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DETECTABILITY OF BIRDS THROUGH THE DAY IN SOFTWOOD SCRUB REMNANTS AND OPEN EUCALYPT FOREST ALONG ROADSIDES AT TALLEGALLA, SOUTH-EAST QUEENSLAND

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Strip transects (300 × 40 m) through softwood scrub remnants and eucalypt open-forest along roadsides in south-east Queensland were censused from sunrise to mid-afternoon to determine diurnal changes in detectability of bird species and individuals. Censuses, comprising two consecutive 40-minute surveys by two teams of 2 to 4 persons, were repeated four times on each of four days over a year.

Fifty-eight species were observed in the softwood scrub and 56 in the eucalypt forest. There were 29 to 40 species and 206 to 400 individual observations per habitat per day. Total number of species and individuals was usually low just after sunrise then increased to a relatively stable level for the remainder of the day in the softwood scrub but declined from early- or mid-morning peaks in the eucalypt forest. However, diurnal patterns of detectability differed between species.

We conclude that total numbers of species and individuals censused on strip transects in communities as rich as those at Tallegalla are largely independent of the time of day, provided the first 1 to 2 h after sunrise are avoided. Censusing should therefore aim to maximize habitat and seasonal replication rather than establish diurnal trends. Where the avifauna is less rich, or emphasis is on a small subset of species, census times will need to be compatible with diurnal changes in detectability.

INTRODUCTION

Studies have been conducted in the Marburg district of South-east Queensland to determine the presence and relative abundance of bird species. Frequency of occurrence was reported by Leach and Hines (1987, 1993) and abundance along roadsides by Leach and Recher (1993). More comprehensive assessment of abundance is a major aim of ongoing monitoring.

Censuses for abundance are especially sensitive to detectability of birds, which in turn is influenced by seasonal and diurnal factors, differences in activity patterns between species, and observer skills (Recher 1988; Arnold 1989; Wiens 1989). Method of censusing also influences the outcome (Recher 1988; Wiens 1989). Transect counts are most widely used and accepted in Australia, mainly because they are less time-demanding and/or more appropriate than point counts and mapping (Recher 1988). To determine how sensitive sequential and opportunistic censuses in two common vegetation associations of the Marburg district were to time of day, we undertook repeated strip transect censuses through the day. They were repeated through the year to sample a range of seasonal factors.

METHODS

Transects

Strip transects were selected as most suitable for comparisons across vegetation of contrasting density, particularly because detectability of most species decreases rapidly beyond 20–30 m from line transects (Recher 1988). Two transects along Woolshed Creek Road, Tallegalla (27°36'S, 152°32'E), were censused. They were 300 m in length and extended 20 m (visually estimated) on each side of a 5 m wide gravel road within a 20 m wide easement.

One transect traversed remnants of softwood scrub (Young 1985; Leach and Hines 1987; Elsol 1991) on the easement and adjacent land. The softwood scrub was mostly within the easement, with approximately 6 m wide strips on each side of the

TABLE 1

Census dates, times of sunrise and censuses, weather and number of observers.

	26 Sept. 1982	5 Dec. 1982	27 Mar. 1983	3 Jul. 1983
Sunrise	5:34	4:44	5:55	6:39
Start	5:47	5:00	6:00	6:20
End	14:17	13:45	15:08	14:57
Temperature °C				
Start	13.0	18.5	17.0	6.5
End	28.0	31.0	30.0	18.0
Wind run, km/2 days	151	215	145	380
Rain in previous 10 days, mm	50	75	53	2
No. of observers:				
Team A	3	4	4	2
Team B	3	4	4	3

Note: Sunrise is the time when the upper limb (edge) of the sun is on the clear or true horizon. (Times provided to the (Brisbane) *Courier Mail* by Queensland Department of Lands). Weather observations were made at Lawes, 15 km west, except temperature which was recorded on the transects. Wind run is the combined total for the 24 h ending at 09:00 on the census day and the following day.

road: it was up to about 7 m in height, usually with a closed canopy (Leach and Recher 1993). The other transect traversed extensive eucalypt open-forest, predominantly 20 to 25 m tall Spotted Gum *Eucalyptus maculata* with a grazed grass understorey. Native and introduced woody weeds, especially Cockspur Thorn *Maclura cochinchinensis* and Lantana *Lantana camara*, were conspicuous on both transects.

Bird censuses

Birds were counted on four days during the year by two teams (A and B) of 2 to 4 experienced observers (Table 1). Team members censused as a group. Each transect was censused eight times between sunrise and mid-afternoon. Teams alternated between transects, each censusing each transect four times through the day. All birds seen or heard while walking along the road over 40 minutes were counted when first observed in each census.

Weather

Censuses were on fine, mostly clear, days (Table 1). Temperatures were above average in September and December. Effective rain had fallen in the 10 days preceding the first three census days, and 183 mm fell in June 1983.

Data analysis

Preliminary appraisal indicated some systematic differences between teams, possibly through scanning different widths of vegetation, so combined counts from the two teams over pairs of consecutive censuses on each transect are presented. The number of individuals observed in the pairs of censuses were averaged, because many of the same individuals would have been counted by both teams. The number of censuses was therefore reduced to four per habitat per day: they are subsequently referred to as censuses 1, 2, 3 and 4.

To obtain an indication of the variation in observations attributable to habitat, season, time of day and their interactions, three-factor analysis of variance was used, with teams as replicates.

RESULTS

Species and individuals

Seventy-eight species were observed, 58 (1 384 individual observations) in the softwood scrub remnants and 56 (943 individual observations) in the eucalypt forest (Table 2). Thirty-six species were common to both habitats.

Between 29 and 40 species were observed on each day in the softwood scrub and 32 to 34 in the eucalypt forest (Table 2). Eight more species were observed in the former habitat than in the latter in September but on other days the difference was four or fewer.

Mean number of individual observations per 40 minutes of census ranged from 34 to 50 in the softwood scrub and 26 to 36 in the eucalypt forest. Numbers were about 50 per cent greater in the former habitat than the latter, except in July when they were only 12 per cent greater.

Effects of time of day

NON-PASSERINES

Effects on non-passerine species are reported separately from those on passerines because there were few non-passerine species and few individual observations of most (Table 2). Furthermore, analyses of variance were not undertaken because outcomes would have been dominated by the variable numbers of lorikeets — up to 44 individual lorikeets were observed in some censuses.

Mean numbers over all days, excluding lorikeets, were relatively constant through the day. Mean number of non-passerine species ranged from 1.2 to 2.8 per pair of 40-minute censuses (i.e. 80 mins of observation) while mean number of individual observations ranged from 1.0 to 4.2 per 40 minutes of census. However,

TABLE 2

Days when species were observed, proportion of 40-minute censuses in which they were observed, and mean (± SE) number of individual observations per 40 minutes census. (S = 26 September, D = 5 December, M = 27 March, and J = 3 July.)

Species[1]	Softwood scrub remnants: Days	Softwood scrub remnants: Censuses	Softwood scrub remnants: Individuals	Eucalypt open-forest: Days	Eucalypt open-forest: Censuses	Eucalypt open-forest: Individuals
Pacific Baza	—	—	—	M	0.03	0.06
Brown Falcon	M	0.03	0.06	—	—	—
Stubble Quail	—	—	—	S	0.06	0.38
Spotted Turtle-dove	D	0.09	0.13	—	—	—
Peaceful Dove	SD	0.19 (0.11)	0.19 (0.11)	DM	0.09 (0.06)	0.25 (0.18)
Bar-shouldered Dove	SDMJ	0.63 (0.05)	1.50 (0.20)	—	—	—
Emerald Dove	D	0.06	0.06	—	—	—
Common Bronzewing	—	—	—	D	0.06	0.19
Crested Pigeon	S	0.03	0.03	MJ	0.09 (0.06)	0.25 (0.21)
Rainbow Lorikeet	—	—	—	D	0.03	0.06
Scaly-breasted Lorikeet	DM	0.25 (0.18)	3.56 (3.24)	SDM	0.38 (0.16)	4.28 (2.97)
Little Lorikeet	S	0.03	0.06	SDMJ	0.41 (0.12)	1.53 (0.38)
Pale-headed Rosella	SD	0.13 (0.09)	0.28 (0.24)	SMJ	0.22 (0.08)	0.44 (0.17)
Brush Cuckoo	—	—	—	M	0.03	0.03
Fan-tailed Cuckoo	SD	0.09 (0.06)	0.09 (0.06)	—	—	—
Shining Bronze-cuckoo	J	0.03	0.03	—	—	—
Channel-billed Cuckoo	—	—	—	D	0.03	0.06
Laughing Kookaburra	SDM	0.13 (0.05)	0.19 (0.11)	SDMJ	0.28 (0.06)	0.31 (0.08)
Sacred Kingfisher	—	—	—	SD	0.28 (0.24)	1.00 (0.96)
Rainbow Bee-eater	M	0.03	0.06	M	0.03	0.06
Dollarbird	—	—	—	D	0.03	0.03
Welcome Swallow	—	—	—	M	0.03	0.09
Black-faced Cuckoo-shrike	SM	0.25 (0.14)	0.38 (0.24)	SDMJ	0.44 (0.08)	1.16 (0.44)
Varied Triller	D	0.03	0.03	—	—	—
Rose Robin	J	0.06	0.06	J	0.03	0.03
Eastern Yellow Robin	SDMJ	0.78 (0.09)	1.03 (0.12)	—	—	—
Jacky Winter	—	—	—	MJ	0.09 (0.06)	0.13 (0.07)
Golden Whistler	SDMJ	0.38 (0.11)	0.41 (0.13)	SJ	0.19 (0.15)	0.25 (0.18)
Rufous Whistler	SDM	0.19 (0.11)	0.22 (0.14)	SDMJ	0.78 (0.11)	1.50 (0.29)
Grey Shrike-thrush	SDMJ	0.28 (0.06)	0.31 (0.08)	SDMJ	0.34 (0.08)	0.47 (0.11)
Black-faced Monarch	—	—	—	S	0.03	0.03
Leaden Flycatcher	—	—	—	SD	0.16 (0.12)	0.22 (0.18)
Restless Flycatcher	J	0.03	0.03	—	—	—
Rufous Fantail	SDM	0.44 (0.17)	0.69 (0.27)	SD	0.06 (0.04)	0.06 (0.04)
Grey Fantail	J	0.25	0.44	SMJ	0.25 (0.14)	0.38 (0.22)
Willie Wagtail	SDMJ	0.72 (0.08)	1.50 (0.30)	SM	0.13 (0.09)	0.13 (0.09)
Eastern Whipbird	SDJ	0.19 (0.08)	0.19 (0.08)	—	—	—
Grey-crowned Babbler	S	0.09	0.44	—	—	—
Tawny Grassbird	S	0.03	0.03	—	—	—
Golden-headed Cisticola	SD	0.06 (0.04)	0.06 (0.04)	—	—	—
Superb Fairy-wren	SDMJ	0.78 (0.08)	3.94 (0.60)	—	—	—
Variegated Fairy-wren	SM	0.16 (0.12)	0.22 (0.18)	D	0.03	0.09
Red-backed Fairy-wren	—	—	—	S	0.06	0.13
White-browed Scrubwren	SDMJ	0.84 (0.06)	2.56 (0.63)	D	0.03	0.03
Speckled Warbler	SDMJ	0.41 (0.09)	0.94(0.40)	SDMJ	0.25 (0.05)	0.59 (0.11)
Weebill	—	—	—	SDMJ	0.38 (0.10)	0.72 (0.21)
White-throated Gerygone	—	—	—	SDMJ	0.16 (0.03)	0.16 (0.03)
Buff-rumped Thornbill	—	—	—	DMJ	0.22 (0.11)	0.50 (0.24)
Yellow-rumped Thornbill	SJ	0.06 (0.04)	0.13 (0.07)	—	—	—
Yellow Thornbill	SDMJ	0.91 (0.06)	3.47 (0.65)	DJ	0.06 (0.04)	0.13 (0.09)

Table 2 — *continued*

Species	Softwood scrub remnants			Eucalypt open-forest		
	Days	Censuses	Individuals	Days	Censuses	Individuals
Varied Sittella	—	—	—	SMJ	0.19 (0.08)	0.66 (0,22)
White-throated Treecreeper	—	—	—	M	0.03	0.03
Striped Honeyeater	SD	0.19 (0.11)	0.22 (0.13)	—	—	—
Little Friarbird	SDM	0.09 (0.03)	0.19 (0.11)	SDJ	0.09 (0.03)	0.19 (0.08)
Noisy Miner	DM	0.06 (0.04)	0.19 (0.15)	SDMJ	0.94 (0.04)	3.22 (0.44)
Lewin's Honeyeater	SDMJ	0.97 (0.03)	3.06 (0.44)	SDMJ	0.22 (0.06)	0.25 (0.09)
Yellow-faced Honeyeater	J	0.06	0.09	SJ	0.25 (0.21)	0.72 (0.64)
White-throated Honeyeater	—	—	—	SDMJ	0.53 (0.09)	1.38 (0.37)
Brown Honeyeater	SDJ	0.53 (0.19)	0.84 (0.31)	—	—	—
Eastern Spinebill	J	0.16	0.31	—	—	—
Scarlet Honeyeater	S	0.03	0.06	SDMJ	0.28 (0.09)	0.72 (0.18)
Mistletoebird	SDMJ	0.44 (0.06)	0.75 (0.29)	DMJ	0.25 (0.14)	0.28 (0.16)
Spotted Pardalote	—	—	—	MJ	0.28 (0.21)	0.78 (0.63)
Striated Pardalote	SJ	0.38 (0.22)	0.75 (0.50)	SDMJ	0.38 (0.11)	0.63 (0.22)
Silvereye	SDMJ	0.88 (0.05)	6.00 (1.87)	SDMJ	0.28 (0.06)	1.03 (0.31)
Red-browed Firetail	S	0.03	0.13	—	—	—
Zebra Finch	MJ	0.16 (0.09)	0.28 (0.18)	—	—	—
Double-barred Finch	SDMJ	0.72 (0.08)	3.06 (0.72)	DMJ	0.25 (0.14)	0.59 (0.43)
Chestnut-breasted Mannikin	S	0.03	0.09	—	—	—
Olive-backed Oriole	D	0.03	0.03	SD	0.16 (0.09)	0.25 (0.18)
Figbird	SDM	0.25 (0.09)	1.16 (0.66)	J	0.03	0.19
Spangled Drongo	M	0.16	0.22	M	0.03	0.03
Australian Magpie-lark	SDJ	0.09 (0.03)	0.16 (0.06)	D	0.03	0.03
Grey Butcherbird	MJ	0.16 (0.09)	0.22 (0.13)	SDJ	0.16 (0.06)	0.19 (0.08)
Pied Butcherbird	SD	0.13 (0.09)	0.16 (0.09)	M	0.09	0.16
Australian Magpie	SDMJ	0.19 (0.04)	0.22 (0.03)	SJ	0.09 (0.06)	0.13 (0.09)
Pied Currawong	MJ	0.16 (0.09)	0.22 (0.13)	—	—	—
Torresian Crow	SDMJ	0.47 (0.09)	1.53 (0.81)	SDMJ	0.63 (0.14)	2.31 (1.05)

Notes: 1. Recommended English Names for Australian Birds. *Emu* 77. Supplement (1978).

around noon (census 3) numbers were relatively low in the softwood scrub (1.2 ± 0.25 species, 1.0 ± 0.5 individual observations) and relatively high (2.8 ± 0.25, 4.1 ± 0.9) in the eucalypt forest.

Single censuses in softwood scrub detected on average 43–58 per cent, and those in eucalypt forest 38–64 per cent, of species detected in each habitat on each day: variability (SE: 5.5–19.4%) was larger than for passerines. Part of the variability was attributable to lorikeets and Laughing Kookaburra which were regularly observed (Table 2) but primarily in early morning.

PASSERINES

The mean number of passerine species per census differed between habitats (Softwood, 13.3; Eucalypt, 8.9; SE ± 0.08; $P < 0.001$) and between dates of census (September, 11.0; December, 9.9; March, 10.8; July, 12.8; SE ± 0.62; $P < 0.05$), but neither times of census nor any interactions produced significant effects. Nevertheless, in the softwood scrub numbers of species appeared to be slightly lower in early morning than later in the day. In the eucalypt forest they appeared to decrease through the day in September and March but increase in July.

Single censuses in softwood scrub detected on average 62–70 per cent, and those in eucalypt forest 42–58 per cent, of the species detected in each habitat on each day (Table 3). Percentages increased to 88 and 80 per cent in softwood scrub and eucalypt forest, respectively, when information from two consecutive censuses was combined and reached 95 per cent when three were combined.

The number of different species in each combined pair of 40 min. censuses (i.e. 80 min. of observation) exceeded the mean number in each 40 min. census by 5.1 ± 0.2 species.

There were 18–53 individual observations in each census in the softwood scrub and 10–36 in the eucalypt forest (Fig. 1). Mean numbers of individual observations differed significantly between habitats ($F = 66.6$, d.f. 1/31, $P < 0.001$) and between times of census ($F = 3.5$, d.f. 3/31, $P < 0.05$). Their interaction was significant ($F = 5.3$, d.f. 3/31, $P < 0.01$), and also that between habitats and dates of census ($F = 4.6$, d.f. 3/31, $P < 0.01$). Counts always increased after the early morning census in the softwood scrub (Fig. 1, Table 3). They remained near their peaks for the remainder of the day in September, decreased later in December and July, but increased in the last counts in March. In the eucalypt forest, numbers increased after early morning counts in December and, especially, July then decreased. Numbers of individuals observed in March in both habitats, and in July in the softwood scrub, suggests individual detectability increases for the last census of the day.

TABLE 3

Percentage of the total number of passerine species and individuals obsecrvd each day which were observed in each census through the day, and cumulative percentages through the day for number of species. Values are means over the four days, with standard errors in parentheses.

Census sequence	Softwood scrub remnants		Eucalypt open-forest	
	Species	Individuals	Species	Individuals
1	64 (3.1)	18 (3.1)	58 (7.2)	30 (4.7)
2	71 (3.6)	29 (0.9)	62 (1.5)	31 (1.5)
3	70 (2.7)	26 (2.2)	52 (3.5)	21 (2.5)
4	62 (4.2)	27 (1.9)	42 (10.9)	18 (1.8)
1 + 2	88 (2.7)		83 (2.1)	
2 + 3	89 (1.4)		77 (0.7)	
1 to 3	96 (1.4)		94 (2.4)	

Diurnal trends in detectability of individual species

The 95 per cent confidence limits associated with diurnal patterns of detectability of individual species were wide, so individual patterns are not presented. Nevertheless, they indicated that detectability increased (e.g. Golden Whistler, Willie Wagtail, Superb Fairy-wren and Noisy Miner), remained relatively stable (e.g. Yellow Thornbill, Lewin's Honeyeater and Silvereye) or decreased (Bar-shouldered Dove, Scaly-breasted Lorikeet and Rufous Whistler) through the day. Some species appeared to be most detectable in the first and last censuses during the day (e.g. Grey Shrike-thrush, Rufous Fantail and Grey Fantail), while others appeared to be most detectable at other times (e.g. Black-faced Cuckoo-shrike, White-browed Scrubwren, White-throated Honeyeater and Mistletoebird).

Team effects

Sixty-four species (1 261 individual observations) were observed by one team and 70 (1 066 individual observations) by the other. Scaly-breasted Lorikeet accounted for the difference in total number of individual observations. Twenty-two species were observed by only one team (A: 8, B: 14), and 17 of them on only one day. The major difference was regular observation of Little Friarbird by only one team.

DISCUSSION

Our main aim was to determine how results of censuses of strip transects in the district depended on time of day. We did not aim to determine the avifauna in different types of vegetation, nor seasonal trends in detectability, both of which would require more intensive survey. Suffice it to note that species detected were representative (cf. Leach and Hines 1987, 1993; Leach and Recher 1993).

Both habitats generally supported more species and individuals per unit area than similarly censused eucalypt forest/woodland in southern Australia (e.g. Kavanagh and Recher 1983; Ford *et al.* 1985; Loyn 1987). Individual observations were up to twice as numerous per unit area in the softwood scrub remnants as in the southern censuses, but in part this may reflect differences in duration of censuses and use of teams of observers.

Effects of time of day on detectability

The number of species and individuals detected in the softwood scrub was largely independent of time of day, but in the eucalypt forest patterns were more variable, with downward trends predominant. A consistent feature in the softwood scrub, also evident on two days in the eucalypt forest, was low numbers of individual observations in the first two hours after sunrise. The feature is consistent with results in remnant eucalypt woodland (Arnold 1989), other eucalypt

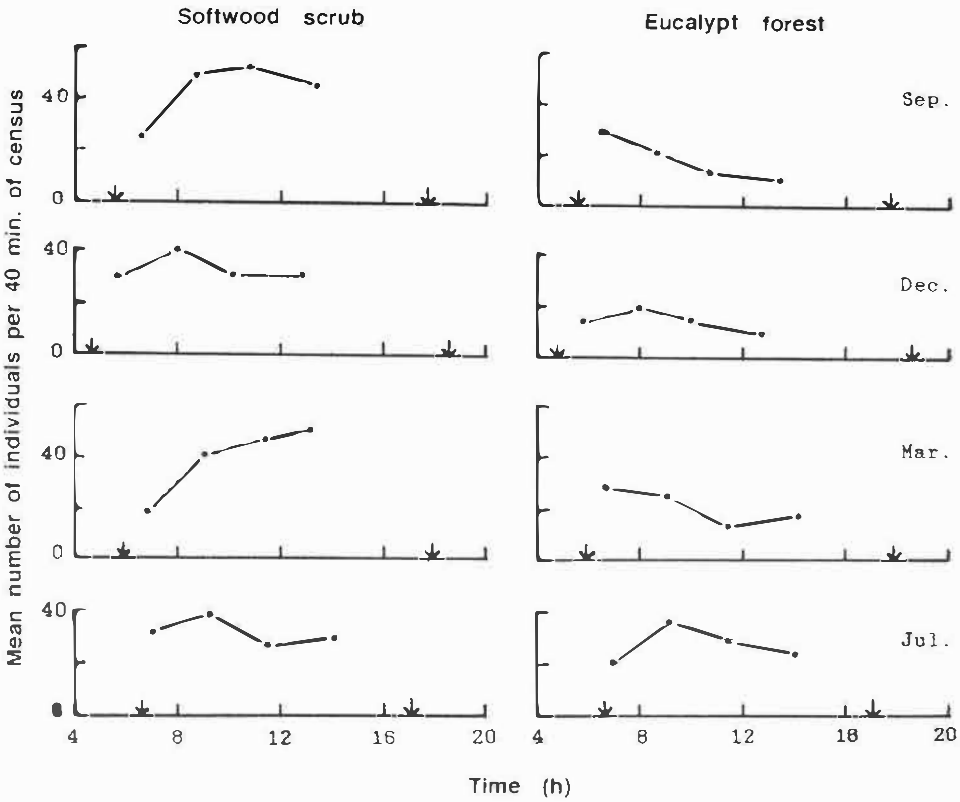

Figure 1. *Number of individual observations of passerine species through each day in each habitat. Each point represents the mean of pairs of consecutive censuses by the two teams (see text). S.E. for each point = ± 5.7. Arrows indicate times of sunrise and sunset.*

associations (Keast 1984) and tall closed-forest (Bell 1982) and in tall forest may indicate movement down the canopy as temperatures rise during the morning (Bell 1982). Different diurnal trends may indicate that the narrow strip of roadside softwood scrub was primarily a refuge, necessitating substantial foraging in adjacent and/or nearby habitats early in the day, while the eucalypt forest provided shelter and adequate foraging resources.

Recher (1988) recognizes, but does not discuss, diurnal trends in detectability. This suggests trends are not sufficiently known in Australia, or consistent enough, to outweigh practical considerations when scheduling censuses. Our results support this assessment and show that sequential censusing of transects for broad-scale comparative purposes (Leach and Recher 1993; G. J. Leach, unpubl. data) is a practical compromise. Priority should be to increase replication rather than determine diurnal patterns, as was also shown in North America (Verner and Ritter 1986).

Use of single transect censuses would detect about half the species in eucalypt forest, and two-thirds of those in roadside softwood scrub that can be detected by transect censuses. This is better than achieved by Bell and Ferrier (1985) and Arnold (1989), so their advocacy of a combination of procedures and a minimum of five to seven censuses per day, respectively, is more stringent than necessary at Tallegalla.

The diurnal range in detectability of individual species parallels North American experience (Blake *et al.* 1991). There was no optimum time for maximising detectabilty of all species. Where emphasis is on individual species, or a subset with similar activity patterns, census times will need to match trends in detectability.

Differences between teams

Observer variability is complex and can affect census results (Kavanagh and Recher 1983; Pyke 1985; Emlen and DeJong 1992). Observers had experience in similar surveys on the transects, but even so, sources of variability are likely to have been at least as great as those identified by Kavanagh and Recher (1983). A mitigating factor was use of teams, rather than single observers, although inability to standardize team size, may itself have led to variability (Preston 1979).

Differences in efficiency of detecting individual species were of minor importance, consequently censuses for total numbers of species and individual observations were relatively consistent. Nevertheless, our experience re-emphasizes the importance of standardizing procedures where subjective judgements are necessary (Kavanagh and Recher 1983; Recher 1988), and balancing the consequences of unavoidable compromise between perfection and practicality.

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