## Chapter 5

## THESIS OVERVIEW AND CONCLUSIONS

### Introduction

This thesis had the following objectives (Chapter 1):

(a) to advance knowledge of the ecology of grassland remnants on Victoria's northern Riverine Plain,

(b) to compare vegetation of this region with grassy ecosystems in other regions,

(c) to establish a broad ecological framework for the conservation management of the region's threatened grassy vegetation.

In each case, considerable knowledge has been gained as explained below:

### Phase 1: Ecology of Existing Remnant Grassy Vegetation (Chapter 2).

By sampling least modified remnants, it was found that grassy vegetation of the Northern Plain is rich in indigenous species, as well as diverse in structure (mainly grassland and grassy woodland) and community composition. This vegetation is unique in Victoria and south-eastern Australia because of the rich and abundant presence of species of the family Chenopodiaceae and diminutive native annuals which are both uncommon in grassy vegetation elsewhere. One such species, *Leptorhynchos scabrus* (annual buttons) was thought to be extinct in Victoria until it was found in great abundance on private property during this study.

As would be expected, the grasslands and grassy woodlands of the region were found to be broadly distinct floristically, however, the community groups identified did not correlate with vegetation types previously described in the region on the basis of structure and dominant species composition. Community variation was more closely linked to environmental and anthropogenic influences. The key environmental factors included geology, soil type (drainage characteristics) and mean annual precipitation. Post-settlement land management (closely linked to land tenure) had an important influence on all vegetation, but its impact on grasslands was particularly striking.

Compared with grasslands, grassy woodlands generally supported greater numbers of native shrubs, perennial tussock grasses and perennial forbs, whilst grasslands contained a greater number of native annual forbs. To some extent these difference could be linked to environmental factors such as soil type and shading, but anthropogenic factors cannot be discounted because the vast majority of grassy woodlands occurred on infrequently disturbed land. In general, frequent stock grazing tends to reduce the richness of perennial native species and if not controlled will eventually result in the loss of all woody plants including trees. Grasslands occurred almost exclusively on the heavily textured (clay loam to clay) non-inundated soils and grassy woodlands occupied a far greater range of soils generally with better drainage characteristics (lighter texture). Whilst some floristic groups were distributed throughout the region, greatest community diversity was recorded in the west. Because of the uniform precipitation gradient across the region, the ecology of geographically isolated vegetation, such as that restricted to the far east of the region, is probably linked to rainfall. No clear trends for either rare or threatened species or exotics species emerged in the study, although a slightly higher richness of weeds was recorded in the east, possibly also because of rainfall patterns. Furthermore, surprisingly, grassy vegetation subject to frequent grazing did not support a higher richness of weeds - a group of plants that are already abundant in even the best quality remnants.

In areas where stock grazing is infrequent or absent, such as along roadsides or rail reserves, the grassland vegetation was dominated by native perennial grasses and forbs, with shrubs a frequent element. In contrast, on long-grazed freehold land (conservative stocking rates), remnant grasslands were dominated by a combination of native perennials (grasses and forbs, but no shrubs) and annuals. Because the distribution of these two grassland types was most closely linked to land tenure (often the boundaries between them coincided with fence lines), a community divergence model was proposed by way of explanation. This model assumed that the former treeless plain vegetation contained floristic elements from both grasslands and that the present day species composition was primarily the consequence of the differential response of the various elements to post-settlement land management. Irrespective of their evolution, both of these grasslands need to be protected in order to conserve regional plant diversity because they contain complementary floristic elements. Furthermore, it must be acknowledged that in order to achieve this objective, the anthropogenic management processes that have “created” these grasslands must also be maintained. Chapter 4 of this thesis aimed to provide experimental evidence to support this model.

Within the Northern Plain, grassy vegetation is floristically closest to riparian *Eucalyptus largiflorens* (black box) woodlands distributed along the major western watercourses. The presence of semi-aquatic flora resulting from infrequent flooding in the black box woodlands, is the main distinguishing factor. Compared with adjacent biogeographic regions, Northern Plain grassy vegetation has closest affinity with that in the Wimmera and across the border into the southern Riverina of NSW. There are few floristic links with the box-ironbark vegetation of the Midlands, although there is an ecotonal region on the lower slopes and rises in the northern reaches of the central Victorian hills.

**Phase 2: Nature of Treeless Plains Vegetation at the Time of European Settlement (Chapter 3).**

Historical information (primarily literature and survey maps) proved to be a useful tool for reconstructing the former distribution and nature of treeless plain vegetation across the Northern Plain. By combining an accurate historical map (showing vegetation boundaries) with recent soil type maps, it was possible to produce a reasonably precise map of the former distribution of treeless plains. In the process, it was also possible to build up an understanding of the ecology of this vegetation, in particular its links with the soil, flooding, topography and other vegetation. Using this technique, at the time of European settlement, it is estimated that treeless plain vegetation occupied about 4000 $km^2$ and was mainly restricted to the drier western portions of the region, west of the Goulburn River. Recent surveys of remnant vegetation across all tenures, suggest that < 2.5% of the former extent remains (0.05% in conservation reserves), much of which is quite degraded and located on private property with an uncertain future. Woodlands and shrublands dominated by *Eucalyptus largiflorens* and *Muehlenbeckia florulenta* occurred in seasonally flooded, clayey drainage lines, swamps and active flood plains. Sandier soils associated with lunettes, palaeo-channels and adjacent geological formations were occupied by woodlands dominated by *Callitris* spp., *Eucalyptus* spp. and *Allocasuarina luehmannii.* The treeless plain vegetation occupied the region in between on heavily textured riverine soils not subject to inundation, confirming the trends evident in remnant vegetation as documented in Chapter 2. Whilst climate and historical burning may have contributed to patterns of treelessness, the physical characteristics of the soils create very difficult conditions for deep-rooted perennial plants and were probably the key factor.

The historical literature, in particular the accounts of Mitchell, Hawdon, Curr and Robinson, provided considerable detail on the nature of treeless plains vegetation during the middle of the 19 th century. In comparison with today's grassland remnants, it is clear that the treeless plain vegetation of the Northern Plain no longer exists in its original form. Its composition, structure and ecological function have been profoundly transformed by 160 years of white occupation and intensive agricultural land use. For instance, the historical accounts note the widespread presence of saltbushes (various types) and pigface which are now regionally extinct or extremely rare. The grassland refugia observed in the landscape today probably contain only a subset of the pre-settlement flora, a conclusion consistent with the community divergence model posed in Chapter 2. The change has been linked to the absence of burning (as practiced by Aborigines), the introduction of domestic stock and other exotic species, and the extinction of native fauna, possibly exacerbated by drought. These conclusions align very closely with those for the southern Riverina of NSW where grasslands are regarded as "disclimax". Irrespective of the recent history of this vegetation, the remaining refugia are scarce and relatively species-rich (often providing habitat for rare and endemic species), and therefore valuable from a conservation perspective. Whilst speculation about the former nature of grasslands is largely irrelevant to the management of significant remnants, it can help to establish a framework for developing longer term conservation management options.

**Phase 3: Disturbance Ecology of a Long-Grazed Species-Rich Grassland (Chapter 4).**

Whilst the small road and rail grassland remnants need to be conserved, in the longer term, grassland conservation may inevitably shift to a handful of very significant larger remnants now under private ownership. The existence of these sites is more due to coincidence than good management and much remains to be learnt regarding conservation management. Chapter 4 sought to answer some of the questions posed in the Chapter 2 especially the appropriateness of maintaining historical (post-settlement) land management practices.

Over the duration of the experiment, the historically conservative grazing regime (light stocking rates, excluded during spring) did sustain vegetation richness, although both exotic and native richness was temporarily reduced as a consequence of drought in 1994. In contrast, exotic or native richness did not increase under grazing exclosure and vastly changed the vegetation structure by increasing the abundance of perennial species and reduced the abundance of interstices (gaps). Although grazing exclosure did not result in the loss of native species over the three years (as was anticipated by the community divergence model posed in Chapter 2), trends suggest a drop may be recorded with more time - perhaps after 5 to 10 years.

Native annual species fluctuated widely in abundance as a consequence of rainfall, particularly winter rainfall, when most germination occurred (the greatest effect of treatments was observed in 1995 when winter rainfall was highest and not a limiting factor). Grazing response was determined by growth form and relative abundance, in relation to interstitial availability which was in turn linked to the growth of perennials (especially grasses) over the previous year. The smaller annuals were generally not grazed because of their stature and were therefore able to better exploit the increased space created or sustained under grazing. However, when relative abundance was modified by either cultivation, burning or over grazing (annuals become more conspicuous), the grazing response was lessened or even reversed.

As has been observed in grasslands elsewhere, cultivation favoured exotic annual grasses, suggesting the soil seed bank is dominated by exotics. In contrast, most native species where eliminated by soil disturbance - the perennials were especially sensitive. Although some native annuals were initially favoured by soil disturbance (species suspected of having a significant soil seed bank), repeated disturbance eliminated all natives and sustained the dominance of the annual exotic grasses. Despite this severe impact, the vegetation did show some signs of recovery with time after the initial disturbance with a gradual increase in both species number and cover-abundance. It is speculated that this recovery was linked more to the movement of seed from the surrounding vegetation rather than regrowth from a soil seed bank. Recovery trends suggest that vegetation could theoretically return to its former state over time, but is unlikely to if soil disturbance occurs on a broad scale. The severe detrimental impact of cultivation on the native flora of grasslands observed under experimental conditions, confirm such soil disturbance as one of the most significant immediate threats to species-rich grassland remnants, especially those on private property and roadsides.

In general, burning had a similar impact on the structure of grassland vegetation to grazing by reducing the cover of all vegetation and increasing the area of interstitial gaps. However, in contrast, it is assumed that the heat associated with burning destroyed seed at and near the soil surface, resulting in reduced annual abundance (native and exotic) despite the greater availability of gaps. The abundance and richness of annuals were kept low with annual burning, and it is speculated that over time they may be entirely eliminated - a situation that has been observed in rail remnants that were historically subject to frequent burning. Less frequent burning however, allowed the annuals to recover, the success of which was linked to the import of seed from immediately adjacent undisturbed vegetation. As with the soil disturbance treatments, the tallest native annuals recovered at a faster rate presumably because these species were more successful seed dispersers. Weed abundance and richness were more significantly reduced by burning compared with the native flora as the exotics are predominantly annual. This differential response to fire suggests burning may have potential as a conservation management tool to enhance/improve significant remnants, although further experimental trials will be necessary to develop effective management prescriptions.

Although some of the results of the experiment were equivocal, the trends that emerged support aspects of the community divergence model posed in Chapter 2. Extrapolation of these trends suggests native richness will diminish under grazing exclosure in time as the area of gaps is maintained at a very low level and accumulates litter (initially having greatest impact on the native annuals). Accordingly, this work suggests that the broad richness - disturbance relationships reported in grasslands elsewhere (i.e. frequently burnt *Themeda triandra* grasslands on the Victorian Volcanic Plain) equally applies in Northern Plain grasslands, but at a much slower rate linked to dominant species composition and climate controlled growth rates. Although further monitoring is required to verify these assertions, at this stage conservative grazing is recommended as the preferred conservation management strategy for historically grazed grassland vegetation. However, the results have highlighted areas in which conservation management is flexible or could be improved

**Future Research**

A number of potential future research opportunities have been identified that would build on or complement the work conducted in this thesis. With respect to the historical research, examination of historical maps and herbarium specimens from the region could help to develop a treeless plain species list at the time of European settlement and clarify the distribution of grasslands within the vicinity of the Goulburn River. This work could be integrated with ecological research and conservation management by reintroducing regionally extinct or rare species (especially shrubs and perennial forbs) into secure remnants. As well as studying the biology of individual species, this work could be extended to examine the impact on the flora, the results of which could have implications for the conservation management of grasslands (e.g. the competitive influence of shrubs such as *Atriplex nummularia* could assist in the maintenance of species diversity in the absence of other disturbances).

As grassy woodlands were not the focus of this study there is considerable potential to look more closely at this interesting and diverse vegetation in a way that would complement the conclusions of Chapter 2. In particular, more thorough sampling of least disturbed remnants on private property in the region will help to address a number of key ecological questions. Furthermore, the experimental work undertaken for grassland vegetation could be modified and implemented in significant grassy woodlands.

It is critically important that the trends identified over the duration of the grassland experiment (Chapter 4) be monitored over the longer term in order to confirm the conclusions drawn and to test speculation about future trends.

Other relevant ecological issues that emerged from the experimental work that could be the subject of complementary research are: (a) soil seed bank composition and dynamics - what natives are represented in the soil seed bank and what are the processes that replenish it?; (b) seed dispersal characteristics - are the taller annuals more successful at dispersing seed over larger distances?; (c) fire enhancement - is the flowering and seed production of perennial forbs enhanced by burning as has been reported in southern Victoria?; and (d) processes that lead to successful plant recruitment - when do perennial forbs recruit and what climatic and structural factors control this process?