

ASSESSING SUCCESSION AND BIODIVERSITY OF INVERTEBRATES WITHIN REVEGETATION AREAS: THE APOLLO BAY AND OTWAYS REVEGETATION PROJECTS

Report on Autumn Collections

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Version control

Date	Version	Description	Author	Reviewed By
5 July 2007	1.0	Version issued to Corangamite CMA	AW	NL

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1 EXECUTIVE SUMMARY

Invertebrates have been used to monitor the health of environments and changes in habitat structure. While used widely in aquatic environments, their use in terrestrial environments has been somewhat limited. Here we test their usefulness as an early monitoring system for revegetation program success in the Corangamite Region. Invertebrates were sampled by pitfall trapping at three sites soon after revegetation in spring and autumn of 2001/02. Two sites, a remnant and partially forested site, were also sampled at the same time to act as controls. These sites were again sampled in autumn of 2006 and will be sampled in spring of 2007. Analyses of autumn samples indicated that invertebrates, identified to order, can be used to monitor revegetation programs. Significant increases were found between samples collected in autumn of 2002 and 2006 in invertebrate order richness at each of the revegetated sites, while no difference was found at the two control sites. Large differences in order abundance were also found at the sites between sampling dates, with most increases in the autumn 2006 samples occurring at the revegetated sites. Several key groups have been identified that could be used as potential indicators for monitoring revegetation programs in the Corangamite Region; the Acari (mites), Coleoptera (beetles), Hymenoptera (wasps, bees, ants), Hemiptera (true bugs) and Araneae (spiders). However, the sensitivity of these taxa to seasonal variations must be tested using the spring samples. Several orders have been identified which should be taken to lower taxonomic levels (Acari, Hymenoptera and Araneae) to increase their sensitivity and also enhance their 'Indicator Value'. This interim report suggests that key groups of invertebrates can be used as an early monitoring system for the success of revegetation programs in the Corangamite Region.

2 INTRODUCTION

2.1 Background

The link between species richness and ecosystem function has been intensively discussed over the past 10-20 years (Peterson, Allen *et al.* 1998). Despite a growing body of literature supporting this linkage and its use in defence of the conservation of biodiversity, its importance is still debated (Schwartz, Brigham *et al.* 2000). At the heart of this debate is the notion that the loss of plant and/or animal species: (1) will bring an ecosystem closer to collapse (Schwartz, Brigham *et al.* 2000); and (2) increase ecosystem vulnerability to invasions by alien species (Knops, Tilman *et al.* 1999).

The homogenous landscapes that agriculture promotes generally results in massive losses in plant and animal biodiversity, which harms the sustainability of environments. These homogenous agricultural landscapes can also affect the sustainability and profitability of agriculture (Tsitsilas, Stuckey *et al.* 2006; Weeks, Lewis *et al.* 2007) and therefore research is now indicating that changes in landscapes which promote biodiversity within agricultural zones can benefit agriculture.

In Australia, the clearing of land for agriculture was considerably drastic in the last century. However, landholders are becoming aware that increasing complexity (biodiversity) within agricultural landscapes can have many benefits. In some regions, concerted efforts by Catchment Management Authorities, Governments and local councils have been concentrated on maintaining remnant vegetation and native grasslands. Land managers have also incorporated habitat margins (shelterbelts) into their agricultural fields for a number of different purposes including preventing land degradation and salinity, shelter for livestock and protection for crops from wind (Weeks, Lewis *et al.* 2007). The rehabilitation of agricultural land is increasingly becoming common practice, whether it is for the aforementioned purposes, or due to an increased awareness of the need to conserve our environment. In any case, there is a need to monitor how these 'revegetation' programs progress through time so that management decisions can be made both on short and long-term timescales.

Vegetation monitoring is generally regarded as a powerful long-term assessment method for monitoring the success of revegetation programs. However, this method is considered too long-term (generally on the order of 5-10 years; (Perner and Malt 2003)) and detrimental effects can occur well within this time which hampers successful revegetation efforts. Therefore, there is a need to develop a short term monitoring system for revegetation programs so that land managers can assess the likely success of their revegetation program(s).

Invertebrates can indicate changes in the environment through their responses at different levels of organization, ranging from the individual animal to the total invertebrate community. The appropriateness of the level chosen to indicate a changing environment depends on the particular factor that is thought to be acting. Responses to single pollutants may be picked up by changes in individual animals or populations of a species, whereas large environmental disturbances (such as habitat degradation or conversely, habitat rehabilitation) may be better indicated by changes in whole invertebrate communities. It is a question of choosing the right indicators for the right questions.

Invertebrates have been used to successfully monitor the rehabilitation of mine sites in Australia (Andersen, Fisher *et al.* 2004; Majer 1983). They have also been used to monitor many different types of habitat change overseas (see Weeks, Lewis *et al.* 2007 for a review). The Corangamite Catchment Management Authority commissioned this study to look at the usefulness of invertebrates as a

monitoring system for assessing the success of revegetation programs in their Region. This study was conducted at three recently established revegetation sites in the Corangamite Region.

2.2 Aims

This project set out to explore the changes that occur in the invertebrate fauna through time at three sites that had recently undergone revegetation, and to develop invertebrates as early monitors of successful revegetation programs.

The specific aims of this study were:

1. To observe the succession of invertebrate fauna through time on revegetated farmland;
2. To document changes in biodiversity as revegetation develops;
3. To compare and contrast methods of revegetation (e.g. direct seedling versus plantings of seedlings); and,
4. Develop indicator invertebrate groups that can be used by land managers and the Corangamite CMA to assess the progress of revegetated sites.

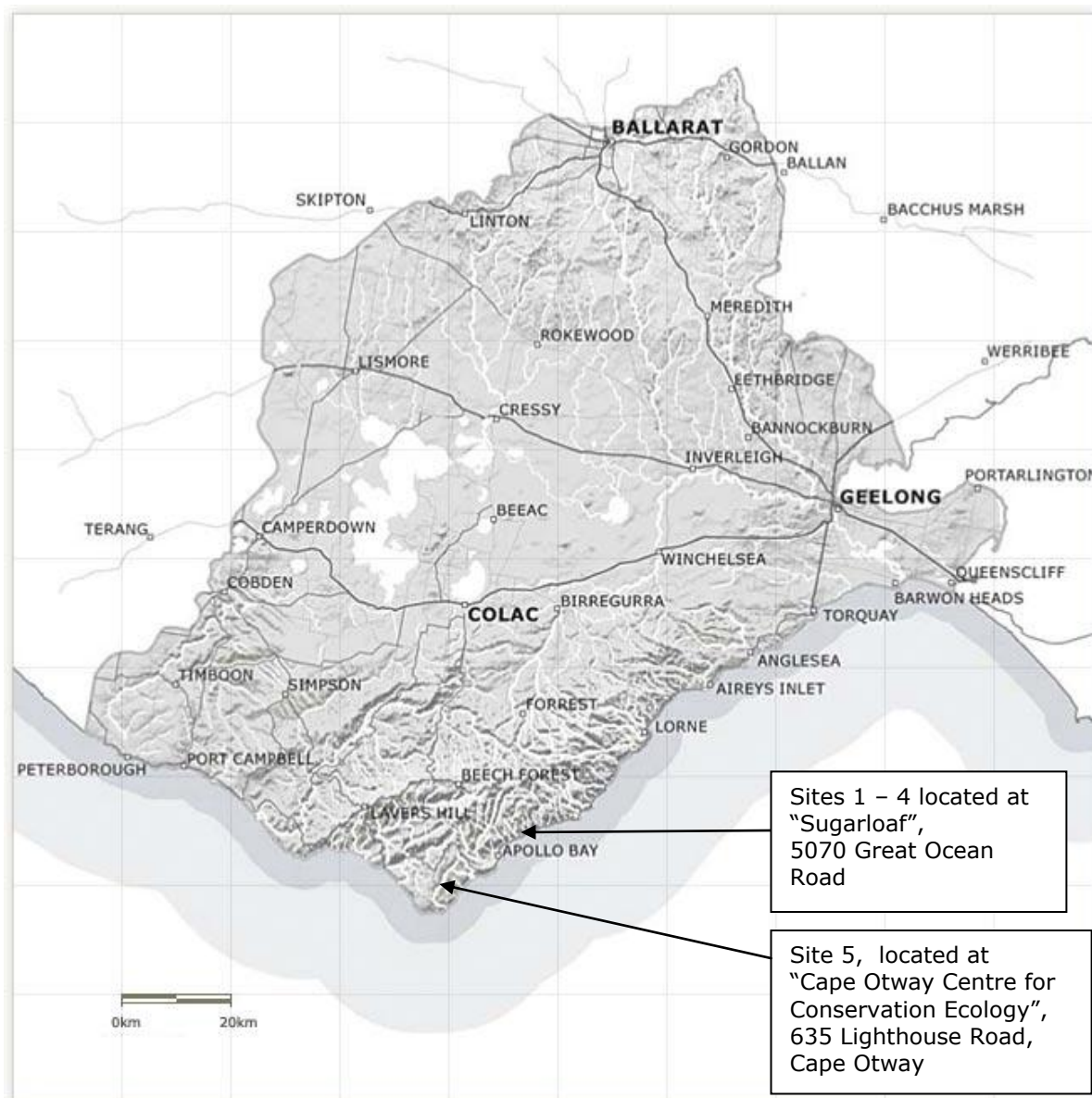
In this interim report we only analyse data from autumn samples collected in 2002 and 2006. A final report will also include an analysis of samples collected in spring of 2002 and 2007 and overall recommendations for revegetation programs in the Corangamite Catchment.

3 MATERIALS AND METHODS

3.1 Field Sites

The field sites were located in two locations in the Corangamite Region. Four sites were located at the “Sugarloaf” property, number 5070 on the Great Ocean Road between Apollo Bay and Lorne, whilst one site was located at the Cape Otway Centre for Conservation Ecology, 635 Lighthouse Road, Cape Otway (Figure 1).

Figure 1. Location of the field sites.



In 2001, a 16.1 Ha area of ‘Sugarloaf’ was replanted using tube stock of locally indigenous tree species. Two invertebrate sampling sites were established in this area, the first on a southerly aspect (“ocean facing”) and the second on a northerly aspect (“inland facing”). A third invertebrate sampling site was established in a partially forested area adjoining the area replanted. A fourth site was established in remnant forest, approximately 300m north of the replanted area.

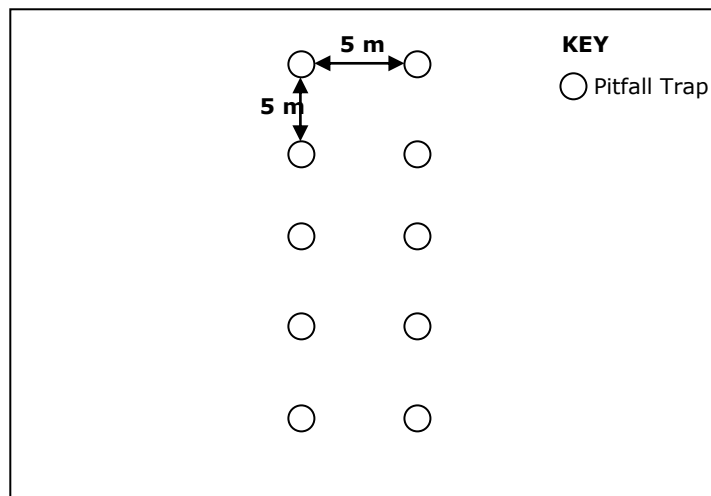
At the same time, an area at the Cape Otway Centre for Conservation Ecology was revegetated using a ‘direct seed technique’, in which seed of a range of locally indigenous species (trees and understorey) is cast over an area that has been ripped and treated for weeds. A fifth invertebrate sampling site was established in the direct seeded area.

Table 1. Location of the five field sites sampled during autumn of 2002 and 2006 in the Corangamite CMA region.

Site	Aspect	Transect	Latitude	Longitude	Elevation (m)
1	Forested	A	38° 41' 23"	143° 47' 11"	176
		B	38° 41' 25"	143° 47' 14"	183
		C	38° 41' 25"	143° 47' 16"	181
2	Partial forested	A	38° 41' 32"	143° 47' 22"	108
		B	38° 41' 32"	143° 47' 24"	76
		C	38° 41' 32"	143° 47' 26"	79
3	Inland facing (Revegetation)	A	38° 41' 39"	143° 47' 25"	110
		B	38° 41' 41"	143° 47' 29"	90
		C	38° 41' 42"	143° 47' 32"	87
4	Ocean facing (Revegetation)	A	38° 41' 44"	143° 47' 29"	67
		B	38° 41' 44"	143° 47' 32"	69
		C	38° 41' 43"	143° 47' 35"	63
5	Direct seeding (Revegetation)	A	38° 49' 36"	143° 31' 33"	147
		B	38° 49' 35"	143° 31' 32"	142
		C	38° 49' 33"	143° 31' 29"	145

3.2 Experimental Design and Pitfall Sampling

Three parallel transects (approximately 25 metres apart), roughly north/south in orientation, were marked at each of the five sampling sites. Along each transect, 10 sampling points were established in two rows (5 metres apart) and pitfall traps were installed at each sampling point (See figure 2).

Figure 2. Layout of pitfall traps

Pitfall traps enable rapid and efficient collection of data amenable to statistical analysis (Topping and Sunderland 1992). Each trap consisted of a 15 ml glass specimen tube inserted into a polyvinyl chloride (PVC) tube (15 mm, Class 15), buried flush to the surface. This method is a minor modification to that of Majer (1978). Traps were filled with 5 ml of 100% ethylene glycol, to prevent evaporation in the exposed fields, and left open for one week. The first sample was taken in Spring 2001, immediately prior to revegetation activities commencing and a second sample was taken in the autumn of 2002, shortly after replanting was completed. A follow-up autumn sample was taken four years later in 2006 (a further spring sample will be taken in 2007). To ensure consistency of collection, any bias caused by digging-in effects (Greenslade 1973) was negated by the removal of traps and PVC tubing, and filling the hole after each collection. Collection points were marked and subsequent collections involved re-installing traps following the exact same procedure as above.

Invertebrates from each trap were sorted to order under a stereo dissecting microscope (Olympus ZS40, Australian Instrument Services, Melbourne, Vic.) following the key of Harvey and Yen (1989). Invertebrates from each trap were then separated by order into individual glass vials containing 95% ethanol and labeled.

3.3 Data Analysis

Only data from the autumn collections in 2002 and 2006 were analysed in this interim report, pending a spring collection in 2007. Data were log-transformed before analysis. Normality of the transformed data was confirmed with Kolmogorov-Smirnov tests in SPSS for Windows (version 15). Analysis of variance (ANOVA) were undertaken to compare differences in the abundance of different orders between sampling dates at the five sampling sites in SPSS.

PC-ORD (version 5.0, MjM Software Design, Oregon) was used to calculate order richness (S), and to conduct a multi-response permutation procedure (MRPP) analysis using both Sorensen and relative Sorensen as distance measures. This analysis determines whether samples from a site collected on

different dates differ in their total order composition and abundance. Finally, PC-ORD was used to calculate an 'Indicator Index' for each invertebrate order from the three revegetation sites.

4 RESULTS

4.1 Invertebrate abundance and order richness

Pitfall trapping across the five sites yielded a total of 14,037 invertebrates comprising 23 different orders over the two sampling dates. A larger number of invertebrates were collected in the autumn 2006 collection (12,969) than in the autumn 2002 collection (1884); however this was largely due to the vast increase in the number of collembolans collected in the 2006 collection across all sites. In this collection, collembolans made up 81% (10,551 individuals) of the survey across sites, compared with only 9.3% (175 individuals) in the autumn 2002 collection. This increase in collembolans was consistent across all sites, with relatively few collembolans found in the autumn 2002 collections and a 17 to 450 fold increase in collembolans at a site in the autumn 2006 collections. If collembolans are removed, then there was a 126%, 0%, 317%, 265% and 505% increase in invertebrate abundance at sites 1, 2, 3, 4 and 5, respectively, in the autumn 2006 collection.

Not including the collembola, the most abundant orders across samples and sites were the acari (30%), hymenoptera (28%), coleoptera (9%), araneae (8%), amphipoda (7%) and the hemiptera (6%). Besides the collembolan, the acari are consistently the most abundant at all sites and in all collections. The majority of the hymenoptera were found at sites 1 and 2, especially in the autumn 2006 samples. Other orders varied between sites and collections (see below).

The autumn 2002 and 2006 collections differed considerably in orders found and their composition at some sites (Table 2). There was a change in order composition at site 1 with a slight increase in the number of orders found between samples. At site 2, there was also a change in order composition, but also a slight decrease in the number of orders found between samples. Sites 3 – 5 showed large changes in the number of orders found between samples, with an increase in the number of orders found at each site in the 2006 samples (Table 2).

Table 2. Invertebrate orders present on two sampling dates at five revegetation sites found in the Corangamite Region.

Order	Site 1		Site 2		Site 3		Site 4		Site 5	
	2002	2006	2002	2006	2002	2006	2002	2006	2002	2006
Acari	√	√	√	√		√	√	√	√	√
Amphipoda	√	√	√		√	√	√	√		√
Aranaea	√	√	√	√	√	√	√	√	√	√
Blattodea	√	√	√			√	√	√		√
Coleoptera	√	√	√	√	√	√	√	√	√	√
Collembola	√	√	√	√	√	√	√	√	√	√
Dermaptera		√						√		
Diplura									√	
Diptera	√	√	√	√	√	√	√	√	√	√
Gastropoda	√				√	√		√	√	√
Haplotoxida	√									
Hemiptera	√	√	√	√		√		√	√	√
Hymenoptera	√	√	√	√	√	√	√	√	√	√
Isopoda										√
Isoptera	√		√					√		√
Julida	√	√			√	√				
Lepidoptera		√				√		√		√
Lithobiida		√	√			√		√		√
Opilionida	√		√		√	√	√	√		√
Orthoptera		√	√	√	√	√	√	√	√	√
Psocoptera		√		√						
Scorpionida	√	√		√						
Thysanoptera		√		√		√		√		√
TOTAL	15	17	13	11	10	16	10	17	10	17

The order richness changed significantly at all revegetation sites between sampling dates, but not at the remnant and partially forested sites (Table 3). At site 3, order richness increased from 2.2 in the

autumn 2002 collection to 5.5 in the autumn 2006 collection. At site 4, order richness increased from 2.46 to 4.96 in the autumn 2006 collection. The largest increase was found at site 5, where order richness increased from 2.75 in the autumn 2002 collection to 7 in the autumn 2006 collection. Clearly, invertebrate diversity, as measured at the order level, has increased across the revegetation sites.

Table 3. The order richness (O) of invertebrates obtained from pitfall traps at one remnant site (site 1), one partially forested site (site 2) and three revegetation sites (sites 3-5), in the Corangamite Catchment.

Site	Autumn 2002	Autumn 2006	P value
1	4.828	4.1	0.106
2	4.31	3.667	0.060
3	2.173	5.5	<0.001
4	2.462	4.962	<0.001
5	2.75	7	<0.001

4.2 Changes in order abundance at the revegetation sites

There were large changes in the abundance of a number of invertebrate orders across the two samples at each site. Table 2 shows the significance of the changes between the samples at each site for the 12 most abundant orders found across sites. While order abundance varied quite considerably, there were several patterns across sites. The Collembola increased significantly at each site from the autumn 2002 samples to the autumn 2006 samples. This is likely to be associated with a general change in environmental variables (i.e. temperature or rainfall) across all sites.

Whilst some orders decreased in abundance, these were mostly associated with the remnant and partially forested sites (sites 1 and 2). Most significant increases in abundance were found at the revegetation sites with 10 orders increasing and only 1 order decreasing at site 3; 4 orders increasing and 1 decreasing at site 4; and 9 orders increasing and none decreasing at site 5 (see Figure 3 and Table 4). This compares with 2 orders increasing and 4 decreasing at the remnant site (site 1) and only 2 orders increasing and 6 decreasing at the partially forested site (Figure 3).

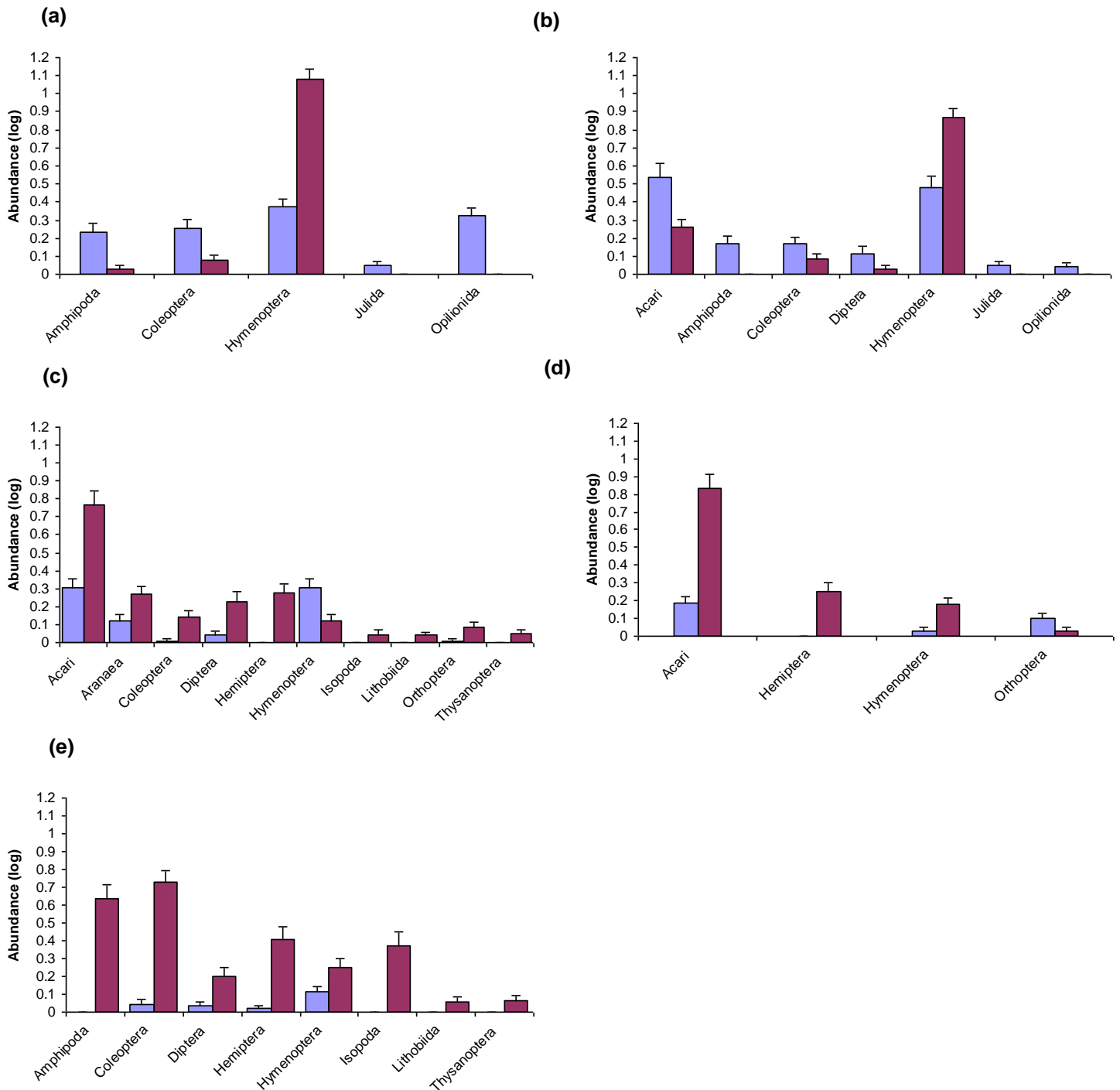
At the revegetation sites, the Hemiptera were the only order to increase significantly at all sites in the autumn 2006 sample compared with the 2002 sample (Figure 3). The Hemiptera were generally absent or at very low numbers in the 2002 samples. The Acari were the next most consistent order, with increases found at all revegetation sites, although significant differences between the samples were only found at sites 3 and 4. Similarly, the Coleoptera increased across all revegetation sites in the 2006 samples with significant differences found at sites 3 and 5. The Hymenoptera significantly increased at sites 4 and 5, but showed a significant decrease at site 3. Most other orders that showed a significant increase at the revegetation sites were site specific and generally involved smaller changes in abundance (Figure 3).

Table 4. Analysis of variance testing the effects of collection period on the abundance of invertebrates (\log_e transformed) obtained from the pitfall traps at one remnant site (site 1), one partially forested site (site 2) and three revegetation sites (sites 3-5) in the Corangamite Region. The twelve most abundant invertebrate orders across the five sites during the two sampling periods are shown. Degrees of freedom in the error term are 59 for sites 1, 3-5, and 58 for site 2.

Order	Site 1			Site 2			Site 3		
	MS	F-value	P-value	MS	F-value	P-value	MS	F-value	P-value
Acari	0.320	3.618	0.062	1.146	10.563	< 0.010	3.124	24.668	< 0.001
Amphipoda	0.601	14.170	< 0.001	0.411	15.181	< 0.001	0.002	1.000	0.321
Araneae	0.020	0.480	0.491	0.001	0.019	0.892	0.331	7.361	< 0.010
Coleoptera	0.488	10.313	< 0.010	0.120	4.231	< 0.050	0.252	12.962	< 0.001
Collembola	19.595	66.024	< 0.001	19.944	61.810	< 0.001	41.248	804.359	< 0.001
Diptera	0.000	0.016	0.899	0.109	4.684	< 0.050	0.536	10.619	< 0.010
Hemiptera	0.002	0.058	0.811	0.116	3.473	0.068	1.166	35.607	< 0.001
Hymenoptera	7.421	110.657	< 0.001	2.253	22.590	< 0.001	0.508	9.676	< 0.010
Isopoda	0.006	1.055	0.309	0.002	1.035	0.313	0.032	4.224	< 0.050
Julida	0.038	5.800	< 0.001	0.033	4.389	< 0.050	0.002	1.000	0.321
Lithobiida	0.002	1.000	0.321	-	-	-	0.024	4.462	< 0.050
Opilionida	1.561	53.837	< 0.001	0.025	4.637	< 0.050	0.010	0.967	0.329
Orthoptera	0.014	3.222	0.078	0.001	0.062	0.804	0.087	6.933	< 0.050
Thysanoptera	0.006	2.071	0.155	0.006	2.001	0.163	0.038	5.800	< 0.050

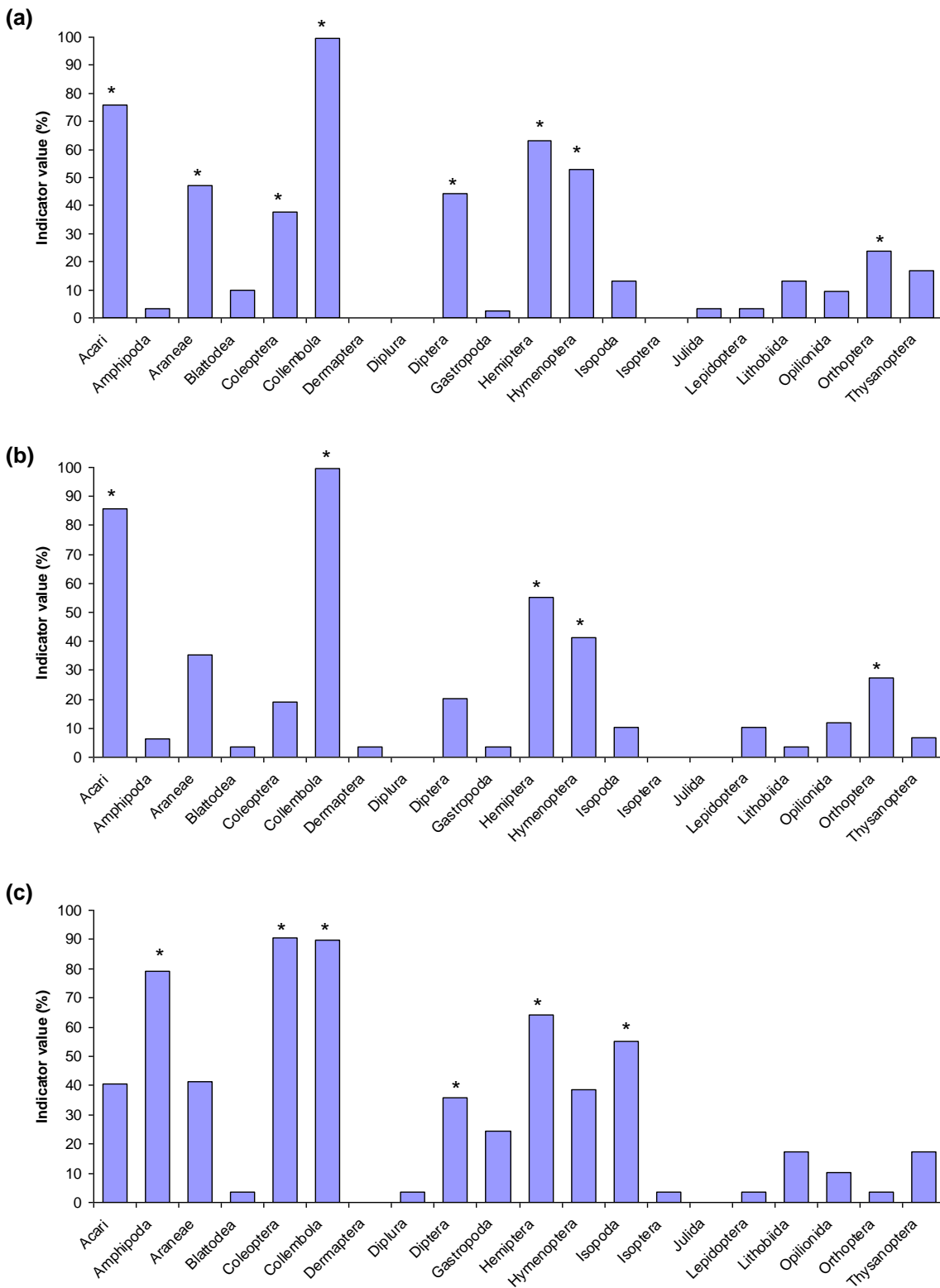
Order	Site 4			Site 5		
	MS	F-value	P-value	MS	F-value	P-value
Acari	6.125	55.351	< 0.001	0.080	0.745	0.392
Amphipoda	0.004	0.192	0.663	5.914	62.055	< 0.001
Araneae	0.001	0.009	0.926	0.128	2.066	0.156
Coleoptera	0.049	2.470	0.122	6.933	106.381	< 0.001
Collembola	52.672	665.786	< 0.001	29.329	148.985	< 0.001
Diptera	0.055	1.718	0.195	0.396	10.259	< 0.010
Hemiptera	0.936	26.581	< 0.001	2.175	27.167	< 0.001
Hymenoptera	0.314	12.469	< 0.001	0.281	5.255	< 0.050
Isopoda	0.014	3.231	0.078	2.003	21.654	< 0.001
Julida	-	-	-	-	-	-
Lithobiida	0.002	1.000	0.322	0.050	5.734	< 0.050
Opilionida	0.006	0.406	0.526	0.014	3.344	0.073
Orthoptera	0.068	4.173	< 0.050	0.001	0.001	0.973
Thysanoptera	0.006	2.074	0.155	0.060	5.669	< 0.050

Figure 3. Invertebrate orders that showed a significant difference in abundance between samples taken in autumn of 2002 and 2006 at one remnant site (site 1), one partially forested site (site 2) and three revegetation sites (sites 3-5) in the Corangamite Catchment: (a) Site 1, (b) Site 2, (c) Site 3, (d) Site 4, and (e) Site 5. Note: the Collembola were excluded from these figures.



By performing an indicator analysis, we are able to determine which orders best indicate the changes observed at the revegetation sites (Figure 4). While the Collembola displayed the highest Indicator Value at each of the revegetation sites, this group is unlikely to be a good indicator of revegetation as similar changes were also observed at the remnant and partially forested sites. The best indicator groups for revegetation sites are likely to be the Acari, which showed a 42% Indicator Value across the three sites, then the Coleoptera (37%), the Hymenoptera (29%), the Hemiptera (27%) and the Araneae (26%). Other invertebrate orders were more site specific, and are likely not to be valuable as general indicator orders.

Figure 4. Indicator values of invertebrate orders sampled using pitfall traps at the three revegetation sites in the Corangamite Catchment: (a) site 3, (b) site 4 and (c) site 5. Stars above bars indicate significant Indicator taxa.



5 DISCUSSION

Invertebrate organisms have been widely regarded as a way to monitoring changes in ecosystems and the management of these ecosystems because of their high numbers, functional importance in environments, their great diversity and likelihood of their response to perturbations (Andersen, Fisher *et al.* 2004). Recent research in this field in Australia has focused on using terrestrial invertebrates as indicators of habitat rehabilitation programs, especially at old mine sites (Andersen, Fisher *et al.* 2004; Majer 1983). Research overseas has indicated that while vegetation monitoring can be a powerful long-term indicator (> 5-10 years) of restoration programs, invertebrate monitoring can be extremely powerful as an indicator, especially at the beginning of the restoration process (< 5 years) (Perner and Malt 2003). In this interim report we have assessed the utility of invertebrates as indicators of revegetation programs in the Corangamite Region.

Three revegetation sites in the Corangamite Region were sampled for invertebrates in autumn 2002, just after establishment. Two control sites, one remnant site and one partially forested site, were also sampled for invertebrates at this time and used as a comparison to the revegetation sites. A sample was also taken in spring 2001 at each of the five sites. These same sites were again sampled in autumn 2006, 4 years after establishment. In this interim report we have analysed the autumn invertebrate samples.

The results from the autumn samples clearly show that, even at the order level, invertebrates can be used as indicators of habitat restoration or revegetation of agricultural land. Order richness increased significantly across all revegetation sites, while remaining similar at the control sites (remnant and partially forested sites). The order Collembola increased the greatest at all revegetation sites, but this group also increased at the control sites and likely reflects some general change in the environment across sites (i.e. higher rainfall, which increases humidity and leaf litter and has been linked to increases in Collembola).

Invertebrate Indicator Groups of Revegetation Programs

There were five orders of invertebrates that showed the clearest responses across the three revegetation sites, but not in the control sites; (i) the Acari, (ii) the Coleoptera, (iii) the Hemiptera, (iv) the Hymenoptera, and (v) the Araneae.

The Acari and Coleoptera showed the clearest trends over the three revegetation sites, increasing at all three sites and displaying high Indicator Values. The Acari are likely to be robust indicators because of their high numbers and their general roles as predators and detritivores in ecosystems (Tsitsilas, Stuckey *et al.* 2006). The Coleoptera have been shown previously to be indicators of rehabilitation of habitats (Perner and Malt 2003) and have been suggested as general indicators of environmental change (Niemela, Kotze *et al.* 2000).

The Hemiptera showed the next clearest response across the three sites, with significant increases across all revegetation sites, although their average Indicator Value across the sites was lower than the Acari and Coleoptera. While this order is likely to be an indicator of revegetation, it is a less desirable group because it consists of plant feeding organisms that are largely considered pests. Large changes in this group could therefore indicate unhealthy or stressed plants and not a successful revegetation program.

The order Hymenoptera was abundant and increased significantly across two of the revegetation sites. However, one site showed a significant decrease from autumn 2002 to autumn 2006. Ants, which are part of this order, have been used in many habitat rehabilitation programs in Australia (Andersen, Fisher *et al.* 2004; Majer 1983) and are considered good general indicators of environmental change (Andersen, Fisher *et al.* 2004). They have also been shown to reflect changes in other invertebrate groups following disturbance (King, Andersen *et al.* 1998; Majer 1983), indicating that they are a good surrogate group for reflecting changes in invertebrate diversity and structure. However, as complexity increases within revegetated sites and bare ground reduces, Hymenopterans (ants) will reduce in numbers (which could be why numbers were reduced at site 3). It is therefore crucial that this group be taken to lower taxonomic levels (see below).

Lastly, the results suggest that the order Araneae may also be a general indicator of revegetation success across the three sites. This group increased at all three revegetation sites, although this was only significant at one site. They were found in reasonably high numbers across all three sites and have previously been shown to be indicators of agricultural land rehabilitation (Perner and Malt 2003). The Indicator Value of this group for monitoring revegetation programs would probably benefit from going to lower taxonomic levels.

Differences between revegetation sites

Although the number of orders found at the revegetated sites did not differ greatly in the autumn 2006 samples, there was a difference in the order richness found at these three sites. The highest order richness was found at the Cape Otway Centre for Conservation Ecology (site 5), whilst sites 3 and 4 had a similar order richness. This could reflect differences in the construction of the revegetated sites (plant species composition) and the method of planting (tube stock versus direct seeding). However statistical comparisons are difficult due to the lack of replication in the design of the experiments.

The revegetation sites at the “Sugarloaf” property (sites 3 and 4) had similar orders present in the autumn 2006 samples (16 and 17 respectively) and a similar overall order richness (5.5 and 4.96 respectively), suggesting that aspect (ocean versus inland facing) did not influence overall diversity. Although, again this comparison is limited due to a lack of replication in the experimental design.

Is there value in identifying invertebrates to lower taxonomic scales?

While a clear response was found between the autumn 2002 and 2006 samples for each revegetation site at the order level, this study would benefit from proceeding to lower taxonomic levels for some groups. The key taxa identified in this interim report were in reasonably high numbers and therefore lower taxonomic levels will still yield sufficient numbers that can be analysed with greater statistical power (i.e. ‘species richness’ will be much more sensitive than ‘order richness’ at differentiating between samples within sites). Lower taxonomic levels will also help to explain some inconsistencies. For example, the order Hymenoptera increased at two sites, but decreased at one site. This may merely reflect a single species dominance at one site and therefore increase the power of this group as an indicator group. Ants have previously been formally structured into functional groups in relation to environmental stress and disturbance (Andersen, Fisher *et al.* 2004) and this study would benefit from identifying ants into these groups.

The Acari also contain several groups that have important ecosystem functions (predators, pests, detritivores) and their ‘Indicator Value’ may also benefit from identification to lower levels. Most pest Acari (those that eat plant material) are not present in autumn (Ridsdill-Smith 1997; Umina,

Hoffmann *et al.* 2004) and therefore this may be more important to differentiate between them in the spring samples.

The 'Indicator Value' of Araneae (spiders) may also benefit from classification to lower taxonomic levels. The number of spiders across the revegetation sites was higher in the autumn 2006 samples, but only significant at one site. Spiders have also been classified into functional groups for bioindication (Perner and Malt 2003) and this study would benefit from classifying them to this level.

Conclusion

The results from the analyses of the autumn 2002 and 2006 samples clearly show that invertebrates can be used as indicators to monitor revegetation programs. The biodiversity has increased substantially at all three revegetation sites, whilst remaining similar at the control sites. There are several invertebrate orders which could be used as surrogates in monitoring programs: the Acari, the Hemiptera, the Hymenoptera, the Coleoptera and the Araneae. However, these results are based on only one season and may not reflect generally across seasons. Analyses of the spring samples will help to further elucidate key invertebrate groups that can be used to monitor revegetation programs in the Corangamite Region.

Other invertebrate orders, which were in low numbers in the autumn samples but showed significant increases in abundance between the 2002 and 2006 samples (i.e. Isopoda and Orthoptera), may become more prominent in spring samples and show more consistent responses across sites. This may change the overall key invertebrate orders identified in this interim report.

Finally, it is recommended for the final report that several groups (the Hymenoptera, the Acari and the Araneae) be taken to lower taxonomic levels (functional groups).

6 ACKNOWLEDGEMENTS

We thank the Cape Otway Centre for Conservation Ecology and Mark Simons and Marianne Fontaine, owners of “Sugarloaf” for use of their land to carry out these experiments, and the Corangamite Catchment Management Authority who commissioned the Centre for Environmental Stress and Adaptation Research to establish the project in 2001/02

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