Health and distribution of the Snow Gum *Eucalyptus pauciflora* ssp. *pauciflora* in the Ballarat region of Victoria

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Abstract

Fifty-three remnant Snow Gum *E. pauciflora* ssp. *pauciflora* sites were assessed within a 40 km radius of Ballarat, Victoria. Thirty sites were part of the 1996 study by Baker, which enabled comparative statistical analysis. Sites were located across various land tenures and soil types, where data was collected on a range of variables contributing to the health and distribution of Snow Gums. Site assessments were conducted from March-August 2008. Snow Gums were located on a range of landforms, with a higher proportion found on parallel or convergent slopes which were gently to moderately inclined. All sites occurred on acidic soils across various soil texture groups. Snow Gums sites were found in five Ecological Vegetation Classes with 166 different species, of which 111 were indigenous and 55 were exotic. Most species occurred infrequently across the sites, and a greater cover abundance of natives compared to weeds correlated with mature Snow Gums in better health. Snow Gum individuals in poor health had lighter fruit crops than trees in very good health. Roadside sites had a significantly higher proportion of mature and regenerating individuals, which were also in better health than freehold and crown land sites. Grazing was found to significantly reduce both the health and regeneration of Snow Gums, with fenced sites containing a large proportion of the total number of trees found in good health. Natural disturbance and road works were found to be beneficial, with a high occurrence of regeneration at these sites. Land tenure and grazing were the key determinants of the health and distribution of Snow Gums in the Ballarat region.

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1. Introduction

The distribution of vegetation in Australia is largely determined by the geological and climatic history of landscapes (Fox 1999). The Snow Gum, *Eucalyptus pauciflora*, was once a dominant and widespread species in woodlands and forests across a range of altitudes in Victoria (Williams 1991). It is suggested that the distribution of this species became restricted as the climate warmed after the last ice age, forming a number of subspecies including the lowland Snow Gum, *E. pauciflora* Sieber ex Spreng. ssp. *pauciflora* Spreng. (Williams 1991). This subspecies generally occurs at lower altitudes than other subspecies, overlapping the range of subsp. *niphophila* and subsp. *acerina* (Nicolle 2006).

While other subspecies of *Eucalyptus pauciflora* remain widespread, rapid clearing of these vegetation types for agriculture and urban development in lowland areas has drastically limited the distribution of this subspecies, which is now restricted to small fragmented populations (Williams 1991). Populations occur in southern New South Wales, Tasmania, Victoria, and extending just over the border into South Australia (Brooker and Kleinig 1983). Most of these remnants are highly disturbed, and occur on roadsides or on private land as small patches or isolated paddock trees, where relatively few are protected from the impacts of grazing, cropping and altered nutrient regimes (Baker 1996). In addition, the prolonged drought in the study area has further stressed this vegetation, reducing their ability to cope with these anthropological impacts. This leads to the decline of these patches through clearing, dieback and gradual senescence of mature trees, and without recruitment of seedlings, will gradually disappear (Gibbons and Boak 2002).

Eucalyptus pauciflora ssp. *pauciflora*, of the Myrtaceae family, derives its name from the Latin words "pauci" meaning "few" and "florus" meaning "flowered" and is also referred to as White Sallee in published literature (Costermans 1994). The name, "few flowers" is quite misleading as *E. pauciflora* flowers profusely from October to January and was the result of a poorly representative sample being collected and named by Franz Sieber in 1823 (Maurice 2003). *E. pauciflora* is a slow growing and long lived species with large fruits and very distinct glossy, thick and waxy leaves with parallel veins (Maurice 2003).

Little is presently known about the limiting factors associated with the health and distribution of *E. pauciflora* ssp. *pauciflora*. The 1996 study by Baker provided some insight into these factors in the Ballarat region, indicating a tendency for this species to inhabit ecotones (the transition zone between two ecotypes). While *E. pauciflora* ssp. *pauciflora* is not listed as threatened in the Ballarat region, they do consist of small fragmented populations. It is this limited distribution, combined with the fragile nature of the sites that makes this a target species for conservation studies.

1.1 Factors affecting *Eucalyptus pauciflora* ssp. *pauciflora* distribution

1.1.1 Landform and soil characteristics

Eucalypt distribution is influenced by variations in soil fertility that occurs with change in slope (Dorrough and Moxham 2005). Soils higher in the landscape are generally more skeletal, with a lower nutrient and water holding capacity, while those on lower slopes and undulating plains are more fertile, and are therefore the areas cleared for agriculture (McKenzie *et al.* 2004). Soil can also limit the distribution of trees by restricting root growth, such as cracking clays in grassland areas (Black 2006).

The study by Baker (1996) examining remnant *E. pauciflora* ssp *pauciflora* in the Ballarat region found 47% of assessed sites occurred on basalt soils, with 63% occurring either on basalt or in the ecotone between basalt and another soil type. An ecotone is a transition zone between two vegetation communities, which is often more diverse due to the presence of species from both communities (Holmgren 1994). The soil information determined by Baker (1996) estimated the position of populations using 1:250 000 scale soil maps. These locations correlate well with the description by Holmgren (1994) which is based on historical records, field observations and published reports, despite the coarse scale of the mapping. Holmgren (1994) states *E. pauciflora* ssp. *pauciflora* would previously have dominated the hillcrests on the less fertile stony red gradational loams in the Daylesford, Newlyn area north of Ballarat.

Most literature states that *E. pauciflora* ssp. *pauciflora* occurs on well-drained soils, yet Bird *et al.* (1992) states that this subspecies can occur on a range of soil types, from sandy loam, loam, gravelly loam and clay loam, and will tolerate a range of drainages, including a degree of flooding. According to Bird *et al.* (1992), soils on the undulating basalt plain are typically loamy clays of varying drainage, with low to medium pH, which is a suitable pH range for *E. pauciflora* ssp *pauciflora*. These red soils derived from basalt are usually Ferrosols, gradational soils generally dominated by kaolinite clays, with high free iron content and an acidic pH range (McKenzie *et al.* 2004). The study by Baker (1996) found no *E. pauciflora* ssp *pauciflora* populations occurred on granite or granite derived soils in the assessed sites, despite this being the primary soil type of subalpine populations, demonstrating a clear difference between subalpine and lowland populations.

1.1.2 Vegetation communities and associated species

E. pauciflora ssp. *pauciflora* inhabits vegetation communities from low open woodland to forest, with varying tree form and heights of 6 to 20m (Nicolle 2006). These descriptions suggest *E. pauciflora* ssp. *pauciflora* may occur in a number of Ecological Vegetation Class (EVC) groups in the Ballarat region, including Plains Woodlands and Forests, Herb-rich Woodlands, and Lower slopes or Hills Woodlands. Ecological Vegetation Classes (EVC) are floristic communities grouped together based on responses to a range of environmental conditions (DSE 2008).

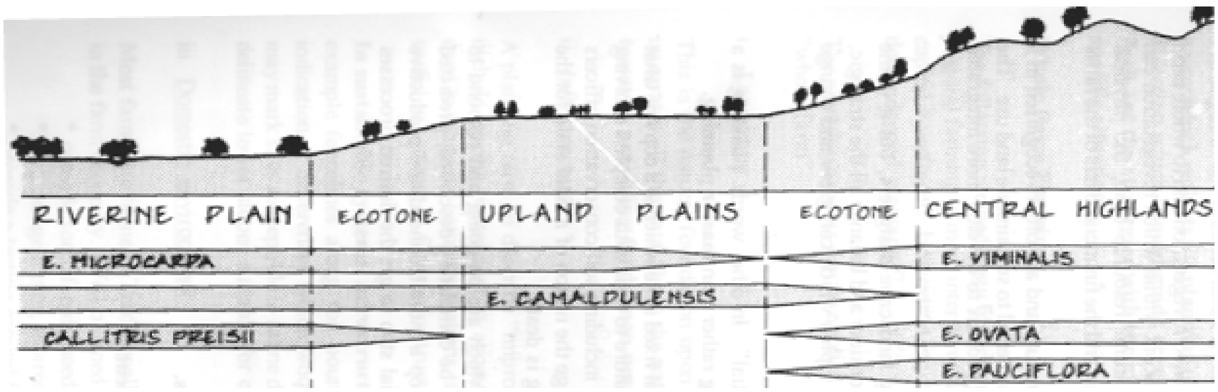

Figure 1. Typical volcanic landscape showing distribution of *E. pauciflora* (adapted from Holmgren 1994)

Figure 1 shows a typical vegetation profile of a volcanic landscape, with *E. pauciflora* a dominant tree on the Central Highlands and in the ecotone between the highlands and the plain (Holmgren 1994).

Associated vegetation described by Baker (1996) is similar to that described by Holmgren (1994), with *E. pauciflora* ssp *pauciflora* commonly found with overstorey species such as Manna Gum *Eucalyptus viminalis,* Swamp Gum *E. ovata,* Candlebark *E. rubida,* Messmate *E. obliqua* and Narrow-leaf Peppermint *E. radiata*, the latter with which *E. pauciflora* ssp *pauciflora* has been found to hybridise. *E. pauciflora* ssp *pauciflora* hybridises with Broad-leaf Peppermint *E. dives* at higher altitudes (Pryor 1976).

Other associated vegetation described includes Blackwood *Acacia melanoxylon* and Silver Wattle *A. dealbata* on the highlands and the ecotone, and Black Wattle *A. mearnsii* on the plains and the ecotone (Holmgren 1994). These species were all found to occur with *E. pauciflora* ssp *pauciflora* in the Ballarat region (Baker 1996). Baker (1996) found ecotones were also more likely to contain hybrids than sites with only one soil type. Hybrids between *E. pauciflora* ssp *pauciflora* and *E. radiata* were found on 11 sites (15%), seven of which occurred in the ecotone (Baker 1996).

Associated vegetation is an important indicator of site quality, and chances of eucalypt regeneration have been found to decrease with an increased abundance of exotic groundcovers (Dorrough and Moxham 2005).

1.1.3 Climate

Climatic factors such as temperature and rainfall largely determine the distribution of vegetation by limiting plant regeneration and growth (Fox 1999). Regeneration and distribution is restricted when a species tolerance levels are reached, and change under different conditions (Ball *et al.* 1991).

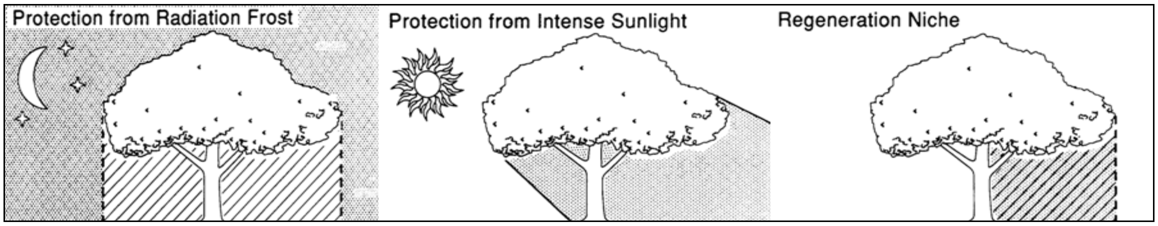

Figure 2. Regeneration niche of high altitude *E. pauciflora* (source: Ball *et al.* 1991)

At higher altitudes, *E. pauciflora* ssp. *pauciflora* seedlings occupy a regeneration niche (Figure 2) under the southern side of the parent tree canopy, providing protection from stress caused by long exposure to intense sunlight and frost (Ball *et al.* 1991). Particularly when trees are isolated, regeneration occurs mostly on the sheltered southern side under the tree canopy, rather than the more exposed northern side, although growth rates can be lower due to decreased light levels (Egerton *et al.* 2000).

These adaptations to extremely cold environments may not be as prevalent in lower altitude populations, which have been exposed to milder climates since the last ice age. However they may have retained many adaptations that enabled them to survive in colder climates, giving them a competitive advantage in frost prone areas. In fact, lowland populations are likely to be exposed to warmer conditions in summer than high altitude populations. Due to the lack of literature on lowland *E. pauciflora* ssp *pauciflora,* it is important to consider impacts of climate on local eucalypt species in the Ballarat region.

Wind is a driving factor of eucalypt distribution patterns, as seed is dispersed predominantly in the direction of the prevailing wind and rarely distances more than twice the height of parent trees (Turnbull and Doran 1987a; Holmgren 1994). Most seed is distributed on the south-east side of the tree with north-westerly winds in summer, indicating the regeneration zone (Greening Australia 2003). Unlike *E. pauciflora* at high altitudes, eucalypt seedlings at lower altitudes are more likely to grow away from canopy shade to reduce competition for light, water and nutrients (Greening Australia 2003). Successful regeneration depends on the quantity of seed fall, the degree of ant predation and germination under appropriate conditions to sustain growth (Semple and Koen 2001). Seedlings that do survive are often subjected to grazing regimes that prevent growth, competition from exotic groundcovers, or climatic extremes such as drought or frost (Semple and Koen 2001).

1.1.4 Landuse and Competition

Seedling establishment and survival is largely determined by the degree of disturbance, and competition from associated vegetation for water and nutrients (McIntyre 2002; Semple and Koen 2001). Grazing directly influences plant distribution by herbivory of plant cover, exposing bare soil to erosion and weed invasion (McIntyre and McIvor 1998). Indirectly vegetation is influenced by changes to soil structure and composition, altering nutrient cycling by reducing litter cover and increasing nutrient load in areas where stock congregate, particularly around isolated trees (McIntyre and McIvor 1998). Soil structure also changes due to compaction, altering the permeability of soil to water (Spooner *et al.* 2002).

Dorrough and Moxham (2005) demonstrated that while eucalypt regeneration was high on ungrazed land, it was virtually non-existent under regular grazing, with some recruitment occurring on intermittently grazed land. This illustrates seedling establishment in grazed paddocks is unlikely unless trees are fenced from stock. Comparisons between fenced and unfenced areas have shown significantly higher eucalypt recruitment in fenced sites (59%), compared to 13% of unfenced sites (Spooner *et al.* 2002). Ground cover was vastly higher for natives than exotics in fenced sites, coinciding with successful tree regeneration (Spooner *et al.* 2002). Light grazing was suggested to provide disturbance necessary to stimulate regeneration, providing grazing was then excluded to allow seedling establishment (Semple and Koen 2001). Holmgren (1994) states that *E. pauciflora* is one of the more palatable eucalypts, so is more likely to be selectively grazed, particularly by rabbits.

Of the 73 sites assessed by Baker (1996) in the Ballarat region, 32 were used for agriculture and 38 were roadsides. Roadsides had *E. pauciflora* ssp. *pauciflora* regeneration in 92% of sites, compared to 3% (one ungrazed site) of agricultural sites (Baker 1996), demonstrating the significant impact of land use on seedling recruitment.

1.1.5 Mechanisms for regeneration

Natural regeneration is affected by a species' ability to utilise resources for seed germination and growth (Dorrough and Moxham 2005). Epicormic buds and lignotubers allow eucalypts to regenerate after stress, however germination of seed is required to recruit new individuals (McIntyre 2002). Natural regeneration of eucalypts requires heavy seed fall, adequate moisture in the seed bed, oxygen, and temperatures suitable for germination (Greening Australia 2003).

As with most eucalypts, optimal germination of *E. pauciflora* ssp. *pauciflora* has been found to occur between 15-20 ºC, with seed damage occurring when temperatures exceed 30 ºC (Beardsell and Mullett 1984). Light is not a germination requirement, however reduced rates can result from moisture stress

(Turnbull and Doran 1987b). High altitude *E. pauciflora* seed requires cold stratification at 3-5 °C in order to germinate, with the degree of dormancy relative to altitude (Beardsell and Mullett 1984). Protection of the embryo by the seed coat prevents germination when conditions are unsuitable for growth and can be broken by environmental cues (Beardsell and Richards 1987). Lowland populations of *E. pauciflora* ssp. *pauciflora* lack this mechanism, germinating regardless of stratification (Beardsell and Mullett 1984; Turnbull and Doran 1987b).

Germination, growth and survival rates have been demonstrated to be higher for larger seeded species (Turnbull and Doran 1987). *E. pauciflora* ssp. *pauciflora* has quite large fruit and seed in comparison to other Victorian eucalypts, with only 59,000 seeds per kg compared to 353,000 seeds per kg for *E. viminalis*, an associated species (Oates and Clarke 1987). Millberg *et al.* (1998) demonstrated a strong relationship between seed mass and nutrient content, and found eucalypts with large seeds developed into larger seedlings under low nutrient conditions. This suggests higher levels of Nitrogen, Phosphorus and Potassium in larger seeds enables them to tolerate harsher conditions of establishment, such as during drought or in established vegetation (Milberg *et al.* 1998). With increased nutrients, growth of smaller seeded eucalypts was greater than larger seeded species, suggesting *E. pauciflora* ssp. *pauciflora* may be competitively disadvantaged on fertile agricultural land where many of the remnants were discovered by Baker (1996).

1.1.6 Effect of patch size

A large proportion of remnant vegetation occurs as small patches or isolated paddock trees, often on private land (Dorrough and Moxham 2005). Small patches are more easily invaded by exotic species which compete for resources, and are often subjected to a range of disturbances (Fox 1999). Paddock trees in particular have a highly modified understorey, and usually occur in cultivated or grazed areas where regeneration is limited (Gibbons and Boak 2002). These isolated trees have higher mortality rates and are generally more prone to insect attack due to increased nutrient levels (Gibbons and Boak 2002).

Eucalypts are pollinated by insects, birds, mammals, and rarely wind, therefore connectivity between remnant *E. pauciflora* ssp *pauciflora* patches is vital (Turnbull and Doran 1987). Eucalypts encourage preferential outcrossing through a system known as cryptic self-incompatibility, when the anthers of bisexual flowers produce pollen at a different time to the stigma becoming receptive, reducing the likelihood of self-pollination (Horsley and Johnson 2007). Increased distances between remnants due to fragmentation can reduce outcrossing, compromising the long-term viability of small populations if inbreeding results in less adaptable offspring (Krauss *et al.* 2007). A broad genetic base is required to reproduce and successfully adapt to changing conditions (McIntyre 2002).

1.2 Factors affecting *Eucalyptus pauciflora* ssp. *pauciflora* health

1.2.1 Soil

Key determinants of species or vegetation communities are soil characteristics. Davidson *et al.* (2007) found that soil attributes explained 72% of the tree health variation of *E. pauciflora* in Tasmania. Healthy sites correlated with soils that have lower total nitrogen (N) and pH, and higher organic carbon (Davidson *et al.* 2007). Soil N is important because agricultural systems input high amounts of N to Australian soils that are naturally N deficient (Edis 2007). This leads to increased N uptake by *E. pauciflora*, contributing to decline in health both directly through N toxicity effects and indirectly via increased herbivore foraging due to increased palatability of leaves and shoots (Davidson *et al.* 2007). Davidson *et al.* (2007) found no association between tree health and soil EC in Tasmania, but no information regarding soil colour or texture correlations with *E. pauciflora* ssp. *pauciflora* health could be located in any literature studied.

1.2.2 Associated Species

Vascular plant species occur within certain vegetation communities and are usually associated with particular flora species. Davidson *et al.* (2007) studied the health of *E. pauciflora* trees at sites in the Midlands of Tasmania, and found that 60% of the variation in overstorey tree health was associated with cover of native shrubs, litter, moss, and lichen in healthy sites, and cover of exotic pasture or weed species in declining or unhealthy sites.

1.2.3 Land Tenure

Differences in management regimes associated with land tenure and land use is expected to have the largest influence on tree health. Poor management decisions undertaken by private and public landholders and managers can have a detrimental impact on the indigenous vegetation throughout the Ballarat region (Baker 1996). Weed and pest control, grazing, fertiliser application, ploughing and slashing determine the severity and frequency of disturbance events and competitive pressures, impacting upon the health of *E. pauciflora* ssp. *pauciflora* populations (Baker 1996; Bryant 1971; Davidson *et al.* 2007).

1.2.4 Grazing

Reduced health status of individual plants and vegetation communities due to herbivorous grazing by introduced species is well documented and is a vital component of the Ballarat *E. pauciflora* ssp. *pauciflora* health assessment (Baker 1996; Bryant 1971; Davidson *et al.* 2007; Thomson *et al.* 2001; Wimbush and Forrester 1988). Grazing contributes to the degradation of a site due to the creation of disturbance events and directly reduces the health status of individuals through reduction of biomass and damage to tissues.

Grazing by introduced ungulate species has resulted in widespread destruction of vegetation communities across Australia (Lunt *et al.* 2007). Livestock grazing was identified by Baker (1996) as a major contributor to health status. Bryant (1971) found that sheep grazing had a detrimental effect on regeneration capacity and exclusion of stock led to establishment of young trees. Protection of *E. pauciflora* sites from livestock grazing by fencing or low frequency and intensity grazing, is strongly associated with good tree health (Davidson *et al.* 2007).

Rabbits can cause significant damage to *E. pauciflora* woodland by gnawing stems down to the vascular cambium, effectively ringbarking the trees, then grazing upon the young basal regrowth (Wimbush and Forrester 1988). Rabbit grazing can have devastating effects on *E.pauciflora* lignotubers and seedling regeneration after a high intensity fire event, eliminating all ground layer recovery efforts (Wimbush and Forrester 1988). Sites with very light to no grazing, with a fire frequency of >10 years and retained ground layer of woody debris were found to be in the best health (Davidson *et al.* 2007).

1.2.5 Regeneration

Recruitment within a vegetation community is as important indicator of the site's overall quality or health. The long term viability of a vegetation community or a particular species is dependant on successive generations outliving the older individuals. Although recruitment is often infrequent or episodic, its total absence can indicate a serious disruption to biotic or abiotic factors that control its occurrence (Parkes *et al.* 2003). If recruitment is occurring, the number of cohorts or age classes present contributes to the ecological health of the site and the species present (Parkes *et al.* 2003). According to the Habitat Hectares approach of vegetation community assessment, recruitment is an important parameter of interest and the absence thereof is regarded as an indication that the site is poor in quality and health (Parkes *et al.* 2003).

1.2.6 Isolation – Edge Effect

Isolated, small patches of trees often suffer from decreased health due to the "edge" effect (Davidson *et al.* 2007). Vegetation communities often suffer from the adverse affects of increased disturbance events and increased weed invasions if the fragment of vegetation is small (Davidson *et al.* 2007). Isolated trees are exposed to greater extremes in temperature, drying winds, drift from agricultural chemicals, and if unfenced, from damage caused from stock "camping" (Davidson *et al.* 2007). Stock camping increases the nutrient content of the soil (especially nitrogen) resulting in leaves that are more palatable to grazing insects and mammals (Knox 2005).

Literature was mixed in regard to the effect of these insect and possum grazing pressures, with Davidson *et al.* (2007) finding that grazing by insects and possums was episodic and not a consistent contributor to the decline in health of the *E. pauciflora* population in Tasmania. Conversely, Thomson *et al.* (2001) found that the abundance of insect herbivores on a tree is determined by the number of new leaves present, not the quality of these leaves. Individual herbivorous insects were larger in size on the damaged or stressed trees, indicating higher nutrient content in the leaf regrowth (Thomson *et al.* 2001). This information is considered as part of the discussion regarding heath status of "paddock tree" Snow Gums under stress from agricultural pressures, although it was not directly assessed at Snow Gum locations.

1.2.7 Other Parameters of Interest

Mistletoe can significantly decrease the health of an individual tree due to increased demand for water and nutrients, resulting in energy allocation to resources focused on survival rather than reproductive purposes (Watson 2001). The same principals may apply to trees that are stressed by general ill health. Photosynthetic energy may be preferentially utilised on leaf and root development or used to fight disease or pests, rather than for bud, flower or fruit production.

The diameter of Ballarat's *E. pauciflora* ssp. *pauciflora* trees can give an insight into the age of these individuals. The variability of diameter can therefore be correlated with health to assess whether *E. pauciflora* ssp. *pauciflora* health is associated with age. Height is not considered a good indicator of the age of eucalypts.

The mallee form of eucalypt is generally associated with harsh environmental conditions such as the low rainfall and poor nutrient soils in North West Victoria (Costermans 1994). The genetic composition of *E. pauciflora* ssp. *pauciflora* allows the occupancy of climatically extreme environments such as mountain tops and areas of cold air drainage, including the mallee form growth habit (Williams 1989). *E. pauciflora* ssp. *pauciflora* is found in its mallee form throughout the Ballarat district but it is unknown whether this form is triggered by environmental cues or simply random genetic variation. The mallee form may be associated with certain environmental parameters, poor health, or a result of coppice regrowth after grazing. Positive correlation would indicate that environmental cues during early development may be responsible for this gene expression and the "hardier" mallee form is better equipped for survival at these sites.

1.3 Industry Relationship

Biodiversity Services, the industry host, provide a range of biodiversity and environmental consultancy services throughout the Ballarat region, and work collaboratively with various agencies including Catchment Management Authorities, Department of Sustainability and Environment, Local government, University of Ballarat, and numerous community groups.

Biodiversity Services aims to promote and preserve biodiversity values, while working to actively engage community groups. Tim D'Ombrain, Project Coordinator and Biodiversity Reserves Manager, was involved in the original project in 1996, and was the industry mentor for this follow up study. This project was of interest to Biodiversity Services as it expands on the original study, and provided an opportunity to assess the conditions of the sites twelve years on.

Tim D'Ombrain was the primary contact within Biodiversity Services. Tim has 20 years of industry experience and his guidance and advice on Ecological Vegetation Classes (EVC), vegetation structure, and data collection techniques was invaluable. His ecological and botanical expertise was an important resource ensuring correct plant ID during the early stages of the project.

Corangamite Catchment Management Authority (CCMA) was the primary sponsor and will benefit from the project as many of the sites assessed lie within the catchment boundary. CCMA has been a leader in implementing the Victorian Volcanic Plains (VVP) Tender, a project which aims to protect and enhance biodiversity across the VVP (Buchan 2006). This is achieved by engaging the community, providing financial support to landholders to manage land for conservation, and conducting research to gain insight into ecosystems on the VVP (Buchan 2006). The majority of the remnant Snow Gum patches surveyed during the 1996 study occurred on the Basalt Plain or on the edge with another soil type; therefore the project provided insight into the presence of a declining species (Baker 1996). The future management of this species will be influenced by the CMA and Biodiversity Services.

2. Project objectives

The objective of this study was to contribute to an existing data set relating to *Eucalyptus pauciflora* ssp. *pauciflora* (Snow Gum) populations in the Ballarat region, Victoria. A wide range of parameters were examined to assess any effect on the health and distribution of this species. Data analysed was compared with the 1996 study by Baker where appropriate, in order to assess changes twelve years later. The following hypotheses were statistically tested to gain further insight:

2.1 Effects on the distribution of Snow Gums in the Ballarat region:

- Regeneration of Snow Gums has increased since Baker's 1996 report
- Landform and slope characteristics have no effect on the distribution or regeneration of Snow Gums
- Snow Gums occur on a range of soil types within an acidic pH range
- Snow Gums tend to inhabit ecotones, the transition zone between two ecotypes
- Snow Gums occur with the same associated species regardless of location in the study area, as a reflection of original Ecological Vegetation Classes
- Land tenure is the primary factor influencing the distribution and regeneration of Snow Gums, as it determines the land use and therefore the degree of disturbance and competition

2.2 Effects on the health of Snow Gums in the Ballarat region:

- The health of the Ballarat Snow Gums has reduced since Baker's 1996 report
- The presence of mistletoe has a detrimental impact on the health of individual Snow Gums
- The health status of individual trees is related to physical features such as form, fruiting, flowering or DBH
- Snow Gums with mallee form are found at sites with poor average tree health due to harsher environmental conditions because this form is associated with harsh environments in sub-alpine areas.
- The health of the Ballarat Snow Gums is dependent on land tenure and exposure to grazing.
- Variation in soil parameters is correlated with the health of the Snow Gum sites
- Sites with low numbers of Snow Gums present will suffer poor health from isolation and edge effects

3. Method

3.1 Study sites

Fifty-three sites were selected from known *E. pauciflora* ssp. *pauciflora* (Snow Gum) sites within a 40km radius of Ballarat, Victoria (37° 33” S 143° 51” E). Refer Appendix I for full list of sites.

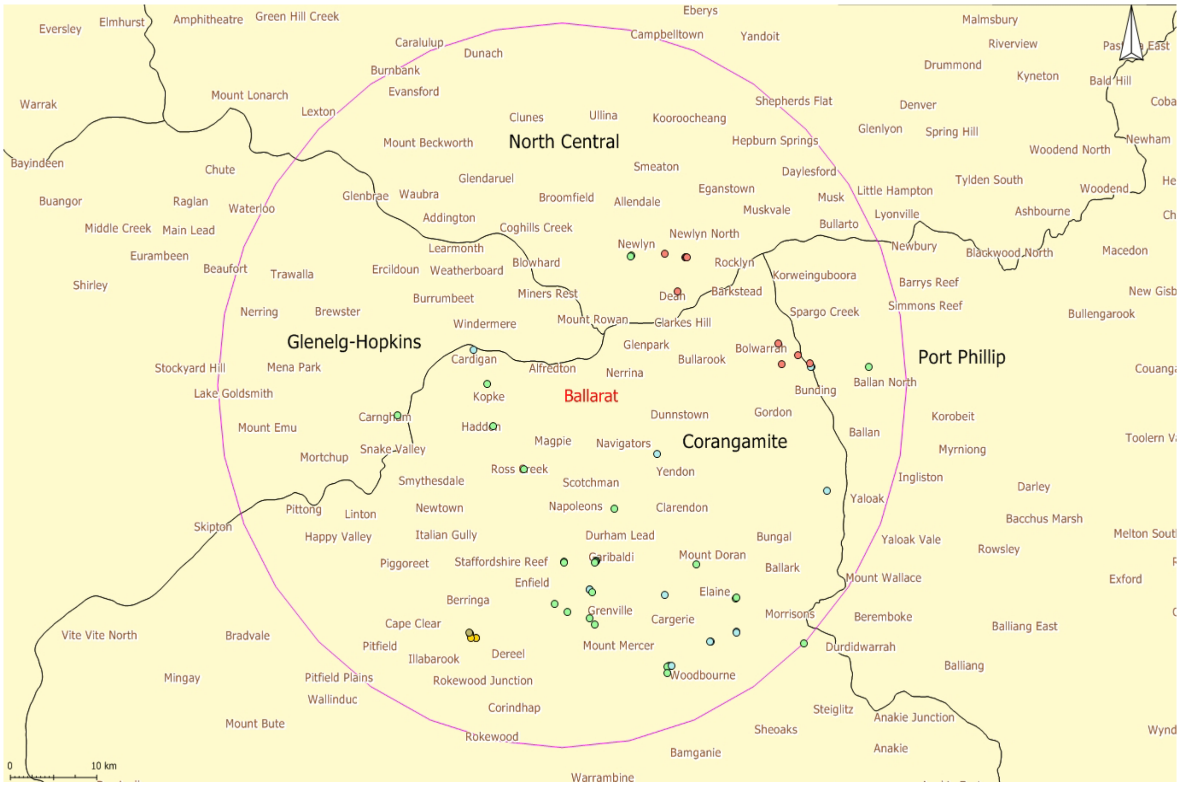

Figure 3. Location of assessed Snow Gum sites in the study area surrounding Ballarat

A good representation of these sites was attempted to ensure a range of land tenures, soil types, and locations in all directions from Ballarat were included (Figure 3). Thirty of the sites surveyed were part of Baker’s 1996 study, with the remaining 23 sites selected from locations discovered since. The original number of sites targeted for survey was forty-five, but time allowed assessment of an additional eight. Assessments were conducted from March-August 2008.

Sites occurred in four Catchment Management Authorities (CMA), with the majority located in the Corangamite CMA. Soils represented in the region were derived from Ordovician marine sandstones and sediments, Quaternary basalt and alluvial sediments from prior streams (Muir 1979). Topography ranged from flat or gently undulating, to low hills and rises. The area received an average of 705mm pa, with an average minimum temperature of 7.7˚C and average maximum temperature of 16.9 ˚C (BOM 2008). Vegetation in the study area varied, with sites occurring in woodlands and forests with grassy, sedgy, heathy or shrubby understoreys.

3.2 Data collection

3.2.1 Data sheet

Data was recorded on field data sheets designed with Microsoft Access 2007 (appendix II). These were developed through several trial sites to provide a comprehensive and convenient account of all variables while out in the field.

3.2.2 Site boundaries

All *E. pauciflora* ssp. *pauciflora* and *E. pauciflora* X *E. radiata* individuals were identified to determine the boundary of the sites occupied by these species. This was defined by the drip lines of the outermost mature or regenerating individuals. If the distance between individuals or patches of Snow Gums or hybrids was greater than 30m, the area became two separate sites for assessment. Different sites were also determined by changes in land tenure, even if trees were less than 30m apart. Site boundaries were recorded by attributing Global Positioning Satellite (GPS) waypoints using a Garmin GPS, recorded in WGS84 (latitude longitude decimal degrees).

3.2.3 Tree assessments

Snow Gums and Snow Gum hybrids were identified with the aid of a key (Appendix III) developed during discussions with Tim D'Ombrain with reference to *"Eucalypts of Victoria and Tasmania – South-Eastern Australia"* (Nicolle 2006) and "*Native trees and shrubs of South-Eastern Australia*" (Costermans 1994).

All mature snow gums were given a GPS waypoint that individual tree data was recorded against. Hybrids were given a GPS waypoint, but no further data was recorded. Trees with a diameter at breast height (dbh) of 5cm or greater were classified as mature, while those with a dbh less than 5cm was classed as regeneration and counted according to age class.

Tree height and dbh was recorded for each single stemmed mature Snow Gum using the methodology outlined in the Code of Forest Mensuration Practice (1999). The diameter of mallee or multi-stemmed trees was taken from the largest of the stems. Tree form was recorded as either single stem (single main trunk), base mallee (multiple stems arising from lignotubers at or below ground level) or multi-stemmed (multiple stems diverging above ground level).

Tree health, fruiting, flowering and presence of mistletoe were recorded using the same method as Baker (1996). Tree health was assessed by estimating the percentage of canopy death, and categorized according to a 5-point scale: 'very good health' (<25% of crown dead), 'good health' (25-50% of crown dead), 'poor health' (50-75% of crown dead), 'very poor health' (only epicormic growth on trunk or branches) or 'tree dead' (completely dead with no chance of regrowth). Fruit crop was categorised as 'light' (fruit or buds sporadic over tree, not easy to find), 'moderate' (fruit or buds distinct and common on tree, easy to find) or 'heavy' (fruit or buds distinct throughout crown, most possible sites are occupied). Presence of flowers or mistletoe was also recorded.

3.2.4 Vegetation communities and associated species

All identified species were recorded for presence and cover abundance at each site. Abundance cover was estimated visually using the Braun-Blanquet scale (Mirkin *et al.* 2005). Unidentified species were collected and labelled with site name, waypoint number and cover abundance, and identified back at the office. Collected species were preserved as herbarium specimens and used in the field to assist with further identification. Photographs were also taken of any difficult to identify species or individual specimens with unusual characteristics.

The vegetation community at the site was recorded, along with the percentage cover of ground covers such as bryophytes, native grasses and forbs, weeds, bare earth, leaf litter, rocks, and road. The length of logs greater than 100mm in diameter was also recorded for each site. These factors are deemed important indicators of habitat quality.

3.2.5 Soil

Sites were selected for soil analysis only if past disturbance was minimal and underground utility assets were absent. Soil samples were obtained using a 50mm soil auger, with each sample location given a GPS waypoint. When suitable, samples were taken both within and outside the site to determine any differences key soil characteristics such as texture, colour, pH and salinity (electrical conductivity). Only one sample was taken at sites with a single tree, while 2-3 samples were taken at larger sites.

The O horizon (litter layer) was measured using a ruler, and then samples were collected from the A and B horizons using the auger. Samples were taken and depths measured at each distinct change in colour or texture, with the B horizons divided into B1, B2, B3 and B4. Samples were placed directly into zip lock sandwich bags and labelled with date, site name, soil waypoint number, horizon and depth at which sample was taken. Additional observations about the site, location of sample within the site or soil characteristics were also recorded on the field data sheet.

All soil tests were conducted in the soil laboratory on the third floor of the Melbourne School of Land and Environment Faculty, Parkville, using equipment and resources supplied by the faculty. Texture was determined using the method described in "A Factual Key for the Recognition of Australian Soils" (Northcote 1979), and grouped for analysis in Soil Texture Groups. Colour was assessed by comparison with a Munsell Soil Colour Chart. Particle size distribution was another method available for determining soil texture, however this was deemed unsuitable for the project due to time constraints. Electrical Conductivity (EC) and pH were calculated using the method outlined in "Australian Soil and Land Survey Handbook" (McDonald *et al.* 1990), which used two replications of each sample in a 1:5 soil to distilled water solution. Replications were averaged for analysis.

3.2.6 Additional parameters

A range of additional parameters were recorded to determine the position of the site relative to the broader landscape. Site morphology and slope curvature categories were based on "Soil Data Entry Handbook" (Milford *et al.* 2001) (Appendix IV). Evidence of salting or erosion, as well as aspect and percentage slope was recorded, with slope estimated using a clinometer. Forms of site disturbance and competition were also recorded, in addition to land tenure, adjacent land use and whether the site had been fenced to exclude grazing. Adjacent land use categories were based on "Soil Data Entry Handbook" (Milford *et al.* 2001) (Appendix V).

Fruits were collected from mature trees by hand or with extendable loppers, and placed in specimen bags clearly labelled with date, site name and tree waypoint number. Seed was cleaned back at the office and kept in clearly labelled specimen jars with a sample of the fruit. Care was taken never to collect more than 10% of available fruit on a tree, and small amounts were taken from several trees in preference over large amounts from just a few.

Photographs were taken of Snow Gums and Snow Gum hybrids, as well as all sites to show the characteristics of sites relative to the surrounding landscape. By ensuring cameras were set to the correct date and time, photographs could be linked to sites by the start and end times for each assessment, and to individual waypoints by recording the photo time on the field data sheet. Where possible, photos were taken from the same vantage point as the original study to document changes visually.

3.2.7 Data loggers

Data loggers were used to record temperature and humidity at a property in Dereel where three separate populations of snow gums were identified for assessment. This site was chosen as the property represents a range of different vegetation communities, and is a Trust for Nature covenanted property set aside for the preservation of Snow Gums. This site also provided a safe location for the data loggers to remain for 12 weeks and to be checked regularly.

Eight locations across the property were selected based on vegetation type and position relative to the Snow Gum populations (refer appendix VI for map showing locations).

Figure 4. Position of temperature and humidity data logger

Three were positioned 20 cm south of the largest snow gum in each population, with the remaining five locations among *Themeda triandra, Xanthorrhea minor, Acacia mearnsii* where no Snow Gum regeneration occurred, as well as amongst regeneration.

At each location a wooden stake was driven into the ground and a plastic cup secured horizontally to the south side of each stake at 10 cm and 59 cm (Figure 4). The bottom of the cup was cut out to prevent accumulation of water and allow air movement. A data logger was attached with blu-tak to the inside upper surface of the cup, and netting secured around the cup to catch loggers if they became detached. Data loggers were programmed to record temperature and humidity every 30 minutes for 12 weeks from 6 July 2008.

3.3 Data Collation and Analysis

Data collected was manually entered (with the exception of the temperature data) into a Microsoft Access database where data could be manipulated and reports printed for proofing. Data analysis and visual presentations of results were created using Microsoft Excel and Microsoft Access.

3.4 Mapping

Maps were produced in Manifold System 8.0 Professional Edition using data linked to the Microsoft SQL Server back end database (Microsoft Access front end database). Polygons were drawn to create each site by connecting the boundary waypoints. Waypoints were colour coded and different symbols used to represent the different types of points – Snow Gums, Snow Gum hybrids, data loggers and soil cores. Areas of polygons were calculated in Microsoft Access.

4. Results

A total of 53 Snow Gum sites were assessed in the study area, 30 of which were part of the original study in 1996 by Baker. An additional 66 sites were known to occur in this area, but could not be assessed in the time available. Assessment was attempted on an additional 22 sites, however were not assessed either due access difficulties or as they could not be located. Sites were located at altitudes ranging from 323 m to 637 m asl.

The total area of 53 assessed study sites occupied by Snow Gums was 32 663 m^2 or 3.27 ha, averaging 616.28 m^2 or 0.06 ha per site. An additional three sites were recorded by GPS but were not assessed due to time constraints, one of which was almost as large as all other sites put together, at 3.14ha. The largest assessed site was 6385 m^2 or 0.6 ha at Souths Rd, Grenville, which also contained the majority of the *E. pauciflora* × *E. radiata* hybrids.

All 53 surveyed sites contained mature Snow Gums. Measurements for 326 mature individuals were recorded, however health data was missing for 1 tree. A total of 1052 Snow Gums were alive, of which 743 were regenerating individuals and an additional 18 mature trees were dead. Fifty *E. pauciflora* × *E. radiata* hybrids were identified and recorded by GPS.

Soil was analysed from 130 soil samples taken from 42 soil cores across the study area. 94 of these samples (28 cores) were within the sites, and 36 samples (14 cores) were outside the sites.

4.1 Distribution of the Ballarat Snow Gums

4.1.1 Landform

Snow Gums sites occupied a range of positions within the landscape in the study area (Table 1). Upper slopes were most frequently observed with 16 sites (30%), and Snow Gums were also frequently found in flat areas and mid slope, both with 12 sites or 23%. Depressions, lower slopes, crests and ridges were also occupied by Snow Gums, but were less common for the assessed sites.

The curvature of slopes where the sites were situated was usually parallel (38 sites), with 11 sites with convergent slope curvature and 4 sites with divergent slopes. A chi square analysis demonstrated a significant relationship between the number of sites in each position on slope according to slope curvature, with a p value of 0.017.

Table 1. Number of sites with Snow Gums at each position in landscape with slope curvature (convergent, divergent, parallel)

Site Morphology	Convergent	Divergent	Parallel	Total No. of Sites	Proportion of sites with regeneration
Depression	2	0	0	**2**	0%
Flat	0	1	11	**12**	50%
Lower Slope	1	0	5	**6**	33%
Mid Slope	3	0	9	**12**	83%
Upper Slope	5	1	10	**16**	56%
Crest	0	2	2	**4**	75%
Ridge	0	0	1	**1**	100%
Total	**11**	**4**	**38**	**53**	
Proportion of sites with regeneration	36%	75%	63%		

Of the assessed sites, Snow Gums only occurred in areas that were very gently inclined to moderately inclined, with no sites occurring when the slope was greater than 32% (Table 2). Most frequently the sites occurred on areas slopes that were very gently inclined, with 25 sites (47%). Gently inclined slopes were also frequently occupied by Snow Gums, with 18 sites (34%). The remaining 10 assessed sites (19%) were found on slopes that were moderately inclined with percentage slopes of 11-32%. Three of these sites were on 30-32% slopes.

Table 2. Number of sites with Snow Gums at each percentage slope

Percentage Slope	Description	Number of Sites	Proportion of sites (%)
0-3%	Very Gently Inclined	25	47
4-10%	Gently Inclined	18	34
11-32%	Moderately Inclined	10	19
33-56%	Steep	0	0

4.1.2 Aspect

The 28 assessed sites with a slope greater than 3% varied in aspect, with no significant difference found between aspects. More sites (seven or 25%) had a southerly aspect, while five sites had westerly and four had north-westerly aspects. Either two or three sites faced each of the other aspects.

Regeneration occurred on at least one site facing each different aspect. Sites facing south had recruitment most often with four sites, while two sites facing north-easterly and south-easterly, and three sites facing west also had regeneration occurring. A higher number of seedlings were found on sites with a northerly, easterly, southerly, or south-westerly aspect. Only six seedlings were found on sites facing west, and five on sites facing north-west. The number of sites facing any particular aspect was not different enough to conclude aspect has an effect on the distribution or regeneration of Snow Gums.

4.1.3 Soil

Soils maps for the region indicated the sites occurred on a range of soils derived from Ordovician marine sediments, sandstones and shales; Quaternary basalt; Tertiary unconsolidated deposits; and Palaeozoic sedimentary sandstones and mudstones (Robinson *et al.* 2003). Nine broad soil groups were identified, as shown in Table 3. Red friable earths (Rx), Yellow duplex soils, grey clays, Red friable earths (Ye), and Yellow duplex soils, mottled duplex soils (Yf) were the most common soil types mapped for the study sites. Ten sites appeared to occur on a change of soil type, and another 19 sites were within a few hundred metres of a different soil type (refer Appendix VII for soil map). This was based on 1:250 000 scale maps, which are subject to inaccuracy due to the coarse scale. These soil groups occurred on a range of Soil Landform Units, which were more accurately mapped from ground truthing in the Corangamite CMA (Robinson *et al.* 2003).

Table 3. Number of study sites on each soil type according to soil maps in the region

Soil Land-form Unit	Code	Soil Group Name	No. of sites	No. of sites on edge with another soil group
14	Dd	Duplex soils	3	1
20	Ma	Mottled duplex soils	1	0
9	Rp	Red duplex soils, Yellow duplex soils	3	0
9, 38, 43, 50, 52	Rx	Red friable earths	15	3
23	Szb	Shallow stony loams, Yellow duplex soils	5	1
50	Yd	Yellow duplex soils, Grey clays	1	0
23, 31, 32, 50	Ye	Yellow duplex soils, Grey clays, Red friable earths	12	5
23, 27	Yf	Yellow duplex soils, Mottled duplex soils	10	0
20	Yt	Yellow earths, Yellow duplex soils	3	0

According to soil map descriptions, soils described range from sands, to sandy soils over a clay sub soil which are strongly acid throughout, and texture contrast soils.

4.1.3.1 Colour

Soil samples from the study area were various hues of yellow, brown, red, and grey, when assessed against Munsell Colour Charts. When grouped into colour classes using the Australian Soil Classification, "brown" soils were most common with 46% of samples within sites, and 56% of samples outside the sites. Also frequently found were "black" soils, with 30% of samples within the sites and 33% of samples outside the sites. "Grey" soils were recorded for 17% of samples within the study sites, and 8% of samples outside the sites. Soils of the colour class "red" were identified for just 7% of samples from inside the sites, and 3% of samples outside the sites. There was no clear difference in colour between samples inside the sites and outside the sites.

4.1.3.2 Texture

Snow Gums were found to occur on a range of soil types across the study area. Soils inside the study sites fall in soil texture groups ranging from sandy loams to light clays at the A horizon, generally increasing in clay content with depth. Soils outside the study sites occurred on sands to light clays at the A horizon, with a range of soil textures with depth.

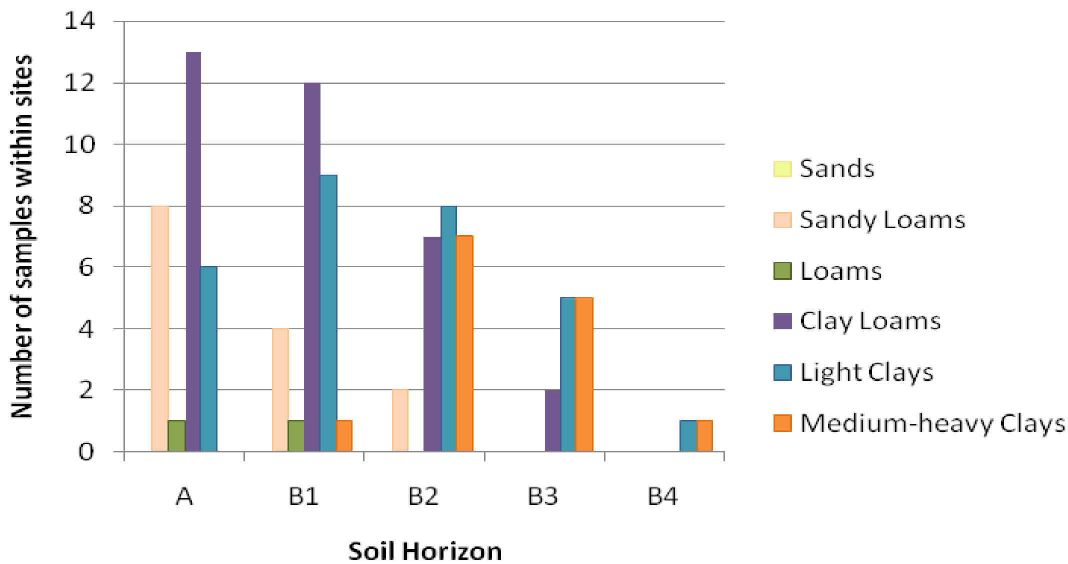

Figure 5. Number of samples within sites of each soil texture group for each horizon

Of the samples analysed within the study sites, the soil texture groups most frequently found were clay loams, light clays, sandy loams and medium-heavy clays (Figure 5). No sampled Snow Gum sites were sands, and only 1 sample in the A and B1 horizons belonged to the loam texture group.

The A horizon samples were most frequently clay loams (13 samples), sandy loams (eight samples) and light clays (six samples). Clay loams were also most common for the B1 horizon with 12 samples, with light clays (nine samples) and sandy loams (four samples) also being frequently found. The B2 horizons increased in clay content, with light clays most frequent (eight samples), followed by medium-heavy clays and clay loams with seven samples each. Increased clay content continued with depth, with the B3 and B4 horizons both mostly found with light clays or medium-heavy clays.

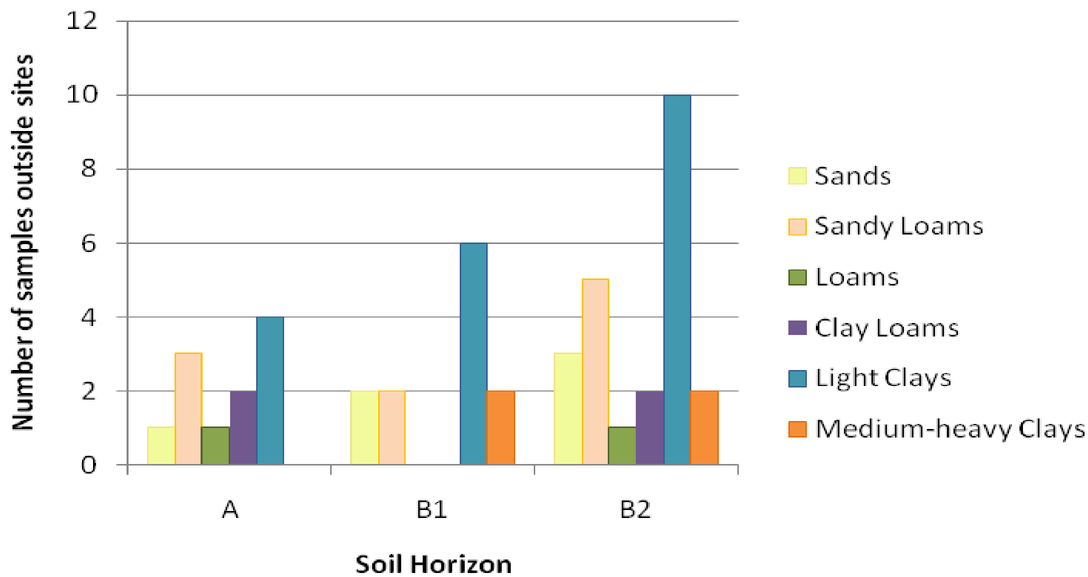

Figure 6. Number of samples outside sites of each soil texture group for each horizon

Soils from outside the sites were most frequently from the soil texture groups of light clays, sandy loams, and sands, however samples of loams, clay loams and medium-heavy clays were also recorded (Figure 6). The A horizons were mostly light clays (four samples), sandy loams (three samples) and clay loams (two samples), while the B1 horizons were also mostly light clays (six samples), with sands, sandy loams and medium-heavy clays also being found for three samples each. All soil texture groups were represented in the B2 horizon, with light clays being the most common with 10 samples. Sandy loams and sands were the next most common samples with five and three samples respectively.

4.1.3.3 pH:

Soil samples collected from within the sites ranged in pH from 3.52 (very strongly acidic) to 6.16 (slightly acidic). Only one site (B071 Remembrance Drive) recorded pH of less than 4 (all samples), an acidity range which most plants will not tolerate. Samples outside the sites ranged in pH from 4.56 (strongly acidic) to 6.20 (slightly acidic).

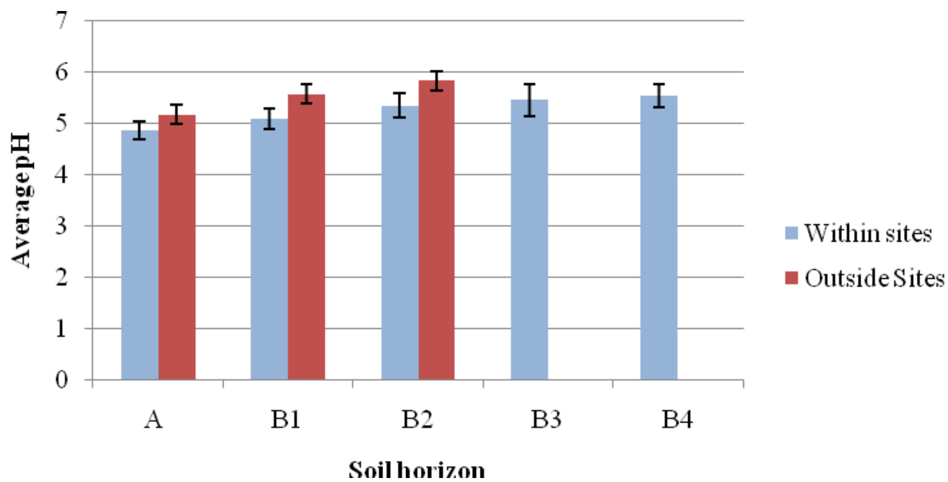

Figure 7. Average pH of each soil horizon within and outside sites in study area, with 95 % confidence interval error bars

Figure 7 compares the average pH of each soil horizon within and outside all sites sampled in the study area with 95% confidence interval error bars. All soils were within the acidic pH range, however there was a clear increase in pH with depth for soil both within and outside the sites. Soils within the study sites were consistently more acidic than soils outside the sites.

The average pH of soils within the sites increased from 4.87 (strongly acidic) at the A horizon to 5.55 (moderately acidic) at the B4 horizon, while the average pH of soils outside the sites increased from 5.19 (moderately acidic) at the A horizon to 5.84 (moderately acidic) at the B2 horizon. There were no B3 and B4 samples at locations outside the sites. With 95% confidence, there was a significant difference in the means of soils within sites and outside sites for the A, B1 and B2 horizons.

4.1.3.4 Electrical Conductivity:

Soils sampled within study sites ranged in EC from 24.04 - 307.5 µs cm^{-1}, with the exception of one sample which recorded 1336 µs cm^{-1}. Soils outside the sites ranged in EC between 11.38 µs cm^{-1} and 151.6 µs cm^{-1}. No soil samples were considered saline, except the one sample of 1336 µs cm^{-1} or 1.336 dS/m at the Remembrance Drive site.

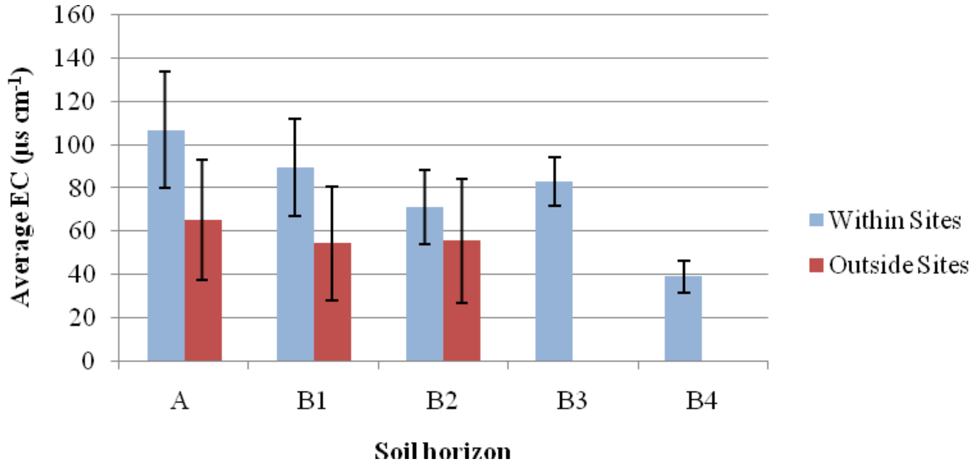

Figure 8. Average EC (µs cm^{-1}) of each soil horizon within and outside sites across study area, with 95% confidence interval error bars

Average EC (µs cm^{-1}) was consistently higher for soil samples inside the study sites compared to outside the sites, with a slight decrease in EC with depth for both groups of samples (Figure 8). However there was no significant difference in the mean EC for soils inside and outside the sites for horizon A, B2 and B2, tested at the 95% confidence interval level. The range of the confidence interval bars shows there was a lot of variability in the means, particularly for A, B1 and B2. There was a significant difference in the average EC of B3 and B4 horizons within the site, with a reduction of 43.84 µs cm^{-1}.

One soil sample was omitted from these results as it was deemed to be an outlier that was skewing the data. This sample was far higher than all other samples, with an average of 1336 µs cm^{-1}. With this result included, the average EC of the B2 horizon was 121.77 µs cm^{-1}, compared to 71.17 µs cm^{-1} as shown in figure 8. The result of no significant difference in mean EC was not affected.

4.1.4 Vegetation community and associated species:

4.1.4.1 Associated species:

At the study sites assessed, *E. pauciflora* ssp *pauciflora* was found associated with 166 different species, of which 111 were indigenous and 55 were exotic (including one native not indigenous to the area). A rare species, Clover Glycine *Glycine latrobeana* was located at two sites. Species indicative of a range of environmental conditions were located, such as *Einadia nutans* (dry conditions), and *Poa labillardieri* and *Juncus spp.* (wet conditions). For full species list refer Appendix VIII.

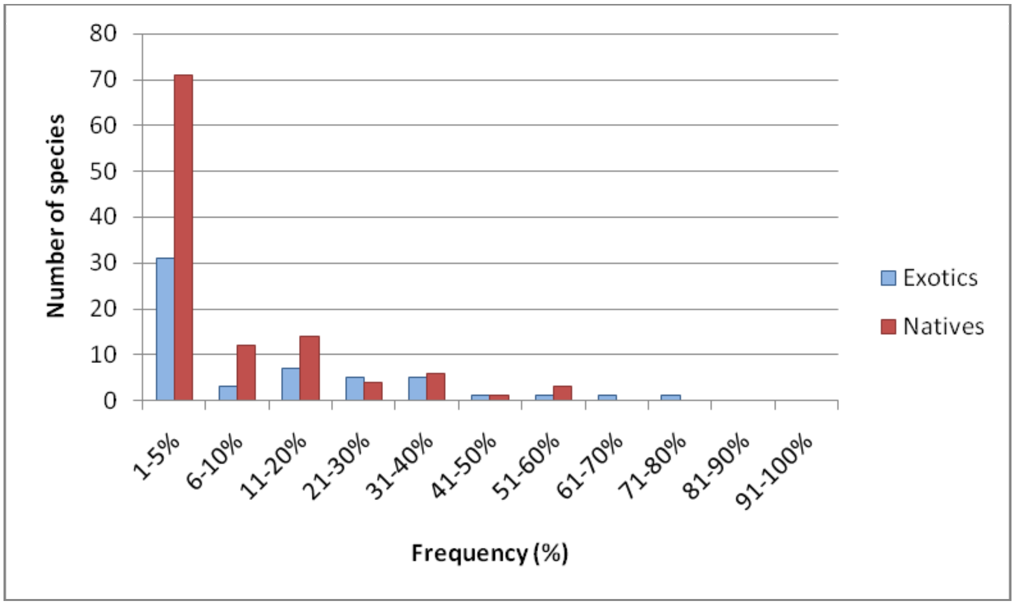

Figure 9. Percentage frequency of occurrence at study sites of exotic and native species

The majority of species recorded (102 species or 61% of the total number of species) were present at only 1-5% of sites (Figure 9). Of these 71 were natives and 31 were exotic. Another 15 species (9%) occurred at 6-10% of the sites, with 12 natives and three exotics. Thirteen native and eight exotic species occurred more frequently at 11-20% of sites, however the number of species continued to decrease with occurrence at a high percentage of quadrats. Only one species occurred in 61-70% and 71-80% of quadrats, both of which were exotics. No species occurred in greater than 80% of sites assessed with Snow Gums.

Trees most commonly found with *E. pauciflora* ssp. *pauciflora* were Blackwood *Acacia melanoxylon* (52%), Black Wattle *Acacia mearnsii* (21%), Radiata Pine *Pinus radiata* (16%), Snow Gum x Narrow-leaf Peppermint Hybrid *E. pauciflora* × *E. radiata* (16%), Swamp Gum *E. ovata* (14%), Manna Gum *E. viminalis* ssp *viminalis* (13%) and Narrow-leaf Peppermint *E. radiata* (9%).

Shrub layer species were most frequently exotics such as Gorse *Ulex europaeus* (32%), Hawthorn *Crataegus monogyna* (29%) and Sweet Briar *Rosa rubiginosa* (21%). Few large native shrubs were identified, however small and prostrate shrubs were frequently identified, including Cranberry Heath *Astroloma humifusum* (23%), Common Rice Flower *Pimelea humilis* (21%), and Creeping Bossiaea *Bossiaea prostrata* (17%).

Ground layer species occurred much more frequently than tree and shrub layer species, with a range of exotic and native species. Exotics included *Acetosella vulgaris* (71%), *Hypochoeris radicata* (70%), *Plantago lanceolata* (57%), *Cirsium vulgare* (45%). Natives included *Lomandra filiformis* (54%), *Oxalis perennans* (52%), *Acaena novae-zelandiae* (43%).

A range of native and exotic grasses were recorded, Kangaroo Grass *Themeda triandra*, Tussock Grass *Poa spp*, Weeping Grass *Microlaena stipoides*, Wallaby Grass *Austrodanthonia spp* and Spear Grass *Austrostipa spp* each occurring in 34-39% of sites. Brown-top Bent *Agrostis capillaris s.l.* and Rough Dog's-tail *Cynosurus echinatus* were the most common exotic grasses in 34% and 27% of sites respectively. Cocksfoot *Dactylis glomerata*, Large Quaking-grass *Briza maxima*, Couch *Cynodon dactylon* and Paspalum *Paspalum dilatatum* were also frequently found, at 14-18% of sites.

While Baker (1996) found 28% sites assessed in 1996 had no native vegetation associated with *E. pauciflora* ssp *pauciflora*, there was native vegetation at 94% of sites in 2008.

4.1.4.2 Ecological Vegetation Classes:

Table 4 shows the number of sites that occurred in the range of Ecological Vegetation Classes (EVC) in the study area, based on EVC maps and keys, and the different species present in each site. Valley Grassy Forest (47) was the most common EVC, occurring at 26 sites (49%).

Plains Grassy Woodland (55) was also frequently represented, occurring at 12 sites (23%), while Herb-rich Foothill Forest occurred at nine sites (17%). Other sites occurred in Grassy Woodland (175) and Valley Heathy Forest (127). While Valley Heathy Forest is not mapped for this area, the diversity and abundance of the associated species at these sites fits better than other EVCs. Refer Appendix IX for EVC map with study sites.

Twenty-four sites (45%) occurred in an ecotone, on the edge with another EVC, which were most commonly EVCs where Snow Gums had been located at other sites. Stony Knoll Shrubland (649) and Damp Sands Herb-rich Woodland (three) were additional EVCs adjoining the sites.

Table 4. Ecological Vegetation Classes (EVC) sites occurred in

EVC Code	EVC Description	No. of Sites	No. of sites on edge with another EVC	Code of adjoining EVCs
23	Herb-rich Foothill Forest	8	1	55
47	Valley Grassy Forest	26	13	3, 23, 55, 649
55	Plains Grassy Woodland	12	6	47
127	Valley Heathy Forest	2	2	47, 175
175	Grassy Woodland	3	2	3, 127

4.1.5 Climate:

Table 5 shows the minimum and maximum temperatures for July, August and September 2008, with height and location of data logger. Temperatures were lowest for all three months at Data Logger location SGP193 in Themeda Grassland, with a minimum of -6 °C in July. Maximum temperatures were recorded at different locations for each month, with the highest temperature recorded in September 2008 of 40.5 °C amongst the Grass Trees (SGP198a). Accuracy in readings was +/- 0.5 °C.

Table 5. Minimum and maximum temperatures for July, August and September 2008, with height and location of data logger

Month	Min	Height (cm)	Location of Logger	Max	Height (cm)	Location of Logger
Jul-08	-6	10	Themeda Grassland (SGP193a)	29	10	Themeda Grassland (SGP193a)
					10	Mature Snow Gum (SGP192a)
Aug-08	-5.5	10	Themeda Grassland (SGP193a)	34	10	Snow Gum Regeneration (SGP 199a)
Sep-08	-4	10	Themeda Grassland (SGP193a)	40.5	10	Grass Trees (SGP198a)

There was variation in average minimum and maximum temperatures across data logger locations at the property in Dereel. Monthly averages ranged from minimum temperatures of 0.29 °C in July at the Themeda Grassland location (SGP193a, 10 cm) to 5.8 °C in September at a mature Snow Gum location (SGP197a 59 cm). Monthly average maximum temperatures were also highly variable between data logger locations, ranging from 11.73 °C in July at a mature Snow Gum (SGP197a 10 cm) to 29.63 °C in September at the Grass Tree location (SGP198a, 10 cm)

4.1.6 Land use and competition:

4.1.6.1 Tenure:

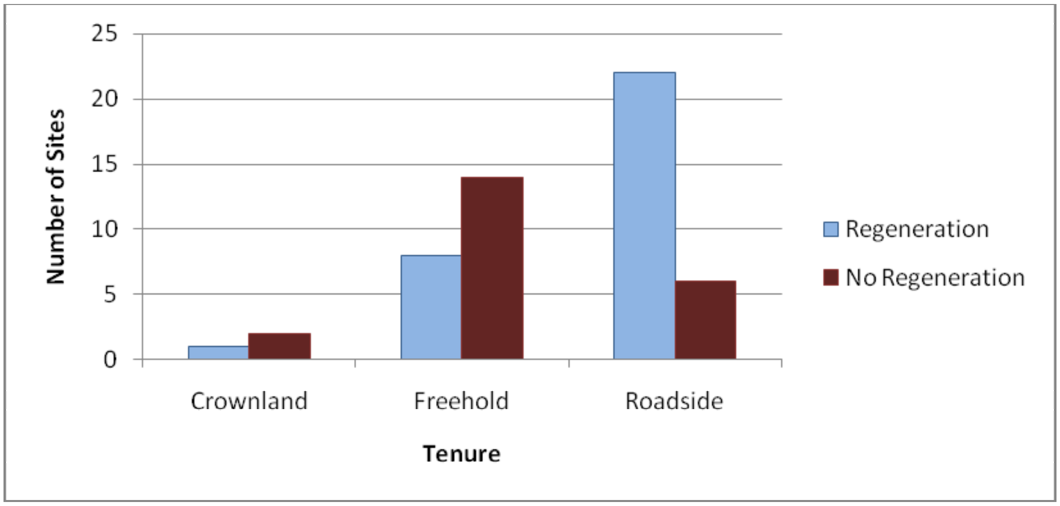

Figure 10. Number of sites on crown land, freehold and roadside with regeneration and no regeneration

Of the 53 sites assessed, 28 were on roadsides, 22 on freehold and three on crown land (Figure 10) Of the roadside sites assessed, 22 (79%) had regeneration and six (21%) had no regeneration. Freehold sites had regeneration occurring on eight sites (36%), while 14 (64%) showed no signs of seedling recruitment. Crown land sites had recruitment on just one of the three sites, and consisted of just one seedling. A chi square analysis of the number of sites with regeneration according to land tenure demonstrated a significant relationship with a P value of 0.038.

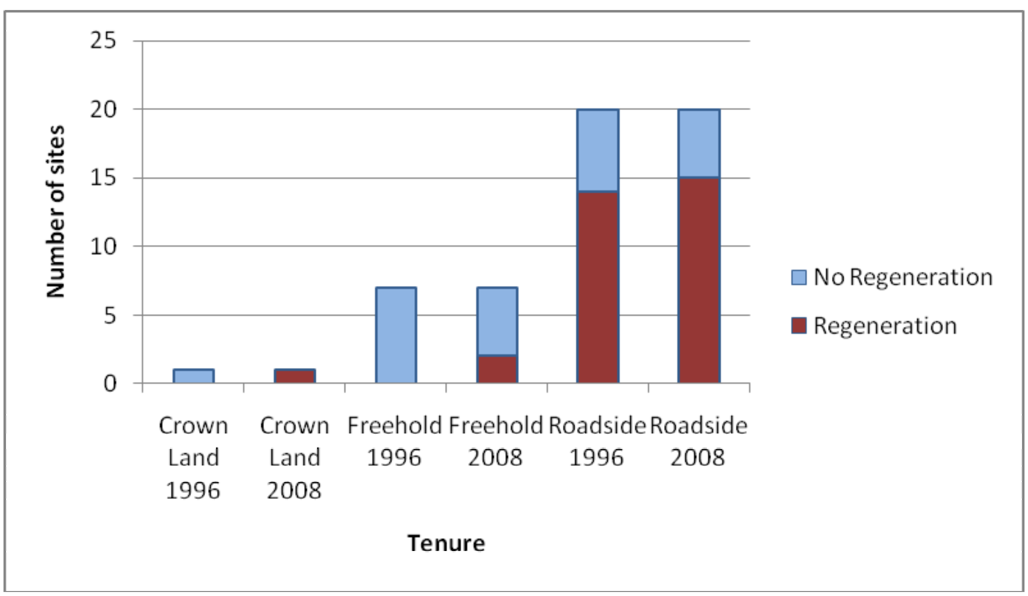

Figure 11. Number of sites with regeneration and no regeneration on different tenure for 1996 and 2008

Of the 30 sites assessed in 1996 that were also assessed in 2008, 28 had regeneration information for comparison (Figure 11). The one crown land site had no regeneration in 1996, however it had one seedling in 2008. The seven freehold sites in 1996 all had no regeneration, while in 2008 two of these sites had regeneration. Of the twenty roadside sites assessed, the number of sites with regeneration increased slightly from 14 to 15, with sites with no regeneration decreasing slightly from six to five. Overall the sites with regeneration present increased from 14 sites in 1996 to 18 in 2008.

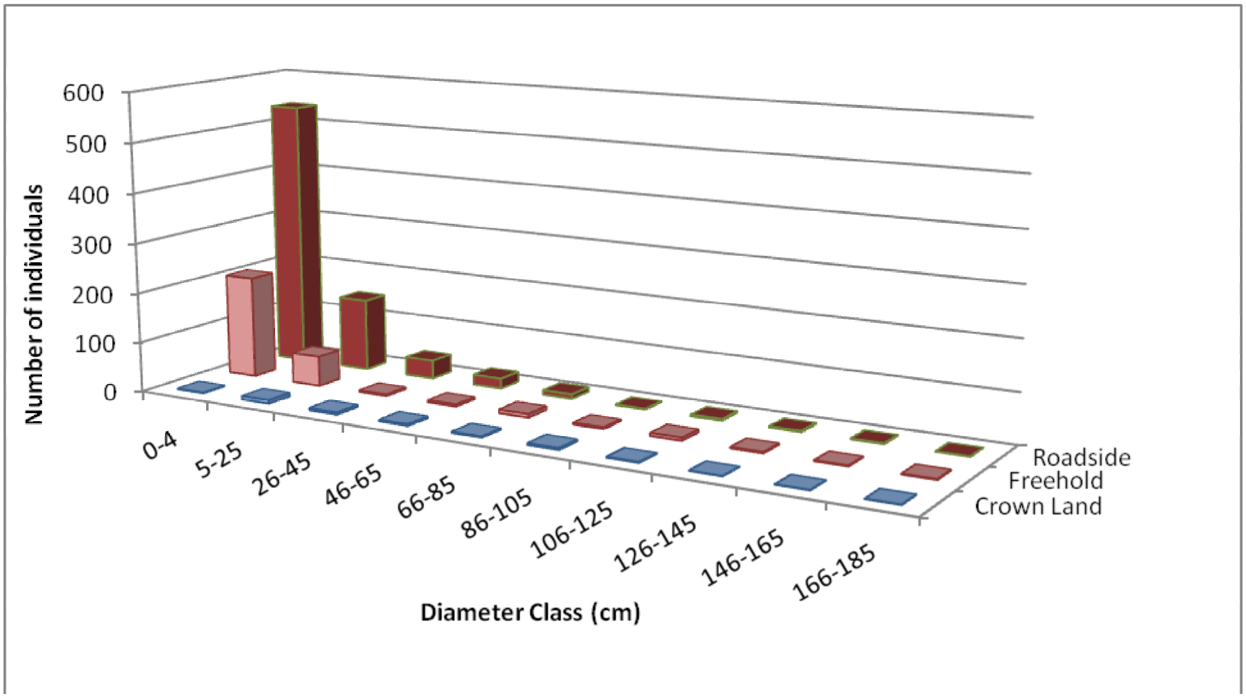

Figure 12. Number of individual Snow Gums in each diameter class (cm) on crown land, freehold and roadsides

Figure 12 displays the number of individual snow gums in each diameter class according to tenure. The number of individuals decreases with an increase in diameter across all tenures, with more individuals recorded on roadsides than freehold or crown land for most diameter classes. The only snow gum in the largest diameter class of 166-185 cm was on freehold.

The majority of Snow Gums occurred in the 0-4 cm diameter class as regeneration on roadsides, with a total of 537 trees. This represented 72% of the total number of recruited individuals on just 55% of the total number of sites. A high number of individuals were also located on roadsides in the 5-25 cm diameter class, with 146 individuals, or 69% of all individuals in that diameter class. The number of individuals continued to decline as the diameter class increased.

Freehold sites decreased rapidly from 205 individuals at 0-4 cm, to 60 individuals at 5-25 cm diameter class, after which few individuals occurred in any diameter class. Crown land sites recorded few individuals in any diameter class, however these three sites only accounted for 5% of the total sites. The highest number (seven individuals) occurred at 5-25 cm diameter class, with only one seedling in 0-4 cm, and no Snow Gums larger than 106-125 cm.

The relationship between the numbers of individuals in each diameter class according land tenure was explored by calculating the chi-square value of 8.38×10^{-20}, demonstrating it was highly significant.

4.1.6.2 Disturbance:

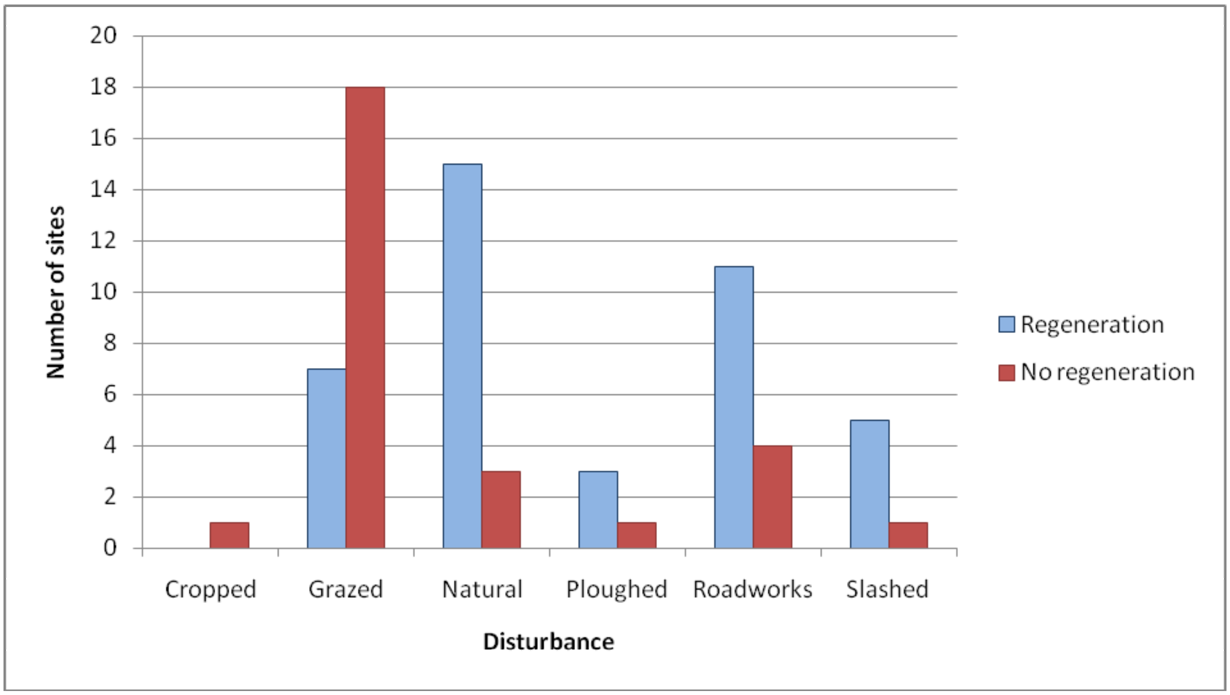

Figure 13. Number of sites with regeneration or no regeneration when exposed to different disturbance

Many sites were subjected to more than one disturbance (Figure 13). Regeneration occurred at the greatest number of sites (15) when under natural disturbance conditions, with just 3 sites where regeneration was restricted.

Of the 25 sites exposed to grazing, 18 had no regeneration and seven had regeneration. Of these sites, 15 were exposed only to grazing as a disturbance, of which 13 had no regeneration. The one site exposed to cropping showed no regeneration. Sites ploughed, slashed or exposed to roadworks recorded more sites with regeneration than no regeneration.

4.2 Health of the Ballarat Snow Gums

4.2.1 Individual Snow Gum health

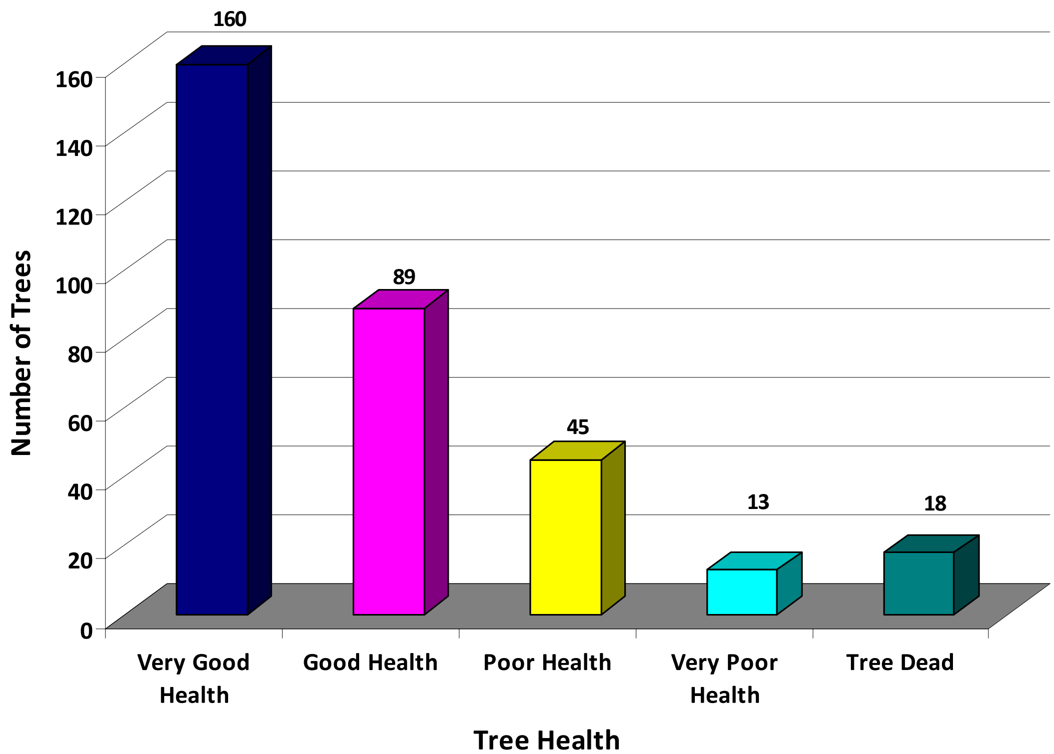

Figure 14: The number of snow gums in each health category

Approximately 49% (160 individuals) of the mature Snow Gums surveyed were found to be in very good health. Less than a quarter of all Snow Gums were found to be dead, in poor health or in very poor health. Figure 14 gives a clear indication of the high proportion of trees in the very good and good health categories

4.2.2 Snow Gum site health

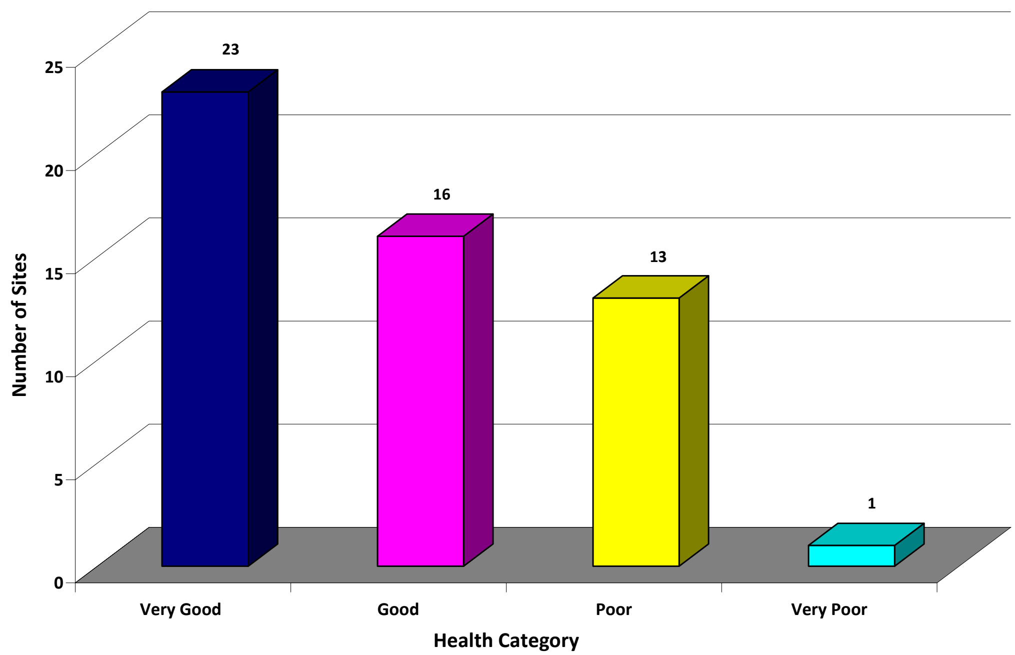

Figure 15: The number of sites in each health category

The overall health of each site was calculated by averaging the health of all trees at that particular location. Almost 75% of surveyed sites were in very good or good health (Figure 15).

4.2.3 Comparison with 1996 data

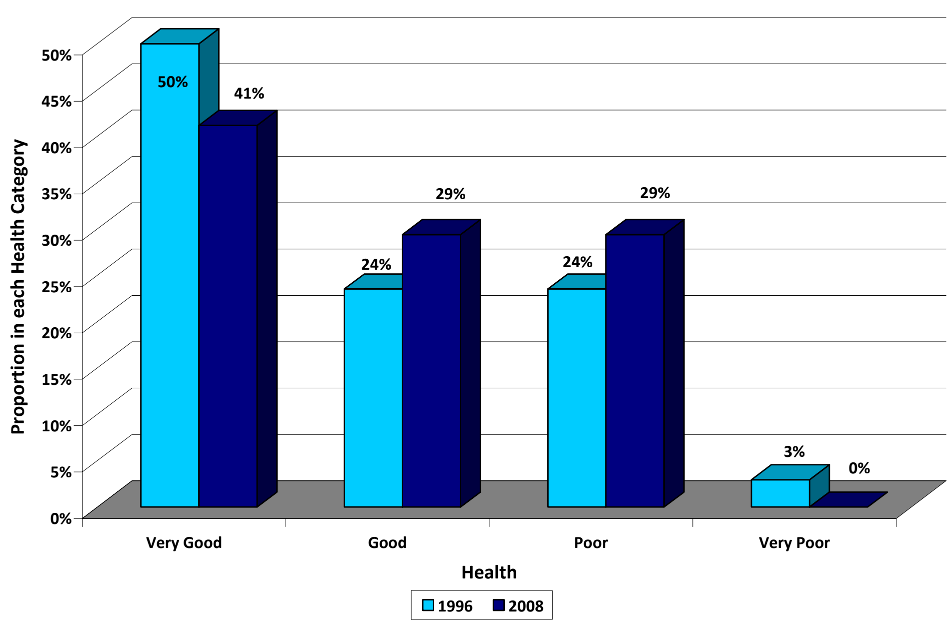

Figure 16: Proportion of sites in each health category

The 2008 study included 30 sites that were surveyed during the original 1996 project. Both studies observed that the majority of trees were in good or very good health (74%). Although the 2008 project assessed a much higher number of trees within the 30 sites due to regeneration since 1996, the proportion of Snow Gums in the very good health category had decreased from 50% to 41% across mutually studied sites. The decrease in trees in very good health has been evenly distributed to the good and poor health categories (Figure 16).

4.2.4 Mistletoe

Table 6: Parameters associated with mistletoe infested trees

Site Number	Health	Fruit Crop	DBH (cm)	Form
6	Very Good	Moderate	60	Multi Stem
6	Very Good	Moderate	19	Multi Stem
16	Poor	Moderate	108	Single Stem
44	Poor	Moderate	166	Single Stem
53	Good	Light	134	Single Stem

Mistletoe infestations amongst the Ballarat Snow Gums appeared to be quite low with only five of 307 trees hosting mistletoe (1.6%). None of the Snow Gums bearing mistletoe was bearing heavy crops of fruit (Table 6).

4.2.5 Flowering

Table 7: Parameters associated with flowering trees

Site Number	Form	Mistletoe Present?	Health	Fruit Crop	Tenure	Fenced?	Survey Date
29	Single Stem	No	Good	Heavy	Freehold	Yes	6/6/2008
41	Single Stem	No	Poor	Moderate	Crown Land	No	3/8/2008
54	Base Mallee	No	Good	Light	Roadside	No	10/6/2008
54	Single Stem	No	Very Good	Light	Roadside	No	10/6/2008
54	Single Stem	No	Poor	Light	Roadside	No	10/6/2008
54	Base Mallee	No	Very Good	Light	Roadside	No	10/6/2008

Only six of the 307 Snow Gums surveyed were in flower (2%). Flowering occurred at only three of the 53 sites with mature Snow Gums present (Table 7) because the survey was conducted outside the normal flowering period of October-January. The individuals flowering ranged in health from poor to very good.

4.2.6 Fruit crop

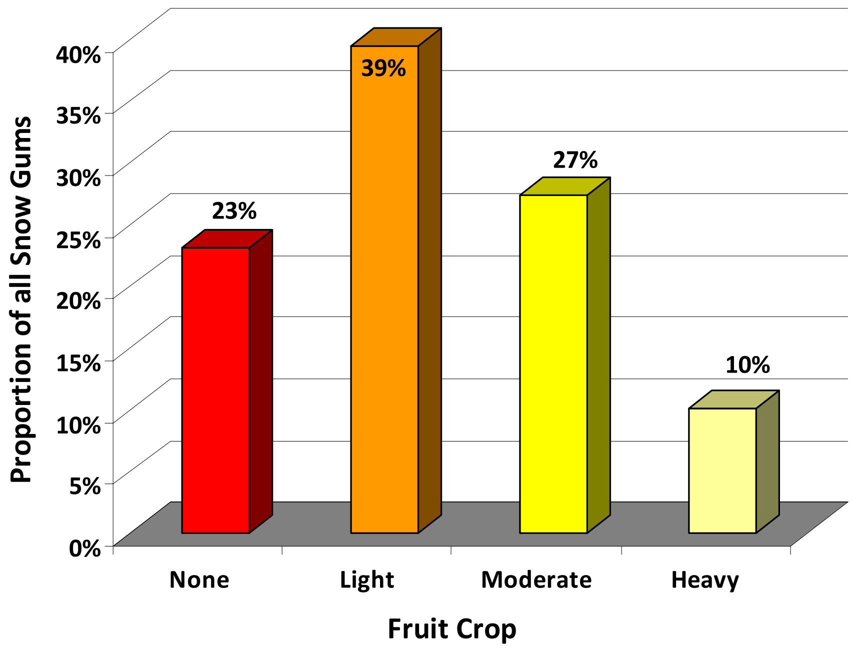

Figure 17: Proportion of Snow Gums in each fruiting status

The fruiting status of the Ballarat Snow Gums is displayed in Figure 17, with a total of 77% of the 307 mature individuals bearing fruit. Only 10% of these trees had a heavy fruit crop whilst two thirds of the surveyed trees had light or moderate crops.

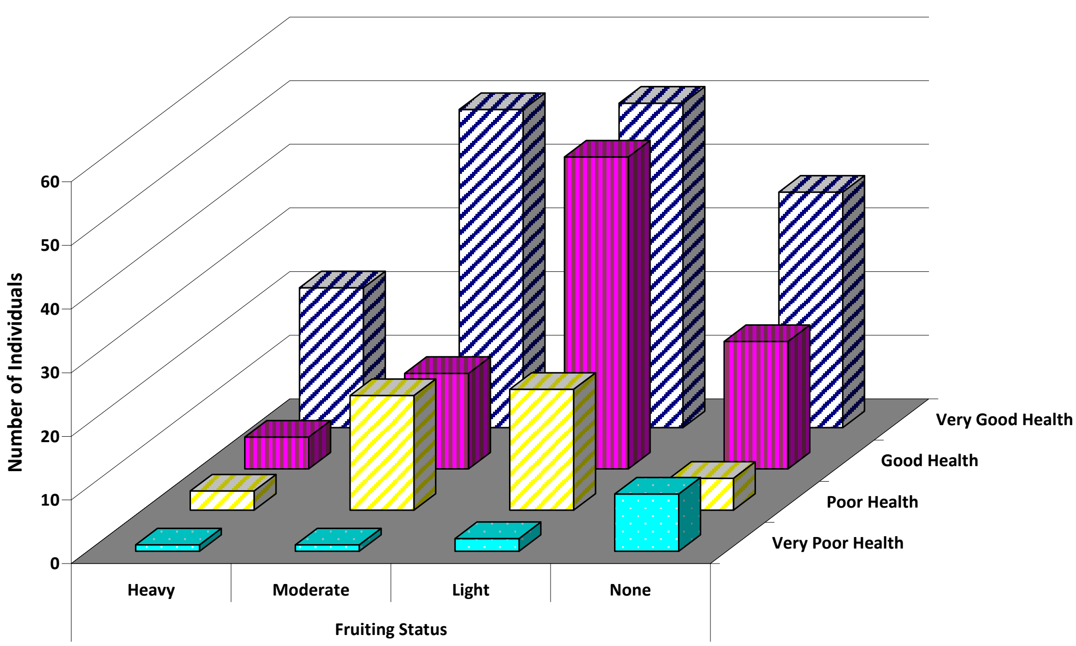

Figure 18: The number of Snow Gums in each fruiting category according to health

The results indicated a positive correlation between the health status of individual Snow Gums and the fruit crop they bear. Figure 18 displays the fruit crop according to health status which had a significant chi square value of $P = 1.7267 \times 10^{-5}$. There were six more trees in very good health with heavy crops and four less with moderate crops than would have been expected if there was no correlation between health and fruiting category. Seven more trees in good health had heavy crops and ten less had moderate crops than was expected, whilst there were 12 less trees in poor health with heavy crops than would be expected if fruiting and tree health were not correlated. There was three times the amount of individuals in very poor health with no fruit than expected.

4.2.7 Tree Form

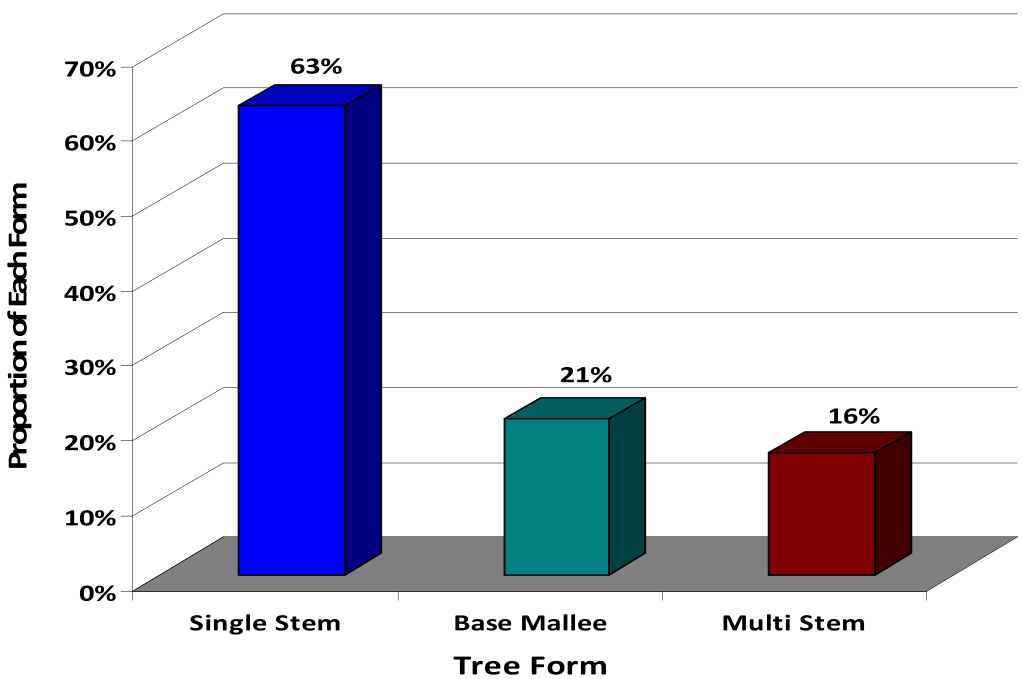

Figure 19: Proportion of Ballarat Snow Gums with each form

The majority of Ballarat Snow Gums (63%) have a single main trunk (Figure 19). Of the 53 sites, 21 contained only single stem trees therefore 32 had either mallee or multi forms present. Only eight of these sites had both mallee and multi-stem forms together. A total of 20 sites had mallee forms present and 20 sites had multi forms present. The Ballarat Snow Gum population contained more individuals with the mallee form than the multi-stem form.

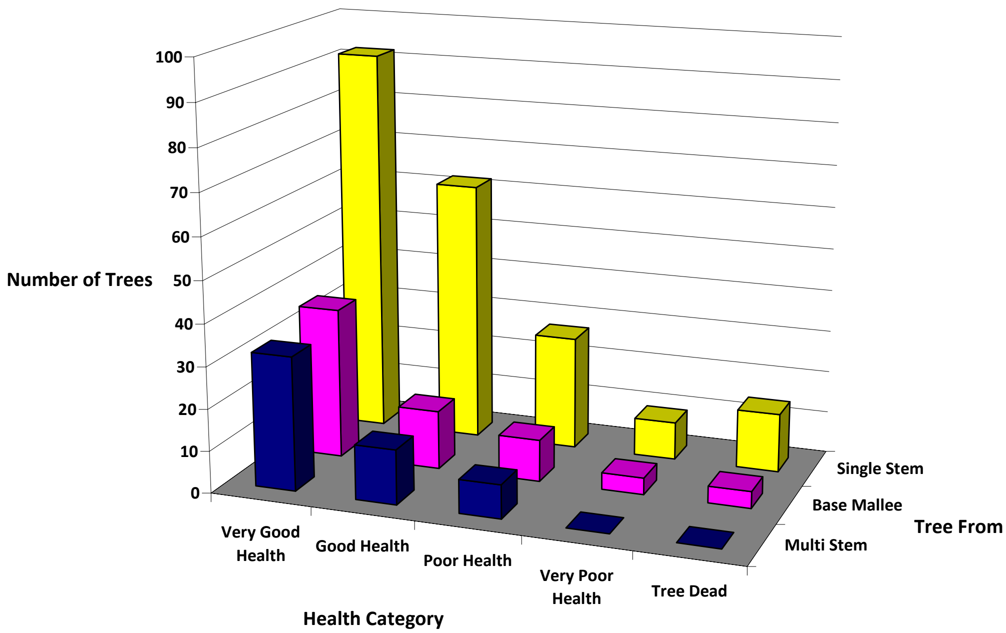

Figure 20: The number of Snow Gums with each form according to health category

Interestingly, the multi stem trees had no individuals in the very poor or dead health categories (Figure 20). The proportion of individuals in good health was much higher for single stemmed trees than mallee or multi-stemmed. Although slight patterns emerged between the health and form of individual trees a chi square analysis found that these parameters were not correlated.

4.2.8 Diameter Breast Height (DBH)

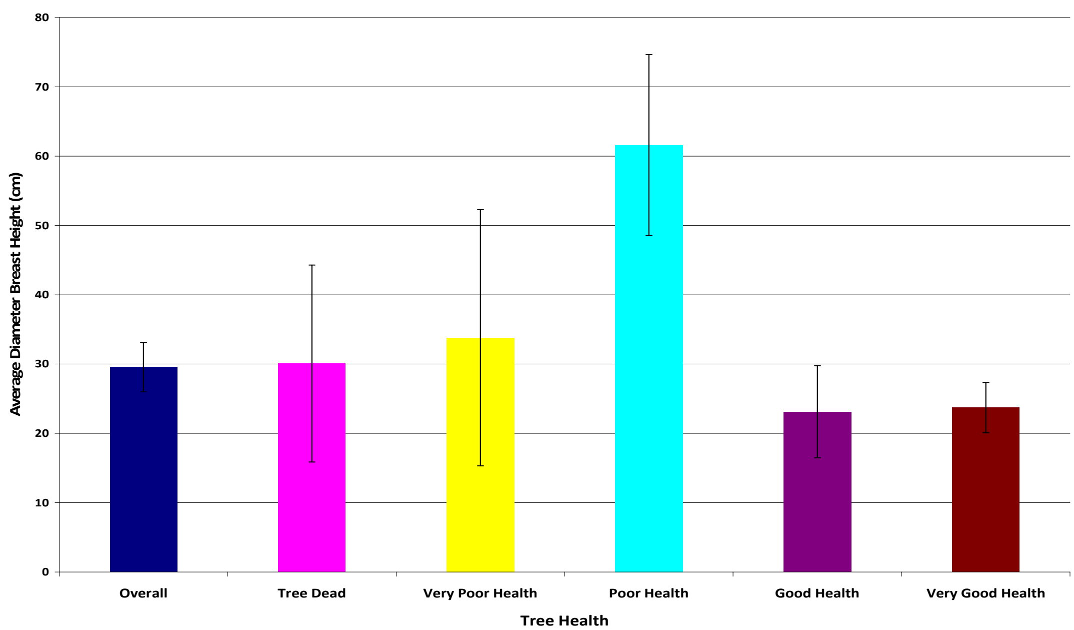

Figure 21: The average diameter at breast height (DBH) of Snow Gums for each health category (95% CI's)

Figure 21 shows the average DBH for each health category. These results show that the Ballarat Snow Gums in poor health are on average significantly larger (62 cm) than any other health category, including the average for the total number of trees. The very good health category (24 cm) was significantly smaller than the average (30 cm) and the poor category.

4.2.9 *Land Tenure*

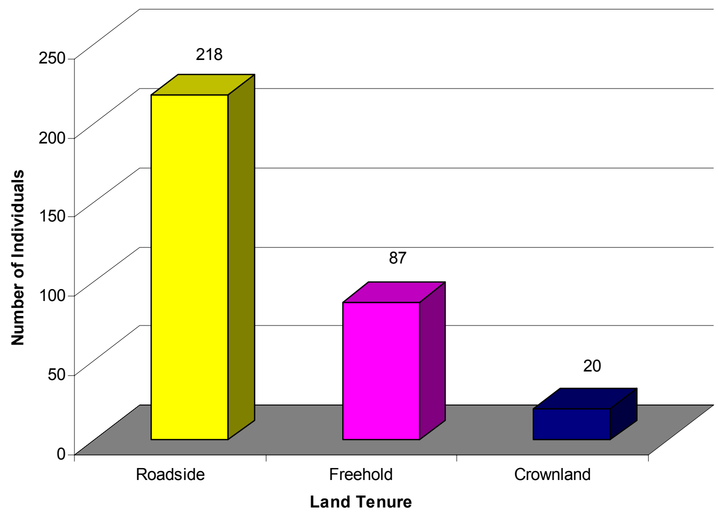

Figure 22: The number of Snow Gums surveyed with each land tenure

The majority of surveyed Snow Gums were along roadsides where 218 individuals or 67% of the total Snow Gums were found (Figure 22).

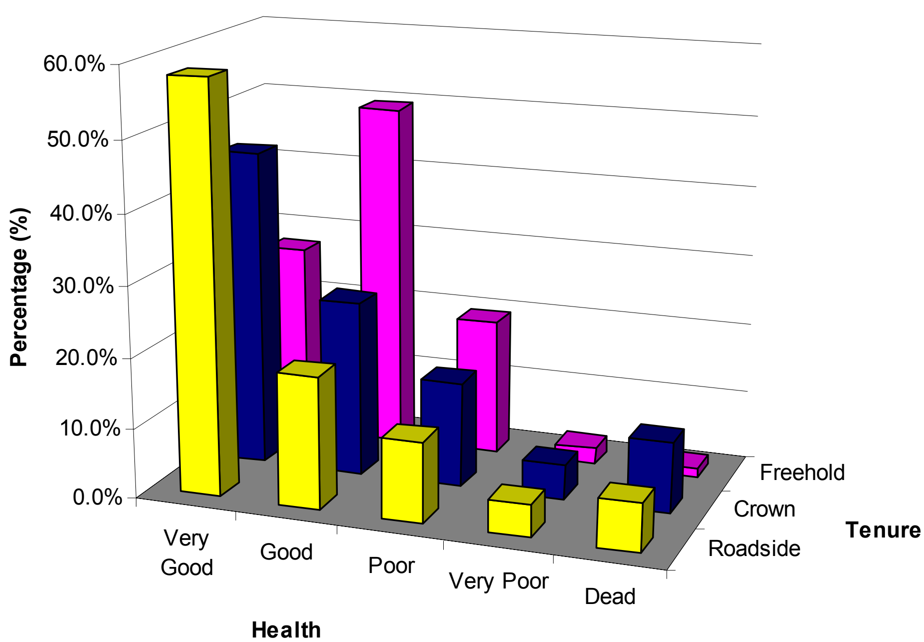

Figure 23: The proportion of Snow Gums in each health category for the three land tenures

A chi-square analysis performed on the health status according to land tenure gave a P value of 1.63813 x 10^{-06}, therefore the health according to land tenure results are highly significant. Figure 23 shows the percentage in each health category for each of the three land tenures. Roadside sites had the greatest proportion of trees in very good health (58.3%) and freehold sites had the lowest proportion in very good health (28%) The freehold sites had the highest proportion of trees in poor health (20%), but also had the lowest proportion in the dead and very poor health categories.

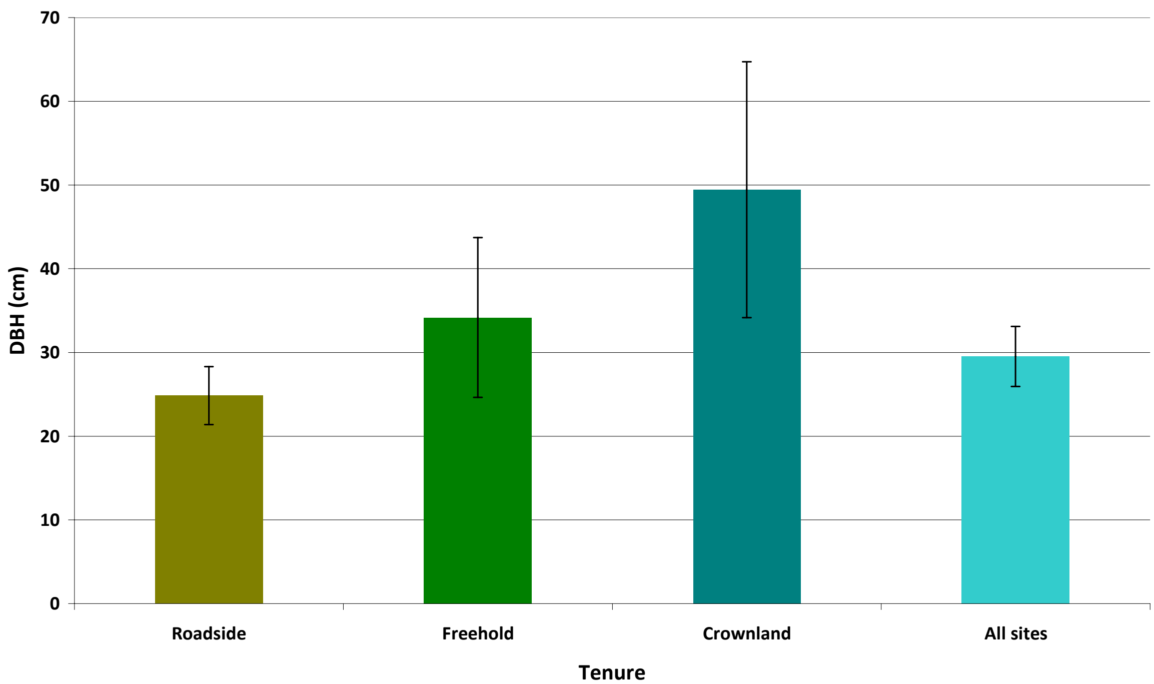

Figure 24: The average diameter at breast height of Snow Gums according to land tenure (95% CI's)

DBH varied according to land tenure (Figure 24) therefore the average age of the Snow Gums varied according to land tenure. The 95% Confidence Intervals (95% CI) show that although the Snow Gums on freehold land were not significantly different from the roadside or crown land sites, the roadside and crown land sites were significantly different from each other and from the overall average.

4.2.10 Grazing

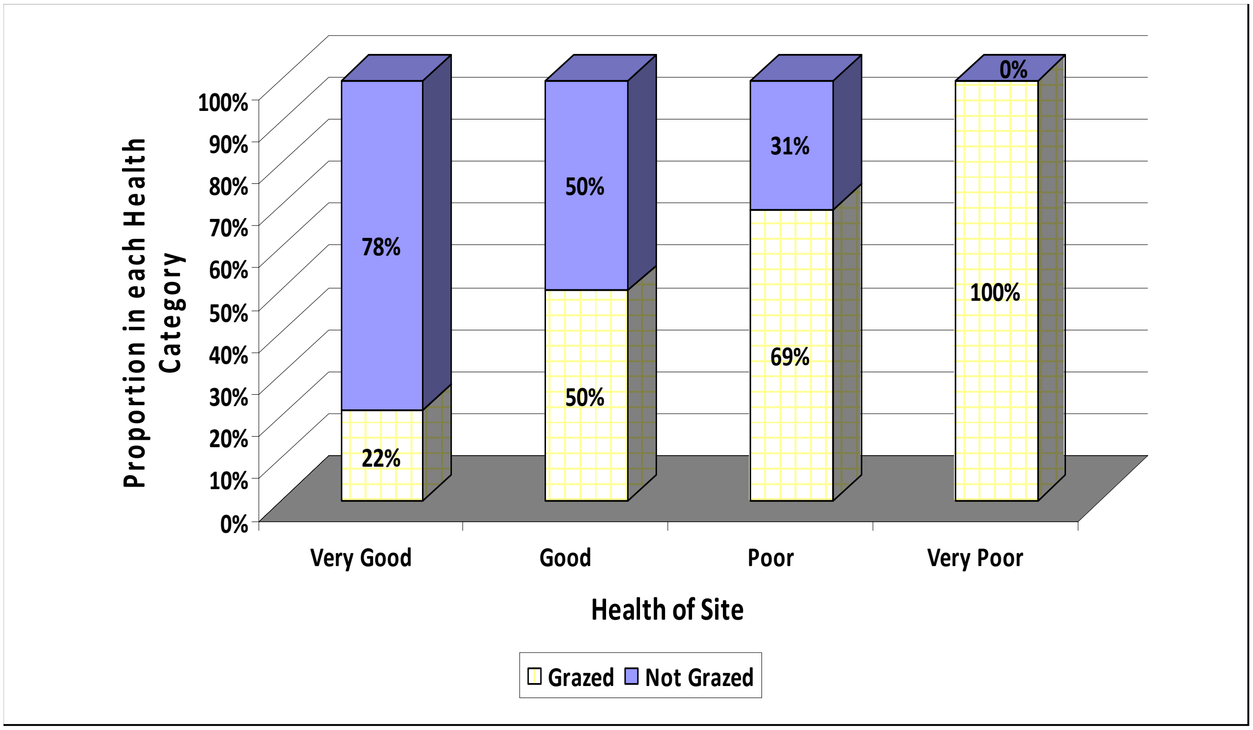

Figure 25: The proportion of sites in each health category which were grazed or not grazed

Grazing was found to occur on 23 of the 53 patches containing mature Snow Gums. A chi square analysis found that grazing had a significant impact on the health of Snow Gum patches and gave a P value of 0.023. Almost 80% of the sites found to be in good health had an absence of grazing whilst 70% of the sites in poor health were exposed to grazing pressures (Figure 25).

4.2.11 Fencing

Table 8: The health of Snow Gums according to whether the site was fenced.

	Health					
	Very Good	Good	Poor	Very Poor	Dead	Totals
Fenced	14	31	5	0	0	50
Not Fenced	146	58	40	13	18	275
Totals	160	89	45	13	18	325
Chi Square $P = 1.4 \times 10^{-7}$						

Five of the 53 sites with mature snow gums were fenced. All of these sites were on freehold land, with an average DBH of 67 cm. This was significantly larger than the overall average of 29.5 cm. Table 8 outlines the health of trees within the fenced sites compared to unfenced sites. A chi square test revealed that the health of the trees in fenced sites is significantly different to unfenced sites. The most interesting results are the high numbers of trees in good health and the low numbers of trees in poor health. Thirty-five percent of all trees in good health were found at fenced sites; however these trees accounted for only 15% of the total tree numbers.

4.2.12 Patch Size

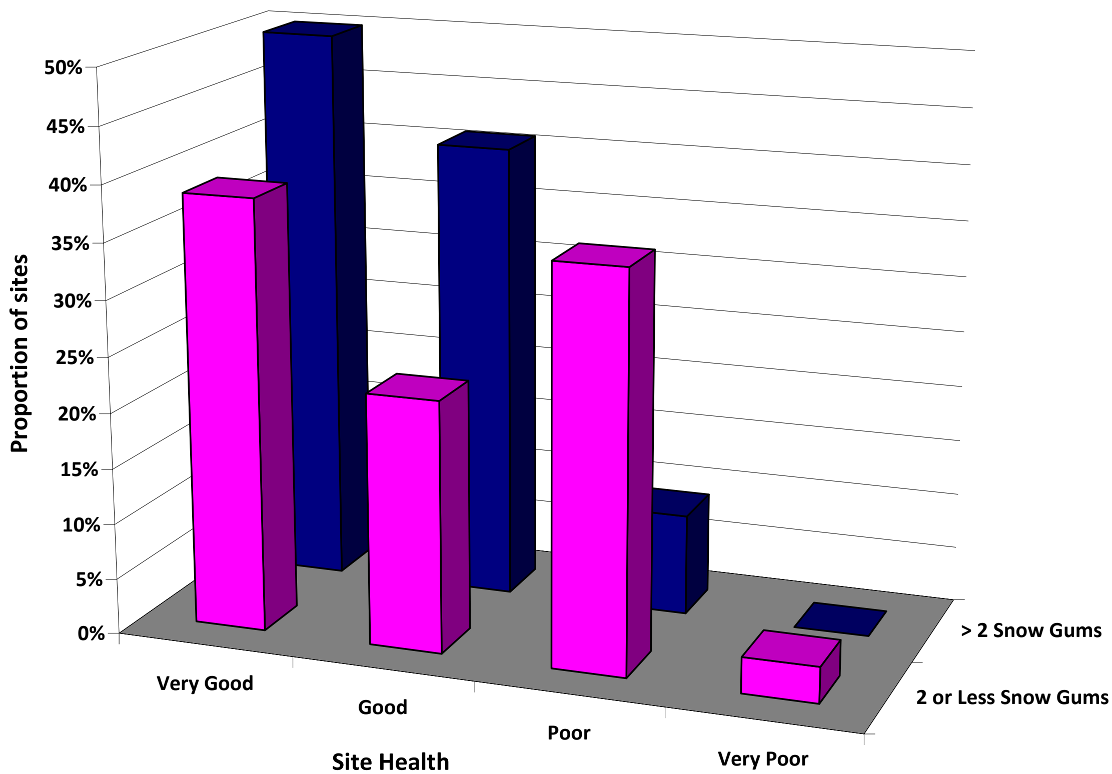

Figure 26: The proportion of sites in each health category according to patch size

The majority of sites surveyed (31 out of 53) contained only two or less mature Snow Gums. The majority of these sites where subjected to grazing (61%), compared with only 18% at the larger patches. Greater than 90% of the sites containing more than two trees were in very good or good health whilst 39% of the small patch size trees were in poor or very poor health (Figure 26). These results were subjected to chi square analysis which found no significant difference between the two groups. Another chi square analysis was then performed that removed the good and very good trees and only included the trees in poor and very poor health. The second chi square test found that patch size and the number of trees found in poor and very poor health was correlated.

4.2.13 Vegetation Community

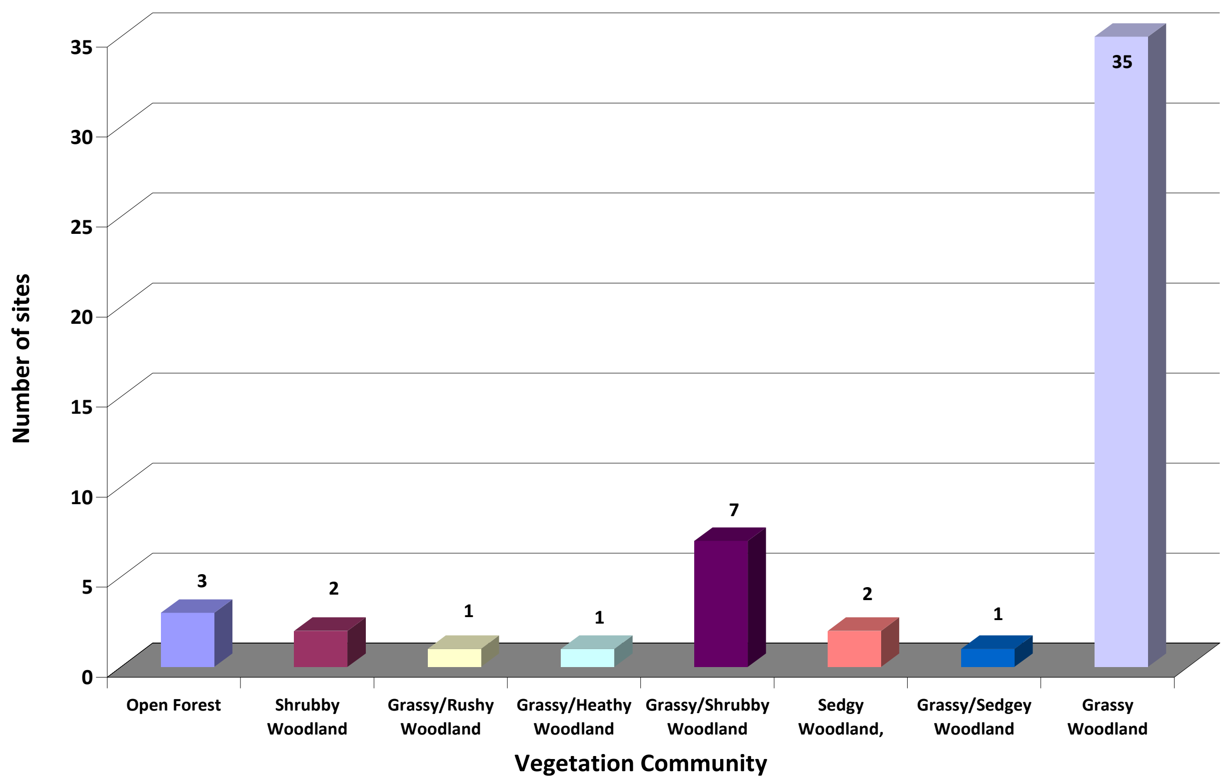

Figure 27: The number of sites surveyed in each vegetation community

The Ballarat Snow Gums were surveyed across a variety of vegetation communities (Figure 27). Over 80% of Snow Gum sites were found in grassy or grassy/shrubby vegetation communities.

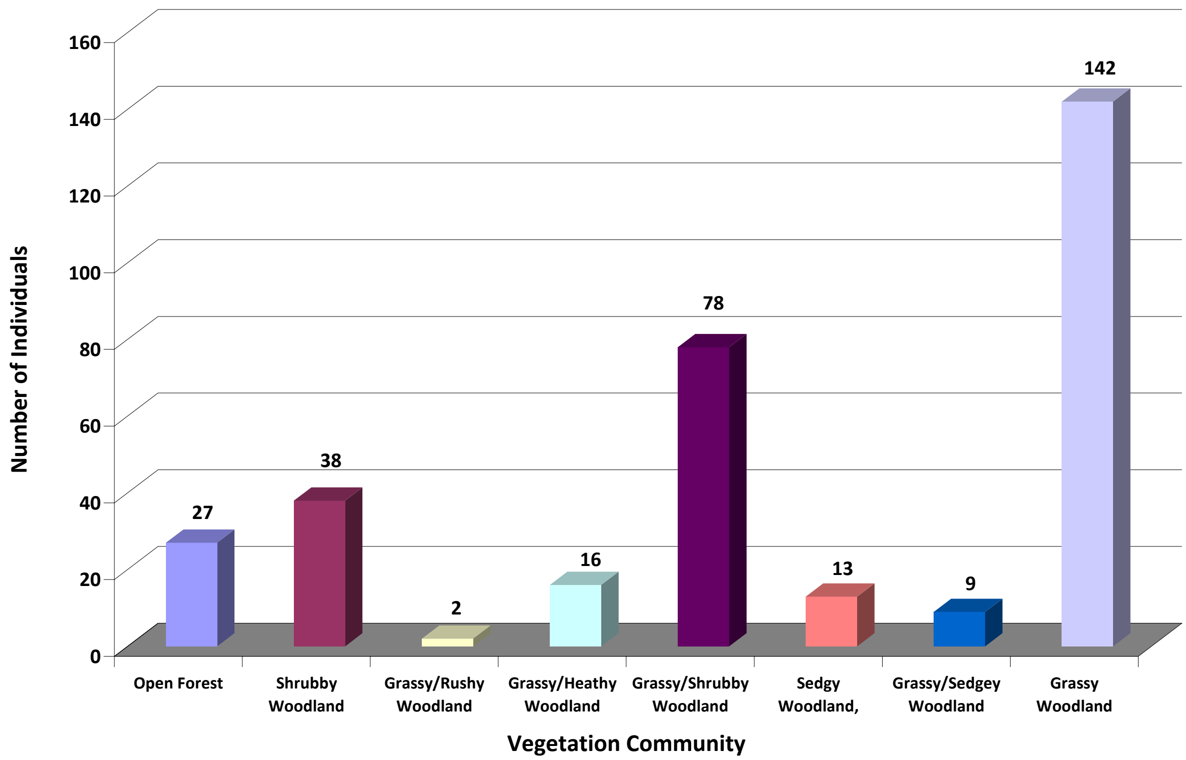

Figure 28: The total number of Snow Gums surveyed at each vegetation community

It is not surprising that the majority of trees surveyed had grassy (142 Snow Gums) or grassy/shrubby vegetation (78 Snow Gums) communities (Figure 28) because these communities were found at the majority of sites

Table 9: Number of Snow Gums in each health category according to vegetation community

	Very Good	Good	Poor	Very Poor	Tree Dead	Totals
Open Forest	19	5	2	1	0	27
Shrubby Understorey - Woodland	5	26	5	0	2	38
Grassy/Rush Understorey – Woodland	0	1	1	0	0	2
Grassy/Heathy Understorey – Woodland	0	7	6	3	0	16
Grassy/Shrubby Understorey - Woodland	40	10	8	5	15	78
Sedgy Understorey - Woodland,	2	6	4	1	0	13
Grassy/Sedgy Understorey - Woodland	2	4	2	1	0	9
Grassy understorey - Woodland	92	30	17	2	1	142
Totals	**160**	**89**	**45**	**13**	**18**	**325**

A Chi square analysis of the assessed sites found that there was a significant difference between the health categories of the Snow Gums according to the vegetation community they were present in. Open Forest sites had more Snow Gums with very good health than expected. Shrubby understorey sites had 16 more trees in the good category but 14 less very good trees than expected. Of the 16 trees found on sites with a heathy understorey, none had very good health and more than was expected had poor health. Grassy/Shrubby sites had less trees in good health and more dead trees than was expected. Grassy vegetation communities contained the Snow Gums in the best health with 22 more trees in very good health than expected. Overall the health of the Snow Gums was much better at sites that had grassy understoreys compared to sites with shrubby understoreys (Table 9).

4.2.14 Weeds

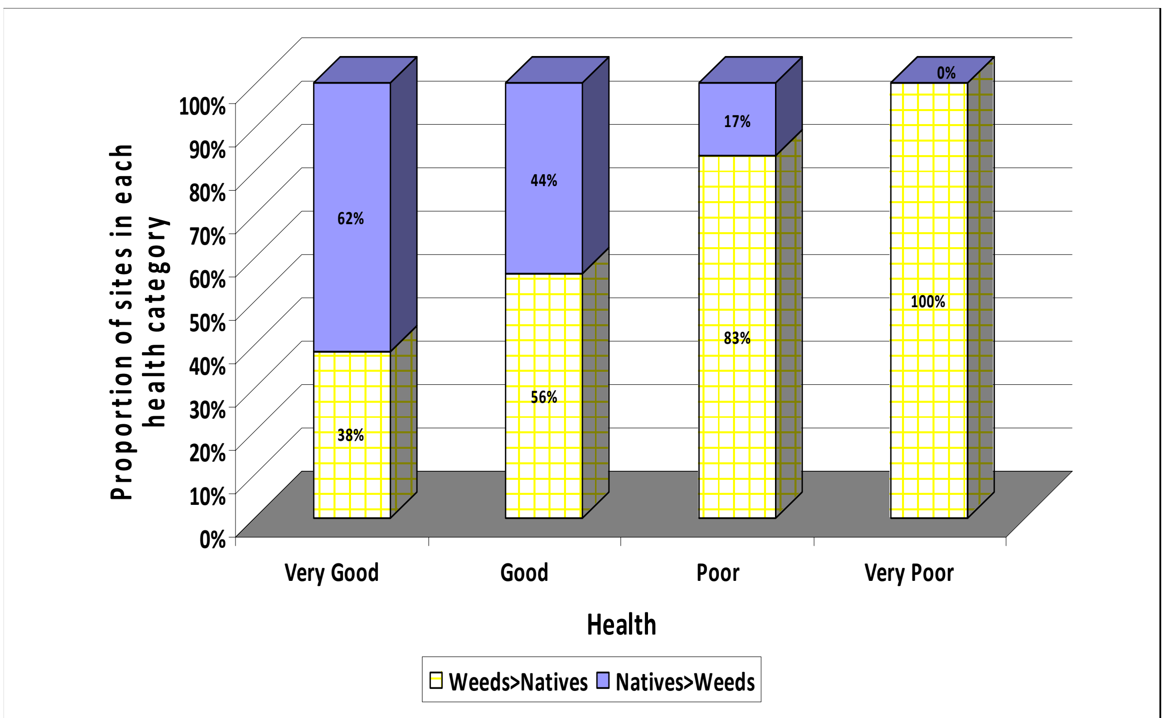

Figure 29: The proportion of sites with more natives or weed species present

Sites were analysed according to the percentage cover of weed and native species. A higher number of sites (29) had a greater percentage cover of weeds than native species, and 22 sites had a greater percentage cover of natives than weeds. Sites with a greater cover of weeds than natives appeared to suffer from poorer health. Eighty percent of sites with poor health had greater covers of weeds than native species. The sites in very good health had greater abundances of weeds than natives 62% of the time. Although percentage cover of weeds and natives appears to influence the health of the Snow Gum patches, a chi square P value of 0.067 indicates this is not a significant relationship.

4.2.15 Soil

Statistical analysis was performed on soil pH and EC and no correlations could be established between these parameters and SNOW GUM health. Sites with an overall health status of poor, good and very good all had the same average pH (5.1). Two sites had soils with ratings of extremely acidic, one site having an average pH of 3.7. The lone tree at this site was poor in health but another site with a pH of 4.3 had two trees present that were very good in health. Although no significant difference could be found between health and EC, the sites in very good health did appear to have lower EC values with a much smaller standard deviation than the other health categories.

4.2.16 Regeneration

Table 10: Snow Gum Regeneration

	Number of Individuals	Percentage of total living Snow Gums
Regeneration	745	70.8%
Living Mature	307	307%
Total Living	**1052**	–

The total number of regenerating Snow Gum individuals was 745, or 71% of all living Snow Gums surveyed (Table 10). Recruitment occurred at 31 of the assessed sites, therefore an average of 24 regeneration individuals occurred at sites with recruitment present. Only three sites with more than two mature trees experienced no regeneration at all.

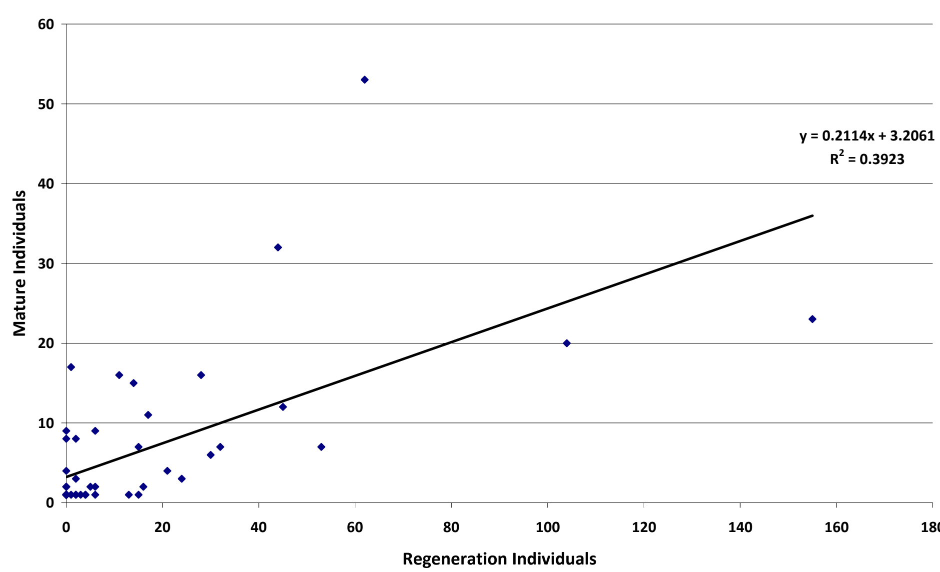

Figure 30: Regression of the number of mature and regeneration individuals

Regression analysis using a linear equation received a R^2 value of 0.4, therefore the number of mature Snow Gums at each site explains 40% of the variation in data collated for the number of regeneration individuals (Figure 30). Further surveying of sites with more than 50 regeneration individuals and 20 mature individuals respectively would be recommended to correlate this relationship with more precision.

Table 11: Regeneration occurrence according to tree health

	Tree Health					
	Very Good	Good	Poor	Very Poor	Dead	Totals
No Regeneration	32	22	16	5	16	91
Regeneration	128	67	29	8	2	234
Totals	160	89	45	13	18	325
Chi Square P = 3.19576×10^{-8}						

Chi square analysis of the health relating to the presence of regeneration found that this is a very highly significant predictor of recruitment (Table 11). Sites without recruitment had a higher proportion of trees in the poor and very poor categories and 16 of the total 18 trees that were found dead during the site assessments were on land with no recruitment.

5. Discussion

5.1 Distribution of the Ballarat Snow Gums

5.1.1 Landform

5.1.1.1 Site morphology

The topographical position of vegetation within the landscape provides an important insight into the habitat preferences of species such as the Snow Gum. The position, shape, steepness and aspect of a slope affects the type of soils likely to occur there, the movement of nutrients and water, and the degree of exposure to environmental conditions (McKenzie *et al.* 2004).

Snow Gums in the study area were found in all landscape categories, from hillcrests and ridges to flat areas and depressions, suggesting this species can tolerate a wide range of conditions. Although dependent on geological history, soils on sites higher in the landscape tend to be shallower and more skeletal, due to the movement of fine soil particles down slope by water, wind and gravity (McKenzie *et al.* 2004). These higher areas tend to be well drained with lower nutrient content, while the lower slopes accumulate the fine clay particles with a higher nutrient and water holding capacity (McKenzie *et al.* 2004).

Most assessed sites occurred on upper slopes, mid slopes and flat areas, which correlates to some degree with Holmgren (1994), who stated that Snow Gums once dominated the upper slopes of the Ballarat region. Landform also strongly influences land use, with the fertile slopes and plains more often cleared for agriculture than the ridges and steeper slopes (McIntyre *et al.* 2002).

The variability in soil type and moisture levels at different positions on the slope suggests the location on slope is not a primary factor driving the distribution of Snow Gums in the Ballarat region. It is more likely that the distribution was due to a tendency for certain parts of the landscape to be left uncleared, such as upper slopes where 30% of sites were located, rather than a habitat preference.

5.1.1.2 Percentage Slope

The steepness of a slope determines the movement of water and nutrients through the landscape (McKenzie *et al.* 2004). Most assessed sites occurred on very gently inclined to gently inclined slopes. It is possible the Snow Gum prefers these habitats as nutrients and water would be retained for longer in the soil prior to moving further down slope. However as the remaining 20% of assessed sites occurred on moderately inclined slopes, of which three sites were 30-32% slopes, it seems likely this species can occupy a range of habitats. It should also be noted that two known sites in the study area that were not assessed due to time constraints were situated on steep slopes.

5.1.1.3 Slope curvature

Slope curvature determines the direction of nutrient and water movement through a site (Milford *et al.* 2001). This may have some influence on Snow Gum distribution, as a chi square analysis demonstrated significant differences in slope curvature at different positions on the slope. Parallel slopes occurred at 72% of Snow Gum sites, however convergent slopes were also found frequently, particularly in areas on upper slopes. These may be zones of accumulated fine soil particles, with higher nutrients and water holding capacity than the surrounding areas on the slope. These conditions may provide preferable habitat for Snow Gums, particularly under drought conditions, than sites with divergent runoff that are likely to be better drained and possibly lower in nutrients. Only four sites, or 7.5% of the total assessed sites, were found to occur on divergent slopes. This differs from high altitude *E. pauciflora* ssp. *pauciflora* which are known to occur on well drained, low nutrient soils.

5.1.1.4 Influence of slope on regeneration

Seed size plays a large part in the successful regeneration of eucalypts, with larger seeded species advantaged in low nutrient conditions, and smaller seeded species advantaged in high nutrient conditions (Millberg *et al.* 1998). Nutrient levels are likely to be higher on convergent slopes, in depressions and on flat areas and lower slopes, where nutrients and organic matter from further upslope may accumulate. Regeneration occurred on only four of 11 sites with convergent runoff, and regeneration was absent in depressions. Recruitment also occurred on only 33% of sites on lower slopes and 50% of sites in flat areas. These sites are likely to be high in nutrients due to agriculture or simply natural accumulation in these lower areas. Seed size may be contributing to the lack of regeneration in these areas, with larger seeded eucalypts such as the Snow Gum competitively disadvantaged in high nutrient conditions (Millberg *et al.* 1998).

However, 91% of all sites without regeneration were subjected to grazing, cultivation, slashing, ploughing, road works, or a combination of these disturbances. Much research confirms that under continuous grazing, regeneration of eucalypts is absent or restricted (McIntyre and McIvor 1998; Dorrough and Moxham 2005; Semple and Koen 2001). This seems the most likely cause of the lack of recruitment in these sites, rather than competition from smaller seeded eucalypts. Without the exclusion of these disturbances from the sites, it is not possible to assess the effect of slope morphology and curvature on the regeneration of Snow Gums.

5.1.1.5 Aspect

Aspect determines the exposure of vegetation to a range of environmental conditions, including moisture, winds, temperature and radiation. Aspect did not appear to strongly influence the distribution of Snow Gums in the study area, with sites varying in aspect. While a quarter of sites with a slope greater than 3% faced a southerly aspect, there were also a number of sites facing westerly and north-westerly. As southerly aspects are likely to be more protected from radiation and winds, and northerly and westerly aspects are more exposed, it appears established Snow Gums are not affected by environmental conditions in these areas.

5.1.1.6 Influence of aspect on regeneration

Aspect can also affect regeneration of eucalypts such as the Snow Gum, which is dependent on adequate seed fall and moisture levels, oxygen and suitable temperatures for germination (Clarke and Davison 2001; Greening Australia 2003). The optimal germination temperature for *E. pauciflora* ssp *pauciflora* occurs between 15-20 ºC, with seed damage occurring at temperatures exceeding 30 ºC (Beardsell and Mullett 1984).

For slopes greater than 3%, seedling recruitment occurred in the greatest number of sites facing a southerly, westerly, north-easterly and south-easterly aspect. It is expected that sites with a westerly aspect may be more exposed to radiation and frosts than southerly and easterly sites. Only a small number of seedlings were found on sites facing west and north-west, which could be an indication of either lower germination rates or increased seedling mortality due to longer exposure and more variation in temperatures and light levels (Ball *et al.* 1991; Egerton *et al.* 2000). Prolonged exposure of seed to temperatures greater than 30 ºC substantially reduces seed viability, and imbibed seed is likely to be destroyed (Beardsell and Mullett 1984). As seed germination occurs in autumn, the imbibed seed may still be exposed to high temperatures in the Ballarat region. Growing seedlings may also be stressed from a combination of frost and radiation (Ball *et al.* 1991, Egerton 2000). Less seedling recruitment could also be due to insufficient moisture levels resulting from this prolonged exposure. However the greatest amount of regeneration occurred on areas facing north, east, south and south-west, which demonstrates no particular pattern.

Wind is the primary dispersal mechanism for eucalypt seed, which tends to be distributed on the south-east side of parent trees in the direction of the prevailing wind (Turnbull and Doran; Holmgren 1994; Greening Australia 2003). Sites sheltered from strong winds may have seed dispersed shorter distances from parent trees. Sites on steeper slopes may have seed dispersed some distance by gravity and may not rely on wind to aid distribution.

The small number of sites facing each aspect makes it difficult to detect a particular trend, particularly as sites without regeneration were subjected to disturbances such as grazing. Assessment of further sites in this area may allow greater insight into the influence of slope and aspect on the distribution of Snow Gums.

5.1.2 Soil

The range of soil types analysed from the assessed sites demonstrates the broad range that Snow Gums inhabit in the study region. Soils were derived from a range of parent materials, including Ordovician marine sediments, sandstones and shales; Quaternary basalt; and alluvial sediments deposited by prior streams (Muir 1979).

Soil maps place a large number of sites (28%) on Red Friable earths (Rx), fertile soils derived from Quaternary basalt on the plain. Three of these sites appear to occur on the change of soil type in the ecotone. A large number of sites (23%) were also located on Yellow duplex soils, grey clays and red friable earths (Ye). These soils were either derived from Quaternary basalt on the plain, or minor occurrences of much older Palaeozoic sedimentary sandstones and mudstones on the hills (Robinson *et al.* 2003). Five of these sites occurred on the ecotone at a soil type change. Many sites (19%) were also located on (Yf) Yellow and mottled duplex soils, derived from Tertiary finely textured unconsolidated deposits on the plain (Robinson *et al.* 2003). Granitic outcrops occurred in the region, however no sites were located on soils derived from granite.

There was little variation in colour when soil samples within the sites were compared with samples outside the sites, falling in the brown, black, grey and red Australian Soil Classification groups. Texture was highly variable within the study sites, ranging from sandy loams to light clays at the surface and generally increasing in clay content with depth. Samples taken outside the sites also fell within these soil texture groups, however 'sands' were also recorded, a texture group not represented within the sites. This suggests Snow Gums may have a preference for sites with a better nutrient and water holding capacity than sands provide. It should be noted that fewer samples were taken outside the sites than within the sites due to the sampling method.

No samples were taken further than the B2 horizon from outside the sites, however these samples reached similar depths as those taken inside the sites. These samples from outside the site went through fewer changes in the profile as those from within the sites, either because they reached clay at shallow depths, or the surface soils were quite deep.

Additional samples at a greater number of sites is required to provide a more complete overview of the effect of soil texture on the distribution of Snow Gums. A more consistent sampling method may have been to sample at set depths regardless of changes in colour and texture.

Soil pH analysis demonstrated that Snow Gums occurred on very strongly acidic to slightly acidic soils throughout the study area. The average pH recorded was strongly acidic (4.87 pH) at the A horizon to moderately acidic (5.55 pH) at the B4 horizon. This trend of increasing pH with depth suggests the acidity may in part be due to land management.

The statistical difference in mean pH of soils within the sites compared to soils outside the sites suggests pH may be a factor in determining the distribution of Snow Gums in the study area. It is possible the slightly higher pH (moderately acidic throughout the profile) in combination with the soil texture of these sites provides less suitable habitat.

No soil samples were considered saline except one sample at Remembrance Drive Cardigan. The reading of 1.336 dS/m was greater than the minimum level for saline soils, 0.4 dS/m in sands and loams, 0.7 dS/m in clays. There was no significant difference between the mean EC for soils inside and outside the sites, and was therefore not deemed a factor in determining the distribution of Snow Gums.

5.1.3 Ecological Vegetation Classes and Associated Species

Recognising the vegetation communities a species such as the Snow Gum is associated with provides insight into its distribution, and the range of conditions it is likely to tolerate. Ecological Vegetation Classes (EVC) have a certain structure and the floristics vary but are often consistent across a region. The suite of indigenous and exotic species can compete with and restrict seedling recruitment of species such as the Snow Gum.

Snow Gums in the Ballarat region were found in five different EVCs, demonstrating a pattern to the distribution of this species. These EVCs had a bioregional conservation status of depleted, vulnerable or endangered in the study area, which immediately highlights the need to preserve these remnants (DSE 2007).

Almost half the assessed sites (49%) occurred in EVC 47 Valley Grassy Forest, a vegetation community found on lower slopes and valleys (DSE 2004c). Many species typically found in this community were located with Snow Gums in both the 1996 study by Baker and the 2008 study, including *E. radiata, E. rubida, A. mearnsii* and a range of native grasses and forbs.

Twenty-four sites (45%) were located on the edge with another EVC, supporting the hypothesis Snow Gums tend to inhabit ecotones between two plant communities in the study area. Fourteen of these occurred in the ecotone between Valley Grassy Forest and Plains Grassy Woodland, two EVCS which naturally grade into each other. Valley Grassy Forest is found on well drained and fertile lower slopes and valleys, while Plains Grassy Woodland occurs on poorly drained fertile plains with sparser tree and shrub cover than Valley Grassy Forest (DSE 2004c; DSE 2004d). Plains Grassy Woodland is typically dominated by River Red Gum *E. camaldulensis* and *E. ovata.*

Also represented in the assessed sites were Herb-rich Foothill Forest (23), Grassy Woodland (175) and Valley Heathy Forest (127). Herb-rich Foothill Forest occurs on eastern and southern lower slopes and in gullies, on relatively well-drained fertile soils, and is typically dominated by *E. ovata, E. obliqua, and E. viminalis ssp viminalis* (DSE 2004b). Grassy Woodland occurs on relatively fertile soils on slopes or hills, and is dominated by *E. ovata,* Drooping Sheoak *Allocasuarina verticillata,* and *Acacia spp* (DSE 2005). These species were all found associated with *E. pauciflora* ssp *pauciflora* in the study area in 1996 and 2008. Valley Heathy Forest seems an unrepresentative community for Snow Gums to occur, with the presence of the Small Grass-tree *Xanthorrhoea minor.*

There are some distinct differences and similarities between the five EVCs where Snow Gums were found. Recruitment in all these EVCs except Valley Heathy Forest is continuous and does not require episodic events (DSE 2004a; DSE 2004b; DSE 2004c; DSE 2004d; DSE 2005). Valley Heathy Forest has a high cover of heathy shrubs that require events such as fire to stimulate regeneration (DSE 2004a). If Snow Gums can inhabit communities which recruit either continuously or episodically, they may have an advantage over other species.

Tree canopy cover varies from 10% in Plains Grassy Woodland to 40% in Herb-rich Foothill Forest, while understorey tree and large shrub cover is less variable at 5-10%. Organic litter cover is a function of tree canopy cover, and also varies from 10-40%. The differences in light infiltrating the lower strata and differences in the fertility levels of the substrate from the organic matter suggests *E. pauciflora* ssp. *pauciflora* is able to persist under a range of conditions.

If these EVCs are typical of Snow Gum habitat, this knowledge could be used to seek out likely locations of further Snow Gum sites. Further analysis is required to examine relationships between regeneration and vegetation communities.

There was much greater diversity of native species compared to exotic species at the sites, and natives were also recorded more frequently. This suggests that although weeds may be more abundant at some sites, the basic components may still be intact, which provides opportunity to improve the conditions of these sites**.** While Baker (1996) found 28% sites assessed in 1996 had no native vegetation associated with *E. pauciflora* ssp *pauciflora*, in 2008 there was native vegetation at 94% of sites, suggesting an overall improvement in the study area.

5.1.4 Climate

The Themeda Grassland data logger location was clearly subjected to greater variation in temperatures than other sites, recording the lowest minimums for all three months. This site also recorded the highest temperature for all locations for July 2008. Consistently lower average minimum temperatures were recorded in the Themeda Grassland location than all other locations, and higher average maximum temperatures than most other sites. In contrast, the sites on which the mature Snow Gums with a large DBH occurred, recorded milder temperatures, therefore it is likely these sites provide protecting from frost and intense radiation, and possibly provide better sites for regenerating seedlings. Greater variation and more extremes in both minimum and maximum temperatures may be contributing to the lack of Snow Gums regenerating in grassland areas, possibly affecting seed germination by exposing seed to higher temperatures.

Further analysis is required regarding the affect climate has on the distribution and health of Snow Gums in this area. There is scope to utilise data recorded on the Dereel property in this analysis, but due to time constraints could not be conducted for this report.

5.1.5 Effect of Patch Size

McIntyre (2002) states the minimum patch size for long term viability of populations is 5-10ha. This is concerning for *E. pauciflora* ssp *pauciflora* in the study area, with an average patch size of 0.06ha and a maximum of 0.6ha. While some of these sites were connected to other vegetation, therefore increasing the patch size, the majority were isolated paddock trees or small patches. These small patches can still provide linkages to larger patches of vegetation, however they are often subjected to increased nutrient levels and compacted soil from the congregation of stock. These trees are also more prone to insect attack due to higher nutrient levels, and are less able to cope than trees in larger patches of vegetation (McIntyre 2002).

These small patches are critical to preserving genetic variation of remnants across the region (McIntyre 2002). However, cross-pollination of Snow Gums can be limited in fragmented landscapes as the mobility of pollinators can be restricted (McIntyre 2002). Inbreeding through self pollination may be the only method of reproduction for some of these isolated trees. The introduction of seed or seedlings from other locations in the region may be necessary to preserve these remnant trees.

Larger patches are also usually of higher diversity, with species flowering at various times throughout the year to provide an ongoing food source for pollinators. Species diversity is a good measure of the quality of a site.

5.1.6 Land use and Competition

Land tenure and disturbance were clearly primary drivers of the distribution of Snow Gums in the study area. Most assessed sites were subjected to more than one disturbance, and were therefore not mutually exclusive and some interpretation of results was required. However some clear trends were evident from the analysis. A chi-square analysis demonstrated a highly significant relationship between the number of Snow Gum individuals in each diameter class on each tenure.

Only one seedling was recorded for the three assessed crown land sites, however all were grazed by cattle. Studies have clearly demonstrated that eucalypt regeneration is virtually non-existent under regular grazing, which correlates with the results of this study (Dorrough and Moxham 2005; Semple and Koen 2001).

Roadsides provided the best sites for regeneration, which occurred on 79% of roadside sites, and accounted for 72% of the total regenerating individuals. This is most likely due to management practices, as these sites were less exposed to disturbances such as grazing and ploughing, and often provide valuable connectivity to other remnant patches in a fragmented landscape.

The number of individuals in each age class also gives some indication as to disturbance regimes in the past. The significant reduction in individuals on roadsides from 537 in the 0-4 cm diameter class to 146 in the 5-25 cm diameter class probably reflects a natural thinning process as seedlings compete for resources. The number of Snow Gums also gradually decreased as diameter increased, however numbers are higher for roadsides than other tenures, suggesting more regeneration has occurred on roadside sites for some time.

Of the 20 roadside sites assessed in both 1996 and 2008, there was an increase from 14 to 15 sites with regeneration. Regeneration that occurred on two sites in 1996 was absent in the 2008 study, one of which was heavily grazed, while the other was severely infested with Gorse and Blackberry. Three sites without seedling recruitment in 1996 had improved in 2008, when they were found with several seedlings. These three sites were previous grazed or infested with Gorse, however in 2008 were found only grazed in part of the site, with some competition from weeds.

Freehold sites had significantly fewer recruited individuals in most diameter classes in comparison to roadsides, with 64% of freehold sites showing no sign of recruitment. These sites were subjected to grazing, cultivation, ploughing, slashing, or a combination of these disturbances. Very few individuals greater than 25 cm diameter occurred on freehold sites, suggesting past management of these sites restricted regeneration.

An increase in the number of individuals in the 5-25 cm and 0-4 cm diameter classes may indicate a change in management of these patches in recent times, allowing more seedling recruitment to occur. Four sites assessed on freehold land had Trust for Nature covenants and are not representative of the bulk of sites assessed. It is most likely the change in management on these few properties has resulted in the overall increase in young Snow Gums, rather than a change in management across the study area. Across the 30 sites assessed both in 1996 and 2008, the increase in regeneration occurrence from none to 2 sites suggests some change in management regimes.

5.2 Health of the Ballarat Snow Gums

5.2.1 General Heath Discoveries

Considering the large number of sites that contained isolated individual trees, it was pleasing to discover that an average of almost 20 Snow Gums were found at each of the surveyed sites. Less than 2% of all Snow Gums were dead, therefore the drought seems not to have contributed to tree death. Although the majority of surveyed trees were classed as regeneration, the large numbers of young Snow Gums indicate that the future of the species around Ballarat appears to be secure.

Almost 50% of the Snow Gums surveyed were found to be in good health. This is a very satisfactory result considering the potentially devastating impacts the prolonged drought could have had on this species. Analysis of the health of each snow gum site found that almost 75% of the sites were in very good or good health, indicating the strong health of the species around Ballarat. The health results of the Ballarat Snow Gums surveyed means that although they are fragmented and limited in distribution, the population appears to be in good overall health.

5.2.2 Comparison with 1996 project

The comparison between 30 sites with health data surveyed during the 1996 and 2008 projects seems to indicate that the sites have degraded slightly. A 9% drop in the number of trees in very good health was redistributed evenly to the good and poor categories. These results were found to be non significant by a chi square analysis therefore the difference in health observed was only due to chance. Future research is required to examine this trend further and although the health assessment technique remained identical, differences in subjective scoring may be responsible for the slight drop in health.

5.2.3 Fruit Crop

Only 23% of the Snow Gums completely lacked a fruit crop. The majority of these individuals were younger trees that were too underdeveloped to bear fruit but were classed as mature because of the survey methodology. The light crop data would also be heavily influenced by these younger trees. Many individuals that were classed as regeneration (DBH < 5 cm) were bearing fruit, but due to the methodology of the project were subsequently excluded from health or fruiting assessments. It would be recommended that future surveys include these individuals as mature individuals but perhaps place them in a DBH less than 5 cm category. The project identified that 77% of the Ballarat Snow Gums were bearing fruit which is probably an expected result for this eucalypt species. Many eucalypt species often produce fruit every second year or according to environmental triggers but Snow Gums often produce fruit crops consistently once they reach maturity (D'Ombrain pers comm. 2008)

The positive correlation established between the health status of the Ballarat Snow Gums and the fruit crop they bear is supported by MacIntyre (1991). This may explain the high proportion of trees in the very poor health category that lacked the presence of any fruit crop. It is proposed that trees in very good health can afford to designate energy and resources towards reproductive purposes.

5.2.4 Flowering

The flowering status of the Ballarat Snow Gums was observed but unfortunately the survey period was conducted outside the Snow Gums flowering period (October-January), therefore this data is not truly representative of the Ballarat Snow Gum population. Although the data collected was too small to draw conclusions from, individuals that were observed to be in flower were all free of mistletoe infestation and none had the multi-stemmed form. The health of the individual tree seemed to be unrelated to the flowering status and environmental triggers such as diurnal exposure to daylight probably control this parameter.

5.2.5 Mistletoe

Mistletoe infestations amongst the Ballarat Snow Gums appears to be quite low and although only five individuals had mistletoe present, the health of these individuals varied from very good to poor. The highest number of mistletoe infestations on a single tree was four, and this tree was in poor health. As with the flowering data, it is misleading to draw conclusions from such a small number of individuals infested. It may be noted however, that none of the Snow Gums bearing mistletoe were bearing heavy fruit crops. Mistletoe infestations were very low and were not impacting the overall health of the Ballarat Snow Gums.

5.2.6 Tree Form

Tree Form was not found to be related to poor tree health and none of the 53 Snow Gums observed with mallee form were dead or in very poor health. It remains inconclusive whether the tree form observed was due to environmental pressures because only three of the 20 sites with mallee form individuals were in poor overall health. It is unknown whether the large number of good and very good health statuses presented at these sites is due to the mallee form displaying better health because they can tolerate poorer environmental conditions, or because of the good environmental conditions at these sites.

5.2.7 Diameter at Breast Height

The health of the Ballarat Snow Gums varied significantly according to DBH. The average DBH of the poor health trees was significantly larger than the other categories, therefore the poor health category contained a disproportionate number of older individuals. Unfortunately the older generation of Snow Gums are in much worse health than the younger trees. It was difficult to determine whether these older trees had decreased in health since Baker's (1996) study (lacked this detail), but the health of several older trees seemed to have improved health from photographic comparisons.

5.2.8 Land Tenure, Grazing and Fencing

A large proportion of Ballarat's Snow Gum patches were remnant populations surviving along roadsides. Roadside are often refuges for species such as *E. pauciflora* largely because the remainder of the landscape has been cleared for agricultural use or urban development. These roadside remnants also contained the highest proportion of trees that had very good health. Often the management of this land excludes grazing and is devoid of other disturbance or competitive pressures, resulting in an environment without these health suppressants.

Differences in DBH according to land tenure indicated the difference in average ages across the tenures. The roadside sites had the smallest average DBH and therefore contained the largest proportion of younger trees, whilst the crown land sites had the largest average DBH, therefore contained the oldest trees. The three crown land surveyed sites had probably been exposed to grazing and other pressures for a long time and subsequently lacked a spread in age classes across individual trees. Roadside have been able to have successive recruitment opportunities and therefore contained many younger Snow Gums.

The results of the freehold sites were the most varied, with the lowest proportion of trees in the very good, very poor and tree dead categories, and the highest proportion of trees in the good and poor health categories across land tenures. These results demonstrate the variety of management practices occurring at these patches, with some sites fenced and protected on Trust for Nature properties whilst many others were single paddock trees exposed to high disturbance and competitive pressures. All three sites conducted on crown land were subjected to grazing. This is a small number of sites and unfortunately they were all subjected to the same management practices resulting in a high proportion of trees that were either dead (10%) or in very poor health (5%) compared with the other land tenures.

Grazing pressures had a significant impact on the health of Ballarat Snow Gums, as was expected. The majority of Snow Gum sites in very good health were located on sites without grazing occurring (78%)

whilst 69% of the sites in poor health were found to be exposed to grazing pressures. All of the sites found to be in very poor health were located on grazed sites.

The fenced sites surveyed demonstrated the benefits of stock removal. Fencing was found to have a significant impact on the health of Ballarat's Snow Gums although only five of the 53 sites were fenced. Fenced sites completely lacked Snow Gums that were dead or in very poor health and 90% of all Snow Gums surveyed were in good or very good health. Large diameters were correlated with poor health across all sites, but large diameter individuals in the fenced sites were almost always good or very good in health. The results of the report support the findings of Baker (1996) regarding Snow Gum health and grazing validating the subsequent fencing actions conducted to reduce grazing pressures in the Ballarat district.

Isolation was found to have a negative impact on health and the number of sites in poor or very poor health was found to be significantly higher at patches with only one or two trees present. These results support the findings of Davidson *et al.* (2007) and show that the stresses placed on isolated individual have a detrimental impact on their health. As expected, a large proportion of the isolated Snow Gums were subjected to grazing pressures which would account for much of the ill health observed.

5.2.9 Vegetation Communities

Chi square analysis found that the differences in health observed at the different vegetation communities were significant. The majority of Snow Gum sites were located in grassy vegetation communities indicating that Grassy Woodlands may have been the vegetation community most often associated with Snow Gums prior to European settlement. Unfortunately the method of assessing vegetation community has skewed this data because paddock trees were placed in this category when they should have been placed in their own category. Even with this anomaly, this vegetation community contained many more trees in very good health than was expected if the health of these trees was due to chance. Sites with shrubby or shrubby/grassy understoreys had much poorer health statuses than other vegetation communities, with fewer trees in good health and many more dead trees than would be expected. Shrubby understoreys would be expected to have reduced exposure to grazing so it is uncertain why Snow Gum health would decrease with the presence of a shrub layer.

5.2.10 Exotic Species

The health of the Ballarat Snow Gums appeared to be influenced by the abundance of weeds although this could not be proven statistically. More sites were surveyed with greater percentage cover of weeds than native species (28 to 22 sites) indicating a high level of disturbance across these sites. Eighty percent of sites in poor health were correlated with a higher proportion of weeds than natives, demonstrating the detrimental impact exotic species have on species in native ecosystems.

5.2.11 Soil

Soil pH and EC did not correlate with the health of the Ballarat Snow Gums although the sites in very good health had lower EC values and smaller standard deviations than sites in good and poor health. The average pH for sites in poor, good and very good health was 5.1 which were classed as moderately acidic (McKenzie *et al.* 2004). Several sites registered pH's that were classed as extremely acidic but the health status of the Snow Gums at these sites varied from poor to very good. The soil parameters of pH and EC seemed to be unrelated to Snow Gum health and the findings of Davidson *et al.* (2007) that the pH at a site was correlated to Snow Gum health was not supported by this projects data.

5.2.12 Regeneration

The presence of regeneration was correlated to the health of the Snow Gums with healthier sites having a greater likelihood of regeneration occurrence. Sites lacking recruitment had much higher proportions of Snow Gums that were poor, very poor or dead. The same pressures contributing to poor health also degrade the Snow Gum sites by preventing regeneration therefore land management decisions, such as grazing, will determine the health status of the remnant Snow Gums and the presence of recruitment. This is typified by the occurrence of regeneration on only three sites on free hold land that were not fenced.

6. Conclusion - Answers to Hypotheses

6.1 Distribution of the Ballarat Snow Gums

Regeneration of Snow Gums had increased slightly since Baker's 1996 report, however the change was insignificant. A greater number of sites assessed in both years with a greater representation of freehold sites may have resulted in a more significant increase.

The relationship between the numbers of sites on each landform according to slope curvature was significant, suggesting Snow Gums may have a preference for convergent or parallel slopes rather than divergent slopes. Aspect appeared to have no particular impact on either the presence or regeneration of Snow Gums.

Snow Gums occurred on soils within an acidic pH range, with a statistically significantly lower mean pH inside the Snow Gum sites compared to soil samples taken outside the sites. Snow Gums also occurred on a range of soil textures and colours, demonstrating the range of conditions tolerated. As sites were never located on sands, it is possible Snow Gums prefer better nutrient and water holding capacity than these soils provide.

Snow Gums occurred with a range of associated species, most of which were native, and were found in several Ecological Vegetation Classes, confirming they can occupy a range of habitats. Ecotones were found to be frequently inhabited by Snow Gums, occurring on the boundaries of a number of EVCs and soil types. This correlated with findings by Baker in 1996.

Land tenure was found to be the primary factor influencing the distribution and regeneration of Snow Gums, by determining land use, disturbance and competition. Regeneration at grazed sites was significantly reduced, while those with only natural disturbance had the highest regeneration. Some disturbance was found to be beneficial, with recruitment occurring at sites exposed to road works.

6.2 Health of the Ballarat Snow Gums

There was a slight reduction in the proportion of sites in very good health across the 30 sites assessed in 1996 and 2008 although this was not a statistically significant change.

The Ballarat Snow Gums contained mistletoe infestations on only five trees, or less than 2% of the mature individuals surveyed. This is too small a number of individuals to determine statistical correlations and the health of these trees varied from poor to very good. The only trend identified was that none of these infested individuals had a heavy crop of fruit.

The form of tree present was not correlated to health. DBH had an inverse correlation with tree health. The larger the DBH, the poorer the tree health usually was. The study was conducted out of the flowering period therefore only five individuals were in flower.

The project results identified a significant relationship between the health status of individual snow gums and the fruit crop they bear. Trees in the very good and good health categories had many more individuals than expected with heavy crops whilst there were three times more trees in poor health that had no fruit crop than expected.

The mallee form was most often correlated with sites in good or very good health therefore this hypothesis appears to be rejected. Further investigations are required to determine whether the large number of good and very good health statuses presented at these sites is due to the mallee form displaying better health because they can tolerate poorer environmental conditions, or because of good environmental conditions at these sites.

The health of the Ballarat Snow Gums was successfully correlated to land tenure. The major component contributing to the declining health of the Snow Gums was grazing pressures, as grazed sites had significantly poorer health than ungrazed sites. Sites that were fenced for stock exclusion had significantly better health statuses than unfenced sites.

Soil pH and EC did not correlate with the health of the Ballarat Snow Gums, although the sites with very good health had lower EC values and smaller standard deviations than sites in good and poor health.

Isolated sites were found to be in poorer health and the number of sites in poor or very poor health was found to be significantly higher at patches with only one or two trees present. Stresses placed on isolated individuals have a detrimental impact on their health.

6.3 Implications for the Ballarat Snow Gum Population

Statistical analysis on the data collated in the comprehensive database confirmed that management within each land tenure has a significant effect on the health and distribution of *E. pauciflora* ssp. *pauciflora*. Roadsides were found to provide vital habitat for the majority of the mature and regenerating Snow Gums. The Snow Gums at these sites were also found to be in the best health.

Substantial evidence was provided of the devastating impacts that grazing has on the health of the mature trees and on regeneration of new individuals. Grazing posed the most significant threat to these remnants, and demonstrated the strong need to encourage landholders to fence these precious remnant populations. Without different age classes to replace senescing mature trees, the long-term viability of the Snow Gum populations in Ballarat is unlikely. Biodiversity Services and Corangamite CMA are in a position to further encourage the protection of these remnants, through community education, training and financial incentives. Revegetation projects which introduce seed collected throughout the project will encourage gene diversity and flow, providing establishing individuals with a greater chance to adapt to changing environmental conditions.

Although the project incorporated a variety of parameters to obtain a holistic understanding of the *E. pauciflora* ssp. *pauciflora* sites, it was impossible to do in-depth analysis on any of these factors in the time available. It would be highly recommended that any of these parameters be the focus of further studies to fully appreciate all the intricacies of these habitats.

6.4 Dissemination Pathway

The major goal of the project was to increase knowledge regarding the factors influencing the health and distribution of *E. pauciflora* ssp. *pauciflora* and present these findings to Biodiversity Services and Corangamite CMA in the form of this report. Biodiversity Services also received a comprehensive Microsoft Access Database containing all data collected, a considerable quantity of Snow Gum seed, an extensive herbarium collection and a selection of Manifold System map layers.

The results of this project may identify further research opportunities that Biodiversity Services or Honours students may be interested in the future. Other parties that may benefit from this research include anyone interested in promoting biodiversity or protecting native vegetation including CMAs, local government, Field Naturalist groups, and various environmental or community groups.

In addition, it may be desirable to try and raise awareness of the project to the wider community. Possibilities include going along to Ballarat Environment Network, Field Naturalist Groups, Australian Plants Society, or other community groups interested in the preservation of native remnants in the region. Raising awareness about a species with limited distribution can help promote and preserve biodiversity in the region. Landholders may be encouraged to conserve remnants on their properties, and find ways to improve their health and encourage regeneration.

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Appendix I - Snow Gum Sites Assessed in Study Area

Site Code	Zone ID	Zone Name	Site Code (1996 Study)
798	14001	Long Swamp Rd, Rocklyn -1	SN11
798	14002	Long Swamp Rd, Rocklyn -2	
798	14003	Long Swamp Rd, Rocklyn -3	
786	14004	Dean-Mollonghip Rd, Dean -1	SN74/SN75
526	14005	Newlyn, Thorpes Rd/Pattersons Lane -1	SN12
513	14006	Souths Rd, Grenville-1	SN45
Mck002	14008	McKerralls Road Property, Grenville -1	SN46
532	14009	Arthurs Lane, Mt Mercer -1	SN48
810	14010	Woodbourne, Bamgannie Rd-1	SN51
810b	14011	Woodbourne, Meredith-Mt Mercer Rd-1	
775	14013	Dereel Snow Gum Block, Berringa Road -1	SN39
775	14014	Dereel Snow Gum Block, Berringa Road -2	
775	14015	Dereel Snow Gum Block, Berringa Road -3	
Myn001	14016	Mynes property, Snow Gum Rd, Dereel -1	
503	14017	Arthurs Lane, Mt Mercer -1	SN49
G054	14018	Snow Gum Road (Berringa-Dereel Rd), Dereel -1	
1191	14019	Snow Gum Property off Snow Gum Road, Dereel -1	
644	14020	Springmount, Binns Road off Sawmill Rd on E bank of creek -1	SN6
644	14021	Springmount, Binns Road off Sawmill Rd at edge of park -2	
514	14022	Burrumbeet-Hillcrest Road, Snake Valley -1	SN27
G095	14023	Glenelg Hwy, Smythes Creek -1	SN32
B071	14024	Remembrance Drive (Avenue Of Honour), Cardigan -1	SN24
G103	14025	Laceys Rd/Ross Creek Rd, Ross Creek -1	
B063	14026	Finchs Road, Kopke -1	SN25
666	14027	Garibaldi, McKees Rd, W of Hardies Hill Rd -1	SN43
666a	14028	Garibaldi, McKees Rd paddock -1	
240	14029	Sedgwick Property, Grenville -1	
B033	14030	Scotts Lane (Scotts Tk To Pryors Rd), Scotsburn -1	
511a	14031	Avenue of Honour paddock, Grenville -1	
M083	14032	Ryans Road, Yendon -1	
M028	14033	Ballan-Meredith Rd, Fiskville -1	SN57
238	14034	Lanes, Grenville - Yarrowee River Banksia/Snow Gum site -1	SN44
238	14035	Lanes, Grenville - Yarrowee River Banksia/Snow Gum site -2	
238	14036	Lanes, Grenville - Yarrowee River Banksia/Snow Gum site -3	
238	14037	Lanes, Grenville - Yarrowee River Banksia/Snow Gum site -4	
M183	14038	Ballan-Daylesford Road, Bunding -1	SN67
484	14039	Nagles Lane & Callaghan Rd E Side Cleever Hill, Bunding -1	SN68/SN69
M221	14040	Midland Highway, Elaine -1	
507	14041	Elaine-Meredith Rail Reserve, Midland Hwy -1	SN53

Site Code	Zone ID	Zone Name	Site Code (1996 Study)
Ela001	14042	Elaine-Morrisons Road, Morrisons -1	SN56
M244	14043	Lewis Road, Elaine -1	
678	14044	Greendale, almost at end of Coles Lane -1	SN72
674	14045	Bunding, Callahans Lane, 400m East of McHughs Lane -1	SN65
nar001	14046	Narmbool Road, Elaine -1	SN52
461	14047	Ballan-Meredith Rd, b/n O'Briens & Scheferles Rds, -1	SN54
461a	14048	Ballan-Meredith Rd Property, b/n O'Briens & Scheferles Rds, -1	
Ela002	14049	Elaine-Morrisons Rd Property, Morrisons -1	
M174	14050	S. Conroys Lane/Developmental Road, Bunding -1	SN70
525	14051	Durdiwarrah (Slate Quarry Road near Reservoir) -1	SN58
675a	14052	Bunding, roadside, intersection Daylesford & Moorabool Rd -1	
675	14053	Bunding, in paddock, intersection Daylesford & Moorabool Rd -1	SN66
511	14054	Avenue Of Honour, Grenville (Buninyong Mt Mercer Road) -1	SN47
810	14055	Woodbourne, Bamgannie Rd -2	SN51

Appendix II – Front and back of field data sheet

Snowgum field data sheet

Start time of Inspection:

*Please ensure camera is set to correct date/time

End time of Inspection:

Date: **Assessor:** Travis Turner & Kristin Monie

Site Code: **Site Waypoint ID Numbers**

Site Name:

Snowgum Number:

Tree Form:
- Single Stem
- Multi Stem
- Mallee

Mistletoe:

Tree Health:
- Tree Dead:
- Very Poor Health
- Poor Health:
- Good Health:
- Very Good Healtl
- Flowering:
- Light Crop:
- Moderate Crop:
- Heavy Crop:

Tree Height (m):
- Dist from tree (m):
- Down:
- Up:

DBH (cm):

E.pauc X E.rad:

Photo Ref (Time):

Tree Waypoint:

% Rock:
% Bare Earth:
% Native Grasses/Forbs:
% Leaf Litter:
% Bryophytes:
% Weeds (introd. grasses)
% Road:

Logs Length (m):
*Logs >100mm in diameter

Regeneration:
Number of Seedlings:
Number of Age Classes:

Tenure:
- Fenced
- Crown Land
- Freehold
- Roadside

INCIDENTAL FLORA: (circle abundance)

Eucalyptus obliqua	+ 1 2 3 4
Eucalyptus ovata	+ 1 2 3 4
Eucalyptus radiata	+ 1 2 3 4
Eucalyptus rubida	+ 1 2 3 4
Eucalyptus viminalis	+ 1 2 3 4
Eucalyptus yarraensis	+ 1 2 3 4
Acacia dealbata	+ 1 2 3 4
Acacia mearnsii	+ 1 2 3 4
Acacia melanoxylon	+ 1 2 3 4
Acacia paradoxa	+ 1 2 3 4
Acaena novae-zelandiae	+ 1 2 3 4
Austrodanthonia spp.	+ 1 2 3 4
Austrostipa spp.	+ 1 2 3 4
Themeda triandra	+ 1 2 3 4
Gahnia radula	+ 1 2 3 4
Gonocarpus tetragynus (Raspwort)	+ 1 2 3 4
Lissanthe strigosa (Peach Heath)	+ 1 2 3 4
Kennedia prostrata	+ 1 2 3 4
Astroloma humifusum (Cranberry Heath)	+ 1 2 3 4
Pteridium esculentum	+ 1 2 3 4
Dichelachne spp. (Plume Grass)	+ 1 2 3 4
Lomandra filiformis	+ 1 2 3 4
Microlaena stipoides (Weeping Grass)	+ 1 2 3 4
Oxalis perennens	+ 1 2 3 4
	+ 1 2 3 4
	+ 1 2 3 4
	+ 1 2 3 4
	+ 1 2 3 4
	+ 1 2 3 4
	+ 1 2 3 4
	+ 1 2 3 4
	+ 1 2 3 4
	+ 1 2 3 4
	+ 1 2 3 4
	+ 1 2 3 4

+ - sparse, cover very low
1 - plentiful, but <5% cover
2 - very numerous, at least 5% cover
3 - any number, covering 25-50%
4 - any number, covering 50-75%

MAJOR WEEDS:

Briza maxima Hawthorn Fog grass *Ulex europaueus*
Rubus spp. *Hyperchoeris radicata*

INCIDENTAL FAUNA:

Tree dead - tree completely dead with no chance of regrowth
Very poor health - only epicormic growth on trunk, lower branches or upper branches
Poor health - 50-75% of crown dead
Good health - 25-50% of crown dead
Very good health - less than 25% of crown dead

Light crop - fruit or buds sporadic over tree, not easy to find
Moderate crop - fruit or buds distinct and common on tree, easy to find
Heavy crop - fruit or buds dense throughout crown, most possible sites are occupied
Mature Tree = > 12metres in height (> 80% of Benchmark Height)

Snowgum field data sheet

Site Code: ☐ Waypoint ID Number: ☐

Vegetation Community:
- Woodland - Grassy Understorey ☐
- Woodland - Sedgy Understorey ☐
- Woodland - Shrubby Understorey ☐
- Woodland - Heathy Understorey ☐
- Open Forest ☐

Slope Curvature:
- Divergent ☐
- Parallel ☐
- Convergent ☐

Site Process:
- Alluvial ☐
- Depositional ☐
- Aeolian ☐

Adjacent Land Use:
- National/State Parks ☐
- Unused/Natural Veg ☐
- Logged Native Forest ☐
- Plantation ☐
- Voluntary/Native Pasture ☐
- Improved Pasture ☐
- Cropping ☐
- Orchard/Vineyard ☐
- Vegetables/Flowers ☐
- Urban ☐
- Industrial ☐
- Quarry/Mining ☐
- Rural Residential ☐
- Other ☐

Site Morphology:
- Flat ☐
- Crest ☐
- Ridge ☐
- Hillock ☐
- Upper Slope ☐
- Mid Slope ☐
- Lower Slope ☐
- Open Depression ☐
- Closed Depression ☐

Site Disturbance:
- Cleared ☐
- Natural ☐
- Grazed ☐
- Ploughed ☐
- Cultivated ☐
- Mown ☐
- Highly Disturbed (Quarrying/ Roadworks Etc) ☐

Competition:
- Cattle ☐
- Sheep ☐
- Kangaroos ☐
- Rabbits ☐
- Ploughing ☐
- Weeds ☐

Salting ☐
Erosion ☐
Aspect : ☐
Slope %: ☐

SOIL ANALYSIS: Soil Waypoint ID: ☐ Start Time: ☐ End Time: ☐

Horizon	Depth(cm):	Colour:	Texture:	pH:	ECsat(dSm-1):
A					
B					
O					

Soil Waypoint ID: ☐ Start Time: ☐ End Time: ☐

Horizon	Depth(cm):	Colour:	Texture:	pH:	ECsat(dSm-1):
A					
B					
O					

Soil Waypoint ID: ☐ Start Time: ☐ End Time: ☐

Horizon	Depth(cm):	Colour:	Texture:	pH:	ECsat(dSm-1):
A					
B					
O					

Soil Waypoint ID: ☐ Start Time: ☐ End Time: ☐

Horizon	Depth(cm):	Colour:	Texture:	pH:	ECsat(dSm-1):
A					
B					
O					

Soil Waypoint ID: ☐ Start Time: ☐ End Time: ☐

Horizon	Depth(cm):	Colour:	Texture:	pH:	ECsat(dSm-1):
A					
B					
O					

Observations/Notes:

Appendix III

Key to help ID E. pauciflora, E. radiata, E. pauciflora X radiata hybrid:

1a. Bark smooth =2
1b. Bark fibrous at least at base =3
2a. Fruits large (7-11mm wide), thick leaves with parallel veins, thick, held pendulously, distinct red stems

= E. pauciflora

2b. All not as above:

i. +/- Fruits of intermediate size

ii. +/- Red stems

iii. +/- Leaves thicker than E. radiata

iv. +/- Leaves held pendulously

v. +/- Peppermint smell not as distinct as in E. radiata

vi. +/- Leaf venation neither distinctly net or parallel

= E. pauciflora X radiata hybrid

3a. Fibrous bark to small branches, small fruits (4-6mm wide), thin leaves, leaves narrower than *E.pauciflora*, peppermint smell distinct when leaves crushed

= E. radiata

3b. All not as above:

i. +/- Fruits of intermediate size

ii. +/- Red stems

iii. +/- Leaves thicker than E. radiata

iv. +/- Leaves held pendulously

v. +/- Peppermint smell not as distinct as E. radiata

vi. +/- Leaf venation neither distinctly net or parallel

= E. pauciflora X radiata hybrid

NOTE: The hybrids fit well with E. willisii ssp falciformis

The new growth on Scent bark has reddish stems. The new growth on genuine Rough-bark Manna Gum usually has bright yellow stems. These two can hybridise.

Identification Key adapted from information from Tim D'Ombrain in combination with *"Eucalypts of Victoria and Tasmania – South-eastern Australia"* (Nicolle 2006).

Appendix IV

Slope Curvature:
Describes the shape of the site perpendicular to the slope

Slope Curvature	Description
Divergent	Slope cross-section is convex – runoff moves away from centre towards edges
Parallel	Slope cross-section is straight – runoff moves directly downslope
Convergent	Slope cross-section is concave – runoff moves from edges towards centre

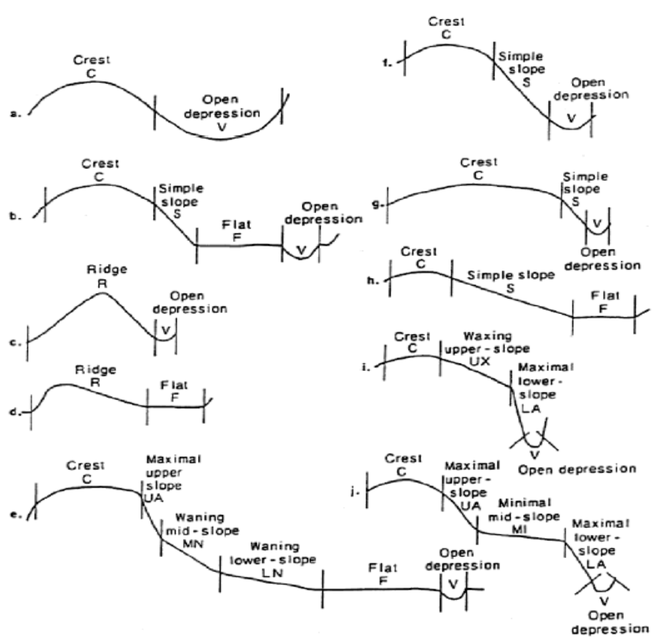
Adapted from Soil Data Entry Handbook 3rd Edition, 2001 (Milford *et al.* 2001)

Site Morphology:
Describes the position of the site relative to the slope (upslope, downslope)

Site Morphology	Description
Flat	Basically level ground, or very gently inclined (<3% slope)
Crest	Higher than adjacent terrain, convex in shape
Ridge	Long, narrow crest, often in line of hills/mountains, sides of ridge usually fairly steep
Simple Slope	Adjacent to crest and flat, two flats, flat and depression, or crest and depression
Lower Slope	Above a flat/depression, but not below a crest/flat
Mid Slope	Above a flat/ depression AND below a crest/flat
Upper Slope	Below a crest or flat
Depression	Lower than adjacent terrain

Adapted from Soil Data Entry Handbook 3rd Edition, 2001 (Milford *et al.* 2001)

Examples of Site Morphology:
For use in the field as reminder of Site Morphology descriptions



Adapted from Soil Data Entry Handbook 3rd Edition, 2001 (Milford *et al.* 2001)

Appendix V

Adjacent Land Use:

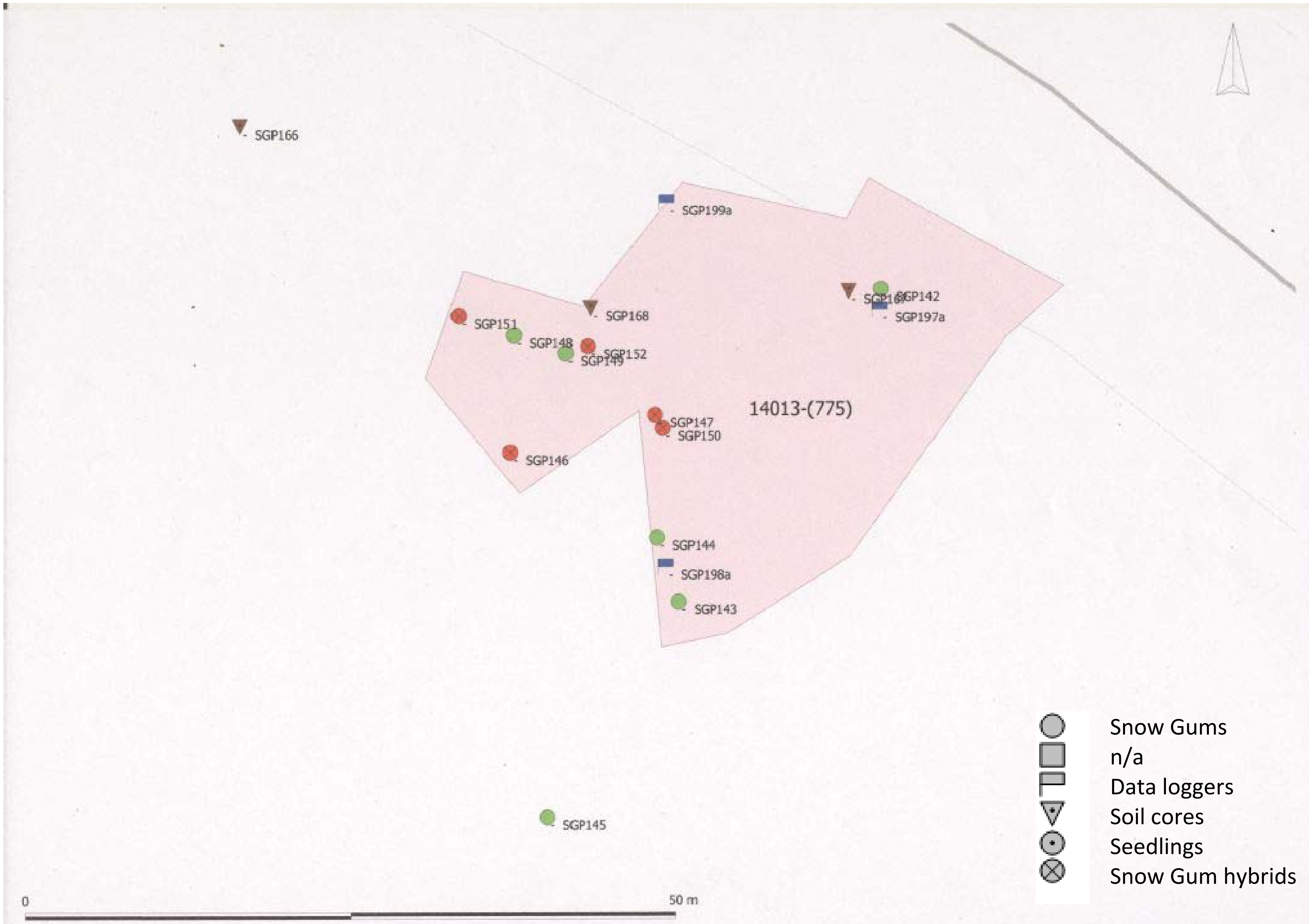
Describes the land use of land immediately adjacent to the site assessed. Used to assess the degree to which adjacent land use affects the health and distribution of *E. pauciflora ssp pauciflora*.

Land Use	Description
Cropping	Cultivated land used for agriculture production – e.g. grains, not vegetables, trees etc
Improved Pasture	Cleared land, may be lightly treed, with mostly exotic grasses/legumes; fertilised
Industrial	Factories, warehouses, sawmills etc and their grounds
Logged Native Forest	Native forest with evidence of past or present logging
National/State Parks	Relatively undisturbed publicly owned land
Orchard/Vineyard	Production of fruit trees or vines
Plantation	Vegetation cleared and replaced with plantation species – e.g. *Pinus radiata, Eucalypt spp.*
Quarry/Mining	Actively used for extractive industry or rehabilitated areas
Rural Residential	Allotments usually >1ha, associated with rural areas
Unused/Natural Vegetation	Ungrazed land being allowed to regenerate; may have been partially cleared in past
Urban	Allotments usually <1ha, associated with cities or towns
Vegetables/Flowers	Production of vegetables and/or flowers
Voluntary/Native Pasture	Cleared land, lightly treed with native or naturalised exotic grasses/legumes
Other	Any land use not covered by other descriptions

Adapted from Soil Data Entry Handbook 3rd Edition, 2001 (Milford *et al.* 2001)

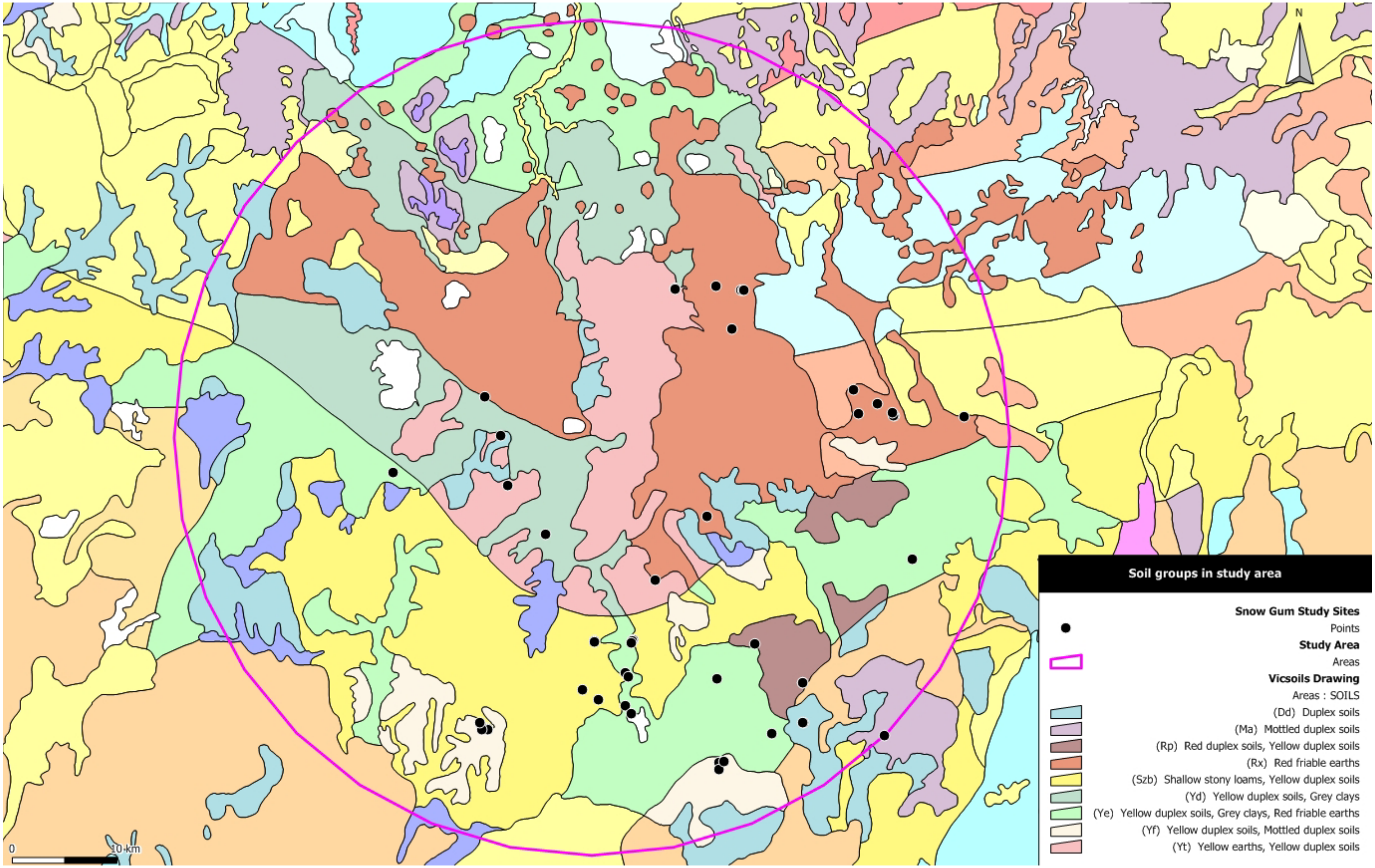
Appendix VI

Data logger locations at property in Dereel, Victoria



Appendix VII

Soil Groups in the Study Area



Appendix VIII – Species list

Native /Weed	Scientific Name	Common Name	Frequency located	Frequency (%)
N	Eucalyptus pauciflora ssp. pauciflora	White Sallee	56	100
W	Acetosella vulgaris	Sheep Sorrel	40	71
W	Hypochoeris radicata	Cat's Ear	39	70
W	Plantago lanceolata	Ribwort	32	57
N	Lomandra filiformis	Wattle Mat-rush	30	54
N	Acacia melanoxylon	Blackwood	29	52
N	Oxalis perennans	Grassland Wood-sorrel	29	52
W	Cirsium vulgare	Spear Thistle	25	45
N	Acaena novae-zelandiae	Bidgee-widgee	24	43
N	Themeda triandra	Kangaroo Grass	22	39
N	Gonocarpus tetragynus	Common Raspwort	22	39
N	Poa spp.	Tussock Grass	21	38
N	Microlaena stipoides var. stipoides	Weeping Grass	21	38
W	Romulea rosea	Onion Grass	21	38
N	Austrodanthonia spp.	Wallaby Grass	21	38
N	Acaena spp.	Sheep's Burr	20	36
W	Agrostis capillaris s.l.	Brown-top Bent	19	34
N	Austrostipa spp.	Spear Grass	19	34
W	Trifolium spp.	Clover	18	32
W	Ulex europaeus	Gorse	18	32
W	Rubus fruticosus spp. agg.	Blackberry	17	30
W	Crataegus monogyna	Hawthorn	16	29
N	Veronica gracilis	Slender Speedwell	16	29
W	Cynosurus echinatus	Rough Dog's-tail	15	27
W	Arctotheca calendula	Cape Weed	15	27
N	Asperula conferta	Common Woodruff	13	23
W	Rosa rubiginosa	Sweet Briar	12	21
N	Astroloma humifusum	Cranberry Heath	12	21
N	Acacia mearnsii	Black Wattle	12	21
N	Pimelea humilis	Common Rice-flower	11	20
N	Geranium spp.	Crane's Bill	11	20
N	Tricoryne elatior	Yellow Rush-lily	10	18
W	Dactylis glomerata	Cocksfoot	10	18
N	Bossiaea prostrata	Creeping Bossiaea	9	16
W	Pinus radiata	Radiata Pine	9	16
W	Briza maxima	Large Quaking-grass	9	16
N	Eucalyptus spp.	Eucalypt	9	16
N	Opercularia ovata	Broad-leaf Stinkweed	8	14
N	Lissanthe strigosa subsp. subulata	Peach Heath	8	14
N	Eucalyptus ovata var. Ovata	Swamp Gum	8	14

N	Cynodon dactylon	Couch	8	14
N	Acrotriche prostrata	Trailing Ground-berry	8	14
W	Paspalum dilatatum	Paspalum	8	14
N	Poa morrisii	Soft Tussock-grass	8	14
W	Plantago coronopus	Buck's-horn Plantain	7	13
N	Eucalyptus viminalis subsp. viminalis	Manna Gum	7	13
W	Genista monspessulana	Montpellier Broom	7	13
W	Solanum nigrum sensu Willis (1972)	Black Nightshade	6	11
N	Arthropodium strictum s.l.	Chocolate Lily	6	11
N	Dichondra repens	Kidney-weed	6	11
N	Hypericum gramineum	Small St John's Wort	5	9
N	Eucalyptus radiata subsp. radiata	Narrow-leaf Peppermint	5	9
N	Calocephalus lacteus	Milky Beauty-heads	5	9
N	Juncus flavidus	Gold Rush	5	9
W	Galium aparine	Cleavers	5	9
N	Rumex spp.	Dock	5	9
N	Hydrocotyle laxiflora	Stinking Pennywort	5	9
N	Burchardia umbellata	Milkmaids	5	9
W	Anagallis arvensis	Pimpernel	5	9
W	Sonchus oleraceus	Common Sow-thistle	4	7
N	Goodenia lanata	Trailing Goodenia	4	7
N	Chrysocephalum apiculatum s.l.	Common Everlasting	4	7
N	Gahnia radula	Thatch Saw-sedge	4	7
N	Amyema pendula	Drooping Mistletoe	4	7
N	Euchiton spp.	Cudweed	4	7
N	Carex iynx	Tussock Sedge	3	5
N	Carex appressa	Tall Sedge	3	5
N	Cassinia arcuata	Drooping Cassinia	3	5
N	Juncus subsecundus	Finger Rush	3	5
N	Plantago spp.	Plantain	3	5
N	Hibbertia riparia	Erect Guinea-flower	3	5
N	Melicytus dentatus s.l.	Tree Violet	3	5
N	Thelymitra spp.	Sun Orchid	3	5
N	Acacia paradoxa	Hedge Wattle	3	5
N	Crassula decumbens var. decumbens	Spreading Crassula	2	4
N	Dianella revoluta s.l.	Black-anther Flax-lily	2	4
N	Dichelachne spp.	Plume Grass	2	4
N	Kennedia prostrata	Running Postman	2	4
N	Drosera peltata	Pale Sundew	2	4
N	Euchiton collinus s.l.	Clustered/Creeping Cudweed	2	4
N	Eucalyptus viminalis subsp. cygnetensis	Rough-barked Manna-gum	2	4
N	Eriochilus cucullatus	Parson's Bands	2	4
N	Hemarthria uncinata var. uncinata	Mat Grass	2	4

N	Acrotriche serrulata	Honey-pots	2	4
W	Cerastium glomeratum s.l.	Common Mouse-ear Chickweed	2	4
N	Acacia dealbata	Silver Wattle	2	4
W	Avena spp.	Oat	2	4
W	Anthoxanthum odoratum	Sweet Vernal-grass	2	4
N	Xanthorrhoea minor subsp. lutea	Small Grass-tree	2	4
N	Viola hederacea sensu Willis (1972)	Ivy-leaf Violet	2	4
W	Taraxacum officinale spp. agg.	Garden Dandelion	2	4
W	Stellaria media	Chickweed	2	4
N	Pteridium esculentum	Austral Bracken	2	4
N	Allocasuarina littoralis	Black Sheoak	2	4
N	Plantago varia	Variable Plantain	2	4
N	Lythrum hyssopifolia	Small Loosestrife	2	4
N	Glycine latrobeana	Clover Glycine	2	4
W	Rumex crispus	Curled Dock	2	4
W	Phalaris aquatica	Toowoomba Canary-grass	2	4
N	Austrodanthonia geniculata	Kneed Wallaby-grass	2	4
N	Brachyloma ciliatum	Fringed Brachyloma	1	2
N	Eucalyptus melliodora	Yellow Box	1	2
N	Eucalyptus brookeriana	Brooker's Gum	1	2
N	Casuarina spp.	Sheoak	1	2
W	Trifolium repens var. repens	White Clover	1	2
N	Cheilanthes austrotenuifolia	Green Rock-fern	1	2
N	Epilobium hirtigerum	Hairy Willow-herb	1	2
W	Tragopogon porrifolius	Salsify	1	2
N	Cymbonotus preissianus	Austral Bear's-ear	1	2
N	Epilobium billardierianum subsp. cinereum	Grey Willow-herb	1	2
N	Crassula spp.	Crassula	1	2
N	Acaena ovina	Australian Sheep's Burr	1	2
N	Bursaria spinosa subsp. spinosa	Sweet Bursaria	1	2
N	Convolvulus erubescens spp. agg.	Pink Bindweed	1	2
N	Eucalyptus obliqua	Messmate Stringybark	1	2
N	Agrostis capillaris s.l.	Bent/Blown Grass	1	2
W	Setaria gracilis var. pauciseta	Slender Pigeon Grass	1	2
N	Acacia montana	Wattle	1	2
N	Rubus parvifolius	Small-leaf Bramble	1	2
W	Lolium perenne	Perennial Rye-grass	1	2
W	Hirschfeldia incana	Buchan Weed	1	2
N	Opercularia varia	Variable Stinkweed	1	2
N	Pelargonium rodneyanum	Magenta Stork's-bill	1	2
N	Pimelea linifolia	Slender Rice-flower	1	2
N	Pimelea spp.	Rice Flower	1	2
N	Platylobium obtusangulum	Common Flat-pea	1	2

N	Poa labillardierei	Common Tussock-grass	1	2
W	Festuca arundinacea	Tall Fescue	1	2
W	Holcus lanatus	Yorkshire Fog	1	2
N	Pterostylis spp.	Greenhood	1	2
W	Urtica urens	Small Nettle	1	2
N	Rumex brownii	Slender Dock	1	2
W	Erodium cicutarium	Common Heron's-bill	1	2
W	Ehrharta longiflora	Annual Veldt-grass	1	2
N	Veronica calycina	Hairy Speedwell	1	2
W	Cytisus scoparius	English Broom	1	2
W	Cupressus macrocarpa	Monterey Cypress	1	2
W	Crepis capillaris	Smooth Hawksbeard	1	2
W	Conyza bonariensis	Flaxleaf Fleabane	1	2
W	Conium maculatum	Hemlock	1	2
N	Pseudognaphalium luteoalbum	Jersey Cudweed	1	2
N	Iridaceae spp.	Irid	1	2
W	Malus spp.	Apple	1	2
N	Eucalyptus rubida	Candlebark	1	2
W	Lolium spp.	Rye Grass	1	2
N	Euchiton collinus s.s.	Creeping Cudweed	1	2
N	Galium spp.	Bedstraw	1	2
N	Geranium sp. 2	Variable Cranesbill	1	2
N	Lomandra longifolia	Spiny-headed Mat-rush	1	2
N	Gnaphalium spp.	Cudweed	1	2
W	Chamaemelum nobile	Common Chamomile	1	2
N	Microtis spp.	Onion Orchid	1	2
N	Helichrysum rutidolepis s.l.	Pale Everlasting	1	2
W	Malva nicaeensis	Mallow of Nice	1	2
N	Juncus pallidus	Pale Rush	1	2
N	Juncus spp.	Rush	1	2
N	Lepidosperma longitudinale	Pithy Sword-sedge	1	2
N	Leptorhynchos squamatus	Scaly Buttons	1	2
N	Leptorhynchos tenuifolius	Wiry Buttons	1	2
N	Leptospermum continentale	Prickly Tea-tree	1	2
N	Leptospermum myrsinoides	Heath Tea-tree	1	2
#	Acacia retinodes	Wirilda	1	2
W	Juncus acutus subsp. acutus	Sharp Rush	1	2
W	Lepidium africanum	Common Peppercress	1	2
W	Bromus spp.	Brome	1	2
N	Einadia nutans	Nodding Saltbush	1	2
W	Centaurium erythraea	Common Centaury	1	2

APPENDIX IX

Ecological Vegetation Classes (EVC) of Snow Gum sites in the study area