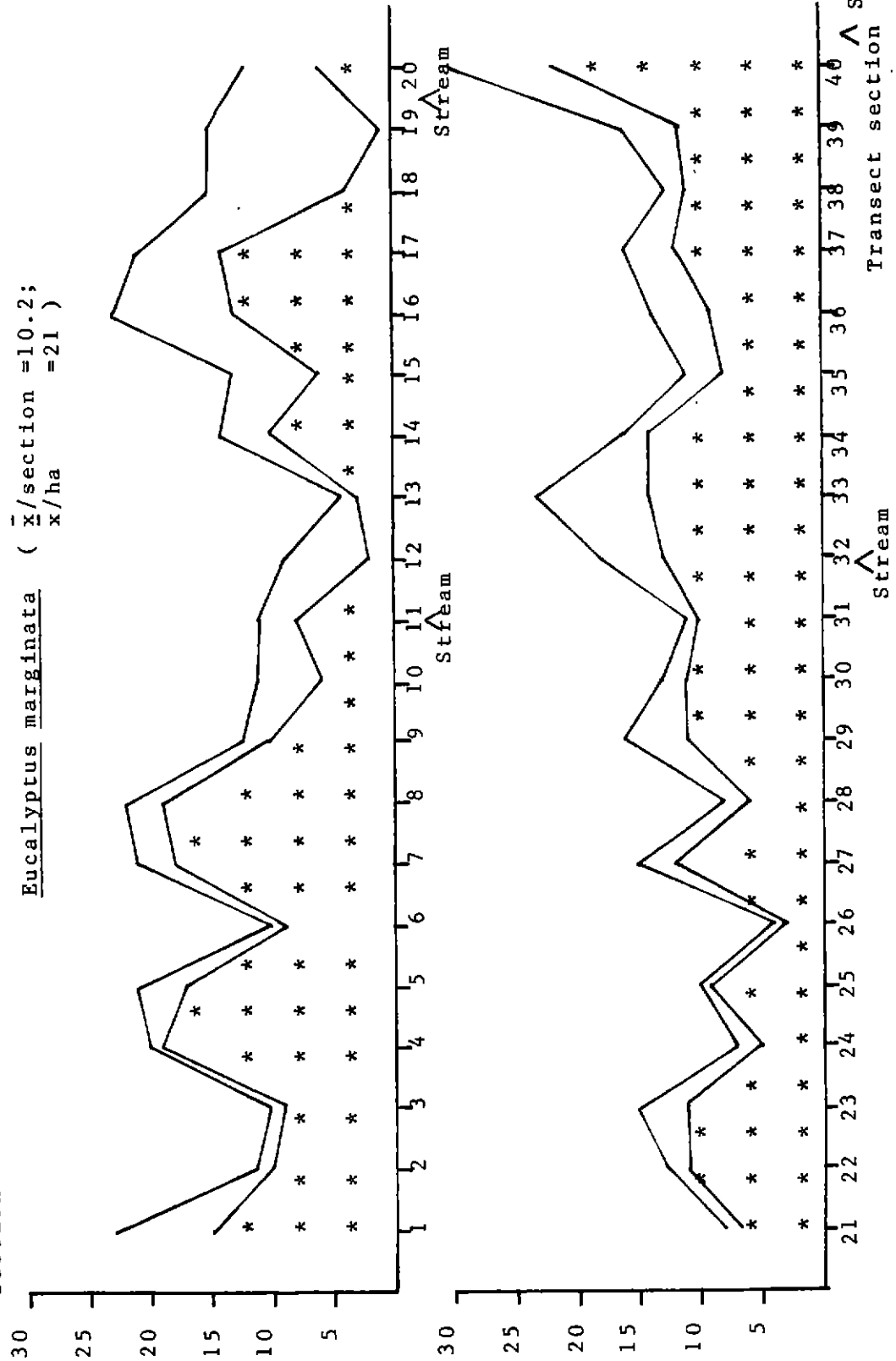
Topography is indicated by noting which transect-sections were close to streams.

Plants/ha



Trees per transect
section

Eucalyptus calophylla (\bar{x} /section =4.1;
x/ha =11)
Eucalyptus marginata (\bar{x} /section =10.2;
x/ha =21)



CHAPTER 4. General characteristics of the avian community

4.1 Avian community composition and densities in the jarrah forest.

The average density of birds in the jarrah forest was 52.2 per 10 ha (Table 5). This is remarkably low when it is considered that there would be only 0.5 birds in the area of one suburban building block. An average of 27 species per census contributed to this density, with a total of 42 species recorded in the 53 ha strip-transect over the two-year research period. The most numerous of these were the Broad-tailed Thornbill (5.2 birds/10 ha), which is a small insectivore of trees and shrubs; the Western Spinebill (6.0 birds/10 ha), a small nectarivore; and the Western Thornbill (4.6 birds/10 ha) and Splendid Wren (3.5 birds/10 ha), two small shrub and ground-foraging insectivores (Tables 5 and 6).

Twenty-four of the 34 species in Table 5 (71%) were primarily insectivores; nectarivores were few in species but relatively dense; while there was a variety of seed-eating parrots, all of relatively low densities. Comparisons with bird communities of forests elsewhere in Australia will be drawn in the discussion, but initial impressions from Table 5 indicate that:

- i. ground-foraging species were poorly represented, with only two large, diurnal insectivores, the Grey Currawong and Raven, and one graminivore, the Painted Quail;
- ii. the bark-foraging guild was depauperate in species and density;
- iii. and nectarivory, which is one of the most prominent guilds in many Australian avifaunas, was poorly represented.

Avian density fluctuated from a maximum of 66 to as low as 38 birds/10 ha, with an apparent pattern of spring/summer peaks and winter lows. This was a similar pattern to that shown by mean daily temperatures and inverse to that of monthly rainfall variation (Figure 7). However, more than the two years data would be needed to reveal the full picture. Species Richness very clearly exhibited spring/summer maxima of around 30 species and minima of around 23 in autumn/winter (Figure 3). These patterns resulted from many species breeding in the jarrah forest whilst partially or totally migrating to winter elsewhere.

Correlation co-efficients were calculated to compare changes in community density and species richness with changes in food-supply and climate over the research period. The variables used were sweep-net and sticky-trap species richness and biomass estimates, nectar estimates for *A. adenanthos*, *B. grandis* and *D. sessilis*, and mean monthly maximum temperatures and monthly rainfalls for the research period. None were significant correlates of total bird density while sweep-net biomass (66% variance explained), sticky-trap biomass (66%) and sweep-net species richness (44%) were correlates of avian species richness. These results suggest that, at least in terms of species present, migrants in the avian community responded directly to changes in food supply rather than to changes in climatic variables.

Table 5. Composition of the jarrah forest avifauna

The species recorded within the 53 ha strip-transect during the research period are grouped into the guilds in which most of their foraging occurred (Chapter 5). Mean densities are given for each species, derived from ten censuses over the two-year research period. Species that were recorded in only one visit and had mean densities of less than 1.0 birds/10 ha were pooled as 'other'. These were the Wedge-tailed Eagle Aquila audax, Common Bronzewing Phaps chalcoptera, Fantailed Cuckoo Cuculus pyrrhophanus, Sacred Kingfisher Halcyon sancta, Black-faced Cuckoo-shrike Coracina novaehollandiae and Rufous Whistler Pachycephala rufiventris.

Guild	Species	Bird densities/10ha (standard deviations)
<u>Insectivore</u>		
a) Ground foraging	Australian Raven, <u>Corvus coronoides</u>	0.1
	Grey Currawong, <u>Strepera versicolor</u>	0.3
	Scarlet Robin, <u>Petroica multicolor</u>	0.7(0.4)
	Western Yellow Robin, <u>Eopsaltria griseogularis</u>	1.8(1.0)
	White-breasted Robin, <u>Eopsaltria georgiana</u>	0.1
	Splendid Wren, <u>Malurus splendens</u>	3.5(1.3)
	White-browed Scrub-wren, <u>Sericornis frontalis</u>	0.3
	Tawny Frogmouth, <u>Podargus strigoides</u>	0.2
	Boobook Owl, <u>Ninox novaeseelandiae</u>	0.3
		7.3
b) Shrub foraging	Western Thornbill, <u>Acanthiza inornata</u>	4.6(2.1)
	Red-winged Fairy Wren, <u>Malurus elegans</u>	1.8(1.)
	Silvereye, <u>Zosterops lateralis gouldi</u>	1.5(1.6)
		7.9
c) Tree foraging	Broad-tailed Thornbill, <u>Acanthiza apicalis</u>	5.2(1.5)
	Golden Whistler, <u>Pachycephala pectoralis</u>	2.3(1.0)
	Western Shrike-thrush, <u>Colluricincla harmonica</u>	0.7(0.5)
	Striated Pardalote, <u>Pardalotus striatus</u>	5.7(4.9)
	Spotted Pardalote, <u>Pardalotus punctatus</u>	1.2(1.2)
	White-naped Honeyeater, <u>Melithreptus lunatus</u>	1.8(1.1)
	Shining Bronze-cuckoo, <u>Corysocolocyx lucidis</u>	0.2
		17.1
d) Bark foraging	Rufous Tree-creeper, <u>Climacteris rufa</u>	1.0(0.5)
	Varied Sittella, <u>Daphoenositta chrysoptera</u>	0.9(1.0)
		1.9
e) Air foraging	Tree Martin, <u>Cecropis nigricans</u>	0.7(0.7)
	Grey Fantail, <u>Rhipidura fuliginosa</u>	2.6(0.9)
	Dusky Woodswallow, <u>Artamus cyanopterus</u>	0.1
	Western Warbler, <u>Gerygone fusca</u>	1.7(1.6)
		5.1
<u>Carnivore</u>		
	Little Eagle, <u>Hieraaetus morphnoides</u>	0.1
	Sparrow-hawk/Goshawk, <u>Accipiter</u> sp.	0.1
	Laughing Kookaburra, <u>Dacelo gigas</u>	0.2
<u>Nectarivore</u>		
	Western Spinebill, <u>Acanthorhynchus superciliosus</u>	6.0(2.7)
	New Holland Honeyeater, <u>Phylidonyris novaehollandiae</u>	1.8(0.6)
	Brown Honeyeater, <u>Lichmera indistincta</u>	0.3
	Little Wattlebird, <u>Antrozous chrysoptera</u>	0.1
		8.2
<u>Grammivore</u>		
	Painted Quail, <u>Turnix varia</u>	0.3
	Western Rosella, <u>Platycercus icterotis</u>	0.3
	Red-tailed Black Cockatoo, <u>Calyptorhynchus magnificus</u>	0.7(0.7)
	Red-capped Parrot, <u>Purpureicephalus spurius</u>	1.8(1.1)
	Port Lincoln Parrot, <u>Barnardius zonarius</u>	1.2(0.5)
		4.3
<u>Others</u>		
	6 species	0.2
TOTAL ($\bar{x} \pm SD$)		52.4 \pm 10.3
\bar{x} species/visit (43 species overall)		27 \pm 4.0

Table 6. Statistical comparison of the avian densities

Kruskal-Wallis analysis of variance (Zar, 1974) was used to test for variance between the densities of the avian species along the strip-transects, using the 10 visits as replicates. Only species of mean ≥ 1.0 birds over the 53ha transect for the research period were included.

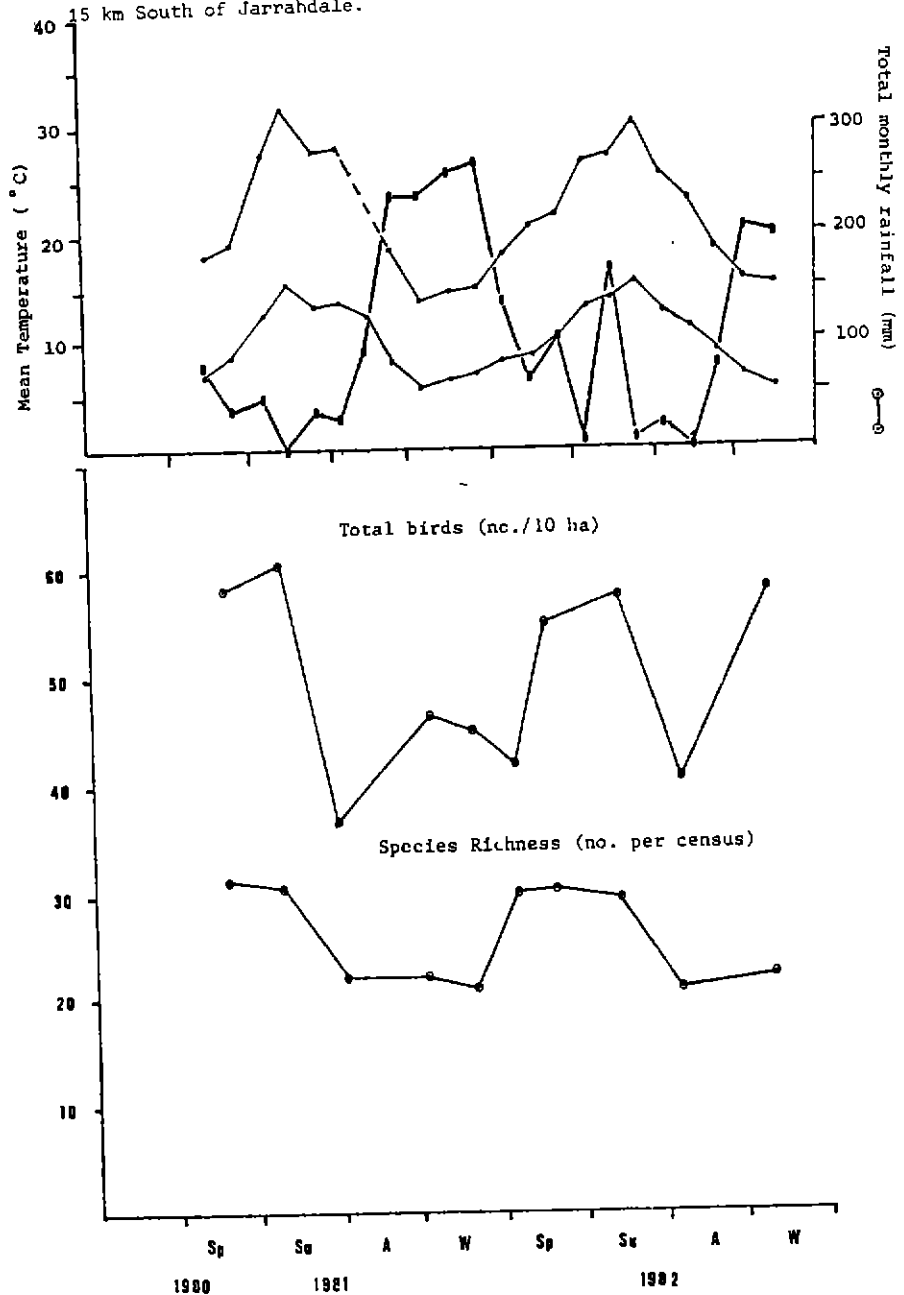
AOV ($\alpha = 0.05$): $H = 154.9$, $\chi^2_{0.05,26} = 38.9$, $P < 0.001$.

The relative importance of particular species was determined by non-parametric, multiple-range testing using the sum ranks of visit by visit densities for each species. The results of the multiple-range testing are presented as homogeneous subsets of visits whose highest and lowest rankings do not differ by more than the shortest significant range for a subset of that size ($\alpha = 0.05$).

Species	Rank
Broad-tailed Thornbill	
Western Spinebill	
Western Thornbill	
Spendid Wren	
Grey Fantail	
Straited Pardalote	
Golden Whistler	
Western Yellow Robin	
New Holland Honeyeater	
Red-capped Parrot	
White-naped Honeyeater	
Red-winged Wren	
Western Warbler	
Port Lincoln Parrot	
Western Silvereye	
Rufous Treecreeper	
Spotted Pardalote	
Scarlet Robin	
Varied Sittella	
Western Shrike-thrush	
Red-tailed Cockatoo	
Tree Martin	
White-browed Scrub-wren	
Tree Martin	
Painted Quail	
Grey Currawong	
Brown Honeyeater	
Western Rosella	

Figure 7. Phenology of the overall avian community

Changes in density and species richness over the research period are presented for the total avian community. Density = number of birds per 10ha, where a total of 53ha was covered for each census. Species richness refers to the total number of species recorded within the strip-transect during each census. Mean monthly maximum and minimum temperature and total monthly rainfall are shown for Karnet, approx. 15 km South of Jarrahdale.



Correlations between changes in density of particular species and these environmental variables are discussed in Chapter 5.

4.2 Habitat utilisation by the Jarrah forest avifauna

4.2.1 Floristic description of the vegetation

The computer print-out of the floristic analysis for the study area is summarised in Table 7. The quadrats that formed each floristic association were grouped horizontally and the definitive plant species-groups vertically. Nine floristic associations were formed by the 120 quadrats, utilising 84 of the 180 species recorded in the quadrats. Plants of Group 1 were found throughout the study area except in the riparian associations 8 and 9; plants of Group 2 were also seldom found near the water-courses but were absent from floristic association 1 - quadrats with very low plant-species diversity; plants of Groups 3 to 10 were confined to one or only a few floristic associations.

Figure 8 presents the distributions of the associations in the study area, and illustrates relationships with topography. Additional information about the floristic associations was obtained by recording the degree of logging and die-back that had affected the vegetation of the quadrats in each association. The following classes were used (following Glossup of Alcoa):

Logging

- Class 1. recent logging; stumps with bark.
- 2. logging some time ago; stumps mildly charred, no bark.
- 3. logging long ago; stumps charred without bark.
- 4. no stumps; probably uncut forest.

Dieback

- Class 1. severe mortality (recent or old) in overstorey.
- 2. severe mortality in understorey; occasional in overstorey.
- 3. some in understorey, occasional in overstorey.
- 4. some in understorey; overstorey healthy.
- 5. no evidence of dieback.

Vegetation descriptions of each Floristic Association

Association 1 (6 quadrats)

- Logging 1 (17%) Class 2 (some time ago)
5 (83%) Class 3 (long ago)
- Dieback 1 (17%) Class 5 (no evidence)

2 (33%) Class 4 (some understorey)

2 (33%) Class 3 (some under-, occasional overstorey)

1 (17%) Class 1 (severe overstorey).

Description: varied aspects (western and eastern slopes, ridges) on the main eastern ridge of the study area where dieback, some clearing of timber with many access tracks, and gravel pitting had resulted in a sparse tree-layer and bare ground coverage except where the low trymalium and taller Dryandra sessilis had colonized.

Floristic composition: extremely depauperate. Group 1 species, which were found throughout the study area, were present, including E. marginata and E. calophylla, Adenanthos barbigera and Conostylis setosa. However, very few plants of any other groups were represented in these quadrats. An exception was Trymalium ledifolium of Group 4, which is also known as a coloniser of open ground in bauxite pits. The original, healthy vegetation on these sites was likely to have been of various floristic types in the scheme devised by Havel (1975b).

Association 2 (16 quadrats)

Logging 1 (6%) Class 2 (some time ago)

15 (94%) Class 3 (long ago)

Dieback 11 (69%) Class 5 (no evidence)

2 (12%) Class 4 (some understorey)

3 (19%) Class 3 (some understorey, occasional overstorey).

Description: Located on shallow eastern slopes of the main N-S ridge and the ridge itself. Tree-layer of jarrah and some marri, sub-canopy of banksia and some casuarina, and a dense shrub-layer dominated by lasiopetalum. Some gaps in tree-layer with associated large, fallen trunks.

Floristic composition: Low species diversity, with only plants of Groups 1 and 2 consistently present. Many of those in Group 2 were found in all of the other upland associations, are known as colonizers of bauxite pits and are fire adapted (Fox et al, 1981). e.g. Platysace, Opercularia and Hibbertia amplexicaulis.

Association 2 is probably Type 5 in Havel's (1975b) classification. This occurs on heavy laterite gravel with a loamy, sandy matrix. Out-crops of laterite ironstone are common and the main bauxite deposits are associated with this vegetation (Havel, op. cit.). In fact, of the 24 quadrats in the present study that were located over the major bauxite deposits identified by Alcoa (Nichols et al, 1981), 10 of these (42%) supported Floristic Association 2 vegetation. Most others (38%) were of FA6.

Table 7. Two-way table of floristic associations and plant-species groups.

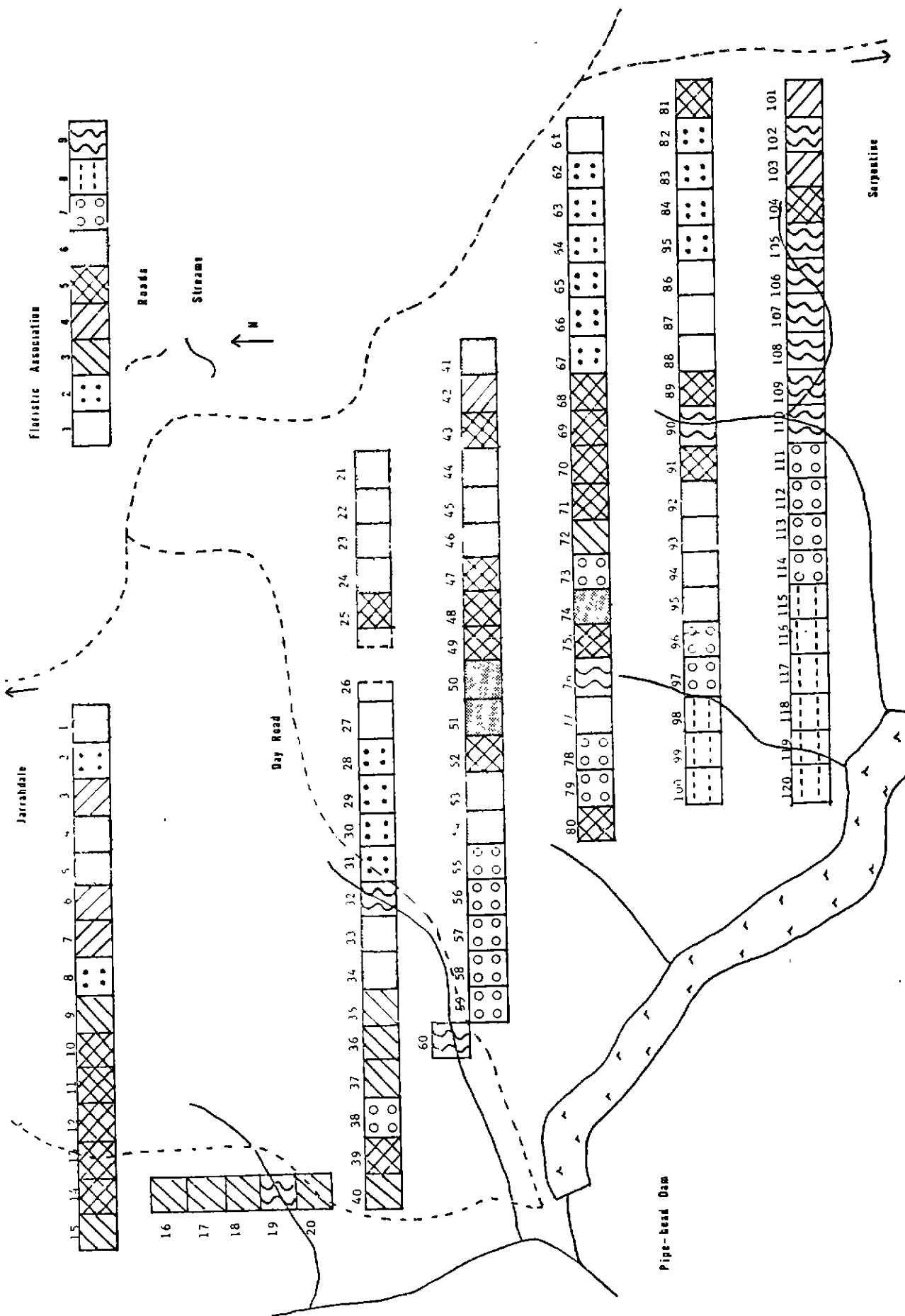
The percentages of quadrats in which each plant species occurred are shown for each floristic association, and the plant species are grouped vertically to best display similarities and differences between the floristic associations. Plant species that were not grouped are not presented. The number of quadrats in each floristic association are given.

An asterisk is placed next to plant species that were found to be the "most abundant and most frequent" species in rehabilitated bauxite pits in the Darling Ranges by Fox et al (1982).

Note that "Lomandra Sp.1" (plant group 3) probably included more than one species, and "Hypochoeris Sp.1" (plant group 2) included Lagenifera stipitata (B. Glossop, pers. comm.).

Association		1	2	3	4	5	6	7	8	9
No. of quadrats		6	16	11	6	22	23	15	9	12
Gp.	Plant Species	0-100	0-100	0-100	0-100	0-100	0-100	0-100	0-100	0-100
1	<i>DRACAENA MARGINATA</i> <i>ANTHURUS PAVONIA</i> * <i>SYLVESTRIUM HIRSIDUM</i> <i>LYALYTUS CALOPHYLLA</i> * <i>LEUCOSTYLIS SETOSA</i> <i>ANTHURUS TENUIFOLIA</i>									
2	* <i>LEUCOSTYLIS COMPRESSA</i> * <i>DIAPHRAGMATA EDROGNEPHALA</i> * <i>HIBBERTIA AMPLENCABULIS</i> <i>MYRTOLETERIS SPI</i> <i>BRASSIA GRANDIS</i> <i>HIBBERTIA MONTANA</i> * <i>LEUCOSTYLIS FLORIBUNDUM</i> * <i>ANTHURUS PASTORIS</i>									
3	<i>ANTHURUS TENUIFOLIA</i> * <i>DIAPHRAGMATA ORNATA</i> <i>LEUCOSTYLIS COLLINA</i> <i>MYRTOLETERIS FLORA</i> <i>MYRTOLETERIS ALOPECUROIDES</i> <i>ANTHURUS SPI</i> * <i>ANTHURUS CANDIDA</i> <i>TRYSANTHUS MULTIFLORUS</i> <i>ANTHURUS PASTORIS</i> <i>ANTHURUS LAEVIS</i> <i>ANTHURUS 3</i> <i>SYLVESTRIUM CALCARATUM</i> <i>ANTHURUS PASTORIS</i>									
4	* <i>ANTHURUS TENUIFOLIA</i> <i>LEUCOSTYLIS AMBUSTATUM</i> <i>ANTHURUS NIVEA</i> <i>HIBBERTIA ACEROSA</i> <i>MYRTOLETERIS CINEREA</i> <i>LEUCOSTYLIS BOLOBA</i> <i>ANTHURUS RUEBELII</i> <i>ANTHURUS 3</i>									
5	* <i>ANTHURUS SPI</i> <i>ANTHURUS PASTORIS</i> <i>ANTHURUS XERANTHEMIFOLIOS</i> <i>ANTHURUS ALBICARPUS</i> <i>ANTHURUS HERMANNI</i> * <i>ANTHURUS CESTRINA</i> <i>ANTHURUS PASTORIS</i>									
6	<i>ANTHURUS STREPTO</i> <i>ANTHURUS LINEARIS</i> <i>ANTHURUS GRACILIS</i> <i>ANTHURUS SONDERI</i> <i>ANTHURUS AMBUSTATUM</i> <i>ANTHURUS TURBIDUS</i> <i>ANTHURUS AUREA</i> <i>ANTHURUS PASTORIS</i>									
7	<i>ANTHURUS TENUIFOLIA</i> <i>ANTHURUS GRACILIS</i> <i>ANTHURUS VIRENS</i> <i>ANTHURUS DUNHAMII</i> <i>ANTHURUS PASTORIS</i> <i>ANTHURUS PASTORIS</i>									
8	<i>ANTHURUS PASTORIS</i> <i>ANTHURUS PASTORIS</i> <i>ANTHURUS PASTORIS</i> <i>ANTHURUS PASTORIS</i> <i>ANTHURUS PASTORIS</i> <i>ANTHURUS PASTORIS</i>									
9	<i>ANTHURUS TENUIFOLIA</i> * <i>ANTHURUS TENUIFOLIA</i> <i>ANTHURUS</i> <i>ANTHURUS GLOCHIDIATUS</i> <i>ANTHURUS CONNOLATA</i> <i>ANTHURUS COLONUM</i> <i>ANTHURUS ASTH. ORTUM</i> <i>ANTHURUS PASTORIS</i> <i>ANTHURUS PASTORIS</i> <i>ANTHURUS PASTORIS</i>									
10	<i>ANTHURUS PASTORIS</i> <i>ANTHURUS PASTORIS</i> <i>ANTHURUS PASTORIS</i> <i>ANTHURUS PASTORIS</i> <i>ANTHURUS PASTORIS</i> <i>ANTHURUS PASTORIS</i> <i>ANTHURUS PASTORIS</i> <i>ANTHURUS PASTORIS</i> <i>ANTHURUS PASTORIS</i> <i>ANTHURUS PASTORIS</i>									

Figure 8. Distributions of floristic associations in the study area.
An indication of quadrat distributions for each floristic association in the study area.



Association 3 (11 Quadrats)

Logging 11 (100%) Class 3 (long ago).

Dieback 11 (100%) Class 5 (no evidence).

Description. Western and south-western slopes, often steep, with tall, relatively dense tree cover. Lasiopetalum sparse in shrub-layer; tall sub-canopy of Banksia grandis.

Floristic composition. More diverse than FA2, with presence of Plant Group 3 - perennial jarrah forest shrubs and herbs such as Xanthorrhoea preissii, Bossiaea ornata, Stylidium calcartum and Tetrarrhena laevis. This is a mature, healthy vegetation type (logging long ago, no dieback) that did not readily fit into Havel's classification.

Association 4 (6 Quadrats)

Logging 6 (100%) Class 3 (long ago)

Dieback 5 (83%) Class 5 (no evidence)

1 (17%) Class 3 (some understorey, occasionally overstorey).

Description. Sparse vegetation lacking a tall shrub-layer but with a dense herb-layer of Loxocarya cineara and trymalium. Generally poor tree-layer with marri absent. These few sites were on lower ridges adjacent to creeks where the open nature of the vegetation may have been natural since there was little recent disturbance or dieback.

Floristic composition. Poor representation of plant groups 1-4 such as marri, Hibbertia montana, Lasiopetalum and X. preissi. Frequent occurrence of Group 4 plants, including Trymalium ledifolium, Dryandra nivea, Hibbertia acerosa, Loxocarya cinearea and Billardiera. This composition fits Havel's Type R - vegetation on valley slopes and ridge crests transitional between granite out-crops and laterite-mantled slopes. The soils for this type are lateritic gravels with a loamy to clayey matrix.

Association 5 (22 Quadrats)

Logging 15 (68%) Class 3 (long ago)

4 (18%) Class 2 (some time ago)

3 (14%) Class 1 (recent)

Dieback 9 (41%) Class 5 (no evidence)

3 (14%) Class 4 (some understorey)

7 (32%) Class 3 (some understorey, occasional overstorey)

1 (5%) Class 2 (severe understorey, occasional overstorey)

2 (9%) Class 1 (severe mortality).

Description. Dry, open forest of shallow slopes adjacent to the main ridges. High species diversity but some disturbance from recent logging and varying degrees of dieback.

Floristic composition. Diverse shrub-layer with species of Plant groups 1 to 4, as well as open areas of disturbance colonized by Group 5 species - ephemerals such as Graphalium sp.1, Levenhookia, Isotoma, Gompholobium and Waitzia, which were unique to F.A.5. B. grandis was very sparse, possibly due to dieback attack, although X. preissii, another sensitive species, was not uncommon. Lasiopetalum was poorly represented.

This F.A. was possibly of disturbed Type P vegetation in Havel's system. Type P occupies gentle slopes within the laterite-mantled uplands, on colluvial soils of sandy gravels.

Association 6 (23 Quadrats)

Logging 2 (9%) Class 4 (uncut)

21 (91%) Class 3 (long ago)

Dieback 18 (78%) Class 5 (no evidence)

2 (9%) Class 4 (some understorey)

3 (13%) Class 3 (some understorey, occasional overstorey).

Description. Healthy jarrah forest of the eastern and western slopes of the ridges, including areas burnt two years earlier (controlled spring burns), and others burnt about seven years ago. A dense, tall tree-layer, and a shrub-layer rich in species, with little bare ground.

Floristic composition. Good representation of Plant groups 1-4, absence of Group 5 ephemerals, unique presence of Group 6 perennials such as Dampiera linearis, Xanthorrhoea gracilis and Stylidium amoenum. None of Group 6 were frequent colonizers of bauxite pits (Fox et al, 1981; Table 7). Jarrah was the principal tree; B. grandis was regularly present as a sub-canopy; Lasiopetalum and Xanthorrhoea preissii were seldom present in the shrub-layer.

This vegetation was equivalent to Havel's Type P, which he characterizes by an absence of species such as Macrozamia of my Plant group 8, and which occurs on gentle lower slopes within the laterite-mantled uplands.

Nine of the 24 quadrats (38%) which occurred on rich bauxite deposits in the study area supported FA6 vegetation (with most other sites being of FA2 vegetation).

Association 7 (15 Quadrats)

Logging 15 (100%) Class 3 (long ago)

Dieback 14 (93%) Class 5 (no evidence)

1 (7%) Class 4 (some understorey).

Description. On moderate to steep, lower south-west and south-facing slopes, with tall, dense understorey and tall, healthy tree-canopy. Soil relatively rich and deep, with granite out-crops.

Floristic composition. Presence of Plant groups 1-3, absence of ridge species (Group 4), species of disturbed ridge habitat (Group 5), and upper slopes (Group 6). Characterized by presence of Plant group 7, including species such as Leucopogon verticillata, Acacia urophylla and Tetratheca viminea. Plant group 8 species, such as Leucopogon propinquus, Persoonia longifolia, Clematis pubescens, Pteridium and Macrozamia, were shared with FA 8. Most of these are shade-tolerant, perennial shrubs and creepers. Jarrah was the predominant tree, with some marri and occasional black-butt (E. patens).

This vegetation has the composition of that described by Christensen and Kimber (1975) as forest not burnt for more than 40 years. Under Havel's system, this F.A. has species of ridge Type S vegetation, as well as those of Type T on steeper slopes.

Association 8 (9 Quadrats)

Logging 3 (33%) Class 4 (none)

6 (66%) Class 3 (long ago)

Dieback 9 (100%) Class 5 (no evidence).

Description. South-facing slopes in valleys with rich, deep soil amongst granite out-crops. Dense, tall, often unlogged tree-layer, tall, dense shrub-layer and relatively open herb-layer.

Floristic composition. Poor occurrence of most jarrah forest species of the ridges and upper slopes (Plant groups 1-8) with the exceptions of a few species such as Xanthorrhoea preissii, Xanthosia candida, and, of course, E. marginata. Typified by shade-tolerant plants of Group 8 (shared with FA7), and the unique presence of Group 9 - primarily small, soft herbs, some introduced, that utilize the moist, dark conditions and rich earth beneath the dense shrub-layer of Pteridium, Macrozamia and Clematis. Wild pigs frequented this habitat and dug over large areas in search of roots.

FA 8 has a similar composition to Havel's Type T, although there are some discrepancies, such as a scarcity of Lasiopetalum in my sites.

Association 9 (12 Quadrats)

Logging 5 (42%) Class 4 (none)

7 (58%) Class 3 (long ago)

Dieback 11 (92%) Class 5 (no evidence)

- 1 (8%) Class 3 (some understorey, occasional overstorey).

Description. Vegetation of the narrow creeks which had year-round flow throughout the study period. The tree-layer was often very sparse along the creeks, with stags remaining. It is not clear whether logging long ago, the fire regime or other factors caused this.

Floristic composition. Poor occurrence of all plant groups except for Group 10, which included Agonis linearifolia, Acacia mooreana and Aotus cordifolia. These species formed a very dense, tall shrub-layer, with emergent Banksia littoralis, along the water-courses. A rich herb-layer of Pteridium and other species of FA's 7 and 8 bordered the dense creek vegetation. Jarrah, marri and some black-butt formed a relatively dense tree-layer at some sites whereas virtually no trees remained at others.

Havel terms this riparian habitat Type C, which occurs where the soil consists of sandy loam to sandy-clay topsoil, with a sandy-clay subsoil, and is permanently wet.

4.2.2 Structural description of the vegetation structure.

Multiple regression analysis was used to test for correlations between distributions of the avian populations and variance in densities of trunks and vegetation strata. Six size-classes of vegetation strata, and total cover, were entered as the independent variables in the regression.

Scores for each of the variables were graphed over the 120 transect-sections in which measurements were taken as an aid to interpreting correlations with avian distribution (available from the author by request). The relationships between these variables and topography of the study area can be briefly summarized as follows:

- | | |
|-----------------------|---|
| Total trunks | - low values in forest disturbed by logging and dieback, particularly areas of ridge, western slopes to the east of the study area and along creeks. High mainly near ridges where there was sapling regrowth amongst medium-aged forest. |
| Trunk 1 (0-15 cm d.) | - very low on disturbed slopes and also in some mature forest of western slopes where there was no regrowth. High values on ridges. Highly intercorrelated with "Total trunks". |
| Trunk 2 (15-30 cm d.) | - high on easterly ridges where <u>Banksia grandis</u> was common; low in disturbed areas, along creeks and in mature forest. |
| Trunk 3 (30-50 cm d.) | - generally low but high along some creeks and in mature forest of western slopes. |

- Trunk 4 (50-60 cm d.) - generally low, but high values on lower western slopes.
- Trunk 5 (60-85 cm d.) - high in healthy, relatively young forest of the major ridges. Low in mature forest, disturbed areas and along creeks.
- Trunk 6 (85 cm d.) - generally low; higher values on westerly slopes and along creeks, including some open, disturbed areas.
- Total vegetation cover- relatively even, but highest values along creeks and on western slopes where the tree-layer was poor. Highly intercorrelated with VC 2 and VC 3.
- Veg. layer 1 (0-20 cm)- generally high values, but low where bare due to disturbance, and beneath the dense, mature canopy of lower western slopes.
- Veg. layer 2 (20cm- 1.6 m) - high values along creeks and on wet, western slopes.
- Veg. layer 3 (1.6-3 m)- high values confined to some open western slopes colonized by Dryandra sessilis, and along some creek sections.
- Veg. layer 4 (3 - 5 m)- high along ridges and creeks; low in disturbed areas.
- Veg. layer 5 (5 - 15m)- high values along ridges in young, healthy forest; low in mature forest of lower western slopes and where disturbed.
- Veg. layer 6 (15-25 m)- low along creeks and in disturbed areas, high in mature forest.
- Veg. layer 7 (25 m+) - generally low, with high values on steep western slopes where old trees have escaped logging.

4.2.3 General relationships between avian distributions and vegetation characteristics

The results of one-way A.O.V. and S.N.K. rankings of the densities of bird species in the floristic associations are presented in Table 8.

The average number of birds/section did not significantly differ between FA's for many visits, but for the research period there were greater abundances along the water courses and in the adjacent vegetation (FA's 8 & 9) than elsewhere. Similarly, the number of species/transect section tended to be higher in FA 9. Significant correlations between species' distributions and floristic associations were disappointingly few in view of the relatively clear definition of floristic associations that

Table 3. Avian distributions amongst floristic associations.

Results are presented for one-way analyses of variance and Student-Newman-Keuls tests applied to abundances (no.birds/transect section) in the floristic associations for each bird species during each visit and pooled for the total research period. Combined abundances and species richness values for all species were also tested. Visits for which a species had means of less than 1/transect-section in all associations were not analysed. Records of bird out-side, as well as inside, the strip-transects were included in the analysis (see methods). S.N.K. tests were applied (and abundances/association presented) where the A.O.V. was significant at $\alpha = 0.05$.

Results of the S.N.K. tests are presented schematically with lines linking means between which significant differences were not found (Zar, 1974). For instance, the results for total species-richness over the research period was:

F.A. 1 5 6 2 7 4 3 8 9

This is interpreted as:

- i) The mean for F.A.9 was greater than for all others.
- ii) The mean for F.A.8 was greater than those for F.A.'s 7,2,6,5 and 1, but not significantly different to those for 3 and 4.
- iii) There were no significant differences between the mean values for F.A.'s 3,4,7,2,6,5 and 1.

The order of presentation of the species is as for Table 5.

Key: Significance of A.O.V. : N.S. = not significant at $P < 0.05$;

x, xx, xxx = $P < 0.05$, 0.01 and 0.001 respectively.

For each F value of the A.O.V.'s, DF = 8,111.

Total abundance (all species)

1. 28-31/10/80	Spring	2.6	x	N.S.															
2. 20/12/80 - 5/1/81	Summer	5.3	xxx	F.A.	6	1	2	5	7	3	4	3	9						
3. 20/2-13/3	Autumn	3.8	xxx	N.S.	1.7	1.7	1.8	1.8	2.0	3	3.2	6.4	9.0						
4. 4-17/6	Winter	0.7	N.S.																
5. 15/7-3/8	Winter	2.2	x	N.S.															
6. 10-14/9	Spring	1.0	N.S.																
7. 29/10-10/11	Spring	3.7	xxx	F.A.	1	5	4	3	6	2	7	3	9						
8. 13-27/1/82	Summer	1.0	N.S.	1.7	1.0	1.3	1.7	2.1	2.6	3.2	4.1	6.0							
9. 15-19/3	Autumn	4.6	xxx	F.A.	1	3	5	7	6	2	4	3	9						
10. 1/6-8/7	Winter	0.6	N.S.	1.2	1.4	1.4	1.8	1.4	1.5	1.5	5.3	6.0							
Total		13.2	xxx	F.A.	1	6	5	2	4	7	3	3	9						
				14.7	16.6	17.3	17.8	18.3	19.5	23.4	33.3	49.1							

Visit	Season	F	Signif.	SHK										
<u>Species Richness</u>														
1.	Spring	2.1	x	N.S.										
2.	Summer	3.9	xxx	F.A.	5	2	6	7	1	4	3	8	3	
				\bar{x}	1.0	1.0	1.0	1.1	1.3	1.8	1.9	2.9	3.7	
3.	Autumn	3.5	xx	F.A.	1	2	4	7	6	3	5	9	3	
				\bar{x}	0	.3	.3	.3	.4	.6	.7	1.8	2.4	
4.	Winter	0.9	N.S.											
5.	Winter	1.6	N.S.											
6.	Spring	0.7	N.S.											
7.	Spring	4.6	xxx	F.A.	1	5	4	3	6	7	2	8	9	
				\bar{x}	.5	.6	1.0	1.1	1.3	1.7	1.8	2.1	3.6	
8.	Summer	1.0	N.S.											
9.	Autumn	2.6	xx	N.S.										
10.	Winter	1.0	N.S.											
Total		10.2	xxx	F.A.	1	5	6	2	7	4	3	8	9	
				\bar{x}	8	10.1	10.2	10.3	11.1	14.2	14.2	18.8	24.9	
<u>Grey Currawong</u>														
Total		0.5	N.S.											
<u>Scarlet Robin</u>														
10.	Winter	1.2	N.S.											
Total		1.4	N.S.											
<u>Yellow Robin</u>														
4.	Winter	1.0	N.S.											
5.	Winter	0.4	N.S.											
7.	Spring	0.6	N.S.											
8.	Summer	0.5	N.S.											
9.	Autumn	1.6	N.S.											
10.	Winter	0.5	N.S.											
Total		1.7	N.S.											
<u>Splendid Wren</u>														
1.	Spring	2.6	x	N.S.										
2.	Summer	3.0	xx	N.S.										
3.	Autumn	1.6	N.S.											
5.	Winter	1.0	N.S.											
6.	Spring	3.6	xxx	F.A.	1	2	6	7	3	4	8	5	9	
				\bar{x}	0	0	0	0	.3	.3	.3	.4	1.3	
7.	Spring	4.8	xxx	F.A.	1	2	3	6	7	5	4	3	3	
				\bar{x}	0	0	0	0	0	.3	.3	1.1	1.2	
8.	Summer	1.3	N.S.											
9.	Autumn	2.6	x	N.S.										
10.	Winter	1.2	N.S.											
Total		15.9	xxx		1	2	6	7	3	5	4	8	9	
					0	0	.4	1.0	1.3	2.5	3.0	7.6	9.2	
<u>White-browed Scrub-wren</u>														
Total		1.5	N.S.											

Visit	Season	F	Signif.	SNK
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Western Thornbill

1.	Spring	1.8	N.S.
2.	Summer	0.9	N.S.
3.	Autumn	1.2	N.S.
4.	Winter	0.9	N.S.
5.	Winter	0.7	N.S.
6.	Spring	1.5	N.S.
7.	Spring	1.9	N.S.
8.	Summer	0.4	N.S.
10.	Winter	0.8	N.S.
Total		1.2	N.S.

Red-winged Wren

2.	Summer	2.3	x	N.S.
Total		2.0	N.S.	

Silvereye

2.	Summer	4.0	xxx	F.A.	1	3	6	5	2	7	4	8	3
				\bar{x}	0	0	.1	.1	.1	.1	.2	1.1	1.9
3.	Autumn	2.0	N.S.										
8.	Summer	1.2	N.S.										
Total		1.8	N.S.										

Broad-tailed Thornbill

1.	Spring	1.7	N.S.										
2.	Summer	2.9	xx	F.A.	1	7	6	9	4	5	2	3	9
				\bar{x}	0	.1	.1	.1	.2	.2	.3	.5	.9
3.	Autumn	1.0	N.S.										
4.	Winter	1.2	N.S.										
5.	Winter	0.7	N.S.										
6.	Spring	0.8	N.S.										
7.	Spring	0.7	N.S.										
8.	Summer	1.5	N.S.										
9.	Autumn	0.7	N.S.										
10.	Winter	0.7	N.S.										
Total		3.4	xx	F.A.	7	6	3	5	1	4	2	8	3
				\bar{x}	2.3	3.1	3.2	3.2	3.5	3.5	4.0	4.1	5.9

Golden Whistler

1.	Spring	1.3	N.S.
2.	Summer	1.0	N.S.
3.	Autumn	0.8	N.S.
4.	Winter	0.6	N.S.
5.	Winter	0.6	N.S.
6.	Spring	1.4	N.S.
7.	Spring	1.8	N.S.
8.	Summer	0.8	N.S.
9.	Autumn	1.2	N.S.
10.	Winter	1.2	N.S.
Total		2.7	N.S.

Western Shrike-thrush

1.	Spring	0.6	N.S.	
4.	Winter	0.9	N.S.	
6.	Spring	1.7	N.S.	
7.	Spring	0.5	N.S.	
8.	Summer	0.9	N.S.	
10.	Winter	1.4	N.S.	
Total		2.2	x	N.S.

Visit	Season	F	Signif.	SHK										
<u>Straited Pardalote</u>														
1.	Spring	0.6	N.S.											
2.	Summer	1.0	N.S.											
3.	Autumn	1.0	N.S.											
6.	Spring	0.9	N.S.											
7.	Spring	0.9	N.S.											
8.	Summer	0.7	N.S.											
9.	Autumn	0.9	N.S.											
10.	Winter	1.1	N.S.											
Total		0.7	N.S.											
<u>Spotted Pardalote</u>														
1.	Spring	2.9	xx	F.A.	5	2	6	3	1	7	9	4	3	
				\bar{x}	.1	.1	.1	.1	.2	.2	.5	.7	.8	
4.	Winter	2.7	x	N.S.										
5.	Winter	1.0	N.S.											
10.	Winter	2.6	x	N.S.										
Total		2.9	xx	F.A.	1	6	5	2	7	9	3	4	9	
				\bar{x}	.3	.6	.6	.9	1.0	1.1	1.2	1.3	2.2	
<u>White-naped Honeyeater</u>														
3.	Autumn	2.5	x	N.S.										
4.	Winter	0.8	N.S.											
5.	Winter	1.5	N.S.											
10.	Winter	1.2	N.S.											
Total		1.7	N.S.											
<u>Rufous Treecreeper</u>														
10.	Winter	0.7	N.S.											
Total		1.5	N.S.											
<u>Varied Sittella</u>														
Total		1.7	N.S.											
<u>Tree Martin</u>														
6.		0.6	N.S.											
7.		1.1	N.S.											
8.		1.0	N.S.											
Total		2.0	N.S.											
<u>Grey Fantail</u>														
1.	Spring	3.4	xx	F.A.	1	6	2	7	3	5	4	9	8	
				\bar{x}	.2	.2	.2	.3	.3	.3	.5	.5	1.3	
2.	Summer	2.4	x	N.S.										
3.	Autumn	1.4	N.S.											
4.	Winter	1.0	N.S.											
5.	Winter	1.7	N.S.											
6.	Spring	1.2	N.S.											
7.	Spring	2.3	x	N.S.										
8.	Summer	1.5	N.S.											
9.	Autumn	1.0	N.S.											
10.	Winter	1.2	N.S.											
Total		7.9	xxx	F.A.	1	6	2	5	7	4	3	9	3	
				\bar{x}	1.0	1.2	1.6	1.7	1.7	2.2	2.9	4.4	5.1	

Visit	Season	F	Signif.	SNK										
<u>Western Warbler</u>														
1.	Spring	1.6	N.S.											
2.	Summer	1.6	N.S.											
3.	Autumn	1.6	N.S.											
6.	Spring	0.3	N.S.											
7.	Spring	0.6	N.S.											
8.	Summer	0.9	N.S.											
9.	Autumn	1.9	N.S.											
Total		2.0	N.S.											
<u>Kookaburra</u>														
Total		0.8	N.S.											
<u>Western Spinebill</u>														
1.	Spring	1.0	N.S.											
2.	Summer	0.6	N.S.											
3.	Autumn	3.6	xxx	F.A.	1	7	3	8	2	6	4	5	9	
				\bar{x}	0	0	.1	.1	.1	.1	.2	.6	1.2	
4.	Winter	1.8	N.S.											
5.	Winter	0.8	N.S.											
6.	Spring	1.3	N.S.											
7.	Spring	2.0	x	F.A.	9	3	5	1	7	8	2	6	4	
				\bar{x}	.1	.2	.3	.3	.3	.3	.5	.5	1.3	
8.	Summer	2.2	x	N.S.										
9.	Autumn	2.7	xx	F.A.	8	5	2	7	6	4	3	1	9	
				\bar{x}	0	.4	.4	.4	.4	.5	.5	1.2	1.8	
10.	Winter	1.6	N.S.											
Total		4.0	xxx	F.A.	8	7	2	3	5	5	9	4	1	
				\bar{x}	1.2	2.5	4.5	4.6	4.8	5.6	7.3	3.2	10.0	
<u>New Holland Honeyeater</u>														
3.	Autumn	6.9	xxx	F.A.	1	2	3	4	6	7	3	5	9	
				\bar{x}	0	0	0	0	0	0	0	0.1	1.4	
4.	Winter	1.6	N.S.											
5.	Winter	1.0	N.S.											
7.	Spring	9.2	xxx	F.A.	1	2	3	5	6	7	3	4	9	
				\bar{x}	0	0	0	0	0	0	0	.3	1.2	
10.	Winter	8.2	xxx	F.A.	2	3	4	6	7	8	5	1	9	
				\bar{x}	0	0	0	0	0	0	.1	.5	1.1	
Total		20.9	xxx	F.A.	7	8	2	6	3	4	5	1	9	
				\bar{x}	0	0	.1	.1	.2	.3	.6	1.7	10.2	
<u>Brown Honeyeater</u>														
Total		1.4	N.S.											
<u>Painted Quail</u>														
Total		0.6	N.S.											
<u>Western Rosella</u>														
Total		1.0	N.S.											

Visit	Season	F	Signif.	SNK
<hr/>				
<u>Red-capped Parrot</u>				
2.	Summer	0.3	N.S.	
3.	Autumn	0.9	N.S.	
4.	Winter	2.0	N.S.	
5.	Winter	0.5	N.S.	
6.	Spring	1.0	N.S.	
7.	Spring	2.7	xx	N.S.
8.	Summer	1.0	N.S.	
9.	Autumn	1.4	N.S.	
10.	Winter	3.0	xx	N.S.
Total		2.5	x	N.S.
<hr/>				
<u>Port Lincoln Parrot</u>				
1.	Spring	1.1	N.S.	
2.	Summer	0.7	N.S.	
3.	Autumn	1.4	N.S.	
4.	Winter	0.8	N.S.	
5.	Winter	0.9	N.S.	
6.	Spring	0.9	N.S.	
10.	Winter	1.0	N.S.	
Total		1.5	N.S.	
<hr/>				
<u>Red-tailed Black Cockatoo</u>				
5.	Winter	1.3	N.S.	
Total		0.5	N.S.	
<hr/>				

resulted from the detailed analysis. This may have been in part due to the low densities at which most species occurred, preventing detection of distribution patterns that actually existed, but there are several reasons to interpret the poor results as correct reflections of the avian ecologies.

Firstly, although nine FA's were identified, the characteristic plant species of each were primarily shrubs and herbs, while the tree-layer of jarrah and marri, and Banksia grandis of the sub-canopy, were virtually ubiquitous. Poor relationships between avian distributions and FA's might therefore be expected since the latter plant-species were those in which many of the bird species foraged (Chapter 4.3). In contrast a similar analysis in Victoria found honeyeater distributions were closely correlated with particular floristic associations, but this was in extremely varied habitats (Wykes, 1982).

Secondly, most of the bird species in the jarrah forest were insectivores that might be expected to forage wherever vegetation of suitable structural, rather than floristic, characteristics occur. This was also in contrast to the Victorian situation where the honeyeaters were specialized foragers of sugary secretions and nectar that were produced by particular plant species (Wykes, 1982). That the jarrah birds were indeed choosing habitat on the basis of structural characteristics of the vegetation was further indicated by the numerous significant correlations found by the regression analysis. Some of these correlations supported the results of the floristic analysis but much additional information about the distributions of the bird species was obtained (c.f. Wykes, op. cit.).

The results of the multiple regression analyses between avian distributions and structural characteristics of the vegetation are summarized in Table 9.

It should be understood that the apparently low percentages of explained variance of the regression equations (rarely as high as 25% - Table 9) are to be expected since individuals of species with low densities would be absent during any one census from many transect-sections that they do utilize.

The distributions of "Total bird density" and "Species Richness" were often positively correlated with i) VL 2, high values of which occurred on undisturbed, wet western slopes and along creeks; ii) VL 3, high values of which were primarily along creeks and iii) TVC which was highly intercorrelated with VL 2 and VL 3. The presence of dense vegetation in these strata might be directly attractive to the birds by providing foraging and nesting sites but other attributes of this habitat, such as insect abundances and availability of water, might also be involved.

Many correlations between individual species' distributions and structural characteristics of the vegetation were also found (Chapter 5). Some of these were interpretable in terms of the birds' ecologies but none have yet been tested as predictors of avian distributions in other areas of jarrah forest.

Table 9. Multiple regression analysis of avian distribution against vegetation structure

The ability to explain variance of avian distributions over the study area by variance in distributions of independent variables of vegetation structure was investigated by a multiple regression analysis for each visit and for the total research period. The step-wise multiple regression SPSS programme of Hull and Nie (1979) was applied. This calculates critical values, $t_{0.05(2)}$, $(n-m-1)$ for testing the significance of the partial regression coefficients associated with each variable added to the equation, where m = no. of t values (i.e. no. of variables) already added, and n = no. of samples/variable. The procedure adds the variables with the next largest t value if it is greater than the critical value ($\alpha = 0.05$), then recalculates the t values and adds the variable with the next highest t , given that it is greater than t critical.

In the present cases, $n = 120$ and therefore for addition of the first variable, $t_c = t_{0.05(2)}$, $(118) = 1.98$ (Zar, 1974). For each avian distribution that was tested against the distributions of the structural variables, the partial correlation co-efficient (r), the significance of the correlation, the sign (+ve/-ve) of the correlation, and the percentage of variance explained by the independent variable are noted.

The levels of significance are indicated by:

N.S. = not significant, $\alpha = 0.05$;

x,xx,xxx = $P < 0.05, 0.01, 0.001$ respectively.

Visits for which there were ≥ 10 sightings/120 transect sections but no significant correlations are listed for each species.

The independent variables in the analysis were:

TT = total number of trunks per sample in each transect section.

T1 = No. of trunks of $> 0, < 15$ cm diameter.
T2 = $\geq 15, < 30$ cm diameter.
T3 = $\geq 30, < 50$ cm diameter.
T4 = $\geq 50, < 60$ cm diameter.
T5 = $\geq 60, < 85$ cm diameter.
T6 = ≥ 85 cm diameter

TVC = Total vegetation cover, obtained by pooling the scores per 20 point quadrats for vegetation present in strata classes.

VL1 = No. of points/20 point quadrats in the height interval
 $> 0, < 20$ cm.

VL2 = height interval ≥ 20 cm, < 1.6 M
VL3 = > 1.6 M, < 3 M
VL4 = ≥ 3 M, < 5 M
VL5 = ≥ 5 M, < 15 M
VL6 = ≥ 15 M, < 25 M
VL7 = ≥ 25 M.

Visit Season	Independent variable	+ve/-ve	t	Significance	% of variance	Total % var. explained
<u>Total Avian Densities</u>						
1 (Sp)	VL 2	+	3.0	xx	10	
	T 3	+	2.6	x	4	14
2 (Su)	VL 2	+	6.3	xxx	25	25
3 (A)	VL 3	+	2.8	xx	6	6
4 (W)	VL 1	+	2.8	x	5	
	T 4	+	2.2	x	4	
	T 2	+	2.2	x	4	12
5 (W)	VL 2	+	2.2	x	6	
	T 1	+	2.1	x	3	9
6 (Sp)	VL 3	+	2.6	x	5	5
7 (Sp)	TVC	+	5.2	xxx	19	19
8 (Su)	VL 3	+	3.9	xxx	8	
	T 4	+	2.6	xx	6	
	TT	-	2.3	x	4	17
9 (A)	VL 2	+	3.9	xxx	12	12
10 (W)				N.S.		
<u>Species Richness</u>						
1 (Sp)	VL 2	+	3.0	xx	7	7
2 (Su)	VL 2	+	6.0	xxx	23	23
3 (A)	VL 2	+	2.0	x	3	3
4 (W)	T 2	+	2.5	x	5	
	VL 1	+		x	5	10
5 (W)	VL 2	+	2.2	x	4	4
6 (Sp)	VL 3	+	2.1	x	4	4
7 (Sp)	TVC	+	5.1	xxx	18	18
8 (Su)	VL 3	+	3.9	xxx	7	
	T 1	-	2.7	xx	7	
	T 4	+	2.3	x	4	17
9 (A)	VL 2	+	2.8	xx	5	6
10 (W)	VL 2	+	2.0	x	3	3
<u>Grey Currawong</u>						
2 (Su)	T 3	+	2.5	x	5	5
4 (W)	T 4	+	2.2	x	4	4
5 (W)	T 4	+	2.9	xx	7	7
<u>Scarlet Robin</u>						
2 (Su)	T 1	+	3.9	xxx	8	
	VL 4	-	2.3	x	4	
	T 6	+	2.0	x	3	15
4 (W)	T 6	+	3.1	xx	5	
	VL 3	-	2.0	x	3	8
6 (Sp)	T 6	+	3.5	xxx	9	9
7 (Sp)	T 6	+	2.4	x	4	4
8 (Su)	T 3	+	2.6	xx	6	6
<u>Yellow Robin</u>						
2 (Su)	T 3	+	2.9	xx	7	7
3 (A)	VL 6	+	3.1	xx	5	
	VL 7	-	2.0	x	3	
4 (W)	VL 3	+	3.8	xxx	11	11
5 (W)				N.S.		
7 (Sp)	T 5	+	2.9	xx	7	7
8 (Su)				N.S.		
9 (A)				N.S.		
10 (W)				N.S.		

Visit Season	Independent variable	+ve/-ve	t	Significance	% of variance	Total % var. explained
<u>Splendid Wren</u>						
1 (Su)	VL 3	+	4.5	xxx	11	
	T 1	-	2.6	xx	5	16
2 (Su)	VL 2	+	3.5	xxx	9	9
3 (A)	T 6	+	3.1	xx	8	8
	TT	-	2.6	xx	5	5
4 (W)	VL 3	+	5.1	xxx	17	
	TT	+	3.6	xxx	4	
	T 1	-	2.7	xx	4	26
5 (W)				N.S.		
6 (Sp)	VL 3	+	4.7	xxx	16	16
7 (Sp)	VL 2	+	4.5	xxx	13	
	TT	-	2.0	x	3	16
8 (Su)	VL 3	+	2.6	x	5	5
9 (A)	VL 2	+	3.2	xx	5	
	T 1	-	2.8	xx	6	11
10 (W)	VL 1	+	2.2	x	4	4
<u>White-browed Scrub Wren</u>						
3 (A)	T 1	+	3.9	xxx	8	
	VL 4	-	2.3	x	4	
	T 6	+	2.0	x	3	15
6 (Sp)	VL 2	+	4.0	xxx	7	
	VL 1	+	3.5	xxx	4	
	TVC	-	2.9	xx	4	
	VL 4	+	2.0	x	3	19
7 (Sp)	VL 3	+	4.3	xxx	14	14
<u>Western Thornbill</u>						
1 (Sp)				N.S.		
2 (Su)				N.S.		
3 (A)	T 5	-	2.0	x	3	3
4 (W)	T 6	+	2.2	x	4	4
5 (W)				N.S.		
6 (Sp)	VL 5	-	2.8	xx	7	
	VL 4	-	2.7	xx	4	
	T 3	-	2.3	x	4	16
7 (Sp)	T 4	+	2.1	x	3	3
8 (Su)	VL 4	-	2.7	xx	6	
	T 3	+	2.1	x	3	10
9 (A)	VL 6	+	3.8	xxx	8	
	T 4	-	2.2	x	4	11
10 (W)				N.S.		
<u>Red-winged Wren</u>						
1 (Sp)	VL 3	+	3.5	xxx	20	
	VL 2	+	2.5	xxx	4	
	T 2	+	2.3	x	2	
	VL 4	-	2.2	x	3	29
2 (Su)	VL 2	+	3.6	xxx	13	
	T 2	+	2.7	xx	4	
	T 6	+	2.0	x	3	20
3 (A)	VL 3	+	2.0	x	3	3
4 (W)	T 4	+	2.7	xx	6	6
6 (Sp)	VL 7	+	3.2	xx	9	
	VL 1	-	2.7	xx	5	15
7 (Sp)	VL 2	+	4.2	xxx	19	
	T 6	+	2.9	xx	6	24
8 (Su)	T 4	+	2.1	x	4	4
9 (A)	VL 2	+	3.3	xx	8	8
10 (W)	VL 3	+	3.0	xx	11	
	T 6	+	2.3	x	4	15

Visit Season	Independent variable	+ve/-ve	t	Significance	% of variance	Total % var. explained
<u>Silvereye</u>						
1 (Sp)	T 1	+	3.0	xx	7	
	T 6	+	2.0	x	3	10
2 (Su)	VL 2	+	2.6	x	19	
	VL 3	+	2.6	x	4	23
3 (A)	VL 3	+	2.6	xx	4	
	T 1	-	2.2	x	4	8
5 (W)	VL 7	+	2.6	xx	6	6
6 (Sp)	VL 7	+	3.3	xx	10	
	VL 1	-	2.1	x	3	13
7 (Sp)	T 6	+	3.0	xx	7	7
8 (Su)	TVC	+	2.6	xx	4	
	T 6	-	2.0	x	3	7
9 (A)	T 6	+	2.5	x	5	5
10 (W)	VL 3	+	3.8	xxx	11	11
<u>Broad-tailed Thornbill</u>						
1 (Sp)	VL 3	+	4.6	xxx	15	15
2 (Su)	VL 3	+	3.4	xxx	9	9
3 (A)	VL 4	-	2.0	x	3	3
4 (W)	T 4	+	2.9	xx	5	
	TT	+	4.2	xxx	5	
	VL 5	-	3.4	xx	4	
	T 1	-	3.1	xx	5	
	VL 1	+	2.2	x	3	23
5 (W)	T 6	+	2.3	x	4	4
6 (Sp)				N.S.		
7 (Sp)	T 6	+	2.6	x	5	5
8 (Su)				N.S.		
9 (A)				N.S.		
10 (W)	T 2	+	3.0	xx	7	7
<u>Golden Whistler</u>						
1 (Sp)				N.S.		
2 (Su)				N.S.		
3 (A)	VL 5	+	2.0	x	3	3
4 (W)				N.S.		
5 (W)				N.S.		
6 (Sp)	T 2	+	2.0	x	3	3
7 (Sp)	VL 7	+	2.5	x	6	6
8 (Su)	T 5	+	2.2	x	4	4
9 (A)				N.S.		
10 (W)	T 2	+	2.1	x	4	4
<u>Western Shrike-thrush</u>						
1 (Sp)				N.S.		
2 (Su)	T 5	+	2.6	xx	6	6
4 (A)	T 6	+	2.2	x	4	4
6 (Sp)				N.S.		
7 (Sp)	VL 3	+	2.1	x	4	4
8 (Su)				N.S.		
10 (W)	VL 7	+	2.9	x	7	7
<u>Striated Pardalote</u>						
1 (Sp)	T 4	+	4.0	xxx	12	12
2 (Su)	TVC	+	3.2	xx	8	8
3 (A)	VL 6	+	2.1	x	4	4
5 (W)	T 6	+	2.0	x	3	3
6 (Sp)				N.S.		
7 (Sp)	VL 6	+	2.8	xx	5	
	T 1	+	2.9	xx	4	
	VL 3	-	2.3	x	4	13
8 (Su)	VL 7	+	2.0	x	3	3
9 (A)	VL 7	+	3.4	xxx	9	9
10 (W)				N.S.		

Visit Season	Independent variable	+ve/-ve	t	Significance	% of variance	Total % var. explained
<u>Spotted Pardulote</u>						
1 (Sp)	VL 2	+	3.5	xxx	8	
	T 3	+	3.0	xx	6	
	TT	-	2.0	x	3	17
2 (Su)	T 2	+	4.3	xxx	16	
	VL 2	+	2.0	x	3	18
4 (W)	T 5	-	2.0	x	3	3
5 (W)	VL 3	+	4.5	xxx	15	15
6 (Sp)	VL 3	+	2.0	x	3	3
7 (Sp)	VL 7	+	3.5	xxx	10	10
8 (Su)	VL 2	+	2.3	x	4	4
10 (W)	VL 7	+	5.3	xxx	19	19
<u>White-naped Honeyeater</u>						
2 (Su)	T 3	+	3.8	xxx	9	
	VL 7	+	2.8	xx	7	
	VL 3	+	2.8	xx	5	21
3 (A)	T 3	+	3.8	xxx	11	
	VL 2	+	2.2	x	3	14
4 (W)	VL 1	+	2.1	x	4	4
5 (W)	VL 7	+	3.1	xx	8	5
9 (A)	VL 6	+	2.1	x	4	4
10 (W)				N.S.		
<u>Varied Sittella</u>						
2 (Su)	T 3	+	3.1	xx	3	3
4 (W)	VL 1	+	2.0	x	3	3
5 (W)	VL 3	+	3.3	xxx	11	11
7 (Sp)	TT	+	3.9	xxx	4	
	T 1	-	3.1	xx	5	
	T 2	-	2.1	x	3	12
3 (Su)	T 5	+	2.4	x	5	5
13 (W)	TVC	-	2.7	xx	6	6
<u>Rufous Treecreeper</u>						
2 (Su)	T 5	+	2.2	x	4	4
3 (A)	T 1	+	2.3	x	4	4
4 (W)	TT	-	2.0	x	3	3
5 (W)	T 3	+	2.2	x	4	4
7 (Sp)	TVC	+	2.5	x	5	5
9 (A)	VL 3	+	2.0	x	3	3
10 (W)				N.S.		
<u>Tree Martin</u>						
1 (Sp)	T 3	+	3.0	xx	7	7
2 (Su)	VL 4	-	2.2	x	4	4
4 (W)	T 4	+	3.0	xx	7	7
6 (Sp)				N.S.		
7 (Sp)	VL 6	+	2.6	x	5	5
3 (Su)				N.S.		
9 (A)	VL 4	-	2.1	x	4	4

Visit Season	Independent variable	+ve/-ve	t	Significance	% of variance	Total % var. explained
<u>Grey Fantail</u>						
1 (Sp)	VL 7	+	3.0	xx	7	7
2 (Su)	VL 2	+	3.6	xxx	10	10
3 (A)	VL 7	+	2.8	xx	6	5
4 (W)	TT	+	25.3	xxx	20	
	T 1	-	21.8	xxx	40	
	T 2	-	11.7	xxx	17	
	T 3	-	5.8	xxx	5	
	T 5	-	3.8	xxx	2	
	T 4	-	2.4	x	1	35
5 (W)	VL 7	+	2.6	x	5	5
6 (Sp)	T 1	+	2.4	x	4	4
7 (Sp)	VL 3	+	4.0	xxx	10	
	T 4	+	3.1	xx	7	17
8 (Su)	VL 3	+	3.3	xxx	8	
	VL 6	+	2.3	x	4	12
9 (A)	T 4	+	2.0	x	3	3
10 (W)	T 3	+	3.3	xx	8	5
<u>Western Warbler</u>						
1 (Sp)	VL 4	-	2.1	x	4	4
2 (Su)				N.S.		
3 (A)	T 3	+	3.0	xx	7	7
4 (W)	T 4	+	2.8	xx	5	5
5 (Sp)				N.S.		
7 (Sp)	VL 4	-	2.4	x	4	4
7 (A)	VL 1	-	3.6	xxx	10	10
<u>Kookaourra</u>						
4 (W)	VL 1	-	2.5	x	4	
	VL 5	+	2.4	x	5	
3 (Su)	T 1	-	2.1	x	4	4
<u>Western Spinetail</u>						
1 (Sp)				N.S.		
2 (Su)	VL 4	+	2.3	xx	5	
	VL 5	-	2.3	x	4	3
3 (A)	VL 3	+	4.7	xxx	16	16
4 (W)	VL 2	-	2.9	xx	5	
	VL 4	+	2.2	x	4	3
5 (W)	T 1	+	2.1	x	4	4
6 (Sp)	T 3	-	2.0	x	3	3
7 (Sp)	VL 2	-	2.0	x	3	5
8 (Su)				N.S.		
9 (A)	VL 3	+	3.6	xxx	10	
	VL 6	-	2.0	x	3	13
10 (W)	VL 5	-	3.7	xxx	10	10
<u>New Holland Honeyeater</u>						
1 (Sp)	VL 3	+	4.5	xxx	15	15
2 (Su)	VL 3	+	4.4	xxx	14	14
3 (A)	VL 3	+	5.7	xxx	22	22
4 (W)	T 6	+	2.7	xx	4	
	VL 7	-	2.3	x	3	
	TT	-	2.2	x	4	11
5 (W)	VL 3	+	4.3	xxx	14	14
6 (Sp)	VL 3	+	2.6	xx	6	5
7 (Sp)	VL 3	+	4.0	xxx	24	
	T 1	-	2.5	xx	3	
	VL 2	+	2.2	x	3	30
8 (Su)	VL 3	+	7.0	xxx	29	29
9 (A)	VL 7	+	2.3	x	4	4
10 (W)	VL 3	+	5.7	xxx	19	
	TT	-	2.3	x	4	23

Visit Season	Independent variable	+ve/-ve	t	Significance	% of variance	Total % var. explained
<u>Brown Honeyeater</u>						
2 (Su)	VL 7	+	2.3	xx	6	10
	T 3	+	2.3	x	4	7
3 (A)	VL 7	+	3.0	xx	7	3
7 (Sp)	T 6	+	2.0	x	3	
<u>Painted Quail</u>						
2 (Su)	VL 4	+	2.3	x	4	4
3 (A)	VL 5	-	2.2	x	4	4
4 (W)	T 6	+	2.0	x	3	3
8 (Su)	VL 2	+	4.1	xxx	13	17
	VL 1	+	2.4	x	4	17
10 (W)	T 4	+	5.1	xxx	17	
<u>Western Rosella</u>						
5 (W)	T 3	+	3.8	xxx	10	13
	T 5	+	2.0	x	3	7
7 (Sp)	T 6	+	2.9	xxx	7	18
9 (A)	T 4	+	5.1	xxx	18	
<u>Port Lincoln Parrot</u>						
1 (Sp)				N.S.		4
2 (Su)	VL 4	+	2.3	x	4	
3 (A)				N.S.		
4 (W)	T 4	+	2.3	xx	4	
	VL 1	+	2.6	x	5	12
	VL 5	-	2.0	x	3	4
5 (W)	TVC	+	2.1	x	4	4
5 (Sp)	VL 4	-	2.2	x	4	
7 (Sp)	VL 3	+	2.4	x	4	3
	T 3	+	2.3	x	5	5
8 (Su)	T 5	+	2.6	x	4	4
9 (A)	VL 7	+	2.4	x	4	7
10 (W)	T 3	+	3.2	xx	3	
<u>Red-capped Parrot</u>						
1 (Sp)	VL 2	+	2.1	x	4	4
2 (Su)	VL 4	-	3.0	xx	7	7
3 (A)	VL 5	+	2.3	x	4	4
4 (W)	VL 6	+	3.3	xx	4	4
5 (W)				N.S.		
6 (Sp)	VL 7	+	2.7	xx	6	10
	T 3	+	2.2	x	4	16
7 (Sp)	VL 3	+	4.7	xxx	16	
3 (Su)				N.S.		
9 (A)	VL 2	+	2.7	xx	4	3
	T 1	-	2.2	x	4	17
10 (W)	VL 3	+	5.0	xxx	17	
<u>Red-tailed Black Cockatoo</u>						
2 (Su)	VL 2	+	2.2	x	4	4
3 (A)	VL 7	+	3.4	xxx	9	9
4 (W)	T 4	+	4.9	xxx	18	21
	VL 5	+	2.1	x	3	6
5 (W)	VL 5	+	2.8	xx	6	4
6 (Sp)	VL 4	+	2.3	x	4	
7 (Sp)	VL 7	+	3.6	xxx	12	12
	T 4	+	2.2	x	4	5
8 (Su)	T 4	+	2.4	x	5	4
10 (W)	TVC	-	2.3	x	4	

4.3 Scenic Drive bird communities

4.3.1 Introduction

Bird community compositions in mine pits that have been rehabilitated using various treatments have been compared in a number of studies (Wykes et al, 1980; Collins et al, in press). These leave no doubt that the more recent treatments have been the most successful in reestablishing the jarrah forest avifauna. I chose to compliment my research on the jarrah forest birds by gathering year-round estimates of community comparison and foraging observations on the birds in one of these more successful plots. This was a 2ha mine-pit at Scenic Drive that was rehabilitated in 1975. It had been a) deep-ripped to 1.5M to encourage root penetrates of the pit floor, b) spot fertilised to encourage seedling growth, c) replaced with seedling marri E. calophylla and d) treated with a layer of freshly - removed litter from a new mine site plus a seed-mixture of jarrah forest species to establish shrub vegetation.

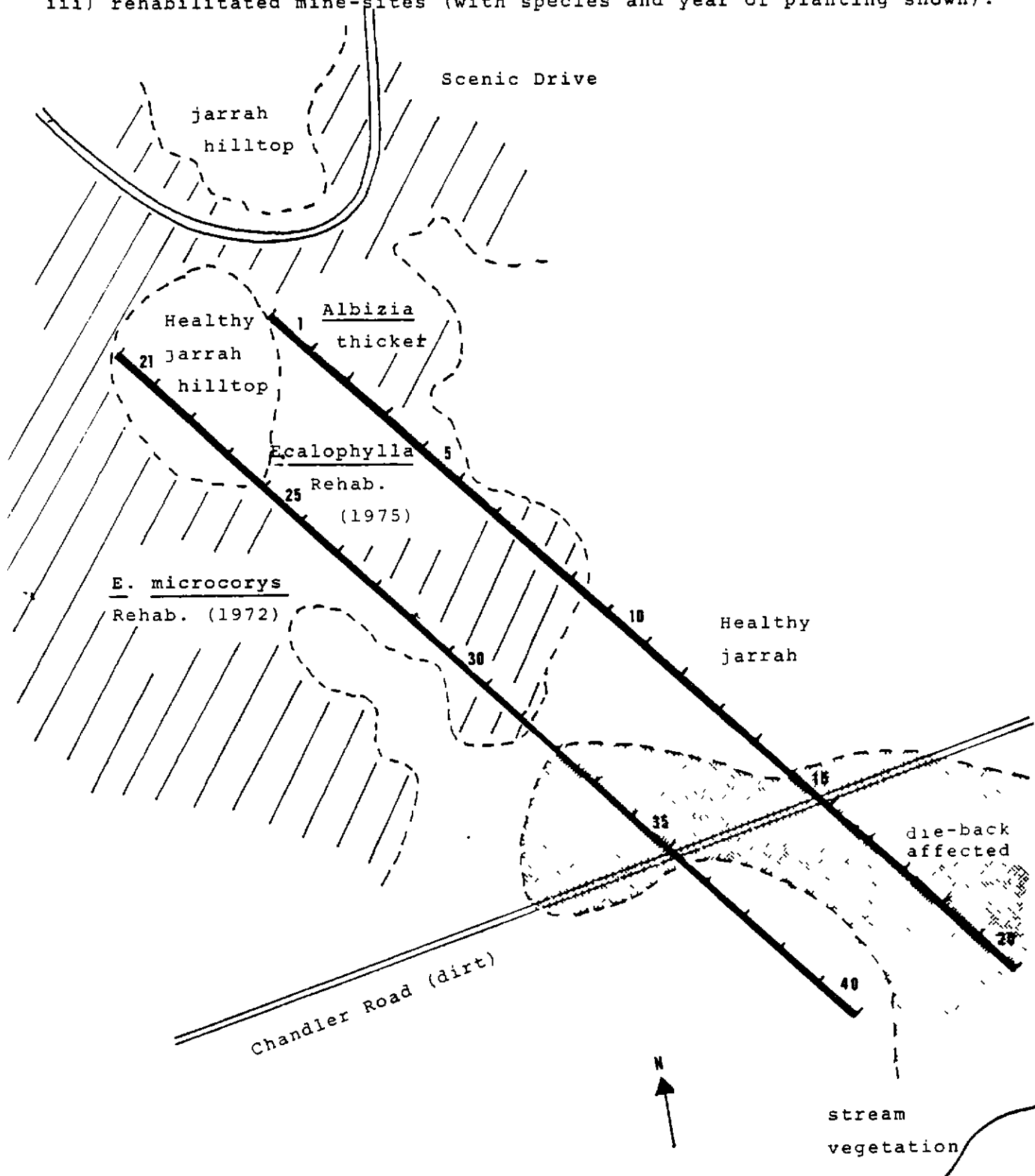
A major difficulty in studying community compositions in rehabilitation bauxite mine-sites is the small sizes of the pits. Individual pairs of bird could be identified in the breeding season but some sort of spot-count or transect method is needed for an all-season survey (Wykes et al, 1980). The method chosen did not fully resolve this problem. A transect was established of two parallel lines that ran for 2km from the Scenic Drive ridge down a S.E. facing slope (Figure 9). It was 40 m wide and was subdivided in forty 50m-long sections for the purposes of recording avian distributions amongst the habitat-types.

Three habitat-types were defined which summarised the major differences in vegetation encountered along the transect.

- a) healthy jarrah forest:- a hilltop island of jarrah forest and belts below the mine-pit were variable in compositions and by no means undisturbed but were dominated by mature, tall jarrah and marri in relatively dense stands over diverse understorey, shrub and ground layers. Acacia armata was particularly common in some shrub-layers, probably due to spread of seed-mix applied to the mine-pit.
- b) die-back affected jarrah forest:- some areas of forest on shallow slopes below the mine-pit were severely disturbed, due to past removal of gravel, which probably introduced the die-back fungus, and then additional removal of all useful timber by the Forests Department. Vegetation composition was similar to that of the depauperate floristic associations 1 & 2 in the Serpentine study area (Chapter 4.2). There were sparse tree, sub-canopy and shrub strata and a dense ground cover of colonisers such as Conostylis setosa, Lepidosperma tenue and Trymalium Tedifolium.
- c) rehabilitated mine-pit:- The marri regrowth was 4-5M high and formed a dense, low non-interlocking canopy of foliage 2-3M in depth. The shrub stratum was poor in patches and in two 50M sections of E. microcorys rehab. but generally formed a dense, 0.5 - 1M layer. It was dominated by Acacia

Figure 9. Scenic Drive Study Site

Sketch map of the Scenic Drive study site (Alcoa Plot 23) in the Alcoa No.2 bauxite mine area at Jarrahdale (Figure 1), showing the 4 km of strip-transect which was divided in 40, 50-m long sections. The habitat-types were summarised for the analysis as i) healthy jarrah forest, ii) jarrah forest disturbed by gravel pits, die-back and excessive timber removal and iii) rehabilitated mine-sites (with species and year of planting shown).



armata, A. browniana and Lasiopetalum floribundum, with low abundances of various other jarrah forest and weed species. There was a dense, 3M tall thicket of Albizia lophantha, Acacia extensa and A. saligna regrowth at the start of the transect (Figure 9).

4.3.2 Results

i) Total densities

A Kruskal-Wallis A.O.V. was performed on the total densities per visit in each of these habitats and for the total densities in the Serpentine study area (using equivalent visits). This gave $H = 11.3$, $\chi^2_{0.05(3)} = 7.8$, $p < 0.05$. A non-parametric multiple comparison of the group then gave:

$$[\text{jarrah} = \text{rehab.} = \text{Serpentine}] < \text{die-back}$$

\bar{x}/visit	65.5	62.7	52.4	17.5
------------------------	------	------	------	------

Thus, for the data obtained over one year at Scenic Drive, the avifauna in the rehabilitated mine-pit did not significantly differ in density from that in adjacent healthy jarrah forest or from that in the main jarrah study area. However, die-back-affected jarrah forest was significantly poorer.

ii) Total species

Comparison of species numbers in the different habitats is only valid where equivalent sample times and sampling areas are used unless there is confidence that all species are detected. This was not the case but comparison was reasonable between the rehab. and jarrah samples at Scenic Drive where sampling areas were similar (3 and 3.2ha, respectively). The results of the Mann-Whitney Test were:

$$U = 20, U_{0.05(2)6}, 6 = 31 \therefore \text{N.S.}$$

$$\text{rehab. } (\bar{x} = 13.0 \text{ spp/visit}) = \text{jarrah } (13.5 \text{ spp/visit}).$$

Thus, species richness values over the year did not differ between the rehabilitated mine-pit and adjacent, healthy jarrah forest.

iii) Guild densities

Most species in all guilds had similar densities in "rehab" and "jarrah" but lower in "die-back" habitat (Table 10). Apparent exceptions were the particularly high densities of the Silver-eye (shrub-layer insectivore) in rehab; the Striated Pardalote and White-naped Honeyeaters (tree-layer insectivore) in jarrah; and the Red-capped Parrot in jarrah, and the Port-Lincoln parrot in rehab.. These differences were unlikely to be confirmed by statistical analysis because of small sample populations but some Kruskal-Wallis A.O.V.'s on the densities of some species were significant ($\chi^2_{0.05(2)} = 5.99$):

Table 10 Compositions of the Scenic Drive avifauna

The species recorded within the strip-transect at Scenic Drive are grouped into the guilds in which most of their foraging occurred. Mean densities are given for each species, derived from 6 visits between June 1981 and August 1982. The transect of 4 km x 40 m (8 ha) was covered three times in each visit. The results are sub-divided into densities for the three general habitat-types that were represented along the transect - healthy jarrah forest ("jarrah" - 3.2 ha), severely disturbed jarrah forest ("die-back" - 1.8 ha) and rehabilitated mine-pit ("rehab." - 3 ha). Species with mean densities of less than 1/10 ha and only recorded for one visit were pooled as "other".

These were the Grey Currawong (rehab), Fan-tailed Cuckoo (rehab), Weebill (jarrah), Dusky Woodswallow (jarrah), Rainbow Bee-eater (jarrah), Accipiter spp (die-back) and Red Wattlebird (rehab).

Guild	Species	Mean density/10 ha		
		Jarrah	Die-back	Rehab.
<u>Insectivore</u>				
a) Ground foraging	Scarlet Robin	1.9	0.9	0.4
	Western Yellow Robin	1.6		1.0
	Splendid Wren	4.7	2.9	6.2
	White-browed Scrub-wren	0.3		1.2
		8.5	3.8	8.8
b) Shrub foraging	Western Thornbill	9.7	1.4	5.0
	Red-winged Wren	1.9		2.3
	Western Silvereye	3.8	2.8	10.6
		15.4	4.2	17.9
c) Tree foraging	Broad-tailed Thornbill	6.5	3.1	6.1
	Golden Whistler	3.3		3.5
	Western Shrike-thrush	0.4		0.6
	Striated Pardalote	5.8	0.8	2.6
	Spotted Pardalote	1.0		0.6
	White-naped Honeyeater	3.6	0.6	
		20.6	3.9	14.0
d) Bark foraging	Varied Sittella	1.0		
		1.0		
e) Air foraging	Tree Martin	1.0	0.3	0.6
	Grey Fantail	6.8	1.2	5.4
	Western Warbler	2.5	1.8	3.0
		10.3	3.3	9.0
<u>Carnivore</u>	Little Eagle	0.5	0.3	0.2
	Laughing Kookaburra	0.6		
		1.1	0.3	0.2
<u>Nectarivore</u>	Western Spinebill	2.1		2.2
	New Holland Honeyeater			1.5
	Little Wattlebird			0.6
<u>Graminivore</u>	Western Rosella	0.4	0.9	
	Red-capped Parrot	3.8		1.5
	Port Lincoln Parrot	1.6	0.8	5.1
	Common Bronzewing			1.1
		5.8	1.7	7.7
<u>'Others'</u>	7 species	0.7	0.3	0.8
		0.7	0.3	0.8
Total (\bar{x} + S.D.).		65.5 + 23.9	17.5 + 18.8	62.7 + 17.4
c.f. Main Study area (Table 5)		52.4 + 10.3		

Western Thornbill:	$\frac{H}{\bar{x}/\text{visit}} = 6.0$	[jarrah = rehab.] > die-back
	9.7 5.0 1.4 ;	
Golden Whistler:	$\frac{H}{\bar{x}/\text{visit}} = 9.0$	[jarrah = rehab.] > die-back
	3.5 3.3 0 ;	
White-naped Honeyeater:	$\frac{H}{\bar{x}/\text{visit}} = 9.0$	jarrah > [rehab. = die-back]
	3.6 0.6 0 ;	
Western Silvereye:	$\frac{H}{\bar{x}/\text{visit}} = 6.4$	rehab. > [jarrah = die-back]
	10.6 3.8 2.8 .	

iv) Comparative densities within habitats.

K-W A.O.V. was also used to rank the densities of the species in each habitat-type (die-back excluded because of too few regular species). The species that were included in the analysis were those that occurred in more than two of the six visits to the habitat. There was no significant variance amongst the "jarrah" habitat species ($H = 18.6$, $X^2 0.05(13) = 23.7$, .. N.S.). There was significant variance amongst the "rehab" species ($H = 28.2$, $X^2 0.05(12) = 21.03$, $P < 0.01$) but non-parametric comparisons of the species' ranks gave no significant difference between the largest and smallest values.

v) Seasonality.

Changes in density of the species that occurred in each habitat-type are shown in Table 11. Seasonal patterns were apparent for some species, as was found at the Serpentine site (Chapter 4.1). For instance, the Western Warbler was a spring/summer immigrant to all habitat. Splendid Wren density in the rehab. appeared to be greatest in spring/summer, in contrast to autumn/winter occurrence of the Red-winged Wren. However, no changes were confirmed by A.O.V., probably because of high variability in counts within each visit in the small sample areas.

Chapter 4.4. Breeding seasons.

An indication of when most jarrah forest species breed was gained by tabulating all breeding records obtained during the research period by myself and Curry and Nichols (1985) (Table 12). My search effort was uniform ($n = 83$) but Curry only searched during the suspected peak period of October-November ($n = 34$). Furthermore, different stages of breeding are more detectable than others, such as breeding of fledglings (45% of records). compared with breeding eggs (5% of records). Thus, there are biases towards the number of records gathered per month and the stages of breeding detected during those months. However, some conclusions can be drawn.

October to December was the peak breeding period for the majority of jarrah forest bird species, while dependent fledglings were often still present until February. Very few species bred from March to September, although records of fledglings for some species in October suggests that less detectable stages of nesting often begin in September or earlier. Some species may have varied from this pattern. New Holland and White-naped Honeyeaters were found building in January and thus may have an

extended breeding seson. Another honeyeater, the Western Spinebill, had a breeding season that peaked in summer and extended into autumn and winter. Two migratory species, the Western Warbler and Striated Pardalote (Chapter 5) may have tended to breed later in the spring/summer period than did most resident species.

Table 11 Changes in bird densities over time within the Scenic Drive Habitats: Species
with mean densities of less than 1.0/10 ha not included.

a) Jarrah

Species	Density/10 ha						$\bar{x} \pm S.D.$
	Winter	Winter	Spring	Summer	Autumn	Winter	
	June 81	Aug 81	Oct 81	Feb 82	Apr 82	Aug 82	
Scarlet Robin	4		6		1		2 ± 2.7
Western Yellow Robin	2	3				4	2 ± 1.8
Splendid Wren	3		9	2		8	5 ± 4.5
Western Thornbill	20		15	6	3	15	10 ± 7.7
Red-winged Fairy Wren	8					3	2 ± 3.4
Western Silvereye	4		2	12	2	2	4 ± 4.5
Broad-tailed Thornbill	14	3	3	3	9	7	6 ± 4.2
Golden Whistler	1	2	4	1	10	2	3 ± 3.5
Striated Pardalote			15	2	11	7	6 ± 6.1
Spotted Pardalote	4					2	1 ± 1.8
White-naped Honeyeater	1	3	1	4	8	4	4 ± 2.5
Varied Sittella	3				3		1 ± 1.6
Tree Martin			3		3		1 ± 1.6
Grey Fantail	6	3	5	7	16	3	7 ± 4.6
Western Warbler			7	5	2		2 ± 3.1
Western Spinebill	4				3	5	2 ± 2.4
Red-capped Parrot	3	8	2	2	8		4 ± 3.2
Port-Lincoln Parrot	1		1	6	2		2 ± 2.3
Total density	38	23	76	54	84	66	66 ± 23.9
Total species	18	7	15	12	16	13	14 ± 3.8

b) Rehab.

Density/10 ha

Species	Winter June 81	Winter Aug 81	Spring Oct 81	Summer Feb 82	Autumn Apr 82	Winter Aug 82	$\bar{x} \pm S.D.$
W. Yellow Robin		2	1		3		1 ± 1.3
Splendid Wren	2	7	7	16	1	6	6 ± 5.2
White-browed Scrub-wren	3	2				2	1 ± 1.4
Western Thornbill	9	7	1	4	3	6	5 ± 2.7
Red-winged Fairy Wren					2	11	2 ± 4.4
Western Silvereye	13	8	11	7	10	14	11 ± 2.9
Broad-tailed Thornbill	6	7	6	4	4	10	6 ± 2.1
Golden Whistler	1		7	6	7	1	3 ± 3.1
Striated Pardalote			6	2		8	3 ± 3.4
Grey Fantail	2		4	21	2	3	5 ± 3.2
Western Warbler	1		12	4			3 ± 4.8
Western Spinebill	3	3	2		1	3	2 ± 1.4
New Holland Honeyeater	2	7					2 ± 2.7
Red-capped Parrot				5.6		3	2 ± 2.4
Port-Lincoln Parrot	7		3	2	8	11	5 ± 4.0
Common Bronzewing					1	6	1 ± 2.2
Total density	53	42	69	75	43	87	63 ± 17.4
Total species	14	8	15	13	14	14	13 ± 2.5

b) Die-back

Density/10 ha

Species	Winter	Winter	Spring	Summer	Autumn	Winter	$\bar{x} \pm S.D.$
Splendid Wren	2	3		7	6		3 ± 3.0
Western Thornbill				6	3		1 ± 2.3
Western Silvereye				17			3 ± 6.8
Broad-tailed Thornbill	4	6	4	6			3 ± 2.5
Grey Fantail			2		6		1 ± 2.3
Western Warbler				11			2 ± 4.5
Total density	7	14	13	54	18	0	18 ± 18.8
Total species	3	3	6	7	5	0	4 ± 2.5

Table 12 Breeding seasons All breeding records obtained in the Serpentine study area and at Scenic Drive in this study and by Curry and Nichols (In prep.) are combined to indicate breeding seasons of the jarrah forest birds.

Key: + = contents of active nest unknown; b = building; e = eggs; n = nestlings; f = fledglings

Species	Month (1980-82 combined)					
	October	November	December	January	February	Mar-Sept
	+ b e n f	+ b e n f	+ b e n f	+ b e n f	+ b e n f	+ b e n f
Grey Currawong	1 1					
Aust. Raven		1				
Boobook Owl				1		
Tawny Frogmouth				2		
White-breasted Robin		1				
Scarlet Robin	2 3 1		1		1	
W. Yellow Robin	1 3	1		1		
White-browed Scrub-wren	2					
Western Thornbill	4 2	2	2	1		
Red-winged Wren	2		1			
W. Silvereye				1	1	
Broad-tailed Thornbill	5 1	1	1			
Fantailed Cuckoo	1					
Shining Bronze-cuckoo		1		1		
Golden Whistler	2					
Striated Pardalote	3 1	2 1	1 1 1	1		
White-naped Honeyeater	1 2 2		1	1 2	1	
Rufous Treecreeper	1					
Tree Martin	1					
Grey Fantail	1 1 1 2					
Western Warbler	1	1 1 1	1	1	1	
Dusky Woodswallow			1			
Sacred Kingfisher		1	1			
L. Kookaburra	1 1	1				
Western Spinebill	1 2 4	1		1 4	1 1	1 1
Brown Honeyeater	1					
New Holland Honeyeater	1			1		
Little Wattlebird	1					
Port-Lincoln Parrot	1					
Elegant Parrot	2			1		
Painted Quail						
Total	5 10 3 20 25	2 2 3 5 3	3 1 2 6	2 2 2 14	1 5	1 1

CHAPTER 5. ECOLOGIES OF THE JARRAH FOREST BIRD SPECIES

5.1 Introduction

The various ecological aspects that were studied will be considered for each of the jarrah forest bird species in the following categories.

1. STATUS IN AUSTRALIA

The geographic distributions of the species that were recorded in the Serpentine area are summarised to indicate the importance of jarrah forest to their conservation.

2. STATUS IN THE JARRAH FOREST

Changes in density of the main species that comprised the jarrah avifauna are presented in Figure 10. Also shown are any significant correlations that were found between these changes and those of various food supply and climatic variations.

3. DISTRIBUTIONS WITHIN JARRAH FOREST

The results of the analysis of bird distributions amongst floristic associations and in relationship to structural characteristics of the vegetation were presented in Chapter 4 (Tables 8 and 9). Interpretations of relationships between particular bird species and microhabitats within the study area are presented here.

4. STATUS AT SCENIC DRIVE

A comparison of avian communities in healthy and disturbed jarrah forest and a rehabilitated mine-pit at Scenic Drive was presented in Chapter 4 (Tables 10 and 11). Comments on the status of each species at the site are given here.

The foraging habits of all species in the Serpentine jarrah forest are shown in Figure 11. The records are presented in a variety of ways appropriate to the types of birds and amounts of data that were obtained. Seasonality in foraging habits was considered whenever sufficient observations were obtained. The species are considered in the order of presentation in Table 5, as members of particular foraging guilds, although the analysis shows that many do not in fact slot comfortably into any single category.

Foraging observations were also gathered in the various habitats at Scenic Drive. These will be discussed where appropriate but are not presented since sample sizes were small and most observations duplicated those obtained at Serpentine. Exceptions were made of the Red-Winged Wren, for which few data were obtained at Serpentine, and the Western Silvereye, which foraged extensively in the rehabilitation (Table 10).

6. BREEDING SEASONS AND NESTING REQUIREMENTS

Too few nesting records were obtained per species to permit a detailed assessment of habits but any indications that a species

might be retarded in its return to the rehabilitated mine-pit by nesting requirements are noted.

7. SUMMARY OF FACTORS RELEVANT TO CONSERVATION

The likely impact of mining on the occurrences of the species in South-western Australia is summarised, with recommendations for particular rehabilitation methods and further research.

Figure 10. Changes in jarrah forest bird species' densities.

Changes in density of the bird species that occurred in the Serpentine study area (Tables 5 and 6) are shown for the research period (mean densities greater than 0.5/10 ha, only). Also given are any environmental variables with which the changes were significantly correlated and the percentages of variance explained.

These variables were:

Sweep-net arthropod abundance (Figure 3)

- Species Richness (Sweep-net Sp. R.)
- Biomass Index (Sweep-net Biom.)

Sticky-trap arthropod abundance (Figure 4)

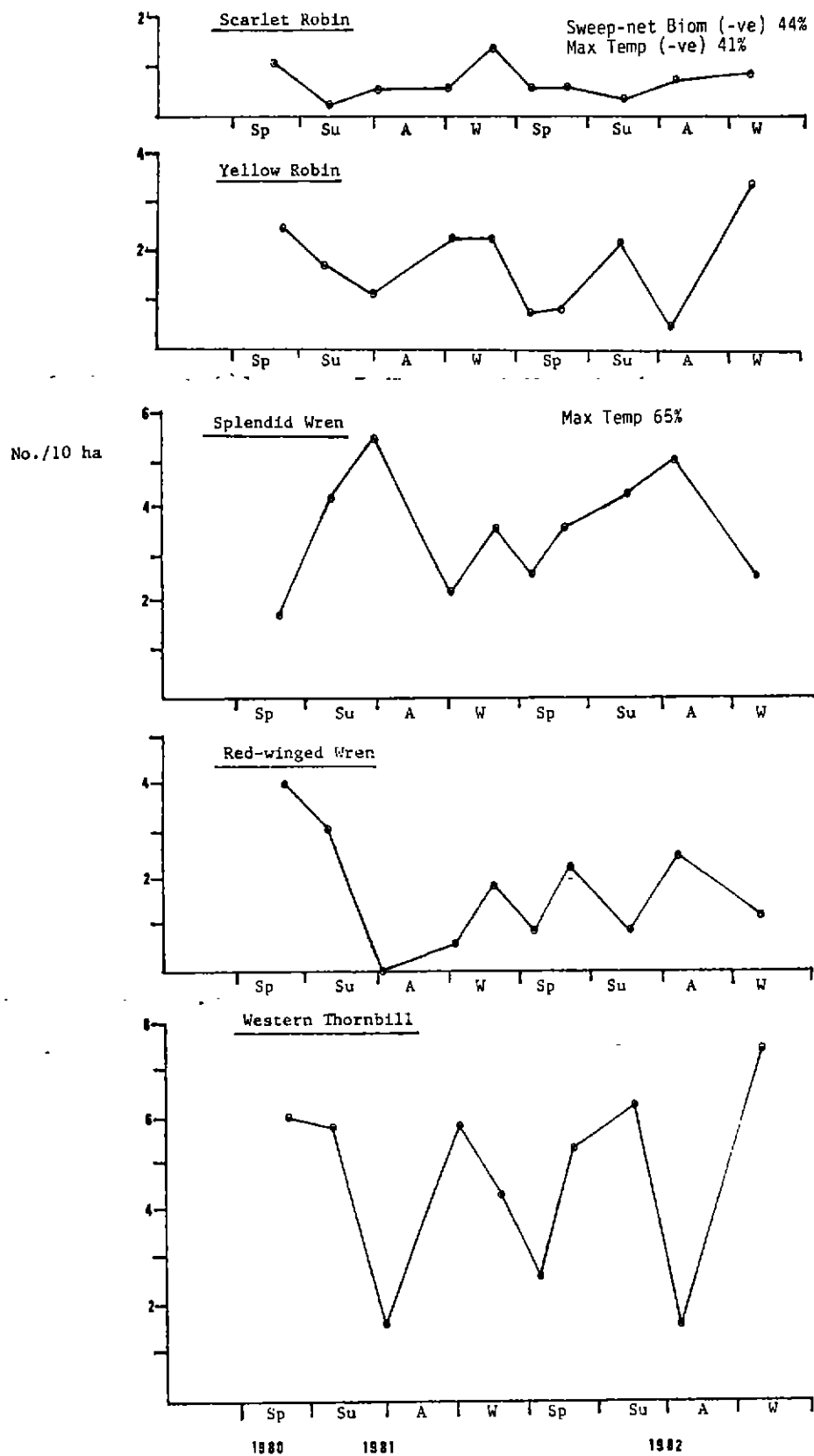
- Species Richness (Sticky-trap Sp. R.)
- Biomass index (Sticky-trap Biom.)

Nectar abundance (Figure 5)

- Adenanthos barbiger (Adenanthos)
- Banksia grandis (Banksia)
- Dryandra sessilis (Dryandra)

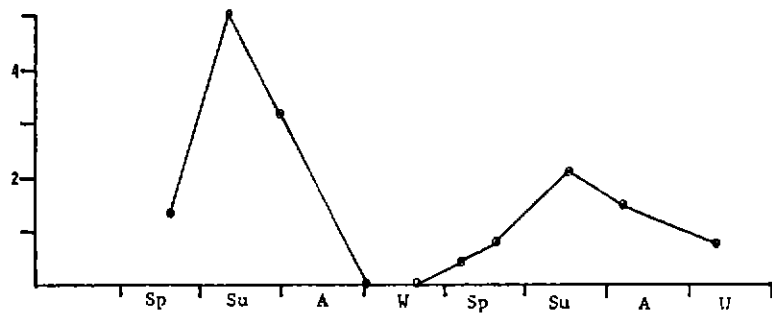
Climate (Figure 7)

- Mean maximum temperature per month (Max Temp)
- total Rainfall per month (Rainfall).



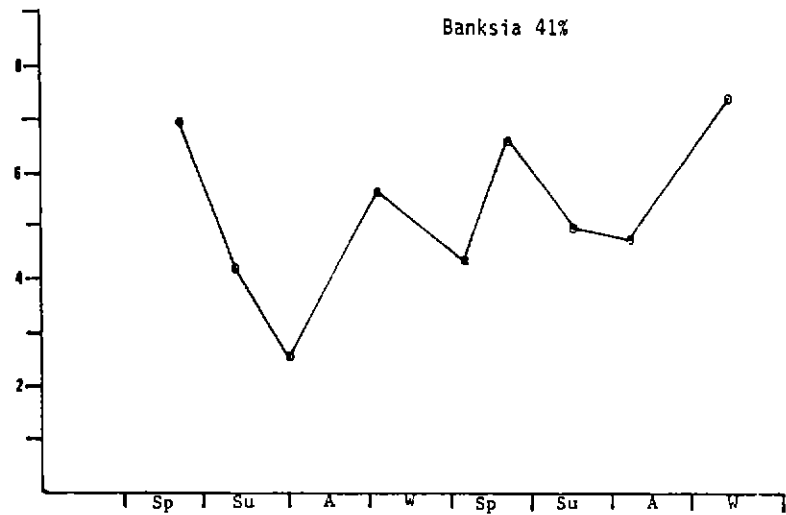
Western Silvereye

Max Temp 75%
Rainfall 50%



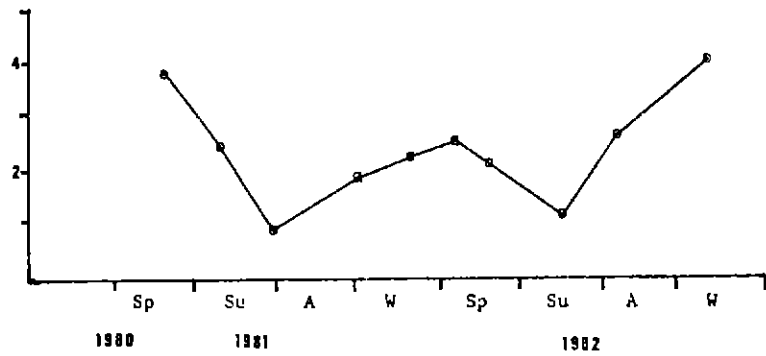
Broad-tailed Thornbill

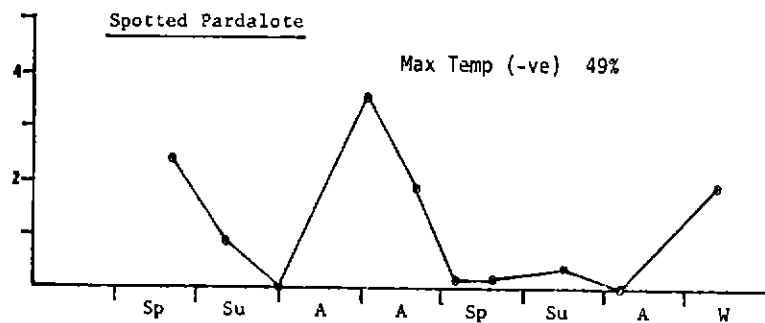
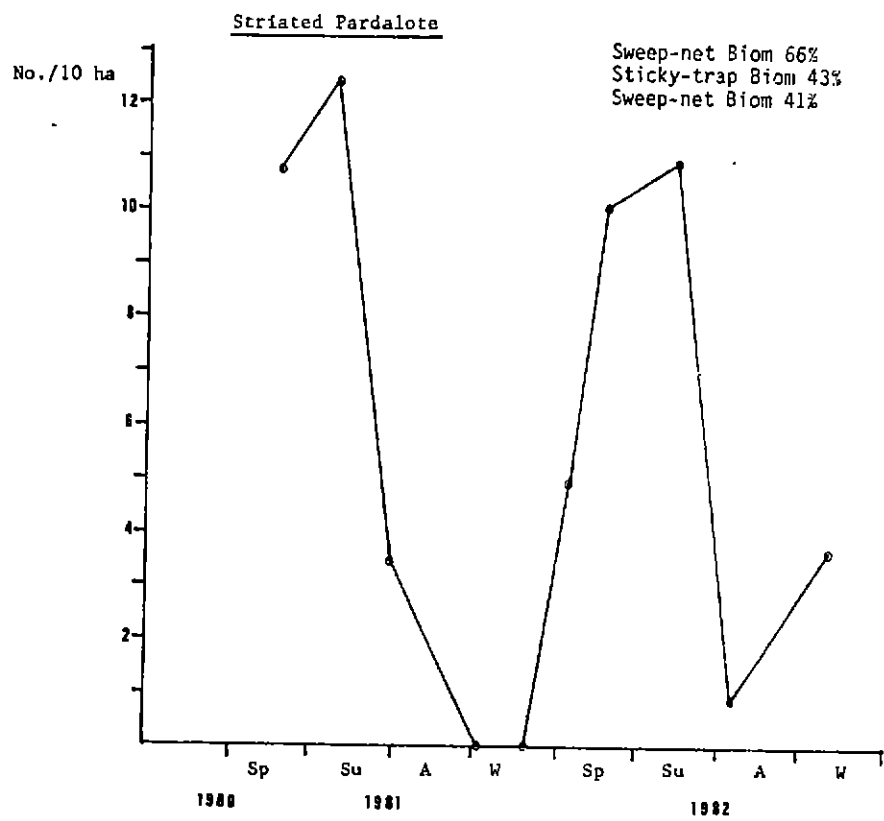
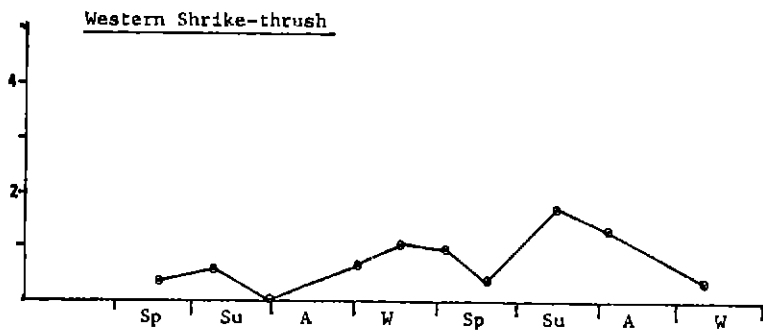
Banksia 41%

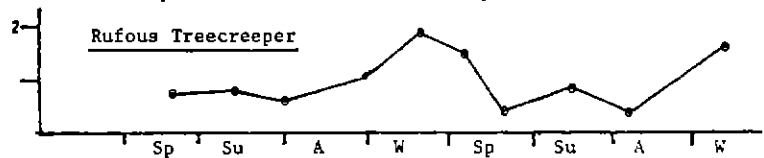
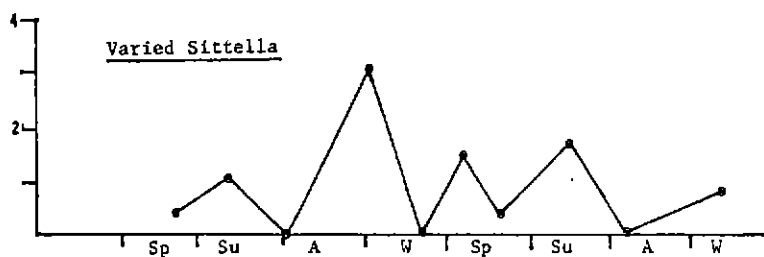
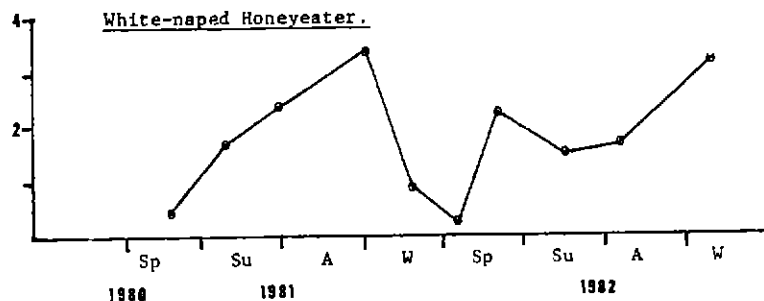


Golden Whistler

No./10 ha

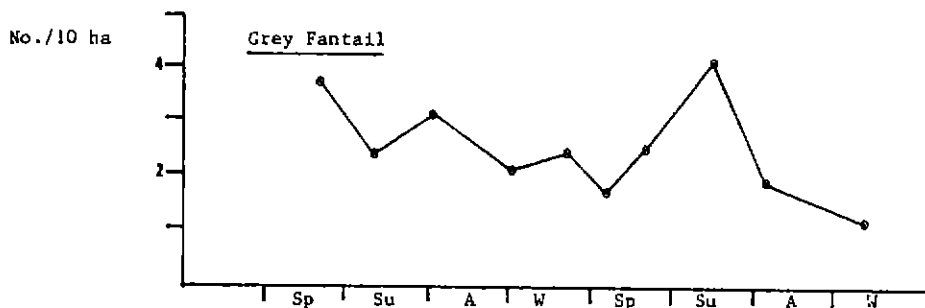
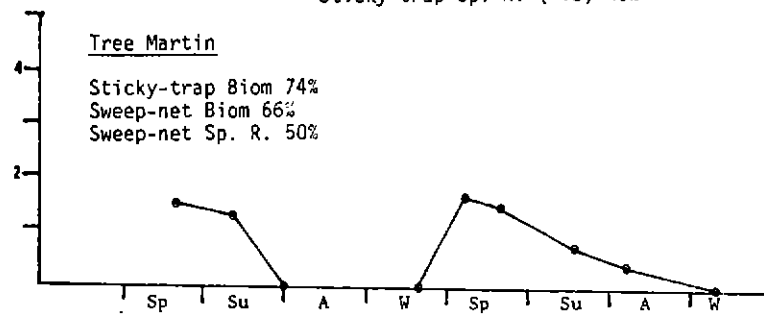


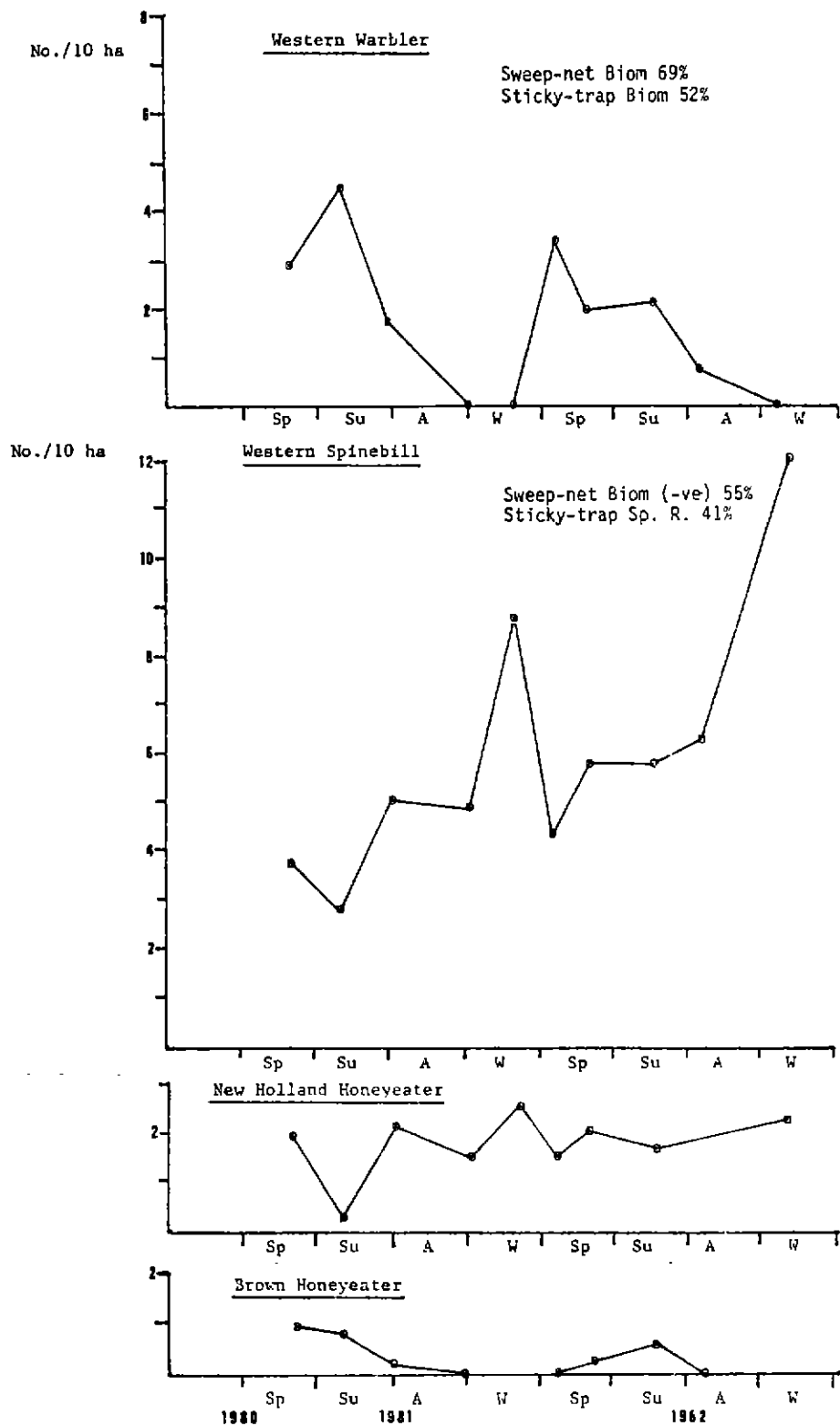




Rainfall 64%
 Dryandra 54%
 Sticky-trap Sp. R. (-ve) 49%

Max Temp (-ve) 44%
 Adenanthos 39%





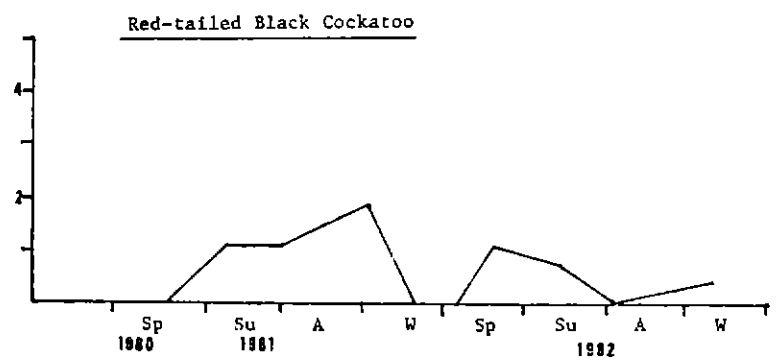
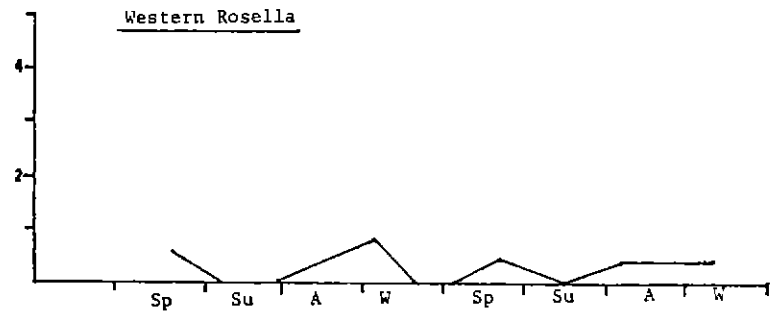
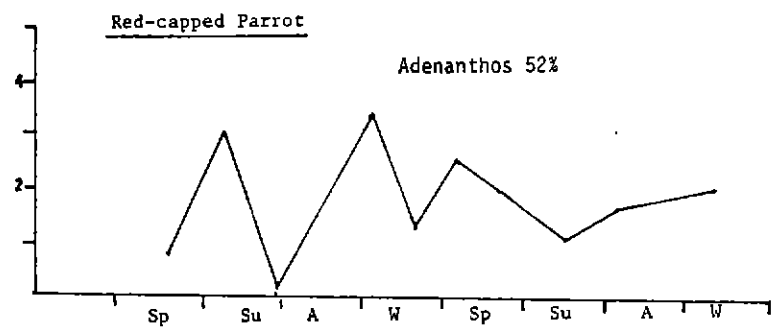
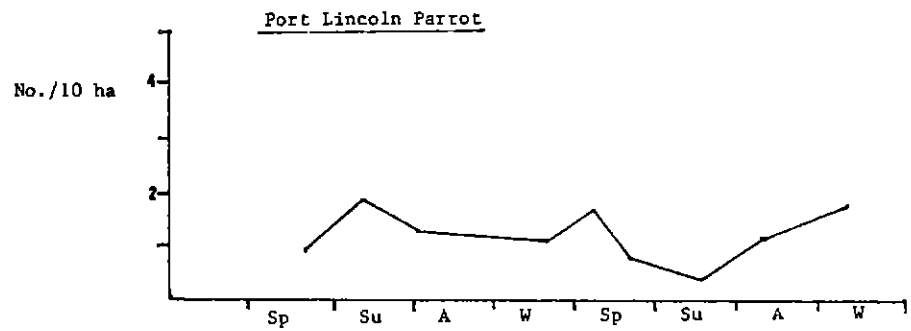


Figure 11. Foraging behaviour of the jarrah forest birds.

Foraging observations are presented for those species at Serpentine on which sufficient observations were obtained. These are grouped into seasons where possible but otherwise pooled for the research period. The records for two species at Scenic Drive - Red-winged Wren and Western Silvereye - were included (see text).

The stratum, plant species utilised and station were noted for each record of a bird feeding (see methods). Subdivisions in the foraging station categories were:

- Ground - litter or logs;
- Bark - trunk (upright, supporting structure of a tree, >20mm diam),
 - limb (major trunk appendage, 10cm diam, > 10cm diam, and including trunks of 20cm diam);
 - branch (wood structure of 3-10cm diam);
 - twig (<3cm diam);
- Air - snatch (active pursuit amongst vegetation),
 - hover (bird airborne, prey on substrate),
 - hawk (bird and prey airborne).

The records for Gramnivorous species were more appropriately tabulated than graphed.

Fig. 11 (i) Ground-Foraging Insectivores

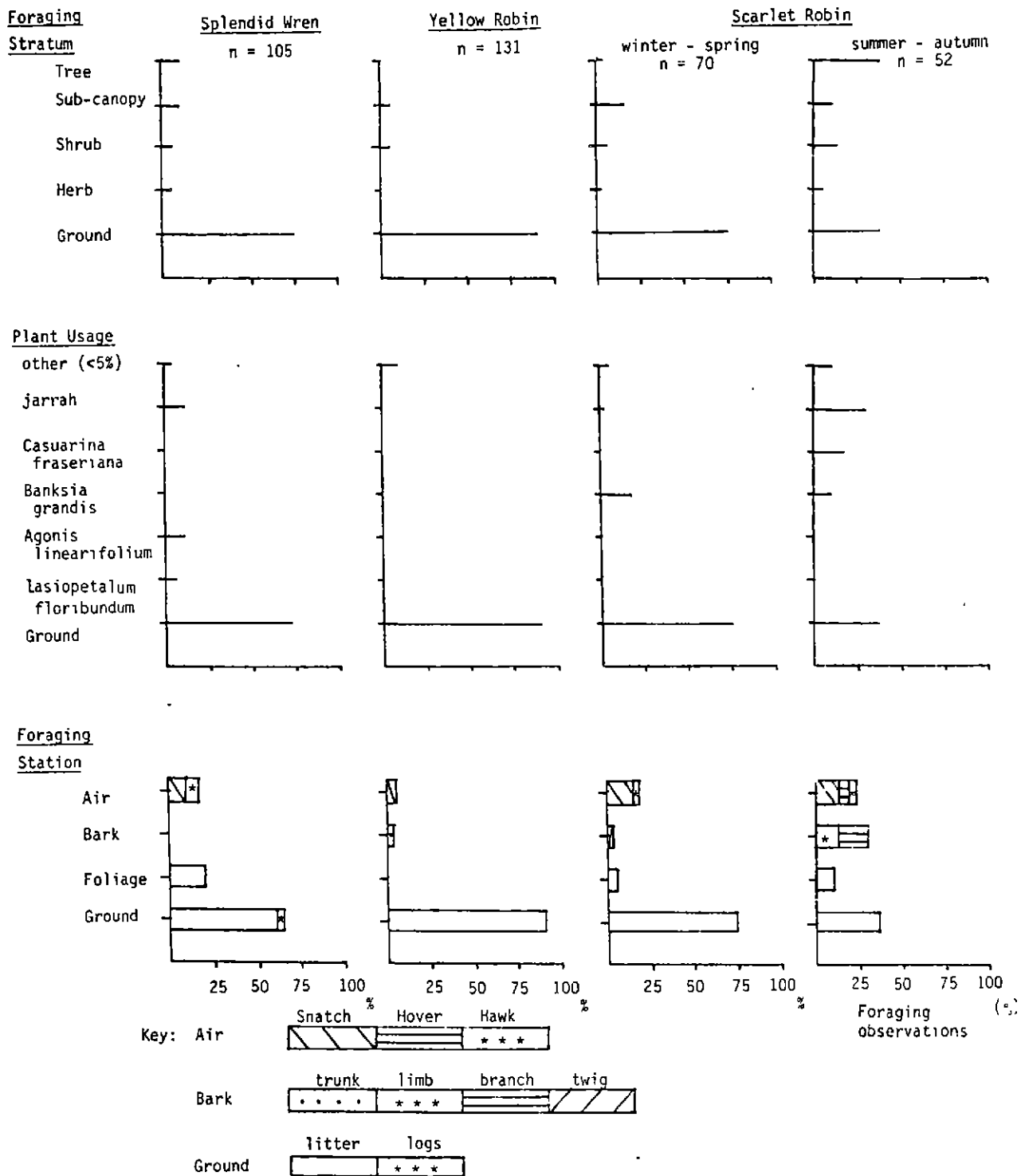


Fig. 11 (ii) Shrub-foraging Insectivores

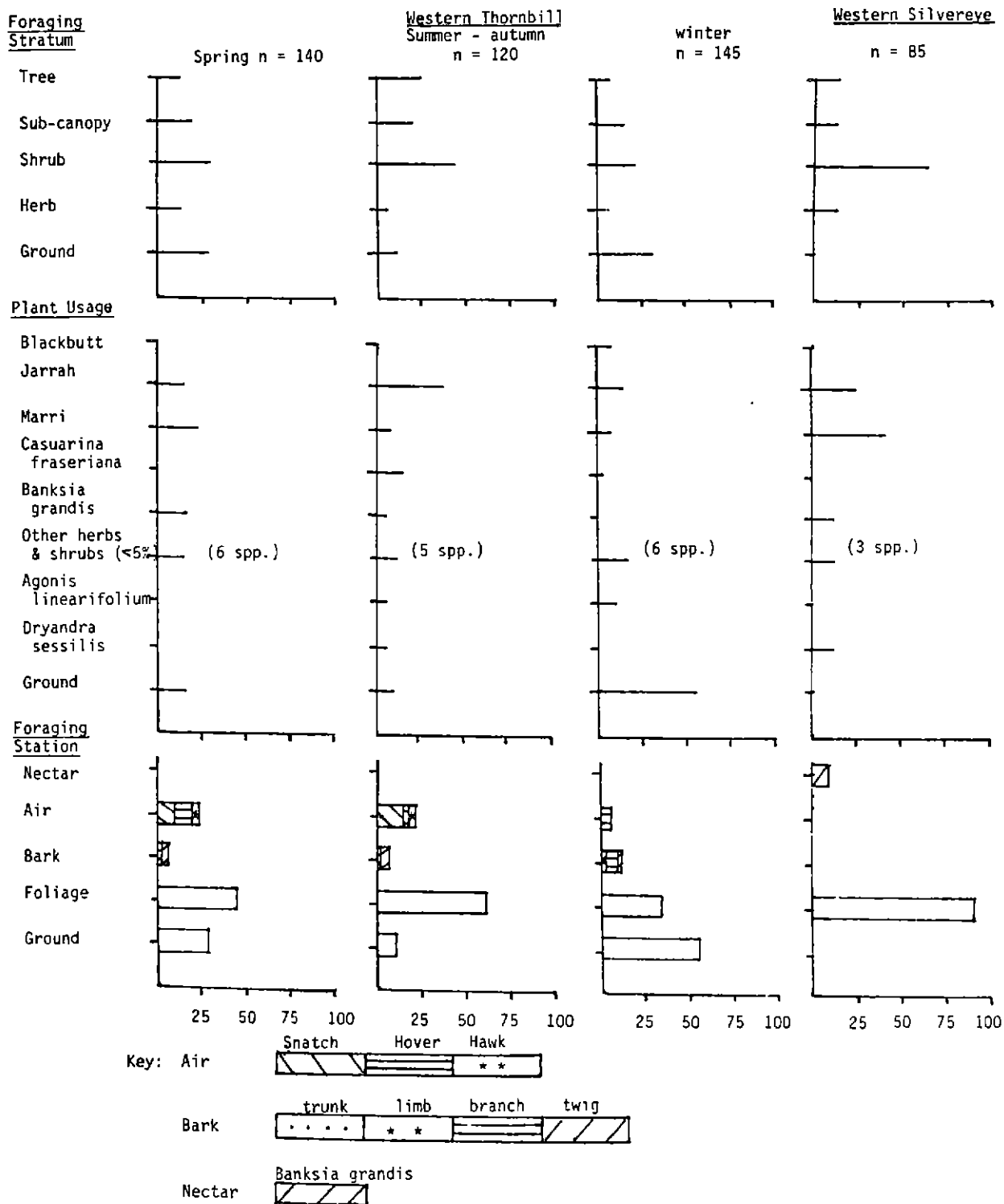
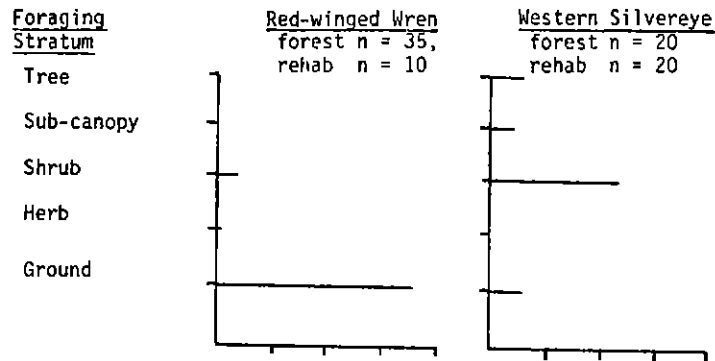
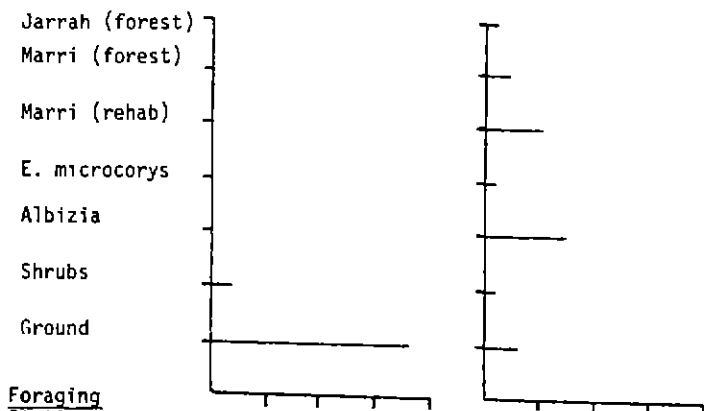


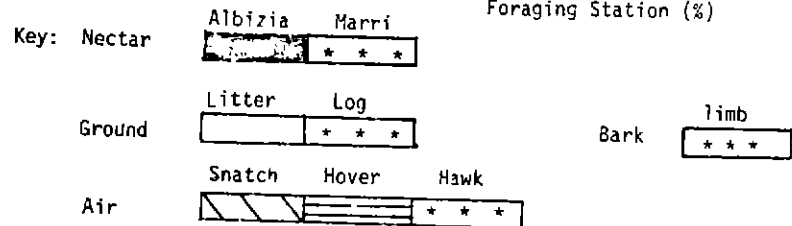
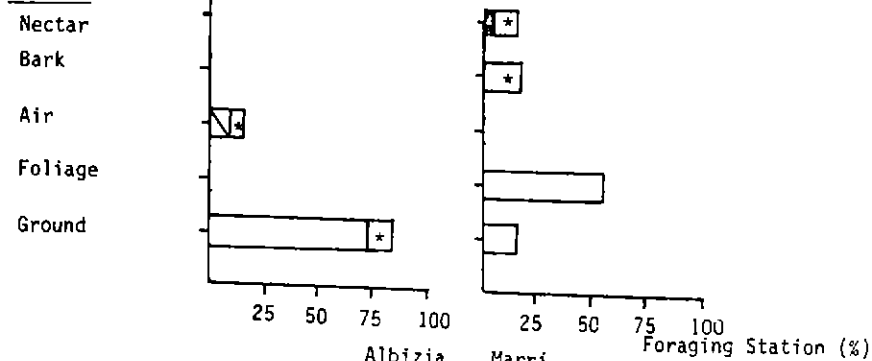
Fig. 11 (ii) Shrub-foraging Insectivores - Scenic Drive observations



Plant Usage



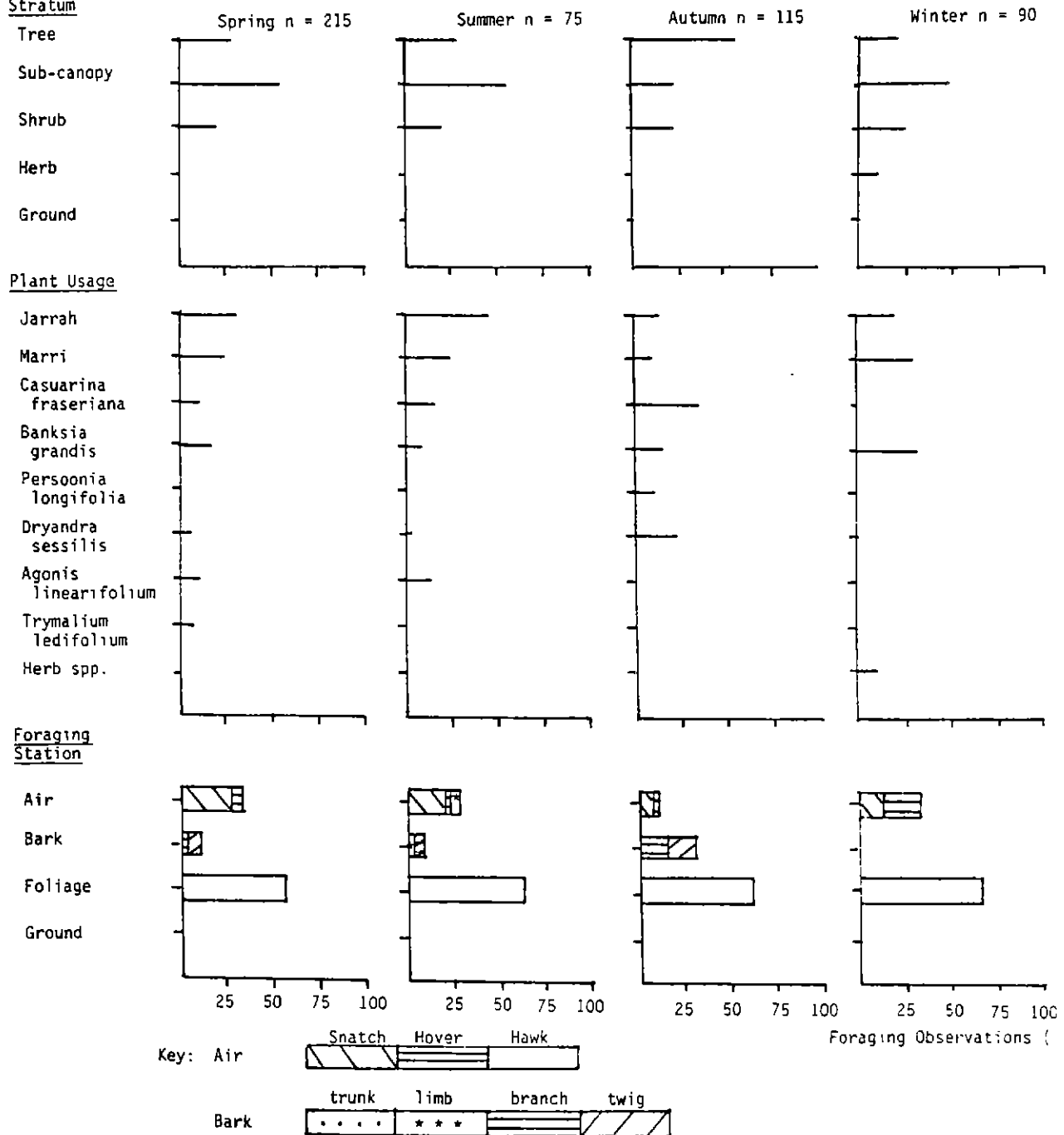
Foraging Station



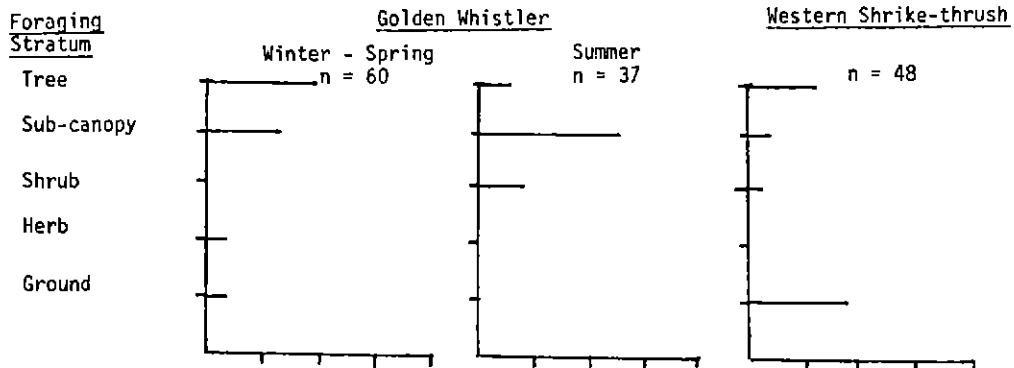
(iii) Tree-foraging Insectivores

Foraging
Stratum

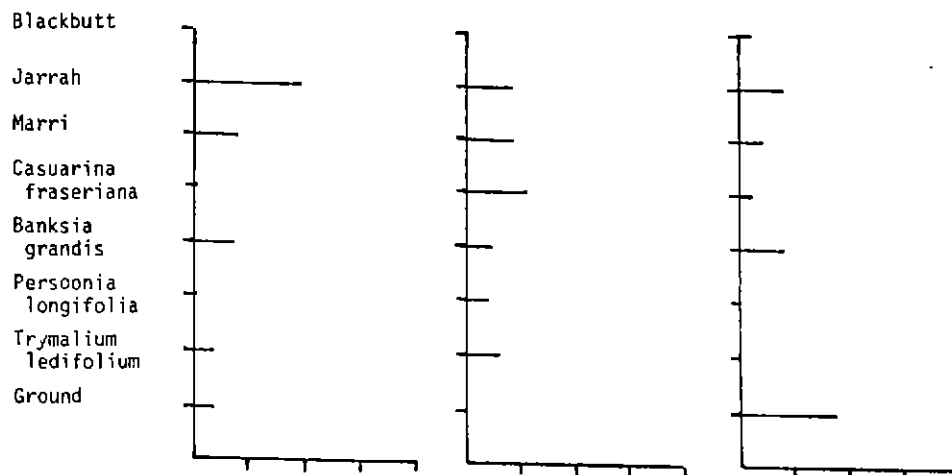
Broad-tailed Thornbill



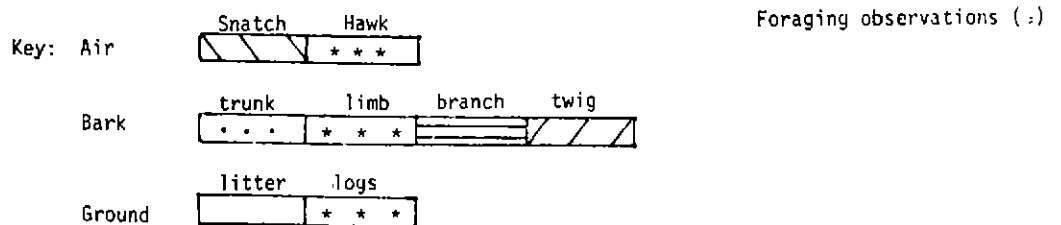
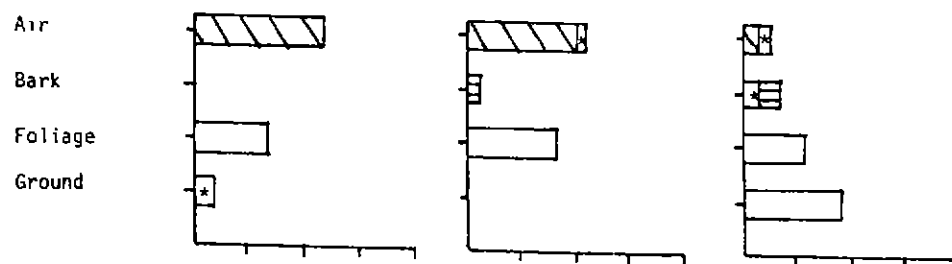
(iii) Tree-foraging Insectivores cont.



Plant Usage



Foraging Station

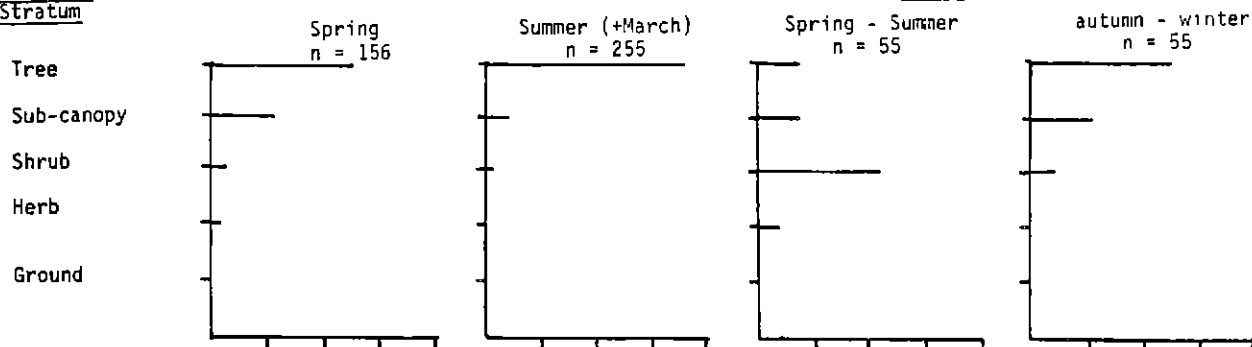


(iii) Tree-foraging Insectivores cont.

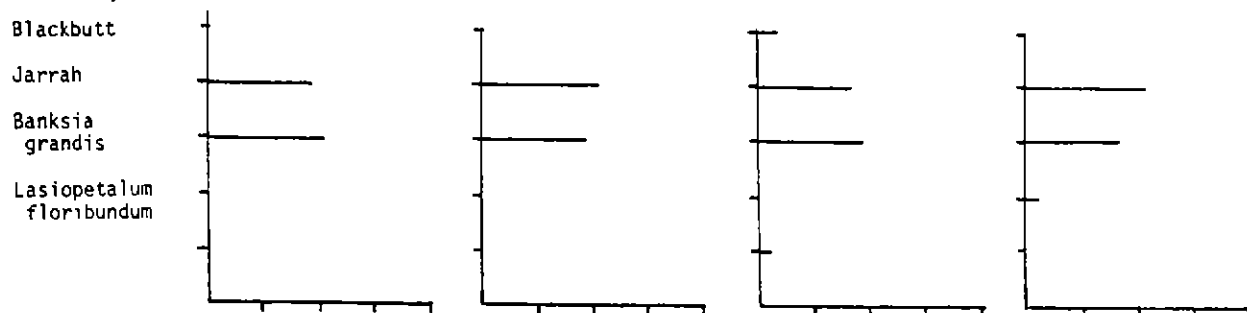
Foraging Stratum

Striated Pardalote

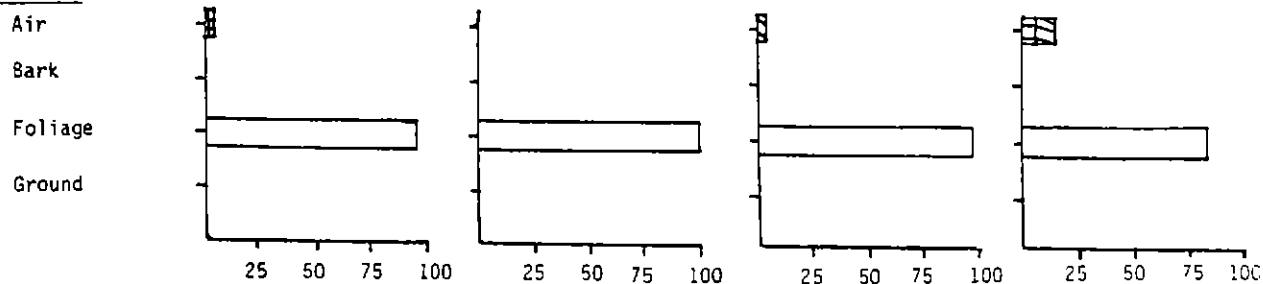
Spotted Pardalote



Plant Usage



Foraging Station

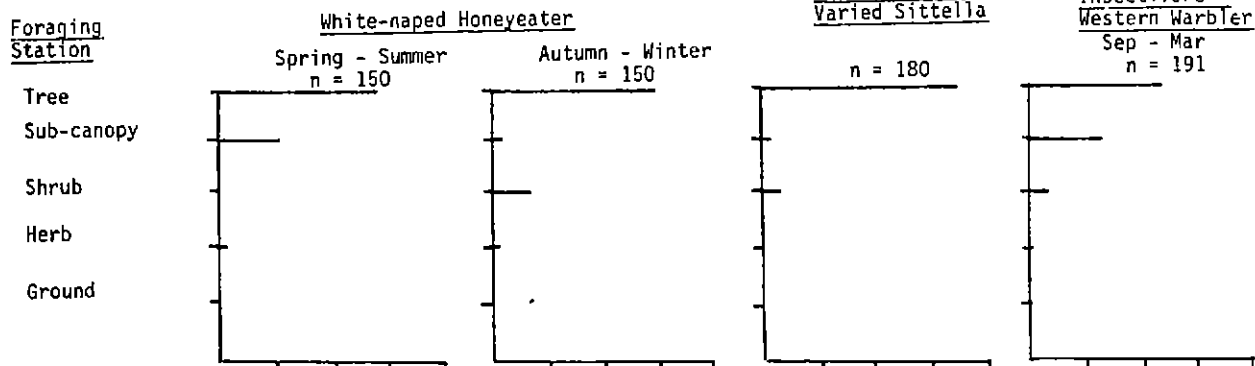


Key: Air

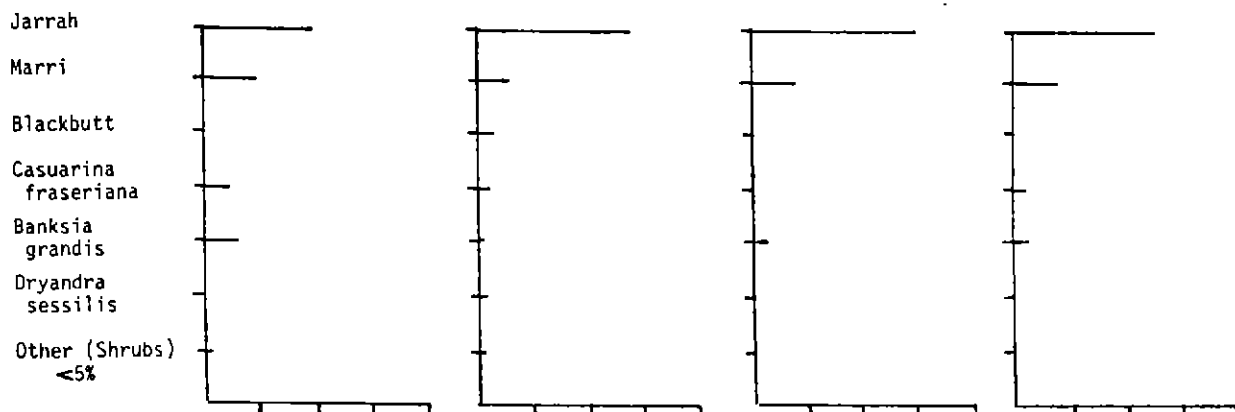
Snatch	Hover	Hawk
▨	▨	▨

Foraging observations (%)

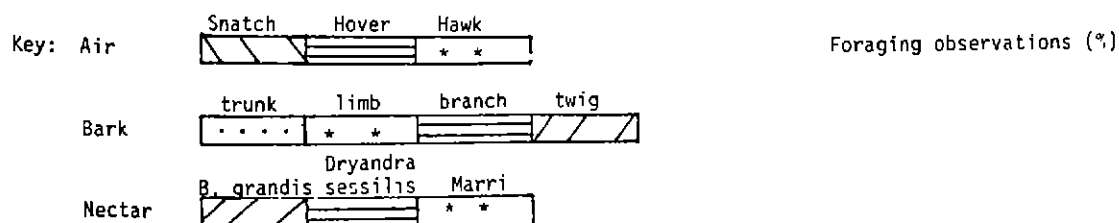
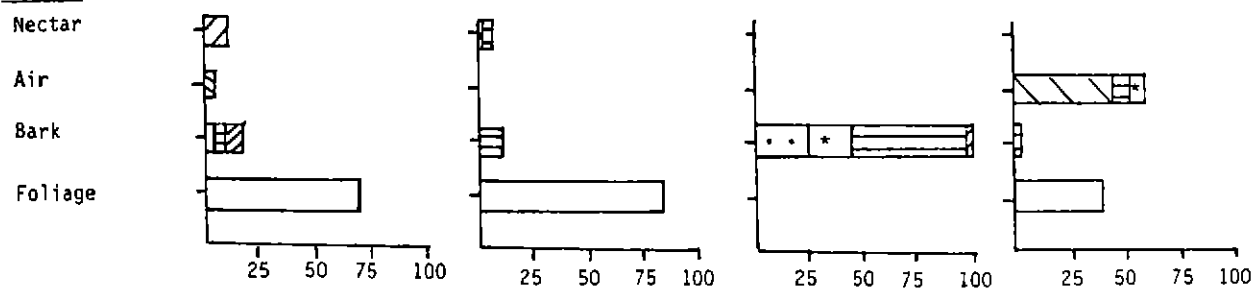
(iii) tree-foraging Insectivores cont.



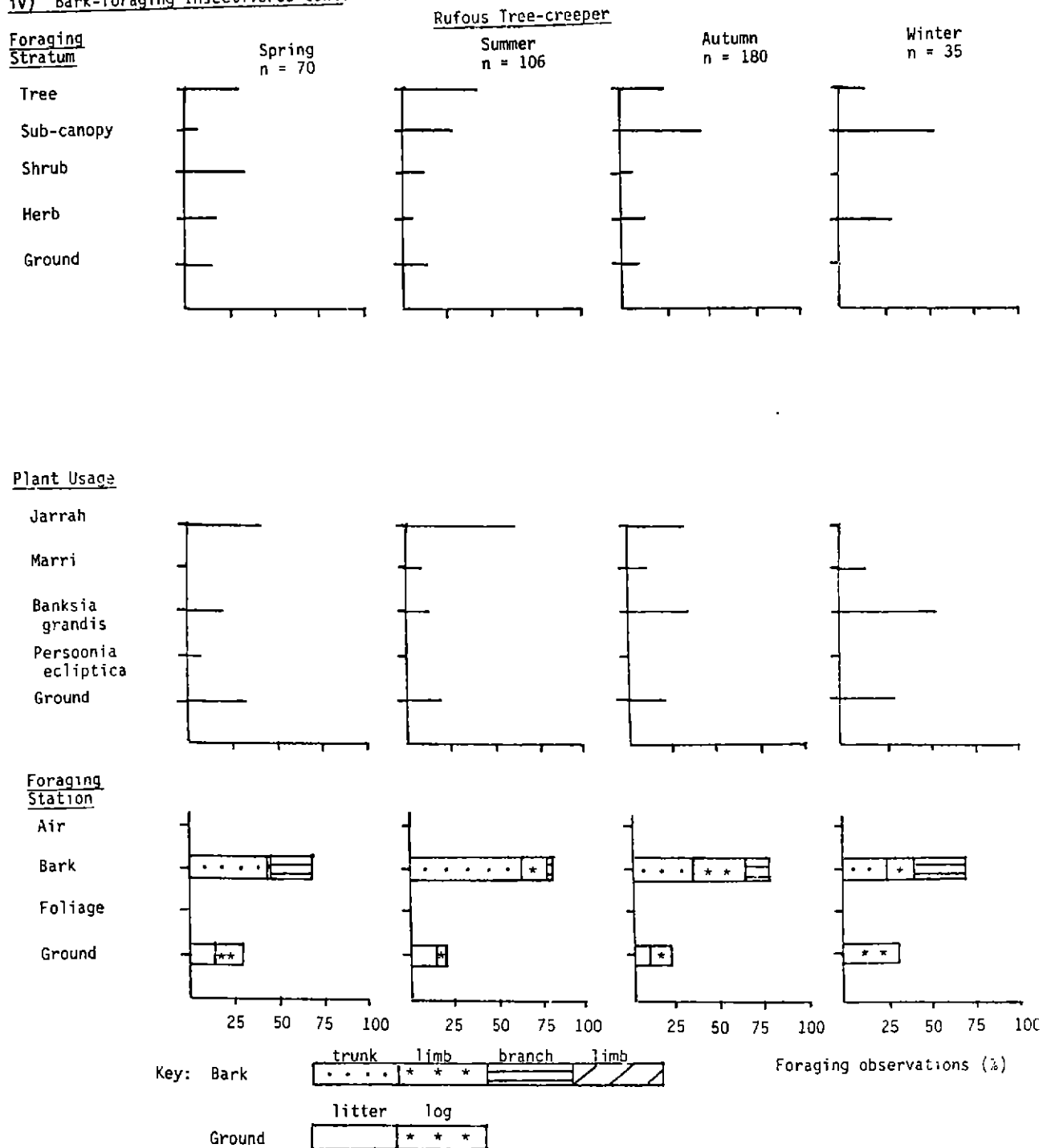
Plant Usage



Foraging Station

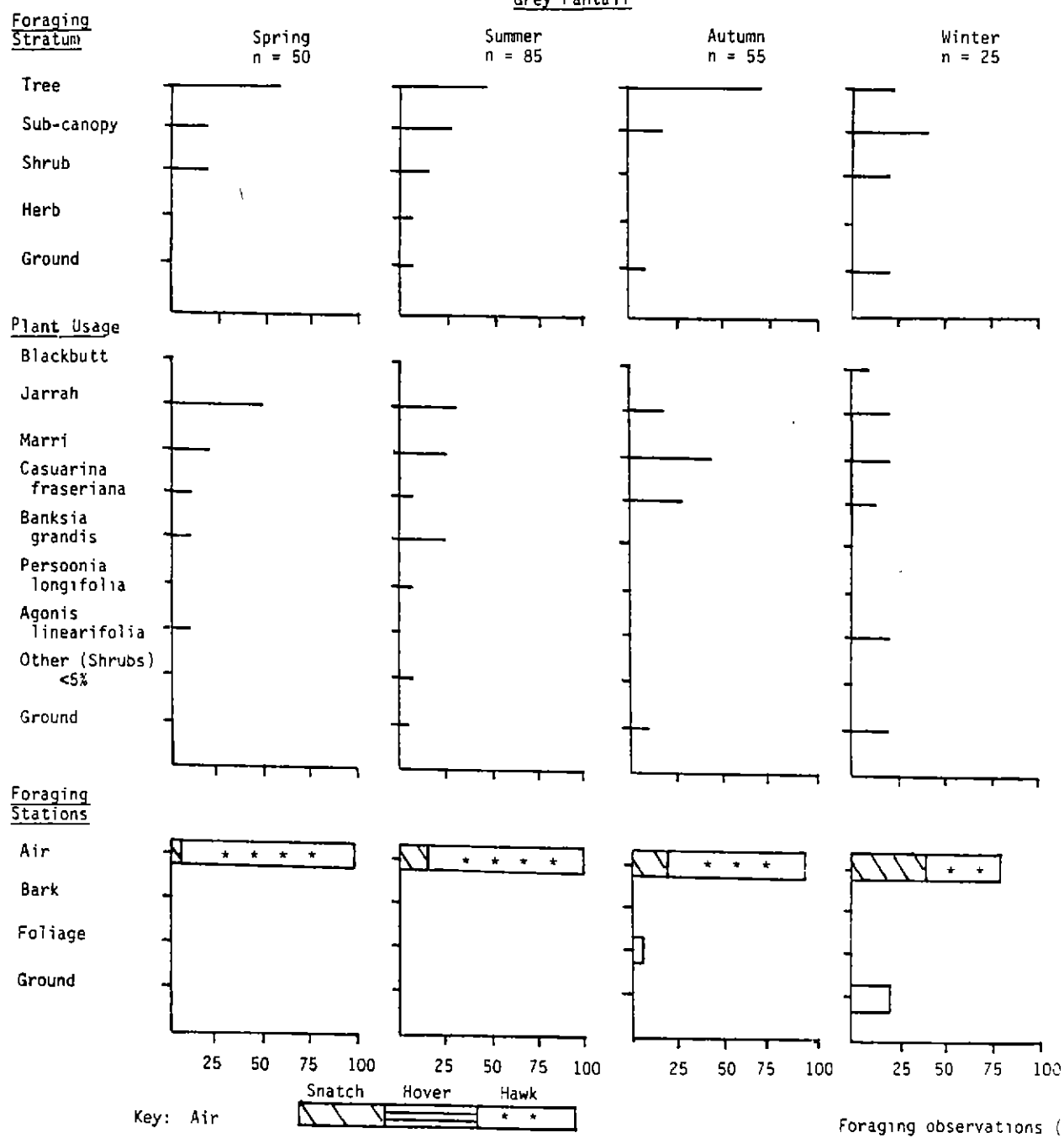


iv) Bark-foraging Insectivores cont.

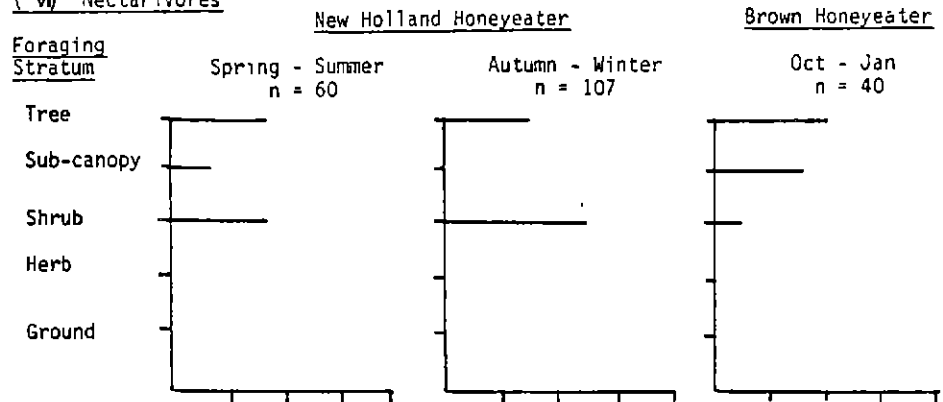


(v) Air-foraging Insectivores cont.

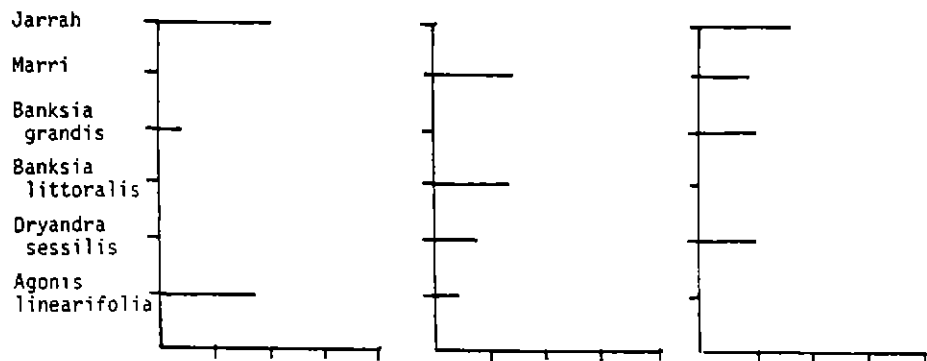
Grey Fantail



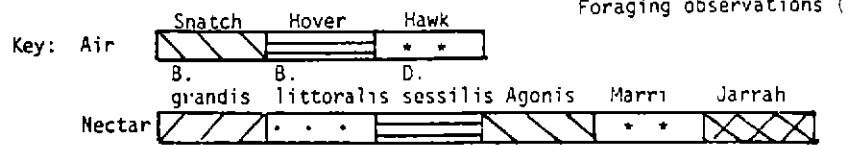
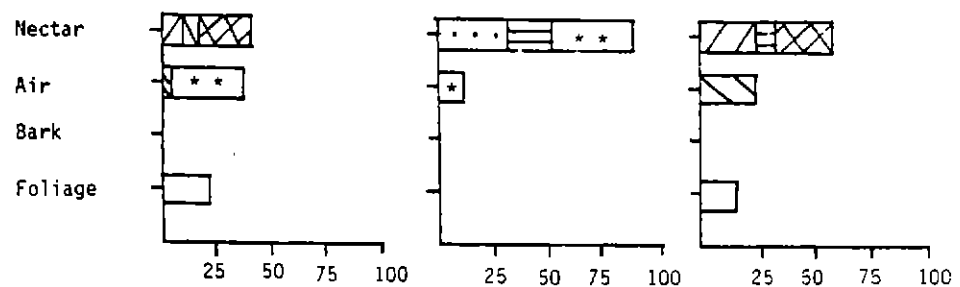
(vi) Nectarivores



Plant Usage

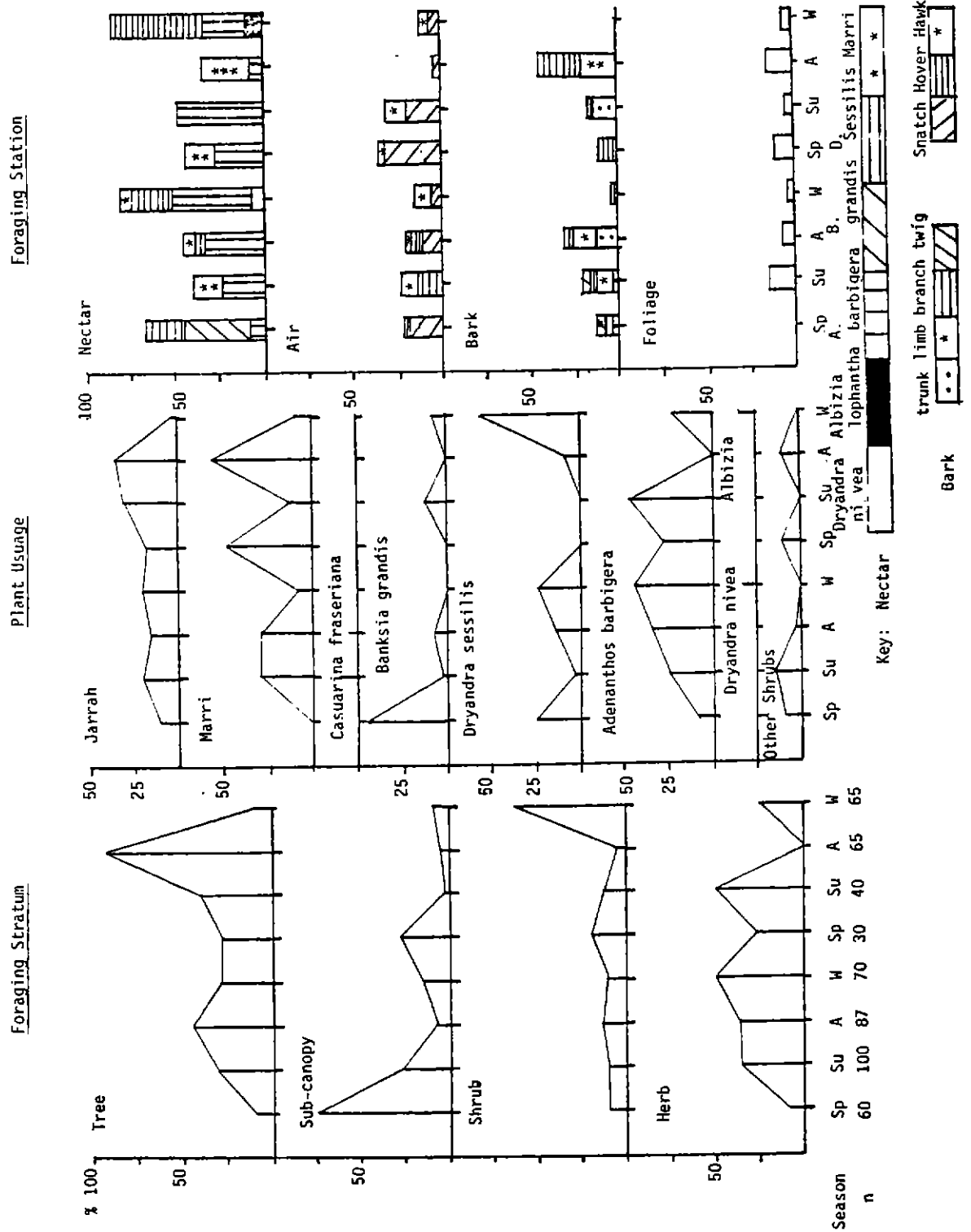


Foraging Stratum



(v1) Nectarivores

Western Spinebill



Season	Spring 1980	Summer 80-81	Autumn 1981	Winter 1981	Spring 1981	Summer 1982	Winter 1982
Red-capped Parrot							
n	30	60		45	35	35	5
Food Source	Jarrah seed 66% B. grandis 34%	Harri seed 66% Casuarina fraseriana seed 33%		Harri seed	Jarrah seed 14% Acacia elata 43% A. pulchella 43%	Harri seed 57% Jarrah seed 43%	Harri seed
Port-Lincoln Parrot							
n	35	30	100	20	25	25	35
Food Source	B. grandis	Xanthorrhoea gracilis 66% psyllid (Hemiptera) 33%	Jarrah seed 70% B. grandis 25% leaf petioles, Harri flowers 5%	Harri fruit 50% Baeckea camphorosmac 50%	Harri fruit 33% B. grandis pollen 66%	Jarrah seed 66% Acacia pulchella seed 33%	Harri fruit
Red-tailed Black Cockatoo							
n	55	25	65	185	70	40	75
Food Source	Harri seed	Casuarina fraseriana seed	Jarrah seed	Jarrah seed	Jarrah seed	Jarrah seed 50% Harri seed 50%	Jarrah seed
White-tailed Black Cockatoo							
n			10		15		30
Food Source			Harri seed		Jarrah seed		B. littoralis seed
Western Rosella							
n				20	5		15
Food Source				Baeckea camphorosmac Physalis peruviana (Cape Gooseberry) fruit 50%	B. grandis pollen		Harri seed 66% Harri leaf-petioles 33%

5.2 RESULTS 1) GROUND FORAGING INSECTIVORES.

Australian Raven

1. Widespread in Australia, most common in farmland.
2. Uncommon resident at Serpentine (mean 0.1/10 ha).
3. Common on the edge of the jarrah forest. A pair nested at Serpentine in a tall trees 0.5 km into the site, but generally foraged in nearby farmland.
4. Some usage of rehabilitation vegetation by pairs nesting in forest was recorded at Scenic Drive (Curry and Nichols, 1985).
5. No foraging records. Generally a ground foraging omnivore that thrives on carrion, grain and insects in farmland. Such items would presumably be much less abundant in the jarrah forest.
6. Builds a stick nest in trees. Rehabilitation sites should be suitable for nesting as they mature but nearby forest is likely to be preferred by the sparsely distributed pairs.
7. Jarrah population of low relevance to status.

Grey Currawong

1. Widespread in southern Australian forest and woodland, including all wooded habitats of the S.W.
2. Sparsely distributed resident pairs in jarrah forest (mean 0.3/10 ha).
3. No significant correlation with particular floristic associations. Correlations with structural variable T4 for two visits indicated occurrence on lower, westerly slopes amongst granite outcrops and on easterly slopes of tall, healthy forest.
4. Occasional occurrence in rehabilitation at Scenic Drive.
5. The pairs at Serpentine foraged amongst thick litter below dense Banksia grandis when infrequently observed undisturbed (20 obs.). The species is omnivorous, feeding on fruit (such as Leucopogon, pers. obs.) and bird nestlings but generally large insects (Frith 1976). It was the only species in the jarrah that foraged by probing into the leaf litter. Frith (1976) also reports feeding under loose bark of trees, a habit not possible on jarrah or marri. A group at the pipe head dam picnic ground area near the study area foraged on picnic scraps.
6. One nest recorded, placed in a tall jarrah. Began in September, fledged in November.
7. The analysis of distribution indicated that currawongs choose habitats with particular characteristics, possibly being

areas with favourable litter invertebrate populations. The low number of fossorial species and the low density of currawongs indicates that litter is generally a poor foraging site in jarrah. This could be manipulated to favour currawongs in the rehabilitation (see discussion) but currawongs are likely to nest in nearby forest until the rehabilitation trees mature.

Western Yellow Robin

1. South-western forest.
2. One of many low-density species (mean 1.8/10 ha) for which apparent fluctuations in density (Figure 10) probably resulted from sampling short-comings.
3. Yellow Robin distribution was significantly correlated with four structural variables which indicated occurrence in dense vegetation where a relatively rich litter layer and numerous trunks would provide attractive habitat for this trunk-perching, ground-forager. These positive correlations were with T3, which was high along some creeks and on westerly slopes; VL6, which had low values in disturbed areas; VL 3, which was high along creeks; and T5, which was high in healthy forest or ridges.
4. Regularly recorded in healthy jarrah and rehabilitation at Scenic Drive.
5. Yellow Robins foraged by observing the ground from a perch until dropping down to land and grab arthropod prey. They perched sideways on large and small trunks of Banksia grandis, Casuarina fraseriana, jarrah saplings and fallen limbs at 1-2 m height. Most items were unidentifiably small but an occasional centipede and grub were noted. Frith (1976) records the diet as ground-dwelling ants, spiders, beetles and cockroaches. The robins often dropped through dense shrubbery onto the prey. The Yellow Robin is a co-operative breeder that occurred in family groups (Brown and Brown, 1980). Groups might be more effective than individuals at detecting prey-rich patches even though the robins rely on stealth to catch the prey. Similarly, robins were often associated with the mixed-species flocks that formed around wren and thornbill groups (see below).
6. The nests are generally placed low down in trees and shrubs (Frith, 1976). Groups bred in various rehabilitation plots and in jarrah forest at Scenic Drive (Curry and Nichols, in prep.) and at 17 m in a jarrah of lower, western slope at Serpentine.
7. A typical jarrah forest species that favours habitat with a dense understorey such as is at present provided by the rehabilitated vegetation. Future management of the habitat in terms of shrub-layer density and litter build-up will affect robin density.

White-breasted Robin

1. South-western forest.
2. Very scarce in the study area (0.1/10 ha).
3. The few birds observed were close to the pipe-head dam in creek vegetation. The species appears to favour denser shrub-layer habitat than does the closely related Yellow Robin and is found more commonly in southern jarrah and Karri forests (Serventy and Whittell, 1976).
4. Not at Scenic Drive but occurs in a rehabilitated plot with a very dense, tall shrub-layer of acacia (Collins et al, in press).
5. Forages similiary to the Yellow Robin but many tend to perch lower (pers. obs.; Frith, 1976). Forages in family groups and is a co-operative breeder (Brown and Brown, 1980).
6. Nests low down in creek vegetation (Serventy and Whittell, 1976). Juveniles recorded in some rehabilitation pits (Curry and Nichols, 1985).
7. A species restricted to forest habitat with a tall, dense shrub-layer, such as along creeks. Suitable habitat can be produced in mine-pits, at least initially, by excessive seeding with acacia. Future burning regimes are likely to determine whether this shrub-layer remains.

Scarlet Robin

1. Southern Australian species of which an isolated sub-species Petroica multicolor campbelli occurs in woodland and forest of the south-west.
2. Low density (mean 0.7/10 ha), with fluctuations negatively correlated with sweep-net Biomass and Temperature (Figure 10). These correlations were unlikely to result from long-distance movements but the population may move to coastal plain or inland jarrah forest during the winter.
3. Vegetation with high values of T6, which occur on disturbed and undisturbed western slopes and along some creeks, was favoured during three visits. This habitat, in which large, old trees remained, had an open ground-layer with relatively deep litter build-up, but did not have numerous trunks for perching. The analysis suggests that the Yellow Robin tended to occur in vegetation with a denser understorey and generally moister conditions than did the similar Scarlet Robin.
4. Primarily in jarrah and only occasionally in rehab. at Scenic Drive.
5. The Scarlet Robin is known to drop onto prey from low perches, similarly to the Yellow Robin (Frith, 1976). This was so in wet, winter periods, when perches of 0.5-2m were used. However, prey were also snatched and plucked from

foliage and bark in the sub-canopy and tree strata and this was the most frequent mode in summer and autumn (Figure 10). This seems contrary to Carati's (1980) finding that large litter invertebrates were most abundant in summer (Chapter 3) but he worked in mature jarrah forest with a dense shrub-layer. Nichols and Watkins (1984) found Yellow but not Scarlet Robin's at this site in a summer survey. Scarlet Robin's favoured habitat was open shrub-layer at Serpentine where the relatively shallow litter was likely to have a poor fauna during hot, dry conditions. Thus, Scarlet Robin's turn to arboreal invertebrates, which are at peak abundance in summer (Chapter 3). They capture these using a wait-and-pounce technique similar to that used on the ground.

The few Scarlet Robins sighted in rehabilitation at Scenic Drive were in the peripheries and no foraging was recorded.

6. All Scarlet Robin nests were in the tree-layer, which contrasts with shrub-layer nesting of the Yellow Robin, and correlates with the tree-layer foraging in the summer. No nests were recorded in rehabilitation.
7. Scarlet Robins are typical jarrah species not yet utilising rehabilitation to any extent. This will not affect their status in Western Australia since they are widespread. Furthermore, they are likely to colonise rehabilitation when the trees mature if the shrub-layer opens up. However, this would be at the loss of species that at present favour dense shrubbery (Chapter 6).

Splendid Wren

1. A southern Australian species, generally of inland distribution, of which the race Malurus splendens splendens occurs in the south-west.
2. Relatively common (3.5/10 ha) and likely to be underestimated since it occurs in dense shrubbery. They were most detectable, as well as more numerous, when with fledglings in summer and autumn, and density consequently fluctuated in positive correlations with temperature over the research period (Figure 10).
3. Splendid Wren distributions were significantly correlated with stream vegetation (F.A.'s 9 and 8) for two spring visits and for the total research period. However, wrens were at times recorded in all associations, including the highly disturbed, depauperate forest (F.A.'s 1 and 2). Correlations with structural characteristics supported these results. There were many positive correlations with tall, dense shrub-layer (V.L. 3), with the dense understorey below mature forest of lower, western slopes (V.L. 2), and indications of occurrence in open areas in autumn and winter (negative correlations with T1 and Total Trunks).
4. Common in jarrah and rehabilitation at Scenic Drive and also ranged into disturbed jarrah.
5. Splendid Wrens mainly foraged amongst litter under dense

shrubby and sometimes in the open. However, they at times ventured into all vegetation strata. Small insects such as ants were gleaned while active insects were gained by snatching amongst foliage and leaping from the ground. The occasional large items were bashed before being eaten. Few observations were obtained on the birds when in dense shrubbery, where more feeding from leaves and twigs would be expected. Small, litter invertebrate populations were considered to be seasonally depauperate in the jarrah forest (Chapter 5.3), which could explain why the wrens were closely associated with creek vegetation where abundances are probably higher. Foraging observations at Scenic Drive were of ground-foraging in litter, open ground and on logs.

Family groups of Splendid Wrens, consisting of a breeding pair and auxilliary males (often in eclipse, brown plumage) and female 'helpers' (Dow, 1980) foraged together.

6. Parties of wrens with dependent fledglings were recorded by myself and Curry and Nichols (1985) in jarrah forest and rehabilitation. They nest low in dense shrubbery (Frith, 1976).
7. This typical jarrah species has recolonised rehabilitation and is likely to be resident while the shrub-layer is dense, but only a seasonal visitor from streams if vegetation becomes more similar to upland jarrah forest.

White-browed Scrub-wren

1. The spotted form of the White-browed Scrub-wren, Sericornis frontalis maculatus occurs across southern Western Australia and South Australia in woodland and forest.
2. An uncommonly recorded resident (mean 0.3/10 ha) that was difficult to detect in dense, creek vegetation except when reacting noisily to the observer or when singing above the shrub-layer in spring.
3. Too few records for analysis but all were in creek vegetation or the dense shrub-layer of lower, western slopes.
4. The Scrub-wren is a litter forager (Frith, 1976) which presumably obtains its diet of arthropods in thick litter below the dense, stream shrub-layer. It occurs in small parties and is a communal breeder in eastern Australia (Bell, 1983). The one bird observed feeding at Scenic Drive was gleaned in the lower foliage of rehabilitation mallee.
6. Nests low down in dense shrubbery (Frith, 1976). Dependent fledglings occurred in tall, dense acacia of a heavily seeded rehabilitation plot (Curry and Nichols, 1985).
7. A species of jarrah forest streams that colonises rehabilitation when the shrub-layer is tall and dense. Whether this continues as the rehabilitation matures will depend on management policy.

Tawny Frogmouth

1. Common in all areas of Australia where there are trees.
2. Relatively common (0.2/10 ha) given its low detectability when roosted in the day. Most observations were of family groups flushed from sub-canopy perches in the summer.
3. No analysis of distribution but presence of a dense banksia sub-canopy for perching and foraging may be important.
4. No records at Scenic Drive.
5. Frogmouths were plentiful along roads and tracks during an evening of spot-lighting in early 1981 (10 + birds in 2 hours) near Serpentine. They were all at perches 1-3 m above the ground, or on the ground. They forage by pouncing onto ground-dwelling insects and spiders (Frith, 1976).
6. Nests placed in trees. Adults with fledglings were recorded at Serpentine in summer.
7. The frogmouth is a widely distributed species that is plentiful in jarrah forest. The rehabilitation shrub-layer at Scenic Drive may be too dense to permit foraging at present but should attract birds if it opens as it matures and the dense tree regrowth should provide attractive roosts.

Bookook Owl

1. Distributed throughout Australia.
2. Occasionally disturbed at roosts (mean 0.2/10 ha). Probably a relatively sparse but typical species in jarrah.
3. Disturbed from areas where there was dense sub-canopy foliage for perching.
4. Not recorded at Scenic Drive.
5. The Bookook is the most insectivorous of the owls. It swoops onto the ground for insects such as beetles and crickets, as well as mice. Other insects such as moths and beetles are taken in the air (Frith, 1976). No foraging was observed.
6. Requires a hollow limb or tree trunk for nesting. These are likely to be uncommon in all but mature jarrah forest. One family group was recorded, on a western slope of mature forest with a dense banksia sub-canopy at Serpentine.
7. These nocturnal predators, as with Tawny Frogmouths, are incessantly mobbed by diurnal insectivores if discovered roosting. All birds were found in dense sub-canopy. The rehabilitation vegetation, with its dense saplings, should be suitable for roosting and one expects owls to be recorded there. However, a high priority must be placed on preserving mature trees in nearby forest if suitable nest-sites are to remain available. The rehabilitation might need to become

more open, as it matures, if it is to provide ideal foraging habitat for the owls.

ii) SHRUB-LAYER FORAGING INSECTIVORES

Red-winged Wren

1. A species of streams and swamps in the south-west that is uncommon in northern jarrah forest (Serventy and Whittell, 1976).
2. Regularly recorded but of limited distribution (mean density of 1.8/10 ha in the overall study area). It was difficult to detect when in very dense stream vegetation and estimated density fluctuated over the research period (Figure 10).
3. Generally recorded in F.A.'s 8 & 9 but there were no significant variances in distribution probably due to low densities. However, occurrence in the dense shrubbery along watercourses and on western slopes was shown by correlations with VL 2, VL 3 and T4. Association with the mature forest on western slopes was also emphasised by correlations with T6 and VL 7. There were no negative correlations with variables such as T1, in contrast to the Splendid Wren, suggesting that Red-winged Wrens ranged less into open areas.
4. Occurred in both jarrah and rehabilitation at Scenic Drive. Unlike the Splendid Wren, it was absent from disturbed jarrah.
5. Little appears to be known of the foraging habits of the Red-winged Wren. Few observations were obtained at Serpentine but I assume that, since it is more confined to dense shrubbery than the Splendid Wren, it more frequently gleans from twigs and foliage, as well as amongst litter. However, most foraging recorded at Scenic Drive was on the ground amongst litter. The wren occurred in family groups and is known to have helpers at the nest (Chapman and Rowley, 1978). These joined mixed species flocks in the rehabilitation, in which they were the main ground foraging species. Small items including gleaned ants and snatched flies formed their diet.
6. Nests low down in dense shrubbery. Breeding was recorded at Serpentine and Curry and Nichols (1985) recorded groups with dependent juveniles in rehabilitation.
7. An uncommon species in the Serpentine region that is confined to dense creek vegetation. It is one of the species that surprisingly occurs in the upland rehabilitation pits, attracted by the dense acacia shrub-layer which provides the necessary structural characteristics of its habitat. It should remain in rehabilitation while the shrub-layer remains tall and dense.

Western Thornbill

1. Confined to forest and woodland of the south-west.
2. The Western Thornbill was a common species at Serpentine

(5.6/10 ha). It is not known to migrate (Serventy and Whittell, 1976) but density fluctuated over the study period (Figure 10). The fluctuations may have resulted from local movement away from the study area but no correlations with environmental variables were found.

3. There were no significant variances in distribution amongst floristic associations. Many of the various structural correlates of Western Thornbill distribution reflected occurrence of this ground and shrub-foraging species in open, often disturbed vegetation. Thus there was a negative correlation with VL 5 for Visit 6 (spring), which has low values in tall marri forest and areas of disturbance; a positive correlation with T 6 for Visit 4 (winter), which has high values on both disturbed and undisturbed westerly slopes; a negative correlation with T5 for Visit 3 (autumn), low values of which occurred along creeks and in disturbed areas; and negative correlations with VL 4 (Visits 6 and 9), which had low values in disturbed areas.
4. Western Thornbills were common in the healthy jarrah and rehabilitation at Scenic Drive and occasionally occurred in disturbed jarrah.
5. The small insects that formed the Western Thornbill diet, such as beetles and Hymenopterans (Matthieson, 1973), were primarily taken at foliage. The shrub-layer was most frequently utilised but the ground, sub-canopy and tree layers were also important. There was a shift from ground foraging in winter to tree-layer foraging in other seasons, as also noted for the Scarlet Robin. It appears that the litter provided a winter-spring food reserve less diminished than arthropod populations of upper foliage, while the upper-foliage populations were abundant in summer and autumn. Arthropods in trees were gleaned and actively captured by snatching and hovering. No particular plant species were favoured, with many herb and shrub species, the sub-canopy banksia and casuarina and the two main eucalypt species all being utilised. (Figure 10).

These observations were duplicated at Scenic Drive, where there was active foraging in the jarrah forest shrub-layer (54% of 55 observations) and, particularly in winter, litter-layer foraging in forest and rehabilitation (46%). The Western Thornbill occurs in family groups of around 6 but of up to 10 or more individuals. It is probably a co-operative breeder, as with other flocking thornbills (Dow, 1980). The groups often formed the nuclei for mixed species flocks of insectivores that systematically moved through the habitat, each species in its preferred stratum. This has also been recorded by Sedgewick (1949) and by Bell (1980) in eastern Australia. The mixed species flocks were most prominent during non-breeding periods of low arthropod abundance and appear to increase food finding for all members through efficient patterns of foraging and disturbance of insects (Morse 1970, 1978).

6. Breeding was recorded at Serpentine and by Curry and Nichols (1985) in jarrah islands at Scenic Drive but not in

rehabilitation. Nest sites include loose bark on trunks and stumps, which are plentiful in mature forest but less abundant in rehabilitation.

7. This is a species of open jarrah forest that primarily forages on the litter in winter and amongst foliage of all layers when breeding. The rehabilitation is primarily utilised for winter foraging, which may be due to a shortage of nesting sites. Suitable nest-sites should become more abundant as the vegetation matures.

Western Silvereye

1. The western race Zosterops lateralis gouldi has a south-western distribution.
2. It had a overall mean of 1.5/10 ha in jarrah forest, but there was a regular winter exodus from the study area. Changes in density were highly correlated with monthly temperature and rainfall but not insect food supplies (Figure 10).
3. Silvereyes were significantly associated with water course FA's during one visit. The structural correlates of distribution demonstrated occurrence on western slopes and along water courses in habitats where there were tall, dense shrub-layers (positive correlations with VL 2, VL 3, VL 7, TVC and VL6).
4. The Silvereye was infrequently recorded in disturbed jarrah, regulary in healthy jarrah and commonly in rehabilitation at Scenic Drive. It was particularly common in rehabilitation during the winter, in contrast to Serpentine.
5. The Western Silvereye mainly occurred in post-breeding flocks. These primarily gleaned from shrubs and eucalypt saplings but also utilised the herb, sub-canopy and tree-layers (Figure 11 (ii)). The Silvereye has an omnivorous diet of fruit, nectar and insects (Fritn, 1976). In the jarrah forest it may also have obtained non-nectar carbohydrates, such as sugary lerps produced by phytophagous psyllids, (Paton, 1980), as well as arthropods, when gleaning from leaves. Silvereyes are considered to be strongly attracted to marri blossom and summers of poor blossom result in heavy attacks on orchards (Robinson, 1960) and vineyards (Rooke, pers. comm.). However, no Silvereyes were seen feeding at the blossom of marri during the short, summer flowering periods at Serpentine. Jarrah blossom was also not attractive to the Silvereyes, even to birds feeding in flowering trees. A few observations were recorded of Silvereyes at Banksia grandis blossom (Figure 11).

The population in rehabilitation at Scenic Drive also primarily foraged on tall shrub-layer foliage. This included gleaning of small thrips and scale insects (Hemiptera) from Albizia leaves and unopened flowers, and psyllid lerps from leaves of marri saplings. Albizia nectar was used by the winter populations at this site while marri nectar in nearby forest was exploited in summer. The Silvereyes were members

of mixed species flocks in the rehabilitation during winter. Here they gleaned on trunks of saplings and in shrub-layer foliage.

6. No breeding was recorded in the study areas except that dependent fledglings were present in summer flocks at Serpentine, while old nest were found in the dense shrub-layer of a rehabilitation pit (Curry and Nichols, 1985).
7. The Silvereye was primarily a post-breeding immigrant in the jarrah forest but breeding pairs probably occurred along the creeks. It occurred throughout the year in relatively high numbers at Scenic Drive and was one of the most abundant species in the marri rehabilitation. Here it exploited a variety of food types and this adaptable species is likely to be common in any rehabilitation that has a dense shrub-layer. Seeding with Albizia is particularly likely to promote Silvereyes.

iii) Tree Foraging Insectivores

Broad-tailed Thornbill

1. Widespread in central and Western Australia, in many habitats.
2. Common resident in the jarrah forest (6.2/10 ha). Estimated density fluctuated, with 41% of variance explained by correlations with flowering of Banksia grandis (Spring) (Figure 10) This was most probably a coincidence due to increased detection and even distribution of pairs when they establish territories at the start of breeding.
3. There was a significantly higher density of Broad-tailed Thornbills in creek vegetation (FA 9) than in many other associations for the total research period. However, it was found throughout the study area and there were few significant variances in distribution for particular visits. Densities in FA's 1 & 2, the highly disturbed habitat, did not rank below those in many others.

A number of structural variables were also significantly correlated with Broad-tailed Thornbill distribution. However, these often only explained small percentages of variance for this widespread, numerous species. The habitats utilised included disturbed areas in autumn (-ve correlation with VL 4), and western slopes and creeks in winter (T6). VL 3 explained relatively high percentages of variance for two breeding season visits, reflecting use of this tall shrub-layer of the creeks for both foraging and nest-placement.

These results reveal some differences in distribution to the closely related Western Thornbill. Both occurred in disturbed and open areas at some times of year, and in fact foraged together in mixed-species flocks, but the Western Thornbill did not favour creeks (or any other particular habitat type) in the breeding season.

4. The Broad-tailed Thornbill was equally common in jarrah and rehabilitation at Scenic Drive and was the most abundant

species in the disturbed jarrah.

5. The Broad-tailed Thornbill is a small tree-layer forager that, unlike most thornbills, seldom occurs in larger groups than pairs. Each pair defends a small territory in the breeding season, within which they forage amongst the foliage of the tree, sub-canopy and to a lesser extent, the shrub strata (Spring, Summer - Figure 11 (iii)). They were active foragers with high percentages of snatching and hovering, particularly when gathering meals for nestlings. All sub-canopy and tree species were utilised but some selectivity was shown at particular times. For instance, insects were often captured amongst blossoms of Agonis and at young tips of the eucalyptus in Spring and Summer. The pairs foraged over large home-ranges in autumn and winter, often adhering to mixed-species flocks, but foraging habits did not markedly alter with season. There may have been a tendency for bark-foraging (twigs and branches) to increase in autumn but this was not sustained into winter (Figure 11 (iii)). Mathieson (1973) only recorded Hymenoptera in a Broad-tailed Thornbill food sample but many small types of insects are taken.

Foraging at Scenic Drive (n = 115) was mainly at foliage. Plant species used in the rehabilitation were Acacia extensa, Albizia, Acacia armata and E. microcorys but very little marri. Jarrah and casuarina were commonly used in nearby forest.

The Broad-tailed Thornbill is considered to be an inland replacement of the eastern-forest Brown Thornbill. Frith (1976) suggests that both it and the Brown Thornbill are shrub-layer foragers but the present study shows that Broad-tailed Thornbills of jarrah forest have extended to the sub-canopy and tree strata. This is possibly an example of expansion into a niche that is filled by the tree-foraging Striated Thornbill Acanthiza lineata (forest) and Little Thornbill A. nana (woodland) in eastern Australia. Similarly the usage of these strata by the Western Thornbill (Table 11 (ii)), which is closely related to the ground-foraging Buff-rumped Thornbill A. reguloides of eastern Australia (Frith, 1976), could also be a response to a depauperate competitor environment in the jarrah forest (Chapter 6).

6. Nests at Serpentine were often placed in the dense shrub-layer of streams. Similarly dense acacia regrowth was used at Scenic Drive (Curry and Nichols, 1985).
7. The Broad-tailed Thornbill is a typical jarrah forest species that readily colonises mine rehabilitation.

Golden Whistler

1. Widespread in southern Australia.
2. The Golden Whistler was a moderately common resident (2.3/10 ha) for which density fluctuations (Figure 10) probably resulted from variable patterns of dispersal and

observability and addition of immatures to the population. Flocks of the closely related Rufous Whistler moved through upland areas of the jarrah forest in Autumn 1981, foraging in the sub-canopy, but were otherwise absent. It is a species of open woodland rather than forest (Frith, 1976).

3. No significant variances in distribution amongst FA's were found and correlations with structural variables only explained small percentages of variance. Positive correlations with T2 for two visits, and VL 5 for one, reflected occurrence in young, healthy forest of dry, easterly slopes and ridges, and avoidance of disturbed areas, creeks and mature forest. Avoidance of these latter habitats may have been because of their poor sub-canopy development, since this was a stratum well-used by Golden Whistlers. However, correlation with VL 7 for Visit 7 (areas in which old, large trees remain) is contrary to this interpretation.
4. Equally common in jarrah and rehabilitation but absent from disturbed jarrah at Scenic Drive.
5. The Golden Whistler is a moderately sized insectivore that hops around, peering amongst foliage, before snatching relatively large arthropod prey (Figure 11 (iii)). It foraged as much in the sub-canopy of casuarina, banksia and persoonia as in the eucalypts. The common occurrence of these species in jarrah forest is probably an important characteristic that benefits the Golden Whistler and other species such as the Broad-tailed Thornbill. Many prey items of the Golden Whistler were identifiable, including 3 grubs, 2 cockroaches, mantid, grasshopper and caterpillar, all of 2-3 cm length. Large items were bashed on a branch before being eaten.
6. Pairs bred in rehabilitation close to forest boundaries and foraged in both rehabilitation (foliage and ground) and in all layers of the forest. The two nests found by Curry and Nichols (1985) were in the shrub-layer, but nesting in forks of saplings and trees is also likely (Frith, 1976).
7. Typical jarrah species that readily colonises mine rehabilitation.

Western Shrike-Thrush

1. The western race (or species) of Grey Shrike-Thrush, Colluricincla harmonica rufiventris, is widespread in wooded habitats of western and central Australia.
2. This large insectivore was relatively sparse in the jarrah forest (0.7/10 ha). Apparent fluctuations in density (Figure 10) were likely to be artifacts of the sampling methods.
3. No variance in distribution amongst FA's was shown by the analysis and there were few correlations with structural variables. This was possibly due to small sample sizes rather than an even distribution.

Positive correlations with T5, T6 and VC 7 suggest that habitat with tall tree-layers was preferred, reflecting utilisation of this layer and the relatively rich litter layer of these habitats when foraging on the ground.

4. Infrequently recorded in jarrah and rehabilitation at Scenic Drive.
5. The Western Shrike-Thrush was a less active hunter, of large insects, than was the similar but smaller Golden Whistler. It was versatile in its use of foraging strata. Most winter observations were of hopping amongst litter on the ground, while foraging in other seasons was by hopping along branches and limbs of banksias and eucalyptus (Figure 11 (iii)). All observations at Scenic Drive were in autumn and winter, possibly of birds that had moved out of their preferred habitat of mature forest. As at Serpentine, foraging was on the ground at this time ($n = 25$), both in the forest and in edges of the rehabilitation. The shrike-thrush was thus similar in switching between winter ground foraging and breeding season tree-layer foraging to the Scarlet Robin.
6. There was no evidence of breeding at Scenic Drive (Curry and Nichols, 1985), suggesting that mature jarrah forest is preferred. Nests are wedged in various sites such as in logs, stumps, banks, rocks and thick shrubs (Frith, 1976).
7. There should be no shortage of nest-sites but a lack of suitable tree-layer foraging sites in immature rehabilitation vegetation discourages breeding season usage.

Striated Pardalote

1. Occurs throughout Australia.
2. The Striated Pardalote was one of the most abundant birds in the jarrah forest during the breeding season (mean 5.7/10 ha, maximum 12.5/10 ha). It flocked in groups of 20+ that moved rapidly through the tree-tops in March 1981 and April 1982, prior to migrating for the winter. Seugewick (1971a) has also reported on migration by this species (referred to as the Red-tipped Pardalote) from the southwest forests to winter in drier areas such as the Pilbara and Great Sandy Desert. No breeding has been recorded in the wintering grounds. The population is only partially migratory in some southern breeding areas but heavily timbered areas are wholly vacated in winter. Striated Pardalotes were completely absent from Jarrahdale during the 1981 winter but some were recorded throughout 1982. These changes in density were highly correlated with changes in arthropod abundance, rather than climatic conditions (Figure 10).
3. A lack of significant variances in distribution amongst floristic associations despite seasonally high densities suggests that this migratory species equally utilised the floristic associations at Serpentine. However, distribution was often correlated with variables representing tall tree canopy (VL 6 for Visits 3 and 7; VL 7 for Visits 8 and 9; T6 for Visit 5), as might be expected for a tree-layer foraging

and nesting species. These variables had highest values on westerly slopes, particularly in mature forest, and lowest in disturbed areas and along creeks. Exceptions were correlations with T4 (Visit 1) and Total Vegetation Cover (Visit 2 - high values along creeks where the tree-layer was poor), when Striated Pardalote density was at a peak (Chapter 3).

4. Striated Pardalotes occurred in jarrah forest at Scenic Drive from spring to autumn, whereas they were only abundant in rehabilitation during spring. The open, disturbed forest was avoided.
5. The Striated Pardalote was a leaf gleaner of jarrah and marri trees and saplings. Mathieson (1973) found a variety of arthropods in a Striated Pardalote food sample but its principle food in the study areas was lerps and, presumably, the psyllid larvae (*O. Hempitera*) beneath. The lerps were at times very abundant on marri, occurring on mature foliage as well as amongst tips. Probably as a consequence, marri was favoured over jarrah by the Striated Pardalote in that marri was half as abundant as jarrah (Chapter 3) but equally utilised (Figure 11 (iii)). Classification of the pardalote as an insectivore is something of a misnomer since lerps are primarily a source of carbohydrates (Paton, 1980). Lerps were gathered for nestlings as well as for adults but small arthropods were presumably also necessary to provide nestlings with protein, as is the case with the lerp-foraging Bellminer of eastern Australia (Wykes, 1982).

The Striated Pardalote is a communal breeder (Dow, 1980) that occurred in small groups during spring and summer and formed flocks of up to 20 in autumn prior to migration. These flocks generally worked rapidly through the tree-layer but some that found clumps of infested trees fed vigorously within small areas. Foraging in the rehabilitation at Scenic Drive ($n = 35$) was of leaf gleaning at 4-6 m in marri, throughout the pit.

6. Many nest sites in knot holes and spouts of tall trees were recorded at Serpentine and in jarrah forest at Scenic Drive. Curry and Nichols (1985) recorded foraging within the rehabilitation by birds nesting in nearby forest.
7. Striated Pardalotes are attracted to rehabilitation eucalypts for foraging but cannot breed there for lack of tree hollows. This might be overcome with nest-boxes but if not, the presence of mature trees in forest patches adjacent to rehabilitation is important while the rehabilitation is young.

Spotted Pardalote

1. Eastern and south-western Australian forests.
2. The Spotted Pardalote was never abundant in the study areas (mean 1.2/10 ha) but an influx was recorded during the 1981 winter, coincident with the absence of Striated Pardalotes (Figure 10). A smaller influx also occurred in the 1982

winter. Sedgewick (1971b) suggests that this species moves north from its breeding grounds in wet, southern forests, such as karri, to winter in the Perth region. Its occurrence in the study area was negatively correlated with Maximum Temperature (Figure 10).

3. There was no significant favouring of particular FA's during the four visits in which Spotted Pardalotes were numerous but there was a significantly higher density of birds in FA 8 than in most other FA's for the pooled data. This reflected occurrence of Spotted Pardalotes in eucalypt saplings adjacent to the water course. Similarly, structural correlations were with VL 2 (westerly slopes and creeks), VL 3 (creeks); T3 (westerly slopes and some watercourse vegetation); negatively with T5 (low values along creeks and in disturbed areas); and positively with VL 7 (steep westerly slopes with large trees).
4. Spotted Pardalotes occurred at Scenic Drive in the winter, primarily in the jarrah habitat.
5. The foraging habits of the Spotted Pardalote were similar to those of the Striated Pardalote and it was not apparent why it should have wintered in jarrah while the other migrated elsewhere. Some differences were that the Spotted Pardalote is 10% smaller in body size (Frith, 1976) and that it foraged actively by snatching items such as moths, as well as gleaned from leaves. It also foraged more in shrub and sub-canopy than did the Striated Pardalote but still mainly in eucalypts (Figure 11). The Spotted Pardalotes at Scenic Drive gleaned from rehabilitation marri but few observations were obtained.
6. No breeding was recorded for the small spring-summer population except for a bird gathering nesting material close to a watercourse at Serpentine. They dig tunnels in dirt banks in contrast to the tree-nesting Striated Pardalote. Suitable sites should be plentiful in rehabilitation pits and it was therefore surprising that breeding was not recorded.
7. The jarrah and rehabilitation attracted Spotted Pardalotes during winter, in the absence of Striated Pardalotes. These areas were apparently suitable for nesting and thus the very low density for breeding Spotted Pardalotes was probably either due to unsuitability of the habitat for foraging or to competition from Striated Pardalote. A study of comparative ecologies and interaction between these two pardalotes in their respective breeding and wintering habitats would be an interesting research subject.

White-naped Honeyeater

1. Eastern Australia and a western race of south-west forests.
2. A forest resident of moderate abundance (1.8/10 ha). No migratory movements are recorded (Serventy and Whittel, 1976) but a virtual exodus in winter/early spring 1981 suggests that other habitats may sometimes be sought (Figure 10).

3. There were no significant variances amongst FA's but there were significant correlations between distributions and structural variables. Correlations with western slope forest of tall, dense trees (VL 7 & VL 6) were not surprising for this tree-forager, while correlations with tall shrub-layer (VL 2 & VL 3) in autumn and winter reflected some shrub-layer nectarivory.
4. Occasionally occurred in rehabilitation but most were observed in healthy jarrah forest.
5. The White-naped Honeyeater was primarily an acrobatic gleaner of tree-layer foliage (Figure 11 (iii)). It utilised jarrah and marri in the same frequencies as their relative abundances in the habitat (2:1, Chapter 3). It is better termed an insectivore than nectarivore but, as for the pardalotes, was likely to obtain carbohydrates (lerps, honeydew and manna) as well as arthropods from leaves, tips, insect 'nests' of clumped leaves and under loose bark. Lerps, honeydew and grubs were seen to be taken. Nectar was utilised to a small extent from Banksia grandis in spring, marri in early autumn and Dryandra sessilis in winter.

Similarly at Scenic Drive, foraging in jarrah forest (n = 100) was of gleaning from foliage of eucalyptus, (often for lerps) nectarivory and snatching insects at banksia cones and nectarivory at marri. Only gleaning from marri leaves was observed in rehabilitation. The eastern Australian race of White-naped Honeyeater often occurs in large groups in all seasons (pers. obs.) and is a communal breeder (Dow, 1980). I seldom saw more than pairs of adult White-naped Honeyeaters in jarrah and suspect that the western race is less sociable. If so, this presents an opportunity to investigate the factors that lead to communal breeding, such as distributions and abundances of food sources, availability of habitat and competition with other species.

6. Nests were suspended in the outer foliage of eucalypts. None were recorded in rehabilitation but breeding pairs foraged in regrowth nearby to nest-sites.
7. This tree foraging and nesting species is likely to greater utilise rehabilitation as the eucalypts mature and when species such as Banksia grandis and Dryandra sessilis mature and flower. It would be an interesting subject for studying the relationships between ecology and social systems.

Black-faced Cuckoo-shrike

1. Australia wide.
2. Occasionally recorded in jarrah forest during summer (mean 0.1/10 ha).
3. Occurred in open, ridge forest.
4. Not recorded during transects at Scenic Drive but occasionally present in the forest.

5. Forages for large arthropods in foliage of trees and shrubs, and drops onto prey on the ground (Frith, 1976).
6. Immature recorded in summer and therefore they may breed in jarrah. Nests are placed in tree forks (Frith, 1976).
7. The Cuckoo-shrike was an unimportant member of the jarrah avian community.

Shining Bronze-cuckoo

1. Widespread in coastal eastern and south-western Australia.
2. Scarce summer immigrant to the jarrah forest (0.02/10 ha).
3. No analysis of distribution.
4. Occasional in all habitats at Scenic Drive but not recorded during transects.
5. Feeds on arthropods such as caterpillars in foliage and shrubs. Few observations collected.
6. Nest parasite of small insectivores such as thornbills which build domed nests (Frith, 1976). Dependent fledglings were recorded with Broad-tailed and Western Thornbills at Serpentine.
7. The food and suitable hosts of this cuckoo are likely to attract birds to rehabilitation. However, density in all habitats may always be sparse since availability of wintering habitat in the Lesser Sunda Islands (Serventy and Whittell, 1976) may limit the population. A worthwhile research project would be to investigate the relationship between conservation of this population and preservation of its wintering-ground habitat.

Fan-tailed Cuckoo

1. Eastern Australia and south-west forest.
2. Occasionally recorded (0.1/10 ha), July to September. The south-west population is not migratory but move out from the primary breeding habitat of karri for the winter (Serventy and Whittell, 1976).
3. No habitat preferences were apparent from the few sightings.
4. Occasionally at Scenic Drive in rehabilitation (June) and forest (not during transects, August and October).
5. Feeds on large arthropods from foliage and ground (Frith, 1976).
6. Nest-parasite of dome-nesting thornbills and occasionally of open-nesting species such as honeyeaters (Frith, 1976). White-browed Scrub-wrens attended a fledgling in rehabilitation (Curry and Nichols, 1985).

7. A species of little significance in the jarrah community.

Bark-foraging insectivores

Varied Sittella

1. The Black-capped form of the Varied Sittella occurs throughout southern Australia except the south-east.
2. A resident of low density (0.9/10 ha) for which fluctuations (Figure 10) were probably due to sampling error.
3. Insignificant variance in distributions amongst FA's but some correlations with structural variables. Most correlations were interpretable as a preference for healthy, dense forest. These were a positive correlation with Total Trunks, a positive correlation with T5 (high on undisturbed ridges), a negative correlation with TVC (avoidance of creeks), and a positive correlation with VL 1 (avoidance of disturbed and mature vegetation).
4. Sittellas at Scenic Drive were regularly recorded in jarrah, once in disturbed jarrah (not during a transect) and never in rehabilitation. Flocks flew across rehabilitation to the hill-top forest islands.
5. The Varied Sittella is a small, bark-foraging specialist. Foraging was confined to tree-layer jarrah and marri, which were attended at similar relative frequencies to their occurrence in the habitat. (2:1 - Chapter 3). They foraged acrobatically in a downward position on branches and, to some extent upper limbs and trunks (Figure 11). Small food items were gained by gleaning and by probing into fissures and under bark of live and dead wood. The diet is reported to include a wide variety of arthropods, without the emphasis on ants shown by tree creepers (Frith, 1976). All birds at Scenic Drive were foraging at bark of forest eucalypts.

The sittellas occurred in tightly-knit parties of 6-10 birds, and as for many other species in the community, are communal breeders (Dow, 1980). The groups travel rapidly and widely which suggests that they occupy home-ranges rather than territories (Frith, 19776). However, there were noisy interactions when two groups met.

6. Nests are placed in small, often dead, vertical forks of trees (Frith, 1976). No breeding was recorded but undoubtedly occurred in this resident population.
7. The rehabilitation eucalypts should mature into suitable foraging and nesting habitat for sittellas.

Rufous Treecreeper

1. South-west forest and woodland.
2. A resident of low density (1.0/10 ha) for which fluctuations in density were probably due to sampling error.

3. There were insignificant variances in distributions amongst FA's and the few correlations with structural variables only explained low percentage of variance. These were occurrence along creeks and on lower, undisturbed slopes (positive with T3, positive with VL3, negative with Total Trunks and positive with TVC), undisturbed ridges (T5) and disturbed slopes and mature forest (negative with T1). Thus, there were no clear habitat preferences indicated.
4. Not recorded during transects at Scenic Drive but a family was regularly sighted in jarrah forest adjacent to rehabilitation.
5. The Rufous Treecreeper is a distinctive bark-foraging specialist that, in contrast to the Sittella, utilised all vegetation strata and favoured the larger bark stations. The birds generally flew to the base of a tree and worked upwards in to the tree-layer but also fed on logs and the ground (Figure 11 (iv)). They occurred in groups of around 4 birds and are co-operative breeders (Noske, 1980). They primarily feed on ants (pers. obs; Frith, 1976). Given the generally high abundances of ants in the forest, there must be some selectivity of prey-types or aspects of foraging energies that limit the treecreeper population to its present low density. For instance, patchiness of food distribution was suggested by observation of spread-out groups moving rapidly through the forest until converging on patches of trees in which all were thoroughly searched. There was selectivity shown for jarrah over marri and banksia was a common foraging site, particularly in autumn and winter (Figure 11 (iv)). The relationship between Rufous Treecreeper density, distribution and food supply warrants further attention.

I attempted to estimate the size of a tree-creeper group's home-range by following 4 birds in healthy, ridge forest (31/3/81, P.M.). I mapped their movements at 10 minute intervals for 2 hours. In that time they indirectly travelled at 300 m/hour and the maximum width of the area covered was 250 m. Their movements were at first associated with those of a mixed-species flock involving 6 other species but the tree-creepers changed direction while the flock continued on, presumably out of the tree-creepers' home-range. The group turned back on its track at another point when calls were exchanged with a second group, 50 m away. A different neighbouring group of 3 birds on the other side were followed on the morning of 1/4/81. They travelled indirectly at 250 m/hr over 100 minutes, and had a maximum range-width of 240 m. 250 was the shortest distance between the two neighbouring ranges, across the range of the initial group of 4 birds. I will therefore assume that this is a reasonable estimate of the diameter of its home-range. The area of a circular home-range with 250 m diameter is approximately 5 ha, and thus the density of tree-creepers in this habitat was around 8/10 ha. This is considerably more than the 1/10 ha estimated for the total study area and the value would be even greater if home-ranges overlap.

6. Nests are placed in a deep hollow limb or tree-trunk, generally close to the ground (Frith, 1976). Such a site was

used in a casuarina in forest at Scenic Drive (Curry and Nichols, 1985). Suitable sites appeared common in the forest but absent from rehabilitation.

7. The tree-creeper was a species of surprisingly low density in jarrah forest compared with apparently high densities in south-west woodland (pers. obs.). Nest-sites are unlikely to be limiting and thus availability of food is the probable limitation. This could be due to a generally low litter fauna in jarrah or a result of litter-reduction burn management (see discussion). This is a readily studied species for which a study of its social system and the relationship between density, distribution and food supply is recommended. The ability of rehabilitation to meet tree-creeper foraging and nesting requirements as it matures cannot be predicted until more is known of its biology.

v) AIR-FORAGING INSECTIVORES

Western Warbler

1. Eucalypt woodland and scrub of inland and western Australia.
2. A common summer immigrant (mean 1.7/10 ha) that breeds in jarrah forest at densities of up to 5/10 ha and then migrates for winter. High percentages of variance were explained by correlations with change in sweep-net and sticky-trap biomass.

The western population breeds in the south-west in a variety of habitats and then partially migrates inland and northwards. Winter migrants are more common and widespread in northern areas when food supplies are presumed to be more plentiful in wet winters, and have been reported as far as southern Kimberley, the Nullarbor plain and the western fringe of the Great Victoria Desert. (Ford, 1981a).

3. The dense breeding populations did not favour particular FA's and there were relatively few correlations of distributions with structural variables and low percentages of variance explained. Highest explained variances were for autumn and winter visits when the population was preparing to migrate or when only remnants were present. They favoured watercourse and western slope vegetation for Visit 3 in autumn (T3); lower western slopes for Visit 4 (T4); and disturbed sites and mature forest for Visit 9 in autumn (-ve correlation with VC 1).
4. The warblers were regularly recorded at Scenic Drive in forest and rehabilitation but only once in disturbed forest.
5. Warblers foraged by snatching small insects amongst eucalypt foliage of the tree and subcanopy layers. They seldom utilised non-eucalypts of the sub-canopy, and foraged in jarrah and marri in the 2:1 ratio in which they occurred. They often foraged by flitting amongst foliage and flicked their wings to disturb insects which were then caught. Matthieson (1973) recorded Hymenoptera and beetles in a stomach sample while small flies, a spider and a grub were

identified as prey at Serpentine. Foraging in rehabilitation at Scenic Drive (n = 45) was of snatching in foliage of marri saplings and snatching and hawking small flies amongst foliage of 2.3 m high Albizia.

6. This migrant probably bred more in summer than during the spring/summer period of residents, in accordance with a summer peak in abundance of active foliage-dwelling insects (sticky-trap results, Chapter 3). Nests were placed amongst foliage of trees and saplings at Serpentine, and in marri and E. microcorys saplings in rehabilitation at Scenic Drive (Curry and Nichols, 1985).
7. A widespread species that occurs wherever there is a canopy in which it snatches seasonally abundant arthropods. It therefore readily recolonizes mine rehabilitation.

Grey Fantail

1. Throughout Australia except the centre. A south-western race R. fuliginosa preissi breeds in the lower south-west and partially migrates northwards to the Pilbara and eastwards into the wheat-belt (Ford, 1981 b).
2. A relatively common resident (2.6/10 ha) for which fluctuations in density were not correlated with variation in climate or food supply and migration apparently did not occur.
3. There was no significant variance in distribution for most visits but an overall favouring of the watercourse vegetation of FA's 8 & 9. The disturbed FA's 1 & 2 were no less utilised than most others. Significant correlations between Grey Fantail distribution and structural habitat variables were found for every visit, with high percentages of variance explained. The maximum was a total of 85% explained by the correlates for Visit 4. VL 7, which had high values on steep western slopes where large trees had escaped logging, was the major correlate of three visits. This habitat, with its open sub-canopy and dense shrub-layer, was possibly attractive because it provided much open space beneath the tree-canopy in which this insectivorous hawk could forage. VL 3 was the main correlate during a spring and summer visit, reflecting an association with creek habitat at these times. Hawking here was conducted above the tall, dense VL 3 shrub-layer beneath an often open, depleted tree-layer. T3, with high values on some creeks and western slopes, was a positive correlate during the winter visit 10; and T4, high on lower western slopes and close to the main road to the east, was a positive correlate for three visits.

The major contributants to the high explained variance of Visit 4 (winter) were Total Trunks (+ve), T1 (-ve) and T2 (-ve). Most birds were therefore avoiding areas with low Total Trunks (disturbed habitat and creeks) but with further variance explained by occurrence in areas lacking small trees (T1 and T2), such as under the dense tree-canopy of mature forest or in disturbed areas.

The overall impression gained was that Grey Fantails utilized much of the study area, but that habitats of particular structural characteristics were favoured more during some visits than others. This variance may have reflected relative abundances of aerial insects which would vary in distribution with season and weather conditions.

4. The Grey Fantail was abundant in all seasons in forest and rehabilitation but scarce in disturbed forest at Scenic Drive. Numbers were particularly high in autumn.
5. The Grey Fantail hawked for small insects both around foliage and in the open air. The tree-layer was the most utilised in all seasons except winter, with sub-canopy and some shrub-layer foraging. There was less tree-layer and more sub-canopy foraging in winter and a high percentage of ground-foraging. Insects were primarily hawked in all seasons except winter, when there was equally frequent snatching from foliage, and a relatively high percentage of snatching on the ground. The major plant species used were jarrah and marri with relatively high percentages of foraging in other tall species in particular seasons - banksia in summer, casuarina in autumn and Agonis in winter. The relative frequencies with which the two eucalypt species were used varied. In spring they were used in the same ratio as their occurrence (2 jarrah to 1 marri) whereas marri was otherwise favoured. This may be because marri tends to have a more open, spreading canopy that suits a hawking species.

The Grey Fantail incessantly flicks its tail, which is possibly a mechanism for disturbing insects from foliage similar to the frequent wing-flicking of warblers. Furthermore, fantails are commonly associated with mixed-species foraging flocks, around which insects might often be disturbed, but did not themselves flock.

The abundant population in rehabilitation at Scenic Drive hawked above the dense shrub-layer amongst marri and E. saligna saplings, and often foraged close to the ground for small flies below Albizia and Acacia saligna in winter (n = 25).

6. Nests are placed in thin forks, low down in trees and saplings (Frith, 1976). Three nests were recorded in rehabilitation pits (two in E. microcorys, one in E. maculata) in dense sapling regrowth. Adults primarily foraged in the rehabilitation for the nestling meals (Curry and Nichols, in prep.).

Tree Martin

1. Throughout Australia.
2. Regularly recorded spring/summer immigrant (mean 0.7/10 ha, maximum 1.5 birds/10 ha). Changes in density were highly correlated with those in sticky-trap Biomass, sweep-net biomass and sweep-net species richness.
3. Tree Martin distribution was correlated with a number of structural variables, including T3 and T4 (occurrence on westerly slopes and along creeks) and negatively with VL 4 (low values in disturbed areas). The low percentage of explained variance suggests that foraging was broadly distributed while the correlations may have indicated which areas had suitable hollows for nesting.
4. Tree Martins were regularly recorded from spring to autumn in the forest and Scenic Drive, less commonly in rehabilitation, and seldomly in disturbed forest.
5. Martins forage on flying insects above the tree-canopy. Foraging height can vary and distribution within the habitat of these sociable birds presumably varies in accordance with abundance and distribution of prey species. The correlations with westerly slopes and creeks may reflect high abundances above these moister habitats during summer. Similarly prey abundances presumably differed over the vegetation types at Scenic Drive.
6. Martins form loose colonies with a number of pairs often nesting in hollow limbs of the one tree or within the one hole. A number of nest-trees were recorded at Serpentine. These were large, old trees on ridges in disturbed and undisturbed forest. It is not obvious whether nest-sites would be limiting in jarrah forest but another advantage of colonial nesting would be exchange of information about prey distribution using the nest-site as an information centre. Nest-sites might be few in severely disturbed jarrah, such as at Scenic Drive, and absent from rehabilitation. This should not however, discourage use of these habitats for foraging by these wide-ranging birds. This was confirmed by a record of breeding in a jarrah spout in the the forest island from which birds foraged over rehabilitation at Scenic Drive.
7. The martin population will have access to rehabilitation if forest islands are preserved for breeding but may not choose to extensively utilise this vegetation for foraging if aerial prey abundances are low while it is immature.

Dusky Woodswallow

1. Eastern forest and a separate south-west forest population. It is migratory in south-east Australia but patterns of movement in the south-west are unclear (Serventy and Whittell, 1976).
2. Uncommon spring-summer occurrence at Serpentine (0.1/10 ha).

3. Woodswallows generally occur in open tracts within jarrah and karri forest (Serventy and Whittell, 1976). Occurred in disturbed, open forest near creeks at Serpentine.
4. Recorded at Scenic Drive during one autumn visit, in jarrah forest.
5. Hawks for insects directly above the tree-layer and at high altitudes.
6. Builds a stick nest in various, exposed sites such as on stumps, in hollows, behind bark and in forks (Frith, 1976). This is a social species that forages and roosts in groups and is a communal breeder in eastern Australia (Dow, 1980). A nest was recorded at Serpentine in December 1980. It was of fine twigs placed amongst upright twigs at 22 m in a jarrah.
7. Dusky Woodswallow distribution has apparently contracted since forest woodland has been cleared in the south-west, which has favoured the Black-faced Woodswallow (Serventy and Whittell, 1976). The biology of this behaviourally interesting species is relatively well-known in eastern Australia (Frith, 1976) but further research on the behaviour and ecological requirements of the restricted south-west population would be desirable. It was not an important species in the jarrah forest at Serpentine and has not as yet colonised rehabilitation but is a species that might be attracted by the diversity of habitats in the mining areas in the future. If particular rehabilitation types prove attractive, this should be encouraged.

CARNIVORES

Laughing Kookaburra

1. Eastern Australia and introduced to south-west Australia.
2. Resident in low density at Serpentine (0.2/10 ha).
3. Only small percentages of variance were explained by the significant correlation of Kookaburra distribution with structural characteristics of the vegetation for the few visits for which sample sizes permitted analysis. These correlations were interpretable in terms of the species' ecology. Distribution was negatively correlated with VL 1 in Visit 4 (winter) and negatively with T1 in Visit 8 (summer) possibly reflecting preference for areas with open understorey through which ground-foraging prey could be detected and captured.
4. Kookaburras were recorded in jarrah forest during two visits and once in disturbed jarrah at Scenic Drive. They did not utilise rehabilitation.
5. Kookaburras generally feed by observing the ground from a vantage point on a stump or in a tree, searching for large prey such as reptiles which are swooped upon and captured with the beak. Curry and Nichols (1985) recorded a bird

carrying a small snake at Scenic Drive. I observed 2 adults bringing food to a nest at Serpentine. Items were brought every 4-8 minutes in the morning, less frequently in the afternoon. Four whole skinks of 10-20 cm in length, a 15 cm tail of a skink, a 5 cm - long grasshopper and another large insect were brought to the nestling. Since Kookaburras have only established in the south-west this century, they may have an adverse affect on prey species that are poorly adapted to avoid predation.

6. Three breeding groups (two nests and a pair with fledglings) were recorded at Serpentine in spring/summer 1981, and probably comprised most of the birds in the study area. Both nests were in tree hollows of large, old marri on lower, westerly slopes in dense mature forest. Such sites would be infrequent in disturbed forest and absent from rehabilitation at Scenic Drive.

This is a communally breeding species (Dow, 1980) but it is likely that offspring would remain for a minimum period in parental territories if the south-west population is still expanding. No groups of more than two, other than pairs with fledglings, were recorded.

7. The occurrence of Kookaburras in jarrah forest is of greatest interest in terms of conservation of their prey. This should be the subject of further research.

Sacred Kingfisher

1. Throughout all but central Australia. Winter migrant to northern islands from southern Australia (Frith, 1976).
2. Uncommon summer immigrant (0.1/10 ha).
3. Along streams in relatively open vegetation.
4. Not recorded at Scenic Drive.
5. Drops onto ground for large insects and small reptiles (Frith, 1976). No foraging recorded.
6. Generally hollows in trees are used for breeding by the south-west population (Serventy and Whittell, 1976). A bird was seen carrying food at Serpentine and a pair nested in a marri tree-hollow in forest near Scenic Drive (Curry and Nichols, 1985).
7. Introduction of the Kookaburra may be a threat to Kingfisher status but the Kingfisher is smaller and appears to feed more on insects than does the Kookaburra (Serventy and Whittell, 1976). Suitable nest-sites may be limiting in young and disturbed forest and completely absent from rehabilitation. Furthermore, unless the rehabilitation shrub-layer becomes more open as it matures, it is unlikely to attract Kingfisher's. However the Kingfisher is not an important member of the jarrah community.

Accipiter spp.

1. The Brown Goshawk and Coloured Sparrowhawk were both identified at Serpentine but not always distinguishable. Both have Australia-wide distributions.
2. Regularly observed, low density species (0.1/10 ha) at Serpentine.
3. Too few data to analyse distribution.
4. Observed in the vicinity of Scenic Drive, particularly in the forest island.
5. Swoops on prey from tree perches, using its talons to grab insects, reptiles, birds and small mammals from the ground, and birds in the air (Frith, 1976). Observations at Serpentine were of a bird dropping onto the ground for 30 seconds, prey unknown; pursuing a Red-capped Parrot high into the sky (female Goshawk); chasing a flock of Western Thornbills (male Sparrowhawk); and carrying a small, long-tailed mammal.
6. Build or re-use stick platforms in trees. A Goshawk pair were regularly calling in the forest island at Scenic Drive in October 1981 and may have nested nearby.
7. The accipiters are unlikely to utilise rehabilitation to any degree until the trees mature and provide vantage points for hunting. There are likely to be sufficient nest-sites for these sparsely distributed canivores in the forest islands amongst the rehabilitation.

Wedge-tailed Eagle

1. Australia wide.
2. Irregularly observed, low density at Serpentine (0.1/10 ha).
3. No habitat preference apparent.
4. Not recorded at Scenic Drive.
5. Prey ranges from reptiles and birds to large mammals, as well as carrion. Foraging usually by soaring at tree-level at dawn and dusk (Frith, 1976). Birds were only observed high above the forest. Open ground is favoured, particularly farmland, and little food is likely to be gained in dense forest. The birds at Serpentine probably gained their food nearby on the partially cleared scarp.
6. Usually nest in tall trees when in forest. Such sites should be available within the large home-ranges of pairs in mined regions.
7. The sparse population is unlikely to be affected by mining in jarrah forest.

Little Eagle

1. Australia wide.
2. Low density, irregularly recorded species (0.1/10 ha).
3. Few data for analysis of distribution.
4. A pair were regularly recorded over all habitats at Scenic Drive in the spring and summer.
5. Swoops onto mammals, birds and reptiles from a vantage point in a tree or while soaring (Frith, 1976). Birds were seen soaring at tree-top level and flushed from perches but no predation recorded.
6. Builds or re-uses a large stick-nest high in a tree (Frith, 1976). A pair were regularly sighted in forest below rehabilitation at Scenic Drive near such a nest but no further evidence of breeding was obtained.
7. Opening of the forest for mining may advantage this raptore but general density of these large, sparsely-distributed birds is unlikely to be affected. Preservation of jarrah islands should provide ample nest-sites.

Other raptores. Other raptores, such as the Australian Hobby Falco longipennis and Square-tailed Kite Lophoictinia isura, were irregularly sighted in the district (Curry and Nichols, 1985) but have such low densities that mining will have little impact, positively or adversely, on their overall populations.

vii) Nectarivores

Western Spinebill

1. Confined to the south-west in forest, woodland and heath.
2. A numerous nectarivore with mean density of 6.0/10 ha. There was a sharp population increase in winter 1981 and another peak of 12/10 ha in winter 1982. These were apparently of birds attracted to nectar producing plants but the changes were correlated with changes in arthropod abundance rather than nectar availability (Figure 10). Large-scale movements are not ascribed to this species (Serventy and Whittell, 1976) but jarrah forest may be a non-breeding refuge for birds of neighbouring habitats. Thus Collins (1980) notes minimum density of spinebills in Wandoo-heath at Wongamine, east of the Darling Range, during late summer and autumn. Newlands and Wykes (1981) used a colour-banded population to show that female and immature spinebills moved into jarrah forest to feed on ephemeral nectar sources whilst males maintained home-ranges in the vicinities of their breeding territories throughout the year.
3. There was no clear-cut distributional pattern for the total research period. FA 1, the greatly disturbed, depauperate vegetation, was amongst the associations with highest Western

Spinebill density because a colonizer of such sites, Dryandra sessilis, was a nectar source for the Spinebill. Another major nectar source, Adenanthos barbigera, occurred in all but FA's 7, 8 & 9 (Table 7). Thus, FA's 7 & 8 were least utilized by the Spinebills. FA 9 (the water-course vegetation) was an autumn refuge (Visits 3 & 9) in which little nectarivory was recorded. The habitat was the least favoured in spring (Visit 7).

There was also a variety of correlations with structural variables for the study period. These were readily interpretable in terms of nectar source distributions and usage of creeks in summer/autumn, as shown by the floristic analysis.

4. Spinebills were regularly recorded in jarrah and rehabilitation but seldom in disturbed jarrah at Scenic Drive. Abundances in both jarrah and rehabilitation appeared least in spring/summer
5. Spinebills were nectarivores in all seasons. The small shrub, Adenanthos barbigera, flowered throughout the year and was only utilised by this small, long-billed honeyeater. Newland and Wykes (1981) found that male spinebills defended breeding territories in jarrah forest where A. barbigera was plentiful and this was also seen here. A. barbigera was a major nectar source in summer 1980 and spring and summer 1981. The adult males remained in their territories while females and immatures sought other sources in autumn and winter. These included marri in late summer and autumn, Dryandra sessilis in disturbed areas in winter, and Banksia grandis in spring.

Arthropods were taken as well as nectar, particularly at the breeding season. Many were gleaned and snatched at various bark sites and amongst foliage, while there was also frequent hawking and hovering. Most insectivory was in the eucalypts except when snatching in conjunction with nectarivory at flowers.

Foraging at Scenic Drive included nectarivory (B. grandis and marri) and hawking, snatching and gleaning amongst foliage in jarrah forest (n = 50). The few records in rehabilitation were of nectarivory at Albizia in June and hawking at the rehabilitation edge.

6. Five nests were recorded at Serpentine. Four were placed amongst foliage of B. grandis in the sub-canopy while one was at 25 m in a jarrah, Curry and Nichols (1985) also recorded a nest at Scenic Drive, in B. grandis within marri rehabilitation. These nest-records and records of fledglings showed that breeding occurred through most of the year, probably because of the year-round nectar available to supplement arthropods in the diet.
7. Spinebills already utilise rehabilitation but there are a variety of nectar-providing species which need to be encouraged if rehabilitation is to support a resident population of breeding birds. In particular, Adenanthos

should be encouraged in the herb-layer. Albizia and marri are already present while Dryandra sessilis is unnaturally abundant in the district since it colonizes disturbed areas. B. grandis is only a short-term nectar source but is clearly a favoured nesting species for the spinebill.

New Holland Honeyeater

1. South-eastern and south-western Australia.
2. The New Holland Honeyeater and Western Spinebill were the only resident nectarivores. The honeyeater occurred at a relatively uniform density of mean 1.8 birds/10 ha throughout the research period. Rooke (1979) similarly found that populations in the Darling Ranges were sedentary, although there were local movements to exploit seasonal nectar sources. Such local movement may have led to few birds being detected along the transects in summer, 1980.
3. Watercourse FA's were generally favoured but the summer populations were more widespread in summer. Disturbed vegetation of FA 1 was also used in winter for Dryandra sessilis nectar. Similarly, the structural analysis gave correlations with VL 3, which was high along creeks, while other correlations probably reflected excursions to gain nectar.
4. Commonly occurred during winter/spring in the rehabilitation at Scenic Drive and occasionally during spring in the jarrah forest. No creek vegetation was covered by the transect.
5. The New Holland Honeyeater was nectarivorous throughout the year. It was based in creek vegetation where nectar of Banksia littoralis was obtained in autumn-winter and sugary exudate from bark of Agonis linearis in spring-summer (less frequently recorded from bark than probably occurs). Family groups and flocks ranged away from the creeks to obtain D. sessilis in disturbed habitat in winter, marri throughout the forest in autumn, B. grandis in spring, and jarrah in summer. These sources were obviously important to the honeyeaters but the population was so small that they were not abundant at the blossom of these species. It may be that availability of breeding habitat limits the density of New Holland Honeyeaters in the jarrah forest.

The nectar was supplemented with small flies, particularly in spring/summer that were generally hawked above the creek shrub-layer. The Scenic Drive population utilized Albizia nectar (and hawked for small flies) in rehabilitation and B. grandis nectar in forest.

6. Curry and Nichols (1985) suggest that New Holland Honeyeaters breed in autumn and in spring in jarrah, as elsewhere in Australia (Frith, 1976). Fledglings were recorded in October at Serpentine and nearby Scenic Drive. Disused nests were found in dense, tall shrub-layer in one rehabilitation pit. Pairs often nest close together, forage in groups, and may have extended families with helpers at the nest (Dow, 1980).

7. These honeyeaters utilise any seasonal nectar sources away from their creek habitat, including those available in rehabilitation. More extensive planting of Agonis would encourage this species in winter while a tall, dense shrub-layer and planting of various proteaceous species attracts breeding pairs to rehabilitation. (Curry and Nichols, in prep.).

Brown Honeyeater

1. Throughout western and northern Australia.
2. Brown Honeyeaters are abundant in some habitats near the Darling Ranges (Collins, 1980), but were absent from the jarrah forest in autumn and winter, and only present at densities of less than 1/10 ha during spring and summer. (mean 0.3/10 ha).
3. Distribution was correlated with VL 7 for two, and T6 for one, of the few visits in which it was present. The reasons for these distributions are difficult to link with the foraging habits of this nectarivore.
4. Not recorded during transects at Scenic Drive but occasionally present in jarrah during spring/summer.
5. Banksia grandis (spring) and jarrah (spring-summer) nectar was utilised by the small population, with insects snatched and gleaned in foliage of the eucalypts.
6. Curry and Nichols (1985) recorded a breeding pair at the edge of rehabilitation forest at Scenic Drive. The nest was placed in low foliage of marri and the fledged young were fed by birds foraging in B. grandis and marri.
7. No indication that the rehabilitation will prove particularly attractive to this insignificant jarrah species.

Little Wattle bird

1. Generally occurs in coastal shrub and heathland of south-east and south-west Australia.
2. Occasional spring occurrence at Serpentine (mean 0.1/10 ha).
3. Ridge forest and along creeks.
4. Uncommonly recorded at Scenic Drive in rehabilitation from spring to autumn and occasionally in jarrah forest.
5. The few foraging records were in B. grandis for nectar in forest and Albizia nectar in rehabilitation.
6. A pair nested in a casuarina in October at Scenic Drive (Curry and Nichols, 1985). It is known to have helpers at the nest (Dow, 1980).
7. An insignificant member of the northern jarrah avifauna.

Red Wattlebird

1. Southern Australia.
2. Not recorded along transects but occasionally observed in late spring to autumn.
3. Too few data.
4. One pair recorded in rehabilitation at Scenic Drive in autumn.
5. Foraged at B. grandis blossom in spring, marri blossom in autumn, and ~~snatched~~ and hawked for small insects amongst foliage.
6. No evidence of breeding. Solitary birds or small groups appeared to be moving through (pers. obs., Curry and Nichols, 1985). Nests are placed in large bushes or trees (Frith, 1976).
7. An insignificant member of northern jarrah avifauna.

Purple-crowned Lorikeet

1. Southern Australia.
2. Flocks occasionally present in summer (not recorded along transect).
3. Too few data.
4. Not recorded at Scenic Drive.
5. Flock of 9+ in December 1980 foraged for nectar or pollen at jarrah blossom (Churchill and Christensen, 1970) and chewed leaves of marri. Marri may attract more Lorikeets in years of abundant blossom (Robinson, 1960).
6. No nesting recorded (nests in tree-hollows, Frith, 1976).
7. Insignificant member of the northern jarrah avifauna.

viii) Gramnivores

Western Rosella

1. Confined to the south-west.
2. Only present in low densities (0.3 birds/10 ha).
3. Surprisingly, there were no significant variances of any parrot distributions amongst FA's despite their diets comprising seeds of particular plant species. However, there were correlations with structural variables. Western Rosellas tended to occur on lower westerly slopes and along creeks (correlations with T3, T4 and T6).

4. Occasional occurrence in jarrah and disturbed jarrah at Scenic Drive.
5. This opportunistic species feeds on various types of seed, fruit and nectar (Frith, 1976). In the jarrah forest they were recorded feeding at nuts of Baeckea camphorasmac which were dropping their seeds, on fruit of introduced Cape Gooseberry in wet gullies, chewing pollen from the stigmas of Banksia grandis cones, eating into the sides of small immature jarrah nuts (pith as well as young seeds), and chewing the petioles of marri leaves. Sugary lerps were taken from jarrah leaves in forest at Scenic Drive in August.
6. Nests in hollows of trees, August-December, but no evidence of breeding at Serpentine or Scenic Drive.
7. The Western Rosella is more common in woodland and borders of forest and farmland, such as on the scarp of the Darling Ranges near the study area. The jarrah forest may provide important food sources at some times of year but Rosella numbers were so low that mining is unlikely to affect this.

Red-capped Parrot

1. Confined to the south-west.
2. Always present but fluctuated in density from over 3 birds/10 ha to virtually nil in late summer of 1981.
3. Red-capped Parrot distribution varied greatly between visits. The birds were primarily recorded along watercourses and on western slopes (positive correlations with VL 3) during Visits 7 and 10, in mature forest where large trees remain for Visits 4 and 6 (positive correlations with VL 6 and VL 7), and in open disturbed areas for Visit 2 (negative correlation with VL 4).
4. Common in jarrah forest but only occasional in rehabilitation at Scenic Drive.
5. The diet in the jarrah forest is primarily eucalypt seeds, gained in various ways from nuts of differing ages. Jarrah seeds were taken by breaking through the openings of hard but green nuts in spring, and by running the lower mandible around the insides of mature nuts in summer.

Marri was taken in winter and summer. Young fruit in winter was eaten by chewing into the bowl to remove the seed, as described by Robinson (1960), and also possibly to eat the pulp itself. Seeds from mature nuts that were opening in summer were removed by running the mandible around the inside.

Casuarina seeds were obtained in summer by chewing into nuts for mature seeds, and by taking seeds from the ground.

Banksia grandis nectar was obtained each spring by thrusting the beak well into the flowers and running the tongue around

the soft, spongy centre where nectar accumulates at the lower end.

A late spring food source was acacia seeds, obtained from green pods by snipping pieces from the sides to reveal the seeds. Robinson (1960) also lists seeds of Xylomelum (which occurred on western slopes of the study area) and Hakea (found in swamps of the Darling Ranges) in Red-capped Parrot diet. However, he and other authors have emphasised the importance of marri to these parrots whereas this study shows that jarrah seeds are equally utilised in the forest. The absence of birds in late summer 1981 may have resulted from a movement to nearby orchards to obtain fruit (Serventy and Whittell, 1976).

The population at Scenic Drive fed on marri, casuarina and jarrah seeds in the forest and on marri seeds in winter and summer in the rehabilitation.

6. Nests high in hollows of trees, generally marri, from August to December (Frith, 1976). No evidence of breeding was obtained but no doubt there was breeding in the study area and in forest at Scenic Drive.
7. This is a unique bird of the south-west that has no close relatives elsewhere. There is some fear that its numbers will decline as a result of clearing but since marri is a widespread, rapid-regenerating species, the situation is not critical (Robinson, 1960). However, its reliance on hollows for nesting means that it can only breed where there are old trees, and its need for seed-types other than marri in some seasons means that marri rehabilitation at Scenic Drive is likely to be only partially utilised. Of particular concern is the possible reduction in jarrah due to die-back and its possible failure to re-establish in mine-pits. However, the Red-capped Parrot may prove capable of exploiting seeds of novel eucalypts grown on the pits. Further study on the ecology and population limitations on this species in the jarrah forest is recommended.

Port Lincoln Parrot

1. A long-billed race is confined to the south-west forests (Serventy and Whittell, 1976).
2. Occurred at around 1.2/10 ha throughout the year.
3. Port Lincoln Parrot distributions correlated with many variables without any in particular recurring or high percentages of variance being explained. This is in keeping with the finding that various food-types were obtained during most visits.
4. The Port Lincoln Parrot was very common in all seasons in rehabilitation, at a moderate density in jarrah, and seldom occurred in disturbed jarrah.
5. It opportunistically exploits a wide-variety of plant foods and more were probably utilised than were recorded. Many

green marri fruits were eaten for their pulp and seeds in winter and spring, while jarrah seeds were obtained by chewing through the openings in summer and by running the bill around the lip in autumn.

Xanthorrhoea gracilis seeds were obtained in summer by walking up the stem of the seed-head until it bent to the ground, from where the soft but brown seeds were extracted. All heads in some areas had been attacked but some seeds were missed on most. Dropped acacia seeds were also collected from the ground along the creeks in summer, while Baeckea seeds were obtained in some swampy, creek vegetation in winter.

B. grandis supplied both nectar (head thrust right into flowers at base of cone) and pollen (stigmas chewed from edge of cone) in spring. Marri flowers were chewed in autumn for either nectar or pollen. The leaf-petioles of young leaves of banksias were also eaten in autumn. Lerps that were abundant on marri leaves in summer were obtained by nipping off the leaves and plucking the lerps, a habit also recorded by Nichols (1978).

Various food-types were utilised in rehabilitation at Scenic Drive. Seeds of Acacia saligna (on ground and from pods in bushes) and Albizia (on ground) were used in February, (n = 20); E. microcorys seeds were obtained from immature and hard nuts in April (n = 25), June (n = 20) and October (n = 5); and rehabilitation marri fruits were eaten in April and June (n = 40).

6. Nests in hollow limbs of eucalypts. No nest recorded at Serpentine although undoubtedly present, while one was recorded in a dead marri in forest near Scenic Drive.
7. This species appears less dependent on particular food-types than the Red-capped Parrot and more widespread but the jarrah forest race may face conservation problems. It has readily recolonised the marri and E. saligna rehabilitation but relies on nearby forest trees for nest-sites.

A detailed study of breeding requirements, ecology and population regulation is recommended.

Red-tailed Black-Cockatoo

1. There are various races throughout much of Australia. In Western Australia there is a population in the Kimberleys and another in the south-west. The latter consists of a small-billed race of open country that has a novel food source of double-gees (Emex australis) and a large-billed race of the south-west forest (Ford, 1980).
2. A very large species that occurred in mobile groups for most visits (mean 0.7/10 ha) with variation in the estimates of density likely to have arisen due to sampling error as well as reflecting actual changes in numbers present. Feeding groups varied in sizes from 2 to 11, but members of flocks were often scattered over large areas, and groups of 17 and

25+ were seen in flight.

3. Red-tailed Black-Cockatoo records were primarily of birds feeding on seeds of the ubiquitous jarrah and marri. Therefore, correlations in distribution with particular habitat variables might indicate whether size of tree, and possibly related aspects such as fruit abundance or maturity and tree distribution, effected choice of foraging habitat. Thus, correlation with VL 7 explained relatively high percentages of variance from Visits 3 and 7 (9 and 12%). Trees of this height (25 m) were primarily found on steep, western slopes where they had escaped logging. Assuming the cockatoos prefer to feed in these trees, explanations might be that these trees are particularly fecund; that more members of a flock of these social animals can feed in the canopy of a single, large tree; or that it is these trees that provide suitable nesting hollows. The other notable correlation was with T4 (Visits 4, 7 and 8), which had high values on westerly slopes close to the reservoir, as well as close to the eastern ridge road.

A tentative conclusion from the results is that cockatoos do discriminate between habitat types within the jarrah forest, and that mature and dense forest is preferred over disturbed, open forest of slopes and watercourses.

4. Single sighting, in jarrah, at Scenic Drive.
5. Jarrah and marri seed was the principle food, with casuarina seed taken in summer. The mature casuarina nuts, some dropping seed, were split open longitudinally with the huge cockatoos mandible and the seeds then delicately hooked out with the tip of the bill. Jarrah nuts were tackled in a similar manner when hard but green in summer and when mature and brown in winter/early spring. Mature marri nuts were chopped into pieces to obtain seeds in spring-summer.

The results indicate that jarrah seeds are particularly important in the cockatoo diet, contrary to an emphasis on marri as the food source (Frith, 1976; Serventy and Whittell, 1976; Ford, 1980). This could explain why the race is more restricted in distribution in the south-west than other parrot species.

This diet of eucalypt and some casuarina seeds compares with an E. baxteri - Casuarina luenmannii diet in south-east Australia (Joseph, 1982a) and casuarina by the Glossy Black-Cockatoo Calyptrorhynchus lathamii on Kangaroo Island (Joseph, 1982b).

6. Nests in a tree-hollow, sometimes twice a year in the south-west (Saunders, 1977). Cats are a major predator of nestlings (Joseph, 1982b). No nest records were obtained and suitable nest-sites may be scarce for this large species. Furthermore, as for the white-tailed Black-Cockatoo, breeding by groups of these birds may cease if traditional nest-sites are lost (Saunders, 1977; 1982).
7. The south-west race of Red-tailed Black-cockatoo may be one

of the most threatened bird populations in the region due to loss of habitat and breeding sites. Mining is certainly not going to improve this situation with the loss of mature forest, reduction in jarrah and loss of nest-sites. A study of breeding requirements, ecology and population dynamics is strongly recommended.

White-tailed Black-Cockatoo

1. Confined to the south-west where there is a long-billed forest race and a short-billed woodland form.
2. Not recorded along transects but occasionally present.
3. Too few present.
4. Not recorded at Scenic Drive.
5. Snipped into mature nuts of marri and hard, green nuts of jarrah to extract seeds. Also fed on Banksia littoralis seeds in a nearby swamp in winter.
6. Nests in hollows of trees. No nesting recorded.
7. An insignificant member of the northern jarrah avifauna.

Painted Quail

1. Widespread in eastern and south-west forests.
2. Regular but infrequently flushed in the forest (mean 0.3/10 ha).
3. Occurred where the low shrub-layer was dense along creeks and on westerly slopes during Visit 8 (+ve correlation with VL 2, 13% of variance explained), and there was a correlation with mature forest of lower, western slopes for Visit 10 (+ve correlation with T4, 17% explained variance).
4. Not recorded at Scenic Drive but Curry and Nichols (1985) found pluckings of a dead bird in a densely vegetated rehabilitation plot, and Wykes et. al. (1980) recorded a quail from a rehabilitation plot of tall eucalypt saplings and sparse shrub-layer. Stubble Quail Coturnix novaezelandiae are reported from newly sown rehabilitation pits.
7. This ground foraging and nesting granivore is only likely to colonise rehabilitation pits if suitable plant-species are present, sufficient cover is present to reduce predation, and fuel-reduction burning is infrequent. Christensen and Kimber (1975) did not consider this species in their study on effects of "prescribed burning". More should be known of the ecology of this species but it would be a very difficult project.

Common Bronzewing

1. Widespread throughout Australia.

2. Not recorded during transects and seldom sighted.
3. No data.
4. Winter occurrence in rehabilitation at Scenic Drive and regularly recorded at other rehabilitation plots.
5. Foraged on Acacia extensa and A. saligna seeds and possibly Albizia seed on ground below tall bushes at Scenic Drive.
6. Nest platform placed in shrub-layer thickets and breeds seasonally (Frith, 1976).
7. Probably reliant on hot fires to promote acacia and other suitable sources such as Gastrolobium in jarrah forest. It will continue to colonise rehabilitation in winter while acacias are promoted in the regrowth but may only be resident if year-round seed sources are provided.

Red-eared Firetail

The Red-eared Firetail Emblema oculata was not seen in the study area but is a relatively scarce species of the south-west that occurs in the vicinity (Nichols et. al., 1982). It is generally associated with vegetation of larger streams than occurred in the study area, where black butt E. patens, bullich E. megacarpa and Melaleuca occur with dense, tall shrub-layers. It feeds on small seeds of trees, shrubs and grass, as well as insects (Frith, 1976). Nichols et. al. (1982) provide data that suggest the species is more abundant than previously thought, has not suffered any recent reduction in range and is not likely to be affected by upland bauxite mining.

Emu

The Emu Dromaius novaehollandiae is widespread in Western Australia but now uncommon near Perth. It was occasionally sighted on the edge of the study area, in an area cleared for farming. It eats various plant materials (Frith, 1976), possibly including flowers of various jarrah forest shrubs and fruits of Macrozamia, Persoonia and Leucopogon, for which I saw no distributors. It was probably once of regular occurrence in the forest but would be difficult to re-establish.

CHAPTER 6. Discussion

6.1 Density, diversity and origins of the Jarrah forest avifauna

The average density of birds in the study area was 52.4/10 ha (± 10.3), with a total of 44 speices and an average of 27 species per census (Chapter 4). However, this says little about the characteristics of the community unless compared with other habitats. Estimates of community compositions have been collected using similar methods to those of this study in Victoria (Wykes, 1975, 1982) and in N.S.W. (Ford and Bell, 1982). Descriptions of the sites are summarized in Table 13 and comparisons of Species Richness and Total Density are shown in Figure 12.

Jarrahdale had lower Species Richness values than did the communities of most other habitats. The winter value for Mt Riddell (Mountain Ash, *E. regnans* forest) was similar but note that the estimates for Mt Riddell, Cape Liptrap and Armidale were based on small sample areas which were likely to generate low Species Richness counts (Table 13). The density values for Jarrahdale were also very low compared with eastern forest habitats and were most similar to those for low, closed heath at Cape Liptrap, where trees only occurred in the gullies. These findings refute the contention that jarrah forest has a rich avian community (Kimber, 1972; Shea, 1975).

The S.W. can be likened to an island of "Bassian" forest isolated from its eastern counterparts (Keast, 1968). As such it might not be surprising that it has in common with most islands an impoverished avifauna (MacArthur and Wilson, 1967; Keast, 1968). However, unlike many islands that are isolated from potential coloniser populations throughout their history, the S.W. has been in contact with various faunal regions and has thus had the potential to support a diverse avifauna. Bassian species remain from the original, continuous, southern forest, inland ("Eyrean") species have invaded and replaced species lost during cold, dry glacial intervals of the Pleistocene, and northern species have extended south (Serventy and Whittell, 1976). Furthermore, the ameliorated conditions of interglacial periods have provided corridors for reinvasion of the forest by eastern species and this situation of periodic contact and isolation is ideal for generation of new races and species. A good example of resultant diversification is that in the genus *Eopsaltria*. Two derivatives of the Eastern Yellow Robin occur in the S.W. - the Grey-breasted Robin *E. georgiana* is thought to be a survivor of an early pan-continental population, while the Western Yellow Robin *E. griseogularis* is considered to be a more recently isolated form (Serventy & Whittell, 1976).

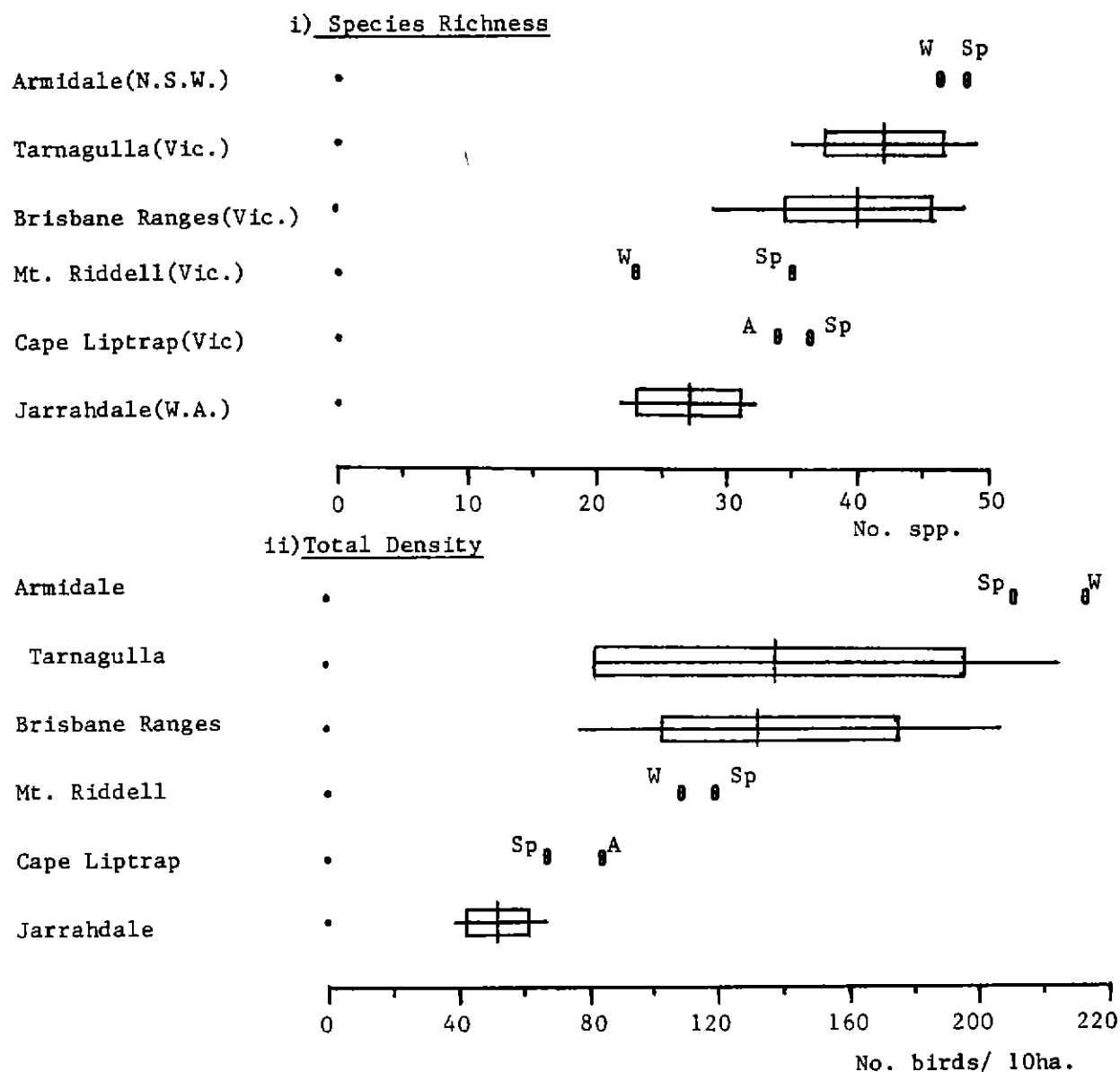
Thus, there has been an historical potential for unusually high diversity of species in the S.W., contrary to the potential of many islands. Two common responses of birds that occur in island habitats of low species diversity is partial compensation through unusually high abundances of the species that are present (density compensation), and through these species broadening their foraging habits to exploit unoccupied niches (niche expansion) (MacArthur and Wilson, 1967). The fact that avian density in the jarrah forest is markedly less than in "similar"

Table 13. Localities of study areas in W.A., N.S.W. and Victoria.

Localities, habitat types (Specht, 1970) and census methods are summarized for the bird communities whose compositions are compared in Figure 12. The winter estimate from Armidale was obtained along a 1 km transect using the method of Emien (1971) while the spring estimate (Ford and Bell, 1982) and values for Tarnagulla and Brisbane Ranges (Wykes, 1982), Mt Riddell and Cape Liptrap (Wykes, 1975) and Jarrahdale (this study) used strip-transect techniques (Chapter 2.2).

Site	Location	Habitat	Transect size (ha) (x repetitions)	Date, season
1. Armidale (30°31'S, 151°40'E)	Northern N.S.W., Great Divide	Open forest	a) 1 km line-transect (x 11) b) 2 ha (x 6)	June-Sept. 1978 (winter) Aug.-Dec. 1979 (spring)
2. Tarnagulla (36°46'S, 143°50'E)	Central Victoria, auriferous lowland	Open and low, open forest	44 ha	Oct. 1976-Sept. 1978 (11 counts, all seasons)
3. Brisbane Ranges (37°53'S, 144°14'E)	Southern Victoria, low scarp of Great Divide	Open and low, open forest	44 ha	Oct. 1976-Aug. 1978 (11 counts, all seasons)
4. Mt Riddell (37°41'S, 145°35'E)	Victoria, Great Divide	Tall, open forest	1.5 ha (x 6)	a) June 1975 (winter) b) Sept. 1975 (spring)
5. Cape Liptrap (38°54'S, 145°55'E)	Victoria, coastal headland	Low, closed heath, and low, wooded gullies	1.4 ha (x 6)	a) May 1975 (autumn) b) Sept. 1975 (spring)
6. Jarrahdale (32°20'S, 116°5'E)	Western Australia, S-W Darling Ranges	Tall, open forest	53 ha	Oct. 1980-July 1982 (10 counts, all seasons).

Figure 12. Comparative Species Richness and Total Density values for avian communities in six Australian habitats.



Values for the jarrah forest avifauna (Jarrahdale) are compared with those for the N.S.W. and Victorian communities described in Table 13. The means, standard deviations and ranges are shown for the series of estimates obtained at Tarnagulla, Brisbane Ranges and Jarrahdale over two year periods, while two estimates in differing seasons were obtained during shorter studies at each of the other sites.

eastern forest communities indicates that present ecological characteristics of the forest, rather than historical factors, maintain the community in its present form.

This is not to say that there will be no niche expansion by the species that are present. Such expansion would be predicted in the absence of competitor species no matter whether diversity was restricted because of historical factors such as isolation or ecological factors such as periods of low food availability. Thus, the two thornbill species (Acanthiza) certainly appeared to forage across the niches utilized by the 3+ species that generally occur in eastern Australian forests (Chapter 5; Ford and Bell, 1982; Wykes, 1982). Similarly, Keast (1968) found that the western race of White-naped Honeyeater Melithreptus lunatus has a longer bill and tarsus than its eastern counterparts, which he attributes to absence of a large, competing Melithreptus species in the S.W.

6.2. Ecological restrictions on Jarrah forest community composition

In this section I will examine some of the ways in which ecological factors may dictate composition of the jarrah forest avifauna.

a) Absence of particular foraging types

Overall species richness and density might be low in jarrah forest because particular types of birds are poorly represented. Table 14 compares absolute values for jarrah and the eastern Australian communities, using the various guilds suggested by Ford and Bell (1982).

The "very small insectivore" category was composed of such species as ground-foraging fairy-wrens, foliage-foraging thornbills and pardalotes, and small aerial foraging fantails and warblers. Overall species richness value varied little between habitats for this category. Cape Liptrap heath lacked a thornbill of open ground and two pardalotes of eucalypts; Mt Riddell montane forest supported some unique sub-canopy species but had a poverty of ground foragers; Armidale lacked wrens of dense shrub-layer; and Jarrahdale had only two thornbill species where ground, shrub and tree-foraging species might be anticipated. The most numerous "very small insectivore" species at most sites were the thornbills and pardalotes. Armidale had particularly high contributions from two thornbill species and a fairy-wren, while two thornbills and a scrub-wren were particularly abundant at Mt Riddell. The contributions of these groups at Jarrahdale and the inland open forest at Tarnagulla (Victoria) were relatively poor and thus total densities for very small insectivores were the lowest for these two sites.

'Small insectivores' included robins, flycatchers, whistlers, cuckoos, woodswallows and swallows. Low species richness at Cape Liptrap was attributable to absence of tree-foragers, Mt Riddell had few active foragers such as flycatchers and swallows (the study did not include a summer sample - Fig. 12), and Jarrahdale also lacked flycatcher (Myiagra) species.

Table 14. Foraging guild compositions of W.A., N.S.W. and Victoria avifaunas.

Species richness (Sp.R.) and density (no./10 ha) values are given in each of the categories erected by Ford & Bell (1982) for the bird communities described in Table 13.

Guild	Armidale (N.S.W.)	Tarnagulla (Victoria)	Brisbane Ranges (Victoria)	Mt Riddell (Victoria)	Cape Liptrap (Victoria)	Jarrahdale (W.A.)
No. of visits	2	11	11	2	2	10
Very small insectivores	Sp.R. 8 no./10 ha 59	10 26	12 47	7 72	8 40	9 27
Small insectivores	Sp.R. 11 no./10 ha 28	14 13	12 14	4 8	5 3	8 6
Bark feeders	Sp.R. 4 no./10 ha 16	8 34	6 17	3 3	2 0	2 2
Medium insectivores	Sp.R. 4 no./10 ha 8	14 7	8 3	4 2	7 7	4 1
Nectarivore	Sp.R. 7 no./10 ha 90	8 45	8 42	4 16	4 18	6 12
Granivore	Sp.R. 6 no./10 ha 18	9 5	8 12	3 6	6 4	4 4
Large birds	Sp.R. 7 no./10 ha 8	12 12	10 4	6 8	9 1	10 2
Total Birds	Spp./visit 47 no./10 ha 225	42 140	40 137	32 114	42 74	27 52

These flycatchers are primarily eastern in distribution but the Restless Flycatcher (M. inquieta) which does occur in the S.W. was absent from Jarrahdale. Highest 'small insectivore' density was at Armidale, where whistlers and robins were abundant, while lowest overall densities were at Jarrahdale and the other two sites with few species.

The 'bark-foraging' category included tree-creepers and sittellas, and also Lichenostomus (formerly Meliphaga) honeyeaters that glean from bark and foliage in the breeding season but are nectarivorous in winter. Carbohydrates associated with phytophagous insects contribute largely to the 'insect' component of these honeyeaters' diets (Wykes, 1982). Bark-foraging species were few in the Cape Liptrap heathland, while other eastern habitats generally supported two tree-creeper species, a sittella, the White-eared Honeyeater Lichenostomus leucotis, and the Shrike-tit Falcunculus frontatus. Tarnagulla and the Brisbane Ranges also had one or two additional Lichenostomus species. In contrast, only a sittella and the Rufous Treecreeper occurred at Jarrahdale.

The Brown Treecreeper Climacterus picumnus of eastern Australia primarily forages on the ground and trunks whereas the White-throated Treecreeper C. leucophaea forages on upper trunks and limbs. The Rufous Treecreeper, closely related to the Brown Treecreeper of the east (Frith, 1976), appears to utilize both of these niches in the jarrah forest (Chapter 5). The presence of only one treecreeper could be attributed to historical factors but its low density (1/10 ha) compared with combined treecreeper densities in some of the eastern habitats (2.6/10 ha at Mt Riddell, 4.0/10 ha at Brisbane Ranges, 6.7/10 ha at Armidale) suggests that the jarrah forest cannot support two species. Similarly, absence in the jarrah forest of the White-eared Honeyeater and Crested Shrike-tit, both of which are bark-foraging species in other S-W habitats (Frith, 1976), indicates that jarrah forest is generally unattractive to bark foragers.

'Medium insectivores' included various types ranging from Button-Quail through Shrike-thrushes to Owlet Nightjars. Jarrahdale and two eastern habitats had equally poor species richness in this category while Jarrahdale had the lowest density. The dry, open forest at Tarnagulla had a wide variety of medium-sized ground-foraging species and greatest overall species richness. Many of the species recorded in the eastern habitats do not occur in the S.W., including the Scaly Thrush Zoothera dauma, Spotted Quail-thrush Cinclosoma punctatum, Olive-backed Oriole Oriolus sagittatus and White-bellied Cuckoo-shrike Coracina papuensis. Others that also occur in Western Australia but not in jarrah were the Crested Bellbird Oreoica gutturalis, Whipbird (Psophodes olivaceus in the east, P. nigrogularis in the west), Chestnut Quail-thrush Cinclosoma castanotum and White-browed Babbler Pomatostomus superciliosus.

I have followed Ford and Bell (1982) in placing species such as the Fuscous Honeyeater (Lichenostomus fuscus) and Brown-headed Honeyeater (Melithreptus brevirostris) as nectarivores but these are equally gleaners of small bark and foliage sites (probably for sugars as well as insects, Wykes, 1982). 'Nectarivore' species were moderately well represented at Jarrahdale relative

to eastern habitats but total density was very low. The regularly recorded species at Jarrahdale were the Western Spinebill (which was the most abundant nectarivore - 6.0/10 ha), Silvereye, White-naped Honeyeater and New Holland Honeyeater. The tall, montane forest at Mt Riddell had a similar nectarivore complement of the Brown-headed Honeyeater (most abundant - 5/10 ha), White-naped Honeyeater, Eastern Spinebill Acanthorhynchus tenuirostris, Silvereye and Crescent Honeyeater Phylidonyris pyrrhoptera. Other sites had extremely common species, such as the Fuscous Honeyeater at Armidale (31/10 ha) and White-naped Honeyeater at Brisbane Ranges (19/10 ha). Many of the species were restricted to eastern Australia (Fuscous Honeyeater, Noisy Friarbird Philemon corniculatus, Black-chinned Honeyeater Melithreptus gularis, and Crescent Honeyeater) but this is not true of the Brown-headed Honeyeater of S-W woodland other than jarrah (Frith, 1976). The conclusion that jarrah is generally unattractive to honeyeaters, rather than lacking potential species through historical factors, is supported by considering the degree to which species with S-W populations utilized the study area. Other than the Western Spinebill and the three other regular but scarce species listed above, only occasional presence of the Red and Little Wattlebirds and Brown Honeyeater were recorded, while other S.W. species (Yellow-throated Miner Manorina flavigula, Singing Honeyeater Lichenostomus virescens, White-cheeked Honeyeater Phylidonyris nigra) did not occur in the jarrah.

The 'graminivore' category included finches, pigeons, parrots and pollen/nectar foraging lorikeets. Some of each of these groups occurred in the two eastern habitats that had high 'graminivore' diversity (Brisbane Ranges, Tarnagulla), while only tree-foraging parrots occurred at Mt Riddell and Jarrahdale. Many of the species of the eastern habitats do not occur in the S.W. (e.g. many lorikeets and finches) but a number that do occur here avoid the jarrah. Thus, the Purple-crowned Lorikeet was only rarely recorded at jarrahdale although found throughout the S.W. (Frith, 1976); the Red-eared Firetail is confined to dense creeks and was not found in the study area (Chapter 5); the Common Bronzewing occurs in rehabilitation plots where acacia is abundant but was not recorded in the study area (Chapter 5).

The species in the 'large bird' category at Jarrahdale were as varied as those recorded in eastern habitats but only heathland had as low a density as jarrah. The abundant species in this category in the eastern habitats were the ground-foraging White-winged Chough Corcorax melanorhamphus (Armidale, Tarnagulla, Brisbane Ranges) and Superb Lyrebird (Mt Riddell), both of which are restricted to the east (Frith, 1976). As in the 'medium insectivore' category, jarrah had few large ground-foraging species (Grey Currawong, Raven - total density 0.4/10 ha).

Summary

The following is a summary of the preceeding comparison of jarrah forest avian community composition with that of eastern Australian habitats.

- i) Very small insectivores were generally well represented in the jarrah community but density was low.

- ii) Flycatchers (*Myiagra*) were an obvious group of small insectivores that were missing from jarrah forest, including the locally occurring Restless Flycatcher. Overall density was low compared with other forest habitats.
 - iii) Bark-foraging species diversity and density were very low. Jarrah forest had only one treecreeper, of low density, and a sittella. The Shrike-tit and White-eared Honeyeater of the S.W. did not occur in jarrah and various other bark-foraging honeyeaters of the east were absent.
 - iv) Medium-sized insectivores were diverse but of relatively low densities in all habitats but few of the ground-foraging species, some confined to the east and others locally distributed, occurred at Jarrahdale.
 - v) A variety of nectarivores occurred in the jarrah forest but, in contrast to eastern communities, none were particularly abundant. The most similar eastern nectarivore community occurred in montane forest at Mt Riddell.
 - vi) The only graminivores in jarrah forest were arboreal parrots and cockatoos whereas these and ground-foraging pigeons, finches and pollen/nectar foraging lorikeets were regular members of eastern communities.
 - vii) Large, ground-foraging species in jarrah forest were not abundant relative to those in eastern habitats. Other large species were diverse but scarce in all habitats.
- b) Possible causes of a general poverty of species and low densities of birds in jarrah

The analysis in the previous section identified particular groups that were poor in species and density in jarrah forest but this poverty was apparent in virtually every category considered. Some of the eastern habitats were equally low in one or two categories but none as consistently as jarrah. Figure 13 is a summary of the comparisons, using relative species richness and density values.

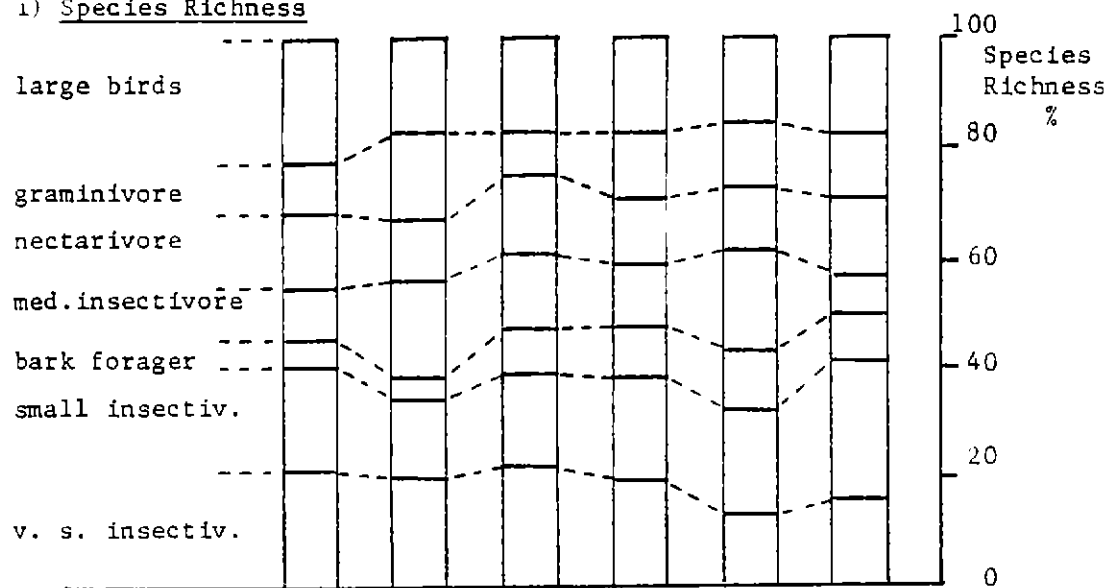
It shows that there were no striking differences in the proportions contributed by the various categories to species richness - just an overall poverty of species at Jarrahdale, only matched by the montane forest at Mt Riddell (which was based on winter and early spring samples). Differences were more apparent in the relative density comparisons, with jarrah similar to montane forest and heathland in dominance of very small insectivores and relatively few nectarivores and bark-foragers compared with the open forest habitats at Brisbane Ranges, Tarnagulla and Armidale.

Specific explanations

It may be that there is a series of separate explanations for the poverty of species and abundances of jarrah birds in the various categories that were considered. Some factors that could be considered in further research are that:

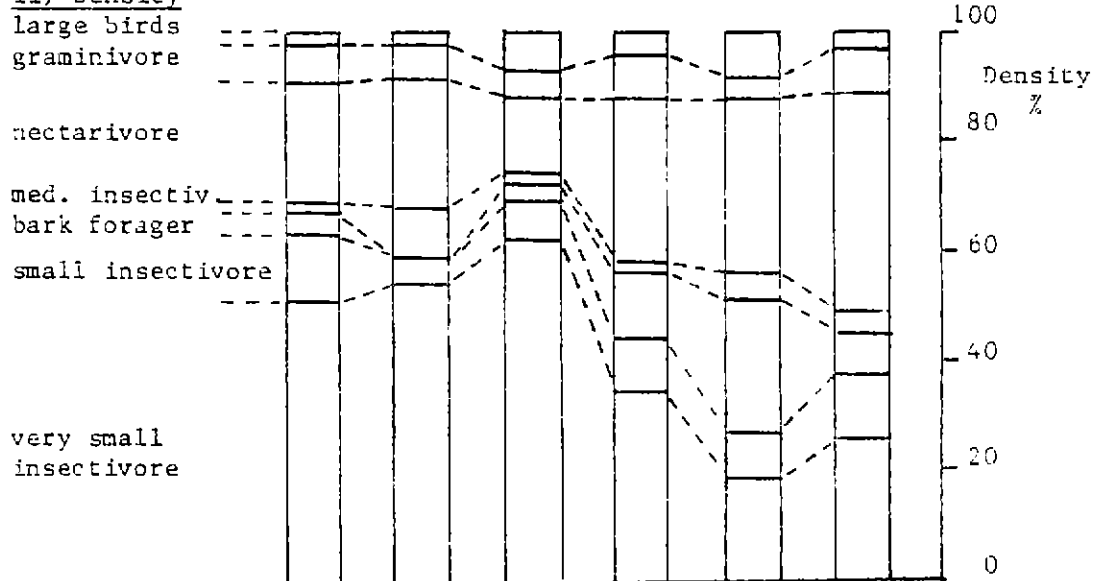
Figure 13. Relative contributions of avian guilds in six Aust. habitats.

i) Species Richness



Site	J-d (WA)	CL (Vic)	MtR (Vic)	BR (Vic)	Tarn (Vic)	Arm (NSW)
X spp/visit (no. visits)	27(10)	35(2)	29(2)	40(11)	42(11)	47(2)
Total species	43	44	36	64	75	57

ii) Density



Site	J-d (WA)	CL (Vic)	MtR (Vic)	BR (Vic)	Tarn (Vic)	Arm (NSW)
no. birds/10ha	52	74	114	137	142	227

Relative Species Richness and Density values are given for the six avian communities described in Table 13 using the categories erected by Ford and Bell(1982).

- burning of the litter-layer reduces food supply;
- lack of decortivating, gum-barked eucalypts restricts bark-foraging potential;
- low nectar availability restricts the nectarivore population.

I will consider each of these propositions in turn.

- i) Jarrah forest has been subjected to periodic fire in recent times in the form of controlled litter-reduction burns (approx. five-year intervals) and by summer wild-fire for at least the past 5,000 years (Christensen and Kimber, 1975; Churchill, 1968). Christensen and Kimber (*op. cit.*) found that few birds appeared to suffer nesting failure as a result of spring burns and that reductions in avian density were only small immediately after a fire. The populations often increased to greater than pre-fire density within two years. Thus, Kimber (1972) suggests that the avifauna is probably adapted to these burns. Those species that rely on ground-foraging might not have survived, which would explain the scarcity of medium and large litter foragers in the jarrah relative to eastern communities. Those that occurred at Jarrahdale were the scarce Grey Currawong, and surface feeders such as wrens that were largely confined to dense, creek vegetation, and robins and Shrike-thrushes that either kept to dense vegetation of southern slopes where fire was infrequent or switched to treelayer foraging in the summer (Chapter 5). However, an alternative explanation is that few species specialize in litter foraging in upland jarrah forest because of very low nutrient-levels in the soil and litter (Shea, 1975). There might be very low decomposer populations in the litter on which birds can forage. As a consequence of low nutrient levels and summer drought. Fire might in fact help breakdown the litter to release nutrients (Springett, 1979) and Whelan *et al* (1980) suggest that litter arthropod populations do not decrease as a direct result of fire, and may increase immediately after a burn.
- ii) A factor which must reduce the potential to forage on bark in jarrah forest is the lack of gum-barked eucalypts. Such species occurred in at least some microhabitats of all eastern Australian study areas. These provide shelter for arthropods under strips of decortivating bark while having phloem close to the surface which is tapped for nutrients by phytophagous insects. The trees often release copious amounts of sugary phloem (manna) at sites of damage while the insects also excrete sugar as honeydew. These sugars form much of the diets of bark-foraging honeyeaters (Wykes, 1982) and attract arboreal ants which are the staple of treecreeper diets (Noske, 1980). Both marri and jarrah have persistent, thick layers of fibrous bark on their woody structures and so it is not surprising that only one treecreeper species and no bark-foraging honeyeaters occur in the forest. The Rufous Treecreeper probably feeds on ants that travel up to the foliage of eucalypts and Banksia grandis for sugars, while also obtaining ants and other arthropods on logs and in the litter (Chapter 5).

- iii) The most simple explanation for low populations of nectarivores in jarrah forest would be poor nectar supplies. However, this did not appear to be so. A variety of widespread, abundant trees and shrubs (Banksia grandis, marri, Adenanthos barbigera, Dryandra sessilis) and others less abundant (Grevillea wilsonii, Banksia littoralis) attracted honeyeaters (Chapter 4), while other sugar food supplies such as lerps on foliage and sap of Agonis linearifolia were also utilized (Chapter 5). It is difficult to compare nectar availability with other habitats until actual levels of nectar production are measured (B. Collins, in prep.). However, my impression was that the potential of seasonal nectar sources such as Banksia grandis and marri blossom was not realized by the resident honeyeater populations and only very small influxes of nectarivores occurred (chapter 4). Thus, at least during the study period, most nectarivory only involved resident honeyeater species that could obtain year-round nectar supplies (the Western Spinebill which was closely associated with Adenanthos barbigera (Newland and Wykes, 1981), and the New Holland Honeyeater which was opportunistic) or species not reliant on nectar (leaf-gleaning White-naped Honeyeater).

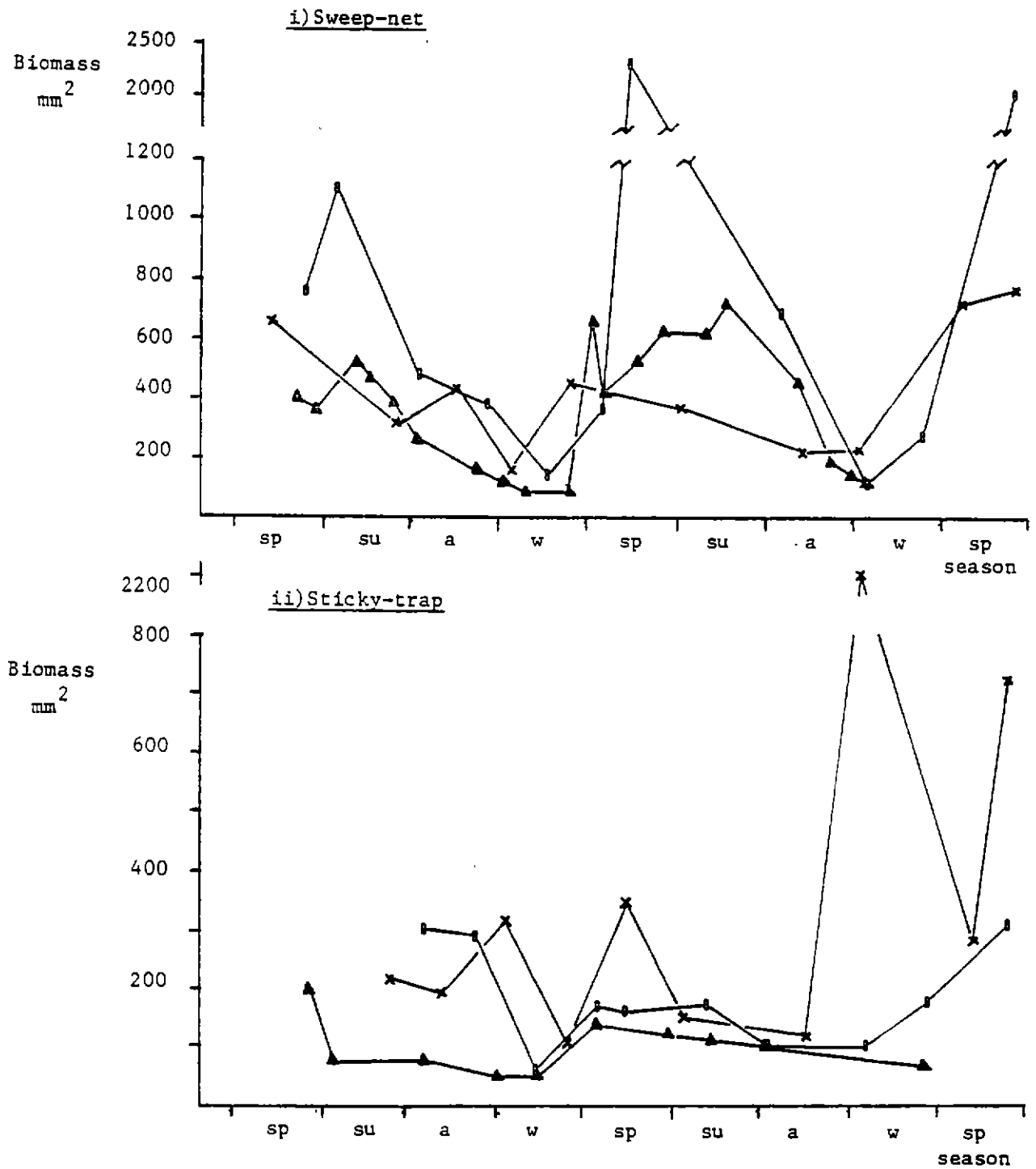
General factors

In addition to a series of specific ecological explanations for the overall poverty of birds in jarrah forest, I suggest that there are likely to be general factors involved. In reference to ground-foraging birds, I alluded to the possibility that food levels may be low because soil nutrients in the region are extremely low. It could be that, despite the height of jarrah forest trees, growth is slow and plant productivity low. Consequently, arthropod abundances and possibly seed production may be significantly less than in structurally similar habitats of eastern Australia. I was not able to directly test this proposition but I can compare relative arthropod abundances as measured by sweep-net and sticky-trap sampling at Jarrahdale, with those obtained at the Brisbane Ranges and Tarnagulla in Victoria (Figure 14).

The jarrah values are only lower than those for Victorian habitats in some seasons and a similar pattern of spring-summer peaks and winter minima occurred at all sites. It is possible that the extremely high values that occurred in some years at the Vicotiran sites are of significance but this is unlikely. High summer sweep-net catches at the Brisbane Ranges resulted from large Hemiptera populations in grass along creeks, while high winter-spring sticky-trap catches at Tarnagulla were dominated by small flies that occurred when surface water was present (Wykes, 1982). If these single, abundant taxa are not considered, then the samples from Jarrahdale would be extremely similar to those from Victoria. Thus, the data do not support the suggestion that a depauperate avian community occurs in jarrah because of generally low arthropod abundances.

Many ecologists now contend that it is too simplistic to consider overall food supply as the means by which animal populations are regulated (Wiens, 1967; Fretwell, 1972). It has been common to

Figure 14. Changes in arthropod biomass in three habitats.



Key : ▲ Jarrahdale(this study) 1980-82
 × Tarnagulla(Wykes,1982) 1976-78
 ◻ Brisbane Ranges(Wykes,1982) 1976-78

Changes in relative abundances of arthropods as measured by sweep-net and sticky-trap are given for Jarrahdale and two Victorian habitats. Methods were similar to those described in Chapter 2. Values are 'area' of insects/50 sweeps and 'area'/sticky-trap.

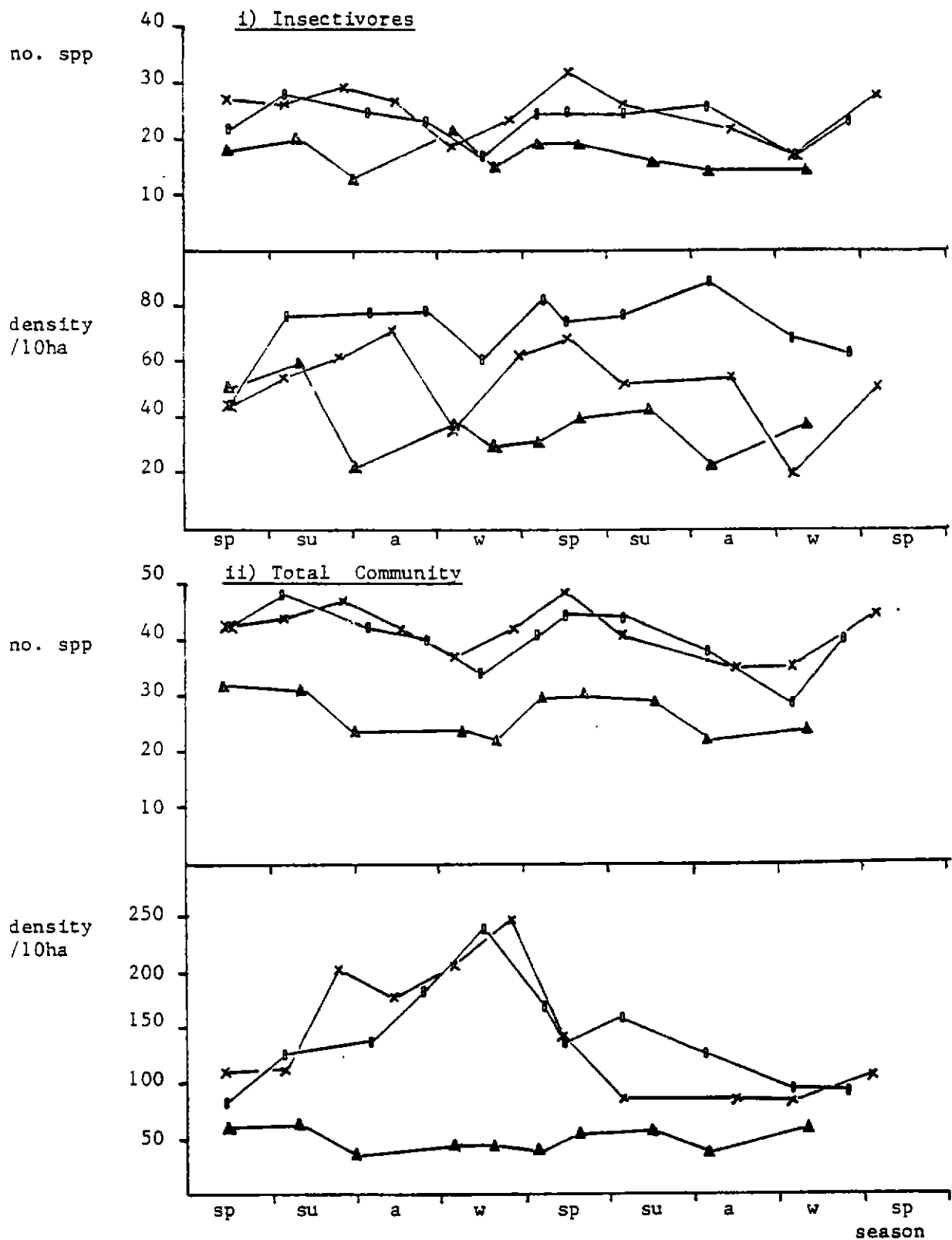
study avian communities in the breeding season (Cody, 1974) but the non-breeding season may be the time when carrying capacity and community structure is determined if food availability fluctuates greatly in a seasonal environment (Fretwell, 1972). The critical period for insectivore food supplies in mediterranean climates is usually the winter, as apparent from Figure 14 for jarrah forest. Many species shift to alternative habitats and/or utilize alternative food supplies to avoid winter food shortages (Morse, 1971). Those that cannot do this suffer extremely high winter mortalities in severe climates (Perrins, 1979).

It is likely that birds of the jarrah forest are less able to avoid food shortages than those in eastern forest communities. Karr (1982) found that when an area of forest became insulated in the Panama Canal (Barro Colorado Island), many small insectivores became extinct. This was partly because populations became non-viably small but also because of reduced ability to utilize habitat mosaics to avoid food shortages. Similarly, Smith et al (1978) found that Galapagos finches were reliant on habitat mosaics related to altitudinal variation for survival and co-existence. Might similar effects arise in jarrah forest, where the S.W. could be considered a large island of forest relative to the extensive forests of eastern Australia?

I compared seasonal changes in species richness and diversity of insectivores and total birds at Jarrahdale with those of the two eastern habitats (Figure 15). The two Victorian communities showed extremely similar insectivore phenologies while the jarrah forest had fewer and less abundant species. However, values for all sites were very similar in winter, indicating that avifauna in the jarrah forest has a smaller non-resident component. I suggest that this is because there are fewer opportunities in W.A. for species to use alternative habitats and food supplies than in the east. The groups of birds that shifted seasonally between habitats in eastern study areas, exploiting the topographic and latitudinal variation that occurs in eastern forests, included aerial foragers (such as martins, swallows and bee-eaters), flycatchers (*Myiagra*), robins, cuckoos and cuckoo-shrikes. All of these were less well represented in jarrah forest both in species richness and density than for many eastern habitats. However, two species that were highly migratory in the jarrah avifauna were the Striated Pardalote and Western Warbler. These were two of the most numerous breeding species in jarrah during the breeding season (Chapter 4) but left to winter in northern and inland woodland. Other migrants that were less common and possibly limited in density by wintering ground availability included Tree Martins, Cuckoos and Dusky Woodswallows. The Spotted Pardalote was unusual in utilising the jarrah forest as a wintering ground (Chapter 4).

I did not include the 'insectivorous' honeyeaters that switch to winter nectarivory as insectivores in Figure 15. Many of these and more specialised nectarivores are migratory in eastern Australian forests, generally seeking nectar in lowland and inland forest and woodland in winter through altitudinal and latitudinal migration. It was winter influxes of these nectarivores that produced the high winter densities of the total communities at Tarnagulla and Brisbane Ranges (Figure 15). Such

Figure 15. Changes in insectivore and total bird species and density in three habitats.



Key: Jarrahdale(this study) 1980-82
Tarnagulla(Wykes,1982) 1976-78
Brisbane Ranges(Wykes,1982) 1976-78

Changes in species richness and density of insectivores and total birds are given for Jarrahdale and two Victorian habitats.

influxes did not occur at Jarrahdale since no seasonal movements were recorded for the three main nectarivores at the site (Figure 10).

Since seasonally abundant nectar sources appeared to go begging, perhaps the small area of the S.W. forest with little altitudinal variation restricts the potential for honeyeaters as well as insectivores to alternate between habitats and food supplies with season. In considering this possibility, it should be emphasized that not only do alternative habitats need to occur but they need to provide seasonally abundant food sources that are not fully exploitable by resident bird species (Wolf, 1970; Herrera, 1978; Wykes, 1982).

6.3. General characteristics of the jarrah forest bird species

I have speculated in the previous sections as to why many species that might be expected in a forest are absent or of low density in jarrah. Does this tell us anything about the birds that do occur there? Table 15 summarises information on distribution and status of the birds that occurred at Jarrahdale. Most (63%) of the species are widespread in Australia or southern Australia. However, there is a high degree of endemism in the S.W. (36%) and these species formed 55% of the total abundances. None of the species was confined to jarrah forest. Thus, of the species from eastern forest habitat, or inland and northern Australia that could potentially have established populations in jarrah forest, most of those that are now present are either widespread habitat generalists or have become isolated in the S.W. where they have survived fluctuating climatic conditions in the past, and are capable of surviving present, seasonal food shortages without shifting to more favourable habitats. They are not specialized to particular habitat types in the S.W., they are not species specialized to foraging or nesting amongst litter, which may be depauperate in food supplies and is burnt regularly, and they are generally not specialised to foraging at bark.

It was therefore not surprising that the analysis of habitat requirements within the study area found that very few species were significantly associated with microhabitats of particular floristic compositions. Instead, densities of most species were correlated with structural characteristics of the vegetation, indicating that they will occur wherever the structure of the vegetation suits their foraging habits. It would be predicted from this conclusion that most species would readily colonise novel habitat provided that it has structural characteristics generally similar to jarrah forest. The test of this prediction has been performed through rehabilitation of bauxite minepits. The results of this study and others (Collins et al, 1984) demonstrate that recolonisation of rehabilitation has been so successful that there is no significant difference in the overall species richness and density values between the natural jarrah forest and recent rehabilitation communities, despite marked differences in composition of shrub and treelayer species and ages of the vegetation (Chapter 4). To emphasize the similarities, Figure 16 shows the changes in species richness and overall density of birds in the main study area, and in rehabilitation, jarrah and disturbed jarrah at the Scenic Drive mine site. Not only are mean values for the study period the

Table 15. Geographic distributions, status in northern jarrah forest and bauxite mine rehabilitation, and research recommendations for jarrah bird species.

All species that were recorded in the avian transects at the Serpentine study area (and five not encountered during the counts) are defined in terms of distribution in Australia, status in jarrah forest and rehabilitation, and whether further research is recommended (summary of Chapter 5).

Geographic distribution (Frith, 1976):

- Type I. Widespread in Australia, Southern Australia;
II. Confined to south-west forest/woodlands as a species or, in parentheses if a race or sub-species;
III. Confined to jarrah forest.

Status in northern jarrah forest

- Type a) the population in the jarrah forest is of low relevance to status;
b) typical jarrah species that is adversely affected by mining in the short term;
c) typical jarrah species adversely affected by mining in the short and probably long term;
d) typical jarrah species that readily recolonises rehabilitation;
e) typical jarrah species of the streams that readily colonises rehabilitation, at least in the short term;
f) uncommon northern jarrah species likely to benefit from rehabilitation of mine pits.

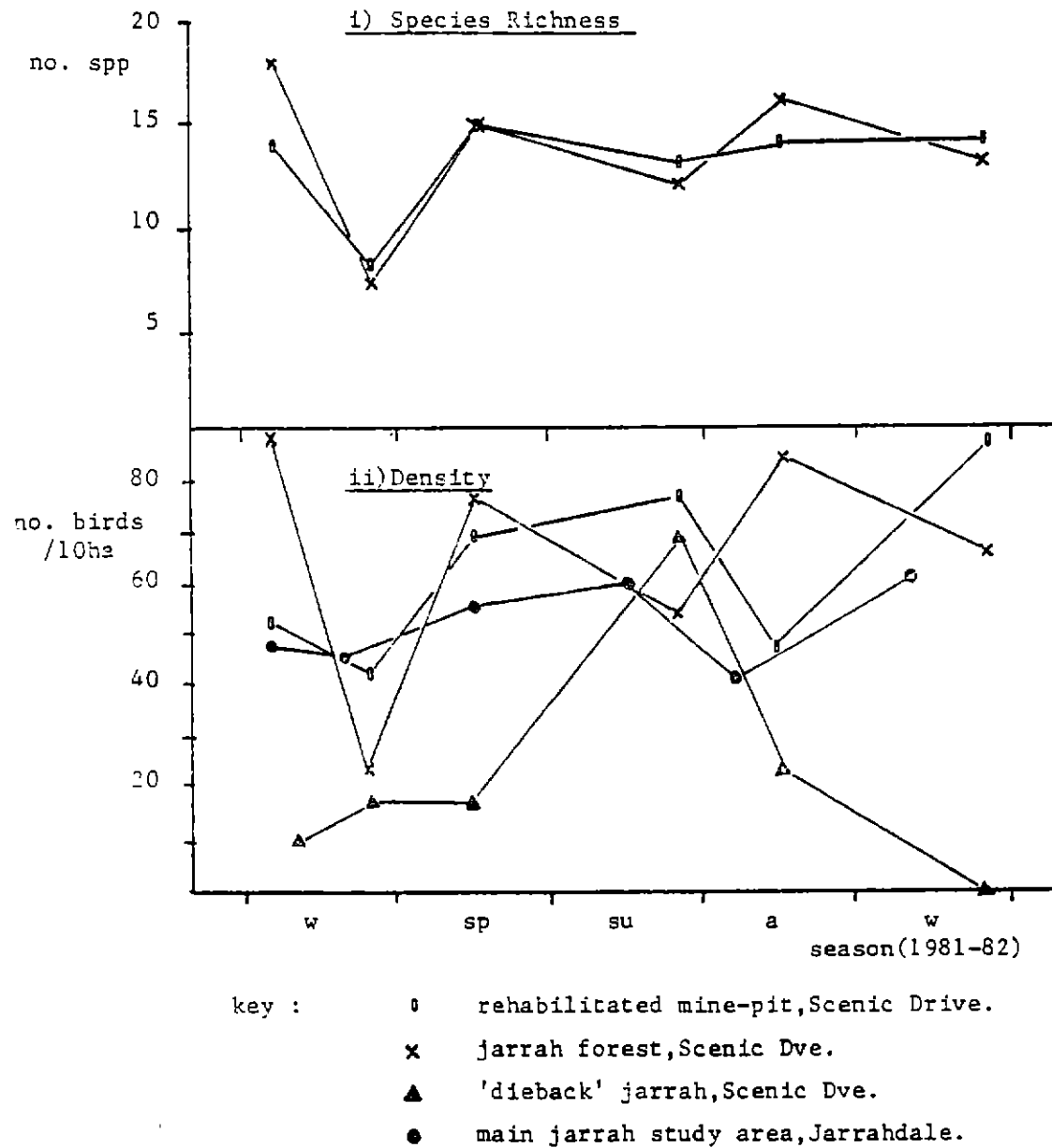
Species of particular interest

- Type A) Species whose long-term status in rehabilitation will be particularly sensitive to management factors such as occurrence of particular plant species, density of the shrub-layer and frequency of fuel-reduction burns and wild-fire.
B) Species on which further ecological research is recommended, generally to determine food and nesting requirements and thus to identify factors that limit population growth and dispersion. In the case of the Kookaburra, to investigate impact on other wildlife.

The five species that are considered here but were not encountered during the surveys are enclosed in brackets.

Guild	Species	Geographic Distributions			Status in northern jarrah forest							Special Interest	
		I	II	III	a	b	c	d	e	f	A	B	
<u>Insectivores</u>													
I) Ground -	Australian Raven	x			x								
	Grey Currawong	x				x						x	
	Western Yellow Robin		x					x					
	White-breasted Robin		x							x		x	
	Scarlet Robin (race)		x			x							
	Splendid Wren (race)		x					x					
	White-browed Scrub-wren	x								x		x	
	Tawny Frogmouth	x						x					
ii) Shrub -	Boobook Owl	x				x							
	Red-winged Wren		x							x		x	
iii) Tree -	Western Thornbill		x					x					
	Western Silvereye (race)	x						x					
	Broad-tailed Thornbill	x						x					
	Golden Whistler	x						x					
	Western Shrike-thrush (race)		x			x							
	Striated Pardalote	x					x						x
	Spotted Pardalote	x				x							x
	White-naped Honeyeater (race)		x				x						x
	Black-faced Cuckoo-shrike	x				x							
	Shining Bronze-Cuckoo	x							x				x
iv) Bark -	Fantailed Cuckoo	x				x							
	Varied Sittella	x					x						
v) Air -	Rufous Treecreeper		x					x					x
	Western Warbler	x							x				
vi) <u>Carnivore</u>	Grey Fantail (race)		x						x				
	Tree Martin	x					x						
	Dusky Woodswallow	x									?		x
	Laughing Kookaburra	x				x							x
	Sacred Kingfisher	x				x							
	Accipiter spp.	x					x						
vii) <u>Nectarivore</u>	Wedge-tailed Eagle	x				x							
	Little Eagle	x				?							
	Western Spinebill		x						x			x	
	New Holland Honeyeater	x								x		x	
	Brown Honeyeater	x				x							
viii) <u>Granivore</u>	Little Wattlebird	x				x							
	Red Wattlebird	x				x							
	(Purple-crowned Lorikeet)	x				?							
	Western Rosella		x			?							
	Red-capped Parrot		x				x						x
	Port-Lincoln Parrot (race)		x						x				
	Red-tailed Black Cockatoo (race)		x						x				x
	(White-tailed Black-Cockatoo) (race)		x				x						
	Painted Quail	x							x			x	
	(Common Bronzewing)	x								x		x	
(Red-eared Firetail)		x				x							
(Emu)	x					x							
Total (%) n = 47		63	36	-	34	21	4	28	6	6			

Figure 16. Changes in species richness and density in jarrah forest and a rehabilitated mine-pit.



Changes in species richness are given for the rehab. vegetation and adjacent jarrah forest at Scenic Drive (other habitats not included because of differing sizes of sample areas), and changes in total density are given for rehab., jarrah and disturbed jarrah ('dieback') at Scenic Drive, and also for jarrah forest of the main study area over the same period.

same for jarrah and rehabilitated communities (Chapter 4), but strikingly similar seasonal patterns of change in species and density were recorded. Further monitoring is needed to statistically verify this impression.

Species with specific food requirements such as parrots, cockatoos and nectarivores might be expected to be less catholic in their habitat usage and susceptible to changes in floristic composition of the vegetation. However, these species have survived the same selection pressures as have insectivores, and have relatively general food requirements. Many are opportunistic species that switch between many food sources that are available within and in neighbouring habitats to the jarrah forest (Port-Lincoln Parrot, Western Rosella, New Holland Honeyeater, Western Spinebill). The Red-capped Parrot and Red-tailed Black Cockatoo are more specific in their diet, feeding on the seeds of but a few tree species but these are the widespread eucalypts and casuarinas of the S.W. (Chapter 5).

6.4. Conservation of the jarrah forest avifauna

A general conclusion from the research is that most jarrah forest bird species are not specialised to, or dependent on, jarrah forest. Their populations should only be threatened if forest habitat is removed altogether. Thus, there should continue to be successful colonisation of rehabilitated vegetation that is structurally similar to natural forests. The most convincing evidence that the jarrah forest species will exploit novel habitat provided that it is structurally suitable is provided by differences in the species composition of rehabilitation and that of jarrah forest. The young rehabilitated vegetation in upland sites at Scenic Drive had a very dense shrub-layer and low tree-canopy, which is structurally similar to vegetation of the streams in jarrah forest. Accordingly, many of the bird species in the rehabilitated plot were not those of upland forest but were species generally restricted to the creeks - fairy-wrens, scrub-wrens, New Holland Honeyeater, and the sparsely occurring White-breasted Robin (Chapter 5).

The conservation considerations noted for the individual species in Chapter 5 are summarised in Table 15. "Status" type a) were species whose populations in the jarrah forest do not appear to be important. Many such as the Sacred Kingfisher only rarely occurred in this habitat but are common elsewhere (e.g. Wandoo woodland). Others may have once regularly occurred in northern jarrah forest but do not do so now and are found elsewhere (Emu, Red-eared Frietail).

The type b) species are likely to be adversely affected by mining in the short-term. For some, this is because the rehabilitated shrub-layer is initially too dense (e.g. Ground-foraging Grey Currawong, Scarlet Robin, Boobook Owl). Whether the rehabilitation retains this characteristic depends on future management policy. Frequent burning and possible re-seeding could be used to maintain a dense shrub-layer, which would continue to favour species of the streams that are now present (types e) and f)). A compromise would be to manage pits in different ways so that a diversity of habitat-types would support somewhat differing communities of jarrah forest species. I have

acknowledged this need for further management considerations by including these species in the "special interest" Type A (Table 15).

A number of other species in type b) (short-term adverse affect of mining) are those not found in immature rehabilitation because they forage in trees. As for the shrub- and sub-canopy foragers, it is extremely likely that these species will forage in rehabilitation as the trees mature. Many other species fall into type d), species which readily colonise rehabilitation, and appear not to require special attention.

I have already noted that the honeyeaters, parrots and cockatoos of the jarrah forest appear to be relatively adaptable despite having specific food requirements. I have placed the Western Spinebill and New Holland Honeyeater in "Special interest Type A - sensitive to management policies" but they should not be difficult to conserve. The foraging requirements of both are relatively well known, they are the subject of present research (B. Collins, WAIT), and are already colonising rehabilitated vegetation because suitable nectar-producing plants are present. I have placed the Red-tailed Black Cockatoo and the Red-capped Parrot in "Type B - requiring further research". These are unique species of the S.W. with relatively specialised food and nesting requirements. Research should aim to determine which factors regulate the densities and distributions of these species. What habitat and nest-sites are needed for breeding? Are these limiting? Is there a period of limiting food supply such as food required for breeding? Can nest-boxes be used to boost their populations? (see more specific notes in Chapter 5).

There are other species that require hollows in which to nest and will not be able to breed in rehabilitation until suitable hollows develop with time. Curry and Nichols (1985) found that a number of these species at present nest in patches of jarrah forest adjacent to the small plots of rehabilitation and some venture into the rehabilitation to forage. It is therefore important that the present policy of maintaining patches of jarrah in the mined areas be continued.

I have included a number of other species in "Type B, recommended for further research". The Rufous Treecreeper is included because its probable food-supply of arboreal ants might be particularly affected by burning policies and plant composition of rehabilitation, while its complex social organisation and use of hollows for nesting might also render it susceptible to change. The Shining Bronze-Cuckoo is singled out because it is unusual in wintering on islands in the north of Australia. Its continued presence and density in the S.W. may thus be dependent on conservation of its wintering grounds but as yet, these have not been studied. The two pardalotes are interesting because of their complimentary migratory patterns (Chapter 4) for which the underlying reasons are unknown. The White-naped Honeyeater race of W.A. shows some differences in morphology to its eastern counterpart (Keast, 1968) and possibly differences in social behaviour (Chapter 5). It would thus be a good subject for further research regarding ecological effects on birds that are isolated in S.W. forests. The Dusky Woodswallow has a S.W. population of which little is apparently known concerning status,

ecology and movements (Serventy and Whittell, 1976). The introduced Laughing Kookaburra is included more for interest in its effects on other species such as potential competitors for food (Sacred Kingfisher) and nest-sites (parrots) and on potential prey species such as bird nestlings and reptiles.

6.5 Conclusions

- I. The avifauna of jarrah forest is relatively depauperate in species numbers and abundances compared with communities of eastern Australian forests. This appears to be due to poor potential for migratory avoidance of limiting periods (low winter food abundance for insectivores, only periodic occurrence of abundant nectar); historical pressures of periodic isolation and contraction of the small forest area with concurrent climatic variation; and specific ecological constraints such as poor potential for litter foragers and bark gleaners. Consequently, most of the insectivores, nectarivores and parrots of the forest are either habitat generalist through out southern Australia or are widespread species in the S.W. that utilize all forest-types.
- II. Predictions for conservation and management of the jarrah forest avifauna in the face of bauxite-mining are optimistic. Firstly, no species of birds are threatened because none are confined to the jarrah forest (for reasons suggested in point I). Secondly, analysis of distribution of birds within the forest showed that most were either confined to or favoured stream vegetation and deep, south-facing slopes, rather than the laterite-capped ridges where mining occurs. Thirdly, the adaptable, opportunistic characteristics of the species (predicted in point I) were verified by their readiness to colonise rehabilitation plots.
- III. The present rehabilitation procedure, which at this stage has produced vegetation of a low 'tree' canopy of various eucalypt species and a dense understorey, was found to successfully attract a comparable avifauna to that which occurs in the natural jarrah forest. Species Richness and overall density values were indistinguishable in all seasons. The rehabilitation more closely resembles stream vegetation than upland forest in structure and this was reflected in avian species composition. Both structure and avian composition should shift towards that of upland forest as it matures although management policy could be directed towards retaining a dense shrub-layer and associated stream-dwelling birds in some pits.
- IV. The ecological characteristics of all jarrah bird species, as far as was determined, are detailed in the report, and recommendations are made for further research to be conducted in a number of cases. In particular, the Red-tailed Black Cockatoo and Red-capped Parrots require attention because they have populations restricted to the S.W. (race and species, respectively), their food resource of eucalypt seeds (and some casuarina seeds) is very specific although apparently widespread and abundant, and they require hollows in which to nest. Conservation

measures for these species cannot be taken until more is known of their ecologies and the factors which regulate their populations.

- V. The report has not reviewed in detail the present rehabilitation procedure or past methods and does not speculate as to the viability of rehabilitated vegetation in terms of usage of non-endemic eucalypts, unnatural soil conditions and die-back fungus attack. Nor does it consider possible effects of mining on neighbouring habitat such as down-stream vegetation. It is obviously important that the situation continues to be monitored as the rehabilitation matures. The results of this report have been reviewed in conjunction with these other considerations by Collins, Wykes and Nichols (1984).

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