Effects Of Grazing, Fencing And Licencing On The Natural Values Of Crown Land Frontages In The Goulburn-Broken Catchment

A background paper to the current CMA review of waterfrontage licences.

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SUMMARY

Introduction

The Goulburn-Broken catchment occupies 17% of Victoria's area. It provides 11% of the Murray Darling Basin's water resources from its 9900 km of streams. The proper management of its land and water resources is consequently of fundamental importance to the long-term environmental and agricultural sustainability of the catchment and of the Murray Darling rivers system. Already, however, the environmental condition of much of the Goulburn-Broken catchment is classed as poor because of past and present degradation of its land and water resources by vegetation clearance, human-induced salinity, erosion, sedimentation, altered water flows, nutrient inputs, agricultural activities, forestry and weed invasion (GBCLPB 1997).

As part of its response to these land degradation issues, the Goulburn Broken Catchment Management Authority (CMA) has prepared a Catchment Strategy (GBCLPB 1997) which, *inter alia*, commits the CMA and the local community to:

- improve the condition of 3000 km of stream to good or excellent over 30 years while maintaining the environmental conditions of streams currently rated good and excellent, and
- complete the review of river frontage licences to achieve adoption of best management practices.

It is these two objectives which form the focus of this background paper. Although a review of licenced water frontages within the catchment is presently in progress, there has been no study done in Victoria which evaluates the effects of stock-grazing or licenced stock-grazing on the ecological values of streamlines.

The Goulburn Valley Environment Group (GVEG) analysed data collected from a survey of 365 kilometres of creekline within the catchment (Robinson & Mann 1996, 1996b) to:

- measure the effects of stock-grazing and licenced grazing on ecological attributes of creeklines
- measure the effectiveness of fencing as a management tool for creekline conservation
- measure the effectiveness of the present licencing system as a sustainable method of stock-grazing on public frontages
- provide background information for incorporation into the licenced frontage review, and
- provide recommendations for 'best management practices' of public frontages and other creeklines.

Results

Licenced frontages were found to be grazed significantly more than unlicenced frontages and had less groundcover biomass, less tree regeneration, fewer shrubs, less lignum, more noxious or regionally controlled weeds, and more bare ground as a result. Regardless of licenced status, more heavily grazed frontages were found to have significantly modified plant species' compositions in the groundlayer and less representation of many species of native plant.

All of these changes significantly reduced the biodiversity values of the riparian and instream environments along the creeks system. More fundamentally, these changes to the riparian environment were found to exacerbate the already poor condition of riparian and aquatic environments in much of the catchment by causing increases in salt, sediment and nutrient loads, increases in runoff, increases in soil erosion, increases in streamflows, increases in water temperature and increases in the probability of algal blooms.

The study thus found that the current management practice of allowing some public land frontages to be licenced for grazing is not environmentally sustainable, as it is causing the active degradation of land and water resources throughout the catchment. It further found that illicit grazing of many unlicenced frontages adjoining agricultural land also contributes significantly to ongoing degradation of land and water resources in the catchment.

By contrast, fencing was found to significantly improve the ecological condition of creeklines. The main cause of the improvement in ecological condition of fenced frontages was decreased stock-grazing, the decrease then permitting the fairly rapid recovery of most of the ecological attributes measured. Fencing of frontages and other creeklines thus provides an effective means of reducing the rate of land and water degradation and of increasing the scope for biodiversity conservation.

Response to the review of licenced water frontages

The review of licenced water frontages (Finney, Whelan & Associates 1997) made the following statements about water frontage management and the effects of stock-grazing:

a) stock grazing causes destruction of native vegetation
b) stock grazing causes increased erosion
c) stock grazing changes the species composition of the plants found at a site
d) stock grazing causes an increase in weeds
e) environmental changes only occur over a long time period
f) 'piecemeal improvement of practices on particular frontages is unlikely to yield the expected overall improvement of the waterway'
g) removal of stock grazing will not lead to the rehabilitation of sites, and
h) fencing of frontages will not lead to the rehabilitation of sites (pp 34-36, Finney, Whelan & Associates 1997).

Results from this study confirmed the first three of these assumptions. The remaining assumptions or statements were found to be false. Decreases in stock-grazing levels were found to lead to significant rehabilitation of sites, while fencing was found to be an effective means of obtaining those lower stocking levels, without needing recourse to other controls. Most importantly, results from the study showed that these changes generally occurred rapidly at given sites, such that land and water benefits along the creeks system could be expected within a few years.

Given these findings, GVEG believes that the CMA can take a far more pro-active approach to riparian management in the catchment than that proposed by the consultants, as improvements in the ecological condition of creeklines appear relatively straightforward to achieve.

Recommendations

1. The CMA should take a leading role within the Goulburn-Broken catchment with regard to the development of 'best management practices' for public frontages and manage them sustainably as an example of how <u>all</u> creeklines should be managed within the catchment.

2. The CMA should implement management practices along public frontages that ensure that it fulfills its legal obligations under the *Flora and Fauna Guarantee Act* (1988) (see Appendix 2), particularly with regards to amelioration of the following threatening processes listed under the Act:

(a) Alteration to the natural flow regimes of rivers and streams
(b) Alteration to the natural temperature regimes of rivers and streams
(c) Degradation of native riparian vegetation along Victorian rivers and streams
(d) Increase in sediment input into Victorian rivers and streams due to human activities
(e) Input of toxic substances into Victorian rivers and streams and
(f) Removal of wood debris from Victorian streams.

3. All public frontages abutting agricultural land in the catchment should be fenced from stock, either as a pre-requisite of licencing arrangements or as part of the landholders' responsibility under the *Land Act* (1958).

4. Licenced grazing should be cancelled or deferred on all public frontages where shrubs have persisted, at least until grazing systems can be developed which ensure that grazing does not diminish the conservation values of those sites.

5. Stocking rates on frontages where licenced grazing is to be permitted should be decreased, as current stocking rates actively contribute towards land and water degradation in the catchment.

6. Fencing should be promoted along all creeklines adjoining agricultural land throughout the catchment so that grazing levels can be reduced. DNRE and the CMA should actively foster the fencing of frontages through policy programs and the Land Protection Incentive Scheme.

7. As part of the above fencing program, DNRE and the CMA should:

a) foster the introduction of off-creek watering schemes and set up some demonstration sites
b) establish a project to monitor the effects of fencing frontages on land and water resources and on biodiversity
c) evaluate the effects of different stocking levels on biodiversity values, and
d) establish a program to re-establish the indigenous shrubs to those protected frontages.

1 INTRODUCTION

The Goulburn-Broken catchment covers an area of 2.1 million hectares (17% of Victoria). It comprises 2% of the Murray Darling Basin's land area but generates 11% of the basin's water resources from its 9900 kilometres of streams. The proper management of its land and water resources is consequently of fundamental importance to the long-term environmental and agricultural sustainability of the catchment and of the Murray Darling rivers system.

This need for better management of land and water resources in the catchment is underlined by the Catchment Managament Authority's (CMA's) estimate that approximately $20 million needs to be spent on resource management every year to ensure long-term sustainability of the catchment's natural, agricultural and social environments (GBCLPB 1997, Appendix 1).

It is acknowledged by the specific objectives and actions contained in the Catchment Strategy that the Goulburn-Broken community needs to:

- manage the salinity of land and water resources and the quality of water in the Shepparton Irrigation Region in order to maintain and, where feasible, improve the social well-being, environmental quality and productive capacity of the region
- reduce groundwater accessions, soil salinisation and waterlogging on farms
- protect and where possible, rehabilitate the natural environment of the region from loss or serious damage from high watertable and salinity
- reduce phosphorus loads from irrigation drains by 50%
- reduce potential phosphorus loads in catchment waterbodies by 65% over 20 years to minimise risks of blue-green algal blooms in the catchment and in the Murray River
- further incorporate biodiversity into the other irrigation and dryland programs, and provide a major focus for the management of reserve areas and how they link into other parcels of private land within the catchment
- implement the public lands component of the Water Quality Strategy with priority on sediment reduction and to maintain or improve the environmental quality and ecological integrity of aquatic ecosystems
- improve the condition of 3000 km of stream to good or excellent over 30 years while maintaining the environmental conditions of streams currently rated good and excellent, and
- complete the review of river frontage licences to achieve adoption of best management practices.

It is the latter two objectives which form the focus of this background paper. The paper comprises: (1) a literature review of some of the environmental issues linked to riparian (creekline) management in the catchment; (2) background information on Crown land frontages and the current review of grazing licences; (3) the results of a study examining the ecological effects of grazing, fencing and licencing on 365 kilometres of public frontage in the Goulburn-Broken catchment; and (4) recommendations for ecologically sustainable management of water frontages and all other streamlines within the catchment.

2 LAND AND WATER ISSUES LINKED TO RIPARIAN MANAGEMENT IN THE CATCHMENT

Because rivers and creeks act as transport corridors for wildlife, soil, salt and nutrients between different parts of the one property, catchment or basin, the appropriate management of streams and their catchments has significant land management ramifications for all points downstream.

2.1 Riparian management and salinity

The Goulburn-Broken catchment presently exports an average of 180,000 tonnes of salt every year from the dryland part of the catchment to either the Shepparton Irrigation Region or the Murray River. This amount is expected to double over the next fifty years and to cause the irreversible degradation of 1500 kilometres of streams in the Irrigation Region if nothing is done (GBCLPB 1997). Rising salinity is also predicted to cause substantial increases in stream salinities in parts of the dryland region (e.g. Broken Riverine Plain), potentially affecting major creek systems such as the Broken and Boosey Creeks (DNRE 1996).

Significant relationships between tree cover and stream salinity have been demonstrated for sub-catchments within the Goulburn-Broken Catchment (DNRE 1996) and for catchments elsewhere in Australia (e.g. Greig & Devonshire 1981; Ruprecht & Schofield 1989; George *et al*. 1995). In every case, the relationship is due to the clearing of deep-rooted native vegetation causing increased runoff, increased recharge and rising groundwater. The retention or restoration of native vegetation along creeklines may minimise further increases in stream salinities and salt export loads through: (1) local lowering of watertables (George *et al*. 1993, 1995; Hydrotechnology 1995a); (2) and interception of surface runoff water containing dissolved salts (Hydrotechnology 1995a).

2.2 Riparian management and physical water quality

Twenty-four percent (2300 km) of streams in the Goulburn-Broken catchment are ranked as being in poor to very poor environmental condition, partly because of erosion or sedimentation problems (Mitchell 1990). Much of this sediment input is due to erosion and movement of soil in the upper parts of the catchment as a result of forestry, agricultural activity along waterways and streamside recreation (CMPS & F 1995). Throughout the catchment, localised erosion, soil movement and sedimentation may also occur in response to over-grazing (CMPS & F 1995). Increased erosion and sedimentation is predicted to occur in the future in some parts of the catchment in response to increasing salt concentrations in streams (Harper 1992).

Overseas studies have found that reduced stock-grazing levels along waterways significantly decreases the rate of streambank erosion (Kauffman *et al*. 1983a) and the rate of runoff (Rauzi & Hanson 1966) because of the presence of more vegetative cover to help bind the soil and trap mobile soil particles (Rauzi & Hanson 1966; Kauffman *et al*. 1983a; Hairsine 1996), and because of less soil compaction (Rauzi & Hanson 1966). Sediment loads in one study were reduced by between 48 and 79% while flowing through 5.6 kilometres of stream protected from grazing (Winegar 1977 in Kauffman & Krueger 1984). The retention or establishment of riparian vegetation consequently exerts a significant impact on physical water quality, as does the level of stock grazing along waterways.

2.3 Riparian management and nutrient loads

The Goulburn-Broken catchment is ranked as the highest priority catchment for nutrient reduction in the Victorian part of the Murray Darling Basin because of its generally high nutrient levels and poor water quality (MDBMC 1994; GBCLPB 1997). Nutrient export loads from the catchment vary considerably in different years but range between 256-615 tonnes of phosphorus and 1613-5121 tonnes of nitrogen every year (GBCLPB 1997). Annual imports of nutrients into catchment streams likewise vary considerably, ranging from between 126-154 tonnes per year for phosphorus and 1980-2340 tonnes per year for total nitrogen in the dryland part of the catchment (CMPS & F 1995). Annual imports of nutrients into catchment streams from the irrigation region are estimated to comprise about 1245 tonnes of phosphorus and 2561 tonnes of nitrogen (Hydrotechnology 1995b).

In the upper-mid catchment, imports of nutrients are considered to be due primarily to soil disturbance from forestry, agricultural activities along waterways and streamside recreation. In the mid-lower and lower catchment, imports of nutrients are due primarily to agricultural activities near waterways, diffuse runoff from irrigated pasture, and forestry (CMPS & F 1995; Hydrotechnology 1995b). High nutrient inputs may also occur following heavy rainfalls and the movement of soil (CMPS & F 1995). In general, these nutrient inputs appear to be due primarily to soil erosion and the movement of soil and nutrients across the surface and through shallow groundwaters (Quinn *et al*. 1993; CMPS & F 1995). The retention or establishment of riparian vegetation consequently exerts a significant impact on nutrient inputs by trapping mobile soil and nutrient particles before they reach the stream (Quinn *et al*. 1993; Hairsine 1996). Decreases in stock-grazing levels next to streams further contribute to decreases in nutrient inputs through reductions in soil erosion, decreases in water runoff (Rauzi & Hanson 1966) and reductions in nutrient inputs from faeces (Quinn *et al*. 1993; CMPS & F 1995; Hydrotechnology 1995b).

2.4 Riparian management and instream environmental condition

Koehn & O’Connor (1990a) note that ‘The importance of streamside vegetation to stream ecosystems [in Victoria] cannot be overemphasised. Naturally occurring native vegetation surrounding a stream is essential for the well being of the aquatic ecosystem.’ In the Goulburn-Broken catchment, however, the condition of riparian vegetation is generally considered to be poor or degraded (OCE 1988), because of extensive clearing of native vegetation from both of the basins and the subsequent use of the riparian land for grazing and agriculture (OCE 1988).

As described above, riparian vegetation helps to reduce salt, sediment and nutrient inputs into streams, all of which may have detrimental effects on some species of aquatic wildlife (OCE 1988; Koehn & O’Connor 1990a, 1990b; SAC 1991a, 1996; Harper 1992; Quinn *et al*. 1993). In addition, riparian vegetation has significant moderating effects on water temperature (Kauffman & Krueger 1984) and therefore on water quality (OCE 1988), the distribution and abundance of native species of fish (Kauffman & Krueger 1984; Koehn & O'Connor 1990a; Koehn 1993) and the composition and abundance of aquatic vegetation and invertebrate communities (Quinn *et al*. 1993). Finally, riparian vegetation is fundamental to the ecology of waterways because it contributes the bulk of organic matter that forms the basis of the aquatic food web (Cadwallader *et al*. 1980; Koehn & O'Connor 1990a, 1990b; Campbell 1993; Cummins 1993) and the bulk of the large woody debris which provides critical habitat for a range of invertebrates and fish (Koehn & O'Connor 1990a, 1990b; Campbell 1993; Cummins 1993; Koehn 1993).

Riparian sites that are grazed, however, have less tree regeneration, fewer shrubs and less groundcover biomass than ungrazed sites (Kauffman *et al*. 1983b; Kauffman & Krueger 1984; Bennett 1994; Bennett *et al*. 1994; Fleischner 1994; Robinson & Mann 1996a; SAC 1996). Protecting creeklines from grazing by stock therefore has the potential to improve the environmental condition of streams by permitting the regeneration of trees, shrubs and groundcover plants along the creekbanks and subsequent increases in shade and litter inputs for those streams (Kauffman & Krueger 1984; Fleischner 1994).

2.5 Riparian management and grazing by stock

Grazing by livestock clearly affects the environmental condition of riparian land and thence contributes to various forms of land and water degradation such as decreases in biodiversity, increases in salinity, increases in nutrient loads, increases in soil erosion and decreases in water quality (see 2.1, 2.2, 2.3).

There are no accurate estimates of what length of streamline in the Goulburn-Broken catchment is currently grazed by domestic livestock. However, it is known that approximately 7610 ha of public frontage (about 24% of all public frontage) or 680 km of streambank is licenced for grazing by DNRE (Barry Green, DNRE, Seymour). It is also clear that a large proportion of unlicenced public frontages is in fact grazed (Robinson & Mann 1996a). The future management of public frontages thus has considerable potential to affect the ecological sustainability of land and water resources in the Goulburn-Broken catchment.

3 PUBLIC LAND FRONTAGES AND GRAZING LICENCES

3.1 Establishment of public frontages

Crown land frontages were established along many of Victoria's rivers and permanent creeks in the latter half of the nineteenth century to ensure access to the Crown land for various uses deemed to be in the public interest (Cabena 1983; Wright 1989). The frontages varied in width depending on the size of the stream but comprised a minimum width of one and a half chains (30 m) each side of the stream bed (Cabena 1983).

The establishment of Crown land frontages in the 1850s was initially driven by a recognised need by the then Governor of Victoria to ensure public access to water for stock and domestic purposes and to prevent monopoly of that resource by squatters (Cabena 1983; Wright 1989). Having established the frontage system, however, officers of the Crown soon recognised the importance of retaining native vegetation along the frontages to prevent the destabilisation of river and creek banks and loss of soil. As a result, a Government Order was introduced in 1874 which prohibited cultivation or timber cutting on public frontages. It was also recommended that frontages be fenced to ensure public access (Cabena 1983).

3.2 Establishment of licenced grazing along frontages

The introduction of licences for grazing rights on public land occurred in the early 1880s and allowed landholders already in occupation of frontages the exclusive rights to graze a portion of Crown land frontage. Subsequently, the private use of waterfrontages for grazing became entrenched following the introduction of the *Unused Roads and Water Frontages Act* (1903) and the establishment of a formalised licencing system for private grazing of these public lands (Cabena 1983). As of 1992, approximately 52,000 hectares of water frontage were licenced for grazing Statewide.

3.3 Current management of grazing licences along Crown land frontages

Until 1994, most grazing licences for Crown land frontages were issued annually by the Department of Natural Resources and Environment. Administration and supervision of those licences were also the responsibility of Departmental staff. In 1994, however, the Victorian Government introduced the *Crown Lands Acts (Amendments) Act* (1994) which increased the length of licence term on public frontages from <u>one year</u> to <u>thirty-five years</u>, with five year review periods. Concurrently, the Government introduced the *Catchment and Land Protection Act* (1994) which determined the formation of the regional Catchment and Land Protection Boards (now Catchment Management Authorities). This Act further committed the newly formed Boards to preparation of a regional catchment strategy which must:

a) assess the land and water resources of the catchments in the region and how they are used
b) assess the nature, causes, extent and severity of land degradation of the catchments in the region and identify areas for priority attention
c) identify objectives for the quality of the land and water resources of the catchments in the region
d) set a program of measures to promote improved use of land and water resources and to treat land degradation

e) state the action necessary to implement the strategy and who should take it and
f) specify procedures for monitoring the implementation of the strategy, achieving the land and water resource quality objectives and assessing the effectiveness of the program set under paragraph (d)....

3.4 Current review of water frontages

As part of the Catchment and Land Protection Board's (CALP's) new responsibilities, the State Government further required that the CALP Boards would '...undertake a review of all water frontage occupations and also make recommendations about unused roads because of their important values in some parts of Victoria as habitat, wildlife corridors and windbreaks.' (DCNR 1995). This review was to occur during the first five years of the thirty-five year licence term granted for water frontages and would determine: (i) whether or not a particular frontage should be licenced for grazing; and (ii) conditions which should be imposed for frontages allowed to be grazed (Finney Whelan & Associates 1997).

3.5 Aims of this briefing paper

Two Victorian catchments were selected as pilots to develop appropriate methodologies to meet these objectives. The Goulburn-Broken catchment is one of the selected pilots and a draft review has just been prepared on its licenced frontages and assessment techniques (Finney Whelan & Associates 1997).

This paper has been prepared in response to that draft. It broadly aims to provide background information on the effects of stock-grazing, licencing and fencing on basic ecological attributes of riparian land in the catchment. More specifically, it aims to test some of the assumptions made in the draft review of licenced frontages that:

- stock grazing causes destruction of native vegetation
- stock grazing causes increased erosion
- stock grazing causes an increase in weeds
- stock grazing changes the species composition of the plants found at a site
- environmental changes only occur over a long time period
- 'piecemeal improvement of practices on particular frontages is unlikely to yield the expected overall improvement of the waterway'
- removal of stock grazing will not lead to the rehabilitation of sites, and
- fencing of frontages will not lead to the rehabilitation of sites (pp 34-36).

4 METHODS

4.1 Basic data collection

Data for this paper were obtained from a biological survey of 365 kilometres of creek frontage along the Broken, Boosey and Nine Mile Creeks in the riverine plains region of the Goulburn-Broken catchment (Robinson & Mann 1996a, 1996b). This creeks system includes a significant proportion (28%, 2143 ha) of all licenced frontage within the Goulburn-Broken catchment. It thus provided an ideal opportunity to examine the effects of grazing, licencing and fencing on riparian values.

The basic sampling unit along the creeks system consisted of consecutive lengths of frontage along each side of the creeks. Each frontage length was called a 'section' and was annotated as a left bank, right bank or off-creek section. Section boundaries were determined by changes in land tenure along the creeks (e.g. private, Crown land frontage or Crown land reserve), changes in management (e.g. fenced or not, next to a road or not), changes in management of the land abutting the creek (e.g. irrigated or dryland, urban or rural), changes in the natural character of the remnant vegetation (e.g. old-growth or regrowth) or by changes in the charcter of the creeks (e.g. narrow or wide, channelised or not). Because land management tended to differ on each side of the creek, we separately surveyed the left and right banks of the creeks. Where land management was identical on both sides of the creek, and management on one side was likely to affect management on the other (e.g. where stock could cross from one side to the other), sections on both sides of the creek were surveyed together. This happened most often in the upper reaches of the creeks system.

Altogether we sampled 473 sections along the creeks system which comprised 340 sections on Crown land frontage, 91 sections in streamside reserve or bushland reserve, 5 sections in wildlife reserves, 2 sections in State Forest, 10 sections on uncomitted Crown land and 21 sections on private land. Surveying of creek sections began in late September 1994, and ended in early June, 1995

For every section surveyed, information was collected in the field on

- width of the frontage or reserve;
- adjoining land use;
- tenure and management;
- vegetation types, their condition and their distribution across the section;
- density and structure of the vegetation;
- shrub and tree species present;
- dominant species of native and introduced groundcover plants;
- plant species of special interest;
- creek condition (e.g. irrigated, channelised);
- grazing by domestic stock;
- earthworks and soil-disturbance;
- cropping;
- industrial structures (e.g. drains, channels, fences, weirs);
- recreation-related uses (e.g. fishing, firewood collecting, rubbish dumping);

- pest animals and noxious weeds;
- site-specific threats; and
- site-specific values

Some additional variables were ascertained from aerial photographs, Parish Plans and land-tenure records at the DNRE office at Benalla, notably: area, grazing-licence status of every section, Crown land width and total width of tree cover, including tree cover extending beyond the Crown land boundary. A full list of variables sampled and their definitions is given in Appendix 1.

4.2 Effects of grazing on ecological attributes

For this study, we examined the effects of grazing, licencing and fencing on the following ecological attributes:

- abundance of tree regeneration
- abundance of shrubs
- abundance of Tangled Lignum *Muehlenbeckia florulenta*
- groundcover biomass
- groundcover composition
- native grass composition
- abundance of weed patches requiring management (troublesome weeds)
- abundance of noxious or regionally controlled weeds
- percentage of bare ground

Basic definitions of all of these attributes are given in Appendix 1. However, a fuller explanation of native grass composition is warranted.

Moore (1970) suggested that, historically, the Northern Plains grassland flora was dominated by a suite of tall, perennial native grass species such as Plains Spear-grass *Stipa aristiglumis*, Kangaroo Grass *Themeda triandra*, Common Wallaby-grass *Danthonia caespitosa* and Silky Blue-grass *Dicantheum sericeum*. As a result of persistent grazing by cattle and sheep, and the addition of superphosphates, these species have become less common and have been replaced by short, cool season growing perennial grasses (e.g. Bristly Wallaby-grass *Danthonia setacea*, Rough Spear-grass *Stipa scabra*) and introduced annuals (e.g. *Hordeum* spp, *Vulpia* spp., *Lolium* spp., *Bromus* spp.). At the most heavily grazed sites, the short, cool season natives become less common and only tough species of sedge and rush (e.g. *Juncus* spp., Knob Sedge *Carex inversa*, Small Spike-rush *Eleocharis pusilla*) or introduced annuals survive (pers. obs).

Using this model of grass species succession, we identified the dominant grass and sedge species at a site as belonging to one of the following groups, as a means of sampling the ecological intactness of the groundlayer. Groups 1, 2, 3 and 4 were considered to be indicative of natural grassland communities. The remainder were considered to represent various stages of modification.

<u>1. Tall warm season perennials</u> (*Stipa aristiglumis*, *Themeda triandra*, *Dicantheum sericeum*, Silky Browntop *Eulalia fulva*);

2. Short warm season perennials (Spider-grass *Enteropogon acicularis*, Umbrella Grasses *Digitaria* spp.);
3. Medium-tall cool season perennials (*Danthonia caespitosa*, Common Wheat-grass *Elymus scaber*, Rigid panic *Homopholis proluta*, Tussock Grass *Poa sieberiana*, Yanganbil *Stipa bigeniculata*, Crested Spear-grass *S. blackii*, Feather Spear-grass *S. elegantissima*);
4. A combination of groups 1 or 2, and 3.
5. A combination of groups 8, and 1 or 2;
6. A combination of groups 8 and 3;
7. Volunteer warm season perennials (Windmill-grass *Chloris truncata*, Red-leg Grass *Bothriochloa macra*, Brush Wire-grass *Aristida behriana*);
8. Short cool season perennials (e.g. *Danthonia caespitosa*, *D. setacea*, Brown-back Wallaby-grass *D. duttoniana*, Rough Spear-grass *Stipa scabra*);
9. Sedges or rushes (*Juncus* spp., *Carex inversa*, *Eleocharis pusilla*);

To analyse the effects of grazing on these ecological attributes, comparisons were restricted to those frontages classified as water frontage or streamside reserve having similar widths and with unmodified tree cover (categories 1-3, see Appendix 1). In addition, comparisons were restricted to those sites with some level of soil disturbance (categories 1 and 2, see Appendix 1), because of the apparent paradox that heavily grazed sites tended to be away from roads and had low levels of soil disturbance as a result of earthworks, whereas lightly grazed sites were often next to roads and highly disturbed as a result of earthworks (see Robinson & Mann 1996a, Table 22). We therefore excluded sites without any soil disturbance to make the two data sets more comparable.

Analyses were done comparing the combined effects of past and recent grazing on each of the attributes. Grazing levels were classed as 'light' (categories 0-3 in the grazing index), 'moderate' (category 4), 'moderately heavy' (category 5) and 'heavy' (category 6).

Because some of the features used to score the grazing level at every site consisted of some of the response attributes being measured - notably the presence or absence of shrubs and young trees (see variables 35, 38 and 39, Appendix 1), we plotted the past grazing score, current grazing score and grazing index score against the dry sheep equivalent (DSE) score for those sites where DSE was measured. DSE was measured by recording the number of animal droppings or clusters of droppings along a 100 metre by 2 metre transect. The resulting 'dropping totals' were converted to DSE units after Margules & Partners (1990). Significant relationships were found between all of the three measures of grazing pressure and DSE scores (Table 1) and we therefore considered our scoring systems to be legitimate measures of the past and present grazing pressure recorded at a given site.

Table 1 Relationships between estimates of past and present grazing pressure, overall grazing index and actual stocking rates along the Broken, Boosey and Nine Mile Creeks system. Sample size = 43 sites. Numbers in body of table indicate the degree of positive or negative (-) correlation between the different attributes measured. Asterisks show significance levels: * = P < 0.05, ** = P < 0.01, *** = P < 0.001. Grazing categories are defined in Appendix 1. Stocking rates were measured by counting the number of droppings along a 100 m transect and converting the number to dry sheep equivalent (DSE) units (see text).

	DSE Score	**Past grazing level**	**Present grazing level**	**Grazing index**
DSE score	1.000***			
Past grazing	0.561***	1.000***		
Present grazing	0.419**	0.103	1.000***	
Grazing index	0.702***	0.787***	0.599***	1.000***

4.3 Effects of grazing on the abundance of native plant species

Plant lists were made for 144 sites along the creeks system. Given the significant relationship obtained between our grazing index and the DSE score for sampled sites (see 4.2), we ranked the plant lists by grazing index and compared the frequency occurrence of different plant species at lightly grazed sites (index categories 0-3), moderately grazed sites (4) and heavily grazed sites (5-6).

4.4 Responses of ecological attributes to decreased grazing pressure

Altogether along the creeks system, 76% of sampled sites were classified as having been severely grazed in the past, 40% of sites were still being grazed severely and 82% of sites were still being grazed at least occasionally (Robinson & Mann 1996a). Given these continuing high levels of grazing on what is predominantly Crown land, we considered it critical to test the assumptions made by Finney Whelan & Associates (1997) that licenced frontages may not rehabilitate following the removal of grazing and/or that the responses of ecological attributes may be slow. Tests were done using the same data set as for the grazing analyses but considered only those sites that had had past heavy grazing (defined as heavy grazing pressure prior to 1992) and where recent grazing levels (post 1992) had diminished in comparison with those sites which continued to be grazed hard. Again, the caveat must be made that these analyses were possibly confounded because some of the features used to score the past and present grazing levels at every site consisted of some of the response attributes being measured (see 4.2). As shown in Table 1, however, we found that our measures of both past and present grazing pressure at sites along the creeks system were significantly related to actual stocking rates at those sites and thus considered our scoring systems to be legitimates measures of past and present grazing levels.

4.5 Effects of licencing on ecological attributes

The effects of licencing on ecological attributes along the Broken, Boosey and Nine Mile Creeks system were tested by comparing the frequency occurrence of different attributes in licenced and unlicenced frontages. To minimise the effects of confounding factors, analyses were restricted to water frontages and streamside reserves along the creeks system that had similar widths, unmodified tree cover and had undergone some level of soil disturbance (see 4.2). We excluded partly licenced sites from the analysis.

4.6 Effects of licencing on ecological attributes of frontages abutting agricultural land

Under the requirements of the *Land Act* (1958) and the *Crown Lands Acts (Amendments) Act* (1994), water frontages abutting agricultural land must either be licenced for grazing and grzed according to the requirements of the government agency, or else must be fenced from the adjacent land to prevent stock access to the Crown land (Sections 403, 404, *Land Act*). To examine the effectiveness of these conditions and their impact on the creeks' natural values, we compared the frequency occurrence of the different ecological attributes between licenced and unlicenced sites. Analysis was restricted to frontages and streamside reserves which abutted agricultural land and were not next to roads (hereafter referred to as unlicenced agricultural frontages and licenced agricultural frontages to avoid confusion with the larger category of unlicenced frontages which includes non-agricultural sites next to roads - see 4.5). The sites were otherwise matched with regards to width, treecover and earthworks. Again partly licenced sections were excluded from the analysis.

4.7 Effects of fencing on ecological attributes of licenced frontages

Fencing and grazing pressure are closely linked. As a consequence, we restricted analysis to those public land sites along the creeks system which were licenced for grazing, were not next to roads, had similar widths and had unmodified tree cover. Within these sites, we compared the average rankings for each ecological attribute between unfenced and wholly fenced sites. Partially fenced sites were excluded from the analysis because of small sample sizes.

4.8 Analysis of data

Because most data collected consisted of rank abundance scores, statistical tests to evaluate the effects of different levels of grazing, fencing and licencing on various ecological attributes were done by comparing the frequency occurrence of different categories of those attributes under the different levels of grazing, licencing or fencing. Comparisons were done using λ^2 tests for independent samples (Siegel 1956). Where sample sizes were too small, we used Fisher exact tests. Correlation tests were done using Spearman Rank Correlation tests.

5 RESULTS

5.1 Effects of past and present grazing levels on ecological attributes of Crown land frontages

For most of the attributes measured, there was a significant gradient in their frequency from lightly grazed sites to heavily grazed sites. Tree regeneration, shrubs, lignum and warm season grasses and tall, cool season perennial grasses were all more abundant at lightly grazed sites than at heavily grazed ones (Table 2). The percentage of bare ground was higher at heavily grazed sites (Table 2).

The frequency occurrence of three of the attributes did not differ significantly in response to grazing pressure but nevertheless showed some interesting patterns. Groundcover composition was found to be similar among all sites, regardless of grazing pressure, and did not differ significantly even when comparisons were restricted to grazing categories 0-3 and 6 ($\lambda^2 = 3.7$, df = 2, $p = 0.16$). Troublesome weeds conversely showed some trend towards increasing frequency as grazing pressure eased (Table 2), while noxious weeds showed a slight trend towards increased frequency under heavier grazing (comparison of grazing categories 0-3 and 6, $\lambda^2 = 2.0$, df = 1, $p = 0.16$).

The implications of these results are that: (1) grazing does not necessarily modify the gross composition (native versus weedy) of the groundlayer vegetation, although it significantly alters the species composition of the plants at given sites (Tables 2, 3); (2) soil disturbance is a far more significant cause of weed invasion than grazing pressure (Table 22, Robinson & Mann 1996a); and (3) decreases in grazing pressure may lead to an apparent increase in weeds because of the increase in biomass of all groundcover plants but especially weedy annuals. As shown by the comparison between the gross composition of the ground layer under different levels of grazing, however, most of the plant species are already present - they simply become more visible as grazing eases.

5.2 Responses of ecological attributes to decreased grazing pressure

Following a decrease in grazing pressure since 1992 at 107 Crown frontage sites along the creeks system, increases in frequency occurrence were recorded at those sites for groundcover biomass, tree regeneration, lignum, the proportion of native plant species in the ground layer and the proportion of warm season or tall, cool season perennial grasses (Table 4). The percentage of bare ground and frequency occurrence of noxious weeds conversely decreased in response to decreases in grazing levels. The frequency occurrence of troublesome weeds evidently decreased with some decrease in grazing pressure but increased when all grazing was removed (Table 4). Again, however, the significant change towards native plant species in the ground layer (Table 4) indicates that the weedy species are unlikely to have invaded sites following the decrease in grazing but simply became more visible as a result of a general increase in plant biomass.

Of interest was the apparently small and slow response shown by shrubs to the decrease in grazing pressure. Shrubs remained absent from about 60% of sites at which grazing levels decreased (Table 4). Further, although there was a significant increase in the frequency occurrence of shrubs at sites with decreased grazing pressure, the increase consisted mostly of the occurrence of a very few shrubs at those sites (i.e. shrub category 1, see Table 4 and Appendix 1) rather than the re-emergence of large numbers of shrubs (Table 4). Comparisons between the frequency occurrence of no shrubs (category 0) and many shrubs (category ≥ 2) at sites with decreased grazing levels (categories 0-1) and sites still grazed heavily (category 2) hence showed no significant difference (Fisher Exact test = 0.08) whereas the frequency occurrence of no shrubs and some shrubs (category 1) at those sites was significantly different ($\lambda^2 = 5.3$, df = 1, $p < 0.05$). These results suggest that persistent over-grazing tends to eliminate most shrubs from the landscape and that shrubs will rarely recolonise sites or will be slow to recolonise sites once they have been eliminated.

5.3 Effects of licencing on ecological attributes

In comparison with unlicenced Crown land along the Broken, Boosey and Nine Mile Creeks system, licenced frontages had less groundcover biomass, less regeneration, less lignum, fewer shrubs and more bare ground (Table 5). Licenced sites did not differ significantly from non-licenced sites with regards to ground layer composition or native grass species composition but showed some trend towards a higher frequency occurrence of warm season perennial grasses and tall, cool season grasses (Table 5).

As reported above for sites with lower grazing pressure, the frequency occurrence of troublesome weeds was higher at unlicenced sites than at licenced sites, mostly because of the increase in biomass of exotic annuals in response to significantly less past and present grazing (Table 5). By contrast, the frequency occurrence of noxious weeds was significantly lower at unlicenced sites than at licenced sites (Table 5).

5.4 Effects of licencing on ecological attributes of frontages abutting agricultural land

Along the creeks system we found no significant difference between the fenced status of licenced and unlicenced agricultural frontages (Table 6). As result, there was no significant difference between the levels of stock grazing on licenced and unlicenced agricultural frontages (Table 6). Furthermore, there was little difference between the ecological condition of licenced and unlicenced agricultural frontages (Table 6).

When compared to the larger subset of unlicenced frontages (Table 5), agricultural frontages tended to have less tree regeneration, less groundcover biomass, less lignum, fewer shrubs, a more modified native grass community and more bare ground, regardless of whether or not they were licenced for grazing (compare values in Table 6 with the unlicenced column in Table 5). That is, frontages adjoining agricultural land tended to be managed as grazing land, regardless of whether or not the the landholders had a licence to do so. These results suggest the current management and monitoring of agricultural frontages is ineffective in at least some parts of the Goulburn Broken catchment.

5.5 Effects of fencing on ecological attributes of licenced frontages

Fenced Crown land frontages had significantly more biomass, regeneration, shrubs, native groundcover plants and warm-season perennial grasses or tall, cool season grasses than unfenced frontages (Table 7). By contrast, the frequency occurrence of extensive areas of troublesome weeds was highest at unfenced sites, while the occurrence of localised patches of weeds was higher at fenced sites (Table 7). The percentage of bare ground did not differ significantly between fenced and unfenced sites but tended to be higher at unfenced sites. Grazing levels were significantly lower at the fenced sites (Table 7).

Table 2. Frequency of occurrence of different categories of ecological attribute in sites with different levels of grazing. Sample sizes shown in bold. Figures in body of table indicate the % of sites belonging to every category. λ^2 tests done on the raw data. Figures in brackets after the row headings and below the table heading indicate the categories included as defined in Appendix 1.

	Grazing Index					
Attribute	0-3	4	5	6		p
Biomass	**40**	**60**	**78**	**55**	**60.2**	**<0.001**
Little (0,1)	10.0	28.3	33.3	81.8	df = 3	
Much (≥ 2)	90.0	71.7	66.7	18.2		
Regeneration	**40**	**61**	**78**	**55**	**64.7**	**< 0.001**
None (0)	5.0	13.1	11.6	58.2	df = 6	
Some (1)	65.0	67.2	76.9	38.2		
Much (2)	30.0	19.7	11.5	3.6		
Shrubs	**40**	**61**	**78**	**56**	**119.4**	**< 0.001**
None (0)	12.5	37.7	59.0	83.9	df = 6	
Some (1)	7.5	24.6	37.2	16.1		
Many (≥ 2)	80.0	37.7	3.8	0.0		
Lignum	**20**	**24**	**29**	**9**	**7.4**	**< 0.01**
Some (1)	5.0	16.7	24.1	77.8	df = 1 (test	
Much(≥ 2)	95.0	83.3	75.9	22.2	between categories 0-4 and 5-6)	
Groundcover type	**40**	**61**	**78**	**56**	**8.0**	**n.s.**
Mostly weedy (0-1)	30.0	32.8	29.5	48.2	df = 6	
Native/weedy (2-3)	45.0	37.7	41.0	37.5		
Mostly native (4-5)	25.0	29.5	29.5	14.3		
Native Grass type	**27**	**40**	**54**	**34**	**42.0**	**< 0.001**
Tall perennials (1-4)	59.3	45.0	25.9	2.9	df = 6	
Tall/short spp. (5-6)	25.9	35.0	31.5	17.7		
Short gr./sedge (7-9)	14.8	20.0	42.6	79.4		
% Bare ground	**40**	**61**	**78**	**56**	**29.8**	**< 0.001**
None	42.5	44.2	44.9	17.9	df = 6	
≤ 10%	45.0	36.1	28.2	26.8		
≥ 11%	12.5	19.7	26.9	55.3		
Abundance index	**40**	**61**	**78**	**56**	**11.8**	**= 0.07**
for troublesome weeds				df = 6		
None (0)	5.0	11.5	21.8	10.7		
Weedy patches (1)	60.0	52.4	53.8	44.6		
Extensive areas (2)	35.0	36.1	24.4	44.6		
Noxious weeds	**40**	**61**	**78**	**55**	**3.7**	**n.s.**
None (0)	45.0	47.5	39.7	30.9	df = 3	
Present (1)	55.0	52.5	60.3	69.1		

Table 3 Frequency of occurrence of selected groundcover plant species in response to different levels of grazing. Only those species that showed decreases in abundance in response to higher levels of grazing are shown here. Abundance frequencies were calculated only for those sites at which plant lists were made. 'p' indicates significance levels of results. n.s. indicates that the differences are not significant.

Common Plant name	**Scientific name**	**Grazing Index**			**p**
		0-3	**4**	**5-6**	
Number of plant lists		**40**	**53**	**51**	
Feathery Spear-grass	*Stipa elegantissima*	30.0	5.7	3.9	< 0.001
Common Wheat-grass	*Elymus scaber*	67.5	39.6	19.6	< 0.01
Tussock-grass	*Poa sieberiana*	45.0	35.8	21.6	= 0.056
Forde Tussock-grass	*Poa fordeana*	42.5	47.2	31.4	n.s.
Crested Spear-grass	*Stipa blackii*	30.0	30.2	11.8	< 0.05
Rigid Panic	*Homopholis proluta*	75.0	58.5	52.9	= 0.09
Common Spider-grass	*Enteropogon acicularis*	67.5	62.3	51.0	n.s.
Kangaroo grass	*Themeda triandra*	25.0	15.1	13.7	n.s.
Many-flowered Mat-rush	*Lomandra multiflora*	27.5	22.6	9.8	= 0.08
Scented Mat-rush	*Lomandra effusa*	27.5	13.2	2.0	< 0.01
Pale Flax-lily	*Dianella longifolia*	65.0	39.6	19.6	< 0.001
Black-anthered Flax-lily	*Dianella revoluta*	65.0	45.3	21.6	< 0.001
Creeping Saltbush	*Atriplex semibaccata*	20.0	13.2	9.8	n.s.
Climbing Saltbush	*Einadia nutans*	52.5	35.8	13.7	< 0.001
Frosted Gosefoot	*Chenopodium desortorum*	27.5	20.7	11.8	n.s.
Black Bluebush	*Maireana decalvans*	20.0	11.3	7.8	n.s.
Blushing Bindweed	*Convolvulus erubescens*	57.5	49.1	31.4	< 0.05
Grey Germander	*Teucrium racemosum*	25.0	15.1	13.7	n.s.
Sweet Hound's-tongue	*Cynoglossum suaveolens*	25.0	9.4	7.8	< 0.05
Blue Devil	*Eryngium ovinum*	42.5	30.2	19.6	= 0.06
Variable Sida	*Sida corrugata*	72.5	62.3	52.9	n.s.
Leafy Templetonia	*Templetonia stenophylla*	35.0	15.1	5.9	= 0.001
Common Eutaxia	*Eutaxia microphylla*	25.0	13.2	3.9	< 0.05
Variable Glycine	*Glycine tabacina*	42.5	20.8	17.6	< 0.05
Curved Rice-flower	*Pimelea curviflora*	47.5	30.2	19.6	< 0.05
Yellowish Bluebell	*Wahlenbergia luteola*	20.0	9.4	13.7	< 0.05
Variable Daisy	*Brachyscome ciliaris*	35.0	20.8	9.8	< 0.05
Swamp Daisy	*Brachyscome basaltica*	35.0	26.4	26.4	n.s.
Lemon Beauty-heads	*Calocephalus citreus*	45.0	43.4	23.5	= 0.05
Smooth Minuria	*Minuria integerrima*	12.5	7.5	5.9	n.s.
Woolly New Holland Daisy	*Vittadinia gracilis*	42.5	24.5	15.7	< 0.05
New Holland Daisy	*Vittadinia cuneata*	47.5	20.8	9.8	< 0.001

Table 4. Frequency of occurrence of different categories of ecological attribute in response to decreased grazing pressure. Data comprises sites with similar past levels of heavy grazing but different, recent levels of grazing. Sample sizes shown in bold. Figures in body of table indicate the % of sites belonging to every category. λ^2 tests done on the raw data. Figures in brackets after the row headings indicate the categories included as defined in Appendix 1.

Attribute	Recent Grazing Pressure 0	1	2	λ^2	p
Biomass	**29**	**77**	**52**	**43.5**	**< 0.001**
Little (0,1)	17.2	32.5	82.7	df = 2	
Much (≥ 2)	82.8	67.5	17.3		
Regeneration	**30**	**77**	**52**	**44.3**	**< 0.001**
None (0)	16.7	10.4	61.5	df = 4	
Some (1)	63.3	76.6	34.6		
Much (2)	20.0	13.0	3.9		
Shrubs	**30**	**77**	**53**	**p = 0.02 and**	**0.20**
None (0)	66.7	59.7	83.0	(Fisher Exact tests comparing	
Some (1)	26.7	35.1	17.0	categories 0 and ≥ 1-2 and	
Many (≥ 2)	6.6	5.2	0.0	0-1 and 2 respectively)	
Lignum	**7**	**29**	**9**		**< 0.01**
Some (1)	0.0	27.6	77.8	(Fisher Exact test comparing	
Much (≥ 2)	100.0	72.4	22.2	(grazing categories 0-1 and 2)	
Groundcover type	**30**	**77**	**53**	**7.9**	**p = 0.09**
Mostly weedy (0-1)	40.0	27.3	49.1	df = 4	
Native/weedy (2-3)	36.7	44.2	37.7	(NB: when all 'decreased' sites	
Mostly native (4-5)	49.1	37.7	13.2	combined, $\lambda^2 = 6.4$, $p < 0.05$)	
Native Grass type	**20**	**52**	**32**	**26.5**	**< 0.001**
Tall perennials (1-4)	55.0	26.9	3.1	df = 4	
Tall/short spp. (5-6)	30.0	28.9	15.6		
Short gr./sedge (7-9)	15.0	44.2	81.3		
% Bare ground	**30**	**77**	**53**	**24.8**	**< 0.001**
None	56.7	42.8	17.0	df = 4	
≤ 10%	33.3	31.2	26.4		
≥ 11%	10.0	26.0	56.6		
Abundance index for troublesome weeds	**30**	**77**	**53**	**12.7**	**< 0.05**
None (0)	3.3	23.4	9.4	df = 4	
Weedy patches (1)	50.0	51.9	45.3		
Extensive areas (2)	46.7	24.7	45.3		
Noxious weeds	**30**	**77**	**52**	**3.7**	**p = 0.07**
None (0)	56.7	41.6	30.8	df = 2	
Present (1)	43.3	58.4	69.2		

Table 5. Frequency of occurrence of different categories of ecological attribute in response to the licenced or unlicenced status of frontages. Sample sizes shown in bold. Figures in body of table indicate the % of sites belonging to every category. λ^2 tests done on the raw data. Figures in brackets after the row headings indicate the categories included as defined in Appendix 1.

Attribute	Grazing Licence Status: Not licenced	Licenced	λ^2	p
Biomass	**138**	**75**	**19.9**	**< 0.001**
Little (0,1)	27.5	58.7	df = 1	
Much (≥ 2)	72.5	41.3		
Regeneration	**139**	**75**	**9.3**	**< 0.01**
None (0)	15.8	30.7	df = 2	
Some (1)	64.8	61.3		
Much (2)	19.4	8.0		
Shrubs	**140**	**75**	**25.3**	**< 0.001**
None (0)	41.4	66.7	df = 2	
Some (1)	22.1	28.0		
Many (≥ 2)	36.4	5.3		
Lignum	**55**	**16**	**(Fisher Exact test)**	**= 0.056)**
Some (1)	16.4	38.9		
Much (≥ 2)	83.6	61.1		
Groundcover type	**140**	**75**	**2.5**	**n.s.**
Mostly weedy (0-1)	37.9	28.0	df = 2	
Native/weedy (2-3)	35.7	45.3		
Mostly native (4-5)	26.4	26.7		
Native Grass type	**96**	**46**	**4.6**	**n.s.**
Tall perennials (1-4)	35.4	21.7	df = 2	
Tall/short spp. (5-6)	32.3	28.3		
Short gr./sedge (7-9)	32.3	50.0		
% Bare ground	**140**	**75**	**6.1**	**< 0.05**
None	42.1	32.0	df = 2	
≤ 10%	35.0	29.3		
≥ 11%	22.9	38.7		
Abundance index for troublesome weeds	**140**	**75**	**8.2**	**< 0.05**
None (0)	15.0	10.7	df = 2	
Weedy patches (1)	45.0	65.3		
Extensive areas (2)	40.0	24.0		
Noxious weeds	**139**	**75**	**8.8**	**< 0.01**
None (0)	47.5	26.7	df = 1	
Present (1)	52.5	73.3		
Grazing Index	**140**	**75**	**19.5**	**< 0.001**
Light (0-3)	23.6	6.7	df = 2	
Moderate (4)	30.7	17.3		
Severe (5-6)	45.0	76.0		

Table 6. Frequency of occurrence of different categories of ecological attribute in response to the licenced or unlicenced status of frontages abutting agricultural land. Sample sizes shown in bold. Figures in body of table indicate the % of sites belonging to every category. λ^2 tests done on the raw data. Figures in brackets after the row headings indicate the categories included as defined in Appendix 1.

	Grazing Licence Status			
Attribute	Not licenced	Licenced	λ^2	p
Biomass	**83**	**128**	**7.7**	**< 0.01**
Little (0,1)	50.6	69.5	df = 1	
Much (≥ 2)	49.4	30.5		
Regeneration	**83**	**129**	**4.2**	**n.s.**
None (0)	36.1	46.5	df = 2	
Some (1)	51.8	48.1		
Much (2)	12.1	5.4		
Shrubs	**83**	**129**	**3.0**	**n.s.**
None (0)	71.1	73.6	df = 2	
Some (1)	21.7	24.0		
Many (≥ 2)	7.2	2.3		
Lignum	**32**	**32**	**0.1**	**n.s.**
Some (1)	53.1	56.3	df = 1	
Much (≥ 2)	46.9	43.7		
Groundcover type	**83**	**129**	**0.8**	**n.s.**
Mostly weedy (0-1)	27.7	33.3	df = 2	
Native/weedy (2-3)	38.6	36.4		
Mostly native (4-5)	33.7	30.2		
Native Grass type	**57**	**77**	**0.1**	**n.s.**
Tall perennials (1-4)	14.0	15.6	df = 2	
Tall/short spp. (5-6)	19.3	20.8		
Short gr./sedge (7-9)	66.7	63.6		
% Bare ground	**83**	**129**	**0.3**	**n.s.**
None	30.1	24.8	df = 2	
≤ 10%	31.3	26.4		
≥ 11%	38.6	48.8		
Abundance index for troublesome weeds	**83**	**128**	**1.6**	**n.s.**
None (0)	21.7	18.7	df = 2	
Weedy patches (1)	45.8	54.7		
Extensive areas (2)	32.5	26.6		
Noxious weeds	**82**	**125**	**0.5**	**n.s.**
None (0)	45.1	40.0	df = 1	
Present (1)	54.9	60.0		
Fencing Status	**83**	**129**	**3.6**	**n.s.**
None (0)	33.7	45.0	df = 2	
Some (1)	28.9	19.4		
All (2)	37.4	35.6		
Grazing Index	**83**	**129**	**3.8**	**n.s.**
Light (0-3)	8.4	3.1	df = 1	
Moderate (4)	14.5	10.9		
Moderate-Severe (5-6)	77.1	86.1		

Table 7. Frequency of occurrence of different categories of ecological attribute in response to the fenced or unfenced status of licenced frontages. Sample sizes shown in bold. Figures in body of table indicate the % of sites belonging to every category. λ^2 tests done on the raw data. Figures in brackets after the row headings indicate the categories included as defined in Appendix 1.

	Fencing Category			
Attribute	None	All	λ^2	p
Biomass	**46**	**44**	**5.9**	**< O.05**
Little (0,1)	80.4	56.8	df = 1	
Much (≥ 2)	19.6	43.2		
Regeneration	**46**	**44**	**5.6**	**< 0.05**
None (0)	56.5	31.8	df = 1	
Present (1,2)	43.5	68.2		
Shrubs	**46**	**44**	**17.1**	**< 0.001**
None (0)	91.3	52.3	(λ^2 test between	
Some (1)	8.7	43.2	categories 0 and 1-2)	
Many (≥ 2)	0.0	4.5	df = 1)	
Lignum	**10**	**12**		**n.s.**
Some (1)	70.0	50.0		
Much (≥ 2)	30.0	50.0		
Groundcover type	**46**	**44**	**13.7**	**= 0.001**
Mostly weedy (0-1)	43.5	9.1	df = 2	
Native/weedy (2-3)	30.4	52.3		
Mostly native (4-5)	26.1	38.6		
Native Grass type	**20**	**38**	**5.8**	**< 0.05**
Tall perennials (1-6)	20.0	52.6	df = 1	
Short gr./sedge (7-9)	80.0	47.4		
% Bare ground	**46**	**44**	**1.8**	**n.s.**
None	21.7	25.0	df = 2	
≤ 10%	23.9	34.1		
≥ 11%	54.4	40.9		
Abundance index for troublesome weeds	**45**	**44**	**5.9**	**= 0.05**
None (0)	28.9	20.5	df = 2	
Weedy patches (1)	46.7	70.4		
Extensive areas (2)	24.4	9.1		
Noxious weeds	**45**	**44**	**0.1**	**n.s.**
None (0)	46.7	43.2	df = 1	
Present (1)	53.3	56.8		
Grazing Index	**46**	**44**	**7.0**	**< 0.01**
Light (0-3)	0.0	0.0	df = 1 (comparing	
Moderate (4)	6.5	27.3	categories 0-4 and 5-6)	
Severe (5-6)	93.5	72.7		

6 DISCUSSION

6.1 Management implications for licenced frontages

The current review of licenced water frontages in the catchment made the following statements about water frontage management and the effects of stock-grazing:

a) stock grazing causes destruction of native vegetation
b) stock grazing causes increased erosion
c) stock grazing changes the species composition of the plants found at a site
d) stock grazing causes an increase in weeds
e) environmental changes only occur over a long time period
f) 'piecemeal improvement of practices on particular frontages is unlikely to yield the expected overall improvement of the waterway'
g) removal of stock grazing will not lead to the rehabilitation of sites, and
h) fencing of frontages will not lead to the rehabilitation of sites (pp 34-36, Finney, Whelan & Associates 1997).

Results from this study confirmed the first three of these assumptions. However, the remaining assumptions or statements were found to be false

Our study found that licenced frontages were found to be grazed significantly more than unlicenced frontages (Table 5) and had less groundcover biomass, less tree regeneration, fewer shrubs, less lignum, more noxious or regionally controlled weeds and more bare ground as a result (Table 5). In addition, regardless of licence status, more heavily grazed frontages were found to have significantly modified plant species' compositions in the groundlayer (Table 2) and significantly less representation of many species of native plant (Table 3).

All of these changes significantly reduce the biodiversity values of the riparian and instream environments (see part 2.4, Tables 2, 3, 4, 5). More fundamentally, these changes to the riparian environment exacerbate the already poor condition of riparian and aquatic environments in much of the Goulburn-Broken catchment by causing increases in salt, sediment and nutrient loads, increases in runoff, increases in soil erosion, increases in streamflows (Hydrotechnology 1995a), increases in water temperature and increases in the probability of algal blooms (MDBMC 1994; Hydrotechnology 1995b).

It is clear, therefore, that the current management practice of allowing some public land frontages to be licenced for grazing is not environmentally sustainable. It is causing the active degradation of land and water resources throughout the catchment.

It is clear, furthermore, that management agencies have generally failed to ensure that public frontages are managed for the public good. Although those frontages licenced for grazing were found to be significantly more degraded than unlicenced frontages (Table 5), unlicenced agricultural frontages were generally found to be managed as grazing land and were often not fenced. As a result, that set of unlicenced agricultural frontages was nearly as degraded as licenced agricultural frontages (Table 6).

By contrast, amongst licenced sites, those frontages that were fenced were found to be in significantly better environmental condition than unfenced frontages (Table 7). The main cause of this difference was decreased grazing levels at the fenced sites (Table 7), the decrease then permitting the fairly rapid recovery of many of the terrestrial ecological attributes measured, with the notable exception of shrubs (5.2; Table 4). Instream ecological attributes have also been found to respond rapidly to decreases in grazing pressure, with some studies reporting decreases in water temperature or water temperature range within four years of the cessation of grazing (references in Kauffman & Krueger 1984). Fencing frontages thus provides an effective means of reducing the rate of land and water degradation in the catchment.

6.2 Management implications for all creeklines in the catchment

In a previous study done by the Goulburn Valley Environment Group on farmers' attitudes to protecting creeklines (Nicholas & Mack 1996b), three of the principal constraints to fencing creeklines were cited as the consequent increases in pests, weeds and fire risk as a result of the increase in plant cover (Table 8). A high proportion of farmers nevertheless acknowledged

Table 8 The principal constraints and benefits perceived to be associated with fencing of creeklines in the Goulburn-Broken catchment. Data taken from a survey of 75 landholders with creeks on their land. Table adapted from Nicholas & Mack (1996b).

Principal constraints	**% ranking**
Fence maintenance	16.6
Weed management	16.2
Fire hazard	15.9
Pest animal management	15.1
Expense of alternative stock watering points	14.7
Stock access to water	13.9
Not good value for money	11.7
Principal benefits	
Less creek bank and bed erosion	40.0
Improved wildlife habitat and biodiversity	18.8
Improved farm value	15.9
Improved water quality	13.9
Increase on farm shelter	12.0

the value of riparian fencing as a means of reducing creekbank and streambed erosion and as a benefit in terms of nature conservation and water quality (Table 8). To encourage landholders to fence their private creeklines to achieve these land and water benefits is therefore going to require solutions to some of the perceived constraints.

Our study corroborated the perception of landholders that fencing off creeklines and reducing grazing levels increases the bulk of plant cover and the extent of some weeds (Tables 2, 4, 7). Importantly, however, our study also showed that: (i) the frequency occurrence of noxious weeds decreased in response to decreases in grazing pressure (Tables 4, 5); and (ii) most other ecological attributes responded positively to decreases in grazing pressure and fencing, such that the increase in the bulk of annual weeds at sites protected from grazing did not indicate degradation of the site but often occurred in conjunction with increases in the abundance of native plants (Tables 2, 3, 4, 7). From an ecological perspective, then, fencing and the consequent reduction in grazing pressure was clearly beneficial for biodiversity values and for improved management of land and water resources along the creeks system. Moreover, fencing and decreased stock-grazing levels at given sites clearly obtained a benefit for nature conservation values along the creeks system (Tables 4, 7), suggesting that the 'piecemeal improvement of practices on particular frontages (Finey, Whelan & Associates 1997, p. 34) can contribute to improvement of the whole waterway in terms of nature conservation (see also Kauffman & Krueger 1984).

7 RECOMMENDATIONS

On the basis of these findings, GVEG recommends that:

1. The CMA should take a leading role within the Goulburn-Broken catchment with regard to the development of 'best management practices' for public frontages and manage them sustainably as an example of how all creeklines should be managed within the catchment.

2. The CMA should implement management practices along public frontages that ensure that it fulfills its legal obligations under the *Flora and Fauna Guarantee Act* (1988) (see Appendix 2), particularly with regards to amelioration of the following threatening processes listed under the Act:

(a) Alteration to the natural flow regimes of rivers and streams (SAC 1992b)
(b) Alteration to the natural temperature regimes of rivers and streams (SAC 1992a)
(c) Degradation of native riparian vegetation along Victorian rivers and streams (SAC 1996)
(d) Increase in sediment input into Victorian rivers and streams due to human activities (SAC 1991a)
(e) Input of toxic substances into Victorian rivers and streams (SAC 1992c), and
(f) Removal of wood debris from Victorian streams (SAC 1991b).

3. All public frontages abutting agricultural land in the catchment should be fenced from stock, either as a pre-requisite of licencing arrangements or as part of the landholders' responsibility under the *Land Act* (1958).

4. Licenced grazing should be cancelled or deferred on all public frontages where shrubs have persisted, at least until grazing systems can be developed which ensure that grazing does not diminish the conservation values of those sites.

5. Stocking rates on frontages where licenced grazing is to be permitted should be decreased, as current stocking rates actively contribute towards land and water degradation in the catchment (Table 5).

6. Fencing should be promoted along all creeklines adjoining agricultural land throughout the catchment so that grazing levels can be reduced. DNRE and the CMA should actively foster the fencing of frontages through policy programs and the Land Protection Incentive Scheme.

7. As part of the above fencing program, DNRE and the CMA should:

a) foster the introduction of off-creek watering schemes and set up some demonstration sites
b) establish a project to monitor the effects of fencing frontages on land and water resources and on biodiversity
c) evaluate the effects of different stocking levels on biodiversity values, and
d) establish a program to re-establish the indigenous shrubs to those protected frontages.

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Appendix 1 Environmental variables measured during the survey of the Broken, Boosey and Nine Mile Creeks system (Robinson & Mann 1996a, 1996b) and definitions of the different categories of every variable

Background Information

1. Site (prefix 1 for left bank, 2 for right bank, 3 for off-creek) = continuous numbers from 1-500+
2. Creek division (broad landscape divisions used along creek to subdivide data).
3. Parish
4. Land tenure (1 = waterfrontage, 2 = streamside or bushland reserve; 3 = wildlife reserve; 4 = State Forest; 5 = unreserved Crown land; 6 = private).
5. LCC code, if there is one
6. Agricultural licence status (2 = all, 1 = part, 0 = none). Categories only apply to Crown land. Information derived from Parish Plans and LIMS printouts
7. Area of section (in ha, measured from parish plans).

Landscape Information

8. Adjoining land use (1 = much tree cover, 2 = some tree cover, some other use; 3 = unimproved, 4 = some unimproved, some improved, 5 = improved, 6= some improved, some irrigated, 7 = irrigated, 8 = part urban, 9 = urban
9. Adjacent houses (1 = yes, 0 = No)
10. Site width (1= <30 m, 2 = 30-50, 3= 50-75, 4= 75-100; 5=100-150; 6=150-200; 7=>200 - number refers to average category
11. Total treecover width (defined as point where aerial photos show connected treecover across both sides of creek and creek less than 8 m wide): 1 = <30 m; 2 = 30-50; 3 = 50-75; 4 = 75-100; 5 = 100-150; 6 = 150-200; 7 = > 200.
12. Creek value (1= channelised and frequently irrigated; 2 = channelised, sometimes irrigated; 3 = not channelised, frequently irrigated; 4 = not channelised, sometimes irrigated; 5 = channelised, rarely irrigated; 6 = not channelised, rarely irrigated; 7 = intact with natural flows.
13. Creek height (refers to how high the land at every site is above the weir level or how much higher the high water level is at a site than its natural level because of the weir). Estimate given in cm or metres.

Vegetation Information

14. Tree Cover (1 = Dense, whereby canopies separated by less than one canopy width 2 = part dense, part scattered, 3 = scattered, 4 = part dense, part none, 5 = part scattered, part none, 6= part scattered or dense, much none; 7 = none).
15. Biomass (3= much, 2 = some, 1= little, 0=none - value = average for all veg. communities). 3 = 100% ground cover of plant material or litter and extensive, deep litter; 2= 20-100% plant cover, and extensive shallow litter or plant height > 5 cm high; 1 = plant cover 1-20%, or scattered litter or plant height less than 5 cm; None = bare ground or less than 1% cover.
16. Tree Dieback (value averaged over all of the site: 2= much (more than 25% of trees affected, 1=some, 0=none, all trees apparently healthy)
17. Causes of dieback: Causes of dieback were scored in the field as due to flooding, irrigation runoff, changed water regimes, stock grazing, rubbing or trampling, soil cultivation, other soil works, creek channelisation works, exposure, soil damage by vehicles. Flooding was recorded as the principal cause where: trees in low points but not higher points, were suffering dieback; trees nearest the creek were toppling over; old trees were dead, the groundlayer included plants that naturally occurred in damper environments (Margules & Partners 1990). Irrigation runoff was readily visible as narrow lines of damper, often weedy vegetation and stricken trees along a drain. Altered water regimes were sometimes apparent because the effects of dieback were restricted to localised areas of damper ground with weedy vegetation and damper trees. Where not enough water was being received, trees tended to be enduring massive insect attack. Stock-related dieback was usually apparent because the effects were localised and restricted to trees with clear evidence of long-term stock-camps (e.g. thistle patches) or physical damage. Cultivation, other earthworks, vehicle disturbance and creek works were likewise apparent because the effects were localised and could be related to a particular practice at a particular tree or trees.

Exposure was listed as the cause where dieback was most evident on trees most exposed to wind and damage was greatest on the windward side.
18. Abundance of trees larger than 1 m: 2 = much(>10/ha); 1= some(<10/ha); 0=none.
19. Trees > 50 cm & < 100 cm: 2 = much (> 20/ha); 1 = some (< 20/ha); 0 = none.
20. Trees > 25 cm & < 50 cm: 2 = much (> 40ha); 1 = some (< 40/ha); 0 = none.
21. Regeneration: 2 = much (> 50/ha and over > 50% of the site); 1 = some (< 50/ha and over <50% of the site); 0 = none.
22. Dominant mature tree species (1 = Grey Box; 2 = Yellow Box; 3 = Black Box; 4 = White Box; 5 = combined box; 6 = box and red gum equal; 7 = River Red Gum.
23. Dominant regeneration species (code as above).
24. Number of all shrubs (excluding lignum): 4 = many (> 50% of site with some shrubs); 3 = moderate (20 - 50% of site or community); 2 = some (5 - 20% of site with shrubs); 1 = few(< 5% of site with shrubs or less than 5 shrubs in total); 0 = none.
25. Number of lignum only. Code as in 24.
26. Groundlayer vegetation: 5 = All Native (> 90% native); 4 = Mostly native (71 - 90% native); 3 = Moderately native (56 - 70%); 2 = 50/50 native and weedy (45 - 55%); 1 = 55-90% weedy; 0 = > 90% weedy. Note that if there is a bare ground component, this calculation only refers to the plant cover columns.
27. Grass value: 1 = tall warm season perennials; 2 = short warm season perennials;; 3 = medium cool season perennials; 4 = combination of 1 or 2 and 4; 5 = combination of 5 and 1 or 2; 6 = combination of 5 and 4; 7 = volunteer short, warm season perennials; 8 = short cool-season perennials; 9 = *Juncus* spp. / *Carex inversa* / *Eleocharis pusilla*; 10 = other (e.g. wetlands).
28. Bare earth (%).
29. Weed trees and shrubs: 2 = many (found over > 50% of site); 1 = some (5 - 50% of site); 0 = none.

Site Management

30. Fenced from grazing or not (if a road site is not fenced but the road is fenced from adjacent paddock then the site is rated as fenced, even if grazing is happening there): 2 = yes, 1 = partly, 0 = no.
31. Fenced from vehicles or not: 2 yes, 1 = partly, 0 = no. This refers only to public vehicles, not vehicles in the adjoining paddock.
32. Publicly accessible: 1 = yes, 0 = no. A site may not be accessible because there is no public road access, it is across the creek from an access point or because of deliberate efforts to discourage access. All are scored as "no".
33. Appropriated: 2 = yes, 1 = partly, 0 = no). A site is appropriated if it has been clearly incorporated into the adjoining farm, if there has been clearing or cultivation of the site, if houses or yards, etc are built on it, if it has been converted to an apparently private driveway, or is signed 'keep out'.
34. Road access: 3 = major road next to or through the site; 2 = minor road but managed by Shire; 1 = bush track but open to everyone; 0 = none.
35. Present grazing levels: 2 = much (many stock, pugging, shit or stock camps apparent, little biomass, any shrubs present chewed or trampled); 2 = some (some stock, shit, or pugging, some species of grazing-sensitive plants, some regenerating trees or shrubs, some biomass); 3 = none (no stock, no shit, higher biomass).
36. Current stockfeeding: 1 = yes, 0 = no.
37. Stock traffic: 3 = heavy traffic route (e.g. to dairy); 2 = frequent stock travel; 1 = occasional stock travel; 0 = none.
38. Past persistent grazing level: 2 = much (extensive pugging, old shit or stock camps; little tree regeneration or shrubs and, if present, young; multi-stemmed tree regeneration because of repeated 'pruning' by stock); 2 = some (some pugging and old shit, some stock camps, some tree regeneration and/or shrubs which may include old specimens that survived light levels in past; 0 = none.
39. Overall grazing index (summarises impacts of 35, 37, 38): 6 = severe (much past heavy grazing and current grazing, or past heavy grazing, some current grazing and stock traffic in levels 3 or 2)); 5 = severe/moderate (much past heavy grazing, some current grazing, some stock traffic (levels 1,2,3)); 4 = moderate (some past grazing but much heavy grazing now or, some past heavy grazing and some grazing now and some stock traffic); 3 = moderate/light (some past heavy grazing and some current grazing or current stock traffic, or much past heavy grazing and none now); 2 = light (some past grazing but no grazing now, or no past grazing but some grazing now); 1 = very light (some past grazing and no current grazing but some stock traffic); 0 = none.
40. Soil extraction: 2 = much; 1= some; 0 = none.
41. Soil dumping: 2 = much; 1= some; 0 = none.

42. Earth-moving or verge grading. 2 = much; 1= some; 0 = none.
43. Road drains. 2 = much; 1= some; 0 = none.
44. Cultivation (ploughing and sowing of pasture or crops only, grass mowing excluded). 2 = much; 1= some; 0 = none.
45. Earthworks summary: 2 = much; 1= some; 0 = none. Note that "2" has been given to all sites that have been cultivated.
46. Pest levels (rabbits, hares, foxes): 2 = high; 1= moderate; 0 = low.
47. Weediness of troublesome weeds: 2 = extensive weed invasion; 1 = patchy areas of weeds, 0 = none.
48. Noxious weeds present: 0 = no; 1=yes.

Recreational uses

49. Bardi grubbing: 2 = much; 1 = some 0 = none.
50. Firewood collection: 2 = much; 1 = some; 0 = none.
51. Shooting: 2 = much; 1 = some; 0 = none.
52. Camping: 2 = much; 1 = some; 0 = none.
53. Fishing: 2 = much; 1 = some; 0 = none.
54. Rubbish dumping: 2 = much; 1 = some; 0 = none.

Appendix 2 *Flora and Fauna Guarantee Act* (1988) Objectives

PART 1

4. (1) The flora and fauna conservation and management objectives are-

(a) to guarantee that all taxa of Victoria's flora and fauna other than the taxa listed in Schedule 1 can survive, flourish and retain their potential for evolutionary development in the wild; and
(b) to conserve Victoria's communities of flora and fauna; and
(c) to manage potentially threatening processes; and
(d) to ensure that any use of flora or fauna by humans is sustainable; and
(e) to ensure that the genetic diversity of flora and fauna is retained; and
(f) to provide programs-
(i) of community education in the conservation of flora and fauna; and
(ii) to encourage co-operative management of flora and fauna; and
(iii) of assisting and giving incentives to people to enable flora and fauna to be conserved; and
(g) to encourage the conserving of flora and fauna through co-operative community endeavours.

(2) A public authority must be administered so as to have regard to the flora and fauna conservation and management objectives.