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Of mistletoe and mechanisms—drivers of declining biodiversity in remnant woodlands

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Abstract

Mistletoe is a prominent component of woodlands throughout south-eastern Australia. Unlike many woodland plants and animals that are becoming increasingly scarce, mistletoe has responded positively to habitat fragmentation and has become more abundant in many areas. These parasitic plants are widely regarded as introduced pests that kill trees and degrade the landscape, yet our research is revealing quite a different story. All mistletoes in Australia are native and they engage in a range of interactions with many animals, having a positive influence on overall biodiversity. Yet, in high densities mistletoes can be detrimental to individual trees and, in extremely high densities, they can contribute to premature tree mortality. Accordingly, we need to understand better the role of mistletoe in remnant woodlands and determine mistletoe densities that achieve these biodiversity benefits without compromising the long-term viability of tree populations. To address this issue, we are conducting a large-scale investigation in the upper Billabong Creek catchment near Holbrook, NSW known as the RIFLE study (Resources in Fragmented Landscapes Experiment). Forty grassy box woodland remnants occurring on private land were selected and surveyed for all terrestrial vertebrates over 12 months. All mistletoes were then removed from twenty of the remnants, leaving the other twenty as controls. Over the next two decades, biodiversity will be compared in these two groups of fragments, with birds, mammals, reptiles and butterflies monitored seasonally and related to a range of resources. Preliminary data indicate that mistletoe provides critical nutritional and nesting resources for many animals, determining distributions for many species and potentially offsetting many of the deleterious consequences of habitat fragmentation. Mistletoe also plays a key role in nutrient dynamics, affecting litter and soil composition which may modify stand-level productivity and successional processes. Rather than a threatening process or a weed that should be controlled, mistletoe appears to be crucial to the ongoing maintenance and conservation of our threatened woodlands. While our research is focused on mistletoe in remnant woodlands, the implications of our work extend much further. Our long term aim is to inform restoration and rehabilitation efforts, augmenting existing practices and giving resource managers the process-based knowledge required to implement on-ground works designed for maximum ecological benefit.

Introduction

The woodlands of southern Australia are in trouble. As with many forested habitats elsewhere, the vast majority has been cleared and most of the remainder consist of isolated and degraded remnants (Yates and Hobbs 1997). This process of habitat fragmentation has had a sever impact on a range of native species, with many formally abundant plants and animals now alarmingly scarce. The dunnarts, daisies and dragons that characterised these habitats as recently as fifty years ago have retreated to the north and west, persisting only in occasional remnants. Although broad-scale clearing no longer occurs, the repercussions are ongoing, with species continuing to decline to extinction, habitats becoming progressively simplified and entire landscapes losing functionality.

The latent impacts of fragmentation at the landscape scale and persistent threats such as grazing and firewood collection at the patch scale, have pervasive effects on faunal assemblages and ecological processes within these remnants (van Dorp and Opdam 1987; Briggs 2001; Driscoll et al. 2000; Watson 2002a; Fahrig 2003; Tews et al. 2004). Most studies relating to biodiversity within agricultural landscapes have focused on birds (Andren 1994; Bennett and Ford 1997; Mac Nally and Watson 1997; Watson et al. 2000; Maron et al. 2004), but results vary widely. Most studies present novel findings, many of them idiosyncratic to that particular region. In addition to differences between regions and associated biota, these studies also vary in their sampling and analytical approaches, further confounding any comparisons or meta-analyses. More recent research has highlighted the dynamic nature of species occurrences in these landscapes, revealing unprecedented levels of species turnover (i.e., species coming and going from fragments; Maron et al. 2005). This suggests that the short time-frame of most studies (typically two years or less) is simply insufficient to distinguish underlying patterns from the background variation or noise.

In recognition of these shortcomings, we have proposed two new ways of studying habitat fragmentation. Firstly, study older landscapes (Watson 2002a; 2003a). After thousands of years (or hundreds of generations), diversity patterns show remarkable congruence across ecosystems, suggesting many of the observed differences between groups and landscapes are transient. While improving our understanding on the longer-term consequences of fragmentation, younger landscapes are still important, accounting for a large (and growing) proportion of fragmented ecosystems. The second strategy advocated is to take an explicit resource-based approach, complementing patch-scale studies and revealing mechanistic effects of fragmentation (Watson 2003a).

One resource that we have been studying in depth is mistletoe. Although popularly viewed as an introduced weed that kills trees and devalues habitat, our research has revealed a different story. Rather than having a negative impact, these native parasitic plants can actually promote biodiversity by providing high quality fruit and nectar, secure nesting and roosting sites, and abundant nutrient-rich litter (Watson 2001; Cooney and Watson 2005; Cooney et al. 2006). Indeed, we proposed that mistletoe functions as a keystone resource, having a disproportionately positive influence on diversity patterns in woodlands and forests worldwide (Watson 2001). A comparison of two woodlands near Canberra (one of which had been cleared of all mistletoe for five years but otherwise similar in all respects) revealed that mistletoe boosted the richness of woodland bird species by approximately 20% (Watson 2002b)—strong evidence that mistletoe can have a substantial direct effect on biodiversity.

Unlike shrubs, hollows and course woody debris that are also beneficial to many woodland species, mistletoes have become more abundant in many fragmented landscapes. Through a combination of fire suppression, fewer leaf-eating marsupials (known to favour mistletoe foliage, Watson 2001; 2004a), and the increased availability of water, nutrients and light in woodlands (especially associated with edge habitats), mistletoe density has increased 10–100 fold in many regions. So, while fragmentation continues to cause widespread declines in woodland biota, mistletoe may be a key factor allowing woodland-dependent animals to persist in the remainder of their habitat, providing critical food and shelter in an otherwise resource-poor ecosystem (Watson 2002b). Moreover, unlike hollows and coarse woody debris that may take centuries to develop, mistletoe responds more rapidly and can therefore be manipulated more easily.

The overall Resource In Fragmented Landscapes Experiment (RIFLE) represents a twenty-year study evaluating the influence of resource availability on distribution patterns of woodland animals. The first phase involves three main activities—biodiversity monitoring (birds, reptiles, amphibians, mammals and arthropods), collecting direct measurements of resource occurrence (initially focused on coarse woody debris and mistletoe, eventually incorporating nectar, leaf litter and litter-dwelling arthropods), and manipulating resource occurrence at the patch scale. The research is being carried out in forty fragments of grassy-box woodland and dry foothill forest in the upper Billabong Creek catchment, all but one of the sites located on private land. The resource manipulation component involved removing all mistletoe plants from 20 fragments of woodland, leaving the remaining 20 fragments as controls. Explicit comparisons between treatment and control woodlands allow quantification of the mechanistic basis of mistletoe's influence on biodiversity. Continued monitoring will reveal the interplay between mistletoe density and species richness over time, suggesting optimal mistletoe densities that maximise biodiversity benefits over the longer term.

Methods

Unlike other studies of occurrence patterns in fragmented landscapes, we use patch-scale methods to obtain biodiversity inventories for the overall remnant. In addition to generating data at the most meaningful biological scale, this approach also yields information relevant to landholders and land managers, needing lists of species associated with each site. Patches vary from 1–25 ha, and range from intact, structurally diverse woodlands to heavily grazed, structurally simplistic sites. Given this range of habitat qualities, results-based stopping rules were used to determine when patch-scale sampling was complete—the standardised search (Watson 2003b, 2004b). All sites were sampled each season until estimated completeness exceeded 80%, hence data are consistent and comparable across sites. More than 140 species of bird were detected during the first year of surveys alone, including all woodland-dependent species known from the catchment—a surprising result given the small size of most of these remnants. Exhaustive trapping (12,900 trap nights) was used to quantify small mammal occurrence in the 40 remnants, with spotlighting used at night to detect arboreal marsupials.

Preliminary results

We are now in the fourth year of the project, having conducted a full year of baseline surveys in 2003, removed over 47 tones of mistletoe in 2004, and then completed the first year of post-treatment biodiversity surveys in 2005. Already, it is clear that mistletoe is having a major influence on the occurrence of woodland dependent animals within the region. Abundance of mistletoe in the forty fragments (pre-removal) explained more than twice the variation in woodland bird richness than fragment area, a surprising results that reinforces the value of focusing on resources explicitly (Fig 1). Rather than acting in isolation, mistletoe abundance clearly interacts with a range of patch and landscape scale factors. Hence, rather than supplanting patch and landscape-scale explanations for distribution patterns of particular taxa, this explicit resource-based approach helps elucidate the underlying reasons why.

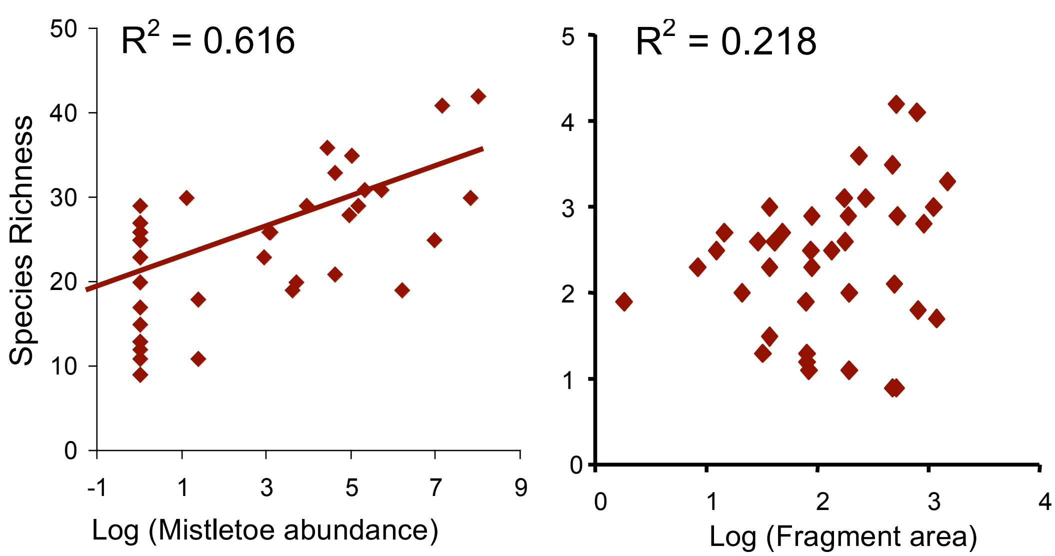

Figure 1. These graphs depict the relationship between species richness of woodland birds on the Y axis with fragment area and mistletoe abundance. While larger patches supported more bird species, the relationship was not clear cut, with variation also increasing as patches became larger. Conversely, mistletoe density had a strong and bounded relationship with species richness—significantly more bird species were associated with sites supporting high mistletoe densities, echoing many previous findings synthesised in Watson (2001).

Implications for management

Mistletoe plants are Australian natives, relying on other plants for their nutrition, and a range of birds for their seed dispersal and pollination. They are preferentially browsed by possums and gliders, and serve as host plants for many butterflies and other insects. Any changes to even one of these interactions can lead to rapid and dramatic changes in mistletoe density. While they have become common in many south-eastern Australian landscapes, most of these changes relate to only two mistletoe species—*Amyema pendula* and *A. miquellii*. Most of the other species are rare or restricted, with many declining toward local extinction.

Despite their value to native wildlife and their utility as indicators of environmental change and ecosystem integrity, mistletoes continue to be considered as weeds. As part of catchment management plans, silvicultural practices and general council policies, mistletoes are routinely removed from native vegetation throughout Australia, often from high value remnants near cities and regional centres. Aside from the fact that these practices are prohibitively expensive, mistletoe removal at the stand and catchment scales is invariably futile—in less than five years, mistletoe will have recolonised the trees and returned to initial densities. In some areas where mistletoe densities have increased, loss of native marsupials, suppression of bushfires and nutrient supplementation from domestic stock and/or fertilizers may be the implicated. Simply removing the mistletoes addresses the symptom, but ignores the underlying problem. By taking a more holistic view and applying our growing understanding of ecological interactions, both short and longer term goals can be readily achieved. By preventing stock from camping directly beneath the crowns of trees, carefully controlled burns and adding next boxes for arboreal marsupials, these underlying processes can be adjusted. Mistletoe density can actually serve as an index of how effective these management actions have been, and can be surveyed over the longer term as part of ongoing monitoring. Hence, while targeted mistletoe removal will always be a useful tool for individual trees, addressing the underlying causes is required for effective long term habitat amelioration.

Prospect

Clearly, there is still a great deal to learn about mistletoe and the role it plays in remnant woodlands. While there is now an emerging understanding of the suite of interactions between mistletoe and its hosts, pollinators, seed dispersers and herbivores, there are many other interactions which are still poorly understood. Having collected baseline data and established this catchment scale experiment, we are well placed to contribute to this growing knowledge base, informing land managers and learning more about the actual mechanisms underlying observed patterns.

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