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School of Environmental Biology

Bulletin No. 20

The Potential of Revegetation Programs to Encourage Invertebrates and Insectivorous Birds

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2001

ISSN No. 0158 3301

17502-2-01

SCHOOL OF ENVIRONMENTAL BIOLOGY BULLETIN

Information for Contributors

Biologists who wish to publish the results of their investigations have access to a large number of journals. For a variety of reasons, however, the editors of most of these journals are unwilling to accept articles that are lengthy, contain information that is preliminary in nature, or form the basis of addresses given at conferences. Nevertheless, some material of this type could be of immense interest and value to other scientists, and should be published. One avenue for dissemination of such material is the School of Environmental Biology Bulletin, a series of occasional papers published by Curtin University of Technology.

Intending contributors should contact Prof Majer, c/- the Department of Environmental Biology, GPO Box U1987, Perth, Western Australia 6845 (Tel. 08 9266 7041; Fax. 09 9266 2495). All submitted papers will be considered by the Editorial Board and appropriate referees. Publication costs for papers that are accepted must be met by authors or their employers.

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Preface

Along roadsides and in agricultural areas throughout Australia, revegetation programs have tended to use tree species that are freely available or easy to propagate. However, many people wonder whether the species planted are the most appropriate ones for providing food and habitat for birds and other wildlife. In 1999, the Gordon Reid Foundation made a grant to the Northam Land Conservation District Council (LCDC) to investigate how effective the trees planted in the Northam District were in supporting invertebrates, an important food resource of insectivorous birds and the most important part of biodiversity. The Northam LCDC contracted the project to Jonathan Majer (Curtin University of Technology) and Harry Recher (Edith Cowan University). This Bulletin of the School of Environmental Biology reports the results of that project and makes recommendations for future landcare plantings.

We thank Mr Ian Hancock, Chairman of the Northam LCDC, and Mr Robert Barton, Secretary, for logistic support doing this work. We were ably assisted in the field by Tamra Chapman, Nadine Guthrie, Joanne Newbury and Roger Clay, and also by Northam residents Malcolm Lawrence, Derek Lawrence, Justin Martin, John Sermon and Helen Job. Melinda Moir, Gyoung Soo Kang and Dr Brian Heterick assisted with invertebrate sorting. The leaf hardness analysis was conducted by Crysania Mok. The preparation of material for leaf nutrient analysis was completed by Daniel Majer. Melinda Moir analysed the results.

Abstract

There are extensive revegetation programs in the wheatbelt of Western Australia. Revegetation has many objectives including lowering water tables to combat water logging and soil salinisation, improving agricultural productivity, and producing a commercial crop of trees for harvesting. Trees are planted by farmers, conservation groups and Government authorities to rehabilitate, beautify and manage degraded agricultural land, parks and road verges. In addition to improving plant diversity and restoring ecosystem functions, revegetation is an opportunity to provide food and habitat for wildlife and to conserve regional biodiversity.

The objective of the study reported here was to investigate whether the tree species planted in the wheatbelt are colonized by invertebrates (e.g., insects and spiders) and whether the abundance and variety of invertebrates on planted trees differs between tree species and between revegetation and remnant native vegetation. The study also investigated the use of revegetation by birds and compared this to bird communities in remnant vegetation. Invertebrates were sampled on trees planted along the Great Eastern Highway as part of the Main Roads Department 'Ribbons of Green' program, as well as trees planted by community groups and Greening Western Australia. We asked whether the best species of trees were being planted to restore and enhance regional biodiversity.

The canopy invertebrate fauna of 10 trees of each of eight species of *Eucalyptus* and jam wattle (*Acacia acuminata*) was sampled by chemical knockdown. Jam wattle and three of the eucalypts, including wandoo (*E. wandoo*), are indigenous to the Northam District. Three of the eucalypts are indigenous to the south coast of Western Australia, one to northwestern Western Australia, and the eighth is indigenous to coastal South Australia. Wandoo was sampled in both revegetation and remnant natural vegetation. In addition to sampling invertebrates, leaf toughness and levels of foliar nutrients (NPK) were sampled for all tree species. Leaf toughness and foliar nutrients were measured as other studies had found relationships between toughness and nutrients, with the abundance and variety of canopy invertebrates.

Moderate to high invertebrate densities were found on all tree species. Indigenous trees tended to support the most diverse and abundant invertebrate faunas: species originating from southern coastal regions and northwestern Western Australia supported the least. Wandoo trees in revegetation tended to have higher populations of some insects than wandoo growing in remnant vegetation. Leaf toughness appeared to affect the size of invertebrate populations on some eucalypt species, but the effects of foliar nutrients were inconsistent, possibly because nutrient levels were elevated as a result of fertiliser applications.

During winter (June), three patches of remnant vegetation and seven replanted areas were surveyed for birds. Twenty-five species of birds were recorded of which three were found only in remnant vegetation and six were found only on the replanted areas. However, all species recorded are widely distributed throughout the Western Australian wheatbelt and, with the possible exception of the White-browed Babbler (*Pomatostomus supercilosus*), no significance can be attributed to the differences in bird species composition between remnant and replanted areas: at least in winter, birds are as likely to use revegetated areas as remnant vegetation. The absence of the babbler from revegetated areas is possibly due to the lack of logs and woody debris on the planted sites. Sixteen of the 25 bird species are predominantly insectivorous, four are nectarivores, four are seed-eaters, and one is a frugivore. This

suggests that a similar range of foraging resources are available in both remnant vegetation and revegetation.

To restore and enhance regional biodiversity, we recommend that revegetation programs, including commercial plantings, should use a variety of tree species and emphasise regional species. Where this is not possible, species from nearby regions should be used. Planted areas should also be diversified by using a variety of indigenous shrubs and herbs, as well as trees, and by adding logs and coarse woody debris to the area planted. Provision of nest boxes would accelerate the colonization of revegetated areas by hole-nesting birds.

1.0 Introduction

Most of the natural vegetation in the Western Australian wheatbelt has been cleared for agriculture: Hobbs and Saunders (1993) and Saunders and Ingram (1995) describe these changes in detail. Throughout the wheatbelt, native trees remain only in isolated, often small and frequently degraded, remnants of native vegetation, as single trees in paddocks, and in narrow, discontinuous strips along roads and drainage lines. As a consequence of such extensive land clearing, rising water tables and increasing soil salinity affect more than 10% of the agricultural lands in the wheatbelt, leading to damage to infrastructure (e.g., roads and buildings) and creeks and rivers. In response to these threats, farmers, state government agencies and local communities in the wheatbelt commenced extensive reafforestation and vegetation restoration programs in the 1980's.

In addition to combating the threats of rising water tables and increased soil and water salinity, reafforestation and 'landcare' plantings are also intended to beautify the landscape and protect and enhance local and regional biodiversity by providing habitat and movement corridors for native fauna (e.g., Majer 1990; Merriam and Saunders 1993; Recher 1993). An important effort has been the 'Ribbons of Green' project along the Great Eastern Highway between Perth and Kalgoorlie by the Main Roads Department, as well as extensive plantings of trees along and on road verges by farmers, conservation groups, and local communities. Although single, isolated trees, as well as those along road edges and in small remnants are capable of sustaining a diverse invertebrate and vertebrate fauna (e.g., Abensperg-Traun 2000; Abensperg-Traun *et al.* 2000; Law *et al.* 2000; Newbey 1999; Majer *et al.* 1999), there are few data on the effectiveness of reafforestation, landcare and road verge plantings in restoring or enhancing biodiversity (see Lefroy *et al.* 1993).

Particularly during the early development of landcare programs, trees and shrubs which were not native to the area were planted. Typically, revegetation consists of single or mixed tree species, generally eucalypts (*Eucalyptus* spp.), that have readily obtainable seed and which can be successfully established. Consequently, many established revegetation areas are a mix of species originating from throughout Australia. Reafforestation and agro-forestry programs continue to promote non-indigenous, but commercially important species.

It is well-known that monocultures and plantations of exotic species sustain many fewer species of native animals than the original native vegetation (e.g., Recher 1982) and recent recommendations for landcare and other environmental revegetation programs emphasise the need to use indigenous plants (e.g., Barrett 2000; Fry and Main 1993; Lefroy *et al.* 1991; Recher 1993). However, the effect on meeting biodiversity objectives by using non-indigenous species in the much smaller and spatially diverse landcare, road verge and farm plantings is not clear.

Southwood (1960, 1961) predicted that indigenous trees were more likely to sustain an abundant and diverse arthropod fauna than non-indigenous species. Bhullar and Majer (2000) confirmed this prediction for street trees in Perth where local *Eucalyptus* species supported a richer arthropod fauna than either non-indigenous eucalypts or species derived from other continents. However, in view of the multiple recommendations to confine landcare plantings to indigenous species of local provenance regardless of convenience or commercial cost, it is important to test Southwood's (1960, 1961) predictions in an agricultural landscape where greater amounts of native vegetation remain than in an urban setting. Here we report on studies of the canopy invertebrates (especially arthropods such as insects, mites and spiders) and birds associated with indigenous and non-indigenous tree species planted for conservation and roadside beautification purposes in the Northam Land Conservation District on the western edge of the Western Australian wheatbelt.

Our objectives in undertaking these studies at Northam were to investigate whether the different tree species planted in the District provided similar opportunities in terms of provision of arthropod abundance and use by arthropod-feeding birds; to quantify the levels of arthropods on trees that have been planted by the Main Roads Department, community groups and Greening Western Australia and to see whether they are planting the best trees to encourage wildlife; and to make recommendations for the best types of tree species to plant.

2.0 Background

2.1 Tree canopy arthropods

Extensive ecological studies of tree canopy arthropods in eucalypt forests have been undertaken (e.g., Majer and Recher 1988; Majer *et al.* 1989; Abbott *et al.* 1992, Recher *et al.* 1996). Eucalypt communities sustain species-rich invertebrate faunas with high levels of taxonomic and ecological complexity. Studies have shown that within one eucalypt forest, arthropod abundance may differ between different tree species (Majer and Recher 1988; Majer *et al.* 1989). This may dictate the usage of such trees by insectivorous birds. In Western Australia, jarrah (*E. marginata*) was shown to have a significantly lower invertebrate abundance than either marri (*E. calophylla*) or wandoo (*E. wandoo*) (Majer and Recher 1988). Similar differences occur between eucalypt species in eastern Australia. The predominance of insect-feeding birds on narrow-leaved ironbark (*E. crebra*) in New South Wales, when compared with the more abundant grey box (*E. mollucana*), is probably associated with higher insect levels on the former tree species (Majer *et al.* 1989). Apparent selection of feeding substrates by birds could be associated with tree architecture, or it may result from a response to differing food availability (Majer *et al.* 1992). These observations suggest that it is desirable for revegetated areas to contain a reasonable proportion of tree species which support good invertebrate food sources (Majer 1990). It is possible that some species planted do not provide suitable habitats for the local arthropod and bird fauna.

Differences in abundance and diversity of arthropods between tree species can be associated with a tree's geographical distribution and recent history in the area and, to a lesser extent, features of tree morphology (Southwood 1960; Southwood *et al.* 1982). This was further supported by a Perth study (Radho-Toly 1999) which found that eastern Australian eucalypts growing in urban bushland sometimes support as many canopy arthropods as the local jarrah and tuart (*E. gomphocephala*), a trend that seems to be related to high foliage nutrient levels. Phytophages appear to be an exception, showing a lower diversity on introduced trees (Southwood et al. 1982). Adaptation of phytophages to a new plant host is likely to depend on frequency of encounter, and the extent to which the new plant's defences are similar to those of its original host. If a tree becomes more abundant through cultivation, in time, an increasing number of arthropods feed on it.

2.2 Tree plantings as habitat for arthropods and birds

Recent studies investigated tree canopy arthropods in eucalypt plantations (Abbott *et al.* 1999) and in street trees (Bhullar and Majer 2000). Abbott *et al.* (1999) reported a diverse and abundant arthropod fauna on the foliage of Tasmanian bluegum (*E. globulus*) planted as a monoculture in southwestern Western Australia. Bhullar and Majer (2000) found that eucalypt species planted as street trees in Perth supported a greater variety of arthropods than non-native tree species that were planted for ornamental purposes. Moreover, a local eucalypt, marri, yielded more invertebrates than *E. conferruminata*, a non-indigenous eucalypt. However, the difference was not great.

The effects of agriculture on birds have been a major focus of recent research activity (Ormerod and Watkinson 2000), although there is limited information available on how birds use revegetated areas (Ryan 1999). Plantings on roadside verges can provide many resources to native birds. After establishment, plantings can become habitat that can provide nesting and sheltering sites, increase the area in which species can forage, and possibly enhance movements between remnants. Preliminary studies show that roadside revegetation often has as many species as are found in remnants. These include many species that have declined in numbers or range as a result of land clearing and habitat degradation (Newbey 1999; Saffer *et al.* 2000). Generalist species, primarily honeyeaters, account for the majority of species recorded in tree plantings. However, it is important to understand that remnant vegetation is the source of species which recolonise revegetation. Remnants also provide essential resources, such as tree hollows for nesting, which take a long time to develop in revegetated sites (Ryan 1999).

Research in jarrah forest mined for bauxite and replanted with eastern Australian eucalypts and no understorey species found low invertebrate and vertebrate abundance and diversity on the revegetated sites (Nichols and Watkins 1984; Nichols and Burrows 1985). However, in rehabilitated forest, seeded with locally occurring species, the abundance and variety of invertebrates and birds is more similar to unmined healthy forest (i.e., not affected by jarrah dieback *Phytophthora cinnamomi*). Understorey seeding in these areas produces a vigorous understorey and groundcover that provide habitat for invertebrates and food for birds

2.3 Foliar nutrients and leaf hardness

The abundances of arthropods on trees are influenced by a range of factors. The level of foliar nutrients, particularly nitrogen is an important limiting agent for the growth and development of phytophagous arthropods (Southwood 1972; Mattson 1980), and could affect the abundance and diversity of arthropods from other trophic levels. In a series of studies in eucalypt forest within eastern and western Australia, Majer *et al.* (1992) and Recher *et al.* (1996) observed that differences in foliar nutrient levels were consistent with trends in the abundance and diversity of foliage arthropods, and in the use of these trees as foraging substrates by birds. The richest and most abundant arthropod and bird communities occur in forests where the dominant eucalypts have the highest levels of foliage nutrients (nitrogen and phosphorous) (Recher *et al.* 1996).

The leaves of eucalypts are typically sclerophyllous, hard and leathery, low in nutrients and water, but rich in secondary compounds (Morrow 1983). A strong negative correlation between nitrogen concentration and leaf toughness exists in foliage of *E. blakelyi*, a southeastern Australian eucalypt (Ohmart *et al.* 1987). For insect herbivores, nitrogenous compounds and leaf toughness appear to be the most important limiters of herbivory (Landsberg and Cork 1997). For example, fecundity and early larval survival of the eucalypt defoliating chrysomelid beetle *Paropsis atomaria* appear to be limited by foliar nitrogen and the leaf toughness.

It is possible that the complex biochemical defences of eucalypts against herbivores (e.g., Cork and Catling 1996) have enhanced the richness of arthropod communities (Recher *et al.* 1996). The need to counter toxins and adapt to phenological changes in leaf chemistry and toughness may result in specialisation to different eucalypt species or groups of species by arthropod herbivores and their associated predators and parasites, (Recher *et al* 1996). Cork and Catling (1996) suggest that there may be threshold levels in nutrients that determine the ability of herbivorous arthropods to detoxify a eucalypt's chemical defences. Thus, arthropod richness may be increased as herbivores adapt to exploiting changing nutrient and toxin levels in eucalypt foliage as it matures and senesces (Recher *et al.* 1996). A consequence is that arthropod herbivores may not be able to detoxify the suite of chemical defences of eucalypts encountered outside their normal distribution. Such trees should therefore have poorer arthropod communities and be less attractive to birds and other vertebrates than local or indigenous species planted on the same site.

3.0 Methods

3.1 Tree species and site descriptions

Trees for arthropod sampling were selected from revegetation and remnant native vegetation near Northam (31° 39'S, 116° 40'E), Western Australia (Figure 1). We sampled eight species of eucalypts and jam wattle *Acacia acuminata* in planted areas. To obtain a measure of resident arthropod communities for comparison with revegetation, wandoo trees were sampled in both revegetation and remnant vegetation.

Trees were located at the following sites:

- **Northam Commons** - previously pasture that had been cleared and then planted with trees and shrubs between 1989 and 1991;
- **Meenar roadside** tree plantings alongside Great Eastern Hwy on the eastern side of Northam - a narrow strip of trees planted between the road and fenced pastures;
- **Grass Valley turnoff** - small group of planted flooded gum *E. rudis*;
- **Aphylla Road** off the Great Eastern Hwy - a remnant roadside stand of wandoo located opposite the Northam commons; and
- **Watson Road** off the Great Eastern Hwy - a remnant wandoo woodland.

Four species were native to the Northam District; flooded gum, wandoo, York gum *E. loxophleba* subsp. *loxophleba*, and jam wattle (Brooker and Kleinig 1990). The remaining four eucalypts occur in the Northam District only as planted trees; *E. spathulata spathulata*, *E. platypus heterophylla*, *E. anceps*, and *E. leucoxylon leucoxylon*. *E. s. spathulata* is widespread in southwest Australia, occurring in the southern wheatbelt and subcoastal plains of southern Western Australia. *E. platypus heterophylla* is restricted to the south coast of Western Australia. *E. anceps* is widespread in southern coastal and subcoastal areas and the southern wheatbelt of Western Australia. It extends east into South Australia. *E. l. leucoxylon* is widespread on the plains and ranges of coastal South Australia. *E. victrix* (coolibah) is a northern box occurring on the flood plain and riparian zone of the Murchison River and the Pilbara. It extends into the Northern Territory (Brooker and Kleinig 1994).

Ten 2-6 m high trees of each species were selected for sampling. *E. leucoxylon* was in flower at the time of sampling, but the other species were not. To obtain a measure of foliage volume, we recorded the height and diameter of the canopy of each tree sampled. In addition, anecdotal notes were made on the health of each tree.

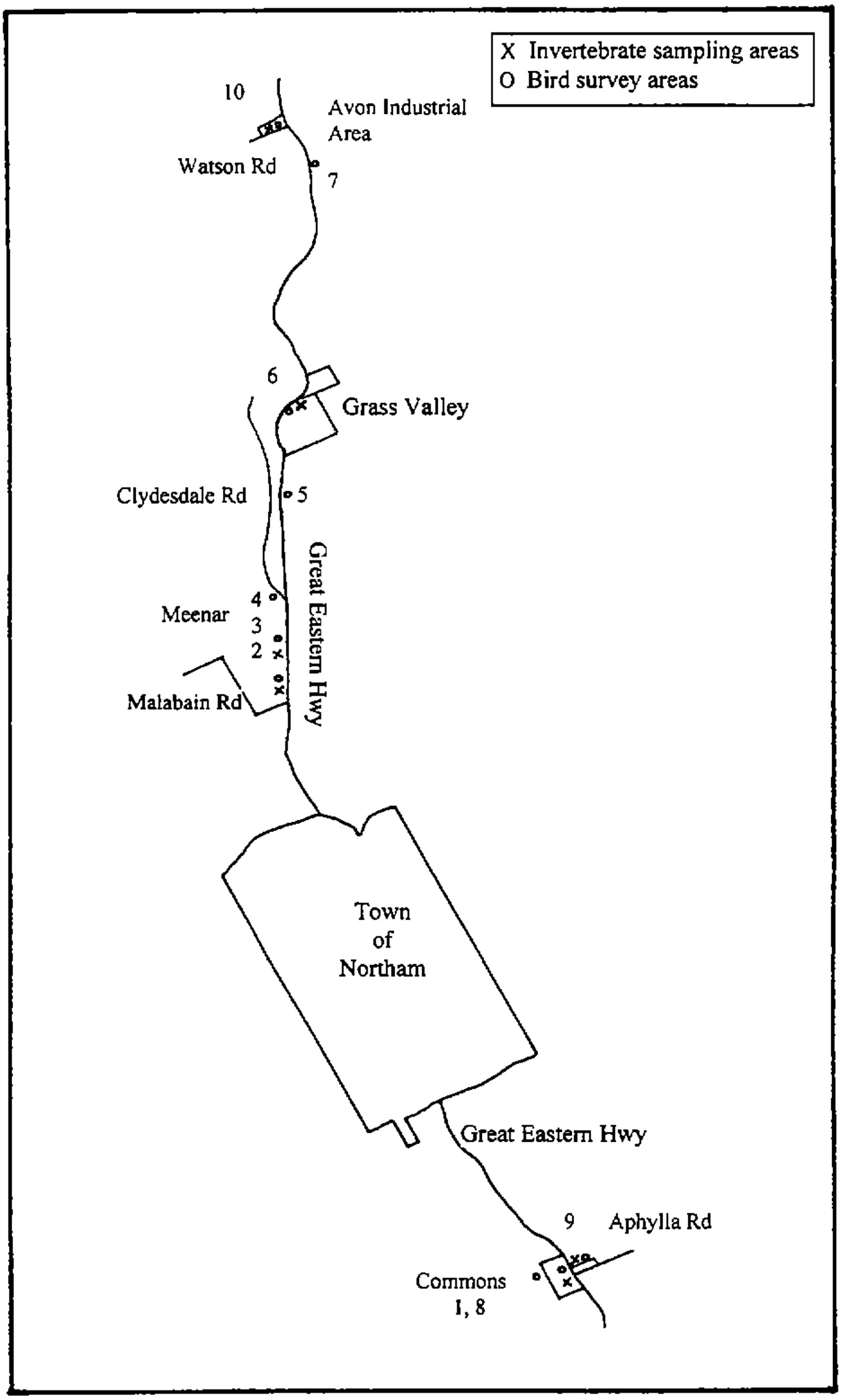

Figure 1. Map of the Shire of Northam showing invertebrate sampling areas and bird survey areas. Code to areas: (plantings) 1 = Commons, 2 = Meenar 1, 3 = Meenar 2, 4 = Meenar 3, 5 = Grass Valley 1, 6 = Grass Valley 2, 7 = Avon Industrial Area; (remnants) 8 = Commons, 9 = Aphylla Rd, and 10 = Watson Rd.

3.2 Bird survey

Birds were surveyed during June 2000 at ten sites along the Great Eastern Highway in the same areas as trees were sampled for invertebrates (Figure 1); seven were in revegetation on the road verge, two were in remnant vegetation on the road verge, and one in a woodland remnant.

Sites were:

- **Northam Commons** – one site within revegetation of mostly non-local tree species and one within remnant marri woodland with jam wattle and *Allocasuarina* sp.;
- **Meenar roadside** revegetation – three sites within revegetation on along the Great Eastern Hwy, near Malabaine Road. Trees were a mix of mostly local species, with some non-local species;
- **Grass Valley turnoff** – two sites within revegetation on the verge of the Great Eastern Hwy;
- **Avon Industrial Estate** – one site within revegetation of mostly local species with some understorey;
- **Watson Road** off the Great Eastern Hwy – remnant wandoo woodland; and
- **Aphylla Road** off the Great Eastern Hwy– remnant wandoo woodland on the road verge.

The revegetation sampled for birds was approximately 10 years old and varied in width between 22 and 68 m. Remnant sites varied between 15 and 100 m in width. The average height of revegetation was 5 to 8 m. Remnant vegetation was between 9 and 12 m in height. Canopy cover was similar between all sites, and ranged between 22 and 44 %. There were fewer shrubs in the revegetation than in remnants.

At each site a 20 m x 50 m plot was marked out. Each plot was surveyed for birds on four consecutive days (twice in the morning between 6:30 - 9:30 am, and twice in the afternoon between 3:00 - 6:00 pm) and all birds seen or heard within the plot during a 30 minute period were recorded. The same observer completed all surveys. During surveys, the observer moved back and forth over the plot taking care not to record the same birds twice. The sequence of sampling plots was at random.

3.3 Invertebrate sampling

Sampling was carried out between 17 and 27 October 1999. Samples were taken in the morning to avoid the hottest part of the day. Each of the 10 trees of each species was sampled by placing two lengths of calico sheeting (4 x 1.5 m) on the ground beneath the canopy, and held there in place by metal pegs (Plate 1). Undergrowth was cleared from beneath each tree so that the sheets could lie flat. The entire canopy was sprayed with a pyrethrin pesticide (Dominex ®) using a Stihl ® petrol-driven mist sprayer (Plate 2). After one hour, trees were shaken to dislodge remaining arthropods and then sheets were folded and taken to the laboratory. Invertebrates were removed from the sheets in the laboratory and placed in vials containing 70% ethanol for later sorting and identification.

3.4 Analysis of foliar nutrient content

Foliage was collected from each individual tree prior to invertebrate sampling. Equal numbers of what were judged to be mature leaves were clipped from the upper and lower

Plate 1. Preparation of a tree for arthropod sampling.

Plate 2. Spraying equipment used for arthropod sampling.

canopy and stored in paper bags, oven dried at 60^0 C to constant weight, and then ground with a Wiley-type mill with a 1 mm sieve for subsequent analysis of nutrients. Upper and lower canopy leaves from each tree were mixed and subsampled for analyses. Samples from each tree were then analysed, resulting in 10 replicated measures. Samples for each tree were analysed for Kjeldahl nitrogen, total phosphorus and total potassium. Samples for the analysis of potassium and phosphorus were digested using a perchloric acid procedure, and for nitrogen using a Technicon ® BD-40 digestion procedure. Potassium levels were then measured on a Varian AA 1475 atomic absorption spectrophotometer. Nitrogen and phosphorus levels were analysed after digestion using a Technicon ® Autoanalyser II. For nitrogen, a phenolic procedure was used and for phosphorus, the molybdenum blue technique was followed.

3.5 Leaf hardness

In July 2000, foliage was collected from 10 individuals of each tree species previously sampled for invertebrates, including wandoo growing in revegetation and remnants. Ten branchlets were selected randomly from the upper and lower canopy of each tree in order to have 100 replicate leaves for each tree species. These were stored with their stems in water to prevent leaves drying out until measurements were made the next day. From each of 10 branchlets, the fifth mature leaf from the tip was selected for measurement. Leaf toughness was measured at two places either side of the mid-vein in the centre of each leaf using a Sonopenetrometer (Suresh Chand and Muralirangan 1999). This device involves weighing the amount of sand granules needed for a needle to penetrate the leaf surface, which is indicated by a sounding buzzer. The weight of the sand granules needed to penetrate the leaf is proportional to the leaf toughness. The two measurements for each leaf were averaged and means were obtained for each tree species.

3.6 Data analyses

Arthropods were sorted and counted according to ordinal level and body length classes (Table 1). Body length excludes antennae, cerci or ovipositors. Larvae were recorded separately from adults for endopterygote orders. Means and standard errors of each invertebrate taxon, body length class, foliar nutrient content (NPK) and leaf hardness for each tree species were then calculated. Tree counts were transformed to $\log_{10}$ (1 + the number of animals) and foliar nutrient contents were transformed to $\log_{10}$ to stabilise the variances and justify normality.

Table 1. Body length classes to which the invertebrates were assigned.

Class	Body length (mm)
1	< 0.5
2	0.5 – 1.0
3	1.0 – 2.0
4	2.0 – 3.0
5	3.0 – 4.0
6	4.0 – 5.0
7	5.0 – 10.0
8	> 10.0

For each tree species, an estimate of arthropod biomass was calculated using the length-weight relationships of eucalypt forest invertebrates described by Gowing and Recher (1984). A power model was used to convert the abundance of arthropods in each body length class to weight, and the eight classes were totalled to give a total weight (mg dry weight). This model is suitable for all taxa in cases where the precision of biomass estimation is not required to be great (Gowing and Recher 1984).

The possibility of calibrating invertebrate catches to compensate for differences in tree size was considered. A pilot regression analysis of tree canopy volume (m^3) and numbers of invertebrates showed conflicting trends and few significant differences among tree species (Figure 2). Regressions of tree height, canopy height, and mean canopy diameter with total invertebrates showed similar results. It is likely that the standardised calico sheet size used to sample invertebrates compensated for tree size and a correction for tree size was not justified

The total invertebrates per order, total invertebrates per body length class, foliar nutrient content (NPK) and leaf hardness were compared between tree species using one-way analysis of variance. Those means which were significantly different from each other were detected using Tukey's pairwise comparisons ($p < 0.05$). The abundance of arthropods within each separate order was ranked and the overall ranking of these values was compared using Kendall's coefficient of concordance. Numbers of birds species were compared between remnants and revegetation by paired t-tests.

4.0 Results

4.1 Trends in arthropod abundance

The mean number of arthropods per order and the overall totals for each tree species are shown in Table 2. *E. spathulata* supported the greatest number of arthropods, and *E. anceps* the lowest, 1523 and 255 individuals respectively. When the overall rank was calculated, which was significant at $p < 0.05$ ($W = 0.22$ all taxa, $W = 0.39$ excluding low represented taxa), the ranked order of tree species changed. Planted *E. wandoo* attained the highest rank of ordinal abundance and, in comparison, naturally-occurring *E. wandoo* ranked seventh. *E. rudis* and *E. platypus* ranked equally second in ordinal abundance, although *E platypus* had fewer arthropods. Even though *E. spathulata* had the greatest arthropod abundance, it ranked fourth. *A. acuminata* ranked fifth, within the middle of the eucalypts. Three of the five species with the greatest ordinal abundances are native to the Northam District. Of the four eucalypts with the lowest abundances, three were introductions, while *E. loxophleba* occurs naturally in the District.

Overall, the most abundant taxa were Homoptera, Hymenoptera (bees and wasps), Hymenoptera (ants), Diptera, Araneae (spiders), Thysanoptera, Coleoptera (adults), and Heteroptera in that order. Of the 19 taxa which were abundant enough to test, 16 differed in abundance between tree species (Table 2). There was no difference in the abundance of Arthropleona and Symphypleona (Collembola) and adult Lepidoptera between tree species. Rare taxa, such as Pseudoscorpiones, Isopoda, and Mantodea, were not included in analyses.

Diptera, Araneae and Psocoptera were significantly more abundant on *E. spathulata* than most other tree species (Table 2). Hemiptera and Aranaeae were more abundant on *E. leucoxylon*, while Blattodea were more abundant on *E. wandoo*. *E. loxophleba* had the most abundant ant (Hymenoptera) fauna. Homoptera were most abundant on *E. rudis*, although

Figure 2. Relationships between tree canopy volume (m^3) and numbers of invertebrates sampled per knockdown sample of the 10 tree species. The relationships are significant for *E. rudis*, *E. platypus* and *E. victrix*.

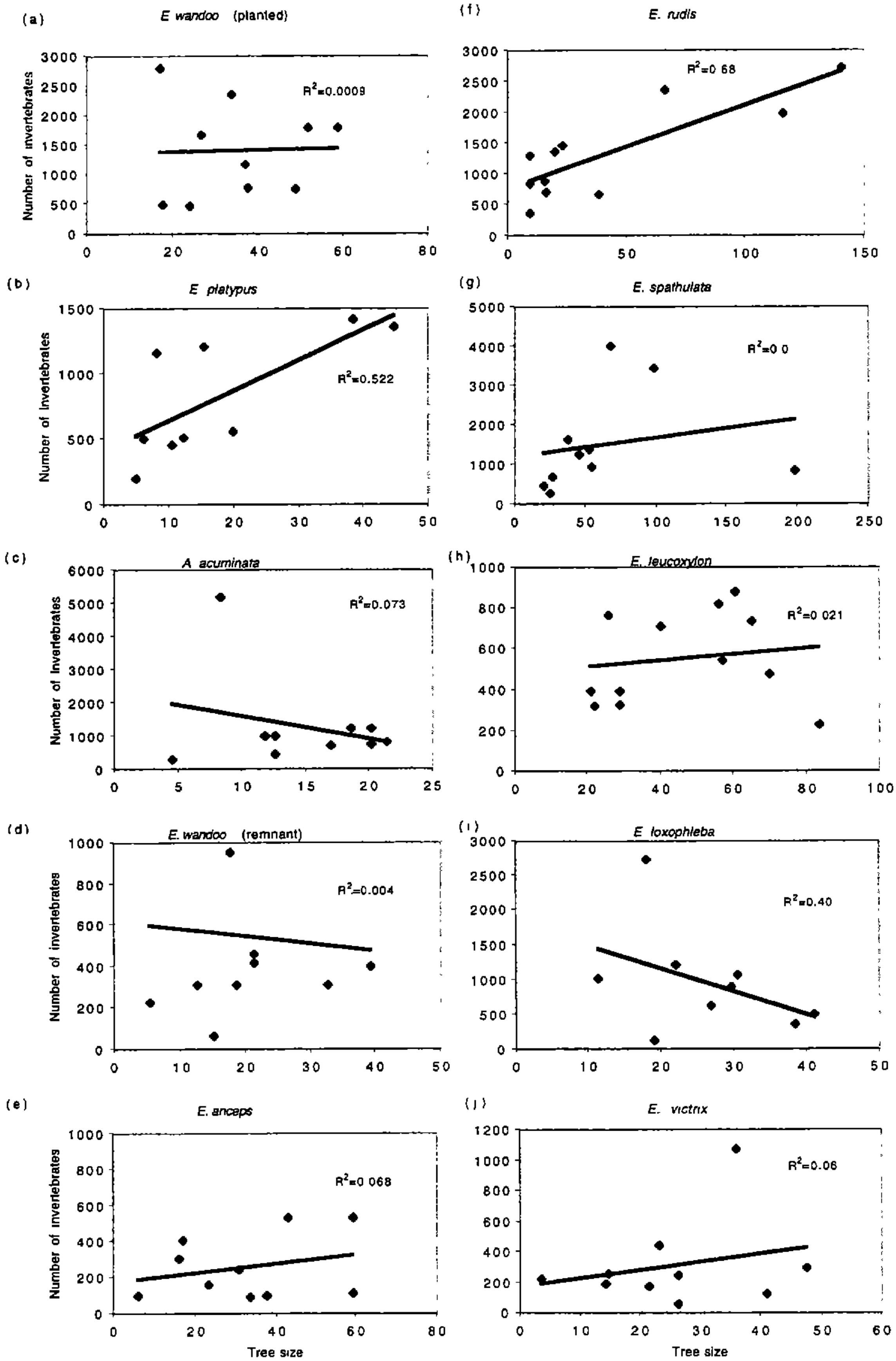

Table 2. Mean numbers and SE of arthropod taxa, body length class and biomass per tree, sampled during October 1999 by chemical knockdown. Means for each species were compared using analysis of variance (ANOVA). Means annotated by different letters indicate that they are significantly different from each other.

Species		*E. wandoo* (planted)			*E. rudis*			*E. platypus*			*E. spathulata*			*A. acuminata*		
Taxon		Mean	SE	Sig.	Mean	SE	Sig.	Mean	SE	Sig.	Mean	SE	Sig.	Mean	SE	Sig.
Gastropoda		0.0	0.0	–	0.0	0.0	–	0.0	0.0	–	0.0	0.0	–	0.1	0.0	–
Araneae		121.3	35.3	bc	90.4	20.2	abc	138.7	22.8	c	163.6	26.9	c	59.2	9.4	abc
Pseudoscorpiones		0.0	0.0	–	0.0	0.0	–	0.1	0.0	–	0.0	0.0	–	0.0	0.0	–
Acarina		5.0	1.4	abc	5.8	2.2	abc	11.9	7.0	abc	4.2	1.0	abc	10.4	2.3	c
Isopoda		0.0	0.0	–	0.0	0.0	–	0.0	0.0	–	0.0	0.0	–	0.0	0.0	–
Polyxenida		0.0	0.0	–	0.0	0.0	–	0.0	0.0	–	0.0	0.0	–	0.0	0.0	–
Arthropleona		0.7	0.2	a	3.4	2.4	a	1.2	0.4	a	2.6	2.0	a	0.3	0.2	a
Symphypleona		1.3	0.8	a	1.1	0.4	a	1.6	1.0	a	0.1	0.0	a	0.5	0.2	a
Thysanura		0.9	0.4	–	0.2	0.0	–	0.4	0.0	–	0.0	0.0	–	0.0	0.0	–
Odonata		0.0	0.0	–	0.1	0.0	–	0.0	0.0	–	0.7	0.0	–	0.2	0.0	–
Blattodea		6.8	1.8	c	5.1	1.9	bc	3.3	1.3	bc	6.2	2.8	bc	0.0	0.0	–
Mantodea		0.2	0.0	–	0.0	0.0	–	1.1	0.8	–	0.7	0.5		0.2	0.0	–
Isoptera		1.3	1.8	–	0.0	0.0	–	0.0	0.0	–	0.0	0.0	–	0.0	0.0	–
Dermaptera		0.0	0.0	–	0.0	0.0	–	0.0	0.0	–	0.1	0.0	–	0.1	0.0	–
Orthoptera		1.0	0.5	ab	1.4	0.5	ab	1.4	0.6	ab	0.9	0.3	ab	0.0	0.0	a
Phasmatodea		0.2	0.0	–	0.0	0.0	–	0.3	0.2	–	0.0	0.0	–	0.0	0.0	–
Psocoptera		68.3	17.7	cd	42.8	11.9	cd	24.7	6.2	bc	110.5	23.9	d	26.6	12.1	bc
Hemiptera	Homoptera	275.9	59.4	c	281.4	72.9	c	193.7	51.3	bc	155.4	23.0	bc	252.7	101.9	bc
Hemiptera	Heteroptera	14.7	6.8	bc	18.2	6.3	c	8.2	3.9	abc	4.9	1.4	abc	99.3	45.8	d
Thysanoptera		104.0	38.8	bc	151.0	59.0	c	138.1	58.9	c	56.6	10.5	abc	161.4	68.2	c
Neuroptera	adults	12.3	3.5	b	6.5	4.0	ab	6.7	3.2	ab	5.7	2.2	ab	3.3	1.5	ab
Neuroptera	larvae	2.4	0.4	b	1.6	1.6	ab	1.1	0.3	ab	0.9	0.4	ab	1.0	1.3	ab
Coleoptera	adults	76.2	15.2	c	72.6	16.0	c	35.4	7.4	c	68.2	21.2	c	70.3	20.0	c
Coleoptera	larvae	4.6	1.6	a	7.0	3.2	a	6.0	2.5	a	0.5	0.4	a	1.7	0.3	a
Mecoptera	adults	0.4	0.4	–	0.2	0.0	–	0.4	0.0	–	0.5	0.2	–	0.5	0.7	–
Diptera	adults	182.9	58.1	cd	147.1	19.0	cd	98.6	20.6	cd	512.3	235.8	d	97.3	44.7	bc
Diptera	larvae	0.3	0.0	–	0.0	0.0	–	0.1	0.0	–	0.1	0.0	–	0.3	0.0	–
Trichoptera		0.0	0.0	–	0.1	0.0	–	0.0	0.0	–	0.0	0.0	–	0.0	0.0	–
Lepidoptera	adults	1.1	0.4	a	1.1	0.2	a	2.8	1.2	a	1.9	0.6	a	0.7	0.2	a
Lepidoptera	larvae	9.5	2.7	abc	14.7	6.0	abc	7.2	2.1	abc	4.8	2.4	ab	18.2	6.3	bc
Hymenoptera	bees, wasps	206.2	49.0	cd	194.8	44.1	cd	121.1	25.0	abcd	205.7	62.3	bcd	373.9	152.6	d
Hymenoptera	ants	302.5	102.3	d	282.9	124.7	d	14.8	3.9	abc	216.9	71.4	d	89.7	29.1	cd
Total		1400.0	255.5		1329.5	226.5		819.0	153.4		1523.5	391.6		1267.9	446.6	
Best Rank		1			2.5			2.5			4			5		
Body length	0-0.5mm	28.3	25.6	a	19.5	6.9	a	9.1	4.1	a	39.8	12.6	a	3.7	2.7	a
	0.5-1.0mm	126.1	27.6	bc	165.9	45.6	bc	118.2	33.6	bc	140.3	44.4	c	191.8	41.9	c
	1.0-2.0mm	537.0	96.8	c	454.2	60.2	c	328.1	56.2	bc	784.9	248.2	c	595.9	248.5	c
	2.0-3.0mm	528.6	132.2	c	511.7	131.7	c	224.9	50.1	bc	422.3	133.5	c	348.9	127.7	bc
	3.0-4.0mm	60.2	11.9	c	91.0	24.5	c	68.4	16.6	c	68.9	21.8	c	67.7	24.9	c
	4.0-5.0mm	48.7	12.1	c	36.7	9.8	bc	25.3	5.7	bc	28.1	8.9	bc	31.7	7.5	bc
	5.0-10.0mm	61.9	15.7	c	42.3	13.2	bc	40.3	6.8	bc	37.7	11.9	bc	25.0	6.6	abc
	> 10.0mm	7.2	2.8	a	8.1	2.8	a	4.6	1.1	a	3.7	1.2	a	3.2	0.9	a
Biomass (mg)		646.0	121.1	b	378.7	126.4	b	390.7	65.7	b	438.7	89.7	b	372.4	110.8	b

Species		*E. leucoxylon*			*E. wandoo* (remnant)			*E. loxophleba*			*E. anceps*			*E. victrix*				
Taxon		Mean	SE	Sig.	Mean	SE	Sig.	Mean	SE	Sig.	Mean	SE	Sig.	Mean	SE	Sig.	F	P
Gastropoda		0.0	0.0	–	0.0	0.0	–	0.0	0.0	–	0.0	0.0	–	0.0	0.0	–		NT
Araneae		108.1	15.1	bc	67.1	15.0	abc	55.8	20.8	ab	54.3	14.2	ab	33.0	5.1	a	5.25	<0.001
Pseudoscorpiones		0.0	0.0	–	0.0	0.0	–	0.0	0.0	–	0.0	0.0	–	0.0	0.0	–		NT
Acarina		9.4	3.7	bc	9.2	4.7	bc	0.6	0.7	a	3.1	4.1	ab	1.7	1.4	ab	4.05	<0.001
Isopoda		0.0	0.0	–	0.1	0.0	–	0.0	0.0	–	0.0	0.0	–	0.0	0.0	–		NT
Polyxenida		0.1	0.0	–	0.0	0.0	–	0.0	0.0	–	0.0	0.0	–	0.0	0.0	–		NT
Arthropleona		2.3	0.7	a	1.1	0.7	a	0.2	0.0	a	0.9	1.1	a	1.5	1.0	a	1.18	NS
Symphypleona		2.2	1.1	a	0.1	0.0	a	0.2	0.0	a	2.2	0.8	a	0.9	0.4	a	1.85	NS
Thysanura		0.3	0.2	–	0.2	0.0	–	0.0	0.0		0.0	0.0	–	0.0	0.0	–		NT
Odonata		0.0	0.0	–	0.0	0.0	–	0.0	0.0	–	0.0	0.0	–	0.0	0.0	–		NT
Blattodea		3.0	0.5	bc	8.3	4.6	c	1.4	0.4	abc	0.1	0.0	a	0.8	0.4	ab	5.87	<0.001
Mantodea		0.6	0.4	–	0.0	0.0	–	0.0	0.0		0.1	0.0	–	0.3	0.2	–		NT
Isoptera		0.2	0.0	–	0.3	0.0	–	0.0	0.0	–	0.0	0.0	–	0.0	0.0	–		NT
Dermaptera		0.0	0.0	–	0.5	0.2	–	0.1	0.0	–	0.0	0.0	–	0.0	0.0	–		NT
Orthoptera		2.4	0.4	b	1.3	0.8	ab	0.3	0.2	a	0.1	0.0	a	1.0	0.7	ab	3.28	<0.005
Phasmatodea		0.2	0.0	–	0.0	0.0	–	0.0	0.0	–	0.2	0.0	–	0.0	0.0	–		NT
Psocoptera		47.2	13.1	cd	7.5	1.9	ab	20.6	3.4	bc	13.9	5.3	ab	6.2	2.0	a	9.09	<0.001
Hemiptera	Homoptera	113.0	15.1	abc	100.7	46.2	ab	155.8	35.9	abc	55.9	15.9	a	56.3	9.6	ab	5.02	<0.001
Hemiptera	Heteroptera	5.3	1.0	abc	13.8	6.0	bc	8.7	4.0	abc	1.2	0.5	a	2.8	2.4	ab	8.49	<0.001
Thysanoptera		42.6	12.2	abc	56.9	14.6	abc	46.2	8.2	abc	25.8	6.1	a	26.6	6.9	ab	4.01	<0.001
Neuroptera	adults	7.2	3.2	ab	3.8	4.0	ab	1.9	0.9	ab	0.8	0.3	ab	0.6	0.3	a	2.41	<0.05
Neuroptera	larvae	0.9	0.1	ab	1.5	0.9	ab	0.4	0.2	ab	0.3	0.0	a	0.2	0.0	a	2.16	<0.05
Coleoptera	adults	27.5	5.2	bc	60.0	11.7	c	36.4	10.0	c	4.9	1.0	a	12.1	3.2	ab	10.54	<0.001
Coleoptera	larvae	4.1	0.8	a	5.2	2.7	a	2.6	0.9	a	0.8	0.3	a	1.2	0.3	a	2.48	<0.05
Mecoptera	adults	0.3	0.0	–	0.0	0.0	–	0.1	0.0	–	0.0	0.0	–	0.0	0.0	–		NT
Diptera	adults	81.3	14.9	bcd	25.4	8.3	ab	47.6	8.8	abc	24.7	7.7	a	33.8	11.8	ab	9.54	<0.001
Diptera	larvae	0.3	0.4	–	0.5	0.7	–	0.0	0.0	–	0.0	0.0	–	0.0	0.0	–		NT
Trichoptera		0.0	0.0	–	0.0	0.0	–	0.0	0.0		0.0	0.0	–	0.0	0.0	–		NT
Lepidoptera	adults	1.2	0.4	a	0.4	0.2	a	0.8	0.3	a	1.0	0.5	a	0.2	0.0	a	1.62	NS
Lepidoptera	larvae	4.1	1.0	ab	17.1	4.1	c	5.6	1.6	abc	3.8	1.3	abc	1.9	0.4	a	3.54	<0.001
Hymenoptera	bees, wasps	70.3	7.1	ab	30.0	10.4	a	127.8	32.0	abcd	56.8	13.0	a	115.7	67.9	ab	6.94	<0.001
Hymenoptera	ants	15.3	6.4	ab	112.9	81.1	bcd	429.1	226.9	d	5.0	3.7	a	9.3	3.8	ab	8.88	<0.001
Total		349.0	64.6		543.9	177.1		942.1	251.1		255.9	56.3		306.1	90.9			
Best Rank		6			7			8			9			10				
Body length	0-0.5mm	10.3	6.4	a	11.9	6.8	a	6.3	4.1	a	2.0	1.1	a	6.8	2.7	a	1.98	NS
	0.5-1.0mm	74.9	10.6	abc	41.6	10.1	ab	108.7	31.0	abc	31.0	6.4	a	91.3	36.9	abc	4.82	<0.001
	1.0-2.0mm	222.7	30.3	abc	185.8	52.0	ab	392.6	170.4	abc	119.7	26.5	a	138.1	38.7	a	6.66	<0.001
	2.0-3.0mm	132.7	22.7	abc	162.4	97.0	ab	379.2	79.5	c	63.0	20.9	a	43.0	10.8	a	9.25	<0.001
	3.0-4.0mm	36.1	7.6	bc	50.1	14.5	bc	19.4	6.5	ab	16.4	5.0	ab	9.3	3.3	a	7.73	<0.001
	4.0-5.0mm	29.5	4.5	bc	29.1	8.0	bc	11.3	4.6	ab	5.8	2.5	a	5.3	2.2	a	8.08	<0.001
	5.0-10.0mm	38.1	9.1	bc	55.1	13.0	c	21.1	7.7	abc	17.5	5.4	ab	10.8	2.8	a	4.00	<0.001
	> 10.0mm	4.8	0.7	a	6.2	2.3	a	3.4	1.2	a	1.6	0.4	a	1.5	0.5	a	1.99	NS
Biomass (mg)		336.9	54.4	b	438.7	125.9	b	301.9	61.2	b	137.2	34.5	a	101.2	29.1	a	6.94	<0.001

Table 3. Mean values and SE of leaf hardness and foliar nutrient levels (mg g^{-1} dry weight) of each nitrogen, phosphorous and potassium per tree. Means for each species were compared using analysis of variance (ANOVA). Means annotated by different letters indicate that they are significantly different from each other.

Species		*E. wandoo* (planted)			*E. rudis*			*E. platypus*			*E. spathulata*			*A. acuminata*			*E. leucoxylon*			*E. wandoo* (remnant)			*E. loxophleba*			*E. anceps*			*E. victrix*				
		Mean	SP	Sig	Mean	SE	Sig	Mean	SE	Sig	Mean	SE	Sig.	Mean	SE	Sig	Mean	SE	Sig.	Mean	SE	Sig	Mean	SE	Sig	Mean	SE	Sig	Mean	SE	Sig	F	P
Leaf hardness		45.07	1.176	bc	38.71	1.176	a	49.91	1.176	c	47.38	1.176	bc	43.1	1.176	b	46.55	1.176	bc	47.24	1.176	bc	54.93	1.176	d	57.98	1.176	d	35.33	1.176	a	32.42	<0.001
Nutrient	Nitrogen	0.96	0.04	a	1.33	0.30	ab	1.10	0.39	ab	1.03	0.05	ab	2.77	0.12	c	1.35	0.25	b	1.12	0.03	ab	1.40	0.12	b	1.15	0.51	ab	1.38	0.06	b	14.38	<0.001
	Phosphorous	0.11	0.02	bc	0.12	0.03	bc	0.08	0.02	ab	0.09	0.01	bc	0.12	0.01	bc	0.09	0.02	bc	0.05	0.00	a	0.15	0.02	c	0.09	0.04	bc	0.07	0.00	ab	4.64	<0.001
	Potassium	0.41	0.02	ab	0.49	0.15	abc	0.42	0.14	ab	0.38	0.02	ab	0.61	0.05	cd	0.48	0.09	bc	0.39	0.01	ab	0.34	0.03	c	0.30	0.16	a	0.75	0.05	d	13.8	<0.001

similar numbers of Homoptera occurred on planted *E. wandoo*. Planted *E. wandoo* also had the greatest numbers of Neuroptera (adults and larvae) and Coleoptera (adults). Planted *E. wandoo* differed from wandoo growing in remnant native vegetation in having significantly greater numbers of Pscoptera, Homoptera, Diptera (adults), and Hymenoptera (bees and wasps) (Table 2). Heteroptera, Thysanoptera, Hymenoptera (bees and wasps) were more abundant on *A. acuminata* than on *Eucalyptus* species. *Acacia* also had a high number of Homoptera.

4.2 Arthropod biomass

Mean arthropod biomass for tree species is shown in Table 2. Arthropod biomass values on *E. anceps* and *E. victrix* were significantly lower than on all other tree species, with mean weights of 137.2 and 103.2 mg respectively. Planted *E. wandoo* had the largest biomass of arthropods (646 mg). However, this was not significantly greater than for the remaining species or for wandoo in remnant vegetation. Abundances of arthropods in each body length class did not vary greatly between species. Generally, those species which ranked lowest had smaller abundances in each size class. For all tree species, the majority of arthropods fell between 1.0 – 3.0 mm in length. Neither the smallest (< 0.5 mm) nor the largest (> 10.0 mm) body length classes differed between tree species (Table 2).

4.3 Foliar nutrients and leaf hardness

A. acuminata had significantly higher levels of foliar nitrogen than the eucalypts ($p < 0.001$). Among the eucalypts, planted *E. wandoo* had higher levels of foliar nitrogen than *E. leucoxylon*, *E. loxophleba* and *E. victrix*. *E. wandoo* growing in remnants had lower levels of foliar phosphorus than *A. acuminata*, *E. spathulata* and *E. rudis*. The difference was significant at $p < 0.001$. *E. loxophleba* had higher levels of foliar phosphorus than *E. platypus*. *A. acuminata*, *E. loxophleba* and *E. victrix* had higher levels of foliar potassium than *E. wandoo* (planted and growing in remnants), *E. platypus*, *E. spathulata* and *E. anceps* ($p < 0.001$). *E. victrix* also had higher levels of foliar potassium than *E. rudis*. *E. victrix* and *E. rudis* had leaves that were softer than other species, while *E. loxophleba* and *E. anceps* had harder leaves than other species (Table 2). There was no relationship between nitrogen content and leaf hardness; tree species with the highest nitrogen levels did not have the softest leaves.

4.5 Avifauna

Twenty-five species of birds were recorded during the survey (Table 4). Ten species were recorded at six or more sites, while 10 were recorded at only one or two sites (Table 4). Of the 25 species, 16 were recorded in the remnant native vegetation and on the revegetated sites. Six species were recorded only in the revegetation and three only in remnant vegetation (Table 4). Bird species richness was higher in the remnants (12.6 species $\pm$ 4.0) than in the revegetation (8.0 $\pm$ 2.6), although the difference was not significant ($t = 1.38$, $p = 0.2$) (Figure 3a). All foraging guilds were represented in both remnants and revegetation (Table 4) and there was no difference in the number of foliage insectivores between remnants and revegetation ($F = 0.57$, $p = 0.5$) (Figure 3b).

Table 4. Mean counts (+/-SD) of bird species recorded within each 30 minute survey at each site.

Common name	Scientific name	Major foraging guild (#)	Remnant sites: Commons	Remnant sites: Aphylla Rd	Remnant sites: Watson Rd	Replanted sites: Commons	Replanted sites: Meenar 1	Replanted sites: Meenar 2	Replanted sites: Meenar 3	Replanted sites: Grass V 1	Replanted sites: Grass V 2	Replanted sites: Avon Ind.
Black-shouldered Kite	*Elanus axillaris*	Predator, Insectivore				0.5 (0.6)				0.5 (0.6)		
Painted Button-quail	*Turnix varia*	Seed eater, Insectivore (ground)					1.2(1.5)					
Crested Pigeon	*Ocyphahps lophotes*	Seed eater	0.8(1.5)						0.2(0.5)	0.5(1.0)	0.5(1.0)	1.5(3.0)
Galah	*Cactua roseicaplila*	Seedeater										0.8(1.5)
Port Lincoln Parrot	*Barnardius zonarius*	Seed eater, Frugivore	1.2(1.5)	2.2(1.7)	1.5(1.0)		1.2(1.5)	0.5(1.0)	0.7(1.5)	0.2(0.5)	1.2(1.5)	1.0(2.0)
Striated Pardalotte	*Pardalotus striatus*	*Insectivore (foliage gleaner)					0.2(0.5)			1.0(1.5)	2.5(2.1)	0.5(1.0)
Spotted Pardalotte	*Pardalotus punctatus*	*Insectivore (foliage gleaner)		0.2(0.5)								
Western Warbler	*Gerygone fusca*	*Insectivore(foliage gleaner)	1.0(0.8)		1.2(0.9)	0.2(0.5)	1.2(0.9)	0.2(0.5)	1.8(0.5)	0.5(0.6)	0.5(1.0)	0.5(0.5)
Yellow-rumped Thornbill	*Acanthiza chrysorrhoa*	Insectivore (ground gleaner)	1.2(1.5)	1.5(1.0)	0.7(1.5)	1.2(1.5)	2.8(1.9)	1.0(1.4)		1.8(2.1)	1.8(3.5)	
Weebill	*Smicrornis brevirostris*	*Insectivore (foliage gleaner)	2.2(1.7)		6.0(2.1)	1.8(2.0)	6.2(2.2)	4.5(2.1)	4.2(3.5)	3.5(2.6)	3.8(2.0)	2.2(2.9)
Red Wattlebird	*Anthochaera carunculata*	*Nectar feeder, Insectivore	1.0(0.8)	0.8(0.9)			0.2(0.5)					
Singing Honeyeater	*Lichensostomus virescens*	*Nectar feeder, Insectivore	1.2(0.5)			1.5(1.0)	0.5(1.0)		0.8(0.9)	0.5(0.6)	1.5(1.0)	0.5(0.6)
Brown-headed Honeyater	*Melithreptus brevirostris*	*Insectivore (bark prober), Nectar feeder		0.8(1.5)							0.8(1.5)	1.0(1.2)
Brown Honeyeater	*Lichmera indistincta*	*Nectar feeder, Insectivore	1.2(1.5)	1.0(2.0)	0.5(0.6)	2.5(1.9)	1.5(1.0)	1.8(0.5)	0.2(0.5)	2.2(0.5)	2.2(1.5)	2.5(0.6)
Red-capped Robin	*Petroica goodenovii*	Insectivore (ground pouncer)			0.2(0.5)					0.2(0.5)		
White-browed Babbler	*Pomatostomus supercilosus*	Insectivore (ground)			0.8(1.5)							
Rufous Whistler	*Pachycephala rufiventris*	*Insectiore (foliage snatcher)	1.0(0.8)		0.5(1.0)		0.2(0.5)	0.2(0.5)			0.5(0.6)	0.2(0.5)
Grey Shrike-thrush	*Collurincla harmonica*	*Insectivore (bark gleaner)					0.25(0.5)					
Willie Wagtail	*Rhipidura leucophrys*	Insectivore (ground)	0.5(1.0)	0.2(0.5)	0.5(1.0)	0.2(0.5)	0.5(0.1)		0.2(0.5)	0.7(0.1)		
Grey Fantail	*Rhipidura fuliginosa*	Insectivore (aerial)	1.5(1.0)			0.8(0.9)	1.0(0.8)	0.5(0.6)	1.0(0.1)		1.0(1.2)	1.5(0.6)
Black-faced Cuckoo Shrike	*Coracina novaehollandiae*	*Insectivore (foliage snatcher), Frugivore	0.2(0.5)									
Australian Magpielark	*Grallina cyanoleuca*	Ground invertebrates									0.5(1.0)	
Australian Magpie	*Gymnorhina tibicen*	Insectivore (ground)	0.2(0.5)	0.2(0.5)	1.0(0.8)			0.5(1.0)	0.8(0.9)	0.5(1.0)		
Australian Raven	*Corvus coronoides*	Omnivore	0.2(0.5)				0.5(1.0)	0.8(1.5)		0.5(1.0)		0.5(0.6)
Mistloetoebird	*Dicaeum hirundinaceum*	*Frugivore, Insectivore (foliage gleaner)	0.5(1.0)								0.5(0.6)	
Total Number of Species			15	8	15	8	14	9	9	13	13	12

\# Classification as of Abbott (1999)

* Species considered to utilise foliage arthropods

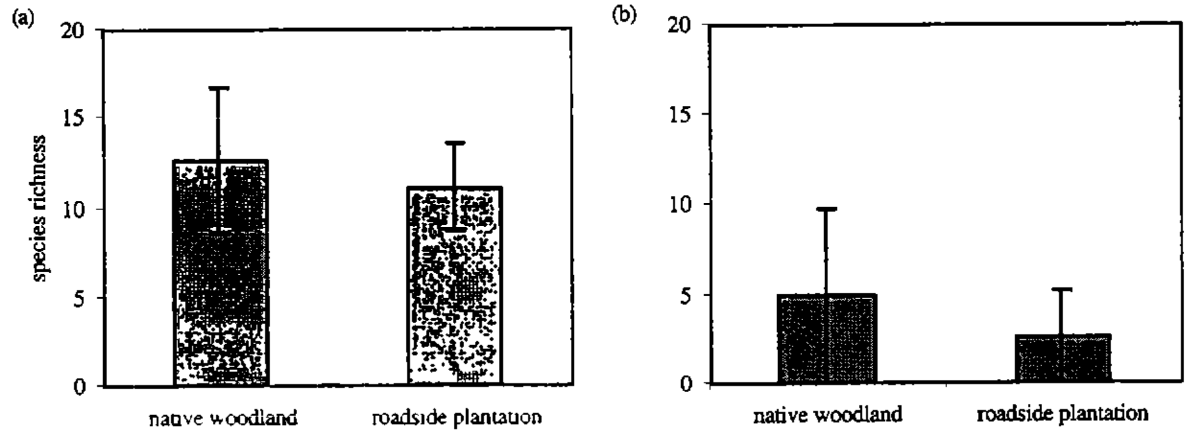

Figure 3. Mean numbers of (a) total bird species and (b) foliage feeding insectivores observed in native woodland (n=3) and roadside plantations (n= 7). t-tests showed no significant differences.

5.0 Discussion

5.1 Trees, arthropods and nutrients

All tree species used for revegetation at Northam supported moderate to high numbers of canopy arthropods, representing all the major taxa. Local species, primarily *E. wandoo, E. rudis* and *A. accuminata,* had relatively high abundances of individual orders, total arthropods and arthropod biomass. Among the species which did not occur naturally in the district, *E. spathulata* and *E. platypus* had relatively large arthropod populations, while *E. anceps* and *E. victrix* had significantly lower populations and arthropod biomass.

E. spathulata, while not native to the Northam District, has a wide distribution in the southwest. *E. platypus* has restricted distribution along the south coast of Western Australia (Brooker and Kleinig 1990), but has been widely planted in the wheatbelt. *E. anceps* also has a wide distribution in southern and coastal districts of Western Australia, while *E. victrix* only occurs naturally in the north of the state. Thus, there was a tendency for tree species which are more closely aligned to the Northam District in biogeographical terms to support higher invertebrate populations. These findings are consistent with Southwood's (1960) predictions that tree species that have been present for a long time in an area will support the greatest variety of arthropods.

However, it is clear that all the eucalypts sampled, regardless of geographic origin, provided habitat for invertebrates. We therefore conclude that revegetation programs of the types sampled at Northam make important contributions to the conservation and enhancement of regional biodiversity. In the instance of *E. wandoo,* the trees used for revegetation supported more invertebrates than individuals in remnant native vegetation. Reasons why invertebrate abundances differed between tree species or between revegetation and remnants are discussed briefly below, but the occurrence of an abundant and diverse invertebrate fauna on planted *E. wandoo* indicates that insects and spiders quickly locate trees in revegetation regardless of whether the trees are planted in blocks or strips, grouped in paddocks or spread out along road verges and fence lines. Majer *et al.* (1999) had previously reported abundant invertebrate faunas on remnant eucalypts in agricultural areas, with significant levels of biodiversity on trees in patches of remnant vegetation, along the edge of remnants, along roads, and as single paddock trees (see also Majer and Recher 2000).

There were differences between tree species and growing situations in canopy invertebrate communities. Some differences may be explained as differences between local and introduced species and the capacity of the indigenous fauna to use or adapt to trees from other regions. However, as demonstrated by the differences between *E. wandoo* in revegetation and remnant and by the abundant faunas on species such as *E. spathulata*, which do not naturally occur in the Northam District, this does not explain all the differences observed. It is possible that differences in palatability, as expressed by the levels of foliar nutrients and leaf toughness (hardness), might account for some of the differences between tree species and growing situations in their invertebrate faunas.

Although trees with higher nutrient levels tend to support higher number of invertebrates (Majer *et al.* 1992; Recher *et al.* 1996), there was no relationship between foliar nutrients and invertebrate abundances among the trees sampled at Northam. In particular, lower nitrogen levels did not appear to limit to arthropod biomass at Northam. For example, *E. wandoo* had one of the highest arthropod abundances and the lowest foliar nitrogen content.

As foliar nutrient levels were fairly high, it is possible that the limiting threshold of nutrient levels was exceeded in the trees sampled. It is also possible that, as relatively young trees, the revegetation directed most of its productivity into growth and less into biochemical defenses against insects. In this case, even relatively low foliar nutrients might be capable of sustaining high arthropod loads, as herbivores had less need of high nutrient levels to enable the detoxification of chemical defenses (*sensu* Cork and Catling 1996; Recher *et al.* 1996). Alternatively, the differences between tree species in arthropod numbers may result from a complex set of interactions between foliar nutrients, leaf hardness, and the tree's chemical defenses against herbivores. There may also be variation between species arising from seasonal factors, the growth stage of the tree, arthropod populations on nearby plants, availability of refugia for insects on the tree or nearby, abundance of predators such as birds, and chance or historical events. None of the interactions between these factors can be identified without considerable additional research. For example, Ohmart *et al.* (1987) reported that eucalypt foliage with high nitrogen levels tended to be softer (less hard) than foliage with low levels of nitrogen, but there was no relationship between leaf hardness and foliar nitrogen among the trees sampled at Northam. This may be typical of the species sampled or a result of the complex interplay of the factors discussed in relation to foliar nutrients and arthropod abundances, but we do not have the data to resolve these issues.

It is possible that revegetation and plantations provide more favourable habitats for arthropods than naturally occurring trees in remnants, especially if the soil has been enriched by fertiliser or animal manure. In the case of *E. wandoo,* planted trees supported more arthropods than naturally occurring trees. Remnant *E. wandoo* had harder leaves and less foliar phosphorus and potassium than planted wandoo which perhaps made them less palatable; however, they had more foliar nitrogen. Some of the remnant *E. wandoo* sampled had regenerated as coppice from parent trees and had a different architecture from planted trees The remnant *E. wandoo* sampled also had less dense canopies than those growing in revegetated areas and were often shaded by taller trees. Perhaps they were less productive than *E. wandoo* on revegetation sites because of shading and/or heightened competition for resources with larger trees. These differences cannot be explained without further work.

5.2 Trees, birds and arthropods

Objectives of revegetation in agricultural areas and along roads include the conservation of biodiversity, the provision of habitat for native wildlife, and the restoration of functional ecosystems. An especially important objective is to enhance regional biodiversity by providing vegetation and habitats for invertebrates. Through their contribution to soil structure and the cycling of nutrients, invertebrates are essential for achieving ecologically sustainable ecosystems. They are also vital as pollinators, as predators (including predation of potential pests), and as food for vertebrates. Vertebrates, such as birds, may not be as important as invertebrates in restoring, creating or sustaining functional ecosystems, but the presence of vertebrates is evidence that ecosystems are functional (i.e., water and nutrients are being recycled) and ecologically sustainable. Conversely, the decline and extinction of vertebrates is evidence of dysfunctional ecosystems which in an agricultural landscape may point to long-term problems with maintaining agricultural production (Recher and Majer 2001). The decline and extinction of birds in the wheatbelt of Western Australia accompanied the clearing of land for farming, but has continued as remnants of native vegetation were degraded by grazing, nutrient enrichment and weed invasion, rising water tables and increasing soil salinisation (see Saunders and Ingram 1995 for a history of the birds in the Western Australian wheatbelt). The loss of birds and other vertebrates from the wheatbelt is evidence that the agricultural ecosystems created are not functional and probably cannot be sustained over time (Recher and Majer 2001).

It is important for revegetation to conserve and enhance invertebrate biodiversity, but it is also important that it attract and sustain populations of birds. The presence of birds in revegetation is evidence that functionality is being restored to the landscape. We recorded 22 species of birds in revegetation at Northam during a single winter survey. The same species are regularly found in remnant native vegetation throughout the wheatbelt (Saunders and Ingram 1995; Newbey 1999). Twelve of the species using revegetation at Northam are species which Newbey (1999) considered to be affected by agriculture and which have declined in abundance throughout the southwest (Newbey's Status 3 species). Of the 25 species of birds recorded in total during the Northam survey, 14 are given a Status 3 ranking by Newbey. Of Status 3 species, only the White-browed Babbler and Spotted Pardalote were absent from remnant vegetation (see Table 4 for scientific names of birds).

As was found for canopy invertebrates, the revegetation sampled in the Northam District attracts and appears capable of sustaining a rich and abundant avifauna. The revegetation provides foraging opportunities in the form of invertebrates and nectar, while also offering adequate cover for protection from weather and predators. No birds were nesting during the survey, which was conducted prior to the breeding season, but all the revegetation sites appeared to offer suitable nest sites for most species (H. Recher pers obs. based on extensive nest site data for wheatbelt birds; unpubl.). Only hollow dependent birds (e.g., parrots, treecreepers, pardalotes) would be affected by a shortage of nesting opportunities, although abundant ground predators in the revegetation (i.e., Feral Cat *Felis catus*, European Fox *Vulpes vulpes*) could discourage ground-nesting species. Only two ground-nesters, Painted Button Quail and Spotted Pardalote, were among the 25 species recorded; eight of the 25 species forage primarily on the ground (foraging guilds based on work of H. Recher and E. Davis unpubl. data).

Based on a survey of birds on 108 farms and 161 road verges in the southwest, Newbey (1999) was able to analyse the relationship between area of vegetation, isolation, grazing, floristic richness, age of vegetation, and presence or absence of understorey (shrubs) vegetation for 69 of 179 species recorded. Four species were negatively associated with patch area; eight species were positively associated with isolation and eight negatively associated; six species were positively associated with older vegetation; seven species were negatively associated with grazing and one was positively associated; and, 16 species were positively associated with a floristically rich mix of trees, shrubs and structural complexity. There were 28% fewer species recorded in revegetation than in remnants on farms, but some of this difference can be attributed to the smaller number of revegetation sites than remnants surveyed (Newbey 1999). Nonetheless, a number birds appear to require mature vegetation. These include hollow-nesters and birds which require structurally complex understorey and shrub vegetation (e.g., cuckoos, fairy-wrens – H. Recher, based on data from Newbey (1999) and unpubl. observations of the species listed by Newbey as absent from revegetation). Saffer *et al.* (2000) also found that revegetated sites with an understorey was more attractive to honeyeaters than revegetation without understorey.

6.0 Conclusion and recommendations

Although less than 15 years old, revegetation on the Northam Commons and on the verge of the Great Eastern Highway, had a diverse and abundant canopy arthropod fauna. It was also used by birds for foraging and almost certainly will provide breeding habitat for birds during the spring. With respect to encouraging use by birds and invertebrate biodiversity, there were no obvious disadvantages in using eucalypt species which were not native to the District. However, local species and those from nearby regions of the southwest appeared to support more abundant insects than species from more remote areas. Different results might have been obtained had there been extensive planting of eucalypts from eastern Australia or had non-Australian species been used. Other studies in the southwest have shown that species alien to Western Australia support far fewer insects than local species, and the benefits of using native plant species for regeneration, particularly with the addition of understorey (shrub) vegetation, have been documented (e.g., Nichols and Watkins 1984; Nichols and Burrows 1985; Newbey 1999). Majer (1990) suggested that a continual belt of mixed trees with a diverse understorey connecting remnants of native vegetation would be an ideal model to follow in revegetation. Recher (1993) and others have made similar recommendations and also suggested the addition of dead wood in the form of logs and woody debris, maximising the width or size of revegetation areas, encouraging a diversity of plant age classes with the revegetation, and using fire to create a mosaic of habitat types.

Detailed recommendations for the revegetation of agricultural land and roadsides to provide foraging and breeding habitat for wildlife, and to allow the movement of animals and plant propagules between remnants of native vegetation need not be repeated here. However, the results from Northam reinforce the importance of using local plant species whenever possible and creating a mix stand of species and age classes. When possible, remnant trees and patches of remnant vegetation should be incorporated within the areas being revegetated. It is also important to plant shrubs, as well as trees, and to encourage other native vegetation such as mistletoes, native grasses and ground plants. If there is a scarcity of mature trees with hollows, then consideration should be given to providing nest boxes for hollow-dependent species. Consideration also needs to be given to predator control. Not only is predator control likely to benefit ground-foraging and ground-nesting birds, it has positive advantages for reptiles and native mammals. Grazing of revegetation and remnant native vegetation by domestic animals must be excluded for maximum biodiversity benefit and to ensure the recovery of functional ecosystems.

If these and other recommendations (see Majer 1990; Recher 1993) are followed, then there is no reason why the pattern of decline and extinction of local plants and animals which accompanied the development of the southwest for agriculture cannot be stabilised and then reversed. Meeting these objectives not only protects biodiversity and restores functional ecosystems, it ensures the long-term sustainability of agriculture within the southwest.

7.0 References

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Appendix 1. Invertebrate data and tree details.

Acacia acuminata

CLASS		tree number	66	68	70	73	74	78	85	86	87	88	Mean	SD	Freq
Gastropoda												1	0.1	0	1
Arachnida	Arachnida		79	40	41	34	109	59	44	26	108	52	59.2	29.77	10
Arachnida	Pseudoscorpiones												0	0	0
Arachnida	Acari		16	10	3	3	5	22	8	6	23	8	10.4	7.412	10
Malacostrac	Isopoda												0	0	0
Diplopoda	Polyxenida												0	0	0
Collembola	Arthropleona		2									1	0.3	0.707	2
Collembola	Symphypleona			2	1	1						1	0.5	0.5	4
Insecta	Thysanura												0	0	0
Insecta	Odonata		1								1		0.2	0	2
Insecta	Blattodea												0	0	0
Insecta	Mantodea			1			1						0.2	0	2
Insecta	Isoptera												0	0	0
Insecta	Dermaptera								1				0.1	0	1
Insecta	Orthoptera												0	0	0
Insecta	Phasmatodea												0	0	0
Insecta	Psocoptera		132	8	26	11	22	8	35	3	8	13	26.6	38.33	10
Insecta	Hemiptera	Auch./Stern.	1072	334	96	105	102	74	132	43	67	502	252.7	322.2	10
Insecta	Hemiptera	Heteroptera	489	10	21	59	166	18	57	12	71	90	99.3	144.9	10
Insecta	Thysanoptera		760	192	138	75	110	92	44	23	105	75	161.4	215.6	10
Insecta	Neuroptera	adults	12		1	4	11	2	1	1	1		3.3	4.673	8
Insecta	Neuroptera	larvae	8				2						1	4.243	2
Insecta	Coleoptera	adults	230	34	96	63	102	19	54	15	40	50	70.3	63.09	10
Insecta	Coleoptera	larvae	4	2	2		1	1	3	2	1	1	1.7	1.054	9
Insecta	Mecoptera	adults	4			1							0.5	2.121	2
Insecta	Diptera	adults	493	29	66	91	91	25	54	17	60	47	97.3	141.3	10
Insecta	Diptera	larvae			3								0.3	0	1
Insecta	Trichoptera												0	0	0
Insecta	Lepidoptera	adults				1	2	1	2			1	0.7	0.548	5
Insecta	Lepidoptera	larvae	65	2	14	10	30	7	9	5	5	35	18.2	19.77	10
Insecta	Hymenoptera	bees, wasps	1714	136	184	220	451	100	222	114	319	279	373.9	482.6	10
Insecta	Hymenoptera	ants	115	192	302	42	34	23	93	26	22	48	89.7	92.13	10
TOTAL			5196	992	994	720	1239	451	759	293	831	1204	1268	1412	

Body length class	66	68	70	73	74	78	85	86	87	88	Mean	SD
0-0.5mm					1	16			17	3	4	8.4
0.5-1.0mm	529	107	129	82	190	120	187	97	275	202	192	132.5
1.0-2.0mm	2793	432	314	423	594	201	315	93	283	511	596	785.7
2.0-3.0mm	1433	308	499	148	296	82	181	58	148	336	349	403.8
3.0-4.0mm	284	67	19	28	72	18	60	20	58	51	68	78.8
4.0-5.0mm	77	54	15	19	45	2	8	17	32	48	32	23.8
5.0-10.0mm	71	24	16	19	36	9	8	3	17	47	25	20.9
> 10.0mm	9		2	1	5	3		5	1	6	3	2.8

Tree details	66	68	70	73	74	78	85	86	87	88
Location	Meenar									
Tree height	3.60	3.10	3.60	4.00	3.80	4.70	4.50	3.30	3.90	3.80
Canopy height	1.50	2.00	2.30	2.80	2.30	1.90	2.90	1.60	2.20	2.00
Canopy diameter 1	2.5	2.5	2.2	2.4	3.2	2.8	2.6	1.6	3.4	3.8
Canopy diameter 2	2.6	2.6	2.5	2.3	2.8	2.7	2.5	1.8	3.3	3.1

Eucalyptus anceps

CLASS		tree number	2	7	12	14	40	54	55	56	57	58	Mean	SD	Freq
	Gastropoda														
Arachnida	Arachnida		47	121	46	148	58	10	20	30	37	26	54.3	44.96	10
Arachnida	Pseudoscorpiones														
Arachnida	Acari		1	1	2	27							3.1	12.84	4
Malacostraca	Isopoda														
Diplopoda	Polyxenida														
Collembola	Arthropleona		7		2								0.9	3.536	2
Collembola	Symphypleona			3		7	2	1	2		7		2.2	2.658	6
Insecta	Thysanura														
Insecta	Odonata														
Insecta	Blattodea					1							0.1	0	1
Insecta	Mantodea									1			0.1	0	1
Insecta	Isoptera														
Insecta	Dermaptera														
Insecta	Orthoptera				1								0.1	0	1
Insecta	Phasmatodea		1		1								0.2	0	2
Insecta	Psocoptera		8	43	41	21	17		1	1	2	5	13.9	16.61	9
Insecta	Hemiptera	Auch./Stern.	110	51	120	146	45	11	20	10	26	20	55.9	50.43	10
Insecta	Hemiptera	Heteroptera		1	1	5	1			1	3		1.2	1.673	6
Insecta	Thysanoptera		25	42	69	35	32		15	8	25	7	25.8	19.25	9
Insecta	Neuroptera	adults	3		1	2	1					1	0.8	0.894	5
Insecta	Neuroptera	larvae	1	1			1						0.3	0	3
Insecta	Coleoptera	adults	6	11	6	8	6	2	1	2	5	2	4.9	3.178	10
Insecta	Coleoptera	larvae		1	3	1					1	2	0.8	0.894	5
Insecta	Mecoptera	adults													
Insecta	Diptera	adults	38	32	71	59	15	8	4	5	8	7	24.7	24.34	10
Insecta	Diptera	larvae													
Insecta	Trichoptera														
Insecta	Lepidoptera	adults	1	2		5				1		1	1	1.732	5
Insecta	Lepidoptera	larvae	3	6	6	14	3	1	2	1	2		3.8	4.116	9
Insecta	Hymenoptera	bees, wasps	51	93	160	51	28	43	32	47	40	23	56.8	41.07	10
Insecta	Hymenoptera	ants	3		2	1	35	1	2	5		1	5	11.7	8
TOTAL			305	408	532	531	244	77	99	112	156	95	255.9	179.8	

Body length class	2	7	12	14	40	54	55	56	57	58	Mean	SD
0-0.5mm	1		1	1		10	1		2	4	2	3.3
0.5-1.0mm	19	4	26	67	36	13	36	31	61	17	31	20.2
1.0-2.0mm	150	177	282	222	89	54	43	49	70	61	120	83.7
2.0-3.0mm	85	163	167	117	57	3	7	14	11	6	63	66.1
3.0-4.0mm	27	34	32	42	14	4	4	3	2	2	16	15.7
4.0-5.0mm	6	5	4	26	7	1		1	7	1	6	7.7
5.0-10.0mm	14	24	16	53	40	3	8	12	1	4	18	17.0
> 10.0mm	3	1	4	3	1			2	2		2	1.1

Tree details	2	7	12	14	40	54	55	56	57	58
Location	Commons									
Tree height	3.65	4.30	5.00	4.10	4.40	4.90	4.60	4.20	4.10	2.90
Canopy height	2.85	2.80	4.20	3.30	3.60	3.40	3.60	3.20	3.50	1.60
Canopy diameter 1	2.0	2.4	3.0	5.1	2.9	2.9	3.4	4.8	2.2	2.2
Canopy diameter 2	2.4	2.3	2.6	3.9	2.5	3.2	2.8	4.4	2.2	1.8

Eucalyptus leucoxylon

CLASS		tree number	1	15	16	22	23	28	30	32	37	46	47	48	Mean	SD	Freq
Gastropoda																	
Arachnida	Arachnida		211	144	138	118	79	173	72	37	81	69	50	125	108.1	52.41	12
Arachnida	Pseudoscorpiones																
Arachnida	Acari		7	25	42	5	4	15	4	4		6	1		9.417	12.89	10
Malacostraca	Isopoda																
Diplopoda	Polyxenida				1										0.083	0	1
Collembola	Arthropleona		9	5	5		6	2							2.25	2.51	5
Collembola	Symphypleona			3		1		3		2	5	12			2.167	3.983	6
Insecta	Thysanura		1	1										2	0.333	0.577	3
Insecta	Odonata																
Insecta	Blattodea		5	4	2	3	6	5	1		1	3	2	4	3	1.679	11
Insecta	Mantodea		1					2	4						0.583	1.528	3
Insecta	Isoptera										2				0.167	0	1
Insecta	Dermaptera																
Insecta	Orthoptera		4		4	3	2	1	3		2	2	2	6	2.417	1.449	10
Insecta	Phasmatodea							1	1						0.167	0	2
Insecta	Psocoptera		101	54	29	31	38	153	16	13	19	10	9	93	47.17	45.42	12
Insecta	Hemiptera	Auch./Stern.	107	71	233	77	154	142	58	73	104	110	62	165	113	52.26	12
Insecta	Hemiptera	Heteroptera	6	8	13	7	10	6		3	3	4		3	5.25	3.335	10
Insecta	Thysanoptera		34	23	88	24	28	26	10	36	29	44	9	160	42.58	42.17	12
Insecta	Neuroptera	adults	32	2	2	12	7	24	1	3	1			2	7.167	10.94	10
Insecta	Neuroptera	larvae	1		2	1		1	1	1	1	1		2	0.917	0.441	9
Insecta	Coleoptera	adults	31	25	54	16	68	28	27	14	15	15	5	32	27.5	17.88	12
Insecta	Coleoptera	larvae	5	2	9	3	3	6	1	3	2	2	3	10	4.083	2.875	12
Insecta	Mecoptera	adults			1		1	1							0.25	0	3
Insecta	Diptera	adults	152	106	193	17	90	77	36	54	37	99	36	78	81.25	51.74	12
Insecta	Diptera	larvae			1				3						0.333	1.414	2
Insecta	Trichoptera																
Insecta	Lepidoptera	adults	5		2		1		1		1	2	1	1	1.167	1.389	8
Insecta	Lepidoptera	larvae	2	6	7	7	7	11	1	1	3	1	2	1	4.083	3.37	12
Insecta	Hymenoptera	bees, wasps	90	45	53	67	125	83	70	80	61	87	40	42	70.25	24.62	12
Insecta	Hymenoptera	ants	17	16	3	1	82	3	11	3	24	8	6	10	15.33	22.1	12
TOTAL			821	540	882	393	711	763	321	327	391	475	228	736	549	223.8	

Body length class	1	15	16	22	23	28	30	32	37	46	47	48	Mean	SD
0-0 5mm		7	12		1	3	2		51	48			10	22.0
0.5 1 0mm	58	36	61	78	80	82	64	60	179	74	37	90	75	36.8
1.0-2.0mm	344	228	338	161	278	361	117	145	86	194	87	333	223	105.0
2.0-3.0mm	216	119	289	84	154	185	63	92	20	109	56	205	133	78.6
3.0-4.0mm	74	55	92	22	42	37	16	8	18	18	11	40	36	26.4
4.0-5.0mm	61	32	41	22	29	48	23	11	33	4	20	30	30	15.6
5.0-10.0mm	63	56	38	22	121	41	32	8	4	24	15	33	38	31.5
> 10.0mm	5	7	11	4	6	6	4	3		4	2	5	5	2.4

Tree details	1	15	16	22	23	28	30	32	37	46	47	48
Location	Commons											
Tree height	3.70	3.40	3.50	2.90	3.40	2.80	3.10	3.90	3.50	4.50	5.10	4.20
Canopy height	3.70	3.40	3.50	2.90	3.40	2.80	2.50	3.30	3.00	4.50	3.70	4.20
Canopy diameter 1	4.0	4.3	4.6	2.2	3.0	2.9	3.2	3.1	3.0	3.6	5.0	3.9
Canopy diameter 2	3.9	4.3	4.1	3.0	3.9	3.3	3.0	2.6	3.3	3.9	5.1	3.8

Eucalyptus platypus

CLASS		tree number	4	20	26	35	36	49	50	52	53	Mean	SD	Freq
Gastropoda														
Arachnida	Arachnida		134	221	238	83	175	56	48	122	171	138.7	68.43	9
Arachnida	Pseudoscorpiones										1	0.111	0	1
Arachnida	Acari		6	47	4	4	43				3	11.89	21.1	6
Malacostraca	Isopoda													
Diplopoda	Polyxenida													
Collembola	Arthropleona		3	3						1	4	1.222	1.258	4
Collembola	Symphypleona		2	3				8			1	1.556	3.109	4
Insecta	Thysanura			2						2		0.444	0	2
Insecta	Odonata													
Insecta	Blattodea		1	3	3	3		2	1	13	4	3.333	3.882	8
Insecta	Mantodea			1			3			6		1.111	2.517	3
Insecta	Isoptera													
Insecta	Dermaptera													
Insecta	Orthoptera				3	1				5	4	1.444	1.708	4
Insecta	Phasmatodea					2					1	0.333	0.707	2
Insecta	Psocoptera		29	43	41	55	26	8	4	6	10	24.67	18.75	9
Insecta	Hemiptera	Auch./Stern.	131	512	339	104	286	150	50	64	107	193.7	154	9
Insecta	Hemiptera	Heteroptera	6	8	14	1	37	3	1	2	2	8.222	11.6	9
Insecta	Thysanoptera		569	71	139	58	249	58	14	61	24	138.1	176.7	9
Insecta	Neuroptera	adults	4	15	28	2	6	1		1	3	6.667	9.457	8
Insecta	Neuroptera	larvae	1	3	1	2				1	2	1.111	0.816	6
Insecta	Coleoptera	adults	63	33	76	33	38	17	3	24	32	35.44	22.24	9
Insecta	Coleoptera	larvae	5	16	5	2	21				5	6	7.616	6
Insecta	Mecoptera	adults	1			1				1	1	0.444	0	4
Insecta	Diptera	adults	161	233	70	74	108	85	41	50	65	98.56	61.71	9
Insecta	Diptera	larvae		1								0.111	0	1
Insecta	Trichoptera													
Insecta	Lepidoptera	adults	8	4			9	1	2	1		2.778	3.545	6
Insecta	Lepidoptera	larvae	11	19	14	8	7	1	4	1		7.222	6.334	8
Insecta	Hymenoptera	bees, wasps	276	115	174	100	162	115	29	66	53	121.1	75.12	9
Insecta	Hymenoptera	ants	4	8	10	27	38	7	5	23	11	14.78	11.79	9
TOTAL			1415	1361	1159	560	1208	512	202	450	504	819	460.1	

Body length class	4	20	26	35	36	49	50	52	53	Mean	SD
0-0.5mm	2	14	1	1	36	18	6		4	9	12.2
0.5-1.0mm	312	107	236	52	167	86	15	28	61	118	100.9
1.0-2.0mm	417	633	490	204	411	253	114	191	240	328	168.6
2.0-3.0mm	457	354	236	173	415	108	33	136	112	225	150.3
3.0-4.0mm	151	134	67	58	100	15	16	41	34	68	49.7
4.0-5.0mm	23	34	61	19	35	11	1	23	21	25	17.0
5.0-10.0mm	49	73	65	48	43	18	17	24	26	40	20.4
> 10.0mm	4	12	3	5	1	3		7	6	5	3.4

Tree details	4	20	26	35	36	49	50	52	53
Location	Commons								
Tree height	4.20	3.10	2.60	3.80	3.40	3.00	2.40	2.10	2.40
Canopy height	4.00	3.10	1.80	3.10	2.70	2.20	1.80	2.00	1.80
Canopy diameter 1	2.8	3.7	2.1	2.2	2.4	2.5	1.5	2.3	1.7
Canopy diameter 2	2.7	4.3	2.3	2.4	2.1	2.3	1.7	2.4	2.0

Eucalyptus rudis

CLASS		tree number	72	75	76	100	101	102	103	5	13	17	21	Mean	SD	Freq
Gastropoda																
Arachnida	Arachnida		46	31	83	31	57	42	70	144	166	243	81	90.36	67.02	11
Arachnida	Pseudoscorpiones															
Arachnida	Acari		1	1	2		2	2	1	12	20	6	17	5.818	7.26	10
Malacostraca	Isopoda															
Diplopoda	Polyxenida															
Collembola	Arthropleona			1	1		1		4	2	2	2	24	3.364	7.891	8
Collembola	Symphypleona		3								1	4	4	1.091	1.414	4
Insecta	Thysanura										2			0.182	0	1
Insecta	Odonata					1								0.091	0	1
Insecta	Blattodea		1			1	6	8	7	21	9	1	2	5.091	6.418	9
Insecta	Mantodea															
Insecta	Isoptera															
Insecta	Dermaptera															
Insecta	Orthoptera				1		2			1	4	2	5	1.364	1.643	6
Insecta	Phasmatodea															
Insecta	Psocoptera		65	5	18	12	14	29	28	114	114	54	18	42.82	39.5	11
Insecta	Hemiptera	Auch./Stern.	73	21	108	262	126	364	196	459	810	130	546	281.4	241.6	11
Insecta	Hemiptera	Heteroptera	2	4	2	12	2	13	28	16	52	7	62	18.18	20.84	11
Insecta	Thysanoptera		90	11	36	58	52	113	385	148	653	28	87	151	195.6	11
Insecta	Neuroptera	adults	2	4	1	1	1	3	4	5	6		45	6.545	13.4	10
Insecta	Neuroptera	larvae	1							1	13	1	2	1.636	5.273	5
Insecta	Coleoptera	adults	33	17	53	43	36	100	158	150	133	20	56	72.64	52.9	11
Insecta	Coleoptera	larvae			1			4	6	21	30	6	9	7	10.52	7
Insecta	Mecoptera	adults							1				1	0.182	0	2
Insecta	Diptera	adults	168	142	211	81	63	243	229	63	159	132	127	147.1	63.04	11
Insecta	Diptera	larvae														
Insecta	Trichoptera					1								0.091	0	1
Insecta	Lepidoptera	adults	2		1	1	3			2	2		1	1.091	0.756	7
Insecta	Lepidoptera	larvae	3			1	3	7	5	51	50	17	25	14 73	19.97	9
Insecta	Hymenoptera	bees, wasps	204	69	218	151	80	565	236	154	116	43	307	194 8	146.2	11
Insecta	Hymenoptera	ants	192	48	96	642	218	494	1355	3	12	7	45	282 9	413.5	11
TOTAL			886	354	832	1298	666	1987	2713	1367	2354	703	1464	1329	751.3	

Body length class	72	75	76	100	101	102	103	5	13	17	21	Mean	SD
0-0.5mm			1	49	31	51	53	4	3	1	22	20	22.8
0.5-1.0mm	132	21	88	158	166	375	502	101	39	23	220	166	151.2
1.0-2.0mm	303	180	466	274	200	728	577	620	676	355	617	454	199.6
2.0-3.0mm	359	69	94	755	235	694	1449	401	1054	131	388	512	436.8
3.0-4.0mm	62	67	148	33	4	87	79	88	311	56	66	91	81.3
4.0-5.0mm	14	7	23	12	11	26	32	32	112	61	74	37	32.7
5.0-10.0mm	16	10	10	16	14	21	18	103	139	49	69	42	43.7
> 10.0mm			2	1	5	5	3	18	20	27	8	8	9.4

Tree details	72	75	76	100	101	102	103	5	13	17	21
Location	Meenar			Grass Valley				Commons			
Tree height	4.40	4.10	3.40	2.10	3.30	5.90	6.10	3.10	4.70	3.70	3.80
Canopy height	3.10	2.60	2.30	2.00	2.60	5.20	5.10	2.90	4.30	2.10	2.90
Canopy diameter 1	2.1	1.6	1.8	2.1	4.3	4.6	5.9	2.6	3.9	3.0	2.7
Canopy diameter 2	1.7	1.5	1.9	2.3	4.0	4.5	4.7	2.4	3.7	2.9	2.9

Eucalyptus victrix

CLASS		tree number	8	10	24	25	27	104	105	106	107	108	Mean	SD	Freq
Gastropoda															
Arachnida	Arachnida		22	33	57	45	57	34	13	26	12	31	33	16.03	10
Arachnida	Pseudoscorpiones														
Arachnida	Acari		3		11					2	1		1.7	4.573	4
Malacostraca	Isopoda														
Diplopoda	Polyxenida														
Collembola	Arthropleona					2		4		8		1	1.5	3.096	4
Collembola	Symphypleona		1	4	1	2	1						0.9	1.304	5
Insecta	Thysanura														
Insecta	Odonata														
Insecta	Blattodea		1			4	2			1			0.8	1.414	4
Insecta	Mantodea					1	2						0.3	0.707	2
Insecta	Isoptera														
Insecta	Dermaptera														
Insecta	Orthoptera		1		1	6		1			1		1	2.236	5
Insecta	Phasmatodea														
Insecta	Psocoptera		16	7	5	20	10			4			6.2	6.408	6
Insecta	Hemiptera	Auch./Stern.	69	22	33	43	69	67	10	109	52	89	56.3	30.45	10
Insecta	Hemiptera	Heteroptera	20	1	1	1	4					1	2.8	7.607	6
Insecta	Thysanoptera		69	24	8	24	11	55	5	25	6	39	26.6	21.74	10
Insecta	Neuroptera	adults	3	1		1	1						0.6	1	4
Insecta	Neuroptera	larvae				1						1	0.2	0	2
Insecta	Coleoptera	adults	26	15	4	9	6	5	1	17	7	31	12.1	9.972	10
Insecta	Coleoptera	larvae	3	2	1	3		1			1	1	1.2	0.951	7
Insecta	Mecoptera	adults													
Insecta	Diptera	adults	104	26	11	26	17	3	7	32	11	101	33.8	37.35	10
Insecta	Diptera	larvae													
Insecta	Trichoptera														
Insecta	Lepidoptera	adults	1	1									0.2	0	2
Insecta	Lepidoptera	larvae	3	4	2	1	4	1			1	3	1.9	1.302	8
Insecta	Hymenoptera	bees, wasps	723	44	26	49	71	37	23	65	20	99	115.7	214.8	10
Insecta	Hymenoptera	ants	6	5	7	4	1	13		7	9	41	9.3	11.97	9
TOTAL			1071	189	168	242	256	221	59	296	121	438	306.1	287.6	

Body length class	8	10	24	25	27	104	105	106	107	108	Mean	SD
0-0.5mm	2		1			11	3	25	11	15	7	8.6
0.5-1.0mm	411	36	40	39	43	88	23	79	31	123	91	116.6
1.0-2.0mm	455	102	90	97	149	89	22	125	47	205	138	122.3
2.0-3.0mm	122	16	20	45	35	30	8	49	27	78	43	34.1
3.0-4.0mm	32	2	7	23	8	1	2	11	1	6	9	10.4
4.0-5.0mm	21	11	1	10	4			3	2	1	5	7.0
5.0-10.0mm	24	19	9	23	15	2	1	4	2	9	11	8.9
> 10.0mm	4	3		5	2					1	2	1.6

Tree details	8	10	24	25	27	104	105	106	107	108
Location	Commons									
Tree height	4.60	3.20	3.80	3.70	3.50	3.50	4.50	5.50	4.80	4.00
Canopy height	4.20	2.90	3.00	3.70	2.20	1.10	3.30	4.20	3.80	3.00
Canopy diameter 1	2.2	2.0	2.3	2.0	2.7	2.1	2.5	2.9	3.4	2.6
Canopy diameter 2	2.6	1.9	2.8	2.5	2.7	1.8	2.8	3.2	2.8	2.8

Eucalyptus wandoo (natural)

CLASS		tree number	59	60	61	62	63	95	96	97	98	99	Mean	SD	Freq
Gastropoda															
Arachnida	Arachnida		44	52	9	83	126	80	165	42	35	35	67 1	47 49	10
Arachnida	Pseudoscorpiones														
Arachnida	Acari		20	6	3	3	4		47	6	1	2	9.2	14.91	9
Malacostraca	Isopoda								1				0.1	0	1
Diplopoda	Polyxenida														
Collembola	Arthropleona						1		6	1	2	1	1.1	2.168	5
Collembola	Symphypleona				1								0.1	0	1
Insecta	Thysanura						1					1	0.2	0	2
Insecta	Odonata														
Insecta	Blattodea		10	3		9	47	4	6	1	2	1	8.3	14.54	9
Insecta	Mantodea														
Insecta	Isoptera											3	0.3	0	1
Insecta	Dermaptera						1		2	2			0.5	0.577	3
Insecta	Orthoptera			1		1	7	2	2				1.3	2.51	5
Insecta	Phasmatodea														
Insecta	Psocoptera		10	2		16	18	11	7	1	6	4	7.5	5.937	9
Insecta	Hemiptera	Auch./Stern.	69	117	10	52	503	42	121	20	35	38	100.7	146.2	10
Insecta	Hemiptera	Heteroptera	8	42	1	5	55	11	9	3	1	3	13.8	18.84	10
Insecta	Thysanoptera		14	39	8	51	112	48	156	27	76	38	56.9	46.11	10
Insecta	Neuroptera	adults					2	2	30	2	2		3.8	12.52	5
Insecta	Neuroptera	larvae	2	8		2	2					1	1.5	2.828	5
Insecta	Coleoptera	adults	36	25	9	61	79	83	135	37	48	87	60	37	10
Insecta	Coleoptera	larvae	2	13		21	14				1	1	5.2	8.501	6
Insecta	Mecoptera	adults													
Insecta	Diptera	adults	12	31	4	15	77		68	12	20	15	25.4	26.22	9
Insecta	Diptera	larvae		1			4						0.5	2.121	2
Insecta	Trichoptera														
Insecta	Lepidoptera	adults	2	1			1						0.4	0.577	3
Insecta	Lepidoptera	larvae	12	41	2	18	38	14	24	5	8	9	17.1	13.4	10
Insecta	Hymenoptera	bees, wasps	42	24	12	51	64	103	109	28	36	31	50	32.85	10
Insecta	Hymenoptera	ants	26	11	4	10	842	60	64	35	36	41	112.9	257	10
TOTAL			309	417	63	398	1998	460	952	222	309	311	543.9	560.2	

Body length class	59	60	61	62	63	95	96	97	98	99	Mean	SD
0-0.5mm	1	3	1		2	5	69	12	9	17	12	21.6
0.5-1.0mm	54	19	10	34	29	79	110	16	26	59	44	31.8
1.0-2.0mm	110	143	29	170	597	191	323	88	92	115	186	164.6
2.0-3.0mm	73	103	9	43	1027	67	160	33	65	44	162	306.6
3.0-4.0mm	31	40	3	75	105	23	149	17	37	21	50	45.9
4.0-5.0mm	18	47	4	35	58	13	80	16	13	7	29	25.2
5.0-10.0mm	17	52	6	33	155	79	54	42	66	47	55	41.2
> 10.0mm	5	10	1	8	25	3	7	1	1	1	6	7.4

Tree details	59	60	61	62	63	95	96	97	98	99
Location	Aphylla Rd					Watson Rd				
Tree height	4.40	3.00	3.90	4.50	2.90	4.20	2.80	2.50	2.80	3.30
Canopy height	3.10	3.00	3.00	3.80	2.50	2.90	2.70	1.80	2.00	3.25
Canopy diameter 1	2.4	2.5	2.1	3.4	2.5	2.6	2.6	1.9	2.1	3.4
Canopy diameter 2	2.0	2.6	1.8	2.6	2.7	2.7	2.4	1.5	3.2	2.9

Eucalyptus wandoo (planted)

CLASS		tree number	41	42	43	44	45	65	67	69	77	90	Mean	SD	Freq
Gastropoda															
Arachnida	Arachnida		226	206	368	29	88	38	90	66	14	88	121.3	111.7	10
Arachnida	Pseudoscorpiones														
Arachnida	Acari		8	9	15	3	5	2	1	5	1	1	5	4.546	10
Malacostraca	Isopoda														
Diplopoda	Polyxenida														
Collembola	Arthropleona			1			1		2		2	1	0.7	0.548	5
Collembola	Symphypleona		3	1				2		7			1.3	2.63	4
Insecta	Thysanura			2	2	1	4						0.9	1.258	4
Insecta	Odonata														
Insecta	Blattodea		12	11	21			7	6	4		7	6.8	5.707	7
Insecta	Mantodea				1		1						0.2	0	2
Insecta	Isoptera			11	1	1							1.3	5.774	3
Insecta	Dermaptera														
Insecta	Orthoptera		2	1	1	1	5						1	1.732	5
Insecta	Phasmatodea		1		1								0.2	0	2
Insecta	Psocoptera		59	38	124	9	32	54	144	165	7	51	68.3	56.06	10
Insecta	Hemiptera	Auch./Stern.	428	198	712	223	162	244	233	176	26	357	275.9	187.7	10
Insecta	Hemiptera	Heteroptera	14	2	69	1	7	13	33	2	3	3	14.7	21.42	10
Insecta	Thysanoptera		74	50	53	43	59	234	409	49	17	52	104	122.6	10
Insecta	Neuroptera	adults	10	4	24			28	30	5		22	12.3	10.98	7
Insecta	Neuroptera	larvae	4	1	2	4	3	3	5	2			2.4	1.309	8
Insecta	Coleoptera	adults	81	76	77	21	19	110	170	79	19	110	76.2	47.96	10
Insecta	Coleoptera	larvae	11	1	15	3	5	3	1	7			4.6	5.007	8
Insecta	Mecoptera	adults						1	3				0.4	1.414	2
Insecta	Diptera	adults	69	48	99	24	118	226	582	157	73	433	182.9	183.8	10
Insecta	Diptera	larvae							3				0.3	0	1
Insecta	Trichoptera														
Insecta	Lepidoptera	adults	1	1				4	3	1	1		1.1	1.329	6
Insecta	Lepidoptera	larvae	22	2	27	5	7	10	11	3		8	9.5	8.531	9
Insecta	Hymenoptera	bees, wasps	109	86	130	94	148	218	499	243	73	462	206.2	154.9	10
Insecta	Hymenoptera	ants	26	19	50	8	83	467	572	827	219	754	302.5	323.4	10
TOTAL			1160	768	1792	470	747	1664	2797	1798	455	2349	1400	808	

Body length class	41	42	43	44	45	65	67	69	77	90	Mean	SD
0-0.5mm	2	5	10	2	4		6	1	6	247	28	80.9
0.5-1.0mm	75	72	80	84	71	218	274	60	67	260	126	87.3
1.0-2.0mm	494	306	883	279	356	497	1062	536	101	856	537	306.1
2.0-3.0mm	293	155	447	67	144	776	1176	1119	254	855	529	418.1
3.0-4.0mm	63	53	102	19	44	82	136	33	16	54	60	37.6
4.0-5.0mm	115	82	94	6	13	44	62	23	8	40	49	38.4
5.0-10.0mm	91	92	158	11	112	42	72	25	3	33	64	49.7
> 10.0mm	27	3	18	2	3	5	9	1		4	7	8.8

Tree details	41	42	43	44	45	65	67	69	77	90
Location	Commons					Meenar				
Tree height	4.10	4.30	4.30	4.30	4.30	4.00	3.30	5.60	4.30	4.60
Canopy height	4.10	3.00	3.90	3.00	4.30	3.50	2.70	5.40	3.20	3.80
Canopy diameter 1	2.7	3.9	3.8	2.2	3.0	2.4	2.0	2.4	2.7	2.8
Canopy diameter 2	2.4	3.5	3.3	2.2	3.0	2.5	2.9	2.4	2.4	2.5

Eucalyptus spathulata

CLASS		tree number	31	33	34	79	80	82	91	92	93	94	Mean	SD	Freq
Gastropoda															
Arachnida	Arachnida		53	235	61	168	216	308	197	201	136	61	163 6	85 16	10
Arachnida	Pseudoscorpiones														
Arachnida	Acari		1	2	2	8	9	6	1	8	5		4.2	3.24	9
Malacostraca	Isopoda														
Diplopoda	Polyxenida														
Collembola	Arthropleona				16		1	3	5	1			2.6	6.261	5
Collembola	Symphypleona					1							0.1	0	1
Insecta	Thysanura														
Insecta	Odonata							1				1	0.2	0	2
Insecta	Blattodea			1		6	9	5	1	6	5	29	6.2	8.988	8
Insecta	Mantodea					4		2		1			0.7	1.528	3
Insecta	Isoptera														
Insecta	Dermaptera										1		0.1	0	1
Insecta	Orthoptera		3		1		2			2	1		0.9	0.837	5
Insecta	Phasmatodea														
Insecta	Psocoptera		13	49	28	121	160	60	144	257	170	103	110.5	75.56	10
Insecta	Hemiptera	Auch./Stern.	54	199	112	288	154	200	107	209	168	63	155.4	72.69	10
Insecta	Hemiptera	Heteroptera		2	2	14	5	4	10	9	3		4.9	4.39	8
Insecta	Thysanoptera		33	14	31	72	65	110	104	59	19	59	56.6	33.1	10
Insecta	Neuroptera	adults			2	13	5	2	1	12	20	2	5.7	7.019	8
Insecta	Neuroptera	larvae	1	2		1	4		1				0.9	1.304	5
Insecta	Coleoptera	adults	8	13	11	38	84	76	47	183	189	33	68.2	67.19	10
Insecta	Coleoptera	larvae		1	3							1	0.5	1.155	3
Insecta	Mecoptera	adults	1	1							2	1	0.5	0.5	4
Insecta	Diptera	adults	17	77	124	308	213	322	99	1804	2020	139	512.3	745.7	10
Insecta	Diptera	larvae				1							0.1	0	1
Insecta	Trichoptera														
Insecta	Lepidoptera	adults		1	1	5	5	3	4				1.9	1.835	6
Insecta	Lepidoptera	larvae		2	1		3	2	1	19	17	3	4.8	7.464	8
Insecta	Hymenoptera	bees, wasps	88	88	67	94	155	330	183	299	696	57	205 7	197	10
Insecta	Hymenoptera	ants	2	11	17	228	165	191	28	360	555	612	216 9	225.7	10
TOTAL			274	698	479	1370	1255	1625	933	3430	4007	1164	1524	1235	

Body length class	31	33	34	79	80	82	91	92	93	94	Mean	SD
0-0.5mm	4	2	12	7	1	4	59	173	96	40	40	56.4
0.5-1.0mm	73	56	56	91	230	308	97	218	221	53	140	93.9
1.0-2.0mm	120	338	213	457	451	634	518	2296	2539	283	785	875.2
2.0-3.0mm	39	229	117	618	419	552	188	476	883	702	422	275.1
3.0-4.0mm	13	34	33	119	112	57	28	153	114	26	69	50.3
4.0-5.0mm	11	16	21	27	25	24	14	59	65	19	28	18.6
5.0-10.0mm	10	21	26	45	14	45	24	71	84	37	38	24.2
> 10.0mm	4	2	1	6	3	1	5	6	5	4	4	1.9

Tree details	31	33	34	79	80	82	91	92	93	94
Location /	Commons			Meenar						
Tree height	4.50	3.50	3.40	4.60	3.50	4.40	4.10	5.50	4.80	6.20
Canopy height	3.50	2.50	2.90	4.10	3.00	4.10	3.70	5.20	3.80	5.90
Canopy diameter 1	2.2	3.3	2.5	3.2	4.4	2.5	4.2	3.9	4.8	6.1
Canopy diameter 2	2.5	3.7	2.6	3.6	3.9	2.7	3.6	4.2	3.9	5.4