Reviewing fire as a vegetation management technique in highly modified riparian ecosystems

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Key Points

- Returning vegetation is facilitating river recovery in Australia, however it is often dominated by environmental weeds. Large-scale management techniques are needed to control invasive species in riparian zones.
- Australia has many fire-adapted flora and a long history of using fire for land management, but there have been few trials for managing highly modified riparian vegetation.
- Infrequent and low intensity burning may have biodiversity benefits for riparian vegetation and be effective for managing exotic species invasions.

Abstract

Rivers in Australia have undergone significant modification since European arrival due to land management practices such as, vegetation clearing and channelization. River recovery in coastal NSW has begun in recent years, facilitated mainly by a significant increase in woody vegetation cover (Fryirs et al., 2018). Although the vegetation driving river recovery has geomorphic benefits, there is concern that its diversity and endemism is low. Cost-effective and large-scale vegetation management options are needed to retain and enhance geomorphic river recovery provided by increased vegetation cover, while improving the biodiversity of riparian zones.

Ecological and Cultural burning present underutilised vegetation management techniques to enhance river recovery and gain positive biodiversity outcomes. However, ideal burn regimes for managing degraded riparian ecosystems are yet to be understood. Preliminary trials in the lower Hunter region in NSW and tropical northern savannah have showed promising results from low intensity burning for managing target invasive species and improving overall biodiversity (Andersen et al., 2005; Mabbott & Fryirs 2018; Radford et al., 2008). This paper will review the potential of fire as a management tool for improving the ecological condition of riparian vegetation in highly modified river systems.

Keywords

River recovery, fire, burning, riparian vegetation, geomorphology, exotic plant species

Introduction

Riparian plant communities host high levels of biodiversity and are some of the most threatened ecosystems in the world (Pittock et al., 2015). They play a critical role in maintaining aquatic ecological health by preventing erosion, inputting leaf litter and wood into stream ecosystems, and moderating temperature and nutrient levels (Naiman & Decamps 1997). However, in coastal NSW, years of intense anthropogenic disturbance from poor land management practices have led to the degradation of riparian systems due to

land clearing, water extraction, sand/ gravel removal, and increased sediment and nutrient loads (Catford & Jansson 2014; Fryirs et al., 2013; Richardson et al., 2007).

Riparian vegetation has been returning since the end of the 20th century due to some extent by passive regeneration, replanting projects and changes in landuse (Fryirs et al., 2018). A noticeable shift towards improved geomorphic conditions of rivers has occurred since the 1970s and is associated with returning vegetation (see Zhang et al., 10ASM; Fryirs et al 2018). However, there is concern that this recovery is being driven by exotic weeds leading to overall poor outcomes for biodiversity in riparian corridors. Anthropogenic disturbances exacerbate conditions that promote exotic weed dominance (Greet et al., 2013). Frequent disturbance from flooding transports seed propagules and creates conditions where exotic ruderal species can establish. Additionally, high nutrient levels from agricultural runoff and edge effects in narrow riparian corridors place additional pressures on river systems and contribute to conditions that promote exotic weed invasion. Cost and time restraints are frequent barriers to effective weed management. There is a need for large-scale, cost-effective techniques for managing riparian vegetation (Macdonald & Williams 2009).

Fire has a long history of use as a tool for land management in Australia. Aboriginal people historically used fire to 'clean up country' for cultural and spiritual reasons and manage natural resources (Gott 2005; Yibarbuk et al., 2001). Many Australian plant communities are adapted to fire disturbance. Fire-adapted species often have seed germination triggered by smoke or high temperatures (serotiny) or resprout from lignotubers after burning (Keeley et al., 2011). However, it is not yet understood what burn regimes are optimal for managing highly modified coastal NSW riparian ecosystems or whether fire can be used as a management tool in systems where environmental weeds are a significant issue.

This paper reviews some of the current knowledge about,

1. The response of eastern Australian riparian ecosystems to fire.
2. How fire could be used as a management tool for coastal NSW riparian vegetation.

Riparian ecosystems and fire

Riparian zones differ from surrounding upland and terrestrial areas and act as an ecotone between aquatic and upland ecosystems. They often have different moisture regimes, microclimates, and a denser structure than terrestrial vegetation (Pettit & Naiman 2007). Due to these conditions, fires in riparian ecosystems often occur at a lower frequency and are less intense than in upland and terrestrial areas.

The presence of naturally mild fire regimes has led to the hypothesis that riparian zones may act as refuges for fire-sensitive species (Andersen et al., 2005; Le Breton et al., 2021). Obligate seeders may thrive in areas with lower fire regimes, such as riparian zones, where they have time to germinate and grow to maturity before another fire (Le Breton et al., 2021). However, total fire suppression may have deleterious ecological effects. It is not yet understood, what effects the history of fire suppression may have had on Australian ecosystems. However, one study found that the repression of traditional Indigenous burning in Oregon, USA changed ecosystem structure and species composition to a higher presence of fire-resistant white fir than historically and that riparian vegetation had become denser due to greater seedling survival (Messier et al., 2012). In this setting, this shift is ecologically undesirable because white fir does not produce decay-resistant large woody debris, beneficial to both terrestrial and aquatic ecosystems.

As seen in the 2019-2020 black summer in eastern NSW, high-intensity bushfires can disproportionately threaten fire-sensitive ecosystems and species in riparian zones compared to upland or other terrestrial areas (Figures 1 and 2). Drought, made more frequent by climate change, can cause 'terrestrialisation' in the riparian zone and increase the risk of high-intensity fires (Pettit & Naiman 2007). Riparian zones can act as fire corridors when upland fuel loads have been depleted (Segura & Snook 1992). Invasive plants may change the flammability of these systems, and their presence may make riparian systems more fire-prone (Verkaik et al., 2013).

Figure 1. Aftermath of the 2019-2020 Gospers Mountain mega-bushfire in Wollemi National Park near Glen Davis, NSW six months post-burn. The intact canopy in the riparian zone at this creek indicates a low to moderate intensity fire that primarily effected understory vegetation. Source of Photo: Elisha Duxbury.

Prescribed burning may mute the effects of high severity wildfires on riparian zones (Verkaik et al., 2013). For example, Bêche et al. (2005) found that that riparian fuel loads were reduced by 80% by a prescribed burn and that it had minimal effects on riparian species diversity, macroinvertebrate community composition, water chemistry and periphyton biomass in a small stream in the Sierra Nevada, California, one-year post-burn. Conversely, suppression of burning in riparian zones in the Pacific North West of the United States has led to fuel accumulation and the potential for higher severity fires, which leave a more significant impact on riparian systems (Messier et al., 2012).

Figure 2. Aftermath of the 2019-2020 Gospers Mountain mega-bushfire in Blue Mountains National Park near Mt Victoria, NSW six months post-burn. Even the wetter riparian systems and more sheltered valley bottom zones were burnt and there is high mortality of both trees and understory vegetation. Source of Photos: Kirstie Fryirs.

History of fire management in riparian landscapes

Fire has been used in Australia for thousands of years to manage landscapes (Enright & Thomas 2008; Gott 2005). Aboriginal people have used it to stimulate edible tuber growth, open landscapes for hunting, clear ways for travel, and for cultural and religious reasons (Gott 2005; Yibarbuk et al., 2001). In northern Australia, there is a continuous tradition of using fire to manage the landscape (Yibarbuk et al., 2001). However, much knowledge of the practice has been lost in southern Australia through colonisation, particularly in the southeast.

Aboriginal fire regimes throughout Australia likely varied depending on vegetation type and resource level. For example, grassy areas were likely to be burnt every few years (frequently), and heavily wooded areas were likely to be burnt less frequently (Enright & Thomas 2008). How and where to burn was probably a matter of local observation and knowledge as it is in Northern Australia today (Gott 2005). Although, low intensity and frequent burns are typical of historical and current Aboriginal burning patterns (Enright & Thomas 2008).

It is generally thought that riparian systems did not burn in pre-European times. However, this has not been confirmed for all eastern Australian riparian ecosystems, nor have their responses to low intensity fires, characteristic of Aboriginal burning regimes, been tested. The most likely scenario is that certain areas were burnt, and others were left unburnt (Enright and Thomas 2008), as historical references to areas left unburnt are not unusual. For example, Rose (1996, pp. 49) describes Wiradjuri people from the Riverina District reserving places where no gathering, hunting, fishing, or burning was allowed. Karskens (2018) relays reports from early settlers that the River-Flat forests of the Hawkesbury-Nepean catchment were dense and difficult to traverse, with a moist fire-resistant understory, contrary to an open, grassy, highly fire managed landscape. She argues that small fires may have been used to clear pathways but probably were not used extensively to manage this vegetation type.

Landscapes on the eastern coast of Australia have changed dramatically since European settlement and vegetation associations have been fundamentally altered. Many ‘novel’ or degraded ecosystems may benefit from burning and with different fire regimes than historically. ‘Novel’ ecosystems (c.f. Hobbs et al., 2009, 2014) with species in new combinations and abundances than in pre-European times are common in coastal riparian ecosystems in Australia and are often characterised by a high presence of invasive environmental

weeds (Catford & Jansson 2014; Fryirs et al. 2018). It is these novel ecosystems that may benefit from new prescribed burning regimes to control weeds and improve biodiversity (Rossiter et al. 2003).

Fire as a management tool in riparian zones

Few experimental studies have been conducted on prescribed burning in riparian ecosystems in eastern Australia. Most current knowledge comes from descriptive studies on bushfires or after terrestrial and upland prescribed burns (Verkaik et al., 2013). There is only a handful of papers globally that have trialed burning in the riparian zone for vegetation management. They have included studies on Indigenous and ecological burning for improving biodiversity (Andersen et al., 2005; Douglas et al., 2015; Hankin et al., 2013) and managing environmental weeds (Mabbott & Fryirs 2018; Radford et al., 2008).

The long-running Kapalga Fire Experiment investigated the response of vegetation in tropical savannah ecosystems in northern Australia to fire (Andersen et al., 2005; Douglas et al., 2015). Riparian vegetation in this region differed from upland vegetation and shared species in common with rainforest communities. It did not have distinct fire-adapted flora, unlike upland savannah communities (Douglas et al., 2015). Experimental burning showed that there was lower species diversity and a grassier open vegetation structure in burnt compared to unburnt plots in the riparian zone. Burning also lowered eucalyptus seed production, woody vegetation density, and tree species diversity, with dramatic effects for high to moderate intensity burns (Andersen et al., 2005; Douglas et al., 2015). The authors recommended low intensity and infrequent burning in the early dry season for managing riparian vegetation communities in tropical savannah landscapes.

A study in California also investigated the seasonal effects of burning on riparian ecosystems using traditional Indigenous burning techniques (Hankins 2013). It found that autumn and spring burning increased native species richness, while individual species abundance increased with spring and summer burning. Prescribed burning did not decrease woody vegetation cover. They found that the increase in native species richness was often due to the reduction in exotic species abundance post-burn and suggested using altered Indigenous burning methods to control exotic weeds. Dominant exotic species at their study sites included those in genera *Rubus* and *Bromus*, both of which have invasive species in eastern Australia. European blackberry (*Rubus fruticosus* aggregate) is listed as a weed of national significance in Australia (DPI 2021).

Two Australian studies have focused on using fire to control target weeds in modified riparian ecosystems, and one was conducted in coastal NSW. Radford et al. (2008) trialed experimental burns in tropical savannah riparian vegetation on commercial grazing leases in north-eastern Australia to investigate the impacts of fire on native vegetation structure, diversity, and on a target invasive woody weed, rubber vine (*Cryptostegia grandiflora*). They burned in both the wet (low intensity) and dry season (moderate intensity), and trialed both single and double burn treatments in plots over four years. They found that burning in the riparian zone in the presence of woody weeds did not have any irreversible effects on native riparian vegetation or lead to ecological degradation. Additionally, it was effective in reducing the presence of *C. grandiflora*. Wet season, lower intensity fires had lower impacts than dry season fires. They found that a single wet season burn was less effective at controlling *C. grandiflora*. However, two wet season burns were as effective as a single dry season burn at controlling the weed and recommended burning when the fire intensity is low (i.e. wet or early dry season) for controlling *C. grandiflora*.

In the temperate Hunter Valley region of southeast Australia, Mabbott and Fryirs (2018) trialed prescribed burning for controlling giant reed *(Arundo donax*) in the Paterson River catchment. Before burning, they treated stands of giant reed through aerial herbicide spraying, with the aim to increase the dead fuel load so that a controlled burn would be able to reach a temperature sufficient to remove above ground biomass and kill or hinder propagules below ground. Treated stands were then burned along a reach of the Patterson River and compared to stands where only aerial herbicide spraying had been applied. They found that prescribed burning was more effective in decreasing the presence of *Arundo donax* than herbicide spraying alone, with limited or no regrowth in burnt areas 12 weeks after the burn. Additionally, burning was effective in reducing the presence of the exotic species Cobbler's Peg (*Bidens pilosa*), Lantana (*Lantana camara*), Wild Tobacco

(*Solanum mauritainum*), and Trad (*Tradescantia fluminensis*). After burning, they found that both native species and a flush of the environmental weed Castor Oil (*Ricinus communis*) regenerated from the seed bank. They suggested an integrated approach incorporating prescribed burning for controlling *A. donax*, accompanied by follow-up weed control to treat secondary exotic species, such as spot herbicide spraying or manual removal.

Conclusions

This review finds that riparian ecosystems most frequently differ from upland ecosystems in their tolerance to fire. Thus, they may benefit from lower frequency and lower intensity burning than upland or terrestrial ecosystems. Riparian ecosystems are heavily impacted by anthropogenic pressures worldwide, with exotic weed invasion being particularly deleterious in Australia (Catford & Jansson 2014). Preliminary research shows that prescribed low intensity burn regimes may be an effective tool for controlling environmental weeds in coastal NSW Australian ecosystems without degrading native vegetation communities (Mabbott & Fryirs 2018).

So far, studies have been geographically restricted, with most of the research taking place in northern Australia (Andersen et al., 2005; Douglas et al., 2015; Radford et al., 2008), one in the western United States (Hankins et al., 2013), and only one study in temperate coastal NSW (Mabbott & Fryirs 2018). The effect of prescribed burning is yet to be understood riparian ecosystems in southeastern Australia, particularly, when conducted with small, low-intensity fires (Bixby et al 2015). The results of one study in the Patterson River Catchment, NSW show promising results for controlling a target riparian exotic weed (Mabbott and Fryirs 2018). However, the impacts of prescribed burning on other biotic and abiotic components of riparian and instream ecosystems need to be considered before implementing prescribed burning for vegetation management, including long-term impacts (Bixby et al 2015).

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