Melbourne Water Corporation

Sheoak Floristic and Golden Sun Moth monitoring

2013 Annual Report

July 2013

Table of contents

Table index

Figure index

Appendices

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1. Introduction

1.1 Background

The Sheoak property is located on the west side of the Melba Highway, approximately 3 kilometres south of Yea. The property was purchased by Melbourne Water Corporation (MWC) in early 2008 for construction of the High-lift Pump Station (HLPS), as part of the Sugarloaf Pipeline Project. During ecological surveys associated with the Sugarloaf Pipeline Project, it became evident that the property supported significant ecological values, including the presence of two fauna species listed under the Commonwealth *Environment Protection and Biodiversity Conservation (EPBC) Act 1999*. These are Striped Legless Lizard (SLL) (*Delma impar*) and Golden Sun Moth (GSM) (*Synemon plana*). In 2011, a third EPBC Act-listed species, Matted Flax-lily (*Dianella amoena*), was discovered on the property by GHD botanists.

Due to the nationally significant ecological values of the site, MWC determined that the large portion of the Sheoak property not required for the HLPS would be set aside for conservation purposes and managed as part of the Project's agreed biodiversity offsets, in accordance with *Victoria's Native Vegetation Management: A Framework for Action* (DNRE 2002). Approximately half of the site will be managed in accordance with the approved offsets package (Offset Management Plan (OMP) area), while the other half will also be managed for conservation purposes (Conservation Management Plan (CMP) area).

A key compensatory action under the offsets package agreed to by the Commonwealth Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC) and the Victorian Department of Sustainability and Environment (DSE) was that parts of the Sheoak property were to be managed in perpetuity for native grassland values, including threatened flora and fauna species such as the GSM (irrespective of land ownership in the future).

Four years of GSM monitoring (late 2008 – early 2012) have now been completed across the Sheoak property using methods that were developed in conjunction with DSE and DSEWPaC prior to pipeline and HLPS construction. These methods comply with the *EPBC Act Policy Statement 3.12 - Significant Impact Guidelines for the Critically Endangered Golden Sun Moth (Synemon plana)*.

While grazing is specifically excluded from the OMP area, a significant management technique for the CMP area will be the use of ecological grazing regimes to control grassland biomass, maintain native species diversity and cover, and maintain/enhance the biodiversity values of the property. There are, however, potential risks in using livestock grazing as an ecological management tool, namely, if the trigger levels for introducing or removing stock are not based upon sound scientific evidence and rigorously applied, then outcomes detrimental to conservation may result, i.e. the grassland may be too heavily grazed, or not grazed enough, both of which may adversely impact the GSM populations on site.

This report presents the results after one monitoring period of a variation to the existing GSM monitoring program. This alteration in monitoring regime builds upon the substantial and valuable data already collected, and using the same approved DSE survey methods (transects in the local flying season), presents a modified monitoring design as requested by MW, to examine the potential impacts of grazing on grassland composition, cover, diversity, dominance, structure and biomass, and hence GSM populations and their conservation management. The new monitoring program provides a framework for adaptive management and the development of triggers for when stock should be introduced or removed from the CMP area.

1.2 Scope

The objective of this project is to develop and implement a long term adaptive monitoring program for both GSM and ground cover vegetation, providing outcomes and associated recommendations that:

- Enable informed decisions on best practice ecological grazing management in the context of a conservation regime aimed at protecting the habitat of GSM;
- Provide guidance for an ongoing ecological grazing regime of sheep and cattle including:
  - Optimum stocking rates and times for the various management zones of the property in order to maintain and enhance habitat for the local populations of GSM;
  - Measureable triggers for movement of stock to other management zones at various times of the year; and
  - Measureable triggers for removing stock altogether.
- Will contribute to the broader body of knowledge about ecological grazing regimes and their influence on grassland habitat for GSM.

The program would be implemented from the summer of 2012/13 to January 2019.

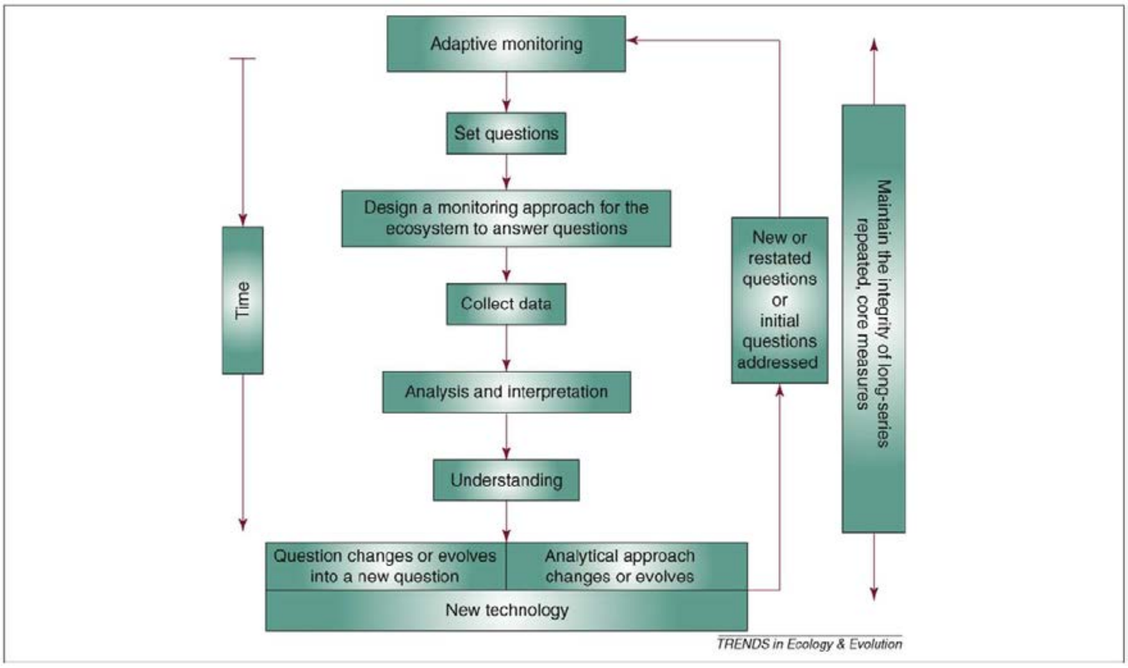
1.3 Adaptive monitoring

Long term ecological research is important for management of complex ecological systems, evaluating responses to disturbances, and evaluating change, causes for change and therefore how management should be altered (Lindenmayer and Likens 2009). There has been substantial recent interest and review of the value of long term ecological and biodiversity monitoring and management (Eyre *et al.* 2011; Lindenmayer and Likens 2009; Lindenmayer and Likens 2010; Lindenmayer *et al.* 2012). This focus is largely due to the recent substantial Commonwealth funding into programs such as the Australian Commonwealth Rangelands Information System (Bastin 2008) and the Terrestrial Ecosystem Research Network (Lindenmayer *et al.* 2012) and recognition that past substantial national investment in monitoring and data collection was generally *ad hoc*, uncoordinated and poorly designed.

The concept of adaptive monitoring aims to resolve many of the problems that have undermined previous attempts to establish long-term research and monitoring by recommending a sensible framework for monitoring (Figure 1). There are four key elements: (i) the requirement to pose tractable (flexible and evolving) questions; (ii) the need to employ rigorous statistical design at the outset; (iii) the use of a conceptual model of the ecosystem or entity being examined; and (iv) acknowledgment that humans (land managers and management agencies) need to know about ecosystem change. This framework is ideal as an overarching framework for this monitoring program as it will:

- Allow key and changing questions regarding GSM, ecological grazing and the effect of grazing on flora and fauna of the property to be addressed;
- Enable statistical analysis of the monitoring data to be undertaken, to firstly develop the monitoring approach based on four years of existing survey data, and then undertake annual analysis of the data to inform the adaptive management;
- Use the conceptual model and knowledge of GSM and grassland ecology to predict changes in grassland composition, diversity and structure, and GSM presence and abundance; and
- Address the need for MWC to understand grazing impacts on GSM and how to manage the CMP area for maximum ecological benefit.

Figure 1 The adaptive monitoring framework (Lindenmayer and Likens 2009)



1.4 Conceptual model

One important component of adaptive monitoring as recommended by Lindenmayer and Likens (2009) is to create a conceptual model that helps refine or restate the management questions being addressed by the monitoring. A conceptual model is a scientific model that is a simplified abstract view of a complex reality – developed by using existing knowledge of the species and ecosystem under examination. In this case our model considers the environmental and ecological factors that might influence GSM distribution and abundance, with respect to the aims of our monitoring program – the interplay of climate, management and landscape with respect to ecological grazing regimes.

The GSM conceptual model (Figure 2) was derived from existing published information on GSM ecology from peer-reviewed journals and the DSEWPaC Golden Sun Moth SPRAT database. The key components of our model as derived from existing data are:

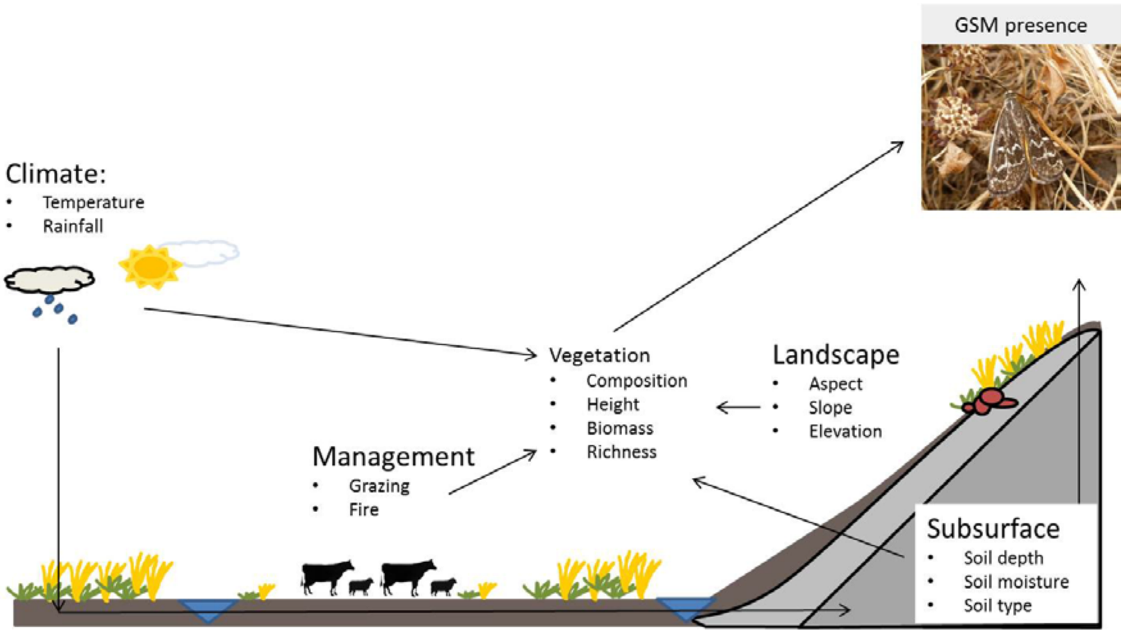
- Suitable habitat is generally native temperate grasslands, and open grassy woodlands where the ground layer is dominated by *Rytidosperma* spp. (Wallaby Grass) (O'Dwyer and Attiwill 2000), though more recent studies show a broader tolerance for other species compositions, including some exotic species (Gilmore et al. 2008);
- GSM adult males will not fly more than 100 m away from suitable habitat and therefore populations separated by distances greater than 200 m are considered effectively isolated, and sites from which the species has gone extinct are highly unlikely to be recolonised (Clarke and O'Dwyer 2000);
- GSM prefers sites with intermediate to low biomass and the density, quality and diversity of the Wallaby Grass at a site may be important (DEC 2007; DSE 2004; Van Praagh 2004);
- Grazing management of grasslands for GSM is complex as lack of grazing may allow perennial native and introduced tussock species to increase biomass and choke out preferred grasses (Van Praagh 2004), though intensive continuous grazing encourages weed invasion and degrades the native component of a grassland (Lunt *et al.* 2007);

- GSM has been known to persist in relatively large numbers over very small areas (e.g. >1000 individuals in less than 400 m²) (Clarke and O'Dwyer 2000);
- The Victorian populations generally occur at elevations between 95 m and 406 m, and in sloping sites (at 3º or less), particularly those with a northerly aspect, and as such there seems to be a relationship between GSM presence, soil moisture and temperature (GHD 2012); and
- Ambient weather conditions (temperature and rainfall) control and effect emergence and breeding (DEWHA 2009).

It should be noted that our conceptual model is just one interpretation of the complex interactions that might determine GSM abundance, and there might be other interpretations regarding the key associations (i.e. the arrows and linkages). However, as a first step it helps us frame the questions we want to answer and design the monitoring program to collect data we need. Over time, the conceptual model might change as new information is collected, or new management information is required.

In summary, the conceptual model suggests that climate, landscape, soil and management regimes all act to influence vegetation composition, structure, richness and biomass, which in turn influence GSM presence and abundance. It is quite possible that climate, landscape and soil may act independently to affect GSM presence and abundance irrespective of vegetation. Nevertheless, it is evident that 'management' (e.g. grazing, fire) is the only real factor within our sphere of influence that can be manipulated to manage GSM populations at Sheoak.

Figure 2 Conceptual model of the relationship between GSM ecology, environment and management



2. Methods and analysis

The development of the sampling array for the new monitoring program followed a number of steps to enable it to: a) be ecologically meaningful, b) draw upon knowledge from previous survey work at Sheoak, and c) collect data in a manner that addressed the scope of works. In effect there are two phases; the analysis and interpretation of the existing data from 2009-2012, and the use of this information to design the new monitoring program. In general this involved:

- Review of the 2009-2012 survey data with respect to climate and environmental factors;
- Analysis and interpretation of the pattern of 2009-2012 survey data; and
- Application of this information, in concert with our conceptual model to refine the monitoring program.

2.1 Previous survey methods, 2008/9-2011/2

The initial GSM surveys on the property were undertaken in the summer of 2008/09. The focus of these surveys was the impact area of the pipeline and construction footprint of the HLPS. The GSM surveys were largely opportunistic presence and absence surveys using broad walking survey sweeps. These were supplemented by pupa case and larvae surveys to determine if there was any breeding activity.

Subsequent surveys in the summers of 2009/10, 2010/11 and 2011/12 assessed abundance of GSM across the entire Sheoak property. Surveys were conducted in the peak flying period (once there was evidence from reference and other sites in Victoria that the GSM had begun to emerge and commenced breeding), and involved random, continuous 100 m transects across the property during the warmest part of the day between 10 am and 2 pm when temperatures were in the recommended range for surveys (usually > 20 degrees Celsius) and when cloud cover and wind were minimal (Clarke and O'Dwyer 2000; Gibson and New 2007). This survey method was recommended by DSE and largely follows the recommendations of DSEWPaC (DEWHA 2009). For each 100 m transect the start and end location, the time and the number of GSM were recorded. No vegetation or habitat data were recorded along these transects.

2.2 Change in GSM distribution, 2008/9-2012/3

Although site specific environmental data were not collected for transects surveyed above, we are able to map the transect locations and identify the presence, absence and abundance of GSM on each of these transects annually. Using these data and knowledge of the broad landscape factors that might determine GSM presence (via our conceptual model, Section 1.4) we were able to examine, using a grid-based analysis, how GSM locations changed on an annual basis and whether the distribution could be predicted by elevation, landscape position, the dominance of native or non-native vegetation, aspect or moisture. The process of data derivation was as follows:

- The property was segregated into a 100 m x 100 m grid pattern;
- *GSM presence* – identify for each of the four years whether individual grid squares intersected with transect(s) where GSM was present or not. If a transect crossed over a grid boundary, both of those grids were considered to have GSM present. Data were calculated for each year of survey;

- *GSM abundance* – for each transect where abundance was recorded that abundance was included as the score for that grid square in a particular year. If the transect intersected a grid square boundary, the proportion of the transect in each grid square represented the proportion of abundance allocated to that grid square (i.e. if 100 GSM were recorded, and 40% of the transect was in one square and 60% in another, then the abundance was allocated 60 and 40 to each). Data were calculated for each year of survey;
- *Environmental variables* – for each grid square the elevation of the centroid and the proportion of native or non-native vegetation, wet or dry landscape, north or south aspect were calculated. For the last three variables, the data can be categorical where the grid square is predominantly (i.e. >50%, <50%) one of those categories (i.e. wet or dry), or continuous (i.e. the proportion of that grid square mapped as wet or dry). The native[1] or non-native vegetation data were derived from mapping undertaken for the Sheoak Biodiversity Management Strategy in the summer of 2011/12 (GHD 2012). The wet or dry data were derived from a digital elevation model, with the property split into areas of run on (wet) and run off (dry). The north or south data were derived from the aspect of the digital elevation model; and
- Finally the property was split into two management zones – the Offset Management Plan (OMP) area and the Conservation Management Plan (CMP) area. The OMP area will eventually have all grazing removed, and the CMP area will be separated into a number of paddocks in which the grazing will be monitored and altered to assist with the conservation management of the GSM. These categorisations were not used in the analysis of the historical data but have been incorporated in the stratification of the new monitoring array (Section 2.4).

We used linear regressions (Section 2.7) to examine the relationship between annual GSM abundance and the landscape variables. This enabled us to examine what factors predicted the distribution of GSM over time, and whether these remained consistent from year to year. Furthermore, we surmise that if these variables were indeed predicting the abundance and distribution of the GSM, they could be confidently used to stratify the new, more permanent monitoring array.

2.3 Weather patterns

Climate and weather patterns (temperature and rainfall) are predicted to influence the distribution and abundance of the GSM to a certain degree, particularly with respect to emergence and breeding (Section 1.4). We reviewed the monthly rainfall totals over the period of the past surveys (2009-2013) and the temperatures during the surveys to examine if there were any apparent patterns. Over the period from 2009 to 2013, the Melbourne weather pattern shifted from a long term drought to record wet conditions and then back to a more normal regime. It is quite probable that this may have influenced GSM abundance at Sheoak. Data were obtained from the Bureau of Meteorology climate averages website (BOM Climate Averages).

[1] Native vegetation was defined as vegetation where greater than 25% of the understorey vegetation cover was native, e.g. if there was 60% vegetative cover, the total cover of native species had to be at least 15% to be classified as a patch of native vegetation.

2.4 Stratification of new monitoring array

As described above the new monitoring array was based on the stratification of the Sheoak property into 16 unique combinations of landscape and environmental factor ('landscape units' (LUs)), namely: broad planning areas (Conservation Management Plan area and Offset Management Plan area; grassland condition (native or non-native); aspect (north or south); landscape position (wet or dry) (Section 2.2).

The location of transects in each of the landscape units was automated by GIS so that a single transect was placed automatically within each discrete landscape unit. It should be noted that transects had to fully fit within a designated landscape unit and not cross over paddock boundaries. Landscape units were not evenly distributed across the property (Appendix B); however, there was sufficient variation to include at least three replicate transects in each of the 16 landscape unit treatments (Table 1).

Overall, a total of 90 transects were permanently established and surveyed across the 16 landscape units. Each landscape unit had a minimum of three and a maximum of 12 replicate transects. Generally, only one transect was placed in each discrete landscape unit; however, as some of the landscape units were large and known to be used by GSM, additional transects were included within a discrete landscape unit in a small number of instances. This only occurred in three discrete landscape units, where an additional seven transects were established.

As part of quality assurance of the final monitoring array, our proposed design and revised survey methods were peer reviewed by Dr John Morgan, Plant Ecology Lab at the Department of Botany, La Trobe University, Victoria.

Table 1 The final distribution of monitoring transects across the treatment combinations

Treatment	Number of transects
CMP, Native, North, Dry	12 (8 LUs)
CMP, Native, North, Wet	7 (7 LUs)
CMP, Native, South, Dry	8 (8 LUs)
CMP, Native, South, Wet	4 (4 LUs)
CMP, Non-native North, Dry	3 (3 LUs)
CMP, Non-native, North, Wet	5 (5 LUs)
CMP, Non-native, South, Dry	3 (3 LUs)
CMP, Non-native, South, Wet	4 (2 LUs)
OMP, Native, North, Dry	8 (8 LUs)
OMP, Native, North, Wet	3 (3 LUs)
OMP, Native, South, Dry	9 (9 LUs)
OMP, Native, South, Wet	3 (3 LUs)
OMP, Non-native, North, Dry	3 (2 LUs)
OMP, Non-native, North, Wet	5 (5 LUs)
OMP, Non-native, South, Dry	6 (6 LUs)
OMP, Non-native, South, Wet	7 (7 LUs)

2.5 GSM survey 2012/3

The GSM survey methods in the new transect array are identical to previous surveys and are in line with those recommended by DSE, and largely follow the recommendations of SEWPaC (DEWHA 2009) (Section 2.1). The only variation is that:

- The surveys were conducted along 90 transects permanently marked at the 0 and 100 m marks (Appendix C);
- The transects are distributed across 16 landscape unit treatment combinations;
- Incidental data on GSM presence and abundance were collected on the walks between the start and end of each transect surveyed; and
- Floristic and structural vegetation data will be collected biannually along transects to aid the interpretation of the GSM patterns and to provide data on trigger points for design of the ecological grazing regime.

The GSM surveys are now conducted over 90 x 100 m transects (9 km of transects) and 7.4 km of incidental transects. This is a very substantial survey effort for a 160 ha property.

2.6 Vegetation survey

The vegetation surveys for the 2012/3 summer were conducted over four days (12, 17-19 December). Survey was completed by pairs of botanists, with the lead botanist undertaking the structure and composition component and the accompanying botanist undertaking the biomass component of the assessment.

Grassland dominance and height was recorded at 50 points along the 100 m transect, at 2 m intervals. The species and height (in 10 cm intervals) of the tallest vegetation touching a 2 m polypipe pole with height gradations marked on it at each point was recorded. The graminoids *Rytidosperma* and *Austrostipa* were only recorded to genus level due to the difficulties in keying them further in the field (especially when infertile). Height was recorded as the upper limit of the category, so that vegetation at a height of 32 cm would be recorded as 40 cm.

At the 50 m mark of each transect, a 5 x 1 m quadrat was established and surveyed. A full species list and Braun-Blanquet cover abundances were recorded for each quadrat.

Vegetation biomass was indexed using a method developed by the Morgan Plant Ecology Lab at La Trobe University in conjunction with Parks Victoria. The method has been trialled in grasslands across Victoria and a significant relationship exists between biomass and golf ball visibility. Five 1 x 1 m quadrats along the transect (20 m apart) were delineated using a collapsible polypipe frame. Into each quadrat 18 orange or yellow golf balls were dropped haphazardly from a height of approximately 1.3 m. If balls rolled out of the frame, they were retrieved and re-dropped. Where golf balls fell atop grass tussocks, the grass was gently parted to allow the ball to fall amongst the vegetation. A photo was then taken parallel to the ground, from a height of 1.3 m, over the centre of the quadrat. The cover of bare ground, native graminoids, native forbs, introduced graminoids and introduced forbs was also recorded at each quadrat.

Photos were analysed following fieldwork. For golf balls where <10% of the surface was visible a score of 0 was attributed. Where 10<90% of the ball was visible a score of 0.5 was given. Where >90% of the ball was visible, a score of 1 was recorded. The scores for each quadrat (maximum possible 18) across the transect were averaged to give a biomass index for the entire transect.

2.7 Statistical analysis

Four types of analysis were used on the past and current GSM and vegetation data, namely simple regression, generalised linear mixed models, multivariate analysis (multidimensional scaling) and non-parametric Mann-Whitney U tests.

2.7.1 Linear and non-linear regression

Linear regression is a method of describing a straight line relationship between one response variable (e.g. GSM abundance) and one or more explanatory variables (e.g. vegetation and landscape variables). The strength of the relationship is estimated of the residuals, that is how far do the observed points deviate from the fitted line (Payne *et al.* 2010a). Nonlinear regression is a general technique to fit a curve through data. It fits data to any equation that defines Y as a function of X and one or more parameters. It finds the values of those parameters that generate the curve that come closest to the data (minimizes the sum of the squares of the vertical distances between data points and curve) (Payne *et al.* 2010a).

2.7.2 Linear mixed models

Linear mixed models (multi-level models) will be used to examine the relationship between GSM abundance and landscape, environment or vegetation variables that might predict GSM abundance. These tests are conducted via the REML package in Genstat 8 (Payne *et al.* 2010b) and they combine both fixed and random terms and estimate the variance within a group against the variance between groups for the random term; therefore, this is a method that can be used to account for both unbalanced sampling design, and the spatial biases in effects due to site locations (e.g. OMP versus CMP biases). Variance components are estimated using the residual maximum likelihood and fixed effects using weighted least squares. The significance of the fixed effect was assessed via the Wald statistic (Payne *et al.* 2010b).

2.7.3 Multivariate analysis

The variation in vegetation composition across, for example, GSM present and absent sites can be examined by multivariate techniques such as multi-dimensional scaling (ordination). This technique uses similarity matrices derived from site environmental data and to plot the relative similarity or distance between sites with respect to their composition. We use non-metric multi-dimensional scaling in the Primer package (Clarke and Gorley 2006) to examine if there were any *a priori* patterns of spatial variation in the vegetation in GSM presence and absence sites. Other tests such as analysis of similarity (ANOSIM) test the efficacy of the categories (i.e. grazed and ungrazed, GSM present or absent) to distinguish composition. ANOSIM calculates a Global R value (analogous to a correlation coefficient), which an absolute measure of group separation is based on the factor tested. Global R is distributed around 0, with 0 indicating completely random grouping, and 1 indicating complete separation (Clarke and Gorley 2006).

2.7.4 Non-parametric analysis

In order to test if there is significant variation in vegetation or environmental factors in sites where GSM is present or absent, we use non-parametric Mann–Whitney *U* test of the null hypothesis that two locations are the same against an alternative hypothesis. These tests assume all the observations from both groups are independent of each other and the responses are ordinal (i.e. one can at least say, of any two observations, which is the greater). We use the program Statistica for these analyses (StatSoft Inc. 2011).

3. Results and discussion

3.1 Previous rainfall

First we examined the broad patterns in rainfall, temperature and GSM abundance over the previous years of survey. According to our conceptual model, we initially predicted that these climate variables would influence GSM abundance and distribution patterns, via an effect on soil moisture and vegetation.

We found that there was a strong negative association between increasing monthly rainfall (i.e. the end of the drought in late 2009/early 2010) where GSM numbers declined severely with the onset of drought-breaking rain (Figure 3). The total number of GSM recorded fall from a peak of over 2,000 (in 2009) where preceding monthly rainfall was between 0 and 100 mm, to a low of less than 100 (2011-12) where the preceding monthly rainfall was between 25 and 150 mm.

The mean survey temperatures for the four periods of survey also declined slightly (from nearly an average of 30 degrees Celcius, to 25 and below) but were above the expected conditions for GSM surveys (>20) (Figure 4). The relationship between GSM abundance and weather patterns seems more strongly linked to rainfall, though temperature and rainfall are typically positively correlated.

Figure 3 Variation in rainfall and GSM abundance from 2009 to 2012. Solid line indicates GSM abundance and dashed line the monthly rainfall total

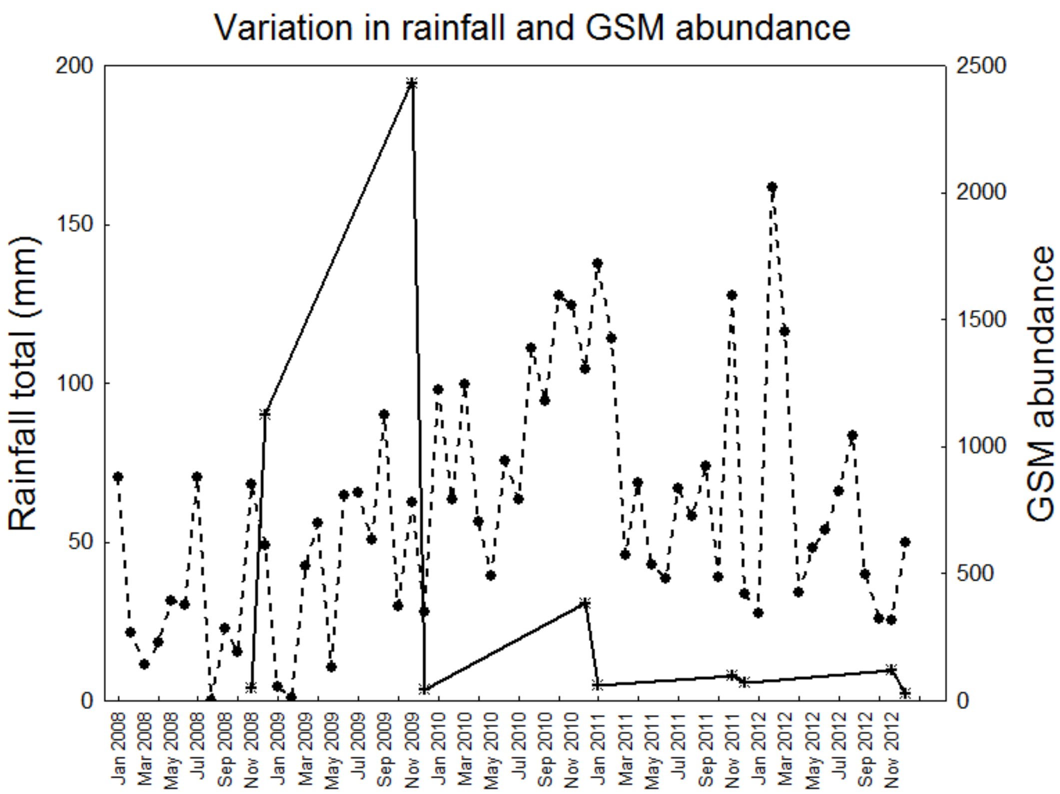
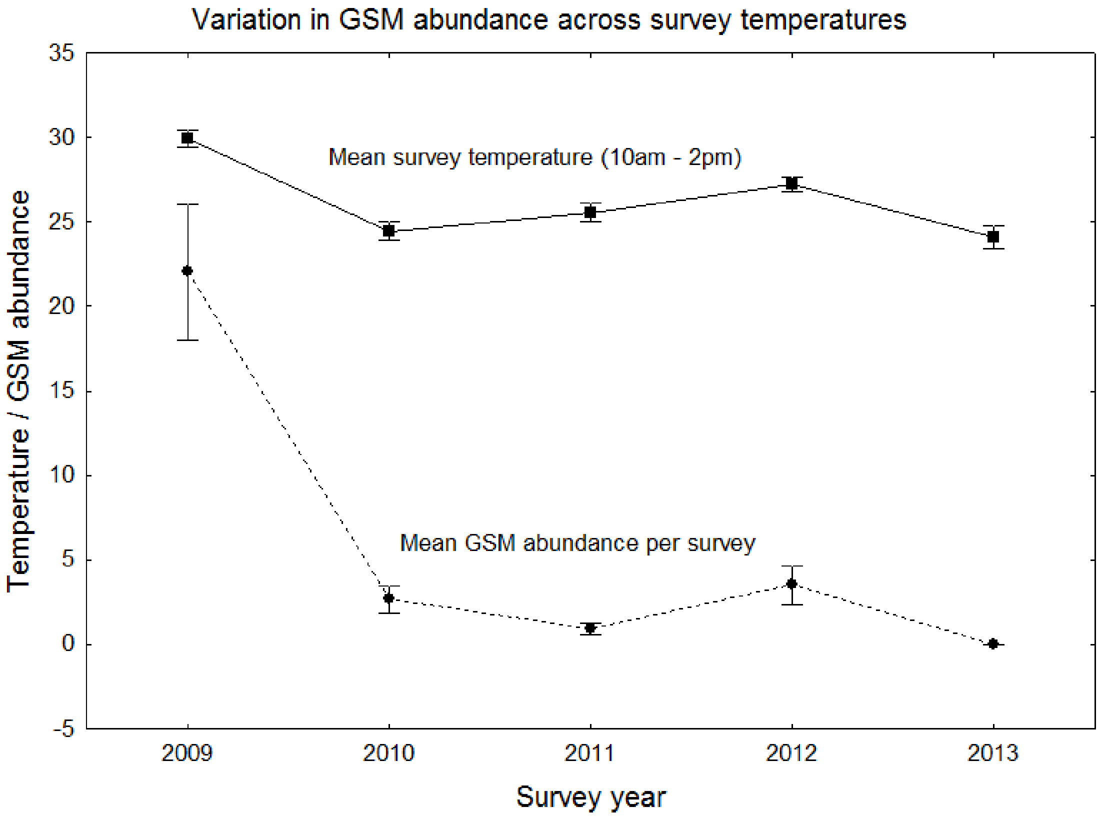


Figure 4 Variation in GSM abundance across annual survey temperatures



3.2 Change in GSM distribution

We examined the change in distribution of GSM presence and absence across the Sheoak property by mapping the grid squares over time as GSM presence (black), GSM absence, interpreted as survey transects within a grid square with no records (white), or GSM unsurveyed (blank) (Appendix A). The key patterns recorded were:

- In 2008/09 only the HLPS area was surveyed, and this was done very extensively. GSM were recorded in all grids and were widely distributed. This period was near the end of a 12 year drought (severe rainfall deficit) in Victoria;
- In 2009/10, the last year of what was a 13 year drought, GSM was still widely distributed across the Sheoak property and within almost 95% of grids);
- In February 2010, drought breaking rainfall commenced. The 2010/11 season was one of the wettest years on record with a seven month period of double average rainfall for each month. As described earlier, the GSM abundance crashed and the distribution across Sheoak contracted markedly;
- In the 2011/12 survey season, the property was still extremely wet after the record rainfall period and the surveys identified GSM presence in approximately 15% of grids, having contracted further from the previous year; and
- In the 2012/13 survey (the first with the new transect array), a return to a more normal rainfall pattern was noted, and the distribution of GSM across the property begun to expand.

There are a number of simple conclusions that can be made regarding the changing patterns in GSM distribution over time; (i) long term climate is a strong determinant of GSM distribution pattern, (ii) long term monitoring can reveal important data regarding GSM persistence and distribution over time, (iii) our data provide a counterpoint to conclusions that GSM has been known to persist in very small areas (Clarke and O'Dwyer 2000), and suggest that distribution can change quite markedly over time; and (iv) the variability in the data have implications for one off surveys to identify presence and absence of EPBC Act-listed species.

Apart from the patterns described above, we undertook a more formal analysis of the relationship between landscape factors and GSM abundance, and how this changed on an annual basis, using regression analysis. Though there was a relationship between elevation, vegetation type, aspect and landscape position and GSM abundance, the nature and significance of the relationship changes annually (Table 2). In 2009/10 there was a strong relationship between elevation, aspect and landscape position, and in subsequent years this changed to elevation and aspect (2010-2011) and then aspect and landscape position. The abundance of GSM altered accordingly, but one important outcome was that there was a shift in the landscape position – GSM becoming more abundant in the "dry" sites once the monthly rainfall increased (Table 3).

Table 2 Regression of GSM abundance and landscape factors ($P<0.1$ in bold)

Factor	2009-10		2010-2011		2011-2012	
	Wald	P	Wald	P	Wald	P
Elevation	10.9	**0.001**	2.8	**0.095**	1.4	0.241
Native / Non-native	1.0	0.318	0.1	0.913	0.2	0.685
North / South	12.4	**<0.001**	3.5	**0.063**	6.4	**0.012**
Wet / Dry	3.4	**0.013**	6.4	0.375	3.0	**0.084**

Table 3 GSM abundance change annually across landscape factors

Year	Native	Non-native	Wet	Dry	North	South
2009-2010	**10.3**	6.4	**11.7**	6.9	**11.5**	4.0
2010-2011	**1.4**	0.9	0.8	**1.5**	**1.5**	0.7
2011-2012	**0.5**	0.2	0.3	**0.5**	**0.5**	0.1

We plotted mean GSM abundance for both landscape position (wet or dry) and aspect for the years 2009-10, 2010-11 and 2011-12 and this demonstrates the patterns more clearly Figure 5, Figure 6):

- The abundance of GSM overall was much higher in 2009-2010 compared to the subsequent years surveys;
- GSM abundance was always higher in north facing sites compared to south facing sites; and
- GSM abundance shifted from being higher in wet sites during the drought period (2009-2010) to being higher in dry sites during the above average rainfall (2010-2011, 2011-2012).

Figure 5 Annual change in GSM abundance according to landscape position

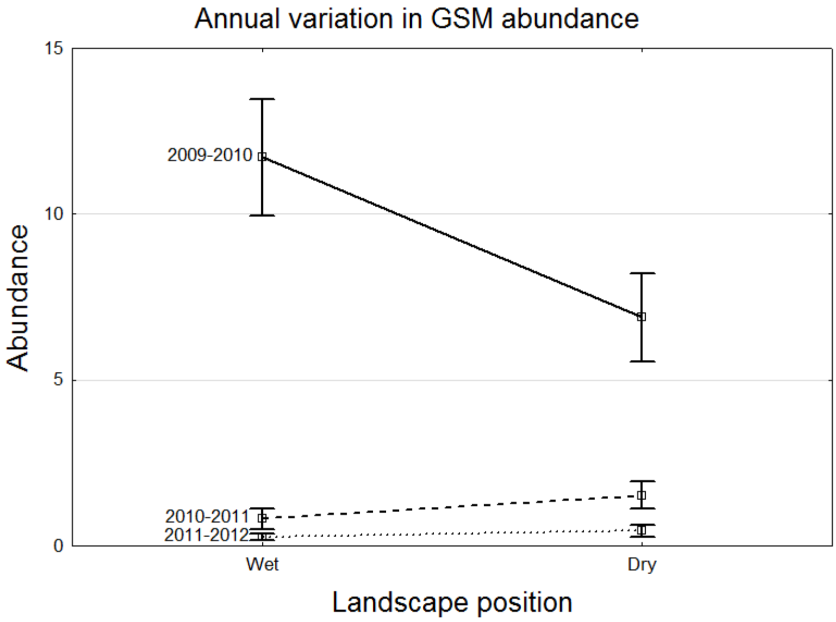
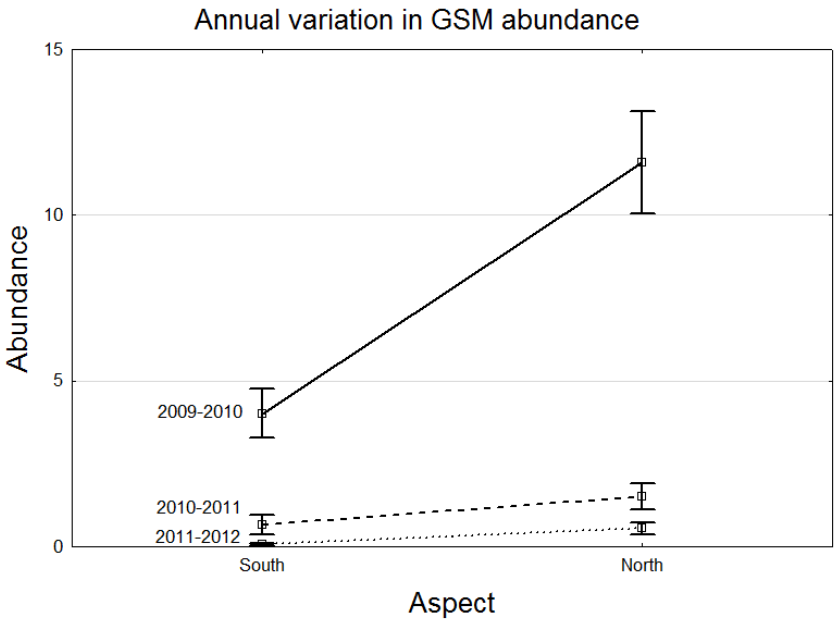


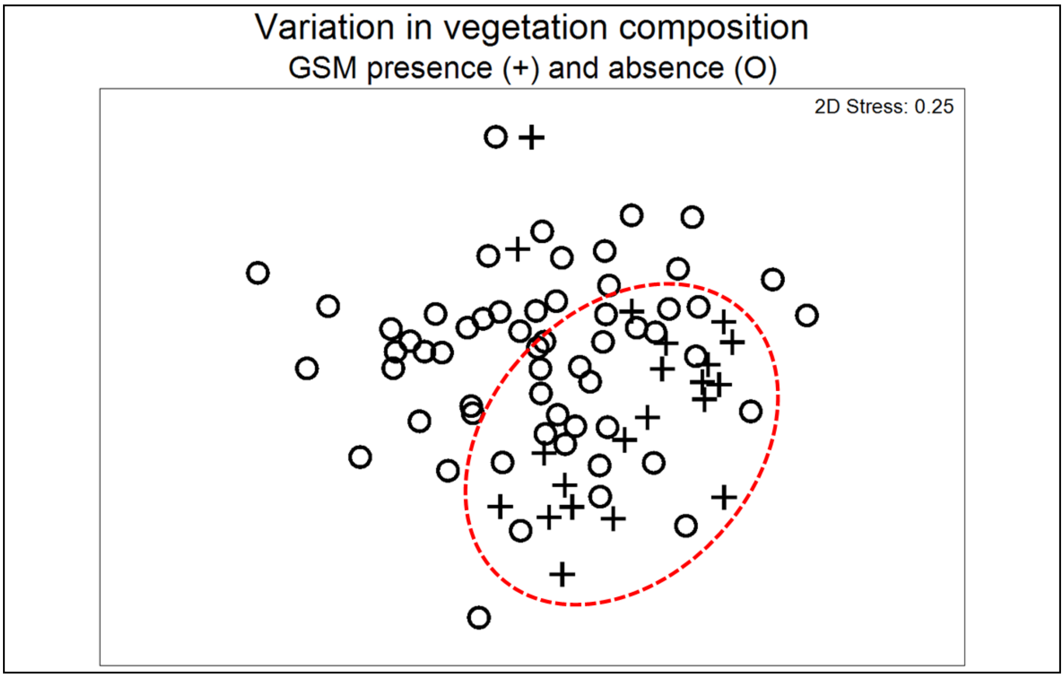
Figure 6 Annual variation in GSM abundance according to aspect



3.3 Vegetation composition

We first used multivariate analysis to explore some of the patterns in the data, especially with respect to variation in vegetation species composition across GSM presence and absence sites. We used the vegetation transect by species recorded array to create a Bray-Curtis dissimilarity matrix, and then using multi-dimensional scaling, examined the distribution of GSM presence and absence sites. Though the GSM presence sites cluster in a loose group in the ordination, there is a large degree of overlap in the vegetation composition of GSM presence and absence sites (Figure 7). This suggests that in general, at least for the first year of survey over the 2012/13 summer, there is little to distinguish vegetation composition between sites where GSM occurs and sites where GSM does not occur. However, this may change in the wet season vegetation survey, and once grazing is removed from the OMP area, and the paddock scale rotation of grazing in the CMP takes full effect.

Figure 7 Variation in vegetation composition in GSM presence and absence transects for 2012/13



3.4 Landscape factors for 2012/13 GSM survey

Following on the analysis of the historical data (Section 3.2) we examined the current 2012/13 survey data to understand what landscape factors might be influencing the most recent pattern of GSM abundance. In this case we used linear mixed models which use fixed and random terms, with the random term accounting for site based effects. Initially, we just examined the fixed effects of the landscape variables, including the division into the OMP and CMP, as these two areas of the property will be managed differently in the future. We also need to understand if there are any inherent differences in abundance across the OMP and CMP, so we can take this into account in our analysis, so there isn't any undue site effects bias from different patterns in abundance in the two areas.

The initial analysis indicated that there is a strong site effect (OMP/CMP) effect for GSM abundance in the current year's survey, as well as a vegetation effect. This suggests that in order to strengthen the analysis of the landscape factor effect, the mixed linear models should include site as a random effect; however, the subsequent analysis indicated that vegetation type is still a significant effect (Table 4). Mean GSM abundance across the landscape treatments indicates that GSM were more abundant in the CMP, native, north and dry sites (Table 5, Figure 8).

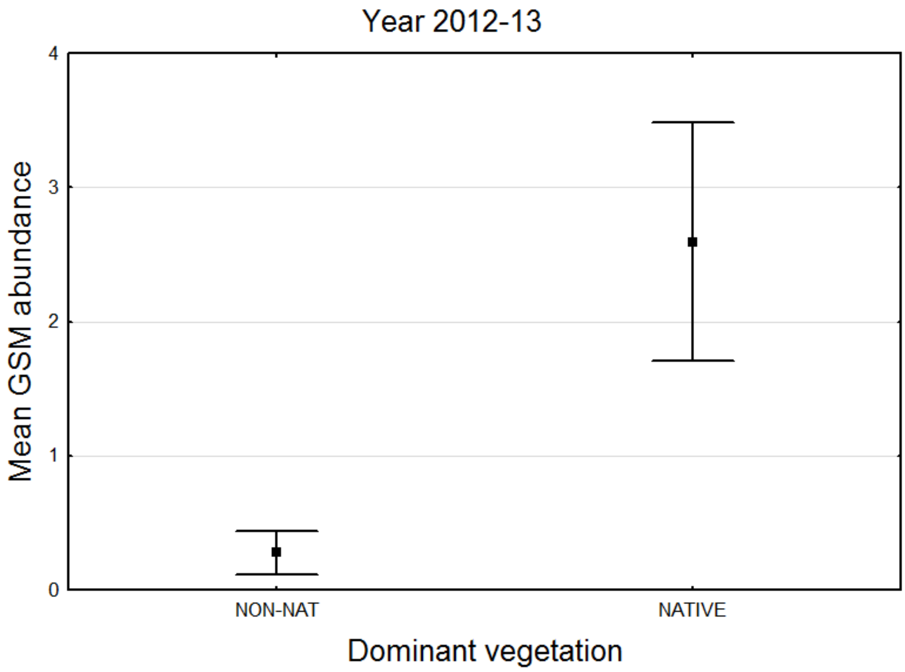
Table 4 GLMM for landscape factors (P<0.1 in bold)

Factor	Wald statistic	P
Fixed effects		
OMP vs CMP	8.1	**0.006**
Elevation	0.5	0.499
Native / Non-native	4.5	**0.038**
North / South	0.8	0.368
Wet / Dry	0.2	0.663
Fixed effects (with property as random effect)		
Elevation	1.4	0.231
Native / Non-native	3.1	**0.079**
North / South	0.1	0.727
Wet / Dry	0.2	0.625

Table 5 Variation in GSM abundance across landscape factors

Factor	OMP	CMP	Native	Non-native	North	South	Wet	Dry
Number of sites	44	46	54	36	46	44	37	53
Mean GSM abundance	0.14	**3.13**	**2.59**	0.28	**2.15**	1.16	1.38	**1.87**

Figure 8 Variation in GSM abundance across dominant vegetation type for 2012-13 surveys



3.5 Regression thresholds

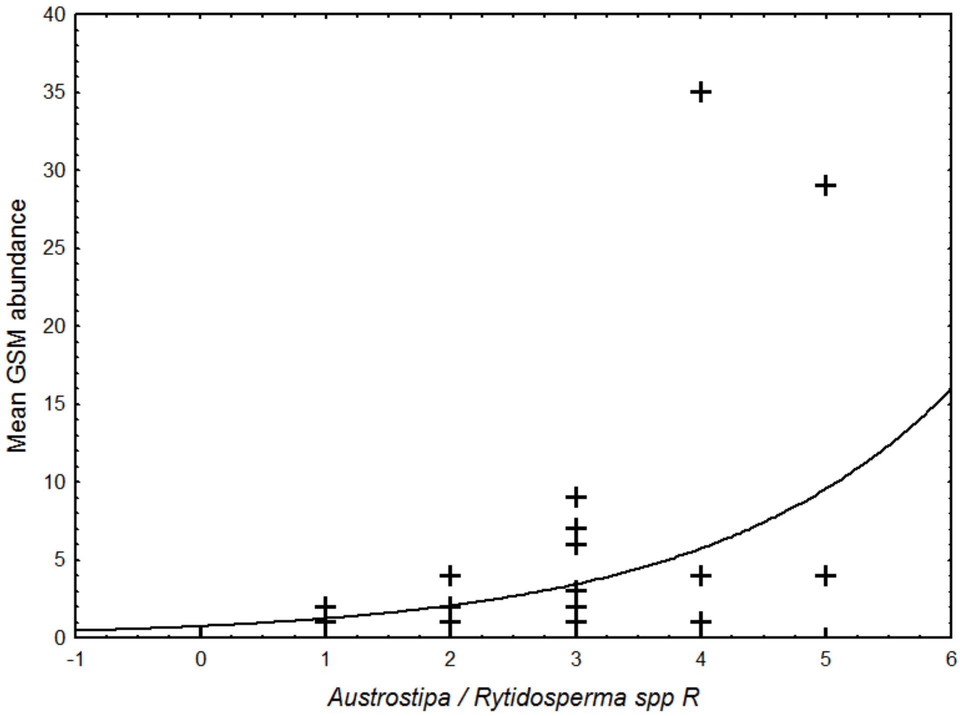
In addition to the landscape analysis above which provides information on the broad landscape scale distribution of GSM at Sheoak, we undertook two further analyses using the detailed vegetation data to investigate preliminary threshold or trigger levels for GSM presence and abundance at the site. There are two approaches – firstly by using regression analysis to investigate if there is a linear or non-linear relationship between continuous vegetation variables and increasing GSM abundance. This allows us to identify key break points where GSM abundance increases most strongly. The second method is non-parametric and simply looks at the mean vegetation variable scores (and variation) for transects where GSM is present or absent; therefore, providing more absolute threshold levels. As we are only examining data from the first year, these results should be considered as preliminary.

First, we looked for any significant relationships between GSM abundance and the 17 vegetation cover and richness variables via regression, using all the transect data across both the OMP and CMP. Four variables were significant predictors of GSM abundance: Native graminoid mean cover (%); *Rytidosperma* spp. mean cover (%); *Austrostipa* spp. richness; and *Austrostipa* and *Rytidosperma* spp. richness (Table 6). This result is in keeping with existing understanding that GSM is strongly associated with native grasses and in particular Wallaby Grasses (DSE 2004). The relationship between *Austrostipa* and *Rytidosperma* spp. richness and GSM abundance indicates that once richness of these species increases to 3 and beyond, GSM abundance increases more rapidly (Figure 9).

Table 6 Regression of GSM abundance and vegetation variables (P<0.1 in bold)

Vegetation and structure variables	Wald	P
Total plant richness	2.0	0.160
Native plant richness	2.5	0.112
Introduced plant richness	0.7	0.409
Forb richness	1.9	0.174
Graminoid richness	0.8	0.387
Biomass mean	0.4	0.537
Bare ground mean cover (%)	0.1	0.832
Native graminoid mean cover (%)	4.8	**0.032**
Non-native graminoid mean cover (%)	1.2	0.285
Native forb mean cover (%)	0.2	0.678
Non-native forb mean cover (%)	0.3	0.603
Austrostipa spp. mean cover (%)	0.3	0.611
Rytidosperma spp. mean cover (%)	4.1	**0.048**
Austrostipa spp. richness	11.9	**<0.001**
Rytidosperma spp. richness	2.5	0.116
Austrostipa and *Rytidosperma* spp. richness	7.2	**0.007**

Figure 9 Non-linear regression of *Austrostipa/Rytidosperma* spp. richness against GSM abundance



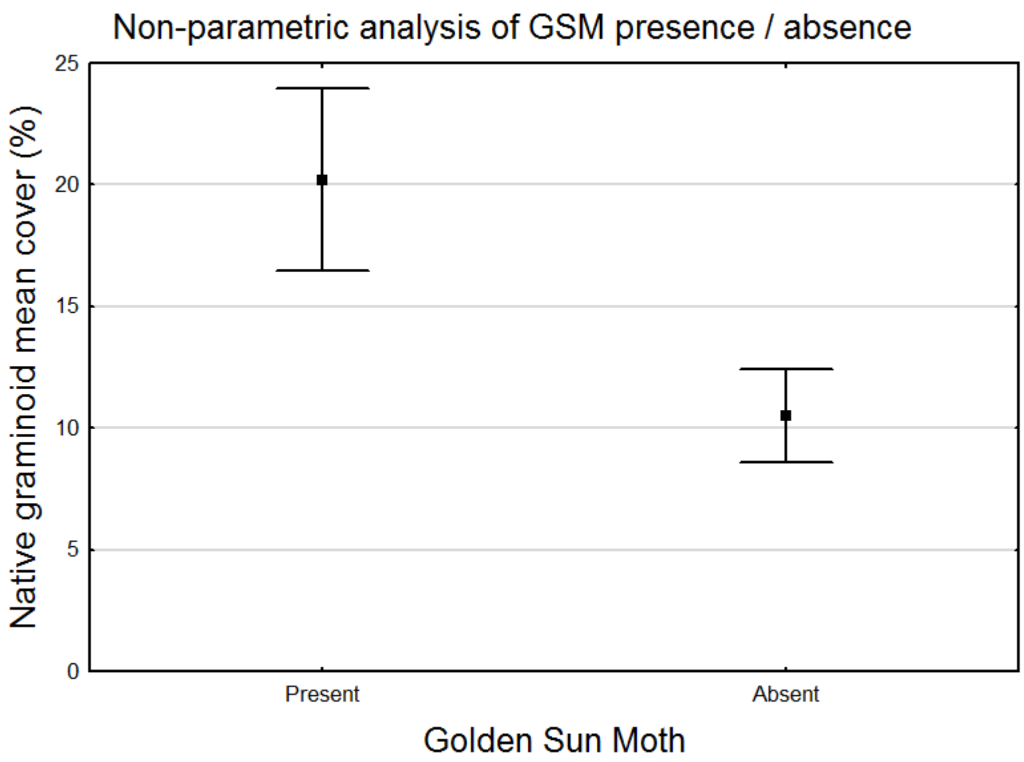
3.6 Presence and absence

We examined the differences in the vegetation variables between GSM present and absent sites using non-parametric Mann-Whitney U tests, to examine where there were significant and measurable differences that might suggest threshold levels for grazing effects. In this case we used only the data from the CMP area, as this was where GSM were more widely distributed across the survey transects. Five variables were significantly more abundant where GSM were present: forb richness; native graminoid mean cover (%); *Rytidosperma* spp. mean cover (%); *Rytidosperma* spp. richness; and *Austrostipa* and *Rytidosperma* spp. richness (Table 7). The whisker plot of the mean and standard error for native graminoid mean cover (%) indicates that where cover is less than about 10%, GSM are absent, but where it increases to 15%, GSM are present (Figure 10).

Table 7 Variation in vegetation factors between GSM presence and absence for CMP only (P<0.1 in bold)

	Z	P	GSM present	GSM absence
Total plant richness	1.14	0.252	14.7	13.2
Native plant richness	0.34	0.734	5.5	4.8
Introduced plant richness	1.33	0.184	9.2	8.4
Forb richness	1.86	**0.062**	**4.0**	3.2
Graminoid richness	0.35	0.722	13.6	9.9
Biomass mean	-0.83	0.404	14.1	14.0
Bare ground mean cover (%)	0.27	0.789	12.7	14.1
Native graminoid mean cover (%)	1.99	**0.046**	**20.2**	10.5
Native forb mean cover (%)	0.76	0.450	0.3	0.8
Austrostipa spp. mean cover (%)	0.94	0.349	7.7	6.2
Rytidosperma spp. mean cover (%)	1.87	**0.062**	**12.9**	8.1
Austrostipa spp. richness	1.42	0.157	1.0	0.7
Rytidosperma spp. richness	1.68	**0.093**	**2.1**	1.6
Austrostipa and *Rytidosperma* spp. richness	1.70	**0.094**	**3.1**	2.3

Figure 10 Whisker plot of change in graminoid mean cover in GSM present and absent sites



4. Conclusion

This report presents the results of the first year of a proposed significant long term monitoring program to assist with the long term conservation of GSM at Sheoak, via the application of ecological grazing management. The purpose of the first year of this program was to investigate the past data collected from the site (2008/09-2011/12) and use this information to design and stratify a sensible and statistically valid adaptive monitoring array, to best guide management of the property. As the 2012/13 summer data only represent the first year of this new survey, interpretation of the data needs to be circumspect; though the preliminary data collected and examined in this report, is very encouraging. The key outcomes of this project to date are:

- The adaptive monitoring framework and the accompanying conceptual model are an excellent framework to approach this new GSM survey program;
- The review of the historical survey data indicated that climate (in particular changing annual weather patterns) are a strong determinant of GSM distribution and abundance, and this is the first time such patterns have been reported convincingly with respect to the biology of this species;
- The initial examination of the vegetation data identified some clear thresholds to guide the ecological grazing management, which match the known ecology of GSM (though these data are very preliminary);
- There is some variation across the CMP and OMP that we need to consider more carefully in the examination of the data and identification of trigger points;
- There are likely to be interactive effects present (i.e. landscape factors and vegetation variables) that need further investigation; and
- Now that the management paddocks are in place, the next phase of analysis needs to include the paddocks as a factor in the analysis and identification of management thresholds and trigger levels.

Though this survey is only the first phase of the monitoring, we can make some brief comments regarding the preliminary outcomes required for the project:

- Enable informed decisions on best practice ecological grazing management in the context of a conservation regime aimed at protecting the habitat of GSM. *The adaptive monitoring framework and revised monitoring array seems to present a successful means of make informed decisions on best practice ecological grazing;*
- Provide guidance for an ongoing ecological grazing regime of sheep and cattle, including optimum stocking rates and times for the various management zones of the property in order to maintain and enhance habitat for the local populations of GSM. *The monitoring data are preliminary and the next phase of data collection will allow thorough investigation and recommendations on management and timing of stocking rates. Once the second year of monitoring data are analysed, we anticipate that there will be sufficient evidence (e.g. knowledge about potential trigger points) to begin directing the movement of livestock between paddocks to promote the presence and abundance of GSM;*
- Measureable triggers for movement of stock to other management zones at various times of the year and measureable triggers for removing stock altogether. *The preliminary data have provided some measurable trigger points and thresholds, regarding vegetation cover and species richness, e.g. GSM present where native graminoid cover is higher than 15%, but absent where native graminoid cover is lower than 10%; and*

- Will contribute to the broader body of knowledge about ecological grazing regimes and their influence on grassland habitat for GSM. *The next step will be to undertake the winter vegetation surveys and to prepare a draft manuscript for submission to a peer-reviewed journal, which reports on the adaptive monitoring framework and historical data review.*

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Appendices

Appendix A - The distribution of GSM across Sheoak from 2009-2013

Paper Size A3

0 50 100 150 200 250

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

Sheoak Fencelines

Presence

Melbourne Water
Sheoaks GSM

Job Number	31-29653
Revision	A
Date	17 May 2013

Absence/Presence 2008-2009

A1

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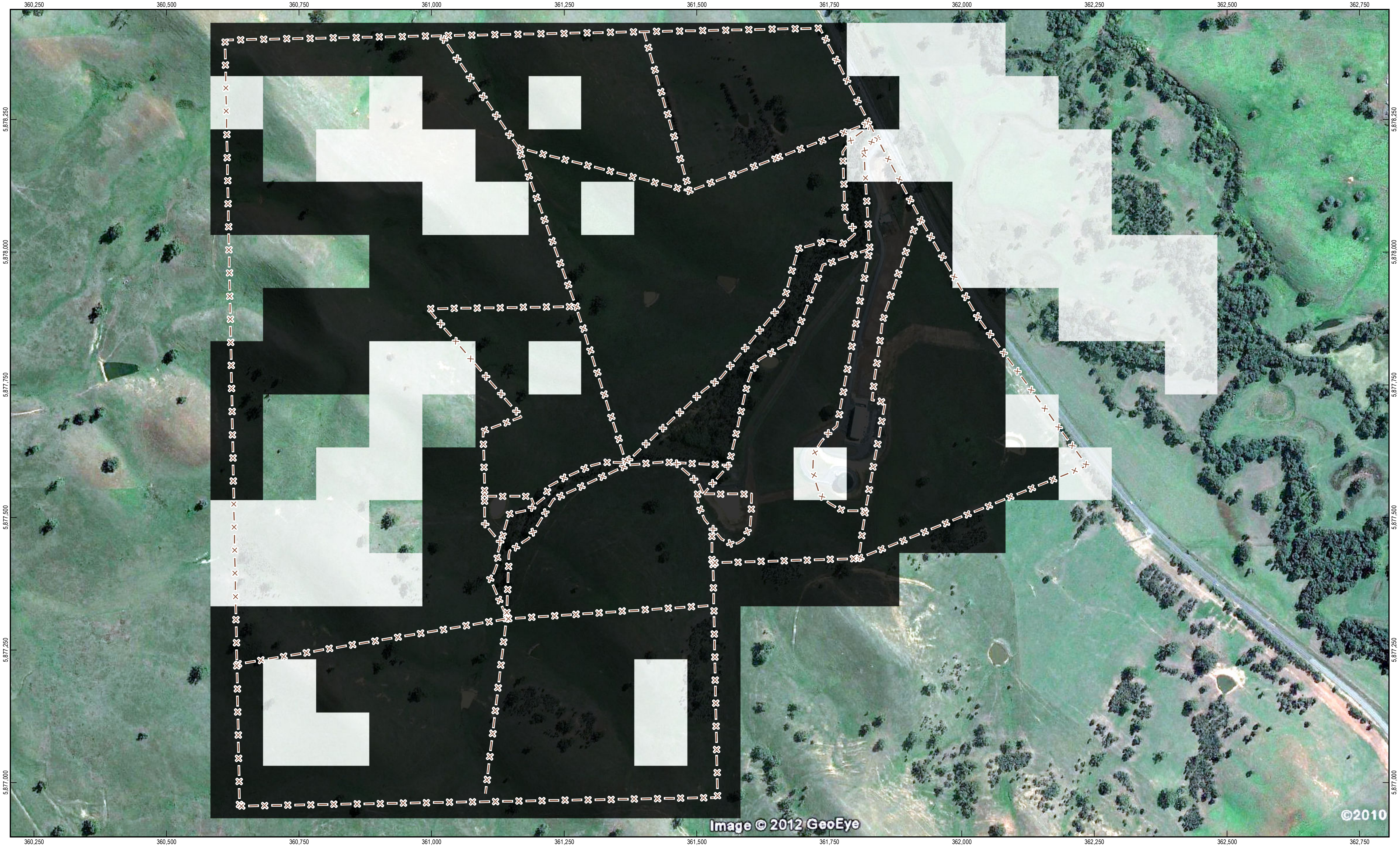
180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: Imagery, Melbourne Water, 2010; Fencelines, Melbourne Water, 2010; Transects, GHD, 2012 Created by:nraska



Paper Size A3

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

Sheoak Fencelines

Absence

Presence

Melbourne Water
Sheoaks GSM

Job Number	31-29653
Revision	A
Date	17 May 2013

GHD

Absence/Presence 2009-2010

A2

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Data source: Imagery, Melbourne Water, 2010; Fencelines, Melbourne Water, 2010; Transects, GHD, 2012 Created by:nraska

Paper Size A3

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

Sheoak Fencelines

Absence

Presence

Melbourne Water
Sheoaks GSM

Job Number	31-29653
Revision	A
Date	17 May 2013

Absence/Presence 2010-2011

A3

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Data source: Imagery, Melbourne Water, 2010; Fencelines, Melbourne Water, 2010; Transects, GHD, 2012 Created by:nraska

Paper Size A3

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

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LEGEND

Sheoak Fencelines

Absence

Presence

Melbourne Water
Sheoaks GSM

Job Number	31-29653
Revision	A
Date	17 May 2013

Absence/Presence 2011-2012

A4

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Data source: Imagery, Melbourne Water, 2010; Fencelines, Melbourne Water, 2010; Transects, GHD, 2012 Created by:nraska

Paper Size A3

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Metres

Map Projection: Transverse Mercator
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Grid: GDA 1994 MGA Zone 55

N

LEGEND

Sheoak Fencelines

Absence

Presence

Melbourne Water
Sheoaks GSM

Job Number	31-29653
Revision	A
Date	17 May 2013

Absence/Presence 2011-2013

A5

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Data source: Imagery, Melbourne Water, 2010; Fencelines, Melbourne Water, 2010; Transects, GHD, 2012 Created by:nraska

Paper Size A3

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

Sheoak Fencelines

Frequency

Never
25%
33%
50%
66%
75%
100%

Melbourne Water
Sheoaks GSM

Job Number	31-29653
Revision	A
Date	17 May 2013

GHD

Frequency 2009-2013

A6

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Data source: Imagery, Melbourne Water, 2010; Fencelines, Melbourne Water, 2010; Transects, GHD, 2012 Created by:nraska

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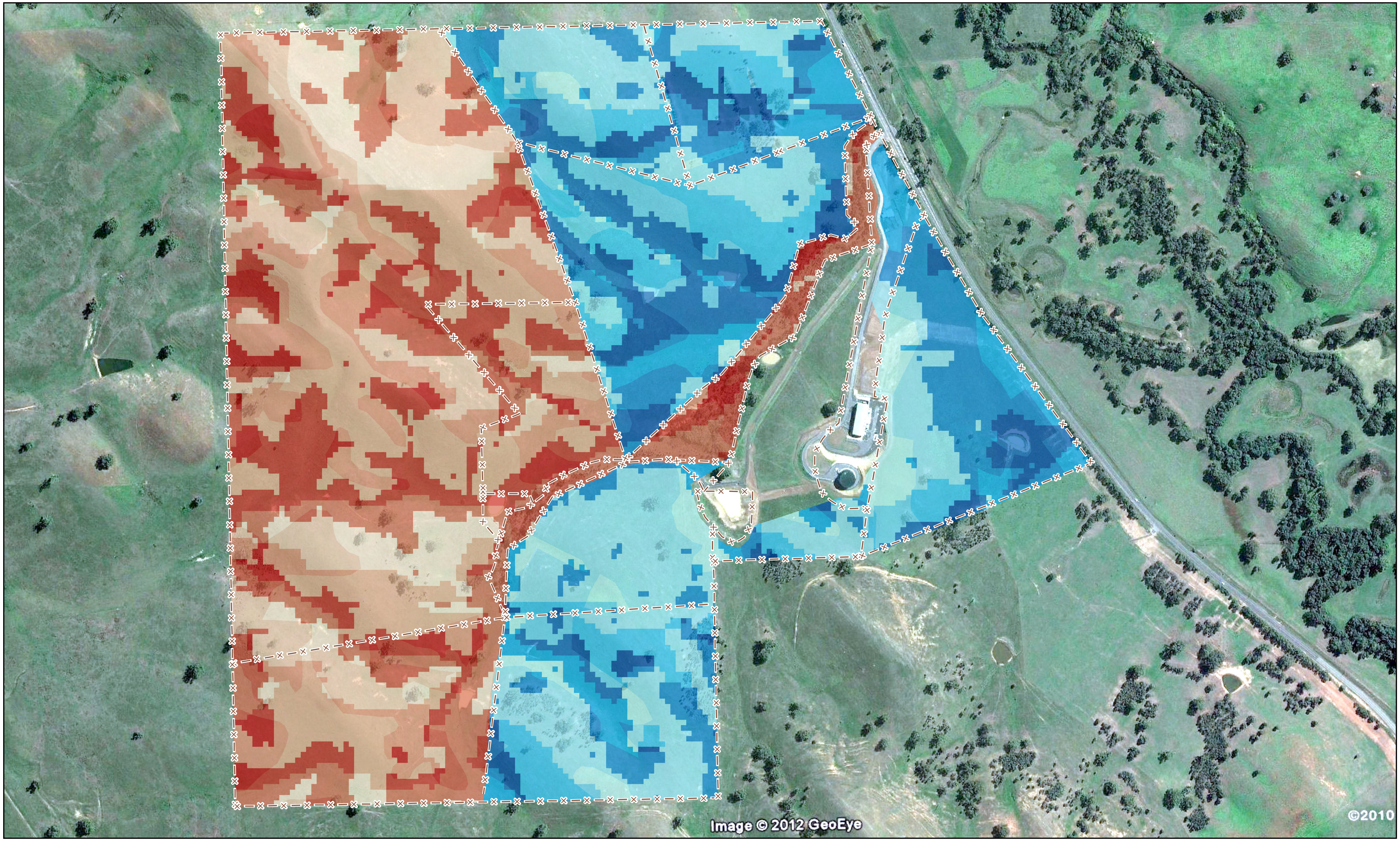
Appendix B – The distribution of the 16 treatment combinations at Sheoak



Paper Size A3

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

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LEGEND

Fencelines			
CMP_Dry_North_Non	CMP_Wet_North_Non	OMP_Dry_North_Non	OMP_Wet_North_Non
CMP_Dry_North_Native	CMP_Wet_North_Native	OMP_Dry_North_Native	OMP_Wet_North_Native
CMP_Dry_South_Non	CMP_Wet_South_Non	OMP_Dry_South_Non	OMP_Wet_South_Non
CMP_Dry_South_Native	CMP_Wet_South_Native	OMP_Dry_South_Native	OMP_Wet_South_Native

GHD

Melbourne Water
Sheoaks GSM

Model Criteria
Combined Treatment

Job Number 31-29653
Revision A
Date 17 May 2013

Appendix B

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Data source: Imagery, Melbourne Water, 2010; Fencelines, Melbourne Water, 2010; Transects, GHD, 2012 Created by:nraska

Appendix C – The final monitoring transect array at Sheoak

Paper Size A3

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

- Transect Lines (ID)
- Transect Incidental (Bearing)
- Fencelines

Melbourne Water
Sheoaks GSM

Job Number	31-29653
Revision	A
Date	17 May 2013

Site Extents and Transect Alignments

Appendix C

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		Name	Signature	Name	Signature	Date
Draft						24/5/13
0	Alex Kutt	Tim Wills		Tim Wills		5/7/13

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