CORELLA

Journal of the Australian Bird Study Association

VOLUME 8 JUNE, 1984 NUMBER 2

Breeding Bird Censuses: An Evaluation of Four Methods for use in Sclerophyll Forest

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Four methods were used to census birds in forest and woodland near Bombala on on the Southern Tablelands of New South Wales. None was completely satisfactory, but a modified strip transect procedure provided repeatable estimates of the relative abundance of most species. The most accurate estimates of the abundance of individual species were obtained by combining territory mapping with colour banding of individuals and intensive searches for nests. Mist netting was necessary to colour band birds, but by itself was not particularly useful as a census procedure. Mist netting was also the most time consuming method used and required the greatest number of people. Mapping and nest searches were also time consuming, but could be done by one person. Transect counts took the least effort and can be regarded as the most efficient use of resources where an estimate of relative abundances is all that is required.

Between 1976 and 1981, we studied birds on two 10 ha plots near Bombala (36°54'S., 149°14'E.) on the Southern Tablelands of N.S.W. As part of this programme we used a strip transect procedure to estimate the numbers of birds on the plots through the year. In 1979 and 1980 we attempted to locate all nests and mapped the territories or home ranges of breeding birds. To assist in these studies, birds were mist netted and individually colour banded (CSIRO bands* were also placed on each bird netted).

* Bands used were provided by the Australian Bird-banding Scheme. Division of Wildlife and Rangelands Research, CSIRO.

Transect counts, territory mapping, nest searches and mist net captures are methods used to estimate the numbers of breeding birds in forests of the northern hemisphere (see Ralph and Scott 1981 for reviews). The breeding season in these habitats tends to be brief and synchronous with most birds being territorial and monogamous (Kendeigh 1944, Welty 1975, Robins 1978). This is not the case in Australia where the breeding season is prolonged, nesting is often asynchronous and communal nesting is common (Dow 1980, Marchant 1981, Recher *et al* 1983a). Census procedures developed in America or Europe therefore need to be tested before they are used widely in Australia (Dwyer, 1972).

Although not designed to compare different census methods, our studies at Bombala during 1979 and 1980 permit us to compare the numbers obtained by strip counts with the numbers of breeding birds estimated by territory mapping, by nests located and by mist netting. In this paper we compare each method and evaluate their effectiveness in estimating the numbers of birds breeding in sclerophyll forests.

Methods

Two plots (Woodlot 1 and Woodlot 2) on private land adjacent to Bondi State Forest (altitude 830 m asl) were used for this study. The plots were 420 m long by 240 m wide and gridded at 30 m intervals. Observations of nesting birds were made up to 60 m outside the boundary of the grids.

The woodlots were mostly regrowth forest and woodland 20 to 80 years old, but remnant mature and overmature trees were abundant. Both were grazed by sheep and cattle. Narrow-leaved Peppermint *Eucalyptus radiata,* Mountain Gum, *E. dalrympleana* and Ribbon Gum *E. viminalis* were the most abundant trees in the forested parts of the Woodlots. Woodland areas were dominated by Snow Gum *E. pauciflora* and Black Sallee *E. stellulata.*

Woodlot 2 was mostly a uniform forest averaging 20 to 25 m in height, but one side was bounded by woodland. This plot was open with a sparse understorey of eucalypts. Shrubs and ground vegetation were absent. About half of Woodlot 1 was woodland. The other half was forested with the canopy reaching 30 to 35 m. Understorey and shrub layers were well developed in the forested section. The woodland portion averaged 10 to 15 m in canopy height. Shrubs and understorey were absent in the woodland, but there was a grassy ground cover. The plots are described in greater detail in other papers (e.g. Recher *et al* 1983a).

Beginning in 1978 the plots were censused monthly during the main part of the breeding season (October-December). We treated each woodlot as two adjacent, non-overlapping transects 420 m long and 120 m wide. The transects were walked slowly and all birds seen or heard within 60 m of either side of the centre line were recorded (Recher *et al* 1983b). Counts were begun within one hour of sunrise. Each transect took two hours to census with the two transects on a plot done consecutively. By using two observers both woodlots were done on the same days. Weather permitting, the woodlots were censused on four consecutive days. The monthly censuses therefore consisted of four two hour counts along each transect, two of which were done early in the morning and two later. In this paper we add together the average of the four counts along the two transects as an estimate of the number of individuals of each species on the woodlots.

We used standard international methods (IBCC 1970) for territory mapping. Each plot was visited on eight or more occasions and thoroughly searched with each bird heard or seen recorded on a map of the study area. Simultaneous observations of the same species were registered and denoted directionally. In combination with clusters of single registrations, simultaneous observations of individuals of the same species allow the construction of accurate maps of the territories of birds or pairs of birds (Kendeigh 1944).

Many individuals had territories or home ranges which extended beyond the limits of the study plot. In the case of these birds, the extent of their movements outside the plot was mapped and only the portion of the territory within the study plot was used to estimate numbers. For example, if a pair spent half its time on the grid and half outside, it was counted as half a territory and as one individual in the census.

Nest searching is a simple and accurate technique for estimating the number of breeding birds (Longcore and Jones 1969, Disney and Stokes 1976). Most nests were located while doing other work, but we made a special effort to locate all nests on the woodlots during 1979 and 1980. We are confident that more than 90 per cent of all nests were found.

Mist netting was done immediately before or after the monthly transect counts. Eighteen 20 m nets were erected on each grid and opened from dawn for six hours on two consecutive days, weather permitting. Sixteen nets were located in a regular configuration around the plot so that all parts of the grid were sampled. These positions were used each month. Two nets were placed opportunistically to capture particular individuals or to take advantage of

birds which had congregated at a food source (e.g. honeyeaters at a flowering shrub). The principal reason for mist netting was to capture individuals for colour-banding to assist with the mapping of movements and studies of the biology of individual species.

Results

Eighty-five species of birds were recorded on the woodlots between 1976 and 1981 (Table 1). Forty-seven species were recorded nesting on the woodlots (Table 1), 25 of which nested each year (Recher *et al* 1983a). Numbers varied seasonally, but transect censuses during spring and summer averaged 35 to 40 species and 175 to 250 individuals per woodlot (Recher *et al* 1983a). Migrants departed in late summer or autumn and returned in spring beginning in August. By early December, all migrants had established territories and were nesting, and the nesting of resident bird species was at its peak (Recher *et al* 1983a).

In comparing census methods it might be preferable to use a different month or period of the breeding season for each species; some resident birds nested as early as July (e.g. Striated Thornbill *Acanthiza lineata*). However, our concern in this paper is with the effectiveness of the different methods in assessing the numbers of birds in a community and not with studies of individual species. Analysis is therefore based on counts made during December.

Our objective was to estimate the numbers of individuals at an instant of time by each of the methods. For some methods, this temporal scale was not appropriate. What are probably better estimates of numbers were obtained from mist netting and from nest searches by using the results obtained over an entire season.

The transect method was the only procedure that sampled the entire avifauna (Table 1). Territory mapping was effective for 19 species and nest searches sampled 31 species. Forty-four species were caught in mist nets during 1979 and 1980, but many of these were caught infrequently. During monthly samples (October-January) in 1979-80 an average of 20 species was caught on Woodlot 1 and 19 species on Woodlot 2. In 1980-81 the monthly (September-January) average was 14 species on Woodlot 1 and 15 species on Woodlot 2. There was a total of 18 netting sessions during 1979 and 1980; nine on each woodlot. Twenty one of the 44 species netted were caught on three or fewer occasions. Only 14 species were netted in nine or more of the sessions and only five of these were caught on 16 or more occasions.

Using the census data for December 1979 and 1980, the estimates of bird numbers obtained by the transect method were significantly different from all other procedures (Wilcoxon Matched-pairs Signs Rank Test, $p < 0.01$). The disparity is largely due to the greater number of species sampled during the transect counts.

Twenty-one species nested on both of the woodlots during 1979 and 1980. Nine species were birds which occured only in small numbers (e.g. Spotted Pardalote *Pardalotus punctatus*, Grey Shrike Thrush *Colluricincla harmonica*), or were cryptic and difficult to census by any method (e.g. Tawny Frogmouth *Podargus strigoides*), or could not be sampled with mist nets by virtue of size (e.g. Laughing Kookaburra *Dacelo novaeguineae*). The remaining 12 species were abundant and could be reasonably expected to be censused by each of the methods tested. Ten of these were selected for a comparison of the numbers estimated for each species by the four census methods (Table 2). Brown and Striated Thornbills *Acanthiza pusilla* and *A. lineata* were not considered as they nested much earlier than the other species.

The species selected for individual analysis represent the range of breeding habits and foraging behaviour seen among forest and woodland birds in southeastern Australia. They illustrate the kinds of problems encountered in using the four census methods tested. For the initial analysis we used the numbers counted by territory mapping and nest searches from mid-November to mid-December and by mist-netting and transect censuses during December in 1979 and 1980. We then compare the seasonal estimates of numbers (September/October-December) for each species by nest searches and mist net capture (Table 3) to the December transect and mapping counts. Results of these comparisons using Wilcoxon Matched-pairs Signs Rank Test are shown in Table 4.

TABLE 1

Status, breeding biology and best census methods for bird species recorded on the Woodlots between 1976 and 1981

BIRD SPECIES		Breeding confirmed WL1	Breeding confirmed WL2	STATUS[a]	BREEDING[b] BIOLOGY	SAMPLED BY[c] CENSUS METHOD (S)	BEST CENSUS METHOD (S)
Wood Duck	*Chenonetta jabata*			V		T	
Square-tailed Kite	*Lophoictinia isura*		B	V		T	
Whistling Kite	*Haliastur sphenurus*			U		T,NS	T
Collared Sparrowhawk	*Accipiter cirrhocephalus*			U		T	
Brown Goshawk	*A. fasciatus*	B	B	U		T,NS	T,NS
Little Eagle	*Hieraaetus morphnoides*			V		T	
Swamp Harrier	*Circus aeruginosus*			V		T	
Little Falcon	*Falco longipennis*			V		T	
Brown Falcon	*F. berigora*			U		T	
Nankeen Kestrel	*F. cenchroides*			V		T	
Yellow-tailed Black Cockatoo	*Calyptorhynchus funereus*			C		T	T
Gang-gang Cockatoo	*Callocepalon fimbriatum*	B		C	H	T	T
Galah	*Cacatua roseicapilla*			U		T	
Sulphur-crested Cockatoo	*C. galerita*			C		T	
King Parrot	*Alisterus scapularis*			V		T	
Crimson Rosella	*Platycercus elegans*		B	C	H,Co	T,NS,MN	T,NS
Eastern Rosella	*P. eximius*			U		T	
Brush Cuckoo	*Cuculus variolosus*			U		T,MN	T
Pallid Cuckoo	*C. pallidus*			U		T	
Fan-tailed Cuckoo	*C. pyrrhophanus*	B		C	P	T,MN	T
Hors field's Bronze Cuckoo	*Chrysococcyx basalis*			U		T	
Golden Bronze Cuckoo	*C. lucidus*			C		T	T
Tawny Frogmouth	*Podargus strigoides*	B	B	U		T	
Spine-tailed Swift	*Hirundapus caudacutus*			C		T	
Laughing Kookaburra*	*Dacelo novaeguineae*	B	B	C	H,S	T,NS,MN	NS,(TM)*
Sacred Kingfisher	*Halcyon sancta*		B	U	H	T,MN	NS,(TM)*
Superb Lyrebird	*Menura novaehollandiae*	B		C		T	NS
Welcome Swallow	*Hirundo neoxena*			C		T	
Tree Martin	*Cecropis nigricans*		B	C	H,Co	T,MN	T
Australian Pipit	*Anthus novaeseelandiae*			V		T,MN	
Black-faced Cuckoo-shrike	*Coracina novaehollandiae*	B	B	C		T,NS	T
Little Cuckoo-shrike	*C. papuensis*		B	U		T	
White-winged Triller	*Lalage sueurii*			V		T	
Ground Thrush	*Zoothera dauma*	B		U		T,NS,MN	MN
European Blackbird	*Turdus merula*			U/I		T	
Rose Robin	*Petroica rosea*	B		U		T,MN	NS,TM
Flame Robin	*P. phoenicea*	B	B	C		T,NS,TM,MN	NS,TM
Scarlet Robin	*P. multicolor*	B	B	C		T,NS,TM,MN	NS,TM
Eastern Yellow Robin	*Eopsaltria australis*	B	B	C		T,NS,TM,MN	TM,NS
Crested Shrike-tit	*Falcunculus frontatus*	B	B	C		T,NS,TM,MN	T,NS
Olive Whistler	*Pachycephala olivacea*			U		T	
Rufous Whistler	*P. rufiventris*	B	B	C		T,TM,NS,MN	NS,TM
Golden Whistler	*P. pectoralis*			C		T,TM,NS,MN	T
Grey Shrike-thrush	*Colluricincla harmonica*	B	B	C	H	T,NS,TM,MN	T,NS,TM
Black-faced Flycatcher	*Monarcha melanopsis*	B		U		T,MN	
Restless Flycatcher	*Myiagra inquieta*		B	U		T,MN	
Leaden Flycatcher	*M. rubecula*			U		T,MN	
Satin Flycatcher	*M. cyanoleuca*	B	B	C	Co	T,NS,MN	NS
Rufous Fantail	*Rhipidura rufifrons*	B		U		T,MN	T
Grey Fantail	*R. fuliginosa*	B	B	C		T,NS,TM,MN	NS,TM
Willie Wagtail	*R. leucophrys*		B	C		T,NS,MN	T

BIRD SPECIES		Breeding confirmed WL1	Breeding confirmed WL2	BREEDING BIOLOGY[b]	STATUS[a]	SAMPLED BY CENSUS METHOD (S)[c]	BEST CENSUS METHOD (S)
Eastern Whipbird	*Psophodes olivaceus*			U		T	T
Superb Blue Wren	*Malurus cyaneus*	B	B	C	S	T,TM,NS,MN	TM,NS
White-browed Scrubwren	*Sericornis frontalis*		B	C		T,TM,MN	T
Brown Thornbill	*Acanthiza pusilla*	B	B	C		T,NS,MN,TM	T,TM
Buff-tailed Thornbill	*A. reguloides*	B		C	S	T,NS,MN,TM	T
Striated Thornbill	*A. lineata*	B	B	C	S	T,NS,MN,TM	T
Yellow-tailed Thornbill	*A. chrysorrhoa*		B	C	S?	T,NS,MN,TM	T
Orange-winged Sittella	*Daphoenositta chrysoptera*	B		U		T,MN	T
White-throated Treecreeper	*Climacteris leucophaea*	B	B	C	S?,H	T,TM,NS,MN	MN,T,NS,TM
Red-browed Treecreeper	*C. erythrops*	B	B	C	S,H	T,TM,NS,MN	MN,NS,TM
Red Wattlebird	*Anthochaera carunculata*		B	C		T,MN	T
Yellow-faced Honeyeater	*Lichenostomus chrysops*	B	B	C		T,NS,MN	T
White-eared Honeyeater	*L. leucotis*			C		T,MN	T
Brown-headed Honeyeater	*Melithreptus brevirostris*			U		T,MN	T
White-naped Honeyeater	*M. lunatus*	B	B	C	S,Co	T,NS,MN	NS
Crescent Honeyeater	*Phylidonyris pyrrhoptera*			U		T,MN	T
Eastern Spinebill	*Acanthorhynchus tenuirostris*	B		C		T,MN	T
Mistletoebird	*Dicaeum hirundinaceum*			U		T	T
Spotted Pardalote	*Pardalotus punctatus*	B	B	C	H	T,NS,TM,MN	NS,TM
Striated Pardalote	*P. striatus*	B	B	C	H	T,NS,TM,MN	NS,TM
Silvereye	*Zosterops lateralis*			C		T,MN	T
European Goldfinch	*Carduelis carduelis*			C/I		T,MN	T
Red-Browed Finch	*Emblema temporalis*	B		C		T,MN	T
Olive-backed Oriole	*Oriolus sagittatus*	B		U		T	NS,(TM)*
Satin Bowerbird	*Ptilonorhynchus violaceus*			U		T	T
White-winged Chough	*Corcorax melanorhamphos*		B	U	S	T,NS	NS
Magpie Lark	*Grallina cyanoleuca*			U		T	T
Dusky Woodswallow	*Artamus cyanopterus*		B	C	Co	T,NS,MN	T,NS
White-browed Woodswallow	*A. superciliosus*		B	V	Co	T,NS,MN	NS
Australian Magpie	*Gymnorhina tibicen*			C		T,MN	T
Pied Currawong	*Strepera graculina*			C		T	T
Grey Currawong	*S. versicolor*	B		C		T,NS,TM	NS,(TM)*
Australian Raven	*Corvus coronoides*			C		T	T
Little Raven	*C. mellori*			V		T	T

a. C = Common; Regular occurrence; U = Uncommon; Irregular occurrence
V = Vagrant; Not normally present.

b. S = Social Nesting; H = Hollow nester; Co = Colonial or Group Nesting.

c. T = Transect; NS = Nest search; TM = Territory Map; = Mist Net.

* at least 20 ha needed for Territory Mapping.

English names of some species referred to in text do not conform to List of Recommended English Names. This has been accepted for publication in this form as the paper is one of a series published in a number of journals.

TABLE 2

Number of individuals recorded on Woodlots 1 and 2 by the four census methods in December 1979 and 1980 for those species analysed in detail.

WOODLOT 1	1979				1980				WOODLOT 2	1979				1980		
	Transect Counts (IX)	Territory Mapping	Nest Search	Mist Netting	Transect Counts (IX)	Territory Mapping	Nest Search	Mist Netting	Transect Counts (IX)	Territory Mapping	Nest Search	Mist Netting	Transect Counts (IX)	Territory Mapping	Nest Search	Mist Netting
Flame Robin	6	8	8	5	8	5	2	3	4	9	10	6	8	13	6	7
Scarlet Robin	4	5	0	2	4	6	6	1	1	2	4	1	1	2	4	1
Eastern Yellow Robin	2	6	8	5	5	6	0	0	7	16	2	10	4	10	8	1
Rufous Whistler	15	11	16	2	16	9	10	1	20	16	16	5	16	14	16	1
Satin Flycatcher	11	N/A	16	2	7	N/A	8	0	10	N/A	2	1	4	N/A	6	1
Grey Fantail	24	24	30	5	19	24	14	0	28	21	24	1	19	21	32	2
Superb Blue Wren	13	12	2	2	5	12	6	1	16	12	0	6	5	12	0	3
White-throated Treecreeper	8	3	0	7	6	4	2	5	11	4	4	7	7	3	2	1
Red-browed Treecreeper	1	3	2	5	2	3	0	1	2	4	2	7	3	3	2	0
White-naped Honeyeater	34	N/A	22	5	19	N/A	8	3	46	N/A	32	6	23	N/A	18	1

Except for Woodlot 1 in 1980, transect counts, territory mapping and nest searches provided similar estimates of the numbers of the 10 species considered (Table 2). There was a significant difference between transect counts and nest searches, and between territory mapping and nest searches on Woodlot 1 during December 1980. We believe that this was due to the drought conditions that prevailed through 1980 on the Southern Tablelands and which led to an earlier than normal cessation of nesting on Woodlot 1. The more uniform forest with its closer canopy on Woodlot 2 apparently buffered nesting birds from the drought better than the open woodlands on Woodlot 1. Mist net results differed from transect counts, territory mapping and nest searches. The differences were significant ($p \leq 0.05$) in 6 of the 12 comparisons and nearly significant in four others.

The number of different individuals of the ten species analysed in detail caught in mist nets from September/October to January was significantly greater than the number caught in December (Table 3). Similarly the number of breeding pairs identified by nest searches over the entire breeding season (August-January) was significantly greater than the number of pairs breeding in December. If the numbers of birds estimated by the seasonal mist net captures and nest searches are compared with the numbers estimated by the December transect counts and territory mapping, the four procedures provide similar estimates of abundance (Table 4). The only significant difference was on Woodlot 2 in 1980 where the number of pairs located by nest searches over the season was greater than the number of individuals recorded on the December transect counts. This may again be a drought effect as an unusually large number of pairs attempted to nest early in the season during 1980 and most of these had finished by December.

TABLE 3

The total number of individuals caught in mist nets or estimated from the number of nests located on the Woodlots during spring and summer in 1979 and 1980.

	Mist Net				Nest Search			
	WL1/79	WL1/80	WL2/79	WL2/80	WL1/79	WL1/80	WL2/79	WL2/80
Flame Robin	47	29	55	20	10	8	18	20
Scarlet Robin	5	5	6	10	8	14	6	4
Eastern Yellow Robin	12	5	15	4	16	14	28	20
Rufous Whistler	10	3	14	6	18	14	20	24
Satin Flycatcher	5	0	2	2	14	20	10	12
Grey Fantail	10	8	21	9	50	62	28	34
Superb Blue Wren	6	10	9	11	2	12	6	2
White-throated Treecreeper	9	7	10	4	0	2	6	6
Red-browed Treecreeper	7	4	10	5	2	2	8	10
White-naped Honeyeater	27	16	44	8	14	18	66	58

Individual Species

In the following we consider each of the 10 species analysed in detail and discuss which method(s) were most useful for estimating numbers.

Flame and Scarlet Robins

Flame Robin *Petroica phoenicea* and Scarlet Robin *P. multicolor* nested on both woodlots, but were absent during winter. The numbers of these robins were underestimated by the transect method. Although males are brightly coloured and sang loudly, females were inconspicuous and were often missed during transect counts. This was especially so when nesting as the females appeared to do most of the incubation.

Territory mapping appeared to provide the most accurate population estimate for both species (Table 2). This is because the breeding cycle was regular, because pairs were territorial and because most individuals were colour-banded. Nest searching alone provided population estimates similar to territory mapping and was an essential part of that procedure. Nest searching was relatively efficient as nests were not difficult to find. However, it was necessary to monitor nests closely, as re-nesting was common and pairs exchanged mates.

Although it was easy to catch robins (their foraging behaviour brings them within mist net

TABLE 4

Significance of differences in the numbers of ten common species sampled by each of the four census procedures.

Pair of census method	WL1/79	WL1/80	WL2/79	WL2/80
T. x TM.	NS	NS	NS	NS
T. x Nest	NS	$p < .05$	NS	NS
T. x MN.	NS*	$p < .02$	NS*	$p < .01$
TM. x MN.	NS	$p < .02$	NS*	$p < .01$
TM. x Nest	NS	$p < .01$	NS	NS
MN. x Nest	NS*	$p < .05$	NS	$p < .02$
Nest/Season x Nest/Dec.	$p < .01$	$p < .01$	$p < .01$	$p < .01$
MN/Season x MN/Dec.	$p < .01$	$p < .01$	$p < .01$	$p < .01$
Nest/Season x Transect	NS	NS	NS	$p < .02$
Nest/Season x TM.	NS	NS	NS	NS
Nest/Season x Transect	NS	NS	NS	NS
MN/Season x TM.	NS*	NS	NS	NS

Test: Wilcoxon Matched-pairs Signed Ranks Test.
H_0 : All census methods give equal estimates of bird populations of the ten species listed in Table 3.
* Not significant at .05, but $p < .10$.
T. = Transect. TM. = Territory Map.
MN. = Mist Net. Nest = Nest search.

range), netting underestimated numbers. Netting, however, provided considerable additional information about the biology of Flame Robins. During late summer, large numbers of apparently nomadic sub-adult birds moved through the woodlots (Recher *et al* 1983a). Although this influx was registered on the monthly transect census, without the information from mist net captures the residency status and age of these birds would have been in question.

Eastern Yellow Robin

The Eastern Yellow Robin *Eopsaltria australis* was a year round breeding resident. Although common, Eastern Yellow Robins were underestimated on transect counts. Like female Flame and Scarlet Robins, Eastern Yellow Robins were cryptic and easily missed on a count where time was limited and the observer was restricted to following a central path.

Territory mapping, where no time limit was imposed and the plots were searched thoroughly, allowed observers to locate birds and plot territories. The sedentary habits of these birds work to the advantage of mapping procedures; simultaneous registrations were facilitated and discrete clusters of observations were numerous. Eastern Yellow Robins were easy to net and most residents were colour banded which greatly assisted mapping individual ranges The principal difficulty concerned the species' communal breeding habits with as many as five birds observed in association on one breeding territory.

Nests were easy to find and the numbers of pairs estimated by nest searches over the breeding season was similar to those estimated by mapping. Eastern Yellow Robins were seriously affected by the drought and in 1980 nesting had finished by early November. Estimates of numbers by nest searches in December 1980 were therefore misleading.

Mist netting gave an intermediate estimate of Eastern Yellow Robin numbers in 1979 and a low estimate in 1980 (Table 3). The drought appeared to affect the foraging behaviour of Eastern Yellow Robins and birds foraged higher in the vegetation where they were less likely to be netted. Eastern Yellow Robins are long-lived and sedentary and it is possible that they learn to avoid mist nets especially when fixed net positions are used.

Rufous Whistler

Rufous Whistlers *Pachycephala rufiventris* were abundant breeding migrants on the study plots. Males and females were conspicuous and a slightly higher estimate was obtained from transect counts than from mapping or nest searches. Transect counts included individuals at the edges of the plot which did not nest or maintain territories within the woodlots but which foraged there. Nests were obvious and easy to monitor. Rufous Whistlers foraged within the height range of mist nets (0-3 m) and most residents were colour banded. However, individuals are long-lived and after being handled once or twice learned to avoid nets. As we had colour banded most residents prior to 1979, mist netting was ineffectual as a procedure to estimate the numbers of Rufous Whistlers during 1979 and 1980.

Satin Flycatcher

An abundant breeding migrant on both woodlots, the numbers of Satin Flycatcher *Myiagra cyanoleuca* appear to have been accurately assessed by transect counts (Table 2). Both sexes were conspicuous, due to loud calls and songs, bright colours and active foraging behaviour.

Satin Flycatchers nested in loose colonies on small portions of each grid. Territory mapping procedures were therefore not applicable. Maps showed clusters of registrations around the nesting colonies which could not be assigned to particular individuals or pairs. Because Satin Flycatchers foraged mostly in the forest canopy, few birds were colour banded and mist netting was not a reliable census procedure. Nests were easy to locate and monitor and nest searches over the breeding season (November and December) gave an accurate population estimate. However, it was necessary to adjust for renesting and the number of active nests at any one time was usually less than the number of breeding pairs.

Grey Fantail

The Grey Fantail *Rhipidura fuliginosa* was one of the most numerous birds on the plots. Their active behaviour, querrulous intraspecies nature, frequently given song and habit of building supernumerary nests made them a confusing species to census. It was easy to double count

birds using transect census procedures, and our estimate from this method was inflated.

Territory mapping was made difficult by the sheer number of registrations, the relatively large areas that individuals moved over, and the small number of colour banded birds. The resultant maps were difficult to interpret, but in combination with nest searches, territory mapping probably gave the best population estimate. Nest search figures were inflated by supernumary nests and to be accurate required daily monitoring of nests. Grey Fantails were not easy to net, and netting is not a useful census procedure for this species.

Superb Blue Wren

The Superb Blue Wren *Malurus cyaneus* was a common species on Woodlot 1, but was restricted to the edges of Woodlot 2. Superb Blue Wrens are communal breeders and groups were easily located and recorded on transect counts. However, numbers were sometimes overestimated due to double counting of individuals.

Groups of wrens maintained territories, and mapping procedures proved satisfactory for plotting their distribution. As fewer than half the birds were colour banded, the main difficulty in mapping was determining the number of individuals in a group. Nests were easy to find, but nest searches did not provide an accurate estimate of numbers of individuals. The ratio of nests to individuals was low, with many subdominant individuals associated with each nest. Nest locations, however, accurately represented the distribution of territories.

Superb Blue Wrens were regularly caught in mist nets, but seasonal data gave a better estimate of numbers than those from a single month. Superb Blue Wrens may learn net posi- with the information communicated to all members of the group thereby reducing the chances of netting new birds.

White-throated and Red-browed Treecreepers

White-throated *Climacteris leucophaea* and Red-browed *C. erythrops* Treecreepers were common year round residents. Because of its loud and distinctive calls and foraging activities, the White-throated Treecreeper was easy to record on a transect census. The Red-browed Treecreeper, a less vocal species, was harder to locate. It was therefore possible to overestimate the numbers of the former by counting individuals twice and to underestimate the latter by over-looking individuals on transect censuses.

Mapping was possible with both species, but territories were larger than 10 ha and adjacent pairs overlapped. Red-browed Treecreeper nests were attended and territories occupied by more than two birds, but White-throated Treecreepers nested in pairs. Mist netting was an effective means of monitoring treecreeper populations. Treecreepers were easy to net and frequently re-captured. Aside from periods of adverse weather (e.g. December 1980), mist net captures gave the highest and probably the best estimate of population densites.

White-naped Honeyeater

White-naped Honeyeaters *Melithreptus lunatus* were the most numerous birds on the woodlots. They were active, gregarious, noisy and highly visible and their numbers were difficult to estimate on a transect census. Many counts were inflated by repeated counting of the same individuals or flock as these moved rapidly from place to place along the transect.

White-naped Honeyeaters nested in loose colonies. The birds were not territorial and territory mapping was not possible. However, nests were easy to locate and nest searches provided an accurate count of the number of breeding pairs or groups on the plots. More than two birds were often in attendance at a nest which complicated estimating the number of individuals from the number of nests. The height of the nests in the canopy and the rapid movements of the birds made it difficult to use colour band combinations to identify individuals.

Although large numbers were caught, mist netting underestimated the number of White-naped Honeyeaters. This was particularly obvious during the adverse netting conditions experienced in 1980. White-naped Honeyeaters, although they forage in all parts of the forest, spend most of their time in the canopy and out of mist net range. Seasonal mist net results provided a better estimate of numbers than any single month.

Discussion

Each of the methods appeared to provide accurate and repeatable estimates of abundance

for at least a few species of forest birds. The transect method was the only procedure we tested which sampled the entire avifauna. Territory mapping was restricted to birds which occupied relatively small territories or home ranges. When combined with nest searches and colour banding, mapping gave the best estimate of absolute abundance. By itself, searching for nests provided a useful index of the abundance of nesting birds and often gave the same answer as mapping. Mist netting was the least reliable method and did not sample any of the larger species (e.g. parrots and raptors) or birds which spent most of their time in the canopy (e.g. *Myiagra* fllycatchers).

In theory the transect method should have counted non-breeding and transient individuals as well as breeding residents. In practice resident individuals and breeding birds were more conspicuous than transients and non-breeding individuals and were therefore more likely to be detected during a count. Singing, territorial defence and nesting behaviour tended to make breeding birds easy to detect. Even outside the breeding season residents were probably more conspicuous than transients. For example, residents may adjust to the presence and activities of people and are thereby less likely to be repulsed than transients which may be at first wary of people.

Mapping and nest searches only sampled breeding residents although mapping would be useful for censusing sedentary species (e.g. thornbills, treecreepers) outside the breeding season. Potentially mist nets sampled all individuals irrespective of their breeding or residency status. However, resident birds may learn to avoid nets after being captured or by observing other individuals caught in the nets.

Transect counts

The use of strip transect procedures in eucalypt forests and woodlands and factors which affect census results are considered by Loyn (1980), Recher *et al* (1983b), Kavanagh and Recher (1983) and Pyke and Recher (in press). There was considerable variability in the number of individuals registered during the four counts of a census. Part of this variation resulted from differences between observers (Kavanagh and Recher 1983), but differences between early and late morning counts and changes in weather between census days also affected results. The number of individuals estimated by the transect method should be viewed as an index of relative abundance and not as an estimate of absolute density. A transect census required 16 hours on each woodlot and could be completed by one person in four days.

Territory Mapping

Territory mapping is generally considered the most accurate census method for breeding birds in the Northern Hemisphere (Robbins 1978) and is arguably the most widely used census method in America and Europe (Berthold 1976). Although one major study has recently employed this method (Loyn 1980), it has not received extensive use in Australia (Recher in press). Territory mapping can only be used to count birds which are resident. Mapping is also labour intensive. On our study plots, territory mapping required 35 to 40 hours of field work on each woodlot by one person. Our experience agrees with the conclusions of Dawson (1981) who indicated that territory mapping is not the most efficient procedure to use where estimates of relative abundance as opposed to absolute densities of breeding birds are sufficient.

We were able to map territories or home ranges for less than half the species which occurred on the study plots during the breeding season (Table 1). For these birds mapping procedures appeared to provide an accurate assessment of the numbers of breeding individuals. The species we could not map had ranges greater than 10 ha or were not territorial. Many were highly social. We were not able to map any of the birds of prey, cuckoos, kingfishers, parrots, swallows, woodswallows, honeyeaters, ravens, currawongs or finches which used our study areas. This does not mean that these birds did not have territories, only that 10 ha was too small to accommodate their movements.

A number of Australian birds are communal nesters with more than two individuals cooperating in rearing young (Rowley 1965, Dow 1980). This caused problems in estimating numbers. It was often difficult to determine the number of birds associated with a territory, and it was possible that some individuals moved between groups. For example, White-naped Honyeaters may have fed young at more than

one nest. Furthermore, group size was not constant and changed through the season.

At least four of the species whose ranges we could map were assisted by immatures from a previous brood (Table 1). Because of the variation in group size and the absence of accurate information on the numbers of birds associated with any particular nesting unit, all territories and nests were considered to represent two birds. This underestimated the numbers of social nesting species as measured by territory mapping. The same problem was encountered with the nest search census method.

In Table 1 we indicate the method which appeared to give the best estimate of numbers for each species. Territory mapping was a good method for 19 of 60 species or one third of the avifauna regularly present during censuses. Better estimates of density could have been obtained and additional species mapped had the size of the study plots been increased to 20 ha. The effort required to survey 20 ha would have prevented us from carrying out other studies, and, in our case, was not practicable.

Nest Search

Nest location helped in establishing the relative positions of pairs and provided an estimate of numbers of non-territorial species nesting on the woodlots. A number of workers cited by Berthold (1976) recommended combining territory mapping with intensive nest searches as the best way to measure breeding bird populations. This, of course, is what we did, but it is worth considering what nest searching by itself can contribute to an understanding of bird numbers.

Important considerations in conducting a nest census is the possibility of disturbing nesting birds and causing desertion of the nest. Therefore as many observations as possible were made from a distance. There is also the risk that repeated visits to a nest will attract predators. We marked nests with coloured surveyors tape and learned that predators (probably Pied Currawong *Strepera graculina* and Grey Currawong *S. versicolor*) quickly learned to associate the tapes with nests. After this discovery, tapes were placed at least two metres from the nest.

Most nests were located while carrying out other studies but from time to time special effort was made to locate particular nests or to confirm that nests had not been overlooked. It is therefore difficult to say exactly how much time was spent solely on nest searching. A conservative estimate is that nest searching alone required about as much time as territory mapping (35 to 40 hours). No species was regarded as impossible to census using this method although many required considerable patience. For example parrots visited their nest hollows infrequently, several species were reluctant to return to their nest in the presence of an observer, and there was some difficulty in determining whether hollow nesting species were nesting in a hollow or merely inspecting it.

Aside from the practical difficulties, complications arose as a result of the asynchronous breeding cycles of the birds on the study plots. At Bombala, nesting began in July and continued through January (Recher *et al* 1983a). Not all species nested at the same time and many renested repeatedly. Some, like the Grey Fantail, built supernumary nests. Many resident species, such as the Eastern Yellow Robin, nested throughout the spring and summer and did not appear to nest more abundantly at one time or another. However, the length of the breeding season did provide more time to determine the location and status of nests. Migrant species, like the Rufous Fantail *R. rufifrons* or the Satin Flycatcher, which had a compressed breeding season, were less difficult. In the case of migrants, all individuals were involved in nesting activities immediately upon their return and were exceptionally conspicuous.

Over the course of the breeding season, nest searches provided accurate information on numbers of nesting pairs for 24 species or 40 per cent of the avifauna (Table 1). However, this was possible only because more than half the birds on our plots were colour banded. We could track individuals as they re-nested, determine the number of individuals associated with each nest and deal with the other complications noted above. As with territory mapping, nest searching did not provide information about non-breeding birds and did not account for the birds which used the study area but nested elsewhere.

In our view, nest searching is best combined with territory mapping. Colour banding facilitates both methods. If the objective of the study is

to determine the numbers of breeding birds, territory mapping and nest searches need to be done throughout the breeding season. In south-eastern forests, this means beginning studies in late winter. If this is not done, the observers must understand that they are sampling only part of the breeding avifauna.

Mist Netting

Mist nets are a useful census procedure (MacArthur and MacArthur 1974, Karr 1981). However, there is the implicit assumption that species are equally easy to net at all times and at all places. If this assumption is correct and the same procedures are followed throughout, the numbers of birds netted can be compared and used as an index of seasonal trends or of different densities in different habitats. However, neither all species nor all individuals are equally easy to net.

Mist netting was the least reliable method used at Bombala and tended to underestimate the numbers of birds of all species netted. There are a number of reasons for this. Mist nets are most useful in habitats with dense shrub and ground vegetation where visibility is poor and it is difficult to detect birds by other means. The woodlots lacked dense vegetation. Visibility was excellent and other census procedures could be used which gave more accurate counts. Moreover, the openness of the plots probably made it easier for birds to detect and avoid the nets.

Mist nets also appeared to be affected more by weather conditions than transect counts or territory mapping. The affectiveness of the nets in catching birds was adversely affected by light winds which did not reduce our ability to detect birds by sight or sound. Birds could detect nets which were in the sun. Moreover, on warm and still days, birds seemed to move less and were therefore less likely to be netted. The smaller number of birds caught in 1980 when compared to 1979 is largely the result of different weather conditions. Throughout 1980 the days on which we netted were warm with gusty winds developing by early morning. It is also possible that the numbers of birds and their behaviour were were affected by drought (Recher *et al* 1983a). By 1980 many residents may also have learned where the nets were and avoided them.

Mist netting required 12 hours of fieldwork on each woodlot, but we needed a minimum of four people on each plot to remove birds from the nets, make measurements and put on bands. Mist netting therefore required a minimum of 48 person-hours. Putting up nets ,closing them at the end of a day and taking them down again required another 24 person-hours, giving a minimum commitment of 72 hours to net each plot each month. Comparing person-hours spent, it is obvious that mist netting was the most time consuming method used in this study. Mist netting would not have been possible at this level of sampling if we had not been able to make use of all personnel, regardless of their ornithological training. It was possible to instruct assistants on mist netting procedures in a relatively short period of time, whereas the other methods required individuals with extensive experience and a knowledge of the local avifauna.

Although our monthly netting programme amounted to 216 net hours on each woodlot for the spring and summer, the sampling period of only 12 hours over two days may have been too brief for an accurate estimate of numbers. The total number of individuals netted each season is closer to the estimates obtained by transect counts and terrtory mapping (Table 3). Obviously, with enough effort all the individuals of species that come within mist net range could be sampled by netting.

Conclusions

No one method satisfied all our requirements. Each of the four methods was useful and the procedures followed in the Northern Hemisphere were reliable under Australian conditions. However, observers must account for communal nesting, non-territorial species and a prolonged nesting season.

What census method is used depends largely on the type of questions asked and the time and people available for the work. Transect counts provide a reliable index of bird numbers (Recher *et al* 1983b). If an accurate estimate of density is required, it would be better to combine territory mapping with nest searches. The use of colour banded birds enhances the value of mapping and standard netting procedures provide an independent index of numbers. Mapping and netting, however, sample only part of the forest avifauna.

Acknowledgements

The work of the Australian Museum at Bombala was supported by a grant from Harris-Daishowa Pty. Ltd. The Forestry Commission of New South Wales provided facilities at Bombala and foresters from the Bombala office provided helpful assistance with the mist-netting programme. Rod Kavanagh reviewed an earlier draft of the manuscript and provided many useful comments. Among others, Greg Gowing, Rod Kavanagh, Wyn Rohan-Jones, Peter Smith and Martin Schulz helped in the field.

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