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The foraging ecology and habitat selection of the Yellow-Plumed Honeyeater (Lichenostomus Ornatus) at Dryandra Woodland, Western Australia

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The Foraging Ecology and Habitat Selection of the Yellow-plumed Honeyeater (Lichenostomus ornatus) at Dryandra Woodland, Western Australia.

by KELLIE WILSON

A thesis submitted in partial fulfilment of the requirements for the award of Bachelor of Science (Environmental Management) Honours

School of Natural Sciences

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USE OF THESIS

The Use of Thesis statement is not included in this version of the thesis.
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Abstract

The foraging ecology and habitat selection of the Yellow-plumed Honeyeater was examined using observations and vegetation surveys at Dryandra Woodland, Western Australia. Foraging ecology data was collected over three seasons (autumn, winter and spring) in 1997 at three sites within Dryandra. Habitat selection studies involved 156 sites being surveyed for the presence or absence of the Yellow-plumed Honeyeater. The vegetation characteristics of the site were measured.

Yellow-plumed Honeyeaters foraged by gleaning foliage most of the time. Bark and aerial foraging were also common. Birds clearly selected for tree height, preferring to forage on larger (older) trees which may be because of the proportionality larger amount of resources available on older trees. This has major implications for management as most remnants are severely degraded and have had the larger trees removed.

There was no significant trends observed in the foraging behaviour over the seasons, although birds at one of the sites demonstrated a seasonal change. Therefore, it is not possible to judge the exact preferred foraging behaviours or substrates used as they fluctuate over time and space.
Habitat selection studies showed Yellow-plumed Honeyeaters have a clear preference for areas with over 70% wandoo (Eucalyptus wandoo) trees. They were present at 25 of the 156 sites surveyed and did not occur in areas with over 30% powderbark wandoo (E. accedens). The resources provided by the two areas are different, and I suggest that it is the absence of a continuous bark resource which prevents Yellow-plumed Honeyeaters residing in powderbark wandoo areas.

Apart from a high abundance of wandoo trees and low abundance of powderbark wandoo trees, there were no vegetation characteristics which were significant in distinguishing areas where the bird was present from areas where they were absent. Clearly, the birds require large areas of wandoo woodland and the retention and management of areas large enough to support the Yellow-plumed Honeyeater is the best option for the conservation of the species.
I certify that this thesis does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any institution of higher education; and that to the best of my knowledge and belief this does not contain any material previously published or written by another person except where due reference is made in the text.
Acknowledgments

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PART 1: INTRODUCTION
Chapter 1: Aims, Outline and Background Information

This chapter provides an overview of the rationale and aims of the research. The history of clearing in the wheatbelt region and its impacts on avifauna are discussed, along with a brief background on the status, systematics, morphology and foraging of the Yellow-plumed Honeyeater. An outline of the study is also given.

1.1 Introduction

The Yellow-plumed Honeyeater was once found extensively throughout the south-west region of Western Australia, but has declined across much of its range (Saunders & Ingram, 1995; Saunders & de Rebeira, 1991; Lynch & Saunders, 1991; Saunders & Curry, 1990; Saunders, 1989) and persists only in a few isolated remnants. It remains abundant at the Dryandra Woodlands and on the eastern fringe of the wheatbelt (Recher & Davis, pers. comm.). The population at Dryandra provides the opportunity to investigate the species biology with the aim of understanding why it has declined and is unable to survive in many wheatbelt remnants.

The loss of the species throughout much of its range has been attributed to the widespread loss and fragmentation of its habitat (Lynch & Saunders, 1991; Saunders, 1989; Lynch et al., 1995; Saunders & Ingram, 1995). However, while the major phase of land clearing may be over, the problem of managing
remaining remnants is not. Remnants are subject to extrinsic pressures and often they cannot support the communities they once contained. For reasons that are not clear, even some of the largest remnants are not able to support the Yellow-plumed Honeyeater.

1.2 Study Aims
The broad aim of the study was to determine why the Yellow-plumed Honeyeater does not survive in remnants by examining the foraging ecology and habitat selection in a large, continuous block of habitat. Information on foraging and habitat use in continuous vegetation provides baseline information on the species resource requirements and how it uses these resources. These data can then be used to investigate resource availability in remnant vegetation to determine whether changes in resource availability and abundance associated with habitat fragmentation are important factors affecting the decline and extinction of Yellow-plumed Honeyeaters in remnant vegetation.
1.2.1 Foraging Ecology

Little is known about the foraging resources required or how Yellow-plumed Honeyeaters respond to shifts in their food resources. The specific aims of the study are to answer a series of questions:

Which behaviours and substrates are used the most frequently?

Do birds select for particular substrate characteristics:
- tree species?
- tree size?

How does the foraging ecology vary spatially?

How does the foraging ecology change over autumn, winter and spring?

An examination of the birds most frequently used behaviours and substrates will enable management decisions to consider these preferences, providing the birds with their optimum resources. While commonly used behaviours and resources are important, other less common behaviours and resources may be just as important in fulfilling energy and protein requirements. The birds may use a narrow or broad foraging range and if they forage using only a few substrates, these essential resources must be present for survival. If the birds use a wide range of resources, they may not be as sensitive to changes occurring in a remnant. Without this knowledge, management for conservation cannot even begin to be effective. Determining temporal and seasonal changes to the foraging ecology is also necessary as it is important to know the full range of foraging requirements of the species.
The selection of trees of a particular size and species is an important issue as it is often the larger trees which are removed from remnants first. The selection of larger trees and their resources would suggest a reason for the decline in Yellow-plumed Honeyeaters, with most wheatbelt remnants in poor condition and likely to have had the larger trees removed. The incorporation of the information on the selection of trees for foraging will enable better management decisions to be made. If Yellow-plumed Honeyeaters select for larger trees, the continued management and retention of areas containing larger trees would be needed. If smaller trees are being selected, attempts at reclaiming and revegetating areas for the Yellow-plumed Honeyeater may prove successful, and if no selection is observed, it would be important that areas containing both older (larger) and younger (smaller) trees were retained and actively managed.

1.2.2 Habitat Selection

The aims of this study are to determine the preferred areas of habitat for the Yellow-plumed Honeyeater based on its presence or absence at a site, and to ascertain which other vegetation characteristics (if any) are associated with the presence of the bird.

Previous work at Dryandra by H. Recher and W.E. Davis (in review) had shown that Yellow-plumed Honeyeaters were resident in and largely restricted to wandoo (Eucalyptus wandoo) woodlands. What was not clear was the extent to which Yellow-plumed Honeyeaters used woodlands dominated by wandoo in contrast to powderbark wandoo (E. accadens) or mixed wandoo/powderbark
wandoo. Based on these observations, this study investigated the selection of wandoo, powderbark wandoo and mixed wandoo/powderbark wandoo vegetation types.

Currently, it is not known why the species doesn’t survive in remnants. I hypothesise that Yellow-plumed Honeyeaters have particular foraging requirements which must be met for long-term survival. By examining several aspects of the foraging ecology, it is possible to determine if the birds have any preferences for particular foraging behaviours, or foraging substrates such as tree size and species. By comparing these to what is available in remnants, the suitability of an area for conservation of the Yellow-plumed Honeyeater can be ascertained. If management efforts continue without considering these optimum foraging requirements, it would guarantee further declines in abundance and more local extinctions. The Numbat (*Myrmecobius fasciatus*) and Rufous Treecreeper (*Climacteris rufa*) are also found within the wandoo woodland at Dryandra, and it is likely that any information which leads to better management of the Yellow-plumed Honeyeater is going to benefit these species as well.

1.3 Thesis Outline

Chapter 2 provides information on the Dryandra study area including vegetation and landforms. Part 2 examines the foraging of the Yellow-plumed Honeyeater in terms of prey-capture behaviour and resource use and selection based on observations at three sites over three seasons. Chapter 3 describes the
methodology used, with the results presented in Chapter 4. A discussion of the results follows in Chapter 5.

Part 3 examines the habitat selection of Yellow-plumed Honeyeater. Chapter 6 describes the two main methods used; presence/absence data and vegetation surveys. The results for the sites are presented in Chapter 7, followed by a discussion in Chapter 8.

Management issues and conclusions are discussed in Part 4 (Chapter 9).
1.4 Background

In order to understand the reasons why the species has declined, it is necessary to understand the scope of the clearing which saw millions of hectares of prime Yellow-plumed Honeyeater habitat converted to agricultural land. The wheat-sheep region of south-western Western Australia is known as the wheatbelt (Saunders & Ingram, 1995), and covers an area of about 14 million hectares (Figure 1).

1.4.1 A history of clearing in the wheatbelt

After Europeans established themselves on the Swan River, they moved into the wheatbelt and began grazing sheep on native vegetation (Saunders & Ingram, 1995). These changes were relatively small and by 1889 the population was 53 000 and only 53 000 ha of land in the south-west had been cleared (Smith, 1987; Saunders et al., 1985; Saunders & Curry, 1990). After the Second World War, with the availability of heavy machinery, the pace of clearing accelerated (Main, 1993; Saunders & Curry, 1990; Saunders, 1989). The release and clearing of land reached its peak in the 1960s when the government made 405 000 ha (1 million acres) of land available annually for wheat and sheep farms under what was known as "conditional purchase"; the condition being that the land was fenced and cleared (Saunders & Ingram, 1995).

By the late 1970s, most of the large scale clearing and development was complete (Saunders & Ingram, 1995). In total around 93% of the native
vegetation was removed (Lynch et al., 1995; Saunders & de Rebeira, 1991; Saunders & Curry, 1990; Lynch & Saunders, 1991; Saunders, 1989; Saunders et al., 1985), with over half of this being removed after 1945 (Saunders et al., 1985; Saunders, 1989). With the loss of such a high percentage of the original vegetation, there were inevitable major impacts on the region’s biota. Three hundred and forty-eight species of plant are listed as rare and endangered in the wheatbelt (Hopper et al., 1990), and at least 24 are believed to be extinct (Leigh et al., 1984). While many vegetation associations may have existed in small or isolated populations before clearing, they are now surrounded by an agricultural matrix and the patches in which they survive are degrading (Saunders & Ingram, 1995). The long-term viability of most of these populations is extremely poor (Saunders & Ingram, 1995).

The remaining vegetation exists in thousands of remnants of varying size, shape, species associations, isolation, ownership and history of landuse (Saunders et al., 1987). These remnants do not represent the original vegetation as some vegetation associations were cleared more than others. For example, woodlands grew on heavy soils and were regarded by the early settlers as indicators of good agricultural land (Beard & Sprenger, 1984) and were preferentially cleared. Less than three percent of the original area of York gum *Eucalyptus loxophleba*, wandoo *E. wandoo* and salmon gum *E. salmonophloia* woodlands remain (Beard & Sprenger, 1984). These woodlands are poorly represented in wheatbelt conservation reserves (Saunders & Ingram, 1995).
During the rapid and widespread clearing of the wheatbelt, no consideration was given to nature conservation. For that reason, the wheatbelt is poorly served by conservation reserves (Saunders & Curry, 1990). Less than 15 percent of the remaining vegetation is in conservation reserves (Saunders & Ingram, 1995) with 639 remnants gazetted as nature reserves ranging in size from 0.4 ha to 309 000 ha (Saunders, 1989). These reserves contain 6.7% of the area of the wheatbelt, but if the three largest reserves are excluded, this figure drops to 2.4% (Wallace & Moore, 1987). The remaining 85 percent of remnant vegetation is on private property and continues to be degraded. A recent assessment of the conservation value of remnant vegetation in the central wheatbelt using satellite imagery showed that only three percent of the area of original vegetation was in good condition (Lambeck & Wallace, 1993). Despite the fact that the major phase of agricultural development and land clearing has finished, the problem of maintaining the remaining vegetation is strongly evident.
FIGURE 1: The Wheatbelt of Western Australia lies between the 300 and 600 mm isohyets. (Saunders & Ingram, 1995)
1.4.2 Changes to the avifauna of the wheatbelt

It is not possible to remove over 90% of the original vegetation without having major effects on the flora and fauna (Saunders & Ingram, 1995). While no species of bird has become extinct in the wheatbelt, the majority of change has taken place during the last 20 to 60 years and it may be that the loss of species in the region will be a slow process (Smith, 1987).

An examination of the data presented in Saunders and Ingram (1995, shows there has been a massive reduction in the range and/or abundance of a large proportion of wheatbelt birds. Forty-nine percent have declined in range and/or abundance since the turn of the century, 17% have increased and no change could be demonstrated for 34% of species. The changes have been beneficial to some birds. Twenty-one species of non-passerine and 13 species of passerine (perching or songbirds) have increased in range and/or abundance over the past 90 years, nine percent of these being exotic (Saunders & Ingram, 1995). The species which have invaded are the ones that feed on grasses, are dependent on water, and forage in open areas (Saunders & Curry, 1990). Some of these species may compete with resident species for resources and compound the effects of habitat fragmentation (Saunders & Curry, 1990). These changes have been stated as directly attributed to the loss of native vegetation (Davies, 1977; Kitchener et al., 1982).

Overall, passerines have fared worse than non-passerines (Saunders & Curry, 1990). Sixty-seven percent of passerines in the wheatbelt have declined in
range and/or abundance, 15% have increased and there has been no apparent change in 18%. Thirty-four percent of non-passerines have declined, 19% increased and 46% have apparently not changed (Saunders & Ingram, 1995). The majority of species that have declined are residents dependent on native vegetation (Saunders & Ingram, 1995). The Yellow-plumed Honeyeater is such a species.

1.5 The Yellow-plumed Honeyeater

The Yellow-plumed Honeyeater (*Lichenostomus ornatus*) is a typical example of a species which, along with its habitat, has experienced a decline in abundance. It is found throughout southern Western Australia, southern South Australia and the New South Wales and Victoria (Simpson & Day, 1989). In Western Australia, it is found in the woodlands and mallee of the higher rainfall areas of the wheatbelt where there are large areas of woodland remaining. However, most remnants in the wheatbelt are small, and for reasons that are not clear, even the largest remnants are often not suitable for the Yellow-plumed Honeyeater.

1.5.1 Changes to populations

The Yellow-plumed Honeyeater has undergone a dramatic decline in abundance, as outlined in Saunders and Ingram (1995). Early this century, it was common to very common in the wheatbelt. For example, it was common in the wandoo country in the Stirling Range (Milligan, 1903), numerous in eucalypts in the Wongan Hills area (Milligan, 1904), the commonest honeyeater...
in the area of Cumminin Station, near Bruce Rock (Crossman, 1909), common in salmon gum belts in the Moora district (Orton & Sandland, 1913), common in open timbered country around Broome Hill (Carter, 1923), and the most common honeyeater in the Kellerberrin area (Leake, 1962). By the 1950s and 1960s, it had disappeared from Wongan Hills (de Rebeira & de Rebeira, 1977) and was reduced to a small population in wandoo woodland on Kodj Kodjin Nature Reserve north of Kellerberrin (Dell, 1978); it no longer occurs there (Saunders & Ingram, 1995). A study by Saunders (1989) found the Yellow-plumed Honeyeater to be rare in the Kondinin district, being seen by only one of 11 observers, and that observer only saw the species once in 29 weeks of recording (Saunders, 1989).

The Yellow-plumed Honeyeater is a rare vagrant in the Kellerberrin district (Lynch and Saunders, 1991; Saunders and de Rebeira, 1991; Saunders and Curry, 1990). However, Lynch and Saunders (1991) found it was widespread and common in the wooded country of the Western Goldfields and Recher and Davis (pers. comm.) found it was abundant near Yellowdine, east of Southern Cross during 1997. The demise of the Yellow-plumed Honeyeater has been attributed more to the effects of land clearing (habitat loss, fragmentation) than to extrinsic species-wide population declines (Lynch & Saunders, 1991; Saunders, 1989; Lynch et al., 1995; Saunders & Ingram, 1995).
1.5.2 Systematics and morphology

The Yellow-plumed Honeyeater (*Lichenostomus ornatus*) belongs to the Family Meliphagidae. In Australia, 67 honeyeater species occur (Simpson & Day, 1989) and the classification of these into genera is in a state of flux. In southern temperate Australia, honeyeaters may be divided into three groups; ‘nectarivorous’ genera such as *Anthochaera*, *Phylidonyris*, *Lichmera* and *Acanthorhynchus*, which feed mainly on nectar; so-called ‘insectivorous’ genera, such as *Melithreptus*, *Manorina* and many species of *Lichenostomus*, which feed mainly by gleaning foliage or probing bark for honeydew, lerp or insects; and ‘frugivorous’ species such as Spiny-cheeked and Singing Honeyeaters, which eat large amounts of fruit, at least in some parts of their range. However, these groups are not rigid, but highlight the morphological specialisation within the Family. Nectarivorous species are generally longer beaked which enables them to probe a greater variety of flowers (Simpson & Day, 1989). The Yellow-plumed Honeyeater is a small species weighing approximately 19 grams (Wykes, 1985) and with a total length of between 15 and 18 cm (Wykes, 1985; Simpson & Day, 1989). It is a small beaked bird with a bill size of 12.1 mm (± 0.79 mm) (Ford & Paton, 1976).

1.5.3 Diet and foraging

The Yellow-plumed Honeyeater is one of the insectivorous honeyeaters which take insects from foliage and bark and include some fruit, nectar and other carbohydrates in their diets (Pyke, 1980; Paton, 1980; Keast 1968, 1976; Ford & Paton, 1976, 1977; Dow, 1977). In a review paper by Pyke (1980), birds from
Lichenostomus were found to feed on nectar 43% of the time, insects 44% of the time and fruit 13% of the time. A study by Ford and Paton (1976) near Adelaide found that Yellow-plumed Honeyeaters ate insects 76% of the time and nectar 24%. Ford and Paton (1977) found Lichenostomus honeyeaters tended to feed on open, cup-shaped flowers. In addition to lerp feeding, Yellow-plumed Honeyeaters feed on honeydew and manna (Paton, 1980). Lerp is the protective covering over foliage-living psyllids (Hemiptera: Psyllidae) (Paton, 1980) and are composed largely of sugars and other carbohydrates (Woinarski, 1984). These are profitable food sources for birds, as is manna (the sugary fluid that exudes from damaged plant material and later crystallises) and honeydew (the sugary secretions of nymphal stages of aphids, coccids and psyllids) (Paton, 1980). These three substances can be considered substitutes for nectar but not for protein (Paton, 1980).

According to Saunders and Ingram (1995), the primary diet of the Yellow-plumed Honeyeater consists of nectar, insects, spiders, and mites. In a South Australian study by Ford and Paton (1976), the Yellow-plumed Honeyeater was found extensively throughout the Mallee and foraged by hawking 27% of the time, on foliage 25%, on nectar 24%, on bark 22%, on the ground 3% and on shrubs 1% of the time. According to Woinarski (1984), honeyeaters of the Lichenostomus genus specialise on lerp-feeding and defend dense patches of lerp. A study of lerp-feeding by Woinarski et al. (1989) showed that the Yellow-plumed Honeyeater did not select for lerp size, but took the lerp and nymph

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* figures as presented by Ford and Paton (1976)
eleven times more than taking the lerp only. In a single study of avian foraging at Dryandra Woodland in spring, Recher and Davis (in review) found the Yellow-plumed Honeyeater to be primarily a bark forager, taking more than half their prey from bark, with around 15 percent of their prey consisting of flying insects caught through hawking. Bark probing was the most common foraging method used (47%), followed by gleaning (28%). Tullis et al. (1982) studied the diets of several small birds in Banksia woodlands near Perth. While the Yellow-plumed Honeyeater was recorded in the area, its foraging was not discussed as it was not abundant. The study found the shorter billed species of honeyeaters (Lichenostomus) fed more on insects than nectar, and gleaned insects from leaves and bark.

The Yellow-plumed Honeyeater is still relatively unresearched. This research will focus on the foraging ecology of the species over three seasons at Dryandra. No study of this type has been conducted on the Yellow-plumed Honeyeater before.
Chapter 2: Study Area

2.1 Background

The Dryandra Woodland (Dryandra and Highbury State Forests) lies approximately 160 km south-east of Perth in the Wheatbelt Region of Western Australia (Figure 2.1). The Dryandra State Forest comprises 24 discrete blocks (Coates, 1993) scattered over a north-south distance of 50 km and is fragmented by areas of agricultural land. The total area is 27,947 ha, with blocks ranging in size from 87 ha to 12,283 ha (Dept. CALM, 1994).

As late as 1962, Dryandra was connected to the main forest belt of the Darling Range, with other areas of remnant bush to the east (Dept. CALM, 1994) (Figure 2.2). Continued clearing has separated the blocks, and despite the overall large size of Dryandra, it is subject problems similar to that of other fragmented landscapes (Dept. CALM, 1994), including vulnerability to local extinctions.

The region experiences a typical Mediterranean climate with mild wet winters and warm to hot, dry summers, and falls within the 500 mm and 600 mm isohyets for mean annual rainfall (Coates, 1993). The landscape is composed of remnant lateritic plateaux flanked by pediments and broad valley floors, with occasional granite outcrops (Burrows et al., 1987). The landforms and soils of the district have been described in detail by McArthur et al. (1977).
has a rich flora, with 12 distinct vegetation associations comprised of 816 native plant species (Coates, 1993) (as shown in Table 1) but a conspicuous feature are the woodlands of wandoo (E. wandoo) and powderbark wandoo (E. accedens).
FIGURE 2.1: The Location of Dryandra Woodland in Western Australia. (CALM, 1994).
FIGURE 2.2: The Clearing and Fragmentation of the Dryandra Area. Black areas represent remnant vegetation outside of Dryandra Woodland (grey areas) (CALM, 1994).
Table 1: Vegetation Associations of Dryandra Woodland. (modified from Coates, 1993)

<table>
<thead>
<tr>
<th>Vegetation Association</th>
<th>Landscape Position</th>
<th>Soil Type</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Eucalyptus accedens</em></td>
<td>steep to gentle upper slopes below the lateritic plateaux and small gravelly rises in mid slope position</td>
<td>sand or sandy loam and gravelly duplex soils</td>
<td>covers extensive areas</td>
</tr>
<tr>
<td>(powderbark) Woodland</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Eucalyptus astringens</em> (brown mallet) Forest</td>
<td>naturally occurring on steep slopes adjoining breakaways or escarpments</td>
<td>clayey soils with laterite</td>
<td>commonly occurring but covering small areas in the natural bushland</td>
</tr>
<tr>
<td><em>Eucalyptus calophylla</em> (marri) Woodland</td>
<td>lower and mid slopes</td>
<td>grey sandy soils</td>
<td>covering small areas only. <em>Eucalyptus marginata</em> occasional</td>
</tr>
<tr>
<td><em>Eucalyptus loxophleba</em> (York gum) Woodland</td>
<td>lower slopes often in association with granite or drainage lines</td>
<td>loam soils over clay</td>
<td>confined to a few small areas. More common on adjacent valley soils, now extensively cleared</td>
</tr>
<tr>
<td>Lateritic plateau Woodlands <em>(E. accedens, E. calophylla, E. marginata</em> and occasionally <em>E. wandoo)</em>. Either species dominant or co-dominant over short distances</td>
<td>lateritic plateaux remnants usually bounded by escarpments, spurs to lower slopes</td>
<td>duricrust, sand and sandy loam ± gravel in depressions, shallow gravelly soils over ironstone</td>
<td>variable mixed understorey of <em>Dryandra</em> and <em>Petrophile</em></td>
</tr>
</tbody>
</table>


Table 1 (continued): Vegetation Associations of Dryandra Woodland.
(modified from Coates, 1993)

<table>
<thead>
<tr>
<th>Vegetation Association</th>
<th>Site Description</th>
<th>Soils Description</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Eucalyptus wandoo</em> (white gum) Woodland</td>
<td>mid to lower slopes, occasionally sandier upper slopes, low lying areas and drainage lines</td>
<td>sandy to sandy loam ± gravel over clay</td>
<td>extensive throughout</td>
</tr>
<tr>
<td><em>Eucalyptus wandoo</em> (white gum) <em>Allocasuarina huegeliana</em> (rock sheoak) Low Forest</td>
<td>mid and lower slopes</td>
<td>sandy soils</td>
<td>commonly occurring but covering only small areas</td>
</tr>
<tr>
<td><em>Allocasuarina huegeliana</em> (rock sheoak) Low Forest</td>
<td>slopes below the lateritic plateaux</td>
<td>sandy soils in association with granite outcrops</td>
<td>relatively common</td>
</tr>
<tr>
<td><em>Acacia acuminata</em> (jam) Low Forest</td>
<td>lower slopes, low lying areas often associated with granite or drainage lines</td>
<td>loam soils sometimes in association with granite</td>
<td>occasionally forms a sparse understorey in <em>E. wandoo</em>. Occasional and covers only small areas</td>
</tr>
<tr>
<td>Short kwongan (diverse mixed shrubland &lt;2 metres)</td>
<td>occasionally on the lateritic plateau usually on slopes below. Sometimes associated with granite rock</td>
<td>shallow gravelly soils, deeper sands and gravels, gravelly duplex soils</td>
<td>commonly occurring but covering only small areas</td>
</tr>
<tr>
<td><em>Dryandra</em> and <em>Petrophile</em> Shrubland (Tall Kwongan) &gt;2 metres when mature</td>
<td>duricrust, usually forming a fringe around the tops of lateritic residuals</td>
<td>shallow gravelly soils over ironstone</td>
<td>covers only small areas and merges with the lateritic plateau woodlands</td>
</tr>
<tr>
<td>Lithic complex - granite</td>
<td>slopes below the lateritic plateau</td>
<td>rock surface and associated soils</td>
<td>small outcrops are relatively common.</td>
</tr>
</tbody>
</table>
A primary value of Dryandra is its role in the conservation of a number of representative plants and animals of the western wheatbelt, including six threatened species (Dept. CALM, 1994). Although the Yellow-plumed Honeyeater has undergone a major decline in abundance and experienced several local extinctions throughout the wheatbelt (Saunders, 1989), it is abundant at Dryandra.

2.2 History of Dryandra Woodland

In the early 1900's, the bark of brown mallet (E. astringens) was a major export commodity and resource for local leather tanneries, with the naturally occurring species being heavily exploited (Dept. CALM, 1994). Plantations of brown mallet were established between 1925 and 1962 (Dept. CALM, 1994; Burbidge, 1977) and now cover approximately 30 percent (8 316 ha) of Dryandra (Dept. CALM, 1994). The remainder of the forest is mostly in its natural state although the wandoo areas have been cut over for timber (Burbidge, 1977). The timber currently harvested in Dryandra supports a number of local industries, but with the disappearance of the economic value of brown mallet as a source of tannins, the forests' main value now lies in other areas, particularly its conservation value (Dept. CALM, 1994).

2.3 Study sites

The study sites were located in several blocks of the Dryandra State Forest. Highbury State Forest and 14 Mile Brook Nature Reserve were not sampled. The foraging ecology study was centred in the largest and most central block as
it contained large areas of wandoo (E. wandoo) woodland and known populations of Yellow-plumed Honeyeaters (Recher & Davis, in review). The habitat selection study involved determining any preferences for particular vegetation associations within sites dominated by wandoo and powderbark wandoo (E. accedens). The sites were distributed in most blocks of the area defined as Dryandra State Forest, including larger blocks and smaller fragments surrounded by farmland.
Chapter 3: Methodology

The foraging ecology study involved gathering data from at least 100 observations each of Yellow-plumed Honeyeaters foraging in three areas of wandoo woodland and over autumn, winter and spring 1997. The procedures used enabled characteristics of their foraging and use of resources to be documented taking into consideration seasonal and spatial variation.

3.1 Null Hypotheses

The methods described in this chapter were designed to test the following null hypotheses:

- There is no difference between foraging behaviour of Yellow-plumed Honeyeaters between autumn, winter and spring;
- There are no differences between the foraging substrates used and the substrates available (including tree size);
- The Yellow-plumed Honeyeater does not preferentially use particular foraging techniques or substrates;
- There is no spatial variation in foraging methods used by the Yellow-plumed Honeyeater.
3.2 Study sites

Three study sites were selected based on the presence of known populations of Yellow-plumed Honeyeaters. A site was considered suitable if a population was known to occur there throughout the year, based on the data of Recher and Davis (in review) and personal observations. Three sites were selected within the main central block at Dryandra, the location of each is shown in Figure 3.1. Using three sites enabled foraging data to be collected over varying wandoo habitats within which the Yellow-plumed Honeyeater is abundant.

3.2.1 Old Mill Dam Site

Located close to the Dryandra settlement village, this site is predominantly wandoo woodland (see Plates 1a and 1b). A random vegetation survey of the area found that wandoo trees accounted for all of the canopy trees (trees 10 m and taller) on the plot (n=78). The occasional Acacia acuminata (jam) tree was present in the sub-canopy layer (5 to 9.9 m) and several jam and rock sheoak (Allocasuarina huegeliana) saplings (under 5 m) were recorded. The average height of the canopy trees throughout the plot was 12 m with individual trees up to 16 m tall. The sub-canopy averaged 7.6 m in height and saplings averaged 3 m. The percent canopy cover was 44%. The understorey was quite open, with an estimated cover of 17 percent which averaged just under 0.40 m tall. The dominant species were Acacia lasiocarpa, Hibbertia commutata and Bossiaea spinescens. The understorey was relatively uniform over the whole plot, with the western border of the plot being the transition from a sparse to thick understorey of Gastrolobium microcarpum. Other borders of the site are
determined by cleared farmland to the south-west and by Turner Block, an *E. astringens* (Brown Mallet) plantation to the south-east, with the northern border being a main road (Tomingley Road) and the Dryandra Block Mallet Plantation. The litter layer was sparse. The history of wildfires in the area is unknown prior to 1938, but since then, there have been no major fires (Dept. Map, 1987). Controlled burns in the area were undertaken 16 years ago (1981) (Dept. CALM, 1997).
FIGURE 3.1: Location of Three Study Sites (CALM, n.d.)

KEY
- Cleared land
- Dryandra Woodland
- Study site

Scale: 1 cm : 50 m
3.2.2 Gura Road Site

Located to the west of Gura Road (Figure 3.1), the study area was situated within an extensive stretch of wandoo (see Plates 2a and 2b). A random vegetation survey revealed 97 percent of the canopy trees, 92 percent of the sub-canopy trees and 89 percent of the saplings on the plot were wandoo. Powderbark wandoo and marri accounted for two and one percent of the canopy respectively. Canopy cover was approximately 45%. The sub-canopy wandoo trees shared the plot with 4 percent jam, three percent marri and the occasional rock sheoak. Along with wandoo, saplings consisted of jam (7%) and marri (4%) at an average height of 3.1 m. Sub-canopy trees averaged 7.3 m in height and canopy trees 11.4 m, with individual canopy trees reaching 15 m. The site was relatively flat and the boundaries not well defined due to relatively uniform vegetation and subtle changes in the understorey. The understorey, which averaged just under 0.5 m in height, was dominated by Gastrolobium microcarpum, with Acacia lasiocarpa and Hibbertia commutata also present. Shrub coverage was approximately 21 percent. There have been no recorded wildfires since 1938, but pre-1938 fire history is unavailable. The area was subjected to a controlled burn in 1981.

3.2.3 Site 33

Positioned to the west of Tomingley Road, a main access road within Dryandra (Figure 3.1), Site 33 is situated within a large expanse of wandoo (Plates 3a and 3b). Ninety-six percent of trees in the canopy and sub-canopy layers were wandoo, with four percent powderbark wandoo making up the canopy, and
three percent in the sub-canopy along with scattered marri. The average canopy height was over 11 m, with individual trees reaching 15 m, and canopy cover was 45%. The sub-canopy had an average height of just under 7 m. Saplings on the site averaged 2.9 m in height and were predominantly wandoo (94%), with marri (2%), powderbark wandoo (2%) and occasionally rock sheoak. The study area is bounded to the west by an increase in elevation accompanied by the presence of powderbark wandoo and a heathy understorey. Northern and southern borders are less defined. The understorey is variable throughout the area but is relatively more dense than the Old Mill Dam and Gura Road sites.

The understorey height was averaged at just under 0.5 m and consisted of Gastrolobium microcarpum, Bossiaea eriocarpa and Astroloma sp., with cover estimated at 42 percent. No wildfires have occurred in the area since 1938 although their incidence prior to 1938 is unknown. A controlled burn was carried out at the site in 1987.

3.3 Bird Data

Data collected on the foraging ecology of the Yellow-plumed Honeyeater included the type of manoeuvre used to catch prey, the substrate of the prey, plant species on which the prey were found and the height at which the prey was taken.
3.3.1 Foraging categories

The prey attack behaviour was recorded and classified to the same categories described by Recher et al. (1985):

(1) probe or prise. In probing, the bird extracts prey from within a substrate such as soil, litter, crevices or soft wood. Prising differs in that the bird lifts up or flakes off part of the substrate. In this analysis, the two are considered together as it was not always possible to distinguish between them.

(2) pounce. The bird flies down from a perch to take a prey organism from the ground or low vegetation. The bird lands and almost simultaneously takes the prey, and then returns to a perch.

(3) glean. A standing or hopping bird takes prey from a nearby substrate. This category also includes 'hang-glean' where the bird hangs upside down while taking prey from the substrate. Recher et al. (1985) classify hang-gleaning and gleaning nectar and seeds as separate categories, but for this study, they are considered as gleaning actions.

(4) hover. A flying bird hovers in the air for a brief period while picking a food item from a substrate.

(5) snatch. The bird flies or jumps up to take prey from a nearby substrate without landing. It usually returns to a different perch from where it started, and most often, the prey is snatched from surfaces a short distance away.

(6) hawk. The bird flies from a perch to capture a flying insect. Tumble-chase, where the bird chases the prey, is a form of hawking and is therefore recorded in this category.
(7) snap. The bird captures a flying insect without leaving the perch. Although
the occasional snap was recorded, there were too few in this category for
separate analysis and so they were included in the “other” category along
with pouncing and snatching for analysis.

3.3.2 Recording procedure

Studies began during Autumn (May), continued into Winter (July to early
August) and finished in Spring (September). Observations began as early as
8 am and continued until no later than 5.30 pm. A minimum total of 100
observations was recorded at each of the three sites for each season. As
Recher and Gebski (1990) observed, at least 60 to 70 observations are needed
before standard errors are stabilised. Samples of 60 to 70 observations fall
between the sample size estimated for 90 and 95% confidence intervals
(Recher & Gebski, 1990). For a 99% confidence interval, over 5 900
observations are required (Recher & Gebski, 1990). Therefore, 100
observations was an appropriate number for this study.

For each bird encountered, the second foraging manoeuvre observed was
recorded when the bird obtained or attempted to obtain a prey item. The first
foraging manoeuvre observed was discarded to avoid over-representing more
conspicuous foraging actions (such as hawking), a problem which Recher and
Gebski (1990) highlighted in their study. Hejl et al. (1990) advised against using
dependent sequential observations in foraging studies as they lead to
inaccurate estimates of variance. This can happen when consecutive
observations are made on the same bird, or the same bird is observed over a period of time. Thus, only one foraging record was taken from each bird encountered. To further increase the independence of foraging data and to avoid recording the same bird twice, observations were made whilst constantly moving around the study areas. Probability levels were set at 0.01 rather than 0.05.

As it was not always possible to determine success, all attempts at obtaining a prey item were recorded whether or not the attempt was actually successful. For each foraging act, the behaviour used by the bird, the height of the food item and where it was located was recorded. Foraging heights were estimated to the nearest metre for trees and the nearest ten centimetres for shrubs.

3.3.3 Vegetation parameters
Vegetation characteristics were recorded with each foraging act. The substrate used, the species and height of the plant used, and the food item obtained (where possible) was recorded. Height was estimated to the nearest metre for large shrubs and trees, and to the nearest 10 cm for smaller plants. For analytical purposes, vegetation was categorised according to vegetation layers into the following size classes: 0 - 0.9 m (low shrubs, debris); 1 - 4.9 m (tall shrubs and saplings); 5 - 9.9 m (sub-canopy trees); and 10 m+ (canopy trees).

The substrates from which food items were taken were recorded and for analysis, were divided into the following categories: foliage (leaves, petioles,
twigs, buds); bark (peeling and smooth bark (from branches and tree trunks), and bark spots); ground (debris and litter); flowers; and air. Due to the low frequency of foraging on buds and eucalypt seed capsules, these were included in the foliage category. Whether the substrate was dead or alive was also noted, but as foraging on dead substrates was not common, dead and alive substrates were included together.

3.3.4 Analysis of bird data
At the end of each season of recording, the results were tallied for each site. Uncommon foraging behaviours (pouncing, snatching, snapping) were placed in an additional category "other". No additional category was necessary in the analysis of foraging substrates as most substrates used were foliage, bark or air, with too few birds using other substrates to allow separate analysis. Combined foraging behaviour-substrate also contained an additional "other" category which was quite large due to the high numbers of combinations available. Only the top three categories (gleaning foliage, gleaning bark and probing bark) were treated separately. Using chi-square tests, sites were tested for differences between them with significance accepted at p<0.01 to compensate for lack of independence in the likelihood of recording the same bird on more than one occasion. As some cells in the contingency tables had fewer than five observations, setting significance at p<0.01 applied the required cautionary interpretation of significant values. Seasonal changes within each sites were tested using the same procedure.
3.4 Vegetation Sampling

It was necessary to obtain a sample of the vegetation present at the three sites in order to make comparisons between the trees actually used by Yellow-plumed Honeyeaters for foraging and those present on the plot. A stratified random sample of the vegetation using the Point-Quarter method was applied. This is particularly useful where the dominant plants are trees (Smith, 1990).

3.4.1 Point-quarter method and positioning

The first of 25 points at each site was positioned 25 m in from the road towards the beginning of the site to avoid sampling road-disturbed vegetation. To contain the points within the area being surveyed for Yellow-plumed Honeyeater foraging, constant bearings suitable for the site were used for positioning subsequent points (see Figure 3.2). For example, the Old Mill Dam site runs west to east lengthwise, so the bearings used were consistently 90°. Points were marked every 50 m moving south until the site border was reached, then east for 50 m, then every 50 m north until the site border, then east 50 m and so on. The distance between each point was 50 m. Although this was just a nominated distance, it was in fact ideal as at all three sites almost the entire area was sampled within 25 points. Recordings at each point followed the procedure of the Point-Quarter method (Smith, 1990).
FIGURE 3.2: Positioning of Points for Point-Quarter Sampling Using Constant Bearings of North-South to East.

The Point-Quarter method involves the position of stationary points at which each is divided into quarters, with certain vegetation characteristics recorded for each quarter. Measurements were recorded for tree saplings (less than 5 m in height), sub-canopy trees (between 5 and 10 m in height) and canopy trees (greater than 10 m in height). For each quarter, the closest canopy and sub-canopy trees and saplings were identified to species level, and their height, diameter (at breast height) and distance from the central point were recorded. The species, height and distance of the closest shrub in each quarter was noted along with the overall percentage cover of shrubs. Trees and shrubs greater than 25 m from the central point were not recorded to avoid sampling trees twice where they were sparse. Following the constant bearing, the next point was marked 50 m away to ensure that no tree or shrub was counted.
twice. This procedure was followed along the width and breadth of each site until 25 points were completed. At every two metres along the route taken, the canopy was recorded as cover/no cover using a tube (3.5 cm diameter) containing cross-hairs. Looking vertically, if there was no vegetation at the intersection of the hairs it was recorded as "no cover". If there was any vegetation at the cross-hair intersection, it was recorded as "cover". Percentage canopy cover was determined by expressing the "covers" over the total number of recordings made.

3.4.2 Analysis of vegetation data

Data were averaged to obtain a mean height of canopy, sub-canopy and saplings. In this regard, the species of each was not considered as the calculation was only necessary to determine the average height of the canopy layer, not the average height of different species at each site. Individual species were treated separately in determining the percentage composition of plant species at each site.

In order to calculate the densities of canopy and sub-canopy trees and saplings where the distance to the closest tree was greater than 25 m, an arbitrary value of 38 m was assigned. The assumption was made that trees falling outside the 25 m radius of the point (which were not sampled) would not have been further than 50 m away. Therefore, half of the unsampled trees would have been between 25 and 37.5 m away, the other half 37.5 to 50 m away. Based on this, 38 m was seen as a reasonable substitute. Density data were then averaged to
determine the number of canopy, sub-canopy trees and saplings at each site. This was compared to the actual usage of trees of different heights by the Yellow-plumed Honeyeater when foraging to show if the birds were selecting for trees of a particular size. Tree species composition of the plot compared to usage was used to determine whether the birds selected for tree species when foraging. Pearson's correlation showed tree diameters on the plot to be correlated to tree heights ($r=0.7$). Therefore, separate analysis using tree diameters was not necessary.
Chapter 4: Results

This chapter describes the use of different foraging behaviours and substrates, how they varied between sites and seasons and the resources available to Yellow-plumed Honeyeaters compared to their use. Data were collected over three seasons (autumn, winter and spring) and at three sites (Old Mill Dam, Gura Road and Site 33). A minimum of 100 observations per site per season were recorded. Because of the likelihood that some birds were sampled on more than one occasion, probability levels were set at 0.01 instead of 0.05 to account for this lack of independence between samples (Recher & Gebski, 1990). The availability of resources was assessed in terms of tree heights, tree diameters and tree species and compared to actual use during foraging.

4.1 Foraging

For the purpose of analysis, uncommon behaviours were pooled and counted in a separate category as “other”. This “other” category was also used in manoeuvre-substrate analysis, with “other” being all additional combinations of foraging-substrate use. Live and dead substrates were not distinguished as dead substrates were used on few occasions. Analysis of foraging substrates was based on the three most common substrates (foliage, bark and air). A combined category for seldom-used substrates was not included because use of other substrates was so low that analysis was not feasible.
4.1.1 Autumn

Data for autumn were collected between 9th May and 13th May, 1997.

Foraging Behaviours

The foraging behaviours used at the three sites were significantly different \( (\chi^2 = 27.9, \text{df}=8, \ p<0.01) \) (Table 2). Gleaning was the most common foraging method used by the Yellow-plumed Honeyeater and accounted for 81% of observed foraging activities at the Old Mill Dam, 59% at the Gura Road site and 67% at Site 33. The differences were due to the lack of probing and higher gleaning activity at the Old Mill Dam site. Significantly more probing occurred at Gura Road during autumn compared to the other sites, with probing accounting for over 16% of all activity at Gura Road. Hovering was significantly more common at Site 33, accounting for almost 13% of foraging manoeuvres. While birds at the Gura Road site foraged intensively by gleaning, they also used a wide variety of foraging techniques, with 41% of the foraging manoeuvres being those other than gleaning. Birds at this site also foraged using rarer behaviours ("other": snapping, pouncing and snatching) more often. There was less variation at the other two sites with only 19% of the foraging at the Old Mill Dam and 33% at Site 33 being attributed to methods of foraging other than gleaning.

Foraging Substrates

Foliage was the most commonly used foraging substrate at all three plots, followed by bark and aerial foraging (Table 3). The substrates used by Yellow-
plumed Honeyeaters differed significantly between sites ($\chi^2=31.03$, df=4, p<0.01). Foraging birds at Gura Road and Site 33 used a wider range of substrates than those at the Old Mill Dam, where foraging was confined predominantly to the foliage (86% of foraging occurred in the foliage). Bark use was significantly low at the Old Mill Dam site (5% use) and higher than expected at Gura Road (36%). Aerial foraging rates were similar at all three sites, ranging from 8% to 11% of the observations. Other substrates were used too infrequently for analysis and percentage values given in the text are of foliage, bark, and air only.

**Combined Behaviour-Substrate**

Combined foraging manoeuvre-substrate use was significantly different between sites ($\chi^2=36.1$, df=6, p<0.01) (Table 4). Foliage gleaning was the most common foraging activity used by Yellow-plumed Honeyeaters at all sites. Bark foraging was significantly less common at the Old Mill Dam site, and this appeared to be compensated for by increased foliage gleaning. The biggest differences between sites were in the frequency of bark probing. No observations of bark probing were made at the Old Mill Dam site, although this accounted for 14% of observations at Gura Road and 6% at Site 33.
4.1.2 Winter

Data for winter were collected between 21st July and 1st August, 1997.

Foraging Behaviours

There was no difference in the foraging behaviours observed at the three sites over winter ($\chi^2=11.59$, df=8, p>0.01) (Table 5). Gleaning was the most common behaviour recorded; accounting for 75% of observations at the Old Mill Dam, 76% at Gura Road and 65% at Site 33. While birds at Site 33 gleaned less and probed substrates more than at other sites, the differences are not significant. Hovering was uncommon at the three sites during winter, accounting for 2 to 5% of all manoeuvres. Hawking for insects was more common, ranging from 10% of all manoeuvres at the Old Mill Dam and Gura Road, to 14% at Site 33. While birds foraged most commonly using gleaning actions, they foraged in a variety of ways at each site during winter, including pouncing, snapping and snatching which have been grouped as "other".

Foraging Substrates

Yellow-plumed Honeyeaters used foliage as a foraging substrate on more occasions than any other substrate followed by bark and air (Table 6). At the Old Mill Dam, foliage accounted for 73% of the most commonly used substrates, 77% at Gura Road and 58% at Site 33. There was no significant difference in the use of substrates between sites ($\chi^2=9.76$, df=4, p>0.01). Ninety-five percent of the substrate use at Site 33 was confined to foliage, bark and air. One-quarter of all observations at Site 33 involved bark substrates.
Although this is higher than at the other two sites, the difference was not significant.

**Combined Behaviour-Substrate**

Foliage gleaning was the most common behaviour-substrate combination used by Yellow-plumed Honeyeaters at three sites in winter, accounting for 65% of observations at the Old Mill Dam, 68% at Gura Road and 57% at Site 33 (Table 7). Foliage gleaning levels at Site 33 were not as high as at the other sites. Instead, there were higher levels of other foraging-substrate combinations including bark probing which accounted for 13% of observations at Site 33, 5% more than at the other sites. These differences between sites were not statistically significant ($\chi^2=92$, df=6, $p>0.01$). Bark gleaning numbers were similar between sites, as was the use of "other" combinations of foraging manoeuvre and substrate.

**4.1.3 Spring**

Data for spring were collected from 5th September to 12th September, 1997.

**Foraging Behaviours**

The foraging behaviours used during spring did not differ significantly between sites ($\chi^2=7.3$, df=8, $p>0.01$) (Table 8). At all sites, gleaning was the most commonly used method of foraging. Gleaning was recorded on 75% of occasions at the Old Mill Dam site, 74% at Gura Road and 67% at Site 33. Hawking was the second most common behaviour at all the sites. Probing
behaviour was less common, accounting for less than 1% of all observations at Gura Road, 4% at Old Mill Dam and 7% at Site 33. Although birds at Site 33 gleaned less, they probed and hovered more here than at other sites. However, these differences were not significant. The use of rarer behaviours was similar at all sites, as was hawking which varied between 12 and 13% of all observations.

Foraging Substrates
In spring, the most commonly used substrate at all sites was foliage (Table 9). Bark and air followed, with additional substrates being too few for analysis. Substrate use was not significantly different between sites ($\chi^2=2.3$, df=4, $p>0.01$). Of those analysed, 66% of substrates used at the Old Mill Dam, 73% at Gura Road and 68% at Site 33 were foliage. Bark foraging was higher at all sites than aerial foraging. Although foliage foraging was slightly less common at the Old Mill Dam, bark foraging was slightly higher, and the differences were not statistically significant.

Combined Behaviour-Substrate
Yellow-plumed Honeyeaters foraged mainly by gleaning foliage at all sites in spring, with no significant difference between sites ($\chi^2=9.83$, df=8, $p>0.01$) (Table 10). Foliage gleaning accounted for 57% of substrate-manoeuvre actions at the Old Mill Dam, 64% at Gura Road and 54% at Site 33. Bark gleaning was the second most common substrate-manoeuvre, ranging from 12% at the Old Mill Dam, to 8% at Gura Road and 7% at Site 33. There was no
bark probing at Gura Road, although numbers at the other two sites were low. Therefore, the absence of bark probing at Gura Road was not statistically significant. Although numbers in the "other" category are high, individual substrate-manoeuvre actions were not numerous enough for separate analysis.

4.2 Seasonal Comparisons

Seasonal comparisons of foraging behaviours, substrates used and combined behaviour-substrate were made on a site by site basis. As before, uncommon behaviours and behaviour-substrate actions were pooled and counted in a separate category as "other". Live and dead substrates were not distinguished. Analysis of foraging substrates was based on the three most common substrates (foliage, bark and air). A combined category for seldom-used substrates was not included because use of other substrates was so low that analysis was not feasible. Probability levels remained at p<0.01.

4.2.1 Old Mill Dam

Foraging Behaviours

There were no significant changes in foraging behaviours at the Old Mill Dam over the seasons ($\chi^2=6.09$, df=6, p>0.01) (Table 11). Gleaning was highest in autumn and remained the most frequent foraging manoeuvre throughout the three seasons. Probing levels remained low, ranging from zero observations in autumn, to five in winter and four in spring. Observed numbers of hovering and hawking did not fluctuate over the seasons, nor did the use of rarer manoeuvres.
Foraging Substrates

Foraging substrates used by Yellow-plumed Honeyeaters did not change significantly over the seasons ($\chi^2=12.6, \text{ df}=4, p>0.01$) (Table 12). Birds foraged in the foliage more than on any other substrate. Eighty-six percent of foraging in autumn, 73% in winter and 66% in spring occurred in the foliage. In autumn, foliage foraging was higher than in other seasons, and bark and air foraging less common than in other seasons. However, the differences were not significant. Bark was the second most commonly used substrate in winter and spring, with aerial foraging the second most frequent in autumn.

Combined Behaviour-Substrate

Changes in foraging manoeuvre-substrate between seasons at the Old Mill Dam were not significant ($\chi^2=13.48, \text{ df}=6, p>0.01$) (Table 13). Foliage gleaning remained the most common behaviour-substrate action throughout the seasons. Foliage gleaning accounted for 75% of the actions in autumn, 65% in winter and 57% in spring. Combined bark gleaning and probing activities were not as common as gleaning foliage alone. Bark gleaning was the second most use action throughout the seasons.

4.2.2 Gura Road

Foraging Behaviours

Foraging manoeuvres observed at Gura Road did not differ significantly between autumn, winter and spring ($\chi^2=12.67, \text{ df}=8, p>0.01$) (Table 14).
Gleaning remained the most commonly observed behaviour at the site over the three seasons. Sixteen percent of manoeuvres observed in autumn were probing, with hawking and rarer behaviours accounting for 10% of the recordings. During winter and spring, the second most commonly recorded foraging behaviour was hawking, accounting for almost 10% and 13% respectively. In winter, there were fewer rarer behaviours observed and more gleaning, although the differences were not significant.

**Foraging Substrates**

Over the seasons, the use of foliage and bark as substrates for foraging differed significantly at Gura Road ($\chi^2=23.02$, df=4, $p<0.01$) (Table 15). There was little variation between winter and spring observations, but these differed significantly in substrate use compared to autumn. Foliage foraging was less common in autumn, but bark foraging was more common. Foliage foraging accounted for 53% of recordings in autumn, compared to 77% in winter and 73% in spring. Bark was used on 36% of occasions in autumn, 12.5% in winter and 13% in spring.

**Combined Behaviour-Substrate**

Although foliage gleaning remained the most common foraging behaviour-substrate action over the three seasons, changes between seasons were statistically significant ($\chi^2=30.31$, df=6, $p<0.01$) (Table 16). Results for autumn show that birds at Gura Road used a wider range of behaviour and substrate combinations. Even though foliage gleaning in autumn was the most common
action used (44% of actions), bark gleaning and probing levels were also high, with each accounting for 14% of the manoeuvre-substrate combinations used for that season. In comparison, in winter and spring, foliage gleaning accounted for much higher percentages of manoeuvre-substrate actions (68 and 65% respectively). There was no bark probing in spring.

4.2.3 Site 33

Foraging Behaviours
Foraging behaviours did not differ significantly over autumn, winter and spring ($\chi^2=16.69$, df=8, p>0.01) (Table 17). Gleaning was the most common behaviour used by foraging Yellow-plumed Honeyeaters at Site 33 and remained so over the three seasons. In autumn, hovering was the second most frequent behaviour used accounting for 13% with probing 9% and hawking 7% of the recorded behaviours. In winter, hawking and probing were the second most used behaviours (14% each). Behind gleaning, the most common manoeuvre observed in spring was hawking, which accounted 13% of recordings.

Foraging Substrates
Changes observed in substrate use at Site 33 over three seasons were not significant ($\chi^2=6.5$, df=4, p>0.01) (Table 18). Foliage foraging was most common at the site at each season, followed by bark and aerial foraging. There was less bark foraging in spring but the difference was not statistically significant. In winter and spring, the birds foraging was widely using foliage,
bark and air. However, in autumn, there was less aerial foraging, with most foraging occurring on foliage and bark.

Combined Behaviour-Substrate
Seasonal changes in the behaviour-substrate actions were not significant at Site 33 ($\chi^2=8.81, \text{df}=6, \ p>0.01$) (Table 19). Foliage gleaning was the most common action over three seasons and was lowest in autumn. Out of the three most commonly used behaviour-substrate combinations in autumn, bark gleaning was the second most common action and in winter, bark probing was the second most common action. In spring, birds foraged by bark gleaning and bark probing on an equal number of occasions, but these accounted for only 7% of the behaviour-substrates used each, with gleaning foliage being 54% of the actions.

4.3 Resource Availability and Resource Use
The availability of resources was assessed in terms of tree heights, tree diameters and tree species and compared to actual use during foraging. Probability levels remained at $p<0.01$ due to the lack of independence of observations.

4.3.1 Tree species
Wandoo trees were the most common trees on all three plots and the most common plant species in which Yellow-plumed Honeyeaters foraged.
Old Mill Dam

Wandoo trees accounted for almost 98% of the tree species at the Old Mill Dam (Figure 4.1). In autumn, 96% of the plant species foraged on were wandoo trees. In winter, birds used 98% wandoo trees for foraging. In spring they used fewer wandoo trees than what was available (94.5%).

Gura Road

The trees at the Gura Road site were 92.5% wandoo (Figure 4.2). In autumn, Yellow-plumed Honeyeaters appeared to select for wandoo trees, as they comprised 95% of plant species used for foraging. In winter an even higher percentage of trees used were wandoo (98%) and in spring the figure was 97%.

Site 33

Wandoo trees accounted for over 95% of available trees at Site 33 (Figure 4.3). In autumn, fewer wandoo trees than are available were used for foraging (90%). In winter, wandoo use was higher than available (97.5%), but in spring it was lower (89%).

4.3.2 Tree height

The densities of trees in three height classes is compared to tree use during foraging. At each site, tree density is expressed as the proportion (percent) of trees in each size class based on their density per hectare, and tree use expressed as the percent of the total trees used by foraging Yellow-plumed
Honeyeaters. Saplings are trees up to 4.9 m tall, sub-canopy trees are between 5 and 9.9 m tall and canopy trees are those 10 m tall and over. Analysis is based on the number of plants in each category and does not make any allowances for differences in foliage volumes or bark area between different sized trees. Subsequent studies will address this issue (Recher, pers. comm.).

Old Mill Dam
Saplings make up approximately 26% of trees present at the Old Mill Dam, with around 6% of them being utilised by foraging Yellow-plumed Honeyeaters (Figure 4.4). Sub-canopy trees make up 38% of the trees at the site but were used at approximately five times the rate of saplings (33% used). Canopy trees were used ten times more frequently than saplings (61%) although they are less than 10% more abundant than the saplings, accounting for around 35% of trees on the plot. Canopy trees were also used twice as much as sub-canopy trees despite being less abundant (5% less) than sub-canopy trees.

Gura Road
Saplings accounted for 18% of the trees at Gura Road, with around 7% being utilised by the birds (Figure 4.5). Sub-canopy trees were almost twice as abundant as saplings (35% of the trees at the site), yet they were used over 4.5 times more often by foraging Yellow-plumed Honeyeaters (30% used). Canopy trees accounted for 47% of trees at the site, making them 29% more abundant than saplings. However, canopy trees were used 10 times more for foraging than saplings, and twice as much as sub-canopy trees.
Site 33

On Site 33, saplings accounted for almost 30% of trees, with the birds using them 10% of the time (Figure 4.6). Sub-canopy trees made up 46% of trees at the site and these were used over three times more for foraging than the saplings (36% used). Canopy trees made up the smallest proportion of trees, accounting for only 24%. However, they were used for foraging in almost 54% of observed foraging acts. This is five times more than sapling use and 1.5 times more than sub-canopy use.

4.3.3 Tree diameter

Tree diameters were found to be correlated to tree heights using Pearson's correlation (r). At the Old Mill Dam site, r=0.65 (df=203, p<0.05), at Gura Road r=0.73 (df=202, p<0.05) and at Site 33 r=0.72 (df=232, p<0.05). The heights and diameters were tallied for the three sites, with r=0.7 (df=643, p<0.05). Therefore, separate analysis of tree diameter composition on the plots compared to tree diameters used was not necessary and is not presented here.
Table 2: Number of Different Foraging Maneuuvres Used by Yellow-plumed Honeyeaters During Autumn at Three Sites.

<table>
<thead>
<tr>
<th></th>
<th>Old Mill Dam</th>
<th>Gura Road</th>
<th>Site 33</th>
<th>TOTALS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glean</td>
<td>82</td>
<td>61</td>
<td>69</td>
<td>212</td>
</tr>
<tr>
<td>Probe</td>
<td>0</td>
<td>17</td>
<td>9</td>
<td>26</td>
</tr>
<tr>
<td>Hover</td>
<td>4</td>
<td>6</td>
<td>13</td>
<td>23</td>
</tr>
<tr>
<td>Hawk</td>
<td>8</td>
<td>10</td>
<td>7</td>
<td>25</td>
</tr>
<tr>
<td>Other¹</td>
<td>7</td>
<td>10</td>
<td>5</td>
<td>22</td>
</tr>
<tr>
<td>TOTALS</td>
<td>101</td>
<td>104</td>
<td>103</td>
<td>308</td>
</tr>
</tbody>
</table>

¹ other: pouncing, snatching and snapping

Table 3: Number of Foraging Substrates Used by Yellow-plumed Honeyeaters During Autumn at Three Sites.

<table>
<thead>
<tr>
<th></th>
<th>Old Mill Dam</th>
<th>Gura Road</th>
<th>Site 33</th>
<th>TOTALS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foliage¹</td>
<td>84</td>
<td>53</td>
<td>58</td>
<td>195</td>
</tr>
<tr>
<td>Bark²</td>
<td>5</td>
<td>36</td>
<td>28</td>
<td>69</td>
</tr>
<tr>
<td>Air</td>
<td>9</td>
<td>11</td>
<td>8</td>
<td>28</td>
</tr>
<tr>
<td>TOTALS</td>
<td>98</td>
<td>100</td>
<td>94</td>
<td>292</td>
</tr>
</tbody>
</table>

¹ includes leaves, petioles, twigs, buds
² includes peeling bark, bark spots, smooth bark on trunks and branches

Table 4: Numbers of Combined Foraging Behaviour and Substrate Usage for Autumn at Three Sites.

<table>
<thead>
<tr>
<th></th>
<th>Old Mill Dam</th>
<th>Gura Road</th>
<th>Site 33</th>
<th>TOTALS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glean Foliage</td>
<td>76</td>
<td>46</td>
<td>51</td>
<td>173</td>
</tr>
<tr>
<td>Glean Bark</td>
<td>3</td>
<td>15</td>
<td>12</td>
<td>30</td>
</tr>
<tr>
<td>Probe Bark</td>
<td>0</td>
<td>15</td>
<td>6</td>
<td>21</td>
</tr>
<tr>
<td>Other¹</td>
<td>22</td>
<td>28</td>
<td>34</td>
<td>84</td>
</tr>
<tr>
<td>TOTALS</td>
<td>101</td>
<td>104</td>
<td>103</td>
<td>308</td>
</tr>
</tbody>
</table>

¹ includes other behaviours such as hawking and pouncing combined with other substrates such as air and flowers
Table 5: Number of Different Foraging Maneuvers Used by Yellow-plumed Honeyeaters during Winter at Three Sites.

<table>
<thead>
<tr>
<th></th>
<th>Old Mill Dam</th>
<th>Gura Road</th>
<th>Site 33</th>
<th>TOTALS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glean</td>
<td>75</td>
<td>78</td>
<td>68</td>
<td>221</td>
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<tr>
<td>Probe</td>
<td>5</td>
<td>6</td>
<td>15</td>
<td>26</td>
</tr>
<tr>
<td>Hover</td>
<td>3</td>
<td>5</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>Hawk</td>
<td>10</td>
<td>10</td>
<td>15</td>
<td>35</td>
</tr>
<tr>
<td>Other¹</td>
<td>7</td>
<td>4</td>
<td>4</td>
<td>15</td>
</tr>
<tr>
<td>TOTALS</td>
<td>100</td>
<td>103</td>
<td>104</td>
<td>307</td>
</tr>
</tbody>
</table>

¹ other: pouncing, snatching and snapping

Table 6: Number of Foraging Substrates Used by Yellow-plumed Honeyeaters during Winter at Three Sites.

<table>
<thead>
<tr>
<th></th>
<th>Old Mill Dam</th>
<th>Gura Road</th>
<th>Site 33</th>
<th>TOTALS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foliage¹</td>
<td>67</td>
<td>74</td>
<td>57</td>
<td>198</td>
</tr>
<tr>
<td>Bark²</td>
<td>15</td>
<td>12</td>
<td>25</td>
<td>52</td>
</tr>
<tr>
<td>Air</td>
<td>10</td>
<td>10</td>
<td>17</td>
<td>37</td>
</tr>
<tr>
<td>TOTALS</td>
<td>92</td>
<td>96</td>
<td>99</td>
<td>287</td>
</tr>
</tbody>
</table>

¹ includes leaves, petioles, twigs, buds
² includes peeling bark, bark spots, smooth bark on trunks and branches

Table 7: Numbers of Combined Foraging Behaviour and Substrate Usage for Winter at Three Sites.

<table>
<thead>
<tr>
<th></th>
<th>Old Mill Dam</th>
<th>Gura Road</th>
<th>Site 33</th>
<th>TOTALS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glean Foliage</td>
<td>65</td>
<td>70</td>
<td>59</td>
<td>194</td>
</tr>
<tr>
<td>Glean Bark</td>
<td>7</td>
<td>4</td>
<td>8</td>
<td>19</td>
</tr>
<tr>
<td>Probe Bark</td>
<td>5</td>
<td>5</td>
<td>14</td>
<td>24</td>
</tr>
<tr>
<td>Other¹</td>
<td>23</td>
<td>24</td>
<td>23</td>
<td>70</td>
</tr>
<tr>
<td>TOTALS</td>
<td>100</td>
<td>103</td>
<td>104</td>
<td>307</td>
</tr>
</tbody>
</table>

¹ includes other behaviours such as hawking and pouncing combined with other substrates such as air and flowers
### Table 8: Number of Different Foraging Maneuvers Used by Yellow-plumed Honeyeaters During Spring at Three Sites.

<table>
<thead>
<tr>
<th></th>
<th>Old Mill Dam</th>
<th>Gura Road</th>
<th>Site 33</th>
<th>TOTALS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glean</td>
<td>77</td>
<td>77</td>
<td>69</td>
<td>223</td>
</tr>
<tr>
<td>Probe</td>
<td>4</td>
<td>1</td>
<td>7</td>
<td>12</td>
</tr>
<tr>
<td>Hover</td>
<td>3</td>
<td>3</td>
<td>6</td>
<td>12</td>
</tr>
<tr>
<td>Hawk</td>
<td>12</td>
<td>14</td>
<td>13</td>
<td>39</td>
</tr>
<tr>
<td>Other¹</td>
<td>6</td>
<td>9</td>
<td>8</td>
<td>23</td>
</tr>
<tr>
<td><strong>TOTALS</strong></td>
<td><strong>102</strong></td>
<td><strong>104</strong></td>
<td><strong>103</strong></td>
<td><strong>309</strong></td>
</tr>
</tbody>
</table>

¹ other: pouncing, snatching and snapping

### Table 9: Number of Foraging Substrates Used by Yellow-plumed Honeyeaters During Spring at Three Sites.

<table>
<thead>
<tr>
<th></th>
<th>Old Mill Dam</th>
<th>Gura Road</th>
<th>Site 33</th>
<th>TOTALS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foliage¹</td>
<td>63</td>
<td>74</td>
<td>65</td>
<td>202</td>
</tr>
<tr>
<td>Bark²</td>
<td>20</td>
<td>13</td>
<td>17</td>
<td>50</td>
</tr>
<tr>
<td>Air</td>
<td>13</td>
<td>14</td>
<td>13</td>
<td>40</td>
</tr>
<tr>
<td><strong>TOTALS</strong></td>
<td><strong>96</strong></td>
<td><strong>101</strong></td>
<td><strong>95</strong></td>
<td><strong>292</strong></td>
</tr>
</tbody>
</table>

¹ includes leaves, petioles, twigs, buds
² includes peeling bark, bark spots, smooth bark on trunks and branches

### Table 10: Numbers of Combined Foraging Behaviour and Substrate Usage for Spring at Three Sites.

<table>
<thead>
<tr>
<th></th>
<th>Old Mill Dam</th>
<th>Gura Road</th>
<th>Site 33</th>
<th>TOTALS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glean Foliage</td>
<td>58</td>
<td>67</td>
<td>56</td>
<td>181</td>
</tr>
<tr>
<td>Glean Bark</td>
<td>12</td>
<td>8</td>
<td>7</td>
<td>27</td>
</tr>
<tr>
<td>Probe Bark</td>
<td>4</td>
<td>0</td>
<td>7</td>
<td>11</td>
</tr>
<tr>
<td>Other¹</td>
<td>28</td>
<td>29</td>
<td>33</td>
<td>90</td>
</tr>
<tr>
<td><strong>TOTALS</strong></td>
<td><strong>102</strong></td>
<td><strong>104</strong></td>
<td><strong>103</strong></td>
<td><strong>309</strong></td>
</tr>
</tbody>
</table>

¹ includes other behaviours such as hawking and pouncing combined with other substrates such as air and flowers
### Table 11: Number of Different Foraging Manoeuvres Used by Yellow-plumed Honeyeaters at the Old Mill Dam over Three Seasons.

<table>
<thead>
<tr>
<th></th>
<th>Autumn</th>
<th>Winter</th>
<th>Spring</th>
<th>TOTALS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glean</td>
<td>82</td>
<td>75</td>
<td>77</td>
<td>234</td>
</tr>
<tr>
<td>Probe</td>
<td>0</td>
<td>5</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>Hover</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>Hawk</td>
<td>8</td>
<td>10</td>
<td>12</td>
<td>30</td>
</tr>
<tr>
<td>Other¹</td>
<td>7</td>
<td>7</td>
<td>6</td>
<td>20</td>
</tr>
<tr>
<td>TOTALS</td>
<td>101</td>
<td>100</td>
<td>102</td>
<td>303</td>
</tr>
</tbody>
</table>

¹ Other: pouncing, snatching and snapping

### Table 12: Number of Foraging Substrates Used by Yellow-plumed Honeyeaters at the Old Mill Dam over Three Seasons.

<table>
<thead>
<tr>
<th></th>
<th>Autumn</th>
<th>Winter</th>
<th>Spring</th>
<th>TOTALS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foliage¹</td>
<td>84</td>
<td>67</td>
<td>63</td>
<td>214</td>
</tr>
<tr>
<td>Bark²</td>
<td>5</td>
<td>15</td>
<td>20</td>
<td>40</td>
</tr>
<tr>
<td>Air</td>
<td>9</td>
<td>10</td>
<td>13</td>
<td>32</td>
</tr>
<tr>
<td>TOTALS</td>
<td>96</td>
<td>92</td>
<td>96</td>
<td>286</td>
</tr>
</tbody>
</table>

¹ Includes leaves, petioles, twigs, buds
² Includes peeling bark, bark spots, smooth bark on trunks and branches

### Table 13: Numbers of Combined Foraging Behaviour and Substrate Usage at the Old Mill Dam over Three Seasons.

<table>
<thead>
<tr>
<th></th>
<th>Autumn</th>
<th>Winter</th>
<th>Spring</th>
<th>TOTALS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glean Foliage</td>
<td>76</td>
<td>65</td>
<td>58</td>
<td>199</td>
</tr>
<tr>
<td>Glean Bark</td>
<td>3</td>
<td>7</td>
<td>12</td>
<td>22</td>
</tr>
<tr>
<td>Probe Bark</td>
<td>0</td>
<td>5</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>Other¹</td>
<td>22</td>
<td>23</td>
<td>28</td>
<td>73</td>
</tr>
<tr>
<td>TOTALS</td>
<td>101</td>
<td>100</td>
<td>102</td>
<td>303</td>
</tr>
</tbody>
</table>

¹ Includes other behaviours such as hawking and pouncing combined with other substrates such as air and flowers
Table 14: Number of Different Foraging Manoeuvres Used by Yellow-plumed Honeyeaters at Gura Road over Three Seasons.

<table>
<thead>
<tr>
<th></th>
<th>Autumn</th>
<th>Winter</th>
<th>Spring</th>
<th>TOTALS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glean</td>
<td>61</td>
<td>78</td>
<td>69</td>
<td>208</td>
</tr>
<tr>
<td>Probe</td>
<td>17</td>
<td>6</td>
<td>7</td>
<td>30</td>
</tr>
<tr>
<td>Hover</td>
<td>6</td>
<td>5</td>
<td>6</td>
<td>17</td>
</tr>
<tr>
<td>Hawk</td>
<td>10</td>
<td>10</td>
<td>13</td>
<td>33</td>
</tr>
<tr>
<td>Other(^1)</td>
<td>10</td>
<td>4</td>
<td>8</td>
<td>22</td>
</tr>
<tr>
<td>TOTALS</td>
<td>104</td>
<td>103</td>
<td>103</td>
<td>310</td>
</tr>
</tbody>
</table>

\(^1\) other: pouncing, snatching and snapping

Table 15: Number of Foraging Substrates Used by Yellow-plumed Honeyeaters at Gura Road over Three Seasons.

<table>
<thead>
<tr>
<th></th>
<th>Autumn</th>
<th>Winter</th>
<th>Spring</th>
<th>TOTALS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foliage(^1)</td>
<td>53</td>
<td>74</td>
<td>74</td>
<td>201</td>
</tr>
<tr>
<td>Bark(^2)</td>
<td>36</td>
<td>12</td>
<td>13</td>
<td>61</td>
</tr>
<tr>
<td>Air</td>
<td>11</td>
<td>10</td>
<td>14</td>
<td>35</td>
</tr>
<tr>
<td>TOTALS</td>
<td>100</td>
<td>96</td>
<td>101</td>
<td>297</td>
</tr>
</tbody>
</table>

\(^1\) includes leaves, petals, twigs, buds
\(^2\) includes peeling bark, bark spots, smooth bark on trunks and branches

Table 16: Numbers of Combined Foraging Behaviour and Substrate Usage at Gura Road over Three Seasons.

<table>
<thead>
<tr>
<th></th>
<th>Autumn</th>
<th>Winter</th>
<th>Spring</th>
<th>TOTALS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glean Foliage</td>
<td>46</td>
<td>70</td>
<td>67</td>
<td>183</td>
</tr>
<tr>
<td>Glean Bark</td>
<td>15</td>
<td>4</td>
<td>8</td>
<td>27</td>
</tr>
<tr>
<td>Probe Bark</td>
<td>15</td>
<td>5</td>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td>Other(^1)</td>
<td>28</td>
<td>24</td>
<td>28</td>
<td>80</td>
</tr>
<tr>
<td>TOTALS</td>
<td>104</td>
<td>103</td>
<td>103</td>
<td>310</td>
</tr>
</tbody>
</table>

\(^1\) includes other behaviours such as hawking and pouncing combined with other substrates such as air and flowers
Table 17: Number of Different Foraging Manoeuvres Used by Yellow-plumed Honeyeaters at Site 33 over Three Seasons.

<table>
<thead>
<tr>
<th></th>
<th>Autumn</th>
<th>Winter</th>
<th>Spring</th>
<th>TOTALS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glean</td>
<td>69</td>
<td>68</td>
<td>69</td>
<td>206</td>
</tr>
<tr>
<td>Probe</td>
<td>9</td>
<td>15</td>
<td>7</td>
<td>31</td>
</tr>
<tr>
<td>Hover</td>
<td>13</td>
<td>2</td>
<td>6</td>
<td>21</td>
</tr>
<tr>
<td>Hawk</td>
<td>7</td>
<td>15</td>
<td>13</td>
<td>35</td>
</tr>
<tr>
<td>Other¹</td>
<td>5</td>
<td>4</td>
<td>8</td>
<td>17</td>
</tr>
<tr>
<td>TOTALS</td>
<td>103</td>
<td>104</td>
<td>103</td>
<td>310</td>
</tr>
</tbody>
</table>

¹ other: pouncing, snatching and snapping

Table 18: Number of Foraging Substrates Used by Yellow-plumed Honeyeaters at Site 33 over Three Seasons.

<table>
<thead>
<tr>
<th></th>
<th>Autumn</th>
<th>Winter</th>
<th>Spring</th>
<th>TOTALS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foliage¹</td>
<td>58</td>
<td>57</td>
<td>65</td>
<td>180</td>
</tr>
<tr>
<td>Bark²</td>
<td>28</td>
<td>25</td>
<td>17</td>
<td>70</td>
</tr>
<tr>
<td>Air</td>
<td>8</td>
<td>17</td>
<td>13</td>
<td>38</td>
</tr>
<tr>
<td>TOTALS</td>
<td>94</td>
<td>99</td>
<td>95</td>
<td>288</td>
</tr>
</tbody>
</table>

¹ includes leaves, petioles, twigs, buds
² includes peeling bark, bark spots, smooth bark on trunks and branches

Table 19: Numbers of Combined Foraging Behaviour and Substrate Usage at Site 33 over Three Seasons.

<table>
<thead>
<tr>
<th></th>
<th>Autumn</th>
<th>Winter</th>
<th>Spring</th>
<th>TOTALS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glean Foliage</td>
<td>51</td>
<td>59</td>
<td>56</td>
<td>166</td>
</tr>
<tr>
<td>Glean Bark</td>
<td>12</td>
<td>8</td>
<td>7</td>
<td>27</td>
</tr>
<tr>
<td>Probe Bark</td>
<td>6</td>
<td>14</td>
<td>7</td>
<td>27</td>
</tr>
<tr>
<td>Other¹</td>
<td>34</td>
<td>23</td>
<td>33</td>
<td>90</td>
</tr>
<tr>
<td>TOTALS</td>
<td>103</td>
<td>104</td>
<td>103</td>
<td>310</td>
</tr>
</tbody>
</table>

¹ includes other behaviours such as hawking and pouncing combined with other substrates such as air and flowers
FIGURE 4.1: Percentage Wandoo Trees Available and Wandoo Trees Used Over Three Seasons at the Old Mill Dam
FIGURE 4.2: Percentage Wandoo Trees Available and Wandoo Trees Used Over Three Seasons at Gura Road

- TREES AVAILABLE
- AUTUMN trees used
- WINTER trees used
- SPRING trees used
FIGURE 4.3: Percentage Wandoo Trees Available and Wandoo Trees Used Over Three Seasons at Site 33
FIGURE 4.4: Percent of trees in each height class and the percent of trees used by Yellow-plumed Honeyeaters at the Old Mill Dam.
FIGURE 4.5: Percent of trees in each height class and the percent of trees used by Yellow-plumed Honeyeaters at Gura Road.
FIGURE 4.6: Percent of trees in each height class and the percent of trees used by Yellow-plumed Honeyeaters at Site 33.
Chapter 5: Discussion

The results from this study illustrate the complexity of foraging ecology. The spatial and seasonal variation observed in the foraging of the Yellow-plumed Honeyeater is likely to be associated with changes in the abundance of prey items. These changes can be due to site differences, weather conditions and seasonal differences, year to year differences, plant species, tree size or they may be due to changing requirements of the bird throughout the year.

5.1 Spatial Variation

Keast (1976) attributed the success of the honeyeater family (Meliphagidae) to the ability of species to adapt themselves to many niches, from gleaning foliage and probing bark to feeding on nectar and fruit. A similar switch in foraging is occurring at Dryandra.

Gleaning foliage was the most frequently used foraging technique observed. Significant differences in foraging behaviour were observed between sites during autumn, although in winter and spring birds at the three sites used similar foraging behaviours. Each site was dominated by wandoo with similar understoreys. However, no two areas are the same and the foraging observed in autumn reflected this. The distribution and abundance of resources varies significantly between habitats and regions even on a small scale, and appeared to be a factor in this study. It is not known what specifically led to the higher levels of gleaning, lower levels of probing and lower levels of hawking at the
Old Mill Dam in autumn, but it can be explained by a change in the insect populations at the site. Arthropod populations are subject to many kinds of external influences from both broad area effects and much smaller changes (Recher et al., 1996a) which may result in fluctuations in abundance. Such differences between similar sites can be explained in terms of small changes including differing understorey, the presence of older trees, or site factors such as aspect, although that is beyond the scope of this study. The differences in foraging behaviours between sites observed in this study may have been due to an abundance of lerps or foliage-dwelling insects at the Old Mill Dam which encouraged birds to exploit this easily available food resource. As these were readily available by gleaning, the birds needed to do less probing and other behaviours.

The ability of the Yellow-plumed Honeyeater to adjust to changes in resources is demonstrated by the wide variety of foraging behaviours observed at the sites. While gleaning was consistently the most frequent behaviour, the birds exhibited a range of foraging techniques including some of the rarer behaviours noted by Recher (pers. comm.), such as snapping. When the range of behaviours used at a site was narrow, it suggests the birds were concentrating their foraging using a few techniques to exploit an abundant food source. When the range of behaviours used is larger, it reflects the variety of foraging opportunities available as the birds forage in a number of ways to obtain a number of different prey items. For example, they may glean insects from foliage, hawk prey in the air, probe bark or hover to take manna.
While it was not always possible to determine what prey items the birds were taking as they were so small, the observations made of birds gleaning foliage suggested they were foraging on lerp. Lerp-forming psyllids are an important feature of Australian eucalypt forests in terms of diversity, high average density and their propensity to form massive outbreaks (Woinarski, 1984). Yellow-plumed Honeyeaters vigorously defend these resources from other species as they provide an easily obtainable carbohydrate resource. Foliage gleaning was the most commonly used foraging action and lerps and insects appeared to be abundant at the sites (pers. obs.). Therefore, if the birds were able to obtain such large amounts of food from foliage, it explains the low numbers of more active foraging, such as hovering, occurring at the sites. However, birds continued to use these active methods (although less frequently) as they had obtained their energy requirements from lerps and could afford to seek out protein-rich arthropods using these methods. Birds were also observed feeding on manna and honeydew. With lerps, these alternative carbohydrate resources mean that Yellow-plumed Honeyeaters should be capable of breeding at times when insects are not freely available and of occupying habitats when insects are scarce (Paton, 1980).

The three sites were dominated by wandoo and were located within the central block at Dryandra. Wandoo areas are believed to occur on the most productive, nutrient rich sites (Recher & Davis, in review) although this area needs further research. It would be expected that invertebrate faunas would be similarly rich
due to high plant growth providing many opportunities for insect foraging and therefore, bird foraging.

5.2 Seasonal Variation

Only birds at Gura Road appeared to change their foraging behaviours and substrate use over seasons (Table 15). The rest remained the same throughout the study period. This shows that birds respond not only to small scale fluctuations in insects (site changes) but on seasonal levels. It is expected that if the eucalypt flowering stage had been included in the study, birds would have switched to exploiting this large energy source. However, like all honeyeaters, Yellow-plumed Honeyeaters need protein which is not available from nectar, manna, honeydew or lerp and despite the abundance of carbohydrate sources available, they continue to forage on arthropods to obtain protein. Seasonal foraging trends may show a temporary increase in some particular behaviours and a decrease in others in response to a number of seasonal factors including different weather, the availability of nectar resources, shifts in arthropod populations and changing requirements of the bird.

The fact that Yellow-plumed Honeyeaters exploit manna provides a possible explanation for the high amount of foliage foraging occurring at the sites. Over some of the observation period it was windy and raining. Rain dissolves the manna and washes it away, and wind can dislodge it (Paton, 1980). The implications of this in the Mediterranean climate of the south-west is that the wet winters would see a decline in the availability of manna and an abundance
in summer although this needs further research. Again, the birds adapt to a shortage of one resource (manna) by switching to another (lerp and foliage arthropods).

Changes in behaviour and in the use of resources between seasons and from year to year are common. These changes will occur in response to weather, to changes in resource abundance and availability, to the differing physiological requirements of birds as they proceed through their moult and reproductive cycles, to the demands of migration and to changes in the species composition of avian communities (Recher et al., 1983). This is evidenced by comparing data obtained for this study to unpublished data of Recher and Davis. They observed the Yellow-plumed Honeyeater at Yellowd" in the Eastern Goldfields during 1997 and found the birds to be foraging predominantly on nectar of Eremophila sp. because it was abundant within their woodland habitat. The birds did not appear to be seeking out the resources, just using them when they were available. At Dryandra, the birds foraged for nectar on few occasions as the nectar-producing plants were not abundant at the sites. There were some Dryandra spp. at Site 33 on which the Yellow-plumed Honeyeaters were observed foraging in spring.

Studies by Recher et al. (1996b) of canopy invertebrate communities in eucalypt forests in eastern and western Australia revealed that almost all invertebrate taxa exhibited significant differences between seasons. In the Western Australian forest, taxa tended to be more abundant in autumn,
followed by spring, winter and summer. However, this trend was not statistically significant. So while seasonal changes in forest invertebrates in Western Australia occur, the trends are not consistent and vary particularly in response to yearly variations in rainfall (Recher et al., 1996b). This follows the results found for this study as there did not appear to be any consistent trends or changes in foraging behaviour or substrates used between seasons. Instead, birds at some sites appeared to be responding to increasing populations of insects (which they exploited), where at other sites there did not appear to be any response and birds foraged using a number of methods and substrates to obtain a number of prey items. Changes in resource abundance not only occur between seasons, but may vary significantly between years. Severe drought conditions in south-eastern Australia during 1982-1983 led to almost total reproductive failure of forest and woodland birds and to increased mortality (Ford et al., 1985; Recher & Holmes, 1985).

This may also help to explain the differences observed between this study and that by Recher and Davis (unpublished). They found Yellow-plumed Honeyeaters at Dryandra forage mostly on bark, whereas this study found foliage gleaning to be the most frequent method used to take prey items. Their data were collected in a different year, suggesting that not only do invertebrate populations, and hence Yellow-plumed Honeyeater populations, change with small-scale spatial variation and seasonal influences, but they may also experience longer-term changes over the course of a year or more.
5.3 Resource Availability and Resource Use

It is difficult to conclude that foraging Yellow-plumed Honeyeaters select for wandoo trees as these were the dominant tree species present at the three study areas. While it can be said that wandoo trees were used as substrates more often than any other tree species, it is not possible to attribute that to a preference for foraging on wandoo because birds may have used other tree species if these species had been more abundant. The birds did not exclude other tree species from their substrate menu. There were a few other species among the wandoo of the sites, including some marri and powderbark wandoo which were occasionally used for foraging. At the Old Mill Dam site, less wandoo trees were used for foraging than were available (the percentage of wandoo on the site). At Gura Road, the availability of wandoo was lower than the birds' usage, and at Site 33 they used more than available in winter, but less in autumn and spring. What is clear is that the bird is abundant in wandoo areas, but its occupation of powderbark wandoo and mixed areas is unknown. This is investigated in Part 3: Habitat Selection and discussed in Chapter 8. This study of foraging ecology has not been able to determine if Yellow-plumed Honeyeaters preferentially select for tree species as there was no obvious apparent reason (apart from an extremely low abundance) why they did not forage on other species.

The relative abundance of alternative carbohydrate materials such as lerp, honeydew and manna varies among plant species (Paton, 1980; Woinarski & Cullen, 1984). A study by Recher et al. (1996a) found that some bird species
selected strongly between tree species as foraging substrates. Birds showing the greatest degree of selection were species that took their prey from foliage and required a source of energy-rich carbohydrates. It is therefore reasonable to suggest that the Yellow-plumed Honeyeater may select for tree species when foraging, although the design of this study prevented this from being fully investigated.

The selection of particular foraging substrate characteristics such as tree size was able to be more clearly investigated. Tree height was chosen as it reflects overall tree size (tree diameters were correlated with \( r=0.7 \)). A clear preference for foraging in larger trees was revealed. This may be due to an obvious increase in the amount of prey resources supported by a large tree due to its larger size. In general, a smaller tree will not be able to support as many insects as a larger tree purely because of its size. Larger trees contain proportionately large numbers of prey items with increased opportunities for foraging and a number of birds can forage in a large tree at the same time. However, the preference displayed for larger trees may be beyond that of just a difference in biomass.

Many potential foraging resources are unique to older, larger trees. A significant number of prey items taken during the study were obtained from loose and decorticating bark which harbour various insects and spiders. These bark resources may be less abundant and sustain smaller prey populations in areas with smaller and younger trees (Recher, 1991). Recent work suggests the
abundance and species richness of bark arthropods differs significantly between trees (unpublished, cited in Recher et al., 1996a). The most abundant and richest bark arthropod communities are associated with eucalypts having a complex bark structure (e.g. deep fissures, decorticating bark) and with tree size (i.e. more bark and a greater bark surface) (Recher et al., 1996a). From personal observations, powderbark wandoo appears to shed its bark quickly which may prevent rich arthropod communities from being present. This is related to the habitat selection study and is discussed further in Chapter 8. As trees age, they may also be subject to increased insect attack, making resources such as manna and honeydew more abundant in the areas containing a large number of older trees. Therefore, in addition to larger size, older trees may support a proportionately larger amount and diversity of resources, and it may be these that the Yellow-plumed Honeyeaters are selecting for.
Chapter 6: Methodology

The habitat selection study involved surveying 156 sites within Dryandra for the presence or absence of the Yellow-plumed Honeyeater. The sites contained mixed vegetation associations ranging from pure wandoo to pure powderbark wandoo with many mixed associations in between. The vegetation at each site was sampled using the Point-quarter method. Presence and absence data were collected on three occasions.

6.1 Null Hypotheses

The methods described in this chapter were designed to test the following hypotheses:

- there is no difference between wandoo, powderbark wandoo and related vegetation associations in terms of the presence or absence of Yellow-plumed Honeyeaters;
- there are no particular vegetation characteristics (such as tree height, shrub cover) to which are related to the presence of the Yellow-plumed Honeyeater.

6.2 Study sites

A minimum of 50 independent sites per vegetation type was required to test habitat selection (Smith, 1990). To meet this criteria, a total of 156 sites were randomly selected and were located over most of the blocks at Dryandra (Figure 6.1). Sites were initially assessed visually in terms of the dominant tree species, with suitable sites being those containing predominantly wandoo
(Plate 4a and 4b), predominantly powderbark wandoo (Plate 5a and 5b) or a mixture of the two (Plate 6a and 6b). The Yellow-plumed Honeyeater is a woodland species which, at Dryandra, is found almost exclusively in wandoo or powderbark associations (H. Recher, pers. comm.). Therefore, other vegetation types were not sampled.

6.2.1 Selection method
A random distance (over 200 m) was driven from a nominated starting point in each of the seven blocks sampled. On arrival at an area, it was visually assessed in terms of the dominant tree species because a relatively even sample of the vegetation types was desired. If the vegetation on both sides of the road was wandoo, powderbark wandoo or a mixture suitable for sampling, a coin was flipped to determine which side of the road was sampled. If only one side contained suitable vegetation, that side was sampled and if neither side were suitable, another random distance was driven and this continued until a suitable site was reached. The process of selecting sample sites continued until 50 of each vegetation type had been located.

6.3 Vegetation Sampling
The purpose of the vegetation surveys was to quantify differences between wandoo, powderbark wandoo and mixed vegetation and determine the particular characteristics of the vegetation which may be influencing the presence or absence of the Yellow-plumed Honeyeater. The Point-Quarter Method was used. Tree characteristics, shrub characteristics and canopy measurements were recorded.
6.3.1 Positioning of points
The first of five points was located ten metres in from the road, using the site flagging as a starting point. Random bearings and distances were used to determine the location of the other four points (Figure 6.2). The maximum distance between each point was 41 m and the shortest distance was 28 m.

![Diagram showing typical positioning of five points.]


6.3.2 Point-quarter method
At each of the five points, the closest tree (described as single stemmed, greater than five metres tall) in each quarter was identified to species level and its height, diameter (at breast height) and distance to the point measured. This was repeated in all quarters. Trees were not recorded if they were more than 18 m from the central point which caused some problems as the minimum
distance between points was only 28 m. This meant that trees were recorded twice on a few occasions. Shrubs were recorded in a similar manner to trees except diameter measurements were not practical. Instead, the total shrub cover within a circle of approximately ten metres radius was estimated at each point.

6.3.3 Canopy measurements

The path between sites was walked and every two metres canopy was measured as cover/no cover. These were tallied and recorded as percentage cover of canopy for the site.

6.3.4 Analysis of vegetation data

Data were averaged to obtain a mean tree height, diameter and density. The species of each was not considered in these calculations as it was only necessary to determine the average height, diameter and density of trees, not the average of different species at each site. Individual species were treated separately in determining the percentage composition of plant species at each site.

In order to calculate the densities of trees where the distance to the closest tree was greater than 18 m, an arbitrary value of 36 m was assigned. The assumption was made that trees falling outside the 18 m radius of the point (which were not sampled) would not have been further than 54 m away. Therefore, half of the trees which were not sampled would have been between
18 and 36 m away, the other half 36 to 54 m away. Based on this, 36 m was seen as a reasonable substitute. Density data were then averaged to determine the number of trees per hectare at each site.

Classification of the sites based on vegetation parameters was done using UPGMA following the Gower-Metric association function of the PATN program. A dendrogram was used to show the relationship between groupings, and boxplots determined which parameters were responsible for some of the major groupings. A decision to limit group numbers to six was made on the basis of clarity, information gain and ease of interpretation.

6.4 Presence and Absence Data

The presence or absence of the Yellow-plumed Honeyeater was recorded at each site. This was to determine where on the continuum of vegetation associations from wandoo to powderbark wandoo the birds are found, and what characteristics of the two tree species are associated with the presence or absence of the Yellow-plumed Honeyeater.

6.4.1 Procedure and analysis

Each site was visited on three occasions on separate days between 22nd July and 12th September 1997. The maximum waiting time for evidence of the bird (calls) was three minutes. As Yellow-plumed Honeyeaters are vocal and visually conspicuous, it was judged that if the birds were present, they would be detected within three minutes, and three visits would be sufficient to determine
their occurrence at any site. The species is resident and colonial at Dryandra and would therefore be present at the same sites at the same times throughout the year. Presence/absence data were only collected in fine weather conditions to ensure the best possibility of detecting the birds if they were at the site. However, there is some movement of Yellow-plumed Honeyeaters through habitat where they are not permanently in residence (pers. obs.). Therefore, Yellow-plumed Honeyeaters were judged to be resident on a site if the species was recorded on all or on two of the three census visits. Where Yellow-plumed Honeyeaters occurred once, or not at all, the bird was judged not to be resident on those sites. This allowed for the chance recording of transient individuals.
Chapter 7: Results

This chapter describes the use of three different habitat types in terms of the presence or absence of Yellow-plumed Honeyeaters. The vegetation samples revealed that for most of the sites, the vegetation did not fall into distinct categories of pure and mixed forms. Instead, they adequately represented the continuum of wandoo into powderbark wandoo essential to meet one of the aims of the study: to find out where along the continuum the birds are and are not residing. By examining eight vegetation characteristics, the sites were grouped in PATN analysis. The measured variables which were not included were judged as trivial and of little use in determining group classifications.

7.1 Presence/Absence and Dominant Vegetation

Yellow-plumed Honeyeaters were present at 25 sites (Figure 6.1). Most of these sites contained between 70 and 100% wandoo trees, although at three sites, this percentage dropped to between 60 and 42%. At these three sites there were few powderbark wandoo trees (no higher than 30% powderbark wandoo). Yellow-plumed Honeyeaters did not occur at sites with less than 40% wandoo or sites with greater than 30% powderbark wandoo. In Figure 7.1, it appears that the birds were present at few sites. However, there was a concentration of birds present in areas containing between 70 and 100% wandoo trees which is masked as these points overlap on the graph. Birds are clearly exhibiting a preference for areas containing predominantly wandoo, if preference is related to their presence or absence from an area. It could also
be assumed that not only are they residing in wandoo in preference to powderbark wandoo, but they may be excluding powderbark wandoo since they were absent from sites containing over 30% powderbark wandoo. One of the outliers, Site 2, contained 42% wandoo, 16% powderbark wandoo and 38% marri. The dominant species at the site was therefore wandoo. At no sites where the birds were present did the percentage of wandoo drop below that of powderbark wandoo.
FIGURE 7.1: WANDOO AND POWDERBARK WANDOO COMPOSITION OF 156 SITES SHOWING PRESENCE OR ABSENCE OF YELLOW-PLUMED HONEYEATERS

Note: much overlap of sites where birds were present occurs between 75-100% wandoo
7.2 PATN Analysis

The sites were allocated to six groups based on eight vegetation parameters. The groups are shown in Table 20.

7.2.1 Site groupings

**Group 1** contained 66 sites, including 21 of the 25 sites where the birds were present. A large number of the sites were located within the largest block of unbroken habitat (sites 1 to 74). Forty-seven of the sites contained more than 80% wandoo in the vegetation. In addition to these, 9 of the sites which contained less than 80% wandoo had no powderbark wandoo trees. **Group 2** contained 33 sites, of which Yellow-plumed Honeyeaters were found in two. None of the sites had over 80% wandoo or powderbark wandoo and all sites contained some of both species. The sites in Group 2 were not confined to any specific area of Dryandra. **Group 3** contained just two sites (113 and 134). Trees on these sites were much more dense than at other sites which would have been the grouping factor (Figure 7.2).

**Group 4** had 10 member sites, with Yellow-plumed Honeyeaters present at two. These two sites had over 80% wandoo trees, with low tree density and a large range of tree sizes (diameter). Sites in Group 4 were scattered throughout Dryandra. There were 26 sites in **Group 5**, and birds were not present at any of the sites. Six sites contained over 80% powderbark wandoo, with one additional site containing no wandoo. This group was also characterised with low wandoo abundance and a large range of tree diameters. There were 19 sites in **Group**
6, of which 17 contained over 80% powderbark wandoo. The other two sites had 70% powderbark. Birds were not present at any of these sites in Group 6.

**TABLE 20: GROUP DIVISIONS- Site Members**

<table>
<thead>
<tr>
<th>GROUP 1</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>10</th>
<th>11</th>
<th>14</th>
<th>15A</th>
</tr>
</thead>
<tbody>
<tr>
<td>15B</td>
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| GROUP 3 | 113| 134| |
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TABLE 21: CRAMER VALUES FOR SITE VEGETATION FACTORS

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<th>Attribute</th>
<th>Cramer Value</th>
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<tr>
<td>Percentage wandoo</td>
<td>0.9076</td>
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<td>Percentage powderbark wandoo</td>
<td>0.9566</td>
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<tr>
<td>Tree height</td>
<td>0.3851</td>
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<td>Tree diameter</td>
<td>0.5042</td>
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<tr>
<td>Tree density</td>
<td>0.7467</td>
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<tr>
<td>Shrub height</td>
<td>0.3317</td>
</tr>
<tr>
<td>Percent shrub cover</td>
<td>0.5089</td>
</tr>
<tr>
<td>Percent canopy cover</td>
<td>0.3886</td>
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</tbody>
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L=lower limit, 1=1st quartile, M=mean, D=median, 3=3rd quartile, U=upper limit,
*=more than one symbol at print position

FIGURE 7.2: BOXPLOT OF TREE DENSITIES (trees/ha) FOR EACH GROUP
7.2.2 Cramer values

Cramer values show the significance of different parameters towards the groupings. A value close to 1 means the attribute was important in distinguishing between groups, and a value close to 0 means the factor was not important in determining groups. In Table 21, attributes that strongly influenced the groupings were the percentage of powderbark wandoo, percentage wandoo and tree density. Shrub cover and tree diameters would not have significantly influenced groupings and tree height, shrub height and percent canopy cover would have played little part.

7.2.3 Dendrogram

Figure 7.3 shows how the groups are related. Groups 2 and 3 were closely associated, as were Groups 5 and 6 (characterised by the occurrence of powderbark wandoo). Groups 5 and 6 were most different to Group 4. Group 1 (characterised by abundant wandoo) was distinct, but showed some association to Group 4. Group 4 had a weak association to Groups 2 and 3.
FIGURE 7.3: DENDROGRAM SHOWING RELATIONSHIPS BETWEEN THE SIX SITE GROUPS BASED ON EIGHT VEGETATION PARAMETERS.

Note: Low association numbers indicate a high level of association. The higher the number, the lower the association.
Chapter 8: Discussion

The results from this study demonstrate the Yellow-plumed Honeyeaters' preference for wandoo vegetation. Their presence or absence at a site is clearly linked to the percentages of wandoo and powderbark wandoo at that site. There are many reasons to explain this preference, some of which are related to the foraging ecology of the species.

8.1 Tree Selection

Out of the 156 sites surveyed, Yellow-plumed Honeyeaters were present in 25 sites. Only three of the sites where the bird was recorded contained a mixture of wandoo and powderbark wandoo (wandoo accounting for between 42 and 60% of trees), the others being wandoo sties. The birds were not present in the powderbark wandoo. The foraging ecology study found that Yellow-plumed Honeyeaters used powderbark wandoo occasionally for foraging when individual trees were present at the study areas. From that study alone, it was not possible to determine any preferences in foraging between wandoo and powderbark wandoo. However, as the habitat selection study shows, if the birds did not preferentially select wandoo trees for foraging it would be expected that more birds would have been present at mixed sites. They were not, and this clearly demonstrates that the birds select for wandoo trees. Birds also foraged in mallet plantations opposite wandoo areas (pers. obs.), taking prey from under strips of bark. Although mallet trees appeared to have a suitable bark
resource, it may be that the foliage fauna are not suitable or abundant enough to sustain Yellow-plumed Honeyeaters. This area needs further research.

8.2 Bark Resources
The obvious selection of wandoo areas can be attributed to the resources within those areas including the bark resources. The richest bark arthropods are associated with complex bark structures (e.g. deep fissures, decorticating bark) (Recher et al., 1996a). These resources are available in the wandoo, particularly in older trees. Powderbark wandoo trees shed their bark all at once (pers. obs.) meaning the rich arthropod faunas that inhabit loose and peeling patches of bark may not be present. If they were present, these arthropods would be an unreliable resource as they would not be available continuously. Instead, arthropods in these areas may be concentrated in the exfoliated bark on the floor. In the foraging ecology study, Yellow-plumed Honeyeaters were rarely seen foraging on the ground. Therefore, powderbark wandoo fails to provide some of the resources required by the Yellow-plumed Honeyeater.

8.3 Site Nutrients
Arthropods respond to site variables, including nutrients. It is believed that wandoo areas inhabit the more productive, nutrient-rich areas, with powderbark wandoo confined to the less productive slopes (Recher & Davis, in review). Therefore, an obvious assumption is that more productive sites have higher plant growth with more opportunities for invertebrates and, consequently, birds. Species of insectivorous birds that are dependent on energy-rich carbohydrates
(such as lerp and manna) select between plant species as foraging substrates on the basis of the kinds of arthropods available and their abundance on each kind of plant (Recher et al., 1996a). The abundance of lerp-producing psyllids differs between tree species (Paton, 1980; Woinarski & Cullen, 1984) but they are most abundant on eucalypts with high foliar nutrient levels (Recher et al., 1991). It is believed that wandoo areas are nutrient rich (Recher & Davis, in review) and is expected that they would contain high levels of foliar nutrients which may explain why Yellow-plumed Honeyeaters are residing there.

8.4 Colonial Species

The Yellow-plumed Honeyeater is colonial at Dryandra. This means that an area must be able to support a colony of birds rather than a few individuals. Although a wandoo area may have the resources, there may not be enough to support the colony. This would happen in an unfragmented landscape where changes in elevation produce small areas of many different types of vegetation. It was observed on numerous occasions how the vegetation changed over a few metres from one association to another. The birds resident in nearby habitat may still forage in these small patches, although the patches themselves may not be large enough for the colony to be resident. Also, these larger areas nearby where the species is resident may only be large enough to support the colony if some residents use these smaller patches some of the time.
8.5 Fragmented Habitat

In fragmented landscape, small areas of suitable habitat are often surrounded by highly modified agricultural areas. There are no colonies nearby to use the areas because they are unable to cross expanses of agricultural terrain. Even if the fragments were large enough to support a colony, the isolated population would still be at risk from factors such as increased predation. Luck (1996) found the Yellow-plumed Honeyeater to be an edge-avoiding species, and therefore, isolated remnants would need to be large enough to reduce the effects of edges to be of any benefit.

8.6 Social Structure

Colonies of Yellow-plumed Honeyeaters aggressively defend their foraging resources (Woinarski, 1984, pers. obs) which may be a factor in determining whether an area is suitable for occupation. As the birds were found to forage predominantly in the foliage, the importance of the defence of this resource would be substantial. Effective defence will only be possible if colonies are large enough to exclude other species from taking their resources. If an area can only support a small colony, defence will be less effective and competition for resources may be great. In these instances, the birds lose their optimum foraging resources, which has implications for their survival. These issues must be addressed in management options for the Yellow-plumed Honeyeater for its long-term survival.
Chapter 9: Conclusions and Management Issues

The loss of species in remnants is a major concern. Until now, reasons suggested as causes for the decline of the Yellow-plumed Honeyeater had not been supported by specific scientific research on the bird. This study has helped clarify some issues, and provide the means to allow management decisions based on information, rather than untested hypotheses. The major findings were related to the preferred foraging technique and substrate used, and the changes in foraging on temporal and spatial scales. Clear habitat preferences were revealed in the results from the habitat selection study.

9.1 Foraging Preferences

Foliage gleaning was the most frequently used foraging method, with aerial and bark foraging also common. This use of bark resources is of particular importance as although bark was used less often than foliage, it was used frequently enough to be a major source of food for Yellow-plumed Honeyeaters. In addition, foraging birds clearly selected large trees, and it is these larger, older trees which provide diverse and abundant bark arthropods. I suggest that larger trees have larger numbers of arthropods not only because of their larger size, but because of the additional resources they provide which are unique to older trees (such as decorticating bark). This is highly significant in terms of the survival of the species in remnants as the larger trees are the first to be removed. Obviously, if the birds’ preferred foraging substrate has been
removed from remnants in the wheatbelt, it will be forced to forage on less than optimum resources. The question on whether or not Dryandra provides their optimum resources is beyond the scope of this study. However, if less preferred alternatives are not sufficient, or if the bird has to travel long distances to find them, then their survival is threatened and they will drop out of the remnants.

9.2 Habitat Selection

This study has answered a long-asked question about the presence of the Yellow-plumed Honeyeater along the continuum of wandoo to powderbark wandoo vegetation. The birds were present at sites where the dominant vegetation was wandoo. With a few exceptions, Yellow-plumed Honeyeaters were not found in areas containing less than 70% wandoo, and did not frequent areas with over 30% powderbark wandoo. A possible explanation given by Recher and Davis (in review) is that areas where wandoo occurs are believed to be more productive, and it is these more productive sites which the Yellow-plumed Honeyeater requires. This has implications for management of declining species through revegetation of areas of the wheatbelt. The land on which the vegetation is restored will not be in its original, highly productive condition, which may reduce success of revegetation programs, and the value of the area for conservation of the Yellow-plumed Honeyeater.

9.3 Threatened Species

The woodlands at Dryandra are also home to the Rufous Treecreeper (Climacteris rufa) which, like the Yellow-plumed Honeyeater, is unable to persist
in many remnants. Although they forage using different resources, the characteristics of a Rufous Treecreeper habitat (coarse woody debris, large logs, snags) are found in the productive wandoo woodland containing the larger and older trees preferred by the Yellow-plumed Honeyeater (Recher & Davis, in review). The information collected during this study and the management options suggested will benefit both species.

9.4 Fragmented Habitats

The Yellow-plumed Honeyeater is a colonial species at Dryandra and therefore it requires sufficiently large areas of habitat. In fragmented landscape, small areas of potentially suitable habitat are surrounded by highly modified areas. Although the birds appeared to be adjusting to variations in their foraging resources on seasonal and temporal scales, they have a narrow range of foraging substrates and require productive habitats. If their optimum foraging resources are not available in remnants and they are unable to cross expanses of agricultural terrain to obtain them, they will drop out of a remnant. Further, reserves in the wheatbelt are small, and may not be able to support the social structure of the Yellow-plumed Honeyeater.

9.5 Management Options

The species is an edge avoider (Luck, 1996) and therefore, isolated remnants would need to be large enough to reduce the effects of edges to be of any benefit to the species. To address this problem, managers should attempt to
reduce the effects of fragmentation by planting extensive corridors, which Yellow-plumed Honeyeaters have been seen to use (Newbey & Newbey, 1987).

The restoration of Yellow-plumed Honeyeater to parts of their former range where they are now extinct will require reclaiming large areas of farmland and restoring them to their previous, highly productive state. Such grand-scale management is an unlikely option. Therefore, the retention and management of areas large enough to support the Yellow-plumed Honeyeater is the best option for the conservation of the species.
PLATE 1a: Vegetation of the Old Mill Dam Site

PLATE 1b: Vegetation of the Old Mill Dam Site
PLATE 3a: Vegetation of Site 33

PLATE 3b: Vegetation of Site 33
PLATE 4a: *Eucalyptus wandoo* dominant vegetation

PLATE 4b: *E. wandoo* dominant vegetation
PLATE 5a: *Eucalyptus accedens* dominant vegetation

PLATE 5b: *E. accedens* dominant vegetation
PLATE 6a: *E. wando*o*o* and *E. accedens* mixed vegetation

PLATE 6b: *E. wando*o*o* and *E. accedens* mixed vegetation
References


Crossman, A.F. (1909) Birds seen at Cumminin Station, Western Australia. Emu 9, 84-90.


Milligan, A.W. (1904) Notes on a trip to the Wongan Hills, Western Australia, with a description of a new Ptilotis. Emu 3, 217-222; Emu 4, 2-11.


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