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IMPORTANCE OF SAMPLING DURATION AND STRIP WIDTH IN USE OF THE FIXED-WIDTH STRIP TRANSECT METHOD FOR ESTIMATION OF BIRD ABUNDANCE AND SPECIES DIVERSITY

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The fixed-width strip transect method is increasingly becoming an important bird sampling technique in Australia. In this survey, different sampling durations and strip widths were evaluated for the sampling of birds in Yellow Box woodland remnants in the ACT.

The survey showed that the choice of sampling duration and strip width had a significant effect on the estimation of bird abundance and species diversity using the fixed-width strip transect method in Yellow Box woodland remnants. Different measures of bird abundance and species diversity were also found to vary in sensitivity with changes in strip width. Use of the logarithm link function to analyse bird counts further demonstrated that the appropriate strip width will depend upon the flocking behaviour of the birds. It is evident from this survey that there is a need for more intensive surveys to develop and validate the fixed-width strip transect method for the sampling of birds in savannah eucalypt woodlands. Until that is done, it is inappropriate to compare results between studies which employ the fixed-width strip transect method, but use different sampling durations and strip widths.

INTRODUCTION

Various sampling techniques have been used by ornithologists to estimate bird abundance and species diversity in Australia. Use of these techniques and associated problems in Australia have been reviewed by Recher (1984, 1988). Attention has been drawn to some of the deficiencies of the fixed-width strip transect method, compared to other methods (e.g. Davies 1982; Arnold 1984; Shields and Recher 1984; Bell and Ferrier 1985; Hewish and Loyn 1989), but, despite its shortcomings, the fixed-width strip transect method has remained popular with Australian ornithologists. This is evidenced from a review of papers on the estimation of bird populations (excluding single species studies) published in *Corella* and *Emu* between January 1980 and March 1994 (Table 1). 42 per cent (15 studies) of studies reviewed used the fixed-width strip transect method.

Use of the fixed-width strip transect method rests on a number of assumptions: (1) all birds within the strip are detected; (2) all birds are correctly identified; (3) no bird moves into or out of the strip in response to the moving observer; (4) no bird is counted more than once; (5) no errors are made in determining whether a bird is within the strip; and (6) detections are independent events, especially when results from more than one transect are pooled (Burnham *et al.* 1980; Verner 1985; Bibby *et al.* 1992; Buckland *et al.* 1993). Violation of any of these assumptions may bias resulting estimates, which may also be influenced by the transect length, sampling duration and strip width (Burnham *et al.* 1980; Verner 1985; Recher *et al.* 1983; Pyke and Recher 1984; Bibby *et al.* 1992; Buckland *et al.* 1993), amongst other factors, such as species detectability (Bell and Ferrier 1985), observer (Kavanagh and Recher 1983) and environmental variation (Arnold

TABLE 1

Methods used to estimate abundance of bird populations (excluding single species studies) (*Emu* and *Corella*, Jan. 1980–Mar. 1994).

Method	Emu Number of Papers	Corella Number of Papers	Total
Fixed-width Strip Transect	7	8	15
Area Search	6	3	9
Point Count	3	2	5
Territory Mapping	3	1	4
Mist Netting	1	2	3

1989). Effects of sampling duration and strip width in the use of the fixed-width strip transect method in Australia have only been studied in rainforest and wet sclerophyll forest in New South Wales (Harden *et al.* 1986). There has been no similar study in savannah eucalypt woodland, a more open habitat, where results may not be comparable. It must be emphasized that while the effects of sampling duration have been studied with respect to the area search method in Australia (Loyn 1986; Slater 1994), the results cannot be used as a guide for the fixed-width transect method as birds are in closer contact with the observer in the area search method than in the fixed-width strip transect method.

The survey described here was conducted as a preliminary to a study on the effects of patch characteristics on bird species diversity in Yellow Box *Eucalyptus melliodora* woodland remnants in the ACT. The fixed-width strip transect method was selected because of its demonstrated simplicity, efficiency and repeatability in the sampling of birds in Wandoo woodland remnants (Arnold 1984, 1988; Arnold *et al.* 1987). We report on the effects of varying sampling duration and strip width on estimates of four different variables: the Shannon-Wiener species diversity index (H); bird population density; the number of bird occurrences per transect; and the number of bird species per transect.

STUDY SITES AND METHODS

Study sites

Three Yellow Box woodland remnants in the Australian Capital Territory were selected for this study: Ainslie Nature Reserve (35°17′00″S, 149°09′00″E) (650 ha); Stirling Park Ridge (35°18′30″S, 149°06′00″E) (12 ha); Callum Brae (35°21′50″S, 149°07′40″E) (750 ha). All three remnants are open woodland dominated by *Eucalyptus melliodora* and *E. blakelyi*, interspersed with *E. mannifera* and *E. bridgesiana*. Understorey consists mainly of grasses and herbs with scatterered regenerating shrubs.

Experimental set-up

In each of the three remnants a single survey site was subjectively chosen on the basis of uniformity in vegetation structure. Sites were at least 200 m from the boundaries to reduce edge effect. At each site, three 50 m transects were set up parallel to and 80 m from each other. Transects were set out, using a 50 m measuring tape and a prismatic compass, and the boundaries were marked with flagging tape at intervals of 10 m.

Results from nine combinations of three strip widths (40, 60 and 80 m) and three sampling durations (5, 10 and 15 min) were compared. Each combination was sampled once in each transect, so that each site was sampled 27 times (three transects × nine combinations). Three days were required to complete sampling of each site, but it was not possible to make these consecutive due to the need to change the strip widths and also because of unfavourable weather.

On each day, strip width was held constant at a particular site, while sampling duration was varied consecutively across all three transects (i.e. 5 min for transect 1, 2 and 3, followed by 10 min for transects 1, 2 and 3 etc.). Transects were sampled in the same order each day for each sampling duration to remove any effects of time of day or location (Harden *et al.* 1986). Between-day effect was minimized by ensuring that sampling was confined to the period between 0700 to 0900 hours on each day (Keast 1984; Blake *et al.* 1991) and days without rain or strong wind (Robbins 1981). One observer made all observations to avoid observer variation.

The survey was completed between 22 December 1993 and 5 February 1994.

Sampling procedure

The observer travelled along the centre line of each transect at a steady rate, checking the time at 10 m intervals to achieve uniform speed. Bird species and numbers within the transect strip were recorded only when birds were seen. Bird calls were used to locate birds and to aid identification. Birds seen flying overhead were noted, but not recorded except when they appeared to be hunting (e.g. raptors) or foraging in the air space above the vegetation (e.g. swallows). The position of each bird when first detected and all bird movements were marked on a map of the transect, as recommended by Recher *et al.* (1983). This helped to keep track of individuals during the survey and reduced the probability of repeated counts. When necessary, the observer deviated slightly from the centre line (±3 m) to confirm the identity or number of birds detected.

Calculation and statistical analysis

The Shannon-Wiener species diversity index (H) was calculated as,

$$H = -\sum_{i=1}^{S} P_i (\log_2 P_i)$$

S = number of species, P_i = proportion of total sample belonging to i[th] species (Krebs 1989).

Bird population density was calculated as the number of individual birds per hectare of transect area.

Statistical analysis involved the establishment of a model with site, and transect nested within site, as random effects, and sampling duration, strip width and the interaction term being fixed effects. This was applied in an ANOVA framework for the analysis of the Shannon-Wiener species diversity index and bird population density. A natural logarithm transformation was applied to bird population density to ensure homogeneity of variance.

The same model was further applied as a generalized linear model for the number of bird species per transect and the number of individual birds per transect. We assumed Poisson-distributed responses and a logarithm link function (McCullagh and Nelder 1989). The responses are counts which should not be analysed by ANOVA techniques because the key assumption of normaliy distributed errors tends to be violated. However, biological counts of such nature may assume a negative binomial or bimodal distribution rather than a Poisson distribution due to the tendency of species to clump or flock together (Krebs 1989). This phenomenon of flocking then required us to test for any violation of the assumption of a Poisson distribution.

Flocking is manifested as an inflation in the residual mean deviance (*rmd*) resulting from fitting the model. We required that the *rmd* not be greater than 1, the value inherent to the Poisson distribution. From Table 2, we observed that this was substantially below 1. Furthermore, examination of the distribution of the responses, residual plots and Cook's statistics showed no departure from the Poisson distribution.

RESULTS AND DISCUSSION

Variation of sampling duration

An increase in sampling duration brought about a significant increase in the resulting estimates of the Shannon-Wiener species diversity index, the number of individual birds per transect, the number of bird species per transect, and bird population density (significance level, $p < 0.001$, Table 2). A longer sampling duration provided extra time for confirmation of bird species and counts. Also, the faster an observer travels (shorter sampling duration), the less attention can be given to areas further away from the centre line (Pyke and Recher 1984).

The rate of increase in the estimates of the Shannon-Wiener species diversity index, the number of individual birds per transect, the number of bird species per transect and bird population density also diminished with increasing sampling duration (Figs 1, 2, 3 and 4). This implies that the change in sampling duration will influence the sampling efficiency with respect to

TABLE 2

Analysis of variance of the Shannon-Wiener index (H), and the bird population density estimate, and analysis by generalized linear model of the number of individual birds and the number of bird species.

	d.f.	H	Bird population density estimate	No. of birds per transect	No. of species per transect
		F value		χ^2 value	
Duration	2	46.2***	43.2***	53.5***	19.2***
Width	2	11.8***	9.9***	8.7***	3.7
Width × Duration	4	0.05	0.06	0.81	0.06
Residual mean deviance (rmd)				0.49	0.28

these indices. More importantly, when the desired sampling duration is less than 10 min, these indices will be more sensitive to changes in sampling duration. This result must be treated on an individual observer basis, since observer competence can greatly influence the optimal sampling duration (Kavanagh and Recher 1983). As the survey dealt with total avifauna, it was not possible to obtain an ideal sampling duration, since various bird species have different detectabilities (Scott and Ramsey 1981) and some birds may be attracted or repelled by the observer (David 1981; Pyke and Recher 1984). In any case,

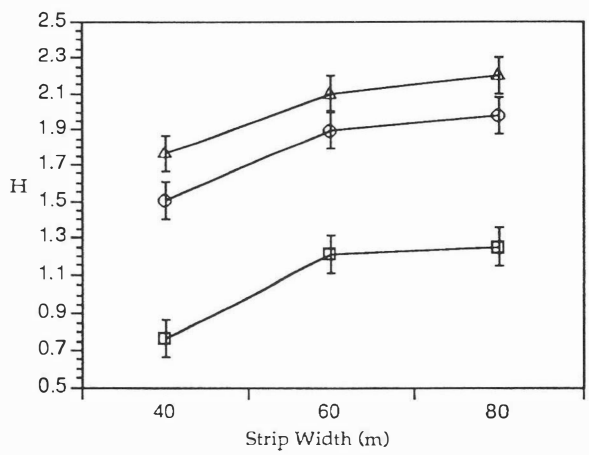

Figure 1. *Graph of Shannon-Wiener species diversity index (H) against sampling duration (min) and strip width (m) with 95 per cent least significant difference bars. Legend: triangle, 15 minutes duration; circle, 10 minutes sampling duration; square, 5 minutes sampling duration.*

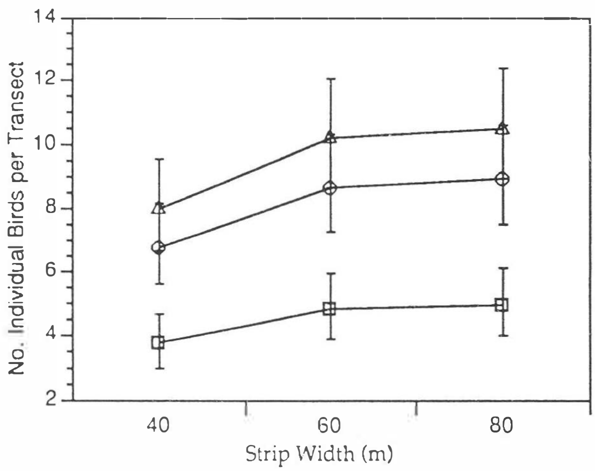

Figure 2. *Graph of number of individual birds per transect against sampling duration (min) and strip width (m) with 95 per cent confidence intervals. Legend: triangle, 15 minutes sampling duration; circle, 10 minutes sampling duration; square, 5 minutes sampling duration.*

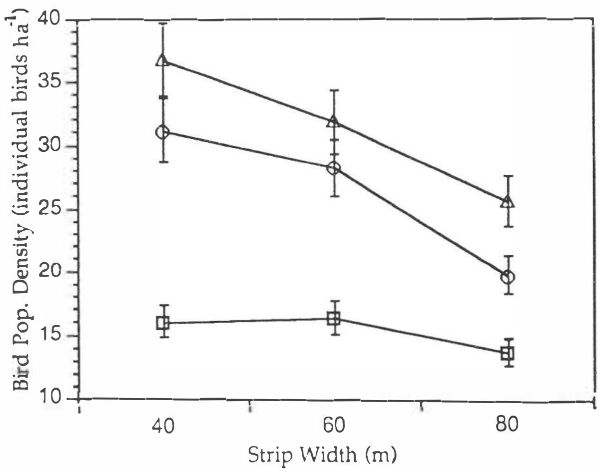

Figure 3. *Graph of bird population density (individual birds ha^{-1}) against sampling duration (min) and strip width (m) with 95 per cent least significant difference bars. Legend: triangle, 15 minutes sampling duration; circle, 10 minutes sampling duration; square, 5 minutes sampling duration.*

one must remember that too short a sampling duration will result in birds being missed, while a long sampling duration will risk a high probability of multiple counts of the same individuals (Burnham *et al.* 1980).

Variation of strip width

As with the variation in sampling duration, the variation of strip width also resulted in significant changes in the estimates of the Shannon-Wiener species diversity index, bird population density and number of individual birds per transect ($p < 0.001$, Table 2). This would be expected since the area of search was increased. Interestingly, this was not observed for the estimates of the number of bird species per transect, which did not change significantly with transect width ($p > 0.05$, Table 2). This is consistent with the statistical indicators which offered no evidence that the birds were in single-species or mixed-species flocks. It is reasonable to expect that if there was little or no tendency to form single or mixed-species flocks in spring/summer (Bell 1980), then increasing the size of the search domain would not increase the number of species found. Were there evidence of significant clustering, however, we would expect the opposite.

The rate of increase in the estimates of the Shannon-Wiener species diversity index and the number of bird occurrences per transect diminished when transect width was increased to 80 m (Figs 1 and 2). This can be attributed to the fact that the further away a bird is from the centre line, the lower its probability of detection (Burnham *et al.* 1980) and it also becomes increasingly difficult to identify. Interestingly, apparent bird population density continued to decrease as the transect width was increased from 40 m to 80 m (Fig. 3). The increase in strip width resulted in an increase in search area which did not increase in linear fashion with the number of individual birds detected (i.e. the rate of increase in area was much greater than rate of increase in individual bird numbers), so that the estimated bird population density, expressed as the number of individual birds ha^{-1}, will tend to decrease as strip width increases.

Hence, it appears that changes in strip width will have an effect on the sampling efficiency as guaged by the Shannon-Wiener species diversity index, the number of individual birds per transect and bird population density. Moreover, these indicators will vary in their responsiveness with strip width changes. Use of a transect width less than 60 m will render estimates of the Shannon-Wiener species diversity index and the number of individual birds per transect more sensitive to changes in strip width, whereas a transect width greater than 60 m will result in the bird population density becoming more sensitive to strip width changes (Fig. 3).

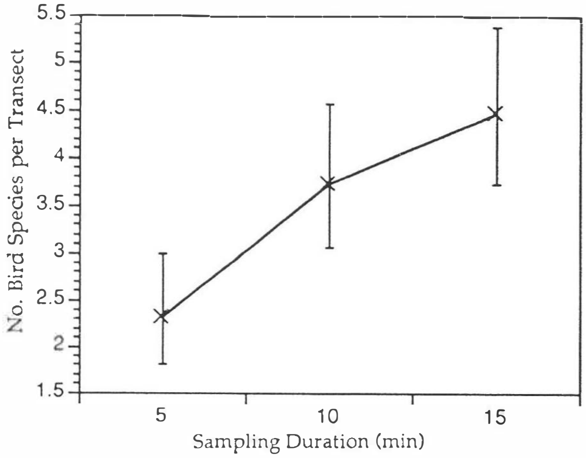

Figure 4. *Graph of number of bird species per transect against sampling duration (min) with 95 per cent confidence intervals.*

Sampling duration and strip width interaction

There was no significant interaction effect between sampling duration and strip width for any response variables ($p > 0.05$, Table 2). This meant that it was statistically valid to compare the individual strip widths and sampling durations.

Time of day effects and between-day effects

Although precautions were taken to minimize both the time of day and between-day effects, they were not statistically accounted for in the experimental design. Hence, the level of significance of the two effects remains unknown. These effects could have been accounted for by increased replication of transects, blocking the replicates across sets of days and further randomization of strip widths within blocks and sampling duration within each day (Harden *et al.* 1986), but it was not undertaken in this survey.

In conclusion, results of this survey demonstrate that: (1) choice of sampling duration and strip width may have a significant effect on the estimation of bird abundance and species diversity when using the fixed-width strip transect method in Yellow Box woodland remnants; (2) different bird abundances and species diversity indices will have varied sensitivities towards a change in strip width; (3) use of a logarithm link function to analyse bird counts can provide useful information regarding the effects of flocking on the use of the fixed-width strip transect method.

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APPENDIX

List of bird species detected in study sites.

FALCONIDAE	
Australian Kestrel	*Falco cenchroides*
POLYTELITIDAE	
King Parrot	*Alisterus scapularis*
PLATYCERCIDAE	
Crimson Rosella	*Platycercus elegans*
Eastern Rosella	*Platycercus eximius*
CUCULIDAE	
Fan-tailed Cuckoo	*Cuculus pyrrhophanus*
CAMPEPHAGIDAE	
Black-faced Cuckoo-shrike	*Coracina novaehollandiae*
MUSCICAPIDAE	
Rufous Whistler	*Pachycephala rufiventris*
Willie Wagtail	*Rhipidura leucophrys*
MALURIDAE	
Superb Fairy-wren	*Malurus cyaneus*
ACANTHIZIDAE	
Speckled Warbler	*Sericornis sagittatus*
Weebill	*Smicrornis brevirostris*
Brown Thornbill	*Acanthiza pusilla*
Buff-rumped Thornbill	*Acanthiza reguloides*
Yellow-rumped Thornbill	*Acanthiza chrysorrhoa*
CLIMACTERIDAE	
White-throated Tree-creeper	*Climacteris leucophaea*
MELIPHAGIDAE	
Red Wattlebird	*Anthochaera carunculata*
Noisy Friarbird	*Philemon corniculatus*
White-eared Honeyeater	*Lichenostomus leucotis*
White-plumed Honeyeater	*Lichenostomus penicillatus*
Eastern Spinebill	*Acanthorhynchus tenuirostris*
GRALLINIDAE	
Australian Magpie-lark	*Grallina cyanoleuca*
CRACTICIDAE	
Australian Magpie	*Gymnorhina tibicen*
CORVIDAE	
Australian Raven	*Corvus coronoides*

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