The value of remnants on farms for invertebrate biodiversity: a preliminary study

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Abstract

Remnant vegetation and biodiversity conservation have been linked to a number of indirect agricultural production benefits, such as salinity discharge and erosion protection, and more direct benefits such as improved livestock, crop and pasture production. However, there is little scientific evidence to support this. In the present economic climate landowners may need to be convinced of the economic value of remnant vegetation and the benefits of the ecosystem services that it provides if remnants and biodiversity are to be conserved on farms. While this type of information is still a few years away, a long-term study in north-central Victoria is addressing the issue.

This paper outlines a pilot study undertaken in Grey Box grassy woodlands on or adjacent to private land. This pilot study investigated the diversity and abundance of insects in remnants of various sizes, and within remnants with varying degrees of habitat structure. The size of the remnant had no influence on insect diversity or abundance, but remnants with greater habitat structural diversity contained more species and individuals of insects, and therefore a probable increased level of pollination and pest control for the surrounding agricultural landscape. These preliminary results suggests that smaller tracts of remnants with more structural diversity might be more valuable on farms in terms of pollination and pest control than large remnants without structural diversity. Longer-term studies and more replicates are required to confirm this work.

Keywords

biodiversity conservation, ecosystem services, fragmentation, grassy woodlands, invertebrates

Introduction

Recent land-use changes in many parts of the world have greatly reduced the extent of natural habitats. In Australia the loss of natural vegetation has been most severe in those areas developed for agriculture and urban development, resulting in a mosaic of cleared, regenerating and unaltered patches of vegetation surrounded by agricultural land. These small patches may provide habitat for some of the flora and fauna species originally present in these habitat types and for the more generalist species, which may provide important ecosystem services to the surrounding agricultural landscape.

Ecologists have long recognised that organisms exhibit patchy distribution patterns. Species are distributed both horizontally and vertically in habitats in response to spatial variation in environmental conditions such as soil type, microclimate, water, vegetation and the pressure exerted by other individuals of the same and of different species. While most studies have focused on the distribution of mammals (e.g. Oxley et al. 1974, Bennett 1993, Laurance 1994) and birds (e.g. Lynch 1987, Andren 1994, Crome et al. 1994, MacNally and Bennett 1997, Brotons and Herrando 2001) few studies that have focused on the distribution of insects. Many of these studies were undertaken in the Northern Hemisphere (e.g. Aizen and Feinsinger 1994b, De Souza and Brown 1994, Collinge 2000), which has markedly different faunas and clearance and grazing histories, and so may not be applicable in the Australian context.

While it is generally accepted that insect diversity and population size will be affected by the size of habitat, it is not known to what degree. Studies on mammals (Bennett 1987) and birds (Loyn 1987, Warkentin et al. 1995, Major et al. 2001) found that small patches supported smaller numbers of species dominated by widespread common species or introduced species. These studies highlighted that larger patches have a greater variety of vegetation types, supply a greater range of food items and hence support larger populations. Many fragmented habitats are too small to support viable populations of vertebrates, and consequently these populations are vulnerable to extinction. Studies of insects in forest patches showed that there were declines in the species richness of dung and carrion beetles (Klein 1989, Gibbs 2001), butterflies (Rodrigues et al. 1993, Hill 1995), termites (Abensperg-Traun *et al*. 1996, De Souza and Brown 1994) and euglossine bees (Aizen and Feinsinger 1994b). Consequently there was a reduction in the ecosystem services provided by insects such as pollination (Aizen and Feinsinger 1994a, Didham *et al*. 1996), decomposition (Klein 1989) and seedling recruitment (Burkey 1993). These declines in services can in turn reduce productivity in surrounding agricultural landscapes.

Ecosystem services flow from natural assets (soil, water, plants, animals, and the atmosphere) to provide a financial, ecological or cultural benefit (CSIRO Sustainable Ecosystems 2001). If natural assets are not maintained the benefits from ecosystem services decline, however if they are used more effectively, agricultural production can benefit from greater returns. With increasing financial pressure on landowners there is a need to demonstrate to landowners the value of native remnant vegetation on their own land and on neighbouring properties to ensure that remnant vegetation is conserved. If it is at all possible to assign a value to remnant vegetation then it may be more likely that landowners will maintain and enhance native vegetation.

This study took place in the agricultural landscape of north-central Victoria, within the former domain of the Box–Ironbark (*Eucalyptus mellidora, E. albens, E. microcarpa*) forest ecosystem (Muir et al. 1995). Over the last 150 years, Box–Ironbark Woodlands and Low Rises Grassy Woodlands have been extensively disturbed by gold mining, timber felling and clearing for agriculture, and most of the remaining vegetation is heavily degraded (ECC 1997). About 85% of the natural vegetation has been cleared and the remaining forests predominately occur on areas with shallow soils of low fertility (Calder et al. 1994). These are some of the most poorly conserved ecological communities in Australia (Specht 1981). This paper presents preliminary data collected during January 2002 and describes the objectives of the longer-term study, outlines the experimental design and the sampling strategy used to collect invertebrates.

Method

Study area

The study area is located within the northern inland slopes bioregion (Berwick 2001), between Shepparton and Benalla within the Goulburn–Broken Catchment, extending from Tarnook in the west to Tamleugh in the south-east and bordered by Dookie College in the north and Violet Town in the south — an area of approximately 600 km^2 (Figure 1). Woodland fragments selected for the study were on gentle slopes and hills on the dry inland side of the Great Dividing Range. The climate of the region is typically Mediterranean, with an average annual rainfall of 555 mm and 99 rain days, with most rain falling in June–October (Bureau of Meteorology 2000). There are an average of 22 frosts annually between April and September (VCAH 1992). January is the hottest month, having a maximum mean monthly temperature of 29.8°C and July is the coolest, having a mean minimum of 4.0°C. Summer temperatures can exceed 42°C and winter temperatures can get below –2°C (Bureau of Meteorology 2000).

The study area is composed of Ordovician Silurian–Devonian sedimentary rocks, which dominate the ridges of steeper slopes above lower slopes of colluvial origin (Tickell 1989). Tenosol soils (Isbell 1993) ('shallow, stoney, skeletal soils' in Northcote 1983) are found on the northern upland slopes and ridges and are naturally low in available nutrients. The A-horizon of these soils is shallow with a high proportion of rock and gravel. The lower slopes are characterised by Chromosol soils (Isbell 1993) ('red or brown duplex soils' in Northcote 1983), which are also low in available nutrients but contain a lower proportion of rock and gravel in the upper horizons.

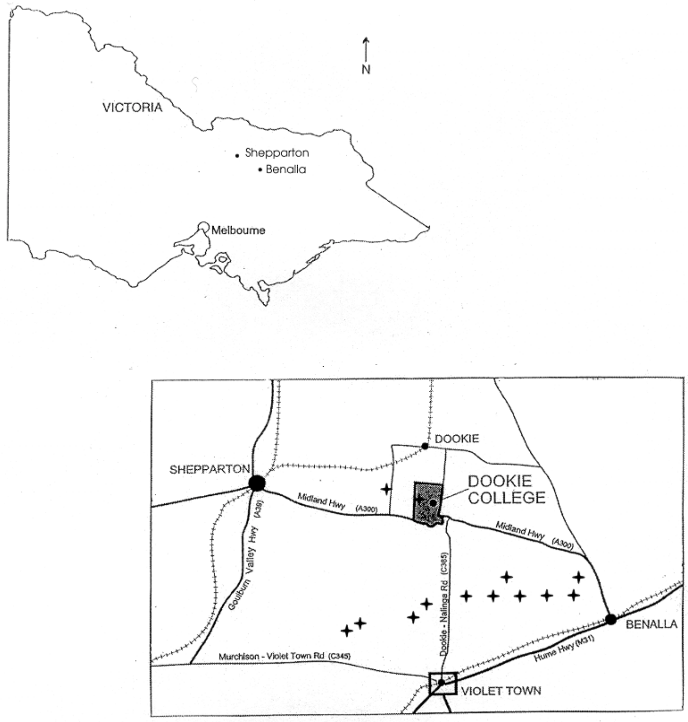

Figure 1 Location of study sites in the Goulburn–Broken Catchment.

Thirteen fragments of isolated sedimentary hill Box–Ironbark Woodlands and Low Rises Grassy Woodland dominated by Grey Box (*Eucalyptus microcarpa*) in north-central Victoria were assessed for vegetation structure, insect diversity and number of individuals of insects. Fragments representing four size classes were located: small (< 5 ha — mean 1.95 ha ± 1.29 sd, $n = 4$), medium (5–10 ha — mean 7.75 ha ± 1.89 sd, $n = 4$), large (20–30 ha — mean 23.3 ha ± 2.88 sd, $n = 3$), and extra large (> 30 ha — mean 165 ha ± 148 sd, $n = 2$).

Insects were collected by sweep-netting. At each site there were two five-minute sweeps with the surveyor walking at a constant pace through the vegetation. Insects were preserved by freezing and identified at least to order, usually to family and in some cases to species. Others were identified to morpho-species using external morphological features. Morpho-species have been used as surrogates for species and provide a good representation of formal species estimates (Oliver and Beatty 1996, Pik et al. 1999).

A visual assessment of vegetation was made to assign the structure of the site to a vegetation state based on a modified version of the 'State Transition Model' as proposed by Westoby et al. (1989):

- State 1 (N = 4), overstorey of Grey Box with a diverse shrub and ground layer. The typical understorey of an undisturbed fragment consisted of Golden Wattle (*Acacia pycnantha*), Spreading Wattle (*A. genistifolia*), Sweet Bursaria (*Bursaria spinosa*), Gorse Bitter-pea (*Daviesia ulicifolia*), Cassinia (*Cassinia arcuata*) and Common Everlasting (*Chrysocephalum apiculatum*), with small herbs and scattered grasses (*Austrodanthonia* spp., *Poa* spp. and *Joycea* sp.) making up the ground layer.
- State 2 (N = 3) had an overstorey of Grey Box with a reduced shrub layer and reduced ground cover.
- State 3 (N = 2) had an overstorey of Grey Box with no shrub layer and minimal ground cover.
- State 4 had an overstorey of Grey Box with a dense understorey of shrubs (usually of the one species; no sites in this study fell within this state).
- State 5 (N = 4), overstorey of Grey-Box had an eroded seedbank and little prospect of natural regeneration.

Data Analysis

The relationship between size of fragment, diversity and abundance was examined using regression analysis. A trend was calculated and a *t*-test was used to determine the significance of the associated r^2 value. Student *t*-tests (corrected for multiple comparisons) were used to compare diversity index (number of morpho-species) and abundance (total individuals) with size and state of remnants. The diversity of species was investigated using Simpson's diversity index and equitability (evenness).

Results

A total of 531 arthropods were collected during the study. Ten orders were detected, with 79 morpho-species identified. Lepidoptera was the most abundant order (comprising 18% of the total number of arthropods) with two families represented (Oecophoridae and Lycanidae). Hemiptera was the most species-rich order (16 morpho-species) comprising 20% of the total number of species collected. Oecophorids were found at all sites regardless of size or structure, but only sites with an understorey contained a diverse array of Hemiptera such as leaf-hoppers (Ricanidae, Cicadillidae), lantern flies (Fulgoridae) and plant-hoppers (Cicconellidae, two species). Chironomids (Diptera) were also found at all sites. Ants (Hymenoptera) were found in all states of vegetation, but were more abundant and diverse in sites categorised as State 1 or 2 (eight individual in three species: *Iridomyrmex* sp. A, *I.* sp. B, *Dolichoderus* sp.) compared to State 5 (one individual of one species, *Myrmecia* sp.). Wasps (Chalcidoidea; Hymenoptera) were more abundant in sites classed as State 1 vegetation type (16 individuals compared to 2 individuals in State 5). Spiders were also more abundant (50 individuals) and more diverse (eight morpho-species) in sites classified as State 1, while only one individual was found in one site classified as State 5.

Overall fragments of remnant vegetation characteristic of State 1 (i.e. more structural diversity), contained a significant two-fold increase in the number of species of insects, and had a greater abundance of individuals (200% increase) compared with fragments with little structure (State 5; $p < 0.05$; Fig 2 and 3). However, the abundance and diversity of arthropods did not significantly differ between fragments of various sizes ($r^2 = 0.55$; $y = 9.99e^{0.279x}$, $p > 0.05$; Figures 4, 5). Nevertheless, this preliminary data (Figure 4) does show that there is a trend towards more insect species occurring in larger sites. The Simpson's diversity index was greatest (7.57) in the large (25 ha) State 1 site and was lowest (3.08) in the small (8 ha) State 1 site (Table 1). The average Simpson's diversity index was lowest (4.92) in sites grouped as State 5, and highest (5.68) in sites grouped as State 1 (Table 1). The equitability values of morpho-species show no distinct trends (Table 1).

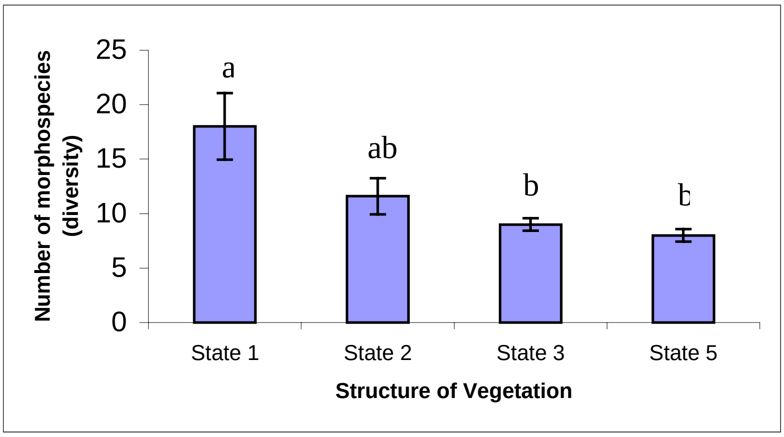

Figure 2 Insect diversity as determined by two 5 minute sweep-netting in 12 sites categorised in to vegetative states. Different letters above the histograms indicate that treatments were significantly different ($p < 0.05$).

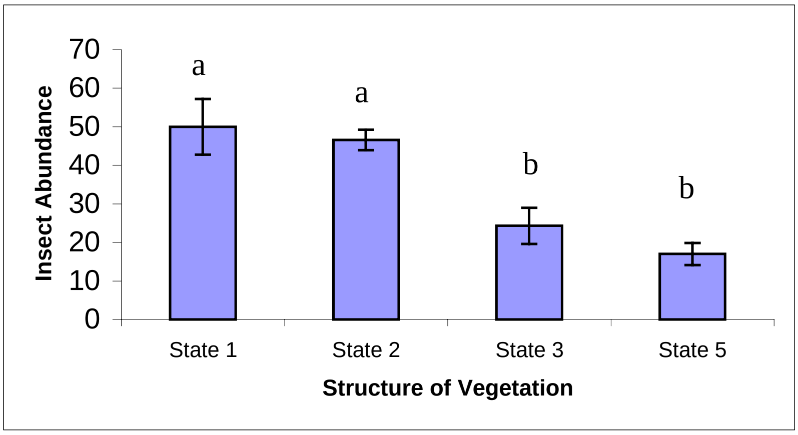

Figure 3 Insect abundance as determined by two five-minute sweep-nettings in 12 sites categorised into vegetative states. Different letters above the histograms indicate that treatments were significantly different ($p < 0.05$).

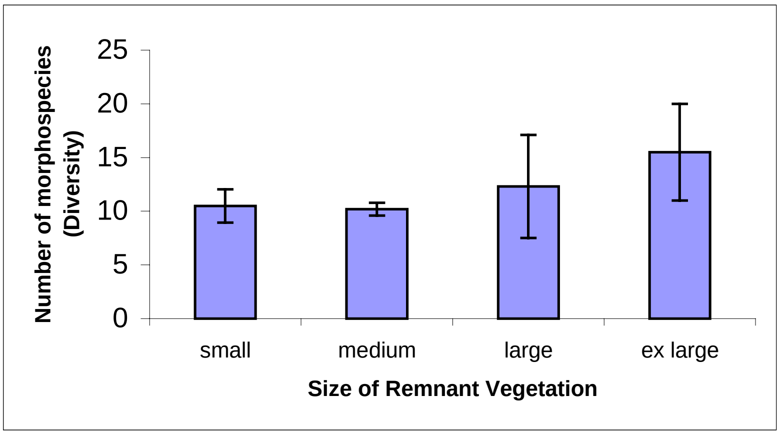

Figure 4 Insect diversity as determined by two five-minute sweep-nettings in 12 sites categorised into small (< 5 ha), medium (5–10 ha), large (20–30 ha) and extra large (> 30 ha) fragments.

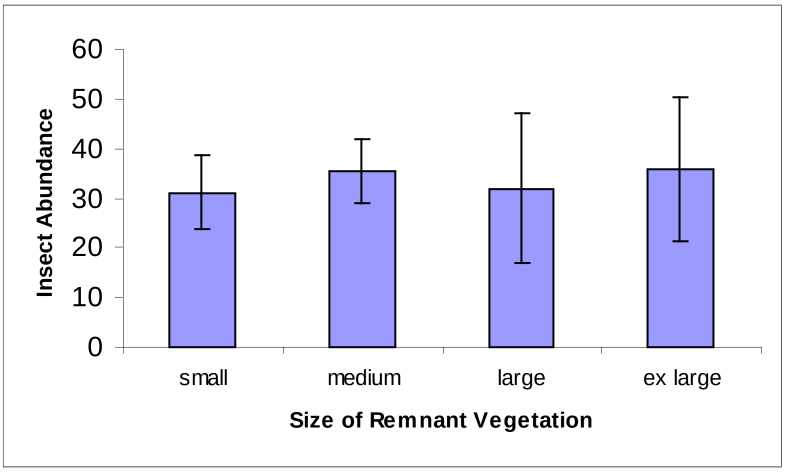

Figure 5 Insect abundance as determined by two 5 minute sweep-netting in 12 sites categorised into small (< 5 ha), medium (5–10 ha), large (20–30 ha) and extra large (> 30 ha) fragments.

Table 1 Simpson's index of morpho-species diversity and equitability for Grey-Box Grassy Woodland within the Goulburn–Broken Catchment.

Site	Vegetative state	Size (ha)	Simpson's index of diversity	Equitability index
Koonda	1	8	3.0828	0.3083
Upotipotpon	1	9	5.6805	0.4734
Straithaird	1	25	7.5669	0.3440
Dookie Reserve	1	270	6.4222	0.3058
Lamonts Rd	2	2.4	6.2593	0.4173
Martins Lane	2	0.5	3.8426	0.4270
Cutting Reserve	2	5	5.5632	0.5563
Gelli-Tonks	3	1.4	6.4284	0.8035
Walls Reserve	3	3.5	5.8442	0.5844
Longs Property	5	9	5.4528	0.6059
Quarry site	5	20	3.8413	0.5488
Lamonts Hill	5	25	4.5000	0.5625
Girral	5	60	5.9025	0.5366

Discussion

An underlying assumption of ecological surveys that use rapid inventory techniques is that native invertebrate diversity will be reflected by native plant diversity. It thus follows that structure provides a variety of niches for insects. Many studies have supported this assumption (Majer 1978, Crisp et al. 1998, Seymour and Dean 1999, Pik et al. 1999, Oliver et al. 2000). Crisp et al. (1998) found that there were more beetle species in the variety of habitats surveyed in New Zealand with the most plant species (both native and introduced). In South Africa, Seymour and Dean (1999) found that invertebrates in general decreased with decreasing total and perennial cover. Toft et al. (2001) found that weevils inhabiting leaf litter (Curculionidae; Coleoptera) decreased in patches in New Zealand that were invaded with the invasive weed *Tradescantia fluminensis*, which reduced vegetation richness. However, this same study also showed that some species of fungus gnats (e.g. *Chiasmoneura fenestrata*: Keroplatidae) increased in areas where vegetation diversity was reduced and were therefore utilising *T. fluminensis* as habitat (Toft et al. 2001).

Changes in the vertical structure of the vegetation can also influence insect diversity. Humphrey et al. (1999) demonstrated that the vertical stand structure of forest sites in the United Kingdom was positively correlated with species richness and diversity of carabids (ground beetles) and syrphids (hoverflies). Carabid beetle diversity and abundance at all our sites was low, but this was more likely due to the collection method, i.e. sweep netting, rather than the lack of species per se. Morris (2000) found that tall grass supports more species, more individuals and a greater diversity of arthropods that do short swards. In our study, sites with a grassy layer, i.e. sites in State 1, 2 and 3, supported the highest diversity and abundance of insects, but there was a decline in diversity in State 3 sites compared to State 1 sites (Figure 2). This might also be due to the collection method. Because sweep-netting tends to collect aerial species, in future a more intensive collection using pitfall traps will be used simultaneously to collect ground-dwelling terrestrial species such as ants and beetles, which usually dominate the ground layer. Insects will be collected seasonally (January, April, July and October) over a number of years to provide information on seasonal effects.

Hemiptera was the most speciose taxon found in all our study sites. This is not surprising, as they are a dominant group occupying a variety of environments. The Australian fauna of Cicadellidae (leaf-hoppers) is rich (664 species) (Zborowski and Storey 1995) and includes a high proportion of arboreal species (Carver et al. 1991). Other studies on Hemiptera have shown that the presence of those in the family Nabidae appear to be determined by the presence of dense and tall vegetation rather than by particular plant species (Morris 1969). This concurs with our study, in which sites with the most abundant and diverse Hemiptera also had the most complex vegetation structure, i.e. State 1. While the majority of insects in Hemiptera are sap feeders, there are predatory species in the family Pentatomidae, Lygaeidae, and Reduviidae (Zborowski and Storey 1995) that prey on the eggs of phytophagous insects and control mosquito larvae. Some species of Hemiptera are also important for the biological control of noxious weeds, such as St John's Wort, *Hypericum perforatum* (Aphididae) and Prickly Pear, *Opuntia robusta* (Coreidae) (Carver et al. 1991).

Oecophoridae (Lepidoptera) were found in all sites of all sizes and all vegetative states. Oecophoridae comprise more than a quarter of the Lepidoptera fauna in Australia — about 5000 species (Common 1994) — and are especially abundant in eucalypt forests and woodlands, where larvae feed on dead eucalypt leaves (Nielson and Common 1991). Hence it is suspected that this group of moths plays an important role in the decomposition of eucalypt leaves.

Hymenoptera are important pollinators, predators and parasites. While Hymenoptera were collected at all sites in our study, the diversity and abundance of individuals were greater in sites classed as State 1. Parasitic wasps (Chalcidoidea) were abundant in State 1, probably feeding on other insects. The value of Hymenoptera as biological control agents was recognised in the early 1900s when species of parasitic wasps were released to apple growers in the Goulburn Valley area to help control woolly aphids (Williams 2001). Other species of insects living in natural vegetation may also facilitate this role.

Fragment size is also thought to influence the diversity and abundance of insects. Abensperg-Traun and Smith (1999) found that small remnants sustained four species of arthropods, but their rate of occurrence increased as remnant size increased. Our preliminary study showed that the size of the remnant is not a factor in influencing diversity or abundance (Figures 4, 5). This may simply be due to the small amount of data collected; more sampling might reduce the standard deviation and validate the trend (although not significant) that appears to be evident in Figure 4. Alternatively, sampling remnants in a size category may be affected by the variation of vegetation structure within each size category. For example, remnants grouped in the < 5 ha contained 4 sites categorised in States 2 and 3, while those grouped in size 5–10 ha contained 4 sites in States 1, 2 and 5. Because of the size and scale of this experiment it is difficult to have adequate control and replication, and therefore it has not been possible to test for interactions between fragment size and structural diversity. Nevertheless our preliminary findings suggest that vegetation structure, rather than the size of the remnant, is important in influencing insect diversity and abundance. However, more intensive surveys are required to validate this conclusion. Additional sites have since been located to increase the rigour of this study.

Not all invertebrates are pests, and many species may be beneficial to agricultural production. Future research based on this preliminary study will focus on the role of individual insect species in the surrounding agricultural landscape to determine what ecosystem services are being provided by these selected species. Current methods of conservation of native vegetation on private land include grants to fence out stock, and legislation. However, grant uptake is still low, and unauthorised clearing still continues. Innovative methods are required. If landowners can see an economic value associated with remnant vegetation then it is more likely to be maintained and enhanced. An additional focus of this longer-term study will investigate the impacts of habitat fragmentation on insect diversity in box forests in central Victoria.

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