Final Report December 2006: Land & Water Australia project reference no. UWA41

Sustainable Grazing on Saline Lands Biodiversity Theme

– INTEGRATING THE INFORMATION FROM THE SGSL NATIONAL RESEARCH SITES

Frontispiece: Antlion (Order:Neuroptera) from a pitfall trap at Tammin, WA.

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Final Report

Land & Water Australia project reference no. UWA41

Project title:
SGSL Biodiversity Theme – Integrating the Information from the SGSL National Research Sites

Principle investigator:
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Project duration:
30/5/05 - 31/12/06

Due date for final report:
31/12/06

Project objectives:
This project sits within the joint Sustainable Grazing on Saline Lands/CRC Salinity initiative that now sits in Program 6, under the Program and Subprogram leadership of Dr David Masters. The activities described here sit within Program 7, Enhancing Biodiversity in Salinising Landscapes.

The objectives of this project are to quantify the impacts of new management systems for salinised land on:

- Invertebrate diversity
- Soil microbial biomass and respiration
- Landscape Functional Analysis
- Plant species diversity

Summary

- All of the Theme administration tasks – protocol development, contracting , training were satisfactorily completed.
- An analysis of the invertebrate pitfall-trap data from two sites (WA1 and NSW) has been presented at two conferences.
- Analysis of the microbial biomass data has demonstrated a relationship with soil EC and with the presence of vegetation. Where bare soil has been sampled, the microbial activity and biomass is almost zero. In the presence of vegetation, microbial activity is about an order of magnitude higher, but still substantially below non-salt-affected pastures.
- Landscape Functional Analysis data revealed similar patterns to that observed with the microbes and provides further detail of some of the ecosystem-function-level consequences of scalded areas.
- It seems reasonable to conclude that salinity does have a negative impact on some measures of biodiversity, especially if the extreme cases of saline scalds are considered. However, at the scale at which this analysis has been (mostly) conducted – whole-plot scale – few measurable changes in any metric of biodiversity result from the effects of the treatments. The available data at sub-plot scale need to be fully explored to reveal biologically important results. The protocols were not set up to capture this fine-scale data and so the data has been collected in an ad-hoc and inconsistent fashion, making analysis and interpretation more difficult. Nevertheless, from the limited analysis of this fine-scale data so far, there is important information to be had. It will form the basis of the SGSL Biodiversity Theme paper at the International Salinity Forum in 2008.

Table of Contents

Achievement Criteria

Theme administration

The protocols were widely circulated for comment and feedback and the final version (Appendix 1) reflects input from a number of sources. The appropriate staff from each site team have been present at key meetings and have been actively involved in protocol development.

The contract between UWA/CRC Salinity and NSW DPI/CSIRO SE was prepared and the contributions of each of the host organisations detailed and costed. These contracts were implemented early in the 2006 calendar year. However, with the resignation of a key staff member from CSIRO SE (Lyn Atkins), the balance of their funds under this contract were transferred to NSW DPI. Further details are listed below under Financial Issues.

Results

The complete analysis of the biodiversity data is made difficult by issues of scale. The SGSL Biodiversity Theme protocols were written to focus on measures of biodiversity at a plot scale. However, the way that salinity is manifested in the landscape means that salt-affected areas may or may not operate at a comparable scale. This is especially apparent in the NSW and VIC projects, where the strongly salt-affected areas constituted only a small proportion of the whole plot. In both of these projects, attempts were made to more closely characterise the environment of these sub-plot areas. This additional data cannot be easily considered with any of the biodiversity data, however, since these have been collected from the whole plot. Under these circumstances, the averages of the environmental data from the whole plot are of questionable value. Nevertheless, for this report, the analysis focuses on the whole-plot data. Where it is available, analysis of the sub-plot data will be presented in the SGSL Biodiversity Theme paper at the International Salinity Conference in 2008.

The data were analysed by considering the differences between the 'control,' 'treatment' and remnant plots. These categories, however, do not easily fit the treatments imposed in the WA1 project, where saltbush and perennial grasses were 'added' in a factorial combination to a 'control' of an annual-grass based pasture. This report focuses on the distinction between the control and all other treatments, and is based on data collected on a seasonal basis.

In addition to the description of biodiversity data itself, this report includes a preliminary examination of the relationship between biodiversity data and some selected environmental data – especially pasture data. A complete analysis, including consideration of all environmental data (esp. soil factors) will be prepared for the SGSL Biodiversity Theme paper.

Invertebrate diversity

In total, more than 100 pitfall trapping 'events' were collected (season × plot). However, not all of these samples were sorted – only 60 were fully identified and included in subsequent analyses. This was considered the minimum dataset to permit a consistent cross-site analysis (Table 1). The additional samples have been kept and stored. In total, nearly 1.2 million invertebrate individuals were sorted from the pitfall trap catches. They were first sorted into Order and then into lower-level taxa such that each taxa could be assigned to a single 'functional group' (detritovore, herbivore, omnivore, predator, parasite). A number of juveniles (1444) and queen-ants (16) have been excluded from further analysis because it was impossible to assign them into functional groups. In addition, a relationship was developed between the size of an invertebrate individual and its weight (Table 2) so that the total weight of each taxon and each functional group could be estimated. From the total pool of samples, invertebrates from 29 Orders were identified and sorted into 144 taxa (Table 3). Between 20 and 23 Orders and 64 and 80 taxa were represented at each site (Table 4). The SA site had the highest number of endemic taxa (13) but, when the WA sites were considered collectively, 21 taxa were endemic to WA. In all, 42 taxa were present at only one site; 36 taxa were present at all sites.

A draft of the introduction and methods sections of a paper detailing the invertebrate component of the SGSL Biodiversity Theme's activities has been prepared (Attachment 2). It contains brief descriptions of prominent taxa and their role in ecosystem functioning, as well as a discussion of the methods used and consideration of relevant data collected elsewhere in Australia and overseas.

Table 1. Pitfall trap sampling events: ×: not collected, ✓:collected and yet to be sorted, ✓✓: collected and sorted

Project	**Plot**	**SeasonYear**				
		Spring2003	Autumn2004	Spring2004	Autumn2005	Spring2006
NSW	Gumble1	×	×	✓✓	✓✓	✓
	Gumble2	×	×	✓✓	✓✓	✓
	Gumble3	×	×	✓✓	✓✓	✓
	Gumble4	×	×	✓✓	✓✓	✓
	Avoca1	×	×	✓✓	✓✓	✓
	Avoca2	×	×	✓✓	✓✓	✓
Victoria	UnImp4	×	×	✓✓	✓✓	×
	UnImp12	×	×	✓✓	✓✓	×
	Imp9	×	×	✓✓	✓✓	×
	Imp11	×	×	✓✓	✓✓	×
	Rem1	×	×	✓✓	✓✓	×
	Rem2	×	×	✓✓	✓✓	×
South Australia	UnImp1	×	×	✓✓	✓✓	×
	UnImp2	×	×	✓✓	✓✓	×
	Imp1	×	×	✓✓	✓✓	×
	Imp2	×	×	✓✓	✓✓	×
	Rem1	×	×	✓✓	✓✓	×
	Rem2	×	×	✓✓	✓✓	×
Western Australia (WA1)	P1	✓✓	✓✓	✓	✓	✓
	P2	✓✓	✓✓	✓	✓	✓
	P3	✓✓	✓✓	✓	✓	✓
	P4	✓✓	✓✓	✓	✓	✓
	P6	✓✓	✓✓	✓	✓	✓
	R	✓✓	✓✓	✓	✓	✓
Western Australia (WA2)	UnImp1	×	×	✓✓	✓✓	×
	UnImp2	×	×	✓✓	✓✓	×
	Imp1	×	×	✓✓	✓✓	×
	Imp2	×	×	✓✓	✓✓	×
	Rem1	×	×	✓✓	✓✓	×
	Rem2	×	×	✓✓	✓✓	×

Table 3. Invertebrate Orders and Taxa identified from the Australia-wide dataset.

Arthropods in pitfall traps

Order	Scientific/common name	functional group
Haplotaxida	Earthworms	detritivore
Arhynchobdellae	Leeches	parasite
Gastropoda	Snails	herbivore
Acarina	Mites/ticks	
	Acariformes	predator
	Acariformes: Oribatida	detritivore
	Acariformes: Prostigmata	predator
	Parasitiformes: Ixododa	parasite
	Parasitiformes: Mesostigmata	predator
	Prostigmata: Anystidae	predator
	Prostigmata: Bdellidae	predator
	Prostigmata: Erythraeidae	omnivore
	Prostigmata: Trombiculidae	predator
Araneae	Spiders	predator
Opilionida	Harvestmen	predator
Pseudoscorpions	Pseudoscorpions	predator
Scorpionida	Scorpions	predator
Amphipoda	Landhoppers / Land shrimp	detritivore
Isopoda	Slaters	detritivore
Chilopoda	Centipedes	predator
Diplopoda	Millipedes	herbivore
Collembola	Springtails	detritivore
Blattodea	Cockroaches	detritivore
Coleoptera	Beetles	
	Adephaga: Carabidae	predator
	Adephaga: Paussinae: Arthropterus sp.	predator
	Archostemata: Cupedidae	omnivore
	Polyphaga: Chrysomelidae	herbivore
	Polyphaga: Cleridae	predator
	Polyphaga: Coccinellidae	predator
	Polyphaga: Corylophidae	herbivore
	Polyphaga: Cucujoidea: Lathridiidae	detritivore
	Polyphaga: Curculionoidea	herbivore
	Polyphaga: Dermestidae	detritivore
	Polyphaga: Elateridae	herbivore
	Polyphaga: Heteroceridae	detritivore
	Polyphaga: Hydrophiloidea: Histeridae	predator
	Polyphaga: Meloidae	omnivore
	Polyphaga: Mordellidae	herbivore
	Polyphaga: Ptinidae	detritivore
	Polyphaga: Scarabaeoidea	different guilds
	Polyphaga: Scarabaeoidea: Onthophagus taurus	detritivore
	Polyphaga: Scarabidae	herbivore
	Polyphaga: Scydmaenidae	predator
	Polyphaga: Staphylinidea	predator
	Polyphaga: Staphilionoidea: Pselaphinae	predator
	Polyphaga: Staphilionoidea: Schistodactylus sp.	predator
	Polyphaga: Tenebrionidae	herbivore
	Polyphaga: Tenebrionoidea: Anthicidae	detritivore
	Polyphaga: Tenebrionoidea: Anthicidae: Notoxini	detritivore
	Polyphaga: Tenebrionoidea: Salpingidae	herbivore
Dermaptera	Dermaptera: Anisolabididae	detritivore
	Dermaptera: Forficulidae	herbivore
	Dermaptera: Labiduridae	herbivore
Diptera	Flies	
	Nematocera: Bibionomorpha	detritivore
	Nematocera: Cecidomyiidae	omnivore
	Nematocera: Chironomidae	herbivore
	Nematocera: Culicidae	parasite
	Nematocera: Culicomorpha	herbivore
	Nematocera: Mycetophilidae	detritivore
	Nematocera: Psychodidae	detritivore
	Nematocera: Scatopsidae	herbivore
	Nematocera: Sciaridae	detritivore
	Nematocera: Tabanoidea	detritivore
	Nematocera: Tanyderidae	detritivore
	Nematocera: Tipulidae	different guilds
	Brachycera: Apioceridae	herbivore
	Brachycera: Asilidae	predator
	Brachycera: Bombyliidae	herbivore
	Brachycera: Dolichopodidae	predator
	Brachycera: Drosophilidae	detritivore
	Brachycera: Empididae	predator

	Brachycera: Ironomyiidae	detritivore
	Brachycera: Muscidae	detritivore
	Brachycera: Phoridae	detritivore
	Brachycera: Sepsidae	herbivore
	Brachycera: Sphaeroceridae	detritivore
	Brachycera: Syrphidae	herbivore
	Brachycera: Tachinidae	parasite
	Brachycera: Tephritidae	herbivore
	Brachycera: Therevidae	herbivore
Embioptera	Webspinners	detritivore
Formicidae	Ants	
	Cerapachyinae: Cerapachys	predator
	Cerapachyinae: Sphinctomyrmex	predator
	Dolichoderinae: Froggattella	predator
	Dolichoderinae: Iridomyrmex	predator
	Dolichoderinae: Ochetellus	predator
	Dolichoderinae: Tapinoma	omnivore
	Dolichoderinae: Technomyrmex	predator
	Formicinae: Campanotus	omnivore
	Formicinae: Melophorus	omnivore
	Formicinae: Notoncus	predator
	Formicinae: Paratrechina	omnivore
	Formicinae: Prolasius	herbivore
	Formicinae: Stigmacros	predator
	Myrmeciinae: Adlerzia	predator
	Myrmeciinae: Myrmecia	omnivore
	Myrmicinae: Aphaenogaster	predator
	Myrmicinae: Cardiocondyla	herbivore
	Myrmicinae: Carebara	predator
	Myrmicinae: Colobostruma	predator
	Myrmicinae: Crematogaster	predator
	Myrmicinae: Epopostruma	predator
	Myrmicinae: Meranoplus	omnivore
	Myrmicinae: Monomorium	omnivore
	Myrmicinae: Pheidole	predator
	Myrmicinae: Podomyrma	predator
	Myrmicinae: Rhoptomyrmex	predator
	Myrmicinae: Tetramorium	predator
	Myrmicinae: Unnamed Genus #2	predator
	Ponerinae: Rhytidoponera	predator
	Ponerinae: Heteroponera	predator
	Ponerinae: Hypoponera	predator
Hemiptera	Bugs	
	Hemiptera (bugs)	herbivore
	Heteroptera: Lygaeidae	predator
	Heteroptera: Reduvioidea	predator
Hymenoptera	Wasps/bees	
	Apoidea (bees)	herbivore
	Apocrita - parasitic wasps	parasite
	Apocrita: Chalcidoidea	parasite
	Apocrita: Cynipoidea	parasite
	Apocrita: Evanioidea: Evaniidae	parasite
	Apocrita: Ichneumonoidea	parasite
	Apocrita: Ichneumonoidea: Alysiinae	parasite
	Apocrita: Ichneumonoidea: Braconidae	parasite
	Apocrita: Ichneumonoidea: Helconinae	parasite
	Apocrita: Prototrupoidea	parasite
	Symphyta: Pergidae	herbivore
	Vespoidea: Dryinidae: Gonatopus sp.	predator
	Vespoidea: Mutillidae	parasite
	Vespoidea: Pompilidae	predator
Isoptera	Termites	herbivore
Lepidoptera	Moths/butterflies	herbivore
Mantodea	Praying mantids	predator
Neuroptera	Lacewings	predator
Orthoptera	Crickets/grasshoppers	herbivore
Psocoptera	Booklice	detritivore
Strepsiptera	Stylops	parasite
Thysanoptera	Thrips	
	Terebrantia: Thripidae	herbivore
	Tubulifera: Phlaeothripidae	predator
Thysanura	Silverfish	detritivore
Juvenile	Juvenile	
	Carabidae larvae	predator
	Coccinellidae larvae	predator
	Coleoptera larvae	different guilds
	Diptera larvae	herbivore
	Lepidoptera larvae	herbivore
	Neuroptera larvae	predator
	Slaters larvae	detritivore

Table 4. Invertebrate abundance and richness at each project site.

Project	No. of individual invertebrates	Biomass of invertebrates (g)	Order-level richness	Taxa-level richness	No. of endemic taxa
NSW	1052478	782.4	20	80	7
VIC	48033	330.1	20	64	6
SA	10211	107.2	21	79	13
WA1	57238	106.8	23	72	7
WA2	17368	75.0	23	72	9

Microbial biomass and respiration

The samples were analysed by Dr. Kathy King at the University of New England using a Respicond™ respirometer. More than 80 samples were analysed during the course of this project from Autumn 2004 to Autumn 2006 (Table 5).

Microbial biomass. When averaged across all plots (except scalded areas and remnant vegetation) the average microbial biomass recorded was 27.65mg Microbial Carbon/100g DM Soil (Fig. 1). Western Australia had the lowest average at 14.83mg Microbial Carbon/100g DM Soil and Victoria had the highest at 37.37mg Microbial Carbon/100g DM Soil. In contrast, the scalded areas were much lower, with average microbial biomass values of 3.90mg Microbial Carbon/100g DM Soil (see Fig. 2 for example) whilst the remnant vegetation areas averaged to be 17.26mg Microbial Carbon/100g DM Soil.

Microbial respiration. When averaged across all plots (except scalded areas and remnant vegetation) the average microbial basal respiration was 0.30mg CO_2/hr/100g DM Soil. Western Australia had the lowest average at 0.13mg CO_2/hr/100g DM Soil and Victoria had the highest at 0.50mg CO_2/hr/100g DM Soil (Fig. 3). In contract the scalded areas were much lower, with an average microbial biomass of 0.09mg CO_2/hr/100g DM Soil whilst the remnant vegetation areas averaged to be 0.22mg CO_2/hr/100g DM Soil.

Analysis of variance was used to examine the effect of the following factors (excluding scalded and remnant areas): State, Year, Season, Treatment (Control vs. Treatment). Statistically significant ($P<0.05$) differences were found for each of these factors.

State	**P**	**NSW**	**SA**	**VIC**	**WA**
Variate: Soil_M	<.001	27.53	35.6	35.25	9.24
Variate: Basal_R	<.001	0.291	0.289	0.336	0.15
Year		**2004**	**2005**	**2006**	
Variate: Soil_M	<.001	24.1	27.22	31.51	
Variate: Basal_R	0.003	0.328	0.234	0.259	
Season		**Winter**	**Spring**	**Summer**	**Autumn**
Variate: Soil_M	<.001	31.97	19.78	25.17	26.82
Variate: Basal_R	<.001	0.434	0.224	0.208	0.226
Type		**Control**	**Treatment**		
Variate: Soil_M	<.001	30.11	24.6		
Variate: Basal_R	0.027	0.303	0.251		

Table 5. Microbial biomass and respiration – soil sampling events. ✓✓ denotes two samples taken from scalded areas – one from a bare scald and from a scald with some vegetative cover.

Project	Plot	SeasonYear								
		Autumn 2004	Winter 2004	Spring 2004	Summer 2004	Autumn 2005	Winter 2005	Spring 2005	Summer 2005	Autumn 2006
NSW	Control	✓	✓			✓	✓	✓	✓	✓
	Treatment	✓	✓			✓	✓	✓	✓	✓
	Remnant									
	Scald		✓			✓	✓	✓	✓	✓
Victoria	Control	✓	✓			✓	✓		✓	
	Treatment	✓	✓			✓	✓		✓	
	Remnant						✓		✓	
	Scald									
South Australia	Control	✓	✓		✓	✓		✓	✓	
	Treatment	✓	✓		✓	✓		✓	✓	
	Remnant	✓	✓		✓	✓	✓	✓	✓	
	Scald									
Western Australia (WA1)	Control	✓	✓	✓	✓	✓		✓	✓	
	Treatment	✓	✓	✓	✓	✓		✓	✓	
	Remnant	✓	✓	✓	✓	✓		✓	✓	
	Scald									
Western Australia (WA2)	Control					✓		✓	✓	
	Treatment					✓		✓	✓	
	Remnant									
	Scald					✓✓		✓✓		

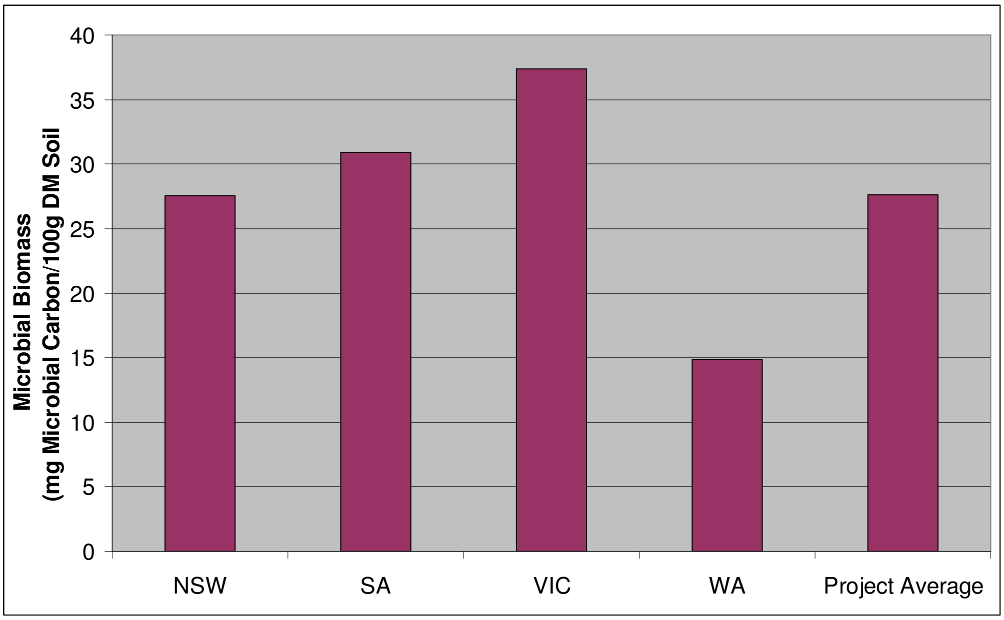


Figure 1. Average soil microbial biomass by site

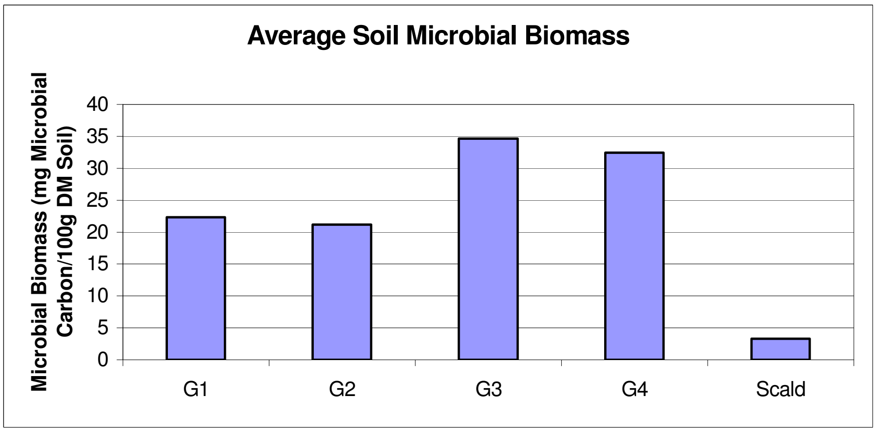


Figure 2. Soil microbial biomass from the Gumble (NSW) site. Values are the average of 4 samples taken in 2004/5.

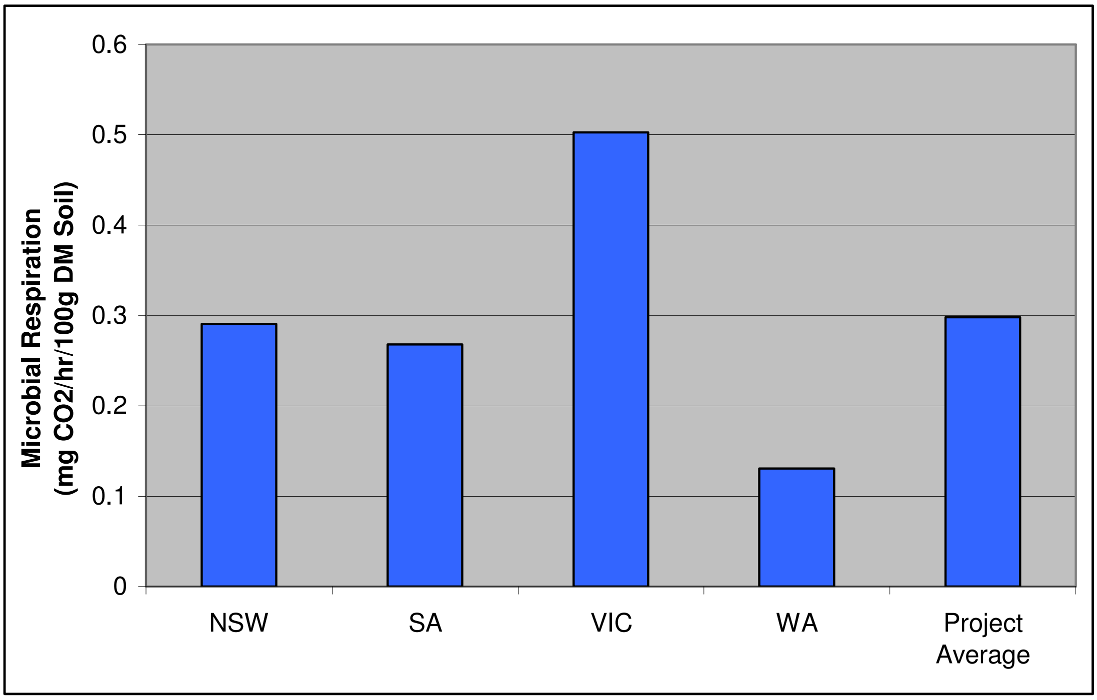


Figure 3. Average Soil Microbial Respiration by site

It is unclear whether the lack of microbial activity at the scalded sites is a cause of reduced plant cover or a consequence. Given the increased risk associated with sowing pastures into such sites, it may be that reduced soil microbial activity is one of the implicated factors.

In addition, an honours project by Margaret Bronicka (CSU, Orange) examined the diversity of soil fungi in salt-affected sites. Her thesis was accepted in September 2006. The results do not show a clear-cut relationship between any measure of salinity and fungal diversity. However, most of her samples were drawn from areas with relatively low soil EC and perhaps the effects of soil salinity become evident only at higher EC levels.

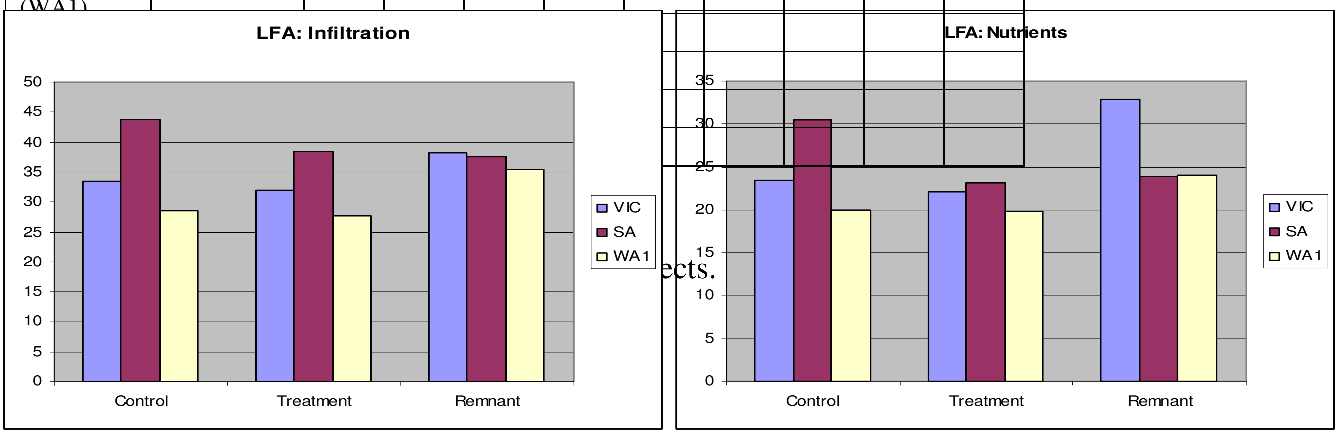
Landscape Functional Analysis

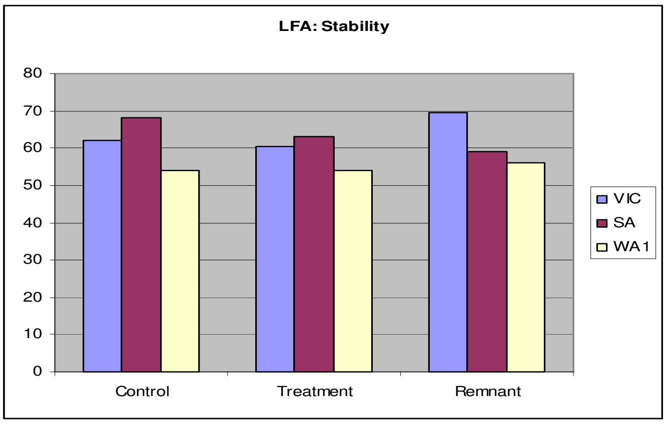
Training of staff at each site in the LFA procedure was completed by David Tongway. Procedures to load the LFA spreadsheet into the database were written and, with some training, worked well. In total, LFA has been recorded on 23 occasions (Table 6). However, the NSW LFA data has been omitted. This is because more-or-less continuous pasture swards were present in NSW (rather than patch-interpatch), which made the determination of LFA problematic and overly subjective. Data from WA2 was not available. Since most of the data that was collected occurred in autumn, all further analyses use only the autumn data.

For the three projects analysed, significant differences ($P<0.05$) were observed between the calculated LFA indices: those from the WA site were lower, on average, than from VIC or SA (Fig. 4). However, the differences between the control, treatment and remnant plots were not significant ($P>0.05$).

Table 6. Landscape Functional Analysis sampling events.

Project	**Plot**	**SeasonYear**								
		Autumn 2004	Winter 2004	Spring 2004	Summer 2004	Autumn 2005	Winter 2005	Spring 2005	Summer 2005	Autumn 2006
NSW	Control									
	Treatment									
	Remnant									
Victoria	Control	✓				✓				✓
	Treatment	✓				✓				✓
	Remnant	✓				✓				✓
South Australia	Control	✓				✓				
	Treatment	✓				✓				
	Remnant	✓	✓			✓	✓			
Western Australia (WA1)	Control	✓		✓						✓
	Treatment	✓		✓						✓





LFA: Stability
80
70
60
50
40
30
20
10
0
Control
Treatment
Remnant
VIC
SA
WA1

Pasture diversity

The collection of nation-wide data on the diversity of pasture species in the SGSL experimental sites has been calculated from data supplied by the 'Pastures' theme. In general, per-plot pasture species richness was low, with a low proportion of native species (Table 6). Average pasture biomass was highly variable between states.

Table 6. Summary of pasture diversity data

State	Pasture Biomass (t/ha)	% Native	%Perennial	Species Richness
NSW	3.29	7	28	10.2
VIC	1.57	13	71	10.4
SA	2.11	0	n/a	24.4
WA1	0.80	27	21	4.9

Relationships between biodiversity and environment

There were no significant (P<0.05) correlations between any measure of biodiversity and only three significant correlations between any biodiversity measure and any environmental factor: LFA(Infiltration) was positively correlated with pasture species richness and Soil Microbial Biomass was negatively correlated with both %Native and %Perennial. The information value of three significant correlations out of more than 60 seems dubious however. With appropriate correction for the number of tests, these relationships become non-significant.

There were substantial differences between states with respect to biodiversity measures. In an ordination that includes all seven measures (the three LFA indices, two microbial measures and two invertebrate metrics), distinct segregation between sample points classified by state was observed (Fig. 5a)

The effects of the treatments on the various metrics of biodiversity showed no difference in two of the three LFA indices (Stability and Infiltration), microbial basal respiration or invertebrate taxon richness. Three statistically significant results did emerge: LFA(Nutrients) was actually significantly *lower* in the treated plots, microbial biomass was lower in the scalded plots and invertebrate biomass was higher in the remnant. An ordination of this data (the same ordination as above, reclassified) shows some slight segregation between the control and treated plots (Fig. 5b)

Figure 5a. Ordination of samples based on seven metrics of biodiversity (the three LFA indices, two microbial measures and two invertebrate metrics), classified by State.

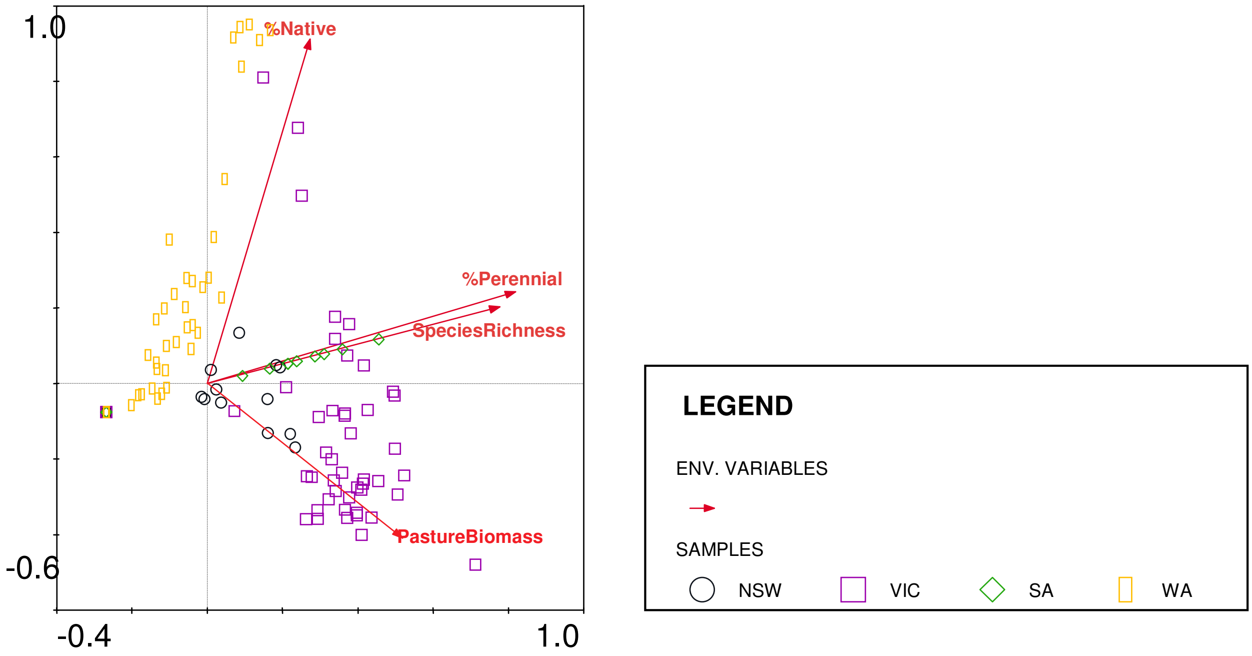
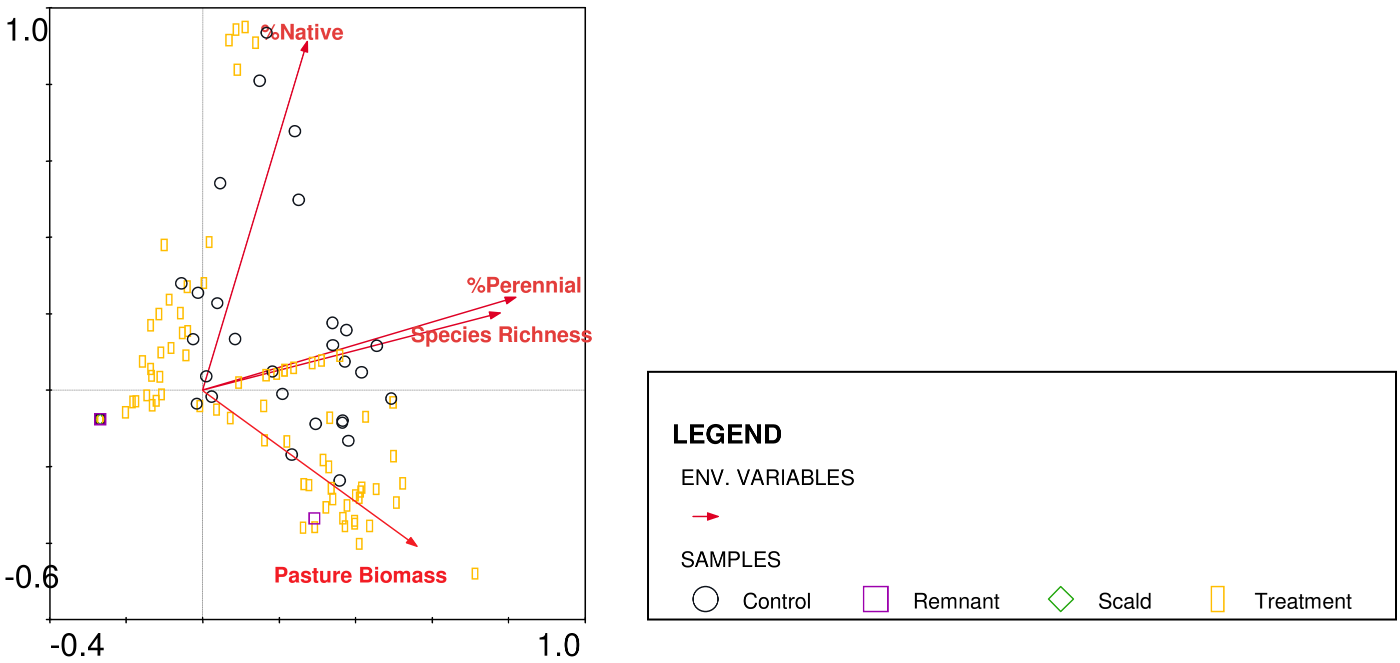


Figure 5b. Ordination of samples based on seven metrics of biodiversity (the three LFA indices, two microbial measures and two invertebrate metrics), classified by Treatment.



Conclusions

At the whole-plot scale, few significant changes were observes between the 'control' and 'treatment' plots, whatever the treatments were. In fact, in one of the LFA indices (Nutrients), the treated plots actually had lower values than the control plots. The native vegetation remnants did have higher levels of invertebrate biomass than either control or treatment plots but few other differences emerged.

It is only when the analysis focuses on within-plot variation that some important differences become evident. Microbial respiration and biomass were significantly lower in scalded areas and this result comes from only a subset of the data collected nationally. This analysis demands further work but it will require a concerted effort to tease out the data that has been collected nationally on a within-plot basis. It is anticipated that his will form the basis of the SGS Biodiversity Theme paper contribution to the International Salinity Forum in 2008.

Financial Issues
The sorting of invertebrates into functional groups is the largest single budget item in this project. Careful consideration of the number and size of submitted samples was made to determine the minimum number of samples that needed to be sorted to provide a consistent dataset. Ten 'events' were sorted from the 17 submitted. The SGSL Biodiversity Theme meeting, held in November 2006 determined that any remaining funds should be used to sort as many of the as-yet unsorted samples as possible. It is likely that sufficient funds would be available to sort all of the samples (or very nearly) and the additional data will add substantial value to the data already generated so far.

Communication Achievements and other outputs

1. A paper was given at Australian Entomological Society conference in Canberra in December 2005 (Attachment 3). Together with a general introduction to the SGSL Program, a 'first cut' of the WA1 data was presented. One of the observations made after the presentation of this data was a preponderance of predators in many of the samples, which was unexpected. Discussion with conference delegates revealed some other examples of similar results and explored possible reasons for this pattern. It appears likely that the predators are functioning as scavengers, relying on prey that has 'blown-in' from outside the immediate area rather than resident in it. Approximately 250 delegates were present.

2. A paper was given at the combined conference of the Australian and New Zealand Ecological Societies, Wellington, NZ in September, 2006 (Attachment 4). Together with a general introduction to the SGSL Program, a preliminary analysis of the nationwide dataset was presented, highlighting the marked differences in functional group relative abundances. Again, the preponderance of predators in many of the WA samples was evident. Regrettably, fewer than 50 delegates were present in this 'agro-ecology' session. Despite this, the presence of agricultural scientists at ecological conferences should be encouraged or the disconnect between agricultural ecology and more 'conservation-oriented' ecology will fester on.

3. Biodiversity theme outputs are consistently used as 'value-adding' components in Field Days run as part of the regular SGSL site activities.

List of Attachments

1. Biodiversity Theme protocols

2. Draft manuscript: The effect of management and environment on the diversity of invertebrate communities of salt-affected sites in Australia.

3. PowerPoint presentation of paper given at Australian Entomological Society conference in Canberra in December 2005.

4. PowerPoint presentation of paper given at combined Australia/New Zealand Ecological Societies conference in Wellington, NZ in September 2006.

Attachment 1:

Biodiversity and landscape function protocol

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Introduction

The term biodiversity encompasses the variety of life at the level of species, genes and ecosystems (Wilson 1988). Brennan (in press) distinguishes between structural and functional interpretations of biodiversity. The structural interpretation views diversity as being valuable in its own right regardless of its impact on the productivity or stability of ecosystems. It is the existence of organisms that make up the diversity of life that is considered valuable, not their instrumental value to humans. In contrast the functional interpretation places value on biodiversity as a means to an end rather than as an end in itself, and is based on the widely held assumption that biodiversity confers superior ecosystem function in the form of primary productivity, nutrient cycling and the stability of these processes.

However, the relationship between biodiversity and ecosystems function has so far defied generalisation, even in simplified managed ecosystems (Houston 1997, Tilman *et al* 1997). In a review of experiments designed to test the relationship between diversity and ecosystem function, Grimes (1997) observed that *"..neither evolutionary theory nor empirical studies have presented convincing evidence that species diversity and ecosystem function are consistently and causally connected*". Grime (1997) concluded that functional characteristics of the dominant plants species are more important than the number of species (see also Cameron 2002).

In addition to the structural and functional interpretations of biodiversity, it is also necessary to consider the two different ways in which farming systems and biodiversity interact. There is the impact of farming systems on biodiversity at landscape scale, and the influence of biodiversity on the productivity of farming systems at paddock scale (Table 1).

Table 1. Experimental approaches to assessing the impact of biodiversity in agricultural landscapes

Biodiversity Value

		Structure & Composition	**Function**
Scale of Impact	**Paddock**	Impact of land use on paddock scale biodiversity	Impact of species and functional group diversity on agricultural production
	Landscape	Impact of land use on biota at landscape and regional scale	Impact of land use on landscape processes (eg fluxes of water and nutrients)

With this background in mind, this protocol has been designed to address four questions.

1) What is the relationship between the diversity of plant functional groups (annual/perennial, herbaceous/woody, legume/non-legume, summer active/winter active) and plant and animal productivity (top right, Table 1)?
2) What is the relationship between point measurements of ecosystem function (Landscape Functional Analysis (Tongway 1998) and microbial respiration) and plant species diversity, plant functional group diversity and plant and animal productivity (top right, Table 1)?
3) What is the relationship between the diversity of above ground invertebrates, plant species diversity, and plant functional group diversity (top left, Table 1)?
4) What are the likely off-site impacts of saline grazing systems on significant species and ecological communities in the region (bottom left, Table 1)?

The last question addresses the area identified in scoping documents for the SGSL project (Land Water and Wool 2001) as the most significant knowledge gap, the impact of saline grazing systems on the broader environment. However as most sites have an emphasis on paddock scale issues, and the broader scale issue of biodiversity conservation is difficult to predict, the consensus amongst SGSL site representatives is that this fourth area be an optional activity only.

Table 2
Summary of the minimum data sets for the biodiversity and landscape function protocol

Measurement	Frequency	Comment
Plant species and plant functional group diversity	Three times a year (prior to grazing, after grazing and at peak biomass)	Based on rank order in BOTANAL quadrats
Landscape Functional Analysis	Twice a year (prior to grazing and just after grazing)	At least one representative to be trained on site in LFA
Soil microbial respiration	Four times a year (spring, summer, autumn and winter)	
Disturbance regime	Whenever disturbance events occur	Maintain a record of the timing and degree of disturbance (fertilisers, pesticides, grazing, flooding, fire and major weather events)

Minimum data sets

Plant diversity

The diversity of plants in the three treatments (unimproved saltland, current best practice saltland pasture and modified saltland pasture) is to be measured through the calibrated estimation of plant biomass by
1) species,
2) lifeform (perennial/annual; woody/herbaceous; grass/forb/legume) and
3) phenology (winter active/summer active)

Sampling for composition of plant biomass is to be carried out as described in the pasture protocol, i.e. rank order of the top three species in terms of biomass in 60 BOTANAL quadrats plus 10 calibration cuts. This is to be carried out three times each season just prior to grazing, just after grazing and at peak biomass. It is strongly recommended that a herbarium be maintained at each site, commencing with the first spring sampling as a training aid to plant identification. The contact person for this protocol is Lyn Atkins, CSIRO Sustainable Ecosystems Perth.

Landscape Functional Analysis

Landscape Functional Analysis (LFA, Tongway and Hindley 1995) was developed as a measure of rangeland condition and has since been used to assess the success of mining rehabilitation and revegetation in agricultural landscapes. It uses 10 measurements of soil surface condition to derive indices of water infiltration, soil surface stability, and nutrient cycling that have been found to correlate well with direct field and laboratory measurements. These three indices are integrated to produce an index of landscape function. The individual measurements are

- perennial basal plant cover
- litter cover
- cryptogam cover
- crust brokenness
- erosion features
- deposited materials
- soil microtopography
- surface nature
- the Slake Test

Short courses on the application of LFA to saline grazing systems will be run at each site by David Tongway. Software developed by Tongway and Hindley (1995) is then used to rapidly generate the three indices of functionality (infiltration, stability and nutrient cycling). The hypothesis under examination is that landscapes with high functional indices as determined using the LFA technique produce higher levels of animal production, more tightly closed water, nutrient and salt cycles and provide higher value habitat for species sensitive to landscape degradation than landscapes with low landscape functional indices. The contact person for this protocol is David Tongway, CSIRO Sustainable Ecosystems Canberra.

Soil microbial respiration

The abundance of soil microbes is very large in comparison with other soil biota. It has been estimated that, for improved pastures in temperate regions of eastern Australia, there are around 4,000 kg/ha of biomass of microbes in the top 10 cm soil. In addition to being very abundant in soil, microbes have a very high respiratory activity which can account for more than 70% of energy expended within improved pastures when compared with other consumers such as sheep and invertebrate animals.

Respiratory activity of soil microbes and their biomass can be measured by respirometry. The production of carbon dioxide within root-free soil occurs mainly through soil microbial respiration. The Respicond system used by the Department of Agronomy and Soil Science at the University of New England estimates both basal respiration rate of soil microbes and their biomass. Soil samples are adjusted to optimal soil moisture for microbial activity and placed in a water bath at 20^{o}C. Basal respiration and microbial biomass are measured over the course of a week. This technique is more sensitive than other methods (e.g. loss of tensile strength in buried cotton strips) and has the advantage over chemical procedures such as fumigation-extraction of being relatively rapid.

Since over 90% of biological activity occurs in the top 10 cm soil, this is the most sensitive depth of sampling. Thirty small soil samples using a standard soil corer of approximately 2 cm diameter are taken at random in each of three treatments (unimproved saltland, current best practice saltland pasture and modified saltland pasture) to a depth of 10 cm and formed into a bulked sample weighing approximately 500 g. This is thoroughly mixed, and three sub-samples sent to Dr. Kathy King, Department of Agronomy and Soil Science, University of New England, Armidale NSW 2351 for analysis.

It is suggested that measurements of microbial activity and microbial biomass be taken 4 times per year as these two measurements will change according to season. The contact person for this protocol is Warren King, NSW Agriculture, Orange.

Disturbance regime

Record the frequency and intensity of the management regime including the timing and intensity of the following events as an aid to interpreting trends in plant and soil surface invertebrate diversity, animal production and materials balance;

- Grazing (frequency, intensity and class of livestock)
- Fertiliser application (timing, form and application rate)
- Herbicide and insecticide use (timing, chemical, rate of application)
- Flooding (frequency, depth and duration of inundation)
- Fire (timing, extent and frequency)
- Extreme weather events (nature and timing)

Optional data sets

Table 3
Summary of the optional data sets for the biodiversity and landscape processes protocol

Measurement	Frequency	Comment
Diversity of above ground invertebrates (Tammin and Wagga Wagga)	Twice per year (after grazing and peak biomass)	Using the Ecowatch protocol developed by CSIRO Entomology
Regional biodiversity impacts of saline grazing systems	Over the course of the experiment	A desk top analysis of the likely impact of the saline grazing system on regionally significant species and ecological communities.

Diversity of above ground invertebrates

Above ground invertebrates are to be sampled using pitfall traps and flight intercept traps based on the 'Ecowatch' project protocol developed by CSIRO Entomology.

The pitfall traps are designed to collect invertebrates moving along the soil surface (Figure 1). Pitfall traps are constructed of 500ml plastic cups half filled with 30% propylene glycol collecting fluid, placed in PVC pipe 'sleeves' sunk into the ground so the cup top surface is level with the soil surface. A 60cm long by 10cm high drift fence of galvanised iron or stiff plastic such as polypropylene garden edging is positioned to direct invertebrates into the trap. Pitfall traps are spaced at approximately 20m intervals, with 10 per sampling site.

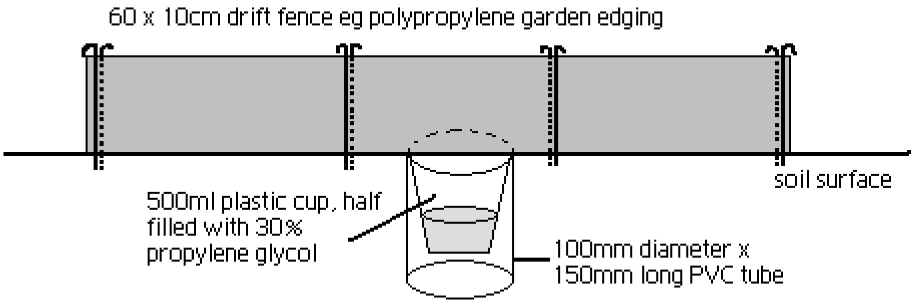

Figure 1. Pitfall trap for ground dwelling

The flight intercept trap is a vertical sheet of fine black gauze suspended over a ground-level trough containing 30% propylene glycol and immediately beneath the centre of a large cone formed from steel rod and covered in fine white gauze that leads to a collecting bottle containing 70% ethyl alcohol (Figure 2). The trap works on the principle that flying insects hit the suspended gauze and either fall into the trough, or fly into the cone to be trapped in the collecting bottle. There are to be two flight intercept traps per treatment.

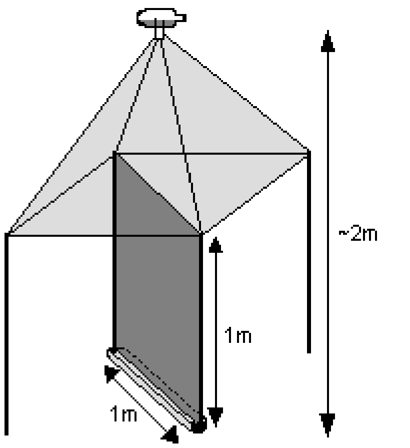

Figure 2. Flight intercept trap for collecting flying

The vertical sheet is black gauze or fine shade cloth 1x1m in size, positioned across the prevailing winds. The trough at the base is a length of 150mm diameter PVC tube cut length ways containing 30% propylene glycol. The cone is covered in white gauze or mosquito netting. The plastic drink bottle at the top should be 2m above ground level and partly filled with 70% ethanol with propylene glycol added during the warmer months to prevent evaporation. It is attached to the cone by a piece of 100mm PVC pipe, with the whole structure supported by four star pickets.

The pitfall traps will be open for one week at a time and the flight intercept traps for two weeks. Collection will be twice per year, once in late spring (October, at peak biomass) and post-grazing in autumn (April). Three treatments are to be sampled, unimproved saline pasture, improved saline pasture and adjacent remnant vegetation, with two sampling lines within each treatment giving 60 pitfall traps in total (3 x 10 x 2), and 6 flight intercept trap (3 x 1 x 2).

The invertebrates caught using these trapping methods will be sorted to the level of Order by the collectors, using the invertebrate key available on http://www.ento.csiro.au/ecowatch/Invertebrate_key/couplet_01.htm or the invertebrate taxonomic guide 'Worms to Wasps' by Harvey and Yen (1989). Specimens are to be stored in 80% ethyl alcohol by Order, grazing treatment and collection date and forwarded to CSIRO Entomology at the end of the experiment.

Ground dwelling insect orders likely to be caught in pitfall traps include silverfish (Thysanura), cockroaches (Blattodea), termites (Isoptera), praying mantids (Mantodea), earwigs (Dermaptera), grasshoppers (Orthoptera), stick-insects (Phasmatodea), web-spinners (Embioptera), booklice (Psocoptera), lice (Phthiraptera), bugs (Hemiptera), thrips (Thysanoptera), beetles (Coleoptera), fleas (Siphonaptera), and ants (Hymenoptera).

Additional invertebrate taxa that may be caught in pitfall traps include phylum Mollusca (snails - orders Diotocarda, Monotocardia, Orthurethra, and Sigmurethra, and slugs - order Soleolifera), phylum Annelida (earthworms - order Haplotaxida and leeches - order Arhynchobdellae), phylum Chelicerata (scorpions - order Scorpionida, spiders - order Araneae, pseudoscorpions - order Pseudoscorpionida, harvestmen - order Opilionida, and mites and ticks -order Acarina), phylum Crustacea (land crayfish - order Decapoda, landhoppers - order Amphipoda, and slaters - order Isopoda), phylum Uniramia (centipedes - orders Scolopendrida, Geophilida, and Scutigerida, dwarf millipedes - order Polyxenida, millipedes - orders Sphaerotheriida, Siphonophorida, Polydesmida, Spirostreptida, and Julida, and springtails - order Collembola).

Insect orders likely to be caught by a flight intercept traps include mayflies (order Ephemeroptera), dragonflies and damselflies (Odonata), stoneflies (Plecoptera), lacewings (Neuroptera), scorpionflies (Mecoptera), flies (Diptera), moths and butterflies (Lepidoptera), wasps and bees (Hymenoptera) and many orders that have already been listed as being likely to be caught in pitfall traps. The contact person for this protocol is Lyn Atkins, CSIRO Sustainable Ecosystems Perth.

Regional biodiversity impacts of saline grazing systems

The purpose of this aspect of the protocol is to carry out a qualitative but systematic benefit-threat analysis of the likely impact of saline grazing systems on native biodiversity. It addresses the broader environmental impact of saline grazing systems, one of the major knowledge gaps identified early in the life of the SGSL project (Land Water and Wool 2001). The question of environmental impact is a function of the particular context, and will vary from site to site depending on the significant native species and ecological communities within a region, the pasture species under investigation, especially their weediness or invasiveness, and the grazing management regime. The following three-stage approach is recommended as a means of assessing the likely positive and negative impacts of saline grazing systems.

Step 1 Identify target species or communities

a) Identify the species and ecological communities that have been formally recognised as being of regional significance by consulting the state and federal information sources listed below.

b) Identify the species and ecological communities that have been less formally recognised as significant through their inclusion in local catchment and region biodiversity management plans or adopted as icon or focal species by local conservation groups.

Table 4. National and State sources of significant species and ecological communities

Links for all states:
<http://www.cbn.org.au/member/cbn/projects/ThreatenedListings/TS_List.html>

National threatened flora list:
<http://www.ea.gov.au/cgi-bin/sprat/public/publicthreatenedlist.pl?wanted=flora>

National threatened fauna list:
<http://www.ea.gov.au/cgi-bin/sprat/public/publicthreatenedlist.pl?wanted=fauna>

National threatened ecological community (TEC) list:
<http://www.ea.gov.au/cgi-bin/sprat/public/publiclookupcommunities.pl>

WA threatened flora:
<http://www.calm.wa.gov.au/plants_animals/pdf_files/wildlife_cons_notice_flora2002.pdf>

WA threatened fauna:
<http://www.calm.wa.gov.au/plants_animals/pdf_files/wildlife_cons_notice_fauna2002.pdf>

Victorian threatened species:
<http://www.dms.dpc.vic.gov.au/l2d/F/ACT00923/3_0.html>

Victorian threatened ecological communities
VIC - <www.nre.vic.gov.au/web…/2947421f94bc2d724a0004fc7b?OpenDocumen>

NSW threatened species/communities

<www.austlii.edu.au/au/legis/nsw/consol_act/tsca1995323/sch1.html>

SA threatened species/communities
<www.austlii.edu.au/au/legis/sa/consol_act/npawa1972247/sch7.html>

The 21 National Action Plan Priority regions

http://www.napswq.gov.au/publications/priority_regions.html.

Step 2. Identify threats to target species and communities

Identify the threats to the presence and viability of the regionally significant species and ecological communities. Threats include the loss and fragmentation of habitat (resulting in a decrease in total area, increase in isolation between patches and a decrease in the connectivity of patches); predation; grazing; altered hydrologic regimes including salinity, altered nutrient regimes, changed fire regimes; the spread of weeds including salt tolerant pasture species; pests and pesticides.

Step 3. Identify impact of saline grazing systems

Identify the role that saline grazing system could potentially play in exacerbating or ameliorating the threats facing target taxa by virtue of their location, design, structure, composition or grazing management (see Table 5). The contact person for this protocol is Ted Lefroy, CSIRO Sustainable Ecosystems, Perth.

Table 5. Benefit-threat matrix for assessing the potential impacts of saline grazing systems on native biodiversity. **Suggested format for qualitative benefit-threat assessment, requiring 1) a statement as to how saline grazing systems are likely to impact on each threat for each target species or community (increase, decrease or don't know) followed by a supporting statement, and 2) identification of the research questions that need answering to improve this assessment.**

Benefit-Threat analysis: 1. Are saline grazing systems likely to increase or decrease the following threats to the viability of target taxa? 2. What are the research questions that would improve this assessment?	**Species/community 1**	**Species/community 2**	**Species/community 3**
Habitat loss			
Habitat isolation			
Habitat connectivity			
Grazing/predation/			
Weed competition			
Altered hydrologic regime			
Altered nutrient regimes			
Changed fire regime			
Agricultural pesticides			

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Attachment 2:

The effect of management and environment on the diversity of invertebrate communities of salt-affected sites in Australia.

Warren King, Lyn Atkins, Holger Loecker, Jaime Mavromihalis, Liz Abraham, & Hayley Norman

The effects of grazing (cattle and sheep) and other agricultural practices on invertebrates is a relatively new area of research in Australia, with studies able to be grouped into those examining responses to variable grazing intensity (grazed and non grazed) and other farming systems. Native grasslands and invertebrates have a low public profile and a lack of public awareness. Decreases in diversity followed by human activities often result back in degradation of soil and its functional processes as well as the soil fauna diversity (Loranger et al. 1998, Yen 1999).

To get a basic understanding of the function of an ecosystem and their parts it is necessary to look at all parts, but often overlooked and misunderstood is the role of invertebrates in a habitat community. All ecosystem-level biological processes (e.g., energy flow, decomposition, pollination, trophic organization, biological control) would collapse rapidly without invertebrates. The use of representative species in a biodiversity assessment depends on their easy recognition and identification to morphospecies (Cranston & Hillman 1992, Hinckley & New 1997), also their role in the ecosystem, their community function, prediction and monitoring value (Churchill 1997).
The attempts to ensure ecosystem sustainability across a wide range of temporal and spatial scales will not be successful if they do not reflect on conservation and protection of their invertebrate communities (Stanisic et al. 2005).

The health of a soil ecosystem is often quantified using biological diversity indicators to estimate the stability of these systems. Soil stability and health of the system relates often back to a greater diversity in the edaphone (soil organisms), which provides a more stabile food web with its species richness. Arthropods associated with agricultural soils are taking an important role in the food web dynamics, they are detritivores (feeding on dead organic substances), herbivores (feeding only on plants), omnivores (generalized feeders on plants and animals), parasites (feeding at least with one life stage on/in other animals) and predators (feeding on other animals). Sustainable agriculture uses systems to minimize the disturbance (physical and chemical inputs) of the soil food webs and therefore has positive influence on soil health. (Rebek et al. 1995)

For the management issues of native grassland habitats as a functional unit, it is important to maintain the native plants as well as the invertebrates as integral part of this community (Oliver et al. 2005). Other issues associated with habitat fragmentation and urban development reflect back on the invertebrate populations in these remnant native patches, like the edge effect, buffer zones, corridors, etc. Pasture practices and fertilisers will influence the invertebrate fauna, the effects will differ depending on crops, geography, some species will increase (e.g. pests) others will decrease (Topping & Sunderland 1992, Oliver et al. 2005, Pétillon et al. 2005), there is usually an increase in soil and litter inhabiting predatory species (e.g. ants). Arthropods may respond to grazing in a variety of ways, Oliver et al 2005 stated that for example disturbance-tolerant beetles from the families Scarabaeidae and Curculionidae, as well as ants from the genera *Iridomyrmex* and *Rhytidoponera* increase when grazed, whereas other not tolerant groups decline and disappear. The effects of grazing, especially grazing and trampling by introduced hard-hoofed animals such as sheep and cattle often result in the removal of native plants, introduction of exotic weeds, damage on soil, and increase in nutrition input. Sheep grazing can alter the microclimate, vegetation, litter and soil structure, by reducing the abundance of litter and microinvertebrates of the top soil, which means the destruction of the habitat for depending species, such as trap-door spiders, cryptic ants and other leaf-litter invertebrates which depend on the ground litter cover. (Yen 1999, King & Hutchinson 1983, Oliver et al. 2005), but it can also be a management method (biological control) of invasive exotic plant species, eg annual grasses. Native grassland is more sensitive to domestic grazing and fertiliser use, results reveal a significant historical impact of land use and a decline of native arthropod biodiversity through reduced abundance and the last step -

extinction. Exotic arthropods tend to increase with agricultural usage of land and therefore there is a shift in the arthropod community composition away from native species (Oliver et al. 2005, Pétillon et al. 2005).

About 97 percent of all animal species described and more than all living plants and animals combined are invertebrates. This huge diversity reflects back on the massive numerical appearance, adaptation on different habitats or niches, ecological variability and opportunism under the invertebrate groups. Approximately 950,000 of the described invertebrate species are insects, but in Australia and other tropical and subtropical parts of the world there are still enormous numbers of undescribed species especially insects. Some are already known from collections and have not been yet described, but many species have not even been collected yet. The unpopularity public awareness and the knowledge we have from invertebrates are often associated with a small number of venomous, disease-transmitting, and agricultural pest species (Yen 1999). Most invertebrates are easy to collect, and the fieldwork does not take that long, but the disadvantage is the long and time consuming amount of laboratory workload, which is often required and necessary to get invertebrates identified to a useful level, and there I am not talking about a species level identification, which most of the time requires an expert (Entomologist) for this task.

Pitfall traps are effective and widely used in collecting ground-dwelling invertebrates, this technique passively traps soil fauna as they move across the soil substrate, such as spiders (Araneae), mites (Acari), centipedes and millipedes (Chilopoda & Myriapoda), springtails (Collembola), beetles (Coleoptera), crickets and grasshoppers (Orthoptera), bees, wasps and ants (Hymenoptera). Although pitfall traps do not collect all arthropod species present in the environment, they serve as one standardized method for comparison. It is a useful tool to examine spatial distribution patterns, compare relative abundance and density throughout the season in different habitats and in community surveys. (Rebek et al. 1995, Topping & Sunderland 1992)
As pitfall traps we used plastic containers (what, size and amount per plot), which was planted into the soil so that the upper edge of the container was sitting at the soil-surface level. The container solution (ethanol and surface tension reducing agent) was designed to kill and preserve the arthropods falling into the traps. Later in the laboratory (Orange Agricultural Institute – Insect Collections Unit) the samples were separated, cleaned from organic matter and sorted for a first taxonomy comparison. Specimens were alcohol washed to remove the rest of the soil and other small particles and separated into major taxonomic groups (Order-level) by sorting under the Stereomicroscope (Leica MZ8, 6.3 – 50 times magnification). Groups of high diversity and different feeding guilds, such as beetles (Coleoptera) and ants (Formicidae), were processed further taxonomically to Family- and Genus-level to receive a better feeding guild resolution. For some distinctive arthropod taxa, like some beetles and wasps we were able to get a species level identification in a reasonable short time.

For the sorting process and identification we used following literature:

- Naumann, I. D., et al. 1991 - The Insects of Australia, Volume I & II
- Shattuck S. O., 1999. Australian Ants: their biology and identification (Online and Hardcopy version), CSIRO Publishing, PO Box 1139, 150 Oxford Street, Collingwood, Vic 3066, Australia; online http://www.ento.csiro.au/science/ants/default.htm
- Rees D., 2004 - Insects of Stored Products, CSIRO Publishing, PO Box 1139, 150 Oxford Street, Collingwood, Vic 3066, Australia
- Matthews E.G, 1980 - A guide to the Genera of Beetles of South Australia (Part 1-5), Special Educational Bulletin Series, South Australian Museum, Adelaide
- Tyndale-Biscoe M., 1990 – Common dung beetles in pastures of south-eastern Australia, CSIRO, Division of Entomology, Canberra, Australia

The key ecological functions and processes that can be ascribed to the target groups can be summarised as follows:

Strepsiptera (Twisted-wing parasites)

Strepsiptera are obligate parasites of insects with exhibit extreme sexual dimorphism, with hosts ranging across 7 orders and 34 families. The adult males are free living, whereas most adult females are neotenic and permanently endoparasitic in the host (Naumann et al. 1999, Maddison, et al. 1996-2006).

Hymenoptera (Wasps and Bees)
Hymenopterans, the "membrane-winged" insects, include bees, ants, and a large number of other insect taxa collectively referred to as wasps. The Hymenoptera include famous examples of social insects, such as honeybees and true ants; these insects have developed regimented social systems in which members are divided into worker, drone, and queen castes. Such social hymenoptera may live together in nests or hives of many thousands of individuals, all descended form a single queen. Not all hymenoptera are social, however; many live a solitary life, coming together only for a brief mating. (Maddison, et al. 1996-2006).

Hymenoptera: Formicidae (Ants)
Because of the ant diversity and their interaction with each other, they can be split into functional groups, including habitat requirements and community dynamics relationships. The functional grouping can be related back to ecological processes and gives an indication to stress and habitat disorder (Anderson 1995). A functional group approach has been widely used, to analyse the effects of environmental disturbance on ant communities in Australia (Stanisic et al 2005). With Functional groups and indicator species it is possible to examine the effects of fire, mining, grazing, clearing and urbanisation (Hoffman & Anderson 2003, Vanderwoulde et al. 1997). Based on a system used for plants, ants seem to respond to stress and disturbance quite different. Consequently they seem to provide an alternative measuring tool to the environmental health of habitat plant communities, and extend of responses to general ecological changes.
Given the functional groups (after Hoffman & Anderson 2003) ants are divided into:

Dominant Dolichoderinae:
abundant, highly active and aggressive ants favouring hot, open habitats; exert a strong competitive influence over other ants. (e.g. *Iridomyrmex)*

Subordinate Camponotini:
co-occurring with, and behaviourally submissive to dominant dolichoderines, but comparatively dominant in their absence; relative abundance is usually low. (e.g. *Camponotus)*

Climate specialists:
ants are centred on three distinct climatic zones; the arid zone (hot climate specialists, like *Melophorus*, *Meranoplus* and parts of *Monomorium*), the humid tropics (tropical climate specialists) and the cool temperate areas (cold climate specialists, like *Prolasius*, *Notoncus* and parts of *Monomorium*). Tropical climate specialists are characteristic of areas where dominant dolichoderine groups are low in numbers. In hotter areas some ants in this group are exceptionally thermophilic, foraging when few other species are active.

Cryptic species:
small to minute ants; forage mostly within soil and litter; have little interaction with ground active ants; mostly in subfamilies *Myrmicinae* (e.g. *Cardiocondyla*, *Carebara* and *Phoptomyrmex*) and *Ponerinae* (e.g. *Heteroponera* and *Hypoponera*)

Opportunists:
unspecialised, 'weedy' species characteristic of disturbed sites, or other habitats supporting low diversity; suffer from competitive interaction with other ants. (e.g. *Rhytidoponera*, *Paratrechina*, *Aphaenogaster, Ochetellus, Tapinoma* and *Tetramorium*)

Generalised Myrmicinae:
cosmopolitan genera occurring in most habitats; not highly active and aggressive, depending on rapid recruitment and mass mobilisation to defend clumped resources; include *Pheidole*, *Monomorium* and *Crematogaster*.

Specialist predators:
medium to large-sized species; specialised predators of other arthropods; include group raiders and solitary foragers such as *Myrmecia*; have little interaction with other ants and typically have low population densities, like *Carapachys, Sphinctomyrmex, Colobostruma, Epopostruma* and other larger ponerines.

Coleoptera (Beetles)
Beetles can be divided into two mayor groups – Adephaga (mostly predacious) and Polyphaga (feed on a variety of diets). The beetles belong to the largest Order of insects with tens of thousands of species worldwide. They are easy to recognise because of their forewings which form heavy covers for their delicate hindwings. During the SGSL survey, more than 20 families were captured.

The Adephaga is the second largest suborder of beetles, with over 40,000 known species. Adephagans are diverse in diet and structure, they contain about 10 families of predatory beetles, includes ground beetles (*Carabidae*) with around 2500 species, predacious diving beetles (*Dytiscidae*) and whirligig beetles (*Gyrinidae*). The majority of species in the suborder belong to the family *Carabidae*. The body-forms of some have become highly modified structurally for life in unusual habitats. In these beetles the testes are tubular and the first abdominal sternum (a plate of the exoskeleton) is divided by the hind coxae (the basal joints of the beetle's legs).
The Polyphaga is the largest suborder, containing more than 300,000 described species in more than 170 families, including weevils (*Curculionidae*) which is the largest family in Australia with around 6000 species, scarab beetles (*Scarabaeidae*) and *Chrysomellidae* with about 3000 species each, followed by *Staphilionidae*, *Tenebrionidae* and *Cerambycidae*.
These beetles can be identified by the cervical sclerites (hardened parts of the head used as points of attachment for muscles) absent in the other suborders. (Maddison, et al. 1996-2006).

e.g. Adephaga: *Carabidae* and relatives (Predatory ground beetles)
Predatory ground beetles are equipped with prominent jaws with which they attack and dismember other insects as food, they are the most diverse group of insects living in the upper soil layers and can be caught in large proportion.

e.g. Polyphaga: *Scarabaeinae* (Dung beetles)
Dung beetles have been chosen as a global biodiversity survey group and have been targeted under different projects (ABRS – Australian Biological Resources Study). They are easy to survey and to identify, and different species can be separated by using their diet (vertebrate dung) and by different soil and vegetation types.

e.g. Polyphaga: *Tenebrionidae* (Darkling beetles)
This large family of beetles is very diverse in form and habits but most feed on dead and decaying vegetable matter which places the group as a major decomposer element in local ecosystems.

Lepidoptera (Butterflies and Moths)

Lepidoptera are one of the largest insect groups, and contain around 10000 described species in Australia. Because of their colouring and elegance this group contains most of the well known and popular insects in Australia. For our purpose it was not necessary to go deeper into the taxonomic identification because they belong mostly in one feeding guild – plant feeding. (Naumann et al. 1999)

Collembola (Springtails)

Springtails have the widest distribution of any hexapod group, occurring throughout the world, including Antarctica. They are probably the most abundant hexapods on Earth, with up to 250.000000 individuals per square acre. They are found in soil, leaf litter, logs, dung, cave, shorelines, etc. There are about 6000 known species (Maddison, et al. 1996-2006).

Diptera (Flies)

Diptera form one of the largest insect orders, are commonly known as (true) flies and include many familiar insects such as mosquitoes, black flies, midges, fruit flies, blow flies and house flies. Flies are generally common with at least 150000 species, and can be found all over the world except Antarctica. Many species are particularly important as vectors of disease in man, other animals, and plants.
Flies are holometabolous insects that mean their life cycle involves a major change in form from a soft-bodied, wingless larval stage to a hardened, winged adult. Larvae have a variety of common names, such as wriggler and maggot (Naumann et al. 1999, Maddison, et al. 1996-2006).

Neuroptera (Lacewings and relatives)

Neuroptera are a small Order with around 5000 described species. They all have two pairs of transparent wings of about the same size. Although they are not very good flier, their wings are large and membranous, with complex vein pattern. Many are cryptically coloured and their bodies are long and soft. They have the biting and chewing mouthparts. Adults and larvae (ant lions) are the predators of other insects. Their size is from very small as 5mm to wings spans as large as 150mm. (Naumann et al. 1999, Chinery. 1993)

Embioptera (Web-spinners)

Web-spinners are one of the smaller, lesser-known orders, they are mainly tropical but some species occur also in warm-temperate climates. They are non specialized and feed on dead leaves and organic matter, small to medium sized elongated bodied insects producing and living in silk galleries (Naumann et al. 1999, Chinery. 1993).

Dermaptera (Earwigs)

Earwigs are a small order of insects containing about 1800 species, but only 60 species are known from Australia. Dermaptera are elongate and slender insects with a prognathous head, the abdomen is highly movable with a pair of unsegmented cerci at its posterior end (forceps). The body length ranges from approximately 4 to 80 mm including cerci. If not wingless, the thorax bears two pairs of wings of which the first one is small and leathery (tegmina), the second pair is large and membranous, and folded at rest, underneath the tegmina in a complicated manner. Most Dermaptera are uniformly coloured brown or black, sometimes with a light brown or yellow pattern. They are distributed throughout the world (except the polar regions), with greatest diversity in the tropics. Most species are omnivorous but predominantly phytophagous or predacious species are also known. Some species live on decaying material (Maddison, et al. 1996-2006, Naumann et al. 1999, Chinery. 1993).

Orthoptera (Crickets and Grasshoppers)

The more than 20000 species in this order have a worldwide distribution but are most diverse in the tropics. Members of the Orthoptera are well known for their abilities to jump and particularly for singing during the night. Body size ranges from less than 5 mm to some of the world's largest insects, with body lengths up to 11,5 cm, and wingspans of over 22 cm.
Orthopterans are a big component of terrestrial insect faunas and include some of the most voracious pests (locusts and certain katydids). Members are generally phytophagous but many species are also omnivores. Some of the best examples of cryptic colouration are seen in this group, involving mimicry of leaves and other vegetation or other resemblance to the background (Maddison, et al. 1996-2006, Naumann et al. 1999, Chinery. 1993).

Dictyoptera: Blattodea (Cockroaches), Isoptera (Termites) and Mantodea (Mantis)

Blattodea: Cockroaches are one of the primitive groups within the Neoptera. There are roughly 4000 species in 6 families. Cockroaches exist worldwide, with the exception of the polar regions and in elevations above 2000 m. Cockroaches are generally either scavengers (animals that consume already dead organic life-forms) or omnivores

Isoptera: A relatively small order, closely related to Blattodea, and mainly found in tropical and subtropical regions. They are soft-bodied insects with cryptic habits, and live in colonies with different castes. Termites feed on wood and other vegetable matter. Termitidae have symbiotic bacteria, other families have symbiotic flagellate protozoans that secrete enzymes that aid in the digestion of wood.

Mantodea: Praying mantids are rather large and flattened predatory terrestrial insects and range from 10 to 120mm, they can be found in the wormer parts of the world, with their characteristic way of standing with forelegs held together as if they were praying. (Naumann et al. 1999, Chinery. 1993)

Hemiptera (True bugs, cicadas, leafhoppers, aphids, etc.)

Hemiptera are a large, cosmopolitan order of insects, comprising some 67500 known species in different suborders. The most characteristic feature is the structure of the mouth parts – the tube like structure is highly efficient for extracting the liquid contents of plants or other animals. Most Hemiptera are terrestrial and phytophagous, only in the suborder Heteroptera (true bugs) there are some carnivourous individuals and groups, which are also aquatic. The name heteroptera comes from their forewings having both membranous and hard portions. It is also essentially this same feature which gives the order its name, hemiptera, coming from the Greek for half-wing (Maddison, et al. 1996-2006, Naumann et al. 1999, Chinery. 1993).

Thysanoptera (Thrips)

There are around 4500 described species around the world, their narrow body ranges from .05 to 15mm length and they can be distinguished from other insects by their asymmetric mouthparts and fringed wings. Thrips species feed, with their paired maxillary stylets, on a large variety of sources both plant and animal by puncturing them and sucking up the contents. A large number of thrips species are found in flowers and are considered pests, because they feed on plants with commercial value. Some species of thrips feed on other insects or mites and are considered beneficial, while some feed on fungal spores or pollen (Chinery. 1993, Maddison, et al. 1996-2006, Naumann et al. 1999).

Psocoptera (Booklice)

Psocoptera are an order of around 3000 species which are commonly known as booklice or barklice, and are found in all regions. Very small, winged or wingless insects, range from 1 to 10mm in length and are often regarded as the most primitive of the hemipteroids. Psocids are often found on foliage or branches of trees and shrubs, on or under bark, in leaf litter, under and on rocks, in caves, in human buildings and in stored products (Chinery. 1993, Maddison, et al. 1996-2006, Naumann et al. 1999).

Thysanura (Bristletails)

Thysanura is an order of small active insects (about 370 species) that includes the familiar silverfish, which have three long caudal filaments on the abdomen. Silverfish are so called due to the silvery glitter of the scales covering their bodies. Their movement is "fish-like" and makes it look as if they're swimming. Silverfish are less than a 1 cm long and found in damp corners or amongst books and paper in houses, they feed on every organic matter (Naumann et al. 1999, Chinery. 1993).

Isopoda (Slaters)

Isopods are one of the most diverse orders of crustaceans, with many species living in all different environments. The Isopoda include approximately 10000 described species, in 10 suborders. Land living crustaceans require moist habitats, most animals range in length from 0,5 to 500mm, and live as scavengers amongst decaying vegetation (Maddison, et al. 1996-2006, Chinery. 1993)

Amphipoda (Landhoppers)

Amphipoda (amphipods) are an order of animals that includes over 7000 described species of small, shrimp-like crustaceans. Terrestrial amphipods such as sand fleas can often be seen amongst grains of sand and pebbles or on beaches, they live on organic matter.

Chilopoda (Centipedes)

Elongated, predatory arthropods with just on pair of legs to each body segment, hind pair of legs long and sensory, a pair of poison claws surround the head, which are used for both defence and for capturing and paralysing prey. Centipedes are dorso-ventrally flattened, and are among the fastest and most agile of non-flying arthropod predators (Maddison, et al. 1996-2006, Chinery. 1993).

Diplopoda (Millipedes)

Millipedes are very elongated arthropods with cylindrical bodies that have two pairs of legs for each one of their 20 to 200 or more body segments. They are slow moving and feed on decaying leaves and other dead plant matter, moisturizing the food with secretions and then scraping it in with the jaws. (Maddison, et al. 1996-2006, Chinery. 1993)

Arachnida (Spiders and relatives)

Acarina (Mites and Ticks)
Araneida (Spiders)
Opilionida (Harvestmen)

Pseudoscorpiones (Pseudoscorpions)
Scorpionida (Scorpions)
Arachnids may be easily distinguished from insects by the fact that arachnids have eight legs whereas insects have six. The first pair of appendages of a typical chelicerate are formed into claws (chelicerae), the second pair of appendages (pedipalps), are also modified in various ways (adapted for sensory, prey capture or reproductive functions).
Arachnids are further distinguished by the fact they have no antennae and no wings. Cheliceramorphs are distinguished by having a body divided into two main divisions, technically called the prosoma (cephalothorax) and the opisthosoma (abdomen). The cephalothorax is derived from the fusion of the cephalon (head) and the thorax.
Arachnids are mostly carnivorous, feeding on the pre-digested (macerated) bodies of insects and other small animals. Many are venomous and they secrete poison from specialized glands to kill prey or enemies. Others are parasites, some of which are carriers of disease (Maddison, et al. 1996-2006, Chinery. 1993).

Among various other biological models, spiders were selected because they are an abundant, diversified, taxonomical group and generalist predators, as well as their general attribute to reflect the specific ecological features of a habitat. (Pétillon et al. 2005)

Gastropoda (Snails)

The gastropods are the largest and most successful class of molluscs, with 60000-75000 known living species. This class contains a vast number of marine and freshwater species as well as many terrestrial ones. They typically have a well-defined head with two or four sensory tentacles, and a ventral foot, the eyes that may be present at the tip of the tentacles range from simple ocelli to more complex pit and even lens eyes. Most members have a shell, which is in one piece and typically coiled or spiralled that usually opens on the right hand side. (Maddison, et al. 1996-2006)

Haplotaxida Earthworms

Oligochaeta (earthworms) are a subclass of the Phylum Annelida. Annelida is a group commonly referred to as segmented worms, and they are found worldwide from the deepest marine sediments to the soils in our city parks and yards.

Oligochaetes feed primarily on detritus and algae, cycle huge quantities of soil through their guts (a process that speeds up the turnover of nutrients in soil and increases productivity), they also help to aerate soil and are well known by the public (Maddison, et al. 1996-2006).

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Attachment 3:

King, W. & Atkins, L. (2005) Invertebrate Diversity in Salinised Agricultural Landscapes across Australia. Biodiversity research in the Sustainable Grazing on Saline Lands program. Australian Entomological Society Conference, Canberra, December 2005.

[On CD]

ATTACHMENT 4:

King, W. (2006) Functional diversity of invertebrates in salinised agricultural landscapes. Biodiversity research in the Sustainable Grazing on Saline Lands program. 'Ecology across the Tasman' combined meeting of the Australian and New Zealand Ecological Societies, Wellington, NZ, September, 2006.

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