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ASSOCIATION OF BIRDS WITH FALLEN TIMBER IN BOX-IRONBARK FOREST OF CENTRAL VICTORIA

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The potential role of fallen timber in influencing avian microhabitat use was examined in box-ironbark forests in the Dunolly forest block in central Victoria, Australia. Six sites with relatively high levels of fallen timber across each site were selected. Within each site, areas with ('debris' areas) and without ('empty' areas) piles of fallen timber were delineated. In another six sites with virtually no fallen timber, comparable areas without fallen timber also were selected. We found that birds occurred more frequently and in greater diversity in areas with fallen timber than in areas without fallen timber, irrespective of whether the latter were in sites where the overall availability of timber was high or low. Thus, the occurrence of piles of fallen timber appears to influence the spatial location of birds in the forests. We consider two explanations for this pattern, namely, food availability and shelter.

INTRODUCTION

The structural complexity of habitats takes many forms including the numbers of floristic elements (Woinarski *et al.* 1988), vertical zonation of vegetation (Anderson *et al.* 1979), structural characteristics of vegetation (size and distribution of trees; Rotenberry 1985; Mac Nally 1990), resource provision (food, nutrients; Harmon *et al.* 1986) and amounts of 'cover' such as rocks or litter (Huey *et al.* 1983). Structural complexity is frequently held to be a crucial element in the provision of refuge from predators or parasites (Sedell *et al.* 1990; Bell *et al.* 1991; Everett and Ruiz 1993). Many organisms rely on a habitat mosaic to fulfil their ontogenetic development (Werner and Gilliam 1984; Mac Nally 1995) or to persist in the face of a wide range of disturbances (Palmer *et al.* 1996).

Species diversity has long been linked to habitat characteristics, especially structural complexity (MacArthur 1972; McGuinness 1984; Barry and Dayton 1991; Hart and Horwitz 1991; Huston 1994). More complex habitats may afford greater potential for resource or microhabitat segregation (MacArthur *et al.* 1966; Allen and Hoekstra 1992; Douglas and Lake 1994). Thus, per unit area/volume, more species may be supported generally leading to a positive correlation between diversity and habitat complexity (O'Connor 1991; Rosenzweig 1995).

The corollary of the generally accepted relationship between structural complexity and diversity (McCoy and Bell 1991) is that the 'simplification' of habitats should lead to a reduction in diversity. This may be due to the loss of exploitable opportunities (i.e. fewer resources) or by the exposure of species to more intense interspecific interactions (Loehle 1991; Everett and Ruiz 1993; Primack 1993). Simplification can occur in many ways. For example, many forests become simplified by not only being much reduced in tree-species diversity, but also because the variety of age structures and successional seres is lessened (Barrett *et al.* 1994; Heywood *et al.* 1995; Woinarski and Fisher 1995).

Since European settlement in Australia in the late eighteenth century, many pressures have been imposed on natural systems including exploitation for agriculture, mining, water use, timber harvesting and recreation (Mackay and Eastburn 1990). Forests and especially inland woodlands have borne the brunt of habitat degradation. Woodlands have been degraded in many ways including overall loss of area but mostly by the simplification of habitat structure (Muir *et al.* 1995). One structural element that has attracted comparatively little attention within Australian woodlands and forests is fallen timber (often referred to as coarse or large woody debris). Much literature from overseas suggests that fallen timber is crucial for providing a wide range of resources for animals (Harmon *et al.* 1986; Spies and Franklin 1996). Compared with estimates from other continents, amounts of fallen timber in Australian forests are often lower by several orders of magnitude (cf. Harmon *et al.* 1986). These deficits are probably due to a combination of firewood collection, post-harvest burning of debris and wildfire, and low soil fertility (Muir *et al.* 1995).

In this study, we outline some work on the association of birds with fallen timber in the 'box-ironbark' system of central Victoria, Australia (see Muir *et al.* 1995). We established a structured sampling design to explore whether birds were differentially associated with areas in which piles of fallen timber occurred.

MATERIALS AND METHODS

Study area

The box-ironbark system covers an extensive area. In Victoria, it occupies the northern hill slopes between the Great Dividing Range to the south and the inland northern plains, and is broadly orientated south-west to north-east. The climate is Mediterranean, with winter rainfall and summer droughts (Muir *et al.* 1995). Vegetation clearance in the system has been extensive, with 25 per cent of the original 1 Mha tree cover remaining, much in a degraded or highly modified condition (ECC 1997).

The study was conducted in one of the major remnant forest blocks of the box-ironbark (Northern Goldfields) ecological vegetation class (*sensu* Muir *et al.* 1995), centred on the town of Dunolly (143°44'E, 36°52'S), 200 km north-west of Melbourne. All study sites were dominated by Red Ironbark *Eucalyptus tricarpa* and Grey Box *E. microcarpa*, with patches of Red Stringybark *E. macrorhyncha* and Yellow Gum *E. leucoxylon*. The area is subject to continuing silviculture.

Site selection for studies of use of fallen timber by birds

Fallen timber of interest here are logs and branches ≥7.5 cm (minimum) diameter and ≥80 cm in length. In April 1996, a visual survey of sites around Dunolly was conducted to locate a set of possible sites for use in the bird studies. Twenty sites were identified, and these were classed into two sets of ten with higher and lower availabilities of timber. We refer to 'high' and 'low' (fallen timber) sites for simplicity. From each set of ten, six sites were randomly selected to overcome potential observer biases in site selection. The sites were geographically interspersed so that no systematic differences in climate and other factors were likely. Each site was 4 ha in extent.

Two randomly located transects of 50 × 20 m were positioned within each 4 ha site and these were used to estimate availabilities of fallen timber. All fallen timber occurring on these transects was measured (end diameters and lengths) and volumes computed (see Harmon *et al.* 1986).

Association of birds with fallen timber

Within the 1 ha squares centred on the six high sites, we identified areas in which there were accumulations of fallen timber and places bereft of debris. We refer to the former as 'debris' areas and the latter as 'empty' areas. In each debris area, there were several piles of fallen timber. At the low sites, there were no debris areas owing to the sparse availability or absence of fallen timber. At the six high sites, two debris and two empty areas were randomly selected. Only two empty areas were randomly identified in the six low sites. Each debris and empty area was a right-triangular area with dimensions of 30 × 30 × 42.4 m (450 m^2) and was randomly oriented with respect to north through the right angle (Fig. 1). Each apex was marked with flagging tape.

Each of the 12 debris and 24 empty areas was visited three times during the period July to September 1996. Each visit consisted of the observer (always N. H. Laven) sitting at the right angle of the area and gathering observations for 1 hour. All birds alighting within a debris or empty area were recorded. The following information was collected for each sighting: (1) species; (2) activity; and (3) substrate used. Sites were visited in a random order. The two (low sites) or four (high sites) areas within sites were viewed in random order within visits.

Two sets of data were analysed: (1) total number of activities of all species within an area summed over all visits ('occurrence'); and (2) species richness of birds using each area, also compiled over the whole study period. Note that in the latter, if a given species were recorded two or more times in one particular area, then that species contributed only one to the count. However, for data set (1), each individual record was counted; i.e. the basic data were total numbers of individual birds using the areas summed over the three 1 hour observational periods per site. Total richness over the observational periods for each triangular area was tallied and the data for the two 'replicates' in each category merged to find the overall richness. Where the same species was recorded in each triangle of a given kind (i.e. both debris or both empty), the species was counted only once. For each site, occurrence data for the two debris and/or two empty areas were pooled and the results were transformed by taking square-roots to stabilize variances. We followed a similar process for species richness apart from the transformations, which proved statistically unnecessary.

Analysis

The sampling design was 'unbalanced' because high sites had two treatments (debris and empty) while the low sites had only the empty treatment. Thus, a standard two-factor analysis of variance could not be used. We employed the dummy variables method for unbalanced designs described by Neter *et al.* (1990: p. 989).

For analysis, we first calculated the sums of squares attributable to sites for the six high sites because there were repeated measurements (i.e. debris, empty). As the design is not fully crossed, there is no interaction term. Last, the sums of square and degrees of freedom of the residual error were adjusted by subtracting the contributions of the repeated-measures term for high sites.

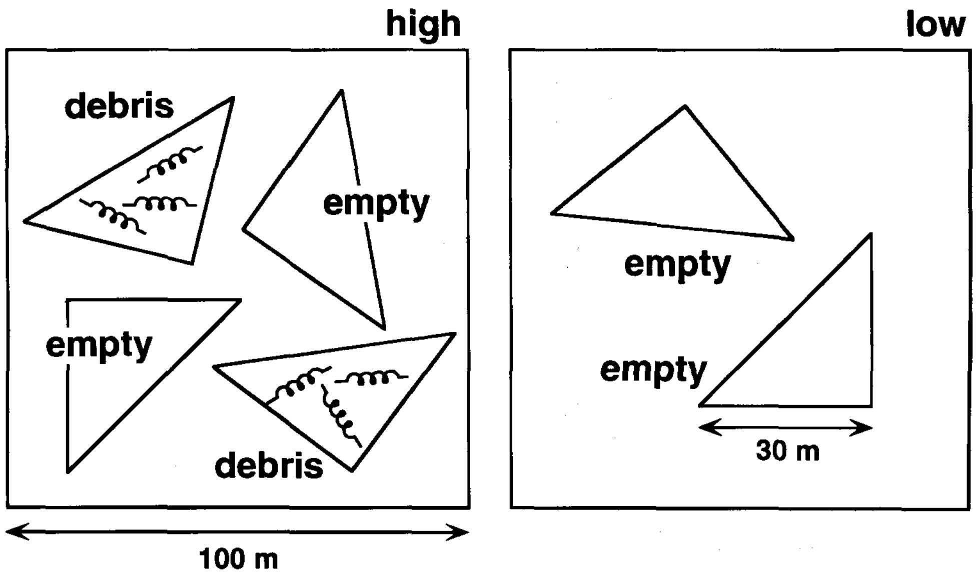

Figure 1. *Schematic design for the small-scale study of use of fallen timber by birds. Each square represents the 1 ha sampling unit within which either four (high) or two (low) triangular areas were randomly positioned and oriented. In high sites, two of the triangular areas were free of fallen timber (empty) while two contained fallen timber piles (debris). Triangular areas were right-triangles with dimensions of 30 m on a side and 42.2 m on the diagonal. 'Resistor' symbols denote piles of fallen timber.*

RESULTS

Availability of fallen timber

The mean availability ($m^3\ ha^{-1}$) of fallen timber in high ($9.6 \pm 1.3\ m^3\ ha^{-1}$, mean and standard deviation) sites was 3.7 times greater than in low ($2.6 \pm 0.5\ m^3\ ha^{-1}$) sites.

Association of birds with fallen timber

There were no differences attributable to general availability of fallen timber (i.e. high *vs* low sites) in the occurrence of birds (Table 1), which means that the average occurrence at high sites was not distinguishably different from low sites (Fig. 2a). However, linear contrasts showed that occurrence in debris areas was significantly greater than use of empty areas ($t_{15} = 2.77$, $P < 0.01$) but that occurrence within empty areas did not differ among high/low sites ($t_{15} = 0.68$, n.s.) (Table 1, Fig. 2a). These results indicate that birds using the ground are more likely to occur in association with piles of fallen timber than in empty areas.

Nine species of birds were observed using the triangular areas: Peaceful Dove *Geopilea cuneata*, Brown Treecreeper *Climacteris picumnus*, Grey Shrike-thrush *Colluricincla harmonica*, Grey Fantail *Rhipidura fuliginosa*, Eastern Yellow Robin *Eopsaltria australis*, Flame Robin *Petroica phoenicea*, Red Wattlebird *Anthochaera carunculata*, Fuscous Honeyeater *Lichenostomus fuscus* and Yellow-tufted Honeyeater *Lichenostomus melanops*. Only the Brown Treecreeper was recorded in empty areas alone, while the Grey Shrike-thrush and the Fuscous and Yellow-tufted Honeyeaters occurred in both debris and empty areas.

Similar results were found for the numbers of species using the triangles in high and low sites as for the occurrence data. There was no significant difference in mean species richness between high and low sites (Table 1, Fig. 2b), but significantly more species used debris triangles than empty triangles irrespective of where those triangles were located ($t_{15} = 3.47$, $P < 0.01$; Fig. 2b). Mean species richness in empty triangles in high sites did not differ significantly from mean richness in empty areas in low sites ($t_{15} = 1.20$, n.s.).

There were 29 instances of perching on fallen timber and 14 ground-foraging acts recorded in debris area compared with just eight ground-foraging records in empty areas. Given that there were twice as many empty areas as debris areas (Fig. 1), use of debris areas per unit observation time was an order of magnitude greater than in empty areas. There was little foraging on piles of fallen timber themselves. The species most commonly using debris areas were Fuscous (42% of observations) and Yellow-tufted (23%) Honeyeaters and Eastern Yellow Robins (12%).

DISCUSSION

The current evidence suggests that birds are preferentially associated with accumulations of fallen timber when available (Table 1, Fig. 2). Mean occurrence was about nine times greater in debris areas than in empty areas, while the corresponding ratio was about three for species richness (Fig. 2). Two of the more likely explanations for these preferences are the provision of greater amounts of food and/or foraging opportunities and shelter.

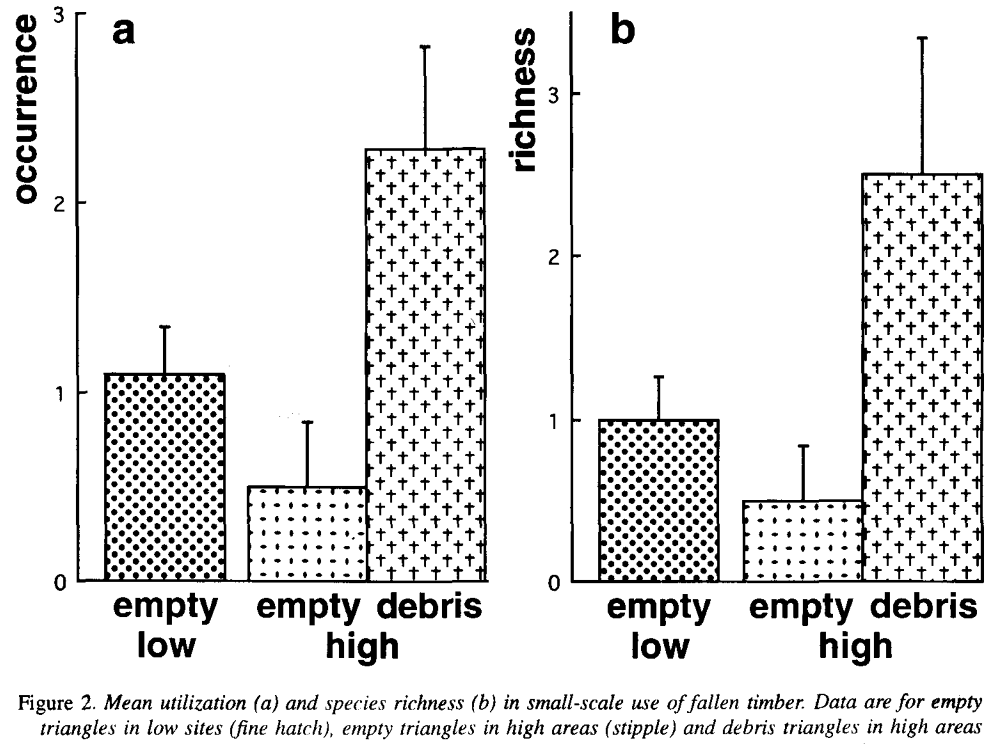

Figure 2. *Mean utilization (a) and species richness (b) in small-scale use of fallen timber. Data are for empty triangles in low sites (fine hatch), empty triangles in high areas (stipple) and debris triangles in high areas (coarse hatch). Bars are standard errors. Data were square-root transformed in (a). All N = 6.*

TABLE 1

Analyses of variance for small-scale utilization of fallen timber piles by birds in box-ironbark forests near Dunolly, Victoria.

Source of variation	Sums of squares	Degrees freedom	Mean squares	*F*-ratio
Occurrence[†]				
sites	6.89	5	1.38	—
high/low	1.06	1	1.06	1.45
debris/empty	9.48	1	9.48	12.99*
residual	7.30	10	0.73	—
Species richness				
sites	11.00	5	2.20	—
high/low	0.75	1	0.75	0.47
debris/empty	11.25	1	11.25	7.03*
residual	16.00	10	1.60	—

[†]data square-root transformed. *$P < 0.05$.

As another component of this study (Laven 1996), we measured the occurrence of diurnally active invertebrates around piles of fallen timber and in bare areas that had dimensions similar to average piles to assess whether differences in food abundance might explain the apparent preferences. Flying and non-flying invertebrates were assayed by using sticky and pit-fall traps respectively. Differences between piles and bare areas were minor in both kinds of invertebrates. This lack of difference is consistent with the small numbers of foraging activities observed on or around piles, which differed little in number from foraging acts recorded in empty areas. We add two caveats to these conclusions. First, invertebrate samples were taken during winter, concurrently with the observations on birds. It is possible that more pronounced differences in invertebrate availability between piles and empty areas may occur during other times of the year. It is possible that this may form an 'association' in the foraging strategies of individual birds that carries through to the winter months when differences are actually marginal. And second, there may be differences but detecting them may require very extensive surveying. Perhaps the use of automated-camera systems would assist in gathering sufficient numbers of observations to make a more definitive judgement. If invertebrate availabilities do differ more in spring, then greater foraging rates on fallen timber may ensue. For example, a number of species often (robins: *Petroica* spp., *Eopsaltria australis*) or occasionally (honeyeaters, especially *Lichenostomus*; fantails: *Rhipidura* spp.) use low vegetation, tree trunks and fallen timber as platforms from which to pounce on grounded prey (R. Mac Nally, pers. obs.). Again, there were few observations of this behaviour in the current study but it remains a possible contributor to some of the differences in utilization between debris/empty areas.

The other explanation mooted above is a preference based on shelter or refuge, a role of fallen timber shown to be important in aquatic communities (Daniel and Robertson 1990; Everett and Ruiz 1993). This idea is difficult to test directly, unlike the possible influence food availability. However, refuge and shelter may enter into the selection of microhabitats by some species. Granivores such as pigeons and some parrots, whose attention when foraging on the ground is focused downwards, may benefit from protection provided against attack by diurnally active raptors (nine species recorded in 1995–97 surveys of the Dunolly district, G. F. B. Horrocks, pers. comm.). On the other hand, large amounts of fallen timber may hinder prey species' vigilance in watching for terrestrial predators that use the timber as cover for 'ambushing' prey. Thus, the suggestion that fallen timber acts as a refuge from predation cannot be easily resolved without greater information on the prevalence of different kinds of predators and their respective impacts on ground-feeding birds.

We believe that this work provides a useful first step in evaluating the significance of fallen timber to avian community composition and resource use in box-ironbark forests. The results indicate that greater research effort needs to be invested in this system in two ways. First, a more extensive observational programme involving year-round studies over several years may provide a more powerful test of whether community-wide differences occur as a result of differences in availability of fallen timber. In the current study, several species known from the box-ironbark forests that might have been expected to use woody debris or forage on the ground were not recorded. A. F. Bennett (pers. comm.) identified the Scarlet *Petroica multicolor* and Red-capped *P. goodenovii* Robins, Painted Button-quail *Turnix varia*, Spotted Quail-thrush *Cinclosoma punctatum*, Superb Fairy-wren *Malurus cyaneus* and Buff-rumped Thornbill *Acanthiza reguloides* as species that might have been expected, but were not recorded. Their absence from records may reflect inadequate sampling. Alternatively, a lack of other resources (e.g. large old trees for breeding) in the heavily managed box-ironbark forests may restrict their occurrence rather than the availability of fallen timber *per se*.

Second, and of more direct significance, would be the implementation of a broad-scale experimental programme in which the availability of fallen timber is manipulated artificially. Of course, such an experiment would need to be replicated sufficiently to detect potential differences and left to run for at least several years if differences take longer periods to become established. The data collected in the current study would be useful for helping to determine operational parameters for such an experiment, especially levels of replication in relation to variance.

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