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An historical snapshot of avian assemblages occupying three threatened forest and woodland communities in Scheyville National Park, New South Wales

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Scheyville National Park encompasses two threatened woodland communities and one *Eucalyptus* forest i.e. Cumberland Plain Woodland, Castlereagh Scribbly Gum Woodland and Shale Gravel Transition Forest. It provides habitat for at least 98 bird species. In 1997, banding, plot counts and species lists were used to examine if these floristic communities contained different avian assemblages. Differences were found among the avian assemblages of all floristic communities and between sites within a floristic community. The richest and most abundant avian assemblage was associated with the presence of a creek with permanent pools of water and dense riparian vegetation. Fewer species were recorded in winter than in other seasons. However, most of the more common species were present all year, although many showed seasonal fluctuations in abundance, either over the entire study area or at certain sites. The patterns varied among species. Some fluctuations, especially in the capture data, appear to be due not to movements or breeding success but to changes in behaviour and habitat use that made the birds more 'catchable' at certain sites at certain times of year. The complex habitat utilisation patterns demonstrated illustrate the importance of maintaining a diversity of forest and woodland habitats for the local avifauna, especially in the face of continuing loss of natural habitat through ever-increasing urbanisation across the region. The study also shows the value of using several different survey methods simultaneously. Each method has certain advantages and biases; using them in combination provides a more complete picture of the bird assemblage.

INTRODUCTION

The eucalypt forest and woodland vegetation on the shale and other soils of the Cumberland Plain of western Sydney supports an avifauna that differs from that of the surrounding sandstone vegetation and is closer to the avifauna of grassy eucalypt woodlands on the tablelands and western slopes of the Great Dividing Range (Hindwood and McGill 1958). Many of the characteristic bird species of grassy eucalypt woodlands in southern Australia have undergone drastic declines because of clearing and fragmentation of the woodlands for agricultural development, and these declines are continuing (Robinson and Traill 1996; Ford *et al*. 2009; Lindenmayer *et al*. 2010). The reasons for the declines and how they might be reversed are major issues for biodiversity conservation in Australia (Ford *et al*. 2001; Ford 2011; Bennett and Watson 2011; Watson 2011).

Banding studies on the birds in an area of eucalypt forest and woodland near Longneck Lagoon on the Cumberland Plain north-west of Sydney were commenced in 1965 and continued irregularly to 1992 (Egan *et al.* 1997), then regularly to 2001 and then in three year-long periods, 2007–8, 2011–12 and 2015–16. The study area now forms part of Scheyville National Park (NP). Lists and other information on birds at Scheyville have been provided by Douglas and Wilson (1985), Antcliff (1988), Kinhill Engineers Pty Ltd (1990), Roberts (1993) and Egan *et al.* (1997). However, these accounts have not examined differences in avian assemblages between the different types of forest and woodland at Scheyville NP.

The natural values of Longneck Lagoon and the adjacent bushland were recognised by their declaration as a wildlife refuge in 1971, and as a Crown Reserve for the study and conservation of native flora and fauna in 1987 (National Parks and Wildlife Service, NPWS 2000). In response to an impending rezoning of the area, with a huge housing development on the drawing board, a more rigorous banding project was implemented in 1992 to monitor changes in the avifauna in the reserve resulting from the transformation of the adjoining bushland to housing. The development did not eventuate and both the reserve and the Landcom land that had been proposed for housing were reserved as Scheyville NP in 1996 (Department of Environment and Climate Change 2009). It was during this project that we became aware of differences in the bird assemblages occupying the three forest and woodland vegetation communities within the park. In 1997, we instigated a study to compare the bird assemblages in these three floristic communities and to investigate movements between the communities. This paper presents our findings in order to document the differences between the communities and to provide a snapshot of the eucalypt forest birds of Scheyville NP in 1997 for comparison with subsequent studies.

STUDY AREA

Scheyville NP covers 954 ha and most of its area is bordered by the Pitt Town – Dural Road in the north, Midson Road to the east and Old Pitt Town Road to the south and west (Fig. 1). It is unique, as it preserves examples of four Cumberland Plain floristic communities, all of which are listed as threatened

under the NSW *Threatened Species Conservation Act 1995*, namely Cumberland Plain Woodland, Castlereagh Scribbly Gum Woodland, Shale Gravel Transition Forest, and Freshwater Wetlands on Coastal Floodplains. The three *Eucalyptus* forest and woodland communities (but not the wetland community) are also listed as threatened under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*. Our banding sites did not include any wetland habitat, but the three forest and woodland communities within which our study was conducted are described below. Their distribution in Scheyville NP has been mapped by Benson (1992) and Tozer (2003).

Ambient temperature and rainfall records from Richmond RAAF Base (Bureau of Meteorology station 067105), approximately 10 km west of Scheyville, indicate that 1997 had below average rainfall of 612.8 mm (128.4 mm below the mean for 1994-2017) and was slightly warmer than average, with a mean maximum temperature of 24.5°C (0.3°C above the mean for 1993-2017).

The vegetation communities

Cumberland Plain Woodland

Dominant tree species in this community were Grey Box *Eucalyptus moluccana*, Forest Red Gum *E. tereticornis* and Narrow-leafed Ironbark *E. crebra*, with an understorey that at the time of this study consisted of thickets of Blackthorn *Bursaria spinosa* and *Acacia* spp. interspersed with large areas of grass. Since then, Blackthorn has spread across most of the grassy areas. Narrow-leafed Ironbarks were common at banding site C, but few grew at banding site A.

Cumberland Plain Woodland is now greatly reduced in extent, but was the typical native vegetation community on the Triassic Wianamatta Shale soils of western Sydney. It is listed as a critically endangered ecological community under both NSW and Commonwealth legislation. The form of the community in Scheyville NP is called Grey Box-Ironbark Woodland by Benson (1992) and Shale Plains Woodland by Tozer (2003).

Castlereagh Scribbly Gum Woodland

This community grew on Tertiary gravels situated near the elevated western extremity of the park adjacent to the Pitt Town – Dural Road. It contained Scribbly Gums *E. sclerophylla* and Narrow-leafed Apples *Angophora bakeri*, the latter being more prevalent and rather stunted. The understorey comprised a variety of shrubs (e.g. *Hakea sericea* and *Melaleuca nodosa*) and open, grassed areas. Castlereagh Scribbly Gum Woodland is listed as a vulnerable ecological community under NSW legislation, and as an endangered ecological community under Commonwealth legislation.

Shale Gravel Transition Forest

This community bordered the Castlereagh Scribbly Gum Woodland on the slope towards Llewellyn Creek. It was clearly defined by tall stands of Broad-leafed Ironbark *E. fibrosa* and Grey Box. A variety of plants made up the understorey in this community, including Blackthorn, *Daviesia ulicifolia*, *Dillwynia juniperina*, *Acacia parramattensis*, *Dillwynia tenuifolia* and *Acacia pubescens*, the last two being threatened species.

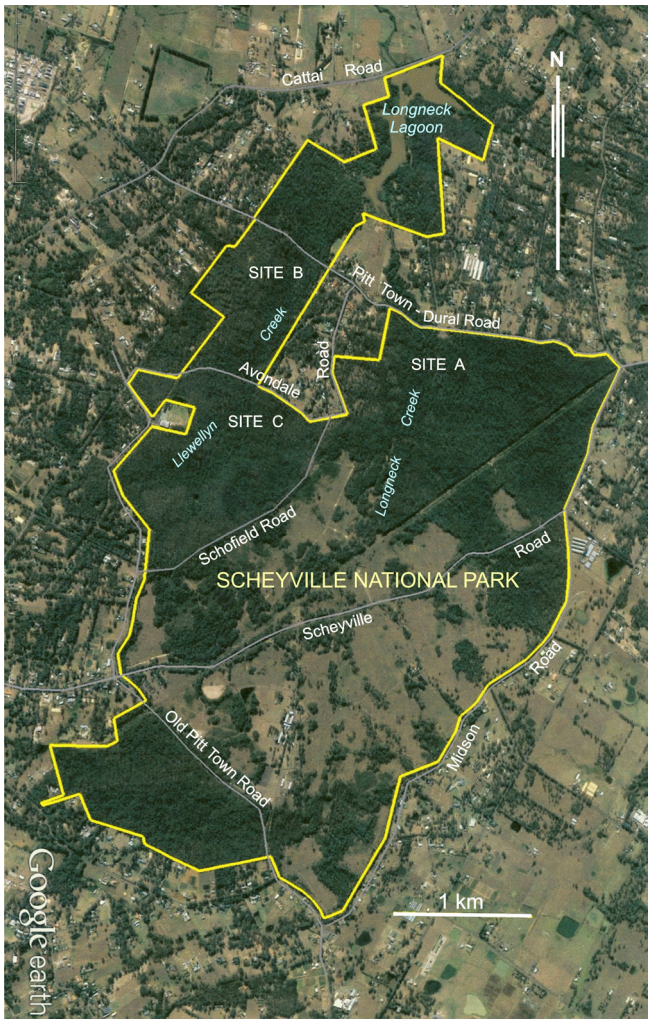

Figure 1. *Satellite image of Scheyville National Park showing the location of the three sites utilised in this study.*
Image courtesy of Google Earth

As its name implies, Shale Gravel Transition Forest occurs on the ecotone between shale and gravel soils. It is listed as an endangered ecological community under NSW legislation. At Commonwealth level, it has been combined with Cumberland Plain Woodland as a single critically endangered ecological community, 'Cumberland Plain Shale Woodlands and Shale-Gravel Transition Forest'.

Three sites were chosen to sample the avifauna in each of these communities and to examine the possible effect of the availability of permanent water on the avifauna within the Cumberland Plain Woodland community:

Site A (Fig. 2)

Site A was just south of the junction between the Pitt Town – Dural Road and Longneck Creek within the Cumberland Plain Woodland. Nets were erected adjacent to this creek, which featured some large, deep pools, some of which do not dry out even during the severest drought. These pools supplied a regular source of water for birds and other animals. The trees along the creek line were more mature than those growing on the slopes away from the creek.

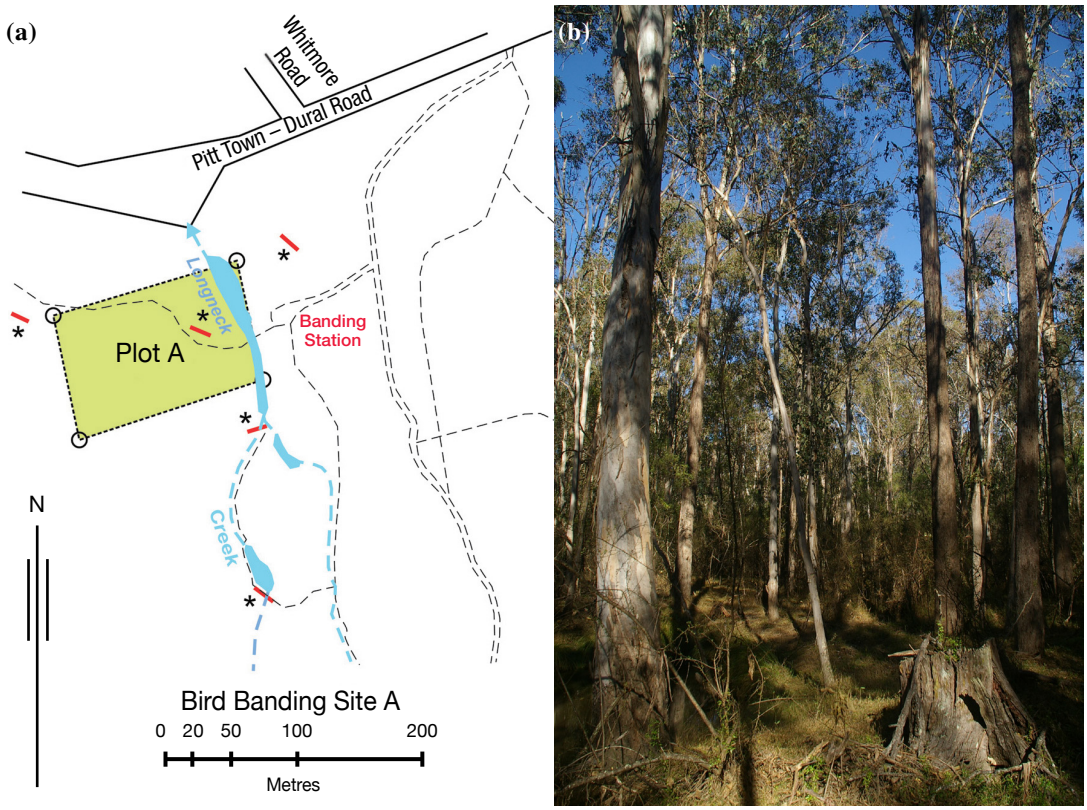

Figure 2. (a) *Map showing position of net lanes and count plot at Site A.* (b) *Recent photograph of a typical scene within the Cumberland Plain Woodland.*

Site B (Fig. 3)

Site B was in a narrow section of the park between its western boundary and Llewellyn Creek. It encompassed two floristic communities: Castlereagh Scribbly Gum Woodland (BR) and Shale Gravel Transition Forest (BF). The Scribbly Gum Woodland was on a low ridge which still showed signs of pits and mounds left over from previous gravel removal. The Transition Forest grew on the slope towards Llewellyn Creek and abutted the Scribbly Gum Woodland.

Site C (Fig. 4)

Site C resembled site A as it was also along a creek line (Llewellyn Creek), but differed in that the creek was more ephemeral and only retained water in shallow depressions for short periods after rain. It was situated within the Cumberland Plain Woodland to the south of Avondale Road.

METHODS

The study area was visited monthly from January to December 1997 to band birds at each study site, to count birds in four 1.5 ha plots, and to record any additional species in the vicinity.

Species Lists

During each monthly visit, a list was compiled of all bird species encountered at each study site, including birds captured in nets, recorded during plot counts or incidentally sighted or heard in the vicinity, including birds flying overhead. No distinction was made in the general species list between the two floristic communities at site B (BF and BR).

Plot Counts

Four 1.5 ha count plots were marked out. Single plots at site A (Fig. 2) and site C (Fig. 4) sampled Cumberland Plain Woodland. At site B, there was one plot in Castlereagh Scribbly Gum Woodland (BR) and another in Shale Gravel Transition Forest (BF) (Fig. 3). On each monthly visit, the birds in each plot were counted by two observers slowly walking through the plot recording all birds sighted or heard within the plot during a 20-minute period between 0900 hours and 1000 hours. Birds flying above the tree canopy were not included in the count. In the elongated plots BR and C, the observers walked along the central track. In plots A and BF, the observers walked a zig-zag pattern through the plot.

Banding

Mist nets (2.7 m high) were erected in five net lanes at site A (Fig. 2) and five at site C (Fig. 4) to sample Cumberland Plain Woodland. Fifteen net lanes were utilized at site B, with six sampling Castlereagh Scribbly Gum Woodland (B2-6, B10; Fig. 3) and nine sampling Shale Gravel Transition Forest (B1, B7-9, B11-15; Fig. 3). The same net lanes were used on each visit. Banding occurred simultaneously at all sites with the assistance of a team of 12 banders. Data collected included: age, sex, date of banding/retrapping and morphometrics (head-bill, tail and wing lengths ± 1mm, and weight ± 1g).

Capture rates were calculated as the number of birds captured per 100 m of nets per hour. The nets were opened within the first 30 minutes after sunrise and closed about 1130 hours AEST/AEDT (Table 1). In every banding session, there were 78 m of nets at site A, 90 at site BF, 144 at site BR, and 78 at site C.

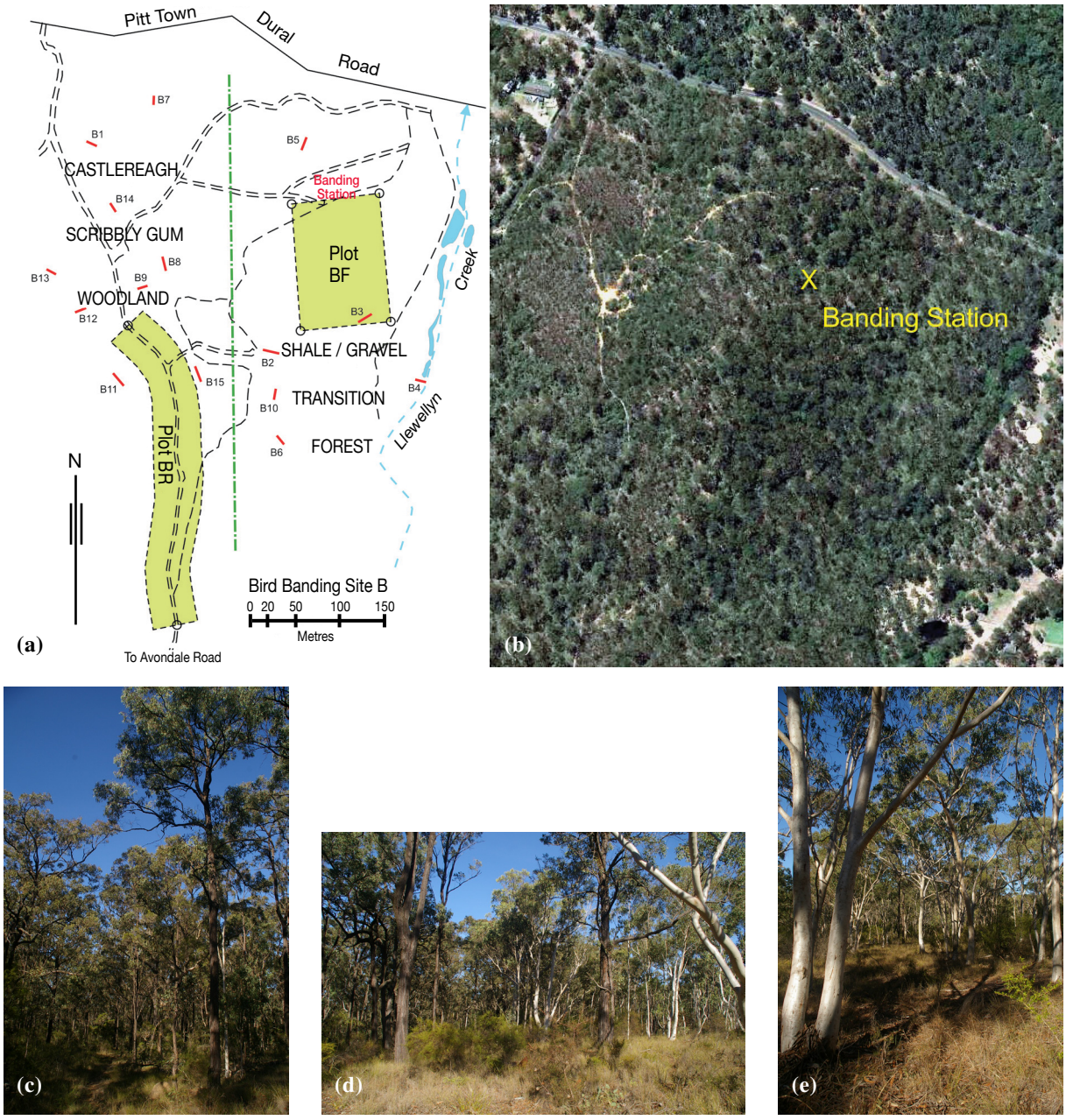

Figure 3. (a) *Map showing position of net lanes and count plots at Site B.* (b) *Satellite image of Site B.* (c) *Photograph of a typical scene within the Shale Gravel Transition Forest.* (d) *Recent photograph of the demarcation between the Shale Gravel Transition Forest (left) and Castlereagh Scribbly Gum Woodland (right).* (e) *Recent photograph of a typical scene within the Castlereagh Scribbly Gum Woodland.*

(Satellite image courtesy of Google Earth)

Records were taken of any bird that was banded at one site and subsequently trapped at another site. Movements included some data collected from previous banding visits from 1993 to 1996 and banding that extended into 1998. Sites A, B and C were approximately one kilometre apart from each other (Fig. 1).

Analysis of Data

Two-factor analysis of variance (ANOVA) was used to test differences between seasons, sites and their interactions, for both banding data and count data. Site B was subdivided into sites BF and BR for analysis. For the banding data, analyses were carried out on the number of species caught per site per visit, total capture rate per site per visit, and capture rate of individual species that were captured in about 20% or more of all site visits. For the count data, analyses were carried out on the number of species recorded per plot per count, total number of birds recorded per plot per count, and number of birds of individual species that were recorded in about 20% or more of all plot counts. When significant differences were found, a *post hoc* Tukey's test was used to test differences within factors.

The monthly banding sessions and plot counts provided three replicates per season in the analyses. There were missing data for some months at some sites (no banding data for site A in July, and no count data for site BF in April, site C in May and site A in July). These gaps were addressed in the analyses by using the mean for the other two months of that season as a dummy replicate.

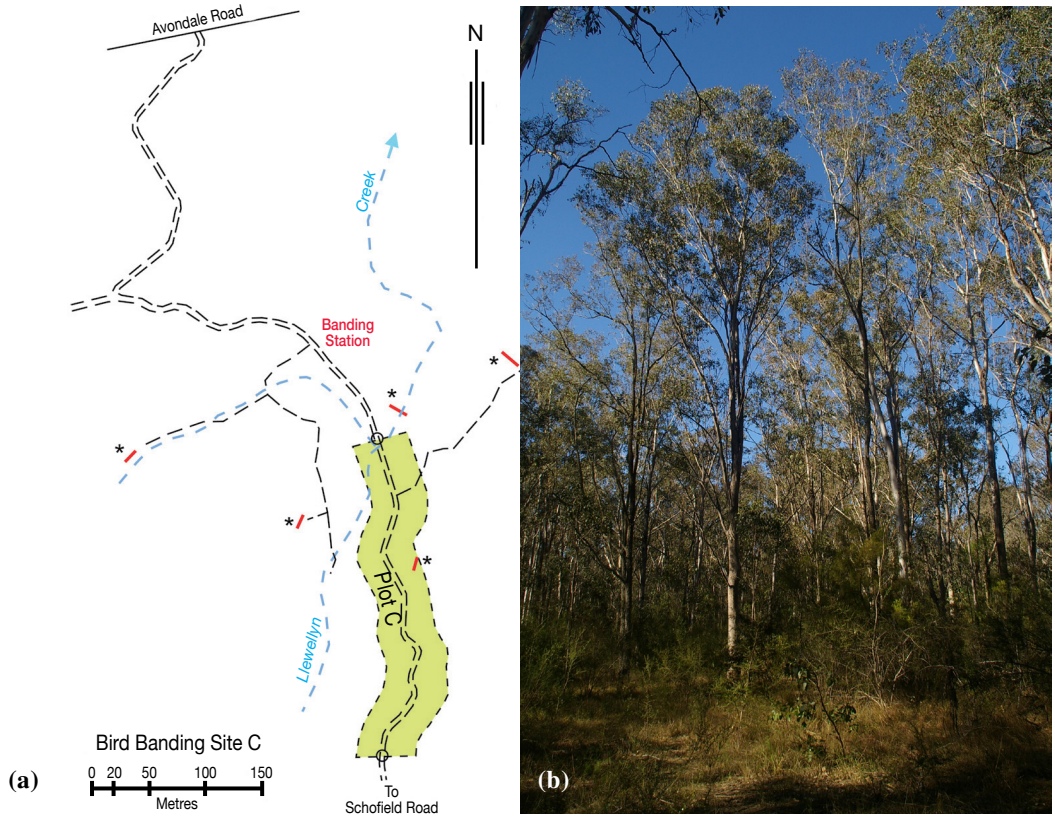

Figure 4. (a) *Map showing position of net lanes and count plot at Site C.* (b) *Recent photograph of a typical scene within the Cumberland Plain Woodland.*

Table 1

Monthly banding effort in 1997. Nets open from 30 minutes after sunrise to 1130 AEST/AEDT.

Month	Number of hours
January	5
February	4.5
March	4.25
April	4.75
May	4.25
June	4
July	4
August	4.5
September	5
October	5.75
November	5.25
December	5.5

Pattern analysis (PATN) (Belbin 1993) was used to assess the level of similarity of the avian assemblages at sites A, BF, BR and C. Separate analyses were carried out on the plot count data (mean count of individuals per species) and the banding data (species capture rates), using Gower's similarity coefficient in a Flexible UPGMA agglomerative hierarchical classification (Belbin and McDonald 1993).

Differences in species diversity between banding sites were further examined using the total number of individuals of each species banded during 1997 (excluding retrapped birds). Shannon-Wiener diversity indices were calculated for each banding site. This index measures species diversity as a combination of number of species (species richness) and evenness of abundance (the more even the number of individuals per species, the higher the diversity).

RESULTS

Species Lists

Ninety-eight species were recorded at the three study sites in 1997, including four introduced species (Table 2). Only one species, the Grey Fantail *Rhipidura albiscapa*, was recorded at every site on every visit. However, 20 species were recorded at least once at every site and in every month during the study (Table 2). At the other end of the scale, 23 species were recorded on just one or two of the 45 site visits.

Fourteen species were recorded only at site A, but most of these were recorded on just one or two occasions (Table 2). The exceptions were: Azure Kingfisher *Ceyx azureus* (on 4 surveys), Cicadabird *Coracina tenuirostris* (3), Dusky Woodswallow *Artamus cyanopterus* (4) and Bell Miner *Manorina melanophrys* (every survey). However, although Bell Miners were recorded on every visit, their territory was to the south of the banding site and their presence was registered by call alone. Nine species were recorded only at site B, and one was recorded only at site C (Table 2), but these were all casual visitors, recorded on just one or two occasions during the year.

Four species were recorded in Cumberland Plain Woodland at both site A and site C, but not in Castlereagh Scribbly Gum Woodland or Shale Gravel Transition Forest at site B: Fuscous Honeyeater *Lichenostomus fuscus*, White-browed Scrubwren *Sericornis frontalis*, Leaden Flycatcher *Myiagra rubecula* and

Table 2

Checklist of all species recorded at the three study sites in 1997. One visit per site per month, except no list available for site A in July. * introduced species.

Species	Sites			Months												Total Records
	A	B	C	*n*=3 except July *n*=2												
	n=11	*n*=12	*n*=12	J	F	M	A	M	J	J	A	S	O	N	D	
Grey Fantail *Rhipidura albiscapa*	11	12	12	3	3	3	3	3	3	2	3	3	3	3	3	35
White-throated Treecreeper *Cormobates leucophaea*	11	11	12	3	3	3	2	3	3	2	3	3	3	3	3	34
Superb Fairy-wren *Malurus cyaneus*	10	12	12	3	3	3	2	3	3	2	3	3	3	3	3	34
Grey Shrike-thrush *Colluricincla harmonica*	10	12	12	3	3	3	3	3	3	2	3	3	3	2	3	34
Australian Raven *Corvus coronoides*	11	12	11	3	2	3	3	3	3	2	3	3	3	3	3	34
Eastern Yellow Robin *Eopsaltria australis*	11	12	11	3	3	3	3	3	3	1	3	3	3	3	3	34
Spotted Pardalote *Pardalotus punctatus*	11	12	9	2	3	3	3	3	2	2	3	3	3	2	3	32
Golden Whistler *Pachycephala pectoralis*	11	10	11	2	3	2	3	3	3	2	3	3	3	3	2	32
Yellow-faced Honeyeater *Lichenostomus chrysops*	10	12	9	3	2	3	3	3	2	2	3	3	3	2	2	31
Yellow Thornbill *Acanthiza nana*	10	12	8	2	2	3	3	3	2	1	3	3	3	2	3	30
Grey Butcherbird *Cracticus torquatus*	8	12	10	1	3	3	3	3	3	2	2	2	2	3	3	30
Peaceful Dove *Geopelia striata*	11	10	9	3	3	3	3	3	1		3	3	3	2	3	30
Black-faced Cuckoo-shrike *Coracina novaehollandiae*	9	11	10	3	3	3	3	2	2		2	3	3	3	3	30
Laughing Kookaburra *Dacelo novaeguineae*	8	11	8	2	3	2	3	2	2	2	3	2	2	2	2	27
Weebill *Smicrornis brevirostris*	5	12	10	2	1	2	2	2	3	2	3	3	2	3	2	27
Eastern Whipbird *Psophodes olivaceus*	11	3	12	2	2	2	2	2	2	2	3	3	2	2	2	26
Red-browed Finch *Neochmia temporalis*	11	5	10	3	2	3	3	2	1	2	2	2	2	2	2	26
Crested Shrike-tit *Falcunculus frontatus*	9	7	8	2	3	1	1	2	2	1	3	3	1	3	2	24
Magpie-lark *Grallina cyanoleuca*	8	9	7	1	2	2	3	2	2	1	1	3	2	3	2	24
Australian Magpie *Cracticus tibicen*	7	11	6		2	3	2	3	2	2	3	2	1	2	2	24
Silvereye *Zosterops lateralis*	6	9	9	3	1	3	3	2		1	2	2	2	3	2	24
Rufous Whistler *Pachycephala rufiventris*	8	8	7	3	3	3	3					2	3	3	3	23
Eastern Rosella *Platycercus eximius*	8	7	6	1	1	1	3	3	2		2	3	3	2		21
Buff-rumped Thornbill *Acanthiza reguloides*	2	12	6	1	1	2	1	3	2	2	3	1	1	2	1	20
White-throated Gerygone *Gerygone albogularis*	5	7	8	2	3	2	1					3	3	3	3	20
Striated Thornbill *Acanthiza lineata*	8	6	4	2	1	3	1	1	2	1	3	1	1	1	1	18
Noisy Miner *Manorina melanocephala*	1	12	4	1	1	2	3	1	2	2	1	1	1	1	1	17
Speckled Warbler *Chthonicola sagittata*	1	10	6	1	2	1	2	3	1	1	1	1		2	2	17
Noisy Friarbird *Philemon corniculatus*	7	5	5	2	1	3	1	2				2	2	3	1	17
Sulphur-crested Cockatoo *Cacatua galerita*	10	7		2	1	1	1	2	2		1	2	1	2	2	17
Shining Bronze-cuckoo *Chalcites lucidus*	5	7	3		1	2		1				3	2	3	3	15
Varied Sittella *Daphoenositta chrysoptera*	2	4	8	1		1	1	2	1	1	2	2	1	1	1	14
Double-barred Finch *Taeniopygia bichenovii*	4	8	2	2	1	1	2	2			1		2	2	1	14
Fuscous Honeyeater *Lichenostomus fuscus*	9		5		1	1	1	1			2	2	2	2	2	14
Fan-tailed Cuckoo *Cacomantis flabelliformis*	8	3	2		1	2	1	1			1	3	1	1	2	13
Rainbow Bee-eater *Merops ornatus*	5	5	3	3	2	1					1	1	1	2	2	13
Mistletoebird *Dicaeum hirundinaceum*	2	7	4	2	1	2		2			1		2	2	1	13
White-winged Chough *Corcorax melanorhamphos*	4	5	4		1		3	2	3	2	1	1				13
Olive-backed Oriole *Oriolus sagittatus*	6	4	3	2							2	2	3	3	1	13
Galah *Eolophus roseicapillus*	6	6		2		2	2	1			1	1	1	2		12
Striated Pardalote *Pardalotus striatus*	4	5	2	2		1	1		2	1	1	1		1	1	11
Pied Currawong *Strepera graculina*	4	6	1		1		1	2	1		1	2	1	2		11
Willie Wagtail *Rhipidura leucophrys*	2	7	2	1	1	1		1					1	3	3	11
Rose Robin *Petroica rosea*	3	4	4				2	2	2	1	3	1				11
Sacred Kingfisher *Todiramphus sanctus*	4	5	2	2	1								3	3	2	11
Bell Miner *Manorina melanophrys*	11			1	1	1	1	1	1		1	1	1	1	1	11
Brown Thornbill *Acanthiza pusilla*	2	3	5	1	1	1		1	2		1		1	1	1	10
*Spotted Dove *Streptopelia chinensis*	4	3	3	1		1		1			1	3	1	1	1	10
Jacky Winter *Microeca fascinans*	3	5	1					1	1		1	2	1	2	1	9
Australian Wood Duck *Chenonetta jubata*	4	4	1		2	1			1			2	2	1		9
Pacific Black Duck *Anas superciliosa*	5	3	1					1			1	2	2	2	1	9
Brown-headed Honeyeater *Melithreptus brevirostris*	1	5	2			1	1	1	1	1		2	1			8
Pallid Cuckoo *Cacomantis pallidus*	4	3	1		1							2	2	3		8
Common Bronzewing *Phaps chalcoptera*	4	4		1	2	1	1		1				1	1		8
White-browed Scrubwren *Sericornis frontalis*	5		3	2			1	1			1			2	1	8
*Common Myna *Sturnus tristis*	3	4		1		1						1	1	1	2	7
Rufous Fantail *Rhipidura rufifrons*	3	3			1								2	1	2	6
Australian Owlet-nightjar *Aegotheles cristatus*	1	2	2	1	1		1			1				1		5

Table 2 (Cont.)

Species	Sites A *n*=11	B *n*=12	C *n*=12	Months *n*=3 except July *n*=2 J	F	M	A	M	J	J	A	S	O	N	D	Total Records
Little Lorikeet *Glossopsitta pusilla*	3	1	1	2								1		1	1	5
Eastern Spinebill *Acanthorhynchus tenuirostris*	1	3	1	1								2		1	1	5
Yellow-tailed Black Cockatoo *Calyptorhynchus funereus*	1	4				1	1	1		1					1	5
Horsfield Bronze-cuckoo *Chalcites basalis*	4	1									1	1	1	1	1	5
Little Corella *Cacatua sanguinea*	3	2			2			1			1	1				5
Brown Goshawk *Accipiter fasciatus*		3	2			1		1			1	2				5
Brown Quail *Coturnix ypsilophora*	1	1	2	1	1		1						1			4
Collared Sparrowhawk *Accipiter cirrocephalus*	1	1	2			1			1				1		1	4
Leaden Flycatcher *Myiagra rubecula*	2		2	1	1	1							1			4
*Red-whiskered Bulbul *Pycnonotus jocosus*	2		2	1								1		1	1	4
Dollarbird *Eurystomus orientalis*	3	1		1									1	1	1	4
Scarlet Honeyeater *Myzomela sanguinolenta*		3	1	1							1	1			1	4
Azure Kingfisher *Ceyx azureus*	4			1				1						1	1	4
Dusky Woodswallow *Artamus cyanopterus*	4				1						1	1		1		4
Brush Cuckoo *Cacomantis variolosus*	1	1	1	1										1	1	3
Crested Pigeon *Ocyphaps lophotes*		1	2			1						2				3
Cicadabird *Coracina tenuirostris*	3			1			1					1				3
Masked Lapwing *Vanellus miles*	1	1					1	1								2
White-bellied Cuckoo-shrike *Coracina papuensis*	1	1			1							1				2
Eastern Koel *Eudynamys orientalis*	1	1													2	2
*Rock Dove *Columba livia*	2			1	1											2
White-faced Heron *Egretta novaehollandiae*	2								1		1					2
White-naped Honeyeater *Melithreptus lunatus*	2			1							1					2
Restless Flycatcher *Myiagra inquieta*	2			1				1								2
Channel-billed Cuckoo *Scythrops novaehollandiae*		2			1								1			2
Tawny Frogmouth *Podargus strigoides*	1				1											1
Black Bittern *Ixobrychus flavicollis*	1														1	1
Painted Button-quail *Turnix varius*	1														1	1
Australian King-Parrot *Alisterus scapularis*	1						1									1
Lewin's Honeyeater *Meliphaga lewinii*	1													1		1
Yellow-tufted Honeyeater *Lichenostomus melanops*	1						1									1
Eastern Great Egret *Ardea modesta*		1							1							1
Pacific Baza *Aviceda subcristata*		1							1							1
Australian Hobby *Falco longipennis*		1						1								1
Yellow-rumped Thornbill *Acanthiza chrysorrhoa*		1				1										1
White-eared Honeyeater *Lichenostomus leucotis*		1				1										1
Little Wattlebird *Anthochaera chrysoptera*		1									1					1
Black-chinned Honeyeater *Melithreptus gularis*		1				1										1
Scarlet Robin *Petroica boodang*		1					1									1
Satin Flycatcher *Myiagra cyanoleuca*			1										1			1
Total species	**88**	**81**	**65**	**61**	**56**	**56**	**52**	**54**	**42**	**31**	**54**	**61**	**60**	**65**	**62**	**99**

Species recorded only at Site A
Species recorded only at Site B
Species recorded only at Site C
Species recorded only in Cumberland Plain Woodland

Red-whiskered Bulbul *Pycnonotus jocosus* (Table 2). However, this was fewer than the number of species recorded only at sites A and B (12) and similar to the number recorded only at sites B and C (3) i.e. species associated only with Cumberland Plain Woodland were not a major feature of the records.

About twice as many species were recorded in the general species lists as were recorded from plot counts or from banding (Table 3). More species were recorded at site A (85) than at site B (79) or C (63). More species were recorded in each month in the period September to January (spring-summer) than at other times of year, but the greatest differences among months were the low numbers of species recorded in June-July (Fig 5).

Table 3

Comparison of number of species recorded in 1997 by different survey methods.

Site	Number of species recorded Species lists	Plot counts	Banding
A	85	44	31
BF		30	28
BR		30	27
BF+BR	79	41	33
C	63	25	23
All	98	53	45

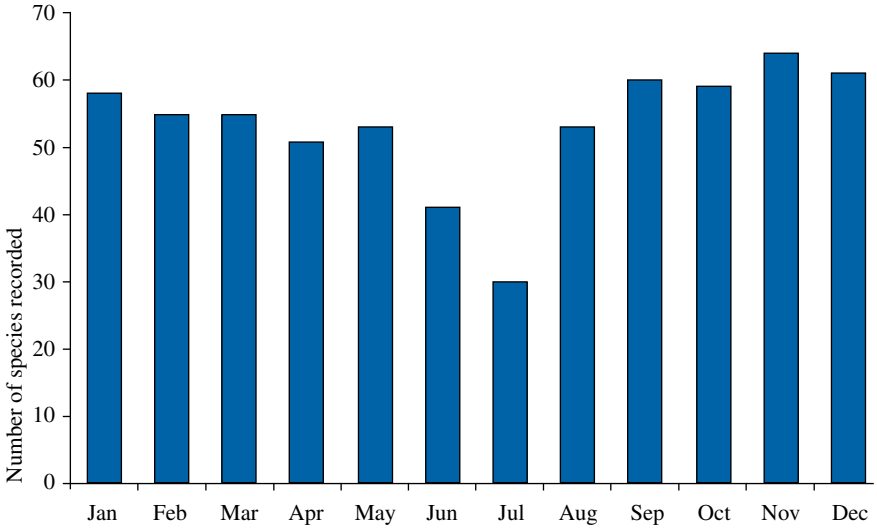

Figure 5. *Number of species recorded per month in 1997 (general species lists).*

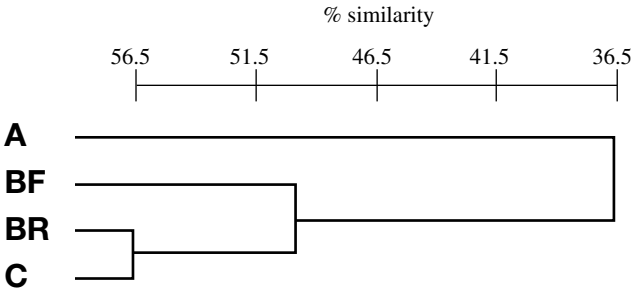

Figure 6. *Classification of the four count plots based on similarity in bird species composition, using Gower's similarity coefficient values calculated from the mean number of individuals per species in all 1997 plot counts.*

Plot Counts

The total number of species recorded in plot counts was much higher in plot A (44) than in plots BF (30), BR (30) or C (25) (Table 3). The Cumberland Plain Woodland plot A also had the most distinct bird species composition of the four plots (Fig. 6), with a higher proportion of the rarer species. More of the 32 species recorded in only one or two count plots were recorded in plot A (23) than in plots BF (11), BR (10) and C (6) (Table 4). The plots with the most similar bird species composition were Cumberland Plain Woodland plot C and Castlereagh Scribbly Gum Woodland plot BR (Fig. 6).

Analysis of variance revealed significant differences among plots in both the number of species and number of birds per count (Tables 4 and 5). Plot A had the highest numbers for both metrics, and plot BR had the lowest numbers. Significant differences were also found among plots for individual species: Eastern Yellow Robins *Eopsaltria australis* were most common in plot A; Red-browed Finches *Neochmia temporalis* were most common in plots A and C; Buff-rumped Thornbills *Acanthiza reguloides* were most common in plot BR; Grey Fantails were less common in plot BR than in the other plots; and White-throated Gerygones *Gerygone albogularis* were more common in plot BF in summer than in other plots and other seasons (Tables 4 and 5).

No significant differences were found among seasons in either the number of species recorded or number of birds per count. However, significant differences were found for individual species (Tables 4 and 5). Thus, the White-throated Gerygone and Rufous Whistler *Pachycephala rufiventris* were spring-summer migrants that were not recorded in late autumn and winter (Table 2). The Grey Fantail was present all year, but less common in autumn. The Eastern Yellow Robin was present all year, but more common in spring.

Banding

More species were banded at site A (31) than at sites BF (28), BR (27) and C (23) (Table 3). Based on mean capture rates, Cumberland Plain Woodland site A had the most distinct bird species composition of the four banding sites (Fig. 7), with a higher proportion of the rarer species. More of the 24 species banded at only one or two sites were captured at site A (11) than at sites BF (8), BR (6) and C (5) (Table 6). The two sites with the most similar bird species composition in the banding data were Cumberland Plain Woodland site C and Castlereagh Scribbly Gum Woodland site BR (Fig. 7). These results all mirror the patterns found in the plot count data.

Analyses of variance revealed significant differences in the number of species caught per site per visit and the total capture rate (Tables 6 and 7). However, the differences were complex, involving interactions between site and season. The significant features were: (a) the high numbers of species caught at site BF in autumn (mean of 12.7 per visit) and site A in spring (12.3), (b) the low number of species caught at site BF in winter (3.7), and (c) the high capture rate of birds at site BF in autumn (mean of 11.6 per 100 m of nets per hour), compared with the mean for all other seasons and sites (4.5).

Significant differences were found between sites for the following species (Tables 6 and 7): Red-browed Finch capture rate was highest at A and lowest at BR; Speckled Warbler *Chthonicola sagittata* and Double-barred Finch *Taeniopygia bichenovii* capture rates were highest at BF in autumn;

Table 4

Mean numbers of individuals recorded in plot counts in 1997. Significant differences between plots or seasons indicated by shading. * introduced species.

Species	Plots				Seasons				Overall mean
	A	BF	BR	C	Sum	Aut	Win	Spr	
	n=11	*n*=11	*n*=12	*n*=11	*n*=12	*n*=10	*n*=11	*n*=12	*n*=45
Superb Fairy-wren	2.18	1.73	0.83	3.00	2.08	1.50	1.55	2.42	1.91
Grey Fantail	2.64	2.45	0.75	1.73	2.08	0.80	1.91	2.50	1.87
Yellow Thornbill	1.45	2.73	1.42	1.36	2.25	0.80	2.18	1.58	1.73
Rufous Whistler	2.36	1.55	0.83	1.36	2.33	0.20		3.17	1.51
Spotted Pardalote	1.36	1.64	1.08	1.27	1.17	1.60	1.91	0.75	1.33
Yellow-faced Honeyeater	1.18	1.91	1.17	1.09	1.67	1.50	1.64	0.58	1.33
Weebill	0.45	2.09	0.83	1.82	0.83	0.60	2.55	1.17	1.29
Red-browed Finch	2.00		0.08	1.55	0.25	2.30	0.64	0.58	0.89
White-throated Treecreeper	0.91	0.91	0.67	0.82	0.58	0.70	1.18	0.83	0.82
Golden Whistler	0.82	0.73	0.25	0.73	0.42	0.80	0.82	0.50	0.62
Eastern Yellow Robin	1.27	0.36	0.33	0.45	0.33	0.50	0.36	1.17	0.60
Fuscous Honeyeater	0.64			1.64	0.25		0.27	1.58	0.56
Striated Thornbill	0.45	1.64			0.67	1.00	0.45		0.51
Buff-rumped Thornbill	0.36	0.18	1.33		0.50	0.90	0.18	0.42	0.49
Silvereye	1.27		0.25	0.36	0.25	1.30	0.45		0.47
Eastern Rosella	0.09		1.42			0.50	0.27	0.83	0.40
Black-faced Cuckoo-shrike	0.36	0.55	0.33	0.36	0.58	0.30		0.67	0.40
Grey Shrike-thrush	0.45	0.27	0.50	0.27	0.33	0.30	0.45	0.42	0.38
White-throated Gerygone	0.27	0.55	0.25	0.09	0.50	0.10		0.50	0.29
Little Lorikeet		0.91			0.83				0.22
Scarlet Honeyeater		0.91			0.83				0.22
Eastern Whipbird	0.64			0.09	0.33	0.20		0.17	0.18
Sulphur-crested Cockatoo	0.64				0.17		0.18	0.25	0.16
Crested Shrike-tit	0.45	0.09		0.09	0.25	0.10	0.09	0.17	0.16
Mistletoebird	0.18	0.09	0.25	0.09	0.33	0.20		0.08	0.16
Sacred Kingfisher	0.18		0.33		0.33			0.17	0.13
Rose Robin	0.45	0.09				0.40	0.18		0.13
Peaceful Dove	0.09	0.09	0.08	0.18	0.33			0.08	0.11
Laughing Kookaburra	0.36	0.09			0.25		0.09	0.08	0.11
Brown-headed Honeyeater			0.25	0.18		0.30	0.18		0.11
Grey Butcherbird		0.09	0.17	0.18	0.08	0.30	0.09		0.11
Australian Magpie		0.27	0.17		0.42				0.11
White-browed Scrubwren	0.36				0.08	0.30			0.09
Brown Thornbill	0.18			0.18	0.17		0.09	0.08	0.09
Striated Pardalote	0.18		0.17				0.36		0.09
Varied Sittella	0.09	0.27				0.10		0.25	0.09
Australian Raven	0.18	0.09	0.08			0.10	0.27		0.09
*Red-whiskered Bulbul	0.18			0.18	0.17			0.17	0.09
White-faced Heron	0.09		0.17				0.27		0.07
Speckled Warbler	0.18	0.09			0.08	0.20			0.07
Rufous Fantail	0.09		0.17		0.08			0.17	0.07
Willie Wagtail		0.27			0.17	0.10			0.07
*Common Myna	0.18		0.08					0.25	0.07
Galah	0.18							0.17	0.04
Shining Bronze-cuckoo	0.09	0.09						0.17	0.04
Fan-tailed Cuckoo	0.18					0.10		0.08	0.04
Rainbow Bee-eater				0.18	0.17				0.04
Common Bronzewing		0.09			0.08				0.02
Yellow-rumped Thornbill			0.08			0.10			0.02
Olive-backed Oriole	0.09							0.08	0.02
Dusky Woodswallow	0.09						0.09		0.02
Magpie-lark			0.08					0.08	0.02
Double-barred Finch	0.09					0.10			0.02
No. birds per count	26.00	22.82	14.42	19.27	22.25	18.30	18.73	22.17	20.49
No. species per count	12.09	8.55	6.67	7.64	8.75	8.10	8.45	9.33	8.69

Table 5

Analyses of variance for plot count data. df degrees of freedom, MS mean square. Significant differences: * $P<0.05$, ** $P<0.01$, *** $P<0.001$.

Variable	Source	df	MS	*F*-value	*P*-value
No. species per count	Plot	3	77.576	8.782	0.0002***
	Season	3	1.632	0.185	0.906
	Plot x season	9	13.632	1.543	0.175
	Residual	32	8.833		
No. birds per count	Plot	3	611.019	3.499	0.027*
	Season	3	54.186	0.310	0.818
	Plot x season	9	362.177	2.074	0.063
	Residual	32	174.609		
No. White-throated Treecreepers	Plot	3	0.200	0.268	0.848
	Season	3	0.839	1.126	0.353
	Plot x season	9	1.348	1.810	0.105
	Residual	32	0.745		
No. Superb Fairy-wrens	Plot	3	10.922	2.386	0.087
	Season	3	1.894	0.414	0.744
	Plot x season	9	3.227	0.705	0.700
	Residual	32	4.578		
No. Weebills	Plot	3	6.144	2.023	0.130
	Season	3	7.561	2.490	0.078
	Plot x season	9	2.802	0.923	0.519
	Residual	32	3.036		
No. White-throated Gerygones	Plot	3	0.436	1.521	0.228
	Season	3	0.797	2.782	0.057
	Plot x season	9	0.732	2.556	0.024*
	Residual	32	0.286		
No. Yellow Thornbills	Plot	3	4.785	0.796	0.505
	Season	3	5.285	0.879	0.462
	Plot x season	9	4.363	0.726	0.682
	Residual	32	6.010		
No. Buff-rumped Thornbills	Plot	3	4.306	3.827	0.019*
	Season	3	0.694	0.617	0.609
	Plot x season	9	0.546	0.486	0.873
	Residual	32	1.125		
No. Spotted Pardalotes	Plot	3	0.714	0.152	0.928
	Season	3	3.158	0.671	0.576
	Plot x season	9	4.973	1.057	0.419
	Residual	32	4.703		
No. Yellow-faced Honeyeaters	Plot	3	1.521	0.549	0.653
	Season	3	3.576	1.291	0.294
	Plot x season	9	5.280	1.906	0.087
	Residual	32	2.771		
No. Black-faced Cuckoo-shrikes	Plot	3	0.130	0.275	0.843
	Season	3	1.102	2.326	0.093
	Plot x season	9	0.473	0.998	0.462
	Residual	32	0.474		
No. Golden Whistlers	Plot	3	0.688	1.065	0.378
	Season	3	0.354	0.548	0.653
	Plot x season	9	1.299	2.011	0.071
	Residual	32	0.646		
No. Rufous Whistlers	Plot	3	3.672	2.183	0.109
	Season	3	29.477	17.522	<<0.001***
	Plot x season	9	1.246	0.741	0.669
	Residual	32	1.682		
No. Grey Shrike-thrushes	Plot	3	0.158	0.333	0.801
	Season	3	0.047	0.099	0.960
	Plot x season	9	0.593	1.252	0.300
	Residual	32	0.474		
No. Grey Fantails	Plot	3	8.644	4.058	0.015*
	Season	3	6.186	2.904	0.0499*
	Plot x season	9	3.246	1.524	0.182
	Residual	32	2.130		
No. Eastern Yellow Robins	Plot	3	2.172	4.793	0.007**
	Season	3	1.894	4.180	0.013*
	Plot x season	9	0.755	1.667	0.139
	Residual	32	0.453		
No. Red-browed Finches	Plot	3	15.686	3.320	0.032*
	Season	3	12.686	2.685	0.063
	Plot x season	9	9.658	2.044	0.066
	Residual	32	4.724		

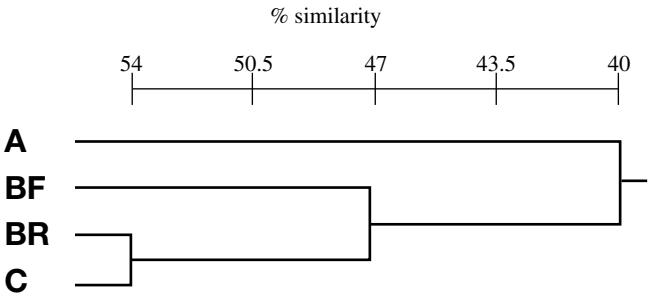

Figure 7. *Classification of the four banding sites based on similarity in bird species composition, using Gower's similarity coefficient values calculated from the mean capture rate per species in all 1997 banding sessions.*

Yellow Thornbill *Acanthiza nana* capture rate was highest at BF in autumn and BR in winter; White-throated Treecreeper *Cormobates leucophaea* capture rate was highest at BF in spring; Weebill *Smicrornis brevirostris* capture rate was highest at BR in winter; Superb Fairy-wren *Malurus cyaneus* capture rate was lowest at BR; and Golden Whistler *Pachycephala pectoralis* capture rate was highest at C. Significant differences among seasons that did not involve site interactions were: Golden Whistler capture rate was highest in autumn and lowest in summer; Rufous Whistler capture rate was highest in spring and summer and it was absent in winter; Striated Thornbill *Acanthiza lineata* capture rate was highest in winter; Silvereye *Zosterops lateralis* capture rate was lowest in winter; and Red-browed Finch capture rate was highest in autumn.

Site BR, although not the richest in species, had the highest Shannon Weiner diversity index because of its more even species abundances (Table 8). The three most common species contributed only 27% of birds banded at site BR, whereas at the other three sites they contributed 42-48%. The most common species varied from site to site. The Superb Fairy-wren and Red-browed Finch were in the top three at each of sites A, BF and C, together with the Spotted Pardalote *Pardalotus punctatus* (site A), Silvereye (site BF) or Eastern Yellow Robin (site C). At site BR, the most common species caught was the Yellow-faced Honeyeater, closely followed by equal numbers of Superb Fairy-wrens, Silvereyes, Yellow Thornbills and Buff-rumped Thornbills. Only a couple of Red-browed Finches were captured at this site.

Numbers of retrapped birds varied among species (Table 6). Among the species for which at least 20 birds were banded, the ones with the highest retrap percentages (24-46% of birds banded were subsequently retrapped) were the Speckled Warbler, Superb Fairy-wren and Eastern Yellow Robin, indicating that they had relatively sedentary populations. The species with the lowest retrap percentages (2-7%) were the Spotted Pardalote, Red-browed Finch and the migratory Rufous Whistler, indicating that they had more mobile populations with many birds moving through the area and not staying around.

Movements among sites

Banded birds of 14 species were recorded moving between the banding sites in 1997 or at other times (Table 9). Intervals for such retrapping events ranged from one month to almost four years. Half of all movements were between sites B and C. The species with the highest numbers of recorded movements were the Eastern Yellow Robin (7), Buff-rumped Thornbill (4), Yellow-faced Honeyeater *Lichenostomus chrysops* (4), Fuscous Honeyeater (3) and Silvereye (3). Buff-rumped Thornbill movements were all between sites B and C, and Fuscous Honeyeater movements all between sites A and C. The other three species were recorded moving among all three sites. The Superb Fairy-wren and Brown Thornbill *Acanthiza pusilla*, which were generally confined to small territories, were recorded moving from site C to B and site A to C, respectively. If they travelled via forested areas, they would have moved more than two kilometres. One Eastern Yellow Robin was the only bird recorded moving from one site to another (site C to B) and then back again.

DISCUSSION

Seasonal patterns

Nineteen species were tested for seasonal patterns of occurrence in Scheyville NP using count and/or banding data. These were the more common forest and woodland birds at Scheyville in 1997 for which there were sufficient records for analysis. Only the Rufous Whistler and White-throated Gerygone were seasonal migrants that departed from the area entirely. Both species were banded and counted in spring, summer and early autumn, but were absent in late autumn and winter (May-August, Table 2). The other common species were all recorded in every season. Other migratory species occur at Scheyville, but are less common. Overall in the Scheyville bird assemblage, fewer species were present in June and July than in other months (Fig. 5).

No significant seasonal fluctuations were evident in the number of species and number of birds recorded in the plot counts. Significant seasonal fluctuations were evident in the banding data, but involved individual sites rather than the study area as a whole. In particular, in the Shale Gravel Transition Forest at site BF, higher numbers of species and birds were caught in autumn, whereas the number of species caught there in winter was low. In the Cumberland Plain Woodland at site A, a higher number of species was caught in spring. However, these patterns were not reflected in the count data and so they may be due to changes in behaviour rather than changes in numbers. Birds may have been captured more frequently at certain sites in certain seasons because they were foraging lower in the vegetation or coming to drink more often at permanent pools. For example, Buff-rumped Thornbills at Scheyville forage more often on the ground outside the breeding season, and Weebills forage higher up in the vegetation in October than in January (Recher 1988).

Some species that were present all year showed significant seasonal fluctuations in numbers of individuals captured or counted. More Golden Whistlers and Red-browed Finches were captured, but fewer Grey Fantails counted, in autumn than in other seasons. More Striated Thornbills, but fewer Silvereyes, were captured in winter than in other seasons. Eastern Yellow Robins were recorded more frequently in the spring counts than in counts in other seasons. Other species showed significant seasonal fluctuations in capture rates at certain sites. At least some of these patterns, especially for the capture data, may be due to changes in behaviour rather than fluctuations in numbers.

Table 6

Mean capture rates (number of birds caught per 100 m of nets per hour) in banding sessions in 1997, and numbers of individual birds banded and retrapped. Retraps after 1997 not included. Significant differences between sites or seasons indicated by shading. * introduced species.

Species	Sites				Seasons				Overall mean	No. of individuals banded	Individuals retrapped	
	A	BF	BR	C	Sum	Aut	Win	Spr			No.	%
	n=11	*n*=12	*n*=12	*n*=12	*n*=12	*n*=12	*n*=11	*n*=12	*n*=47			
Superb Fairy-wren	1.56	1.06	0.32	1.25	1.08	1.45	0.95	0.66	1.04	133	39	29
Red-browed Finch	1.20	0.71	0.02	0.51	0.24	1.34	0.43	0.37	0.60	96	7	7
Eastern Yellow Robin	0.56	0.36	0.20	0.62	0.59	0.36	0.41	0.37	0.43	62	15	24
Silvereye	0.43	0.64	0.16	0.23	0.55	0.50	0.05	0.33	0.36	63	10	16
Yellow-faced Honeyeater	0.56	0.30	0.21	0.36	0.53	0.31	0.30	0.28	0.35	65	7	11
Spotted Pardalote	0.68	0.06	0.06	0.21	0.64	0.12	0.14	0.06	0.24	44	1	2
Golden Whistler	0.15	0.16	0.09	0.43	0.05	0.33	0.25	0.21	0.21	34	5	15
Speckled Warbler	0.14	0.29	0.10	0.24	0.14	0.34	0.17	0.12	0.19	24	11	46
Yellow Thornbill	0.07	0.29	0.22	0.10	0.08	0.24	0.24	0.13	0.17	33	6	18
Grey Fantail	0.15	0.19	0.12	0.20	0.18	0.21	0.10	0.15	0.16	31	3	10
Double-barred Finch	0.02	0.36	0.13		0.08	0.44			0.13	26	3	12
Buff-rumped Thornbill	0.08	0.04	0.23	0.10	0.09	0.14	0.20	0.03	0.11	24	3	13
Rufous Whistler	0.15	0.08	0.03	0.14	0.20	0.04		0.15	0.10	20	1	5
Fuscous Honeyeater	0.26			0.16	0.04		0.10	0.26	0.10	16	3	19
White-throated Treecreeper	0.12	0.16	0.03	0.06	0.08	0.03	0.05	0.22	0.09	16	4	25
Weebill	0.02	0.02	0.16	0.06	0.05	0.03	0.14	0.06	0.07	16	1	6
Striated Thornbill	0.05	0.04	0.09	0.10	0.03	0.06	0.18	0.02	0.07	13	2	15
White-browed Scrubwren	0.12			0.09	0.06	0.03	0.08	0.04	0.05	7	1	14
Grey Shrike-thrush	0.02	0.09	0.04	0.02	0.04	0.05	0.02	0.07	0.04	9	1	11
Scarlet Honeyeater		0.15			0.15				0.04	8	0	
Rose Robin		0.04	0.03	0.04		0.03	0.04	0.04	0.03	6	0	
Azure Kingfisher	0.12				0.06	0.03		0.02	0.03	4	1	25
Sacred Kingfisher	0.04	0.04	0.02		0.03			0.07	0.02	6	0	
Noisy Miner		0.09						0.09	0.02	5	0	
Brown-headed Honeyeater			0.07				0.02	0.06	0.02	5	1	20
Dusky Woodswallow	0.07							0.06	0.02	3	0	
White-throated Gerygone		0.04	0.02		0.05			0.01	0.01	4	0	
Peaceful Dove	0.02		0.01	0.02	0.01			0.04	0.01	3	0	
Shining Bronze-cuckoo		0.02	0.02		0.01	0.02		0.01	0.01	3	0	
Eastern Spinebill	0.02	0.02	0.01		0.02			0.03	0.01	3	0	
Olive-backed Oriole	0.02							0.02	0.01	1	0	
Laughing Kookaburra				0.04	0.02			0.02	0.01	2	0	
Grey Butcherbird	0.02	0.02				0.02		0.02	0.01	2	0	
Rufous Fantail	0.02		0.01					0.03	0.01	2	0	
Willie Wagtail		0.04			0.04				0.01	2	0	
*Spotted Dove	0.02				0.02				0.01	1	0	
Fan-tailed Cuckoo	0.02					0.02			0.01	1	0	
Brown Thornbill				0.05		0.03		0.02	0.01	1	1	100
Yellow-tufted Honeyeater	0.02					0.02			0.01	1	0	
Black-chinned Honeyeater		0.02				0.02			0.01	1	0	
Leaden Flycatcher	0.03				0.02				0.01	1	0	
Jacky Winter		0.02				0.02			0.01	1	0	
Eastern Whipbird				0.02				0.02	0.005	1	0	
Australian Owlet-nightjar			0.01		0.01				0.003	1	0	
Black-faced Cuckoo-shrike			0.01					0.01	0.003	1	0	
Total capture rate	**6.79**	**5.34**	**2.45**	**5.06**	**5.19**	**6.22**	**3.87**	**4.12**	**4.87**			
No. species caught per session	**8.91**	**7.92**	**8.67**	**8.08**	**9.17**	**8.50**	**6.45**	**9.25**	**8.38**			
Total individuals										**801**	**126**	**16**

Table 7

Analyses of variance for banding data. CR capture rate, df degrees of freedom, MS mean square. Significant differences: * P<0.05, ** P<0.01, *** P<0.001.

Variable	Source	df	MS	*F*-value	*P*-value
No. species caught per visit	Site	3	2.519	0.356	0.785
	Season	3	17.880	2.526	0.075
	Site x season	9	21.047	2.974	0.011*
	Residual	32	7.078		
Total capture rate	Site	3	40.810	5.398	0.004**
	Season	3	11.509	1.522	0.228
	Site x season	9	19.201	2.540	0.025*
	Residual	32	7.560		
White-throated Treecreeper CR	Site	3	0.041	1.744	0.178
	Season	3	0.086	3.654	0.023*
	Site x season	9	0.057	2.434	0.031*
	Residual	32	0.024		
Superb Fairy-wren CR	Site	3	3.841	5.350	0.004**
	Season	3	1.237	1.723	0.182
	Site x season	9	1.402	1.952	0.079
	Residual	32	0.718		
Speckled Warbler CR	Site	3	0.091	1.161	0.340
	Season	3	0.113	1.451	0.246
	Site x season	9	0.182	2.330	0.038*
	Residual	32	0.078		
Weebill CR	Site	3	0.055	5.108	0.005**
	Season	3	0.023	2.093	0.121
	Site x season	9	0.052	4.804	0.0004***
	Residual	32	0.011		
Striated Thornbill CR	Site	3	0.007	0.365	0.779
	Season	3	0.059	2.919	0.049*
	Site x season	9	0.011	0.547	0.829
	Residual	32	0.020		
Yellow Thornbill CR	Site	3	0.121	2.418	0.084
	Season	3	0.073	1.463	0.243
	Site x season	9	0.136	2.716	0.018*
	Residual	32	0.050		
Buff-rumped Thornbill CR	Site	3	0.082	2.735	0.060
	Season	3	0.055	1.821	0.163
	Site x season	9	0.052	1.730	0.123
	Residual	32	0.030		
Spotted Pardalote CR	Site	3	0.942	1.516	0.229
	Season	3	0.861	1.385	0.265
	Site x season	9	0.763	1.228	0.313
	Residual	32	0.621		
Yellow-faced Honeyeater CR	Site	3	0.264	0.743	0.534
	Season	3	0.159	0.447	0.721
	Site x season	9	0.298	0.839	0.587
	Residual	32	0.356		
Golden Whistler CR	Site	3	0.280	5.252	0.005**
	Season	3	0.156	2.919	0.049*
	Site x season	9	0.036	0.673	0.727
	Residual	32	0.053		
Rufous Whistler CR	Site	3	0.034	1.362	0.272
	Season	3	0.104	4.109	0.014*
	Site x season	9	0.043	1.704	0.129
	Residual	32	0.025		
Grey Shrike-thrush CR	Site	3	0.015	1.375	0.268
	Season	3	0.007	0.647	0.591
	Site x season	9	0.007	0.672	0.728
	Residual	32	0.011		
Grey Fantail CR	Site	3	0.018	0.377	0.770
	Season	3	0.024	0.520	0.672
	Site x season	9	0.065	1.388	0.234
	Residual	32	0.047		
Eastern Yellow Robin CR	Site	3	0.485	2.040	0.128
	Season	3	0.137	0.576	0.635
	Site x season	9	0.319	1.342	0.255
	Residual	32	0.237		
Silvereye CR	Site	3	0.547	2.747	0.059
	Season	3	0.587	2.950	0.047*
	Site x season	9	0.267	1.339	0.256
	Residual	32	0.199		
Double-barred Finch CR	Site	3	0.330	10.342	0.0001***
	Season	3	0.535	16.786	<<0.001***
	Site x season	9	0.299	9.366	<<0.001***
	Residual	32	0.032		
Red-browed Finch CR	Site	3	2.891	3.298	0.033*
	Season	3	2.972	3.391	0.030*
	Site x season	9	1.057	1.206	0.326
	Residual	32	0.877		

Table 8

Measures of species diversity at the four banding sites, based on the numbers of individuals banded (excluding retraps). The evenness value is the ratio of the Shannon-Wiener index to its maximum value for that number of species, when all species are equally abundant.

Measure	**Site A**	**Site BF**	**Site BR**	**Site C**
Number of species banded	31	28	27	23
Shannon-Wiener diversity index	2.67	2.82	2.95	2.61
Evenness	0.78	0.84	0.89	0.83
% contribution of 3 most common species	48	42	27	46
% contribution of 5 most common species	64	55	44	62
% contribution of 10 most common species	82	77	74	83

Table 9

List of birds that moved from one banding site to another and the intervening time between banding and recapture

Species	Band No.	Site banded	Site retrapped	Time elapsed
Grey Fantail	016-67560	A	B	2 yrs 1 mth
Grey Fantail	016-69376	C	A	3yrs 10 mths
Eastern Yellow Robin	023-01332	C	B	1 yr 6 mths
Eastern Yellow Robin	023-07344	C	B	1 yr 1 mth
Eastern Yellow Robin	023-01334	C	B	1 yr 6 mths
and returned to Site C		B	C	3 mths
Eastern Yellow Robin	025-36914	C	B	5 mths
Eastern Yellow Robin	025-13587	C	B	3 mths
Eastern Yellow Robin	024-66560	A	C	1 yr 6 mths
Golden Whistler	034-49986	B	C	11 mths
Rufous Whistler	031-18207	A	B	3 yrs
Grey Shrike-thrush	051-78103	C	B	9 mths
Grey Shrike-thrush	051-48218	C	B	1 yr 9 mths
Yellow Thornbill	017-13211	A	B	2 yrs 6 mths
Yellow Thornbill	012-19095	C	A	8 mths
Brown Thornbill	017-36522	A	C	3 yrs 10 mths
Buff-rumped Thornbill	017-26694	B	C	4 mths
Buff-rumped Thornbill	011-19118	B	C	1 yr 11 mths
Buff-rumped Thornbill	018-03007	B	C	4 mths
Buff-rumped Thornbill	018-03402	B	C	2 mths
Speckled Warbler	017-36420	B	C	1 mth
Superb Fairy-wren	012-19096	C	B	8 mths
Silvereye	017-60195	B	C	1 yr 3 mths
Silvereye	016-69360	A	B	2 yrs 5 mths
Silvereye	016-89873	A	B	4 yrs 11 mths
Fuscous Honeyeater	025-37235	C	A	1 yr 1 mth
Fuscous Honeyeater	025-37237	C	A	1 yr 2 mths
Fuscous Honeyeater	025-37239	C	A	1 yr 10 mths
Yellow-faced Honeyeater	025-36835	A	B	1 yr 9 mths
Yellow-faced Honeyeater	024-62044	A	B	2 yrs 6 mths
Yellow-faced Honeyeater	024-10170	B	A	4 yrs 4 mths
Yellow-faced Honeyeater	025-13646	C	A	2 yrs 1 mth
Red-browed Finch	018-03881	B	A	2 mths

Some may be due to local movements of birds between banding sites rather than broader-scale movements. The patterns vary among species and sites, and so they do not show up as general seasonal patterns in the numbers of species and birds recorded.

Differences among sites

There were marked differences in avian assemblages among all four banding sites, not just between the three vegetation communities. The assemblages at sites A and C in Cumberland Plain Woodland were as different from each other as they were from the assemblages at site BF in Shale Gravel Transition Forest and site BR in Castlereagh Scribbly Gum Woodland. In fact, site C was much closer in species composition to site BR than to site A (Figs 6 and 7).

The Cumberland Plain Woodland at site A had the most distinct avian assemblage (Figs 6 and 7), with a higher proportion of the rarer species (Tables 4 and 6). It had the highest number of bird species, which was evident from the total number of species recorded by each of the three survey methods (Table 3), from the mean number of species recorded per plot count (Table 4,) and from the mean number of species caught per banding session (Table 6). In addition, both the mean number of individual birds per plot count (Table 4) and the mean total capture rate per banding session (Table 6) were higher at site A than at the other sites, especially site BR. Among the more common species, ones that were significantly more abundant at site A were the Eastern Yellow Robin (counts) and Red-browed Finch (captures and counts). The richness of the site A avifauna may be due to the presence of large, permanent pools of water along the creek that provide suitable habitat for wetland birds, such as the Black Bittern *Ixobrychus flavicollis*, White-faced Heron *Egretta novaehollandiae* and Azure Kingfisher, and a reliable drinking water supply for other birds. Furthermore, the denser riparian vegetation along the creek line favoured species such as the Eastern Yellow Robin and Lewin's Honeyeater *Meliphaga lewinii*.

The bird assemblage at site C, the other Cumberland Plain Woodland site, showed some similarities to the site A bird assemblage. Most notably, the Fuscous Honeyeater, a moderately common species in the study area, was only ever recorded (captures, counts and incidental records) at sites A and C, never at site B (Table 2), and was also recorded moving between sites A and C (Table 9). Red-browed Finches were also significantly more numerous in counts at sites A and C than at sites BF and BR (Table 4). However, site C differed from site A in that it had the fewest species of any site by each survey method, whereas site A had the most species by each method (Table 3). Like site A, site C included a creek line, but the creek was more ephemeral and lacked the permanent pools of water and dense creek-side vegetation of site A. These differences appear to have made site C a poorer habitat for birds than site A. Other features of site C were the significantly higher capture rate of Golden Whistlers than at the other three sites (Table 6), and the absence of Buff-rumped Thornbills in all plot counts (Table 4). However, these differences were not evident in the Golden Whistler plot counts (Table 4) and Buff-rumped Thornbill capture data (Table 6) and may thus be artefacts of the survey method.

Site BF in the Shale Gravel Transition Forest was characterised by high capture rates in the autumn banding sessions, including the number of species caught, the total capture rate, and the capture rates of Yellow Thornbills, Speckled Warblers and Double-barred Finches (Table 6). It also had high capture rates of White-throated Treecreepers in spring (Table 6) and high counts of White-throated Gerygones in summer (Table 4). The White-throated Gerygone count pattern was matched by high capture rates (Table 6) and appears to represent a real peak in abundance of this species at this site in summer. However, the peaks in capture rates of these three species in autumn, and of White-throated Treecreepers in spring, were not mirrored by corresponding trends in the count data. As discussed above, they may be due to changes in behaviour making birds more 'catchable' at certain sites in certain seasons, rather than to changes in abundance associated with movements or breeding success. Nevertheless, they do indicate differences in habitat use between site BF and the other sites, even though the basis for the differences is uncertain.

Site BR within the Castlereagh Scribbly Gum Woodland had the lowest numbers of species and birds per count of any site. It was also characterised by high counts of Buff-rumped Thornbills, low counts of Grey Fantails, low capture rates of Superb Fairy-wrens and Red-browed Finches, and high capture rates of Weebills and Yellow Thornbills in winter (Tables 4 and 6). In fact, Acanthizids (thornbills, Weebill, White-throated Gerygone, Speckled Warbler and White-browed Scrubwren) made up a higher proportion of the birds captured at site BR (34%) than at any of the other three sites (7–14%). In the counts, Acanthizids made up a higher proportion of the total number of birds counted at sites BR and BF (27–32%) than at the two Cumberland Plain Woodland sites A and C (14–18%). The relatively low capture rates of Superb Fairy-wrens and Red-browed Finches at site BR resulted in a more even species composition in the catch than those at the other three sites, making it the most diverse avian assemblage as measured by the Shannon-Wiener diversity index, despite its low species richness (Table 8). These two species made up 14% of the catch at site BR, but 33–41% of the catch at the other sites (Table 6). Superb Fairy-wrens and Red-browed Finches were less dominant in the counts, making up 6–8% of the counts at sites BR and BF, and 16–24% of those at sites A and C (Table 4).

Three species recorded at site B (Black-chinned Honeyeater *Melithreptus gularis*, Scarlet Robin *Petroica boodang* and Yellow-rumped Thornbill *Acanthiza chrysorrhoa*) were in severe decline and very rarely observed in 1997 (Egan *et al.* 1997). These species prefer to forage in open woodland, but as Blackthorn thickets progressively extended onto the grassed areas, sites A and C became overgrown. These bird species then retreated to the more open areas within the Castlereagh Scribbly Gum Woodland at site B. They have now disappeared from the area (Saunders 2016; Farrell *et al*. in prep.). Changes in the bird assemblage of Scheyville NP before and after 1997 will be described elsewhere.

Comparison of survey methods

Each of the survey methods employed in this study, species lists, plot counts and banding, had advantages and disadvantages. They provided different perspectives on the forest bird assemblage of Scheyville NP. This is illustrated

Table 10

Comparison of species rankings by frequency in species lists, mean number of individuals in plot counts, and mean capture rate in banding. Species in the table are those that were in the first 15 by at least one measure.

Species	Species lists	Plot counts	Banding
Superb Fairy-wren	equal 2nd	1st	1st
Grey Fantail	1st	2nd	10th
Yellow Thornbill	equal 10th	3rd	9th
Rufous Whistler	22nd	4th	13th
Yellow-faced Honeyeater	9th	equal 5th	5th
Spotted Pardalote	equal 7th	equal 5th	6th
Weebill	equal 14th	7th	17th
Red-browed Finch	equal 16th	8th	2nd
White-throated Treecreeper	equal 2nd	9th	15th
Golden Whistler	equal 7th	10th	7th
Easterrn Yellow Robin	equal 2nd	11th	3rd
Fuscous Honeyeater	equal 32nd	12th	14th
Striated Thornbill	26th	13th	16th
Buff-rumped Thornbill	equal 24th	14th	12th
Silvereye	equal 18th	15th	4th
Black-faced Cuckoo-shrike	equal 10th	equal 16th	44th
Grey Shrike-thrush	equal 2nd	18th	19th
Peaceful Dove	equal 10th	equal 28th	29th
Grey Butcherbird	equal 10th	equal 28th	32nd
Laughing Kookaburra	equal 14th	equal 28th	33rd
Australian Raven	equal 2nd	equal 33rd	none caught
Speckled Warbler	equal 27th	equal 39th	8th
Double-barred Finch	equal 32nd	equal 48th	11th

by the marked differences in the rankings of the 15 most common species recorded by each survey method (Table 10). The general species lists provided the most comprehensive account of the richness of bird species in the assemblage, with about twice as many species being recorded in the species lists as in either plot counts or banding (Table 3). However, the relative abundance of some species was overestimated by their frequency of occurrence in the species lists. Thus, species that are visually prominent or have loud and distinctive calls, such as the Australian Raven *Corvus coronoides*, Grey Shrike-thrush *Colluricincla harmonica* and White-throated Treecreeper, were recorded more frequently in the species lists than in plot counts or banding captures (Table 10). This was especially so for the Australian Raven, particularly as the plot counts did not include birds flying overhead, which was typically how this species was recorded.

The plot counts provide information on the numbers of individuals of each species present in a defined search area, as distinct from the general species lists which record relative abundance only in terms of the frequency of occurrence of each species over a series of visits. In general, the plot counts are probably more reliable indicators of relative abundance than the banding data. However, the high capture rates of species such as the Silvereye, Speckled Warbler and Double-barred Finch, compared with their low rankings by the other survey methods, suggests that the relative abundance of these species was being underestimated by both the plot counts and the general species lists.

The banding data provide an alternative measure of the numbers of individuals of each species present at the banding sites. However, these data are strongly influenced by 'catchability'. For example, the slow, highly agile flight of the Grey Fantail makes it difficult to catch in mist nets, with the result that its abundance is underestimated by banding captures compared with plot counts and species lists (Table 10). On the other hand, the abundance of a species that feeds on the ground or in low vegetation and is easy to catch, such as the Red-browed Finch, is overestimated by banding captures. Furthermore, as discussed above, differences in capture rates between seasons may be due to seasonal differences in 'catchability' resulting from changes in behaviour rather than abundance, such as birds feeding higher or lower in the vegetation at different times of year.

Interpretation of capture rate data should be conducted with caution. Nonetheless, banding provides insights into the bird assemblage that are not possible from survey methods that do not involve identification of individual birds. For example, differences in retrap percentages distinguish species with relatively sedentary populations from those with more mobile populations (Table 6).

The combination of survey methods employed in this study allowed patterns evident from one survey method to be compared with those yielded by other survey methods. Thus, the biases of each survey method could be more readily identified. Together, the three survey methods provided more information on the forest bird assemblage in Scheyville NP than it was possible to obtain from any one method alone.

CONCLUSIONS

The results of this 1997 study show a complex pattern of utilisation of habitats by birds in Scheyville NP. There were differences between the avian assemblages of each floristic community, and differences between those of sites within a community. The richest and most abundant avian assemblage was associated with the presence of a creek with permanent pools of water and dense riparian vegetation. There was evidence of some species moving between habitats, and into and out of the entire Scheyville area. Fewer species were recorded in winter than in other seasons. However, most of the more common species were present all year, although many showed seasonal fluctuations in abundance, either over the entire study area or at certain sites. The patterns varied among species. Some fluctuations, especially in the capture data, appear to be due not to movements or breeding success but to changes in behaviour and habitat use that make the birds more 'catchable' at certain sites at certain times of year. The complex habitat utilisation patterns demonstrated in this study illustrate the importance of maintaining a diversity of forest and woodland habitats for the local avifauna, especially in the face of continuing loss of natural habitat through ever-increasing urbanisation across the Cumberland Plain region of western Sydney. Some species have declined in Scheyville NP before and after this study. Their decline will be reported elsewhere. This study also shows the value of using several different survey methods simultaneously. Each method has certain advantages and biases; using the three methods in combination provides a more complete picture of the bird assemblage.

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