Gnangara Sustainability Strategy

An across-government initiative

Groundwater – Biodiversity – Land use

FIRE AND THE BANKSIA WOODLANDS OF THE SWAN COASTAL PLAIN – FUEL REDUCTION BURNS AND WATER RECHARGE ON THE GNANGARA MOUND: PRELIMINARY REPORT

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Department of Environment and Conservation

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This document has been commissioned/produced as part of the Gnangara Sustainability Strategy (GSS). The GSS is a State Government initiative which aims to provide a framework for a whole of government approach to address land use and water planning issues associated with the Gnangara groundwater system. For more information go to www.gnangara.water.wa.gov.au

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GOVERNMENT OF WESTERN AUSTRALIA
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Contents

Introduction

The Gnangara Groundwater System is located on the Swan Coastal Plain (SWA2) IBRA sub-region, north of the Swan River, Perth, Western Australia and covers an area of approximately 2,200 square kilometres. The Gnangara Groundwater System consists of an unconfined, superficial aquifer known as the Gnangara Mound that overlies the confined Leederville and Yarragadee aquifers, as well as the smaller Mirrabooka and Kings Park aquifers (Government of Western Australia 2008). The area covered by the Gnangara Groundwater System represents a distinct water catchment that extends from Perth (Swan River) in the south, to the Moore River and Gingin Brook in the north, and from the Ellen Brook in the east to the Indian Ocean in the west (Government of Western Australia 2008). The Gnangara Mound is directly recharged by rainfall (Allen 1981; Government of Western Australia 2008), and provides the city of Perth with approximately 60% of its drinking water and supports numerous significant biodiversity assets, including the largest patch of remnant vegetation south of the Moore River, a number of Bush Forever sites, threatened species and ecological communities, and a suite of approximately 600 wetlands. However, declining rainfall and recharge levels in addition to increased abstraction in the past 30 years have heavily impacted on water availability and the ecosystems in the region.

The impacts of a drying climate and declining groundwater levels are of particular concern to the water levels of the Gnangara Groundwater System (Horwitz et al. 2008; Froend et al. 2004; Government of Western Australia 2008). Since the late 1960s, monthly rainfall has generally been below average (Yesertner 2007), resulting in decreased flows to public water supply dams and declining groundwater levels in the aquifers (Department of Water 2007; Vogwill et al. 2008). Indeed, groundwater levels have dropped by up to 4 m in the centre of the Gnangara Mound and the eastern, north-eastern and coastal mound areas have experienced drops in the water table of 1 – 2 m (Yesertner 2007). In addition, there are a number of other threatening processes to biodiversity in the region, including habitat clearing, fragmentation, altered fire regimes and impacts of *Phytophthora cinnamomi* (Mitchell et al. 2003; Government of Western Australia 2000).

The Gnangara Sustainability Strategy

Maintaining biodiversity is fundamental to maintaining ecosystem processes and is an environmental priority of both Commonwealth and State Governments in Australia. To better integrate across government response to access to groundwater, the Gnangara Sustainability Strategy (GSS) was initiated to provide a framework for balancing water, land and environmental issues; and to develop a water management regime that is socially, economically and environmentally sustainable for the Gnangara Groundwater System (Department of Water 2008). A multi-agency taskforce was established in 2007 to undertake the GSS project that incorporates views of existing land and water use policies, studies on the ecosystem assets and processes, and the development of a decision making process to integrate values, risks and planning processes (Department of Water 2008).

Our current understanding of biodiversity values, ecosystem processes and the dynamics of the Gnangara Groundwater System, particularly at landscapes scales, are inadequate (Government of Western Australia 2008). Gaps in our capacity to measure impacts on biodiversity, landscape condition and ecosystem processes as a result of disturbances (e.g. climate change, changed water regimes, fire, plant pathogens) are likely to result in ineffective management actions and lower quality outcomes. The ability to develop successful planning relies on the quality of the biodiversity information available (Pressey 1999; Wilson et al. 2005). Indeed, unless an adequate understanding of these issues is available, justification of changed management actions in the face of potentially degrading impacts on biodiversity is difficult.

Project Scope

One of the challenges involved in developing a land and water use management plan for the Gnangara Mound is the strong interconnectedness between land uses and the hydrological balance, which in turn affects consumptive water yields and the health of water-dependent ecosystems and other terrestrial ecosystems. Modification to the fire regime on Crown land has been proposed as a cost effective option to enhance water yield to Gnangara Mound (Canci 2005; Yesertener 2007). In order for this to become a cost-effective management option, the biodiversity consequences must be understood and the water yield and biodiversity balance quantified. This project seeks to address these gaps by improving our knowledge and measurement of the impacts of fuel reduction burns on biodiversity values and groundwater recharge on the Gnangara Mound.

The *Fire and the Banksia Woodlands of the Swan Coastal Plain – Fuel Reduction Burns and Water Recharge on the Gnangara Mound* project consists of two complementary projects that are running from 2008 to 2010:

1. The first project is being undertaken by CSIRO and is looking at the effect of fire on ground water recharge. This project was designed to determine the changes in water recharge to the groundwater table under native vegetation following fire, and the time course of recharge accompanying recovery of the vegetation after fire. CSIRO are investigating the impact of fire on groundwater recharge by measuring differences in soil moisture profiles, groundwater response, rainfall, evapotranspiration and CFC dating measurements between the burnt and unburnt sites. It is hypothesised that there will be a higher amount of water recharge to the groundwater table from rainfall in the localised area of a burn, due to the lack of vegetation or leaf litter that reduces or prevents water from percolating down to the water table, in comparison to the level of water recharge in an unburnt area, which is more likely to have higher evaporation and lower draw-down rates due to the presence of vegetation.

2. The second project, and the subject of this report, is being undertaken by DEC looking at the impact of fire on biodiversity in the Swan Coastal Plain. This was carried out by investigations at a case study site in the GSS study area to evaluate: (i) the impact of fire and grazing on vegetation regeneration and (ii) the impact of fire and grazing on fuel accumulation. The investigation of the impact of fire on fauna was a component of two studies of the DEC *Biodiversity values on the Gnangara Groundwater System* project, and more information can be found in the *Patterns of Ground-Dwelling Vertebrate Biodiversity in the Gnangara Sustainability Strategy Study Area* Report and the *GSS - Biodiversity Report*.

Document Scope

This document is a preliminary report for the DEC component of the *Fire and the Banksia Woodlands of the Swan Coastal Plain – Fuel Reduction Burns and Water Recharge on the Gnangara Mound* project, as this project is ongoing until 2010. This document does not present information or results from the CSIRO project investigating the affect of fire on groundwater recharge which will be presented in a separate CSIRO report (pending).

Project Objectives and Hypotheses

The objectives of this project were to investigate the following in the Swan Coastal Plain, using a case study in the GSS study area:

1. To simultaneously investigate the impact of fire and grazing on vegetation regeneration, by comparing differences in vegetation attributes between burnt and unburnt plots, and fenced (non-grazed) and unfenced (grazed) plots. The vegetation attributes that were measured included: species richness, species diversity, dominant species cover, vegetation structure, vegetation cover, time to flowering of plants post-burn and litter and soil cover.

2. To investigate the impact of both fire and grazing on the amount of litter depth between burnt and unburnt plots, and fenced (non-grazed) and unfenced (grazed) plots, which could be used in the future for measuring the rate of fuel accumulation between treatments.

3. To establish long-term monitoring sites that may become part of a state-wide vegetation condition assessment program using Landsat imagery.

Methodology

Site Selection

The selection of the site for the burn trial was important to ensure accurate results for both the DEC and CSIRO components of this project. Site selection was based the following key attributes, including:

- The site is on relatively uniform Banksia woodland on the Gnangara Mound (Spearwood or Bassendean Dunes) and on a site with few other disturbance factors;
- The site had a known fire history and was long unburnt (15 years plus) since the last fire;
- DEC had already identified that this site was due for a prescribed burn as part of the Department's Master Burn Plan;
- The site was a suitable size to conduct the burn trial and to measure the recharge effect in a burnt/unburnt design; and
- The site had good access for the establishment and monitoring of the water recharge equipment and vegetation quadrats.

The burn trial site was located in Unallocated Crown Land (UCL) known as Caraban UCL in the northern end of the GSS study area, west of Military Road (Figure 1). The total area of the burn trial site was 754 ha and was 23 years since last burnt.

Caraban is located in the Swan Coastal Plain IBRA subregion (Drummond Botanical Subdistrict) (Beard 1990). The region is characterised by low *Banksia* woodlands on leached sands with Melaleuca swamps in poorly drained areas (Beard 1990). Tuart (*Eucalyptus gomphocephala*), Jarrah (*E. marginata*) and Marri (*Corymbia calophylla*) woodlands occur where soils are less leached, while laterite pavement and gravelly sandplains support scrub heath (Beard 1990, Desmond 2001).

The burn trial site was divided in half. The eastern half was burnt on 6 June 2008 and the western half was left unburnt as a control (Figure 2). The area of the burnt and unburnt sites were both approximately 375 ha each. An existing firebreak track running north-south divided the burn trial site in half. The eastern side was burnt because it had a low fuel age on its eastern boundary and Military Road provided an effective fire break on the east side so that the burn could be comfortably undertaken on a south westerly winds.

June 2008 Burn - Methodology

A few months prior to the burn, Leigh Sage, Fire Operations Officer in DEC's Swan Coastal District, prepared a prescription to guide operations on the day of the burn. The burn prescription, including detailed maps, outlined the location description, issues to be aware of such as Declared Rare Flora, apiary sites and powerlines, and the strategy for successfully completing the burn, including wind direction and direction of lighting that would achieve the desired effect. Liaison with all relevant agencies, stakeholders and surrounding landowners was required to provide notification of the proposed burn and potential smoke issues (e.g. over Military Rd) during the burn and to gain approval from Managers within DEC to proceed with the burn. For a full copy of the burn prescription prepared for the Caraban UCL burn trial see Appendix 2.

The burn site was 67 km north of the Perth CBD and 50% (410 ha) of the entire area was proposed to be burnt. In preparation for the burn, all the boundary breaks had been upgraded to the approved standards. The DEC Swan Coastal District staff had to wait a few weeks for suitable weather conditions to undertake the burn according to the prescription. The burn was planned to be completed under the influence of a south westerly wind, to avoid the chances of smoke blowing towards the Perth CBD. However available days for burning with dry enough condition and a south westerly wind direction were limited. Therefore it was decided to undertake the burn with a north easterly wind direction.

On Friday 6 June 2008, the temperature was 21º C, relative humidity (RH) 42 %, and wind direction E-ENE at 5-14 knots, gusting to 20 knots. Resources required on the day included five DEC officers with light units, six Heavy Duty and Gang Trucks, one Front End Loader and one Flame Thrower.

Due to the easterly/north-easterly winds, the lighting strategy was modified from the lighting strategy outlined in the original burn prescription, which had assumed that the burn would be undertaken when the winds were from the south west.

The southern boundary of the burn (the side to be burnt as part of the trial) was lit up at 1300 with a flame-thrower, lighting continuously along this southern edge from west to east. This edge was then patrolled by light units and trucks until secure. Once secure the western edge was lit by flamethrower starting from the south west corner and heading north along the western boundary firebreak track. At the location of the vegetation plots the flame-thrower ceased to be used and hand-lighting was used for the remaining duration of the burn. As the western edge continued to be lit in 500 m sections heading north, handlighters walked through the bush from west to east, stripping the burn area out with a kerosene drippy torch. Two to three lighters walked through at each time, spaced 20 m apart. As they came out on the eastern boundary of the burn they would be picked up in a vehicle and driven around to the western boundary to walk through again, starting 500 m north of where they'd walked through before. Officers and trucks continually patrolled up and down the western boundary extinguishing any hopovers to ensure the western side of the burn trial remained unburnt. Mop-up along the edge of the actual burn was also undertaken.

The flame height was approximately 0.2-1.5 m high and the estimated rate of spread varied between 20-80 m/hr. Intensity across such a large burn is hard to measure as fire is less intense on the edges and down-slope, but is more intense burning up-slope, in heavier fuels and during the hottest part of the day. Overall, the intensity of the burn at this site under the conditions of the day ranged from mild to moderate.

The northern portion of the burn was not completed before the temperature dropped in the evening (falling hazard) and the introduction of further fire was ineffective (especially through the wetland system in the north). The remaining portion of the burn was completed on Saturday 7 June 2008. Approximately 70-80 % of the entire proposed burn area was burnt. It is worth noting that extra fire was needed in the two 75 m^2 plots with drip torches to ensure the vegetation in these plots burnt due to the lack of continuous ground fuel in these plots.

Impact of Fire and Grazing on Vegetation Recovery

To investigate the impacts of fire and grazing on vegetation recovery, two adjacent pairs of 75 x 75 m vegetation plots were established in the burn study site. The two pairs of vegetation plots were located opposite each other on the burnt and unburnt sides of the trial, positioned close to the north-south firebreak track that divided the burn trial site in half (Figure 3).

Herbivores were excluded by fencing the plots shortly after the burn had been completed. The fence was designed to exclude all types of grazers; for example kangaroos that could jump over low fencing, pigs that could push through weak fencing or rabbits that could dig to get under fencing. Thus the materials chosen were robust enough so that the fence would last for a long period of time.

Within a few weeks of the burn, fencing of two of the plots (one on the burnt side, one on the unburnt side) was completed to exclude herbivores from grazing on the re-sprouting and newly emerging vegetation following the burn in order to provide a direct comparison of grazing impacts. The fenced plots were the two closest to the firebreak track, to provide ease of access for hauling the fencing materials.

Conservation employees erected the fence onsite, with the materials and design intended to ensure it was both kangaroo and rabbit proof. Griplock fencing, a product specifically designed for exotic animal exclusion, formed the main barrier around the perimeter of each fenced 75 x 75 m plot, extending from ground level to two metres in height. Three metre-high pine Permapoles were used as strainers at the corners of each plot and Galstar extreme posts provided appropriate tension along the fence line. Rabbit netting of 1 m in height was overlaid on the Griplock fencing, extending vertically from ground-level to 50 cm up the vertical fence and extending 50 cm horizontally out from the fence like a skirt over the ground. The edge of the rabbit netting on the ground was buried, and the rabbit netting that extended up the Griplock fence was fastened to the fence at both the base and top. This design was intended to prevent rabbits from either digging under the fence or jumping through the larger holes in the Griplock fence. Pedestrian gates were established on the southern boundary of each enclosure, closest to the central track.

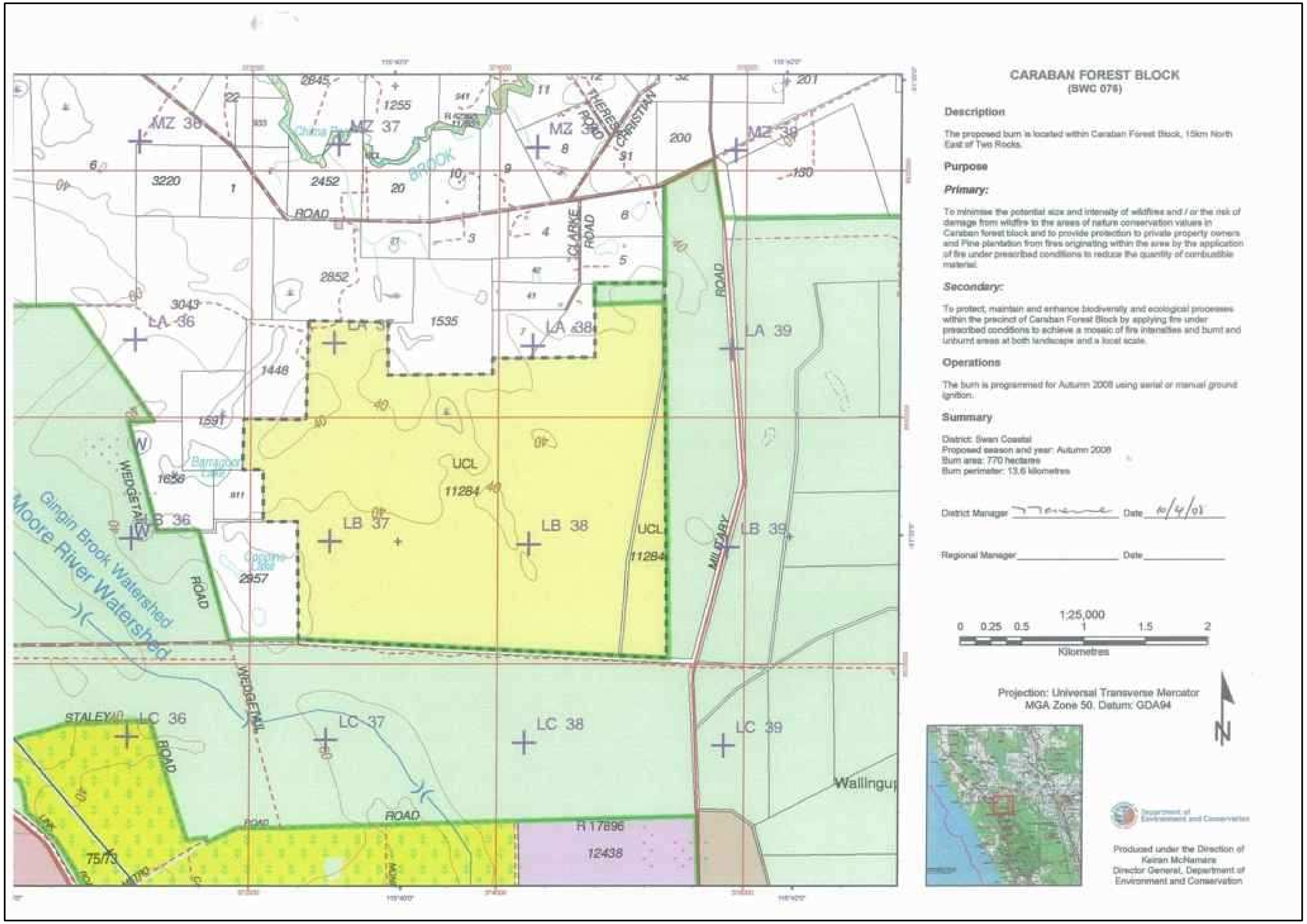


Figure 1: The location of the burn trial site was in Unallocated Crown Land (UCL), known as Caraban UCL.

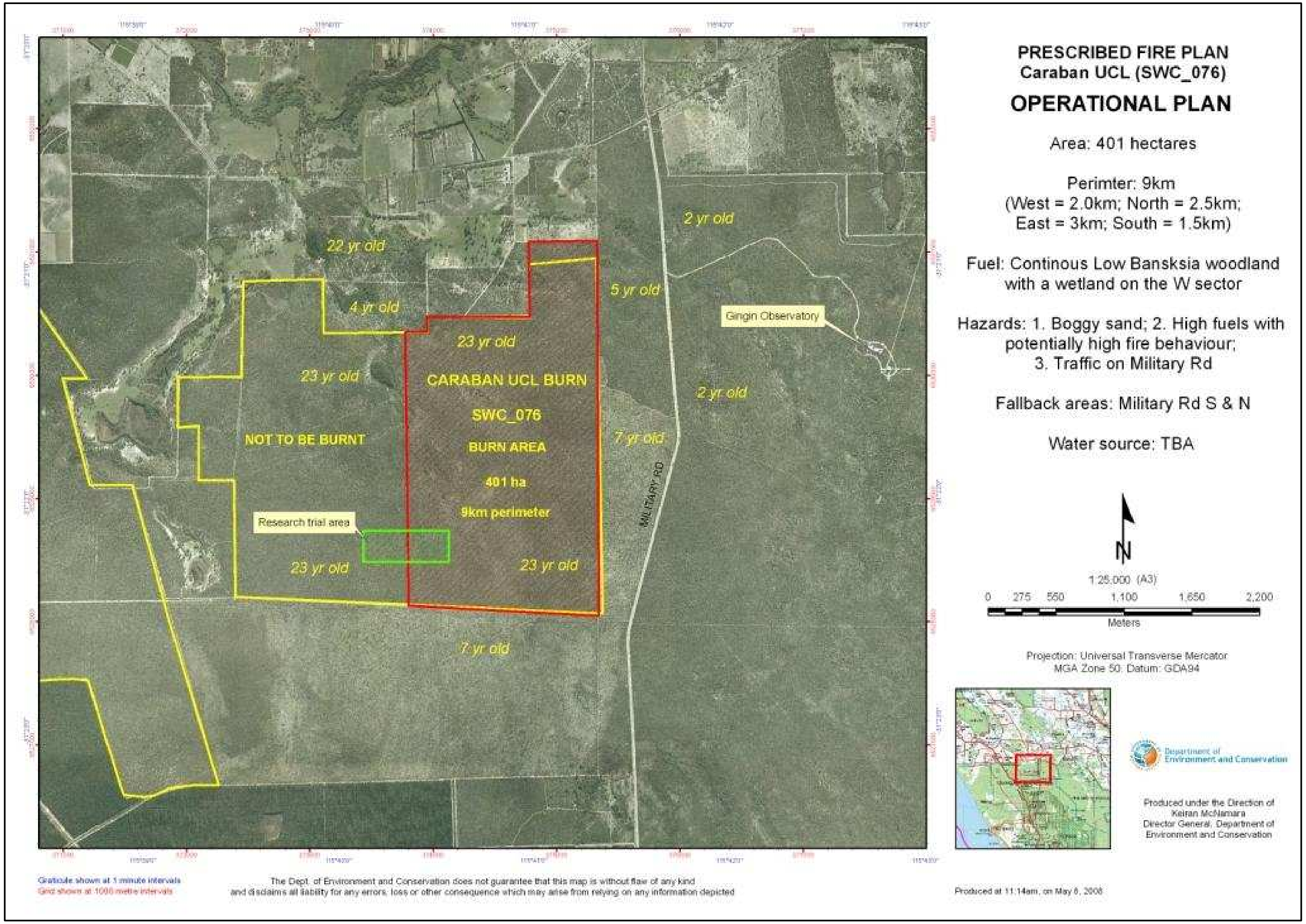


Figure 2: Outline of the burn trial area in Caraban UCL.

Peg	Easting	Northing
1	373815.75	6528528.30
6	373810.94	6528602.57
5	373885.48	6528608.79
4	373959.05	6528612.58
3	373963.58	6528536.51
2	373888.26	6528532.44
7	373763.65	6528529.83
8	373688.17	6528527.41
9	373614.32	6528530.06
10	373614.35	6528606.07
11	373689.54	6528606.56
12	373763.50	6528608.32

Figure 3: Location of the four treatment plots in the burn trial site.

The erection of exclusion fencing generated four treatments measuring impacts upon vegetation at the burn trial site:

1. Fenced and unburnt
2. Unfenced and unburnt
3. Fenced and burnt
4. Unfenced and burnt

The size of the paired vegetation plots was chosen to be 75 x 75 m in order to be compatible with the remote sensing tool Landsat. Landsat imagery was used to demonstrate how vegetation cover in these plots change over time. As Landsat images are comprised of pixels with dimensions of 25 x 25 m each, the vegetation plots were made up of nine Landsat pixels with the central pixel being able to ‘move’ slightly between coverage’s and still remain within the 75 x 75 m treatment plot.

Vegetation recovery was assessed by measuring the following vegetation attributes before the burn, at one month post-burn and six months post-burn:

- Floristic assessment: e.g. species richness, species diversity, dominant species cover;
- Assessment of juvenile period and response to fire;
- Vegetation structure;
- Canopy cover;
- Vegetation cover;
- Soil cover;
- Litter cover; and
- Litter depth.

Floristic Assessment

A total of twelve 10 x 10 m floristic quadrats were established and monitored by Mattiske Consulting Pty Ltd in May-June 2008 to assess the effects of grazing after fire on vegetation, specifically to determine the difference in species regrowth with and without grazing between burnt and unburnt areas. The twelve 10 x 10 m floristic quadrats were divided equally amongst the four 75 x 75 m plots, with three quadrats in each of the four treatments. The 10 x 10 m floristic quadrats were established in regular pattern and numbered as show in Figure 4. One of the three quadrats was positioned in the centre pixel of the Landsat imagery.

An assessment of the floristics within each of the 10 x 10 m floristic quadrats was completed by consultant botanists from Mattiske Consulting Pty Ltd prior to the burn (May-June 2008) and in the summer months of early 2009.

At each 10 x 10 m floristic quadrat, the following site factors were recorded:

- GPS location of the corners of each quadrat;
- Topography;
- Percentage litter cover;
- Soil type and colour;
- Percentage of bare ground;
- Outcropping rocks and their type;
- Gravel type and size; and
- Time since fire.

Each 10 x 10 m floristic quadrats was divided into 2 x 2 m sub-quadrats, inside which the following was recorded for each vascular plant species:

- Maximum height (cm);
- Number of individuals alive and dead;
- Percentage cover of individuals alive and dead

Plant species that were not recognisable in the field were collected from outside the 10 x 10 m floristic quadrat. All plant specimens collected during the field surveys were dried and fumigated in accordance with the requirements of the Western Australian Herbarium. The plant species were identified through comparisons with pressed specimens housed at the Western Australian Herbarium and existing identified collections by Mattiske Consulting Pty Ltd from the Gnangara Mound. Nomenclature of the species recorded was in accordance with the Department of Environment and Conservation (2009a; b). Digital photographs were taken at each quadrat as a visual record of condition, and were taken at the NW corner of each 10 x 10 m floristic quadrat.

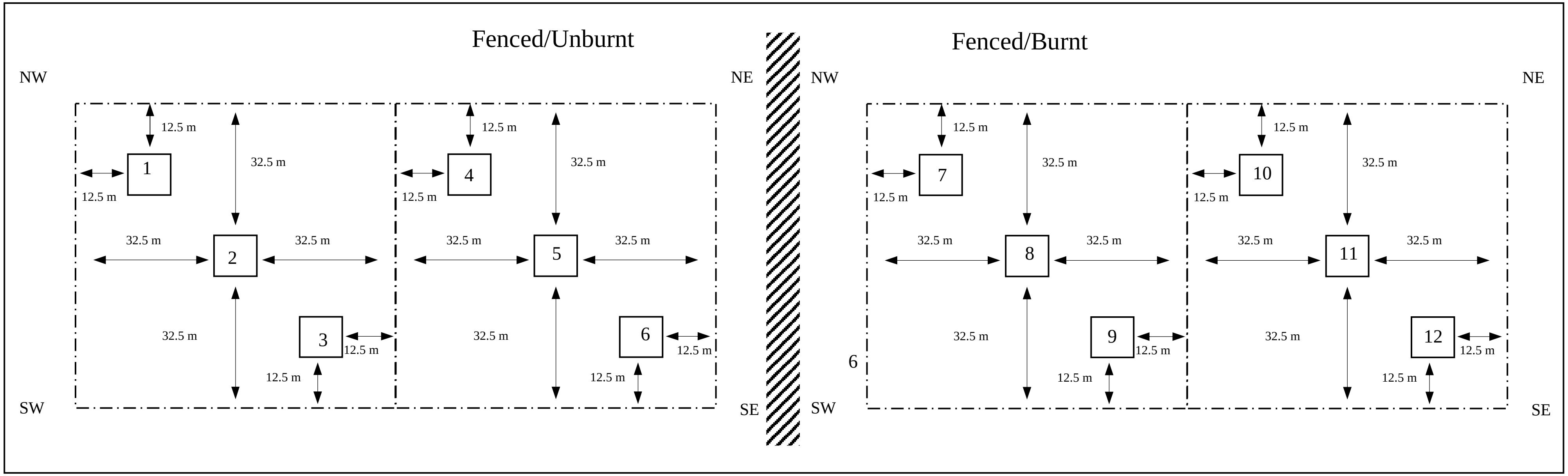


Figure 4: Layout of 10 x 10 m floristic quadrats inside the 75 x 75 m treatment plots (from Mattiske Consulting Pty Ltd 2009).

Assessment of Juvenile Period and Post-fire Regeneration Strategies

To help calculate what should be an appropriate fire regime for Banksia woodland on the Northern Swan Coastal Plain, data was collected by DEC staff during monthly inspections between August 2008 and February 2009 about the juvenile period and post-fire regeneration strategies of flora species in the unfenced and fenced plots of the prescribed burn treatment.

The juvenile period and post-fire regeneration strategy was assessed from individuals displaying 100% leaf scorch or stem girdling from the prescribed burn. Midstorey and understorey species were assessed only from within the 10 x 10 m floristic quadrats set up by Mattiske Consulting Pty. Ltd, whereas overstorey species such as *Eucalyptus todtiana* and *Allocasuarina fraseriana* were assessed from the entire 75 x 75 m plots. Juvenile period was measured using methodology based on Burrows et al. (2008), and was estimated by a visual assessment of the population of plants and is based on an estimate of the time taken for 50% of the population to reach flowering post-fire. At each inspection time, and for each species, a visual rating was given based on:

(1) < 50% of plants in the population had flowers
(2) > 50% of plants in the population had flowers

If a species had 50% or more of the plants in the population that were flowering, then the species at that location was deemed to have reached juvenile period.

Each plant population that was in the quadrats were assigned a post-fire regeneration strategy based on whether plants regenerated from canopy-stored seed, soil-stored seed, soil suckers, basal sprouts, epicormic shoots or apical buds or a number of these modes. The methodology and classifications for these assessments are based on those described in Burrows et al. (2008).

A fire regime that is appropriate is important as it will have a fire interval that is long enough so that it does not negatively affect the slowest flowering species in the ecosystem. As such, information on juvenile period may need to be collected over several years (2-5 years) in order to determine an appropriate fire regime for a particular area (e.g. Burrows et al. 2008).

Vegetation Structure

The vegetation structure assessment was completed prior to the burn for each treatment, and was measured using a 2 m touchpole for each of the three quadrats in each 75 x 75 m plot. The touchpole was divided into seven sections (0-20 cm, 20-40 cm, 40-60 cm, 60-80 cm, 80-100 cm, 100-150 cm and 150-200 cm) and was used to assess vegetation structure by recording the number of plant ‘touches’ at each height section on the touchpole. Structure data was recorded along two diagonal transects from opposite corners in each plot. Data was recorded at 10 points along each diagonal transect at approximately 10 m spacing, giving a total of 20 data points per plot and treatment.

One month after the burn (July 2008), vegetation structure data was collected again in the treatments on the burnt side only. At six months after the burn (December 2008), vegetation structure data was recorded (and photos taken from the corner points of all quadrats) in all four plots (i.e. burnt and unburnt sides).

Vegetation, Litter, Soil and Canopy Cover and Litter Depth

In addition to the assessment of vegetation structure outlined above, canopy cover, vegetation cover, litter cover, soil cover and litter depth data were collected at each of the touchpole points (n = 20) in all four 75 x 75 m plots.

The percentage of canopy cover was measured at each touchpole point using a densiometer. The percentage of vegetation, litter and soil cover (adding up to 100 %) were each visually estimated in 1 m^2 area around the touchpole point, with the touchpole point in the centre of the 1 m^2 area. The depth of litter in centimetres was measured at each touchpole point using a ruler.

All data was collected prior to the burn and then again one month after the burn (July 2008) on the burnt side only, and at six months after the burn (December 2008) in all four treatment plots (i.e. burnt and unburnt sides).

Impact of Grazing

To measure the grazing impacts on vegetation recovery herbivores were excluded from two of the plots (one on the burnt site and one on the unburnt site) by fencing the plots. To estimate the impact of grazing, two types of data were collected 6 months after the burn within the 1 m^2 area around the touchpole point (as above): (1) the number of scats and the species they belonged to; and (2) presence or absence of evidence of grazing (recorded as the percentage of 1 m^2 area around the touchpole points that exhibited evidence of grazing), including the flora species that had been grazed.

Remote Sensing

The experimental design has been set up to be able to use Landsat imagery to analyse changes in vegetation cover in each of the four experimental quadrats over the long term. The remote sensing work for this project has not been conducted to date, but methodologies have been determined and access to Landsat has been purchased.

Statistical Analyses

The experiment was in the design of a Before-After-Control-Impact (BACI; Stewart-Oaten et al. 1986). The BACI ANOVA included time (before fire, 6 months after fire), fire treatment (burnt, unburnt) and grazing treatment (grazed, ungrazed). Interaction terms for fire*grazing and time*fire*grazing were also included to test for a significant interaction between fire, grazing and time. A 3-way Analysis of Variance (ANOVA) (using SPSS, version 17) was used. If a significant interaction was detected, results were interpreted using means and 95% confidence intervals and displayed graphically. All variables were examined for normality and heteroscedasticity using box plots, Q-Q plots and residual plots. Touch-pole counts (vegetation structure) and litter depth were square-root transformed to meet assumptions of ANOVA. Variables recording percentage cover (vegetation cover, soil cover, litter cover, canopy cover), were adjusted by arcsine square-root transformation (Zar 1999). All of the variables, except for Canopy Cover ‘violated’ Levene’s Test of Equality of Error Variance. This was due to a lot of variance in the dataset, therefore the results were interpreted with caution.

Results and Discussion

Impact of Fire and Grazing on Vegetation Recovery

Floristic Assessment

Overall 136 taxa were recorded incorporating 70 different genera and 29 families. The most common families recorded were the Myrtaceae (20 species), Proteaceae (13 species), and Haemodoraceae (12 species) (Mattiske 2009). In 2008 the most common species recorded across all monitoring quadrats were *Mesomelaena pseudostygia*, *Patersonia occidentalis*, *Scholtzia involucrate* and *Lomandra hermaphrodita*. In 2009 the most common species recorded across all monitoring quadrats were *Mesomelaena pseudostygia*, *Patersonia occidentalis*, *Drosera erythrorhiza*, and *Scholtzia involucrate*.

Mean species density in the burnt quadrats was significantly higher in the fenced quadrats compared to the unfenced quadrats indicating an increase in the number of species when animal grazing was excluded. The Summer 2009 monitoring showed higher species richness in the burnt fenced quadrats compared to the burnt unfenced quadrats however the difference was not significant. This indicates that eliminating grazing and trampling allows for more young species to establish. More seedlings were recorded of species such as *Adenanthos cygnorum* and *Banksia menziesii*. This is to be expected as many native Australian species have reproductive cycles that are cued to post-fire conditions (Mattiske 2009).

The Summer 2009 monitoring showed significant difference in foliage cover between unburnt fenced and unburnt unfenced quadrats. This indicates that grazing does significantly reduce foliage cover however may not necessarily affect species density. The monitoring in Winter 2008 and Summer 2009 of the unburnt quadrats showed dead species density in the unburnt quadrats were higher in the unfenced quadrats compared to the fenced quadrats. Although not significantly lower over time this could become more prominent as grazing will continue in unfenced quadrats and more plants will get eaten or trampled (Mattiske 2009).

In both the burnt and unburnt plots the fenced plots showed a higher species richness and density, which indicates that the fencing does prevent grazing and trampling in both burnt and unburnt plots. Species such as *Calytrix fraseri*, *Conostephium pendulum* and *Conostylis setigera* had increased in density in the fenced areas in both burnt and unburnt plots, indicating better species establishment when not under pressure from grazing (Mattiske 2009). The report by Mattiske Consulting Pty Ltd can be found in Appendix 1.

Assessment of Juvenile Period and Post-fire Regeneration Strategies

A total of 72 species were found to exhibit some flowering in the 7 months following the fire. The most common families encountered were Haemodoraceae (7 species), Anthericaceae (5 species) and Droseraceae (4 species) and Stylidiaceae (4 species). The unfenced plot had 49 species from 23 families whilst the fenced plot had 66 species from 28 families. No species from the family Poaceae were seen in the unfenced-burnt treatment area whereas there were two that had reached flowering age in the fenced-burnt treatment.

Of the total number of species recorded by Mattiske Consulting for the floristic assessment (136 taxa), 40 species (29%) had reached juvenile period (i.e. > 50 % of plants in the population had flowers) in the fenced-burnt plot, and 26 species (19%) had reached juvenile period in the unfenced-burnt plot. Of the species that had reached juvenile period, 95 % were re-sprouters and only 5 % were annual re-seeders. This proportion of re-sprouters and re-seeders was expected during this short time (7 months) after the burn, as re-sprouter species would not have been killed by the fire and would therefore have the potential to flower more quickly. In contrast, re-seeder species need more time to germinate, grow and mature enough before they will flower, and therefore will take longer to reach juvenile period in comparison to re-sprouters. No perennial re-seeders were found to have reached juvenile period; however *Adenanthos cygnorum* subsp. *cygnorum*, *Banksia menziesii* and *Banksia attenuata* were observed to have seedlings present.

The results presented in this report are preliminary as the data collected to date is the time to flowering and juvenile period of species in the burn plots for only the first seven months following the burn. Observations of the minimum flowering age for new plants/recruits will need to be collected during future surveys over time.

Vegetation, Litter, Soil and Canopy Cover

Vegetation cover showed a significant interaction between fire, grazing and time (Table 1). There was a significant impact of fire on vegetation cover, and, to a lesser extent, an impact of grazing. Figure 6 shows that, as expected, pre-burn mean vegetation cover was consistent between all four plots despite high variability in the data. In the burnt plots, post-fire (6 months post-burn) vegetation cover was significantly lower than before the fire (Figure 7), due to the removal of vegetation from fire. In the unburnt plots, vegetation cover was greater in the grazed plots. This could be due to grazing by herbivores promoting some localised growth of affected vegetation. Vegetation cover was similar in the unburnt sites before and after the burn.

Table 1: ANOVA F-values for vegetation variables for Fire, Grazing, Time, Fire x Grazing, and Fire x Grazing x Time.

Variable	**Fire**	**Grazing**	**Time**	**Fire x Grazing**	**Fire x Grazing x Time**
Vegetation Cover	**7.896****	0.055	**10.747****	**6.635***	**5.794****
Litter Cover	**6.631***	0.520	1.444	1.614	1.683
Soil Cover	**12.776****	0.196	**8.211****	0.106	**2.845***
Litter Depth	**4.986***	1.313	**21.889****	0.045	0.701
Canopy Cover	**12.015****	0.310	0.873	**7.123****	0.900
Structure (0-20 cm)	**12.666****	1.817	2.791	0.095	**4.611****
Structure (20-40 cm)	**12.488****	0.062	0.152	1.384	**4.810****
Structure (100-200 cm)	**7.125****	0.358	2.948	1.017	1.373

* $p < 0.05$; ** $p < 0.01$

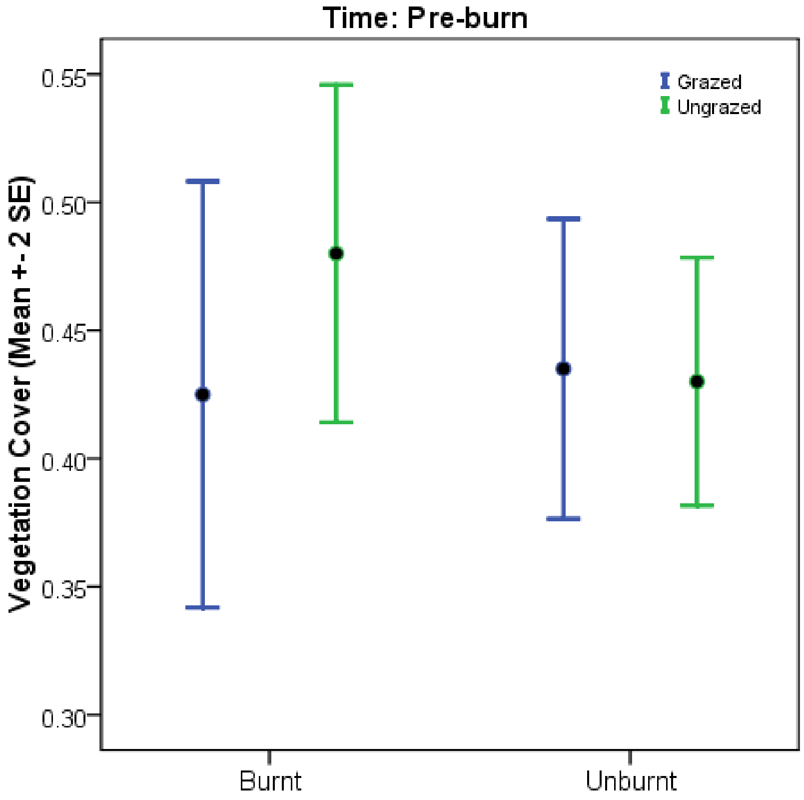


Figure 6: Mean vegetation cover before the June 2008 burn in all four treatment plots.

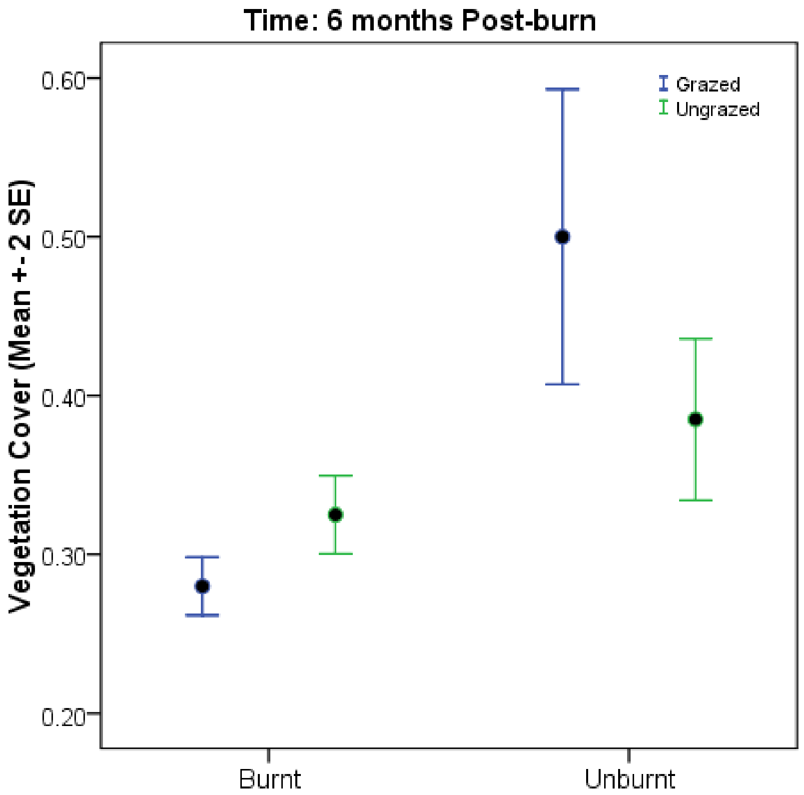


Figure 7: Mean vegetation cover was significantly lower 6 months post-burn as compared to before the June 2008 burn.

Fire had a significant impact on litter cover (Table 1), with litter cover significantly lower in the burnt plots as compared to the unburnt plots (Figure 8). This result was expected as the fire would have removed the litter in the plots that were burnt.

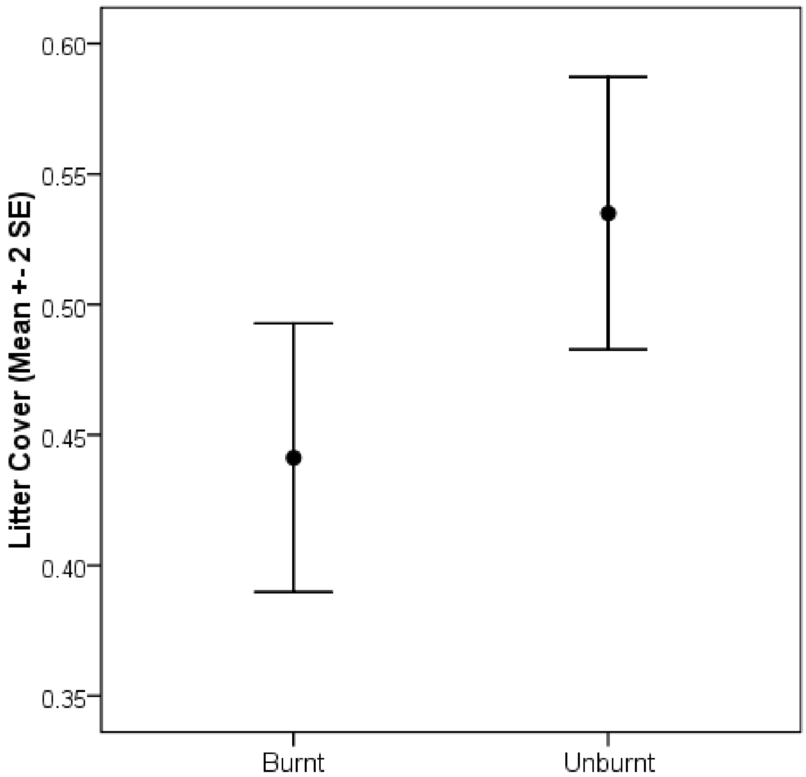


Figure 8: Mean litter cover was significantly lower in the burnt plots as compared to the unburnt plots.

Soil cover showed a significant interaction between fire, grazing and time (Table 1). Figure 9 shows that, as expected, pre-burn mean soil cover was consistent between all four plots despite high variability in the data. In the 6 month post-burn time period, soil cover was significantly higher in the burnt plots than in the unburnt plots (Figure 10). Due to the removal of litter after the fire, a greater proportion of soil would have been exposed in the burnt plots.

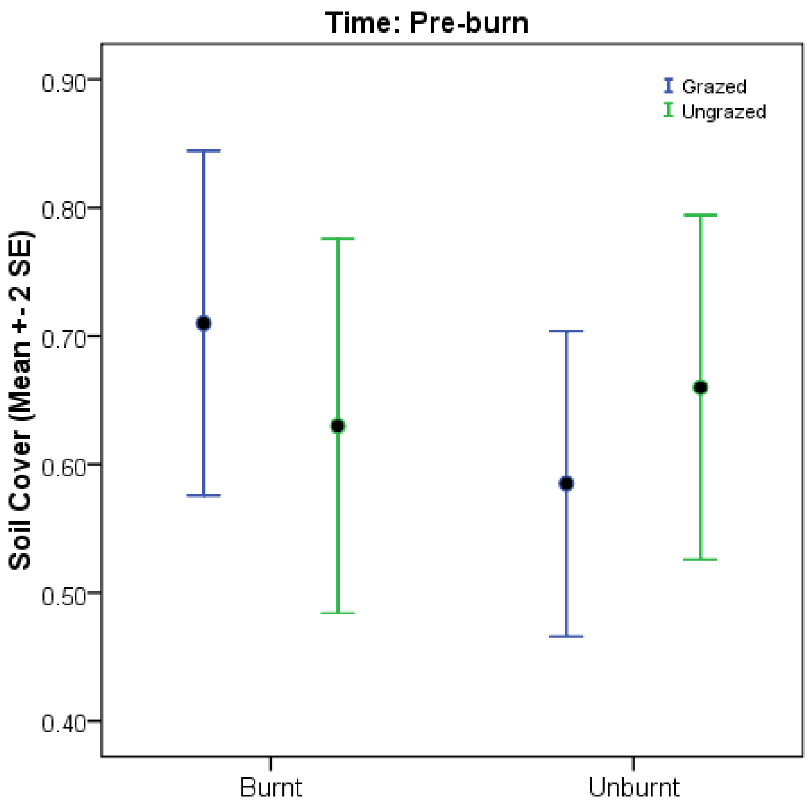


Figure 9: Mean soil cover before the June 2008 burn in all four treatment plots.

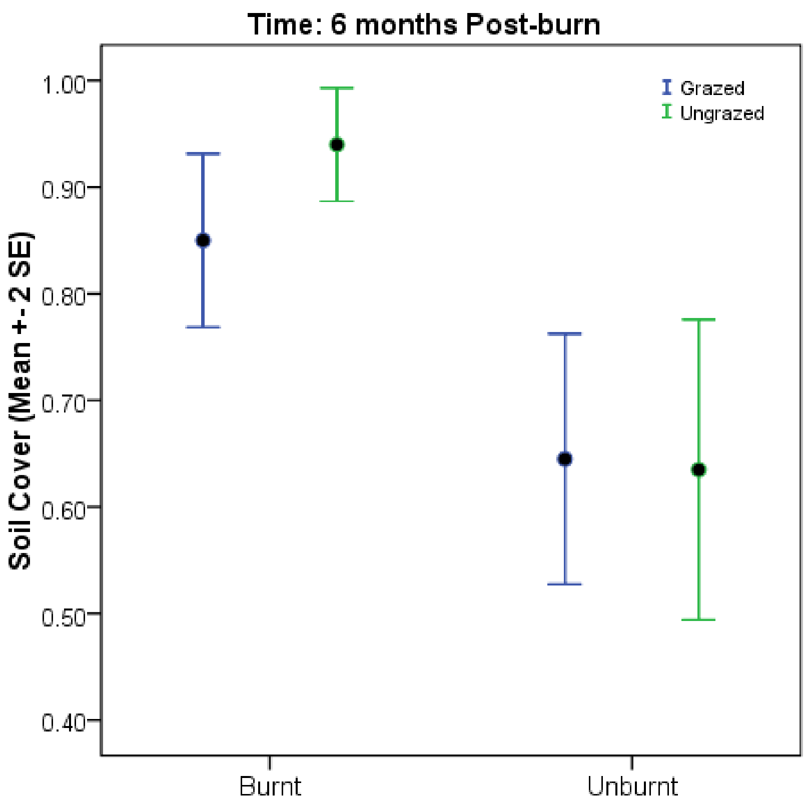


Figure 10: Mean soil cover was significantly higher in the burnt than in the unburnt plots at the 6 month post-burn time period.

Canopy cover showed a significant interaction between fire, grazing and time (Table 1). Figure 11 shows that pre-burn mean canopy cover was consistent between all four plots despite high variability in the data. Under DEC prescribed burning conditions, canopy cover should not have been affected by fire because during such prescribed burns, the scorch height is lower than the height of the canopy. Therefore, it was expected that canopy cover would not be significantly different between the four treatment plots. However, canopy cover was lower in the grazed unburnt plot (Figure 12). This may be a reflection of some tree deaths in this plot, which would open up the canopy and reduce the amount of canopy cover.

Vegetation Structure

Vegetation structure in the 0-20 cm and 20-40 cm height classes showed a significant interaction between fire, grazing and time (Table 1). Figure 13(a) (0-20 cm) and 14(b) (20-40 cm) shows that pre-burn vegetation structure in these two height classes was consistent between all four plots despite high variability in the data. There was a significant effect of fire on vegetation structure (0-20 and 20-40 cm) (Figure 14(a) (0-20cm) and 15(b) (20-40 cm). This was expected because the mild prescribed burn would have removed low level vegetation in the burnt plots. Grazing did not appear to have an effect on vegetation structure at these heights.

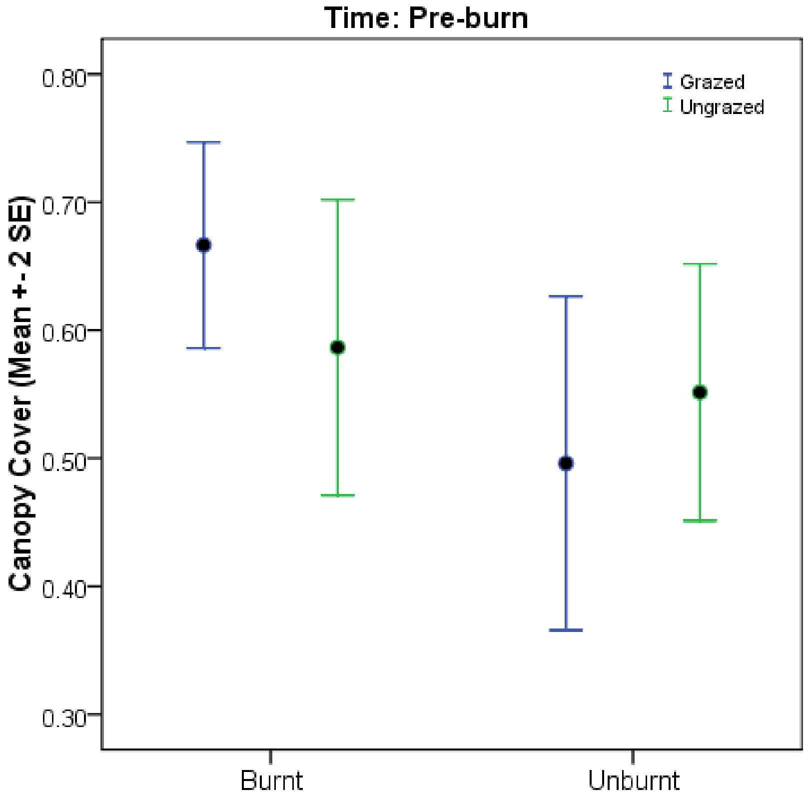


Figure 11: Mean canopy cover before the June 2008 burn in all four treatment plots.

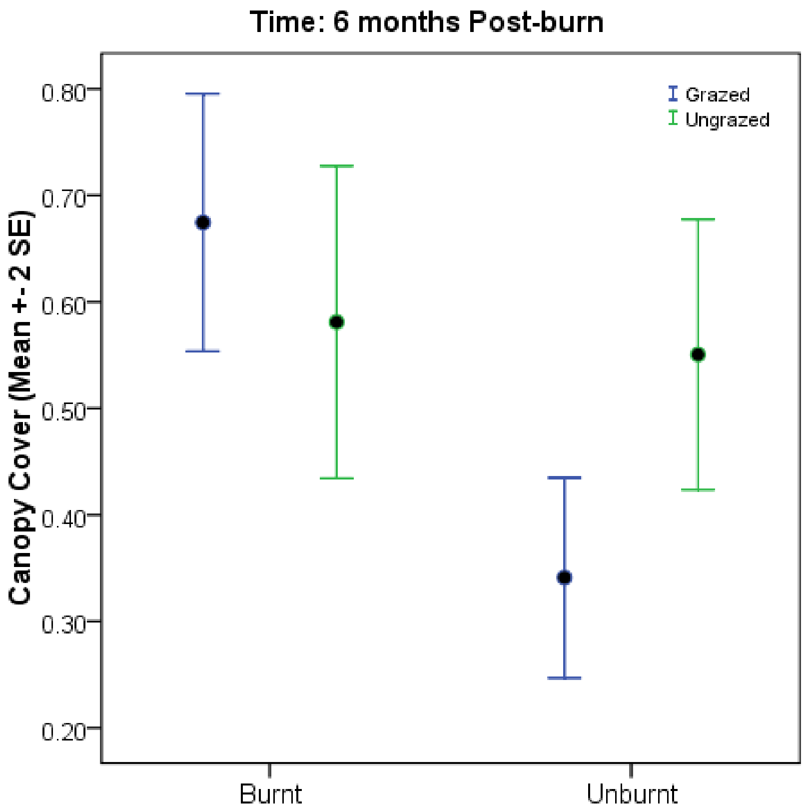
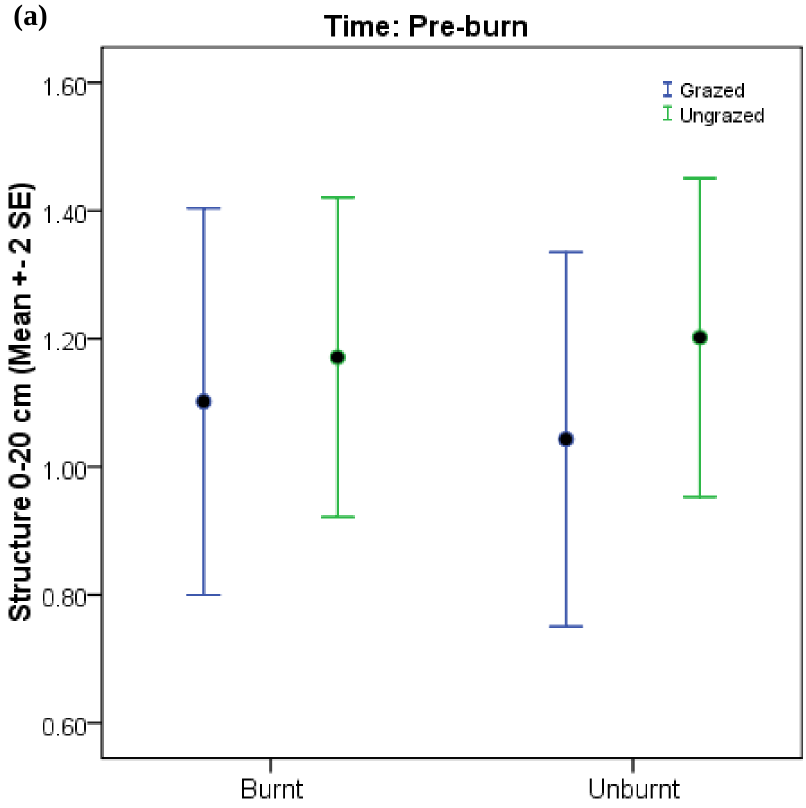


Figure 12: Mean canopy cover in the four treatment for the 6 months post-burn time period.

(a)



(b)

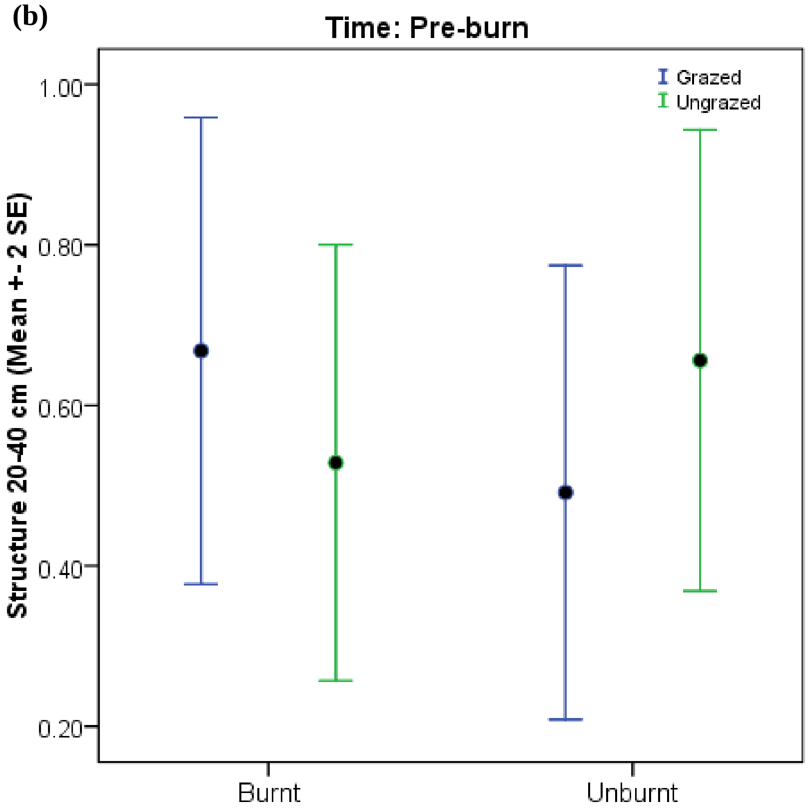
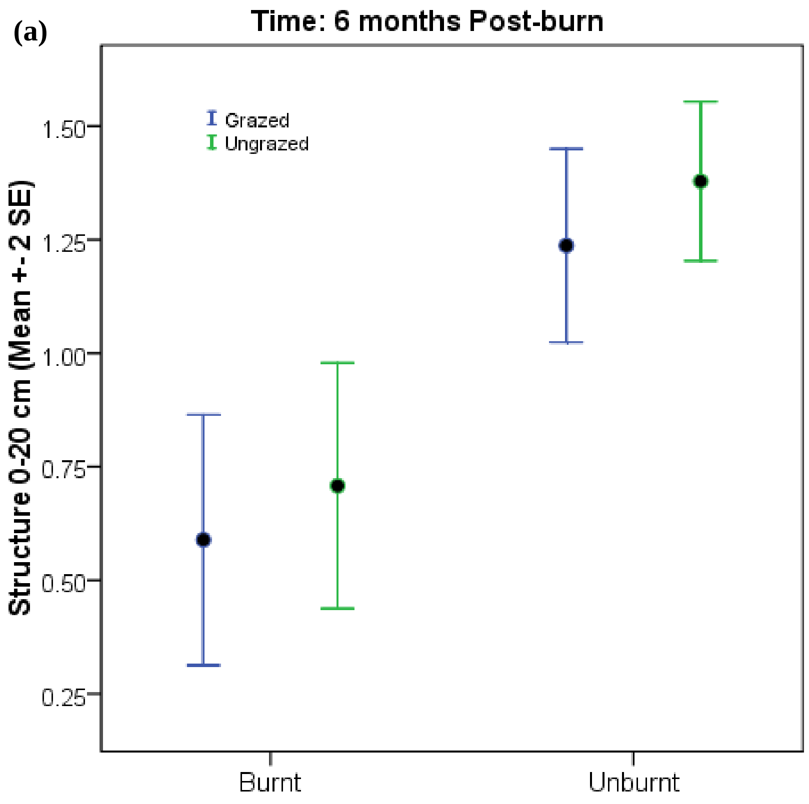


Figure 13 (a) and (b): Pre-burn vegetation structure in the (a) 0-20cm and (b) 20-40 cm height class was consistent between all four treatment plots.

(a)



(b)

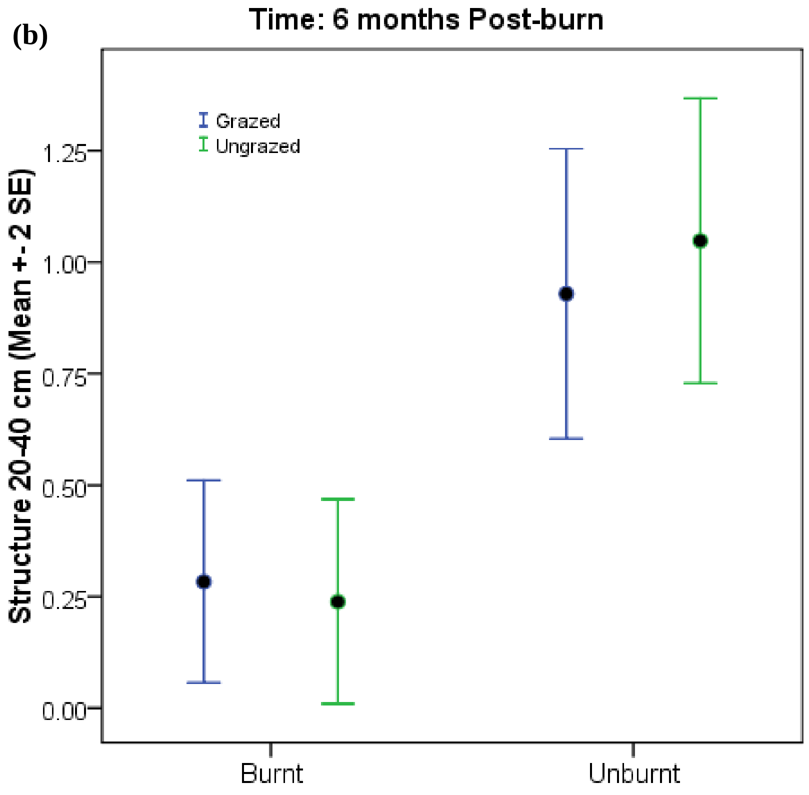


Figure 14 (a) and (b): There was a significant effect of fire on vegetation structure in the (a) 0-20cm and (b) 20-40 cm height class.

Vegetation in the two highest structure classes (100-150 cm and 150-200 cm) (which were combined to form one class: 100-200 cm) was significantly different between the burnt and unburnt plots (Figure 15). It was expected that fire would have reduced the amount of vegetation at this height in the burnt plots. However, vegetation at this height was more abundant in the burnt plots. One explanation for this could be the differences in vegetation composition between the burnt and unburnt plots. In the burnt plots, there was a greater proportion of *Adenanthos cygnorum* subsp. *cygnorum* (Common Woollybush). This species is approximately 4 m tall, with vegetation growing from ground level (and would have been commonly recorded in the 100-200 cm structure class). This species is in greater densities in the burnt plots than the unburnt plots. As the height of the prescribed burn was less than 2 metres, this species may have been largely unaffected by the fire in the 100-200 cm height class. Therefore, the result in this study may be a reflection of the difference in vegetation composition between the burnt and unburnt plots.

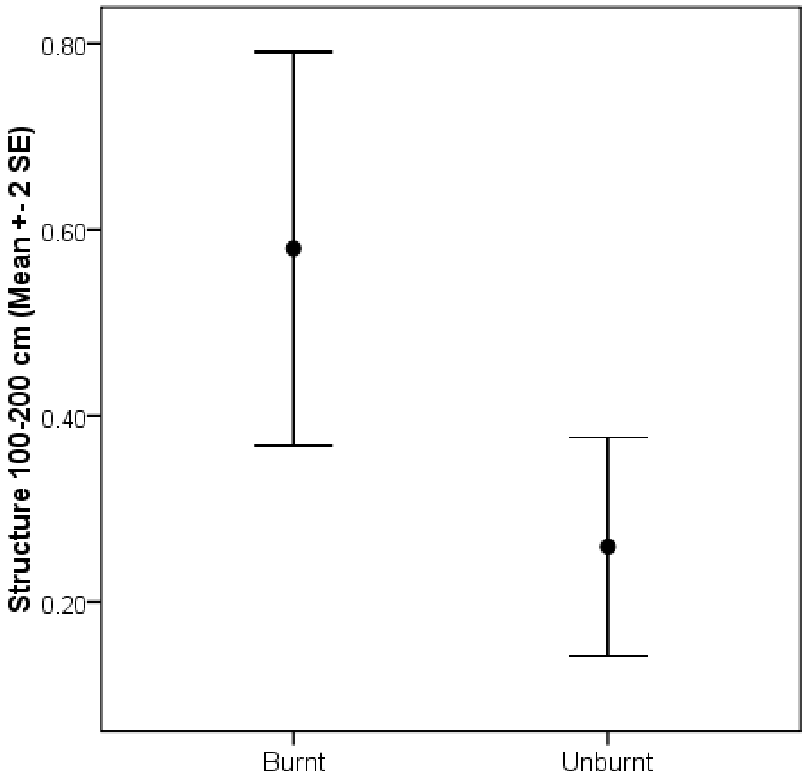


Figure 15: Vegetation structure in the 100-200 cm height class differed significantly between the burn and unburnt treatment plots.

Impact of Grazing

There were two species of flora that showed obvious signs that they were being grazed: *Phlebocarya ciliata* and *Mesomelaena pseudostygia*. However, it should be noted that it is difficult to distinguish between some species of Haemodoraceae and species of Iridaceae before they have flowered and especially if their foliage has been grazed. A third species, *Haemodorum spicatum* had not had the foliage grazed but the roots had been dug up. There is also the possibility that some species were absent from the unfenced treatment because of being preferentially grazed. The only scats observed belonged to *Macropus fuliginosus*, therefore it was presumed to be the primary herbivorous grazer in these plots.

Figure 16 shows a clear distinction in the percentage of grazing evidence between the plots that were fenced to exclude grazers and the plots that were unfenced. The high percentage (70%) of grazing evidence in the burnt unfenced plot (burnt grazed) was expected, as kangaroos would have access to the new regenerating shoots and seedlings following the burn. The evidence of grazing was lower in the unburnt unfenced plots, and most likely reflects that kangaroos were not as attracted to this plot due to the lack of succulent new growth as compared to the burnt side of the trial. As expected, there was no evidence of grazing in both of the fenced plots. Ongoing data collection in all four plots may demonstrate that grazing may have an effect on fuel accumulation rates.

Impact of Fire on Fuel Accumulation

Pre-burn litter depth was significantly greater than post-burn litter depth (Figure 18). This was expected as the burn would have removed the litter from the ground in the burnt plots. At one month post-burn, the litter depth was similar in both the grazed and ungrazed plots that had been burnt. However six months after the burn the litter depth in the ungrazed plot was significantly greater than in the grazed (unfenced) plot. This suggests that grazing influences the build-up of litter, and therefore fuel accumulation rates. Further data collection over time would be useful to investigate this further.

If the impact of grazing is discounted, the rate of fuel accumulation over time would be expected to follow the model in Burrow et al. (2008) of post-fire vegetation dynamics in Jarrah forest. The proportion of dead vegetation should increase quite rapidly with time since fire and then stabilise with time.

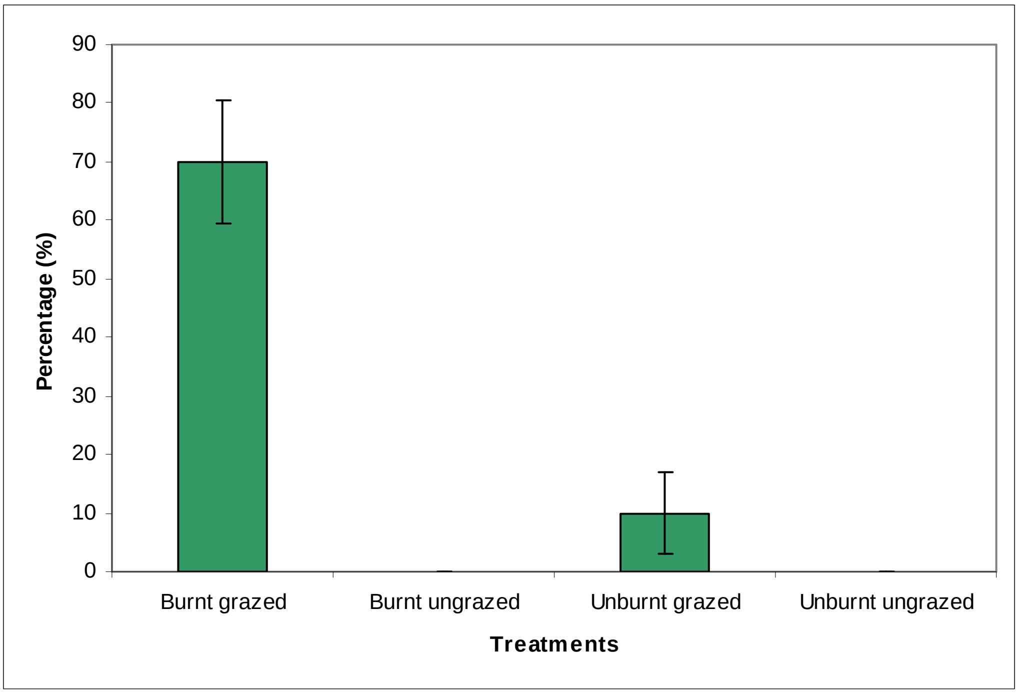


Figure 16: Percentage of 1 m^2 areas around the touchpole points that exhibited signs of grazing evidence 6 months post-burn.

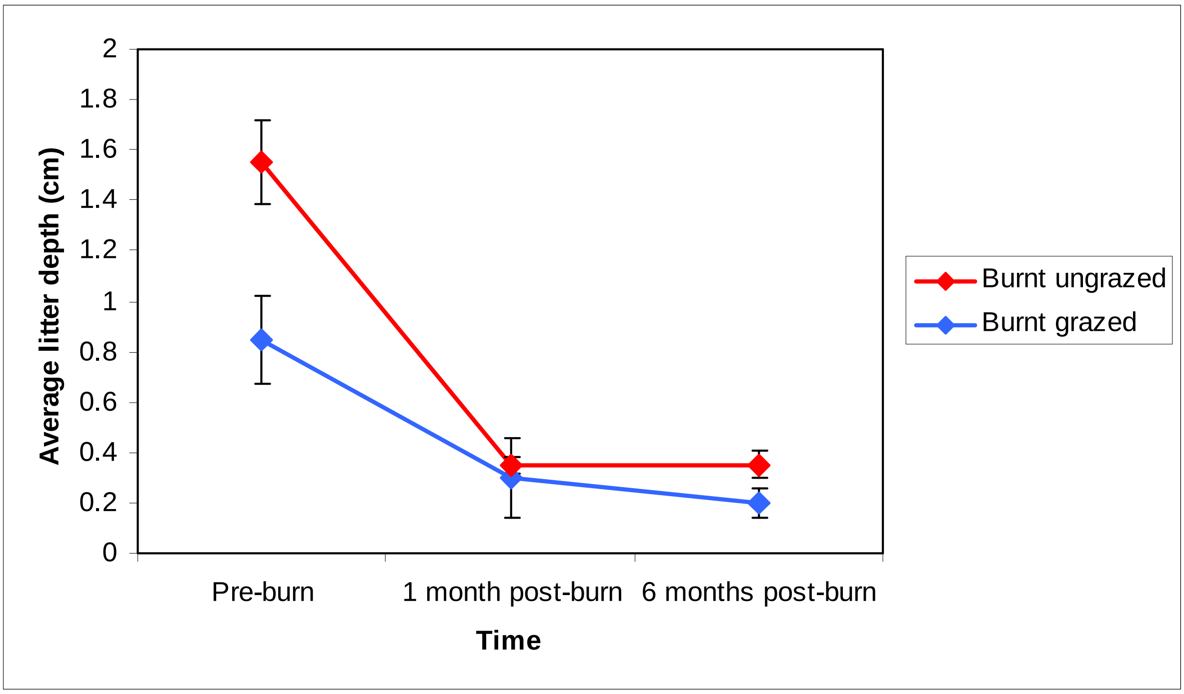


Figure 18: Change in litter depth (cm) over time in the 2 burnt plots.

Discussion and Recommendations

The results presented in this report have shown that fire and grazing can have a significant impact on biodiversity in the GSS study area, such as vegetation cover and litter depth. However, these results are preliminary, and further data will be collected in the remaining time of the project. It is planned that in May 2009, data will be collected again for certain vegetation attributes (cover, litter depth) and evidence of grazing to further investigate the impact fire and grazing on vegetation regeneration.

This study is very limited by sample size because it is a preliminary study. It is recommended that to further investigate the impact of fire and grazing on biodiversity values in the GSS study area, the sample size and study area should be increased, and other work be conducted in the future, as described below.

While the data collected on juvenile periods and post-fire regeneration strategies are preliminary, this is the first step in the process of assessing the juvenile period of the flora species in order to determine the appropriate fire interval for the Banksia woodland on the Northern Swan Coastal Plain. To fully understand the effects of fire on juvenile period of Banksia woodland species, a much longer and broader study would need to be undertaken, and information gathered on key fire species – for example, species that have very long juvenile periods and species that require frequent fire. This study should ideally be long enough for a majority of species to have reached juvenile period. A period of 2-5 years was required by Burrows et al. (2008) to achieve this in the Jarrah forest. A comparison between the juvenile period of species found in both the Jarrah forest (Burrows et al. 2008) and Banksia woodlands from this study would be useful to gauge climatic variation within species. Future work should include tabulating the regeneration strategy and flowering age of each species in the pre-burn floristic data (recorded by Mattiske Consulting Pty Ltd), and monitoring the time to flowering for each species.

An ecologically appropriate fire regime for the Banksia woodland on the Northern Swan Coastal Plain should take into account juvenile period of the slower growing species as well as the amount of fuel and its accumulation rate. Therefore future work should also include calculating the amount of fuel and fuel accumulation rates over time in the treatment plots. This could include the assessment of the amount of dead scrub, ground litter, and live scrub, similar to the methods used by Burrows and McCaw (1989). Burrows and McCaw (1989) found that the amount of fuel accumulation in four years after a fire (5.5 tonnes per hectare) was sufficient to support an intense and fast moving fire under extreme weather conditions.

Future work of the impact of grazing on vegetation could include an investigation into whether more sensitive methods should be used to pick up evidence of grazing. In addition, as *Macropus fuliginosus* (western gray kangaroo) is most likely the primary herbivorous grazer in the unfenced plots, future work could examine preferential grazing impacts of this species.

While this project did not investigate the impact of fire on fauna, it was investigated by two studies of the DEC *Biodiversity values on the Gnangara Groundwater System* project, and more information can be found on the impact of fire on fauna in the *Patterns of Ground-Dwelling Vertebrate Biodiversity in the Gnangara Sustainability Strategy Study Area* Report and the *GSS - Biodiversity* Report.

Another important aspect of this project is the consideration of it as a long-term site for monitoring vegetation condition on the Swan Coastal Plain, possibly as part of a long-term Adaptive Management Project.

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Appendix 1: Mattiske Consulting Pty Ltd report.

(Attached as a separate document)

Appendix 2: DEC Burn Prescription for the Caraban UCL Burn Trial

(Attached as a separate document)