Ecological benefits of riparian restoration—with particular application to Victoria

Summary

- Riparian zones represent the interface between aquatic and terrestrial ecosystems.
- They are often areas of exceptionally high productivity and diversity, and fulfil many key ecological roles integral to the functioning of both aquatic and terrestrial ecosystems, including:
    - Moderating stream temperature
    - Mediating the input of sediment and nutrients into streams—a major determinant of water quality
    - Providing habitat and food sources for aquatic organisms
    - Contributing to terrestrial food webs
    - Providing habitat for obligate and opportunistic riparian biota
    - Acting as dispersal corridors and refuges for terrestrial plants and animals—a role that is amplified in fragmented landscapes, during times of drought, and under forecasted climate change scenarios
- Riparian zones have been extensively degraded in Victoria:
    - Riparian vegetation has been denuded along more than half of the length of Victoria's rivers and only 14% remains in excellent condition (Norris *et al.* 2001; DSE 2005)
    - Many ecological functions have been compromised or, in some cases, lost
- Case-studies from past riparian restoration projects in Victoria and overseas demonstrate that efforts to restore riparian zones—primarily stock exclusion and revegetation—may provide many ecological benefits, including improved:
    - Water quality
    - Aquatic biodiversity
    - Terrestrial biodiversity
    - Resistance and resilience of plant and animal populations
    - Conservation of threatened species
- Evidence suggests that to achieve these benefits, efforts to restore riparian zones must occur at appropriately large spatial scales and other drivers of degradation (e.g. surrounding land-use and insufficient or altered flow) must be addressed.
- Past studies and scientific literature provide guidelines for the effective design and implementation of restoration efforts:
    - Targets should be set to inform on-ground works
    - Multiple drivers of degradation and potential constraints to recovery should be identified, prioritised and addressed
    - An adaptive monitoring regime should be employed to inform and improve restoration efficiency and effectiveness over time

Riparian zones are ecologically important environments of exceptionally high biodiversity

Riparian zones are the interface between terrestrial and aquatic ecosystems (Gregory *et al.* 1991; Naiman and Décamps 1997). They encompass parts of the landscape that exert direct influence on, or receive direct influence from, stream channels. By definition, streams, riparian zones and the surrounding landscape are functionally interconnected (Gregory *et al*. 1991; Naiman and Décamps 1997).

Riparian zones influence physical and ecological attributes of streams. Characteristics of riparian vegetation affect bank stability, erosion, channel morphology, stream flow, water temperature, and inputs of sediment, nutrients and organic litter, which underpin water quality and aquatic food webs. Riparian zones also influence the surrounding landscape. Aquatic and riparian communities provide food sources for terrestrial communities (Ballinger and Lake, 2006). For example, Tetrigidae grasshoppers and water birds may graze on algal mats, and emerged aquatic insects provide an important food source for populations of birds, bats, ants and spiders (reviewed in Ballinger and Lake 2006). In otherwise highly fragmented landscapes and during drought, riparian zones provide crucial refuge and dispersal habitat.

Riparian zones are important ecosystems in their own right. As often the most nutrient-rich and dynamic part of a landscape, riparian zones are often areas of high productivity and provide unique habitats for riparian specialist and opportunist plant and animal species. Consequently, while riparian zones may only represent a small proportion of the landscape, they often have disproportionately high biodiversity values and support distinct communities (Sabo *et al.* 2005). For example, several ecological vegetation classes in Victoria occur solely in riparian areas (DSE 2009). Several species of birds, other animals and plants specialise on riparian zones; for example, in Victoria, platypus (*Ornithorhynchus anatinus*), water rat (*Hydromys chrysogaster*) and large-footed myotis (*Myotis adversus*) are mammals that are obligate riparian species (Menkhorst, 1995). Other species rely on riparian zones for parts of their lives or for certain activities; for example, some aquatic insects inhabit riparian zones during their adult phase (e.g. Psephenidae beetles), while others depend on these areas for breeding (e.g. Leptoceridae caddisflies) (Towns 1983).

The capacity to perform these diverse ecological roles within the landscape depends on attributes of the riparian zone. For example, the composition (Read *et al.* 2008), cover, connectivity (Weller *et al.* 1998) and width (Hansen *et al*. 2010) of riparian vegetation influences the capacity of the riparian zone to filter and process incoming nutrients and sediments, and therefore influences the quality of water entering the stream. Composition, cover, connectivity and width of riparian vegetation will also shape aquatic and terrestrial communities by determining the quality and quantity of habitat and food sources (Reid *et al.* 2008a,b; Hansen *et al.* 2010). The interconnectivity of riparian zones, waterways and the surrounding landscape means that the consequences of degrading riparian zones may propagate throughout the landscape.

Most riparian zones in Victoria are degraded

Riparian zones in Australia have been subjected to widespread and severe degradation. Nearly 80% of the total length of Victoria's rivers is in moderate to very poor condition with only 14% of the riparian zone remaining in excellent condition (DSE 2005). Approximately half (53%) of the river length measured by the Assessment of River Condition had substantially or severely modified riparian vegetation, to the extent that very little riparian vegetation is left (Norris *et al*. 2001). Major drivers of degradation include: land clearance; alterations to hydrology, encompassing water extractions, altered stream flow and salinity; stock access; and invasion of exotic plant and animal species (Lovett and Price 1999; Norris *et al.* 2001). As a result, the ecological functioning of Victoria's riparian zones is degraded: increased sediment and nutrients are being delivered into waterways, water quality has declined, and terrestrial and aquatic biodiversity has been lost particularly on local and regional scales (Norris *et al.* 2001; Hansen *et al.* 2010). With continuing stock access, the condition of Victoria's riparian zones, and the streams to which they are integrally linked, will remain poor or decline further.

Riparian restoration can help restore ecological function and biodiversity
Fortunately, the continual decline of Victoria's riparian zones is not a *fait accompli*. Efforts to restore riparian vegetation have been shown to halt decline and restore some of the ecological functions of riparian zones.

Riparian restoration = excluding stock and planting
In Victoria, efforts to restore riparian zones typically involve fencing to exclude stock from a buffer of riparian land around the stream followed by reintroducing native plant species by planting tubestock of trees and shrubs (Brooks and Lake 2007). Often restoration efforts will involve some initial weed control, such as the mechanical removal of woody weeds (e.g. willows, *Salix* spp.) or spraying grassy and broadleaved weeds.

Riparian restoration can improve water quality
Riparian vegetation is critical in maintaining water quality by reducing erosion and intercepting and processing nutrients before they enter the stream. High loads of sediment and nutrients may lead to turbid water, toxic algal blooms, and depauperate aquatic communities. Restoration of riparian vegetation may help to maintain water quality through three main pathways.

First, riparian vegetation prevents erosion by stabilising soil and stream banks. Riparian vegetation provides ground cover that limits rainfall and wind erosion, decreases the velocity of overland flow and maintains the stability of stream banks (Gregory *et al.* 1991; Abernethy and Rutherfurd 1999; Prosser *et al.* 2001; Parkyn *et al.* 2003). For example, a study conducted on nine streams in northern New Zealand found that sites with restored or remnant riparian vegetation had more stable banks with less erosion than unfenced and grazed sites on the same streams (Parkyn *et al.* 2003).

Second, riparian vegetation may act as a buffer to filter and retain incoming sediments and nutrients. Through reducing soil erosion, riparian vegetation is critical in reducing the input of sediment and sediment-bound nutrients into streams. Restoration efforts can improve the capacity of riparian zones to reduce sediment and nutrient input into streams via filtering. For example, six years after fencing to exclude livestock and planting eucalypts in a sub-catchment in Western Australia, suspended sediment concentrations decreased by an order of magnitude (McKergow *et al.* 2003).

Third, riparian vegetation plays an important role in processing nutrients and reducing their input into streams (Peterson *et al.* 2001; Fisher *et al.* 2004; Montreuil *et al.* 2010). The capacity for riparian zones to retain and process nutrients depends on the concentration of inputs as well as the width, cover and composition of riparian vegetation, soil type, slope, and hydrology (Lowrance *et al.* 1997; McDowell *et al.* 2004; Ocampo *et al.* 2006; Montreuil *et al.* 2010). Plants and animals can only use nutrients such as nitrogen and phosphorus if they are in certain forms. One major pathway for the conversion of nutrients into bioavailable forms is microbial transformation, which depends largely on the condition of soils—in particular their carbon content (reviewed in Jackson *et al.* 2008). Riparian restoration creates well-vegetated riparian zones that have more carbon inputs and a greater capacity for processing nutrients than degraded riparian zones (Burger *et al.* 2010; Box 1). Likewise, restoration can increase carbon availability to streams, which improves in-stream nutrient processing and has been shown to decrease nitrate and ammonium levels in streams (Craig *et al.* 2008).

There are two important caveats on the relationship between riparian vegetation and water quality. First, responses depend on the continuity of riparian vegetation: studies have shown that even small gaps in riparian vegetation along a stream can compromise function (e.g. Weller *et al.* 1998). Second, responses depend on surrounding land-use: large amounts of nutrients applied onto land adjacent to riparian zones may exceed the amount that can be intercepted or transformed by riparian plants and soils (e.g. Burger *et al.* 2010; Montreuil *et al.* 2010).

Riparian restoration can improve in-stream biodiversity
Riparian vegetation is critical to aquatic communities, influencing attributes of water and habitat. Restoration of riparian vegetation may influence aquatic communities in three main ways.

First, as discussed above, riparian vegetation can reduce nutrient and sediment loads in streams. Sediment and nutrient loads in-stream have substantial influences on aquatic communities. By buffering inputs of sediment, nutrients and salt into streams, riparian vegetation may have positive effects on the condition of in-stream communities including macroinvertebrates, aquatic plants and fish (Kauffman and Krueger 1984; Quinn et al. 1993; Growns *et al.* 1998).

Second, riparian vegetation shades the stream, which moderates water temperature. Removal of vegetation causes increased light and temperature (Quinn *et al.* 1993; Rutherford *et al.* 2004). Aquatic organisms may be especially sensitive to elevated water temperatures and associated reductions in the availability of dissolved oxygen. For example, temperatures above 22˚ C are lethal for mayfly larvae (Davies *et al.* 2004). Elevated temperatures may reduce the growth and reproduction of some fish species, and reduce their capacity to tolerate other toxicants (Pusey and Arthington 2003). Increased light may also promote algal growth: light, elevated nutrients and an inoculum are the three major ingredients for algal blooms. Restoration of canopy cover may be effective in decreasing stream temperature: as a general guide, 10% increase in riparian cover causes approximately 1º C decrease in water temperature (Davies 2010).

Third, riparian vegetation contributes litter, coarse woody debris and other organic matter into streams. These inputs provide important habitat and food sources for aquatic communities (Cadwallader *et al*. 1980; Pusey and Arthington 2003; Mac Nally *et al.* 2002; Reid *et al.* 2008a,b). Carbon inputs in the form of vegetative litter are a basal resource for stream food webs, influence in-stream nutrient cycling and retention, and determine bioavailability of nitrogen and phosphorus. For example, inputs of leaf litter from river red gums (*Eucalyptus camaldulensis*) contribute food and habitat that structures aquatic food webs in lowland streams in Victoria (Reid *et al.* 2008b). Canopy cover of 50% or more is required to provide a reliable supply of leaf litter to support the aquatic food web (Reid *et al.* 2008a) and to provide sufficient shading to moderate water temperature in these lowland streams (Davies and Bunn

1999). Coarse woody debris is important in the provision of in-stream habitat and maintenance of microhabitat complexity (Harmon *et al.* 1986). For example, in forest streams in East Gippsland, coarse woody debris creates debris dams and pool habitats that are especially important for fish species (Webb and Erskine 2001). Furthermore, coarse woody debris creates refuges for aquatic biota during flooding (Mac Nally *et al.* 2002).

One of the few longer-term studies of aquatic responses to riparian restoration (Becker and Robson 2009) shows that the benefits of riparian restoration to macroinvertebrate communities may be slow or equivocal. Macroinvertebrate communities in the Otway Ranges in Victoria showed little recovery from degradation eight years after restoration activities (Becker and Robson 2009). Response rates are likely to be contingent on width, connectivity and character of riparian vegetation, as well as landscape context. The condition of aquatic communities will influence their capacity to provide food sources for riparian and terrestrial communities, such as birds, bats, spiders and ants (Ballinger and Lake 2006).

Riparian restoration can improve terrestrial biodiversity

Riparian zones are important areas for terrestrial biodiversity in three main ways, each of which may be enhanced by restoration.

First, riparian zones may be composed of distinctive plant communities not found elsewhere (e.g. DSE 2009). For example, Victoria's cool temperate rainforest communities of myrtle beech (*Nothofagus cunninghamii*) and southern sassafras (*Atherospermum moschatum*) may persist primarily as gallery forests within riparian zones, contingent on appropriate disturbance regimes (Simkin and Baker 2008). As a consequence, riparian zones can contribute to regional and catchment scale biodiversity (Sabo *et al.* 2005). However, degradation by livestock has been shown to compromise riparian plant communities (Robertson and Rowling 2000). Riparian zones that are grazed have less regeneration of trees, fewer shrubs and less biomass of groundcover species compared with ungrazed sites (Kauffman and Krueger 1984; Fleischner 1994; Robertson and Rowling 2000; Box 2). Restoration can improve the condition of riparian vegetation. For example, where sources of seed or vegetative propagules are present, the exclusion of stock from riparian zones may facilitate the regeneration of trees, shrubs and ground layer vegetation, leading to increased shading and litter inputs into streams (Kauffman and Krueger 1984; Fleischner 1994; Robertson and Rowling 2000; Box 2).

Second, riparian zones are mesic (moderately wet) and highly productive parts of the landscape. These conditions mean that trees tend to be larger, flowering may be more regular and the growth of plants and invertebrates may be more reliable in riparian systems (Bennett *et al.* 1994; Catterall *et al.* 2007). As a consequence, riparian areas may provide some of the most favourable environments within a landscape for the restoration of terrestrial biodiversity (Thomson *et al.* 2009). For example, bird assemblages were more species rich in riparian restoration sites than in comparable non-riparian restoration sites (Munro *et al.* 2010).

Third, riparian zones provide refuge, foraging and breeding habitat for species that specialise on riparian zones or use riparian zones opportunistically. For example, riparian sites support significantly greater abundance and species richness of birds than non-riparian sites (Palmer and Bennett 2006) and several studies have shown that riparian zones contribute to landscape-scale bird diversity (Mac Nally *et al.* 2000; Palmer and Bennett 2006; Johnson *et al.* 2007; Munro *et al.* 2010). The importance of riparian zones for bird communities is further amplified in degraded environments (Jansen and Robertson 2001; Palmer and Bennett 2006;

Johnson *et al.* 2007). For example, riparian zones provide especially important habitat for bird populations in highly modified, agricultural landscapes in central Victoria (Johnson *et al.* 2007). However, degradation by livestock compromises the capacity for riparian zones to provide habitat for a wide range of animals including amphibians (Healey *et al.* 1997), freshwater crayfish (March and Robson 2006) and birds (Jansen and Robertson 2001). Some terrestrial habitat may be restored rapidly with restoration efforts, particularly in rainforest-dominated systems. For example, efforts to restore rainforest riparian zones provided habitat for bird species within three years of planting on the Atherton Tablelands in Queensland (Jansen 2005) and in East Gippsland in Victoria (Box 3).

Riparian restoration can increase community resistance and resilience
Riparian zones may provide corridors for dispersal and habitat for the persistence of wildlife and plant species. In Victoria, remnant patches of intact vegetation often exist as isolated fragments in landscapes that have otherwise been highly altered by agriculture or urbanisation. As a consequence, the role of riparian zones as habitat and as corridors for dispersal is increasingly important. Riparian zones may also provide refuge for species during drought. By acting as biolinks through the landscape, restored riparian zones may increase the capacity of populations to persist through unfavourable periods and in otherwise unfavourable landscapes. Restoration can enhance or facilitate the capacity of riparian zones to act as refuges and dispersal corridors by augmenting habitat and improving connectivity among remnant riparian zones and intact fragments of vegetation.

Improving habitat and landscape connectivity is especially pertinent given projected climate change, whereby the capacity for species to adapt and persist depends on the sustenance of sufficient population size, connectivity among populations and the capacity to migrate (Seavy *et al.* 2009). In instances where species cannot migrate due to immutable geographical barriers (e.g., ocean, desert or urbanisation), restoration of riparian zones might also be used to improve the resilience of populations to climate change. For example, restoring or augmenting canopy cover may help mitigate the effects of increased stream temperatures and allow freshwater species to persist (Davies 2010).

Riparian restoration can help to conserve some threatened species
Restoration of riparian vegetation may provide important habitat for some threatened species and reduce the risk to others by providing improved habitat and habitat connectivity. Riparian land has particular significance to many rare and threatened species in Victoria. Many species and communities listed under the Flora and Fauna Guarantee Act 1988 depend in part on riparian zones (DSE 2010). Of these species, several are directly threatened by degradation of riparian habitats including Bibron's toadlet (*Pseudophryne bibronii*), the growling grass frog (*Litoria raniformis*) and swamp skink (*Egernia coventryi*) (Ecology Australia 2009). In addition, riparian restoration may play a pivotal role in ameliorating several threatening processes that are listed under the Flora and Fauna Guarantee Act 1988, including: alteration to the natural temperature regimes of rivers and streams; alteration to the natural flow regimes of rivers and streams; degradation of native riparian vegetation along Victorian rivers and streams; and removal of wood debris from Victorian streams (DSE 2010).

Ecological benefits depend on riparian attributes and catchment context, but 'some is better than none'
The ecological benefits that are achieved by riparian restoration depend on (1) catchment context, (2) large-scale factors that may override restoration efforts, (3) time, and (4) attributes of the restored vegetation.

Catchment context, in particular the land-uses upstream and adjacent to the waterway, will influence the effectiveness of riparian restoration. Despite efforts to restore riparian zones, adjacent land-uses may continue to damage ecosystems or limit their recovery (Kauffman *et al.* 1997). For example, agricultural activities may persist and continue to contribute pollutants, excess nutrients and sediments into the stream, or alter local hydrology through impoundments.

In addition to catchment context, large-scale factors that might override the ecological benefits of restoration efforts include hydrology (Stromberg *et al*. 2007a,b), drought (Bond and Lake 2005; Box 4) and fire (Simkin and Baker 2008). Studies from overseas and Australia have shown that the effectiveness of restoration efforts depends on identifying and addressing the drivers of degradation rather than simply the symptom. For example, flow regimes drive the relative recruitment success of native trees and exotic trees along streams in western North America (Stromberg *et al.* 2007a). Efforts to increase native tree populations by removing exotics and planting natives have been ineffective, whilst efforts that address the large-scale constraint by reinstating flow-regimes have been effective (Stromberg *et al.* 2007b). Many studies have shown the fundamental influence of flow regimes on riparian vegetation dynamics in Australia and show changes to the structure, composition and function occur when flow regimes are altered (e.g., Bren 1988; Bren 1992; Kingsford 2000; Capon 2005; Horner *et al.* 2009).

To effectively restore riparian zones, the multiple drivers of degradation need to be addressed in unison. Even then, removing the drivers of degradation may not always be sufficient to assure full recovery of a system. The challenge is to identify the relative importance of the different drivers of degradation and to prioritise the order of interventions (Stewart-Koster *et al.* 2010). For example, in riparian forest on the Barmah-Millewa floodplain, Lunt *et al.* (2007) found little effect of long-term grazing exclusion on the condition of herbaceous plant communities. This lack of response may be attributable to the overriding effects of past land-use intensity, low site productivity and drought, and indicates that, on its own, removing grazing may be insufficient to ensure full ecosystem recovery. In addition to stock exclusion, highly degraded environments may require substantial interventions for successful recovery. For example, locally extirpated biota may be unable to recolonise sites and may require active reintroduction—this appears to be the case for restoring riparian vegetation along degraded streams in central Victoria, where the soil seed bank possesses only a limited suite of native species and shows little potential to aid self-recovery (Williams *et al.* 2008).

Some benefits of riparian restoration may occur quickly, while others may take considerable time. For example, bare ground can show rapid decline with stock exclusion (Robertson and Rowling 2000; Box 4). In contrast, there may be significant time lags between restoration efforts and the development of habitat that is required for some biodiversity benefits; for example, between planting trees and their maturation to produce hollows (Vesk *et al.* 2008; Mac Nally 2008; but cf. Box 3).

Ecological benefits of riparian restoration are contingent upon the width and connectivity of riparian vegetation (Weller *et al.* 1998; Hansen *et al.* 2010). The interconnectivity between riparian zones and the surrounding landscape means that the restoration of narrow riparian buffers may not bring the full ecological benefits of an intact riparian zone in an intact landscape. In catchments with major and ongoing degradation from farming or urbanization, it may be necessary to have riparian buffers that are wider than natural riparian zones in order to protect streams from catchment pressures. Nevertheless, the available evidence suggests that the restoration of some riparian land will achieve some benefits (Hansen *et al.* 2010).

Not all Victorian riparian zones are the same. Riparian zones and their waterways may differ in size, altitude, soil, climate, adjacent land-use and catchment inputs, condition prior to restoration, and more. These differences will influence the response of sites to restoration efforts and the ecological benefits that are achieved. Furthermore, these differences suggest that the nature of restoration efforts will need to vary (Stewart-Koster *et al.* 2010). However, virtually all efforts to restore riparian zones will require initial exclusion of livestock on both banks (Hansen *et al.* 2010). In addition, both local case studies and global literature show that efforts to restore riparian zones will confer some ecological benefits.

Conclusions and future recommendations

- Riparian zones fulfil important ecological roles for both aquatic and terrestrial ecosystems, but they have been extensively degraded in Victoria.
- Past research from Australia and overseas shows the considerable potential for riparian restoration to mitigate damage to riparian ecosystems and to the streams and terrestrial landscapes with which they are integrally linked.
- Overwhelming evidence shows that stock access in waterways leads to progressive and continued damage, whilst excluding stock halts decline and some passive recovery is possible.
- Active restoration shows further potential in re-establishing the structure and composition of plant communities and capacity to recover broader ecological functions of riparian zones.
- Riparian zones are among the most effective and efficient parts of the landscape to target for restoration and riparian restoration can help improve water quality, aquatic biodiversity, terrestrial biodiversity and the resistance and resilience of populations to stressors including climate change.
- The capacity for restoration efforts to reinstate the ecological benefits of intact riparian zones depends on identifying and addressing the multiple drivers of degradation and potential constraints to recovery (e.g., altered flow, site context and disturbance history).
- Targets for restoration outcomes should be set and used to inform on-ground works and monitoring.
- An adaptive monitoring regime should be implemented, which both informs and improves restoration techniques over time to develop increasing efficiency and effectiveness of restoration methods.
- Restoration is a timely issue considering the current state of Victoria's riparian zones and rivers, their pivotal role in maintaining the function of both aquatic and terrestrial systems, the time-lags likely to be involved in restoring habitat, and future stressors such as climate change.

BOX 1
Riparian restoration and soil condition in central Victoria

Soils play important roles in the functioning of riparian zones. In particular, the condition of riparian soils influences their capacity to retain and/or transform nutrients (Lowrance *et al.* 1997).

To assess the effects of riparian restoration on soil condition, riparian zones were surveyed in the Victorian Riverina bioregion near Euroa (Burger *et al.* 2010). Of the eighteen sites surveyed, six sites were in poor condition with stock access and little remaining riparian vegetation, six had remnant riparian vegetation and six were restoration sites that had stock excluded and trees and shrubs replanted six to 12 years ago. In the restored sites, organic litter and carbon content of soils was found to be higher than in poor condition sites. The effect of adjacent land-use on inputs of nutrients was evident, with both poor condition and restoration sites showing significant relationships between nutrient concentrations in the soil of adjacent paddocks and the riparian zone. However, remnant vegetation was able to more effectively process nutrients and buffer the effects of high NO_3^- and plant-available phosphorus on adjacent land.

Sampling soil in a riparian zone. Photo: Katherine Rainbow.

For further information: Burger, B., Reich, P. and Cavagnaro, T.R. (2010) Trajectories of change: riparian vegetation and soil conditions following livestock removal and replanting. *Austral Ecology*.

BOX 2
Stock exclusion improves riparian condition in the Goulburn-Broken

The Goulburn-Broken catchment covers 10.5% of the area of Victoria and accounts for 11% of the water resources in the Murray Darling Basin (GBCMA 2010). Overall, 83% of the total length of streams in the Goulburn-Broken catchment is in moderate to poor condition, ranking the catchment as in slightly worse condition than the state average (DSE 2005). Across the catchment, threats to riparian and stream condition come from forestry and farming practices, with grazing a dominant driver of degradation in lowland areas.

The effect of livestock grazing on riparian condition was assessed across 473 sites—a total of 365 km of creekline—in the riverine plains region of the Goulburn-Broken catchment (Robinson and Mann 1996a, 1996b, 1998). This survey corroborated the negative effects of grazing on the condition of riparian vegetation. Grazed sites had fewer trees, less biomass, more bare ground and an altered composition of ground layer vegetation. Riparian condition did improve with stock exclusion. Sites that were fenced to exclude stock had less bare ground, more recruitment of trees and increased biomass of ground layer vegetation. This survey shows that some attributes of riparian vegetation may have the capacity to passively recover when stock are excluded.


View of the landscape in the Goulburn Broken Catchment near Euroa (left) including a site with recent stock exclusion and planting (right). Photos: Paul Reich.

For further information: Robinson, D. and Mann, S. (1998) Effects of grazing, fencing and licencing on the natural values of crown land frontages in the Goulburn-Broken catchment. Report to Goulburn-Broken Catchment Management Authority. Goulburn Valley Environment Group, Shepparton.

BOX 3
Restoration of riparian rain forest in East Gippsland

The East Gippsland catchment region covers approximately 10% of Victoria and, overall, the condition of its rivers is among the best in Victoria (DSE 2005). However, agriculture and associated threats, including land clearance, grazing and introduction of exotic species, have degraded the condition of some riparian zones in the region. Some riparian zones have been denuded of their native rain forest vegetation and instead become dominated by exotic species in particular willows (*Salix* spp.) and kikuyu (*Pennisetum clandestinum*). Resultant effects of these changes in vegetation composition and structure proliferate throughout the ecosystem, influencing water quality and the condition of in-stream and terrestrial communities (Greenwood *et al.* 2004; Holland Clift and Davies 2007)

Efforts to restore rain forest communities have been undertaken at several riparian sites dominated by exotic vegetation in East Gippsland (Peel 2010). An approach has been developed and implemented across these sites, which exploits principles of vegetation dynamics to restore plant communities. For example, initial species are selected that will cast shade sufficient to outcompete exotic ground-layer species such as kikuyu.

These efforts have been successful in restoring native vegetation and providing biodiversity benefits. Restoration sites have been documented as approaching remnant, intact forests in terms of the richness of native plant species and specialist bird species—both established indicators of ecosystem condition and function (Croonquist and Brooks 1991; Hooper *et al.* 2005; Sekercioglu 2006). Rapid benefits to terrestrial biodiversity have also been recorded. For example, bird habitat has developed within three years and natural regeneration—indicative of a persistent and self-sustaining plant community—has been recorded after five years.

For further information: Peel, B. (2010) Rainforest restoration manual for south-eastern Australia. CSIRO.

BOX 4

Riparian restoration in the southern Murray Darling Basin

To examine the ecological effects of riparian restoration, an experiment has been established to monitor ecological responses to restoration efforts on lowland streams in the southern Murray Darling Basin. Paired sites, each approximately 1 km in length, were established on each of five streams; on each stream, one site was fenced and planted with native tube-stock on both sides of the stream, whilst land-management and stock access was unchanged on the other site to provide a control.

Here we will discuss results from the first site to undergo restoration treatment. This site was established in 2004 and restoration efforts were undertaken in 2005. The site is on Faithful Creek in the Goulburn-Broken Catchment and prior to degradation represented an endangered Ecological Vegetation Class—Creekline Grassy Woodland—that has been reduced to 16% of its area since European settlement (DSE and GBCMA 2005). Some responses to stock exclusion were rapid despite the below average rainfall and drought conditions that have prevailed across the study region for the past 12 years. For example, bare ground decreased at the restoration site by 13% in three years and by 15% in five years, whilst at the paired control site, bare ground increased (by 31% after 3 years and 10% after five years). Successful natural recruitment of river red gums (*Eucalyptus camaldulensis*), a keystone species in lowland riparian ecosystems, has also been observed at the treatment site, whilst low rates of germination and survival have continued at the control site. However, other responses have been hampered by the drought. For example, the abundance and diversity of macrophytes and aquatic fauna has declined steadily over time at both the control and treatment sites due to drought conditions.

Faithful Creek control site (left) and treatment site (right) in winter 2009, four years after stock exclusion and planting at the treatment site. Photos: Matthew Johnson

For further information: http://www.mdba.gov.au/riparian-restoration-experiment/

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