



Hardwood Plantations

**Quantifying conservation
and environmental service benefits**

**A report for the
RIRDC/L&W Australia/FWPRDC
Joint Venture Agroforestry Program**

**Supported by the
Natural Heritage Trust**

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Foreword

Farm forestry activities are increasing dramatically and farm forestry has future potential to be a major land use over much of southern Australia. While economic benefits and the likely impacts in slowing water table rise and other forms of land degradation have been examined, there is limited information on the role that farm forestry might play in the conservation of biodiversity.

This report presents a detailed case study from southwestern Australia which investigates the vertebrate and invertebrate fauna found within plantations of *Eucalyptus globulus* (Bluegum), and provides the first detailed information on faunal use of extensive bluegum plantations.

This project was funded by the Joint Venture Agroforestry Program (JVAP) and the Natural Heritage Trust. The JVAP is supported by three R&D Corporations — Rural Industries, Land & Water Australia and Forest and Wood Products — as well as the Murray-Darling Basin Commission. These agencies are funded principally by the Federal Government.

This report, a new addition to RIRDC's diverse range of over 800 research publications, forms part of our Agroforestry and Farm Forestry R&D program, which aims to integrate sustainable and productive agroforestry within Australian farming systems.

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Executive Summary

1. Farm forestry is expanding rapidly in parts of southern Australia, and is seen by many as an opportunity to develop profitable timber products and at the same time address environmental problems. To date there has been little investigation of the possible biodiversity benefits associated with farm forestry. This report presents information derived from a detailed study of the vertebrate and invertebrate fauna found in *Eucalyptus globulus* plantations in southwestern Australia.
2. The project had the following aims:
 - a. Quantify the extent to which native hardwood farm forestry on cleared agricultural land can contribute to achieving biological conservation goals.
 - b. Quantify the relationship between floristic diversity, natural enemy diversity and insect herbivore damage in farm forestry.
 - c. Identify which farm forestry practices have positive or negative impacts on particular biological conservation goals, and how these practices may be modified to increase these conservation benefits without jeopardising commercial benefits.
 - d. Provide input to guideline development for farm forestry which promote enhancement of native biota e.g. birds, mammals and insects, and minimize insect herbivore damage.
3. An overview of current plantation practices is presented, with examples from the main areas where activity is currently greatest. This overview indicates that current practice includes little consideration of possible biodiversity benefits.
4. The field program consisted of four sampling periods in Spring and Autumn during 1999-2001. Four study areas were established in the Albany – Mount Barker region of southwestern Australia, each of which consisted of a large block of native vegetation, a plantation adjacent to this, and another plantation isolated from the native vegetation. At each site, sampling was carried out within the native vegetation, at the edge of the plantation adjoining the remnant, at the centre of the plantation, and at the edge adjoining agricultural land. In the isolated plantation, samples were also taken at the edge and in the centre of the plantation, and a sample plot was also set up within the agricultural land.
5. At each of these sample areas, vegetation structure and composition was assessed, and by trapping and/or observations, estimates of abundance were made for birds, bats, amphibians, lizards and mammals. At the same sites, invertebrate groups were sampled by a variety of means, including knockdown, light and malaise trapping.
6. Native vegetation has a heterogeneous tree cover and diverse shrub and ground cover layers with some fallen timber and leaf litter. Plantations have a more homogeneous and closed tree cover and an almost complete absence of shrub and ground cover layers. Agricultural land had no trees or shrubs, but a complete cover of introduced pasture with no litter.
7. Ten species of amphibian and twelve species of reptile were recorded during the four surveys. Twice as many species (17) were recorded in the remnant vegetation than in any one of the plantation habitats (3-7 species) or the agricultural land (7 species). The number of species recorded in sites in the plantations and the agricultural land were very similar and there was no obvious difference between the number of species using the edge of plantations and the interior of plantations.
8. Ninety nine species of bird were recorded during the four surveys. More species were found in native vegetation (51) compared within plantations (31-36) and on agricultural land (30).

Overall abundance of birds was considerably lower in plantations compared with native vegetation. Individual species showed a variety of patterns of abundance, with some species being most abundant at plantation edges and others showing no obvious habitat preferences. Numbers of observations of species considered at conservation risk were higher in plantations next to native vegetation compared with isolated plantations. Overall bird species richness was highly correlated with the mean Habitat Complexity Score estimated for each habitat type, which was highest in the remnant vegetation and lowest in the agricultural land.

9. Eight species of bat were recorded during the four surveys. The number of passes that were recorded in each habitat was used as an index of the overall quality of each as foraging areas for bats. Over half of the passes were recorded in remnant vegetation, with a further third recorded in plantations abutting remnants.
10. Thirteen species of ground-dwelling mammal were recorded during the four surveys; eight native and five introduced. Native mammals were largely restricted to remnant vegetation. The only native mammal to occur in all habitats was the Western Grey Kangaroo. However, most of the introduced species, including foxes, cats and rabbits, occurred in all habitats
11. We collected 295 species of moth from 26 families. The majority of species were found in remnant vegetation (244/295). Almost two thirds of the species found in plantations were also found in remnant vegetation (104/155). When compared with the samples from remnant forest, the plantation samples were relatively more dominated by a few abundant moth species.
12. We identified 103 species of Coleoptera from light traps. The majority of species were found in remnant vegetation. More than half of the species found in plantations were also found in remnant vegetation. Beetles were much more abundant in light traps in plantations (3519 individuals) than in remnant vegetation light traps (1501 individuals).
13. We identified 185 species of Coleoptera from malaise samples. The greatest species richness was in pasture, followed by remnant vegetation, then plantations. More than half of the species found in plantations were also found in remnant vegetation. The plantation edge habitat was richer than the interior.
14. We identified 307 species of beetles from canopy knockdown samples. The majority of species were found in remnant vegetation. Sixty percent of the species found in plantations were also found in remnants. Species richness of canopy beetles was lowest for the interior plantation habitat. The plantation edge sites were marginally richer than the interior. Not only were remnant samples and plantation samples different in species richness, but they were distinctive in species composition and abundance. Beetles were slightly more abundant in the remnant canopy than in plantation trees and plantation samples were relatively dominated by a few very abundant species. The most common beetle in both habitats (but reaching very large populations in plantation) was *Gonipterus scutellatus*. This pest species, native to east coast Australia, appears to have migrated from plantation forest into remnant forest, where it is a potentially harmful invader.
15. We collected 8162 Hymenopteran insects that could be identified into six major taxonomic groups: The most abundant were the ants (3486), Ichneumonid wasps (2146) and Braconid wasps (1304). Ants were more abundant in the remnant and agricultural habitat than in plantations. Braconid wasps were least abundant in plantation interior sites, while Ichneumonid wasps were similarly abundant in all habitats
16. Overall, the invertebrate fauna of remnant vegetation was richer in species than the fauna of the plantation forests. Among the canopy-collected and malaise collected beetle samples there was some evidence for greater faunal use of edge habitats. We found little evidence in

the invertebrate data that would indicate a consistent effect of adjacency to remnant forest on the fauna of plantations.

17. Many predator and parasitoid insects were found in remnant and plantation sites. They could therefore contribute to the natural biocontrol of pest insects both in the plantation and the surrounding agriculture. The true potential of this natural service could not be determined in this study, and the possible benefits were undermined by the use of broad-spectrum insecticides in plantations, which kill beneficial and pest insects alike. Based on the information we have on natural enemies, it appears there has not been a general increase in natural enemies in plantations compared to remnants such as would be necessary to control populations of abundant leaf feeders.
18. Plantations as they are currently managed deliver a biodiversity benefit which represents a 15-25% improvement over agricultural land, based on habitat complexity scores (for vertebrates). While this represents a relatively small improvement, this may nevertheless constitute an important addition to the potential conservation value of the overall landscape. Further improvement of the habitat value of commercial plantations in southern Australia will involve tradeoffs with commercial considerations.
19. The main result from this project is that the major limiting factor to realisation of greater biodiversity benefits appears to be the structural simplicity of farm forestry plantations. If managers wish to build in more structural complexity, an array of options is available including planting a greater mixture of tree and understorey species, and including habitat structures such as ground cover and logs.

Chapter 1.

Introduction

1.1 Background

Farm forestry activities are increasing dramatically and farm forestry promises to be a major land use over much of southern Australia. While economic benefits and the likely impacts in slowing water table rise and other forms of land degradation are clear, there is limited information on the role that farm forestry might play in the conservation of biodiversity.

Loss of biodiversity is ranked as one of Australia's most pressing environmental issues (Williams, 2001), with habitat loss and modification being among the primary causes. Removal and fragmentation of native vegetation in the nation's agricultural regions is a clear manifestation of this, and it is increasingly recognised that effective biodiversity conservation cannot be achieved only through designated reserves in these areas, but also has to involve effective management of the broader landscape. In particular, revegetation may provide the opportunity to return some habitat value to degrading agricultural landscapes (e.g. Barrett & Davidson, 2000; Hobbs, 1993; Ryan, 2000). Farm forestry is generally practiced to generate an economic return or to address land degradation issues, and need not have biodiversity conservation as a primary goal. Nevertheless, there may be some conservation benefit deriving from the conversion of agricultural land to farm forestry. We need to ask whether farm forestry might have a contribution to make to conserving biodiversity. If we assume that remnant vegetation has a high biodiversity value, while that for agricultural land is fairly low, where does farm forestry sit between these two extremes (Figure 1.1)? And more broadly, do plantations provide any ecosystem services such as increasing the abundances of insect predators which target pest species?

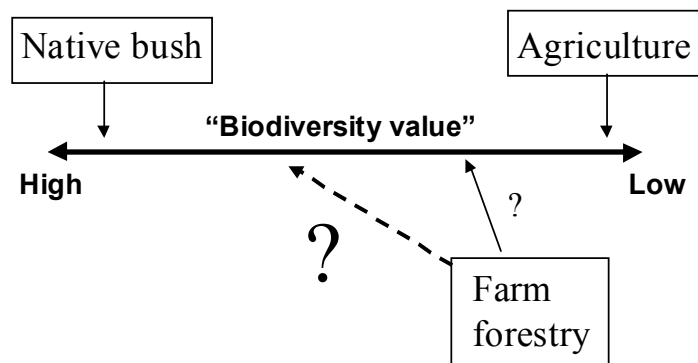


Figure 1.1. Where does farm forestry sit in terms of its contribution to biodiversity conservation, along a hypothesised continuum between agricultural land and native bush?

To date, there has been relatively little information available to help answer these questions. This project was thus undertaken, with funding from the Joint Venture Agroforestry

Program and the Natural Heritage Trust, with the aim of providing some of the first detailed information on the potential contribution of farm forestry to biodiversity conservation, and of helping develop guidelines for the design of plantations which can increase their value to biodiversity without compromising their productivity and profitability.

1.2 Aims of the project

The following aims were identified for the project:

1. Quantify the extent to which native hardwood farm forestry on cleared agricultural land can contribute to achieving biological conservation goals.
2. Quantify the relationship between floristic diversity, natural enemy diversity and insect herbivore damage in farm forestry.
3. Identify which farm forestry practices have positive or negative impacts on particular biological conservation goals, and how these practices may be modified to increase these conservation benefits without jeopardising commercial benefits.
4. Provide input to guideline development for farm forestry which promote enhancement of native biota e.g. birds, mammals and insects, and minimize insect herbivore damage.

1.3 Structure of the report

This report consists of the following chapters:

Chapter 2 examines current farm forestry practices, determined by a survey of a range of enterprises across southern Australia, and considers the likely value of current activities in terms of biodiversity conservation. Accepted wisdom on factors likely to improve biodiversity outcomes is also presented.

Chapter 3 introduces the rationale, methods, and sites used in a detailed study of faunal use of *Eucalyptus globulus* (Bluegum) plantations in southwestern Australia, in which faunal use is compared across remnant vegetation, sites at the edges and interior of plantations both adjacent to and distant from large blocks of native vegetation, and agricultural land.

Chapter 4 presents a study of the vertebrate assemblages found across the range of remnant, plantation and agricultural habitats described in Chapter 3.

Chapter 5 presents a study of the invertebrate assemblages found across the range of remnant, plantation and agricultural habitats described in Chapter 3.

Chapter 6 discusses the implications of the work and presents recommendations for the development of guidelines for management of plantations which will increase their value for biodiversity conservation.

Chapter 2.

Farm forestry: current practices and their implications for biodiversity

(Compiled by J. Ive)

2.1 Introduction

Much of Australia's farmlands are facing a range of serious environmental problems. Land and water degradation alone are calculated to be costing Australia \$1.4 billion/year (Virtual Consulting Group and Griffin nrm Pty Ltd, 2000). Although more difficult to quantify, costs associated with ecosystem decline, including the impact upon biodiversity, are estimated to be in excess of \$600 m/year or approaching 20 per cent of the annual value of farm production. Farm forestry has been widely promoted as not only a potentially commercial activity for inclusion in traditional farming areas, but also as an activity that will alleviate some of these environmental costs and contribute to halting the slide in biodiversity values of our agricultural lands.

Farm forestry is supported by a network of Regional Plantation Committees and a Farm Forestry Roundtable responsible for championing the cause of this growing rural activity. The location of the 19 regions delineated in Figure 2.1 identifies the geographical focus of farm forestry activity. All but five abut the coast and have relatively high retention of native vegetation cover (Wells *et al.*, 1984; Ive and Cocks, 1988). The five non-coastal regions cover portions of the nation's agricultural lands that have in the past borne the brunt of clearing to accommodate expanding agriculture. Reliable high rainfall and therefore commercial necessity rather than environmental priority has been the primary driver in locating plantation activity. The Farm Forestry Roundtable is now addressing this issue by developing a low rainfall farm forestry strategy (National Farm Forestry Roundtable, in prep.) in an attempt to extend and increase farm forestry activity into drier areas (250-600 mm annual rainfall).

The combination of clearing and the expansion of agriculture has precipitated the environmental problems now being experienced, leading the Australia, State of the Environment (1996) to conclude that *"two of the six major environmental problems affecting Australia are loss of biodiversity and land degradation resulting from over clearing of native vegetation"*. These problems are inextricably inter-linked.

In addition, with clearing of native vegetation on private land now strictly controlled in most states and limited availability of native forests on public land for logging, cleared agricultural land increasingly is being targeted for establishing plantations to meet projected demand for wood products (Plantation 2020 Vision Implementation Committee, 1997). Farm forestry is taking two major paths. The first where the individual farmer and landowner plants relatively small areas of trees on the farm as part of diversifying farm income and the second where individual farms are being purchased or leased by plantation companies for the purpose of establishing whole-of-farm plantations. The separation of land-ownership from tree ownership in legislation in some states has provided opportunity for other commercial arrangements. The dominant structural form of farm forestry varies from region to region.

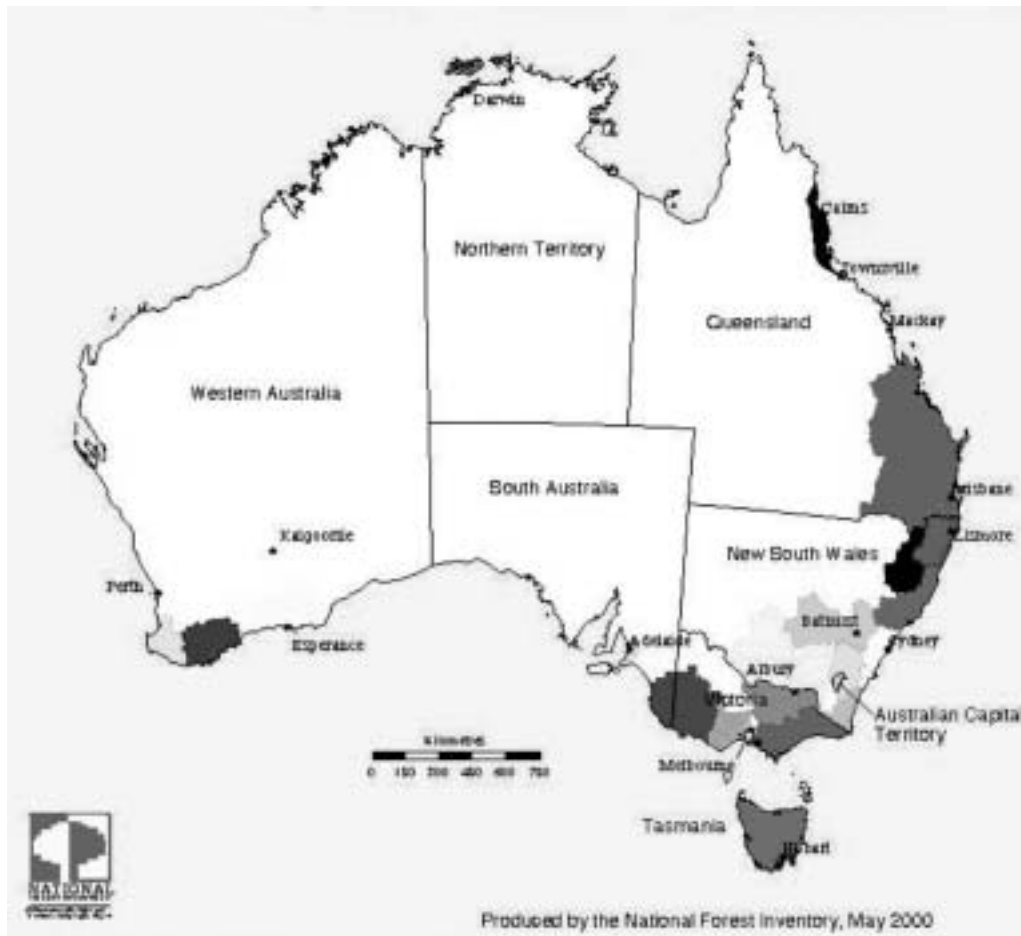


Figure 2.1. The geographical delineation of the nation’s 19 Regional Plantation Committees (shaded). Note the coastal dominance reflecting the commercial importance of reliable high rainfall in addition to infrastructure and port access for determining location of farm forestry activity. For colour image see centre section.

The first farm forestry survey (National Farm Forestry Inventory) currently being undertaken by the National Forestry Inventory will combine with the existing National Plantation Inventory (Bureau of Resource Sciences, 2000; Stephens, pers. comm.) to complete a national perspective on all farm forestry activity across the regions. Currently, the area of farm forestry contributed by individual farmers and landowners in Australia is largely unknown. For instance, no comprehensive data on farm forestry plantings is available for a number of regions e.g. southern tablelands of NSW and is very limited in other regions e.g. north east Victoria. The segmentation of farm forestry into two components for survey and recording purposes has been arbitrarily set at 1000 hectares per ‘individual’. From the limited information available two points can be made:

1. Farm forestry is currently undergoing a rapid expansion. For instance, the area of hardwood plantings in Western Australia has increased by threefold (to 15 600 ha) and for the Green Triangle (Vic- SA) by more than fourfold since 1995 (to 3 500 ha).
2. The species range used in plantings is very limited with *Eucalyptus globulus* plantings dominant. For instance, in Western Australia all but 3% of hardwood plantings are *E. globulus* and in the Green Triangle 99% are *E. globulus*.

The expansion of farm forestry activity in a number of regions is dominated by the activities of plantation companies purchasing or leasing farmland for the sole purpose of establishing hardwood plantations, almost without exception using *E. globulus*. These companies are specialising in maximising the timber for pulp production in acquired areas. This narrow business focus has strained relations between the plantation companies and neighboring farming and rural people who seek to continue more traditional agricultural activities (e.g. Melbourne University, 2000). One of the items of dispute has been company policy towards retained remnants in the agricultural landscape (e.g. Weekly Times, 2000a). The current actions of some commercial plantation companies negate the opportunity to realise the environmental goals promoted by Landcare (Commonwealth of Australia, 1991) and Plantation 2020 Vision Implementation Committee (1997) initiatives. Market-based mechanisms (e.g. biodiversity credits etc.) are advocated to promote the integration of plantations on individual farms as a more environmentally beneficial approach warranting greater attention and support in future rural policies (Melbourne University, 2000).

Evidence of the gulf between the practices undertaken by plantation companies and those conducive to fostering environmental values and biodiversity in particular are apparent. Companies operating on purchased or leased farm land are accused of clearing native vegetation remnants which provided high habitat value for endangered species (Weekly Times, 2000a) and of clearing publicly funded landcare plantings from farm land as a precursor to plantation establishment (Weekly Times, 2000b). These examples highlight the difference between the preferred commercial strategy for the individual and that for the broader society, and jeopardise the anecdotal view that farm forestry will enhance biodiversity values. Until biodiversity and conservation are demonstrated to deliver values and returns to individuals who make the effort to promote environmental values this tension will remain. This conflict is currently the topic of a public inquiry (Inquiry into public good conservation- impact of environmental measures imposed on landholders, House of Representatives Standing Committee on Environment and Heritage Inquiry, 2000).

The price now offered for farmland with trees is discounted by as much as 80% (Weekly Times, 2000c) and reflects the imposition such vegetation makes upon the commercial prospects of farm forestry operations. The bonus of this strategy is that totally cleared land with arguably the highest priority for the reintroduction of trees will be sought by plantation companies; however, the degree to which current plantation practices can regain biodiversity lost from these totally cleared landscapes remains to be seen. The more disturbing downside is that on-farm native vegetation is seen as a hefty financial burden- hardly the image to cultivate a positive mindset nor a sympathetic approach amongst the farming community for retention and management of on-farm remnants. Overall there is a disincentive to the full integration of plantations into an agricultural landscape hosting retained remnants, a situation that conceivably will limit the realisation of its biodiversity potential. For instance, many trees remaining in agricultural landscapes are old and provide niche conditions unlikely to be duplicated by a fast growing plantation of limited life expectancy. Therefore, the non-integration of plantations into agricultural areas retaining aging trees limits opportunities to develop habitat values associated with the greater structural complexity offered by those trees.

2.2 Implications for biodiversity

Biodiversity is recognised as applying at three levels a) genetic, b) species, c) landscape, with the expectation that endemic variety at each of these levels is beneficial. The underlying principle of biodiversity is that heterogeneity in the landscape provides greater opportunity for encouraging a variety of species in that landscape, and it is further proposed that this variety is central to ecosystem health and function. Agricultural landscapes have seen a prolonged period of clearing of native vegetation and from a biodiversity perspective

non-sympathetic management of the remaining remnants (Walpole *et al.*, 1998) such that much of the biodiversity of these areas has been lost, albeit unwittingly. The introduction of cropping and pasture systems with a pre-dominance of annual species and invariably monoculture stands supported by frequent use of pesticides, herbicides and fertilizer has further reduced biodiversity in our agricultural landscapes.

Within many agricultural zones there has been a tendency to concentrate on a particular form of agriculture, which at any time is managed in much the same manner across the zone. Consequently, the trend is for agricultural landscapes to become progressively more homogeneous, a trend that is contrary to retaining biodiversity values. Driving forces for this trend include economies of scale, simplifying management, selection and breeding from superior individuals and varieties. Of the 5500 breeds of livestock used in agriculture world-wide, one-third risk extinction because alternative or competing breeds offer superior production opportunities (Hammond, 2000). Retention of inferior breeds is not recognised by production-oriented livestock producers as of value, nor is value attached to elements deemed as redundant to the agricultural production paradigm.

It is hypothesised that for generations the mental focus of the farming community upon identification and proliferation of superior breeds, varieties and individuals creates and continually reinforces a mind set diametrically at odds with the concepts underlying biodiversity. By definition, biodiversity values the full spectrum of variation at gene, species and landscape scale. Further, as the focus upon commercialisation intensifies, the pressure mounts for selection, increasingly supported by sophisticated technology, of the superior-performing component of the gene pool. The plantation industry (*viz.* witness *E. globulus* program) is no different from other production-oriented industries, having already embarked upon this route with selection trials identifying not only superior provenances but also individuals with superior production traits. These individuals once identified are then subjected to cloning to maximise the proliferation of the identified gene pool subset and minimise its dilution.

To date, nature conservation and biodiversity considerations have not been a major consideration in farm forestry plantations. Even for the more environmentally focussed landcare plantings, nature conservation and wildlife habitat (categories most akin to biodiversity) have accounted for less than 2% of plantings (Wilson *et al.*, 1995) although some biodiversity benefits are now being recorded as a by-product (Francis, 1997). However, the dominance of monoculture plantings in single age class stands receiving silvicultural and management practices aimed at maximising mean annual growth rate significantly constrains opportunities for realising biodiversity benefits. To capture the setting under which farm forestry currently is conducted some regional examples of operations are described.

2.3 Farm forestry examples

Silvicultural practices currently being applied in three regions are described to convey an appreciation of the range of practices undertaken in the developing farm forestry sector. The description is not intended to be definitive as it is recognised that other forms of silvicultural practice no doubt occur in each region. However, it is believed that the descriptions cover the dominant practices that apply to the majority of the area going into farm forestry in each of the respective regions. It is quite conceivable that a minority subset have adopted practices that are achieving greater biodiversity gains than that achieved by the majority. However, by definition their influence is small and probably declining in the face of the rapid expansion of the majority model currently underway.

2.3.1. Western Australia: Great Southern Region

Established companies (e.g. Bunnings Treefarms, Integrated Tree Cropping Limited, Australian Plantation Timbers) dominate farm forestry plantation development in the region. The major activity is the planting of *E. globulus* for the production of wood chip for export. The dominant form of partnership involves a leasing agreement with an initial payment to the landholder and then annual indexed payments for the expected life of the plantation (aiming for 10 years) with an option for second growing cycle. By aiming for a 10-year rotation the need for thinning can be avoided. If however, trees are to be grown on for sawlogs (a further 20 years) then thinning and form pruning is necessary. Cleared land that has been used for cropping and grazing for at least five years and which receives 600 mm (some companies have a 700 mm limit) or more annual rainfall within 150 km of Albany is targeted. Initial effort focuses upon land evaluation assessment to ensure only areas meeting the production targets are planted. Initial assessment involves detailed soil drilling as part of assessing site productivity. Selected sites are accurately mapped and the plantation layout planned in terms of soil, slope and other features. Soils are dominantly a deep sandy upper horizon frequently overlaying a structurally-impeding lateritic rock strata. Ground preparation commences with deep ripping (up to 1.2 m) and where soils include a lateritic strata it is important that this is fractured to allow unimpeded passage of tree roots to depth. This is necessary in sandy soils with low water holding capacity in a Mediterranean climate with little rainfall during the six month summer period. Tree seedlings are planted onto mounds prepared with prior application of herbicide to limit competition from weeds. Fertiliser is applied (e.g. approx 100 gm/tree in the first year) to achieve high growth rates. Heavy insect infestation is controlled by use of insecticides. Weeds are regularly controlled by spraying in the early stages and frequently by grazing sheep as the plantation reach a stage where it is safe from grazing. Canopy closure is reached in about year four. As the plantation approaches canopy closure, competition from understorey grass, residual pasture and weeds declines resulting in little ground cover beneath the plantations (Fig. 2.2). Wind can cause a tunneling effect under the canopy in exposed situations following loss of the lower branches further reducing the ground cover beneath plantations. Fire is of major concern in plantations, a risk accentuated by the effectively rain-free summer period. A vegetation-free buffer is maintained around plantation blocks as a firebreak. In addition, the area of individual plantation blocks are usually kept to less than 10 ha and a road network maintained around each block for fire control purposes. It is expected that by the time current plantations reach harvesting age that the genetic gain made during the period will warrant replanting with improved genetic stock rather than relying upon coppicing from the established rootstock.



Figure 2.2. A young vigorously growing plantation nearing canopy closure that has been pruned but not thinned. Note the limited understorey covering and simplicity and repetitiveness in structural form.

While some plantation managers are conscious of environmental issues (e.g. Bunnings Forest Products, 1999), attention tends to focus on promotion of the virtues of tree plantations in lowering groundwater levels as a means of controlling dryland salinity (indirectly a major threat to remaining biodiversity (Ive *et al.*, 2000)). Other environmental foci are harvesting and waste disposal issues, requirements for achieving international accreditation for forestry operations. Current plantation management practices do not appear to recognise opportunities for enhancing biodiversity prospects and the potential benefits.

2.3.2. Victoria: North east Region

A partially state funded initiative was adopted to provide a catalyst for expanding farm forestry in the north eastern Victoria (Taylor, 1997). The regional aim is to establish an area of at least 16 000 ha over 20 years which is the area required to support a hardwood board mill. At this stage, no consideration has been given to growing hardwood plantations for pulp- although this could change if a commercial outlet were to appear and prices were attractive, particularly as an outlet for the residues and thinnings. The project has attracted international interest with Indian and Japanese investors looking to acquire up to 20 000 ha for plantation establishment in the area. At the end of state involvement in the project a Japanese backed company has continued to develop farm forestry plantations in the area.

Under the state scheme, properties with cleared land receiving a mean annual rainfall of 700 mm or higher were targeted provided the land was capable of annual growth increments approaching 30 m³/annum or better (range in area is 12-38 m³/annum). As a result, some of the higher quality agricultural land in this region was targeted. This contrasts to some extent with landcare-motivated plantings where usually land of poorest quality (either inherently or because of magnitude of degradation) is targeted for planting to ameliorate degradation processes. Such poor sites were not considered viable options for farm forestry. In any year, individual plantings need to be at least 10 ha. Landholders retained ownership of land and trees contributing an up front payment of \$500/ha to the total tangible establishment costs of around \$1900/ha. Average value of land put under plantations during the scheme was around \$700/ha- land that had a carrying capacity of around 5-8 DSE/ha. Landholders were responsible for undertaking fencing of the site to exclude domestic livestock for an agreed period, pest eradication program (primarily rabbits and hares) prior to planting and follow up control of pests as necessary (e.g. grasshoppers, stink beetles).

Following site assessment and planning, sites were ripped (to 70cm with winged ripper), mounded, weeds controlled (Roundup® (knockdown) and Simazine® (residual)), planted and fertilised (300 kg/ha/an, a rate exceeding that used previously while under crop or pasture). Landholders were

responsible for follow up weed control as required (Fusilade® and Longlathin®) and in-fill replacement of planting casualties in the first year. Grasshoppers and stink beetles are controlled by spraying as required, often involving a number of treatments per year. Tree planting spacings are 4 m row centres and 2.5 m within the row providing a stem density of around 1000 stems/ha; establishment rates are over 90%. Current densities and input are aimed at crown closure by the end of the second year with no provision for understorey species or border plantings. Post-planting management is the responsibility of the landholder and after four years since the first plantations were established it is obvious that landholders have taken widely different approaches. On one-hand plantations have been thinned, form-pruned and undergrowth controlled by grazing, slashing and herbicides. At the other extreme, plantations apparently have not received any attention since planting with multiple stem and bad form trees retaining branching to the ground in a dense sward of pasture grasses particularly *Phalaris* to over a metre in height. It is not immediately obvious that the lack of silvicultural attention has enhanced biodiversity prospects (nor reduced survival and growth rates for that matter) of these plantations despite the forfeiture of commercial options.

A narrow selection of species (*E. globulus*, *E. saligna*, *E. nitens* and *E. grandis*) have been planted in the area with any one plantation usually using only one species (Fig. 2.3). One case was observed where *E. globulus* and *E. saligna* were alternated in each row, a species combination that had no apparent commercial or biodiversity benefit. This practice however, with more dissimilar species (e.g. eucalypts and acacias) can provide multiple benefits (Greening Australia, in prep). Current thinking is to narrow the genetic base further by selection of high performing (growth rate and form) individuals and then cloning these rather than exploring a wider range of species or undertaking multi-species plantings. This strategy is akin to that responsible for significant increase in growth rates and form characteristics in *Pinus radiata*.



Figure 2.3. A recently established plantation of *Eucalyptus globulus*. The juvenile foliage is prone to insect attack that is usually controlled by pesticide application.

Current expectation is that a final harvest by clear felling will be undertaken 12-15 years after planting. Current practice would aim for a second rotation from coppicing before replanting with superior genetic selections. This length of growth cycle can be compared to that of native forests which take at least 60 years for regrowth harvesting. Apart from the implications for timber quality, milling and processing (Washusen *et al.*, 2000) e.g checking and cracking, density etc, the shortening of the rotation period is a further limitation upon the biodiversity potential that will be realised.

The prime purpose of the farm forestry plantations is to provide an attractive economic return; any other benefits will be largely a bonus. The concentration on a narrowing genetic base that is largely foreign to the area provides little direct biodiversity opportunity in its own right. The high level of fertiliser application (300 kg/ha) would be expected to have a substantial impact upon composition, balance and activity of the soil fauna. It is recommended that trees are grown at a density and pruned to ensure single straight main stem for the production of clear wood and at such a short rotation

interval there is no likelihood that hollows will develop for wildlife habitat. Managed trees are much akin to an agricultural crop in terms of non-discriminating use of pesticide sprays for controlling leaf-eating insects; this has implications for populations of non-target species.

2.3.3. New South Wales: Murray Riverina Region

The hardwood product is mainly sawlogs for solid wood products because of the distance from processing facilities and a suitable port in this non-coastal region. Because of the location and rainfall no plantation company is established in the area and farm forestry activities are undertaken by interested landholders frequently with the assistance of local farm forestry consultants and/or managers. The life cycle for sawlog production is longer (up to 60 years) than that practiced for wood chip plantations. This product choice and the slower growth rates associated with the relative low rainfall of a non-coastal region are potential positives for enhancing biodiversity prospects. There is an opportunity within any area to have a wider range of age classes and individual plantations are more likely to be selectively logged as trees reach sawlog specifications rather than clear-felled. Selective logging further enhances opportunities for multiple age classes within the plantation either by natural regeneration or replanting infills as trees are selectively logged.

Despite known salinity problems and ground water at 2-5 metres, plantations are often irrigated to enhance growth. Ironically, despite interest in establishing plantations arising from concern over rising water tables and salinity, irrigation is still used when water is available. This means that irrigation is least in the dry years and most in the wetter years (up to 6 megl/ha spread over 4-5 irrigations/year), a strategy that accentuates the between-year variation not only in tree growth rates but also in habitat cover in and around the plantations. Plantations watered monthly during summer are claimed to use all the added water before next month's watering. The plantation areas selected are frequently flood irrigation areas where soil type or extent of cut and fill do not warrant laser leveling, current practice for irrigated crops and pastures. Nevertheless, flood irrigation is still used (Fig. 2.4) with water ponded up to 20cm, a practice that can leave surface water for up to 2 weeks indicating the low infiltration rate of the heavy clay soils. This feature of the soils apparently limits rooting depth to about 60 cm and therefore it is unlikely that this watering strategy will lower groundwater levels. In fact, there is no evidence that trees are interacting with the groundwater on the heavier soils. As water price increases irrigation of plantations inevitably will become increasingly uneconomic. An exception is likely to be where irrigation uses effluent (Myers *et al.*, 2000).



Figure 2.4. Use of flood irrigation during the establishment phase of a farm forestry plantation. Depending upon water availability, irrigation is used well after trees have become established to gain higher growth rates.

Indicative plantation establishment practices recommended for the area include pre-planting incorporation of Trifluralin® (2 l/ha) into planting mounds to provide residual weed control. After

planting, trees are over-sprayed with Simazine® (5 l/ha) and Fusilade® (0.5 l/ha) and Roundup® is sprayed between the rows for weed control. Weed control between trees and rows is repeated at intervals up to the end of the second year, after which the area between rows is slashed in spring or grazed for as long as possible. Recommended fertilizer application includes DAP (300 kg/ha) incorporated into mounds prior to planting followed by DAP (100 gm/tree or equivalent to about 100 kg/ha) in subsequent years.

Species include *E. calamdulensis*, *Coymbia maculata*, *E. globulus*, *E. grandis* and *Acacia melanoxylon*. Pests and diseases are major problems that appear to be accentuated in the lower rainfall areas particularly with single species plantations. As a result new plantings in particular have to be monitored regularly as part of the control program involving timely blanket pesticide spraying. An urgent need has been identified for the isolation of insect resistant phenotypes for inclusion in tree improvement programs. Leaf eating insect attack upon otherwise well-developed eucalypt block plantings (at 8 m) leave trees appearing to be deciduous.

2.4 Enhancing biodiversity

These three regional synopses provide little tangible evidence that farm forestry is being undertaken with any intention other than to maximise commercial return. The extent to which farm forestry enhances regional biodiversity values will be a bonus, even the realisation of other environmental values is not universally guaranteed (e.g. flood irrigation of plantations in areas with shallow watertable). In essence, capturing wider biodiversity values in farm forestry plantations requires the introduction or development of more complexity into the plantations than is currently practiced (Fig. 2.5). The challenge is to establish the extent to which this is acceptable to plantation owners and the cost effectiveness. Basically, farm forestry increasingly is relying on the planting of cloned high producing selections of a single species growing in single age class stands receiving high inputs of fertiliser, weedicides and pesticides for a relatively short life time before being clear-felled for product harvest. To a large extent farm forestry parallels the production system of many agricultural products- albeit with longer time frames.

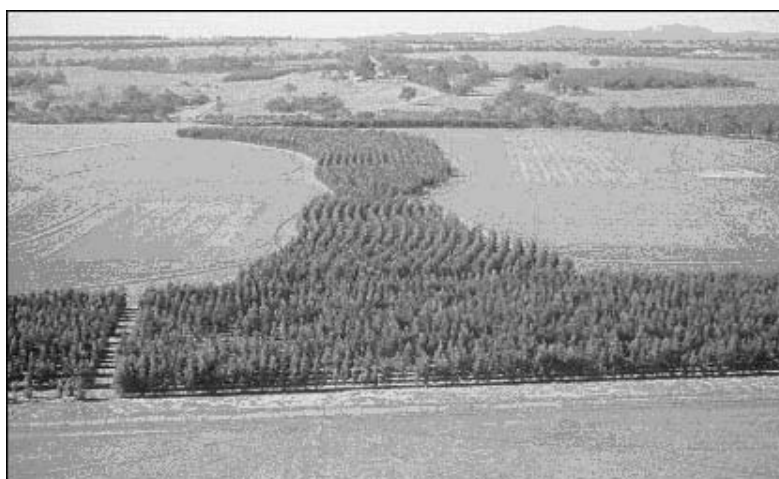


Figure 2.5. A non-conventional farm forestry layout where trees have been integrated into the agricultural landscape forming a matrix of land use including retained remnants, vegetated stream verges, pasture interspersed with special crops involving raised beds and other configurations.

It would be unrealistic to expect farm forestry owners and managers to completely modify their management practices to cater for biodiversity conservation. What is more realistic is to sensitise the owners and managers to the factors that may be limiting realisation of biodiversity so that when they make decisions, biodiversity considerations can be taken into account along with the direct commercial considerations.

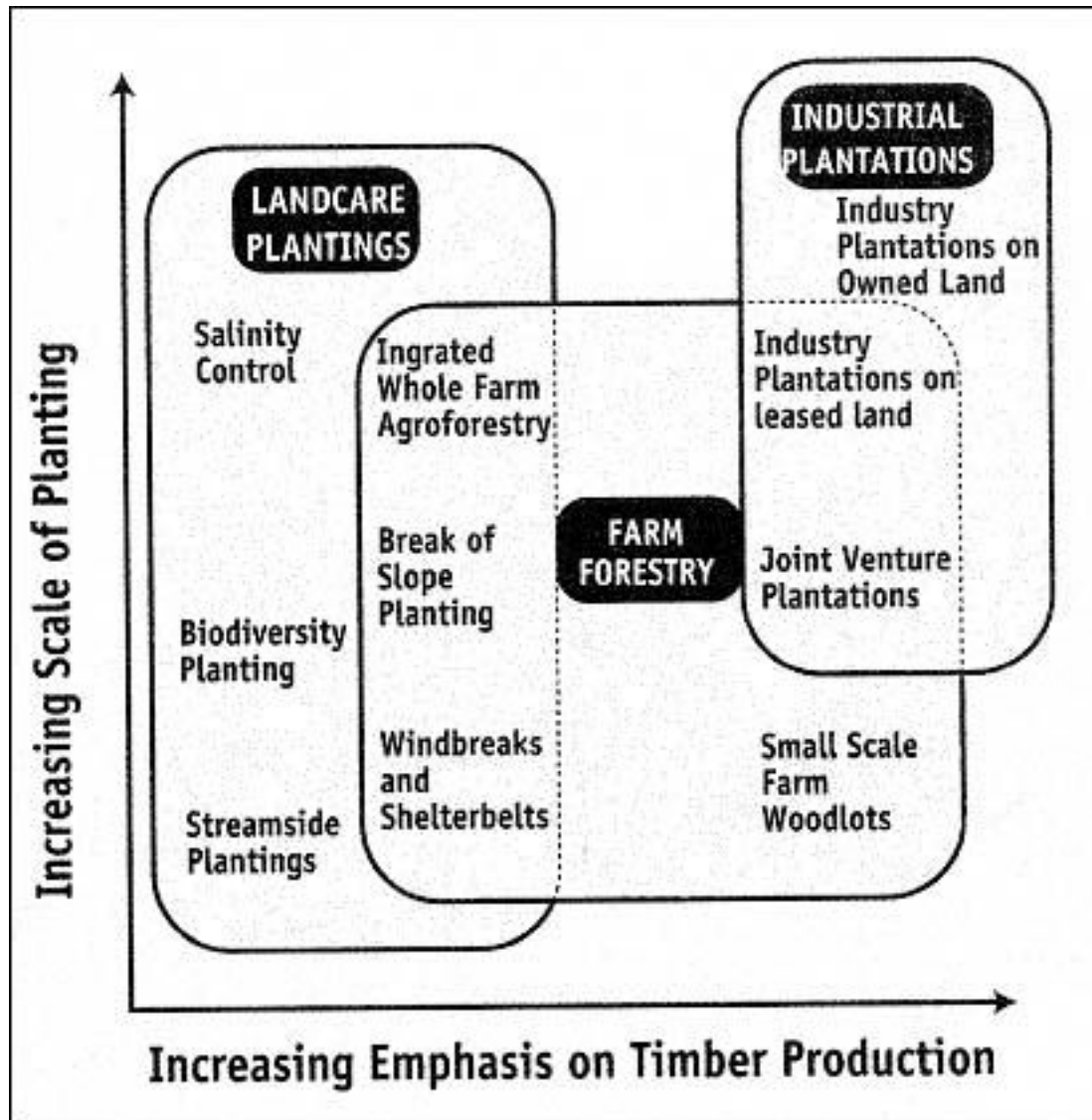


Figure 2.6: An industry view of the relationship between different forms of tree planting. In this perspective, biodiversity is limited to specialist plantings under the umbrella of landcare. A more environmentally rewarding view would be to recognise the potential for biodiversity gain across all three categories and seek to achieve those gains within the primary objective of the particular operation. In particular, farm forestry needs to recognise and capture the multiple benefits including biodiversity and salinity control, thereby provide benefits to the agricultural landscape beyond the plantation.

Industry promotion (Commonwealth of Australia, 1998) conveys restricted opportunities for biodiversity from tree planting, proposing that biodiversity opportunities are only realised from dedicated plantings (Fig. 2.6). A more encouraging view would be to promote a mindset of the possibility for biodiversity benefits from across the spectrum of tree planting categories and then promote management actions required for realising the biodiversity opportunities in a commercially-driven setting.

While biodiversity benefits have been proposed as a major potential advantage flowing from the uptake of farm forestry (e.g. Plantation 2020 Vision Implementation Committee, 1997), the evidence to date suggests that farm forestry is being driven by the appeal of expected direct economic benefits. Ironically the same appeal drove agricultural activity for the last two-hundred years precipitating the environmental issues now confronting our agricultural landscapes.

If history is not to repeat itself a greater balance between the economic and environmental considerations is required. However, until it is demonstrated and accepted that more environmentally sensitive actions deliver greater values and returns (including cost-sharing considerations) to the individuals who make the effort to promote environmental values this balance is unlikely to be widely achieved.

Consequently, in the absence of management practices that are sympathetic to the realisation of biodiversity benefits, gains are likely to remain disappointing against the expected and promoted virtues. The slippage of public concern for environmental issues over the past decade in Australia (Francis, 2000), particularly as evidenced by 'Landcare burnout' (Boyd, 2000) and out-right rural skepticism (Explorer, 2000, Small, 1994), will not contribute to a broadening of the perspective required to embrace wider environmental values- including biodiversity- acclaimed of farm forestry.

Chapter 3.

Faunal use of bluegum (*Eucalyptus globulus*) plantations in southwestern Australia: rationale, methods and site descriptions

3.1 Introduction

The Australian State of the Environment Report (Commonwealth of Australia 1996) concluded that two of the six major environmental problems affecting Australia are loss of biodiversity and land degradation resulting from over-clearing of native vegetation. Concurrently, the increasing shortfall projected in timber production emanating from the decline in available domestic native forest resources has provided the commercial stimulus for developing a blueprint endorsed by a Ministerial Council (Plantation 2020 Vision Implementation Committee 1997). This blueprint proposes trebling the rate of farm forestry plantation (to 80 000ha annually) by 2020. Due to controls on clearing of native vegetation, these future forestry plantations will be, of necessity, predominantly on cleared agricultural land. Large areas in medium rainfall parts of Victoria, New South Wales and Western Australia are currently being planted to eucalypt and pine plantations.

Farm forestry offers a potential economically viable solution to many of the land degradation problems facing agricultural regions of Australia. It also potentially can provide benefits in terms of biodiversity conservation, but the extent of these benefits for cleared agricultural lands has not been assessed. While characteristics of remnants such as size and shape can account for the presence or absence of a species (Briggs et al., 2001; Freudenberger, 1999; Reid, 2000) it is becoming increasingly obvious that the matrix of habitat surrounding the remnant plays an important role in helping to determine the species composition of a remnant (Saab, 1999). It is critical to understand the role played by plantations in the future matrix and how the potential biodiversity benefits of farm forestry may be enhanced without interfering with economic goals (Lamb, 1998). The creation of landscape heterogeneity by the establishment of plantations in a cleared agricultural landscape increase the opportunities for species that require multiple resources to persist (Lambeck & Saunders, 1993; Law & Dickman, 1998) and biodiversity should benefit.

Bennett and Ford (1997) demonstrated that woodland bird species richness decreased as the area of native vegetation cover decreased to the point where many species of woodland birds disappeared from extensively cleared landscapes. Cleared pasture supports few species (Green & Caterall, 1998) and they are often habitat generalists and tolerant of humans. Often after severe disturbance to native forest exotic species invade the habitat particularly in the early stages post disturbance. For example, after grazing by domestic stock (Catling & Burt, 1995a), inappropriate fire regimes (Catling, 1991) or planting of pine plantations (Suckling et al., 1976). The question is whether exotic species will invade hardwood plantations planted with species foreign to the area.

The paucity of information on the biodiversity opportunities offered by farm forestry on cleared agricultural land was highlighted in a recent report (AACM, 1998). There was a lack of knowledge of the biodiversity impacts of farm forests compared to agricultural land uses and the challenge is to determine whether commercially viable forestry practices can deliver ecological benefits to our ailing agricultural systems (AACM 1998). The biodiversity contribution that forestry plantings can make

on agricultural land relative to that of native forests is an important comparison, but a more practical objective would be to establish the contribution forestry plantings could make to biodiversity relative to its level under current agricultural activity.

In New Zealand there has been considerable debate about plantation forestry and its contribution to biodiversity. Some see biodiversity conservation as a threat to plantation forestry without any positive values (Purey-Cust, 1996; Sutton, 1995) and others believe it does not need to be in conflict (Norton, 1998). Goals in plantation forest management should be to integrate productive and protective uses in the same landscape, rather than replacing one with the other (Norton 1998).

When ecosystems become simplified, such as when forests are cleared for agriculture there is a simplification of the environment and its function is disrupted and pest outbreaks often result. For example, the noisy miner has invaded areas that have been cleared and they exclude other bird species (Grey et al., 1998; Grey et al., 1997) thus disrupting the normal predation on leaf-eating and leaf-sucking insects and so contributing to the spread of dieback in eucalypts (Ford, 1985; Ford & Bell, 1981). Introduced mammals are more likely to be found in pine plantations than in native forests (Barnett et al., 1977). Some studies have compared fauna in eucalypt plantations on such areas as rehabilitated mine sites with nearby native forests and found that species richness and abundance were generally lower in the plantations. The difference was attributed to greater structural diversity in the native forest due to presence of understorey shrubs, fallen timber and a wet litter layer (Woinarski, 1979).

There are many grades of habitat between an undisturbed forest or woodland and a treeless agricultural landscape. The question is where do plantations of native forest sit in that spectrum in regard to their contribution to biodiversity conservation? Once clearing has taken place and only a few isolated trees remain then only a few open-country species and those tolerant to disturbance can survive. For agriculture to take place there must be some degree of disturbance, but disturbance at such a high level almost certainly means little or no long-term future for the enterprise (Barr & Cary, 1992; Roberts, 1992).

The loss of biological diversity is perhaps our most serious environmental problem. In many cases, the destruction of habitat, the major cause of biodiversity loss, is continuing at an alarming rate (Commonwealth of Australia 1996). While clearing has unequivocally contributed to the loss of biodiversity it remains to be established the extent to which this loss can be reversed on land long-cleared for agriculture by re-establishing trees when commercial timber production is the primary management objective. It is however, heartening to note that despite no active attempt to foster biodiversity, an improvement is now being recorded as a by-product of revegetation undertaken for landcare purposes on agricultural land (e.g. Chilcott *et al.* (in press), (Francis, 1997; Wilson et al., 1995). A by-product recovery may be less certain for agricultural land if farm forestry employs only commercial plantation practices for planting and management.

In this study, we examined the faunal use of *Eucalyptus globulus* plantations in southern Western Australia. In this area, eucalypt plantations have been established over the past decade, with increasing areas being planted recently, such that about 12,000ha per annum are currently being established. These are mostly large block plantations established and maintained by timber companies who lease the land from the resident farmers. Plantations now make up a significant part of the landscape, and yet relatively little is known of their impact on native fauna. This study aimed to provide some basic information on the use of plantations by selected faunal groups, and to compare use of plantations in different positions relative to large tracts of remnant vegetation. Comparative data was also obtained from remnant vegetation and agricultural land.

The study employed a strategic field-monitoring program to quantify communities for a cross-section of vertebrates, invertebrates and plants in areas converted from cleared agricultural land to farm forestry. Achieving non-commercial biodiversity benefits may require modification of current commercial practices. The study investigated and quantified the potential biodiversity benefits of

farm forestry as it is currently practiced, with the aim of developing practical management guidelines that enhance the contribution to the achievement of regional conservation goals. The study focuses on specific biological conservation objectives, rather than broadly stated goals such as "the enhancement of biodiversity" within a well-defined geographical area. This study has focused on particular fauna and flora groups (birds, mammals, reptiles, and amphibians).

The following questions were addressed by the study design:

1. What is the faunal use of plantations in comparison with adjacent remnant vegetation and with open pasture?
2. Do fauna use plantations edges more than interiors?
3. Does adjacency to remnant vegetation increase plantation use or alter the species complement?

3.2 Methods

3.2.1 Survey Design

The Region selected for the study was the far southwest of Western Australia between Albany (35° 00' S, 117° 55' W) and Mt Barker (34° 43' S, 117° 40' W) (Fig. 3.1). In July 1999 six potential study areas were selected and were reduced to four after a reconnaissance trip in September 1999. Study areas were selected for their closeness to suitable remnant vegetation or agricultural land and accessibility. The study areas were selected to provide a replicated (non-orthogonal) statistical design recognising plantation size, age and structure, distance to native remnants, position in the landscape and land class within the constraints of the existing plantations. The four study areas utilised plantations 4-6 years in age on commercially established farm forestry operations containing similar management treatments (e.g. size, shape, topographic position and distance to native remnant). The sites on agricultural land had domestic stock present on most surveys, the plantations had low numbers of domestic stock on them at varying times during the study and one patch of remnant vegetation had domestic stock present on one survey. Plantation sites were sprayed according to normal management practice – although not during the survey period. In addition, the agricultural land site at Millbrook west and the agricultural land adjacent to the edge plantation site at Millbrook south were ripped in April 2000, and had 30cm trees in Nov 2000.

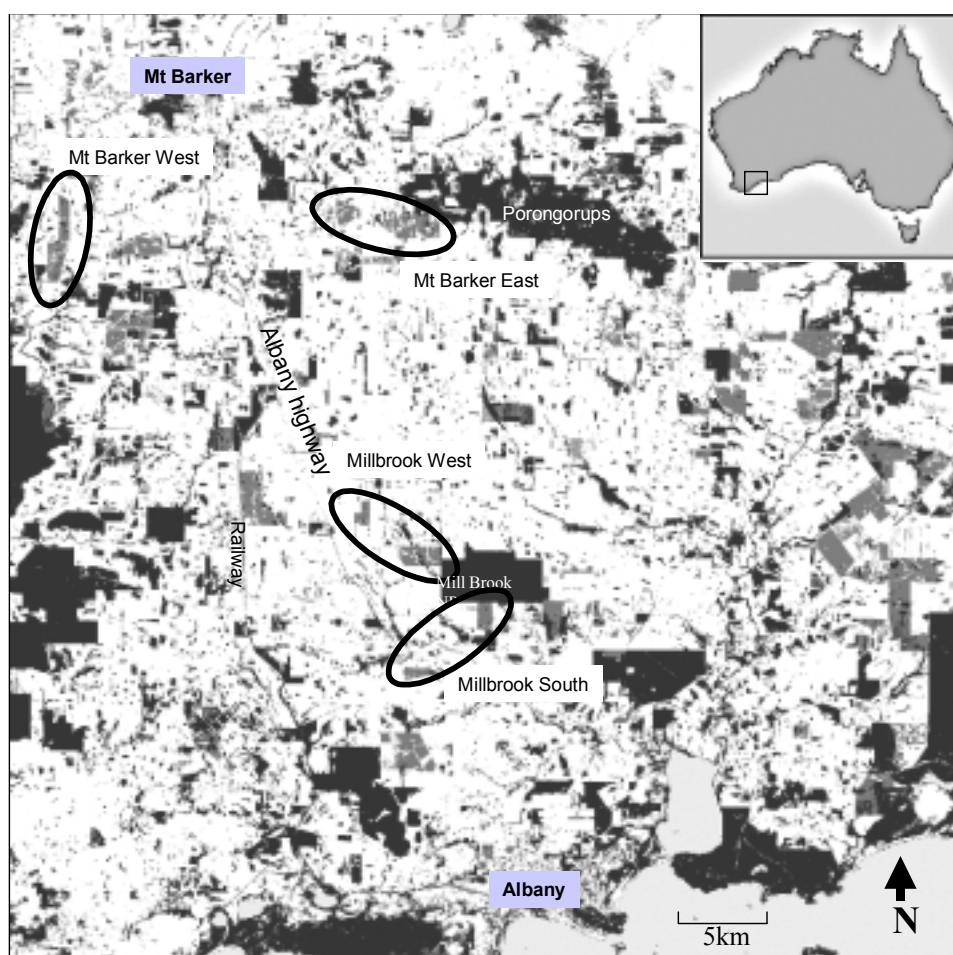


Figure 3.1. Map of the area north of Albany, Western Australia, indicating location of the four study areas. Remnant vegetation is indicated as black, and *E. globulus* plantations as grey. Derived from Landsat TM data compiled by J. Wallace, CSIRO Mathematics and Information Science.

Each study area consisted of a plantation adjacent to a large patch of remnant vegetation and a plantation found in agricultural land away from remnant vegetation. Seven sampling sites were established in each study area (Fig. 3.2) giving a total of twenty eight sampling sites across the four study areas. Each study area had a sampling site established in:

- R** - Remnant vegetation - good quality native vegetation
- Pre** - Plantation adjacent to remnant vegetation - edge
- Pri** - Plantation adjacent to remnant vegetation - interior
- Prag** - Plantation adjacent to remnant vegetation - edge to agricultural land
- Pagi** - Plantation in agricultural land - interior
- Page** - Plantation in agricultural land - edge
- Ag** - Agricultural land (pasture)

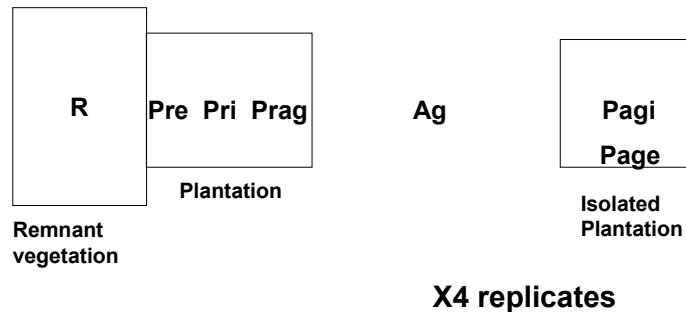


Figure 3.2. The sampling design, indicating sampling sites within each of the four study areas, as follows: R - Remnant vegetation - good quality native vegetation; Pre - Plantation adjacent to remnant vegetation - edge ; Pri - Plantation adjacent to remnant vegetation – interior; Prag - Plantation adjacent to remnant vegetation - edge to agricultural land; Pagi - Plantation in agricultural land – interior; Page - Plantation in agricultural land – edge; Ag - Agricultural land (pasture)

3.2.2 Study areas

Area 1 - Mt Barker East

The plantation adjacent to the remnant was 12 km east of Mt Barker and covered 807 ha with 88.1 ha of retained remnant vegetation. Site R was located 300m into ungrazed native vegetation on private land that abutted the Porongorup Range. Site Pre was 20m from the native vegetation, Site Pri was in the middle of the plantation and 600m from a small remnant (3ha) within the plantation, Site Prag was 20 m from agricultural land and 300m from a small remnant (3.5 ha) in the plantation.

The isolated plantation was 3 km west of the plantation adjacent to a remnant and covered 134.8 ha with 2 ha of retained remnant. Site Pagi was 500m into the plantation and 300m from the remnant vegetation (2ha). Site Page was 20m from agricultural land and 600m from remnant vegetation. Site Ag was in an open paddock and 500m from remnant vegetation.

Area 2 - Mt Barker West

The plantation adjacent to the remnant was 10 km west of Mt Barker and covered 90 ha with 8 ha of retained remnant vegetation. Site R was located 200m into a 25 ha patch of native vegetation on private land which was grazed by sheep. Site Pre was 20m from the native vegetation, Site Pri was in the middle of the plantation and 350m from a small remnant (3ha) within the plantation, Site Prag was 20 m from agricultural land and 500m from a small remnant (3ha) in the plantation.

The isolated plantation was 1 km north of the plantation adjacent to a remnant, but was connected to it by plantation except for a 100m wide powerline easement. It covered 40ha with 2ha of retained remnant. Site Pagi was 250m into the plantation and 300m from a remnant (3ha). Site Page was 20m from agricultural land and 200m from a remnant (1.5 ha) in the plantation. Site Ag was in a paddock with a remnant patch (2ha) 100m away.

Area 3 - Millbrook West

The plantation adjacent to the remnant was 21 km north of Albany and covered 181 ha with 25.5 ha of retained remnant vegetation. Site R was located 100m into Millbrook Nature Reserve, Site Pre was 20m from the native vegetation in Millbrook Nature Reserve, Site Pri was in the middle of the

plantation and 450m from remnant vegetation in Millbrook Nature Reserve, Site Prag was 20 m from agricultural land and 450m from a linear remnant along a drainage line.

The isolated plantation was 3 km NW of the plantation adjacent to a remnant and covered 79.4 ha with 2.8 ha of retained remnant vegetation. Site Pagi was 100m into the plantation and 150m from a narrow linear strip of remnant vegetation (1.6ha). Site Page was 20m from agricultural land and 400m from remnant vegetation. Site Ag was in an open paddock 300m from a small grove of trees.

Area 4 – Millbrook South

The plantation adjacent to the remnant was 16 km north of Albany and covered 222ha with 15.1 ha of retained remnant vegetation. Site R was located 100m into Millbrook Nature Reserve, Site Pre was 20m from the native vegetation in Millbrook NR, Site Pri was in the middle of the plantation and 300m from a small remnant (1ha) within the plantation, Site Prag was 20 m from agricultural land and 150m from a small remnant (1ha) in the plantation.

The isolated plantation was 6 km SW of the plantation adjacent to a remnant and covered 56.3 ha with a few large native trees retained throughout. Site Pagi was 100m into the plantation and 120m from a narrow linear strip of roadside vegetation. Site Page was 20m from agricultural land and 300m from remnant vegetation. Site Ag was in an open paddock.

3.2.3 Vegetation sampling

Four nested quadrats were set up in October 1999 at each sampling site. One quadrat was located at the faunal sampling site, one 20-30 m further to the interior, and one each 20-30m to left and right of the trapping grid. Trees were counted within a 20x20m quadrat and cover estimated in the following classes: 0-2%, 2-10%, 10-30%, 30-70%, 70-100% (Muir, 1977). Any calculations used the median of these classes (1, 6, 20, 50, 85). Within each 20x20m quadrat, two 5x5m quadrats were established and shrub species cover estimated, and within each 5x5m quadrat, cover of annual species was estimated in one 1x1m quadrat. Bare ground and moss cover were also recorded in the annual quadrats. Therefore there were 4 tree quadrats, 8 shrub and 8 annual quadrats per site.

3.2.4 Habitat Complexity Scores

At each sampling site a circular plot of approximately 0.25 hectare was scored for the complexity of fauna habitat (Newsome & Catling 1979; (Catling & Burt, 1995b) on the basis of five features (1) canopy cover; (2) shrub cover; (3) ground vegetation cover; (4) the amount of litter, fallen logs and rocks and (5) a moisture rating. Each feature was rated on a scale of 0-3 and the scores of the five features tallied to a total. Generally a score of four or five denotes a forest with poor structure with few understorey shrubs and little ground cover whereas a score of nine or 10 is a forest with a thick understorey, and good ground and litter cover.

3.3 Results

3.3.1 Vegetation

Vegetation data are summarized in Tables 3.1 and 3.2. The remnant native vegetation in the study areas was very diverse, with a mixed tree canopy consisting of *Corymbia calophylla*, *Eucalyptus marginata*, *Eucalytus patens*, *Banksia attenuata*, *Banksia grandis* and a few other minor species. A diverse array of shrub species were present at the study sites. Mt Barker east had 31 species in total over all 8 quadrats, ranging from 9-15 species in each 5x5m quadrat. The most common species were (in order from most common to 5th most common): *Leucopogon revolutus*, Poaceae (perennial grass species), *Tetraria octandra*, *Dampiera linearis* and *Bossiaea linophylla*., Mt Barker west had 31 species in total, ranging from 8-13 species in each 5x5m quadrat. The most common species, in terms of area covered, were *Agonis flexuosa*, *Agonis parviceps*, *Scaevola striata*, *Bossiaea ornata*, and *Leucopogon revolutus*. Millbrook west had 45 species in total, ranging from, *Anarthria prolifera*, *Hakea lasiantha*, *Agonis flexuosa*, and *Lepidosperma* sp. Millbrook south had 44 species in total, ranging from 14-22 species in each 5x5m quadrat. The most common species were *Anarthria*

prolifera, *Lepidosperma squamatum*, *Hakea ferruginea*, *Dasypogon bromelliodes* and *Agonis parviceps*.

Shrub species were not found in any paddock site, and only in a few plantation sites, Inkweed (*Phytolacca octandra*, found in the Millbrook South isolated plantation edge and interior sites). The Mount Barker East plantation adjacent to remnant site had 1 species (*Acacia leioderma*, which is also found on the adjacent remnant) found on 2 of the 8 quadrats. Site The Millbrook West isolated plantation edge site had 2 species in 3 of the 8 quadrats, *Kennedia coccinea* and *Gompholobium scabrum*.

Native annual species were sparse in both remnant vegetation and plantations, and introduced annuals were virtually absent in native vegetation, but more abundant in the plantations. Paddocks were composed almost entirely of introduced annual species.

Considerably more bare ground was present in plantation sites than in native vegetation, and moss covered almost 30% of the ground in plantations, but was virtually absent in native vegetation.

Table 3. 1. Remnant native vegetation: numbers of species recorded and cover estimates in 4 nested quadrats at each site.

Site	Mt Barker East	Mt Barker West	Millbrook West	Millbrook South
Trees				
Number of species	2	6	5	6
Cover	33.5	34	19	17
Shrubs				
Total species	31	31	45	45
Species per 5x5 quadrat (Mean $\pm$ SE)	12 $\pm$ 0.7	10 $\pm$ 0.5	16 $\pm$ 0.6	19 $\pm$ 1.1
Cover	66.2	57.1	123.5	113.6
Native annuals				
No of species	5	10	2	4
Cover	3.4	1.4	0.5	0.5
Introduced annuals				
No of species	2	0	2	0
Cover	0.9	0	0.2	0

Table 3.2. (a) Species numbers and abundance in remnant vegetation compared with plantations (means $\pm$ SE over 4 replicates for remnant areas and 20 replicates for plantations. All comparisons between remnant, plantation and agricultural land are significantly different at $p < 0.05$ or less, as determined by t-test, except where indicated by “ns”).

	Remnant	Plantation	Agricultural land
Trees			
Canopy cover	25.75 ± 2.25	38.75 ± 3.39	0
Density per 20x20m	45.0 ± 2.27	38.75 ± 1.29	0
Number of species	2-6	1	0
Shrubs			
Cover	90.1 ± 8.30	0.1 ± 0.1	0
Number of species	38.0 ± 2.2	0.6 ± 0.5	0
Native annuals			
Cover	1.19 ± 0.51	0.05 ± 0.04	0.09 ± 0.06 (ns)
Number of species	5.25 ± 1.70	0.15 ± 0.13	0.50 ± 0.29 (ns)
Introduced annuals			
Cover	0.28 ± 0.21	11.1 ± 5.69	81.59 ± 13.45
Number of species	1.0 ± 0.58	6.4 ± 0.59	11.25 ± 1.11
Bare ground	0.41 ± 0.41	18.31 ± 3.81	2.22 ± 1.81 (ns)
Moss	3.81 ± 3.00	29.92 ± 2.12	0

3.3.2 Habitat Complexity Scores

The average habitat complexity score for the sites in each habitat are presented in Fig 3.3. The average for the sites in native vegetation (7.5) were mostly twice as complex as those for the plantations (3.25 – 4) and three times as complex as the agricultural land (2.5).

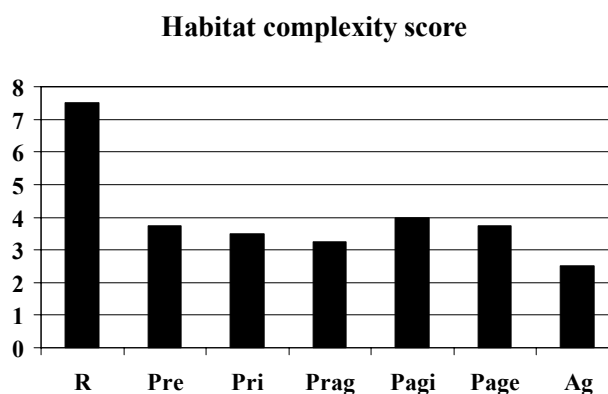


Figure 3.3. Mean Habitat Complexity Scores (n=4) for the various habitats sampled. Habitat codes as in Fig 3.2.

3.4 Discussion

3.4.1. Habitat differences

The habitat differences between native vegetation, plantations and agricultural land are obvious from Table 3.2, and these differences are depicted diagrammatically in Figure 3.4. Native vegetation has a heterogeneous tree cover and diverse shrub and ground cover layers with some fallen timber and leaf litter. Plantations have a more homogeneous and closed tree cover and an almost complete absence of shrub and ground cover layers with some leaf litter. Introduced annuals were more abundant in plantations, as was moss cover. The absence of a shrub layer can be related to both the density of the tree canopy (although interestingly, tree cover only averaged 38.75% in the study plantations) and plantation management practices. Agricultural land had no trees or shrubs, but a complete cover of introduced pasture with no litter.

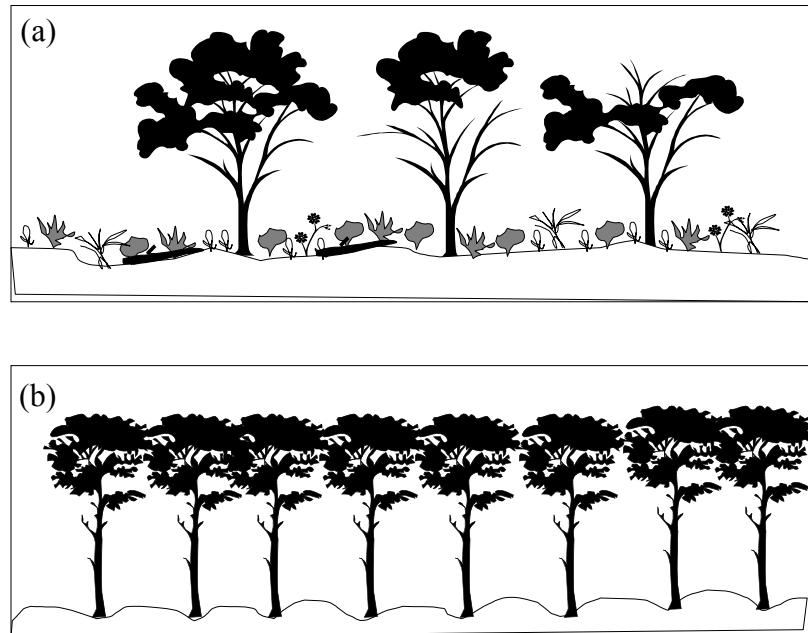


Figure 3.4 Diagrammatic presentation of the structural complexity of (a) remnant native vegetation and (b) a eucalypt plantation.

Chapter 4.

Faunal use of bluegum (*Eucalyptus globulus*) plantations in southwestern Australia: vertebrates

4.1 Introduction

In this chapter we investigate the use of plantations by vertebrate fauna, in comparison with remnant vegetation and agricultural land. The study sites used are as described in Chapter 3.

4.2 Methods

4.2.1 Vertebrate Survey Procedures

Standardised collection and survey techniques were used to sample five major groups of the vertebrate fauna: amphibians, reptiles, birds, ground-dwelling mammals and volant mammals. The techniques used to assess the presence and abundance of the five groups follow those well established in the literature (c.f. Braithwaite *et al.* 1991; Braithwaite, 1988; Catling & Burt, 1994; Catling & Burt, 1997; Schodde *et al.*, 1992). The vertebrates were sampled at each of the twenty eight sites in October 1999, April 2000, October 2000 and April 2001 by the methods summarized below.

Amphibians and reptiles were sampled for three consecutive days using four dry pitfall traps placed in a "T" shape. Traps were 7 m apart with a 12m drift fence placed down the middle of each line. Also, amphibians and reptiles were sampled at each site using three visual counts; one in the morning, afternoon and evening, of 20 minutes duration each.

Bush birds were sampled using three visual and sound counts of 15 minutes duration in the early morning on different days. Nocturnal bush birds were sampled by spotlight (see below).

Small ground-dwelling mammals were sampled using twenty type A Elliot traps baited with peanut butter and rolled oats. Traps were placed in two parallel lines, 10 m apart and containing 10 traps each, placed 7 m apart. Traps were set for three consecutive nights.

Medium-sized and large ground-dwelling mammals and large reptiles were sampled on five 10m x 1m soil plots. One soil plot was placed at the site and the others placed 200m apart in the vicinity of each site in the same habitat. The tracks of animals on the five soil plots were recorded for three consecutive days. Also, large and medium-sized mammals, volant mammals (bats) and nocturnal birds were surveyed on two nights by spotlight from a vehicle on a 1 km transect around and including each site.

Bats were sampled in October 1999 by recording echolocation calls using bat detectors in tandem with a control unit that allowed their operation throughout the night as outlined by (Kunz *et al.*, 1996). The echolocation calls were identified by Greg Richards and apart from those in the genus *Nyctophilus*, all species have a high level of detectability (Richards, 1996). Four of the seven sites in each area were sampled on one night when weather conditions were suitable. Sites sampled were remnant vegetation (R), centre of the plantation next to the remnant (Pri), the centre of the plantation in agricultural land (Pagi) and on agricultural land (Ag)(see Fig. 4.2).

All random observations (mostly visual but some sound) of fauna within each study area and in the region were recorded. Wingless invertebrates were collected daily from pitfall traps set to sample the herpetofauna, preserved in 80% alcohol, and analysed and reported in chapter 5.

4.2.2 Groups for Analyses

Amphibians and reptiles were treated as one group as were the volant mammals. Ground-dwelling mammals were divided into native and introduced. The bush birds were divided into nine functional groups based on their feeding location and principal diet: 1 = understorey/ground feeder - insectivore; 2 = understorey/ground feeder – granivore; 3 = understorey/ground feeder – insectivore/carnivore; 4 = canopy/ understorey/ground feeder – insectivore/carnivore; 5 = canopy/ understorey/ground feeder – granivore/frugivore; 6 = canopy/ understorey/ground feeder – insectivore; 7 = canopy/ understorey/ground feeder – nectarivore/frugivore/insectivore; 8 = open country/pasture – all diets; 9 = waterbirds – all diets.

The scientific and common names used in the text follow Cogger (1986) and Barker et al. (1995) for amphibians and Cogger (1986) for reptiles, Strahan (1995) for mammals, Stanger et al. (1998) for birds, and Boland et al. (1984) for the canopy vegetation.

4.2.3 Analyses

The study was carried out over two years and in two seasons within those years (autumn and spring). The four surveys were regarded as repeated measurements taken on the same experimental units and the sample sites in the same habitat across the four study areas were considered as replicate sites. We have not examined differences between years or between seasons, but have pooled the data to examine the three questions presented in the Section 3.1. The data were examined in two ways by presence/absence of species and by the abundance of species across the seven habitat types (Fig. 3.2).

4.3 Results

4.3.1 Amphibians and Reptiles

Ten species of amphibian and twelve species of reptile were recorded during the four surveys (Table 4.1). An additional two species of reptile, the Dugite *Pseudonaja affinis* and the Crowned Snake, *Drysdalia coronata* were recorded in the region, but not on the formal counts. Twice as many species (17) were recorded in the remnant vegetation than in any one of the plantation habitats (3-7 species) or the agricultural land (7 species)(Table 4.1). The number of species recorded in sites in the plantations and the agricultural land were very similar and there was no obvious difference between the number of species using the edge of plantations and the interior of plantations. Two species, the western banjo frog and the lowlands earless skink were recorded at all sites. The western banjo frog was abundant in all habitats and the lowlands earless skink was abundant in all habitats except the agricultural land. Several other species were recorded in remnants, plantations and on agricultural land, but not at all sites (Table 4.1). The south-western Crevise-skink was recorded in the remnant vegetation only. The western green and golden bell frog was common on agricultural land, but found in other habitats. Most other species were recorded infrequently in all habitats except the remnant vegetation.

Table 4.1 Number of amphibians and reptiles recorded in each habitat during the four surveys. X = recorded in habitat outside the formal survey. Blank = not recorded.

	Species	R	Pre	Pri	Prag	Pagi	Page	Ag
Tschudi's Froglet	<i>Crinia georgiana</i>	2	2					
Glauert's Froglet	<i>Crinia glauerti</i>	X						1
False Western Froglet	<i>Crinia pseudinsignifera</i>	X	1		1			X
Small Western Froglet	<i>Crinia subinsignifera</i>							X
Indeterminate Western Froglet	<i>Crinia sp</i>					1		
Moaning Frog	<i>Helioporus eyrei</i>	X	4	2				
Western Banjo Frog	<i>Limnodynastes dorsalis</i>	5	8	13	6	10	19	10
Slender Tree Frog	<i>Litoria adelaidensis</i>	2			1			
Western Green and Golden Bell Frog	<i>Litoria moorei</i>	3	1		1			6
Lea's Frog	<i>Geocrinia leai</i>	X						
Gunther's Toadlet	<i>Pseudophryne guentheri</i>			1				
Oblong Turtle	<i>Chelodina oblonga</i>				X			
Marbled Gecko	<i>Christinus marmoratus</i>	18				X		X
South-western Cool-skink	<i>Bassiana trilineata</i>	9	1	1		1		
South-western Crevice-skink	<i>Egernia napoleonis</i>	30						
Lowlands Earless Skink	<i>Hemiergis peronii</i>	28	59	9	30	15	15	1
Common South-west Ctenotus	<i>Ctenotus labillardieri</i>	X						
Common Dwarf Skink	<i>Menetia greyii</i>				1		X	
South-western Slider	<i>Lerista microtis</i>	1						
Shingle-back	<i>Trachydosaurus rugosus</i>	X		1				
Heath Monitor	<i>Varanus rosenbergi</i>					X		
Square-nosed Snake	<i>Rhinoplocephalus bicolor</i>	1						
Black Tiger Snake	<i>Notechis ater</i>	2	X			2		
Total number of species (22)		17	7	6	7	7	3	7

4.3.2 Birds

Ninety nine species of bird were recorded during the four surveys, and of those 59 species (including nocturnal birds) were recorded during the formal surveys (Table 4.2). There were differences in numbers of species found in native vegetation (51) compared to within plantations, although differences among plantation sites were relatively small (31-36). The least number of species was found on agricultural land (30) (Figure 4.1a; Table 4.2).

Overall abundance of birds was considerably lower in plantations compared with native vegetation (Fig. 4.2a). This was true for most functional groups, most notably Group1 and Groups 4-7 (Figure 4.2b). Individual species showed a variety of patterns of abundance (Figure 4.3). Here, it can be seen that the New Holland Honeyeater was largely restricted to the native vegetation, and was only observed infrequently in the plantations, and only in plantations adjacent to native bush. In contrast, the White-naped Honeyeater was almost as frequently observed in plantations as in remnant vegetation, but seldom observed in agricultural land. The Grey Shrike Thrush showed a steady decline in occurrence with distance away from remnant vegetation, but was still relatively abundant in the plantations. A contrasting distribution is seen for the White-breasted Robin, which was most abundant in the native vegetation but occurred at the edge of the plantation adjacent to the bush and in the isolated plantations.

In order to assess the importance of plantations to bird species that might be considered to be of particular conservation significance, we identified species considered to be potentially “at risk” from assessments made by (Saunders & Ingram, 1995; Wallace, 1998). If only these species are considered (Figure 4.4) it is again apparent that these species are most abundant in the native vegetation, but that they do occur in reasonable numbers in the plantations. Numbers of observations are higher in plantations next to native vegetation compared with isolated plantations.

Overall bird species richness was highly correlated with the mean Habitat Complexity Score estimated for each habitat type (Figure 4.5).

Table 4.2 Numbers of birds recorded in each habitat during the four surveys. X = recorded in habitat outside the formal survey. Blank = not recorded. * indicates species considered to be ‘at risk’.

Functional Group	Species	Genus	Species	Subspecies	R	Pre	Pri	Pr ag	Pag i	Pag e	Ag
1	Pallid Cuckoo	<i>Cuculus</i>	<i>pallidus</i>								X
1	Fan-tailed Cuckoo	<i>Cacomantis</i>	<i>flabelliformis</i>	<i>flabelliformis</i>					2	1	
1	Horsfield's Bronze-Cuckoo	<i>Chalcites</i>	<i>basalis</i>		1						
1	Shining Bronze-Cuckoo	<i>Chalcites</i>	<i>lucidus</i>	<i>plagosus</i>		X	2	1		1	
1	Willie Wagtail	<i>Rhipidura</i>	<i>leucophrys</i>	<i>leucophrys</i>				4			4
1	Restless Flycatcher*	<i>Myiagra</i>	<i>inquieta</i>		1						
1	Scarlet Robin	<i>Petroica</i>	<i>boodang</i>	<i>campbelli</i>	2	9	3	X	2	4	X
1	Red-capped Robin	<i>Petroica</i>	<i>goodenovii</i>							X	
1	White-breasted Robin	<i>Eopsaltria</i>	<i>georgiana</i>		14	3			2	5	
1	Western Yellow Robin*	<i>Eopsaltria</i>	<i>griseogularis</i>		X	9	8		4	5	
1	White-fronted Chat	<i>Epthianura</i>	<i>albifrons</i>								1
1	Western Thornbill*	<i>Acanthiza</i>	<i>inornata</i>		X						
1	Yellow-rumped Thornbill	<i>Acanthiza</i>	<i>chrysorrhoa</i>	<i>chrysorrhoa</i>	4	15		19	4	4	
1	White-browed Scrubwren	<i>Sericornis</i>	<i>frontalis</i>	<i>maculatus</i>	38	2				10	
1	Brown Songlark	<i>Cincloramphus</i>	<i>cruralis</i>								
1	Splendid Fairy-wren	<i>Malurus</i>	<i>splendens</i>	<i>splendens</i>	8	4	4	6			2
1	Red-winged Fairy-wren	<i>Malurus</i>	<i>elegans</i>		44						
				Total Species (17)	10	7	5	5	5	8	5
2	Stubble Quail	<i>Coturnix</i>	<i>pectoralis</i>					X			X
2	Brown Quail	<i>Coturnix</i>	<i>ypsilophora</i>	<i>australis</i>							
2	Painted Button-quail	<i>Turnix</i>	<i>varia</i>	<i>varia</i>	X				X		
2	Common Bronzewing	<i>Phaps</i>	<i>chalcoptera</i>		1	1	X	X	X		X
2	Brush Bronzewing	<i>Phaps</i>	<i>elegans</i>	<i>occidentalis</i>	X						
2	Crested Pigeon	<i>Ocyphaps</i>	<i>lophotes</i>	<i>whitlocki</i>					1		
2	Galah	<i>Eolophus</i>	<i>roseicapillus</i>	<i>roseicapillus</i>							
2	Elegant Parrot	<i>Neophema</i>	<i>elegans</i>	<i>carteri</i>	5			X			X
2	Australian Pipit	<i>Anthus</i>	<i>australis</i>	<i>bilbali</i>		1					6
2	European Goldfinch	<i>Carduelis</i>	<i>carduelis</i>	<i>britannica</i>							
				Total Species (11)	4	2	1	3	3		4
3	Southern Boobook	<i>Ninox</i>	<i>boobook</i>	<i>ocellata</i>	7		1	1			
3	Barn Owl	<i>Tyto</i>	<i>alba</i>	<i>delicatula</i>							1
3	Masked Owl	<i>Tyto</i>	<i>novaeahollandiae</i>	<i>novaeahollandiae</i>	X						
3	Tawny Frogmouth	<i>Podargus</i>	<i>strigoides</i>	<i>brachypterus</i>	4	10	3	7	1	2	
				Total Species (4)	3	1	2	2	1	1	1
4	Square-tailed Kite	<i>Lophoictinia</i>	<i>isura</i>				X			X	
4	Black-shouldered Kite	<i>Elanus</i>	<i>axillaris</i>		X						1
4	Australian Hobby	<i>Falco</i>	<i>longipennis</i>	<i>longipennis</i>	X						X
4	Peregrine Falcon	<i>Falco</i>	<i>peregrinus</i>	<i>macropus</i>		1					
4	Laughing Kookaburra	<i>Dacelo</i>	<i>novaeaguineae</i>	<i>novaeaguineae</i>			3	3		1	7
4	Sacred Kingfisher	<i>Todiramphus</i>	<i>sanctus</i>	<i>sanctus</i>	1				1		
4	Grey Shrike-thrush	<i>Colluricincla</i>	<i>harmonica</i>	<i>rufiventris</i>	20	16	10	9	4	4	
4	Red-eared Firetail	<i>Stagonopleura</i>	<i>oculata</i>		1						
4	Grey Currawong*	<i>Strepera</i>	<i>versicolor</i>	<i>plumbea</i>		1		2			
4	Grey Butcherbird	<i>Cracticus</i>	<i>torquatus</i>	<i>leucopterus</i>							

4	Australian Magpie	<i>Gymnorhina</i>	<i>tibicen</i>	<i>dorsalis</i>	19	12		16	17	14	21
4	Australian Raven	<i>Corvus</i>	<i>coronoides</i>	<i>perplexus</i>	60	33	42	16	21	24	10
				Total Species (12)	7	5	4	5	4	5	5
5	Red-tailed Black-Cockatoo	<i>Calyptrorhynchus</i>	<i>banksii</i>	<i>naso</i>	X				3		
5	Long-billed Black-Cockatoo*	<i>Calyptrorhynchus</i>	<i>baudinii</i>		26	30	X	X	2	X	
5	Regent Parrot*	<i>Polytelis</i>	<i>anthopeplus</i>	<i>anthopeplus</i>					X	6	
5	Western Rosella*	<i>Platycercus</i>	<i>icterotis</i>	<i>icterotis</i>	110	44	13	29	7	20	7
5	Red-capped Parrot*	<i>Purpureicephalus</i>	<i>spurius</i>		45	10	3	12	2	20	18
5	Australian Ringneck	<i>Barnardius</i>	<i>zonarius</i>	<i>semitorquatus</i>	14	4		7	3	3	8
				Total Species (6)	5	4	3	4	6	5	3
6	Australian Owlet-nightjar	<i>Aegotheles</i>	<i>cristatus</i>	<i>cristatus</i>	5	X					
6	Welcome Swallow	<i>Hirundo</i>	<i>neoxena</i>	<i>carteri</i>			2	1			
6	Tree Martin	<i>Petrochelidon</i>	<i>nigricans</i>	<i>neglecta</i>	53	5	4	15	10	3	30
6	Grey Fantail	<i>Rhipidura</i>	<i>albiscapa</i>	<i>preissi</i>	48	46	27	25	38	41	4
6	Golden Whistler	<i>Pachycephala</i>	<i>pectoralis</i>	<i>fuliginosa</i>	56	30	43	34	37	24	
6	Rufous Whistler	<i>Pachycephala</i>	<i>rufiventris</i>	<i>rufiventris</i>						X	
6	Black-faced Cuckoo-shrike	<i>Coracina</i>	<i>novaeahollandiae</i>	<i>melanops</i>	4			1	3	1	
6	White-winged Triller	<i>Lalage</i>	<i>sueurii</i>		X						
6	Western Gerygone*	<i>Gerygone</i>	<i>fusca</i>	<i>fusca</i>	6	5		4	11	9	
6	Inland Thornbill*	<i>Acanthiza</i>	<i>apicalis</i>	<i>apicalis</i>	50	13	20	35	26	8	
6	Varied Sittella	<i>Daphoenositta</i>	<i>chrysoptera</i>	<i>pileata</i>	6						
6	Spotted Pardalote	<i>Pardalotus</i>	<i>punctatus</i>	<i>punctatus</i>	2	2	2	2		2	
6	Striated Pardalote	<i>Pardalotus</i>	<i>striatus</i>	<i>substriatus</i>	19	2	1	3	1		
				Total Species (13)	11	8	7	9	7	8	2
7	Purple-crowned Lorikeet	<i>Glossopsitta</i>	<i>porphyrocephala</i>			4	1		2	10	1
7	Dusky Woodswallow	<i>Artamus</i>	<i>cyanopterus</i>		4	X				4	
7	Silveryeye	<i>Zosterops</i>	<i>lateralis</i>	<i>chloronotus</i>	25	38	24	37	57	94	54
7	White-naped Honeyeater	<i>Melithreptus</i>	<i>lunatus</i>	<i>chloropsis</i>	40	35	34	38	31	35	5
7	Western Spinebill*	<i>Acanthorhynchus</i>	<i>superciliosus</i>		42	19	8	17			
7	Brown Honeyeater	<i>Lichmera</i>	<i>indistincta</i>	<i>indistincta</i>	20	5	1		1	X	
7	New Holland Honeyeater	<i>Phylidonyris</i>	<i>novaeahollandiae</i>	<i>longirostris</i>	144	9	6	1	X		
7	Red Wattlebird	<i>Anthochaera</i>	<i>carunculata</i>	<i>woodwardi</i>	31	7	11	8	3	10	4
7	Western Wattlebird	<i>Anthochaera</i>	<i>chrysoptera</i>			1					
				Total Species (9)	7	9	7	5	6	6	4
8	Emu	<i>Dromaius</i>	<i>novaeahollandiae</i>	<i>novaeahollandiae</i>							
8	Australian White Ibis	<i>Threskiornis</i>	<i>molucca</i>								
8	Straw-necked Ibis	<i>Threskiornis</i>	<i>spinicollis</i>								
8	Australian Wood Duck	<i>Chenonetta</i>	<i>jubata</i>					3			3
8	Australian Shelduck	<i>Tadorna</i>	<i>tadornoides</i>				X				
8	Swamp Harrier	<i>Circus</i>	<i>approximans</i>		X						
8	Brown Goshawk*	<i>Accipiter</i>	<i>fasciatus</i>	<i>fasciatus</i>			1		X		
8	Collared Sparrowhawk	<i>Accipiter</i>	<i>cirrocephalus</i>	<i>cirrocephalus</i>	X						
8	Wedge-tailed Eagle	<i>Aquila</i>	<i>audax</i>	<i>audax</i>	X						X
8	Little Eagle	<i>Hieraaetus</i>	<i>morphnoides</i>	<i>morphnoides</i>							
8	Brown Falcon	<i>Falco</i>	<i>berigora</i>	<i>berigora</i>							
8	Nankeen Kestrel	<i>Falco</i>	<i>cenchroides</i>								X
8	Magpie-lark	<i>Grallina</i>	<i>cyanoleuca</i>	<i>cyanoleuca</i>	3				X	10	11
				Total Species (13)	4		2	1	2	1	4

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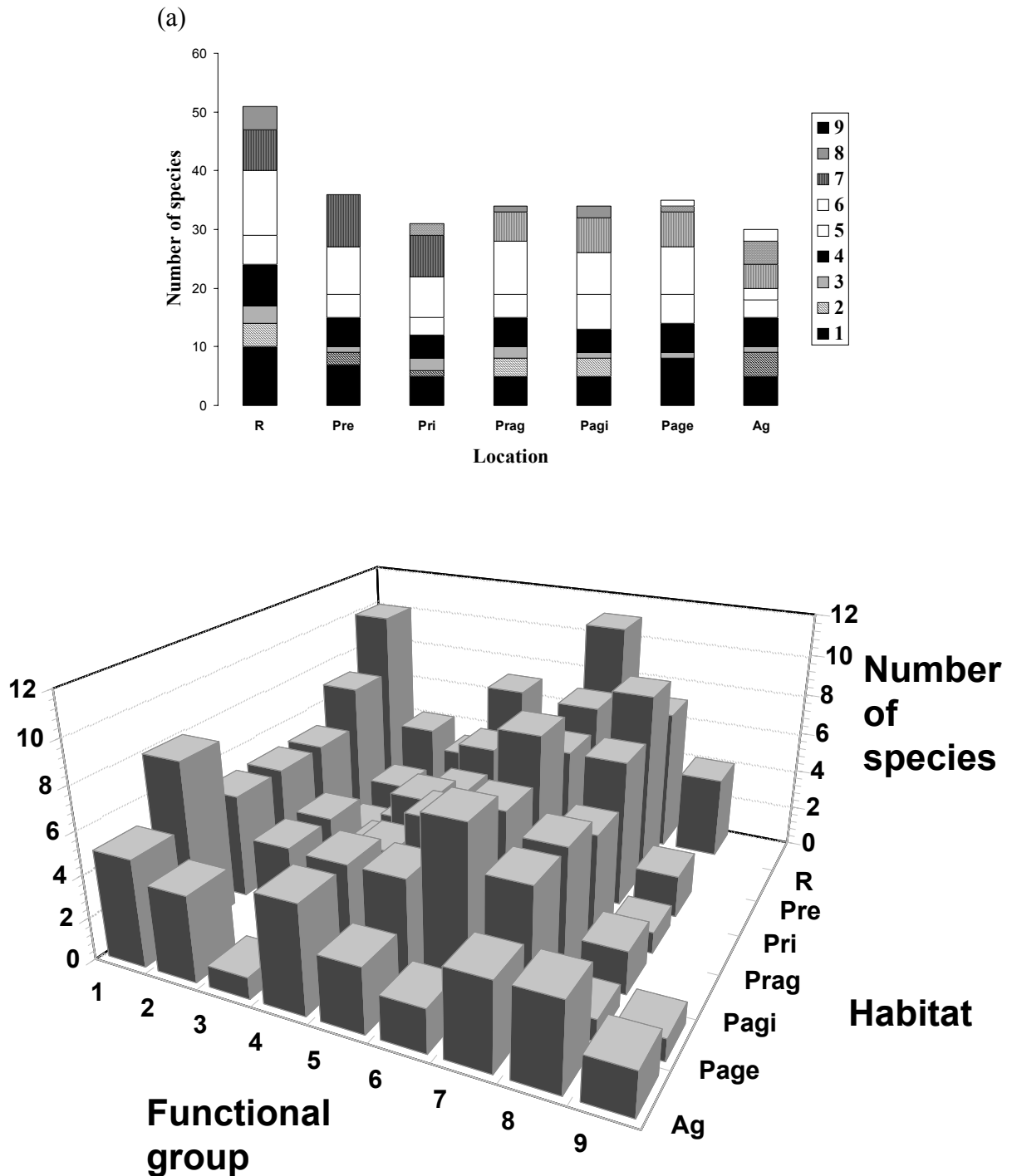


Figure 4.1 The number of bird species in each functional group found in each habitat over the course of the study (total number of species over 4 replicates and 4 sampling periods). See Figure 3.2 for habitat key. Functional groups are: 1 = understorey/ground feeder - insectivore; 2 = understorey/ground feeder – granivore; 3 = understorey/ground feeder – insectivore/carnivore; 4 = canopy/ understorey/ground feeder – insectivore/carnivore; 5 = canopy/ understorey/ground feeder – granivore/frugivore; 6 = canopy/ understorey/ground feeder – insectivore; 7 = canopy/ understorey/ground feeder – nectarivore/frugivore/insectivore; 8 = open country/pasture – all diets. (a) Data organised by habitat type (b) Data organised by functional group on the x axis and habitat type on the z axis.

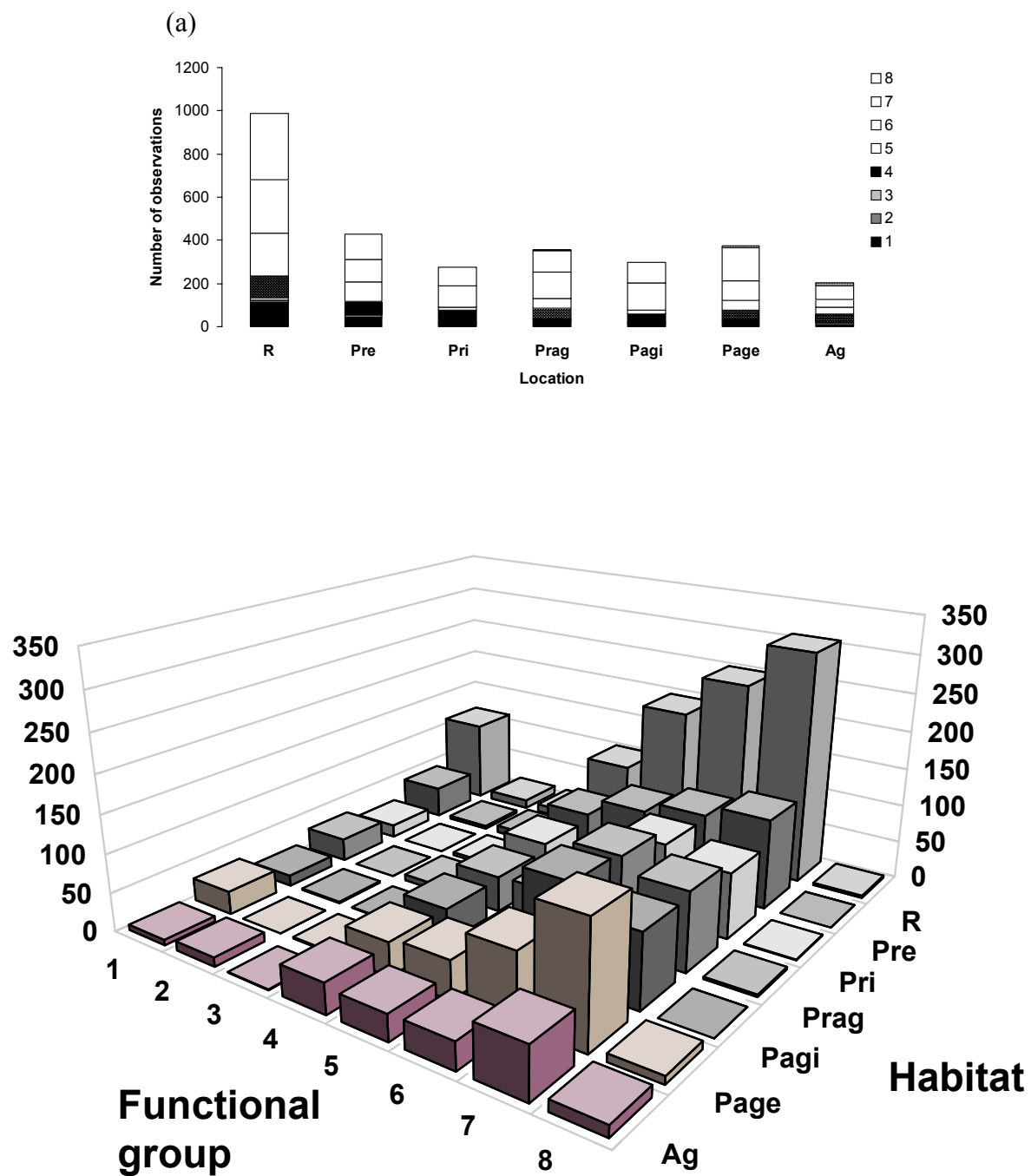


Figure 4.2 The number of observations of birds in each functional group in each habitat (total number of observations over 4 replicates and 4 sampling periods). Habitats as in Fig 3.2 and functional groups as in Fig 4.1

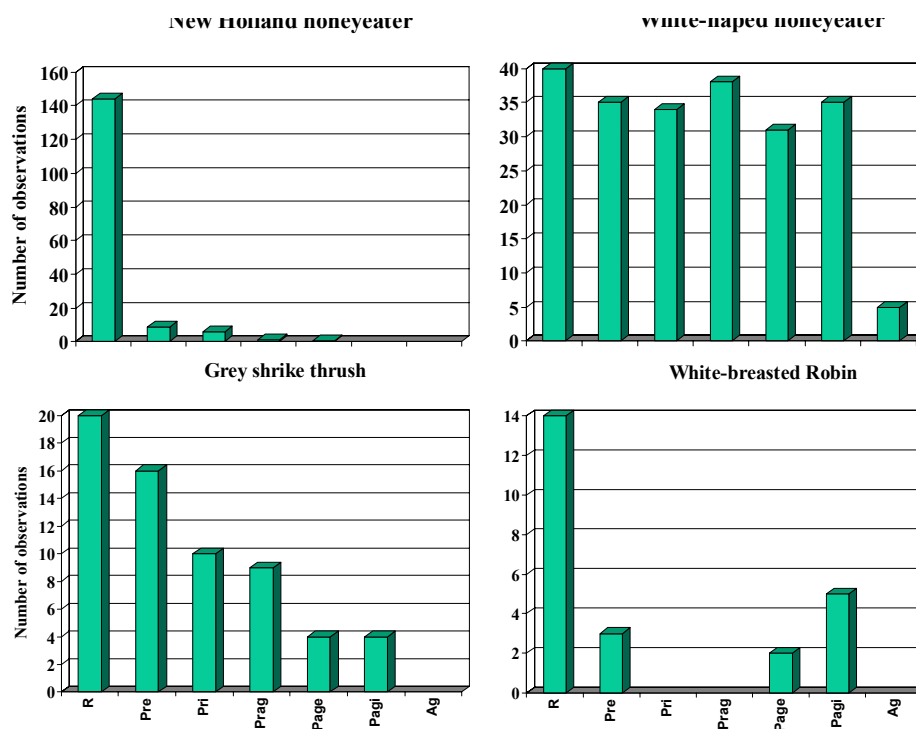


Figure 4.3. The number of observations of New Holland Honeyeater, White-naped Honeyeater, Grey Shrike Thrush and White-breasted Robin in each habitat type (total observations over 4 replicates and 4 sampling periods). Habitats as in Fig 3.2.

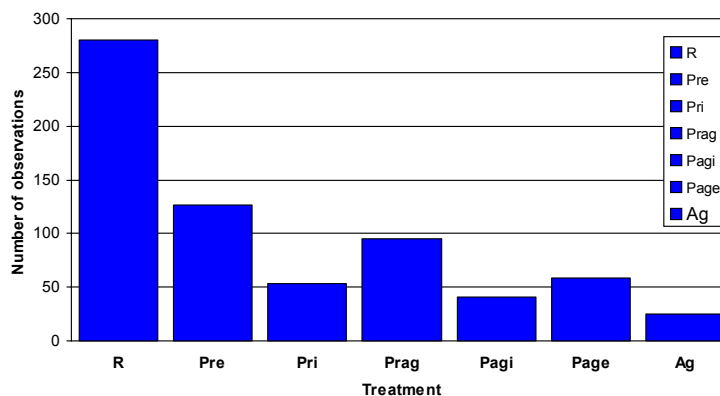


Figure 4.4. The number of bird species recognized as being “at risk” in each habitat (as indicated in Table 4.2). (Total number of species over 4 replicates and 4 sampling periods). Habitat types as in Fig 3.2.

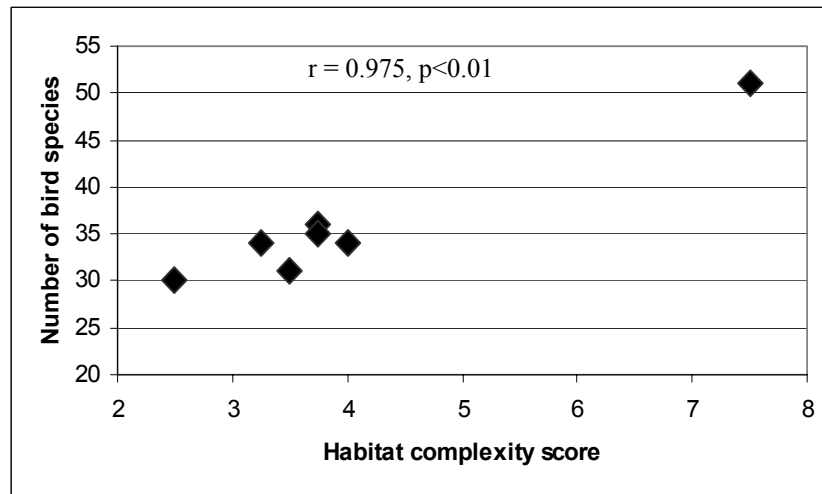


Figure 4.5 Relationship between total number of bird species found in each habitat type and mean Habitat Complexity Score.

4.3.3 Bats

Eight species of bat were recorded during the four surveys (Table 4.3). The number of passes that were recorded in each habitat was used as an index of the overall quality of each as foraging areas for bats. Over half of the passes were recorded in remnant vegetation, with a further third recorded in plantations abutting remnants, and together these habitats had 87.6% of all passes (Table 4.3). Less than 3% of the calls were recorded in isolated plantations, and less than 10% were recorded in grazing land (Table 4.3). All species (8) were recorded in the remnant vegetation which was double that found in the other habitats (Table 4.3). The number of species recorded in the plantations and the agricultural land were very similar (2-4)(Table 4.3). Three species were found in the remnant native vegetation only.

Table 4.3 Abundance of bats recorded in each habitat in October 1999. Numbers are the number of bat passes over one night in October 1999. Blank = not recorded.

Habitat		Remnant Vegetation	Plantation next to remnant	Plantation in agricultural land	Agricultural land
Southern Forest Bat	<i>Vespadelus regulus</i>	34	27		7
Chocolate Wattled Bat	<i>Chalinobus morio</i>	3	2	1	
Gould's Wattled Bat	<i>Chalinobus gouldii</i>	4	3		
Inland Freetail Bat	<i>Mormopterus planiceps</i>	5			3
White-striped Freetail Bat	<i>Tadarida australis</i>	11	8	3	4
Western Falsistrelle	<i>Falsistrellus mckenziei</i>	4			
Lesser Long-eared Bat	<i>Nyctophilus geoffroyi</i>	1			
Western Long-eared Bat	<i>Nyctophilus major</i>	1			
Unidentifiable sequences		12	12		
Total number of species (8)		8	4	2	3
Total passes		75	52	4	14
% in habitat		51.7	35.9	2.8	9.7

The Southern Forest Bat and White-striped Freetail Bat were common but only in the remnant vegetation and the plantations next to a remnant (Table 4.3). However, both species were also recorded less frequently on agricultural land. As well as indicating habitat quality overall, the number of passes can be used to gauge the influence of habitat quality upon each species. In situations where some species prefer densely forested habitats, and others prefer more open ones, (although they will use both), then this preference can be determined by a change in the rank, or relative abundance.

Table 4.4 shows the rank of each species in each habitat, based upon the number of passes. The analysis showed that:

- *V.regulus* and *T.australis* together maintained the highest ranks across all habitats, with the exception of *V.regulus* being absent in isolated plantations.
- *Tadarida australis* maintained a high rank across all habitats.
- *Mormopterus planiceps* was found only in remnants and grazing land, and at the same rank in both. It is possible that if the vegetation was dense in plantations, then until more open flight space evolved then this species would not use this habitat.
- *Chalinolobus gouldii* was found only in remnants or plantations near remnants, and at a low rank in both, perhaps indicating that there is a preference for forest habitat in large tracts.
- *Falsistrellus mckenziei* was only found in remnant vegetation (where it ranked fourth in relative abundance), and nowhere else. In eastern Australia, the sibling species *F.tasmaniensis* is a habitat specialist, and is generally only found in high altitude forest, but it has been recorded using plantations in Victoria (Brown *et al* 1991).
- *Chalinolobus morio* was found in all habitats except grazing land, at a low rank in remnants and plantations near remnants (and in low abundance), but in the absence of other species in isolated plantations, its rank improves, but there is very little data.

Table 4.4 Ranked Relative Abundance analysis using the total passes of all bat species except *Nyctophilus* over all four replicates. Species are listed in order of their rank in primary habitat.

Habitat	Remnant		Plantation		Isolated plantation		Grazing land	
	Passes	Rank	Passes	Rank	Passes	Rank	Passes	Rank
<i>V. regulatus</i>	34	1	27	1	0	-	7	1
<i>T. australis</i>	11	2	8	2	3	1	4	2
<i>M. planiceps</i>	5	3	0	-	0	-	3	3
<i>C. gouldii</i>	4	4	3	3	0	-	0	-
<i>F. mackenziei</i>	4	4	0	-	0	-	0	-
<i>C. morio</i>	3	5	2	4	1	2	0	-

4.3.4 Ground-dwelling Mammals

Thirteen species of ground-dwelling mammal were recorded during the four surveys; eight native and five introduced (Table 4.5a and b). The Honey-possum, *Tarsipes rostratus* was recorded, but not on the study sites. The only native mammal to occur in all habitats was the Western Grey Kangaroo (Table 4.5a). However, most of the introduced species occurred in all habitats (Table 4.5b).

Of the native species Western Grey Kangaroo was common in all habitats. The Southern Brown Bandicoot and Bush Rat were also common, but in the native vegetation only (Table 4.5a). Of the introduced species the House Mouse, Rabbit and Fox were common in all habitats and the Cat was reasonably abundant in most habitats, but common in the native vegetation.

Table 4.5 Abundance of (a) native and (b) introduced ground-dwelling mammals recorded in each habitat over the four surveys. For yellow-footed antechinus, bush rat, black rat and house mice values are numbers per 960 trap nights, and for the rest, number of plots with tracks per 240 plots. X = recorded in habitat outside the formal survey. Blank = not recorded.

	Habitat	R	Pre	Pri	Prag	Pagi	Page	Ag
	Species							
(a) Native	Southern Brown Bandicoot	49						4
	Common Brushtail Possum	7	1					3
	Western Ringtail Possum	2						
	Western Grey Kangaroo	108	63	47	42	50	43	5
	Western Pygmy Possum		X					
	Grey-bellied Dunnart		X					
	Yellow-footed Antechinus	3						
(b) Introduced	Bush Rat	40						
	Black Rat	2						
	House Mouse	3	10	9	12	26	16	5
	Fox	61	32	30	47	28	55	102
	Cat	18	5		1	1	2	5
	Rabbit	92	119	18	70	5	5	91
Total Species (13)		11	8	5	5	5	5	7

4.4 Discussion

4.4.1 Vertebrate Faunal use

It is possible to relate faunal use of plantations to these differences in vegetation. Clearly plantations offer more habitat structure than an annual pasture, but the additional structure is only in the form of tree stems and canopy. Little or no habitat is present at the ground layer in the plantations. The development of a habitat complexity score provided an index of habitats of fauna that was independent of plant species, and related mainly to differences in the biomass of vegetation (Newsome and Catling 1979). In the forests of eastern New South Wales the abundance of ground-dwelling mammals varies considerably, due to differences in habitat complexity ((Catling & Burt, 1995a); Catling *et al.* 1998; 2000). Some species are positively related and others negatively related to habitat complexity, and the features of habitat complexity, tree canopy cover, shrub cover, ground cover, litter cover and wetness, are significant in many models (Catling *et al.* 1998; 2000). Recently, similar results have been obtained for birds in the woodlands of the Australian Capital Territory (Freudenberger, 1999).

In answer to the main questions posed in the Section 3.1, we can draw the following conclusions:

1. Faunal use of plantations is generally less than in comparison with adjacent remnant vegetation, but more than in open pasture. For all faunal groups there were almost twice as many species recorded in the native vegetation than in any site in the plantations or on agricultural land and they were in greater abundance. This was particularly obvious for the volant and ground-dwelling native mammals and birds, where a number of species were found exclusively in the native vegetation. Note also, however, that some bird species used the plantations to the same extent as the remnant vegetation, especially where the plantation was adjacent to remnant vegetation (e.g. Grey Shrike Thrush, Figure). The distinction was not as clear for the herpetofauna. Many of the amphibians and reptiles are generalists and of the 22 species recorded in the surveys, 16 of those did occur somewhere in the plantations, although they were usually recorded once or twice only (Table 4.1). *Geocrinia leai* was only recorded in the remnant habitat and it is probably restricted to that habitat; *Christinus marmoratus* is a specialist which requires suitable tree bark, the foliage of *Xanthorrhoea* spp. or general litter for cover; *Egernia napoleonis* is a generalist which was abundant in native vegetation and was expected to be recorded at other sites, but suitable cover did not exist; *Ctenotus labillardieri* was expected to be more abundant, but was only recorded once and in native vegetation; *Lerista microtis* and *Rhinoplocephalus bicolour* were recorded once only inside stick-nest ant colony in native vegetation.

2. Faunal use of plantation edges and interiors did not show consistent patterns. Edges next to remnants were most frequently used by some species, but individual species showed a wide range of patterns of use across the various habitat types studied. More species of bird identified as being “at risk” were found in plantation edges than in interiors.

3. Adjacency to remnant vegetation increases plantation use by some species, but the overall differences between isolated plantations and those adjacent to remnant vegetation were relatively small. Fewer species of bat used isolated plantations.

Chapter 5.

Faunal use of bluegum (*Eucalyptus globulus*) plantations in southwestern Australia: invertebrates

(Authors: S. A. Cunningham and R. B. Floyd)

5.1 Introduction

Invertebrate animals are very important both in their contribution to the world's biodiversity, and through the ecological functions they perform. Most of the world's biodiversity is constituted by invertebrate animals. Insects, the biggest group of invertebrate animals, are so diverse that scientists cannot yet determine how many species there are in the world. A recent study put the figure at approximately 5 million species (Novotny et al 2002). In contrast, the number of bird species is known to be about 10,000. Invertebrates are also abundant in most habitats, and because most insects are small and can fly, they tend to be among the first species to occupy new or disturbed habitats, such as a newly planted tree plantation.

Invertebrates are also thought to be very important in maintaining a functioning ecosystem. They help condition the soil by processing their food into fine organic matter, and then mixing it into the soil. They help plants to reproduce by pollinating flowers and dispersing seeds. They can also be considered pests in a plantation context because they eat plants and might therefore limit growth of trees. Many insects and all spiders are predators or parasitoids, and therefore contribute to the control of insect populations, including the control of potential pest species. Invertebrates are also essential diet items for many vertebrate species such as birds, and mammals. Therefore a substantial invertebrate population is necessary to support a healthy vertebrate population.

In this chapter we report on a survey of the invertebrate fauna in *Eucalyptus globulus* plantations using the study sites already described (chapter 3) to address the objectives described in chapter 3.

5.2 Methods

5.2.1 Sampling techniques

We used four different techniques for sampling insects and related invertebrates:

- (1) Insecticidal knockdown was used to collect insects from the canopy.
- (2) Light traps were used to collect light-attracted night-flying insects.
- (3) Malaise traps were used to passively collect flying insects.
- (4) Pit-fall traps were used to collect ground-active insects.

We chose to focus on 3 major groups from the diversity of insects and related invertebrates collected using these techniques. Coleoptera is one of the most species rich orders of insects, including many species that are herbivorous, and therefore of interest to plantation managers. We refer to members of this order by their common name, "beetles". Lepidoptera is another major insect order, including the moths and butterflies. As larvae they are all herbivorous. The Lepidoptera collected in this study were only night-flying species, which are commonly called moths. Other studies have found that beetles and moths are among the most abundant and species rich groups of invertebrates associated with *Eucalyptus* (Abbott *et al.*, 2000; Majer *et al.*, 2000; Abbott *et al.*, 1999; Recher *et al.*, 1996; Abbott *et al.*, 1992; Majer & Recher, 1988). For both the beetles and moths we were usually able to sort specimens to species level.

The third major order we examined were the Hymenoptera, which includes wasps (many families), bees (superfamily Apoidea) and ants (family Formicidae). We chose to focus on 4 major groups of wasps that are known to be parasitoids, and therefore kill other insects. In addition we counted bees, because they are important in pollination, and ants, because they are diverse and fulfil many important ecological roles. For the Hymenoptera we did not identify species, and present data only on abundance at the family or subfamily level.

In addition to these major groups we present a small amount of information on spiders and Hemiptera. We counted the herbivorous Hemiptera (i.e. excluding the small number of specimens of predatory species) from canopy-collected samples because they represent a potentially abundant group of herbivores (Abbott *et al.*, 2000; Majer *et al.*, 2000; Abbott *et al.*, 1999; Recher *et al.*, 1996; Abbott *et al.*, 1992; Majer & Recher, 1988). We also counted the Spiders (class Arachnida, order Araneae) because they can be important predators of insects. For the Hemiptera and Spiders we did not identify species, and present data only on abundance at the ordinal level.

We sampled insects and related invertebrates from eight different habitats, in four different areas (as described in Chapter 3)) on four survey trips (October 1999 5-22, April 18 – May 7 2000, November 2000, 2-17, May 2001, 6-27). However, not all collection methods were used in all habitats, and some planned sampling events in some sites were missed due to bad weather (Table 5.1). We did not sample insects from the Mt Barker West isolated plantation (Pagi or Page: except by pitfall trap) because we felt it was not isolated sufficiently to limit the movement of flying insects (see section 3.2.2). We did not sample the “Page” habitat in any sites (except by pitfall trap), but did add a habitat not sampled for vertebrates. This habitat was the edge of remnant vegetation facing the adjacent plantation (Rpe: Table 5.1).

Table 5.1: The habitats sampled using different techniques, and the symbols used to represent them in figures.

Code	Habitat	Canopy	Malaise	Light trap	Pitfall	Symbol
R	Remnant	✓ ¹	✓ ³	✓	✓	
Rpe	Remnant edge to plantation	✓ ²	✓ ²	x	x	□
Pre	Plantation edge to remnant	✓ ¹	✓	x	✓	△
Pri	Interior of plantation adjacent to remnant	✓ ³	✓	✓	✓	▲
Pagi	Interior of plantation not adjacent to remnant	✓ ^{4,1}	✓ ⁴	x	✓	▼
Prag	Edge to agriculture of adjacent plantation	✓ ¹	✓	x	✓	▽
Ag	Agricultural land	x	✓	x	✓	
Page	Edge to agriculture of plantation not adjacent to remnant	x	x	x	✓	

✓¹?2 samples not collected

✓²?No collection on first survey trip

✓³?1 sample not collected

✓⁴?Not including Mt Barker West

5.2.2 Light traps

We operated light traps with vertical 30cm 8 watt ultra-violet tubes, between dusk and dawn in “R” and “Pri” sites in all four sites (8 sampling locations). We did three nights of trapping in each of 4 trips (i.e. 12 collecting events), with an extra night in one site, in one trip. Thus the total number of samples was 98 ($8 * 12 + 2$).

Light traps attracted moths and beetles. To reduce the samples to a manageable size we discarded all moths with a forewing span of $<15\text{mm}$, then pinned and identified the rest. All moths were sorted to species level by Ted Edwards, a moth specialist with the Australian National Insect Collection (ANIC). We also kept all beetles collected from light traps. They were identified by Tom Weir, a beetle specialist with ANIC.

5.2.3 Malaise traps

Malaise traps passively intercept flying insects, and then capture those that fly upwards into the collecting funnel. We used malaise traps in which the intercept area (the central baffle) was approximately 910mm tall by 165mm wide. These were erected in all habitats in all sites except “Page”, on all survey trips. We left traps erected for 7 or 8 fine days on each trip. We did not count days that were cold and wet for most of the day because flying insect activity is much reduced in these conditions. On the first survey trip there were only 4 fine days for the “Ag”, Millbrook West and 5 fine days for “Ag”, Millbrook South

Cattle were attracted to the malaise traps and frequently knocked them over in the “Ag” sites Millbrook South and Millbrook West. To avoid this problem we moved the malaise traps at these sites such that on the 2nd, 3rd and 4th surveys they were placed within the boundary fence of the “Pagi” site, but placed in the firebreak such that they were more than 30m from the plantation, and only 2m from the pasture.

From the malaise traps samples we sorted out Hymenoptera, and then counted the abundance of insects in these categories: Ichneumonidae (family: Ichneumonid wasps), Braconidae (family: Braconid wasps), Evanioidea (superfamily: Evanioid wasps), Bethyidae (family: Bethyid wasps), Formicidae (family: ants), Apoidea (superfamily: bees). Malaise trapping also collected many Diptera (flies) but we had insufficient resources to sort and count these.

The sorting of Hymenoptera was done by non-experts, who had been trained by systematists to rapidly sort specimens to the appropriate family or superfamily (for a discussion of this general approach, see Beattie & Oliver, 1994; Oliver & Beattie, 1996). This approach is useful for generating quantitative data, and can allow ecological interpretation when the higher level taxonomy is associated with particular functional groupings. For example, the wasp families considered are parasitoids and therefore feed on other insects, whereas bees specialise in visiting flowers for pollen and nectar. However, it is inevitable that non-experts will be less precise in assigning specimens to families, especially for very small or obscure specimens. Therefore less emphasis should be placed on small differences in number. It also means no information was available on species level diversity.

We also examined all beetles caught in malaise traps. These specimens were sorted to species level, identified by Rolf Oberprieler (ANIC, weevil specialist) and Tom Weir (all other beetles) and counted.

5.2.4 Canopy sampling

To sample the fauna of the canopy we used an insecticidal knockdown technique. We used “Dominex 100” (a synthetic pyrethroid, active agent = alpha-cypermethrin) at a concentration of 100mg per litre. This was sprayed up into the canopy using a backpack mistblower (Stihl SR400), spraying until the foliage was visibly wet. We sprayed as high in the canopy as was possible when standing on the roof of a 4-wheel drive vehicle. We arranged 13m² of white tarpaulins under the sprayed tree and collected all insects that fell on the tarpaulins. Collection continued for at least of 90 minutes, after which time the rain of insects from the canopy was greatly diminished.

We did not attempt to sample the canopy in this way if it was raining or windy. Given the limited survey time, it was not possible to sample all trees at the same time of day. Canopy spraying was done between 6 am and 4 pm.

In the plantations the trees we sampled were all *Eucalyptus globulus*. In the remnant vegetation we chose to sample *Eucalyptus marginata* Donn ex Smith ("Jarrah") because they were present and abundant in all sites (see 3.3.1). When spraying remnant trees we were usually able to wet all the foliage. In the plantation sites, however, trees were sometimes too tall, and the lower canopy too dense, for the insecticide to effectively wet the highest leaves. In this way we expect the plantation trees to be under-sampled relative to the remnant trees. However, because the canopy of plantation trees was denser than for the remnant trees the area of leaves wetted was probably greater. Considering these limitations, the samples cannot be regarded as exhaustive collections of the sampled tree canopies, nor can they be treated as samples of the same canopy volume in each case. They do nevertheless follow a repeatable method, and provide indicative samples of this important part of the invertebrate fauna.

We sampled one tree in every habitat (except Ag), in each of the four sites, on each survey trip (except the first in which some trees were missed due to bad weather: Table 5.1). We never re-sampled the same trees. In total we sampled 26 remnant trees and 53 plantation trees. The mean height of remnant trees was 8.7m (+/- 0.46 1SE), and the mean height of plantation trees was 15.4 m (+/- 0.403, 1SE). For trees at edge sites (Re, Pre, Prag) we chose trees approximately 10m from the edge to avoid the effect of wind on sample collection. From canopy knockdown samples we sorted, identified and counted all coleoptera to species level. We also counted the total number of spiders and herbivorous hemiptera.

5.2.5 Pitfall trapping

Invertebrates captured within the pitfall traps used for vertebrate sampling (see Chapter 3) were sorted and the abundance of beetles, ants and spiders determined. Samples were not sorted to species level.

5.2.6 Analyses

The invertebrate fauna is generally so species rich that it is usually very difficult to discover the true number of species in a given sampling location. Most studies find that an increase in sampling effort leads to an increase in the number of species detected record (Abbott *et al.*, 1992). Therefore invertebrate ecologists have developed tools to estimate the true species number on the basis of the abundance and diversity of species in the samples collected. These approaches are based on extrapolation from the "collection curve", which describes the relationship between sampling effort and the number of species found. To estimate true species richness from our samples we used the Chao 2 estimator because it has been found to be a useful and robust estimator (Colwell & Coddington, 1994). To calculate Chao 2 we used the "EstimateS 6.0b1" software.

To compare the fauna of one site to another it is useful to have measures of similarity. We were interested in similarity between samples considering both species composition and abundance. However, because some samples were dominated by a few abundant species there was a danger that the similarity measure would mostly reflect these abundant species. Therefore to reduce the influence of abundant species we used the square root of true abundance, and then calculated Bray Curtis similarities (Clarke, 1993). Finally we used non-metric multidimensional scaling (NMDS) as a method to translate the multidimensional complex of similarities between multiple samples into an easier to interpret two-dimensional space. To perform NMDS we used Genstat (Lawes Agricultural Trust, 2000).

Species of moths and beetles vary greatly in their feeding behaviour. We were interested in examining whether there were differences between remnant and plantation faunas in the prevalence of different feeding behaviours. Of greatest interest was the abundance of insects that can eat *Eucalyptus*, and therefore might be of concern to plantation managers. However, given the number of species collected, it would be extremely difficult to determine the feeding behaviours of them all.

This problem arises not only because of the number of species, but because there is insufficient knowledge of the ecology of many of them – especially the less common species. Therefore we chose only to examine the feeding biology of the ten most abundant species in canopy beetle, malaise beetle, and light-trapped moth samples. Because of the numerical dominance of these faunas by the more abundant species, this approach still allowed us to examine the biology of the majority of individuals collected. In some cases we inferred likely feeding behaviour on the basis of the known behaviour of near relatives of the species. Even using this approach, there were a number of species for which we were unable confidently to infer feeding behaviour.

5.3 Results

5.3.1 Moths

The abundance of moths collected by light trapping was similar in the remnant vegetation (1464 individuals) and plantations (1408 individuals) (Figure 5.1). The five most abundant species accounted for a greater fraction of the plantation samples than for the remnant sample (Figure 5.1). We identified 295 species in 26 families (Table 5.2). The majority of species were found in remnant vegetation (244/295) (Figure 5.2). Almost two thirds of the species found in plantations were also found in remnant vegetation (104/155) (Figure 5.2).

The estimated species richness of the Mt Barker East remnant site was greatest, at 260. In comparison, the adjacent Mt Barker East plantation had an estimated species richness of only 123 (Figure 5.3). The pattern of greater species richness in remnant vegetation was similar for all four site pairs, and non-overlapping stand errors indicate that these differences were statistically significant (Figure 5.3).

Moth communities of remnant sites (R) were, on average, more similar to each other in composition and abundance of species than they were to their adjacent plantation sites (Pri) (Figure 5.4). In NMDS similarity space, two non-overlapping groups can be defined (Figure 5.7). The one remnant site that is closest to the plantation sites in similarity space is also the site with the highest estimated moth species richness (Mt Barker East: Figure 5.3). This suggests that its richness is due to the sum of a large complement of species also found in plantations (which make it similar to plantation fauna) plus a large complement of the distinctive remnant fauna.

Moths that were among the ten most abundant species, and were known to feed on *Eucalyptus* leaves, were 8.3% (122/1464) of the total sample in remnant forest, and slightly more abundant at 13.1% (185/1408) of the total sample in plantation forest (Table 5.3). However, ecological information is simply unavailable for many of these species, so that abundant species (i.e. in top ten) of unknown feeding behaviour were 8.4% (123/1464) of the total sample in remnant forest, and at 17.3% (243/1408) of the total sample in plantation forest (Table 5.3).

Table 5.2: Number of moth individuals collected in plantation (Pri) and remnant sites (R), organized into family or subfamily.

<i>Family</i>	<i>Subfamily</i>	<i>Plantation</i>	<i>Remnant</i>
Anthelidae	-	1	2
Arctiidae	-	93	255
Carposinidae	-	7	38
Depressariidae	-	0	7
Drepanidae	-	0	1
Gelechiidae	-	4	44
Geometridae	Ennominae	75	179
-	Geometrinae	20	31
-	Larentiinae	20	43
-	Oenochrominae	40	93
-	Sterrhinae	20	17
Hepialidae	-	19	24
Hypertrophidae	-	1	0
Lasiocampidae	-	1	2
Limacodidae	-	0	1
Lymantriidae	-	0	5
Noctuidae	Acontiinae	1	8
-	Amphipyridae	71	88
-	Catocalinae	9	12
-	Chloephorinae	1	0
-	Hadeninae	47	33
-	Heliothinae	0	3
-	Hypeninae	13	8
-	Noctuinae	33	35
-	Plusiinae	0	1
Nolidae	-	11	42
Notodontidae	Notodontinae	3	6
-	Thaumetopoeidae	0	17
Oecophoridae	Oecophorinae	610	204
-	Xyloryctidae	16	42
Oenosandridae	-	11	0
Palaephathidae	-	2	2
Psychidae	-	10	9
Pyralidae	Crambinae	3	3
-	Epipaschiinae	9	15
-	Galleriinae	12	2
-	Musotiminae	1	0
-	Nymphulinae	53	32
-	Phycitinae	80	36
-	Pyalinae	1	0
-	Pyraustinae	15	35
-	Scopariinae	42	9
Stenomatidae	-	2	40
Tineidae	-	10	5
Tortricidae	-	40	35
unknown	-	1	0

Table 5.3: The identity and biology of the ten most abundant moth species collected by light trap, comparing remnant, and plantation samples.

Species	Number in remnant sample	Number in plantation sample	Biology
Scoliacma xuthopis	85		Relatives feed on moss and lichen
Scoliacma pasteophara	122		Relatives feed on moss and lichen
Undescribed sp. (Arctiidae, Lithosiinae)	38	50	Biology unknown
<i>Mnesampela privata</i>		26	Feeds on Eucalyptus leaves
<i>Plesiolaia promacha</i>	46		Biology unknown.
<i>Ardozyga sp.</i>	39		Biology unknown.
<i>Dichromodes diffusaria</i>	43		Relatives known to feed on Myrtaceae (the family that includes <i>Eucalyptus</i>).
<i>Nearcha atyla</i>		29	Biology unknown
<i>Dasygaster padockina</i>		27	Feeds on grass (is a pest of grasslands)
<i>Proteuxoa sp.</i>	54		Biology of a few species is known and they feed on a wide range of grasses and herbs
<i>Euchaetis sp.</i>	44	159	Relatives feed on leaves of <i>Eucalyptus</i>
Philobota xanthastis	53	321	Relatives feed on grass or <i>Eucalyptus</i> leaf litter
Micramicta flaccida		69	Biology unknown
<i>Hygraula nitens</i>		53	Aquatic species, feeds on water plants.
Undescribed sp. Pp 7		55	Biology unknown
<i>Scoparia sp.</i>		40	Biology unknown
<i>Agriophara sp. 19.</i>	35		Some species of <i>Agriophara</i> tie and feed on green leaves of <i>Eucalyptus</i>

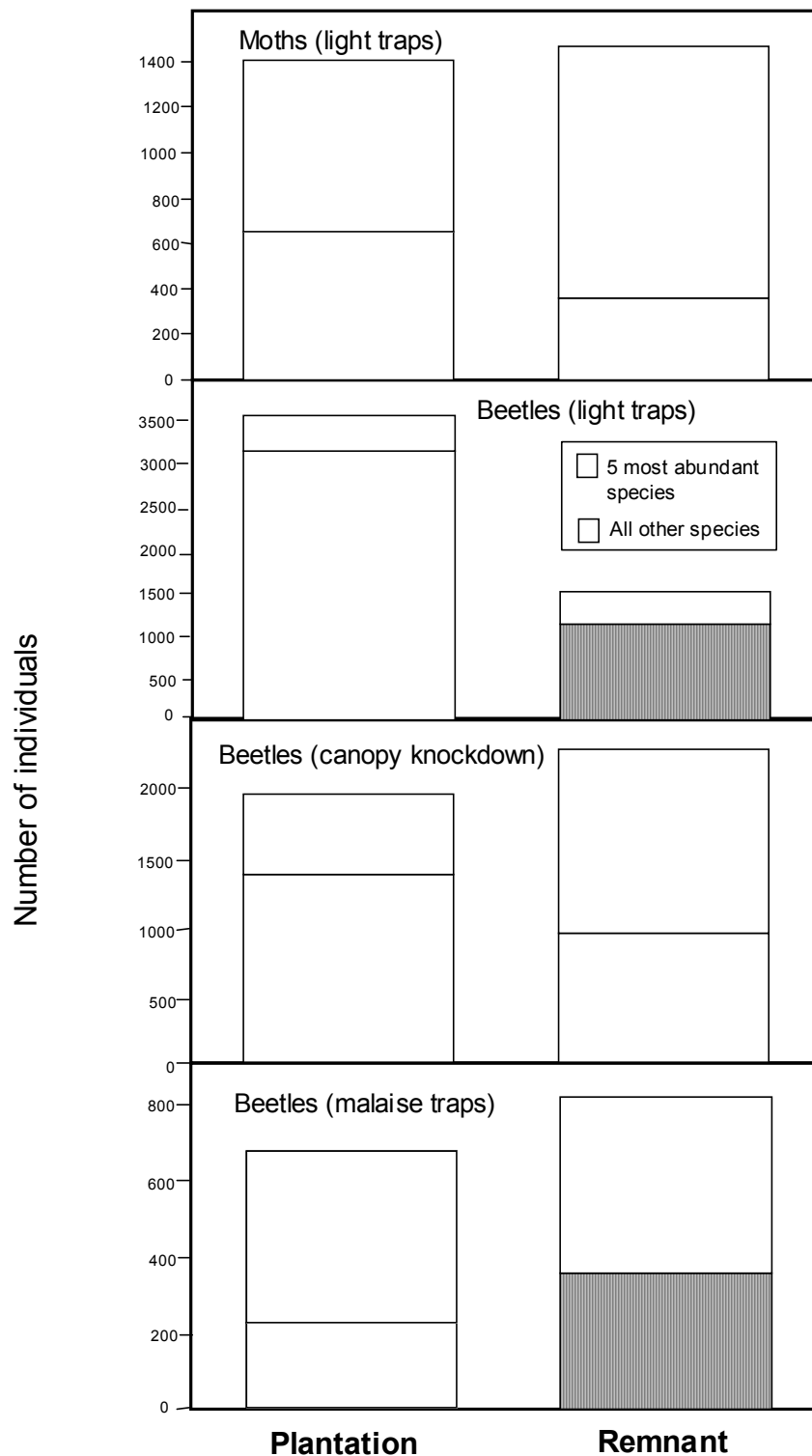


Figure 5.1: The abundance of insects (i.e. total number of individuals in samples) collected in plantation sites and remnant sites. The graphs present the data for four different fractions of the insect fauna: For the moths and beetles from light traps the data represents the whole sampling effort, which included only habitat “R” and “Pri”. For the canopy knockdown and malaise-collected beetles we sub-sampled our data to ensure that the sampling effort was equal in the two habitat types: remnant sites include “R” and “Rpe” habitats, and plantation sites include “Pre” and “Pri”. To represent the degree to which samples are dominated by a few abundant species, the number of specimens accounted for by the 5 most abundant species is represented by heavy stippling and the number of specimens accounted for by the remaining species is represented by light stippling. To determine the number of species in each sample, see figure 5.2.

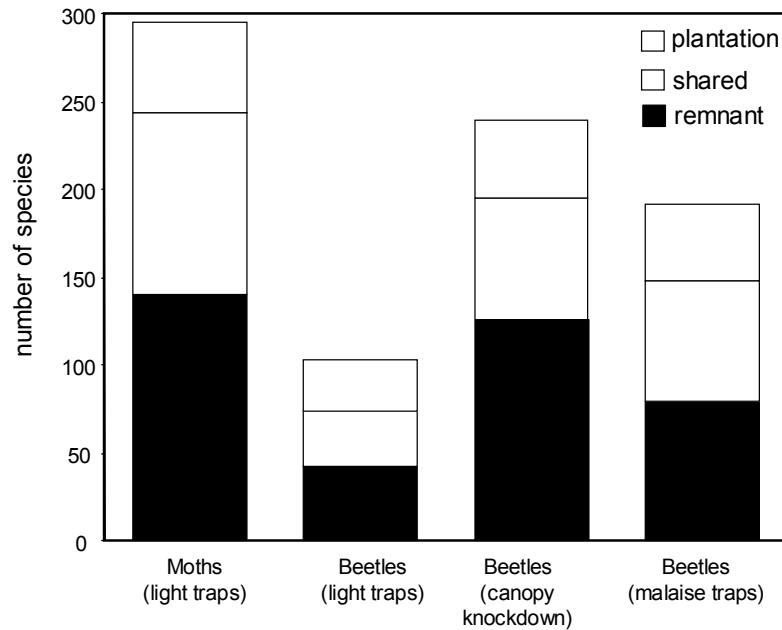


Figure 5.2: A comparison of the species richness in remnant vegetation and *Eucalyptus globulus* plantations for four different fractions of the insect fauna. The solid area of the bar represents species found in remnant vegetation only, the lightly stippled area of the bar represents species found in plantations only and the heavily stippled area of the bar represents species found in both remnant and plantation samples. For the moths and beetles from light traps the data represents the whole sampling effort, which included only habitat “R” and “Pri”. For the canopy knockdown and malaise-collected beetles we sub-sampled our data to ensure that the sampling effort was equal in the two habitat types: remnant sites include “R” and “Rpe” habitats, and plantation sites include “Pre” and “Pri”.

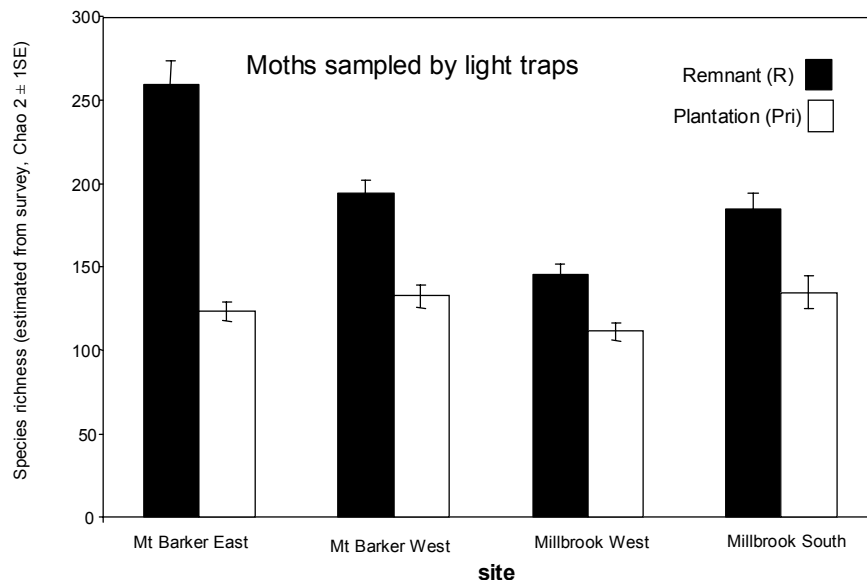


Figure 5.3: Moth species richness of remnant and plantation habitats in four different locations. Sampling comprises 3 nights of light trapping on 4 survey visits (i.e. 12 samples) for remnant sites (R) and plantation sites (Pri) considered separately for each of four different locations. Remnant samples are represented by solid columns and plantation samples are represented by stippled columns. Species richness numbers are estimated from the sample data using the Chao2 index (Colwell & Coddington, 1994). Variance around these estimates is represented by the error bars (± 1 SE).

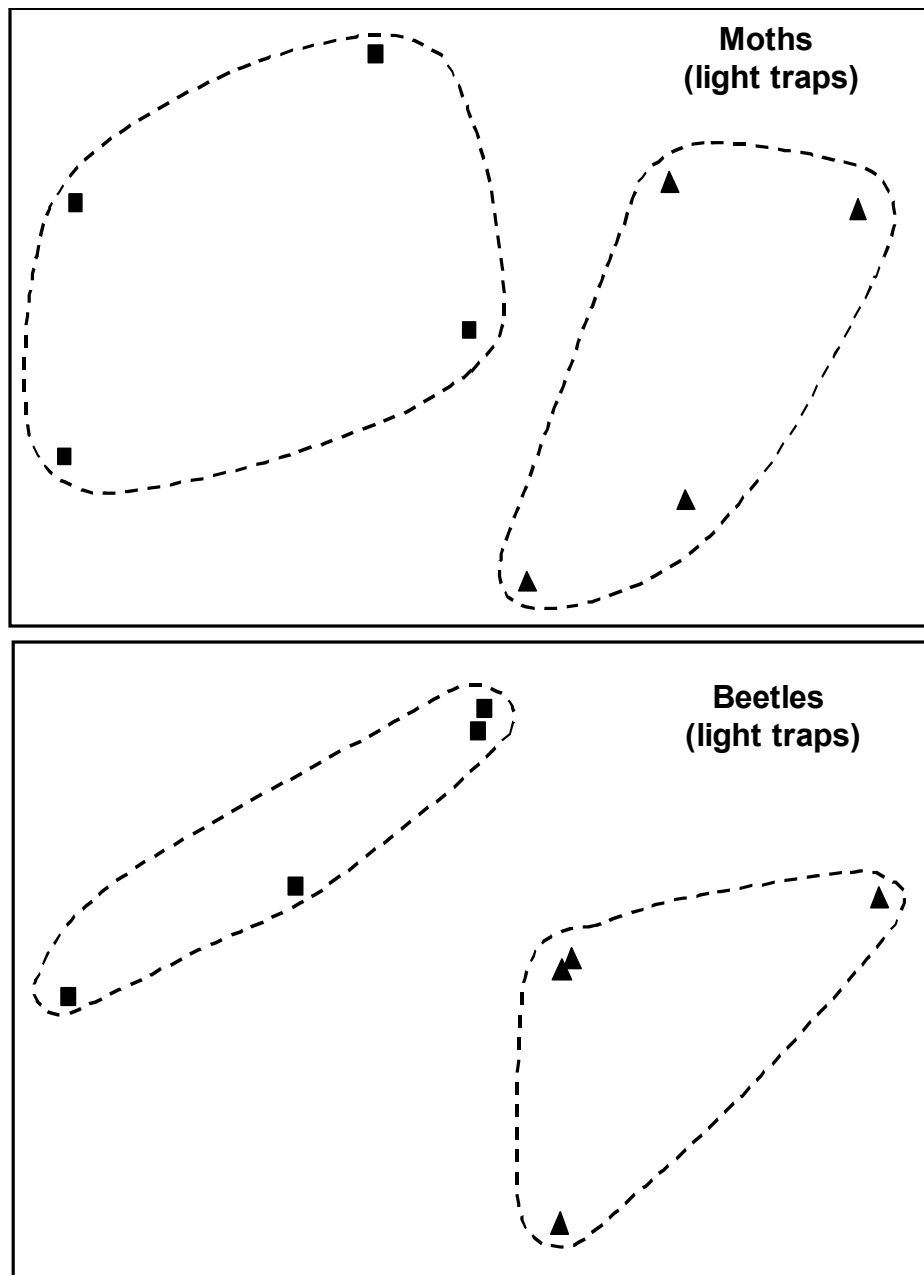


Figure 5.4: Ordination of insect communities in two dimensional similarity space, based on light trap collection of moths and beetles. Samples that are similar to each other in composition are near to each other in space. Mapping in similarity space is the result of non-metric multidimensional scaling (NMDS) analysis of Bray-Curtis similarity matrices based on the square-root transformed abundances of all species represented by more than one specimen (184 species for Lepidoptera, stress = 0.075; 69 species for Coleoptera, stress=0.045). Remnant sites (R) are represented by solid squares, plantations sites (Pri) are represented by solid triangles. Dotted lines are used only to visually associate groups of similar samples – they have no other analytical meaning.

5.3.2 Beetles – light trapped

Beetles were much more abundant in light traps in plantations (3519 individuals) than in remnant vegetation light traps (1501 individuals) (Fig 5.1). The domination of the samples by the five most abundant species was similar in the plantation and remnant samples (Figure 5.1). We identified 103 species of Coleoptera from light traps (Figure 5.2). The majority of species were found in remnant vegetation (73/103). More than half of the species found in plantations were also found in remnant vegetation (31/61) (Figure 5.2).

The beetle communities of remnant sites (R) were, on average, more similar to each other in composition and abundance of species than they were to their adjacent plantation sites (Pri) (Figure 5.4). In NMDS similarity space, two non-overlapping groups can be defined (Figure 5.4).

5.3.3 Beetles – canopy knockdown

We used insecticidal spray to sample the canopies of 26 *Eucalyptus marginata* trees in remnant sites and 53 *Eucalyptus globulus* trees in plantations over four survey trips. We collected 2270 beetles from remnant trees and 3990 from the plantation trees (appendix one). Much of this imbalance in numbers, however, was due to unequal sampling effort. After balancing samples so that the collecting effort was similar, beetles were slightly more abundant in the remnant canopy (R + Rpe) than in plantation trees (Pri + Pre) (Figure 5.1). The mean number of beetles collected per remnant tree was 87 ± 16 (1SE), and the mean per plantation tree was 75 ± 10 (1SE). The domination of the samples by the five most abundant species was greater in the plantation than in the remnant samples (Figure 5.1).

We compared the species richness in remnant (R + Rpe) and plantation (Pri + Pre) sites, after subsampling to ensure equal collecting effort. We identified 307 species of beetles from these canopy knockdown samples (Figure 5.2). The majority of species were found in remnant vegetation (194/307) (Figure 5.2). More than 60% of the species found in plantations were also found in remnant vegetation (69/113) (Figure 5.2).

The estimated species richness of canopy beetles was lowest for the interior plantation habitat (Pri, Pagi: Figure 5.5). The plantation edge sites (Pre, Prag) were richer than the interior (Figure 5.5). Species richness of the “Prag” site was only marginally less than for the remnant interior (R), such that the standard errors overlap (Figure 5.5). The habitat with the greatest estimated species richness of canopy beetles was the remnant edge (Rpe), which at 311 was about twice as rich as the plantation interior habitats (153, 158: Figure 5.5). Because we have pooled samples collected in the same habitat, but different sites, these estimates represent estimates of regional species richness rather than site species richness. Therefore some of the richness comes from differences between sites in species composition.

The emphasis of our sampling design was not to determine the canopy fauna in any one site, but rather to allow regional habitat comparisons – therefore we have replication in space, and habitat comparisons, at the cost of replication of sampling within any one site. To allow for comparison with the literature it is interesting, nevertheless, to examine some site-specific results. To examine the number of canopy beetles sampled in remnants we pooled the remnant interior tree samples (R) with the remnant edge samples from the same site (Rpe), for all survey trips. Counting this way we collected 126 species from Mt Barker East (7 trees), 111 species from Mt Barker West (7 trees), 90 species from Millbrook West (6 trees), and 87 species from Millbrook South (6 trees). In a recent study using a similar canopy knockdown technique on *Eucalyptus marginata*, and sampling 40 trees in Karragullen, Western Australia (10 trees at each of 4 surveys in one year), 99 beetle morphospecies were collected (Majer *et al.*, 2000; Recher *et al.*, 1996). Thus our study recorded canopy beetle faunas that ranged from 12 fewer species, to 27 more species than the Karragullen study, in spite of using about 1/6th the sampling intensity. This difference could be due to an inter-annual component of richness detected in our two year study, or a small scale spatial component of diversity contributed by our sampling of edge trees (Rpe). There could also be site characteristics

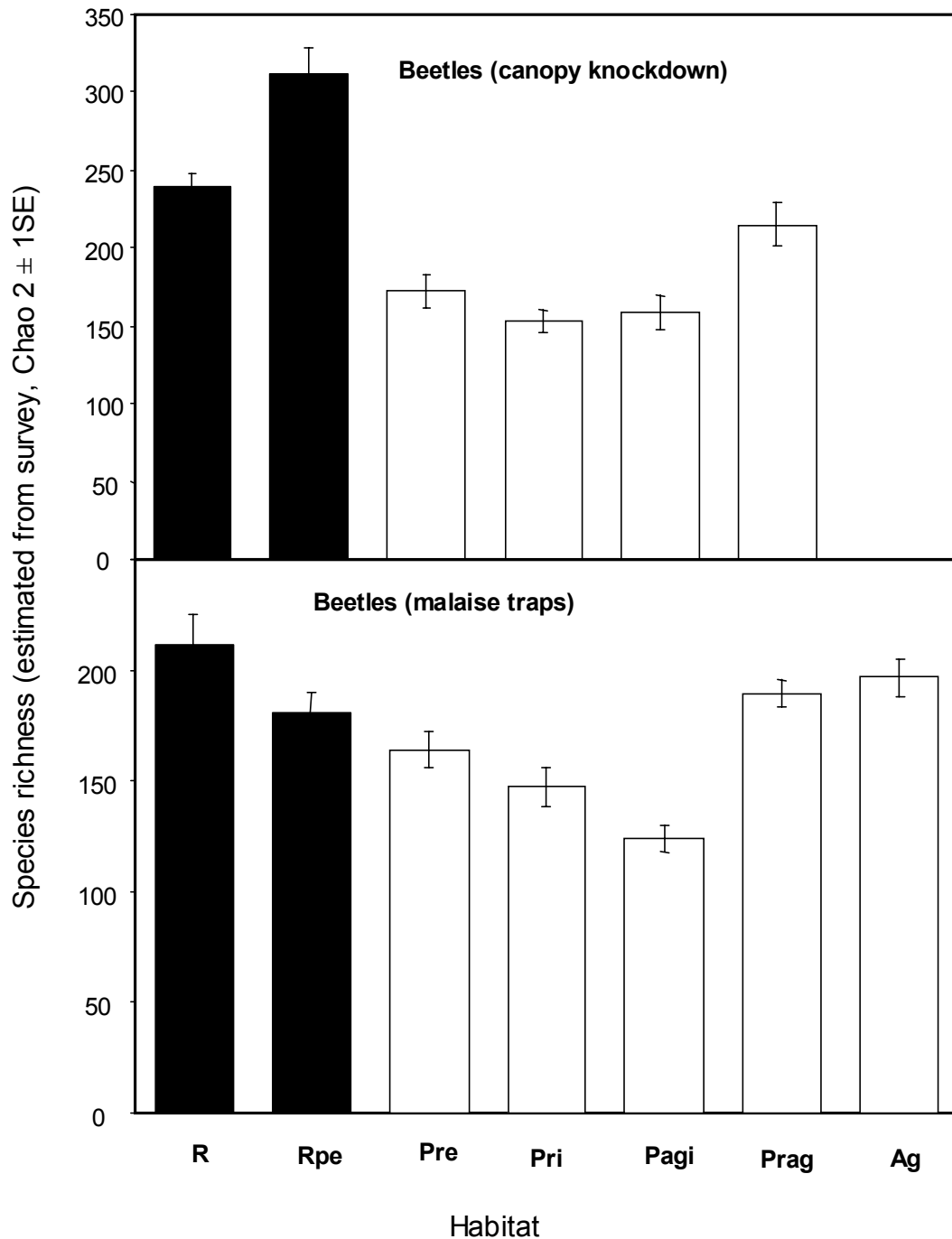


Figure 5.5: Species richness of beetles collected by canopy knockdown, and beetles collected by malaise traps in 7 different habitats. Canopy knockdown sampling effort for each habitat varies between 10 trees (Pagi) and 15 trees (Pri), based on collections from one tree at each of up to four sites for each of up to 4 survey visits. Malaise trapping sampling effort for each habitat varies between 12 collections (Rpe) and 16 collections (R, Pre, Pri, Page, Ag), based on one week of malaise trapping at each of up to four sites for each of up to 4 survey visits. Species richness numbers are estimated from the sample data using the Chao2 index (Colwell & Coddington, 1994). The variance around these estimates is represented by the error bars (± 1 SE). The complete list of beetles collected appears in appendix one.

that make Karragullen relatively species poor. Some differences in species richness could be due to differences in method – for example some beetle morphospecies could have included multiple species that are recognised and separated by beetle taxonomists, and therefore counted in our study.

All of the remnant tree canopy beetle samples (R, Rpe) grouped in a separate area of similarity space from the plantation samples (Figure 5.6), indicating that, on average, they were more like one another in species abundance and composition, and relatively different to the plantation samples. There was no separation between “R” and “Rpe” sites, and no apparent tendency for pairing in space between a given “R” sample, and its geographically nearest “Rpe”. Within the plantation samples two relatively clustered, but overlapping, groups of similar samples can be defined: the “Pri” and “Pre” groups. The remaining samples (Pagi and Prag) are relatively scattered, but are some distance in similarity space away from the remnant samples (Figure 5.6).

Predators were more abundant in remnants (124/1240, 10%) than in plantation samples (zero in top ten: Table 5.4). Leaf-feeding beetles were among the most abundant collected by canopy knockdown (Table 5.4). Leaf-feeding beetles in the top ten for plantation samples account for 79% of all specimens (2399/3054), compared to only 48% for the remnant tree samples (595/1240). The single most abundant beetle in remnants and plantations was the leaf feeding weevil, *Gonipterus scutellatus*. In addition to the abundant adult specimens, in Spring of 2000 we collected approximately 4030 weevil larvae which, given their form and abundance, are likely to also be mostly *Gonipterus scutellatus*. They were so abundant in the plantation that the mean number per sample (estimated from weight) was around 200 for “Pre”, “Pri” and “Prage”, and nearly 600 for “Pragi” (due to one sample with 1337 larvae: Figure 5.7).

Considering both the adult and larval specimens, it is clear that *Gonipterus scutellatus* forms a very large population, particularly in plantations. Plantation managers sometimes spray plantations to control this species (Andrew Loch, pers comm.). The same species is known as a plantation pest in other parts of the world where *Eucalyptus* is grown.

5.3.4 Beetles – malaise trapped

We collected 1797 beetles in malaise traps in plantations, 814 in remnant vegetation and 363 in agricultural pastures (appendix one). Much of this imbalance in numbers, however, was due to unequal sampling effort. After balancing samples so that the collecting effort was similar, beetles were slightly more abundant in malaise traps in plantations (Pri + Pre) than in remnant vegetation traps (R + Rpe) (Figure 5.1). The domination of the samples by the five most abundant species was similar in the plantation and remnant samples (Figure 5.1). Abundance data from pasture samples (Ag) was not graphed because it has half the number of samples collected as remnant vegetation. However, the abundance of beetles per trap was similar to that from the other habitats.

We compared the species richness in remnant (R + Rpe) and plantation (Pri + Pre) sites, after sub-sampling to ensure equal collecting effort. We identified 185 species of Coleoptera from these malaise samples (Figure 5.2). The majority of species were found in remnant vegetation (141/185). More than half of the species found in plantations were also found in remnant vegetation (62/106: Figure 5.2). We also examined the three-way overlap between remnant vegetation (R only), plantation vegetation (Pri only) and pasture vegetation (Ag), considering equal collecting effort (Figure 5.8). The richest habitat was pasture (105 species), then remnant vegetation (84 species: Figure 5.8). The least species rich was the plantation sample (71 species: Figure 5.8). Remnant vegetation had a similar overlap in species composition with plantation and pasture. The plantation samples shared more species with pasture (37/71) than with remnant vegetation (29/71: Figure 5.8).

Table 5.4: The identity and biology of the ten most abundant beetles species collected by canopy knockdown, comparing remnant and plantation samples. The complete list of beetles collected appears in appendix one.

Species	Abundance in plantation samples	Biology
<i>Gonipterus scutellatus</i>	1215	Leaf feeder, introduced to WA from east coast
<i>Edusella</i> sp 1	635	Leaf feeder
<i>Litochrus</i> sp 1	315	Fungus feeder
<i>Anisomeristes</i> sp 1	258	Fungus feeder
<i>Chrysophtharta variicollis</i>	256	Leaf feeder
<i>Terillus suturalis</i>	107	Leaf feeder
Aleocharine, unknown sp 5	82	Unknown biology
Oxyops c.f. pictipennis	78	Eucalypt leaf feeder
Chrysophtharta nobilitata	56	Leaf feeder
Polyphrades aesolon	52	Generalist leaf and shoot feeders
Species	Abundance in remnant samples	Biology
<i>Gonipterus scutellatus</i>	389	Leaf feeder, introduced to WA from east coast
<i>Ancyttalia</i> sp. 2	267	Little known, but may breed in <i>Eucalyptus</i> flowers or buds
<i>Livolia</i> sp 1	149	Leaf feeder
<i>Emplesis</i> sp.4	74	Little known, but may breed in <i>Eucalyptus</i> flowers or buds
<i>Rhyzobius</i> sp 1	71	Scale predator
<i>Emplesis</i> unsorted	67	Little known, but may breed in <i>Eucalyptus</i> flowers or buds
<i>Scymnus</i> sp 2	64	Scale predator
<i>Rhyzobius</i> sp 2	60	Scale predator
<i>Pascoellus</i> sp.	57	Leaf feeder
<i>Emplesis</i> sp.1	42	Little known, but may breed in <i>Eucalyptus</i> flowers or buds

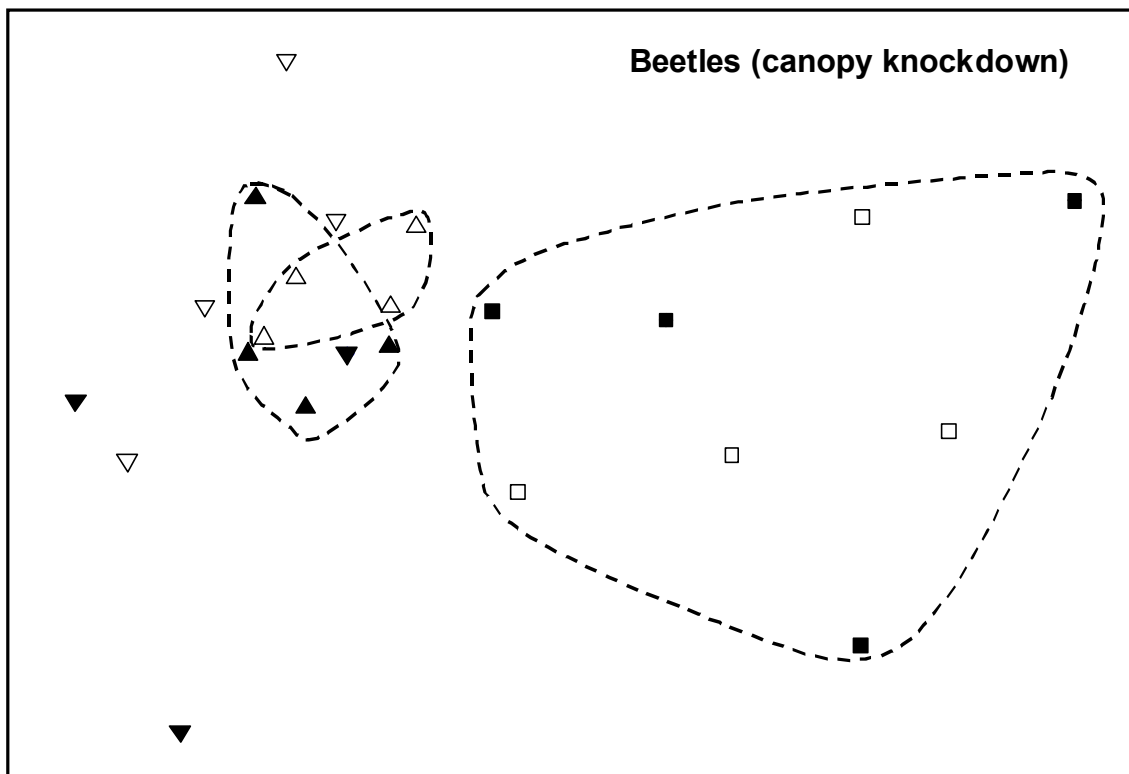


Figure 5.6: Ordination in similarity space of beetle communities collected by insecticidal knockdown from tree canopies. Samples that are similar to each other in composition are near each other in space. Mapping in similarity space is the result of non-metric multidimensional scaling (NMDS) analysis of Bray-Curtis similarity matrices based on the square-root transformed abundances of all species represented by more than one specimen (195 species, stress=0.177). Dotted lines are used only to visually associate groups of similar samples – they have no other analytical meaning.

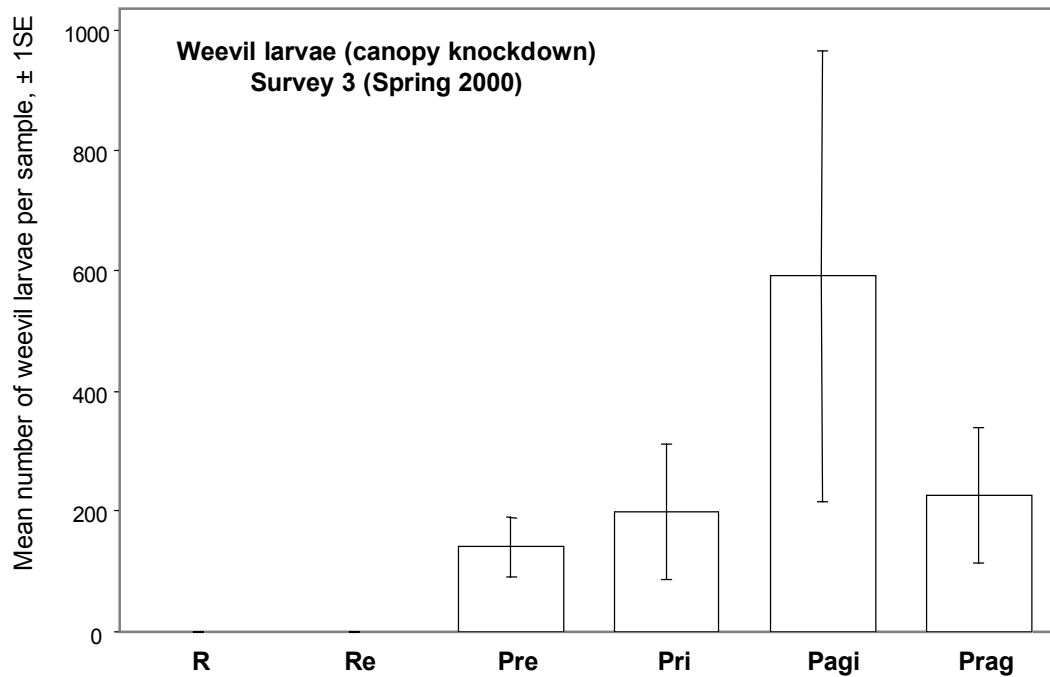


Figure 5.7: The mean number of weevil larvae per sample (± 1 SE) collected by insecticidal knockdown from the canopy in six habitats (for habitat legend, see Table 5.1). Samples from remnant vegetation are represented by a solid black column. Samples from *Eucalyptus globulus* plantations are represented by stippled columns. These data relate to only one collecting survey, in Spring of 2000. On other surveys the larvae were relatively uncommon.

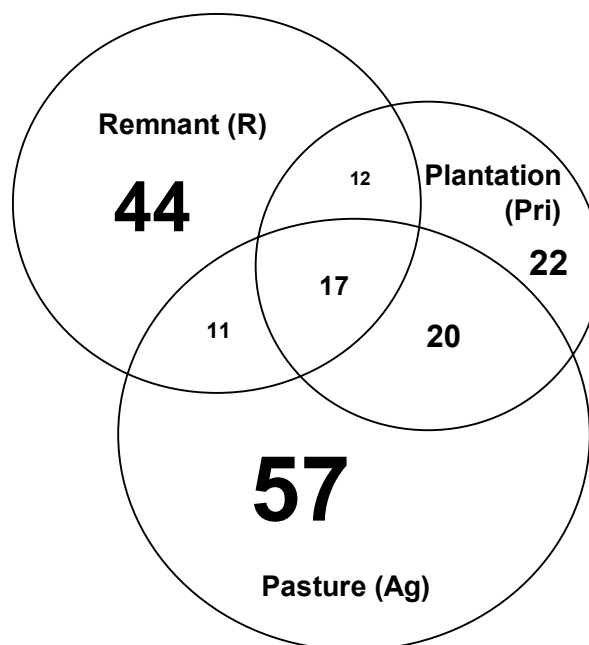


Figure 5.8: A comparison of the species richness in remnant vegetation, *Eucalyptus globulus* plantations, and agricultural pasture, for malaise-collected beetles. Overlapping areas of the circles represent the fauna shared by those two or three habitats. The numbers represent the number of species in each part of the fauna. We sub-sampled our data to ensure that the sampling effort was equal in the three habitat types: remnant sites include “R” only, plantation sites include “Pri” only.

The estimated species richness of malaise-collected beetles was lowest for the interior plantation habitats (Pri, Pagi: Figure 5.5). The plantation edge habitat (Rpe, Prag) was richer than the interior (Figure 5.5). Species richness of the Prag site was greater than for the remnant edge (Rpe), although the standard errors overlap (Figure 5.5). The pasture habitat also had a relatively high species richness of malaise-collected beetles (Figure 5.5). The habitat with the greatest estimated species richness of malaise-collected beetles was the remnant interior (R) (Figure 5.5).

All of the remnant habitat malaise-collected beetle samples (R, Rpe) grouped in a separate area of similarity space from the plantation samples (Figure 5.9), indicating that, on average, they were more like one another in species abundance and composition, and relatively different to the plantation samples. There was a clustering of R samples within this, such that they were more like one another than the Rpe sites (Figure 5.9). The agricultural habitat samples (Ag) were also grouped in similarity space, such that they were most dissimilar to remnant samples, and more similar to the plantation samples (Figure 5.9). The plantation habitat samples (Pre, Pri, Prage, Pagi) are scattered such that there is no apparent grouping of the different habitat samples in similarity space (Figure 5.9).

Leaf feeding beetles were less abundant in the malaise samples than in the canopy knockdown samples (Table 5.5). Because the malaise samples are not as greatly dominated by a few abundant species (Figure 5.1), it is difficult to extrapolate from the biology of the abundant species, to the likely composition by feeding group of the whole sample. If we focus on the composition by feeding group of the abundant beetles only, then the plantation samples have a greater percentage of leaf feeding beetles (23.5%, 195/831) than the remnant (17.4%, 85/489) or pasture samples (15.2%, 25/164). Unfortunately, nothing is known about the diet of the single most abundant species from plantation malaise samples, which was therefore excluded from the calculated proportions. If this species proved to be a leaf feeder, the percentage would increase to 40%. Predators were more abundant in the top ten species in plantation (197/831, 23.7%) than in remnant samples (15/489, 3.1%) (Table 5.5).

Table 5.5: The identity and biology of the ten most abundant beetles species collected by malaise trap, comparing remnant, plantation and pasture samples. The complete list of beetles collected appears in appendix one.

Species	Abundance in remnants	Abundance in plantation	Abundance in pasture	Biology
<i>Ancyrtalia</i> sp. 2	31			Little known, but may breed in <i>Eucalyptus</i> flowers or buds
<i>Anisomeristes</i> sp 1			11	Fungus feeder
<i>Aplopsis</i> sp nov nr <i>punctulata</i>		51		Flower/pollen feeder
<i>Carphurus</i> sp 1			24	Flower associate
Colymbomorpha lineata		136	21	Unknown
<i>Conoderus</i> sp 4			12	Unknown
<i>Corticicara</i> sp 2		58		Fungus feeder
<i>Corticicara</i> sp 3		55	24	Fungus feeder
<i>Corticicara</i> sp 4			10	Fungus feeder
Cryptophagine, unknown sp 1	124			Fungus feeder
<i>Dasytes</i> sp 1	48			Flower associate
<i>Edusella</i> sp 1		147		Leaf feeder
<i>Edusella</i> sp 1			14	Leaf feeder
<i>Helcogaster parallelus</i>	42			Flower associate
<i>Heteromastix</i> sp 2	58	54		Flower associate
Heteronyx costulatus			11	Leaf feeder
<i>Heteronyx</i> sp 4		48		Leaf feeder
<i>Leptacinus</i> sp 1		116		Predator
<i>Livolia</i> sp 1	64			Leaf feeder
<i>Livolia</i> sp 2	21			Leaf feeder
<i>Mordella</i> sp 1	62			Flower associate
<i>Nargomorphus</i> sp 1		85		Fungus feeder
Sarothrocrepis benefica	15	81	16	Predator
<i>Sarothrocrepis</i> sp 1			21	Predator
<i>Trogoderma</i> sp 1	24			Little known, but not a leaf feeder

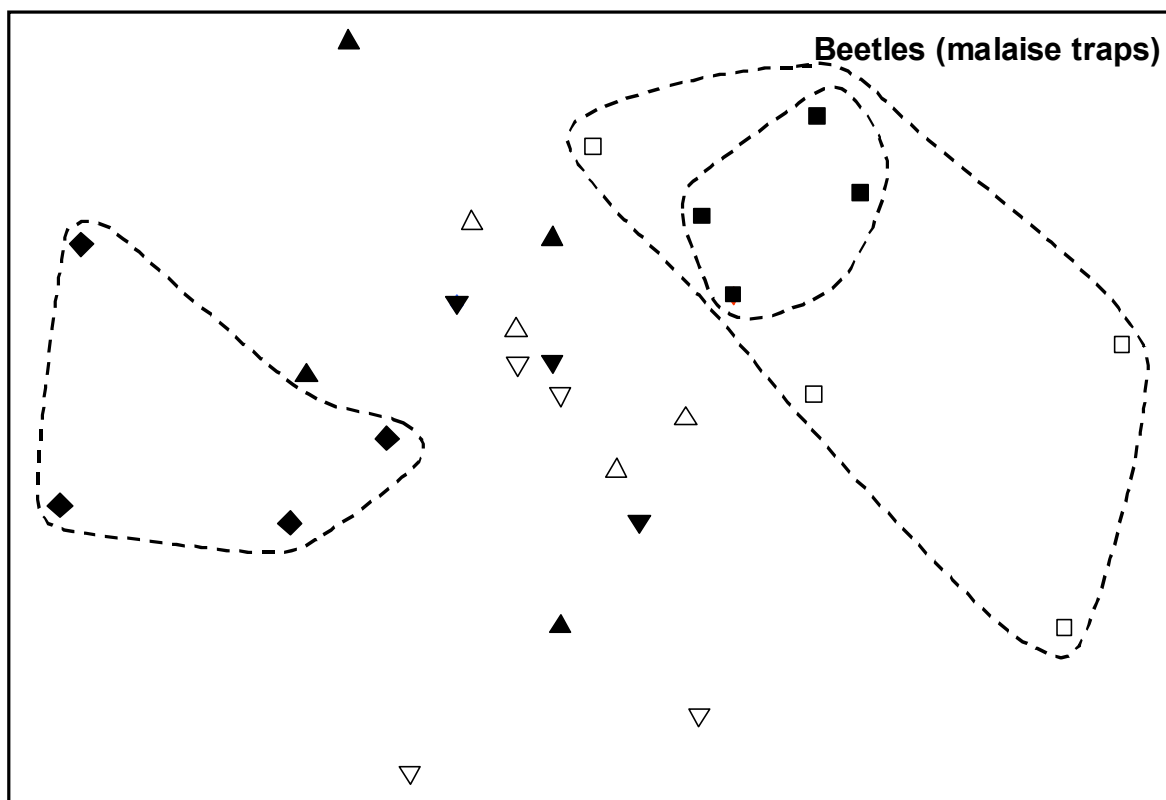


Figure 5.9: Ordination in similarity space of beetle communities collected by malaise trap. Samples that are similar to each other in composition are near to each other in space. Mapping in similarity space is the result of non-metric multidimensional scaling (NMDS) analysis of Bray-Curtis similarity matrices based on the square-root transformed abundances of all species represented by more than one specimen (159 species, stress=0.238). Dotted lines are used only to visually associate groups of similar samples – they have no other analytical meaning.

5.3.5 Hymenoptera

We collected 8162 individuals of Hymenoptera that could be identified into six major taxonomic groups: The most abundant were the ants (3486), Ichneumonid wasps (2146) and Braconid wasps (1304). The less abundant groups were Bethyid wasps (709), Evanoid wasps (277) and bees (240).

Ants were more abundant in the remnant and agricultural habitat than in plantations (Figure 5.10). Bees were more abundant in remnant habitat than in plantations or remnants (U-test: R & Re vs Pre & Pri, N=27 samples (balanced), U=141.5, $P<0.001$) (Figure 10). The pattern for Evanoid wasps was similar (U-test: R & Re vs Pre & Pri, N=27 samples (balanced), U=206, $P=0.005$) (Figure 5.10). Bethyid wasps were more abundant in plantation habitat than in remnant or agricultural habitat (Figure 10), but there was considerable variation among samples and consequently no statistically significant contrasts. Braconid wasps were least abundant in interior sites (U-test: Pre & Prag vs Pri & Pagi, N=28 samples (balanced), U=213.5, $P=0.003$) (Figure 5.10). Ichneumonid wasps were similarly abundant in all habitats (Figure 5.4).

The remnant samples (R, Rpe) grouped in their own area of similarity space, overlapping with only one Ag and one Prag sample (Figure 5.11), indicating that, on average, they were more like one another in species abundance and composition, and relatively different to the plantation and agricultural land samples. There was also some separation between R and Rpe samples. Among the plantation samples there were three clusters in similarity space with little overlap: Pri, Pre and Pagi. These clusters were close to one another, and the Pre cluster sat between Pre and Rpe, suggesting that its composition was intermediate between the two (Figure 5.11). The remaining samples (Ag, Prage) showed no clustering in similarity space (Figure 5.11).

5.3.6 Invertebrates in pitfall traps

There were no consistent differences between habitats in the number of ants or spiders trapped in pitfall traps. There was, however, a difference in the abundance of beetles caught in pitfall traps. Beetles were greatly more abundant in pitfalls in pasture sites (Ag) than in any of the forested sites (Figure 5.12). There were also more abundant in the plantations sites than in the remnant habitat (Figure 5.12: note that Re habitat was not sampled by pitfall traps).

5.3.7 Spiders and hemiptera from canopy knockdown

Spiders and herbivorous hemiptera were relatively abundant in canopy knockdown samples. There were, however, no consistent patterns in their abundance, and relatively large variance among samples (Figure 5.13).

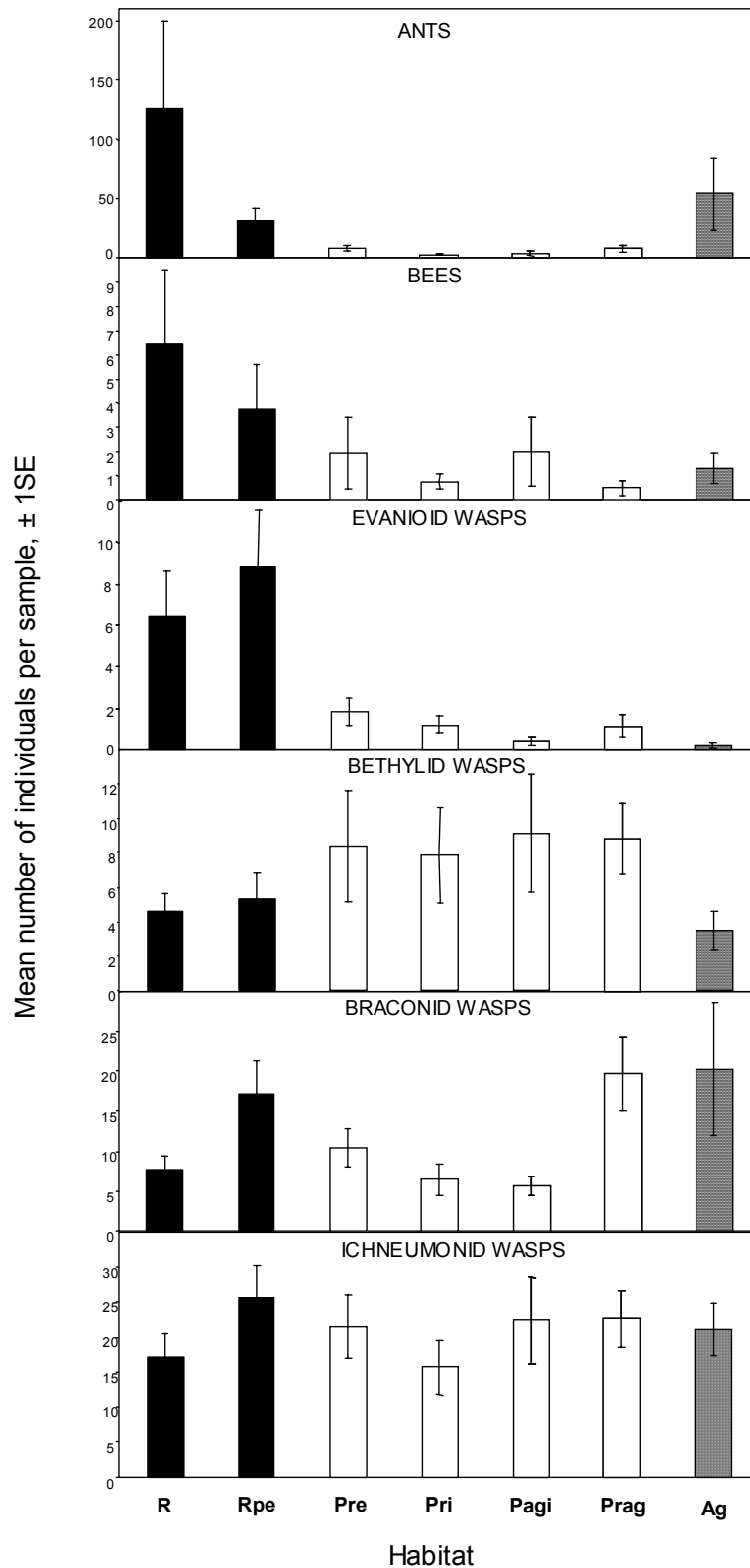


Figure 5.10: The mean number of individuals per sample (± 1 SE) for 6 major Hymenopteran groups in seven habitats (for habitat legend, see Table 5.1) collected using malaise traps. Samples from remnant vegetation are represented by solid black columns. Samples from *Eucalyptus globulus* plantations are represented by stippled columns, and samples from agricultural land are represented by the cross hatched column. For each habitat there were 4 replicate sites (except I, which has 3) and samples collected on four different collecting trips (except Rpe, which has only 3). Thus there were 12 to 16 samples per habitat.

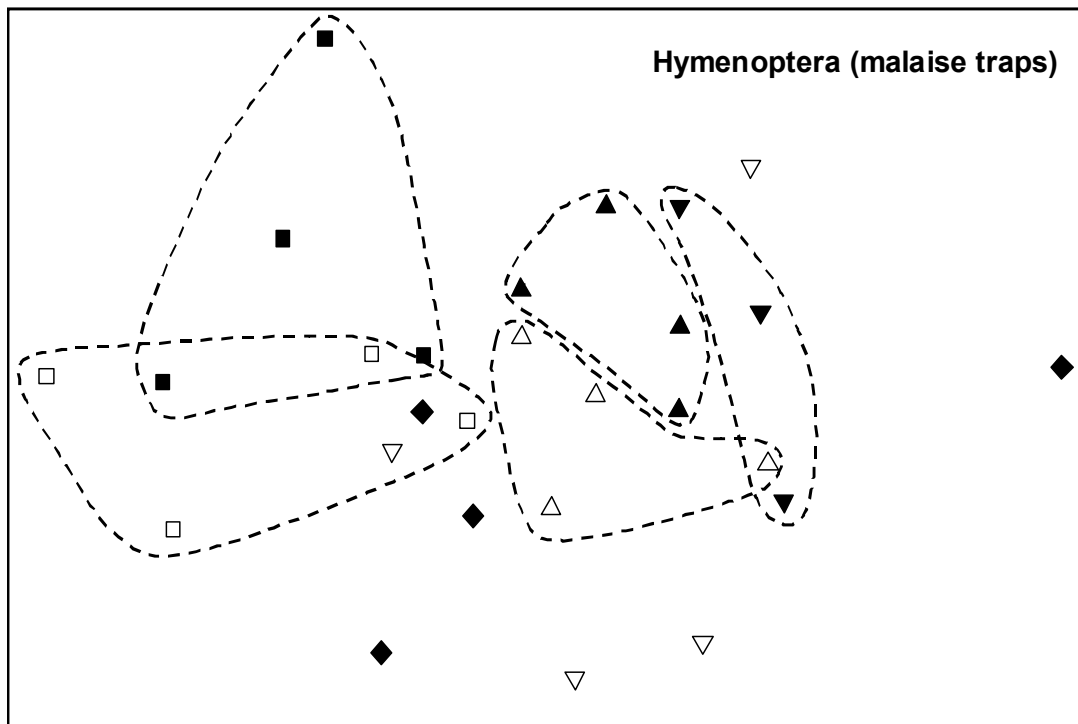


Figure 5.11: Grouping of Hymenoptera communities in similarity space, based on malaise trap collections. Samples that are similar to each other in composition are near to each other in space. Mapping in similarity space is the result of non-metric multidimensional scaling (NMDS) analysis of Bray-Curtis similarity matrices based on the square-root transformed abundances of all the 6 main groups (Fig 5.3) (stress = 0.201). Dotted lines are used only to visually associate groups of similar samples – they have no other analytical meaning.

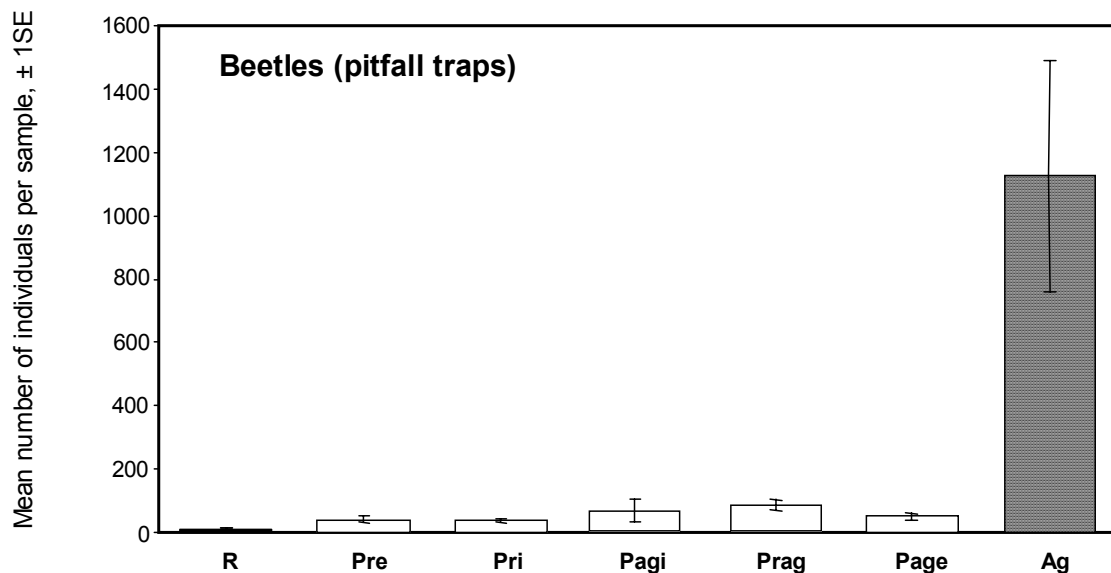


Figure 5.12: The mean number of individuals per sample (± 1 SE) for pitfall trap collected beetles in seven habitats (for habitat legend, see Table 5.1). Samples from remnant vegetation are represented by a solid black column. Samples from *Eucalyptus globulus* plantations are represented by stippled columns, and the sample from agricultural land are represented by the cross hatched column. For each habitat there were 4 replicate sites and samples collected on four different collecting trips.

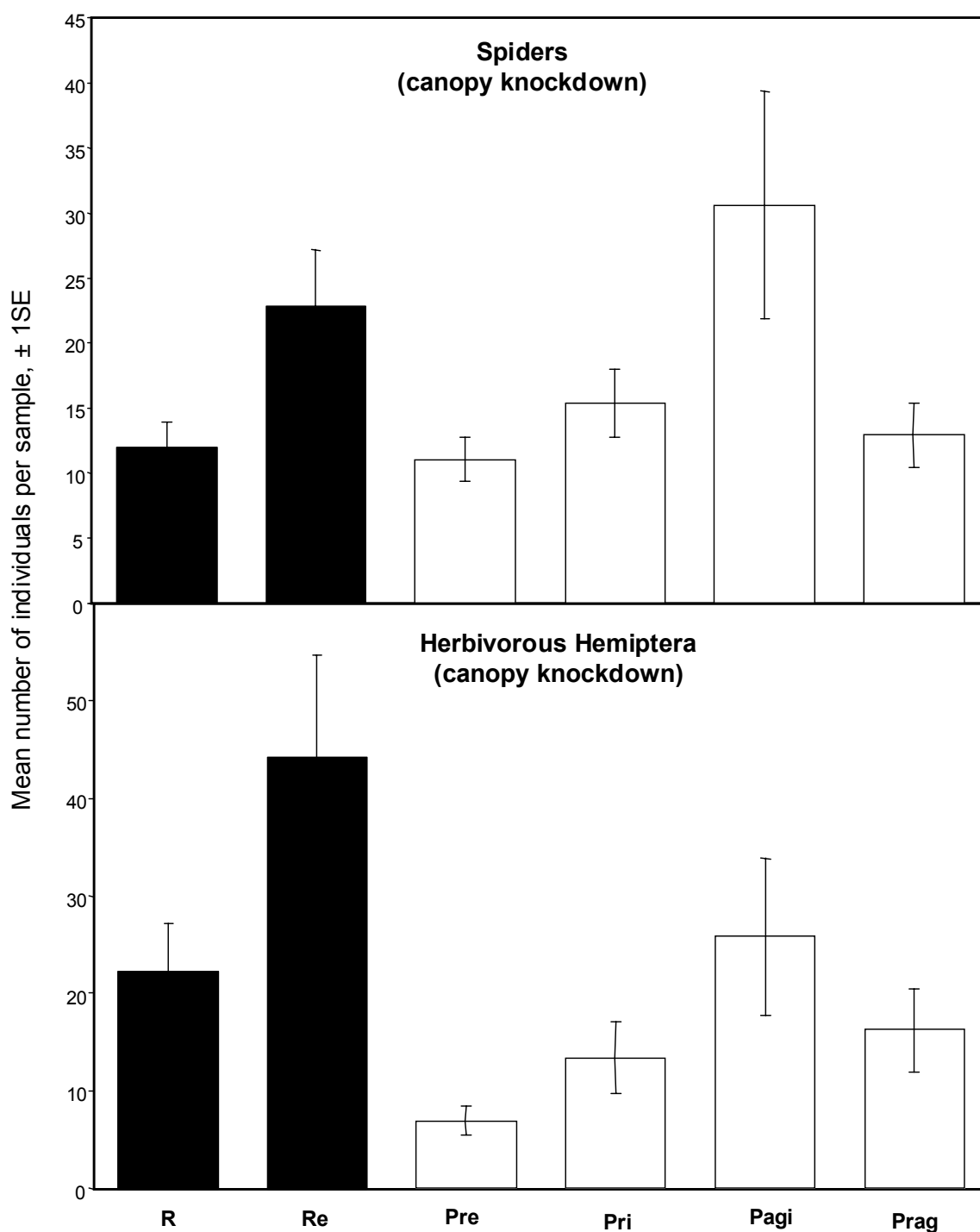


Figure 5.13: The mean number of individuals per sample (± 1 SE) for spiders and herbivorous hemiptera, collected by insecticidal knockdown from the canopy in six habitats (for habitat legend, see Table 5.1). Samples from remnant vegetation are represented by a solid black column. Samples from *Eucalyptus globulus* plantations are represented by stippled columns. Canopy knockdown sampling effort for each habitat varies between 10 trees (Pagi) and 15 trees (Pri), based on collections from one tree at each of up to four sites for each of up to 4 survey visits.

5.4 Discussion

5.4.1 What is the faunal use of plantations in comparison with adjacent remnant vegetation and with open pasture?

The fauna of remnant forest was richer in species than the fauna of the plantation forests. This was most striking in the results from the two richest collecting techniques: moths from light traps and beetles from canopy samples. Not only did the remnant forest have a richer fauna, but many of the species found in plantation forests were shared with remnant forests, such that the plantation forest fauna could be described as a depauperate sample of the richer remnant fauna. There was, nevertheless, a group of species collected only from plantations. These species may represent species that are plantation specialists, which are truly absent from the remnant forest, or they may be species that occur in both kinds of forest that are more easily found in plantations because their populations are greater there. There is good evidence from this study and others that the plantation environment favours certain species. For example, *Gonipterus scutellatus*, *Oxyops c.f. pictipennis* (beetles) and *Mnesampela privata* (moth) are species that are known as *Eucalyptus* plantation pests elsewhere. In this study we have also shown that, compared to the remnant forest fauna, the plantation fauna is relatively more dominated by a few abundant species (Figure 5.1).

One of the most abundant species collected in this study was *Gonipterus scutellatus*. This beetle, from the weevil family, was very abundant as an adult in the *Eucalyptus* canopy. The abundant weevil larvae found in our third survey trip (Figure 5.7) were most likely also of this species. Although this species was most abundant in plantation samples, it was also an abundant species in remnant forest. This pattern is particularly interesting in light of the possibility that this species did not originally occur in Western Australia. *Gonipterus scutellatus* is wide-spread in southeast Australia but there are no early records of it occurring in Western Australia. *Gonipterus scutellatus* has been accidentally introduced to New Zealand, Africa, South America and southern Europe and become a major pest of eucalypt plantations in all these areas. There are no other species of *Gonipterus* known from WA, except an old description (1897) of *Gonipterus citrophagus* from 'Swan River' (recorded as damaging citrus trees). It appears that this species may be the same as *Gonipterus scutellatus*, but proper study is required to confirm this. We suggest that *Gonipterus scutellatus* may have established in Western Australia with the expansion of *Eucalyptus* plantation forestry, and since moved into the remnant forest from the plantations. It is uncertain if the populations in remnant forests are self-sustaining, or if they are effectively overflow from the plantations. Regardless, they are now abundant in the remnants. The spread of a plantation pest species into native forest is an issue of significant conservation concern, and might have been facilitated by the placement of plantation forestry adjacent to remnant forest (Strauss, 2001).

For the Hymenoptera we cannot compare levels of species diversity, but in terms of abundance the remnant samples were different to plantation samples in having more ants, bees and Evanioid wasps, and fewer Bethyloid wasps.

The pasture fauna was, of course, different to the forest samples because there was no canopy to sample. Because it was structurally more simple than forest, it would be expected to harbour less species diversity. We can, however, compare the samples of flying insects caught by malaise trap. Considering beetles only, the pasture was more species rich than remnant forest or plantation (Figure 5.8). Although most of these species were known from pasture only, there was considerable overlap with the plantation fauna. The pitfall traps showed a greater abundance of beetles in pasture compared to all other habitats (Figure 5.12). Although we have not identified the species collected in pitfall traps, it is likely that the pasture samples are dominated by abundant pasture specialists, such as grass-feeding scarab beetles.

Among the Hymenoptera, the pasture samples (Ag) were comparable to plantation samples except with regards Ants (which were more common in pasture) and Evanioid wasps (which were uncommon in pasture) (Figure 5.10).

These differences in species composition and abundance mean that in general remnant, plantation and pasture samples were grouped in distinct areas of similarity space, indicating that samples from the different habitats were usually more similar in composition to other samples from the same habitat, than they were to samples from other habitats (Figures 5.4, 5.6, 5.9, 5.11).

5.4.2 Do fauna use edges more than interiors?

Among the canopy-collected and malaise collected beetle samples there was evidence for greater faunal use of edge habitats. Species richness was greater in the plantation edge sites compared to plantation interior sites (Pre, Prag > Pri, Pagi: Figure 5.5). This difference was greatest when comparing the edge to agriculture (Prag) to interior sites (Pri, Pagi), such that non-overlapping error bars suggest significant differences. The contrast between the edge to remnant forest (Pre) and interior sites (Pri, Pagi) is less, and overlapping error bars suggest this difference is not significant. The greater edge effect at an agricultural edge than at an edge to remnant forest is likely to be due to the greater light exposure at the agricultural edge causing a greater contrast in environments. Some insects are more active in sunny or warm environments and some are known to favour the more vigorous plants found growing in high light (Cromartie, 1975; Moore *et al.*, 1988). In their study of carabid beetles and spiders, Beford and Usher also detected greater species richness at the margin between forest and farm (Bedford & Usher, 1994)

Comparing the remnant edge to the remnant interior (Rpe versus R) there was greater species richness at the edge for canopy beetles (non-overlapping error bars indicate significant difference: Figure 5.5) but lower species richness for malaise-collected beetles (overlapping error bars suggest no significant difference: Figure 5.5).

Considering the abundance of Hymenoptera, there were no apparent edge effects (Figure 5.10), although the edge sites do separate from the interior sites in similarity space (Pre vs Pri, Rpe vs R) indicating that the communities are different in their composition of the six hymenopteran groups (Figure 5.11).

5.4.3 Does adjacency to remnant vegetation increase plantation use, or alter the species compliment?

We addressed this question by comparing the fauna of the adjacent plantation interior habitat (Pri) to the fauna of isolated plantation interior habitat (Pagi). We found little evidence in the invertebrate data that would indicate a consistent effect of adjacency to remnant forest on the fauna of plantations.

The canopy beetle fauna is similar in species richness in the adjacent plantation (Pri) and isolated plantation (Pagi) habitat (Figure 5.5). The abundance of the different Hymenopteran groups is similar comparing in the adjacent plantation (Pri) and isolated plantation (Pagi) habitats (Figure 5.10), although there was some separation of these samples in similarity space (Figure 5.11) suggesting some differences in species composition. For the malaise-trapped beetles there was marginally greater species richness in the adjacent plantation (Pri) than in the isolated plantation habitat (Pagi), with non overlapping error bars suggesting this difference was significant. In contrast, the isolated plantation habitat (Pagi) hosted a greater abundance of spiders and hemiptera in the canopy than the adjacent plantation (Pri: Figure 5.13).

5.4.4 Do plantations have a similar profile of functional groups?

Among the canopy-collected beetles, leaf feeders appear to constitute a greater proportion of the total beetle population in plantations (79%) than in remnant forests (48%) (Table 5.4). The same was true for light-trapped moths (Table 5.3) and malaise-collected beetles (Table 5.5), although the difference was smaller (13.1% vs. 8.3%, and 23.5% vs 17.4%). This is consistent with the resource concentration hypothesis (Kareiva, 1983) that predicts greater populations of herbivores in monocultures (such as the plantation) where there is great availability of one appropriate host (i.e. *Eucalyptus globulus*) compared to polycultures (such as the remnant vegetation) where the any given host (e.g. *E. marginata*) is less dense. It is important to note that the plantations are managed by aerial spraying with insecticide, and one would expect the populations of pestiferous leaf feeders to be even greater in the absence of this form of management. Because we were unable to prevent aerial spraying during the course of this research project, we cannot know how abundant leaf feeding insects would become in plantations in the absence of this control.

Predators and parasitoids (natural enemies) may contribute to the control of populations of abundant insects, such as the leaf feeders. It is difficult to predict, however, whether plantations would be more or less conducive to developing large populations of natural enemies. In some other studies their numbers were found to be limited in simplified environments, such as a plantation, because of the reduced availability of alternative diet items (e.g. nectar) (Risch *et al.*, 1983; Andow & Risch, 1985; Andow, 1991; Tonhasca & Byrne, 1994). They might also be reduced in number by the application of broad-spectrum insecticides. If, however, the plantation is host to large populations of potential prey, such as we know to be the case in this instance, these host populations might allow the natural enemy populations to build up.

Among our malaise-collected beetles, predators were more abundant in the top ten species in plantation (197/831, 23.7%) than in remnant samples (15/489, 3.1%: Table 5.5). In contrast, among canopy-collected beetles predators were more abundant in the top ten species in remnants (124/1240, 10%) than in plantation samples (zero: Table 5.4).

Among the parasitoids wasps, the Braconids and Ichneuemonids were similarly abundant in remnant and plantation sites (Figure 5.10): these wasp families include species that are parasitoids on a very wider range of insect hosts. Bethyloid wasps were marginally more abundant in plantation sites: this family includes parasitoids of beetles and lepidoptera (Naumann, 1991), and may benefit from the abundance of moth and beetle leaf-feeders. Evanoid wasps were significantly more common in remnant vegetation than in the plantations: this family includes parasitoids of cockroaches, wasps, bees, and wood-boring beetles (Naumann, 1991) and might therefore benefit from the greater habitat complexity in remnant forest.

Within each of these parasitoid groups there are many different species that vary in their biology. Some may be generalists, and other specialists. Some may be known parasitoids of important pest species, while others may specialise on insects of little interest to plantation managers (such as cockroach parasitoids). Without further sorting and identifying these hymenopteran species it is not possible to adequately compare the fauna of natural enemies in remnants and plantations. There are also many other important groups of natural enemies, such as in the Diptera, for which we have no data.

Based on the information we do have on natural enemies, it appears there has not been a general increase in natural enemies in plantations compared to remnants such as would be necessary to control populations of abundant leaf feeders. The natural enemy populations might be limited by other food or habitat resources in the simplified plantation environment, or might be depressed by the application of insecticides.

Chapter 6.

Implications and recommendations

6.1 Vertebrate fauna

The detailed studies presented here relate directly only to plantations in the southwestern part of the country. Similar detailed studies are needed in plantations in eastern Australia before the findings can be extrapolated with any degree of confidence. Having said that, the findings do provide useful insights into the role of plantations in habitat or resource provision for a range of vertebrate and invertebrate species, and constitutes one of the few detailed case studies in Australia with such information.

The project was framed to address a perception that, although commercially driven, plantation forests may provide environmental benefits without compromising commercial attractiveness thereby also providing an opportunity to redress biodiversity decline and land degradation problems. The role and contribution that farm forestry can make to reversing the decline of native biota in our agricultural areas has hitherto been largely unknown and unstudied. In a review of studies on the use of revegetated areas by vertebrate fauna in Australia, Ryan (2000) found that revegetated sites provide habitat for a wide range of bird species, but the majority were common species capable of exploiting a range of natural and disturbed habitats. The important point was that few species with specialized habitat requirements were recorded utilizing revegetated areas (Ryan, 2000). Similarly, recent studies by Barrett and Davidson (2000) and Barrett (2000) found that areas revegetated for landcare purposes provided some value in terms of habitat for some bird species, including some of conservation concern. Our study indicates that the same is true for plantations developed purely for commercial use. While faunal use was certainly less overall than in the remnant vegetation areas, the plantations were used by a subset of the fauna, mostly, but not exclusively those that are generalists.

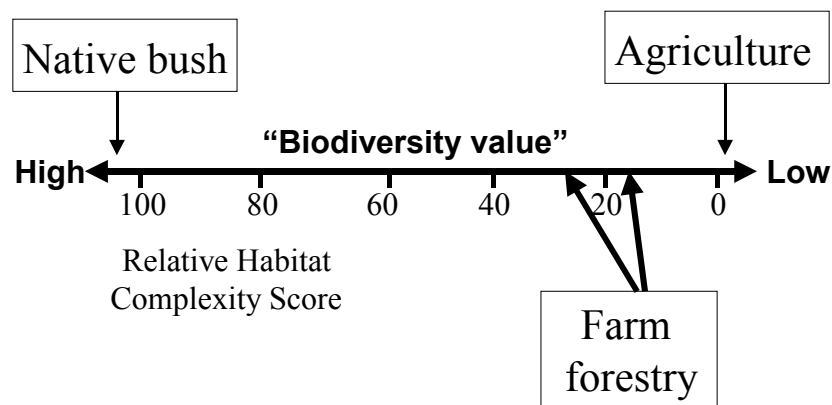


Figure 6.1 The relative biodiversity value of the farm forestry plantations studied in this report can be depicted by considering the relative habitat complexity scores derived in Chapter 3. If agricultural land is given the lowest score (0) and native vegetation in good condition the highest score (100), then the plantations studied here score between 15 and 25%.

Plantations as they are currently managed deliver a biodiversity benefit which represents a 15-25% improvement over agricultural land (Fig 6.1). While this represents a relatively small improvement, this may nevertheless constitute an important addition to the potential conservation value of the overall landscape. Further improvement of the habitat value of commercial plantations in southern Australia will involve tradeoffs with commercial considerations, as has been suggested elsewhere (Lamb, 1998).

From a biodiversity perspective, the direct benefit from adopting current commercial forestry plantation practices for cleared agricultural land may be only marginal because the range of tree species selected is narrow and species are frequently planted beyond their original geographic range. The commercial commitment to increase mean annual increment by selection, cloning and hybridisation of superior individuals will further reduce the genetic diversity of the primary plantings. The current management regime discourages the establishment of any plant species other than the tree crop, and the rotation length is generally 10 years (for plantations that are grown for woodchips). Hence there is little likelihood that the plantations will encourage regeneration of native species or develop a more complex structure in a way similar to that noted elsewhere (Geldenhuys, 1997; Guariguata et al., 1995; Oberhauser, 1997; Parrotta, 1995). It is also unlikely that trees in plantations would ever be suitable breeding habitat for many species. As an extreme example, consider den sites for possums. The average age of trees inhabited by brushtail and ringtail possums could be as high as 500 years for Jarrah and 400 years for Marri in Western Australia (Inions et al. 1989). Most den trees are found amongst the mature, overmature and dead trees of a stand (Abbott 1984; Macowaski 1984). The agents of decay take a long time to act, so hollows are more often associated with large, older trees (Inions et al. 1989).

6.2. Invertebrate assemblages

The insect communities of the plantation forest are different from native forest both because fewer insect species are present, and because they tend to be dominated by a few very abundant insect species. Some of the dominant species in plantations are "pest" species (i.e. *Eucalyptus* feeders that can do economic damage). There are a number of ways in which the plantation environment differs from the remnant forest -- they are sprayed with insecticides, they have less habitat complexity, even age of trees, and less light penetrating to the ground. Although a number of these might affect species diversity, other insect studies have found that, because so many insects eat only a few different plant species, insect diversity is linked to the number of plant species present. We suggest that it is the planting of only one plant species (*Eucalyptus globulus*) that most contributes to lower species richness in plantations. Therefore to increase insect diversity in plantations we recommend planting more than one species. This can be achieved by planting a mixture of commercial tree species, or by keeping one tree species, but allowing space and light for some understorey plant species.

The insect fauna of pastures is quite different from the insect fauna of plantations and remnant forests, because some insects are pasture specialists and some insects are tree specialists. Because the fauna of these different habitats is relatively distinct, the greatest regional biodiversity would be achieved by having some tree plantation and some pasture, rather than by having a landscape covered by one of these habitats exclusively. Whether or not pastures support endemic species will depend on whether the pre-agricultural landscape included open grasslands, and on the degree to which pastures include native grasses.

In terms of insect species richness, there is little difference between the edge and the interior of plantations. We also found that the insect fauna of plantations surrounded by agriculture is not very different to the insect fauna of plantations adjacent to remnant vegetation. Therefore we suggest that increasing the amount of plantation edge and planting plantations near remnant vegetation are not important principles for enhancing insect diversity. Other constraints on the shape and placement of plantations (such as the suitability of the site for trees) should be given a higher priority.

The insect survey also indicates that there can be negative consequences of planting plantations beside remnants. We discovered that a major *Eucalyptus* feeding pest species, introduced to western Australia, has moved from the plantation environment into native forest, where it may have a detrimental effect. This problem might be mitigated by planting tree species that are native to the local area (cf. *E. globulus* which is from eastern Australia) and by separating large monocultural plantations from sensitive native remnants.

Many predator and parasitoid insects were found in remnant and plantation sites. They could therefore contribute to the natural biocontrol of pest insects both in the plantation and the surrounding agriculture. The true potential of this natural service cannot be determined in this study, and the possible benefits are undermined by the use of broad-spectrum insecticides in these plantations, which kill beneficial and pest insects alike.

6.3 Recommendations

Our study has provided information on faunal assemblages found within plantations adjacent to and isolated from remnant vegetation. The results are equivocal in terms of what they tell us about the placement of plantations in relation to remnant vegetation. Some species are more likely to be found in plantations adjacent to remnant vegetation, but this is by no means general across the range of species found here. Similarly faunal use of plantation edge versus plantation interior did not show consistent patterns. Hence the results of this study do not provide clear guidance on questions of adjacency with remnant vegetation or of shape (i.e. in terms of relative edge:interior ratios). In many ways this is to be expected, since species behave individually and hence will show a range of responses to changing landscape compositions and configurations. Clear enunciation of conservation goals, preferably directed at particular species, is required for more detailed consideration of these questions.

The main result from this project is that the major limiting factor to realisation of greater biodiversity benefits appears to be the structural simplicity of farm forestry plantations. If managers wish to build in more structural complexity, an array of options is available (Spellerberg and Sawyer, 1997) including:

- a). Diversify age structure of plantation: single age class stands provide a narrow niche at any one time and thereby limit biodiversity opportunities. Evidence from native forests where age class has been synchronised by a catastrophic wildfire indicates that habitat appeal to a range of native species can be serially segmented rather than continuous (Baird *et al.*, 1994), thereby limiting the biodiversity at any one time. Establishment of multi-age class stands would no doubt be seen as an impediment to farm forestry operations except in the case where the harvestable product lends itself to selective logging (e.g. high value sawlogs for furniture timber). However, other plantation designs may provide a compromise. For instance, smaller plantation blocks of a single age class that allow infill in subsequent years would provide an age class distribution within an area. Possibly these designs could be extended to a banded design where stands of different age are planted in strips interspersed by strips of different ages. These designs would overcome some of the impacts that clear fell harvesting would have because trees would be harvested also in a sequential manner. Such designs also have implications for the efficiency with which surface water is used by the plantation (Silberstein *et al.*, in press).
- b). Provide open space habitat: boundary and edge zones are regarded as providing enhanced habitat value beyond that of the two bounding forms in isolation. Plantation areas seek to include all the possible area under plantation leaving minimal area as firebreaks and unplanted to trees. The perimeter of plantations is usually managed to provide a firebreak and the closely cropped vegetation and bare ground provides little habitat value to the plantation. (e.g. Plantation 2020 Vision Implementation Committee, 1997).

c). Provide dying and dead wood: prior to plantation establishment current practice involves removal of all timber whether living or dead, standing or fallen thereby removing important habitat components from the planting area. Much in the manner that dead timber is seen as an impediment to agricultural practices the same view prevails in farm forestry operations. A further concern for farm forestry operations may be the risk that dead and dying timber may provide a haven for timber diseases in a plantation.

d). Increase tree species richness: plantations are dominantly planted to one species and increasingly to clones of superior producing individuals thereby generating a monoculture with a narrow genetic base- the ultimate in ecological simplicity. Ecologically mixed-species plantings have the potential to add considerably to the habitat quality of plantations. In the case of *Pinus radiata* plantations the planting of a border of mixed native species (eucalypts and acacias) around the perimeter of the pines is attributed with significantly increasing the fauna (particularly birds) recorded in and adjacent to the pine plantation (Klomp and Costello, 1997; Greening Australia, in prep.).

e). Maintain stands of mature trees beyond normal economic maturity: the biodiversity purpose of retaining trees beyond economic maturity is two-fold. Firstly, an attempt to retain trees in agricultural landscapes that prior to plantation establishment were largely devoid of trees and secondly, to increase the age structure of trees in these areas when second or subsequent rotations are established. The incentive to do so is in direct conflict with achieving the economic objective and on current evidence is unlikely to gain acceptance. For instance, where the *sustainable* harvest of individual native trees retained on agricultural land has been outlawed, owners have sought parliamentary and financial compensation (Weekly Times, 2000c; House of Representatives Standing Committee on Environment and Heritage Inquiry, 2000).

f). Sensitive management of riparian zones, woodland set-asides and remnants of indigenous vegetation: riparian areas are not only recognised as providing valuable and complex habitat opportunities but are also vulnerable particularly when vegetation is removed- a fact recognised in legislation well before clearing controls. Remnants for much of the agricultural landscapes are small, degraded and under threat from a number of processes (e.g. Walpole *et al.*, 1998), nevertheless they represent the last remaining token of native vegetation and suite of associated taxa. Unfortunately a number of disturbing cases have arisen where remnants have been sacrificed when establishing plantations (Weekly Times, 2000a). The negative effects of plantations upon remnants also need to be considered. Evidence is emerging that remnant survival may be jeopardised when plantations are established adjacent to remnants. Planting configuration has been demonstrated to significantly influence water availability of adjacent areas (Silberstein *et al.*, in press). A vigorously establishing plantation may draw down groundwater too quickly for the mature remnant already adjusted to elevated levels to readjust its rooting depth to maintain an adequate water supply. Further, there is the risk of hybridisation of the plantation species (invariably an introduction to the area) with the remnant species compromising the genetic integrity of the remnant. The physical escape of plantation species into remnants poses another risk given that plantation species have been primarily selected for their early growth performance and therefore potentially have a competitive advantage. The purposeful development of native hybrids (e.g. *E. camaldulensis* X *E. globulus*) for plantations (Anon., 1997) may further increase the threat to remnants. This study highlights another risk of adjacency that has previously attracted little attention – the risk that insect pests from the plantation will move into the remnant forest where they may have adverse effects.

g). Increase resources for wildlife e.g. nest boxes: the limited range of habitats offered by plantations imposes a cap on the biodiversity potential that can be realised. The short life cycle of plantations negates the development of hollows- a habitat requirement for a number of bird, reptile and arboreal mammal species. Provision of nesting boxes (preferably species specific to reduce risk colonisation by pest species) can remove a limiting factor to colonisation by some of these species. Overcoming such factors may contribute to achieving other objectives as has been the case in other agricultural systems, e.g. providing owl nesting boxes in sugar cane areas has led to recolonisation of owls which prey on rats.

h). Landscape design: substantial biodiversity values may be realised by a landscape design approach to land use that recognises and incorporates the range of values that individuals and the broader community seek from our landscapes. Farm forestry plantations are a component of these

landscapes. Ideally a catchment-wide approach should be taken such that individual land use decisions are made in the context of the whole catchment and the collective values of its community.

i). Sensitive management of understorey vegetation: farm forestry plantations are largely devoid of understorey. Pre-planting preparation and post planting management are aimed at minimising competition and therefore understorey and groundcover are kept to a minimum usually by use of herbicides and/or mowing between the rows. The extent that this practice may contribute to increased populations of leaf eating pests is not known. However, a grassy understorey has been found to be an essential habitat requirement for predatory mites in orange groves (Colloff, pers. com.). In the absence of predatory mites, thrips populations reach economically important levels requiring implementation of regular and intensive pesticide spraying. The relatively minor cost and any inconvenience of a grassy understorey is offset against the saving in regular pesticide spraying for the control of thrips. Given the significance of leaf eating insects upon young plantations in particular, the role of understorey as a critical habitat requirement for insect predators should not be overlooked.

The inclusion of more species or a more diverse structure in the plantations may increase their use by fauna, but would also increase the management costs. However, there may be ways to increase diversity and structure which have less impact on plantation management – for instance, understorey shrubs could be planted round the edges of the plantation, or blocks of understorey and other non-commercial species could be interspersed with the commercial blocks. This study has not addressed the value of these activities directly, but will contribute to the development of management guidelines in a follow-on project “Trees and Biodiversity: Increasing the Benefits of Farm Trees to Native Biota”.

The extent to which commercial farm forestry plantings encourage the presence and activity of native biota is likely also to depend upon the indirect effects primary plantings offer, such as greater landscape diversity providing refugia, increasing connectivity and impeding disturbance. While traditional conservation biology thinks of fragmented landscapes in terms of patches of habitat in a matrix of non-habitat, increasing attention is being paid to the potential role that the matrix might play in determining population persistence (Ricketts, 2001). Modelling work has suggested that increasing the quality of the non-habitat landscape matrix as habitat may significantly improve population persistence in fragmented habitats (Fahrig, 2001). This mirrors the idea that a goal for landscape management should be to “re-variegate” fragmented landscapes – in other words, improve the value of the non-habitat matrix to increased landscape connectivity (McIntyre & Hobbs, 1999, 2000).

Gains in biodiversity emanating from farm forestry on cleared agricultural land represent gains for the entire community, and biodiversity considerations have become the focus of national policy statements that now influence all levels of government. Hence it is becoming increasingly important to consider how current plantation management practices contribute to biodiversity conservation and how they can be modified to increase that benefit. Our study has indicated that current plantation management does provide limited biodiversity benefits, and provides some pointers as to how those benefits can be increased. The extent to which biodiversity versus commercial benefits are enhanced will depend on an improved ability to maximise both. Such an ability will develop only through further study of how the biota use plantations of different types and purposes.

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Appendix one

Number of individuals of each beetle species collected by light trap in remnants (LR), and in plantation (LP), Canopy knockdown in remnants (CR), and in plantation (CP) and malaise trapping in remnants (MR) plantations (MP) and pasture (MAG).

Family, sub-family	Genus and Species	LR	LP	CR	CP	MR	MP	MAG
Caraboidea, Carabidae	<i>Agonocheila</i> sp 1			1	2			
	<i>Agonocheila</i> sp 2			3	1			1
	<i>Agonocheila</i> sp 3	1						
	<i>Amblytelus leai</i>			8	9			
	<i>Amblytelus</i> sp 1			13	2	1	1	
	<i>Amblytelus</i> sp 2			2				
	<i>Calosoma schayeri</i>		1					
	<i>Harpalus fulvicornis</i>				1	5	26	3
	<i>Homethes sericeus</i>	2						
	<i>Hypharpax</i> sp 1				1			
	<i>Mecyclothorax punctipennis</i>	42	6	2	10	5	3	
	near <i>Ochyra</i> sp				1			
	<i>Notagonum submetallicum</i>	1						
	<i>Peltoschema</i> sp 1			1				
	<i>Physoloesthus australis</i>	1						
	<i>Sarothrocrepis benefica</i>	1	5	8	20	15	81	16
	<i>Sarothrocrepis</i> sp 1		2	9	3		9	21
	<i>Scopodes</i> sp 1				1		2	
	<i>Tachys</i> sp 1	1		4	1	4		
	<i>Trigonothops</i> sp 1			1	5		5	
Caraboidea, Dytiscidae	<i>Copelatus ater</i>	4	13					
	<i>Lancetes lanceolatus</i>	11	10					
	<i>Liodessus inornatus</i>	4						
	<i>Platynectes brownei</i>	4	1					
	<i>Platynectes ocularis</i>		2					
	<i>Rhantus suturalis</i>	2	5					
Anthribidae, Anthribinae	<i>Euciodes ? suturalis</i>						1	1
	<i>Streneoderma planatum</i>						1	
	<i>Anthribidae</i> sp. 1						1	
	<i>Anthribidae</i> sp. 2			1				
	<i>Anthribinae</i> indet. Gen.							1
Attelabidae, Rhynchitinae	<i>Auletobius</i> sp. 1			28	9			1
	<i>Auletobius</i> sp. 2			2	1			
	<i>Auletobius</i> sp. 3			7				
Belidae, Belinae	<i>Araiobelus acicularis</i>			7	6	1	2	
	<i>Araiobelus filum</i>				1			
Brentidae, Apioninae	<i>Apion</i> sp. 1			3	6		4	6
	<i>Apion</i> sp. 2							1
	<i>Apion</i> sp. 3						1	

Family, sub-family	Genus and Species	LR	LP	CR	CP	MR	MP	MAG
Curculionidae, Curculioninae	<i>Iphisaxus aethiops</i>	4						
	<i>Iphisaxus asper</i>							1
	<i>Ophthalmorychus</i> sp.							1
	<i>Pelororhinus crassus</i>					1		1
	<i>Rhinaria aberrans</i>			18	51	2	22	3
	<i>Cryptoplus</i> sp. 1			23				
	<i>Cryptoplus</i> sp. 2			1				
	<i>Cryptoplus</i> sp. 3			1				
	<i>Cryptoplus</i> sp. 4			2				
	<i>Haplonyx</i> sp. 1			5				
	<i>Haplonyx</i> sp. 2			1				
	<i>Cryptorhynchini</i> sp. 1			5				
	<i>Cryptorhynchini</i> sp. 2			2				
	<i>Cryptorhynchini</i> sp. 3			1			1	
	<i>Decilaus</i> sp.1			3				
	<i>Decilaus</i> sp.2			1				
	<i>Achopera</i> sp.				1			
	<i>Ampagia</i> sp.			12				
	<i>Aromagis</i> sp.			2				
	<i>Atelicus</i> sp.			2	1			
	<i>Asynonychus cervinus</i>			3	33		7	4
	<i>Catasarcus impressipennis</i>			1				
	<i>Entimini</i> sp. 1	1		6				
	<i>Entimini</i> sp. 2			2				
	<i>Entimini</i> sp. 3	1		1				
	<i>Otiorhynchus cribricollis</i>							9
	<i>Pascoellus</i> sp.			57	2		1	
	<i>Phlyctinus callosus</i>		1		25		8	2
	<i>Polyphrades oesalon</i>		2	10	52		1	
	<i>Sitona discoideus</i>						1	5
	<i>Ancyttalia</i> sp. 1					2	32	
	<i>Ancyttalia</i> sp. 2			267	2	31	10	
	<i>Eugnomini</i> weevil sp.1			6	3			
	<i>Eugnomini</i> weevil sp.2			1				
	<i>Meriphus ? longirostris</i>				1	3		
	<i>Meriphus</i> sp.					1		
	<i>Gonipterus scutellatus</i>			389	1215	3	12	8
	<i>Oxyops c.f. pictipennis</i>			11	78		5	
	<i>Oxyops fasciatus</i>			4				
	<i>Syarbis</i> sp.			2				
	<i>Anorthorhinus</i> sp.		1					1
	<i>Steriphus</i> sp. 1		1					
	<i>Steriphus</i> sp. 2				1			
	<i>Laemosacellus</i> sp. 1			1	4			
	<i>Laemosacellus</i> sp. 2				6			
	<i>Laemosacellus</i> sp. 3			3	2			
	<i>Neolaemosaccus</i> sp.			5	1			
	<i>Notomagdalis</i> sp.				16			

Family, sub-family	Genus and Species	LR	LP	CR	CP	MR	MP	MAG
Curculionidae, Curculioninae	<i>Orthorhinus sp.</i>						5	2
	<i>Rhamphus sp.</i>					2		
	<i>Emplesis</i> or gen. nr. sp. 1			34	4			
	<i>Emplesis</i> or gen. nr. sp. 1					1		
	<i>Emplesis</i> or gen. nr. sp. 2			1				
	<i>Emplesis</i> or gen. nr. sp. 3				1			
	<i>Emplesis</i> or gen. nr. sp. 4				1			
	<i>Emplesis</i> sp. 1			42	1	3		
	<i>Emplesis</i> sp. 2			24	1			
	<i>Emplesis</i> sp. 3				1		1	
	<i>Emplesis</i> sp. 4			74	11	1	2	1
	<i>Emplesis</i> sp. 5				3			
	<i>Emplesis</i> sp. 6				1			
	<i>Emplesis</i> unsorted			67				
	<i>Storeus sp.</i>				1	2	1	1
	<i>Anarciarthrun sp.</i>			7				1
	<i>Cissowhitea sp.</i>			34	4	1	1	
	<i>Eniopea sp. 1</i>			15	1			
	<i>Eniopea sp. 2</i>					1		2
	<i>Eniopea sp. 2</i>			40	2			
	<i>Epamoebus sp. 1</i>			3	2	1	2	
	<i>Epamoebus sp. 2</i>				2			
	<i>Eristinus sp. 1</i>				16		5	1
	<i>Eristinus sp. 2</i>				2	1		3
	<i>Gerynassa sp.</i>			1				
	<i>Parazeta sp.</i>							1
	<i>Rachiodes sp.</i>				1			
	<i>Thechia sp.</i>			1				
	<i>Themelia sp. 1</i>							2
	<i>Themelia sp. 2</i>			1				2
	<i>Themelia sp. 3</i>			2				
	<i>Tychiini sp. 1</i>			16	7	2		
	<i>Tychiini sp. 2</i>						2	
	<i>Tychiini sp. 3</i>						1	
	<i>Tychiini sp. 4</i>					1		
	<i>Tychiini sp. 5</i>						1	
	<i>Tychiini sp. 6</i>							1
	<i>Tychiini sp. 7</i>					1		
	<i>Tychiini sp. 8</i>							1
	<i>Tychiini sp. 9</i>					1	3	1
	indet 1							1
	indet 2			1				
Curculionidae, Eirrhinae	<i>Echinocnemus sp.</i>			5	44			1
Curculionidae, Scolytinae	<i>Scolytinae 1</i>						1	
	<i>Scolytinae 2</i>						1	

Family, sub-family	Genus and Species	LR	LP	CR	CP	MR	MP	MAG
Bostrichoidea, Anobiidae	<i>Deltocryptus sp 1</i>				1		3	
	<i>Deltocryptus sp 2</i>			1				
	<i>Dorcatoma sp 1</i>						1	
	<i>Dorcatoma sp 2</i>					1		
	<i>Dryophilodes sp 1</i>			18	10	2		2
	<i>Dryophilodes sp 2</i>			4	15	3	5	
	<i>Dryophilodes sp 3</i>	19		13	1			
	<i>Dryophilodes sp 4</i>			4				
	<i>Dryophilodes sp 5</i>			18	1		2	
	<i>Dryophilodes sp 6</i>			1				
	<i>Dryophilodes sp 7</i>			1				
	<i>Dryophilodes sp 8</i>					1		
	<i>Hadrobregmus australiensis</i>		1					
	<i>Ptinus sp 1</i>						6	
Bostrichoidea, Bostrichidae	<i>Xylopsocus rubidus</i>					1		
Bostrichoidea, Dermestidae	<i>Trogoderma sp 1</i>	7	1	4		24	7	
	<i>Trogoderma sp 2</i>					3	7	
	<i>Trogoderma sp 3</i>					2		
Byrrhoidea, Byrrhidae	<i>Morychus sp 1</i>			1				
Byrrhoidea, Heteroceridae	<i>Heterocerus sp 1</i>	4						
	<i>Heterocerus sp 2</i>	4						
Chrysomeloidea, Cerambycidae	<i>Adrium sp 1</i>		1				1	
	<i>Atesta sp 1</i>							1
	<i>Bethelium sp 1</i>				3		8	1
	lamiine unknown sp 1					1	1	1
	<i>Lygesis sp nov</i>				1			
	<i>Obrida sp 1</i>				3		1	
	<i>Pseudocephalus mirus</i>				4		2	
	<i>Stenoderus sp 1</i>					4	7	
	<i>Uracanthus sp 1</i>	4						
	<i>Uracanthus triangularis</i>	2						
Chrysomeloidea, Chrysomelidae	<i>Agetinella minuta</i>				1			
	<i>Aporocera bynoei</i>				2			
	<i>Aporocera carnifex</i>				1			
	<i>Aporocera sp 1</i>	1		6	6	2	3	
	<i>Aporocera sp 2</i>				5			
	<i>Aporocera sp 4</i>				1	1		
	<i>Arsipoda sp 1</i>			3			1	
	<i>Arsipoda sp 2</i>						1	
	<i>Cadmus crucicollis</i>						1	
	chrysomeline unknown sp 1			1				
	<i>Chrysophtharta amoena</i>			6	2			
	<i>Chrysophtharta mentatrix</i>			2	3			
	<i>Chrysophtharta nobilitata</i>			11	56			1
	<i>Chrysophtharta sp 1</i>				1			
	<i>Chrysophtharta variicollis</i>			6	256	1	7	3
	<i>Coenobius sp 1</i>			2				

Family, sub-family	Genus and Species	LR	LP	CR	CP	MR	MP	MAG
Chrysomeloidea, Chrysomelidae	<i>Ditropidus</i> sp 1			9				
	<i>Ditropidus</i> sp 2			3		3		
	<i>Ditropidus</i> sp 3			3				
	<i>Ditropidus</i> sp 4			4			1	
	<i>Ditropidus</i> sp 5					1		
	<i>Ditropidus</i> sp 6			1				
	<i>Eboo</i> sp 1			12	5	3	7	1
	<i>Eboo</i> sp 2					1		
	<i>Eboo</i> sp 3				3	2	11	1
	<i>Edusella</i> sp 1		2	10	635	3	147	14
	<i>Edusella</i> sp 2						23	
	galerucine unknown sp 1						1	
	galerucine unknown sp 2					1		
	<i>Leasia australis</i>						2	
	<i>Livolia</i> sp 1			149	6	64	14	
	<i>Livolia</i> sp 2			1		21	1	
	<i>Longitarsus</i> sp 1							1
	<i>Paropsis</i> <i>geographica</i>						1	
	<i>Paropsis</i> sp 1				1			
	<i>Paropsis</i> sp 2			1	5			
	<i>Paropsis</i> sp 3			1	4			
	<i>Pelrororhinus</i> sp.							2
	<i>Pentagonica vittipennis</i>		1					
	<i>Terillus suturalis</i>		3	18	107	2	16	
	<i>Trachymela</i> sp 1			1				
	<i>Trachymela</i> sp 2			1	8			
	<i>Trachymela</i> sp 4				1			
Cleroidea, Cleridae	<i>Blackburniella intricata</i>				2		19	
	<i>Lemidia hilaris</i>						1	
	<i>Lemidia nitens</i>				1	3	7	
	<i>Lemidia</i> sp 1			2				
	<i>Lemidia</i> sp 2			36	1			1
	<i>Lemidia</i> sp 3					1		
	<i>Tenerus abbreviatus</i>						1	
Cleroidea, Melyridae	<i>Carphurus</i> sp 1			9	30	4	8	24
	<i>Dasytes</i> sp 1			1		48	12	
	<i>Helcogaster parallelus</i>			2		42	7	
	<i>Helcogaster</i> sp 1			9		2	1	
	<i>Hypattalus</i> sp 1			2		2	1	
	<i>Hypattalus</i> sp 2			2				
Cucujoidea, Boganiidae	<i>Boganium</i> sp 1			1				

Family, sub-family	Genus and Species	LR	LP	CR	CP	MR	MP	MAG
Cucujoidea, Coccinellidae	<i>Bucolellus ornatus</i>			2	1			
	<i>Cleobora mellyi</i>				27		2	
	<i>Coccinella transversalis</i>						1	2
	<i>Coccinella undecimpunctata</i>			3			1	4
	<i>Diomus notescens</i>				2	5	9	3
	<i>Diomus</i> sp 1			10	1			
	<i>Diomus</i> sp 2				1	5		
	<i>Diomus</i> sp 3				1			1
	<i>Paraprius australasiae</i>			3				
	<i>Rhyzobius</i> sp 1			71	1			1
	<i>Rhyzobius</i> sp 2			60	4	1	1	1
	<i>Rhyzobius</i> sp 3			1	4	4	15	3
	<i>Rhyzobius</i> sp 4			5				
	<i>Rhyzobius</i> sp 5	1				4	2	
	<i>Rhyzobius</i> sp 6					1	1	
	<i>Rhyzobius</i> sp 7				2			
	<i>Rodolia</i> sp 1					1	1	
	<i>Scymnus</i> sp 1			7	52		1	
	<i>Scymnus</i> sp 2			64			2	2
	<i>Scymnus</i> sp 3				4			
	<i>Scymnus</i> sp 4							1
	<i>Scymnus</i> sp 5			1	1			
	<i>Stethorus</i> sp 1				24	1		6
Cucujoidea, Corylophidae	<i>Alloparmulus</i> sp 1			5			10	
	<i>Alloparmulus</i> sp 2			1	4	1		
	<i>Alloparmulus</i> sp 3							1
	<i>Alloparmulus</i> sp 4			2	2			
	<i>Alloparmulus</i> sp 5							1
	<i>Anisomeristes</i> sp 1			41	258	6	10	11
	<i>Anisomeristes</i> sp 2			4	4	1	4	5
	<i>Orthoperus</i> sp 1			5	1			
Cucujoidea, Cryptophagidae	cryptophagine unknown sp 1			1	1	124	13	3
	cryptophagine unknown sp 2						1	
Cucujoidea, Erotilidae	<i>Hoplepiscapha longicornis</i>			2				
	<i>Thallis occidentalis</i>		2				1	
Cucujoidea, Laemophloeidae	<i>Cryptolestes</i> sp 1			2	3			
Cucujoidea, Lathridiidae	<i>Aridius australicus</i>					1		
	<i>Aridius nodifer</i>				7	1	10	
	<i>Cartodere constricta</i>			2	1			
	<i>Corticaria</i> sp 1			2	5		4	9
	<i>Corticaria</i> sp 1			2	5		8	1
	<i>Corticaria</i> sp 2			1	8	8	58	5
	<i>Corticaria</i> sp 3			9	18	9	55	24
	<i>Corticaria</i> sp 4			2	5		34	10
	<i>Enicmus</i> sp 1					5	9	

Family, sub-family	Genus and Species	LR	LP	CR	CP	MR	MP	MAG
Cucujoidea, Nitidulidae	<i>Amlearcha sp 1</i>			4				
	<i>Brachypeplus sp 1</i>			1	1			
	<i>Epuraea sp 1</i>			1	4			1
	<i>Notobrachypterus sp 1</i>			1				
	<i>Notobrachypterus sp 2</i>			4		3		
	<i>Stelidota sp 1</i>				22	4	23	2
	<i>Thalycrodes sp 1</i>	1	6		4	2	8	
Cucujoidea, Phalacridae	<i>Litochrus sp 1</i>			17	315		6	5
	<i>Litochrus sp 2</i>					1	2	1
	<i>Litochrus sp 3</i>					1		
	<i>Parasemus sp 1</i>				2	2		
	<i>Pepila sp 1</i>				1			
	<i>Phalacrinus sp 1</i>			1	14	2	11	1
	<i>Phalacrinus sp 2</i>			1				
Cucujoidea, Silvanidae	<i>Phalacrus sp 1</i>			4		1		
	<i>Ahasversus advena</i>			1	1		2	4
	<i>Cryptamorphia sp 1</i>					3		1
Elateroidea, Cantharidae	<i>Cryptamorphia sp 2</i>			1				
	<i>Heteromastix sp 1</i>			7	2	1	1	
	<i>Heteromastix sp 2</i>			3	2	58	54	
Elateroidea, Elateridae	<i>Heteromastix sp 3</i>					9	1	
	<i>Agrypnus sp 1</i>				17			
	<i>Conoderus sp 1</i>		10				1	1
	<i>Conoderus sp 2</i>		1		1		4	5
	<i>Conoderus sp 3</i>					1		
	<i>Conoderus sp 4</i>	58	24				2	12
	<i>Conoderus sp 5</i>	1						
	<i>Conoderus sp 6</i>	1	1		1	1	4	3
	<i>Conoderus sp 7</i>	2						
	<i>Conoderus sp 8</i>	1						
	<i>Conoderus sp 9</i>	2						
	<i>Conoderus sp 10</i>	2				1		
	<i>Crepidomenus occidualis</i>				21		18	1
	<i>denticolline unkown sp 1</i>	5		1				
	<i>Parablax rumaiy</i>					2	1	
	<i>Paracardiophorus venustus</i>					1		
	<i>Pseudaesolus australis</i>					1		
Elateroidea, Eucnemidae	<i>Dromaeolus sp 1</i>						6	
Elateroidea, Lycidae	<i>Metriorrhynchus sp 1</i>						1	
	<i>Metriorrhynchus sp 2</i>				3		3	
	<i>Metriorrhynchus sp 3</i>				1	3	1	
	<i>Xylobanus sp 1</i>					1		
Hydrophiloidea, Histeridae	<i>Acritus sp 1</i>			1	1			
	<i>Hypocacculus sp 1</i>			1				
Hydrophiloidea, Hydrophilidae	<i>Ercyodes sp 1</i>			1	1			
	<i>Limnoxenus sp 1</i>	301	507					
	<i>Pachysternum sp 1</i>				1			
	<i>Paracymus pygmaeus</i>	101	36	1	2			

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Hydrophiloidea, Throscidae	<i>Aulonothroscus sp 1</i>					3	21	1
Scarabaeoidea, Scarabaeidae	<i>Aphodius lividus</i>	1	4					
	<i>Aplopsis punctulata</i>		83				2	
	<i>Aplopsis sp 1</i>				1			
	<i>Aplopsis sp nov nr punctulata</i>	495	53		4	1	51	
	<i>Australaphodius frenchi</i>		1	14	7			
	<i>Automolius immitis</i>			1	3		4	
	<i>Colpochila abdita</i>	1	1					
	<i>Colymbomorpha lineata</i>		1	1	3	10	136	21
	<i>Colymbomorpha sp nov</i>					2	47	5
	<i>Cryptodus goerlingi</i>	1						
	<i>Diphucephala sp 1</i>						1	
	<i>Drepanocanthoides neglectus</i>	9			6			
	<i>Heteronyx agrestis</i>	1						
	<i>Heteronyx costulatus</i>	11	318			13	42	11
	<i>Heteronyx disjunctus</i>	5	41			1	4	
	<i>Heteronyx disjunctus</i>							
	<i>Heteronyx imitator</i>		3	7	2	4	38	2
	<i>Heteronyx iridiventrtris</i>							1
	<i>Heteronyx proprius</i>		3					
	<i>Heteronyx proxima</i>	21	24			1	2	2
	<i>Heteronyx sp 1</i>	47	309					
	<i>Heteronyx sp 2</i>		4				2	
	<i>Heteronyx sp 3</i>	36						
	<i>Heteronyx sp 4</i>	3	16		1	3	48	
	<i>Heteronyx sp 5</i>	153	1422		5	1	26	2
	<i>Heteronyx sp 6</i>		3					
	<i>Heteronyx sp 7</i>	5						
	<i>Heteronyx sp 9</i>	19	546					
	<i>Heteronyx sp 10</i>		2					1
	<i>Heteronyx sp 11</i>	3	1					
	<i>Heteronyx sp 12</i>	1						
	<i>Heteronyx sp 13</i>	3	4				1	
	<i>Heteronyx sp 14</i>	1						
	<i>Heteronyx sp 15</i>	20						
	<i>Heteronyx sp 16</i>	3						
	<i>Heteronyx sp 17</i>	1					1	
	<i>Heteronyx sp 18</i>		1					
	<i>Heteronyx sp 19</i>					1	4	
	<i>Heteronyx sp 20</i>	2	1					
	<i>Heteronyx sp nov nr agrestis</i>	24					1	
	<i>Liparetrus jenkinsi</i>				10		2	
	<i>Maechidius major</i>		1					
	<i>Neophyllotocus sp 1</i>	4				1		
	<i>Neophyllotocus sp 2</i>					1		
	<i>Onthophagus evanidus</i>			2	1			
	<i>Onthophagus ferox</i>	5	6					
	<i>Onthophagus vermiculatus</i>				2			

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Scarabaeoidea, Scarabaeidae	<i>Rhyssomus blackburni</i>				1			
	<i>Semanopterus leai</i>		1					
Scirtoidea, Clambidae	<i>Clambus simsoni</i>				8	1		
Scirtoidea, Eucinetidae	<i>Eucinetus sp 1</i>					1		
Scirtoidea, Scirtidae	<i>Pseudomicrocara sp 1</i>						4	1
	<i>Pseudomicrocara sp 2</i>	2						
	<i>Pseudomicrocara sp 3</i>		1					
	<i>Pseudomicrocara sp 4</i>		3				1	
	<i>Pseudomicrocara sp 5</i>							1
	<i>Pseudomicrocara sp 6</i>							1
	<i>Scirtes sp 1</i>	1	1				1	
Staphylinioida, Hydraenidae	<i>Tympallopattrum sp 1</i>			1	3		1	
Staphylinioida, Leiodidae	<i>Aglyptinus sp 1</i>		2		8			
	<i>Colon sp 1</i>					2		
	<i>Colon sp 2</i>	4		1		1		
	<i>Colon sp 3</i>	1						
	<i>Colon sp 4</i>					1		
	<i>Dietta sp 1</i>	9	1					
	<i>Myrmecoleva sp 1</i>	3	2					
	<i>Nargomorphus sp 1</i>				1	5	85	1
	<i>Zeadolopus sp 1</i>	1				1		
Staphylinioida, Pselaphidae	<i>Abascantodes sannio</i>			1				
	<i>Eupinella sp 1</i>			1	1			
	pselaphine unknown sp 1					1	1	
	pselaphine unknown sp 2				1		1	
	pselaphine unknown sp 3			1	4			
	pselaphine unknown sp 4				2		1	
	pselaphine unknown sp 5			1				1
Staphylinioida, Ptiliidae	<i>Acrotrichis sp 1</i>			1	3		1	
Staphylinioida, Scydmaenidae	<i>Euconnus sp 1</i>			1				
	<i>Euconnus sp 2</i>						2	
Staphylinioida, Silphidae	<i>Ptomaphila lacrymosa</i>	2						
Staphylinioida, Staphylinidae	aleocharineunknown sp 1			5				
	aleocharineunknown sp 2			1				
	aleocharineunknown sp 3				2			
	aleocharineunknown sp 4			2	18	4		
	aleocharineunknown sp 5			4	82	11	3	
	aleocharineunknown sp 6						1	
	aleocharineunknown sp 7			32	5	8	7	1
	aleocharineunknown sp 8						1	
	aleocharineunknown sp 9			3	7	7	11	1
	aleocharineunknown sp 10				1	1		
	aleocharineunknown sp 11			2				
	aleocharineunknown sp 12					1	2	
	aleocharineunknown sp 13						1	
	aleocharineunknown sp 14						1	
	aleocharineunknown sp 15						1	
	aleocharineunknown sp 16				1			

Family, sub-family	Genus and Species	LR	LP	CR	CP	MR	MP	MAG
Staphylinioidea, Staphylinidae	aleocharineunknown sp 17						1	
	aleocharineunknown sp 18			2				
	aleocharineunknown sp 19			2				
	<i>Anotylus</i> sp 1			6	11	1	4	1
	<i>Austrolophrum cribripes</i>			2				
	<i>Falagria</i> sp 1					1	1	
	<i>Ischnosoma</i> sp 1				2		10	
	<i>Leptacinus</i> sp 1			11	11	3	116	5
	<i>Pseudophloeocharis</i> sp 1			6	1			
	<i>Quedius</i> sp 1			1		3	32	
	<i>Scaphisoma</i> sp 1				1	2	11	
	<i>Sepedophilus</i> sp 1	2		15	4		1	1
	<i>Sepedophilus</i> sp 2					1	1	
Tenebrionoidea, Aderidae	<i>Aderus</i> sp 1			2				
Tenebrionoidea, Anthicidae	<i>Anthicus</i> sp 1			3	2		2	2
	<i>Anthicus</i> sp 2				1	2		
	<i>Anthicus</i> sp 3			5		2	1	
	<i>Anthicus</i> sp 4							
	<i>Anthicus</i> sp 5					1		1
	<i>Anthicus</i> sp 6			2		1	1	2
	<i>Trichananca</i> sp 1					1		
Tenebrionoidea, Ciidae	<i>Cis</i> sp 1			29				
	<i>Cis</i> sp 2				1			
Tenebrionoidea, Colydiidae	<i>Docalis elongatus</i>			2				
Tenebrionoidea, Melandryidae	<i>Orchesia</i> sp 1						1	
Tenebrionoidea, Mordellidae	<i>Mordella</i> sp 1					62	27	3
	<i>Mordella</i> sp 2					10		
Tenebrionoidea, Mycetophagidae	<i>Litargus balteatus</i>					2		
Tenebrionoidea, Pythidae	<i>Temnopalpus</i> sp 1					1		
Tenebrionoidea, Salpingidae	<i>Orphanotrophium</i> sp 1			5				
	<i>Orphanotrophium</i> sp 2						1	
	salpingineunknown sp 1			2	2	1		
Tenebrionoidea, Scaptiidae	<i>Scaptia</i> sp 1			27	1	5	6	1
Tenebrionoidea, Tenebrionidae	<i>Adelium brevicorne</i>			1	19			
	<i>Chalcopteroides</i> sp 1				7			1
	<i>Cheirodes caulobioides</i>	1	7					
	<i>Chromomoea</i> sp 1					6		
	<i>Ecnolagria aeneoviolace</i>				1			
	<i>Euomma</i> sp 1	1	6			1	3	
	<i>Gonocephalum arenarium</i>		1		7		5	2
	<i>Hemicistela</i> sp 1					2	1	
	<i>Hemicistela</i> sp 2	1				2	3	
	<i>Hemicistela</i> sp 3	1						
	<i>Mitrothorax breweri</i>			2				
	<i>Tetragonomenes</i> sp 1			4				
	<i>Titaena</i> sp 1			3				