Introduction
Large integrated research and development projects are becoming the norm. The success of major national projects such as Sustainable Grazing Systems (SGS) and Sustainable Grazing on Saline Lands (SGSL) have led to the adoption of models that integrate between scientific disciplines and are inclusive of a wide range of stakeholders, such as farmers, regional and national land management agencies, researchers and research and development corporations (Mason et al. 2003). These projects are able to deliver a variety of outcomes to a range of stakeholders, however there are huge transaction costs associated with meeting the expectations of all stakeholders (Dovers and Price 2007). The experience of these earlier projects has meant that more recent projects such as Grain & Graze, have a budget (financial and time allocation) for these transaction costs. This paper introduces the biodiversity component of the Grain & Graze program. We describe the approach taken to the project, and some of the preliminary results that we have found.

Grain & Graze
Grain & Graze is a national research and development program co-funded by Meat & Livestock Australia, the Grains Research and Development Corporation, Australian Wool Innovation Limited and Land & Water Australia, (http://www.grainandgraze.com.au).

The program targets are:
- A 10% increase in mixed farming profitability, driven by a 5% increase in grain yields and a 10% increase in livestock production;
- Improved condition of natural resources on mixed farms in line with regional or catchment targets; and
- Confident and knowledgeable mixed farmers making decisions and using tools that sustain production and promote biodiversity.

Nine regions are involved in Grain & Graze throughout the wheat-sheep, mixed farming areas of Australia. Each region participates in at least one of four national research programs (feed-base management, whole farm economics, social influences and biodiversity), in addition to their own regional projects. The BiGG project commenced in September 2005 and will be completed in June 2008. This paper will concentrate on the biodiversity component of Grain & Graze, particularly on BiGG and the Central West/Lachlan’s (CWL) role in BiGG and in other biodiversity research in their region.
**Biodiversity in Grain & Graze - What is BiGG?**
The national biodiversity project is jointly funded by Grain & Graze and the Natural Heritage Trust. The project was developed to form some general hypothesis about biodiversity in mixed farming systems, and to raise awareness of biodiversity in these systems. There are four expected outcomes:

1) Engagement of landholders in 8 regions across Australia on the issue of biodiversity and its relationship to mixed farming.

2) A national database containing information on the status of biodiversity on 40 farms across Australia.

3) Answers to three key questions on the relationship between agriculture and biodiversity in the mixed farming zone:
   a) The extent to which farm scale measures of biodiversity (in the form of plant functional group diversity, bird species diversity, soil biological activity, vegetation condition score and species abundance for selected invertebrate taxa) are related to agricultural production.
   b) The influence of the type and intensity of agricultural management on native biodiversity on farms (as measured by surveys of birds, soil surface invertebrate species diversity, and the area and condition of native vegetation).
   c) The relative influence of site (climate, soils, topography and proximity and distribution of remnant vegetation in the landscape) and system features (cropping intensity, grazing management and native vegetation management) on selected measures of biodiversity (plant functional group diversity, bird species diversity, soil biological activity, vegetation condition score and species abundance for selected invertebrate taxa).

4) Recommendations on farming practices and landscape management likely to improve the status of natural diversity in Australian agricultural landscapes.

The objectives of the BiGG program are very challenging, but succinctly, this project will explore what biodiversity values (plants, invertebrates, birds, soil fungi) are likely to be found in cropped paddocks compared to rotation (break crop, pasture phase), permanent pasture and remnant vegetation. This will assist in determining the difference in native biodiversity between different land use classes.

This information may be modelled at a farm and landscape scale to give an approximate inventory of how mixed farming systems support biodiversity, which will help ascertain what biodiversity values exist on mixed farms.

The project will also explore how the arrangement of paddocks on farms, and farms in landscapes, support or impact on native biodiversity. This will help establish whether farms that are close to large reserves have more native biodiversity than farms that are isolated from large areas of remnant vegetation.
Managing BiGG
This project is multi-disciplinary, involving numerous agencies and approximately 100 staff assisting with data collection, interpretation and co-ordination, across the wheat-sheep zone of Australia. Therefore it is not just a research project but it is also a huge social project. The project is a top-down approach and is managed by a steering committee which oversees the role of the national biodiversity co-ordinator who in turn oversees the data collection, analysis and interpretation of different measures of biodiversity in four different paddock types on mixed farms across the sheep-wheat belt zone.

Collaborators within each region were responsible for identifying participating farms and farmers, paddocks on each farm and sites within paddocks according to broad criteria set out in the protocol manual (Bridle et al. 2006).

The national co-ordinator brought together a team of invertebrate ecologists, geographic information systems specialists and microbiologists to cover all components of the research who are located at the University of Tasmania.

The project started in September 2005 with data collection times scheduled for autumn and spring 2006 and 2007. Initially eight of the Grain and Graze regions were asked to choose five farmers who were interested in supporting the biodiversity project. The number of farms varied between regions, with CWL only nominating two due to a commitment to a regional biodiversity project. A total of 42 farms were sampled in autumn 2006 and an extra region bringing an extra 5 farms in spring 2006.

Ensuring that data are collected in a consistent and systematic manner is important to the success of the project. This is an important part of the co-ordinator’s role. Adequate resources were allocated to ensure that the co-ordinator could meet with regional personnel in each of the regions, and that regional personnel had the opportunity to meet each other at least twice during the life of the project.

Before the first data collection period in autumn 2006, the co-ordinator, with help from others in the BiGG team, developed a protocol manual which outlined what data were to be collected and how they should be collected in order to have the same methodology applied across all farms in all regions. At least one representative from each region attended a three day workshop in late January 2006 in order to road-test the draft protocol manual and to field test the data collection techniques.

Experimental methods
Four paddocks were chosen on each participating farm to represent a crop, a pasture in a crop/pasture rotation, a permanent pasture and an area of remnant vegetation. Measurements were taken of vegetation type and condition, soil health and function, invertebrates, and birds, within each paddock.
Vegetation cover was assessed in 10 randomly allocated quadrats that were >5m apart on two parallel transects, which were 50m in length and 10m apart. Quadrats were measured at different points on the same transects at each of the 4 sampling times (autumn and spring, 2006 and 2007). A 1 x 1 m quadrat subdivided into 100 10 x 10 cm squares was used to estimate percentage cover and height of each species plus bare ground, litter (standing and detached), moss, lichen and rocks. A vegetation condition assessment was an additional measurement performed on areas of remnant vegetation, using the Victorian condition assessment method (DSE 2005).

Pitfall trapping was used for collecting ground dwelling invertebrates (Bridle et al. 2006). 10 pitfall traps, 75mm in diameter and 100mm in depth, filled with Ethylene glycol, were placed at the centre of the vegetation monitoring quadrats, after monitoring had been completed. Traps were established and allowed to settle for seven days before being set (Ethylene glycol added) for a further seven days. Samples were sent to UTAS for sorting into morpho-species in the broader functional groups of beetles, ants, spiders and ‘other’.

Chemical soil fertility was assessed from 10 soil cores (10 x 5cm) randomly taken from the vicinity of the parallel transects in autumn 2006. Soil samples were bulked for each paddock and a complete nutrient and particle size analysis was conducted by CSBP Laboratories in W.A.

Soil microbial activity was assessed by the decomposition of cotton strip using the method of vertically inserting pieces of cotton fabric into the soil and leaving them to degrade over time (King and Pankhurst 1996). Twenty-four cotton strips were inserted into the soil in each paddock, eight at three points between the two transects, located at least 25m apart. Natural cotton fabric (calico) was used and the fabric pre-washed in a mild detergent and rinsed to remove any preservative coating. The cotton strips were approximately 10 cm long and 2 cm wide. They were folded in half and were buried in the top 5 cm of the soil for two weeks in autumn 2006 (see Bridle et al. 2006 for details). On retrieval, all available cotton strips were placed in a labelled plastic bag. In many cases less than 24 strips were retrieved from each paddock. They were transported in a cool box and were placed in a freezer within the same day of sampling. The cotton strips were then transported frozen to UTAS.

Cotton strips were defrosted on the day of analysis. A tensiometer was used to measure the force taken in Newtons to tear the cotton strip apart. This force is taken to be inversely correlated with the degree of decomposition of the material. A mean value was calculated from all samples from each paddock. This value was entered into the larger data set and was used for statistical analyses.

Very little degradation of cotton strips was found in autumn and spring 2006 due to lack of soil moisture at sampling. For the 2007 measurements the cotton strips were soaked in water before burial.

The bird surveys were undertaken by Birds Australia atlassers. The 2 ha, 20 min standard survey was used in each paddock.
Each participating farmer was surveyed on his knowledge of and attitude to biodiversity. This survey was also used to collect some broader information on the livestock and cropping systems on each property plus property history and maps of vegetation and land-use.

**Sampling issues and people management**

The data from the first collection time, autumn 2006, illustrated that each region differed in their experience and ability working in an ecological context. This was evident in the data received. A combination of regional approaches and personal interpretations delivered a range of land use classes or ‘treatments’ with differing impacts on the data analyses. For example, some regions had lucerne dominated break-crops while others identified lucerne as permanent pasture. Pasture was interpreted over a variety of lifeforms, e.g. saltbush, lucerne and perennial pasture grasses (introduced and native).

Remnant condition varied considerably within and between regions. Land use in remnants also varied, with some being used for grazing, therefore potentially overlapping with permanent pastures that were also native. In addition, interpretations of ‘remnant’ were broad across the group. In one region, ground cover vegetation surveys from four of the five farms yielded no native species in the understorey.

The drought added to the difficulty of surveying, with lack of moisture affecting sampling of cotton strips, which were torn when inserted, and pitfall traps, which succumbed to evaporation, crows, pigs and stock in autumn 2006.

These issues changed our approach to data analysis. We realised that the protocol manual was not specific enough in places, e.g. describing what remnant vegetation was, and that in some regions the ecological expertise was lacking to undertake detailed vegetation surveys, especially the 1 x 1 m quadrats. Therefore the data that were received and subsequently analysed were of variable quality. Our plan to use standard techniques for analyses of the complete data set was unlikely to be possible. Bayesian statistical approaches are currently being investigated as a means of analysing the large, inconsistent data sets that that have been collected by this project.

As the invertebrate and cotton-strip samples were sent to UTAS for analysis, this gave us some confidence in the consistency of some parts of the project. In addition, as all bird surveys were undertaken by Birds Australia atlassers, these too were ‘reliable’ data. The real issue was with the choice of farms/paddocks/remnants and the vegetation data.

After reviewing the data sheets from autumn 2006, the protocol manual was revised and updates were sent out before the spring data collection period.

In addition, it became apparent that the context for the data collection was not obvious to most of the field project officers. One person is responsible for sorting the 1680 invertebrate samples into beetles, ants, spiders and ‘other’, which can take many months with further time needed to allocate scientific names to the animals. This produced a
significant time lag between the collection of samples and the return of results. Many
regional field officers gained an impression that the data were disappearing into a black
hole and they weren’t sure when they would see the results.

The research project needs to deliver the stated objectives, However, engaging with
farmers, through regional staff, meant that the information needed to be processed in a
way that suited each particular audience and was different in each situation.

Project management became as much about recognising and managing expectations as it
did about consolidating and analysing data. A second workshop in January 2007 at UTAS
demonstrated the ‘production line’ to the regional staff and presented preliminary results
to them. Valuable discussions were held on what could be achieved and how expectations
could be met. The regional project officers went away with a better understanding of
what we were trying to achieve, and why results took so long to get back to them.

**Preliminary Results and Discussion from the Central West/Lachlan (CWL) Region**

Species richness for beetles, spiders and ants infer that more species of spiders and
beetles are found at ‘Gillinghall’, whereas more species of ants are found in the pasture
and the remnant at ‘Waitara’, but there was no consistent pattern related to land use
(Figure 1).

Figure 1 The number of species of spiders, beetles and ants between the different farms
(‘Gillinghall’ and ‘Waitara’) and land use (crop, pasture in rotation, permanent pasture
and remnant vegetation) in the Central West Lachlan Grain and Graze region, measured
in autumn 2006.
The composition of invertebrate species differed between regions, within regions between farms, and within farms between land use classes. An ordination analysis of invertebrate samples in the CWL region indicated that the two farms separated geographically (Figure 2). These preliminary data can only suggest why the farms are differentiated on the presence of beetles, spiders and ants. What is clear from Figure 2 is that there are many shared species in the pasture and the remnant at ‘Waitara’. The vegetation data show that the pasture paddock at ‘Waitara’ contains native species as ground cover, species that also occur in the remnant vegetation. At ‘Gillinghall’, differences between land use types are less clear.

Figure 2 Ordination diagram illustrating the differences in invertebrate species composition between the different farms (‘Gillinghall’ and ‘Waitara’) and the overlap of species between land use classes (crop, pasture in rotation, permanent pasture and remnant vegetation) in the Central West Lachlan Grain and Graze region, measured in autumn 2006.

The vegetation data show large differences in the amount of bare ground between the two properties in autumn 2006 (Figure 3). Vegetation structure, of which bare ground is a component, can impact on the number and type of ground dwelling invertebrates found on the farms (Downie et al. 2000). Further analyses of the complete data set (all farms, all regions) will determine whether the amount of bare ground has any impact on invertebrate species composition.
Figure 3 Mean amount of bare ground (%) between the different farms (‘Gillinghall’ and ‘Waitara’) and land use (crop, pasture in rotation, permanent pasture and remnant vegetation) in the Central West Lachlan Grain and Graze region, measured in autumn 2006.

Information on the ecological function of invertebrate species (e.g. pest or beneficial species) and their habitat requirements will help farmers make more holistic decisions in the management of their farms. Table 1 provides an example of more detailed information which may assist in managing particular species.

<table>
<thead>
<tr>
<th>Species</th>
<th>Ecological Function</th>
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<tbody>
<tr>
<td><strong>Spiders</strong></td>
<td></td>
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<tr>
<td>Gnaphosidae: Drassodinae (2 species)</td>
<td>Predator: Ground hunter</td>
</tr>
<tr>
<td>Lamponidae: Centrothelinae</td>
<td>Predator: Ground hunter</td>
</tr>
<tr>
<td>Liocrinidae</td>
<td>Predator</td>
</tr>
<tr>
<td>Lycosidae: Lycosinae</td>
<td>Predator: Ground hunter</td>
</tr>
<tr>
<td>Lycosidae: Venoniinae (2 species)</td>
<td>Predator: Ground hunter</td>
</tr>
<tr>
<td>Malkaridae: Sternoidea</td>
<td>Predator</td>
</tr>
<tr>
<td>Micropholcommatidae</td>
<td>Predator</td>
</tr>
<tr>
<td>Salticidae (most) (3 species)</td>
<td>Predator: Ground or Foliage or Bark Hunter</td>
</tr>
<tr>
<td>Tengellidae 1</td>
<td>Predator</td>
</tr>
<tr>
<td>Trochanteridae</td>
<td>Predator</td>
</tr>
<tr>
<td>Zodariidae: Castlaninerinae (most) 4</td>
<td>Predator</td>
</tr>
<tr>
<td>Zodariidae: Storeninae</td>
<td>Ant predator: Ground hunter</td>
</tr>
</tbody>
</table>
Cotton-strips were used as a crude measure of decomposition. As conditions during autumn 06 were dry, there were very little differences in decomposition between the two farms or between different land use types. In autumn 2007, the strips were soaked before burial. There was a strong difference in the response of the crop paddock at ‘Gillinghall’ compared to ‘Waitara’, indicating that there was a greater degree of microbial activity.
Figure 4 Decomposition of cotton strips determined by the force taken (N) to break cotton strips from different farms (‘Gillinghall’ and ‘Waitara’) and land use (crop, pasture in rotation, permanent pasture and remnant vegetation) in the Central West Lachlan Grain and Graze region, measured in autumn 2006.

Interpretation of results by regional staff indicated that a summer ‘cover’ crop was grown in their crop paddock on ‘Gillinghall’, while the same treatment type at ‘Waitara’ was bare. While these results need to be tested as part of the larger data set (all 47 farms), being able to discuss the results with regional project officers is invaluable as any interpretation of the data needs to be in context.

Conclusion
This overview of the project has highlighted many of the issues we have faced in using such a complex model to collect, collate, interpret and disseminate data. However, despite initial reservations, the project will deliver good baseline data on measured components of biodiversity (particularly beetles, ants, spiders and birds) in mixed farming systems around Australia.

While the project was designed as a research project, i.e. a hypothesis generating approach, to exploring the presence and role of biodiversity in mixed farming systems (Mason et al. 2004), it is also a large social project that needs to address the expectations of a wide range of stakeholders. The forty-seven farmers have a general interest in the biodiversity of their properties, but would also like to know how to manage for beneficial species. The nine regions would like to know information on what impacts on biodiversity at the farm and catchment scale in order to advise management decisions in the CMAs. The research and development corporations want to see the project deliver on all of the expected outcomes.

Actively engaging all of the stakeholders, especially the regional personnel and through them the farmers will ensure the success of this project. Interactions between the regions and the national project team are essential in order to provide context for the research findings. What is encouraging is that the data collected so far are in agreement with other projects within regions. This suggests that scientific data collection undertaken by many different people in different circumstances can be of value to ecological projects.

This project will not reach the stage of offering best management practice guidelines in any detail. We may not even be able to develop decision support systems. What it will achieve is the following: the collection of baseline data on a number of biodiversity measures in mixed farming systems across Australia; a greater understanding of the relationship between biodiversity and land use in mixed farming systems; capacity building in ecological data collection and interpretation within regions and the development of good working relationships across a number of different agencies.
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References


