Journal of the Royal Society of Western Australia, 85:103-111, 2002

Foraging profile of a Salmon Gum woodland avifauna in Western Australia

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(Manuscript received January 2002; accepted June 2002)

Abstract

During studies of the foraging ecology of birds in the western Goldfields of Western Australia in Spring 1997, 63 species were recorded. The majority were resident and insectivorous, but we estimate that about 25% were migratory or nomadic. Our interpretation of the data is that migrants and nomads had aggregated in the area in response to an abundance of nectar and insects, following good rains in autumn and winter. In addition, there were seven species of raptors, possibly attracted by the numerous nectar-feeders. Ground-foragers dominated the avifauna, but many species foraged in the shrub and canopy layers by gleaning and snatching insects from the foliage. Feeding on flying insects was also prominent and accentuated by the availability of flying termites (Isoptera) at dusk. In contrast, bark was a poorly used foraging substrate compared with other woodlands that have been studied. Differences in community-wide foraging profiles can be explained by temporal and spatial variation in the kinds and abundance of prey (including nectar), but have important implications for the conservation of woodland bird communities. Conserving woodland birds requires large and multiple reserves on a supra-landscape scale, and the restoration of ground substrates and vegetation: both are necessary if all parts of the avifauna, nomads, migrants and residents, are to be conserved.

Keywords: foraging ecology, birds, Salmon Gum, woodland, Western Australia, conservation

Introduction

Prior to European settlement, Salmon Gum (*Eucalyptus salmonophloia*) formed extensive woodlands throughout the Wheatbelt and Goldfield regions of Western Australia where it occurred in association with other eucalypts (Boland *et al.* 1984) including Black Morrel (*E. melanoxylon*), Gimlet (*E. salubris*), Redwood (*E. transcontinentalis*), Red Morrel (*E. longicornis*) and York Gum (*E. loxophleba*). Within the Wheatbelt, eucalypt woodlands have been extensively cleared and continuous Salmon Gum woodlands remain only in the Goldfields and along the mulga-eucalypt line at the northern limits of the Wheatbelt.

Although the avifauna of remnant eucalypt woodlands in the Wheatbelt has been extensively documented (*e.g.* Kitchener *et al.* 1982; Saunders 1989; Cale 1990; Saunders & Ingram 1995; Arnold & Weeldenberg 1998), there are few descriptions of the bird communities and their ecology in the woodlands of the Goldfields or along the mulga-eucalypt line. As these communities may retain components of the avifauna lost from remnant vegetation in the Wheatbelt, details on species composition and the use of resources by birds in these habitats are important in understanding patterns of species loss from remnants and for designing reserve systems with the capacity to sustain all elements of the avifauna.

In this paper, we describe the breeding season foraging ecology of birds in Salmon Gum woodlands in the western Goldfields at the eastern limits of the Wheatbelt. Our objective was to document the foraging profile of the avifauna in a brief period and thereby avoid changes in resource abundance. Changes in foraging behaviour over time can blur differences between species and confuse analyses of community-wide foraging patterns (*e.g.* guild structure). Although information on seasonal and year to year patterns of abundance, breeding cycles and population sizes is necessary for a complete analysis, foraging data identify essential resource requirements for birds and can be used to develop revegetation programmes to maximise conservation benefits.

Methods

Study area and vegetation

From September 12 to 20, 1997, using the same procedures as Recher & Davis (1998), we sampled woodlands at 12 sites along 20 km of the Great Eastern Highway centred on Yellowdine (31° 17' S, 119° 39' E; ~ 400-450 m asl). Each site was about 10 ha in area. Data on foraging birds were obtained within woodlands dominated by Salmon Gum, Gimlet, Red Morrel and mallee eucalypts. The shrub layer, 1-4 m tall, was floristically rich and multiple-layered with *Acacia*, *Cassia*, *Dodonea*, *Eremophila*, *Exocarpus*, *Grevillea*, *Melaleuca* and *Santalum* species dominating. Mistletoes were common in the eucalypt canopy. Canopy vegetation ranged from

8 to 15 m in height with individual Salmon Gums to 18 m and morrels to 16 m. Small trees and mallees, which included Yorrell (*E. yilgarnensis*), Square-fruited Mallee (*E. callycogona*), Redwood and Gimlet ranged from 3 to 6 m in height. Among the mallees, Yorrell dominated and on the lower parts of the landscape formed extensive grassy woodlands with Gimlet. The result was a complexly structured canopy and subcanopy vegetation with considerable open space and variation in the composition and height of the dominant plants. The shrub layer was variable. In places, it was nearly continuous, but elsewhere was sparse. Ground cover was also variable, but floristically diverse and included species of *Atriplex*, *Brachycome*, *Maireana* and *Ptilotus*, as well as grasses. In places where shrubs were abundant, the soil was nearly bare, while sites with few shrubs were dominated by a nearly continuous growth of grasses and forbs. Throughout the study area, litter was sparse and wind driven into concentrations around the base of shrubs and trees, within clumps of mallee, against logs or where there was an accumulation of coarse woody debris. Coarse woody debris and logs were abundant throughout. On average, nearly 50% of the ground surface was bare.

Most of the area had been selectively logged prior to the 1970s but, as noted by Newbey *et al.* (1995), it was difficult to identify the effects on the vegetation. The most obvious changes resulted from the cutting of *Melaleuca* for posts, with many stands failing to recover. There was no sign of grazing by domestic stock, but macropods and rabbits appeared abundant.

Foraging Data

Foraging observations commenced shortly after sunrise and continued to dusk.

We began at a different site each day and changed sites during the day whenever we felt that we had sampled all available individuals. Some sites were visited on two or more occasions. Our objective in selecting different sites was to sample the range of habitats within the study area and our sites were allocated between the different plant associations in about the proportion that each occurred.

Foraging observations were recorded for all species of birds encountered. For each individual, we recorded up to five consecutive foraging manoeuvres following the procedures of Recher *et al.* (1985) as modified by Recher & Gebski (1989). We avoided recording data on the same individual on the same day by moving continuously and changing sites frequently. For some rare and/or difficult to observe species (*e.g.* Gilbert's Whistler, Chestnut Quail-thrush; species names of birds are given in Appendix 1), we recorded up to 20 continuous observations per individual. As our objective was to describe the foraging profile of the avifauna, multiple observations of individual birds increased the chance of recording infrequent or unusual behaviour (Recher *et al.* 1985), while also providing sufficient data for description. By recording behaviour from early morning to late afternoon, any changes in foraging activities associated with possible changes in food availability (*e.g.* emergence of flying insects near dusk, depletion of nectar near mid-day) are recorded and incorporated equally in the data.

Only foraging manoeuvres in which the bird obtained or attempted to obtain a prey item were recorded ('attack behaviour' of Remsen & Robinson 1990). For each of these, we recorded the species of bird, the substrate and height of the prey, and the manoeuvre used by the bird. Foraging manoeuvres were described following the terminology of Recher *et al.* (1985). However, in this paper we separate hawking manoeuvres into two types; 'hawk' in which a perched bird takes flight and captures a flying insect (equivalent to sally of Remsen & Robinson 1990), and 'sweep' in which airborne insects are caught on the wing by birds, such as swallows which forage in flight (after Mac Nally 1994). In addition, we use 'flitting' (after Crome 1978) to describe the behaviour of Willie Wagtails and Grey Fantails as they search for and pursue prey in the air and on the ground by short darts or runs, and short, twisting flights with the rapid changing of perches (see Cameron 1985). In previous papers, we described the behaviour of wagtails and fantails as 'hawking' and/or 'gleaning' (*e.g.* Recher *et al.* 1985; Recher & Davis 1997, 1998), but this does not adequately portray their behaviour.

For substrates we recorded the following categories; 1, Ground (including ground vegetation, litter, logs and coarse woody debris); 2, Bark (including small (< 2.5 cm diameter) and large (> 2.5 cm diameter) branches, and the main stem or trunk); substrates with loose or decorticating bark were recorded separately from other bark surfaces; 3, Foliage (including twigs, petioles, eucalypt seed capsules, and leaves); 4, Flowers; and 5, Air (for aerial prey). Dead substrates were distinguished from live substrates. The height of the prey taken was estimated to the nearest 0.1 m below 2 m and to the nearest 0.5 m above 2 m. Plants on which birds were foraging were identified to genus and, where possible, to species.

Species Abundances

An estimate of the number of individuals of all bird species was made at each site where we recorded foraging data. These estimates were made over one to several hours as a 'running tally' of birds detected during the collection of foraging data. Counts were conducted at different times of the day and under different weather conditions, although the weather was always fine and sunny. On most days, one count was done during the morning and a second during the afternoon at a different site. Although these estimates cannot be used as measures of absolute abundances or to compare population densities between species and sites, they indicate relative numbers and are an index of variation in the composition and species richness of the avifauna on the sites where we collected foraging data.

Data Analysis and Presentation

For each species we present the total number of foraging manoeuvres observed and the percentage use of substrates, prey-attack behaviours, and foraging heights based on these totals. Data from all sites are combined. Although substrates were recorded as finely as possible, sample sizes for many categories were too small for separate analysis and have been grouped as Ground, Bark (Branches & Trunk), Foliage, Flowers (nectar and insect feeding) and Air. Species were sorted into foraging

Table 1

Use of vegetation layers (%) and foraging height of birds in Salmon Gum woodlands at Yellowdine during September 1997.

Species (n)	Vegetation layer (m)				
	Ground 0–0.1	Shrub 0.2–1	Sub-canopy 1.1–5	Canopy >5	Height (m)*
Ground					
Chestnut Quail-thrush (49)	100	0	0	0	0(0.01)
Emu (20)	100	0	0	0	0(0)
Galah (25)	100	0	0	0	0(0)
Redthroat (30)	100	0	0	0	0(0.02)
Yellow-rumped Thornbill (77)	100	0	0	0	0(0.02)
White-browed Babbler (29)	83	7	10	0	0.3(0.8)
Rufous Treecreeper (169)	84	4	11	5	0.7(1.7)
Ground & shrub					
Willie Wagtail (132)	43	8	38	11	2.2(2.6)
Gilbert's Whistler (32)	22	59	19	0	0.6(0.6)
Chestnut-rumped Thornbill (191)	19	21	47	13	2.2(2.3)
White-eared Honeyeater (35)	11	3	77	9	3.5(2.7)
Grey Fantail (57)	9	7	84	0	3.4(1.5)
Ground & canopy					
Port Lincoln Parrot (106)	74	9	5	12	1.8(4.8)
Grey Shrike-thrush (11)	64	9	9	18	1.7(2.9)
Yellow-throated Miner (20)	50	0	25	25	3.4(4.2)
Red-capped Robin (50)	38	0	38	24	2.7(2.7)
Jacky Winter (76)	26	23	26	25	2.9(3.7)
Grey Butcherbird (34)	18	12	32	38	5.7(5.4)
Shrub & canopy					
Spiny-cheeked Honeyeater (104)	0	26	50	24	3.2(2.8)
Yellow-plumed Honeyeater (375)	0	1	61	38	4.8(2.8)
Broad-tailed Thornbill (155)	4	17	66	13	3.2(2.2)
Horsfield's Bronze Cuckoo (10)	0	0	70	30	5.2(1.5)
Brown Honeyeater (52)	4	6	75	15	3.5(2.7)
Brown-headed Honeyeater (51)	0	0	75	25	5(2.3)
White-fronted Honeyeater (59)	0	1	90	9	3.6(1.4)
Canopy					
Weebill (264)	0	2	73	25	4.3(2.1)
Red Wattlebird (54)	0	0	54	46	5.4(2.1)
Purple-crowned Lorikeet (218)	0	0	53	47	6(2.6)
Striated Pardalote (202)	0	0	46	54	6.2(3.1)
Black-capped Sittella (18)	0	0	33	67	7.1(3.2)
Black-faced Cuckoo-shrike (35)	0	0	14	86	7.6(2)
Above & within canopy					
Dusky Woodswallow (73)	0	0	12	88	15.3(9.6)
Tree Martin (124)	0	0	8	92	20.6(8.9)

*values are mean with standard deviation in parentheses

guilds based on percent use of foraging manoeuvres, substrates and foraging heights. The point of division was arbitrary, but generally grouped species using a particular height range, substrate, manoeuvre or combination of height, substrate and manoeuvre for 40% or more of recorded observations. Ten or more observations were recorded for 33 species (Table 1). Species for which we recorded fewer than ten foraging manoeuvres were not analysed.

Results

Species richness

Sixty-three species of birds were recorded within the study area (Appendix 1). The maximum number of species observed during a count was 36 and the minimum was eight (16 ± sd 8, n = 24). The wide variation in species number is partly due to differences between counts in the time of day, temperature and habitat. In early morning counts when temperatures were less than 20 °C (min 10 °C), more individuals and species were recorded than in counts later in the day or when temperatures were higher (max 28 °C). The greatest number of species were recorded in complexly structured Salmon Gum forest with four vegetation strata: ground (0 - 0.1 m), low shrub (0.2 - 1 m), mallee and tall shrub (1.1 - 6 m), and canopy eucalypts (> 12 m). Gimlet/Yorrell woodlands with a grassy ground vegetation and comparatively few shrubs had the fewest species of birds present.

An index of abundance (total number of individuals recorded during counts; n = 24) is presented in Appendix 1. However, most species were represented by few birds and the frequency with which species were recorded on counts (*i.e.* presence/absence) may be a better indicator of relative abundance. The distribution of species among sites was patchy and most species were only recorded on a small number of counts (Appendix 1). Nineteen of the 63 species (30%) were

recorded on only 1 or 2 counts, while 32 (51%) occurred on five or fewer counts. Fifty-one species (81%) were recorded on 11 or fewer counts, while only five species (8%) occurred on 19 or more counts. No species was recorded on all counts (Appendix 1).

Foraging heights

Ten species (30%) took more than 50% or more of their food from the ground or from ground vegetation less than 10 cm in height (Table 1). Including ground-foragers, twelve species (36%) took 50% or more of their food from within 1 m of the ground.

Twelve species (36%), including Yellow-throated Miner and Red-capped Robin, foraged from the ground through the shrub and subcanopy vegetation into the canopy (Table 1). This includes species which foraged primarily on the ground, such as Rufous Treecreeper. The Grey Fantail also forages over this height range, but we did not record it foraging in the canopy during this study. Eighteen species (55%) took more than 40% of their food from shrubs and mallee eucalypts within a height range of 0.2-5 m. Only Gilbert's Whistler foraged predominantly (59% of foraging manoeuvres) in shrubs within a metre of the ground. Brown, Spiny-cheeked, White-eared, Yellow-plumed and White-fronted Honeyeaters took nectar from a variety of tall shrubs (mainly *Eremophila* spp) 1-1.8 m in height, and also visited flowering mallees 2.5-6 m in height. Most observations of Purple-crowned Lorikeets were of birds foraging on mallee blossom.

Eight species (24%), Black-faced Cuckoo-shrike, Brown-headed Honeyeater, Horsfield's Bronze Cuckoo, Purple-crowned Lorikeet, Red Wattlebird, Striated Pardalote, Weebill, and Yellow-plumed Honeyeater, foraged predominantly (> 95% of foraging manoeuvres) in the canopy (> 4 m) of mallees and other eucalypts. Black-capped Sittella foraged on the trunks of trees and stems of eucalypts from < 2 m to more than 13 m above

Table 2

Use of substrates (%) by foraging birds in Salmon Gum woodland at Yellowdine during September 1997. See Table 1 for sample sizes and Appendix 1 for scientific names.

Species	Substrate					
	Ground	Bark		Foliage	Air	Flower
		Branch	Trunk			
Ground foragers						
Chestnut Quail-thrush	100	0	0	0	0	0
Emu	100	0	0	0	0	0
Galah	100	0	0	0	0	0
Redthroat	100	0	0	0	0	0
Yellow-rumped Thornbill	100	0	0	0	0	0
White-browed Babbler	83	17	0	0	0	0
Rufous Treecreeper	80	9	8	3	0	0
Port Lincoln Parrot	74	0	12	7	0	7
Grey Shrike-thrush	64	9	0	0	17	0
Ground & foliage						
Yellow-throated Miner	40	0	5	55	0	0
Gilbert's Whistler	22	9	0	69	0	0
Chestnut-rumped Thornbill	18	9	2	62	6	3
Ground & aerial foragers						
Red-capped Robin	40	7	2	7	44	0
Willie Wagtail	34	0	0	12	54	0
Grey Butcherbird	33	10	7	14	36	0
Jacky Winter	29	3	11	4	53	0
Aerial foragers						
Tree Martin	0	0	0	0	100	0
Dusky Woodswallow	0	2	5	3	88	2
Grey Fantail	0	9	0	16	75	0
Foliage foragers						
Striated Pardalote	0	0	0	100	0	0
Horsfield's Bronze Cuckoo	0	0	0	100	0	0
Broad-tailed Thornbill	5	7	1	84	1	2
Black-faced Cuckoo-shrike	0	0	3	83	14	0
Weebill	0	5	0	78	1	16
Bark foragers						
Black-capped Sittella	0	96	4	0	0	0
Nectar foragers						
Purple-crowned Lorikeet	0	0	0	0	0	100
Brown Honeyeater	4	0	0	4	2	90
Spiny-cheeked Honeyeater	0	2	0	8	4	86
White-fronted Honeyeater	0	0	0	5	10	85
Yellow-plumed Honeyeater	0	3	1	23	12	61
Red Wattlebird	0	10	5	20	8	57
White-eared Honeyeater	12	3	9	15	9	52
Brown-headed Honeyeater	0	0	2	47	0	51

the ground. Tree Martins and Dusky Woodswallows foraged within and above the canopy.

Substrates

Nine species took 60% or more of their food from the ground, including litter, coarse woody debris, logs and ground vegetation (Table 2). Eight species took more than 50% of their prey from foliage, including five which took more than 75% of prey from foliage (Table 2). Seven species took more than 35% of their prey from the air. Aerial foragers fell into two groups. One group (ground and aerial foragers) took more than 25% of their prey from the ground, while the second group (aerial foragers) took more than 75% of prey from the air.

The Black-capped Sittella was the only species to forage exclusively on bark substrates (Table 2). Bark was little used by birds at Yellowdine and only five species, including the sittella, took 15% or more of their prey from branches or trunks. Other than the sittella, none took more than 17% of their prey from bark.

Nectar-feeders were a conspicuous component of the avifauna at Yellowdine. Seven honeyeaters and the Purple-crowned Lorikeet fed at flowers on more than 50% of observed foraging manoeuvres. Apart from the lorikeet, nectar-feeders also took food from foliage, bark and the air (Table 2). The Weebill, an insectivore, was observed feeding at flowers 16% of the time and appeared to be taking nectar, not insects. The observations (7%) of Port Lincoln Parrot foraging on flowers were of birds eating the soft base (cup) of the inflorescence.

Foraging manoeuvre

Probing and gleaning were the most common foraging behaviours used by birds at Yellowdine (Table 3). Eight species of nectar-feeders took more than 50% of their food by probing flowers for nectar. Four nectar-feeders gleaned extensively and took arthropods and alternative carbohydrates (*e.g.* lerp, honeydew) from foliage and bark. Nectar-feeders also hawked and snatched insects and on occasion hovered at flowers or foliage to feed (Table 3). Ground-foragers took most food by gleaning and probing the soil surface, litter and low ground vegetation. Five

Table 3

Use of foraging manoeuvres (%) by birds in a Salmon Gum woodland at Yellowdine during September 1997. See Table 1 for sample sizes and Appendix 1 for scientific names.

Species	Foraging Manoeuvre					
	Pounce	Probe	Glean	Hover	Snatch	Hawk
Nectar feeders						
Purple-crowned Lorikeet	0	100	0	0	0	0
Brown Honeyeater	0	90	2	4	2	2
Spiny-cheeked Honeyeater	0	87	7	0	2	4
White-fronted Honeyeater	0	85	3	0	2	10
White-eared Honeyeater	0	69	20	3	0	8
Yellow-plumed Honeyeater	0	61	24	1	2	12
Red Wattlebird	0	58	32	0	8	2
Brown-headed Honeyeater	0	53	43	4	0	0
Ground gleaners & probers						
Chestnut Quail-thrush	0	0	100	0	0	0
Emu	0	0	100	0	0	0
Galah	0	0	100	0	0	0
Port Lincoln Parrot	0	14	86	0	0	0
Yellow-rumped Thornbill	0	14	86	0	0	0
Redthroat	0	33	67	0	0	0
Rufous Treecreeper	0	37	63	0	1	0
Grey Shrike-thrush	0	45	45	0	10	0
White-browed Babbler	0	97	3	0	0	0
Foliage gleaners						
Horsfield's Bronze Cuckoo	0	0	100	0	0	0
Striated Pardalote	0	0	94	1	9	0
Weebill	0	8	58	14	18	2
Yellow-throated Miner	0	45	55	0	0	0
Foliage/ bark gleaners & snatchers						
Chestnut-rumped Thornbill	0	3	59	5	28	5
Broad-tailed Thornbill	0	0	59	3	37	1
Gilbert's Whistler	0	0	47	0	53	0
Black-faced Cuckoo-shrike	0	20	0	0	80	0
Bark gleaners						
Black-capped Sittella	0	25	75	0	0	0
Pouncers & hawkers						
Red-capped Robin	38	15	6	0	2	39
Jacky Winter	29	0	1	0	0	54
Grey Butcherbird	29	14	18	0	5	34
Hawkers						
Tree Martin	0	0	0	0	0	100
Dusky Woodswallow	0	0	0	0	10	90
Grey Fantail	0	0	11	0	14	75
Willie Wagtail	2	12	26	0	4	56

species of ground-foragers took more than 85% of their food by gleaning. These included the Emu, Galah and Port Lincoln Parrot, which appeared to feed mainly on foliage (soft leaves) and seeds, including entire seed pods (*e.g.* of *Acacia*). Three other ground-foragers took a third or more of their prey by probing, usually into and under litter and debris. White-browed Babblers foraged almost exclusively by probing for prey in litter, debris and under the bark of branches (Tables 2, 3).

The Black-capped Sittella took prey from on and under bark by gleaning and probing. This included flaking bark from branches to expose arthropods. Four species were primarily foliage-gleaners and took more than 50% of their prey in this way. Weebills also hovered and snatched prey from foliage and probed flowers. The Yellow-throated Miner probed and gleaned prey from foliage and also foraged on the ground (Table 2). Gilbert's Whistler and Chestnut-rumped and Broad-tailed Thornbills took prey from bark and foliage by gleaning and snatching, while Black-faced Cuckoo-shrikes foraged almost exclusively on large insects snatched from foliage in the canopy.

Three species, Red-capped Robin, Jacky Winter and Grey Butcherbird, took more than 25% of their prey by pouncing, but took the largest proportion of their prey by hawking (Table 3). A group of four species took more than 50% of their prey by hawking, Grey Fantails and Willie Wagtails by flitting and Tree Martins by sweeping. Dusky Woodswallows took flying insects by both sweeping and hawking, but also snatched prey from bark and foliage. Grey fantails also gleaned and snatched prey from bark and foliage, while Willie Wagtails took prey from the ground and ground vegetation by a combination of methods, but mainly by gleaning (Table 3).

Discussion

The pattern of resource use by birds in the Salmon Gum woodlands at Yellowdine is similar to that reported for wandoo (*Eucalyptus wandoo* and *E. accedens*) woodlands at Dryandra on the western margin of the Wheatbelt (Recher & Davis 1998). At Yellowdine and Dryandra, ground-foraging was a major component of community-wide foraging with 45% and 61% of species, respectively, taking 20% or more of their prey from ground substrates. Using data from other localities, another 19 species recorded at Yellowdine but for which there are fewer than ten foraging observations, are principally ground-foragers; Australian Magpie, Australian Raven, Brown Falcon, Common Bronzewing, Fan-tailed and Pallid Cuckoos, Grey Currawong, Nankeen Kestrel, Little Crow (*Corvus bennetti*), Major Mitchell Cockatoo, Magpie-lark, Pied Butcherbird, Red-backed and Sacred Kingfishers, Regent Parrot, Southern Scrubrobin, Tawny Frogmouth (*Podargus strigoides*), Wedge-tailed Eagle and White-winged Triller.

Foliage was the next most important substrate in both Yellowdine and Dryandra woodlands, with 30% and 49% of species, respectively, taking 20% or more of prey from foliage. Aerial foragers comprised 21% of species in both woodlands, but in wandoo woodland 30% of species foraged extensively on bark, whereas only one species (3%) at Yellowdine took more than 20% of its prey from bark. Nectar-feeders were frequent at Yellowdine with 24% of species foraging predominantly on nectar, but only 9% at Dryandra. Note that since species took prey from multiple substrates and used more than one foraging manoeuvre, percents of species can sum to more than 100.

Morris & Wooller (2001) studied the abundance and foraging ecology of small birds in Salmon Gum woodland near Kambalda, Western Australia (31° 12' S, 121° 38' E) from February 1981 to June 1982. They found that insectivorous birds were largely resident and that their abundances did not change greatly over the 18 months sampled. Numbers and species composition of honeyeaters were more variable. Morris & Wooller (2001) suggested that this reflected the 'temporal inconsistency' of eucalypt flowering on their study area. Nectar from *Eremophila* spp was also available during winter at Kambalda, but shrubs were dispersed and may not have been attractive to honeyeaters.

At Yellowdine, eucalypt and *Eremophila* nectar was abundant during September 1997. Although we did not measure nectar abundance nor score flowers, the amount of eucalypt and *Eremophila* blossom was one of the greatest we have encountered in 20 years of fieldwork in eucalypt woodlands in eastern and western Australia. With the exception of the Singing Honeyeater (*Lichenostomus virescens*), which was absent from Yellowdine, the same honeyeaters occurred at Yellowdine and Kambalda. The nectar dependent Purple-crowned Lorikeet was abundant at Yellowdine (Appendix 1), but absent at Kambalda. At neither location did Yellow-throated Miners forage for nectar (2% of observations at Kambalda). Of the remaining seven species of honeyeaters present at both locations, more than 50% of foraging observations at Yellowdine were of birds taking nectar from eucalypt and *Eremophila* flowers (Table 2). At Kambalda, only three species (Brown and White-fronted Honeyeaters and Red Wattlebird) were recorded nectar-feeding on more than 50% of observations. Instead, most honeyeaters foraged by gleaning and probing foliage and bark (Morris & Wooller 2001). At Yellowdine, gleaning or probing foliage and bark comprised more than 20% of foraging observations for White-eared, Yellow-plumed and Brown-headed Honeyeaters, and Red Wattlebird (Table 2).

The high incidence of nectar-feeding at Yellowdine relative to Kambalda and Dryandra reflects the large amount of blossom at Yellowdine during our observations and illustrates how nectar-feeders shift between substrates and habitats in response to changes in the availability of nectar and other energy-rich carbohydrates (*i.e.* lerp, manna and honeydew). Changes in the abundance and species composition of nectar-feeders, as well as movements between habitats, in response to temporal availability of nectar has been extensively documented (*e.g.* Pyke & Recher 1986, 1988; Pyke *et al.* 1993) and the differences in our observations from those a Kambalda fit this pattern. For example, at Kambalda, the White-eared Honeyeater took most of its food by gleaning and probing bark, but visited flowers extensively (> 20% of observations) in spring and summer when nectar was more abundant (Morris & Wooller 2001). Wilson & Recher (2001) found that Yellow-plumed Honeyeaters at Dryandra foraged primarily by gleaning lerp from eucalypt foliage, but

during some sample periods foraged by gleaning and probing bark. At Yellowdine, Yellow-plumed Honeyeaters seldom foraged on bark (Table 2).

Although not reported for Kambalda (Morris & Wooller 2001), resident and migratory insectivores in Australian woodlands also exploit different prey and foraging substrates at different places and times (*e.g.* Recher *et al.* 1987; Recher 1989). For example, at Yellowdine, a number of insectivores hawked termites as these swarmed late in the day. This included species which normally take prey by pouncing to the ground, such as Red-capped Robin (Recher *et al.* 2002). Although the swarming of termites is a diurnal phenomenon, it is also seasonal and most likely to occur following rain when it is warm and humid (*e.g.* spring and early summer). The differences in foraging behaviour between the observations at Kambalda and ours at Yellowdine suggest substantial temporal variation in the spatial distribution, type and abundance of food resources in eucalypt woodlands. In Jarrah (*Eucalyptus marginata*) forest near Perth, there are significant changes in the abundance of canopy arthropods between seasons and years (Recher *et al.* 1996). Similar seasonal and annual differences have been demonstrated in the bark arthropod fauna in Jarrah forest and wandoo woodlands with significant changes in the pattern of bark foraging by birds (J Majer, C Norwood & H Recher, unpublished observations).

Although some individuals may be sedentary and remain resident, based on fieldwork at Yellowdine since 1997 and extensive studies in similar habitats elsewhere, we have reached the conclusion that a much larger number of insectivorous bird species in eucalypt and acacia woodlands are migratory or nomadic than is generally accepted; woodswallows, cuckoo-shrikes, trillers, pardalotes, whistlers and cuckoos are birds that appear to move seasonally between habitats and regions and aggregate wherever food is abundant. Thus, of the 63 species recorded at Yellowdine, we conservatively estimate that 16 (25%) present in 1997 were nomadic or migratory. In addition, we recorded seven species of hawks, all of which aggregate in areas of high food abundance and are also nomadic and migratory. More than a third of the bird species we observed at Yellowdine may therefore not be resident and censuses at another time may reveal a much poorer (or richer) avifauna. We suggest that the large number of nomads and migrants, which we recorded were present in response to abundant nectar and insects. Similarly, we suggest that raptors aggregated in the area in response to the abundance of honeyeaters and lorikeets on flowering eucalypts, as well as an abundant insect fauna. Obviously, our ideas and observations require confirmation, but the implications for regional and continental conservation are profound, if as we contend, our interpretation of the data is correct.

Conclusion

Salmon Gum woodlands in the western Goldfields sustain a rich and diverse avifauna. While the majority of species are resident and insectivorous (Morris & Wooller 2001; this study), a substantial proportion of individuals and species are migratory or nomadic. We suggest that these birds aggregate whenever food resources in the form of nectar, lerp, insects and other birds are abundant. This component of the avifauna may be especially sensitive to habitat loss and fragmentation that not only decreases the amount of available food making it difficult to locate patches of abundant food, but could result in absolute shortages in some seasons or years by chance alone. The natural temporal and spatial variability of the flowering of eucalypts (Davies 1976) makes this an increasingly likely event as habitat is diminished. We further suggest that it is not only nectar and carbohydrate-dependent species, such as honeyeaters, pardalotes and lorikeets, that may be affected, but also insectivorous species, such as woodswallows, martins, cuckoo-shrikes and trillers, and raptors. It appears to us that it is unlikely that the spatial and temporal variation in resources on which this avifauna relies can be accommodated in a conventional system of reserves sampling only a small part of the land area. Conserving woodland bird communities in the Goldfields and elsewhere therefore requires the retention of large areas of habitat as functional ecosystems between and within which the avifauna can move in response to a dynamic and shifting resource base.

***Acknowledgments*:** This work was conducted while WED was a visiting SASTEC Fellow at Edith Cowan University. The participation of HFR was supported by a Professorial grant from Edith Cowan University. Ron Wooller and two anonymous referees made helpful comments on an earlier draft of the manuscript.

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Appendix 1

An index of abundance of birds recorded at Yellowdine, Western Australia during September 1997. Abundances are the total number of individuals recorded during counts at all sites where foraging data were collected. The number of counts (n = 24) on which a species was recorded is shown in parentheses and is a measure of habitat breadth and relative abundance (frequency of occurrence). Species are listed in alphabetical order of English names, with scientific names after Johnstone (2001). *Daphoenositta pileata* (Black-capped Sittella) is retained as a species.

SPECIES		ABUNDANCE
Brown Goshawk	*Accipter fasciatus*	7 (5)
Australian Magpie	*Gymnorhina tibicen*	2 (2)
Australian Raven	*Corvus coronoides*	20 (11)
Black-capped Sittella	*Daphoenositta pileata*	7 (1)
Black-eared Cuckoo	*Chrysococcyx osculans*	4 (4)
Black-faced Cuckoo-shrike	*Coracina novaehollandiae*	41 (19)
Broad-tailed (Inland) Thornbill	*Acanthiza apicalis*	57 (12)
Brown Falcon	*Falco berigora*	1 (1)
Brown Honeyeater	*Lichmera indistincta*	7 (4)
Brown-headed Honeyeater	*Melithreptus brevirostris*	59 (10)
Chestnut Quail-thrush	*Cinclosoma castanotum*	4 (2)
Chestnut-rumped Thornbill	*Acanthiza uropygialis*	41 (17)
Collared Sparrowhawk	*Accipter cirrhocephalus*	2 (2)
Common Bronzewing	*Phaps chalcoptera*	3 (2)
Crested Bellbird	*Oreoica gutturalis*	12 (9)
Crested Pigeon	*Ocyphaps lophotes*	4 (3)
Dusky Woodswallow	*Artamus cyanopterus*	28 (8)
Emu	*Dromaius novaehollandiae*	4 (3)
Fan-tailed Cuckoo	*Cacomantis flabelliformis*	1 (1)
Galah	*Eolophus roseicapillus*	24 (9)
Gilbert's Whistler	*Pachycephala inornata*	9 (5)
Golden Whistler	*Pachycephala pectoralis*	1 (1)
Grey Butcherbird	*Craticus torquatus*	12 (9)
Grey Currawong	*Strepera versicolor*	11 (8)
Grey Fantail	*Rhipidura fuliginosa*	4 (4)
Grey Shrike-thrush	*Colluricincla harmonica*	27 (15)
Horsfield's Bronze Cuckoo	*Chrysococcyx basalis*	11 (11)
Jacky Winter	*Microeca fascinans*	9 (6)
Little Eagle	*Hieraaetus morphnoides*	2 (1)
Little Falcon	*Falco longipennis*	3 (2)
Major Mitchell Cockatoo	*Cacatua leadbeateri*	6 (4)
Mistletoebird	*Dicaeum hirundinaceum*	3 (3)
Nankeen Kestrel	*Falco cenchroides*	2 (2)
Pallid Cuckoo	*Cuculus pallidus*	9 (8)
Magpie Lark	*Grallina cyanoleuca*	1 (1)
Pied Butcherbird	*Cracticus nigrogularis*	16 (11)
Port Lincoln Parrot	*Barnardius zonarius*	37 (15)
Purple-crowned Lorikeet	*Glossopsitta porphyrocephala*	123 (15)
Red-backed Kingfisher	*Todiramphus pyrrhopygia*	2 (2)
Red-capped Robin	*Petroica goodenovii*	20 (11)
Red Wattlebird	*Anthochaera carunculata*	155 (23)
Redthroat	*Pyrrholaemus brunneus*	16 (5)
Regent Parrot	*Polytelis anthopeplus*	8 (4)
Rufous Treecreeper	*Climacteris rufa*	30 (15)
Rufous Whistler	*Pachycephala rufiventris*	6 (4)
Sacred Kingfisher	*Todiramphus sanctus*	1 (1)
Southern Scrubrobin	*Drymodes brunneopygia*	4 (2)
Spiny-cheeked Honeyeater	*Acanthagenys rufogularis*	78 (11)
Spotted Harrier	*Circus assimilis*	2 (2)
Striated Pardalote	*Pardalotus striatus*	155 (21)
Tree Martin	*Hirundo nigricans*	18 (6)
Weebill	*Smicrornis brevirostris*	171 (19)
Wedge-tailed Eagle	*Aquila audax*	2 (2)
White-browed Babbler	*Pomatostomus supercilliosus*	7 (2)
White-eared Honeyeater	*Lichenostomus leucotis*	23 (8)
White-fronted Honeyeater	*Phylidonyris albifrons*	21 (8)
White-winged Triller	*Lalage sueurii*	2 (2)
Willie Wagtail	*Rhipidura leucophrys*	33 (16)
Yellow-plumed Honeyeater	*Lichenostomus ornatus*	237 (20)
Yellow-rumped Thornbill	*Acanthiza chrysorrhoa*	28 (11)
Yellow-throated Miner	*Manorina flavigula*	17 (4)