



Cotton Catchment Communities CRC

**SUMMER SCHOLARSHIP
Final Report**

Part 1 - Summary Details

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for cotton landscapes

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1. Background:

Natural pest control is an important ecosystem service to the Australian cotton industry. The modern industry has reduced its reliance on pesticide sprays using a combination of approaches and is much more environmentally aware than it has been in the past. Techniques employed to reduce reliance on pesticides include the introduction of BT cotton, development of soft, pest-specific chemicals and encouraging or releasing beneficial (predatory) invertebrates into crops.

To date, the focus of natural pest control in the Australian cotton industry has been on managing beneficial invertebrate numbers in crops. However, work by Nancy Schellhorn's group (CSIRO), Allan House's group (CSIRO) and Geoff Gurr's group (Charles Sturt University) is showing that the wider landscape can have an important influence on the abundance of pest and beneficial invertebrate species in crop. Some attention has been paid to the value of microbats in providing natural pest control services (i.e. Leah MacKinnon's Masters research and various projects by Martin Dillon et al.), but little attention has been paid to birds and the role they may play. In addition, there is little information on where in the cotton landscape birds and microbats reside, or the effect that the proportion of different land cover types at a landscape scale can have on populations of these natural pest controlling organisms.

Momentum is now growing around on-farm biodiversity conservation as research continues to show the importance of biodiversity and ecosystem services to cotton growers. This new interest has been helped by pioneering growers such as Andrew Watson who have significantly decreased their use of pesticide sprays by managing their native vegetation, without a significant impact on their bottom line. However, many growers are currently unaware of the potential value of their on-farm native vegetation for natural pest control, and those that are aware, may lack the knowledge or skills to determine the condition of and manage it appropriately. Tools are required to allow growers to benchmark their current situation and inform management to maximise natural pest control services.

1.1 Biodiversity assessments

Biodiversity assessments in Australia are generally conducted using vegetation as a surrogate for biodiversity, because direct measurement of biodiversity is difficult and time consuming for most organisms. Vegetation condition assessment for biodiversity conservation is conducted in most states, with examples including Biometric in New South Wales (Gibbons et al. 2008), Habitat Hectares in Victoria (DSE 2004), BioCondition in Queensland

(Eyre et al. 2008) and Bushland Condition Monitoring in South Australia (Croft et al. 2009). Other vegetation condition assessments have been developed for specific purposes, for example, assessing habitat complexity (Freudenberger and Drew 2001) or assessing bird-friendly habitat on farms (Cleland 2008). Vegetation condition assessments have also been conducted to assess sustainable rangeland management (e.g. Westoby et al. 1989), forestry (i.e. woody biomass production potential) and ecological function (Ludwig et al. 1997). These vegetation condition assessments don't tell us about the biodiversity residing in a patch of vegetation, just the potential for biodiversity to exist in that patch. In the context of biodiversity conservation, the general understanding is that the more habitat features the vegetation has, the more biodiversity it will harbour. This thinking is akin to the field of dreams hypothesis, i.e. 'if you build it they will come' (Hilderbrand et al. 2005; Palmer et al. 1997).

Vegetation condition can also be assessed in terms of its capacity to provide ecosystem goods and services (Vegetation Assets, States and Transitions - VAST: Thackway & Lesslie 2006). The VAST framework classifies vegetation by the degree of human modification as a series of states, from intact native vegetation through to total removal. A benchmark is identified for each vegetation association based on structure, composition and current regenerative capacity. Benchmarks are based on the best understanding of pre-European conditions (sometimes called 'fully natural'). Relative change in condition from this benchmark is assessed for each site or patch. VAST was developed to highlight the links between land management and vegetation condition, provide a mechanism for describing the consequences of land management on vegetation condition, and contribute to the analysis of ecosystem services provided by vegetation. However, indicators of ecosystem goods and services provided by vegetation, and indicators to assess the management of vegetation resources for sustainable production have yet to be developed and tested for most ecosystem services.

To date, we have not seen a vegetation condition assessment tool that relates natural pest control services specifically to vegetation condition. Hence, growers do not have the information to manage non-crop vegetation to maximise natural pest control services on farm. Some basic principles were outlined in the most recent edition of the *Cotton Production Manual* (2011 edition) and the *Pest and Beneficials in Cotton Landscapes* extension documents, but more detailed information and data is required to encourage more growers to investigate the potential of managing native vegetation and other non-crop vegetation to encourage birds, microbats and beneficial invertebrates into their farming systems. An easy-to-use tool is required to allow growers to benchmark and monitor biodiversity and the presence of natural pest control providing organisms on their farms to chart their progress and assist in managing for natural pest control.

2. Aims and Objectives:

Several projects aimed at maximising biodiversity and multiple ecosystem service benefits from on-farm native vegetation are in the pipeline (e.g. the CFoC project: *Cotton Growers Working Together for a Sustainable Landscape* and the federal government's *Carbon Farming Initiative*). There is also a push through MyBMP for growers to monitor biodiversity on-farm. A standardised assessment protocol is required for biodiversity monitoring and project evaluation across cotton landscapes. We also need to know more about the influence of different site and landscape scale habitat measures on the potential for provision of natural pest control services. Finally, data illustrating the value of different vegetation types on cotton farms in providing habitat for pest controlling organisms is required.

This aims of this project were to:

1. Develop a rapid biodiversity assessment protocol after evaluation of several alternate vegetation condition assessment tools.
2. Determine the importance of different habitats and the degree of non-crop habitat in cotton landscapes for biodiversity conservation and potential provision of natural pest control services.
3. Survey biodiversity relevant to natural pest control – birds, microbats and invertebrates in cotton landscapes

3. Methodology:

3.1 Biodiversity assessment development

Vegetation condition indicators currently used in metrics to assess biodiversity conservation value of sites in New South Wales (Biometric: Gibbons et al. 2008), Victoria (Habitat Hectares: DSE 2004), Queensland (BioCondition: Eyre et al. 2008) and South Australia (Bushland Condition Monitoring: Croft et al. 2009) were compared. From the list of indicators compiled from each of the vegetation condition metrics, a condensed list of indicators was used to create an assessment methodology to assess vegetation condition for biodiversity conservation and natural pest control on cotton farms.

3.2 Field site selection

Farms were chosen in three locations in the upper-Namoi Valley: two at Boggabri (Kilmarnock and Nandewar), two near Harparary/Maules Creek (Warilea and Glenelg) and two between Narrabri and Wee Waa (Oakville and Federation Farm). Farms were chosen so that one in each location had little non-crop vegetation in the surrounding landscape, while the other had substantially more non-cop vegetation than the first. The level of non-crop vegetation surrounding each site was measured using Google Earth imagery in a 5 km area encompassing all four sites at each farm. One grassland site,

one cotton crop, one stand of remnant woodland vegetation and one tree planting were chosen for survey at each farm.

Table 1: Landscape-scale (5 km radius) land cover and classification at each farm visited during this project.

	Kilmarnock	Nandewar	Warilea	Glenelg	Oakville	Federation Farm
Woodland	13	44	2	12	15	5
Crop	71	41	90	58	26	53
Grassland	14	14	7	25	54	37
Total non-crop vegetation	27	58	9	37	69	42
Non-crop:crop ratio	0.38	1.41	0.10	0.64	2.65	0.79
Landscape type	low	high	low	high	high	low

3.3 Field methods

Field surveys were carried out during the period 11–17th February 2012. Habitat complexity (Rhiannon), birds (Stuart and Chris), microbats (song meter recordings) and invertebrates (Chris and Rhiannon) were surveyed at each site. Photos were taken at each site for future reference of seasonal conditions and vegetation response. Habitat complexity was measured using a modified version of the Habitat Complexity Assessment of Freudenberger and Drew (2001).

The Freudenberger and Drew (2001) Habitat Complexity Assessment was specifically designed to assess habitat provision for birds at stock route sites in northern NSW. However, this assessment has been widely used elsewhere and for a range of different organisms. The Habitat Complexity Assessment originally used three classes to qualitatively assess canopy, tall shrub, low shrub, ground storey, litter and log and fallen branch cover, with a possible score out of fifteen indicating the degree of habitat complexity. In this study, we recorded percent cover of the same indicators, which concentrate on habitat structure, but do not take into account landscape context, vegetation composition or ecosystem functioning. The Habitat Complexity Assessment in its original form can not be used to assess the condition of different sites for biodiversity conservation as it automatically downgrades sites such as natural grasslands which may provide habitat for a range of species, but are physically simplistic in their structure. However, it does separate different habitat types and can provide information on the types of species that are likely to be recorded at a site given knowledge of the species habitat preferences.

Birds were surveyed between dawn (0620) and 1100 each day during the survey period. A 20 minute, 2 ha survey was conducted twice on non-consecutive days. Conditions were fine and sunny or with some cloud and still or breezy during the sample period. Birds seen or heard within a sample area were recorded. Opportunistically encountered species across the farm were also noted but not reported here.

Microbats were recorded using eight Song Meter SM2+ ultrasonic recorders (Wildlife Acoustics, Inc.) powered by 4 alkaline D cell batteries. Two 32GB flash cards were used for data storage. Each song meter was set up to continuously record from local sunset to local sunrise. The sample rate was limited to 19200Hz to capture all microbats potentially occurring in the study area but minimise data storage needs. One Song Meter was set up at each site and recorded microbats over two consecutive nights before being moved to the next site. All sites west of Narrabri were recorded on the nights of the 11th and 12th February, all sites near Harparary/Maules Creek on the 13th and 14th and all Boggabri sites on the 15th and 16th. Each Song Meter was set up on a pole, two metres above the ground within the habitat to be sampled for crops, grasslands and open remnant woodland vegetation or plantings. In denser remnant woodland vegetation and plantings, the Song Meter was set up on the edge of the habitat to allow the greatest chance of recording microbats.

Greg Ford (Balance! Environmental Consulting, Toowoomba) analysed the microbat calls recorded by the Song Meters. Species names used in this summary follow Churchill (2008), except for *Mormopterus* species, which follow van Dyck & Strahan (2008) and Reardon *et al.* (2008). Call identification was based on call descriptions and keys presented in Reinhold *et al.* (2001) and/or Pennay *et al.* (2004) as well as reference calls collected in south-eastern Queensland and northern New South Wales. Species' identification was further refined by considering probability of occurrence based on distributional information presented in Churchill (2008) and van Dyck & Strahan (2008). Some calls were weak and/or noisy and/or of short duration and lacked sufficient detail for attribution to species level. All such calls were within frequency ranges of species otherwise identified in the table and were unlikely to represent additional species. Only calls that were positively identified were used in the analysis of microbat community composition, but all calls recorded were used in the analysis of microbat activity between different vegetation types and landscape contexts.

Invertebrates were sampled using a modified version of the beat-sheet method. A large, clear-plastic bag with dimensions of one metre deep and 50 centimetres wide were carefully placed over entire plants or branches of trees or shrubs and sealed before using secateurs to remove the vegetation. Both understorey and overstorey vegetation was sampled where possible and the number of samples taken in each stratum or on different species was determined by the proportion total biomass at a site contained in each stratum (or species). Commercially available insect spray was sprayed into the bag and the bag was resealed and left for a minimum of half an hour. Each bag was then opened and the vegetative matter was shaken violently so that the invertebrates captured were left in the bottom of the bag. The vegetative matter was then discarded.

The invertebrates captured were removed from the plastic bags each night and preserved in a specimen jar containing 80% ethanol until they could be returned to the lab for identification. Invertebrates were identified using the Pests and Beneficials in Australian Cotton Landscapes guide and classified as pests or beneficials. The field method employed in this project was used as the experience required to identify invertebrates on the ground before they fly off was not available in this project. The modified method allowed us to collect the invertebrates for a more reliable identification. A quick comparison in the field using the commonly used beat sheet method revealed no new species that hadn't already been collected using the modified method.

3.4 Data analyses

One-way analysis of variance (ANOVA) was carried out using Statistix 8 (Analytical Software 2003) to test for significant differences in the abundance of insectivorous birds, beneficial invertebrates, pest invertebrates, the beneficial:pest ratio and microbat activity in each vegetation type and between landscapes with high vs low non-crop vegetation cover. All assumptions of each model were met ($\ln[x+1]$ transformation was necessary in most instances) and a level of $P < 0.05$ was taken as indicating statistical significance. Tukey's HSD pairwise comparisons were used to analyse differences between vegetation and landscape types.

Non-metric multi-dimensional scaling (NMDS) was used to ordinate sites separately according to habitat complexity, bird, microbat and invertebrate community composition in PRIMER 6.1.11 (Clarke & Warwick 2006). Data were log-transformed ($\ln[x+1]$) and site similarity calculated using the Bray-Curtis index. Cluster analysis illustrated the dissimilarity in habitat types between sites and vegetation types in the form of a dendrogram. Ordination after conducting a Principal Components Analysis (PCA) highlighted the differences in habitat composition for each vegetation type. Analysis of Similarity (ANOSIM: numerically) and NMDS (visually) illustrated, in multi-dimensional space, the similarity (or dissimilarity) in bird, microbat and invertebrate community composition between sites, vegetation types and landscape contexts.

4. Results:

4.1 Vegetation condition assessment

A total of 31 indicators were identified between the four vegetation condition metrics currently in use in eastern Australia (Table 2). Of these, four indicators assessed landscape context, eleven assessed vegetation composition, fourteen assessed habitat structure and two were used to assess ecosystem functioning. A vegetation condition assessment was developed for use by cotton farmers interested in biodiversity conservation and natural pest control service provision using these indicators as a guide (Appendix 1). The

vegetation condition assessment was simplified by Stacey Vogel (Namoi CMA) to make it more appropriate for people wanting a more rapid assessment tool which could be a fun activity for children to be involved with (Appendix 2).

Table 2: Indicators of vegetation condition currently in use in eastern Australian vegetation condition assessment metrics.

	BioMetric (NSW)	BioCon (Qld)	Bush Con (SA)	Hab Hect (Vic)
Landscape context				
Connectivity	✓	✓		✓
Landscape Context	✓	✓		✓
Patch size	✓	✓	✓	✓
Distance to water		✓		
Composition				
Species list/species checklist		✓	✓	✓
Species richness	✓			
Percent cover of native tree layer	✓			
Percent cover of native shrub layer	✓			
Percent cover of native ground shrub layer	✓			
Percent cover of native grass layer	✓			
Percent cover of native other ground layer	✓			
Percent cover of native perennial grasses		✓		
Percent cover of native perennial forb & non-grass layer		✓		
Percent cover of native annual forb & non-grass layer		✓		
Percent cover of all exotic vegetation	✓	✓	✓	✓
Structure				
Percent tree cover		✓	✓	✓
Percent cover of shrubs		✓		
Vegetation cover of each life form			✓	✓
Number of life forms present in understorey				✓
Percent cover of leaf litter		✓	✓	✓
Number of large trees (live)	✓	✓	✓	✓
Number of hollow-bearing trees	✓	✓	✓	
Fallen logs (number or length)	✓	✓	✓	✓
Height of tallest stratum		✓		
Percent cover of rocks			✓	
Percent cover of microphytic crusts			✓	
Number of stems in specified stem size classes	✓			
Total number of stems			✓	
Percent cover of bare ground			✓	
Function				
Regeneration of indigenous woody vegetation	✓	✓	✓	✓
Canopy health		✓	✓	✓

4.2 Habitat complexity

Analyses showed that each of the vegetation types surveyed during the study provided a unique combination of habitat characteristics (ANOSIM $R = 0.933$, $P < 0.001$). Cluster analysis confirmed that sites within each vegetation type

were similar to each other in their habitat complexity and each vegetation type provided distinctly different habitat complexity compared to the other vegetation types (Figure 1). Cotton crops were highly dissimilar from the other three vegetation types in terms of habitat provision. Grasslands were moderately dissimilar from remnant woodland vegetation and plantings, while the latter two vegetation types were somewhat similar in their habitat complexity. The planted site at Nandewar was different from the other plantings in that it consisted of one tree species only (*Eucalyptus argophloia*) while the other plantings were mixed tree and shrub plantings. The planting at Nandewar had been planted for agroforestry purposes while the other plantings were for environmental benefits.

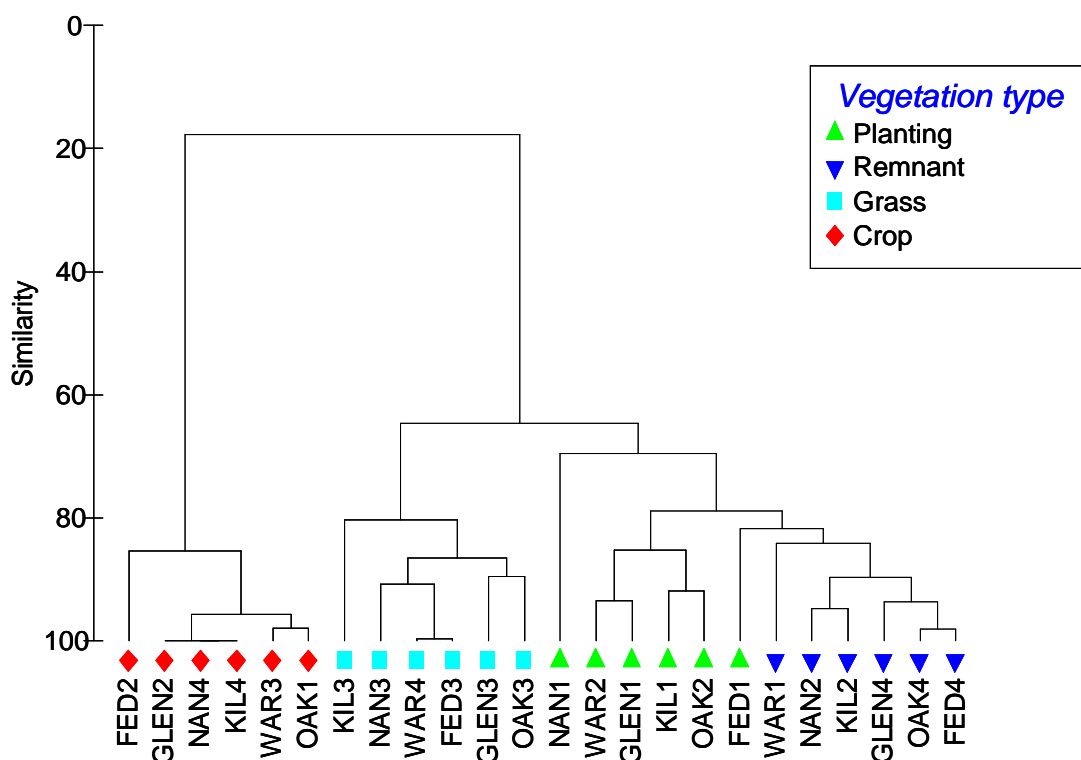


Figure 1: Cluster analysis showing similarity in habitat complexity between sites and the vegetation types they represent.

Ordination of principal components showed that habitat complexity in cotton crops was distinctly different from the other vegetation types and dominated by low shrub cover (i.e. cotton plants), and very little herbaceous and litter cover (Figure 2). Grasslands also provided a distinctly different habitat from the other vegetation types, and were dominated by herbaceous vegetation cover, a dense litter layer and little canopy, low shrub and tall shrub cover. Planted and remnant woodland vegetation were different from each other, but more similar to each other than the other vegetation types having high canopy, tall shrub and low shrub cover, and a well-developed litter layer. PC1 represented the ground cover component of sites, with decreasing litter cover, and increasing herbaceous vegetation and low shrub cover. PC2 represented

the canopy and associated components of sites with decreasing canopy cover, tall shrub cover, and logs and fallen branches.

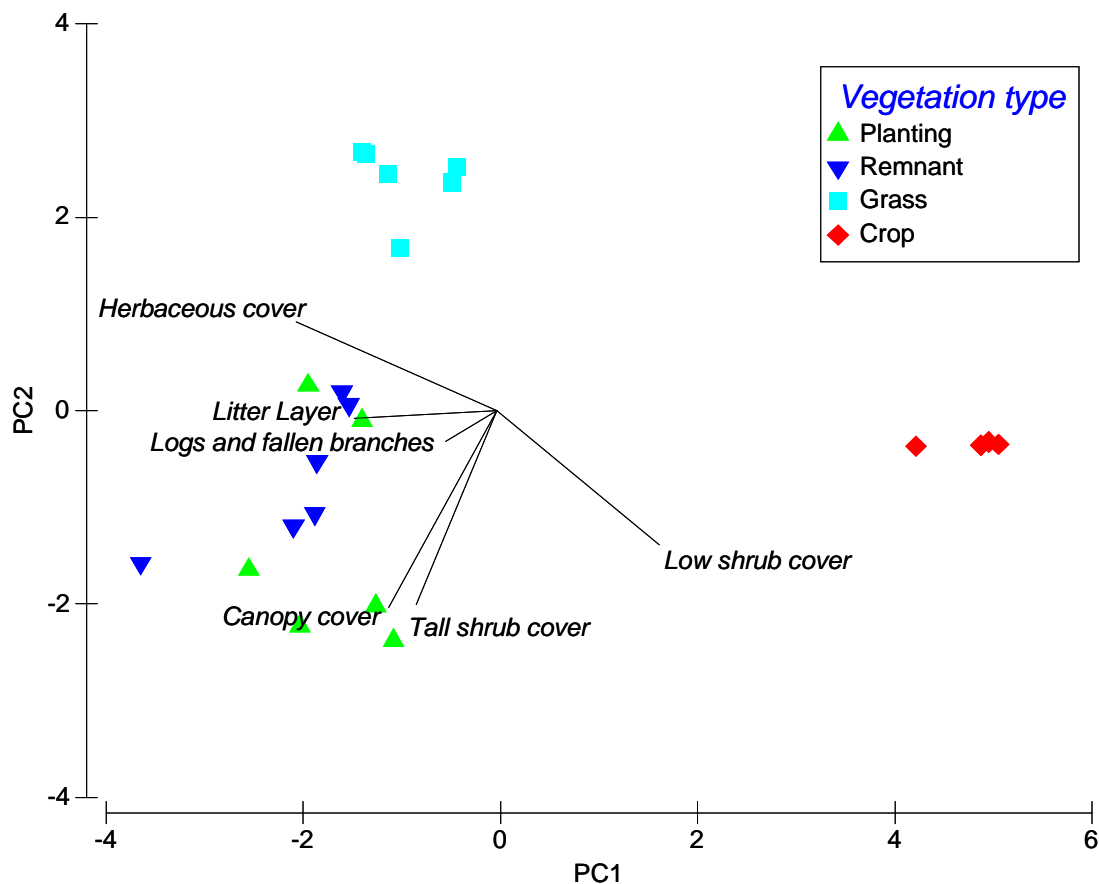


Figure 2: PCA ordination of six habitat complexity variables.

4.3 Birds

A total of 57 bird species were recorded in survey transects during the 20-minute survey time after waterbirds and species that were either flying over or through were removed. Of the species recorded, 37 were insectivorous and therefore potentially important in providing natural pest control services. No bird species recorded during our surveys were listed as threatened under state or federal legislation.

Significant differences were found in the number of insectivorous birds recorded between vegetation types (Figure 2). The highest number of insectivorous birds was recorded in remnant woodland vegetation and tree plantings, followed by grasslands and finally cotton crops. No significant differences were found in the number of insectivorous birds between sites within different landscape contexts ($F = 0.05$, $P = 0.825$).

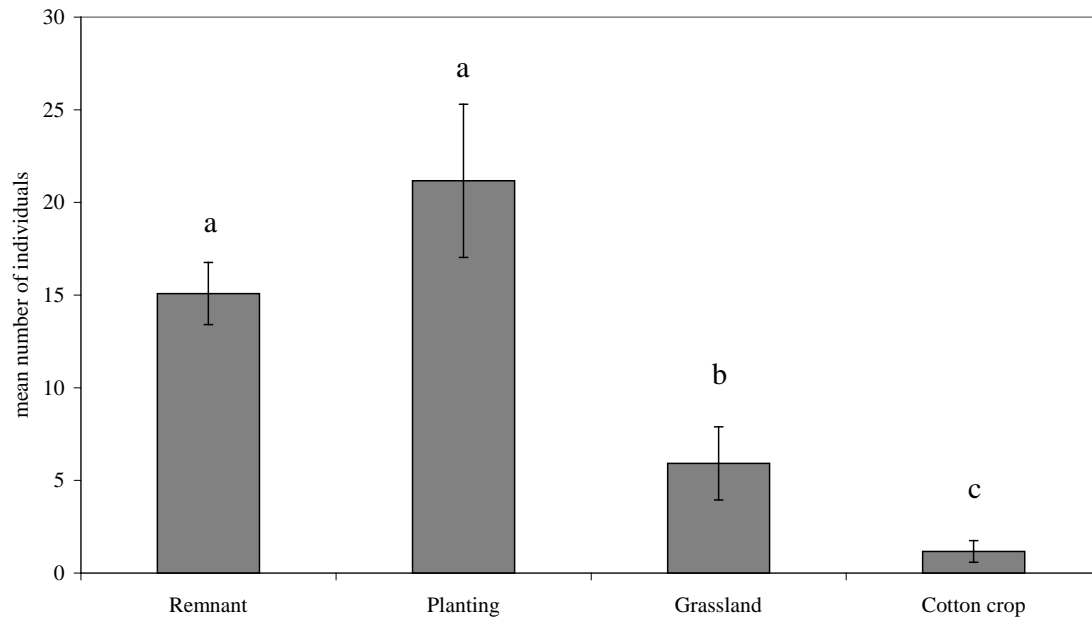


Figure 2: Mean number of insectivorous birds recorded in each vegetation type (± 1 SE). Significant differences are indicated by different letters.

Each of the four vegetation types had a unique bird assemblage associated with it when all recorded species were included (ANOSIM $R = 0.736$, $P < 0.001$). The bird assemblage at grassland sites was variable as indicated by the spread of sites on the NMDS ordination (Figure 3). One of the planted sites was ordinated half-way between the other planted vegetation sites and the grassland sites as it was very young and had an open canopy structure, which encouraged a range of grassland bird species into the site. The remnant woodland vegetation and planted vegetation sites were ordinated in the same area of the NMDS graph while the crop sites and grassland sites were ordinated on the opposite sides of the NMDS graph. This result indicated that the bird community assemblages at the remnant woodland and planted sites were more similar to each other than the crop and grassland sites.

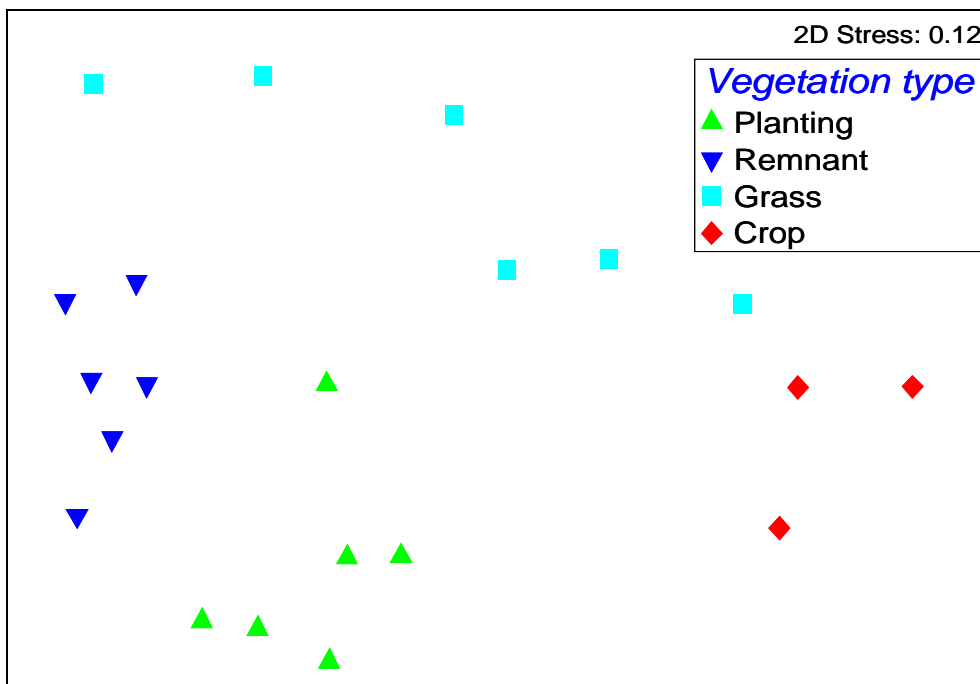


Figure 3: NMDS ordination of bird community data at 21 sites classified according to vegetation type. Three crop sites were excluded from this analysis as no birds were recorded at those sites.

There were no significant differences in bird community composition between sites with different levels of non-crop vegetation at the landscape scale (ANOSIM $R = -0.08$, $P = 0.9$). When bird community data were ordinated using NMDS, there was no discernable pattern in the distribution of sites in multi-dimensional space as a result of the level of non-crop habitat in the surrounding landscape (Figure 4).

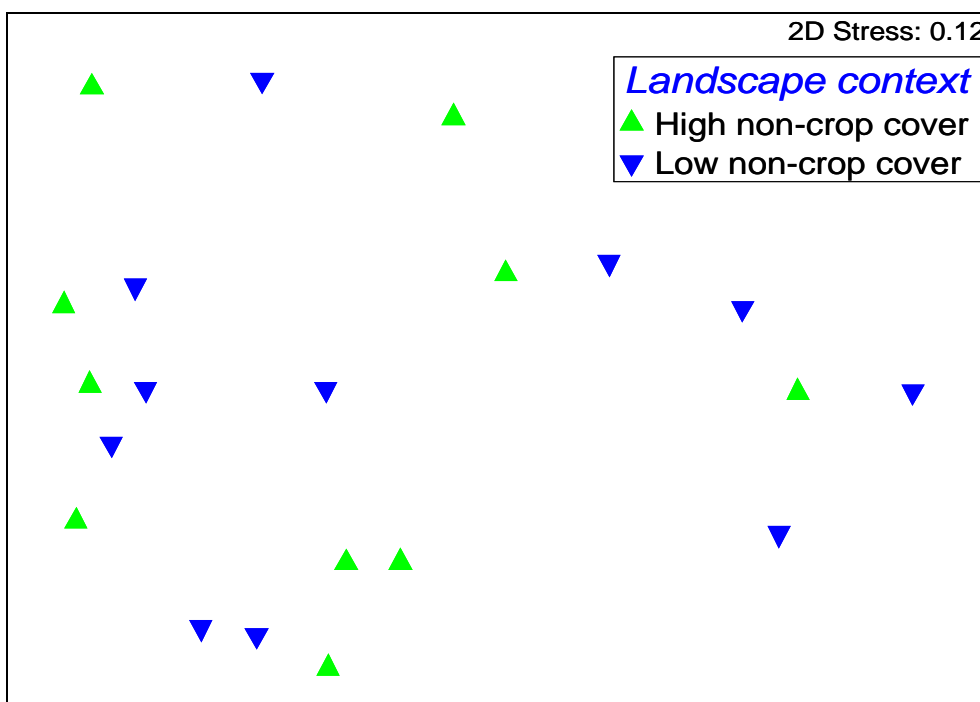


Figure 4: NMDS ordination of bird communities at 21 sites classified according to the level of non-crop vegetation in the surrounding landscape.

4.4 Microbats

A total of 13 microbats were positively identified during surveys. One of those species, the Yellow-bellied Sheath-tail-bat is listed as vulnerable in NSW under the *Threatened Species Conservation Act 1999 (TSC Act 1999)*. Two species, the Eastern Horse-shoe Bat and Eastern Cave Bat were recorded once only at one site only.

Significant differences were found in the number of microbat calls recorded between vegetation types (Figure 5). There were generally more microbats recorded in remnant woodland vegetation and tree plantings than in grasslands. Due to the high variability in the number of calls recorded in remnant woodland vegetation and tree plantings, there was no significant difference in the number of microbat recordings between remnant woodland vegetation, plantings and cotton crops. There was also no significant difference in the number of microbat calls as a result of landscape context ($F = 0.25, P = 0.620$).

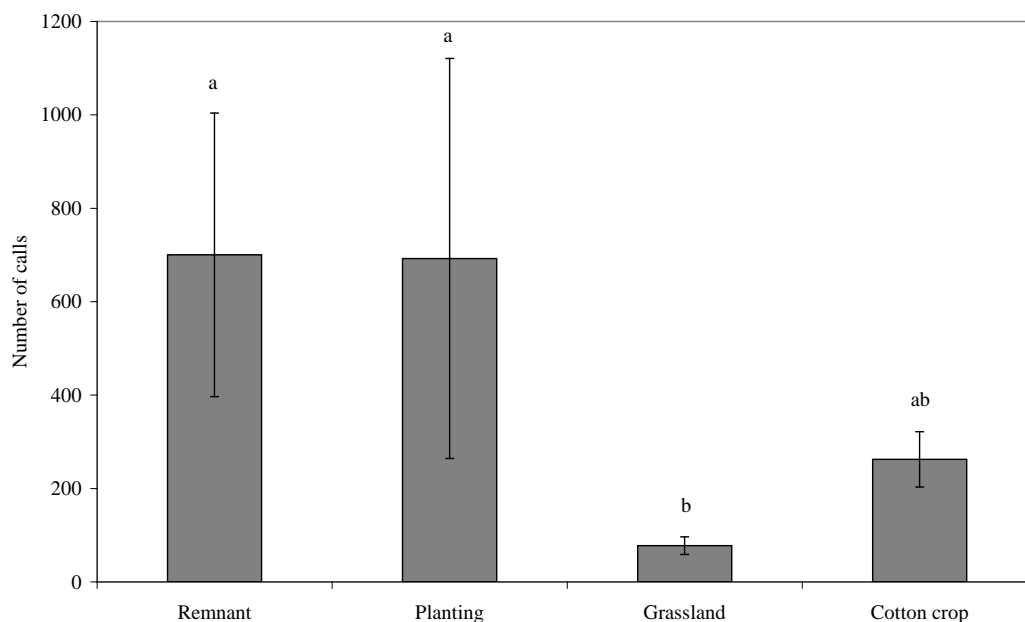


Figure 5: Microbat activity measured by the number of calls recorded over two sample nights within four vegetation types (mean \pm SE). Significant differences are indicated by different letters.

Remnant woodland vegetation, plantings and cotton crops had similar microbat communities, but grasslands had their own, distinct microbat community (ANOSIM $R = 0.182, P = 0.006$) (Figure 6). Remnant woodland vegetation sites and crop vegetation sites had marginally different microbat communities ($P = 0.069$). The grassland site at Nandewar had a different microbat community from the other grassland sites as there were large, mature trees in the vicinity where microbats may have been roosting at night.

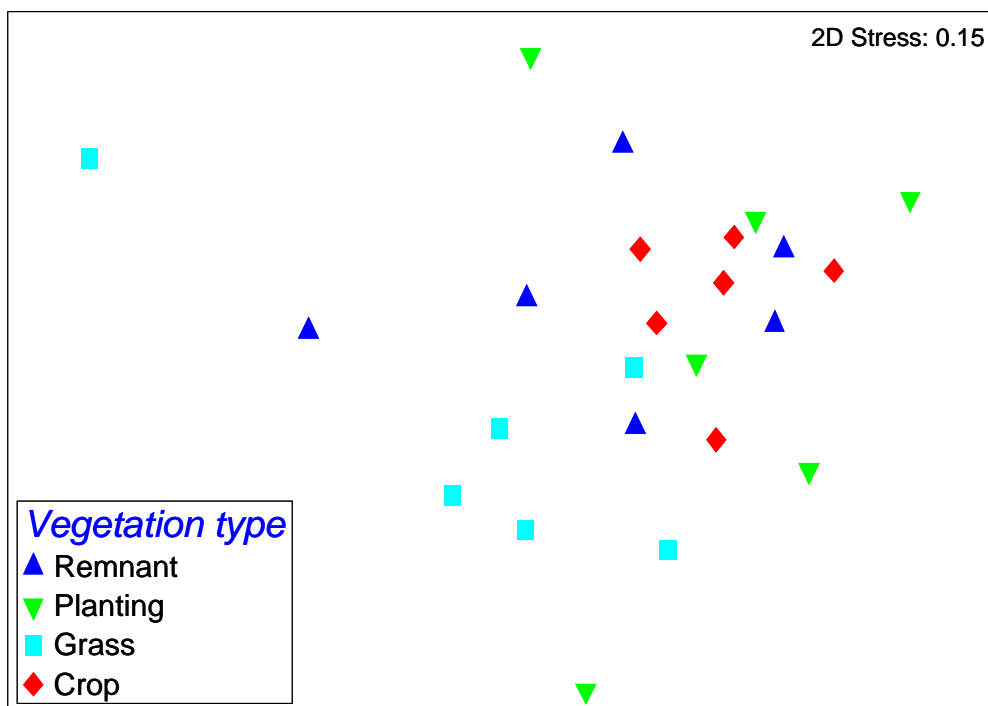


Figure 6: NMDS ordination of microbat community data at 24 sites classified according to vegetation type.

There were no clear differences in microbat community composition between sites with different levels of non-crop vegetation at the landscape scale (ANOSIM $R = -0.026$, $P = 0.6$). When the microbat communities were ordinated using NMDS, there was no discernable pattern in the distribution of sites in multi-dimensional space as a result of the level of non-crop habitat in the landscape surrounding each site (Figure 7).

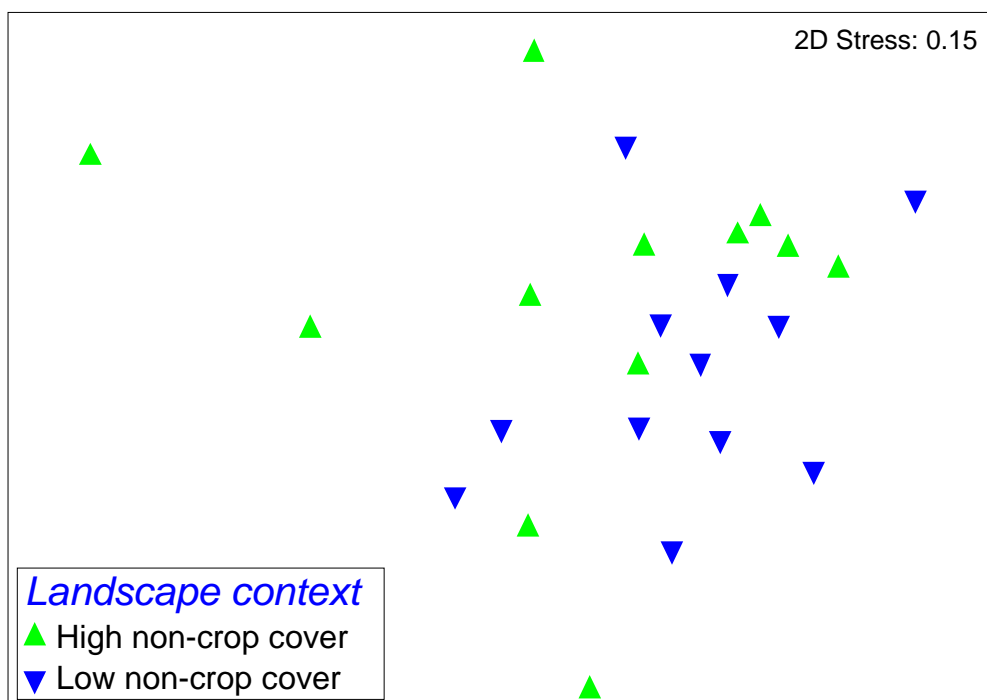


Figure 7: NMDS ordination of microbat communities at 24 sites classified according to the level of non-crop vegetation in the surrounding landscape.

4.5 Invertebrates

Significant differences were found in the number of pests and beneficials caught between vegetation types (Figure 8). There were generally more pests and less beneficials captured in cotton crops, while fewer pests were recorded in grasslands and tree plantings. There were significantly more beneficials recorded in remnant woodland vegetation and tree plantings compared to grasslands and cotton crops. The beneficial:pest ratio was higher in remnant woodland vegetation, plantings and grasslands than in cotton crops (Figure 9). There were no significant differences in the number of beneficials ($F = 0.01$, $P = 0.925$), pests ($F = 0.38$, $P = 0.546$) or the beneficial to pest ratio ($F = 0.42$, $P = 0.522$) due to landscape context.

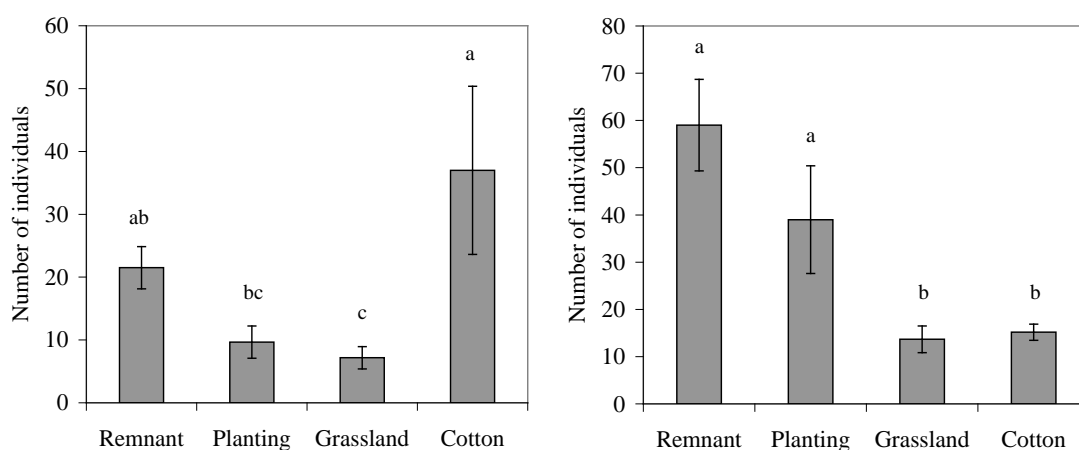


Figure 8: (a) Total number of pests captured in each vegetation type (± 1 SE) and (b) Total number of beneficials captured in each vegetation type (± 1 SE). Significant differences are indicated by different letters.

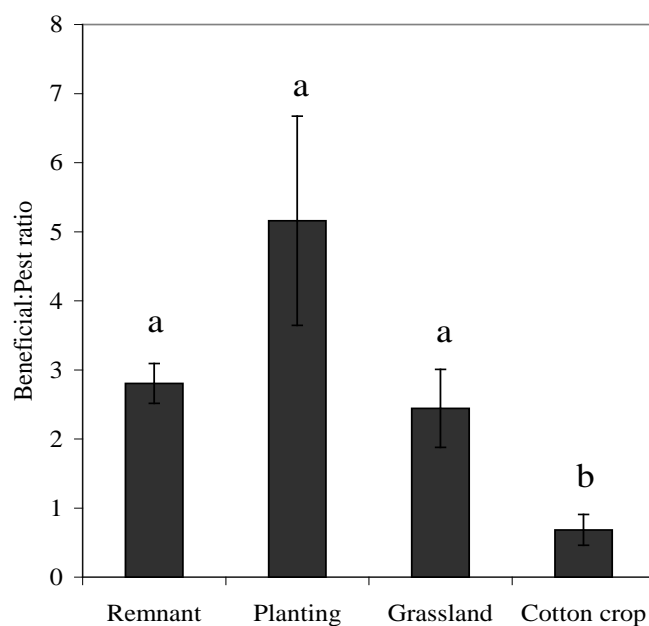


Figure 9: Beneficial:pest ratio (± 1 SE). Significant differences are indicated by different letters.

Except for the remnant woodland and planted vegetation, which had similar invertebrate communities, each vegetation type had a unique invertebrate assemblage from all other vegetation types (ANOSIM $R = 0.467$, $P < 0.001$). The invertebrate assemblages associated with each of the vegetation types were variable, as indicated by the spread of sites on the NMDS ordination (Figure 10). One of the planted sites was ordinated amongst the grassland sites as it had an open canopy structure, which encouraged a range of ground-dwelling invertebrate species into the site. The remnant woodland vegetation and planted vegetation sites were ordinated in the same area of the NMDS graph while the crop sites and grassland sites were ordinated on the opposite side of the NMDS graph. This result indicated that the invertebrate community assemblages at the remnant woodland and planted sites were more similar to each other than the crop and grassland sites.

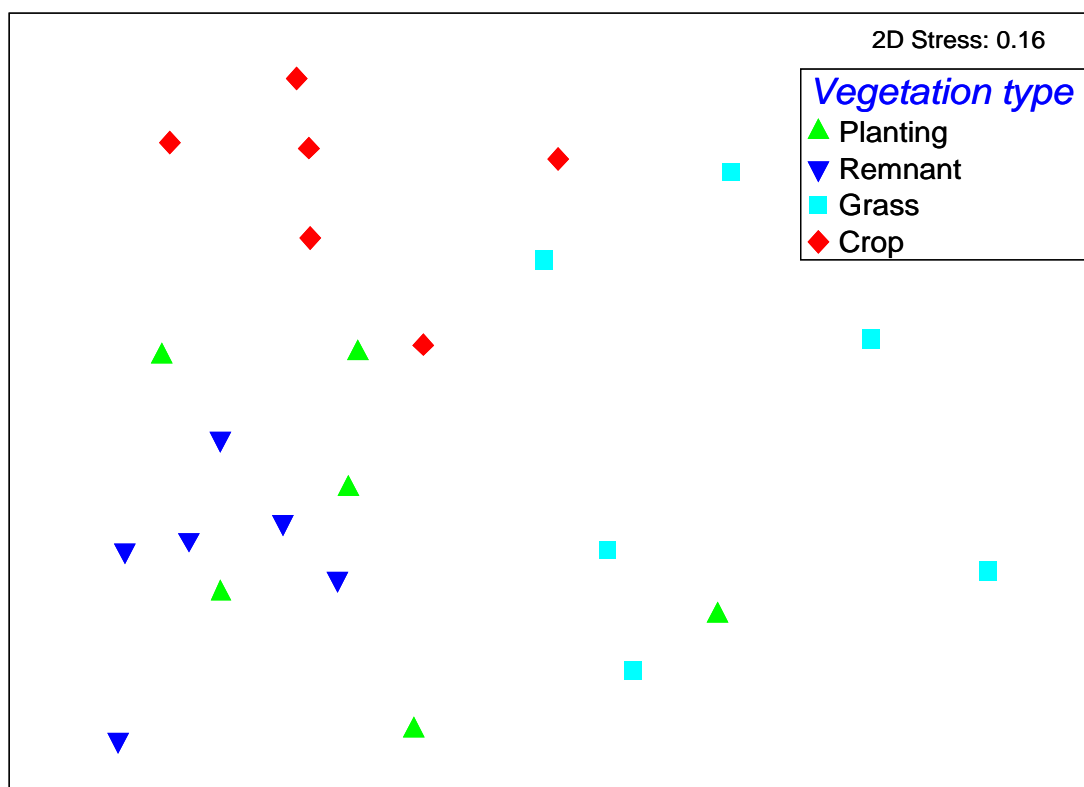


Figure 10: NMDS ordination of invertebrate community data at 24 sites classified according to vegetation type.

There were no clear differences in invertebrate community composition between sites with different levels of vegetation at the landscape scale (ANOSIM $R = -0.026$, $P = 0.64$). When the invertebrate communities were ordinated using NMDS, there was no discernable pattern in the distribution of sites in multi-dimensional space as a result of the level of non-crop habitat in the landscape surrounding each site (Figure 11).

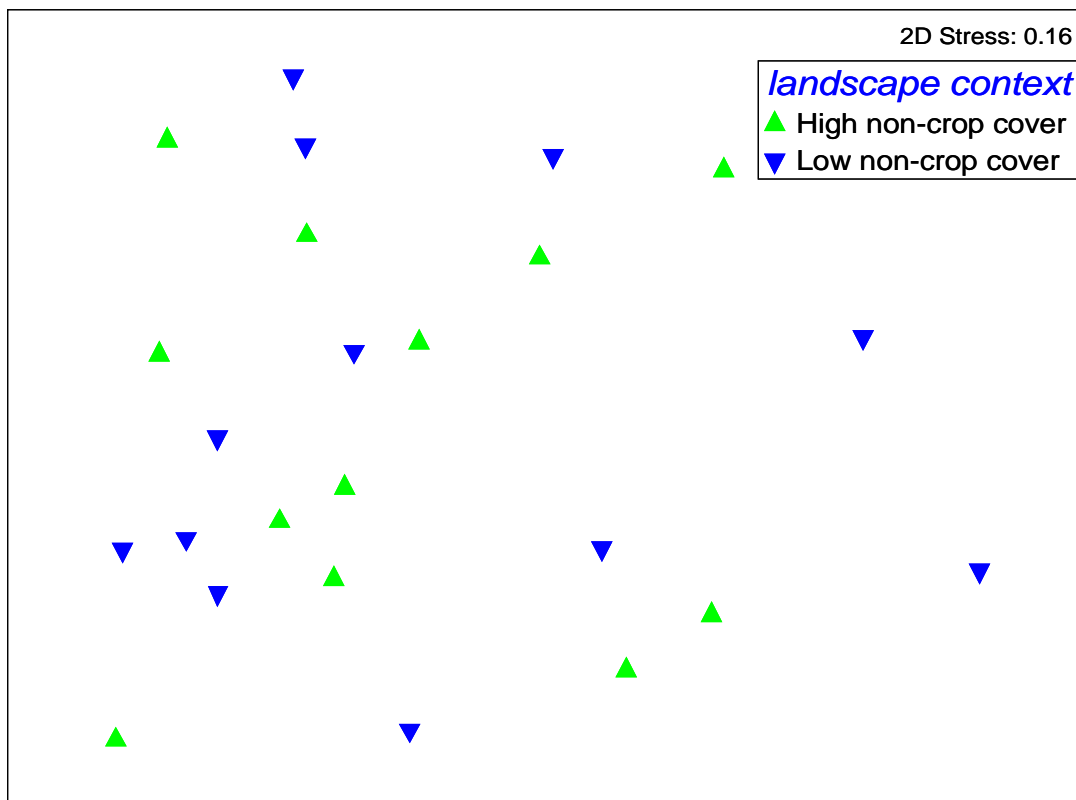


Figure 11: NMDS ordination of invertebrate communities at 24 sites classified according to the level of non-crop vegetation in the surrounding landscape.

5. Discussion:

Birds, microbats and beneficial invertebrates were in higher abundance in non-crop vegetation, in particular, remnant native woodland vegetation and tree plantings as opposed to cotton crops on farms near Boggabri, Harparary/Maules Creek and Narrabri. The beneficial:pest ratio was higher in non-crop vegetation compared to cotton crops, while pest numbers were higher in cotton crops compared to non-crop vegetation. The results of this study reinforce findings by Nancy Schellhorn, Ingrid Rencken, Letitia Silberbauer, Allan House, Felix Bianchi David Perovic and others who have shown that landholders need to be thinking outside the square (i.e. the cotton paddock) when it comes to natural pest control. While the aforementioned research concentrated on beneficial invertebrates, this project has shown that other natural pest controlling organisms such as microbats and insectivorous birds exist in native vegetation on cotton farms.

5.1 Birds

The highest numbers of insectivorous birds were recorded in remnant woodland vegetation and plantings. In grasslands, there were fewer species overall, and the majority of species recorded were granivores (i.e. they ate predominantly grass seeds). Only three insectivorous bird species were recorded in cotton crops including willie wagtails, cisticolas and white-winged fairy-wrens. White-winged fairy-wrens were observed moving

between a tree planting and the adjacent cotton crop to prey on insects before moving back to the planting again.

The highest insectivorous bird species richness (21 species) was recorded in a riparian remnant woodland site at Glenelg. Riparian gallery forests have high fertility and productivity and hence support a much larger faunal community than adjacent floodplains and uplands (Naiman et al. 2005). Riparian vegetation communities across Australia are noted for their importance in the conservation of distinct bird communities, especially those in fragmented and semi-arid landscapes (e.g. Fischer & Goldney 1997; MacNally et al. 2000; Martin et al. 2006; Palmer & Bennett 2006; Woinarski et al. 2000). Many bird species are also more abundant on forest edges as a result of greater abundance of foraging opportunities in the edge and adjacent, more open habitat (Berry 2001; Howe 1984). Many birds use adjacent grasslands and open areas for hunting or foraging, while nesting in woodlands or forests, making both habitat types equally important in a landscape mosaic (Law & Dickman 1998).

5.2 Microbats

A large degree of variation was evident in the number of microbat calls recorded in remnant woodland vegetation and plantings. While there was less than half the mean number of microbat calls recorded in cotton crops compared to remnant woodland vegetation and plantings, this difference was not significant. Research by Lumsden (2004) in northern Victoria produced similar results, recording no difference in the activity levels of bats between remnants with different tree densities ranging from densely-vegetated blocks to single paddock trees. However, sites in open paddocks devoid of trees differed significantly from all types of wooded remnants and had significantly lower levels of bat activity.

Microbats are highly mobile, travelling several kilometres from their roosts in tree hollows or under bark to their hunting grounds and water (Kunz and Lumsden 2003). Some microbat species use a number of roost sites in different vegetation types and landscape elements, which allows them to follow different prey around the landscape (Lumsden 2004). Therefore, it is not surprising that there was a high degree of variability in the number of microbats found in each habitat type.

Microbat community composition did not differ significantly between remnant woodland vegetation, plantings and cotton crops, but a distinct microbat community was recorded in grasslands. Lumsden (2004) also found that grasslands had a different species composition from wooded vegetation sites. As with birds, different microbat species use different types of habitat, and their habitat preferences probably relate to their chosen diet and roost requirements (Lumsden 2004). Habitat complexity probably has a strong

influence on microbat species composition in different vegetation types because different microbat species use different foraging techniques to take prey (Lumsden 2004). Species such as Gould's Wattled Bat take prey from within the canopy, while others such as the Little Forest Bat forages amongst the shrub layer. Presence of hollow-bearing trees may also be important for some microbat species that use hollows as roost sites.

5.3 Invertebrates

Significantly more beneficials were captured in remnant woodland vegetation and tree plantings than grasslands or cotton crops in this study. Previous research has shown that remnant woodland vegetation and tree plantings provide habitat for natural enemies (Bianchi et al. 2006; Rencken 2006). A review by Langellotto and Denno (2004) encompassing 43 studies indicated that there is a positive relationship between structural diversity in vegetation and the abundance of beneficial invertebrates. Low habitat complexity in grasslands may therefore explain why there were significantly less beneficials in grasslands compared to remnant woodland vegetation and tree plantings.

There were significantly more pests recorded in cotton crops than in grasslands and planted vegetation, however, the variability in pest numbers in cotton crops was such that there was not a significant difference in pest numbers between cotton crops and remnant woodland vegetation. There were more beneficials than pests captured in all four vegetation types tested, as indicated by the beneficial:pest ratio. However, the beneficial:pest ratio was significantly lower in cotton crops compared to the three non-crop vegetation types. While there were some pests found in remnant woodland vegetation, there was approximately three-times more beneficials to control pest numbers and therefore it is unlikely that pest numbers would explode in remnant woodland vegetation.

There were significantly different invertebrate communities residing in each of the four vegetation types sampled during this study. As with birds and microbats, different invertebrates have different habitat preferences and some species use multiple vegetation types during different times in their life cycle. For example, the damsel bug and white-collared lady bird appear to prefer herbaceous vegetation, while the green lacewing appears to prefer treed habitats (Rencken 2006). It is therefore necessary to consider a range of different vegetation types in efforts to provide habitat for beneficial invertebrates.

5.4 Influence of landscape scale land cover

Interestingly, there were no significant differences in insectivorous bird, microbat, pest or beneficial invertebrate abundance or community composition as a result of landscape scale land cover. One would expect that given there are more birds, microbats and beneficial invertebrates in non-crop

vegetation, landscapes with a high proportion of non-crop vegetation would have higher abundances of these organisms. This result may be explained by the way the sites were classified into high or low non-crop vegetation cover. Given that this project has shown that some vegetation types provide better habitat value than others, perhaps in future studies a better way to classify landscapes would be by focusing on those vegetation types such as woodland and plantings where natural pest providing organisms were present in highest abundance.

5.5 Future Research

While this project has shown that birds, microbats and beneficial invertebrates can be found in high densities in remnant woodland vegetation and tree plantings on cotton farms, a number of new questions have been raised. For example, growers will want to know what, and how much these organisms are eating in terms of their problem pest species. They may also like to know how far they are moving into cotton crops from the non-crop habitats. Another important question that needs to be answered relates to the preference of these organisms for strip versus block habitat area. Will a grower get more bang-for-their-buck by planting a block of vegetation or a strip? Answers to these sorts of questions will help to develop an 'ideal configuration' of crop and non-crop vegetation to maximise natural pest control on cotton farms.

6. Conclusion:

This study showed that birds, microbats and beneficial invertebrates are in higher abundance in non-crop vegetation, in particular, remnant native woodland vegetation and tree plantings as opposed to cotton crops on farms near Boggabri, Harparary/Maules Creek and Narrabri. The beneficial:pest ratio was higher in non-crop vegetation compared to cotton crops, while pest numbers were higher in cotton crops compared to non-crop vegetation. These results indicate that non-crop vegetation is providing important habitat and refuge for insectivorous birds, microbats and beneficial invertebrates on cotton farms. Retention and management of native vegetation could therefore have a dramatic impact on the number of pests and beneficials growers have in their crops and their level of reliance on pesticide sprays.

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8. Presentations and public relations:

Data from this project was presented by Rhiannon Smith as part of a lecture titled 'Native Vegetation and Biodiversity on Cotton Farms' for the Cotton Production Course at UNE – 14th May 2012.

This project would not have been possible without the support and enthusiasm of these landholders:

John and Andrew Watson 'Kilmarnock' and 'Nandewar'
Chris and Amanda Goulden 'Glenelg'
Jack Warnock 'Warilea'
Mike Logan 'Oakville'
Gary Coulton 'Federation Farm'

8. Highlights:



Chris Jacobs and Stuart Green with a song meter after setting it up to record microbat activity in a cotton field at Federation Farm.



Chris Jacobs and Rhiannon Smith collecting invertebrate samples in grassland near Harparary/Maules Creek.



Chris Jacobs with a car full of invertebrate samples ready to sort



Chris Jacobs and Stuart Green pick bugs from vegetation at the Narrabri Council Caravan Park after a long day in the field.



Song meter set up in a grassland site near Boggabri

9. Executive Summary:

Birds, bats and beneficial invertebrates provide natural pest control services to cotton growers who can provide habitat for them. This study investigated the abundance of insectivorous birds, microbats and beneficial invertebrates on cotton farms near Boggabri, Maules Creek and Narrabri. Cotton farms with lots of non-crop vegetation and farms with little were compared to look at landscape-scale differences in natural pest control providing organisms. Within each farm, insectivorous birds, microbats and beneficial invertebrate communities were surveyed in native remnant woodland vegetation, tree plantings, grasslands and cotton crops. We showed that habitat complexity at the site scale was more important than the degree of non-crop vegetation at the landscape scale in determining the abundance and community composition of insectivorous birds, microbats, pests and beneficials. This indicated that for maximum biodiversity conservation and natural pest control, a range of different vegetation types is just as important as the amount of non-crop vegetation at the landscape scale. A vegetation assessment methodology was created as part of this project to encourage landholders to look at how they can improve their native vegetation to maximise biodiversity and natural pest control services.

Appendix 1: Pro forma for vegetation condition assessment on cotton farms.



Vegetation Condition Assessment for Natural Pest Control on Cotton Farms

Site establishment and details

Site name _____ Assessor _____ Date _____

Site location (GPS location) _____

Vegetation type (e.g. grassland, shrubland, woodland/forest) _____

Describe any recent disturbances at the site (e.g. fire, cultivation, timber collection – fence posts, firewood etc, cleaning up). Include the date(s) the disturbance occurred _____

Establish a photo survey point by putting in a star post somewhere near the centre of your vegetation patch. Take photos using a digital camera looking north, then south, then east, then west. Label photos with the site name, date and compass direction (e.g. sitename_1.1.12_North). Keep your photos in a dedicated folder on your computer for comparisons between survey times. You should revisit your site once in every season (i.e. 4 times per year).

Spatial considerations and management (applicable to all vegetation types)

	Good	Better	Best
Patch shape (roughly)	\	■	●
Patch size	<2ha	2-10ha	>10ha
Minimum patch width	<50m	50-100m	>100m
Distance to nearest remnant of >20ha size	>1km	300m - 1km	<300
Proportion of the landscape with non-crop vegetation (within 1 km)	<30%	30-60%	>60%
Proportion of the landscape with non-crop vegetation (within 5 km)	<30%	30-60%	>60%
Distance to water (e.g. channel, storage, river)	500m	250-500m	<250m
Grazing duration	Continuously	Occasionally	Not grazed
Grazing intensity	Heavily grazed	Light grazing	Not grazed

Site habitat complexity

	Needs attention	Good	Better	Best
Old trees (with hollows) (#/ha)*	<5 trees	5-10 trees	10-20 trees	>20 trees
Young trees (regeneration) (#/ha)*	<5 trees	5-10 trees	10-20 trees	>20 trees
Tall shrubs (>1m high) (e.g. Acacia, Wilga, Rosewood)*	Absent		Present	
Low shrubs (0.5 - 1m high) (e.g. lignum, saltbushes, rolypoly) (% cover)	<30	30-50%	50-80%	>80%
Groundstorey vegetation (e.g. grass, herbs) (% cover)	<30	30-50%	50-80%	>80%
Litter (% cover)	<30	30-50%	50-80%	>80%
Logs and fallen branches > 10cm diameter* (m/ha)	<5	5-10	10-25	>25

* may not be applicable in grasslands

Vegetation diversity

How many different tree species can you identify in 1 ha? _____

Can you identify them (list them)? _____

How many different tall shrub species can you identify in 1 ha? _____

Can you identify them (list them)? _____

How many different low shrub species can you identify in 1 ha? _____

Can you identify them (list them)? _____

How many different grass species can you identify in 1 ha? _____

Can you identify them (list them)? _____

How many different herb species can you identify in 1 ha? _____

Can you identify them (list them)? _____

Notes (what actions can you take to improve the value of this site for biodiversity conservation and ecosystem service provision?): _____

Appendix 2: Pro forma for simplified vegetation condition assessment on cotton farms.

Tracks, Scats and Traces Biodiversity Competition

Name _____ Date _____

Site location _____

What does your patch of bush look like? *Circle the most appropriate one.*

Grassland (> 10% grasses) Shrubland (> 10% shrubs) Woodland/forest (> 10% trees)

Take and attach a photo of your patch of bush: _____

Consider establishing a permanent photo survey point that you can come back to overtime to record how it changes over time, remember to always take the photo from the same point and looking in the same direction

Can you describe your patch of bush using the table below?

	Good	Better	Best
Patch shape (roughly)		\ <i>Corridor</i>	■ <i>Block</i>
Patch size	<i><2ha</i>	<i>2-10ha</i>	<i>>10ha</i>
Minimum patch width	<i><50m</i>	<i>50-100m</i>	<i>>100m</i>
Distance to nearest patch of bush >20ha size	<i>>1km</i>	<i>300m - 1km</i>	<i><300</i>
Distance to water (e.g. channel, storage, river, billabong)	<i>500m</i>	<i>250-500m</i>	<i><250m</i>
Grazing duration	<i>Continuously</i>	<i>Occasionally</i>	<i>Not grazed</i>

How much potential habitat does your patch of bush have?

	Needs attention	Good	Better	Best
Old trees with hollows eg large holes (#/ha)*	<i><5 trees</i>	<i>5-10 trees</i>	<i>10-20 trees</i>	<i>>20 trees</i>
Litter eg leaves and small sticks (% cover)	<i><30</i>	<i>30-50%</i>	<i>50-80%</i>	<i>>80%</i>
Logs and fallen branches > 10cm diameter (m/ha)	<i><5</i>	<i>5-10</i>	<i>10-25</i>	<i>>25</i>

Does your patch of bush have different tree species in it? YES NO

Can you name any of them? _____

Does your patch of bush have different shrub species in it? YES NO

Can you name any of them? _____

Does your patch of bush have different grasses and herbs in it? YES NO

Can you name any of them? _____

Can you see any animal scats (poo) or tracks? Who do they belong to?

Can you draw some animal tracks you've seen on your property here:

How can you improve the health of your patch of bush? (Hint: refer to Mum's Sustainable Landscape Action Plan)

Appendix 3: Habitat complexity at each site assessed using the method of Freudenberger and Drew (2001).

Site	Vegetation type	Canopy cover	Tall shrub cover	Low shrub cover	Herbaceous cover	Logs and fallen branches	Litter Layer
NAN1	Planting	25	0	0.5	10	0	80
NAN2	Remnant	15	0	5	90	5	20
NAN3	Grass	0.01	0	0.5	90	1	20
NAN4	Crop	0	0	85	0	0	0.5
KIL1	Planting	15	15	15	50	0	30
KIL2	Remnant	10	0	5	80	10	30
KIL3	Grass	1	0	2	90	3	15
KIL4	Crop	0	0	85	0	0	0.5
WAR1	Remnant	20	20	1	90	10	90
WAR2	Planting	30	30	1	20	0.5	20
WAR3	Crop	0	0	85	0.1	0	0.1
WAR4	Grass	0	0	0	85	0	30
GLEN1	Planting	20	30	1	65	0.1	20
GLEN2	Crop	0	0	85	0	0	0.5
GLEN3	Grass	0	0	0	45	0	8
GLEN4	Remnant	5	5	5	80	11	30
OAK1	Crop	0	0	85	0	0	0
OAK2	Planting	35	10	10	20	0	30
OAK3	Grass	0	0	1	75	0	10
OAK4	Remnant	10	8	5	80	5	20
FED1	Planting	10	2	1	90	0	20
FED2	Crop	0	0	85	0.1	0	5
FED3	Grass	0	0	0	90	0	30
FED4	Remnant	10	10	5	80	5	30

Appendix 4: Bird and microbat species previously recorded in the study area and their status (Atlas of NSW Wildlife: OEH 2011)

Scientific name	Common Name
<i>Dromaius novaehollandiae</i>	Emu
<i>Alectura lathamii</i>	Australian Brush-turkey
<i>Coturnix pectoralis</i>	Stubble Quail
<i>Coturnix ypsilophora</i>	Brown Quail
<i>Excalfactoria chinensis</i>	King Quail
<i>Anseranas semipalmata</i>	Magpie Goose (V)
<i>Anas gracilis</i>	Grey Teal
<i>Anas rhynchotis</i>	Australasian Shoveler
<i>Anas superciliosa</i>	Pacific Black Duck
<i>Aythya australis</i>	Hardhead
<i>Chenonetta jubata</i>	Australian Wood Duck
<i>Cygnus atratus</i>	Black Swan
<i>Dendrocygna arcuata</i>	Wandering Whistling-Duck
<i>Dendrocygna eytoni</i>	Plumed Whistling-Duck
<i>Malacorhynchus membranaceus</i>	Pink-eared Duck
<i>Stictonetta naevosa</i>	Freckled Duck (V)
<i>small grebe sp.</i>	Small grebe
<i>Tachybaptus novaehollandiae</i>	Australasian Grebe
<i>Columba livia</i>	Rock Dove*
<i>Geopelia cuneata</i>	Diamond Dove
<i>Geopelia humeralis</i>	Bar-shouldered Dove
<i>Geopelia striata</i>	Peaceful Dove
<i>Ocyphaps lophotes</i>	Crested Pigeon
<i>Phaps chalcoptera</i>	Common Bronzewing
<i>Podargus strigoides</i>	Tawny Frogmouth
<i>Eurostopodus mystacalis</i>	White-throated Nightjar
<i>Aegotheles cristatus</i>	Australian Owlet-nightjar
<i>Apus pacificus</i>	Fork-tailed Swift
<i>Hirundapus caudacutus</i>	White-throated Needletail
<i>Anhinga novaehollandiae</i>	Australasian Darter
<i>Microcarbo melanoleucos</i>	Little Pied Cormorant
<i>Phalacrocorax carbo</i>	Great Cormorant
<i>Phalacrocorax sulcirostris</i>	Little Black Cormorant
<i>Phalacrocorax varius</i>	Pied Cormorant
<i>Pelecanus conspicillatus</i>	Australian Pelican
<i>Ephippiorhynchus asiaticus</i>	Black-necked Stork (E1)
<i>Ardea ibis</i>	Cattle Egret
<i>Ardea intermedia</i>	Intermediate Egret
<i>Ardea modesta</i>	Eastern Great Egret
<i>Ardea pacifica</i>	White-necked Heron
<i>Ardea/Egretta sp.</i>	Unidentified Egret
<i>Egretta novaehollandiae</i>	White-faced Heron
<i>Nycticorax caledonicus</i>	Nankeen Night Heron

<i>Platalea flavipes</i>	Yellow-billed Spoonbill
<i>Platalea regia</i>	Royal Spoonbill
<i>Plegadis falcinellus</i>	Glossy Ibis
<i>Threskiornis molucca</i>	Australian White Ibis
<i>Threskiornis spinicollis</i>	Straw-necked Ibis
<i>Hamirostra melanosternon</i>	Black-breasted Buzzard (V)
<i>Accipiter cirrocephalus</i>	Collared Sparrowhawk
<i>Accipiter fasciatus</i>	Brown Goshawk
<i>Aquila audax</i>	Wedge-tailed Eagle
<i>Circus assimilis</i>	Spotted Harrier (V)
<i>Elanus axillaris</i>	Black-shouldered Kite
<i>Haliaeetus leucogaster</i>	White-bellied Sea-Eagle
<i>Haliastur sphenurus</i>	Whistling Kite
<i>Hieraaetus morphnoides</i>	Little Eagle (V)
<i>Milvus migrans</i>	Black Kite
<i>Falco berigora</i>	Brown Falcon
<i>Falco cenchroides</i>	Nankeen Kestrel
<i>Falco longipennis</i>	Australian Hobby
<i>Falco peregrinus</i>	Peregrine Falcon
<i>Falco subniger</i>	Black Falcon
<i>Fulica atra</i>	Eurasian Coot
<i>Gallinula tenebrosa</i>	Dusky Moorhen
<i>Gallirallus philippensis</i>	Buff-banded Rail
<i>Lewinia pectoralis</i>	Lewin's Rail
<i>Porphyrio porphyrio</i>	Purple Swamphen
<i>Porzana fluminea</i>	Australian Spotted Crake
<i>Porzana tabuensis</i>	Spotless Crake
<i>Tribonyx ventralis</i>	Black-tailed Native-hen
<i>Himantopus himantopus</i>	Black-winged Stilt
<i>Recurvirostra novaehollandiae</i>	Red-necked Avocet
<i>Elsya melanops</i>	Black-fronted Dotterel
<i>Erythrogonys cinctus</i>	Red-kneed Dotterel
<i>Vanellus miles</i>	Masked Lapwing
<i>Vanellus miles novaehollandiae</i>	[Spur-winged Plover]
<i>Rostratula benghalensis australis</i>	Painted Snipe (Australian subspecies) (E1)
<i>Turnix pyrrhorthorax</i>	Red-chested Button-quail
<i>Turnix varius</i>	Painted Button-quail
<i>Turnix velox</i>	Little Button-quail
<i>Chlidonias hybrida</i>	Whiskered Tern
<i>Chroicocephalus novaehollandiae</i>	Silver Gull
<i>Sterna sp.</i>	Tern
<i>Calyptorhynchus banksii</i>	Red-tailed Black-Cockatoo
<i>Calyptorhynchus lathami</i>	Glossy Black-Cockatoo (V)
<i>Cacatua galerita</i>	Sulphur-crested Cockatoo
<i>Cacatua sanguinea</i>	Little Corella
<i>Calyptorhynchus funereus</i>	Yellow-tailed Black-Cockatoo
<i>Eolophus roseicapillus</i>	Galah

<i>Nymphicus hollandicus</i>	Cockatiel
<i>Neophema pulchella</i>	Turquoise Parrot (V)
<i>Polytelis swainsonii</i>	Superb Parrot (V)
<i>Alisterus scapularis</i>	Australian King-Parrot
<i>Aprosmictus erythropterus</i>	Red-winged Parrot
<i>Barnardius zonarius</i>	Australian Ringneck
<i>Barnardius zonarius barnardi</i>	[Mallee Ringneck]
<i>Glossopsitta concinna</i>	Musk Lorikeet
<i>Glossopsitta pusilla</i>	Little Lorikeet (V)
<i>Melopsittacus undulatus</i>	Budgerigar
<i>Northiella haematogaster</i>	Blue Bonnet
<i>Platycercus adscitus</i>	White Cheeked Rosella
<i>Platycercus elegans</i>	Crimson Rosella
<i>Platycercus eximius</i>	Eastern Rosella
<i>Psephotus haematonotus</i>	Red-rumped Parrot
<i>Trichoglossus haematodus</i>	Rainbow Lorikeet
<i>Centropus phasianinus</i>	Pheasant Coucal
<i>Cacomantis flabelliformis</i>	Fan-tailed Cuckoo
<i>Cacomantis pallidus</i>	Pallid Cuckoo
<i>Chalcites basalis</i>	Horsfield's Bronze-Cuckoo
<i>Chalcites lucidus</i>	Shining Bronze-Cuckoo
<i>Chalcites osculans</i>	Black-eared Cuckoo
<i>Eudynamys orientalis</i>	Eastern Koel
<i>Scythrops novaehollandiae</i>	Channel-billed Cuckoo
<i>Ninox connivens</i>	Barking Owl (V)
<i>Ninox novaeseelandiae</i>	Southern Boobook
<i>Tyto capensis</i>	Grass Owl (V)
<i>Tyto novaehollandiae</i>	Masked Owl (V)
<i>Tyto javanica</i>	Eastern Barn Owl
<i>Ceyx azureus</i>	Azure Kingfisher
<i>Dacelo novaeguineae</i>	Laughing Kookaburra
<i>Todiramphus sanctus</i>	Sacred Kingfisher
<i>Merops ornatus</i>	Rainbow Bee-eater
<i>Eurystomus orientalis</i>	Dollarbird
<i>Climacteris picumnus</i>	Brown Treecreeper
<i>Climacteris picumnus victoriae</i>	Brown Treecreeper (eastern subspecies) (V)
<i>Cormobates leucophaea</i>	White-throated Treecreeper
<i>Ptilonorhynchus maculatus</i>	Spotted Bowerbird
<i>Malurus cyaneus</i>	Superb Fairy-wren
<i>Malurus lamberti</i>	Variegated Fairy-wren
<i>Malurus leucopterus</i>	White-winged Fairy-wren
<i>Acanthiza apicalis</i>	Inland Thornbill
<i>Acanthiza chrysorrhoa</i>	Yellow-rumped Thornbill
<i>Acanthiza lineata</i>	Striated Thornbill
<i>Acanthiza nana</i>	Yellow Thornbill
<i>Acanthiza pusilla</i>	Brown Thornbill
<i>Acanthiza reguloides</i>	Buff-rumped Thornbill

<i>Acanthiza uropygialis</i>	Chestnut-rumped Thornbill
<i>Aphelocephala leucopsis</i>	Southern Whiteface
<i>Gerygone albogularis</i>	White-throated Gerygone
<i>Gerygone fusca</i>	Western Gerygone
<i>Hylacola pyrrhopygia</i>	Chestnut-rumped Heathwren
<i>Pyrrholaemus saggitatus</i>	Speckled Warbler (V)
<i>Sericornis frontalis</i>	White-browed Scrubwren
<i>Smicrornis brevirostris</i>	Weebill
<i>Pardalotus punctatus</i>	Spotted Pardalote
<i>Pardalotus striatus</i>	Striated Pardalote
<i>Acanthagenys rufogularis</i>	Spiny-cheeked Honeyeater
<i>Acanthorhynchus tenuirostris</i>	Eastern Spinebill
<i>Anthochaera carunculata</i>	Red Wattlebird
<i>Anthochaera phrygia</i>	Regent Honeyeater (E4A)
<i>Entomyzon cyanotis</i>	Blue-faced Honeyeater
<i>Epthianura albifrons</i>	White-fronted Chat (V)
<i>Lichenostomus chrysops</i>	Yellow-faced Honeyeater
<i>Lichenostomus fuscus</i>	Fuscous Honeyeater
<i>Lichenostomus leucotis</i>	White-eared Honeyeater
<i>Lichenostomus melanops</i>	Yellow-tufted Honeyeater
<i>Lichenostomus penicillatus</i>	White-plumed Honeyeater
<i>Lichenostomus virescens</i>	Singing Honeyeater
<i>Lichmera indistincta</i>	Brown Honeyeater
<i>Manorina flavigula</i>	Yellow-throated Miner
<i>Manorina melanocephala</i>	Noisy Miner
<i>Meliphaga lewinii</i>	Lewin's Honeyeater
<i>Melithreptus brevirostris</i>	Brown-headed Honeyeater
<i>Melithreptus gularis gularis</i>	Black-chinned Honeyeater (eastern subspecies) (V)
<i>Melithreptus lunatus</i>	White-naped Honeyeater
<i>Philemon citreogularis</i>	Little Friarbird
<i>Philemon corniculatus</i>	Noisy Friarbird
<i>Phylidonyris niger</i>	White-cheeked Honeyeater
<i>Plectorhyncha lanceolata</i>	Striped Honeyeater
<i>Sugomel niger</i>	Black Honeyeater
<i>Pomatostomus superciliosus</i>	White-browed Babbler
<i>Pomatostomus temporalis temporalis</i>	Grey-crowned Babbler (eastern subspecies) (V)
<i>Cinlosoma punctatum</i>	Spotted Quail-thrush
<i>Daphoenositta chrysoptera</i>	Varied Sittella (V)
<i>Coracina maxima</i>	Ground Cuckoo-shrike
<i>Coracina novaehollandiae</i>	Black-faced Cuckoo-shrike
<i>Coracina papuensis</i>	White-bellied Cuckoo-shrike
<i>Coracina tenuirostris</i>	Cicadabird
<i>Lalage sueurii</i>	White-winged Triller
<i>Colluricincla harmonica</i>	Grey Shrike-thrush
<i>Falcunculus frontatus frontatus</i>	Eastern Shrike-tit
<i>Pachycephala pectoralis</i>	Golden Whistler
<i>Pachycephala rufiventris</i>	Rufous Whistler

<i>Oriolus sagittatus</i>	Olive-backed Oriole
<i>Artamus cinereus</i>	Black-faced Woodswallow
<i>Artamus cyanopterus</i>	Dusky Woodswallow
<i>Artamus leucorhynchus</i>	White-breasted Woodswallow
<i>Artamus minor</i>	Little Woodswallow
<i>Cracticus nigrogularis</i>	Pied Butcherbird
<i>Cracticus tibicen</i>	Australian Magpie
<i>Cracticus torquatus</i>	Grey Butcherbird
<i>Strepera graculina</i>	Pied Currawong
<i>Rhipidura albiscapa</i>	Grey Fantail
<i>Rhipidura leucophrys</i>	Willie Wagtail
<i>Rhipidura rufifrons</i>	Rufous Fantail
<i>Corvus coronoides</i>	Australian Raven
<i>Grallina cyanoleuca</i>	Magpie-lark
<i>Myiagra cyanoleuca</i>	Satin Flycatcher
<i>Myiagra inquieta</i>	Restless Flycatcher
<i>Myiagra rubecula</i>	Leaden Flycatcher
<i>Corcorax melanorhamphos</i>	White-winged Chough
<i>Struthidea cinerea</i>	Apostlebird
<i>Eopsaltria australis</i>	Eastern Yellow Robin
<i>Melanodryas cucullata</i>	Hooded Robin
<i>Microeca fascinans</i>	Jacky Winter
<i>Petroica boodang</i>	Scarlet Robin (V)
<i>Petroica goodenovii</i>	Red-capped Robin
<i>Mirafra javanica</i>	Horsfield's Bushlark
<i>Cisticola exilis</i>	Golden-headed Cisticola
<i>Acrocephalus australis</i>	Australian Reed-Warbler
<i>Cincloramphus cruralis</i>	Brown Songlark
<i>Cincloramphus mathewsi</i>	Rufous Songlark
<i>Megalurus gramineus</i>	Little Grassbird
<i>Zosterops lateralis</i>	Silvereye
<i>Cheramoeca leucosterna</i>	White-backed Swallow
<i>Hirundo neoxena</i>	Welcome Swallow
<i>Petrochelidon ariel</i>	Fairy Martin
<i>Petrochelidon nigricans</i>	Tree Martin
<i>Turdus merula</i>	Eurasian Blackbird*
<i>Sturnus tristis</i>	Common Myna*
<i>Sturnus vulgaris</i>	Common Starling*
<i>Dicaeum hirundinaceum</i>	Mistletoebird
<i>Lonchura punctulata</i>	Nutmeg Mannikin*
<i>Neochmia modesta</i>	Plum-headed Finch
<i>Neochmia temporalis</i>	Red-browed Finch
<i>Stagonopleura guttata</i>	Diamond Firetail (V)
<i>Taeniopygia bichenovii</i>	Double-barred Finch
<i>Taeniopygia guttata</i>	Zebra Finch
<i>Passer domesticus</i>	House Sparrow*
<i>Anthus novaeseelandiae</i>	Australian Pipit

<i>Rhinolophus megaphyllus</i>	Eastern Horseshoe-bat
<i>Saccolaimus flaviventris</i>	Yellow-bellied Sheathtail-bat (V)
<i>Mormopterus "Species 3" (little penis)</i>	
<i>Mormopterus "Species 4" (big penis)</i>	
<i>Mormopterus planiceps</i>	Little Mastiff-bat
<i>Tadarida australis</i>	White-striped Freetail-bat
<i>Chalinolobus dwyeri</i>	Large-eared Pied Bat (V)
<i>Chalinolobus gouldii</i>	Gould's Wattled Bat
<i>Chalinolobus morio</i>	Chocolate Wattled Bat
<i>Nyctophilus geoffroyi</i>	Lesser Long-eared Bat
<i>Nyctophilus gouldi</i>	Gould's Long-eared Bat
<i>Nyctophilus sp.</i>	long-eared bat
<i>Nyctophilus timoriensis</i>	Greater Long-eared Bat (V)
(South-eastern form)	
<i>Scotorepens balstoni</i>	Inland Broad-nosed Bat
<i>Scotorepens greyii</i>	Little Broad-nosed Bat
<i>Scotorepens sp 1</i>	Central-eastern Broad-nosed Bat
<i>Vespadelus vulturnus</i>	Little Forest Bat

Note: * = introduced

Appendix 5: Habitat complexity data for each site. Values are percentages.

Site	Vegetation type	Canopy cover	Tall shrub cover	Low shrub cover	Herbaceous cover	Logs and fallen branches	Litter Layer
NAN1	Planting	25	0	0.5	10	0	80
NAN2	Remnant	15	0	5	90	5	20
NAN3	Grass	0.01	0	0.5	90	1	20
NAN4	Crop	0	0	85	0	0	0.5
KIL1	Planting	15	15	15	50	0	30
KIL2	Remnant	10	0	5	80	10	30
KIL3	Grass	1	0	2	90	3	15
KIL4	Crop	0	0	85	0	0	0.5
WAR1	Remnant	20	20	1	90	10	90
WAR2	Planting	30	30	1	20	0.5	20
WAR3	Crop	0	0	85	0.1	0	0.1
WAR4	Grass	0	0	0	85	0	30
GLEN1	Planting	20	30	1	65	0.1	20
GLEN2	Crop	0	0	85	0	0	0.5
GLEN3	Grass	0	0	0	45	0	8
GLEN4	Remnant	5	5	5	80	11	30
OAK1	Crop	0	0	85	0	0	0
OAK2	Planting	35	10	10	20	0	30
OAK3	Grass	0	0	1	75	0	10
OAK4	Remnant	10	8	5	80	5	20
FED1	Planting	10	2	1	90	0	20
FED2	Crop	0	0	85	0.1	0	5
FED3	Grass	0	0	0	90	0	30
FED4	Remnant	10	10	5	80	5	30

Appendix 6: Mean bird data at each site for two mornings sampling

Common name	Scientific name	Nandewar				Kilmarnock				Glenelg				Warilea			Fed Farm					Oakville			
		P	R	G	C	P	R	G	C	P	C	G	R	R	P	C	G	P	C	G	R	C	P	G	R
Apostle Bird	<i>Struthidea cinerea</i>	3.5	7	0	0	0	0	0	0	4	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0
Australian Magpie	<i>Gymnorhina tibicen</i>	0.5	0	0	0	0	3.5	0	0	2.5	0	1.5	0	1	0	0	0	2	0	0	1	0	1	0	1
Australian Pelican	<i>Pelecanus conspicillatus</i>	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Australian Raven	<i>Corvus coronoides</i>	0	1	0	0	0	0.5	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Australian Wood Duck	<i>Chenonetta jubata</i>	0	0	0	0	0	0.5	0	0	0	0	0	2.5	1	0	0	0	0	0	0	0	0	0	0	0
Black Kite	<i>Milvus migrans</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Black-faced Cuckoo-shrike	<i>Coracina novaehollandiae</i>	0	0	0	0	1	0	0	0	1.5	0	0	0	0	0.5	0	0	0	0	0	0.5	0	1	0	0
Black-shouldered kite	<i>Elanus axillaris</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Blue Bonnet	<i>Northiella haematogaster</i>	0	0	0	0	0	0	0	0	1.5	0	0	0	0	1	0	0	4.5	0	0	5.5	0	0	0	0
Brown Falcon	<i>Falco berigora</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0
Brown Quail	<i>Coturnix ypsilophora</i>	0.5	1	0	0	0	0.5	0.5	0	0.5	0	1	0	0	0	0	1	1	0	0	0	0	0	0	0
Cockatiel	<i>Nymphicus hollandicus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Common Starling	<i>Sturnus vulgaris</i>	0	0	0	0	0	9	0	0	0	0	0	1	0	0	0	0	0	0	0	3.5	0	0	0	0
Crested Pigeon	<i>Ocyphaps lophotes</i>	1	1.5	0	0	1.5	0	0	0	1	0	0	1	1.5	2	0	0	12.5	0	0	5	0	0.5	0	0.5
Darter	<i>Anhinga melanogaster</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5
Eastern Rosella	<i>Platycercus eximius</i>	0	3.5	0	0	1	3	0	0	0	0	0	1	3	4	0	0	1.5	0	0	1.5	0	0.5	0	12.5
Galah	<i>Cacatua roseicapilla</i>	0	3	0	0	0	11	0	0	0	0	0	4.5	2	0	0	0	1	0	0	2	0	0	0	0
Golden-headed Cisticola	<i>Cisticola exilis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.5	0.5	0	3	1	0	1.5	0	0	0
Grey Butcherbird	<i>Cracticus torquatus</i>	0	0.5	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Grey Teal	<i>Anas gracilis</i>	0	0	0	0	0	0	0	0	0	0	0	2.5	0	0	0	0	0	0	0	0	0	0	0	0
Grey-crowned Babbler	<i>Pomatostomus temporalis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0
Common Myna	<i>Acridotheres tristis</i>	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	1.5	0	0	0	0
Kestrel	<i>Falco cenchroides</i>	0	0	0	0	0	0.5	0	0	0	0	0.5	0	0	0	0	0.5	0	0	0	0.5	0	0	0	0
Kookaburra	<i>Dacelo novaeguineae</i>	1	0.5	0	0	0.5	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	2
Little Friarbird	<i>Philemon citreogularis</i>	0	1	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0.5	0	0
Lorekeet	<i>Trichoglossua sp.</i>	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Magpie-lark	<i>Grallina cyanoleuca</i>	0	0	0	0	0	0.5	0	0	0.5	0	0	2	1	3.5	0	0	1	0	0	0.5	0	0.5	0	0
Mistletoebird	<i>Dicaeum hirundinaceum</i>	0	0	0	0	1.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Noisy Minor	<i>Manorina melanocephala</i>	0	3	2.5	0	0	4	0.5	0	0	0	0	3.5	5.5	0	0	0	0.5	0	0	3.5	0	0	0	6.5
Pacific Black Duck	<i>Anas superciliosa</i>	0	0	0	0	0	0.5	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1.5
Pale-headed Rosella	<i>Platycercus adscitus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5
Pale-headed x Eastern Rosella	<i>Platycercus adscitus x eximius</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0
Pallid Cuckoo	<i>Cuculus pallidus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0

Pied Butcherbird	<i>Cracticus nigrogularis</i>	0	1.5	0.5	0	0.5	0.5	1	0	0	0	0	0	0	0	0	0	0.5	0	0	0.5	0	0	1	1	
Red-winged Parrot	<i>Aprosmictus erythropterus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	
Sacred Kingfisher	<i>Todiramphus sanctus</i>	1	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	
Singing Bushlark	<i>Mirafra javanica</i>	0	0	0	0	0	0	0	0	0	0	3.5	0	0	0	0	0	0	0	0	0	0	0	0	0	
Spiny-cheeked Honeyeater	<i>Acanthagenys rufogularis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	
Spotted Bowerbird	<i>Chlamydera maculata</i>	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Striated Pardalote	<i>Pardalotus striatus</i>	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Stubble Quail	<i>Coturnix pectoralis</i>	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2	0	0	0	0	0	
Sulphur-crested Cockatoo	<i>Cacatua galerita</i>	0	0	0	0	0	0	0	0	0	0	7.5	1	0	0	0	0	0	0	1.5	0	0	0	0	0	
Superb Fairy-Wren	<i>Malurus cyaneus</i>	0.5	0	0	0	2	0	0	0	3	0	0	3.5	1.5	9.5	0	0	0	0	0	0	0	14.5	0	0	
Variegated Fairy-Wren	<i>Malurus lamberti</i>	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	4.5	0	0	
Weebill	<i>Smicromnis brevirostris</i>	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Plumed Whistle Duck	<i>Dendrocygna arcuata</i>	0	0	0	0	0	0	0	0	0	0	1.5	0	0	0	0	0	0	0	0	0	0	0	0	0	
Whistling Kite	<i>Haliastur sphenurus</i>	0	0	0	0	0	0	0	0	0	0	1.5	0.5	0	0	0	0	0	0	0	0	0	0	0	0	
White-faced Heron	<i>Ardea novaehollandiae</i>	0	0	0	0	0	0	0	0	0	0	1.5	0	0	0	0	0	0	0	0.5	0	0	0	0	0	
White-plumed Honeyeater	<i>Lichenostomus penicillatus</i>	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	
White-winged Chough	<i>Corcorax melanorhamphos</i>	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	
White-winged Fairy-wren	<i>Malurus leucopterus</i>	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	1.5	14.5	0	1.5	0	0.5	9.5	14	0	
Willie Wagtail	<i>Rhipidura leucophrys</i>	0	0	0	0	0	0	0	0	0.5	0	0	0.5	0	0	0	0	0	0.5	0	0	0	0	0	0	
Yellow Thornbill	<i>Acanthiza nana</i>	1.5	0	0	0	2.5	0	0	0	1	0	0	0	0	3	0	0	0	0	0	0	0	1.5	0	0	
Yellow-billed Spoonbill	<i>Platalea flavipes</i>	0	0	0	0	0	0	0	0	2	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	
Yellow-rumped Thornbill	<i>Acanthiza chrysorrhoa</i>	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	
Yellow-throated Miner	<i>Manorina flavigula</i>	0	0	0	0	1	0	0	0	0.5	0	0	0	0	3	0	0	0.5	0	0	0	0	0	3	0	0
Zebra Finch	<i>Taeniopygia guttata</i>	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

Appendix 7: Microbat data at each site. Values are the number of positively recorded bat calls over two nights sampling.

Common name	Scientific name	Nandewar				Kilmarnock				Glenelg				Warilea			Fed Farm				Oakville							
		P	R	G	C	P	R	G	C	P	C	G	R	R	P	C	G	P	C	G	R	C	P	G	R			
Eastern horseshoe bat	<i>Rhinolophus megaphyllus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Gould's wattled bat	<i>Chalinolobus gouldii</i>	4	7	12	53	76	744	10	35	120	75	17	356	161	776	11	3	108	9	7	51	43	29	3	64			
Chocolate wattled bat	<i>Chalinolobus morio</i>	6	1	0	3	16	1	0	1	38	6	1	61	14	192	2	2	7	0	0	1	1	0	0	1			
Long-eared bat	<i>Nyctophilus species</i>	4	0	0	6	6	1	1	5	0	17	5	6	7	78	14	3	4	1	3	2	5	3	1	0			
Western broad-nosed bat	<i>Scotorepend balstoni</i>	5	0	0	17	0	6	3	5	0	17	5	15	18	54	3	0	9	22	2	28	13	53	3	5			
Little broad-nosed bat	<i>Scotorepend greyii</i>	0	1	0	5	2	0	1	4	0	54	4	7	2	33	13	5	8	6	5	5	1	16	3	1			
Eastern cave bat	<i>Vespadelus troughtoni</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0			
Little forest bat	<i>Vespadelus vulturnus</i>	6	1	1	5	63	4	4	15	3	46	19	14	87	144	27	20	11	7	1	7	0	5	3	8			
White-striped free-tail bat	<i>Austronomus australis</i>	0	0	0	4	0	3	0	5	1	3	1	1	0	1	2	0	0	0	0	0	0	2	0	0			
Free-tailed bat	<i>Mormopterus species 2</i>	0	1	0	10	18	8	3	23	1	82	4	59	24	62	7	2	6	16	3	2	14	22	8	1			
Free-tailed bat	<i>Mormopterus species 3</i>	0	3	0	38	0	4	0	37	7	20	12	17	6	40	3	5	4	16	5		13	47	1	4			
Free-tailed bat	<i>Mormopterus species 4</i>	0	0	0	5	0	0	0	3	0	8	0	1	0	13	1	2	1	1	0	1	0	4	0	0			
Yellow-bellied sheath-tailed bat	<i>Saccolaimus flaviventris</i>	0	0	4	8	0	9	0	2	0	8	0	3	2	5	0	0	0	1	0	0	0	1	0	0			

Appendix 8: Invertebrate data taken from nine samples collected at each site in one morning. Values are total numbers captured.

Common name	Scientific name	Nandewar				Kilmarnock				Glenelg				Warilea				Fed Farm				Oakville			
		P	R	G	C	P	R	G	C	P	C	G	R	R	P	C	G	P	C	G	R	C	P	G	R
Spiders	<i>Araneae</i>	27	33	10	16	14	63	6	9	6	11	5	20	42	24	6	12	83	11	6	43	12	23	9	42
Mosquito	<i>Culicidae</i>	0	2	0	1	1	6	0	1	3	2	1	4	1	1	0	0	2	0	0	6	0	9	3	22
Ant	<i>Formicidae</i>	12	1	0	0	1	6	3	2	0	3	1	0	0	0	0	3	4	3	0	5	0	1	1	15
Shield bug	<i>Oechalia schellenbergii</i> <i>Cermatulus nasalis</i>	0	3	0	1	1	6	0	0	0	0	0	3	2	1	0	0	1	0	0	0	2	0	0	4
Ladybird beetles	<i>Coccinellinae</i>	0	0	1	1	5	1	0	0	1	0	0	7	1	0	2	1	2	0	1	1	0	1	3	3
Wasp	<i>Apocrita</i>	1	0	0	0	0	0	0	0	5	1	0	1	0	0	0	5	0	2	0	1	2	1	6	8
Green soldier beetle	<i>Chauliognathus pulchellus</i>	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0
Praying mantis	<i>Mantodea</i>	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Green Carab Beetle	<i>Calosoma schayeri</i>	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Damsel Fly	<i>Nabis kinbergii</i>	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Earwig	<i>Labidura truncata</i> , <i>Nala lividipes</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Total beneficials		41	39	14	21	22	82	9	12	16	17	8	37	46	27	9	22	93	16	7	56	16	35	22	94
Grasshoppers	<i>Caelifera</i>	0	5	0	3	0	1	2	0	0	0	1	1	1	0	0	2	0	0	0	2	0	1	2	1
Flower beetles	<i>Carpophilus ssp.</i>	14	7	5	94	10	7	0	46	1	7	3	6	5	0	9	0	4	32	0	16	20	7	0	6
Catapillar	<i>Lepidoptera</i>	4	1	0	1	3	13	0	0	1	1	1	0	12	0	0	2	2	0	0	4	2	1	1	3
Cottonseed bug	<i>Oxycarenus luctus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Red eyes bug	<i>Leptocoris mitellata</i>	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pumpkin beetle	<i>Aulacophora hilaris</i> , <i>Aulacophora abdominalis</i>	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bollworm	<i>Pectinophora gossypiella</i> , <i>Pectinophora scutigera</i>	0	2	0	0	0	0	0	0	1	0	0	0	0	2	0	0	1	0	4	1	0	1	0	2
Wireworm	<i>Agrypnus spp.</i> , <i>Pterohelaeus spp.</i> , <i>Gonocephalum spp.</i> , <i>Saragus spp.</i>	0	5	0	0	0	0	0	0	0	0	7	1	0	2	2	2	0	0	0	0	0	0	0	1
Weevil	<i>Phlyctinus callosus</i>	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Green vegetable bug	<i>Nezara viridula</i>	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	1	0	0	1	0	0	0
Sliverleaf Whitefly	<i>Bemisia tabaci</i>	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Aphid	<i>Aphis gossypii</i>	0	0	0	0	0	0	0	0	0	0	1	3	0	0	0	0	1	0	0	0	0	0	2	23
Cocoon		0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0
Leafhopper	<i>Austroasca viridigrisea</i> , <i>Amrasca terraereginae</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0
Flea Beetle	<i>Halticinae</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Total pests		20	20	6	98	13	21	2	46	3	10	15	11	18	4	12	7	8	33	5	23	23	10	8	36