



Short communication

The disproportionate value of scattered trees

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ABSTRACT

Scattered trees are declining in agricultural landscapes worldwide. They are considered keystone structures because their effect on ecosystem functioning is believed to be disproportionate relative to the small area occupied by any individual tree. We empirically demonstrate the disproportionate value of scattered trees for birds and bats in an Australian livestock grazing landscape. We surveyed birds at 108 sites and bats at 63 sites. Sites spanned the full range of tree densities in the study area, from zero to over 100 trees per hectare. The marginal value of individual trees was highest when trees occurred at low densities. Compared to treeless sites, bird richness doubled with the presence of the first tree; bat richness tripled with the presence of 3–5 trees; and bat activity increased by a factor of 100 with the presence of 3–5 trees. Thereafter, the marginal effect of additional trees on birds and bats diminished rapidly. Although specialist species were restricted to large areas of dense tree cover, scattered trees effectively maintained moderate levels of bird and bat activity throughout largely cleared parts of the landscape. Future management activities should recognize the disproportionate value of scattered trees.

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1. Introduction

Scattered trees represent the last remaining relicts of largely cleared woodlands and forests in agricultural landscapes around the world (Janzen, 1986; Harvey et al., 2006; Gibbons et al., 2008). They are considered keystone structures because their effect on ecosystem functioning is believed to be disproportionate relative to the small area occupied by any individual tree (Tews et al., 2004; Manning et al., 2006). However, unequivocal evidence of their disproportionately large effect is scarce. Because scattered trees are declining rapidly in agricultural landscapes around the world (Gibbons et al., 2008), explicit tests of their effects on species and ecosystem processes are urgently needed.

In this study, we examined the contribution of scattered trees to the species richness of birds and bats, as well as bat activity levels, in livestock grazing pastures in eastern Australia. Specifically, we investigated the change in bird and bat species richness, and bat activity, with an increasing density of trees. We calculated the mean marginal change in richness or activity per individual tree as the number of trees increased. If scattered trees do indeed have a disproportionate effect on birds and bats, the marginal contribution of trees should be highest where trees occur at low densities.

2. Methods

2.1. Study area

The study was conducted in the Upper Lachlan Catchment of New South Wales, Australia. Prior to European settlement, the region was dominated by relatively continuous woodland vegetation. Tree cover across the study area was approximately 15%, and approximately one third of remnant tree cover occurred as scattered trees (Fischer et al., 2010). We established 108 2-ha survey sites on a total of 33 farms. Sites were separated by at least several 100 m, and all were commercially grazed by livestock. Sites spanned the full range of tree densities in the region, from zero to several 100 trees per site; 34 sites had less than or equal to five trees. We acknowledge that tree density within a given site is only one of several variables influencing the distribution of birds and bats. Other potentially important variables include: (1) tree species composition (e.g. rough-barked species are preferred by some birds (Lindenmayer et al., 2007)); (2) tree age distribution (older trees are more likely to contain hollows (Gibbons and Lindenmayer, 2002)); (3) shrub cover (some birds forage in shrubs (Seddon et al., 2003)); and (4) landscape context (mobile species will be influenced less by the degree of isolation from extensive vegetation (Lumsden et al., 2002)). Rather than account for site-level variability in these variables in our analyses, we averaged across them. Our results therefore describe expected 'average' changes in bird and bat activity at a landscape scale, but we made no attempt to accu-

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rately predict bird and bat activity at any particular site. A detailed description of the study area and the site selection protocol is provided by Fischer et al. (2009b).

2.2. Bird surveys

Each site was surveyed for birds in four separate 20 min area searches, following the methodology recommended by Barrett et al. (2003). Two observers each searched every site once in Spring 2007 and again in Spring 2008, on fine mornings. For each site, data were pooled across all surveys, and species richness was tabulated. Two potential caveats warrant explanation. First, observer heterogeneity has been considered a potential problem in bird studies (Cunningham et al., 1999; Johnson, 2008). This was not a problem in our study because the same two observers visited every site (JF and JS). Second, detectability of birds may differ between sites in structure and observers were experienced. Importantly, overall survey effort was high and equal across all sites (80 min total). On this basis, we consider our estimates of species richness reliable indices of true species richness (Johnson, 2008).

2.3. Bat surveys

Bat surveys were undertaken at 63 sites, which were a subset of the sites used for bird surveys. Each site was surveyed using Anabat detectors, with two detectors per site, for a total of four nights in November/December 2008, and then again in February/March 2009, resulting in a total of 16 detector-nights of data recorded from each site. This survey protocol was used on the basis of a published pilot study, which showed that activity levels could be accurately estimated with this amount of effort (Fischer et al., 2009a).

We screened data for differences in activity levels between the two survey periods, and there were no strong systematic differences. We excluded all nights where rainfall or strong wind was recorded at nearby weather stations. We also excluded all nights where the minimum nightly temperature at nearby weather stations was under 10 °C. Anabat files were analysed using Anascheme software, as outlined by Fischer et al. (2009a) and Law and Chidel (2006). We then calculated the nightly median number of passes for each species at each site as an index of median activity. We summarised bat data for each site by: (1) adding the median activity levels across all bat species, and (2) tabulating species richness. Once summed across species, median activity levels were (natural) log-transformed because they were highly skewed.

2.4. Data analysis

We grouped sites into tree density classes with approximately equal numbers of sites in the different classes. For each class, we calculated the means and associated standard errors of bird richness, bat richness and bat activity. In addition, for any two adjacent tree density classes, the absolute change in mean richness or activity from one class to the next was divided by the mean number of trees in the higher density class minus the maximum number of trees in the lower density class. The resulting figure was interpreted as the mean marginal contribution to richness or activity of an individual tree in a given density class.

3. Results

Bird species richness increased with the number of trees in the site (Fig. 1a). Species composition also changed with an increase in tree density, with a decline in grassland specialists and an increase

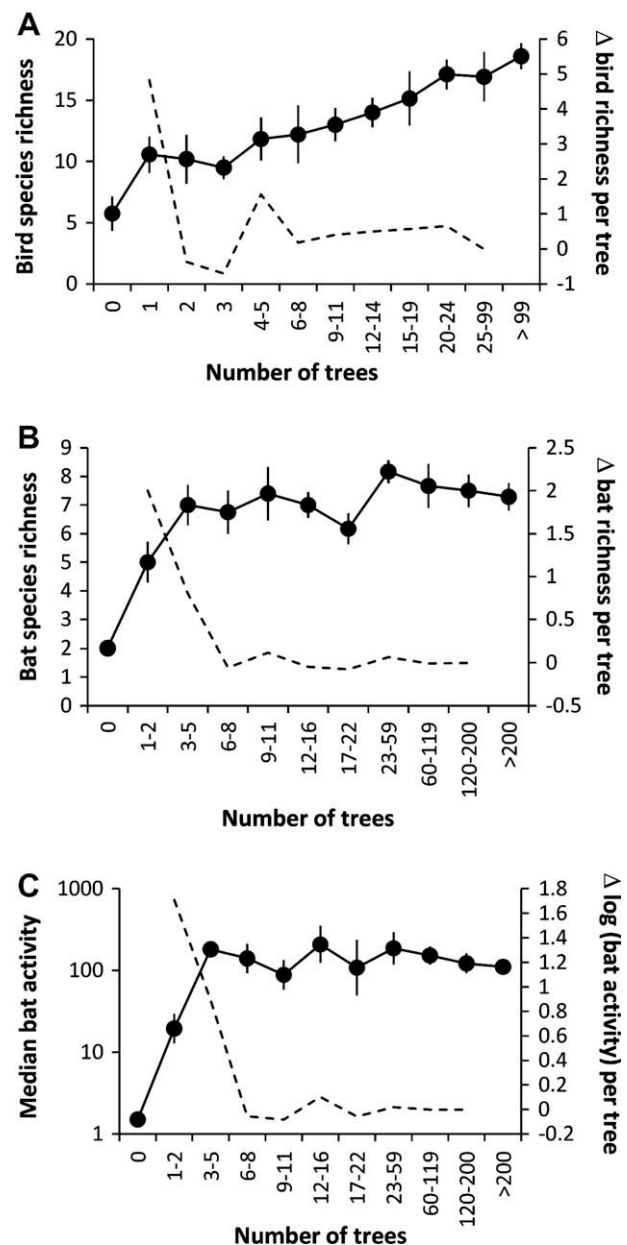


Fig. 1. Contribution of an increasing number of trees to species richness of birds and bats, and nightly bat activity per 2-ha site (see Section 2). Solid lines show means (+/– standard error; left vertical axis); dotted lines show mean marginal change per additional tree (right vertical axis).

in species dependent on woody vegetation (Fig. S1). Notably, the mean species richness of sites with just a single isolated tree was approximately double the richness of a site with no tree (Fig. 1a). The marginal contribution of the first tree to species richness was disproportionately high, with approximately five bird species added with the presence of the first tree (Fig. 1a). The marginal contribution of subsequent trees to bird richness was substantially lower, typically less than half a species per additional tree (Fig. 1a).

For bats, species richness increased from two species at a treeless site to five species at sites with one or two trees, before reaching an asymptote at seven to eight species when there were five or more trees in the site (Fig. 1b). Bat activity levels, irrespective of the species involved, increased by a factor of 10 when the first two trees were present, and increased again by a factor of 10 with the presence of two or three additional trees (Fig. 1c). Activity lev-

els reached an asymptote if there were five or more trees within the site (Fig. 1c).

4. Discussion

Our results confirm the disproportionate value of sparsely scattered trees in pastures for maintaining moderate levels of bat and bird activity throughout the landscape. Although specialist woodland species are restricted to extensive dense tree cover (Watson et al., 2001; Fig. S1), many species of birds and bats can use the resources associated with mature scattered trees (e.g. tree hollows) (Law et al., 2000; Fischer and Lindenmayer, 2002; Manning et al., 2004; Lumsden and Bennett, 2005). For birds, natural woodland conditions harboured approximately 18 species per 2 ha, as opposed to approximately 10 species in scattered tree sites and only 5 species in treeless sites. For bats, the corresponding figures were 8 species, 7 species and 2 species (Fig. 1). Although these values cannot be translated directly to landscape scale beta diversity, our results clearly show that maintaining even sparse tree cover makes a major difference to birds and bats compared with having no trees at all (Law et al., 2000; Fischer and Lindenmayer, 2002; Lumsden and Bennett, 2005) (Fig. 1). Scattered trees may not be source habitat for a range of species, but the presence of birds and bats throughout the landscape is likely to provide valuable ecosystem services, including pest control (Williams-Guillen et al., 2008) and seed dispersal (Sekercioglu, 2006).

We acknowledge that richness and activity of birds and bats by themselves are not measures of ecosystem functioning. However, recent evidence suggests that species richness is positively related to ecosystem functioning (Hector and Bagchi, 2007). In addition, similar disproportionate effects may also exist for other species and ecological processes, such as canopy invertebrates and water infiltration (Manning et al., 2006). We suggest that the simple methodology used by us also could be applied to other species and ecosystem functions. A key working hypothesis is that the marginal value of an individual isolated tree is higher than the marginal value of a tree that is part of a patch of many trees. If this working hypothesis holds up in future tests, it strongly suggests that the value of scattered trees should not be discounted simply because they are not part of a large patch. By contrast, the loss of scattered trees from entire landscapes may have major negative consequences. Ecosystems potentially under threat from a loss of scattered trees include farming landscapes in Australia (Fischer et al., 2009b), southern Europe (Plieninger and Schaar, 2008), North America (DeMars, 2008) and Central America (Janzen, 1986).

Current conservation strategies afford weak protection to scattered trees (Gibbons et al., 2008). In Australia, scattered trees are regularly cleared for cropping and irrigation machinery (Maron and Fitzsimons, 2007). Strategies to offset the effects of their clearing tend to target existing woodland patches rather than establish new scattered trees elsewhere (Gibbons et al., 2009). In Australian grazing landscapes, tens of millions of scattered trees will be lost within 50 years from now because they are not regenerating (Dorrough and Moxham, 2005; Fischer et al., 2009b). Restoration practices, too, are focused primarily on expanding or connecting large woodland patches, essentially discounting the value of scattered trees. Although large patches are important, the complementary role of scattered trees at a landscape scale must be recognised (Harvey et al., 2006; Haslem and Bennett, 2008).

5. Conclusion

The potential keystone role of scattered trees warrants a balanced approach to conservation and restoration, in which scattered trees must be protected and perpetuated alongside the application

of traditional conservation measures that focus on patches and corridors (Dorrough and Moxham, 2005; Gibbons et al., 2008; Fischer et al., 2009b). In the absence of a paradigm shift regarding the role of scattered trees, currently common keystone structures will be lost from agricultural landscapes around the world (Gibbons et al., 2008).

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.biocon.2010.03.030.

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