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The effectiveness of active and passive restoration on recovery of indigenous vegetation in riparian zones in the Western Cape, South Africa: A preliminary assessment

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ABSTRACT

Riparian ecosystems in South Africa's fynbos biome are heavily invaded by alien woody plants. Although large-scale clearing of these species is underway, the assumption that native vegetation will self-repair after clearing has not been thoroughly tested. Understanding the processes that mediate the recruitment of native species following clearing of invasive species is crucial for optimising restoration techniques.

This study aimed to determine native species recovery patterns following implementation of different management interventions. We tested the influence of two clearing treatments ("fell & remove" and "fell & stack burn") on the outcomes of passive restoration (natural recovery of native riparian species) and active restoration (seed sowing and planting of cuttings) along the Berg River in the Western Cape. Under greenhouse conditions we investigated seed viability and germination pre-treatments of selected native species.

There was no recruitment of native species in sites that were not seeded (passive restoration sites), possibly because of the dominance of alien herbaceous species and graminoids or the lack of native species in the soil-stored seed bank. Germination of our targeted native species in the field was low in both "fell & remove" and "fell & stack burn" treatments. However, "fell & stack burn" gave better germination for the species *Searsia angustifolia*, *Leonotis leonurus* and *Melianthus major*. Seedling survival in the field was significantly reduced in summer, with drought stress being the main cause for seedling mortality. Germination rates in the greenhouse were high, an indication that harvested seeds were viable. Most seeds germinated without germination pre-treatments.

We conclude that failure of native seeds to germinate under field conditions, secondary invasion of alien herbs and graminoids, the lack of native species in the soil-stored seed bank, and dry summer conditions hamper seedling establishment and recovery on sites cleared of dense stands of alien trees. For active restoration to achieve its goals, effective recruitment and propagation strategies need to be established.

1. Introduction

Riparian habitats provide many ecosystem services, including riverbank stabilisation, nutrient cycling, flood attenuation, regulation of streamflows and stream temperatures, groundwater recharge and water purification (Richardson et al., 2007). However, natural and human-related disturbances occurring along riparian systems have facilitated their invasion by alien plants (Richardson et al., 2007). Alien species diversity and abundance have increased in riparian systems worldwide (Hood and Naiman, 2000; Richardson et al., 2007). Most rivers in South Africa's fynbos biome are lined by dense stands of Australian *Acacia* and *Eucalyptus* species (Forsyth et al., 2004; Richardson and Van Wilgen, 2004; Meek et al., 2010, 2013). These invasions have displaced native species (Richardson et al., 1997; Richardson and Van Wilgen, 2004) and have caused significant changes to both above- and below-ground (seed bank) vegetation composition and guild structure (Vosse et al., 2008). Furthermore, alien tree invasions have substantially reduced streamflow (Dye and Poulter, 1995).

The Working for Water Programme (WfW) was established in 1995 to reduce the impacts of alien species in South Africa. One objective of this programme is to protect and maximise water resources by controlling invasive alien plants (Van Wilgen et al., 1998). Several studies have shown that streamflow increases after the removal of alien tree stands (Dye and Poulter, 1995; Prinsloo and Scott, 1999), but the extent to which native species recover after the removal of the alien trees is variable (Galatowitsch and Richardson, 2005; Blanchard and Holmes, 2008; Pretorius et al., 2008). There is an urgent need to improve our understanding of the impacts of clearing and the factors that influence the subsequent recovery of native species (Holmes et al., 2008).

Little attention has been given to deciding which removal strategy is not only most successful and practical, but also best in promoting natural (unassisted) native species recovery (passive restoration). A study by Blanchard and Holmes (2008) on Australian *Acacia* species in the

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mountain stream and foothill reaches of different rivers in the fynbos biome identified “fell & removal” as the best method for clearing stands of invasive species to facilitate the recovery of indigenous vegetation. On the other hand, burning is known to reduce the abundance of alien species, whilst also stimulating the germination of indigenous fynbos species (Blanchard and Holmes, 2008). But, fire also stimulates germination of alien species which potentially hinders restoration initiatives (Holmes et al., 2008). WfW teams typically fell alien trees and stack slash before burning it after allowing it to dry. Where necessary, herbicide is applied to the stumps to prevent the alien trees from resprouting. Although these clearing treatments are widely applied, their effectiveness has yet to be tested scientifically. The first aim of our study was thus to test the effectiveness of the two clearing treatments used by WfW, namely “fell & remove” and “fell & stack burn”, in promoting natural (unassisted) native species recovery.

Currently, WfW assumes that indigenous vegetation will “self-repair” and that ecosystems will be set on a trajectory towards restoration of pre-invasion structure and function once the main stressor (dense stands of alien invaders) has been removed (Esler et al., 2008). However, studies have shown that it takes several years for passive restoration to be successful mainly due to secondary invasion (Reinecke et al., 2008), resource alteration (Galatowitsch and Richardson, 2005) or ‘legacy effects’ — long-lasting changes in ecosystem structure (Holmes et al., 2008; Le Maitre et al., 2011). More recent research has shown that passive restoration may be difficult to achieve where key biotic and abiotic thresholds have been crossed and resilience has been reduced (Le Maitre et al., 2011; Gaertner et al., 2012); this is most likely in sites where dense invasive stands have been present for several decades (Holmes et al., 2008). This has led to suggestions that active restoration is needed when dealing with heavily invaded sites where thresholds have been passed (Holmes et al., 2008; Gaertner et al., 2012). However, very few studies have examined the effectiveness of active restoration in riparian systems.

Active restoration includes additional restoration interventions beyond removal of the invader so as to facilitate recovery (Holl and Aide, 2011). Such interventions are expensive, but because of the perceived benefits, several options have been tested in riparian ecosystems (Holmes et al., 2008). These include reintroducing propagules of native plants or animals, soil manipulations after alien removal and the active manipulation of disturbance regimes such as fire and flooding (Holmes et al., 2008). To our knowledge, only one study has examined the effectiveness of active restoration in riparian ecosystems in the Western Cape. This study looked at the effectiveness of sowing a mixture of seeds of indigenous plant species in restoring riparian vegetation (Pretorius et al., 2008). In this case the observed presence of native vegetation, eight years after the initial sowing, pointed to the potential of active restoration to facilitate recovery of native vegetation after alien removal.

Two of the commonly used planting techniques in active restoration include direct seeding and the transplanting of seedlings (Doust et al., 2008). Advantages and disadvantages of these techniques have been extensively studied under greenhouse conditions. However, only a few studies have tested these methods under field conditions. Propagated plants have been used simply because they establish more rapidly and increase the chances of restoration success; however they are costly and labour intensive. To our knowledge, no study has examined the direct introduction of cuttings in the field, as a less expensive technique compared to propagating such cuttings (or seedlings) in the greenhouse. Therefore, the second aim of our study was to determine the patterns of early native species recovery following seeding and planting of cuttings.

Some of the challenges faced in active restoration programmes include granivory or herbivory where restoration sites are not enclosed (Iponga et al., 2005) and the failure of native species to germinate due to dormancy (Florentine et al., 2011). Several studies have shown that seed predators, particularly herbivores and granivores, have the potential to significantly reduce seed germination (Crawley, 1992; Milton, 1995). Although seed burial reduces predation thereby enhancing seed survival and germination chances, Christian and Stanton (2004) showed that deeper burial can cause delayed seed emergence. To increase chances of seed germination, several seed pre-treatments for breaking dormancy and accelerating germination have been suggested (Budy et al., 1986). Our third aim was to test seed germination under various pre-treatments in the greenhouse. This is one of the few studies to test various germination treatments for fynbos species targeted for restoration (but see Brown and Botha, 2004).

To achieve our aims we addressed the following questions: (1) Which clearing method is most effective for promoting natural (unassisted) recovery of native species (passive restoration)? (2) How effective is active restoration (by means of seeding and cutting planting) for restoring indigenous vegetation following two treatments for removing stands of the invasive tree *Eucalyptus camaldulensis*: fell & remove and fell & stack burn? (3) Were seeds of introduced native species viable and which germination pre-treatment is appropriate for each of them?

2. Methods

2.1. Study site

The study area was situated along the Berg River in South Africa's Western Cape Province (Fig. 1). The river, approximately 294 km long with a catchment area of about 7 715 km^2, flows into the Atlantic Ocean at Velddrif (de Villiers, 2007). The geology of the upper Berg River catchment is dominated by sandstone and quartzites of the Cape supergroup, whereas the rest of the catchment is underlain by Cape granites and Malmesbury shale (de Villiers, 2007). The catchment is characterised by nutrient-poor lithologies, but some areas consist of deep alluvial flood plains with fertile sediments (de Villiers, 2007). Almost 50% of the catchment area is cultivated agricultural land. River flow peaks during the winter rainy season, from June to August, with rainfall averaging between 300 and 600 mm per annum. The part of the river where the study was conducted is located in the renosterveld (Mucina and Rutherford, 2006). Although fire plays an important role in shaping vegetation communities in the renosterveld (Van der Merwe and Van Rooyen, 2011), riparian vegetation along rivers like the Berg rarely burns. The small area of the remaining native vegetation along the Berg River is dominated by typical riparian species of the region, including *Kiggelaria africana*, *Olea europaea*, *Melianthus major* and *Searsia angustifolia* (Geldenhuys, 2008). The whole river stretch is heavily invaded by alien trees, mainly *E. camaldulensis*, with less abundant stands of other invasive alien plants, notably *Acacia longifolia*, *A. mearnsii* and *Populus* species (Tererai et al., 2013). Invasion of the Berg River by *E. camaldulensis* appears to have started about 50 years ago, but little is known about the early stages of invasion of the river (Geldenhuys, 2008). Also, no studies have reported on the pre-invasion conditions of the Berg River. Further details of the study sites are provided by Ruwanza et al. (2013a).

2.2. Passive and active restoration experiments

To examine the efficacy of both passive and active restoration, twelve sites representing four treatments (each replicated three times), namely two clearing treatments of fell & remove (F&R) and fell & stack burn (F&SB) as well as two control treatments of invaded (IS) and natural sites (NS), were selected. These were set up in the dry bank of the Berg River as the wet bank was very narrow. Prior to clearing, our sites (F&R and F&SB) were heavily invaded by *E. camaldulensis* (>75% canopy cover). In F&R, cut alien trees were removed from the riparian zone using heavy harvesting machines whilst in F&SB the cut alien trees were stacked and left to dry before being burnt. Clearing was completed in December 2010 and burning was conducted in