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Identifying Best Management Practices for Riparian Habitats in Gippsland Dairy Regions: Riparian Condition and Relationships with Farm Management.

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EXECUTIVE SUMMARY

1. This report presents the findings of a field project undertaken in the west and south Gippsland region of Victoria between May and December 2002. The specific aims of this project were: (1) to determine the current condition of riparian (streamside) habitats across the west and south Gippsland dairy region, (2) to investigate the relationships between landholder management practices and riparian condition, and (3) to make recommendations for management practices that could be investigated at demonstration sites planned for the region.

2. We surveyed 107 riparian sites and conducted 28 landholder interviews to gain information on the variation in the ecological condition of riparian habitats and management practices among farmers.

3. We used a rapid appraisal index of riparian condition developed in previous studies on the impacts of cattle on riparian habitats (Jansen & Robertson 2001a) and modified it for use in the Gippsland dairy region. Scoring of variables used in the index was based on surveys of seven reference sites in the Gippsland region. We stratified our sampling of sites according to landform (Gippsland Plain=flat sites; Strezlecki Ranges=hilly sites) and broad management categories for riparian habitats encountered in the region (grazed, planted after fencing, fenced remnants of riparian vegetation).

4. The farm sizes, herd numbers and stocking rates of the 28 farms we visited for interviews were typical of dairy farms in Gippsland. Farms visited were typically small (most <200ha) with herd sizes that result in mean annual stocking rates of 25-73 $DSE.ha^{-1}annum^{-1}$. In most cases farmers used 100% of their properties for pasture production to support their milking herds. Most paddocks that contained streambank habitat were managed in the same way as other paddocks, except when they were very wet, when farmers removed stock.

5. Eighty-four percent of farmers interviewed had fenced-off some portion of their riparian areas from stock. The most common reason given for fencing was for stock management purposes. Nevertheless, the very active Landcare groups in the region

point to the number of dairy farmers with a motivation to conserve streambanks and biodiversity be fencing and replanting riparian habitats.

6. The current condition of riparian sites on dairy farms in south and west Gippsland is generally very poor, with no significant differences between sites in the flat terrain of the Gippsland Plain or hilly terrain of the Strezlecki Ranges. Riparian sites in paddocks that are used for livestock grazing of milking herds are generally in very poor condition. Sites in best condition are those in patches of remnant riparian forest that had been fenced-off to prevent stock access.

7. In-stream metabolism (often used as an ecosystem measure of river "health") was measured at a sub-set of 20 sites. Metabolism showed a gradient of values over the sites and was dominated by high rates of respiration; probably a function of elevated nutrient status. The condition index scores from the rapid assessments were correlated to in-stream primary production and respiration. This indicates a relationship between riparian condition and shows how rapid measures (index coefficient) are valuable surrogate measures of in-stream condition.

8. Riparian sites that had been fenced-off and replanted (=planted sites in our terminology) generally received a low condition index score owing to the short time that had elapsed since site works. There was a significant, positive linear relationship between site condition and the time since rehabilitation work was completed, with more than 16 years required for planted sites to attain an excellent condition index score.

9. There was no statistically significant relationship between stocking rate and the index of riparian condition on dairy farms in Gippsland and there was only a very weak negative relationship between cowpat counts (our index of livestock activity in the riparian zone) and condition scores. There was also no evidence that the positioning of alternative watering points on dairy farms in Gippsland had resulted in better condition index scores for riparian sites. Thus, two generic best practices recommended for riparian habitats - rotations of stock in riparian paddocks and the provision of off-stream watering points will not be effective in rehabilitating riparian habitats under the current stocking rates used on Gippsland dairy farms.

10. Our results also indicated that condition index values for fenced remnants of riparian vegetation reached a plateau when vegetation was 30 metres wide on either side of a stream. Thus it appears that such a width is required in the Gippsland dairy region to obtain an excellent condition score.

11. The following recommendations regarding best practice arise directly from the results of this study.

- Rehabilitation of degraded riparian sites currently subject to direct access by dairy cows is best achieved by fencing-off riparian areas so they are inaccessible to cattle. Other recommended practices such as the provision of off-stream watering points and 'spelling' of riparian paddocks are not effective on dairy farms in Gippsland under current stocking rates.
- In order to restore riparian sites to somewhere near excellent condition (as measured by our index of riparian condition) fenced riparian strips will need to be at least 30 metres wide on either side of a stream or river.
- When siting new dairy sheds on farms, they should be as far away from streams as possible.

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1.0 INTRODUCTION

This report presents the findings of a field project undertaken in the west and south Gippsland region of Victoria between May and December 2002. The work is a component of the larger Gippsland Dairy Riparian Project funded by the Dairy Research and Development Corporation and GippsDairy. The aim of the larger project is to determine, demonstrate and communicate Best Management Practices for riparian habitats in landscapes dominated by dairy farming.

In this project, we surveyed 107 sites and conducted 28 landholder interviews to gain information on the variation in the ecological condition of riparian habitats and management practices among farmers in the west and south Gippsland region. The specific aims of the project were:

- To determine the current condition of riparian habitats across the west and south Gippsland dairy region.
- To investigate the relationships between landholder management practices and riparian condition.
- To make recommendations for management practices that could be investigated at demonstration sites planned for the region.

2.0 BACKGROUND

2.1 Dairy industry in west and south Gippsland

Australian dairy farmers support an industry with an annual value of $3 billion. As part of their plan for the future the Australian dairy industry has made the management and preservation of natural resources one of it's highest priorities. The recent review of the industry provided in the report 'Sustaining Our Natural Resources – Dairying for Tomorrow' highlighted the industry's desire to sustain natural resources while increasing productivity in the context of a highly competitive market (Anon. 2001). The Dairying for Tomorrow report contains a national strategy and eight regional action plans for resource management in Australia's recognised dairying areas. The national strategy also provided guidelines for generic best practice management of major resources and processes under the headings: Water, Land, Soil Conservation, Nutrient run-off, Effluent and Biodiversity.

Victorian dairy farmers account for a major portion of the Australian dairy industry's annual milk production and approximately 60% of the industry's farms are located in Victoria. Much of the state's primary dairy production is focused in the Gippsland region[1], east of Melbourne. Approximately $1.2 billion worth of exports come from this region annually (Anon. 2001).

Total production in the Gippsland region expected to increase by 50% in the next 10 years (Anon. 2001), consequently the implementation of sound management practices that target both environmental and production issues are vital to the future of the region's dairy industry. Historical clearing of steep catchments and the intensive nature of the production systems (high stocking rates and fertiliser application on small farms with small economic margins) combined with high rainfalls (1000-2000 mm per year) have combined to produce a region with severely impaired landscape functions. Land slippage is common on steep slopes. A reduction of biodiversity has occurred as a consequence of removal, fragmentation and reductions in the quality of habitats. Subsequently 60% of the waterways in west Gippsland are estimated to be in poor to very poor condition (Anon. 2001).

The Gippsland Regional Action Plan (GippsDairy 2001) was developed as a joint venture between the GippsDairy Regional Development Program and the West Gippsland Catchment Management Authority (WGCMA). The action plan aims to maintain productivity while promoting an environmentally sustainable industry. The key resource management issues for the region's dairy industry were identified as:

- Development of whole farm plans
- Managing land use change and local planning
- Achieving sustainable productivity gains
- Increasing water use efficiency
- Nutrient management
- Effluent management
- Increasing biodiversity

[1] Milk production in Gippsland comes from two major regions: west and south Gippsland. Farms are located in the Strezlecki Ranges and on the Gippsland Plain, and east Gippsland where production is focused on the Gippsland Plain with a large number of farms supported by irrigation (Anon. 2001).

- Land protection

Many of these issues are closely related to the appropriate management of the boundaries between paddocks and waterways on farms, i.e. riparian habitats.

Despite the availability of generic management recommendations for riparian habitats (e.g. Anon. 2001) and the information that resides with individual farmers, catchment coordinators and agency staff in the Gippsland region, there is little specific information available to dairy farmers in Gippsland regarding best management practices for their riparian areas. This lack of information has been recognised by the dairy industry as an impediment to successful management:

> *A more scientifically based appreciation of how such measures* (fencing to exclude stock*) also contribute to the health of aquatic systems would be of value. There is a need to better appreciate the direct impact of farm management practices on the health of catchments (Anon. 2001, pp40).*

For the Gippsland Regional Action Plan (GippsDairy 2001) to be implemented successfully, scientific information specific to the dairy regions needs to form the basis for extension programs for the sustainable management of waterways. For this reason the Dairy Research and Development Corporation and GippsDairy combined to support the larger Gippsland Dairy Riparian Project, of which this current project is a part.

2.2 Identifying Best Management Practices for riparian habitats in the west and south Gippsland dairy region

Recommendations for the appropriate management of livestock in riparian habitats in dryland regions of Australia typically includes provision of off-river water supplies, rotational grazing practices where access to riparian areas occurs infrequently for short periods, strategic fencing of parts of the riparian zone combined with replanting of native species, and the retention of grass buffer strips to intercept runoff and minimise inputs to streams (MacLeod 2002). There is now good evidence that the application of these approaches can result in significant increases in the condition of riparian habitats without impacting on the economic viability of grazing enterprises (Jansen & Robertson 2001a, Curtis *et al.* 2001).

However, it is unknown to what degree such management initiatives will be effective or acceptable to dairy farmers in the very different landscape and economic situations in Gippsland.

2.3. This study

In this study we used rapid assessments (e.g. Jansen & Robertson 2001a) at a large number of sites to provide information on riparian condition and farm management specific to west and south Gippsland dairy farms. We collected information on the current status of riparian habitats in the two major bioregions (DPI 2002) of west and south Gippsland (Strezlecki Ranges and the Gippsland Plain). Riparian habitats in these bioregions were further divided into those that had received riparian management initiatives in the form of exclusion of stock, and those that had not. By linking the information on riparian condition with information on current management of dairy farms obtained by interviewing landholders we were able to investigate how different practices influenced the condition of riparian habitats, and therefore identify possible best practices.

3.0 METHODS

3.1 Study Region

The study area was located within the west and south Gippsland dairy regions of southeastern Victoria. All sites were within the areas governed by the West Gippsland Catchment Management Authority (WGCMA). The WGCMA boundaries extend from the alpine areas below Mansfield in the north to Wilson's Promontory in the south and from Warragul in the west to Sale in the east (see Figure 1). West Gippsland is divided into 3 state-recognised river basins; the Latrobe and Thomson basins, which flow to Lake Wellington in the east, and the South Gippsland basin that flows to the southern coast and adjacent inlets.

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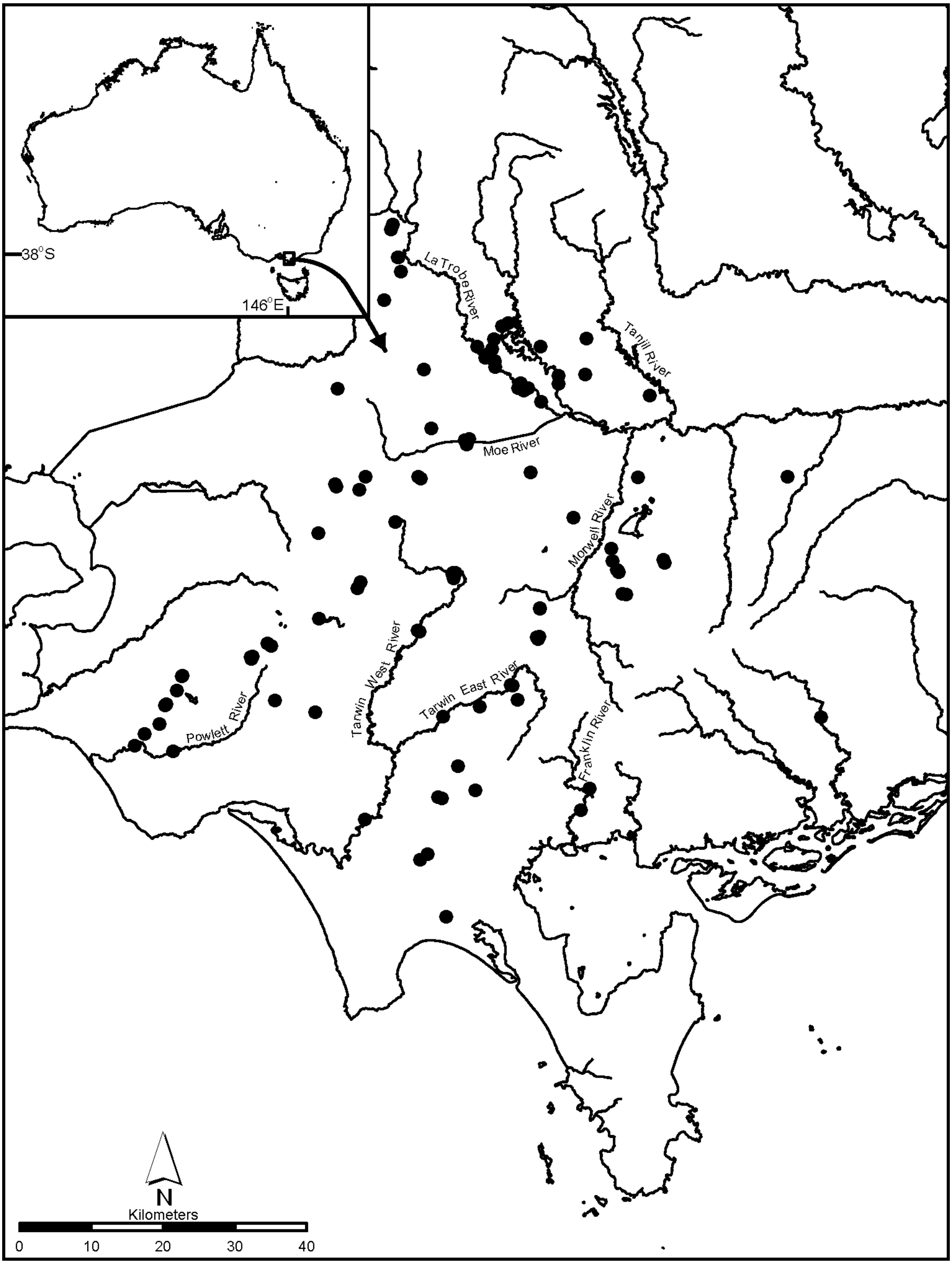

Figure 1. Map of the study area showing the south and west Gippsland dairy regions and the location of the survey sites and reference sites. Some dot points are indistinguishable as they are close together.

Industry in the area is dominated by those that draw directly from the region's natural resources (e.g. agriculture, electricity and forestry) with the region being the most densely settled area in the state outside metropolitan Melbourne (Waterwatch 2000). Agriculture is dominated by dryland pasture farming usually of dairy and beef cows. Dairy farming in the region began in the mid 1800's with extensive clearing throughout the catchment continuing well in to the 1950's (Anon. n.d.). The average herd size is 166 milking cows. This number is steadily increasing as smaller farms succumb to competition from larger farms and the difficulties of farming small acreage on steep land.

The area experiences warm dry summers (average maximum 24.0 ºC in January) and cold wet winters (average maximum 12.2 ºC in July). The study area takes in the designated bioregions of the Gippsland Plain and the Strezlecki Ranges. Mean annual rainfall ranges from approximately 900mm in the drier Gippsland Plain up to 2000mm in the much wetter Strezlecki Ranges (Bureau of Meteorology 2003). Topography varies significantly across the two bioregions. The Gippsland Plain includes lowland coastal and alluvial plains characterised by gently undulating terrain, while the Strezlecki Ranges consists of moderate to steep slopes with deeply dissected blocks of sandstone, siltstone and shales (DPI 2002). The rich soils support wet and damp forests as well as shrubby foothill forest.

Each bioregion has distinctly different vegetation communities and consist of different Ecological Vegetation Classes (EVC's). Each EVC represents one or more floristic communities that occur in similar types of environments and tend to show similar ecological responses to environmental disturbance (DPI 2002). Each bioregion has dominant known and expected (pre 1750's) EVC's.

The Gippsland Plain is dominated by the Lowland Forest EVC. The floristic community of this EVC is severely depleted due to intensive clearing for agriculture. Soils vary from damp sands to sandy topsoils over gravel or clay subsoils. Dominant overstorey vegetation includes White Stringybark *(Eucalyptus globoidea*), Narrow-leaf Peppermint (*Eucalyptus radiata*), Blackwood *(Acacia melanoxylon*) and Silver Wattle (*Acacia dealbata*). Austral Bracken *(Pteridium esculentum*), Kangaroo Grass

(*Themeda triandra*) and various Tussock species (*Poa* spp.) would have dominated the dense groundcover (RFA 1999). (See Appendix 1a for detailed species list and EVC description).

The Strezlecki bioregion supports three major EVC's being Wet Forest, Damp Forest and Shrubby Foothill Forest. The Wet and Damp Forest EVC's support similar floristic communities with Wet Forest more common on topographically protected high rainfall areas and headwaters of south flowing streams and Damp Forest (see Appendix 1b) extending to lower elevations and rainfall areas. Dominant eucalypts include Messmate (*Eucalyptus obliqua*), Mountain Grey Gum (*Eucalyptus cypellocarpa*) and Blackwood (*Acacia melanoxylon*) with Mountain Ash (*Eucalyptus regnans*) more dominant in Wet Forests (see Appendix 1c). Typical understoreys include a variety of moisture dependent fern species such as Rough Tree fern (*Cyathea australis*), Soft Tree fern (*Dicksonia antarctica*), Common Ground fern (*Calochlaena dubia*) and Mother Shield fern (*Polystichum proliferum*) (RFA 1999).

Shrubby Foothill Forest occurs in habitats at the drier end of Damp Forest on fertile well-drained soils. This EVC is dominated by overstorey species of Narrow-leaf Peppermint (*Eucalyptus radiata*), Messmate (*Eucalyptus obliqua*) and Mountain Grey Gum (*Eucalyptus cypellocarpa*). Ground cover is very species poor and includes Austral Bracken *(Pteridium esculentum*) and Tall Sword-sedge (*Lepidosperma elatius*) (RFA 1999) (see Appendix 1d).

3.2 Study design

All sites were riparian areas on dairy farms with no major irrigation. Sites were divided into stream size categories; tributaries and small creeks (1^{st} - 2^{nd} order streams), and large creek and rivers ($\geq 3^{rd}$ order streams). In most cases small stream sizes occurred in the Strezlecki Ranges (hilly) bioregion and larger creeks and rivers occurred on the Gippsland Plain (flats). These two stream size categories were then each further spilt into two site categories: a) remnant or planted and b) grazed (see Figure 2).

Although the study involved a balanced design, site selection was random within each of the four final categories. Size of creeks and their current management were not known until arrival at the site.

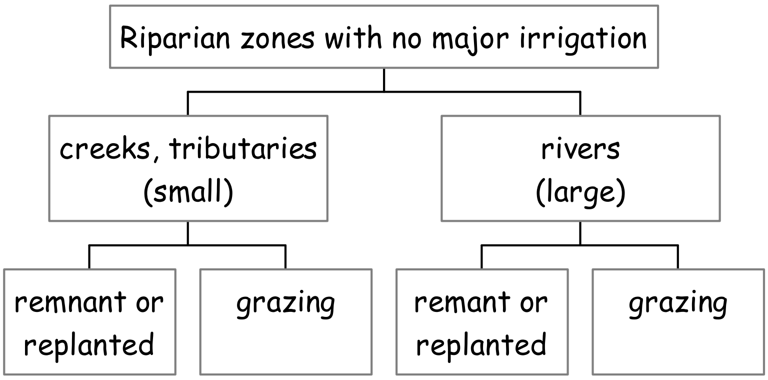

Figure 2. A summary of the study design. Each of the 4 bottom level groups contained 25-30 individual riparian sites (n=107).

Twenty-eight individual farmers were interviewed in relation to current and past on-farm management practices. Participants were chosen randomly with all farmers answering the same questions set prior to the interview being conducted. Although farmers were chosen randomly some declined to participate in the interview due to time constraints on the farm (interview time was approximately 1hour).

Surveys of riparian condition were conducted at 107 sites between June and November. Condition index measurements included measures of habitat, cover, debris, natives and species (see section 3.4 later). Of the 107 sites for which riparian condition was measured 38 were linked to farmer interview data as some of the interviewed farmers had more than one riparian area.

3.3 Landholder interviews

Interviews were conducted with 28 different landholders. Interview questions pertained to both past and present on-farm management practices and did not include any questions relating to social aspects of riparian management (e.g. farmer perceptions of riparian areas, why they are important, why restoration has or hasn't been attempted).

Questions were divided into 5 broad categories. 1) General questions that included questions about farm size, ownership and past land use. 2) Stocking rates and paddock sizes with questions about the break up of current stocking rates, past stocking rates, number and size of paddocks and rotational grazing practices employed. 3) Streambanks and watering points that included questions about flooding, numbers of riparian paddocks, total length of creek/river frontage, riparian restoration (if any) and weed management techniques. 4) Effluent, irrigation and stock loss that included methods and frequency of irrigation, types of effluent systems and management of effluent and loss of stock in creek/river associated areas. 5) Conservation and new management regimes, which included questions about any new management that has resulted in an improved farm environment, whether this new management was cost positive and if they were members of Landcare (see Appendix 2 for full interview).

3.4 Ecological condition and rapid appraisal

Owing to the spatial scales of human impacts on the landscape and the need for assessment of ecological change, there is an expanding field of research focused on rapid appraisal techniques to measure ecosystem condition or integrity (Fairweather 1999; Boulton 1999). Condition refers to the degree to which human-altered ecosystems diverge from local semi-natural ecosystems in their ability to support a community of organisms and perform ecological functions (Karr 1999).

In order to investigate the condition of riparian areas on private properties, we used rapid surveys of the ecological condition of riparian habitats (Appendix 3). During the surveys we obtained measures for a number of indicator variables that are linked to physical, biotic community and landscape functions of riparian habitats (Table 1).

Recently, Jansen and Robertson (2001a) developed and tested an index for the rapid appraisal of the ecological condition of riparian and floodplain habitats on the Murrumbidgee River using a sub-set of the indicators proposed by Ladson *et al.* (1999). The index was made up of six sub-indices, each with a number of indicator variables. In this study, we used an amended version of the Jansen and Robertson (2001a) index with five sub-indices as shown in Appendix 4. The five sub-indices included in the rapid assessment were: (1) width and longitudinal continuity of vegetation, (2) vegetation cover and structural complexity, (3) standing and fallen debris, (4) dominance of natives *vs* exotics, and (5) a series of special features including regeneration of canopy species, presence or absence of reeds and tree ferns and weed species declared noxious for the region.

In order to choose appropriate indicator variables for each of the sub-indices and to set appropriate scores for indicators we used seven reference sites across the west and south Gippsland regions (Table 2). The two major criteria used for choosing reference sites were: (1) that riparian vegetation structure was similar to that expected for the pre 1750 Ecological Vegetation Classes (see RFA 1999 and Appendix 1a-d) in the two bioregions of west and south Gippsland (Gippsland Plain, Strezlecki Ranges), and (2) where domestic livestock had been excluded from the site for more than 15 years.

On the basis of the observed vegetation structure at the reference sites, where there were four distinct layers (upper canopy, sub-canopy, understorey and ground cover) we increased the number of variables in the sub-index vegetation cover from three in the original index (Jansen & Robertson 2001a) to four for the Gippsland surveys. In addition, owing to the shading provided by the well-developed canopies and sub-canopies in the riparian habitats in the Strezlecki bioregion, (RFA 1999) we adjusted the scoring for the groundcover layer for all HILLY sites to 0=absent or 1=present. Scores for both HILLY and FLAT sites were scaled to scores out of 50 so that comparisons could be made across the region (see Appendix 4).

Note that choice as a reference site did not mean that the vegetation species composition was equivalent to the Ecological Vegetation Classes (see RFA 1999; DPI 2002) expected for these sites. This was because most sites had significant numbers of exotic plant species and some had significant understories of noxious weeds. Thus while they allowed us to establish indicators and scores for the rapid appraisal index based on structural attributes of the vegetation they did not score the maximum value for condition using the rapid appraisal index (see later).

Table 1. Functions of the riparian zone at different levels of organisation, the components of the riparian ecosystem which perform those functions, and the indicators of the function used in this study.

Functions	Components	Indicators
Physical:		
Reduction of erosion of banks	Roots	Tree cover
Sediment trapping	Roots	Tree cover
Controlling stream microclimate/ discharge/ water temperatures	Riparian forest	Tree cover
Filtering of nutrients	Vegetation, leaf litter	Ground cover vegetation Leaf litter cover
Community:		
Provision of organic matter to aquatic food chains	Vegetation	Vegetation cover Leaf litter cover
Retention of plant propagules	Terrestrial coarse woody debris, leaf litter	Terrestrial coarse woody debris Leaf litter cover
Maintenance of plant diversity	Regeneration of dominant species, presence of important species, dominance of natives vs exotics	Amount of regeneration Damage to regeneration Presence of reeds Dominance of native vs exotic vegetation
Provision of habitat for fauna	Terrestrial coarse woody debris, leaf litter, standing dead trees/hollows, riparian forest, habitat complexity	Terrestrial coarse woody debris Leaf litter cover Standing dead trees Vegetation cover Number of vegetation layers
Landscape:		
Provision of biological connections in the landscape	Riparian forest (cover, width, connectedness)	Vegetation cover Width of riparian forest Longitudinal continuity of riparian forest
Provision of refuge in droughts	Riparian forest	Tree cover

Table 2. Classification of the seven reference sites according to bioregions and locations, with brief descriptions of the vegetation structure at each site.

Gippsland bioregions[1] and reference sites	Map reference (Longitude, Latitude)	Description
Gippsland Plain		Alluvial, flat to undulating terrain. Dominant vegetation types (before agriculture) were lowland forest, grasslands, and grassy woodlands.
• Moondara State Park	146.30455 38.10278	
• Tyres State Park	146.40676 38.12935	
• Private property 1	145.59525 38.54847	
Strezlecki Ranges		
• Mt Worth State Park	146.41175 38.57626	Moderate to steep slopes. Dominant vegetation types are wet and damp forests with shrubby foothill forests
• Tarra Bulga National Park	146.62552 38.47721	
• Bull Beef Creek	146.23348 38.06656	
• Private property 2	146.38751 38.23259	

1. Based on DPI 2002.

Each site survey, to assess condition, was a 150-metre section of the riparian zone. At sites where stock could readily cross the creek both sides of the river/creek were assessed. At sites were stock could not access the opposite bank, one side of the river/creek was assessed. The same, trained observer conducted all surveys. At each site, the following parameters were scored:

- Longitudinal continuity of vegetation along the riverbank was assessed to determine the length and number of any discontinuities (gaps of at least 10 m) in canopy cover.

Four transects (30 m x 5 m) (perpendicular to the direction of river flow) were evenly spaced along the river or creek bank to record:

- channel width and width of the riparian vegetation (on the side(s) of the river being assessed),
- vegetation cover within four layers (ground cover - grasses, herbs, reeds and sedges to 1 m tall; understorey - herbs, reeds, shrubs and saplings 1-5 m tall; sub-canopy - trees >5 m tall and canopy >20m tall), and the percentage which was native

- the number of vegetation layers,
- leaf litter cover on the ground and the percentage which was native species,
- the presence or absence of standing dead trees (snags),
- the abundance of coarse woody debris (>10 cm in diameter) and the percentage which was native species,
- abundance of canopy species seedlings (<1 m tall),
- grazing damage to canopy species seedlings,
- the presence or absence of reeds and tree ferns, and
- the number of species of declared noxious weeds for the region.

Because livestock concentrate their activities at land-water interfaces, stocking rates may not be the best estimate of livestock impact on riparian areas (Robertson 1997). In this study, cowpat counts were used as an index of cattle activity at each site. Cowpats were counted within the four 30 metre transects and within 1 metre of the line on each transect.

At each site estimates for each indicator were averaged, scored and weighted, then summed to give a total score (see Appendix 4). Potential scores for the total condition index ranged from 0 (worst condition) to 50 (best condition). In order to summarise some of our results, we grouped total condition scores for surveyed sites into five categories, as follows: very poor condition <25, poor condition ≥25<30, average condition ≥30<35, good condition ≥35<40, and excellent condition ≥40. Correlations between variables were tested using Pearson's correlation coefficient (r).

As part of the study we wanted to determine whether a condition index score based on assessment of riverbank vegetation and litter provided a proxy assessment of in-stream condition. Measures of in-stream metabolism (daily rates of primary production (P) and respiration (R) for stream sediments and resultant P:R ratios to assess net autotrophy or heterotrophy) have been found to provide excellent indicators of in-stream "health" (Bunn *et al.* 1999). At a sub-set of 20 riparian sites in Gippsland where we had information to calculate the index of riparian condition we measured in-stream metabolism using the methods and equipment described in Bunn *et al.* 1999. The sites were chosen to represent a range of condition scores, stream sizes and spread evenly over the two bioregions. Regressions of in-stream metabolism on condition index scores (and sub-index scores) showed many significant relationships (see Appendix 5).

Another aspect of the study was determining the relationship between the riparian condition index scores, grazing impacts and riparian bird communities. There were two reasons for this: (1) A significant impact of grazing on riparian bird communities, and a significant relationship between riparian condition and bird communities would suggest that grazing, and associated decline in riparian health, is having far-reaching impacts on native bird populations in the region; and (2) A relationship between riparian condition and bird communities suggests the possibility that some bird species might be used as indicators of the success of altered land management practices to restore riparian areas. We recorded all birds seen and heard in the riparian zone during surveys to assess riparian condition scores. Each survey was completed in approximately thirty minutes, and covered an area of approximately 150x50m. For this preliminary study, only one survey was conducted at each site.

To examine the effects of grazing and riparian condition on the bird communities recorded at each site, we used Distance-based Multivariate Analysis for a Linear Model (Anderson 2001), and to illustrate how bird communities varied according to riparian condition, we used Non-metric Multi-dimensional Scaling in PRIMER (Clarke 1993). All analyses were done on presence-absence data, and similarities between sites were calculated using the Bray-Curtis metric. A Similarity Percentages Analysis was conducted in PRIMER (Clarke & Warwick 1994) to determine those bird species characteristic of riparian sites in poor and good condition. The results of these analyses are presented in Appendix 6.

4.0 RESULTS

4.1 Dairy farmer interviews

Farms ranged in size from 70 to 312 hectares and most had always operated as dairy farms (Table 3). All farms had a large number of small paddocks with the range of average sizes between 1.2-3.6 hectares. More than half the farms had been "in the family" for at least two generations but there was a wide range in the period of time that the present owners/managers had managed properties (Table 3).

Table 3. Size and tenure attributes for dairy farms where interviews were conducted with landholders (n=28 farms).

Attributes	Response
Farm size	70-312 ha
Time under current manager	1.7-46 yrs
Percentage of farms passed down through the family	56%
Always operated as a dairy farm	88%
Total number of paddocks	24-66
Mean size of paddocks	1.2-3.6 ha

There was a wide range in the size of milking herds (110-581 cows), and the mean annual stocking rates ranged from 25 to 73 DSE per hectare (McLaren 1997) (Table 4) (see Appendix 7 for DSE conversion rates). Three-quarters of the managers employed 12-hour rotations of cows in grazing paddocks. All farmers interviewed removed cows from paddocks when they were very wet.

Table 4. Milking herd size and stock management practices on dairy farms where interviews were conducted with landholders (n=28 farms).

Management practices	Response
Milking herd size	110-581 cows
Annual stocking rate	25-73 DSE/ha
Percentage of total farm area allocated to milking herd	70-100%
Percentage of farms using 12 hour rotation	76%
Adoption of on/off grazing on wet paddocks	100%

Sixty percent of farmers interviewed had ponds to hold milking shed effluent and more than two-thirds of farmers used this effluent to irrigate pastures. Nearly a third of farmers interviewed either allowed effluent to move directly on to pastures from the dairy shed or had no effluent management system (Table 5). All farmers interviewed used some form of fertiliser to increase production on paddocks adjacent to rivers/creeks (Table 5).

Table 5. Irrigation and effluent management practices on dairy farms where interviews were conducted with landholders (n=28 farms).

Management practice	Response
Percentage of farms using irrigation	80%
Percentage of farms using effluent for irrigation	68%
Most common method of irrigation	Spray irrigation
Dairy effluent systems in use:	
• Single pond	28%
• Two ponds	32%
• Direct to pasture	24%
• No system	8%
• Other	8%
Frequency of cleaning of effluent systems*	
• Daily	28%
• 2-3 times per year	16%
• Once yearly	16%
• Less than annually	24%
Percentage of farms that apply fertilisers to river/creek frontage paddocks	100%

* Some participants declined to answer this question and percentages are calculated based on those that did.

More than half of the farmers interviewed had more than one river/creek frontage on their property but less than 20% of those interviewed used these rivers/creeks as the main watering points for livestock (Table 6). However, on most farms the milking herd had access to a majority of the total farm area (Table 4) and in most cases cows readily accessed riparian habitats. Most farms were subject to flooding in most years and floodwaters inundated significant areas of these relatively small properties (Table 6). The majority of farmers had put in place some fencing initiatives to reduce stock access to river/creek frontages. This often included alternative watering points for livestock and fencing-off of riparian areas. The most common reason given for fencing was to prevent stock accessing neighbouring paddocks (Table 6). However, most fenced off riparian areas were replanted with native plants (Table 6), indicating a conservation perspective among farmers.

Table 6. Attributes of river/creek frontages and management practices related to riparian areas on dairy farms where interviews were conducted with landholders (n=28 farms).

Management practice	Response
Percentage of farms affected by flooding	60%
Distance floodwaters can reach laterally from creek bed	20-500m
Mean distance from river/creek frontage to other watering points	40-400m
Percentage of farms with more than one river/creek frontage	56%
Percentage of farms that use river/creek as main watering points	16%
Percentage of farms with some fenced river/creek frontage	84%
Percentage of fenced areas replanted with trees	76%
Most common reason for fencing river/creek frontage	Prevent stock accessing neighbouring paddocks
Most common method of weed management in fenced areas	Spot spraying
Percentage of farms where fencing river/creek frontage reduced time required for stock management	72%

Nearly three-quarters of farmers interviewed indicated that fencing of riparian areas resulted in a significant time saving in stock management, and fencing and other new resource management initiatives focused on the riparian zone were generally (84% of those interviewed) seen to be positive in terms of cost effectiveness (Table 7).

Table 7. The introduction of new resource management practices on dairy farms where interviews were conducted with landholders (n=28 farms).

Management practice	Response
Newly adopted land management practices resulting in improved farm environment*	
• Fencing of remnant vegetation	32%
• Fencing waterways	40%
• Tree planting	36%
• Grazing techniques	56%
• Fertiliser plans/soil tests	64%
• Other**	44%
Most common effect of these new practices	Increased production
Cost effectiveness of new practices	
• Cost positive	80%
• Cost negative	4%
• Cost neutral	16%
Percentage of owners who were Landcare members	68%

* Multiple answers for this question
** Examples include pasture renovation, re-fencing and installation of water troughs.

Many of the farmers interviewed had introduced a range of new farm practices to both increase production and conserve resources. Sixty-four percent used soil testing to monitor nutrient levels in pastures and more than half had introduced new grazing rotations and installed new water troughs. A third of those interviewed had recently fenced-off remnants of native vegetation and streambanks to control livestock (Table 7).

4.2 Condition of riparian sites and relationships with dairy farm management

General patterns

With the exception of some sites in patches of remnant vegetation most riparian sites on dairy farms across south and west Gippsland were in very poor condition (Fig. 3). This was particularly true for grazed sites where livestock had direct access to streams and associated riparian habitats. Generally, most planted sites were in very poor condition. Most fenced remnants of well-developed riparian forest were in good to excellent condition (Fig 3).

When riparian sites on dairy farm sites were considered according to topographic categories (flat or hilly country) and the context of the four major management land management practices it was clear that topography had no significant effect on mean condition index scores (Fig. 4). However, there were significant differences between management practices and riparian sites. Remnants were in better condition than those in planted sites, which in turn were in better condition than those sites that were grazed. Grazed sites in both topographic categories had means scores below 15 out of a possible maximum score of 50 (Fig. 4; Table 8).

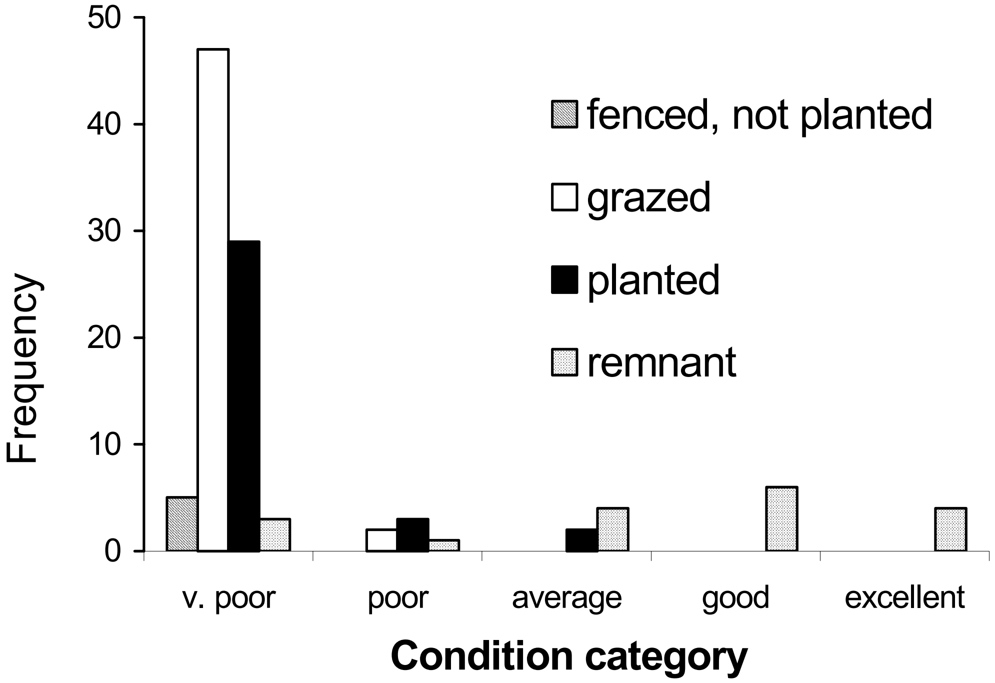

Figure 3. Frequency of condition index score categories for riparian sites subject to different management on dairy farms in south and west Gippsland. Data pooled over flat and hilly regions.

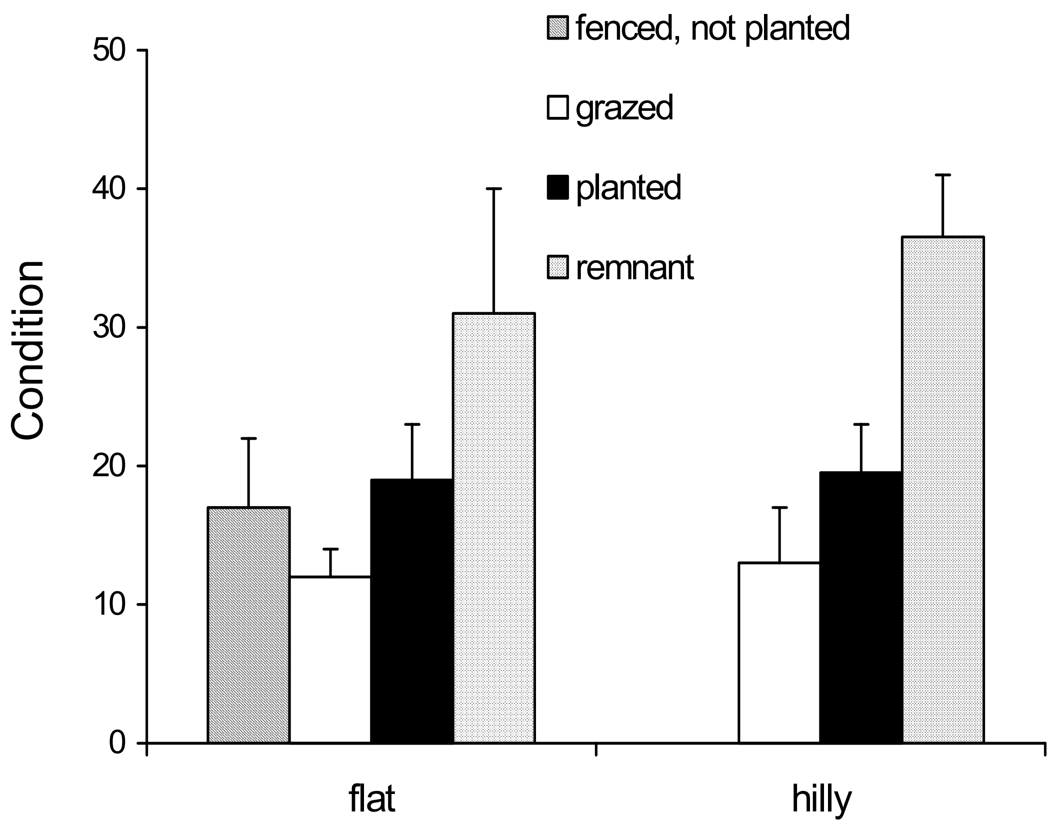

Figure 4. Mean (+ 95% CL) condition index scores for riparian sites subject to

different management on dairy farms in flat and hilly regions of west and south Gippsland.

Table 8. Analysis of variance for condition index scores for riparian areas subject to different management on dairy farms in flat and hilly regions of south and west Gippsland. ***, $p < 0.001$; g=grazed, p=planted, r=remnant. Note, fenced but not planted sites were not included in the analysis.

Source of variation	**SS**	**df**	**MS**	**F**	**Post-hoc comparisons**
Management regime	5724.4	3	1908.1	50.1***	r > p > g
Error	3880.7	102	38.0		
Total	46701.5	106			

Table 9. Summary of analyses of variance for mean scores of the five components of the condition index in riparian sites under management (r= remnant sites, p=planted sites, g=grazed) on dairy farms in different regions (flat, hilly) of south and west Gippsland. **, $p < 0.01$; ***, $p < 0.001$; ns = not significant. Results of post-hoc comparisons of means are also shown.

	Components of Condition Index				
Factor	**HABITAT**	**COVER**	**NATIVES**	**SPECIES**	**DEBRIS**
Slope type (S)	** **hilly>flat**	ns	p=0.058 **hilly>flats**	ns	ns
Management (M)	*** **r>p>g**	*** see below	*** **r>p>g**	*** **r>p=g**	*** **r>p=g**
Interaction (S x M)	ns	** Condition at **g** and **p** sites in hilly regions less than in flat regions. Condition at **r** sites in hilly regions greater than in flat regions	ns	ns	ns

Subindices of the overall index of condition contributed in different ways to total index scores (see Appendix 8a-b). Thus, the mean scores of several of the components of the overall index exhibited different patterns with respect to terrain and management practices (Table 9). The mean condition scores for the HABITAT (=

habitat continuity and extent) and NATIVE (=dominance of natives versus exotics) components were significantly greater in hilly sites than in flat sites, while overall mean scores were greater for remnants than replanted sites and those for replanted sites were greater than for grazed sites. For COVER (=vegetation cover and complexity) mean scores at grazed and replanted sites in hilly regions were less than they were in flat regions, while remnant sites in hilly regions had greater mean scores than those in flat regions. Mean scores for SPECIES (=indicative species) and DEBRIS (=standing and fallen debris) components showed similar patterns to the overall condition index (Tables 8 and 9).

For fenced and planted sites we wished to explore how long was required for riparian condition to approach that of reference sites in the region (mean condition score for the seven reference sites = 37). Our data (Fig. 5) indicates that there exists a strong positive correlation between planting age and riparian condition scores, but that it takes more than 16 years for planted sites to approach excellent condition (i.e. an index score >40).

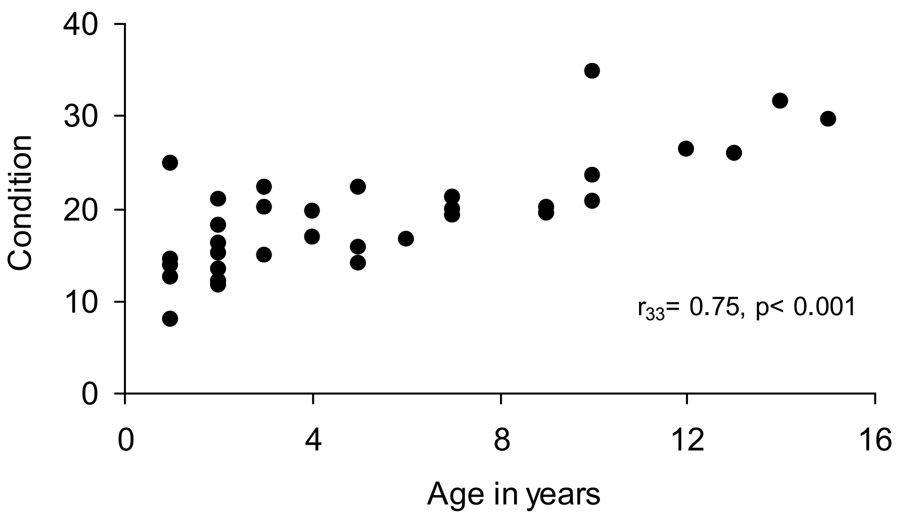

Figure 5. Condition index scores for fenced and replanted riparian sites of different age (since restoration) in flat and hilly regions of west and south Gippsland.

Relationships with other aspects of farms and their management

For those farms for which we had accurate information on annual stocking rates derived from interviews with farmers it was clear that there was no relationship between stocking rates and the condition index for riparian sites subject to grazing by livestock (Fig. 6).

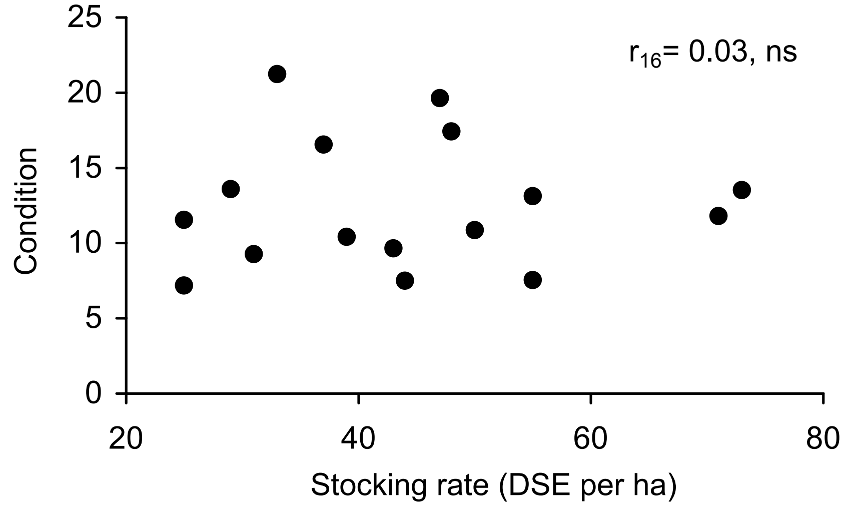

Figure 6. Condition of riparian sites plotted against the mean annual stocking rate (Dry Sheep Equivalents per hectare) for the dairy farms on which interviews and surveys were conducted. Data for grazed sites only.

Because average stocking rates are not necessarily a good predictor of cattle activity near water, we also investigated the relationship between the density of cowpats and condition at a number of riparian sites that were grazed (Fig. 7). There was only a very weak relationship between the two variables. Interestingly, there was a stronger negative relationship between cowpat densities and the index of riparian condition for sites that had been fenced and replanted (Fig. 8), although the level of significance of the relationship was obviously influenced by the large number of sites with zero cowpats. Clearly cows had accessed many replanted sites prior to the surveys and many sites were fenced at the top of the bank so cowpats were still counted outside the fence and condition was poorest at sites with greater densities of cowpats.

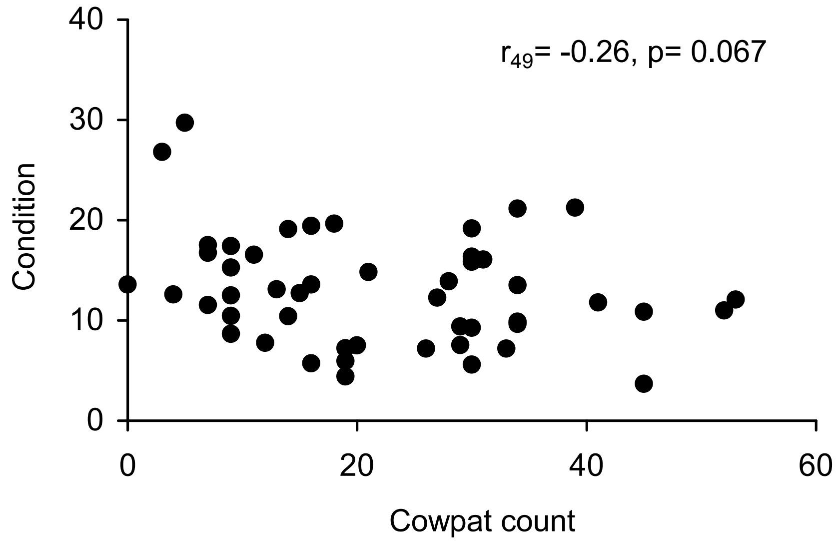

Figure 7. For grazed riparian sites, condition plotted against the number of cowpats (used as an indicator of cattle activity).

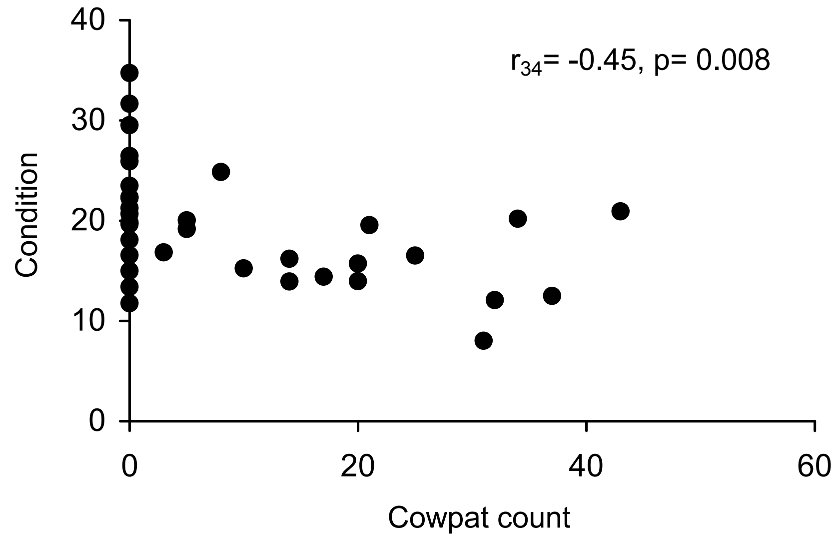

Figure 8. For planted riparian sites, condition plotted against the number of cowpats counted at the site (used as an indicator of cattle activity). Although fenced-off, half of the planted sites (17 of 34) had been accessed by cattle or were very narrow plantings.

There was a significant, positive relationship between the value of the riparian condition index and the distance of the riparian survey site from the dairy shed (Fig. 9). However, there was no relationship between the value of the condition index and the distance to the nearest artificial water sources (such as troughs or dams) (Fig. 10).

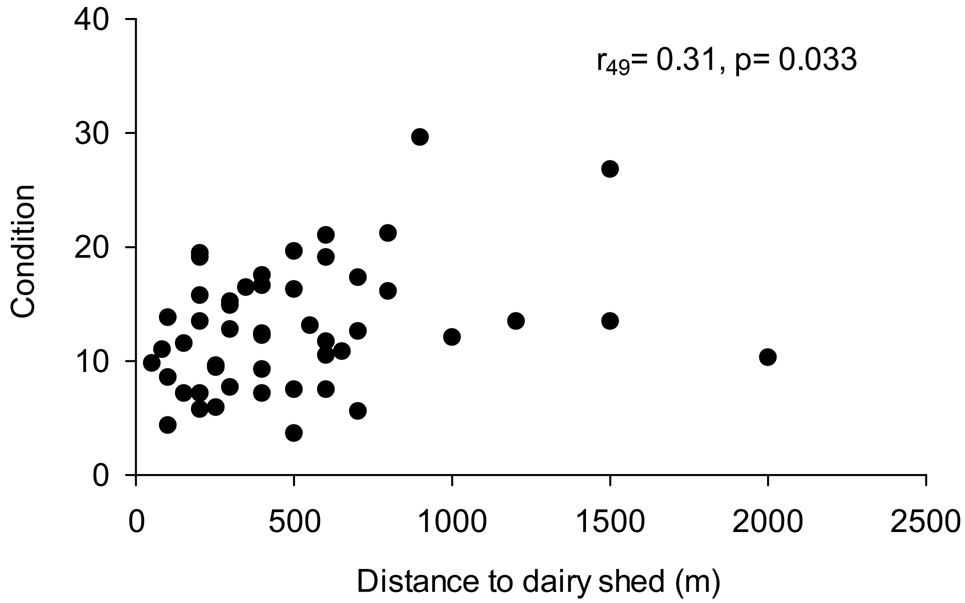

Figure 9. The condition of riparian sites plotted against the distance from the riparian site to the dairy shed used for milking. Analysis restricted to sites subject to grazing by the dairy herd.

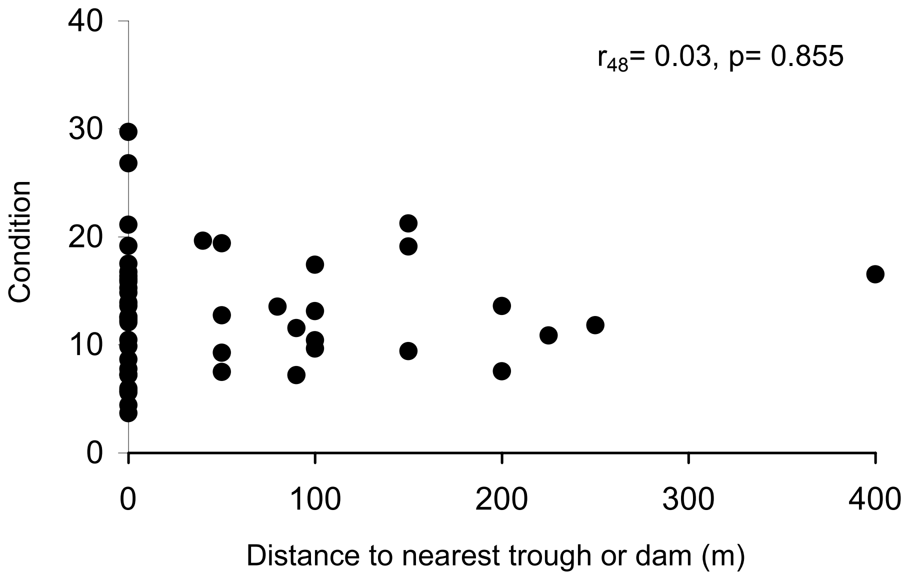

Figure 10. The condition of riparian sites plotted against the distance from the riparian site to the nearest artificial watering point (trough or dam). Analysis was restricted to sites subject to grazing by the dairy herd.

There were no significant relationships between farm size (Fig. 11) or the area of the farm used by the milking herd (Fig. 12) and the index of condition of riparian sites.

This was maintained for sites that were grazed and sites that were fenced and replanted.

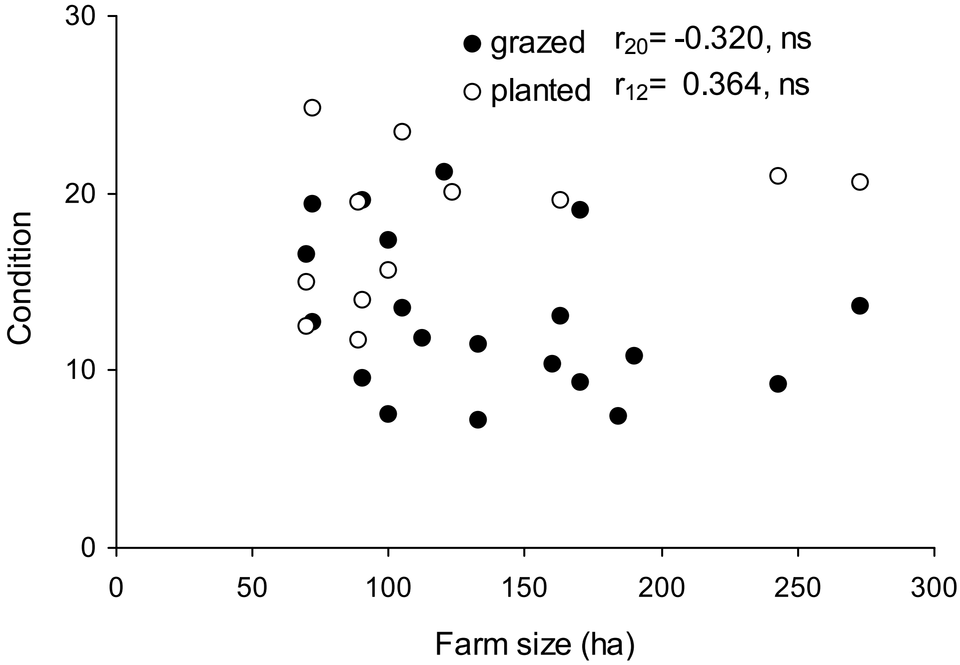

Figure 11. Condition of grazed and planted (fenced) riparian sites on dairy farms plotted against total farm size (ns = not significant).

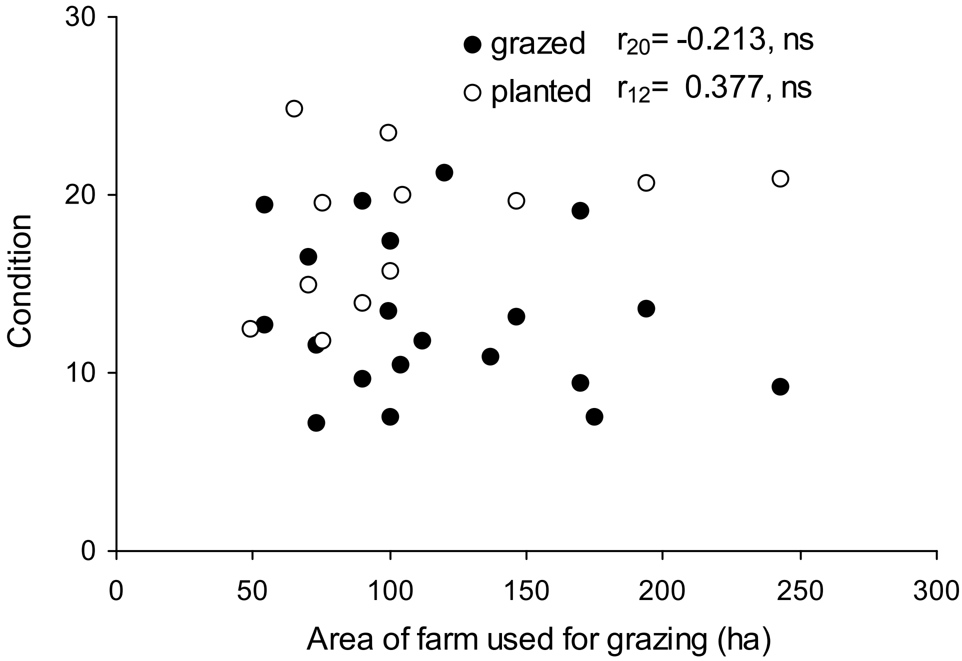

Figure 12. Condition of grazed and planted (fenced) riparian sites on dairy farms plotted against the area of the farm used for grazing (ns = not significant).

We plotted the condition index scores for remnant patches of riparian vegetation against the width of the riparian remnants in order to determine if there was a relationship that might suggest optimal design for rehabilitation sites on dairy farms in the study region. As we measured the total width of remnants we plotted half of the width (i.e. one side of a creek/river). Although there is a significant linear correlation between the two variables (r_{18}= 0.65, p=0.0036) the results reveal a relationship where condition index values appear to reach an asymptote between 30 and 40 metres (Fig. 13). However, caution is required when interpreting this relationship, as the maximum condition index score we recorded in these remnants was 33.25 out of a possible 40.

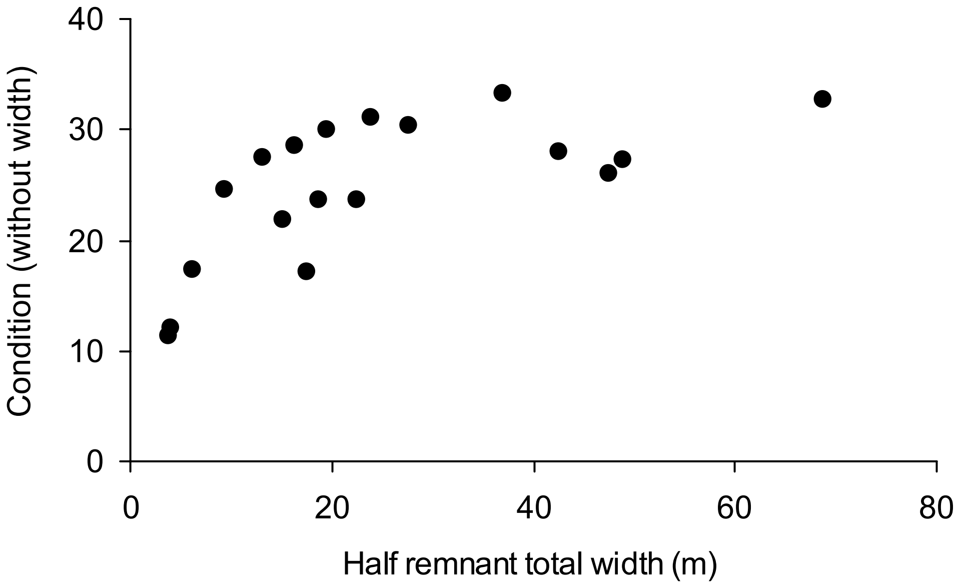

Figure 13. Relationship between the width of remnant patches of riparian vegetation and the condition index scores for the sites. Sites were "pooled" over flat and hilly terrain. Note that the metric associated with the width of riparian vegetation was excluded from the calculation of the condition index scores, and consequently the maximum score for the condition index is 40.

5.0 DISCUSSION

5.1 Dairy farm management and riparian condition

The sizes, herd numbers and stocking rates of the 30 farms we visited for interviews were typical of dairy farms in Gippsland (Australian Bureau of Statistics 1998) and subsequently our findings are considered to be relevant across the region. Dairy farms in Gippsland are intensive enterprises, and owing to the activities of cattle (Fleischner 1994; Trimble & Mendel 1995) one predictable outcome is degradation of riparian habitats. Farms we visited for farmer interviews were typically small (most <200ha) with stocking rates between 25-73 DSE.ha^{-1}. In most cases farmers use all of their properties for pasture production to support their herds. Despite finding that a majority of farmers interviewed had some portion of their riparian areas fenced-off from stock, most paddocks that contained streambank habitat were generally managed in the same way as other paddocks, except when very wet, when farmers removed stock.

Large amounts of waste from dairies and holding areas present a challenge for dairy farmers. While most farmers interviewed had effluent ponds to manage waste, they were not managed with any consistent practice, and some farmers allowed waste to return directly to paddocks. Efficient effluent and fertiliser management is considered critical to sustainable pasture and ecosystem management in dairy regions (Anon. 2001).

An important step in managing the disposal of concentrated waste from dairy operations in a sustainable manner will be the maintenance of riparian strips to minimise transport of nutrients to waterways. The efficacy of soils and riparian strips to intercept phosphorus and other nutrients in the high rainfall, steep country typical of parts of the Gippsland dairy region varies with soil type and other factors. Much of the phosphorus mobilised during high rainfall events is in dissolved form which may not be intercepted by riparian vegetation strips at some sites (Nash & Halliwell 1999, Nash *et al*. 2000) but may be effectively trapped at others (Burkitt *et al.* 2001, Target 10 2002). Adoption of appropriate management strategies for the application of phosphorus fertiliser promoted by extension programs include soil testing and appropriate timing and siting of application (not near streams prior to predicted high rainfall events) (e.g. Target 10 2002).

What was clear from interviews with dairy farmers was that due to the relatively small size of dairy properties in the region, the trade situation has led to the necessity to maintain high stocking rates. Consequently there is little ‘room to move’ for farmers wishing to protect their riparian habitats. While many farmers in the region are using fencing to exclude stock from streambank habitats, the most common reason given for fencing was to prevent cattle having access to neighbouring paddocks (i.e. for stock management purposes). Nevertheless, the very active Landcare groups in the region attest to the number of dairy farmers with a motivation for fencing and replanting of riparian habitats to conserve streambanks and associated biodiversity.

It is clear from our data that past and present management of the landscape for dairy farming in south and west Gippsland has resulted in severe degradation of riparian habitats. The severity of degradation was similar in the flat terrain of the Gippsland Plain and hilly terrain of the Strezlecki Ranges. The riparian sites in ‘best’ condition were in patches of fenced remnant riparian forest. However, even the remnants did not receive maximum condition index scores owing to abundance of weeds, the lack of vegetation complexity and only small amounts of organic debris (relative to reference site conditions).

Riparian sites that had been fenced off and replanted (=planted sites in our results) received relatively low condition index scores. Generally, this reflected the fact that rehabilitation of these sites was recent and most sites only planted canopy-forming species (i.e. no understorey). When we compared planted sites of different ages it was clear that it takes more than 16 years for these planted sites to attain an excellent condition index score.

Riparian sites in paddocks that are used for grazing of herds were generally in very poor condition. Clearing of vegetation to create pastures, past grazing and present intensive grazing practices with high stocking rates have resulted in riparian sites that have little or no overstorey, abundance of exotic pasture grasses and little or no terrestrial litter. There is consequently little or no shading of streams and little input of terrestrial organic matter to streams, resulting in degraded in-stream habitat structure and food web dynamics (Bunn *et al.* 1999, Robertson *et al.* 1999). There is also little ground cover, coarse woody debris and leaf litter cover on the ground within riparian vegetation thickets, decreasing local biodiversity.

What was clear from the information we collected was that, apart from fencing riparian habitats from the activities of cattle, other recommended management initiatives aimed at reducing the impacts of livestock on riparian zones will not be effective in rehabilitating riparian habitats under the current stocking rates used on Gippsland dairy farms. For instance, different rotations of stock in riparian paddocks and the provision of off-stream watering points (LWRRDC 1996) are often effective in protecting riparian habitats in drier regions where stocking rates are low (Elmore 1992, Jansen & Robertson 2001a, MacLeod 2002). However, for Gippsland dairy farms we found no relationship between stocking rate and the index of riparian condition. Although stocking rate is generally a poor predictor of the activities of livestock on riparian habitats (Robertson 1997), with the small size of paddocks in Gippsland dairy farms cattle are likely to exert similar pressure on all vegetation within the paddock. It is thus not surprising that we observed only a very weak relationship between cowpat counts (our index of cattle activity in the riparian zone) and condition scores. This contrasted to our previous work in beef-grazing country on the floodplain of the Murrumbidgee River in New South Wales, where cowpat counts explained significant proportions of the variation in riparian condition index scores and biodiversity responses in riparian habitats (Jansen & Robertson 2001a,b).

We also found no evidence that the positioning of alternative watering points resulted in better condition index scores for riparian sites. In lower rainfall areas, where mean annual stocking rates were generally <5 DSE.ha^{-1} and paddock sizes are much larger, there is good evidence that the provision of off-stream watering points form part of successful strategies to improve riparian condition (Jansen & Robertson 2001a, Macleod 2002).

Interestingly we found a statistically significant correlation between distances of riparian sites from dairy sheds and riparian condition index score for those sites. Since our condition index was based on structural features that are used as proxy measures of riparian function (Table 1), it is likely that a cause of such a relationship is proximity to dairy sheds increases the likelihood of physical damage to riparian vegetation by cattle. Gourley and Durling (2002) have reported that soil phosphorus levels increase with proximity to dairy sheds in Gippsland, presumably as a result of dairy cow waste being concentrated in these areas. This indicates both that most soils are efficient traps for phosphorus and that placement of dairy sheds as far as possible from streams will decrease the loss of nutrients to streams as well as physical damage to riparian habitats.

One of the most vexing questions relating to the restoration of river/creek banks is what width of riparian vegetation is required to maintain natural functions of riparian systems. There is no simple answer to such a question, since riparian habitats support a variety of ecosystem functions (Naiman & Decamps 1997). Within regions, variation in each functional attribute can occur with position in catchment, soil type, season and stream flow.

In this study when scores of riparian index condition were plotted against width of riparian vegetation (for 18 sites that had intact remnants of riparian vegetation communities) we found that condition values reached a plateau when vegetation was 30 metres wide on either side of a stream. Thus, it appears that such a width is required in the Gippsland dairy region to obtain an excellent condition score.

5.2 Recommendations

We set out to explore relationships between the management of dairy farms and the condition of riparian habitats across Gippsland, and consequently to identify possible best management practices. These would be further investigated at demonstration sites to be established on dairy farms. Our recommendations are not tempered by what might be cost-effective, but rather what would be most beneficial from an ecological point of view.

The following recommendations regarding best practice arise directly from the results of this study.

- Rehabilitation of degraded riparian sites currently subject to direct access by dairy cattle is best achieved by fencing-off riparian areas. Other recommended practices such as the provision of off-stream watering points and ‘spelling’ of riparian paddocks are not as effective on dairy farms in Gippsland given current stocking rates.
- In order to restore riparian sites to near excellent condition (as measured by our index of riparian condition) fenced riparian strips will need to be at least 30 metres wide on either side of a stream or river.
- When siting new dairy sheds on farms, they should be as far away from streams as possible.

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APPENDICIES

Appendix 1. (a) Ecological Vegetation Class (EVC) description and dominant species list for Gippsland Plain bioregion and Lowland Forest EVC. All information from:

RFA (1999) *Regional Forest Agreements, Victoria* (online), http://www.rfa.gov.au/rfa/vic/gipps/raa/biodiv/index.html [Accessed April 2002].

Gippsland Plains Lowland Forest is only recorded from the pre-1750 mapping project. It would have occurred on the Tertiary and early Pleistocene terraces of the Perry land system, often in a mosaic with Damp Sands Herb-rich Woodland on the plains south and west of Moormung State Forest. This depleted floristic community is only found today in a few road reserves in the area where it has been mapped as Depauperate Lowland Forest due to a high fire frequency over time resulting in a very species depauperate understorey. Soils consist of aeolian and marine sands of low dunes with a clay base which can be penetrated by shrub and tree roots. Elevation is in the range of 5 to 120m above sea level and annual average rainfall is approximately 550-700 mm.

This floristic community would have had an overstorey dominated by White Stringybark *Eucalyptus globoidea* and But But *E. bridgesiana* with a dense understorey of smaller trees and shrubs including Blackwood *Acacia melanoxylon*, Lightwood *A. implexa*, Silver Wattle *A. dealbata*, Spike Wattle *A. oxycedrus*, Shiny Cassinia *Cassinia longifolia*, Hop Bitter-pea *Daviesia latifolia*, Burgan *Kunzea ericoides,* Silver Banksia *Banksia marginata* (tree-form), Purple Coral-pea *Hardenbergia violacea* and Smooth Parrot-pea *Dillwynia glaberrima*. A dense ground cover of bracken, grasses and forbs would have included Austral Bracken *Pteridium esculentum*, Grey Tussock-grass *Poa sieberiana*, Kangaroo Grass *Themeda triandra*, Weeping Grass *Microlaena stipoides*, Common Raspwort *Gonocarpus tetragynus,* Germander Raspwort *G. teucrioides*, Small Poranthera *Poranthera microphylla*, Common Lagenifera *Lagenifera stipitata* and *Glycine* spp. Thatch Saw-sedge *Gahnia radula*, Spiny-headed Mat-rush *Lomandra longifolia* and Wattle Mat-rush *L. filiformis* would also have been present.

Latrobe Valley Lowland Forest is found across the Gippsland plains but includes areas south of Traralgon at Gormandale. It grows on loose, light-grey to white sandy topsoil over a cemented gravel, clay or sand subsoil. The sandy topsoil promotes the occurrence of various healthy understorey species that reflects a floristic association with Heathy Woodland. Average annual rainfall is 800-900 mm and elevation is 180-220m above sea level.

The overstorey is usually dominated by Yertchuk *E. consideniana,* Narrow-leaf Peppermint *E.radiata* but *E. obliqua* and *E. viminalis* ssp. *pryoriana* may also be present. Species in the shrub layer include Sunshine Wattle *Acacia terminalis*, Burgan *Kunzea ericoides*, Showy Bossiaea *Bossiaea cinerea*, Prickly Tea-tree *Leptospermum continentale*, Common Heath *Epacris impressa,* Snow Daisy-bush *Olearia lirata*, Broom Spurge *Amperea xiphoclada* and scattered Saw Banksia *Banksia serrata.*

The ground layer includes dense Austral Bracken *Pteridium esculentum* in addition to Common Raspwort, *Gonocarpos tetragynus*, Thatch Saw-sedge *Gahnia radula* and Tussock-grass *Poa sp.*

Appendix 1. (b) Ecological Vegetation Class (EVC) description and dominant species list for Strezlecki Ranges bioregion and Damp Forest EVC.

Damp Forest is widespread in Gippsland in moderately fertile areas between Wet Forest, the drier end of Shrubby Foothill Forest and the driest forest types such as Lowland Forest, Herb-rich Foothill Forest, and Heathy Woodland. It develops on the drier sites in Wet Forest or on the margins of Warm Temperate Rainforest. It also occurs on protected slopes associated with *Tussocky* Herb-rich Foothill Forest, Lowland Forest or even Heathy Woodland, provided topographic protection is sufficient.

In the lowlands and dissected country below 700m Damp Forest favours gullies or eastern and southern slopes. Above this elevation and in higher rainfall zones the effect of cloud cover at ground level and the subsequent fog drip permits this class to expand out of the gullies onto broad ridges and northern and western aspects. It occurs on a wide range of geologies and soils are usually colluvial, deep and well-structured with moderate to high levels of humus in the upper soil horizons (Woodgate *et al*. 1994). Rainfall is approximately 800-1600 mm per annum and elevation ranges from sea level in South Gippsland to up to 1000m in the montane areas where it merges into Montane Damp Forest.

The dominant eucalypts are commonly Messmate *Eucalyptus obliqua* and Mountain Grey Gum *E. cypellocarpa*. A range of other species may be present as well such as Yellow Stringybark *E.muelleriana* (in South Gippsland with Sticky Wattle *Acacia howittii* present in the understorey), Silvertop *E.sieberi*, Gippsland Blue Gum *E .globulus* ssp. *pseudoglobulus*, Narrow-leaf Peppermint *E.radiata*, Gippsland Peppermint *E. croajingolensis*, Brown Stringybark *E. baxteri* and Swamp Gum *E. ovata* in the vicinity of poorer drainage. Trees of Blackwood *Acacia melanoxylon* and Silver Wattle *Acacia dealbata* are often present.

The understorey typically includes moisture-dependent fern species such as Common Ground-fern *Calochlaena dubia,* Gristle Fern *Blechnum cartilagineum*, Mother Shield-fern *Polystichum proliferum* and Rough Tree-fern *Cyathea australis*, and the presence of broad-leaved species typical of wet forest mixed with elements from dry forest types such as Lowland Forest.

Broad-leaved species include Hazel Pomaderris *Pomaderris aspera*, Victorian Christmas-bush *Prostanthera lasianthos*, Snow Daisy-bush *Olearia lirata*, *Cassinia* spp, Hop Goodenia *Goodenia ovata*, Elderberry Panax *Polyscias sambucifolia* and White Elderberry *Sambucus gaudichaudiana*. Sweet Pittosporum *Pittosporum undulatum* is often present in South Gippsland. The wet forest shrub, Prickly Currant-bush *Coprosma quadrifida,* and Fireweed Groundsel *Senecio linearifolius* are also common. Drier shrubby elements include Prickly Moses *Acacia verticillata,* Prickly Bush Pea *Pultenaea juniperina*, Narrow-leaf Wattle *Acacia mucronata* and Varnish Wattle *Acacia verniciflua*. Other species commonly present are Austral Bracken

Pteridium esculentum and Forest Wire-grass *Tetrarrhena juncea*, Broad-leaf Stinkweed *Opercularia ovata,* Tall Sword-sedge *Lepidosperma elatius,* Wonga Vine *Pandorea pandorana* and Mountain Clematis *Clematis aristata*.

At the drier end of Damp Forest a number of species start to appear such as Narrow-leaf Peppermint *Eucalyptus radiata*, Narrow-leaf Wattle *Acacia mucronata*, Cherry Ballart *Exocarpos cupressiformis*, Grey Tussock-grass *Poa sieberiana*, Prickly Tea-tree *Leptospermum continentale* and Thatch Saw-sedge *Gahnia radula*. At Wilsons Promontory, the shrub Blue Olive-berry *Elaeocarpus reticulatus* is a common species which indicates its close affinities with *Wilson's Promontory Overlap* Warm Temperate Rainforest.

Riparian habitats in Damp Forest contain indicator species of Riparian Forest such as Soft Water-fern *Blechnum minus,* Fishbone Water-fern *Blechnum nudum,* Austral King-fern *Todea barbara*, Scrambling Coral-fern *Gleichenia microphylla*, Tall Saw-sedge *Gahnia clarkei* and Tall Sedge *Carex appressa.*

Appendix 1. (c) Ecological Vegetation Class (EVC) description and dominant species list for Strezlecki Ranges bioregion and Wet Forest EVC.

This EVC includes a very wide range of structural variation ranging from tall old-growth forest up to 60m in height through to regrowth forest and scrub which has the potential to support tall forest. It also includes treeless areas dominated by wet scrub and even "oldfields" which were once cleared but are now dominated by native vegetation.

Wet Forest is dominated by Mountain Ash *Eucalyptus regnans* but may be dominated locally by Blackwood *Acacia melanoxylon* or Silver Wattle *A. dealbata*. A range of other eucalypt species can be present but these tend to be on the periphery of extensive areas dominated by Mountain Ash *E. regnans*. These include Manna Gum *E. viminalis* (often occurring along major river flats and on associated slopes), Strzelecki Gum *Eucalyptus strzeleckii*, Gippsland Blue Gum *E. globulus* ssp. *pseudoglobulus*, Messmate *E. obliqua,* and Mountain Grey Gum *E. cypellocarpa* which occurs on the edges of Wet Forest stronghold areas immediately before Damp Forest becomes more developed. Tree-ferns are sometimes present, particularly Rough Tree-fern *Cyathea australis* on the slopes and Soft Tree-fern *Dicksonia antarctica* along the creek lines as well as some of the "wet-ferns" such as Mother Shield-fern *Polystichum proliferum* and Hard Water-fern *Blechnum wattsii*.

Common understorey species are the broad-leaved shrubs such as Snow Daisy-bush *Olearia lirata*, Musk Daisy-bush *O. argophylla,* Blanket Leaf *Bedfordia arborescens*, Hazel Pomaderris *Pomaderris aspera, Cassinia* spp., Tree Lomatia *Lomatia fraseri* and Austral Mulberry *Hedycarya angustifolia.* The prickly shrub, Prickly Currant-bush *Coprosma quadrifida,* and the vines Mountain Clematis *Clematis aristata* and Wonga Vine *Pandorea pandorana* are also often present. Other shrubs sometimes include Sweet Pittosporum *Pittosporum undulatum*, Tree Lomatia *Lomatia fraseri* and Victorian Christmas-bush *Prostanthera lasianthos*. At the drier end of this group the understorey becomes very low in stature (less than 2m) and broad-leaved species other than Snow Daisy-bush *Olearia lirata* are notably absent. This variant tends to occur on the most exposed, drier northerly aspects.

Wet Forest develops extensively around the localised areas of Cool Temperate Rainforest in the study area. At the dry end of its range it changes to Damp Forest and Shrubby Foothill Forest, which tends to first appear on the drier, steeper aspects associated with Wet Forest in the more protected sites.

There are two floristic communities of Wet Forest: *Gippsland 1* Wet Forest and *Gippsland 2* Wet Forest.

Floristic Community: *Gippsland 1* Wet Forest
Gippsland 1 Wet Forest occurs across the study area along creeks and on south-facing slopes and gullies. It grows on a variety of geologies, which combine with high rainfall and moist loamy organic soils to provide a fertile environment for tall trees, broad-leaf shrubs and ferns. Average rainfall is high ranging from 700–1200mm, with high effective rainfall on protected southerly slopes. It grows at a range of altitudes from 500-1100m above sea level.

The overstorey may carry a range of eucalypts including Messmate Stringybark *Eucalyptus obliqua,* Gippsland Peppermint *Eucalyptus croajingolensis*, Narrow-leaf Peppermint *E. radiata* in the west of the study area and *E. croajingolensis* to the east of the study area. Manna Gum *Eucalyptus viminalis* and *E. obliqua* may co-dominante in some areas

Silver Wattle *Acacia dealbata* is the ubiquitous understorey tree in this EVC. A diversity of tall broad-leaved shrubs are prominent and often form a complete cover, although this may be broken by an equally dense layer of tree ferns. The most common tall shrubs include Hazel Pomaderris *Pomaderris aspera*, Blanket Leaf *Bedfordia arborescens*, Musk Daisy-bush *Olearia argophylla*, and Rough Coprosma *Coprosma hirtella*. Common Cassinia *Cassinia aculeata*, Prickly Currant-bush *Coprosma quadrifida,* Elderberry Panax *Polyscias sambucifolia*, Snow Daisy-bush *Olearia lirata* and Dusty Daisy-bush *O. phlogopappa* form a shorter layer beneath the taller shrub layer.

Tree ferns are often present with Soft Tree-fern *Dicksonia antarctica* at the wettest sites and Rough Tree-fern *Cyathea australis* at lower elevations and on slightly drier sites. Ground ferns include Austral Bracken *Pteridium esculentum*, Mother Shield-fern *Polystichum proliferum* and Fishbone Water-fern *Blechnum nudum*.

The ground layer is equally rich in species, dominated by large moisture-loving herbs, and graminoids such as the large tussocks of Tasman Flax-lily *Dianella tasmanica*, Tussock-grasses *Poa* spp. and Tall-headed Mat-rush Lomandra longifolia. The diverse array of smaller forbs include Ivy-leaf Violet *Viola hederacea*, Soft Cranesbill *Geranium potentilloides,* Bidgee Widgee *Acaena novae-zelandiae,* Hairy Pennywort *Hydrocotyle hirta* and Common Lagenifera *Lagenifera stipitata*. Forbs indicative of Wet Forest include Mountain Cotula *Leptinella filicula*, Scrub Nettle *Urtica incisa* and Forest Starwort *Stellaria flaccida*.

Floristic Community:*Gippsland 2* Wet Forest

Gippsland 2 Wet Forest grows in similar environments to *Gippsland 1* Wet Forest. Rainfall is very high, ranging from 950–1350mm per annum and effective rainfall extremely high. It ranges in elevation from 700 to 1160m above sea level, thus reaching montane environments.

Gippsland 2 Wet Forest is the wettest of the eucalypt-dominated vegetation types. At higher elevations Alpine Ash *Eucalyptus delegatensis* dominates the overstorey whilst at lower elevations Mountain Ash *E. regnans* dominates wetter sites and Manna Gum *Eucalyptus viminalis* and species of the narrow-leaved peppermint group are prominent (for example, Narrow-leaved Peppermint *Eucalyptus radiata* s.s., Monaro Peppermint *Eucalyptus radiata* ssp. *robertsonii* and Gippsland Peppermint *Eucalyptus croajingolensis*). The understorey tree layer is well developed with Silver Wattle *Acacia dealbata* and Blackwood *A. melanoxylon* dominating.

The shrub layer is usually very dense and may form an almost impenetrable thicket, especially after disturbance. It is most often dominated by Soft Tree-fern *Dicksonia antarctica* and a mixture of large mesic shrubs including Banyalla *Pittosporum bicolor*, Mountain Tea-tree *Leptospermum grandifolium*, Blanket-leaf *Bedfordia arborescens*, Victorian Christmas Bush *Prostanthera lasianthos*, Mountain Pepper *Tasmannia lanceolata,* Hazel Pomaderris *Pomaderris aspera* and Musk Daisy-bush *Olearia argophylla*. Several smaller shrubs are also common including Common Cassinia *Cassinia aculeata*, Elderberry Panax *Polyscias sambucifolia*, White Elderberry *Sambucus gaudichaudiana* and Dusty Daisy-bush *Olearia phlogopappa*..

The ground layer is also very dense and is dominated by ferns. Mother Shield-fern *Polystichum proliferum*, Fishbone Water-fern *Blechnum nudum*, Hard Water-fern *B. wattsii*, Ray Water-fern *B. fluviatile* and Austral Bracken *Pteridium esculentum* commonly form a complete cover.

Common herbs and graminoids including Tussock-grasses *Poa spp*, Scrub Nettle *Urtica incisa*, Shade Nettle *Australina pusilla* and Bidgee Widgee *Acaena novae-zelandiae* may reach high densities in open patches, often created by local disturbance, or where the substrate is rocky. Other herbs and graminoids include Tall Sedge *Carex appressa*, Tasman Flax-lily *Dianella tasmanica*, Small-leaf Bramble *Rubus parvifolius*, Hairy Pennywort *Hydrocotyle hirta*, Ivy-leaf Violet *Viola hederacea,* Mountain Cotula *Leptinella filicula*, Forest Mint *Mentha laxiflora* and Forest Starwort *Stellaria flaccida*. Forest Wire-grass *Tetrarrhena juncea* is also common.

Vines are particularly rich in this community of Damp Forest. Mountain Clematis *Clematis aristata* is most common with Common Apple-berry *Billardiera scandens*, Love Creeper *Comesperma volubile*, Austral Sarsaparilla *Smilax australis*, Wombat Berry *Eustrephus latifolius* and Wonga Vine *Pandorea pandorana* often present. Climbers and scramblers are very prominent and the presence of Wombat Berry *Eustrephus latifolia* and Austral Sarsaparilla *Smilax australis* emphasises floristic links for Warm Temperate Rainforest.

Appendix 1. (d) Ecological Vegetation Class (EVC) description and dominant species list for Strezlecki Ranges bioregion and Shrubby Foothill Forest EVC.

Strzelecki's Shrubby Foothill Forest is found mainly on the northern and western aspects of the higher slopes of the Strezlecki Ranges. It occurs in habitats at the drier end of Damp Forest extending from Carrajung on the eastern flank of the Strzelecki's to Loch in the west. Soils are fertile, well-drained, grey-brown loams and clay loams of Cretaceous origin. This EVC has been even more extensively cleared than Wet Forest in the Strzelecki's with some of the few remaining intact remnant patches being found at the Karl Harmann Reserve north-east of Leongatha and at Dickies Hill near Mirboo North. It is floristically and geographically closely associated with Herb-rich Foothill Forest. Elevation ranges from 100-500m above sea level and average annual rainfall is 900-1100 mm.

The overstorey is dominated by Narrow-leaf Peppermint *Eucalyptus radiata*, Messmate *E. obliqua*, Mountain Grey Gum *E. cypellocarpa* and to a lesser extent Silver-top *E. sieberi*. A diverse, shrubby understorey characterises this EVC with a limited range of herbs and grasses in the ground layer.

Characteristic shrubs include Narrow-leaf Wattle *Acacia mucronata*, Dusty Miller *Spyridium parvifolium,* Prickly Currant-bush *Coprosma quadrifida,* Hazel Pomaderris *Pomaderris aspera,* Snow Daisy-bush *Olearia lirata,* Shiny Cassinia *Cassinia longifolia,* Hop Goodenia *Goodenia ovata,* Handsome Flat-pea *Platylobium formosum* and Wiry Bauera *Bauera rubioides.*

The ground layer is very species poor and helps distinguish this EVC from Herb-rich Foothill Forest. It includes Ivy-leaf Violet *Viola hederacea,* Forest Wire-grass *Tetrarrhena juncea,* Austral Bracken *Pteridium esculentum* and Tall Sword-sedge *Lepidosperma elatius.*

Appendix 2. Interview sheet used by the interviewer for on-farm management practices on dairy farms in west and south Gippsland

LANDHOLDER INTERVIEW – On-farm Management
(For interviewer's use only)

Points to remember to tell farmer:

- What project is about
- What is riparian area in simple terms
- All information completely confidential, names not used in reports (and you will be provided with a copy of the reports)
- Do you mind of I take photos of your creek for my future reference (your name will not be placed with the photograph)?
- I am going to ask you questions about: stocking rates and management as well as streambank management (inform of what questions are coming using subheadings)

Owner/Manager:	Interview Date:
Property Name:	Location:
Interviewees:	Ph. Number:
Mailing Address:	Creek Name:

General Questions

- How big is your property?
  ______Hectares/acres
- How long have you owned/managed this property?
  ______Months/years
- Is this a family property (passed down through generations)?
  YES/NO
- If YES, for how long has it been in the family?
  ______Years
- Has the property always operated as a dairy farm?
  YES/NO
- If NO, what is the farm's history (if known)?

Stocking Rates and Paddock Sizes

- What is the annual total stocking rate on your property?
  ______Total or Cow/Ha
- Do your stocking rates vary by large numbers throughout the year (with seasons)?
  YES/NO
- If YES, by how many does it vary through the year (give a number or %)?
  ______No. or %
- Has your farm ever carried more stock than the annual stocking rate in the past?
  YES/NO
- If YES, what was the maximum number it ran in the past?
  ______Total or Cow/Ha

- Of the current amount, how many cows constitute:
    - Milking herd? ______
    - Heifers? ______
    - Dry cows? ______
    - Calves? ______
    - Beef herd? ______
- What approximate % maximum area of the farm do the milking herd occupy throughout the year?
  ______% area
- How many paddocks are there on your property?
  ______No. Paddocks
- What is the average size of your paddocks
  ______Avg.
- How many of your paddocks have rivers/creeks running through them
  ______No. Paddocks
- What rotational grazing practices do you employ for your milking herd?
  Day v.'s night ❑
  12 hour ❑
  24 hour ❑
  Other ❑ please specify

- Is the on/off grazing procedure on wet paddocks familiar to you?
  YES/NO
- If YES, how often do you employ this method of grazing?
  Regularly ❑
  As needed ❑

Streambanks and watering points

- Is there more than one river/creek running through your property (if so how many)?
  YES/NO
  ______No. Rivers/creeks
- Are the rivers/creeks on your property the main watering point for your stock
  YES/NO
- If NO, on average, how far are the watering points from the streambanks?
  ______Metres
- Does flooding ever affect the movement/rotation of stock by loss of paddock use?

  YES/NO
- If YES, how often does this *usually* occur and for what length of time (duration)?
  ______How often
  ______Length of time
- If flooding occurs, how far out of the creek channel do waters usually spread?
  ______Metres
- How far are your dairy sheds located from your closest river/creek frontage?

______Meters

- Do you graze your river/creek frontage paddocks continuously or on a rotational basis?
  Continuous/rotation
- Approximately how many metres/kilometres of your land have river/creek frontage?
  ______Metres/Kilometres
- Have any areas of your river/creek frontage been fenced to exclude livestock?
  YES/NO
- If YES, what was your primary reason for fencing off your river/creek frontage?
  - Prevent stock loss ❑
  - Improve condition/health of waterway/water quality ❑
  - Prevent stock accessing neighboring paddocks ❑
  - Prevent banks destabilizing ❑
  - Increase presence of flora and fauna species ❑
  - Better Stock Management ❑
  - Other (please specify) ❑

- Approximately how many metres/kilometres have been fenced?
  _____Metres/kilometres
- How long has this areas(s) been fenced off for?
  ______Months/Years
- Have you planted the fenced area with trees or understorey in any way?
  YES/NO
- What methods of weed management (if any) do you employ in these fenced waterway areas?
  - Mechanical (hand removal) ❑
  - Spot spraying ❑
  - Broad herbicide treatment ❑
  - Crash grazing ❑
  - No treatment ❑
  - Other ❑ please specify

- Do you allow stock into these fenced areas for any period of time?
  YES/NO
- What do you think is the ideal fencing width of waterways?
  ______Width

Effluent, Irrigation and Stock Loss

- Are any irrigation methods employed on your property?
  YES/NO

- If YES, on average how often is irrigation used?
  - Daily ❑
  - Weekly ❑
  - Monthly ❑
  - 2-3 time per year ❑
  - As needed ❑
  - Other ❑ please specify

- What is your primary method of irrigation?
  - Spray irrigation ❑
  - Flood irrigation ❑
  - Lateral sprinkler ❑
  - Other ❑ please specify

- Do you apply fertilisers to your river/creek frontage paddocks?
  YES/NO
- Do you use your dairy shed effluent on river/creek frontage paddocks for irrigation purposes?
  YES/NO
- What best describes your current dairy effluent system?
  - Single pond ❑
  - Two pond system ❑
  - Direct to pasture ❑
  - No system ❑
  - Other ❑ please specify
- Are you happy with your current dairy effluent system?
  YES/NO
- Would you like to change your current management of dairy shed effluent in the future?
  YES/NO
- If YES, what would you like to do in the future?

- How often are your dairy effluent systems usually drained and/or cleaned?
  - Daily ❑
  - Weekly ❑
  - 2-3 times per year ❑
  - Once yearly ❑
  - Less than annually ❑
- If you fenced off the stream banks on your farm would this reduce your time needed for stock surveillance and stock mustering?
  YES/NO

- If YES, how much time would you save in an average week on the farm?
  ______Hours/Mins
- What is the estimate of cow deaths on your farm each year in the following three water associated areas:
  - Creeks and rivers ❑
  - Dams and swamps ❑
  - Erosion gullies and tunnels ❑

Conservation and New Management Regimes

- What new land management practices has your farm adopted recently that has resulted in an improvement in the farm environment?
  - Fencing remnants ❑
  - Fencing rivers/creeks/drainage areas ❑
  - Tree planting ❑
  - Grazing techniques ❑
  - Fertiliser plans/soil tests ❑
  - Other (please specify) ❑

- What has been the effect of this new land management practice?

- Do you think these new land management practices were:
  - Cost positive ❑
  - Cost negative ❑
  - Cost neutral ❑
- Is there a Landcare group in your local area?
  YES/NO
- If YES, are you a member of the Landcare group in you area and which one is this?
  YES/NO
  Group? ___________________

Appendix 3. Field data sheet for rapid assessments of riparian condition on dairy farms in west and south Gippsland.

PROPERTY ID ☐ SITE ID ☐

Riparian Habitat Condition Score Sheet

Site:
Phone: Date:
Creek name: Observer:
Cowpat count: Northing:
Bed Composition: Easting:
Slope range:
Comments:

Longitudinal continuity of riparian overstorey vegetation (≥ 5m canopy width) Score

0 = <30% vegetated bank, **1** = 30-49%, **2** = 50-69%, **3** = 70-94%, **4** = >95% (mark exotic sections)

Width of riparian vegetation

Measurement	Channel Width (m)	Vegetation Width (m)
1		
2		
3		
4		

Vegetation cover: UpperCanopy >20m, SubCanopy>5m, Understorey 1-5m, Ground cover (GC) <1m

Transect	Upper Canopy	% Native	Sub Canopy	% Native	Understorey	% Native	GC	% Native	# Layers
1									
2									
3									
4									

Cover: **0** = absent, **1**= 1-25%, **2** = 26-50%, **3** = 51-75%, **4** = >75%
% Native: **0** = none, **1** = 1-25%, **2** =26-50 %, **3** = 51-75%, **4** = >75%

Debris

Transect	Leaf litter	% Native	Snags	Coarse Woody Debris	% Native
1					
2					
3					
4					

Leaf litter: **0** = none, **1** = 1-30%, **2** = 31-60%, **3** = >60%
% Native: **0** = none, **1** = 1-25%, **2** =26-50 %, **3** = 51-75%, **4** = >75%
Standing dead trees: **0** = absent, **1** = present
CWD (≥10cm diameter): **0** = none, **1** = small quantity, **2** = medium quantity (removal), **3** = abundant

Special Features

Transect	Canopy spp. regeneration	Grazing damage to regeneration	Reeds	Tree Ferns	Weed Species
1					
2					
3					
4					

Seedlings <1m tall: **0** = none, **1** = scattered, **2** = abundant
Damage: **0** = all damaged**,** **1** = some damaged, **2** = no damage
Reeds: **0** = absent, **1** = present
Ferns: **0** = absent, **1** = present
Weed Spp: **0** > 6 spp., **1** = 4-6 spp., **2** = 1-3 spp., **3** = no weed spp.

Bird Species List (score for ecological diversity)

Appendix 4. Subindices (and their weighting in the final score) and indicators of the index of riparian condition, the range within which each was scored, the method of scoring for each indicator, and the number of measurements per site for each indicator (*n*)

Sub-index	Indicator	Range	Method of scoring	*n*
HABITAT (10/50)	Width of riparian vegetation	0-4	Width standardised by channel width (CW): 0 = < 0.25 * CW, 1 = 0.25-0.49 * CW, 2 = 0.5-1.49 * CW, 3 = 1.5-2.9 * CW, 4 = ≥ 3 * CW	4
	Longitudinal continuity of riparian vegetation	0-4	0 = < 30% vegetated bank, 1 = 30-49% vegetated bank, 2 = 50-69% vegetated bank, 3 = 70-94% vegetated bank, 4 = ≥ 95% vegetated bank, with one point taken off for each significant discontinuity	1
COVER (10/50)	Canopy cover	0-4	0 = absent, 1 = 1-25%, 2 = 26-50%, 3 = 51-75%, 4 = >75% cover	4
	Sub canopy cover	0-4	0 = absent, 1 = 1-25%, 2 = 26-50%, 3 = 51-75%, 4 = >75% cover	
	Understorey cover	0-4	0 = absent, 1 = 1-25%, 2 = 26-50%, 3 = 51-75%, 4 = >75% cover	4
	Ground cover	0-4	0 = absent, 1 = 1-25%, 2 = 26-50%, 3 = 51-75%, 4 = >75% cover	4
	Number of layers	0-4	0 = no vegetation layers to 4 = ground cover, understorey, sub canopy and upper canopy layers	4
DEBRIS (10/50)	Leaf litter	0-3	0 = none, 1 = 1-30%, 2 = 31-60%, 3 = >60% ground cover	4
	Standing dead trees	0-1	0 = absent, 1 = present	4
	Terrestrial coarse woody debris	0-3	0 = none, 1 = small quantities, 2 = abundant but some removed, 3 = abundant with no signs of removal	4
NATIVES (10/50)	Canopy	0-4	0 = none, 1 = 1-25%, 2 = 26-50%, 3 = 51-75%, 4 = >75% cover	4
	Sub canopy	0-4	0 = none, 1 = 1-25%, 2 = 26-50%, 3 = 51-75%, 4 = >75% cover	
	Understorey	0-4	0 = none, 1 = 1-25%, 2 = 26-50%, 3 = 51-75%, 4 = >75% cover	4
	Ground cover	0-4	0 = none, 1 = 1-25%, 2 = 26-50%, 3 = 51-75%, 4 = >75% cover	4
SPECIES (10/50)	Canopy species regeneration	0-2	0 = none, 1 = scattered, and 2 = abundant seedlings	4
	Damage to regeneration	0-2	0 = all damaged, 1 = some damaged, 2 = no damage	4
	Reeds	0-1	0 = absent, 1 = present	4
	Tree ferns	0-1	0 = absent, 1 = present	4
	Noxious weed species	0-3	0 = >6 species, 1 = 4-6 species, 2 = 1-3 species, 3 = no weed species	4

Appendix 5. Relationships between condition index scores and in-stream metabolism.

Measurements of river metabolism are fundamental to the understanding of how ecosystems function (Bott *et al*. 1978; Bunn & Davies 2001). Metabolism is essentially the movement of carbon; a basic building block of ecosystems and the element most modified by human activities within agricultural catchments. Carbon movement is described by gross primary production (GPP) and respiration (R) which represent the amount of organic carbon produced and consumed within an ecosystem respectively (Davies 1999).

In the Gippsland study, field-based measurements of benthic metabolism were determined by measuring the net change in dissolved oxygen within clear dome-shaped perspex chambers (diameter = 29.5cm, height = 35cm) over a 24 hour period. For measurements from these habitats, chambers were pushed into the sediment enclosing a water volume of five litres. A consistent insertion depth was achieved by making sure a rim on the outside of the chamber was flush with the sediment surface (Figure A6).

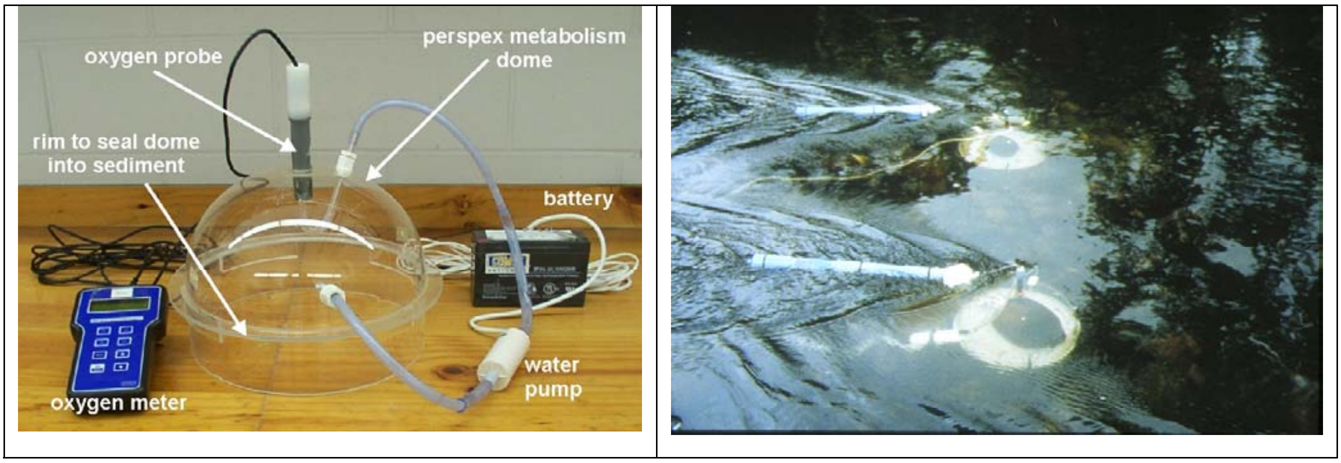

Figure A5. Components of the metabolism chambers (left) and their use *in situ.*

An oxygen sensor (YSI 5739, USA) and attached data-logger (TPS 601) was attached in the top of all chambers and a 12V pump recirculated water within the chamber to reduce boundary layer effects at the sediment water interface and ensure flow saturation across the membrane of the oxygen probe. An adjustable valve ensured flow did not unduly disturb the sediment in the chamber. All oxygen probes were calibrated in the laboratory prior to the field trip and checked in the field immediately prior to and after the 24h deployment when the probes were collected. Changes in dissolved oxygen concentrations over time (mg O_2 $l^{-1}hr^{-1}$) were converted to units of carbon assuming that 1 mole of C is fixed for every mole of O_2 produced (*i.e.* 1 mg O_2 = 0.375 mg C, Davies 1999).

Metabolic parameters

Different aspects of benthic metabolism were calculated by comparing the rate of O_2 change in the chambers at different times of the day. These are the daily respiration (R_{24}; taking the night time respiration rate and assuming this rate is constant over 24h), gross primary productivity (GPP; the daily O_2 production plus the O_2 consumed by respiration during the day, calculated using the night time respiration rate), net daily metabolism (NDM; equal to GPP - R_{24}) and the P/R ratio (GPP divided by R_{24}). If a system has NDM (*i.e.* P/R > 1), it is a net producer of organic carbon *i.e.* accruing biomass and termed "autotrophic". If P/R = 1 the system is in steady state (NDM = 0) and, if NDM (*i.e.* P/R < 1) the system is a net consumer of organic carbon or "heterotrophic". The photoperiod was determined as the part of the day when GPP exceeded net respiration.

Results

All the sites studied were net consumers of carbon (*e.g.* negative NDM) except one site that had slightly positive rates (85mgC.m^{-2}.day^{-1}). The dominance of heterotrophy (negative NDM) is typical of upland streams across of arrange of Australian biomes (Bunn & Davies 2000). Overall, rates of all metabolic processes measured in the study sites were elevated compared to forested systems elsewhere in Australia (Bunn *et al*. 1999); this undoubtedly reflects the nutrient-enriched status of the streams in Gippsland.

Gross Primary Production

Mean rates of GPP (in mgC.m^{-2}day^{-1}) ranged from 12-26 through to 1083-2105. This represents a considerable gradient of metabolism values and indicates fundamental changes in ecosystem processes across the study sites. Rates of GPP were positively correlated to measurements of the natives sub index ($r=0.65$, $p<0.001$). In small streams, GPP is typically regulated by below canopy light (Bunn *et al*. 1998; Mosisch *et al.* 2001).

Respiration

Rates of respiration (R_{24}) were elevated at most sites; reflecting the dominance of heterotrophy. Rates ranged from 487 mgC.m^{-2}day^{-1} to 3880 mgC.m^{-2}day^{-1}. Again, this is a range of values across an order of magnitude, which represents a gradient of ecosystem conditions.

Net Daily Metabolism

Net daily metabolism (NDM) is the absolute rate of metabolism. NDM values were all negative indicating sites as net consumers of carbon. Values ranged from positive values to substantial negative values (-2309 mgC.m^{-2}day^{-1}). NDM was correlated to respiration; indicating respiration dominated overall NDM.

Temperature range

Daily ranges in temperature were highly variable amongst sites. Lowest diel difference was 1.3 ^{o}C. Highest diel differences in temperature were recorded at two sites 8.3 ^{o}C and 5.1 ^{o}C respectively. Elevated temperatures can directly impact on the temperature-tolerance of aquatic species and through reduction of dissolved oxygen (DO) able to held in solution (as % saturation).

Conclusions

Overall rates of metabolism were relatively elevated undoubtedly reflecting the ambient conditions of elevated nutrient status. The strong relationship between the dominant metabolic process (respiration) indicates the rapid assessment technique is related to river health. In contrast to the rapid assessment approach, the measurement of metabolism can be technically-difficult.

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Appendix 6. Relationships between grazing, riparian condition and bird communities.

Bird communities differed significantly between ungrazed (fenced and planted, fenced but unplanted and remnant sites) and grazed sites (DISTLM: pseudo-$F_{1,104}$=3.25, p<0.001). This difference was accounted for by the strong relationship between riparian condition and associated bird communities (DISTLM: pseudo-$F_{1,104}$=8.33, p<0.001). Figure A8 shows the 106 sites at which bird communities were recorded – the relative locations of sites on the figure reflects the similarities in the bird communities of each site (thus sites with similar bird communities are close together while those with very different bird communities are far apart). Superimposed on the sites' locations are the condition score categories recorded at those sites. It is clear that there was a strong trend of changing bird communities as condition scores varied.

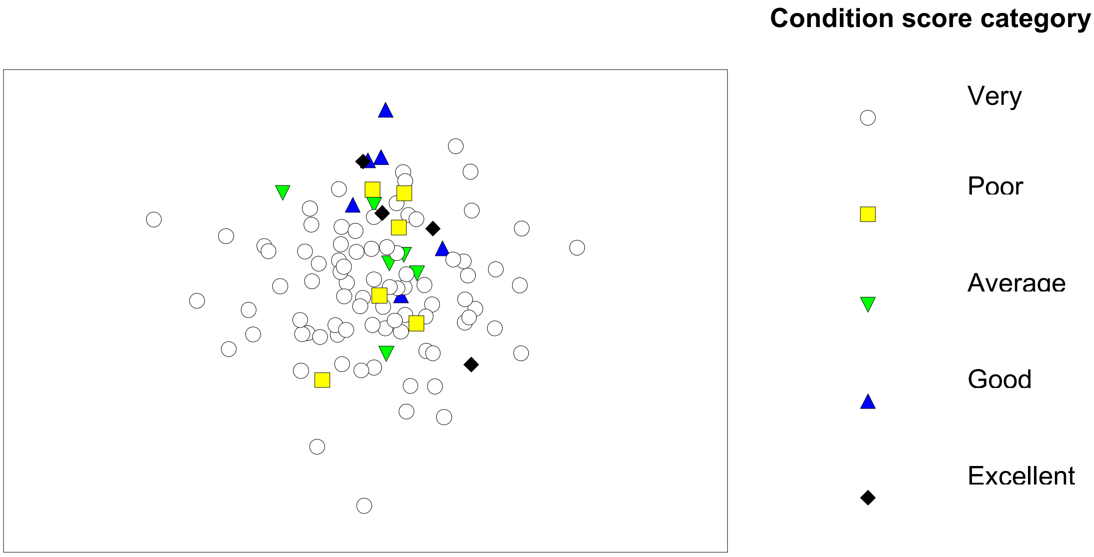


Figure A6. Non-metric multi-dimensional scaling plot of 106 riparian sites according to their bird communities (Stress=0.28).

Bird communities varied significantly with all sub-indices of the riparian condition index, but most strongly with the proportion of native species and the amount of woody debris and leaf litter, and quite strongly with the amount of habitat and the amount of vegetation cover. Thus the most significant aspects of riparian habitat condition for healthy bird communities include dominance by native species of plants, and good quantities of fallen timber and leaf litter on the ground.

Particular species of birds were characteristic of sites with different riparian condition scores. Those characteristic of sites in good to excellent condition, and those characteristic of sites in poor to very poor condition, are shown in Table A8.

Table A6. Bird species characteristic of riparian sites in good to excellent condition, and those characteristic of sites in poor to very poor condition (these 20 species contribute 60% of the dissimilarity between the two sets of sites, using a Similarity Percentages Analysis).

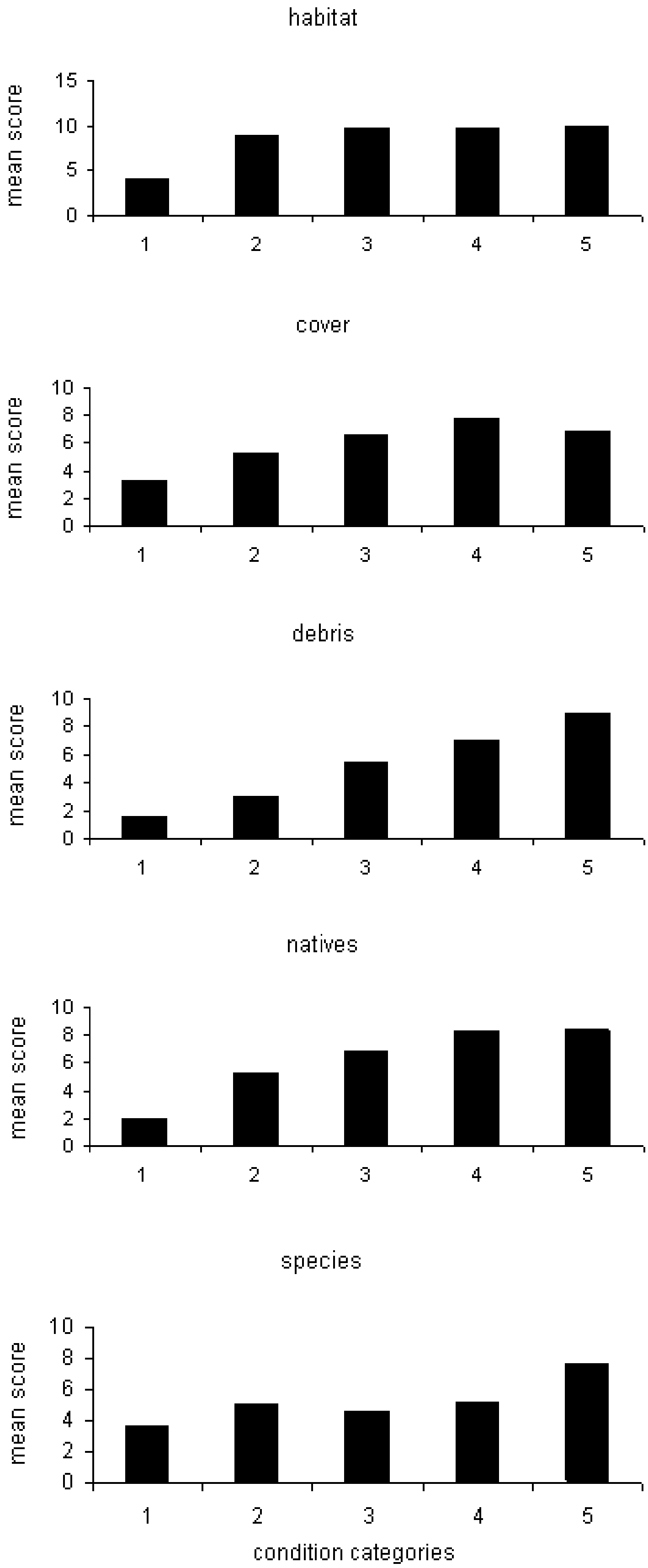
Poor and very poor condition	Good and excellent condition
Australian Magpie	Crimson Rosella
Australian Raven	Red-browed Treecreeper
Welcome Swallow	White-browed Scrubwren
Common Starling	Brown Thornbill
	Common Blackbird
	Red-browed Finch
	Grey Shrike-thrush
	Laughing Kookaburra
	Eastern Yellow Robin
	Rufous Whistler
	White-plumed Honeyeater
	Striated Thornbill
	Grey Fantail
	Bell Miner
	Red Wattlebird
	Lewin's Honeyeater

It can be seen that the majority of birds characteristic of riparian sites in good condition were small, forest-dwelling species while those characteristic of sites in poor condition were typical open paddock species. Of the species characteristic of riparian sites in good condition, the Crimson Rosella, White-browed Scrubwren and Grey Fantail were relatively abundant, making them good candidates as indicators of the health of riparian zones, and potentially as indicators of the success of restoration efforts in riparian zones in the Gippsland region.

Appendix 7. Dry Sheep Equivalents (DSE) conversion rates used for the Gippsland Dairy Riparian Project (after McLaren 1997).

STOCK	DSE		
	JERSEY	FRESIAN/ HOLSTEIN	SHEEP
Weaned calves	6	7	
Heifers	8	9	
Dry cows (maintaining weight)	6	8	
Dry cows (last 3 months pregnancy)	8	11	
Milking cows – 15L/day	18	19	
20L/day	23	23	
Cow and calf unit	15	17	
Bulls	8	11	
Rams			2
Wethers			1
Ewes			1.5
Weaner lambs			1.5

Appendix 8. (a) Mean scores for condition sub-indices against overall condition categories. See below for statistical analysis of data.



Appendix 8. (b) Stepwise regression of sub-indices on total condition index scores

Model	Adjusted R square	SE of the estimate	Predictors
1	0.896	3.091	NATIVES
2	0.934	2.457	NATIVES, HABITAT
3	0.970	1.686	NATIVES, HABITAT, DEBRIS
4	0.994	0.770	NATIVES, HABITAT, DEBRIS, SPECIES
5	1	0	NATIVES, HABITAT, DEBRIS, SPECIES, COVER