CHAPTER 9

Impacts of land management practices on riparian land

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Summary

~ Land management practices on and surrounding riparian land can lead to its degradation if they are not compatible with its special properties and functions. Land uses on riparian land, whether for agriculture, other commerce, or for urban development, need to be planned and managed carefully.

~ When allowed uncontrolled access to riparian land, domestic stock can degrade riparian vegetation by grazing and trampling, leading to consequent increases in rates of erosion, to changes in floral communities by way of preferential grazing, and to invasion by exotic weeds.

~ Uncontrolled grazing, especially by cattle which favour riparian areas, often results in increased stream turbidity, as well as increased input of nutrients and bacteria into the stream. Such disturbance of the stream has deleterious effects on aquatic ecosystems and on the quality of water available to downstream users.

~ Exclusion of stock from riparian land can allow riparian vegetation and riparian habitats to recover, although a return to pre-disturbance conditions does not always occur.

~ Altered fire regimes also have major impacts on the functioning of riparian ecosystems.

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9.1 Grazing by domestic stock on riparian land

Riparian land is often a very productive part of the landscape. Human settlement has always been focused on rivers, and the activities of people are often a major determinant of riparian structure and function (e.g. Dynesius & Nilsson 1994). The introduction to Australia of domestic livestock has also had a particularly pervasive influence on riparian habitats (see Fleischner 1994, Trimble & Mendel 1995), with grazing management practices among the most widespread agents of chronic modification to land-water interfaces (McComb & Lake 1988, Wilson 1990, Walker 1993, Morton, Short & Barker 1995, Robertson 1998). In a recent assessment of biodiversity values of riparian zones in Australia, grazing has been identified as the most extensive threatening process (Sattler & Creighton 2002). As a result, this chapter focuses mainly on the impacts of grazing by domestic stock on riparian land, with some information on the effects of fire. Other human activities such as cropping and urban land use also have major impacts on riparian land since they generally involve complete removal of riparian vegetation and loss of the riparian ecosystem, and they are also briefly discussed.

Since European settlement, riverine landscapes and wetlands have been used by Australian farmers as watering points for stock, as well as valuable sources of feed. Riparian and wetland habitats, as well as areas around artificial watering points in pastoral regions, suffer greater impacts from domestic and feral grazing herds than do dryland habitats because stock concentrate around water sources (Robertson 1997, James, Landsberg & Morton 1999). Riparian land is typically more fertile and moist than adjacent lands and consequently supports a higher quality and more diverse forage than do upland areas (Gillen, Krueger & Miller 1985, Platts & Nelson 1985). In the hotter seasons, stock are attracted to the cooler microclimates that characterise riparian lands and (especially for cattle) may spend extended periods loafing in the shade or standing in pools found there. These effects are exacerbated during drought years, when water becomes scarce in the landscape (Robertson, 1998, James, Landsberg & Morton 1999).

A comprehensive review of livestock impacts on riparian ecosystems in the western United States found that stock can have negative impacts on stream geomorphology and hydrology, riparian soils, in-stream water quality, and aquatic and riparian vegetation (Belsky, Matzke & Uselman 1999). Along floodplain rivers, livestock can also have impacts on the soil, water and vegetation of wetlands in the riparian zone (Robertson 1997). In the following section we summarise the findings of work on the impacts of stock on the physical characteristics of streams, including riparian soils, stream geomorphology, hydrology and in-stream water quality; this is mainly based on overseas studies as little work on this topic has been done in Australia. We discuss in more detail work on vegetation, some of which has been done in Australia, and include information from work in non-riparian areas. The impacts of grazing by livestock on riparian wildlife were discussed in the previous chapter. Finally, we will discuss the effects of exclusion of stock from riparian areas that have previously been degraded by grazing.

The impacts of stock

The impacts of stock on physical characteristics of streams

Livestock consume vegetation and remove ground cover from the soil surface through trampling, leading to increased amounts of bare ground and compaction of the soil. These factors in turn lead to increased erosion and delivery of sediment to streams, as well as lower infiltration rates and reduced fertility of riparian soils (Belsky, Matzke & Uselman 1999).

Decreased infiltration rates, combined with increased erosion in catchments as a result of livestock grazing, lead to greater runoff into streams and riparian zones during rainfall events. This changes the nature of flooding in streams with generally bigger flood events and more variable flows, as less water is stored in the soil to be released during drier periods (Belsky, Matzke & Uselman 1999). These changes, as well as the trampling of stream banks by livestock, alter channel shape (deepening and widening), causing siltation of pools and depositional areas of the stream, and loss of stream bank stability (Belsky, Matzke & Uselman 1999). The impacts of stock on these processes depend on:

~ soil type,
~ soil moisture content,
~ size of stream,
~ regional climate,
~ intensity, season and duration of grazing,
~ type of stock,
~ grazing history,
~ condition and type of vegetation.

Research has shown that grazed stream banks may erode three to six times faster than those that are ungrazed (Trimble & Mendel 1995). This erosion mainly occurs along the tracks that stock create in accessing streams, and can result in losses of about 40 m^3 of bank material

Bank undercutting caused by cattle impact. Photo John Dowe.

Cattle at a restricted water access point but are still content to stand in the water rather than moving back out to pasture. Photo Peter Hairsine.

For more information on stock management

Stock and waterways: a manager's guide, Staton, J. & O'Sullivan, J. 2005.

'Managing stock', *River and Riparian Management Fact Sheet*, no. 6, Lovett, S. & Price P. 2002.

Wool industry river management guides, Price, P., Lovett, S. & Lovett, J. 2005.

These publications are available from the website www.rivers.gov.au

Cows and Fish, a Canadian program to assist ranchers better manage cattle in riparian areas that has fact sheets and information resources of very high quality — website www.cowsandfish.org

Channel widening and bank collapse with removal of riparian vegetation by uncontrolled grazing. Photo Amy Jansen.

Soil bared by overgrazing is easily eroded. Photo Land, Water & Wool.

a year along a single reach. Australian work on the effects of ground cover on soil loss has shown that when ground cover of pasture and litter is greater than 70%, little runoff and soil loss occur in most rainfall events (Costin 1980). Stock also wear tracks through riparian vegetation, and these become pathways for sediments and nutrients to enter streams (Hairsine, Bormann & Brophy 2001). Tracks created along the edges of stream banks are eroded quickly, and parts of the undercut bank may eventually slump into the stream.

Stream size has an important bearing on the degree to which stock affect stream banks. Stock have a greater impact on small streams than they do on large streams (Williamson, Smith & Quinn 1992). Small streams have low stream banks and shallower water, allowing easier stock access at many points. Larger streams have steeper banks, which tends to limit stock access to a few, heavily-used places. Here, much of the erosion occurs as undercutting. Stream banks on the Murray River show signs of undercutting and subsequent collapse, with losses of up to 900 m^3 of bank material along 150 metres of stream bank (Frankenberg 1994). By contrast, ungrazed banks protected by the reed *Phragmites australis* show only minimal erosion and no undercutting.

In addition to those changes that can be seen at the individual stream reach scale, it has also been suggested that grazing has been a major cause of landscape-scale changes in the geomorphology of Australian rangelands (Pringle & Tinley 2003).

Erosion by scour (left hand side of photo) and mass failure (right hand side) along a large river. Photo Ian Prosser.

The impact of stock on water quality

In the Kimberley region of north-western Australia cattle overgrazing of the native vegetation has caused major erosion and river siltation problems (Williams et al. 1996, Winter 1990). Increases in nutrient concentrations from stock excrement, high bacterial and protozoan loads, as well as large sediment loads and high turbidity from trampling near the water edge all cause poor water quality. This situation is made even worse when riparian areas are cleared and grazed so that there is no shade over the stream. High water temperatures and increased light combine with the high nutrient conditions to reduce oxygen concentrations in the stream (Kauffman & Krueger 1984, Belsky, Matzke & Uselman 1999). This situation develops in the following way:

~ nutrient concentrations increase as a result of runoff from disturbed stream banks and direct deposition of livestock urine and manure,
~ bacteria and protozoa increase due to direct contamination by livestock faecal material in streams and in runoff, and toxic algae may grow in-stream in response to the increased light, temperature, and nutrient availability,
~ sediment loads and turbidity increase due to in-stream trampling, erosion from denuded banks, reduced filtering capacity of the riparian vegetation, and increased peak flows due to the compaction of upslope soils,
~ water temperatures and light levels increase as a result of the loss of riparian shade,
~ dissolved oxygen levels decrease as a result of the higher water temperatures, and greater biological demand for oxygen as a consequence of high nutrient loads leading to increased organic matter.

The "ecotrough" developed by woolgrowers David and Ruth Read showing reeds planted in a restricting container to provide shade and reduce the water temperature, keeping the water highly palatable for sheep. Photo David and Ruth Read.

Livestock wastes contaminate streams, while the faecal organisms contained in the wastes can lead to health problems for humans (Miner et al. 1992). Streams contaminated with faecal material can be the source of a range of diseases, such as giardiasis, salmonellosis, gastroenteritis, typhoid fever, hepatitis A, amoebiasis and viral gastroenteritis (Splichen 1992). The good news is that the use of riparian buffers and the exclusion of stock from the riparian zone can reduce by up to 90% the faecal inputs that create the conditions for these diseases.

Impacts of livestock on in-stream water quality can also have major effects on in-stream fauna such as fish and aquatic invertebrates (Larsen et al. 1998, Belsky, Matzke & Uselman 1999). Stock effects on water quality and in-stream life can be particularly severe during periods of low flow, for example in the tropical dry season, as animals congregate at the few remaining waterholes in the landscape (Burrows & Butler 2001).

Stock not only affect water quality but are also affected by it. Work in Canada has demonstrated that gains in stock productivity of up to 25% can be achieved through the provision of watering systems such as troughs based on a clean and uncontaminated water source (Willms et al. 1994). In Australia, this may have important implications for streams which have reduced seasonal flows and which are freely accessed by stock. Trials in Western Australia demonstrated that wethers which drank from polluted dam water lost 1.7 kilograms more body weight and consumed 33% less water than those drinking solely from fresh water (Parlevliet 1983).

The impacts of stock on vegetation

Livestock have a variety of impacts on vegetation. The most obvious is the direct grazing and trampling of ground covers, shrubs and saplings. Undisturbed riparian vegetation usually contains a diverse range of species, including trees and shrubs of various ages, height and form, as well as ground covers (including grasses, sedges and herbs). This contributes not only to the site's biodiversity but also to its structural diversity. The presence of a range of different plants influences the nature of the root zone and the depths to which roots penetrate and this, in turn, affects the water table in stream banks and their stability (see Chapter 2). Plant

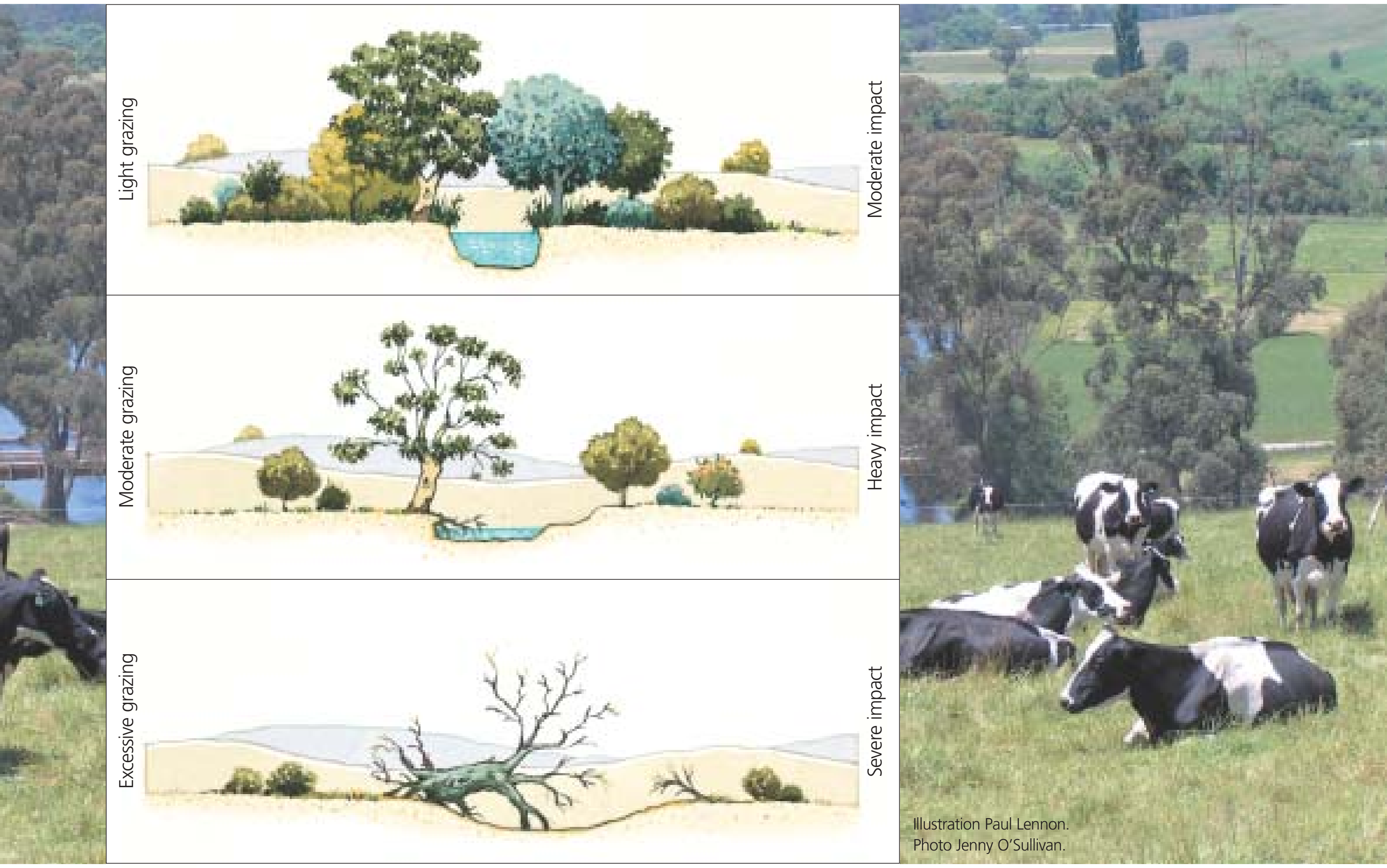


Illustration Paul Lennon.
Photo Jenny O'Sullivan.

diversity supports enhanced nutrient cycling and uptake, soil aeration, soil structure and levels of microbial activity (Earl & Jones 1996). As discussed in the previous section, riparian vegetation is a major controller of geomorphological processes occurring in the riparian zone, and also has strong influences on water quality in-stream. In the previous chapter the importance of intact riparian vegetation to wildlife was discussed.

Table 9.1 summarises the major influences of livestock grazing on riparian vegetation, the causes of these effects, and their impacts on riparian ecosystems. When stock graze they remove plant parts from ground cover vegetation, shrubs and saplings, and also damage them through trampling. These changes lead to loss of ground cover and biomass of vegetation, and through the loss of grazing-sensitive species, to declines in native plant diversity. Soil compaction due to trampling reduces the macrospore space in soil and this reduces infiltration, root growth and overall plant production (Bohn & Buckhouse 1985). The loss of important species or functional groups within riparian vegetation affects the diversity at a particular site and can thereby result in changes in microclimate, nutrient cycling and soil structure. These changes can lead to disruption of ecosystem function and degeneration of the system which cannot be easily reversed.

Stock preferentially graze more palatable plant species, either removing them from a site or reducing them to compact, low tussocks, coppices or rosettes. Plants with different life forms respond to grazing in different ways. Grazing may favour sedges, grasses and other species whose growing point is protected from grazing animals (for example, by being at or below the soil surface and thus able to survive, albeit with reduced vigour) over other life forms. These processes lead to shifts in plant community composition towards species more tolerant of grazing (Fleischner 1994). In Australia, these shifts tend to involve loss of native specialist riparian species and replacement with exotic annual species (Pettit 1999, Jansen & Robertson 2001a, Jansen & Robertson 2005), something that has also been recorded as occurring in North America (Fleischner 1994, Belsky, Matzke & Uselman 1999). Livestock can also promote invasion of weeds (usually annual, ruderal

Above: Uncontrolled stock access degrades riparian lands and allows establishment of exotic weeds. Photo Guy Roth. Below left: Ungrazed riparian areas have a diversity of small native perennial plant species. Below middle: Native perennial tussock ground cover. Below right: *Poa labillardierei*, an example of a large tussock grass found in riparian areas. Small photos Amy Jansen.

Table 9.1. Impacts of livestock grazing and trampling on vegetation and riparian ecosystems (Summarised from Belsky, Matzke & Uselman 1999).

Influence on	Response	Causes	Impacts
Cover, biomass, productivity and native diversity of herbaceous vegetation	Decline	Grazing and trampling by livestock, selective grazing of palatable species, loss of grazing-sensitive species, changed microclimates	Lowered food inputs for aquatic organisms, degraded habitat for aquatic and riparian fauna, reduced biodiversity, replacement of riparian specialists with weedy generalists, loss of ecosystem resiliency
Species composition	Altered	Preferential grazing of palatable species, loss of grazing-sensitive species, changed microclimates, increased disturbance	Replacement of riparian species by upland and exotic weeds, reduction in riparian area
Overhanging vegetation	Declines	Grazing and browsing by livestock	Less shade, greater fluctuations in water temperature, lower food inputs into stream
Tree and shrub biomass and cover	Decline	Browsing and trampling of shrubs and saplings	Loss of complex vegetation structure for wildlife
Structure (vertical and horizontal)	Simplified	Loss of trees and shrubs	Loss of sensitive bird species, reduction in wildlife habitat
Plant age-structure	Becomes even-aged	Reduced recruitment and survival due to grazing and trampling	Reduced riparian habitat, loss of riparian-dependent wildlife

species), which can bring about changes in vegetation structure (Fleischner 1994). The creation of open sites by grazing or trampling provides a perfect opportunity for weed species to become established. Weeds are also spread by the movement of stock, either in their faeces or by attachment to the animal. Stock faeces and urine also contribute large quantities of nutrient to the soil (especially nitrogen and phosphorus), that further encourages the growth and spread of weed species.

Shrubs and trees may be only moderately affected by grazing in the short term but over longer time frames become increasingly degraded. Overgrazing restricts the recruitment of most riparian plants, particularly overstorey plants, and so prevents the replacement of plants as they mature and senesce. This occurs because new seedlings are grazed, or because trampling leads to changes in the soil structure which prevent germination. The reduced tree or shrub canopy may then favour the development or expansion of ground covers (Trimble & Mendel 1995) especially of annual plants that require higher light levels, further restricting germination of woody species (Kirkpatrick 1991). In addition to the direct impacts that livestock have on shrubs and saplings through browsing and trampling, grazing in Australia usually goes hand-in-hand with the clearing of overstorey vegetation. This means that heavily grazed sites tend to have a very simplified vegetation structure, with few trees and shrubs and little recruitment of either (e.g. Pettit 1999, Robertson & Rowling 2000, Jansen & Robertson 2001a). Over time, heavy grazing can result in the development of even-aged stands of vegetation, a reduction in species diversity, or both. These changes to vegetation structure have significant consequences for riparian wildlife (see previous chapter).

In addition to direct impacts of grazing on vegetation, there can be much more subtle effects. For example, Meeson et al. (2002) found that heavily grazed sites had more seed-eating ants than lightly or ungrazed sites, and that rates of predation of river red gum seeds were higher in the heavily grazed sites. Thus, recruitment of river red gum trees was potentially limited in more heavily grazed sites by the availability of seeds. Another complication to this finding is the influence of changed flooding regimes. It was found that sites which flooded less frequently (as is often the case on regulated rivers), were more strongly influenced by the effects of grazing, having greater populations of seed-eating ants, than those which flooded regularly (Meeson, Robertson & Jansen 2002). Hence, grazing may interact with altered flooding regimes to have even more significant impacts on riparian vegetation than would be the case for either effect on its own.

Buffalo Brook, 1986.

When stock are excluded from riparian land

While it is clear that grazing livestock can have profound effects on riparian vegetation and other aspects of riparian zone function, exclusion of grazing from riparian zones can have mixed results. Certainly exclusion of stock can result in rapid recovery of physical functions such as prevention of erosion. For example, after stock were excluded from riparian land in Ohio in the United States, average annual soil loss from streams was 40% lower and sediment concentrations in storm flows 60% lower (Owens, Edwards & Van Keuren 1996). On the Murrumbidgee River in south-east Australia, exclusion of livestock led to decreases in the amount of bare ground in the riparian zone, thus improving riparian zone function (Robertson & Rowling, 2000).

Responses of vegetation to exclusion of livestock grazing can vary due to a number of factors. These include:

- prior adaptation of the vegetation to grazing by livestock,
- availability of seed sources for recruitment,
- extent of degradation of the vegetation,
- other factors such as floods, weeds, etc.

At sites that have had a long history of grazing and where the riparian vegetation has adapted to this form of disturbance, the exclusion of livestock may result in changes to the vegetation structure, such as invasion by woody plants and a reduction in species diversity (Milchunas & Lauenroth 1993). Experiments with grazing exclusion in riparian vegetation have shown a reduction in species richness and an increase in plant cover (Kauffman, Krueger & Vavra 1983). These studies advocate management which excludes grazing for some period of the year (or in particular years) so that vegetation can recover and recruitment can take place. In Australia, however, riparian vegetation is not pre-adapted to grazing by hard-hooved grazing animals. Here, it is unlikely that grazing will be beneficial to

The extent of natural regeneration that has occurred in a 20-year period of stock exclusion, Buffalo Brook, Tasmania. Photos Lindsay Nicolson.

riparian zone function, except in situations where the vegetation is so degraded that grazing can be used as a tool to manage weeds and fire risk.

Fencing out stock can lead to a variety of outcomes. For example, in Tasmania stock were excluded from Buffalo Brook in 1986. In the 11 years to 1997 there was extensive regeneration of native trees (*Acacia dealbata* and *A. melanoxylon*), shrubs (*Leptospermum lanigerum* and *Micrantheum hexandrum*) and ground covers (*Poa labillardierei* and *Lomandra longifolia*). Adjacent grazed sections of the stream failed to regenerate to the same extent. Conversely, riparian land fenced out along the Elizabeth River in the Tasmanian Midlands has become overrun with woody weeds, including *Ulex europaeus* and *Crataegus monogyna* (Askey-Doran et al. 1999). Past land-use history, present practices, availability of propagules (seed bank and proximity to native vegetation), regeneration characteristics of the vegetation, and the composition of the vegetation (introduced versus native) will all influence the progress of regeneration.

Other research has shown that there has been no recovery of ground cover plant communities after 10 years of exclusion of livestock grazing from river red gum forests at Barmah-Millewa in south-east Australia (Kenny 2003). Past degradation, lack of seed sources and resource limitation due to the continuous canopy cover may all have contributed to this lack of recovery. On the Murrumbidgee River, however, exclusion of grazing from riparian zones for periods between one and 30 years has led to significantly different plant communities, with fewer exotic annual grasses in ungrazed than grazed sites. Lower stocking rates were also associated with more native annual grasses, tall perennial forbs and small perennial sedges (Jansen & Robertson 2005). Exclusion or partial exclusion of grazing from riparian zones in the Goulburn-Broken Catchment has also been associated with increased native plant biodiversity, increased abundance of native grasses and decreased numbers of introduced species, including noxious weeds (Goulburn Broken Catchment Management Authority and Land & Water Australia 2002).

Predicting which particular species are most affected by livestock grazing and which species are likely to return after stock exclusion is important for the rehabilitation of degraded riparian areas. This may depend on particular traits of individual species — such as life form, ability to resprout after defoliation, seed production, seed dispersal techniques, seed dormancy and the ability to

This creek is seasonally wet or dry and occasionally burnt. The mix of riparian species present is dependent on this wetting and drying cycle. Photos Michael Douglas.

form a seed bank. After one year of excluding stock in a grazing exclusion experiment on riparian land on the Blackwood River in Western Australia, native perennial herbs showed the greatest increase in vegetation cover. There was also successful recruitment of the overstorey species *Casuarina obesa* in the exclosure plots, which did not occur in the grazed plots (N. Pettit, unpublished data).

Germination studies of Tasmanian riparian land indicate that the recruitment of woody species after exclusion of grazing is a lengthy process. After almost three years of exclusion there was only limited recruitment of woody species in the monitored plots (Askey-Doran et al. 1999). Marsupial grazing is likely to be influencing this, but other factors (such as suppression by the grass layer, unsuitable germination conditions, and a depauperate seed bank) may also be implicated. Successful recruitment of many species may be episodic, relying on the coincidence of several factors (such as winter flooding, early receding of floodwaters corresponding with seedfall, and some summer rainfall). Recruitment requiring particular environmental conditions has been documented in some plant communities (e.g. Askey-Doran et al. 1999, Pettit & Froend 2001, Pettit, Froend & Davies 2001), and grazing may interfere with any such 'window of opportunity' for recruitment.

9.2 Other impacts

Unmanaged or poorly controlled grazing by domestic stock is a major cause of continuing degradation of riparian land in agricultural areas and is therefore the primary focus of this chapter. However, there are a range of other activities that impact upon riparian areas, and these are covered here.

Fire

Parson (1991) cites several references to the use of fire by Aboriginal people along rivers, including the Namoi, Gwydir, Barwon, Bogan, Macquarie and Narran Rivers. Similarly, the use of fire to stimulate regrowth of grass along watercourses in Central Queensland has been reported (Parson 1991). Aboriginal use of fire would have impeded regeneration of river red gum but favoured woodland development and the maintenance of forest grassland boundaries (Chesterfield 1986). The impact of fire on riparian communities depends on their floristic and structural composition and on the intensity, season and frequency of burning. Different species respond differently to fire. In general, riparian communities are generally not adapted to frequent burning, with many

Fire regime (frequency, season and intensity) can have a major influence on the composition and health of riparian vegetation. Photo Ian Dixon.

species sensitive to fire. Young river red gums are examples of a species sensitive to even low-intensity fires (Dexter 1978); their lack of lignotubers making them more susceptible to death from fire than many other eucalypts (NSW Forestry Commission 1986, cited in Parson 1991). The vulnerability of river red gum to fire means that very little control burning occurs in these forests (Parson 1991). Low fuel loads and depauperate shrub layers limit the need to reduce fuel loads. Other species, such as *Callitris oblonga*, may be killed outright by fire, but the death of the parent facilitates seed fall and regeneration (Harris & Kirkpatrick 1991).

Frequent fire can encourage fire-tolerant species and discourage fire-sensitive species, leading to changes in the composition and structure of plant communities. In the south-western United States, *Populus* spp. were missing from burnt stands whilst *Salix* spp. were able to persist (Busch 1995). Fire in these communities encouraged the invasion of the exotic species *Tamarix* and *Tessaria*. In Australia, 'bush run' country is regularly burnt for 'green pick' for stock. If these fires are of low intensity and well controlled they should not affect riparian vegetation. However, escaping fires do burn into riparian areas and can lead to the death of plants. The common practice of controlling weed species with fire poses a threat to riparian land. For example, some

Examples of development on or near riparian land that affect its functions and water quality or river health. Photos: (top left and right) Guy Roth, (bottom left) Phil Price, (bottom right) David Morgan.

fires burn intensely and produce embers which can be blown into riparian areas or the fires can burn into the riparian zone (Askey-Doran et al. 1999).

Work in the savanna country of the northern territory has shown that early dry season burns are much less damaging than late dry season burns to riparian zone vegetation (Andersen et al. 2005) and to stream water quality during early wet season run-off events (Townsend & Douglas 2000). However, late dry season burns lead to flushes in growth of aquatic vegetation and associated aquatic fauna which are absent from unburnt sites and those burnt early in the dry season (Andersen et al. 2005).

Cropping

As noted elsewhere in this document, riparian land is often a very productive part of the landscape, and may therefore be cultivated for agricultural or horticultural crops. Removal of the native vegetation and cultivation of the soil leads to complete loss of many important riparian functions, with consequent deleterious impacts on both the terrestrial and aquatic ecosystems. As cropping land is valuable, the temptation is strong to crop up to the edge of the channel, and sometimes into the channel itself. Careful planning of the paddock layout, for example, to incorporate a track and area for turning machinery, a grassed filter strip, and thin band of shading riparian vegetation, can restore some of these functions.

Urban development

Urban development can be equally deleterious, even when some riparian vegetation is retained. Increased run-off from impervious urban surfaces has been dealt with in the past by converting the natural channel into a straight concrete drain to maximise flood conveyance (Ferguson, Hardie & Miller 2004). This process is being reversed in some areas, at considerable expense, but other problems remain of weed invasion, contamination with nutrients and rubbish, and erosion and modification of vegetation from over-use.

River regulation

Changes to stream flow regime can have large impacts on riparian vegetation, and these are outlined in Chapter 5. Channel straightening and 'de-snagging' undertaken in the past with the aim of increasing flood conveyance and reducing the inundation of riparian land, can also impact directly and indirectly on riparian zones. Both can lead to increased flow velocity and enhanced erosion of the channel bed and banks, with potential for channel avulsion, flood-outs, head-cutting and loss of riparian vegetation and land. Loss of important in-stream habitat can have flow-on effects to the adjacent riparian land as explained in Chapter 8. Even where native riparian vegetation has been retained it may take many decades for the natural level of in-stream wood to be restored, and where the vegetation has been cleared or lost there is no likelihood of restoration to more natural flow conditions.

Construction of weirs, dams and reservoirs can also have a major impact on the health and functions of riparian land (Ogden & Thoms 2001). A large impoundment can greatly reduce the frequency and extent of the flood peaks required by some riparian plants for reproduction or survival, and releases timed to meet the needs of downstream irrigators (summer and early autumn) may reverse the natural flood season (spring in Southern Australia). Frequent releases may result in rapid changes in water level that increase bank erosion but do not provide the conditions necessary for successful recruitment of riparian species. Massive alteration to disturbance regimes is an important contributor to declining condition of riparian lands in many regulated catchments.

Sand and gravel extraction

Rivers have been used as important sources of materials for road base and concrete, often with little thought given to the potential effects of their removal. Changing the balance between flow/erosive power and sediment supply can lead to episodes of bed or bank erosion and channel widening, establishment of nick points and head-cuts, and loss of water quality and in-stream habitat. Sand and gravel extraction is another activity that can have direct (at stream access points) and indirect (through changes to the channel and flow) impacts on riparian land and its functions. The need for restoration of extraction sites should be incorporated into the permitting process.

Weed invasion

For many people, an important deterrent to changing stock management in riparian areas is the fear that they will become havens for weeds and pest animals, as well as posing a fire risk. These are issues that must be taken into account in planning the management of riparian areas. Fortunately many landholders have found ways to improve their management of riparian areas without significant invasion or establishment by weeds. An important principle of weed management is that most weed species find it difficult to invade and establish into intact riparian vegetation. In general, if vigorous pasture and healthy native vegetation is maintained or established in riparian areas, weeds will find it harder to compete and establish. Managing grazing so that plant cover of established pasture and native vegetation is maintained is the key management practice to prevent weeds becoming a problem.

Bamboo grass and artichokes shown here, can be difficult weeds to contain in riparian areas once they take hold. Photo Phil Price.

On riparian land that has become degraded by past land use and management, and on areas that are affected by flood, frost, or wildfire, it is vital to promote natural regeneration or to deliberately revegetate as soon as possible after the disturbance, otherwise weed invasion is almost certain and it will be much harder to bring the area back to a natural condition.

However, even with this careful approach to management, some weed species especially suited to riparian areas may become established. Weeds can be brought in through wind dispersal of seeds, seeds passing through the droppings of birds and other animals, or seeds and pieces of vegetation arriving from upstream during peak flows. Where these invaders are successful, carefully-managed and selective grazing in the riparian area can be used, as well as selective control with herbicide or hand-weeding. Pulling individual weeds out by hand or grubbing out with a hoe can be effective when numbers are low.

In many regions, riparian areas have already been invaded by woody weeds. These plants, which might include willows, pepper trees, olives, desert ash, tamarisk and other species, may provide some benefits (for example, they may shade the stream or help strengthen banks against erosion), but overall their influence is negative, and in the long run they should be replaced with local native species. Willows, for example, will

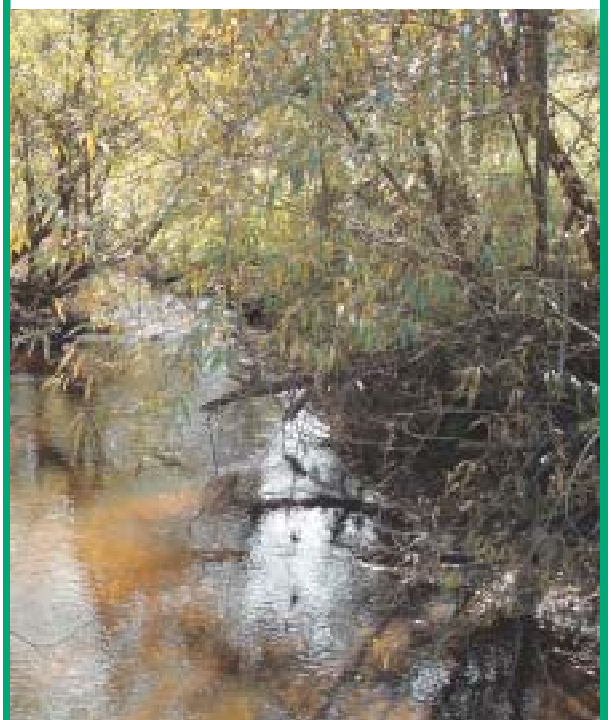
The problem with willows in riparian areas

In many high rainfall areas, willows have been used extensively to help stabilise many stream banks. Willows establish easily, grow rapidly, produce fine matted roots ideal for stabilising soil, and require little attention after planting. However, over time the consistent use of willows (and the planting of male and female plants of most species that successfully spread by seed), has caused changes to the ecology and flows of rivers and streams. Some southern rivers are now completely choked by invasive willows. Willows have displaced native riparian species and colonised sand and gravel bars in streams, diverting floods and causing erosion on vulnerable banks. The soft textured leaves that are all dropped at the same time do not provide a year-round food source for native in-stream animals. This, together with the extreme shade provided by willows has reduced biodiversity wherever willows dominate riparian areas. Willows are also prodigious users of water, and en masse can reduce natural water flow. Some of these features also apply to other invasive species found in the riparian zone including poplars, she-oaks, olives and desert ash.

Willows are now listed as a weed of national significance. For more information see the website www.weeds.org.au/WoNS/willows/.

For more on how to manage willows see:
'Controlling willows along Australian rivers', *River and Riparian Technical Guideline*, no. 6, Land & Water Australia. Available in hard copy and on the web at www.rivers.gov.au.

Text source: Department of Land & Water Conservation. Photo Lizzie Pope.



Foxes are a major threat to livestock production and to wildlife. Photo Jan and Neville Lubke.

gradually grow into the stream, blocking the channel, and causing additional flooding. They can be highly aggressive, and now that both sexes in most species are present in Australia there have been some huge seeding events, with millions of seedlings becoming established downstream, completely choking some channels. Willows also use a lot of water, and are harmful to native in-stream animals as they drop all their leaves at once into the stream where they decompose and create anoxic (no oxygen) conditions.

Pest animals

The development of catchments for agriculture or urban use has disturbed natural systems and forced or enabled some animal species to become pests. Loss of natural habitat combined with greater availability of water and quality food (in the form of crops) has led to some species increasing their population while others declined. There is a risk that unmanaged or revegetated riparian areas may provide harbour for pest animals, which can include both native and feral species. Wallabies, kangaroos, possums and some bird species can cause significant damage to native vegetation. Feral species, including pigs, foxes, rabbits, deer, wild dogs and cats, are also deleterious to native plants and wildlife, can be predators of farm animals and may pose a disease risk. In closely-settled areas, where riparian areas are likely to include grazed pasture and small areas of native vegetation, the eradication of these pests is normally not a problem. However, over larger areas, particularly in pastoral country, this is an issue that must be considered as part of overall riparian management strategies and eradication programs put in place.

Current research

Long-term exclusion of livestock from riparian land in the Burdekin Catchment

Four sites at which cross-stream fencing separates areas with stock access and without were studied. Stock had been removed from riparian zones one side of the fence for at least 15 years. Results indicated that the dominant trees species had a greater density and cover in the unstocked areas. This was most likely not through greater levels of regeneration following removal of stock, but due to the degradation and/or loss of the dominant tree species through the activities of stock. Additionally, the time frame is too limited for the germination, establishment, and growth to maturity of large slow growing species such as broad-leaved *Melaleuca* spp. and *Eucalyptus camaldulensis*. The life span of dominant trees may be significantly reduced by soil compaction, erosion generated by trampling and track formation, and the input of faecal materials into the soil below the trees. Conversely, at the study sites at least, there was a greater cover and abundance of deleterious weeds in the unstocked area, but overall there was no significant differences of species adundances or species composition between the stocked and unstocked sites. It was concluded that stock have a significant detrimental impact on the persistence of established dominant trees in riparian zones.

Researcher: John L. Dowe, Australian Centre for Tropical Freshwater Research, James Cook University, Townsville

Exclusion experiments in the Burdekin Catchment

Nine stock exclosures each with an average cover of 1500 m^2 were constructed at three sites in the Burdekin catchment in late 2002. The sites have been monitored bi-annually since November 2002 on a pre wet season (November) and post wet season (May) basis. Each site consists of three exclosure plots and two to four control plots. The sites are also graded as steeply sloping, moderately sloping and gently sloping. In the first surveys following establishment, grass cover was significantly greater within the exclosures compared to the controls, primarily because of no grazing. Levels of grass cover have more or less remained at a high level within the exclosures, whilst in the controls levels of grass cover reflected seasonal rainfall patterns and subsequent levels of grazing. In most exclosures, one or two exotic pasture grass species have come to be dominant at the expense of others, including native grass species, that were initially of greater abundance. There have been no significant changes in species composition at any of the sites, although abundance (as determined by percentage cover) has altered for many grass species. There was no evidence of greater weed occurrence within the exclosures, and no change in the number of species present in any plot. It was concluded that in the short term, some grass species respond to not being grazed, and are able to out-compete others that may benefit from grazing.

Researcher: John L. Dowe (as previous)

Exclusion experiments in the Riverina

Grazing experiments were established at three sites which were continuously grazed prior to 2001. Starting in 2001, Millewa was only grazed in summer, Cuba North was only grazed in winter, and Cuba South continued to be continuously grazed. Five fenced and five unfenced plots were established at each site and baseline monitoring of plants occurred in the spring of 2001. All sites were virtually ungrazed throughout 2002, due to the drought, and baseline monitoring of ants occurred in the late spring of 2002. Some grazing occurred at Millewa and Cuba South but not at Cuba North in 2003, and all sites had some stock in 2004. Plants were resampled in spring of 2003 and 2004, and ants in late spring of 2004. While there have been changes from year-to-year in the plant and ant communities, no differences have developed over time between the fenced and unfenced plots at any site, for either plants or ants. There are three possible explanations:

1. The time frame has been too short to allow differences to develop (this seems unlikely, given that ants, at least are known to respond relatively quickly to changes in land management).
2. The sites have reached a level of degradation where recovery in response to the removal of grazing is unlikely (again this seems unlikely as the sites chosen, especially Millewa, are in relatively good condition).
3. The stocking rates adopted by state forests for these sites, and particularly the extremely low stocking during the drought, may be so low that there is no detectable effect.

The main conclusion is that stocking rates and grazing regimes used in state forests in the Riverina floodplain in recent years are unlikely to cause any more degradation of riparian habitats than has already occurred. There is also no evidence that any recovery of riparian habitats is likely to occur, either under light grazing or with total exclusion of grazing.

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