Science of the Total Environment 542 (2016) 591–602

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Seed banks as a source of vegetation regeneration to support the recovery of degraded rivers: A comparison of river reaches of varying condition

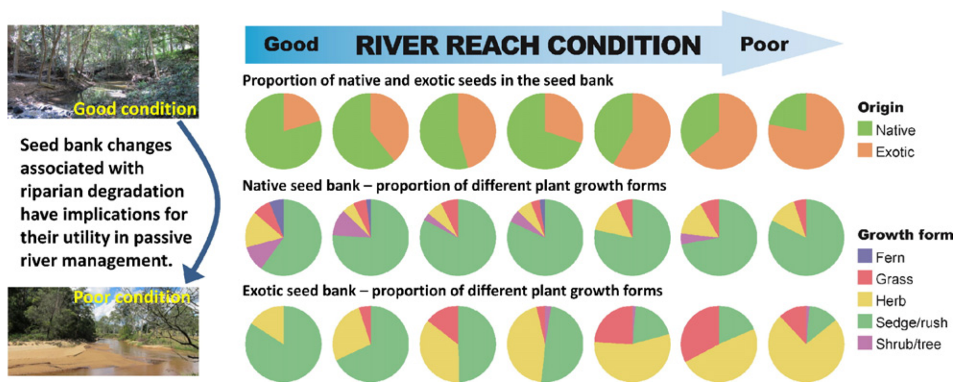
Jessica O'Donnell [a,*], Kirstie A. Fryirs [a], Michelle R. Leishman [b]

[a] Department of Environmental Sciences, Macquarie University, North Ryde, NSW 2109, Australia
[b] Department of Biological Sciences, Macquarie University, North Ryde, NSW 2109, Australia

HIGHLIGHTS

- Seed bank based-revegetation can support passive river management.
- We compare seed bank composition between seven river reaches of varying condition.
- Seed banks reflect changes in vegetation associated with riparian degradation.
- Terrestrial and exotic seeds dominate the seed banks of degraded river reaches.
- Seed bank-based revegetation may be best applied to highly degraded river reaches.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 12 September 2015
Received in revised form 22 October 2015
Accepted 24 October 2015
Available online 3 November 2015

Editor: D. Barcelo

Keywords:
Condition assessment
Ecosystem restoration
Revegetation
River degradation
Propagule bank

ABSTRACT

Anthropogenic disturbance has contributed to widespread geomorphic adjustment and the degradation of many rivers. This research compares for river reaches of varying condition, the potential for seed banks to support geomorphic river recovery through vegetation regeneration. Seven river reaches in the lower Hunter catchment of south-eastern Australia were assessed as being in poor, moderate, or good condition, based on geomorphic and ecological indicators. Seed bank composition within the channel and floodplain (determined in a seedling emergence study) was compared to standing vegetation. Seed bank potential for supporting geomorphic recovery was assessed by measuring native species richness, and the abundance of different plant growth forms, with consideration of the roles played by different growth forms in geomorphic adjustment. The exotic seed bank was considered a limiting factor for achieving ecological restoration goals, and similarly analysed. Seed bank native species richness was comparable between the reaches, and regardless of condition, early successional and pioneer herbs, sedges, grasses and rushes dominated the seed bank. The capacity for these growth forms to colonise and stabilise non-cohesive sediments and initiate biogeomorphic succession, indicates high potential for the seed banks of even highly degraded reaches to contribute to geomorphic river recovery. However, exotic propagules increasingly dominated the seed banks of moderate and poor condition reaches and reflected increasing encroachment by terrestrial exotic vegetation associated with riparian degradation. As the degree of riparian degradation increases, the resources required to control the regeneration of exotic species will similarly increase, if seed bank-based regeneration is to contribute to both geomorphic and ecological restoration goals.

* Corresponding author.
E-mail address: jessica.odonnell77@gmail.com (J. O'Donnell).

http://dx.doi.org/10.1016/j.scitotenv.2015.10.118

1. Introduction

Anthropogenic disturbances such as river regulation and the clearing of riparian vegetation have contributed to widespread geomorphic adjustment and the degradation of rivers across the globe (Galay, 1983; Nilsson and Berggren, 2000). In the last three decades, river management has been globally transformed into a multi-disciplinary enterprise that addresses a great diversity of river values and ecosystem needs (Fryirs et al., 2008; Piegay et al., 2008; Rowntree and Du Preez, 2008; Wohl et al., 2008; Fryirs et al., 2013). Part of this transition is the recognition that once deterioration in riparian condition begins, it is not only costly and difficult to arrest, but even mild deterioration can significantly impair freshwater ecosystems (Hobbs and Harris, 2001; Chessman et al., 2006). Part of a modern approach to river rehabilitation and repair is to work with rivers that are in good or moderate condition to enhance recovery (Rutherfurd et al., 2000; Brierley and Fryirs, 2005, 2008; Ayres et al., 2014). As part of this approach, passive restoration techniques associated with vegetation management are becoming more popular (De Steven et al., 2006; Vosse et al., 2008; Hough-Snee et al., 2013). One aspect of passive restoration that is receiving more recent attention is how to better utilise riparian seed banks in order to support the rehabilitation of vegetation and riparian condition (Middleton, 2003; Nishihiro et al., 2006; Boudell and Stromberg, 2008; Jensen et al., 2008; Vosse et al., 2008; O'Donnell et al., 2015).

Seed banks are recognised as a potential seed source for revegetation associated with ecosystem restoration (ter Heerdt and Drost, 1994; Brock and Rogers, 1998; Middleton, 2003; Bossuyt and Honnay, 2008; Boudell and Stromberg, 2008; Vosse et al., 2008; Marchante et al., 2011; Cui et al., 2013). There has been hope that in degraded environments the seed bank may harbour native species that are able to establish given appropriate active above-ground management strategies. The removal of exotic species, the application of germination promoters such as smoke and related extracts, disturbance of topsoil, removal of livestock grazing and the alteration of inundation or watering regimes are but a few examples of such management approaches (Roche et al., 1997; Crosslé and Brock, 2002; Sarr, 2002; Thomas et al., 2003; Vosse et al., 2008; Marchante et al., 2011; Ruwanza et al., 2013; Sarneel et al., 2014).

In riparian zones, consideration of seed bank-based revegetation has rarely extended beyond the regeneration of floodplain vegetation (Brock and Rogers, 1998; Middleton, 2003; Robertson and James, 2007; Boudell and Stromberg, 2008; Williams et al., 2008; Greet et al., 2012). However, for unstable river reaches prone to erosion, bank slumping and channel widening, it is recognised that re-establishing both channel and floodplain vegetation can aid geomorphic recovery through stabilising sediment, introducing roughness to the channel and promoting deposition (Hupp, 1992; Abernethy and Rutherfurd, 1998; Corenblit et al., 2009b). Whilst these functions might be equally performed by native or exotic species, the regeneration of primarily native riparian plants would support other restoration goals associated with the enhancement of native biodiversity, including aesthetic improvements and the provision of habitat for native fauna. However, to what extent does riparian degradation change the capacity of the seed bank to support geomorphic recovery and contribute to native plant diversity?

Close to two decades of research has revealed some common strengths and limitations of seed banks for riparian revegetation, with different implications for their support of geomorphic *versus* general ecological river recovery. Riparian seed banks are often species rich, owing to seed inputs from both upstream and local vegetation assemblages, and frequently contain many species in addition to those immediately observed in the standing vegetation (Jansson et al., 2005; Capon and Brock, 2006; Webb et al., 2006; Williams et al., 2008; O'Donnell et al., 2015). However, ruderal or pioneer species and early successional growth forms typically dominate the seed bank, limiting the regenerative potential for shrubs and trees (Middleton, 2003; Capon and Brock, 2006; Hopfensperger, 2007; Bossuyt and Honnay, 2008; Williams et al., 2008). From a biogeomorphic standpoint, trees (and the wood they provide) possibly exert the greatest influence on riparian geomorphology, however early successional growth forms such as herbs, grasses, sedges and rushes also perform important functions such as stabilising sediment and introducing roughness to river channels (Hupp and Simon, 1991; Hupp, 1992; Abernethy and Rutherfurd, 1999; Erskine et al., 2009). Fast growing annual herbs, sedges and rushes are often the first to colonise and improve the stability of frequently inundated and disturbed sediments such as bars, and initiate channel contraction processes *via* bench growth (Hupp, 1992; Pywell et al., 2003; Corenblit et al., 2009b). Early successional species also modify conditions such as moisture and nutrient retention in bare sediment or soils that can facilitate the establishment of later-successional species, whether they recruit naturally or are purposefully planted, thus potentially supporting both geomorphic and ecological recovery (Prach et al., 2001).

Perhaps the greatest challenge associated with seed bank-based revegetation is the presence of exotic and invasive species in the seed bank (Williams et al., 2008; Tererai et al., 2014). Indeed the ability to form a seed bank is one of a number of traits that have contributed toward the success of many invasive species (Pyšek and Richardson, 2007). In terms of geomorphic river recovery, exotic species may perform useful functions. Historically exotic species have often been planted with the aim of fulfilling particular geomorphic goals, such as the planting of willows (*Salix* spp.) to aid bank stabilisation (Brooks and Lake, 2007). In many cases however, the intentional or unintentional presence of exotic species along rivers has contributed to adverse ecological or environmental effects, not to mention other unexpected geomorphic issues. Dense willow assemblages for example, were found to force the diversion of water and cause bank erosion in other locations (Brooks and Lake, 2007). In many cases, issues stem from exotics being ill-adapted to local conditions, such as the inadequacy of introduced *Acacia* species' root development to withstand discharges associated with some South African flood regimes, or willows exacerbating drought conditions in arid Australia through their high rates of water extraction (D'Antonio and Meyerson, 2002; Brooks and Lake, 2007). In more recent times, the active removal or control of exotic species has become a key component of river management and restoration activities in many countries (*e.g.* Holmes et al., 2005; Shafroth et al., 2005; Brooks and Lake, 2007). As such, seed bank-based regeneration to support geomorphic river recovery should aim to be consistent with these other ecological or environmental restoration goals.

Within riparian systems, the establishment and succession of vegetation and the formation of seed banks are governed by dynamic processes that are easily affected by riparian degradation. The clearing of native vegetation for example, will reduce native propagule inputs to seed banks. Equally, the encroachment of exotic species associated with anthropogenic disturbance increases exotic propagule input, with the river providing an effective conduit for the hydrochoric (water-mediated) dispersal and the deposition of propagules within seed banks (DeFerrari and Naiman, 1994; Richardson et al., 2007; Nilsson et al., 2010). Flowing water and associated fluvial processes – the erosion, transport and deposition of sediment – may equally remove or disturb existing plant assemblages, deposit propagules on sediment surfaces, or facilitate the formation of seed banks in deposited sediments (Goodson et al., 2001, 2003; Gurnell et al., 2008). The influence of these processes varies laterally and with increasing elevation from the channel bed to the floodplain, increasing the spatial complexity of disturbances (Amoros and Bornette, 2002; Lite et al., 2005; O'Donnell et al., 2014). In contrast, simplification of geomorphic structure is likely to reduce the spatial complexity of seed bank deposition, with flow on effects for the diversity of plant assemblages regenerating from the seed bank (Bendix and Hupp, 2000).