RESTORE REGENERATE REVEGETATE

A Conference on Restoring Ecological Processes, Ecosystems and Landscapes in a Changing World

5-9 February 2017, Armidale NSW Australia

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February 2018

Restore, Regenerate, Revegetate

A Conference on Restoring Ecological processes, Ecosystems and landscapes in a Changing World

Proceedings of the Conference

Armidale, New South Wales

February 2018

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Foreword

The sustainable management and restoration of terrestrial ecosystems has never been more important and challenging, given humankind's growing reach throughout the biosphere and the resulting accelerating changes from local to global level.

In February 2017, *Restore, Regenerate, Revegetate* conference delegates convened at the University of New England to share our understanding of the challenges and successes in restoration science in a fast-changing world. We hosted some of Australia's and the world's leading practitioners, scientists, consultants and advisers working in this space. A decade had passed since the revegetation industry, landcarers, mine rehabilitation experts, carbon farmers, wildlife scientists, natural resource managers, restoration ecologists, conservation biologists and social scientists last met nationally to review current theory and practice in restoration and landscape repair to sustain ecosystems and services for multiple objectives.

More than 360 delegates attended *Restore, Regenerate, Revegetate*, which featured 190 presentations including 27 plenary and keynote speakers. Delegates included scientists, practitioners, landholders, Indigenous land managers and groups, and government and non-government organisations. The program covered a full spectrum of restoration topics, including the social and political facets of restoration; the practical aspects of restoration project design and execution; the sustainability of restoration in the face of continuing landscape and climate change, and restoration end points, goals and case studies. The symposia topics included:

- Seed genetics and management
- Broad-acre revegetation strategies and techniques
- Riparian restoration and revegetation
- Cost-effective revegetation and restoration
- Connectivity for biodiversity in fragmented landscapes
- Sustainable revegetation in a changing world: planning and design issues
- Revegetation for ecosystem service provision
- Restoration and indigenous NRM
- Sociology of restoration, revegetation and landscape repair
- Grazing management for biodiversity conservation
- Restoration on farms
- Soils and restoration
- Monitoring, evaluation, reporting and improvement of restoration and revegetation programs
- Policy drivers for restoration
- Invasive species and agri-ecosystem restoration
- The role of fauna in restoration

The role of the arts in communicating environmental messages was explored through engaging performance, artwork and a public forum in the Armidale Town Hall, and delegates visited local restoration projects and practitioners during a ¾-day field trip.

In addition to these conference proceedings, video recordings of most conference presentations may be found at: https://www.une.edu.au/about-une/academic-schools/school-of-environmental-and-rural-science/ers-news-and-events/restore-regenerate-revegetate-conference-2017

The first of two journal special issues containing invited papers by conference plenary and keynote speakers can be found at: *The Rangeland Journal*, Vol. 39(5 & 6), 2017 http://www.publish.csiro.au/rj

The second is due to be published as a special online issue of *Ecological Management and Restoration* later in 2018 at http://onlinelibrary.wiley.com/journal/10.1111/(ISSN)1442-8903

On behalf of all my fellow organisers, I would like to extend my thanks to all the conference delegates who made the conference such a memorable event, to our generous sponsors shown on the opposite page, and to Dr Rhiannon Smith who singlehandedly managed the editing and refereeing of these conference proceedings.

Professor Nick C. H. Reid
Chair, Conference Organising Committee
University of New England

18 February 2018

The Armidale Declaration

Agreed to by the approximately 120 delegates attending the final plenary session on 9 February 2017, at:

Restore, Regenerate, Revegetate: A Conference about Restoring Ecological Processes, Ecosystems and Landscapes in a Changing World

The delegates at the *Restore, Regenerate, Revegetate* Conference held at the University of New England, Armidale, New South Wales, from 5–9 February 2017, shared an impressive body of practical and scientific knowledge of how we are restoring Australia's natural heritage and environmental capital across the continent. However, the conference also highlighted several key points that must be addressed if we are to truly meet the challenges and opportunities of land repair.

- We acknowledge the success of the last 30 years of land restoration and rehabilitation, but decry the continuing decline in the extent and condition of Australia's native terrestrial and aquatic ecosystems and the impact that this will have on the health, prosperity, wellbeing and cultural legacy of future Australians.
- We celebrate the significant contributions of many communities across Australia to repair their local environments. However, we have only just begun to address the vast challenge that confronts us. We have developed the skills, knowledge and passion to meet this challenge, but lack the market drivers to achieve the scale of response required.
- We urge support for Indigenous groups so they can continue to work on country to manage our natural resources through the application of cultural science.
- We urge effective action to limit human-induced climate change, which is crucial if we are to build on present and future restoration efforts.
- We recommend ensuring that the principle of 'net gain in biodiversity' underpins all environmental regulation.
- We recommend the development of a stable investment process that is decoupled from politics, has bipartisan support, retains and enhances social capital, and is independently administered, to support the actions and research required to reverse the ongoing decline in Australia's natural terrestrial and aquatic ecosystems (natural capital).
- We recommend the establishment of a federal agency as the premier research and development organisation for promoting the productive and sustainable use of resources in rural Australia, in accord with the 2011 recommendations of the Productivity Commission.
- We recommend the support and continued development of stable, long-term government institutions for natural resource administration and management, and the facilitation of strong partnerships between government, community and industry.
- Finally, we recommend commonwealth, state and local governments define and mandate the use of native flora as an essential component in restoration and landscaping works associated with publicly funded road, rail and other infrastructure programs.

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FOFI5M: Taking threatened species recovery to the next level

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Abstract

Multiple native fauna are threatened by predation and competition. These ecological processes limit their reestablishment and recovery outside of the few high-security conservation reserves they presently occupy. Rangeland sheep and goat production is likewise limited by these same processes, and their population trends reflect those of 'threatened species' in some places. Decline of sheep in particular, has led to a resurgence of investment in pest-proof netting fencing on a scale not seen in Australia since European settlers first erected such fences. Now, for the first time in 100 years, widespread erection of pest-proof fencing on livestock properties has made eradication of large vertebrate pests (e.g. wild dogs, feral pigs, foxes, feral goats, overabundant kangaroos, etc.) possible across vast areas, offering simultaneous and substantial benefits to both agriculture and the environment. These infrastructure developments, driven by agriculture, also mean that fauna and flora conservation aspirations embodied in the nation's first Threatened Species Strategy – namely, the widespread reestablishment and recovery of multiple threatened species outside of reserves – are now within reach on pest-fenced livestock properties. In this context, the FOFI5M RD&E initiative seeks to assist livestock producers with complete eradication of five target pests ('five out'), restore populations of at least five threatened fauna ('five in'), and increase livestock production by five million sheep or their equivalents ('five million'). Convergence of agricultural and environmental investment around a shared problem in this way has the potential to permanently transform the status of threatened fauna and livestock alike.

Threatened species recovery: the big picture

Australia is the largest island in the world, it has one of the most arid and unpredictable climates in the world, it has a host of endemic fauna, and is also – unfortunately – the country with highest number of fauna extinctions in the world (Woinarski 2015). Declines of small-medium sized mammals have been particularly severe, related primarily to competition and predation following the introduction of a variety of animals to the continent, including European rabbits (*Oryctolagus cuniculus*), wild dogs (*Canis familiaris*), European red foxes (*Vulpes vulpes*) and feral cats (*Felis catus*). The general mechanism for these declines is 'vegetation removal followed by predation' (Allen 2011; Woinarski 2015). Many species now exist only on small, offshore islands and in high-security fenced reserves dotted across the country. These reserves house some of the most endangered and vulnerable fauna in Australia, and are critical to the preservation and eventual restoration of these fauna to areas outside of these reserves; but alone, these reserves are insufficient.

The ultimate aspiration of threatened fauna recovery efforts is to establish free-ranging and self-sustaining populations of fauna outside of reserves in areas where populations can remain robust despite the presence of threatening processes (Australian Government 2015). However, attempts to achieve such goals are usually met with rapid failure, due often to unsustainable levels of predation (e.g. Moseby 2011). New approaches are needed to overcome this important challenge.

Land use across approximately half of Australia is dedicated to the extensive grazing of sheep (*Ovis aries*), goats (*Capra hircus*) and beef cattle (*Bos indicus* or *Bos taurus*). Livestock properties will ultimately be the place where threatened fauna will need to be restored to, because the national reserve system is insufficient to protect all of Australia's threatened species. Pest animals are not only responsible for the declines of threatened fauna, but they are responsible for declines of sheep (and in some places, goats) as well. In one sense, sheep are also a 'threatened species', having suffered precipitous declines in density and distribution over the last 50 years, which declines are not wholly driven by economic or market-driven factors (Allen 2013; Allen 2015). Pest animal impacts constrain threatened fauna recovery just as they likewise constrain the recovery of sheep and goats. Decline of sheep in particular, has led to a resurgence of pest-proof netting fencing on a scale not seen in Australia since European settlers first erected such fences. Individual livestock producers are now fencing their perimeters, and groups of neighbouring producers are banding together to fence themselves in, in a process often referred to as 'cluster fencing'. For the first time in about 100 years, this widespread erection of pest-proof fencing on livestock properties has made eradication of large vertebrate pest animals (e.g. wild dogs, feral pigs *Sus scrofa*, foxes, feral goats, overabundant kangaroo species etc.) possible across vast areas, offering simultaneous and substantial benefits to both agriculture and the environment. These fences are being installed primarily to advance livestock production interests (Clark in press), but there exists an unprecedented opportunity to simultaneously advance threatened fauna interests as well.

FOFI5M: Five pests out, five threatened fauna in, and five million sheep

Taking threatened species recovery to the next level requires active on-farm fauna conservation efforts (Neilly 2016), which is already being done incidentally within pest-fenced areas from which pest animals are being eradicated (Clark in press). The FOFI5M research, development and extension (RD&E) initiative, as proposed here, works across three main themes: pest eradications, threatened species recovery, and livestock productivity growth. In our effort to transition threatened fauna from high-security fenced reserves to established free-ranging populations, cluster-fenced or pest-fenced areas on livestock properties offer the intermediate ‘next step’ towards achieving national threatened fauna recovery aspirations (Fig. 1).

Fig. 1. Diagrammatical representation of the role of cluster-fenced areas in achieving threatened fauna recovery aspirations.

There are 32 high-security fenced reserves across the country, enclosing ~360 km^2 of pest-free land (Legge 2017, and associated unpublished data). In contrast, there are now 39 pest-fenced areas enclosing 43,859 km^2 of pest-free land on livestock properties; and these are only the publically-subsidised areas in southwest Queensland, which do not include other privately funded pest-fenced areas or those outside this zone, which probably represent somewhere in the order of another 5,000–10,000 km^2 more than this. Many target pests have already been eradicated from many clusters, which are appearing in or planned for all sheep production areas of mainland Australia. In Queensland, these cluster-fenced areas are already occupied by several high-value threatened species, including yellow-footed rock wallabies (*Petrogale xanthopus celeris*), plains wanderers (*Pedionomus torquatus*) and koalas (*Phascolarctos cinereus*), and are within a very short distance of remnant populations of other species including night parrots (*Pezoporus occidentalis*) and bilbies (*Macrotis lagotis*). Progress towards the FOFI5M vision is presently piecemeal and slow, but willingness to participate appears high. This is because practical alignment of agricultural and environmental effort and investment around the shared interest of pest animal control can potentially achieve national threatened species recovery targets several orders of magnitude greater than current efforts can provide, while simultaneously increasing livestock production. Alignment of investment and commitment to act remains the only impediment to achieving these agricultural and environmental benefits.

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Landscape scale conservation: incentives for cross-property action

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Abstract

Production landscapes are critical for biodiversity conservation. Individual landholders can contribute but the real challenge is coordinated cross-property action at a landscape scale. This paper describes 2 projects through which we have attempted to better understand that challenge. The 'Communities in Landscapes' project (Caring for Our Country 2009-2012) provided coordinated advice and training to develop cross-property biodiversity plans and $70k for each of 7 landholder groups for the initial phase of the implementation. The project generated collaboration on landscape scale biodiversity conservation, but without ongoing support the benefits achieved could be soon lost. The 'Increasing landholder collaboration for landscape scale conservation' project (NSW Environmental Trust 2016-2017) is exploring the nature and extent of collaboration, and the opportunities provided by collaboration for public and private benefit. The vision is for landholders to develop 'Landscape Corporations' which are the vehicle for integrating production and conservation for landholders sharing the same landscape.

Introduction

Achieving coordinated landscape-scale conservation is both critical and complex. It is critical because biodiversity remains in decline largely because our production landscapes lack connectivity and suitable habitat in more productive areas. It is complex because productive areas are also valuable for agriculture. This means that the opportunity cost for taking these areas out of production is high. This is exacerbated by low farm incomes, increasing debt, decline in rural communities, and fragmentary, episodic and inadequate policy responses of governments (Hutchings & Nordblom 2011, Ikin et al 2016). The Australian Government Environment Stewardship Program in its various iterations provided support for successful landholders to manage key areas of endangered ecological communities for conservation. This included the opportunity cost of avoided grazing as well as the cost of fencing, planting and management. However, it required landholders to apply individually, competing with each other for least cost conservation. While existing stewardship contracts will be honoured, the program has now been discontinued. Landscape scale conservation has been a high profile objective of ongoing programs, such as the Greater Eastern Ranges Initiative, which seek to build corridors between the ranges and the coast to facilitate the movement of species. They rely largely on the altruistic actions of landholders with some small grant support from a number of sources to fence off areas from livestock, undertake conservation plantings and manage weeds and pest animals. It is widely recognised that, while these and other actions are worthwhile, their impacts are too small and fragmented to make a significant impact at a landscape scale (Natural Resource Management Ministerial Council 2010; Biodiversity Working Group 2016). In order to address these concerns, we have been active in two projects which we have summarized in this paper. Both are action research projects based on the idea that landscape scale conservation across production landscapes can best be achieved by engaged, connected and empowered communities.

Method

Two case studies are analyzed; the first is 'Communities in Landscapes' (2009-2012), a $4.2million (AUD) project funded by the Australian Governments 'Caring for Our Country program to 'integrate conservation and production across Box-Gum woodlands'. It was managed by Landcare NSW and brought farmers, extensionists and researchers together from 8 community, research, government and non-government organisations to work with people living in and managing Box-Gum Woodlands. Through this project 7 cross property groups were established, and training and facilitation provided to help each group develop landscape scale biodiversity plans. They then had $70,000 in project funds to undertake on-ground works to begin implementing their plan. The short-term success of this initiative stimulated us to look for longer term approaches to maintain successful collaboration. The second is 'Increasing landholder collaboration for landscape scale conservation' (2016-2017), a $150,000 project funded by NSW Environmental Trust. We aim to better understand how to support greater landholder collaboration on landscape scale conservation and sustainable agriculture. It is a partnership between 3 universities actively supported by Local Land Services and Landcare (NSW, Watershed, Little River and Hovell's Creek). Both projects used participatory rural appraisal (PRA) which consists of: key informant interviews for orientation and recruitment of participants; forming a team of researchers and locals to conduct semi-structured interviews of community members; team meetings to build a 'rich picture' of the local situation; and a community meeting to present findings and generate dialogue. In the first project, the PRA consisted of 84 interviews across 3 locations focused on identifying key eco-innovations and eco-innovators. This was followed by selection of groups for cross property biodiversity planning, then working with those groups to develop and implement their plans. At the conclusion of the project, participants joined a focus group discussion to evaluate its success of the cross property component. In the second, 10 key informant interviews set the scene for 55 interviews across 2 locations focused on identifying examples of collaboration, barriers to collaboration and issues on which landholders perceived more collaboration was needed.

Results

The cross property component of the Communities in Landscapes project resulted in 7 locations with cross property biodiversity plans and on-ground works completed according to each plan which impacted on 66,000ha. It built awareness in participants of the need for landscape scale management, and it increased landholders' ownership of the issues in that they viewed themselves as key to implementation. It also generated a thirst for knowledge about how to achieve better landscapes for production and conservation and provided a new purpose for existing Landcare groups, generating ongoing engagement which opened up opportunities for collaboration and social interaction.

The key informant interviews for the landholder collaboration project uncovered the following themes and challenges for incentivising cross-property action including: the need to develop flexible and transferable models of collaboration; the constantly changing and fragmentary role of government was a significant frustration and the availability of funding for groups was critical; the role of industry is becoming more critical due to the diminution and inconsistency of government actions; the role of education is critical in broadening minds, catalysing and stabilising collaboration ; the need to market strategies well; the importance of social cohesion as a catalyst for collaboration and an enabler of group success; the importance of broader community involvement such as from absentee landlords and urban people; the need to facilitate succession of groups by having a large enough pool of people to help transition from one leader to the next; and integrating production and conservation in that participants need to be economically viable, using strategies that are both environmentally and economically beneficial.

The PRA process identified evidence of strong collaboration on: biodiversity management; fire safety and management; cross-property grazing; and pest and weed control. The major barriers to collaboration were: lack of time and burnout; individualistic mentality of some landholders; social dynamics; lack of trust and contact; and lack of fast and reliable telecommunications. Analysis of the information gathered through the PRAs suggests that communities would benefit from greater collaboration to achieve: greater habitat connectivity; shared costs for pest and weed management; shared branding and marketing of produce; development of mobile chicken and bee hive business models; and developing eco-tourism opportunities such as bird-watching, cultural tourism, agricultural tourism and mountain biking.

Discussion and conclusions

It is local communities that maintain continuity in a natural resource management environment that is dominated by projects conducted by people employed on short-term contracts with no real career trajectory. We aimed to support communities to integrate production and conservation using strategies that maintain or improve complex ecosystems and the services they provide, while generating marketable products and services that support livelihoods. A key component is to support communities to generate the social capital needed to collaborate across properties. We found that cross property collaboration is already happening and is highly motivating for those involved. There is great potential for enhanced levels of collaboration to have both private and public benefits. Some landholders are looking for greater collaboration and there is a role for government to support landholder groups who have capability in and motivation for delivering landscape scale conservation. We call for financial incentives for collaboration to catalyse action towards landscape scale conservation, such as a grant providing ongoing support for established groups following a successful participatory process. Such incentives would facilitate the development of 'landscape corporations': legal entities comprising landholders sharing the same landscape and collaborating for a combination of public and private benefits.

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Kangaroos and conservation: can people be better predators?

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Abstract

Populations of the large kangaroo species that can be harvested commercially fluctuate dramatically, and at times cause damage to conservation and agricultural production areas. The commercial kangaroo industry is not achieving sufficient control of irrupting kangaroo populations for reasons which include the nature of harvesting, low demand for kangaroo products and obstructive interactions between the industry, the regulators and landholders. The reintroduction of the Gray Wolf into Yellowstone National Park has assisted in refocusing attention on the impact of top-order predators on herbivores and ecological benefits of such a trophic cascade. In the absence of effective non-human predators of kangaroos in production landscapes, there is a clear role for people to mimic natural top-down predation. The current system of commercial harvesting and damage mitigation permits is ad hoc, allowing kangaroo populations to recover and increase. In this paper, the shortcomings of the status quo are described and a new direction is proposed which involves integrating aspects of native predator behavior with more effective kangaroo culling to provide production and conservation benefits.

Kangaroo management today

As native fauna, kangaroos are legally protected and cannot be killed without lawful permit. Landholders, who consider that numbers are causing or are high enough to cause damage, can apply for a damage mitigation permit and legally shoot kangaroos, but often choose to shoot without a permit. This illegal cull is unregulated and unmeasured. The damage mitigation system is generally under-utilized because it is regarded as ineffective and has not been integrated with the commercial harvesting system (Ampt and Baumber 2006). If a property is in a zone where commercial harvesting is allowed, a landholder can provide access to professional shooters who supply processors with wild-harvested animals under a quota system designed to ensure harvesting will not affect the sustainability of the local kangaroo population.

Much has been written and debated about management of Australia's iconic large kangaroo species. Some of those concerned about the environmental damage caused by sheep have advocated kangaroos as a replacement for farmed animals. Kangaroos are abundant, superbly adapted animals that, cause less environmental damage under normal conditions/ and emit less methane (Ampt and Baumber 2006; Munn *et al.* 2008; Wilson and Edwards 2008). The commercial industry can provide high quality wild-harvested products (meat and skins) but suffers from low domestic consumer demand, unpredictable and unreliable international markets, and frequent campaigns against harvesting by animal rights advocacy groups (Ampt and Owen 2008). In response to the latter, a major domestic processor has implemented male-only harvesting to overcome the 'orphaned joey' issue. Farmers are also using fencing in an attempt to control kangaroo impacts (cluster fencing to exclude kangaroos in Qld and Total Grazing Pressure (TGP) fencing in Western NSW). In NSW, farmers are urging Local Land Services to step in (Kangaroo Management Workshop in Deniliquin and Cobar in 2016), and harvesting regulations are being reviewed.

There is potential for change in the industry and its regulation, but progress is slow and as a result, for many years quotas have not been taken. This, coupled with a scarcity of natural predators, has meant that kangaroo populations have undergone extreme fluctuations. They increase rapidly in arid areas experiencing a series of wet years then, as the landscape dries, they move in large numbers causing damage to fences, crops, pastures and native vegetation, and many die of starvation. For managers of the conservation estate, the damage to native vegetation is a concern as it impacts both flora and fauna. Kangaroo impact on conservation values is greatest during drying years when livestock density, predation pressure and commercial harvesting are low. As a result, kangaroo management is currently not effective for either production or conservation (Ampt and Baumber 2012) and there is an obvious need to consider alternatives.

Understanding predator-prey relationships

Since wolves were reintroduced to Yellowstone National Park in California from 1995 they have caused what has been described as a trophic cascade. For example: despite beavers being Gray Wolf prey, beaver colonies increased from 1 to 18 due to improved plant communities and this has improved the health of rivers; Elk populations have less impact on vegetation because their population has declined and they are moved on by the wolves. These changes have increased regeneration diversity and abundance and reduced riverbank erosion (Beschta and Ripple 2016). Whilst every ecosystem is different and it would be simplistic to think predator reintroductions in Australia would have a similar impact (Morgan et al 2016), the Yellowstone experience suggests a new direction for kangaroo management in Australia.

When predators are present they create a 'landscape of fear' which has non-consumptive as well as consumptive impacts on prey (Laundre *et al.* 2014). For example, kangaroos display anti-predator vigilance (stand upright) in the presence of predators that is both behavioural and ecological, is enhanced by greater predator presence and is instigated by extra-vigilant individuals. For example, kangaroos display anti-predator vigilance (stand upright) in the presence of predators that has both behavioural and ecological effects: they will stop chewing when perceived predator risk is greater; this is increased by greater predator numbers; and is instigated by extra-vigilant individuals (Favreau *et al.* 2014; Favreau *et al.* 2015). Kangaroos also detect predator faeces by smell (eg. Dingo and Red Fox) and avoid areas where it is present (Mella *et al.* 2014). Evidence suggests that Dingo control leads to increased kangaroo numbers if livestock density is low, that kangaroo control is enhanced by allowing greater predation by Dingoes, and that Dingo control reduces predation pressure on prey species (Allen 2015; Prowse *et al.* 2015). However, Dingoes interbreed freely with feral dogs which cause significant sheep losses, with the prediction that it may cause rangeland sheep production to disappear in 30-40 years (Allen and West 2013). Consequently it is likely that any move to increase Dingo numbers will be highly controversial.

The future of kangaroo management

Rather than relying solely on kangaroo culling and harvesting, there is a place for kangaroo repellents such as dingo urine and faeces (or synthetic equivalents) in areas of high stock losses together with Livestock Guardian Dogs whose presence can replace natural predators (van Bommel and Johnson 2016). An integrated approach incorporating these methods and also with a focus on humans as predators could generate significant benefits. Research in Norway into the impact of multiple predators on Roe Deer suggests that the combined effect of a consistent presence of adaptive human hunters and other predators increased avoidance behaviour (Norum *et al.* 2015). Human mimicking of 'predation behaviour', may have an impact on prey behaviour that could reduce damage caused to both production output and conservation values. What should be trialled is for humans to impose an intelligent predatory presence that can maximising anti-predator vigilance by creating a 'landscape of fear'. This could be achieved by an integrated program of applying a constant but variable "predator presence" with or without harvesting, dependent on the outcomes of the former. Harvesting and non-harvesting zones could be created if required through manipulating natural predator-prey behaviours. Culling could also be included as a pre-emptive action to reduce kangaroo numbers prior to an irruption if predicted by environmental conditions. Landholders can hold the key to achieving better management of kangaroos by being keen observers of kangaroo behaviour, seeking partnerships with wildlife experts, and implementing locally-based collaborative strategies.

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Grazing eco-innovators: are they regenerative?

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Abstract

The 'Communities in Landscapes' program sought to work with local people to identify strategies that integrated conservation and production to improve the extent and condition of grasslands derived from box gum grassy woodlands. The program uncovered a community of practice of innovators who claimed to be successfully and profitably regenerating native grasslands by using adaptive grazing management involving short duration high density stocking with long rest periods. This study aimed to investigate the impact of the innovators' management. Ten paddocks managed by 10 different innovators were compared across a fence-line with paddocks subject to continuous stocking by a neighbour. Full paddock histories and farming system descriptions were obtained from all innovators and neighbours. Perennial plant and litter cover, landscape function and vegetation diversity were measured on all sites, and soil chemical, physical and microbiological analysis were conducted on 4 sites. The innovators' paddocks had greater native plant diversity, perennial plant and litter cover, landscape function indices of nutrient cycling, water infiltration, soil stability, and levels of soil P, N, C and pH. The innovators were highly enthusiastic about the impact of their management and were motivated to continue to adapt their practices. Whilst detailed financial analyses were not undertaken, innovators reported sustained or increased profitability and optimism about future viability and long-term sustainability. The study concluded that widespread adoption of the adaptive grazing management used by the innovators would improve the extent and condition of grasslands and the sustainability of the grazing system.

Introduction

The establishment of 'improved' pastures not only destroys native grasslands, but their profitability, productivity and longevity have not lived up to expectations, causing ecosystem instability which leaves landscapes vulnerable to the highly variable seasons (Kemp and Dowling 2000; Dowling et al 2006). At the same time, cereal cropping has become increasingly risky due to the combined impact of climatic unpredictability, increasing input prices and market uncertainties. Despite continued advice to persist with these practices, many farmers have turned towards alternative approaches such as those offered by Holistic Resource Management and Grazing for Profit organisations who advocate management that encourages perennial native grasses to regenerate. These approaches involve various forms of rotational grazing which have been adopted on grasslands in many parts of the world. Meta analyses of studies comparing rotational to more conventional grazing systems have shown little benefit, but are of limited applicability as none took an adaptive, complex system approach incorporating bio-physical and social objectives (Briske *et al.* 2011). With funding from Australian Government natural resource management programs, we have engaged with the emerging community of innovators who have adopted and adapted alternatives to conventional pasture, grazing and cropping practices with particular emphasis on high intensity – low frequency stocking (HILF). A key activity was a benchmarking study that aimed to identify and comprehensively describe the key eco-innovations and assess the economic, social and environmental impact of identified innovative practices.

Methods

The research program started in 2010 with a participatory rural appraisal (PRA) based around the towns of Wellington, Cowra and Wagga Wagga in the mixed cropping and grazing zone of SE Australia. The PRA involved an interdisciplinary team conducting on-site interviews with 84 landholders followed by workshops to make sense of the interviews. Key innovators were identified and recruited for the benchmarking study. Ten eco-innovators were selected for the Benchmarking Study of Innovators (BM) according to the following criteria: successful adoption of a practice or suite of practices for a period of more than 5 years; recognition from peers that the adopted practice/s have led to improved environmental and production outcomes; identification of a suitable sampling site next to a comparison site on a neighbouring property; and willingness of the innovator and neighbour to participate. Semi-structured interviews were conducted with all innovators and comparison landholders. Landscape function analysis (LFA) and vegetation surveys were conducting on all 10 sites. Soil sampling and analysis for chemical, physical and microbiological characteristics was conducted on four of the sites. An individual report was completed for each site and sent to the participants for feedback. The individual reports were evaluated and pooled where appropriate so that broad conclusions and recommendations could be developed.

Results and discussion

The innovator sites all had significantly and substantially higher mature perennial grass basal cover and LFA values for nutrient cycling, water infiltration and soil stability (Table 1). Soil microbial communities were different in several measures including abundance, diversity and activity. Soil chemical and physical analyses revealed significantly higher soil pH, C and P values and a lower bulk density in the top 10 cm on the innovators' paddocks (Table 2 not presented due to lack of space). Analyses of the paddock histories and management practices led to the conclusion that the key difference between the innovators' and neighbours' systems was grazing management. An adaptive form of rotational stocking was used by all innovators who aimed for a high stocking density for a short stocking period (1–5 days) so that the whole paddock would be disturbed relatively uniformly (standing grasses trampled, plants grazed to a pre-determined level) in the time the animals were on the paddock.

All innovators did some form of feed budgeting which involved estimating how many grazing days were available ahead, and had a formal or informal method for monitoring grazing impact and time needed for recovery. They varied their grazing plans with shifting environmental and market conditions. All were highly adaptive in their approach and were working to better understand how their land and livestock responded to changing conditions, and none applied a rigid formula. All innovators were strongly motivated to continue along the path they had chosen and were optimistic about the potential for further improvement. As a result, they were looking forward to a viable future on the property. Comparison sites were stocked more or less continuously, with infrequent periods of rest of less than 30 days when the paddock looked bare. Stocking rates overall varied from very low to above average for the district. In some sites, innovators' stocking rates were higher than comparisons'.

Table 1. Differences in LFA indicator values between innovator and comparison sites (mean ± SE) and the p-values for paired t-tests.

LFA indicator	Innovator	Comparison	Difference	p-value	% increase
Stability	72.4 ± 1.0	61.6 ± 1.5	10.8 ± 1.1	<0.001	17.5
Water Infiltration	44.0 ± 1.9	31.5 ± 1.2	12.5 ± 1.0	<0.001	40
Nutrient Cycling	38.4 ± 1.6	23.2 ± 1.1	15.2 ± 0.9	<0.001	65

Conclusions

Carefully managed short duration (1–7 days), high-intensity grazing (enough stock per unit area to create the 'right level' of disturbance) followed by long rest periods (60–180 days) can increase the perennial (usually native) component of a pasture and increase litter. System productivity is highly likely to increase due to:

- organic matter accumulation and no soil loss
- higher water infiltration and reduced run-off
- perennial grasses accessing greater soil volume
- higher percentage of plant growth becoming litter
- decomposition of litter by more abundant, diverse and active microbial ecology.

This study and other research activities in this program suggest that the innovators are part of a community of practice that is successfully integrating agricultural production with environmental management (Cross and Ampt, 2016). Their adaptive approach challenges existing agronomic paradigms and the integrative research approach used in this study was effective in representing the nature of the changes their practices had caused. If more widely adopted, their management principles and practices could be highly regenerative and contribute significantly to the viability of rural communities. This study used an ecological research approach that integrated production and conservation components. A conventional agronomic approach is not compatible with the adaptive nature of grazing eco-innovators. Greater adoption of eco-innovator practices is likely to have a positive impact on production and help regenerate grasslands.

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Unlocking the self-sustaining restoration potential of drained wetlands

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Abstract

The great opportunity presented by addressing water management as a restoration method at strategically selected former (drained) wetland sites is the ability to trigger a self-sustaining spontaneous process of habitat recovery. The goal of this approach is to unlock the natural regeneration potential of wetland flora and fauna species that are adapted to respond to dynamic hydrological conditions. In some circumstances inundation can provide excellent natural weed control and reduce competition, while simultaneously promoting an aquatic vegetation response – making rapid improvements in ecosystem condition possible. This paper provides practical examples of where this approach has been successfully employed by Nature Glenelg Trust in South Australia and Victoria and the broad range of benefits (which extend far beyond ecology) that have resulted from the projects undertaken in recent years.

Introduction

Nature Glenelg Trust (NGT) is a charitable, not-for-profit environmental organisation operating in south-eastern Australia, with a particular emphasis on wetland restoration enshrined in its charter. NGT has worked on a wide range of wetland restoration projects across both private and public land in south-eastern South Australia and western Victoria, two regions that have suffered a severe decline in wetland extent, with over 90% and 60% respectively lost since European settlement. The drivers of this change (to water resources and wetlands) are multiple and complex. They include: climatic trends, plantation establishment, urban and rural development, water extraction for irrigation, and perhaps most importantly, artificial drainage. Crucially, while some of these factors either can't be managed or take protracted timeframes to influence, drainage is usually the most feasible threat to manage with demonstrable immediate results. This paper shares NGT's experience at case study sites, using the logic and tools of wetland restoration to illustrate self-sustaining habitat recovery in practice.

The logic of wetland restoration

Comprehensive artificial drainage on private land for agricultural development has left many former wetland features in a highly modified or degraded state. One attempt to remediate such areas includes a large-scale, long-term hydrological restoration project within the Piccaninnie Ponds wetland system of SA (Bachmann 2016). One of the components of the project was the successful restoration of former farmland at Pick Swamp; a site that was purchased for addition to the neighbouring Conservation Park in 2005. Restoration commenced with the backfilling of drains in 2007 and the property quickly responded, with an immediate and spontaneous recovery of aquatic flora and habitat. This process of 'just adding water' culminated in the area being recognised as part of Australia's newest Ramsar site (Piccaninnie Ponds Karst Wetlands) in 2012.

The tools of wetland restoration

While the recovery of the natural water regime is the ultimate goal for wetland restoration projects, there are a number of important steps and information requirements that need to be considered. This includes evaluating important background information such as:

- site history, tenure and number of affected landowners;
- current condition, remnant values and predicted response;
- location in catchment and water security; and
- configuration of artificial drainage.

Aerial imagery and digital terrain modelling (based on LiDAR data) form the basis for assessing development history and running predicted inundation scenarios, and are also a critical tool for communicating expected impacts to stakeholders and designing intervention works. Fig. 1 illustrates this method for one of the case study sites, Scale Swamp.

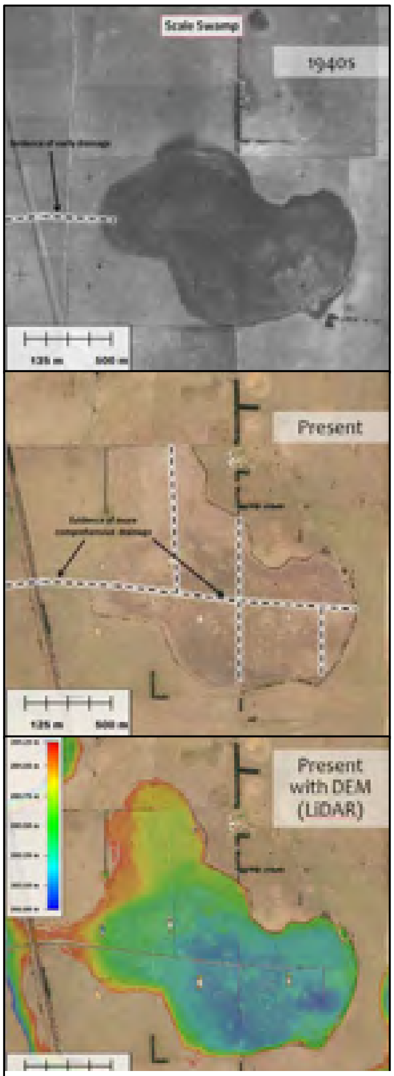

Fig. 1. Tools for restoration planning at Scale Swamp, Victoria. Historic / modern aerial imagery and use of a Digital Elevation Model.

For situations with a high degree of uncertainty, designs can be tested and refined using trial measures to test assumptions through 'learning by doing', such as constructing geo-fabric sandbag weirs. In other situations, where a consensus exists and confidence levels are high, immediate permanent earthworks or concrete structures can be installed. The key consideration that governs the process is the fact that every site is different, with its own particular set of circumstances that require proper investigation, before formulating a proposed restoration response and works. Three examples of NGT projects showing site characteristics where different methods have been used to achieve restoration are summarised in Table 1.

Table 1. Evaluation of three NGT restoration sites.

Characteristic	**Scale Swamp (Vic)**	**Green Swamp (Vic)**	**Mt Burr Swamp (SA)**
Tenure	Private	Private & Public	Private
Catchment location	Top of closed catchment	Mid-catchment in a wider drainage network	Top of catchment
Nature/impact of artificial drainage	Comprehensive (>50 yrs), minor seasonal inundation	Sill level lowered (<10 yrs), deepest areas still inundate	Comprehensive (>25 yrs), minor seasonal inundation
Historic aerial images	1940s	1940s	1950s
Confidence in predicted inundation extent and water security	High	High	High
Agreement from affected neighbours	Yes	Yes	N/a
Other design considerations	Need for stock crossing	Need to accommodate passing flows	Need to manage level during property transition
Chosen restoration method to reverse artificial drainage	 Earthen block, with track	 Levee and concrete spillway	 Adjustable sandbag weir
Immediate ecological response	Yes – waterfowl and native replacement of exotic plants	Yes – including threatened species	Yes – including threatened species

Discussion

Thanks to the persistence of a remnant seed bank and/or rhizomes (and no history of cropping), spontaneous aquatic ecological recovery has taken place at all three case study sites, and two of the sites are known to support populations of *EPBC Act* listed species. The recovery of habitat at Mt Burr Swamp after drain regulation in August 2016, is shown in Fig. 2 (right) facilitating an immediate recovery of a bed of Water Ribbons (*Triglochin procerum*), habitat favoured by the Growling Grass Frog (*Litoria raniformis*). Indeed the immediate response of this nationally threatened amphibian to restoration works has already been recorded (Bachmann 2017). However, the capacity for rapid ecological recovery is only a part of the wider story of wetland restoration benefits, which include: aquifer recharge and water retention in the landscape, buffering against climate variability/change, water filtration, flood buffering, aesthetics and recreation, and for sharing stories of hope in a time of growing environmental despair.

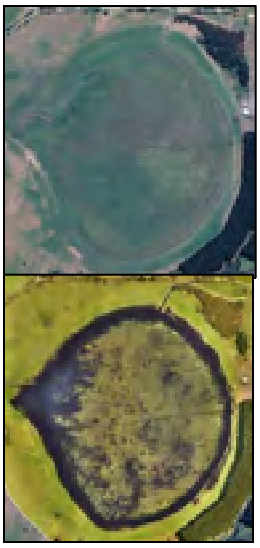

Fig. 2. Restoration of Mt Burr Swamp, SA. Aerial imagery from Dec 2015 to Nov 2016.

Conclusion

At strategically selected sites in degraded landscapes, wetlands are capable of rapid, self-sustaining ecological recovery. The potentially higher up-front land or opportunity costs are usually offset by fast environmental returns and lower ongoing investment in maintenance. In summary, water is an excellent medium for restoration – both literally (as demonstrated), but also conceptually – because it forces us to think outside of linear boundaries and pushes beyond the limitations often encountered with terrestrial restoration. Using water as a restoration tool, natural processes can have great effect.

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Breaking long-term deadlocks to restore wetlands on public and private land

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Abstract

The science of environmental restoration in many respects is extremely well advanced, but how do we turn the science into practice? How do we work with a wide range of people from different backgrounds to deliver on-ground action? When confronted with doubt and opposition, scientists often retreat to what they know and come back later with more data and evidence to prove that they are 'right', only to meet the same resistance. There are also times when information gaps exist that prevent people from ever being able to have all the answers they need before they begin, meaning restoration options may need to be trialled first. Fortunately, as well as what people know, achieving on-ground action also relies on how confident people feel about the issue; which means building trust is crucial. This paper explores how trust is built, by looking at the way scientific ideas are shared and communicated, and how people – both within management agencies and the wider public – can become part of a restoration journey. Practical examples of wetland restoration projects are used to illustrate how long-term deadlocks, hampering the progress of restoration projects on both public and private land, can be overcome; in some cases, shifting positions or mindsets that had been entrenched for decades.

Introduction

Nature Glenelg Trust (NGT) has been working to restore habitats across a broad geographic area (specifically NRM regions situated between Melbourne, Victoria and Adelaide, SA) of south-eastern Australia, since the launch of the organisation in January 2012. NGT is a registered charity and not-for-profit organisation that applies ecological expertise to fill the gaps that often emerge between academia, policy and practice. This approach, combined with a willingness to tackle issues across all land tenures, demands maximum flexibility; hence project delivery by the organisation deliberately varies according to the individual circumstances and needs of each site, including their socio-political context. This unique approach has brought NGT into contact with some difficult, at times seemingly irresolvable, and complex issues – particularly those that involve working with water on public land, or those at the public/private land interface.

Indeed, water management is a crucial theme in western Victoria and south-eastern South Australia, where over 60% and 90% respectively of the original wetland extent has been lost since European settlement as a result of drainage and development. The biodiversity impact of this landscape-scale change has been dramatic, and hence the restoration and recovery of the ecological values of modified wetlands in this region, especially on public land given its already reserved status, is a clear immediate priority. With this background in mind, the two wetland systems that are the focus of this paper are those associated with the upper Wannon River, near Dunkeld (Victoria) and Long Swamp, near Nelson (Victoria).

Background to the case study sites

Gooseneck Swamp and Brady Swamp are two of four floodplain wetlands (about 1000 hectares in total area) associated with the upper Wannon River, at the terminus of an inland delta that has formed over a large, flat area where the river reaches the plains after exiting the mountains of the Grampians. The destination for flows from the Wannon River, en route to the ocean after it joins the Glenelg River, is the coastal estuary at Nelson, near the border with South Australia. It is here that Long Swamp, a 15km long wetland system (over 1000 hectares in size), also discharges fresh water flows into the Glenelg River estuary near its mouth. To understand the ecological issues and socio-political context surrounding both systems, please refer to Table 1.

Table 1. Characteristics of the two case study wetland sites.

Characteristic	Upper Wannon Wetlands	Long Swamp
Large, functional (albeit modified) wetland system	Yes	Yes
Important remnant populations of nationally threatened species	Yes	Yes
Decades-old artificial drainage impacting on water regime and biodiversity values	Yes	Yes
Local communities supportive of restoration, but hit institutional barriers to action	Yes (for 25 years)	Yes (for 15 years)
Land tenure	Public & Private	Public
Restoration efforts stalled due to government agency caution about impacts on:	Neighbouring land	Biodiversity values

Studies were commissioned but no on-ground restoration action occurred because of ongoing uncertainty within government about the options for works, their potential impacts and the perceived risks. Hence despite strong community support, restoration efforts at both sites stalled; leading to an escalation of community frustration.

The method for a way forward – it all comes down to good communication

Resolving these issues required a process of flexible, effective communication, tailored to suit the needs of each site. Some methods common to both sites that helped to diffuse tension and create an atmosphere between parties conducive to finding a way forward included:

- Talking openly to all the players and listening to their concerns, in a place where they are comfortable;
- Doing the homework necessary to identify if the obstacles to action were perceived or real;
- Removing or addressing active sources of tension (e.g. pulling the issue out of the political arena); and,
- Providing a fresh, independent, scientific and well-informed perspective on the issue.

Throughout this process, NGT worked as both an informed intermediary and active participant, building the necessary trust with all parties; something that is often easier to do when not a historical player in the issue and also greatly assisted by being independent of government (for building trust with the community). Reaching the next stage, where everyone is listening and open to receiving new information, is a critical step because this type of trust is the pre-requisite for finding solutions. Confidence levels can then further grow, as:

- A strategy is agreed to address real information gaps;
- A way forward that everyone can support is devised and communicated;
- Trial measures are employed to test ideas and assumptions (learning by doing) when still in doubt;
- The difference between real and perceived risks becomes clearer; and,
- Lasting options often then emerge that everyone can agree to work towards.

Results at the case study sites

After working through this approach, the steps towards restoration at our case study sites are explained in Table 2.

Table 2. Working towards lasting restoration at the case study sites.

Steps towards lasting restoration	Upper Wannon Wetlands	Long Swamp
1. Key information gaps addressed	• Drainage history • Elevation data • Communication with neighbours	• Baseline Survey • Review of historic change • Elevation data evaluation
2. Restoration trials initiated (led by NGT, reducing risk to government)	• 3 geo-fabric sandbag structures installed in 2013 and 2014 (these are reversible, adjustable, and not a fixed asset)	• 1 major geo-fabric sandbag structure in 2015 (after 2 earlier trials in 2014) • Final structure level adjusted upwards during the trial to improve results
3. Reviewing outcomes of the trials	• Hydrological (and ecological) response quickly answered key questions • All parties confident to move immediately towards a permanent solution	• Extended monitoring period showing positive hydrological and ecological response trajectory • Growing interest in converting the trial to a more permanent solution
4. Lasting restoration	• Outcomes justified the case to seek funding for permanent works (complete backfilling of drains) • 3 wetlands permanently restored in early 2015, with a Victorian Government grant	• A project to assess project outcomes so far and design a permanent solution commenced in 2017, led by NGT and funded by the Glenelg-Hopkins CMA

Discussion

Wetland restoration is particularly suited to trial solutions, to build confidence of all parties. Not only are geo-fabric sandbag structures reversible, adjustable and able to withstand a range of conditions, they also provide an opportunity for hands-on community participation. This type of practical activity, directly contributing towards a lasting solution is also therapeutic for community members frustrated by the preceding years of inaction. As so, after 25 and 15 years respectively of waiting for action, progress was made in a short space of time at our case study sites. At the upper Wannon Wetlands, permanent restoration works have occurred, while at Long Swamp (Fig. 1), the final steps towards a permanent restoration solution are now in place.

Fig. 1. The Long Swamp Restoration Trial

Conclusion

From working through these complex issues that at first seemed intractable, it is clear that if you (a) do your homework and earn respect, (b) bring everyone together and then along on the journey, and (c) invite the community to participate in the solution, then great things in wetland restoration become possible. This story has been shared in the hope it will inspire similar action at other important wetlands in the future.

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From illegal clearance to restoration reserve – the story of Eaglehawk Waterhole

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Abstract

Eaglehawk Waterhole is a 684 hectare (1700 acre) private nature reserve owned and managed by Nature Glenelg Trust, situated near the western end of the Little Desert National Park, on the border between SA and Victoria. The property has a chequered history, including a successful state government prosecution of a previous owner for illegal clearance, which left a legacy of a complex legal and management framework over the site. This paper explores how the policy drivers and systems that govern native vegetation clearance in South Australia played a role in making the future protection of the property a more feasible proposition, several years after the illegal clearance issue was resolved. Having policy mechanisms in place, capable of creating a positive legacy from otherwise negative circumstances, has a critical role to play in environmental management and restoration. But a word of caution – policy alone is never the answer for achieving lasting or strategic on-ground results – and when the property was placed on the open market, its future management appeared uncertain. At that point, a new partnership between Nature Glenelg Trust, the Native Vegetation Council and Nature Foundation SA Inc. resulted in the majority of the actively farmed portion of the property (i.e. 510 of the 684 hectares) being secured for conservation and restoration – meaning this story has a happy ending.

Introduction

Nature Glenelg Trust (NGT) is a charitable, not-for-profit environmental organisation operating in south-eastern Australia, with a particular emphasis on habitat restoration enshrined in its charter. Since its launch in January 2012, the organisation has worked on a wide range of projects to restore habitat across both private and public land in South Australia and Victoria. In some cases however, when restoration of a strategically located site requires a whole-of-property scale solution, NGT has also been willing to develop funding partnerships to allow purchase and establishment as private Habitat Restoration Reserves. NGT now owns and manages two such reserves: Mt Burr Swamp (near Millicent, SA) purchased in 2016 and Eaglehawk Waterhole (the subject of this paper, near Frances, SA; Fig. 1) purchased in 2013. Eaglehawk Waterhole is a 684 ha (1700 acre) woodland property, situated within 2km of the state border, near the western edge of the Little Desert National Park in Victoria. The property was part of a large pastoral station (Run 447) until 1923, when the wider area was sub-divided for closer settlement as the Hundred of Geegeela. Throughout this period the site was grazed, but the property escaped physical clearance until the late 1960s; a time when accelerated rates of land clearance in the surrounding landscape saw large areas of land converted to more intensive agricultural uses.

The role of government native vegetation policy

This pattern of accelerating land clearance continued in the wider landscape until the introduction of South Australia's first native vegetation laws. Hence, on the 12th of May 1983 statutory controls (in the form of Regulations under the *Planning Act 1982*) were introduced; later superseded by the *Native Vegetation Management Act 1985* and finally the *Native Vegetation Act 1991*, which is still current and the statutory responsibility of the Native Vegetation Council (NVC).

The last broad-acre clearance at Eaglehawk Waterhole occurred in 1981, and although grazing of the site continued, the new laws left the property in a partially developed state. The previous owners (immediately prior to NGT) purchased the property in 1987 and it continued to be used for grazing, but without major investment in agricultural improvement for several subsequent years, leaving many natural values either intact or recovering (through the process of natural regeneration). However, a period of renewed activity on the property in the early 2000s involved 1109 trees being cleared without consent from the NVC. The matter was investigated in 2003, and the owner was convicted and fined in 2007. An application to clear regrowth was submitted in 2006, but this was put on hold pending the outcome of the earlier legal proceedings. Remnant tree cover on the property at that time can be seen in Fig. 1. Further legal proceedings to 'make good' the clearance were imposed with the registration of a Court Order and Heritage Agreement over parts of the property in 2009.

Fig. 1. Eaglehawk Waterhole.

In terms of pro-active policy, a Biodiversity Offset Incentive Scheme (also in 2009) made a payment for fencing and destocking of all of the large, intact areas of native vegetation on the property. This duplicated some of the outcomes of the court order, and led to a further on-title agreement, under a separate Act.

Policy 'carrots and sticks' only go so far

While these legislative mechanisms played a decisive role in preserving (and preventing the further loss of) the biodiversity values of the property, the policy carrots (incentives) and sticks (legal proceedings) are limited in what they can ultimately achieve, by both practical constraints when farming is the predominant land use and the intentions and attitude of the landholder. In the case of Eaglehawk Waterhole, the net effect of these policies resulted in:

- Permanently protected areas almost exclusively consisting of habitat associated with the lowest fertility soil types, such as stringybark woodlands over deep sands;
- The highest fertility soil types, featuring the more threatened box, buloke and gum grassy woodlands, being preferentially cleared and continuing to be grazed;
- Poor layout and configuration of conservation areas; and,
- A total of 510 ha of the 684 ha property, much of which retained significant biodiversity values, still being outside formal conservation and under long-term threat.

This was the situation when the property was placed on the open market for sale in mid-2013, and brought to the attention of NGT. At this point the property faced an uncertain future. If it remained as a mixed farm, land-use intensification was likely, whereas if it were purchased and consolidated for biodiversity conservation, it would present a unique opportunity for whole-of-property scale restoration in a priority landscape.

Results

After NGT secured the property under contract, an intense period of negotiation to set-up the necessary funding partnerships with the NVC and Nature Foundation SA Inc. resulted in the purchase being settled in December 2013; commencing a restoration journey that continues today. In July 2015, NGT completed a Management and Restoration Plan for the property (Haywood et al. 2015), and three partnership projects are currently underway to complement natural regeneration with active revegetation works; i.e. Landscape Links (SA Department of Environment, Water and Natural Resources) (see Fig. 2), 20 Million Trees (NGT with Australian Government funding) and Habitat 141 revegetation (Greening Australia). Additionally, thousands of volunteer hours have so far helped with a range of activities to improve the values of the property, such as: internal fence removal, tree planting and guarding, fauna surveys, nest box installation, and ground habitat restoration (such as log placement). NGT ultimately intends to enter a new, whole-of-property Heritage Agreement to offer permanent protection, while also working to simplify the current complex (in some cases overlapping and now unnecessary) legal protections over the property that are a by-product of the history described.

Fig. 2. Before and after images of revegetation work.

Discussion

It is clear from the story of Eaglehawk Waterhole that the 'carrot and stick' approach of good native vegetation policy played a role in enabling the environmental values of the property to persist despite agricultural pressures. However, policy mechanisms are often designed to 'block' (stop the bad) whereas active restoration requires creative means that go 'over and above' arbitrary legal thresholds (to enable and encourage the good). Hence, policy alone (which can't, for example, prevent the ongoing continuation or intensification of farming practices) is not – and likely never will be – enough to force whole-of-property outcomes in strategic places where they would ideally occur, but can certainly help encourage that outcome. As illustrated in this example, these projects won't happen by themselves if left to policy mechanisms alone, and that is where the non-government conservation sector can step in. It is also noteworthy that a NVC Significant Environmental Benefit (SEB) grant, which is comprised of funds from past fines or offsets payments in the region, provided the major funding source that helped to secure the property for restoration and perpetual protection. Given the NVC's history of legal involvement with the site, this is a fitting end to the story; demonstrating the strategic value of the SEB fund in achieving a positive legacy - a previously unimaginable, permanent environmental outcome for the property.

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Comprehensive, reliable vegetation classification and mapping is vital for terrestrial restoration ecology

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Abstract
Comprehensive ecological classification capturing ecological diversity and processes is fundamental to biodiversity assessment and restoration ecology. Three approaches to NSW, Australia vegetation type mapping are discussed 1. wet film API with field checking; 2. digital 3-D API with high resolution imagery; 3. species distribution modelling x pattern recognition of imagery generating computer maps. The first two produce reliable type maps with some attributes recorded that reflect condition, relevant to restoration. The third, produces unreliable type maps. An example of approach 1 is the numerical classification and map of remnants in the Guyra region, New England Tableland. Remnants to <1 ha are mapped with >80% accuracy to the correct type. Polygons are coded for type, structure, canopy disturbance and naturalness of ground cover. Risk codes and conservation status are assigned per type. Recent acquisition of digital high resolution airborne imagery enabled faster digital API (DAPI) mapping using 3-D interpretation at large 1:2000 scale detecting canopy species, understorey structure and tree crown dieback. This new DAPI method was overlooked for the NSW State Vegetation Type Map that is adopting the species modelling x pattern recognition approach to auto-generate maps. Independent validations reveal this State mapping is <30% accurate to type with limitations of plot data leading to many types not mapped. Pattern recognition software confuses vegetation types with disturbance classes. If the State Map became a regulation or similar, biodiversity assessments, offsetting and restoration could be compromised with adverse outcomes in some circumstances.

Introduction

Restoration of disturbed landscapes or sites is increasingly important due to the level of broad-scale destruction of habitats, however, prevention of habitat loss in the first place should remain the priority. There are cost-benefits in maintaining habitat compared to ecological restoration. A prerequisite to protecting what is left of nature and restoring areas to notional benchmark condition, is thorough habitat classification accurately mapped. Such data are critical to guide environmental planning and biodiversity site assessments. Examples being accurate mapping of inland floodplain vegetation for environmental flow water allocations and accurately mapping listed threatened ecological communities (TECs) to minimise damage to them from developments. Given its importance, three methods of vegetation mapping used recently in NSW are discussed with summaries of their attributes in Table 1.

1: Numerical classification and wet film API map: Guyra

Benson and Ashby (2000) plot-sampled, numerically classified and mapped 24 plant community types (PCT) of native woody vegetation and montane wetlands in the 75% cleared Guyra region of the NSW New England bioregion. Mapping was by plant ecologists using aerial photographic interpretation (API) of 1:25000 colour wet film imagery with extensive field checks. The map is >80% accurate to vegetation type map to 1 ha remnant size. Classification preceded mapping. Polygon attributes recorded include ground-cover naturalness. Threatened plant species and sites of good condition or conservation significance are documented. IUCN-like risk codes and protected area status are assigned to each PCT. This project set a benchmark for classification and mapping agricultural landscapes producing data suitable for planning restoration activities.

2: Digital API map of defined types in mid-Murrumbidgee, NSW South Western Slopes Bioregion

In 2007 NSW began acquiring high resolution ADS-40 digital airborne imagery able to be interpreted at large scale (1:2000) in 3-D, on-screen into GIS using DAPI. This raised capacity for more rapidly and accurately mapping vegetation types compared to previous wet film API. The method was employed by Maguire et al. (2012) using expert API specialists working with plant ecologists in mapping 100 defined vegetation types (Benson 2008) over 2.7 million hectares of the fragmented, agricultural landscapes of the NSW South Western Slopes. Independent validation revealed the mapping is approximately 50% accurate to the correct type rising to >85% if including “near miss” types. Due to the quality of the imagery in 3-D, a range of condition attributes can be recorded including degree of both natural regeneration and dieback of canopy species. These attributes on type and condition inform restoration of heavily modified landscapes.

3: Pattern recognition x modelled mapping (segmentation) NSW State Vegetation Type Map

In 2009, NSW initiated computer-based pattern recognition and modelling to produce a State Vegetation Type Map. A supporting science argument was repeatability but an imperative was rapidity of coverage at lower cost. The mapping is conducted by spatial analysts applying pattern recognition software to digital satellite or airborne imagery. The computer-generated polygons are assigned types via modified GAM x boosted regression tree species distribution algorithms (Elith et al. 2008) using available floristic plot data (NSW OEH 2017). In 2011, the project committed to map all NSW PCTs (circa 1400) to 70% accuracy within five years. Independent validations indicate accuracy to correct type is 17-30% (Hunter 2015 and anecdotal checks by others). Accuracy claims are increased by counting as affirmative the presence of up to three PCTs in map polygons. Manual changes to the computer-generated polygons ensures the mapping is not as repeatable as suggested.

Table 1. Comparison of three NSW vegetation type mapping projects.

Attributes	Guyra API Map	NSW SW Slopes DAPI Map	Segmentation State Map
Method	Wet film API & intensive field traverse by plant ecologists	Digital API in 3-D by experience experts guided by plant ecologists	Species models x pattern recognition by spatial analysts with some corrections by mainly 2-D API
GIS scale	1:25000	1:4000	1:25000
Proportion of PCTs mapped present in mapping area	>95%	>95%	50-80%, (poorly sampled types, some highly distinct, are not model-mapped)
Accuracy to correct type#	80-95%	45-60%	15-30%
Height density of canopy	yes	yes	yes
Canopy condition e.g. dieback	yes	yes (superior)	limited
Understorey structure	no	yes	no
Ground cover naturalness	yes	yes	no
Key benefits	High accuracy. Vast majority of types mapped	High accuracy and reliable linework. Vast majority of types mapped. Relatively cost-effective and efficient	Generates polygons quickly using computer segmentation technology. Labelled repeatable but manual API checks alter auto-labelled polygons
Key limitations	Degree of effort including field checks. Lack of repeatability of manual wet film API. Many 'legacy' projects used this method	Lack of repeatability, however this can be minimised by standardizing different observers and registering spectral signatures per type	Inaccurate PCT maps. Some PCTs not mapped due to lack of data for modelling. Produces anomalous overly detailed vegetation polygons that bear little relationship to natural floristic vegetation patterns due to shadows, ground and canopy disturbance

Note: #Accuracy of type to polygon rises if second or third preferential types are recorded as valid.

Discussion

Selection of methods to classify and map habitats can be driven by expediency or ideology. It is prudent, however, to meet user-needs yet these are often over-looked in top-down approaches. Restoration ecologists require reliable data to plan what to restore at sites and across landscapes. This is aided if there are reliable species and habitat data for adjacent remnants. Species or vegetation models may assist restoration if based on sound data. Increasingly, statistically complex models such as Lyons et al. (2016), that employs clustering algorithms with model-fitting to choose best-fit classifications that meet predictions of individual species, are being mooted. However, these require comprehensive data to produce reliable outputs and such data are lacking over most of Australia and the world. If such methods are over-applied the results could be adverse for biodiversity protection. If unreliable maps are made into biodiversity protection regulations for site decisions, offsetting and environmental planning, the result could be biodiversity loss. In NSW, a solution to meet majority-user needs was to adopt the expert DAPI 3-D ADS40 approach (Maguire et al. 2012) including to produce the State Vegetation Type Map. Perhaps this was rejected because of fixation on computer auto-generated methods integrating with political imperatives to produce standardized vegetation mapping expediently.

Conclusions

Restoration of biodiversity benefits from comprehensive habitat classifications mapped accurately at scales of land-use decisions. The Guyra API and the DAPI ADS-40 methods, described above, are reliable enough to guide restoration of cleared or disturbed lands. Quests for rapid jurisdictional map coverages through species modelling and pattern recognition have thus far produced unreliable products unsuitable for in site-base decisions, regional conservation plans and "like for like" offsets. Expert ecologists should direct vegetation classification and mapping rather than over-relying on modellers or spatial analysists who are unfamiliar with landscapes and species. Mapping should be subject to third party, independent validation emphasising correct type to polygon so users appreciate levels of error.

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After the gold rush - What happens 'on the ground' after the final payment and the report is done?

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Abstract
NSW regional and statewide NRM targets have been set for improvements in the condition of soil, water and native vegetation on private land that will assist in the long-term viability of agricultural communities. Various projects have been funded with the aim of achieving these targets. All of these projects require some level of monitoring, evaluation and measurement of success to justify the investment. Lessons learnt from historic restoration and revegetation programs and more recent scientific research have contributed to the development of new approaches and techniques with the aim of improving outcomes for ecological restoration and revegetation projects. This paper presents an analysis comparing baseline and follow-up surveys of environmental attributes four years after environmental plantings were implemented and how these results may help NRM decision makers.

Introduction

NRM investment decision makers are faced with the dilemma of taking into account available resources and expertise, the commitment to long term monitoring, and a clear justification of knowledge needs. Lessons learnt from historic restoration and revegetation programs (since the 1980's) and more recent scientific research have contributed to the development of new approaches and techniques with the aim of improving outcomes.

From 2008 to 2014 the Border Rivers-Gwydir Catchment Management Authority (BR-G CMA, now part of Northern Tablelands Local Land Services and North West Local Land Services) embarked on a biophysical monitoring program (Monitoring, Evaluation, Reporting and Improvement - MERI) to assess ecological outcomes of CMA investment in Caring for Country funded projects designed to implement better land management practices across the catchment (Croker 2011). The program followed the methodology set out in the operational manual for the Practical Partnerships program, with the aim of delivering consistent, standardized short-term investment projects to achieve and measure ecological outcomes (Oliver *et al*, 2004). Baseline field surveys of flora, fauna, soils, water quality and in-stream fauna were followed up after four years at selected sites on private properties supported in part by CMA funds. Sites were selected to cover a representative range of landscape and investment in changed management activities, (weeds & feral pests, erosion, grazing, conservation, environmental planting and perennial pasture establishment). In order to understand the effectiveness of the investment in facilitating land management change, an analysis of the results of vegetation condition responses comparing baseline (2008, 2009) and follow-up surveys (2012, 2013) for BR-G CMA MERI projects was undertaken by OEH (O'Keefe *et al* 2015). This talk is about results of baseline and follow-up vegetation condition monitoring for the BR-G CMA MERI program and asking 'what happens on the ground after the funding has been spent?'

Methods

Paired treatment and control sites were monitored to help detect differences in vegetation condition between background levels of land use and biophysical changes due to land management change. Hypothetical examples of these effects in control (solid line) and treatment (dotted line) plots are shown in Figure 1.

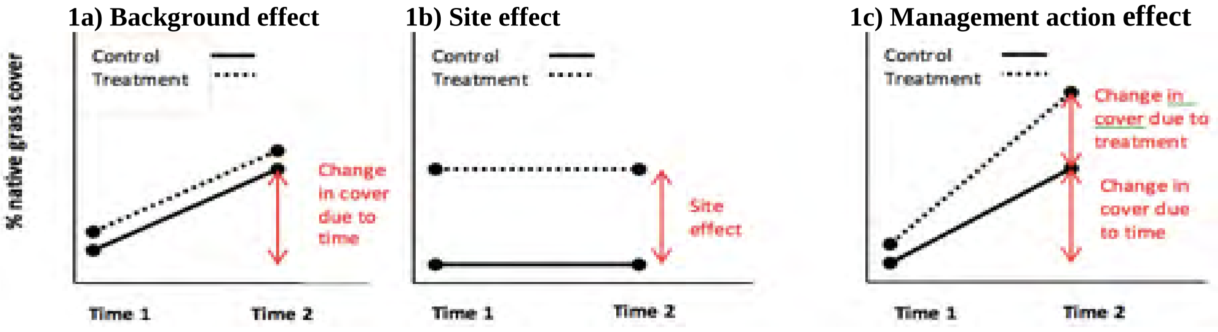

Fig. 1. A hypothetical example of the average change in resource condition attribute due to change in site management. In this example, the change in resource condition is measured by % native grass cover (O'Keefe *et al*. 2015). Note, divergent slope lines between control and treatment (1c) indicate a trend due to management actions.

Vegetation condition data were analysed using ANOVA. F probability (P-values) were generated to determine whether statistically significant differences (P-value <0.05) could be found between group means, for background, site and management action effects.

Results

Comparing baseline and follow-up data revealed very few biologically significant effects in response to management actions after four years. Figure 2, illustrates some results from the BRG MERI program from 2008 to 2012 which show some examples of trends in resource condition over time.

2a) Background effect **2b) Site effect** **2c) Management action effect**

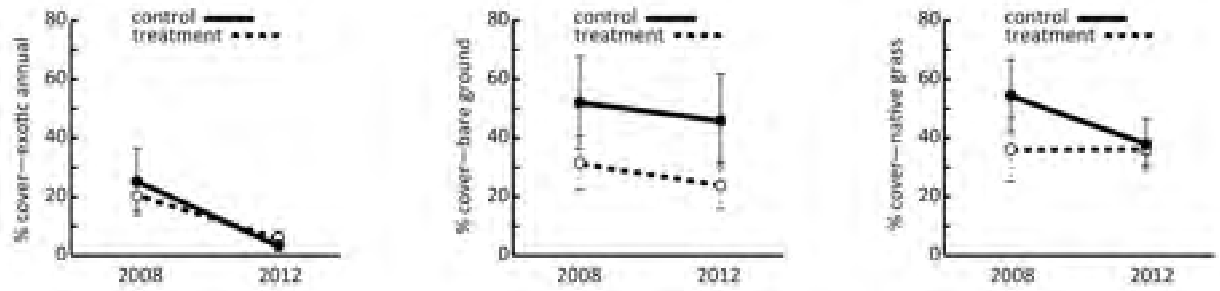

Fig. 2. Examples from BRG MERI data 2008–2012 group means with error bars for changes in resource condition over time. 2a) background effects; 2b) site effects; and, 2c) management action effects.

Analysis of variance of these examples (Table 1) indicated a strong background effect for exotic annual cover, and site effect for bare ground cover in pasture establishment sites. However, the management action effect for native grass cover in environmental planting sites was not significant (P-value, 0.097).

Table 1. F probability values for vegetation condition variables illustrated in Figure 2.

Effect type	Condition variables	Incentive Type	P-values (untransformed)	P-values * (log(X+1))
Background effect (Fig 2a)	exotic annual cover (transect)	Pasture Establishment	0.008	0.057
Site effect (Fig 2b)	bare ground (transect)	Pasture Establishment	0.003	0.020
Management effect (Fig 2c)	native grass cover (quadrat)	Environmental Planting	0.097	NA

*skewed data sets were transformed using log(X+1)

Analyses of trends in ecological outcomes in response to management actions for all incentive types in the BR-G CMA MERI program were inconclusive. There are a number of possible factors contributing to the lack of statistical power required to detect change: precision (only one follow up monitoring event, low numbers of replicates); spatial variance (site selection, actual management actions undertaken on treatment and control sites); and, temporal variance (climate effects, response times for different variables). Condition indices with longer-term ecological responses (lag-time up to 10 years or more) constrain the opportunity to monitor, detect and evaluate ecological outcomes of changes to land management (O'Keefe, *pers. com*).

Discussion

The decision to monitor ecological outcomes should be determined with a clear understanding of questions, objectives, intended outcomes, mechanism of change and predicted response. Knowing what to monitor requires the collaborative efforts of natural resource managers, scientists, statisticians and policy makers to ensure desired outcomes, and the means by which they will be detected, are realistic and achievable (O'Keefe *et al*. 2015).

Not all NRM interventions require the measurement of ecological outcomes to evaluate program success. There are alternatives measures that are more achievable and able to provide program level evaluation within relatively short timeframes. Capacity building is another important tool for bringing about land management change. Education and training activities were an integral part of the BR-G CMA on-ground works incentive programs (such as farm planning, conservation grazing and conservation farming on their properties). Often land managers need support, training and education to keep up the momentum because of the time-lag between funded management actions and on-ground responses beyond funding timelines.

Adaptive Management is an ongoing process of trialing, monitoring and evaluating new approaches and techniques used by land managers at the site level and new approaches to program delivery by NRM managers. Evaluation of the project and program outcomes is an opportunity to consider what worked, what didn't work, how could techniques and management be improved and what are the risks of not implementing change? So here we are in 21st century - hopefully not at the end of the gold rush for restoration funding and hopefully mother nature will be 'on the run' toward improvements in ecosystem health, with many helping hands from land managers ready to try new techniques to adapt to change.

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Lessons from the Aboriginal Riverkeeper Team Project, Georges River, Sydney

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Abstract
The Aboriginal[i] Riverkeeper Team (ART) project operated within Sydney's Georges River catchment between 2014–2017. The project employed an Aboriginal project manager, and a team supervisor (non-Indigenous) to lead a small, full-time team of Aboriginal trainees. The eight trainees gained qualified in Certificate II Conservation and Land Management (CLM), and four of these trainees completed Cert. III Indigenous Land Management (ILM). The project incorporated strong Aboriginal cultural components through engagement with Local Aboriginal Land Councils (LALCs), Elders and knowledge holders. The project involved numerous partners and was funded by the Australian Government. The project was delivered by consultants Eco Logical Australia (ELA), facilitated by the Georges River Combined Councils Committee (GRCCC), and TAFE NSW was the registered training organisation that provided the formal qualifications. The project produced environmental outcomes such as bush regeneration and ecological restoration; as well as socio-cultural outcomes such as, strengthening the cultural identities of the trainees by engaging them with Aboriginal Elders and knowledge holders while they gained formal qualifications and practical skills during paid employment. Positive relationships were also built between the project's partners. This paper outlines the project and highlights some of the lessons learnt, the aim is to provide proponents of similar projects (including Indigenous specific or mainstream projects) with take-home messages that they can use in developing and delivering similar projects and initiatives in the future.

Introduction

The ART project engaged eight Aboriginal trainees who completed Conservation and Land Management work-based traineeships. The project ran for three years, during which time the team worked across 17 locations in the Georges River catchment, primarily undertaking bush regeneration. The trainees received formal training from TAFE NSW and participated in a wide range of Aboriginal cultural activities as part of the traineeship. The Georges River catchment is 960 km^2, and with over 1 million residents, it is predominantly urban (GRCCC 2017). There are approximately 14 000 Australian Indigenous people living in the catchment (ABS 2012a, b)[ii]. By combining science and culture over the course of the traineeships, the trainees strengthened their own personal Aboriginal identities as well as gaining formal qualifications and practical skills. Through this culture-rich approach, the project continued the concept of Indigenous Caring for Country in a modern, highly urbanised setting, south-western Sydney. This paper describes five lessons that were crucial to the project's success, and briefly mentions other lessons that are worthy of sharing with those undertaking or considering similar projects.

Lessons learnt

Lesson One – Training occurred at the worksites rather than the classroom wherever possible
The ART trainees learnt the fundamentals of bush regeneration through daily on-the-job training from the team supervisor, as well as regular engagement with TAFE NSW. The TAFE teachers visited the worksites to train the team in Cert. II CLM or Cert. III ILM. Undertaking training at their worksites was successful as the trainees engaged theory and practice *in situ*, learning about nature in nature, rather than contemplating how theory and practice apply remotely from a classroom. It also meant that the trainees were not required to travel to the TAFE campus weekly to attend class; their training was incorporated into their normal working day.

Lesson Two – Aboriginal culture and cultural education was a prominent feature of the project
In addition to western scientific training, the project incorporated strong Aboriginal cultural components. This was achieved through the involvement of LALCs in the conception of the project, as well as ongoing LALC involvement throughout the project delivery via an Aboriginal Steering Committee. This emphasis on the incorporation of Aboriginal perspectives resulted in the trainees attending regular cultural days where they spent time with Elders and knowledge holders to learn local Aboriginal culture and history. Through these cultural activities, the trainees learnt about Aboriginal values and sites in their worksites and how to adapt their bush regeneration work to avoid damaging these values. The team participated at local Aboriginal community events such as holding stalls at NAIDOC celebrations and at Sydney Living Museum's Eel Festival at Elizabeth Farm, as well as attending commemorative events such as Appin Massacre Memorial and the repatriation of ancestral remains within Gandangara LALC.

Lesson Three – The importance of a stable, flexible, supportive employer organisation
Before winning the ART project contract, ELA had many years of experience operating restoration ecology teams, including trainees, in south-western Sydney. Throughout the project, ELA invested many hours of support to maintain the successful operation of the team. This included providing human resource (HR) services beyond the usual recruitment, induction and development capacity. The additional HR contribution involved working closely with the team to explore and expand the trainees' basic work readiness, to provide early career advice and development, and to explore post-traineeship employment and ongoing support.

Lesson Four – The team supervisor role is key to the success of the team
Initially the project's goal was to have an all-Aboriginal team including project manager and team supervisor. When no suitable Indigenous team supervisor was identified during recruitment, approval was granted through the

funding body and project steering committee (including Aboriginal members) to modify this goal and recruit a non-Indigenous team supervisor. This was by no means ideal; however, due to this alteration, the project was able to progress and produce eight qualified and experienced Aboriginal people. The team supervisor had to be a confident, experienced and qualified bush regenerator given the types of work and sites being managed. They needed to be flexible, pragmatic and able to relate to trainees. They also must be able to negotiate at the interface of engaging with trainees, Aboriginal project partners such as LALCs, Elders and knowledge holders, and with local council staff, contractors, TAFE teachers and members of the public. A replacement for the team supervisor role was also needed, to cover annual leave breaks and unforeseen leave; this person must have a similar skill set. Due to the company's land management business ELA had a bank of substitute team supervisors.

Lesson Five – What worked well with recruiting and maintaining the trainees
Ideally, employ trainees who are 'work ready' and have adequate stable support at home. Our experience of employing trainees who had to relocate presented many challenges, such as the expense of living away from home, which was difficult on a trainee wage. We assisted in finding accommodation for trainees within Aboriginal hostels. However, homesickness and unaffordability was a significant issue and despite significant support and cultural engagement many of these trainees left. From our experience those living at home with family who could support and motivate them to complete the traineeship were more likely to succeed, as were those who had already participated in work readiness or environmental programs such as Green Army Teams. For some trainees, this was their first employment and ELA assisted them to set-up superannuation accounts, and to obtain tax file numbers, Opal travel concession cards and indentured employee concession identification, as well as engaging the trainees with government support through the New Careers for Aboriginal People and Industry NSW services. All these factors were helpful in assisting the trainee both financially and practically, during their traineeships.

Other lessons – lessons that were not explored in this paper
Additional lessons worthy of consideration include: (1) allowing for alterations from the original project design - initially tenders were sought only from Indigenous organisations and companies. When this process failed, tenders were open to mainstream non-Indigenous organisations, which allowed the project to proceed and achieve positive outcomes – however, there is a space for increased cross-company collaboration to improve Indigenous organisations' success in winning these contracts as per the original design; (2) planned wet-weather options for the team included arrangements with council nurseries, education centres and local national parks offices where the team could undertake training or work; (3) preplanning basic logistics for the team (such as access to toilets during work hours in relatively inaccessible areas); (4) communication of the company's bereavement leave policy, acceptable mobile phone use during work hours policy and social media policy with the trainees as part of their induction and, followed-up as needed; (5) fair partnerships with Aboriginal organisations – the project partners were prepared to reciprocate time, effort, knowledge and generosity with Aboriginal project partners so that the relationship was fair (i.e. meaning a genuine engagement with Aboriginal project partners to encourage that they could achieve some of their organisation's priorities); (6) facilitate trainee engagement with mentors who have industry experience where the trainee wishes to work in the future (mentoring assistance can be provided by Industry NSW &/or arranged by the project staff); (7) be prepared and be proactive in maintaining communication with trainees after the traineeship has been completed; their onward journey may benefit from your ongoing support; (8) ensure your workplace is culturally competent and has a good understanding of the local and generic issues faced by Indigenous Australians and our shared history; be aware of casual and institutional racism, and be prepared to educate and reform to eradicate prejudice.

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[i] In this paper the word 'Aboriginal' is used as a proper noun and in referring to First Nations people from the Australian mainland. Where 'Indigenous' appears, it relates to a formal name of the qualification and where Australian First Nations peoples are being discussed inclusively (i.e. includes Aboriginal and Torres Strait Islanders peoples).
ii This statistic was obtained by comparing the ABS 2011 Census data, specifically the Indigenous Profile data to the total populations within the ABS 2011 Census Community Profiles for each LGA in the Georges River catchment.

Saving the Planet with Ecodrama: Transformational and Experiential Theatre within a Living Stage

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Abstract

Ecodrama can be defined as theatre which explores the reciprocal connection between humans and the 'more-than-human' world. This paper focuses on an ecodrama event performed in Armidale at the Black Gully Music Festival as part of the EcoArts Australia Ephemera project (November 2016). Integral to this work was the concept of the Living Stage – a recyclable, biodegradable and partially edible performance space, which combines stage design with living plants and community engagement. Armidale's Living Stage (entitled The Bower Stage) was central to the celebration of the newly restored Black Gully, behind the New England Regional Art Museum (NERAM) which has increasingly become a hub for environmental and creative activity. Using the Bower Stage as our Performance space, we created an ecodrama which engaged students from three local High Schools in devising theatre that explored environmental issues. Theatre and music created an immersive and experiential performance. The style was vaudeville, and the audience were invited to enter on a journey into "The Environment", which was presented as a pristine and precious commodity. The themes included: our connection with the natural world; climate change; water security; human impacts on the environment, and our individual and collective responsibility. This paper examines how ecodrama can be used as a tool for the Arts to contribute to environmental issues.

Introduction

This paper describes an ecodrama event performed in Armidale at the Black Gully Music Festival as part of the EcoArts Australia Ephemera project (November 2016). Integral to this work was the concept of the Living Stage – a recyclable, biodegradable and partially edible performance space, which combines stage design with living plants and community engagement. Armidale's Living Stage (entitled The Bower Stage) was central to the celebration of the newly restored Black Gully, behind the New England Regional Art Museum (NERAM), which has increasingly become a hub for environmental and creative activity. The stage was created by ecoscenographer (ecological stage designer) Tanja Beer. Using the Bower Stage as our Performance space, we (Julie Collins, lecturer and theatre practitioner, Camille Dunsford, school teacher and Katy Walsh, school teacher), created an ecodrama which engaged students from three local High Schools in devising theatre that explored environmental issues.

The Project

Transdisciplinary practice has been identified as an essential component of tackling the complex problems of the future for regenerative development (Hirsch et al. 2008). The Arts can make an important contribution in increasing our creative capacity to generate solutions to environmental problems. Ecodrama, defined as theatre which explores the reciprocal connection between humans and the more-than-human world, describes works with environmental themes that deepen our awareness of our ecological identity (May 2007). Participatory and performative events have the potential to build empathy and inspire changes in behaviour; our intention in performing an ecodrama at Black Gully was to raise environmental consciousness in the context of place, identity and community. The style of our theatre piece was vaudeville, and the audience were invited to enter on a journey into "The Environment", which was presented as a pristine and precious commodity. The themes included: our connection with the natural world; climate change; water security; human impacts on the environment, and our individual and collective responsibility. The young people involved were encouraged to research the topics and reflect on their own attitudes and behaviours.

Integral to the work was the concept of the Living Stage – a recyclable, biodegradable and partially edible performance space, combining stage design with living plants and community engagement. The stage included kokedamas (or moss balls), a Japanese art-form where a plant's root system is wrapped in moss and bound with string, transforming it into a sculptural and suspended art form. Capturing the Japanese aesthetic of Wabi-sabi[1], kokedama-making is an appreciation of natural beauty, where ideas of simplicity, fragility, humility, adaptation and growth are moulded and wrapped into spherical forms. Each moss ball was lovingly crafted and hung in the space to create a suspended forest of living globes. The beauty of kokedamas is tempered by the fact that they are ephemeral, they need to be nurtured and watered and eventually, planted out; thus they are a good symbol for our relationship with the natural world. Kokedamas are symbols of beauty and tranquillity but they are also a reminder of the fragility of nature, and what we stand to lose if we disconnect from the environment that nurtures and supports us. There were several workshops where people were able to make the moss balls, in a symbolic act of developing a nurturing relationship with the living systems. Working with living systems allowed the

[1] Wabi-Sabi is a Japanese concept of aesthetics which includes notions of authenticity, modesty, rustic elegance, refined beauty, humility, imperfection, transience and a connection to nature. Nature's cycles of growth, decay, and erosion are embodied in artefacts that accentuate natural materials, rough textures, frayed edges and subtle hues.

participants to see themselves as intrinsically connected to nature, to experience the environment not as something to tame or control, but rather as an extension of themselves.

The form of theatre used in our Ecodrama was immersive, site specific and interactive. In immersive theatre, the audience members are not passive bystanders (Machon 2013). They are part of the story; that role may be as a witness or even an actual character; they are empowered to act. This contrasts with the conventional model of theatre, where an audience sits silently in the dark, feeling comforted, or defeated by the performance, but unable to take action. Our vaudeville sideshow was recreated in the University grounds for the opening of the *Restore, Regenerate,Revegetate* Conference (February 2017). It transformed in response to the changed environment of landscaped gardens, and water features and we introduced new characters to inhabit the space.

The goals of this production were:

1. To raise awareness of environmental issues in the audience and participants alike;
2. To encourage emotional responses to these issues, including empathy or anger;
3. To encourage a sense of community engagement;

While these goals guided us in the making of the work, a larger question became about how to measure the impact of immersive theatre and artistic work. Can it really change people's thoughts and feelings, and most notably actions towards the environment? As an exercise in community engagement, our ecodrama was undoubtedly successful. Many people volunteered their time to help and participate. The audience at Black Gully were from a very broad and multicultural demographic, but mainly children and their families, which was an ideal target audience for conveying messages about environmental issues. Anecdotally, many audience members reported feeling moved by the performance. This was largely because the environmental messages were delivered by children and young people –those who will be most impacted by our inaction on environmental issues and who are symbolic of all future generations.

An effective tool for measuring the initial impact of this type of work could be an attitudinal survey to allow participants and audience members to report thoughts, feelings, and attitudes towards various statements that correspond to the articulated goals.

Discussion

There is no doubt that Science employs a great deal of creativity, but recent debates over science education have asked how that should be achieved; do we merely do more maths, or do we deliberately foster creativity? A cognitive understanding of scientific concepts does not necessarily facilitate tangible and constructive action on global issues (Evans 2014). Personal and collective transformation requires creative, participatory processes and adaptive capacities that foster hands-on resilience, collective learning and transformative action in response to socio-ecological issues (Curtis et al. 2013; Beer 2015; Heras & Tabara 2016). There is evidence that the Arts can help educate people on environmental themes, communicate ideas and provoke emotional responses such as empathy and anger that may invoke behavioural changes in audience members. This provides an argument for scientists to work closely with artists to communicate facts and ideas that impact strongly on the real World. This promotes an integration of the Science and Arts in the same way that Indigenous peoples conceive of knowledge, with an appreciation of its holistic nature; Indigenous Australian understandings of 'caring for country,' embeds social, cultural and ecological connection to place (Zurba & Berkes 2014).

Ecodrama in the context of the Black Gully Music Festival reached a wide multicultural and intergenerational audience. By delivering an engaging and immersive story on a living stage in a non-didactic way, it is hoped that a seed of good intention was planted in the hearts and minds of participants and audience alike; from little things, big things can surely grow.

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A decade of working with private landholders to restore a biodiversity hotspot

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Abstract
The Tweed is one of the most biodiverse regions in Australia. The Tweed Vegetation Management Strategy recognised that much of the shire's biodiversity is found on private land and effective management of habitat on private land is essential for functional regional habitat connectivity. Council's Private Land Conservation Program provides landholders with financial incentives, technical advice and education to help them conserve biodiversity. To date, 2,300 hectares of habitat has been restored on 486 properties and 86 kilometres of waterway has been rehabilitated. One-hundred and sixty Land for Wildlife members conserve 3.6% of the Shire's bushland outside formal reserves and over 200 Backyard Habitat for Wildlife members protect native habitat in backyards. Program strengths include a flexible grant application process and the capacity to tailor projects to site-specific ecological priorities and landholder needs. Challenges include grant prioritisation and maximising return on investment. Emerging weed threats and climate change are new challenges that require careful management.

Introduction

The area covered by the Tweed Local Government Area, in far north east New South Wales, contains considerable biodiversity. Straddling the Mount Warning Caldera, the Tweed and surrounding environs supports the highest richness of endemic taxa within the Australian subtropics (Weber et al. 2014). Eighty per cent of the shire's bushland has high conservation status and it contains outstanding examples of World Heritage rainforests. The region supports Australia's highest concentration of threatened plant species and more species of birds, fish, amphibia and mammals than Kakadu (Kingston et al 2004). Vertebrate biodiversity is comparable to the Queensland Wet Tropics. Although the formal reserve system contains significant biodiversity, it is fragmented and accounts for only 29% of the shire's area. The Tweed Vegetation Management Strategy, adopted by Tweed Shire Council in 2007, recognised that private land encompasses much of the shire's biodiversity and effective habitat management on private land is a fundamental component of regional habitat connectivity. It found a number of processes threatening biodiversity on private land and recommended that an incentive program be established to help landholders actively manage these. In response, Council's Biodiversity Grant Program was launched in 2009. Council now has an integrated Private Land Conservation (PLC) Program. This paper describes the PLC Program and discusses its key achievements, benefits and challenges.

Council's PLC Program

Council's PLC Program comprises the Biodiversity Grant Program and River Health Grant Program incentive schemes and the Land for Wildlife and Backyard Habitat for Wildlife property registration schemes.

Biodiversity Grant Program and River Health Grant Program

The Biodiversity Grant Program provides financial support to assist private landowners, community groups and researchers undertake projects that help conserve the shire's biodiversity values. Most applications seek support for ecological restoration including mitigation of weed threats to threatened flora species. Applications for on-ground works are assessed on site with the landholder primarily on the basis of property ecological status, potential ecological benefit and the capacity of the landholder to maintain the work site. An agreement between Council and the landholder describes the scope of works and shared responsibilities. A bush regenerator then partners with the landholder to carry out the work. Projects are completed within 18 months of grant approval.

The River Health Grant Program, launched in 2006, aims to enhance the environmental condition of the Tweed's waterways and improve the quality of raw water extracted for potable water supply at Council's water treatment plants. Private landholders may apply for financial assistance to carry out projects that improve stream bank condition, riparian habitat and aquatic ecosystem health in the Tweed River and its catchment. These outcomes improve potable water quality and reduce the operating costs of Council's water treatment plant. Eligible activities include fencing to restrict livestock access to waterways, stream bank stabilisation and weed control. Quality assurance for both incentive schemes consists of site inspections and discussions with stakeholders to assess project success. The effectiveness of both programs is reviewed annually.

Land for Wildlife and Backyard Habitat for Wildlife Programs

Council's incentive schemes are complemented by two non-financial support programs. In 2013 Council became an approved regional provider of Land for Wildlife, a voluntary property registration scheme providing support for private landholders managing habitat on their land. The program encourages and supports nature conservation irrespective of other land uses. Landholders receive a written assessment of their nominated habitat, recommendations for its effective management and a resource kit. Ongoing technical advice, field-based workshops and other events strengthen their capacity to actively manage native habitat. Council launched the local chapter of Backyard Habitat for Wildlife in 2015. Similar to the Land for Wildlife program, Backyard Habitat for Wildlife provides support to urban landholders who have wildlife-friendly habitat in their backyards.

Achievements
Initially, PLC Program targets were not set due to resource uncertainties, lack of best practice benchmarks and to allow sufficient administrative flexibility to capitalise on strategic conservation investment opportunities as they arose. Since 2006, however, the program has greatly exceeded expectation. Under the two incentive schemes, 2,300 hectares of habitat has been restored on 486 properties. Ecological restoration has mitigated weed threats to 25 known threatened flora species and the Lowland Rainforest in the NSW North Coast and Sydney Basin Bioregions Endangered Ecological Community. Much of this work has been conducted in areas adjacent to national parks or within recognised fauna corridors, buffering core areas of high conservation value vegetation and strengthening regional habitat connectivity. Eighty-six kilometres of waterway has been rehabilitated leading to improved riparian habitat and water quality. Fifteen grants supporting ecological research have led to recommendations for improved management of a number of fauna species including the Endangered *Thersites mitchellae* Mitchell's Rainforest Snail and the Endangered *Antechinus arktos* Black-tailed Antechinus. With Council support, the Caldera Art project has become a major annual regional event aimed directly at promoting the region's biodiversity values. Under the Land for Wildlife Program, 160 landholders protect 2,578 hectares of habitat constituting 3.6% of the Tweed's bushland outside formal reserves. Two-hundred landholders registered to Backyard Habitat for Wildlife maintain vital areas of urban backyard habitat.

Strengths and benefits
Council's PLC Program has a number of strengths. Firstly, the incentive schemes use flexible, informal application processes that enable Council to build enduring partnerships with landholders. Strong relationships, which would be much more difficult to achieve using formal competitive processes, underpin effective long-term habitat management. Secondly, projects carried out under incentive schemes are tailored to site-specific ecological priorities and unique landholder learning needs. Each project provides excellent opportunities for one-on-one tuition enabling the landholder to acquire the plant identification, weed control technique and other skills required to manage specific in-situ threats to biodiversity. Experiential learning workshops and information days held under the Land for Wildlife program provide additional learning opportunities and avenues for landholders to motivate and inspire each other by sharing their knowledge and experience. Thirdly, the discretionary nature of funds expenditure is a distinct advantage. Depending on the number and type of grant applications on hand and opportunities for strategic investment, program managers may set aside funds to leverage significant external funding to invest in long-term, large-scale environmental projects. Since 2009, $600,000 of funding has been used in this way as in-kind contributions to help secure $5M of state and federal funding for projects delivering strategic, landscape-scale biodiversity conservation outcomes.

The Program has significant benefits and feedback from landholders has been overwhelmingly positive. It has fostered a growing sense of land custodianship and greater community involvement in conservation. Observations made during site assessments help Council build a more accurate floristic picture of the shire's vegetation communities, ecosystem health and the abundance and distribution of threatened species. Landholders alert Council to natural resource management issues which inform policy development and program implementation. The Program complements Council's planning and regulatory framework for biodiversity conservation.

Challenges
Program administration involves a number of challenges. Project prioritisation can be difficult due to limited funding, myriad grant applications and the challenges associated with comparing different sites and landholder capabilities. Grants are typically modest. For example, grants for ecological restoration projects under the Biodiversity Grant Program are less than $5,000 and on-ground work is completed within 18 months. These constraints restrict the extent of primary and follow-up weed control and necessitate careful prioritisation of weed threats and realistic appraisal of what can be achieved to budget. Once a project is completed, site maintenance becomes the landholder's responsibility. Given that long-term site rehabilitation is time-consuming, often strenuous work requiring specialist skills and knowledge, perhaps the biggest challenge lies in helping landholders meet their site maintenance obligation. To ensure effective investment of public monies, projects are restricted to manageable areas and Council provides landholders with ongoing technical support. New weed species and the uncertainties associated with climate change are significant emerging threats to the Tweed's biodiversity. These and other challenges may require re-appraisal of existing ecological restoration strategies.

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Ephemera: a case study in how the arts can create empathy for ecological restoration

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Abstract

Australia's natural areas have long been a source of inspiration for artists. Ecological art is an artform in which living ecosystems are incorporated into the artwork and many ecological artworks have an ecological restoration function or seek to create an empathy among viewers towards the natural environment. *Ephemera* was a recent project conducted by EcoArts Australis Inc. and funded by Festivals Australia. It was built into the Black Gully Music Festival (in Armidale Australia), and the 'Environment Science Community Arts People Entertainment' program of events. Five artists were employed to create ephemeral artworks around the festival site. These included: unfired pottery made from the clay dug from the Black Gully creek by Andrew Parker; intimate ephemeral artworks created from natural materials along the creek by Greer Taylor; an eel trap sculpture woven using traditional Aboriginal weaving practices by two Indigenous weavers Amy Hammond and Gabi Briggs; and a living stage created by Tanja Beer in which performances were staged by students from three local secondary schools. The Black Gully site itself has been the result of many years of active ecological restoration by the Armidale community. It is our contention, that incorporating the arts into ecological restoration programs such as this event allows a greater level of communication with the general public, and allows the creation of emotional affinity for ecological restoration.

Introduction

Modern life in Western society has disconnected most people from the natural environment. An emotional affinity with nature is as powerful to predict pro-environmental behaviour as indignation and interest in nature (Kals *et al.* 1999; Fig. 1). Emotional affinity with nature can frequently be traced back to direct experiences of the natural environment. However the arts too have an ability to enhance an emotional affinity with nature (Curtis 2009). The arts can also provide a cognitive interest in nature, say through enhancing environmental education (Curtis, 2011), and can increase an emotional indignation about insufficient nature protection or can increase a cognitive interest in the environment (Curtis 2012). This paper focuses on the arts providing an emotional affinity toward nature, and in particular to ecological restoration through the examination of a particular case study.

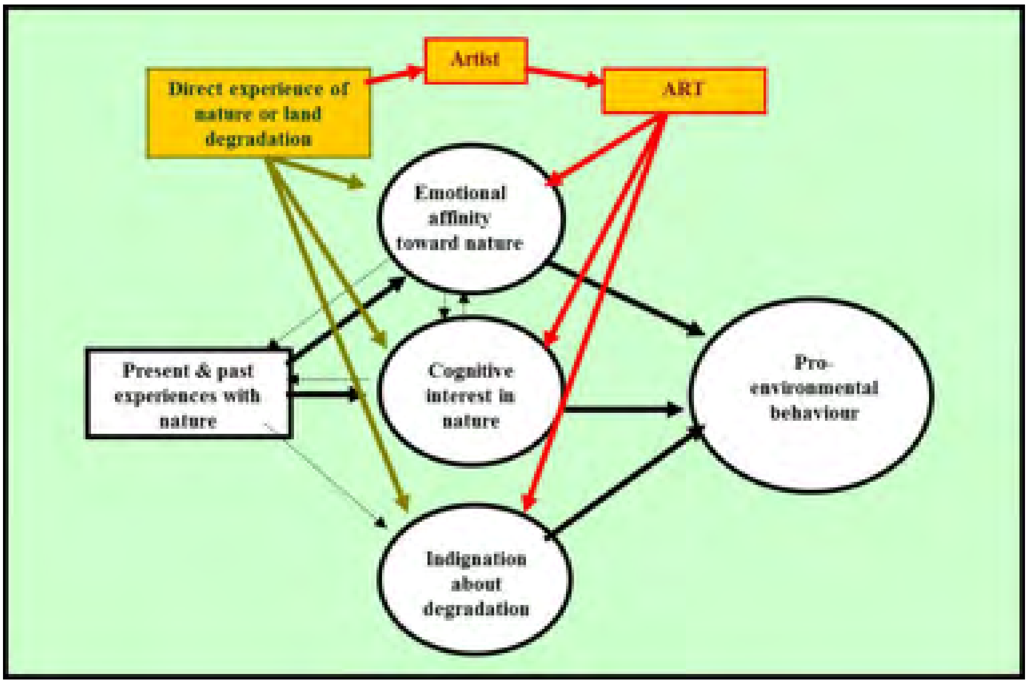

Fig. 1. Model to show how the arts affect environmental behaviour, by increasing an emotional affinity towards nature, generating a cognitive interest in nature, and provoking emotional indignation about insufficient nature protection (from Kals *et al*. 1999 — the model of Kals *et al*. has been expanded to depict the ways in which the arts shape environmental behaviour).

Case Study

We examined a recent project, *Ephemera*, conducted by EcoArts Australis Inc. and funded by Festivals Australia (EcoArts Australis 2017). The project was integrated into the Black Gully Music Festival and the 'Environment Science Community Arts People Entertainment' program of events, in the rural city of Armidale, NSW, Australia. Five artists were employed to create ephemeral artworks around the festival site. These included: a living stage created by Tanja Beer in which performances were staged by students from Armidale High School, Duval High School and the Armidale Waldorf School (Fig. 2); an eel trap sculpture woven from *Lomandra longifolia* using traditional Aboriginal weaving practices by two Indigenous weavers Amy Hammond and Gabi Briggs (Fig. 3); intimate ephemeral artworks created from natural materials along the creek by Greer Taylor (Fig. 4); and unfired pottery made from the clay dug from the Black Gully creek and impregnated with native plant seeds by Andrew Parker (Fig. 5). The music festival also included an array of performances from local musicians, activities in the adjacent New England Regional Art Museum, and stalls from local artisans and sustainability groups. The Black Gully site has been the result of many years of active ecological restoration by the Armidale community. The case study was observed through participant observation (both authors were involved in organising the event and Parker was a participating artist) and semi-formal interviews with participants and organisers. It was recorded with extensive photographic and video documentation (Social Ventures Media 2017). About 200 people participated in the workshops preceding the festival to assist in making the artworks and performances for the event, and about 2000 attended the festival and were exposed to the artworks. The project was considered successful by organisers of the Black Gully event in increasing the audience to the festival, to messages of sustainability and the experience of ecological restoration on the site. It was also considered successful in augmenting the number of community organisations involved in the broader event.

Fig.2. Living Stage, artist Tanja Beer. **Fig. 3.** Eel Trap, artists Amy Briggs and Gabi Hammond, **Fig. 4.** Ephemeral artwork, artist Greer Taylor. **Fig. 5.** Ephemeral clay sculpture with impregnated native seeds, artist Andrew Parker. Photos David Curtis

Discussion and Conclusion

Ritual is frequently used to reinforce social values and transmit the values and structures of a society from one generation to the next and to maintain those structures over time (Meekison and Higgs 1998). However, rituals can be used in innovative ways to challenge dominant symbols and cause change in individuals' lives and affect changes in behaviour at a societal level (Szerzynski 2002). Many groups are creating new rituals to connect people directly with, and assist them to celebrate the community (e.g. Clifford, 2000; Fox, 2002) and the natural environment and ecological restoration (Jordon 2003; Meekison and Higgs 1998; Curtis 2011; Beer, 2017).

The art described in this paper exemplify the important role of artists in aiding an understanding of the Australian natural environment and its native flora and fauna, complementing the role of ecologists. By experiencing artistic explorations a community can develop empathy toward the natural environment, and this is vital in developing a caring relationship for it. We contend that there is great value in incorporating art into ecological restoration projects, to use the pulling power of the arts to increase the public's acceptance of ecological restoration.

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Ecological Integrity – the whole or some of the parts?

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Abstract

The concepts 'Ecological Integrity' (EI) and 'Biodiversity' (living variation) are founding principles of ecologically-sustainable development under NSW environmental legislation, including NSW's Biodiversity Conservation Act (2016). Ecological Integrity is a high-level goal for biodiversity conservation requiring integration of habitat repair and management of intact ecosystems across whole regions. An ecological system with high integrity implies biological, physical, and human interactions that support adaptation and resilience. Individual features have value in their own right; however, EI is concerned less with parts and more with wholes. Ecological Integrity is a complex concept; yet our ability to quantify, anticipate and influence changes to EI relies on the development of practical and representative indicators. Tools at our disposal include existing conceptual models, site-based information, and regional-scale modelling tools. Here, we suggest some conceptual grounding as a prelude to designing indicators of EI, based on existing and proposed state-wide spatial modelling.

Introduction

The NSW Biodiversity Conservation Act 2016 (NSW Government 2016a; NSW Government 2016b) represents an overhaul of legislation governing the management of biodiversity in NSW. Relaxed clearing regulations in some areas are accompanied by conservation offsets and boosted public investment in private land conservation and management of threatened species. The first two purposes of the Act (of 15 purposes) are to: (a) to conserve biodiversity at bioregional and state scales and (b) to maintain the diversity and quality of ecosystems and enhance their capacity to adapt to change and provide for the needs of future generations – which corresponds to the IUCN definition of Ecological Integrity (EI) (https://www.iucn.org/downloads/en_iucn__glossary_definitions.pdf). For the purpose of the Act, biodiversity is the variety of living animal and plant life from all sources, and includes diversity within and between species and diversity of ecosystems.

Biodiversity in this context, concerns the variety of tangible entities, and biodiversity assessment relates largely to the status of the variety of a region and complementarity, which, mathematically, is a derivation of set theory reflecting how individual areas contribute to that whole. Ecological Integrity, on the other hand, is concerned with non-tangible properties: ecological resilience, the ability to adapt over time, and the maintenance of ecological function. Meaningful, measurable indicators of EI are more achievable if EI can be articulated as a "state", such as in the establishment, management and monitoring of Key Biodiversity Areas (IUCN 2016). However, under the Act, EI more than just state variables are needed. Concepts such as 'maintain' or 'enhance' imply effective management; and 'capacity to adapt to change' suggests a requirement to understand ecological mechanisms, including cause and effect relationships. As a prelude to developing EI indicators, we suggest adopting three phenomena from complex systems theory: emergence (Holland 1998), self-organisation (Müller 2005) and fractal patterns (Brown 2002).

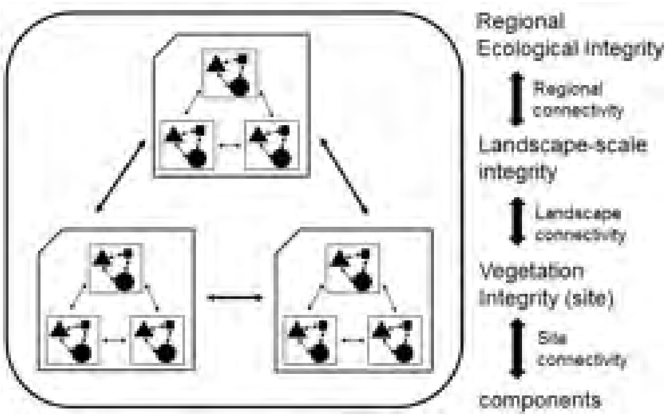

Fig. 1. A conceptualisation of the 'tangible' ecological components (geometrical shapes' grouped into nested levels of organisation through habitat connectivity.

Systems and Complexity

Regardless of the rigour applied to maintaining an inventory of organisms, populations and habitats, "a system's behaviour cannot be summarized simply by adding up the behaviour of the individual parts" (Costanza 1992). Emergence describes how higher levels of organisation display qualities that are not present at lower levels. Emergence has been directly linked with the principle of ecosystem integrity and emergent properties, such as population viability and adaptive capacity, properties that would make ideal indicators (Müller *et al.* 2000; Müller 2005), but are themselves not easily measured.

Noss's (1990) proposed framework of indicators for monitoring aspects of biodiversity spans multiple levels of organisation – from genes to landscapes, wherein each level comprises observable properties of composition, structure and function. This fits well with the concept of fractals: self-replicating patterns in nature. At each level, novel properties emerge through self-organisation of the components at the lower level (see Fig. 1). Ecological Integrity is relevant across spatial scales. In the Act, the site-level equates to Vegetation Integrity, but conceptually EI can be applied at any scale, up to and including the entire planet. Properties relevant to any scale are measured, and these inherently incorporate the properties of finer scales. The NSW government has adopted the Essential Biodiversity Variables (EBV) concept in which emergent properties of biodiversity such as species richness, compositional turnover and endemism, are to be monitored (Turak *et al.* 2017). Haase *et al.* (2018) recommended linking the Essential Biodiversity Variables concept to EI.

Restoring the whole and the sum of the parts

Ecological restoration is defined as the process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed (McDonald *et al.* 2016). At broad spatial scales, EI can only be 'maintained'; not readily restored. At fine scales EI can be restored relatively quickly– through revegetation, removal of pests and weeds, or changed management. But, only if suitable physical conditions prevail, and only if species are able to re-establish – this being contingent on EI at broader scales (Prober *et al.* 2017).

Conclusion

Under the new Act, NSW is required to develop regional and state-wide indicators of EI, and NSW will enter an era of increased reporting of conservation actions and strategic monitoring and assessment of management effectiveness in relation to biodiversity outcomes. This process will also lead to improved prioritisation for investment in biodiversity values. New South Wales has a legacy of model development, whereby issues of connectivity and climate adaptation are being addressed (Drielsma *et al.* 2014; Turak *et al.* 2011; OEH 2016; OEH in press), and is therefore well-placed to meet the challenge of monitoring EI. However, new approaches will be needed, ones that are suited to managing the complexities inherent to natural biological systems, where the whole is necessarily greater than the sum of the parts.

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Counting the Cost of Revegetation: is Direct Seeding Cheaper than Planting Tube–stock?

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Abstract
Direct seeding is often assumed to be cheaper than planting tube–stock, but limited data exist to compare the relative costs of the two techniques. At four riparian sites in Victoria, we assessed the number of plants established over time in the months after direct seeding or planting. The costs of surviving plants and of weed management were calculated. Plants were 11 times cheaper when established by seeding ($1.88/plant) than when planted ($21.03/plant). Incorporating weed management costs, direct seeding was 1.3–2.4 times more cost–effective than planting tube–stock, although costs were high for both techniques.

Introduction

Active revegetation involves either planting nursery–grown stock or direct seeding. Planting is generally considered to be a more reliable revegetation technique because the early phases of plant establishment, when a seedling is most vulnerable, have been completed prior to planting. In contrast, establishment from seed sown directly into a site may be constrained by adverse environmental conditions, resulting in low establishment rates.

In terms of direct costs however, it is more expensive to plant than to sow (Palma and Laurence 2015; Schirmer and Field 2000), due to the relative costs of plants and planting compared with seed and sowing. Although these costs are well understood, there are few published studies analysing the cost–effectiveness of the two revegetation techniques, in terms of plant establishment over time. Assessing plant numbers at 18 months since establishment, Grose (2013) found that planting slender banksia (*Banksia attenuata*) in Western Australia cost approximately 10 times more than sowing seed, while Cole *et al.* (2011) costed planting at 10–30 times more expensive than seeding for rainforest species in Costa Rica, based on plant survival after two years. A trial in riparian sites in California found that planting was twice as expensive as niche direct seeding (Palmerlee and Young 2010).

Historically, riparian revegetation in the Melbourne region has involved planting tube–stock into sites which are spot–sprayed prior to planting, with regular post–planting weed maintenance undertaken to manage the high weed abundance frequently found in riparian areas. Herbivore protection measures are also often required. Although relatively successful, such planting operations are expensive which limits the potential extent of revegetation, so there is interest in determining if direct seeding is more cost–effective. The limited use of direct seeding to date is due to a perception of unreliable outcomes, compounded by the difficultly of undertaking post–sowing weed control. The aim of this study was to compare the cost–effectiveness of planting and direct seeding tree and shrub species at riparian sites, taking into account weed management costs before and after plant establishment.

Methods

Plant numbers were assessed in sown and planted areas at four riparian sites where both revegetation techniques had been used. The cost/surviving plant was then calculated. To estimate this figure for plants in sown areas we assumed seed cost $1 500/kg and was sown at 1kg/ha. Including the cost of sowing, estimated at $1 800/ha, brought the total cost of seeding to $3 300/ha. For tube-stock plants, the cost to supply, plant and guard plants was $15.70/plant at the Yarra River and Sheepstation Creek sites and $19.70/plant at the Deep Creek and Emu Creek sites (based on existing Melbourne Water data). The cost/surviving plant was calculated by allocating the total cost of installing all the tube-stock plants initially planted, across those plants surviving at the time of assessment.

Weed management costs before and after revegetation were then added to the plant costs to estimate overall project costs. All activities were costed using commercial labour rates and included project management costs. A four-person field crew was costed at $1 700 per day. Pre–planting weed control required two spray applications ($3 400/ha), while it cost $13 600/ha to prepare sites for direct seeding (four spray applications requiring two crew days each). Weed control after planting was costed at $4.80/plant over two years, while herbicide–only maintenance of direct seeded sites was costed at $10 200/ha (six spray applications over two years). Hand weeding direct seeded sites monthly for the first three months required 18 crew days, with three additional spray applications required in the following months, costing a total of $35 700/ha. Estimates of the time required to hand weed were based on three projects only and it is anticipated that the time required will vary between sites.

Results

Survival of tube–stock decreased over time from 100% at the youngest site to 67% at the oldest site (Table 1). The cost of each surviving tube-stock plant ranged between $15.70 and $23.66, averaging $21.03/plant across all sites. In contrast, the average cost of each direct seeded plant was 11 times cheaper at $1.88/plant (Table 1). These costs incorporated planting and sowing costs only.

Adding weed management costs to the costs of establishing 2 500 stems per hectare (sph) showed that planting tube–stock was 2.4 times more expensive than direct seeding using only herbicide post–sowing (Table 2). It was still 1.3 times more expensive to plant tube–stock than to hand weed direct seeded sites, even though hand weeding monthly for the first three months after sowing considerably increased the costs of direct seeding.

Table 1. Cost per surviving plant of seedlings either planted or sown in riparian revegetation sites.

Site	Planted tube-stock			Direct seeded		
	Site age (months)	Survival	Cost per surviving plant	Site age (months)	Density (plants/ha)	Cost per surviving plant
Yarra River [E]	30	67%	$23.43	30	1980	$1.67
Deep Creek [N]	7	82%	$23.66	19	2730	$1.21
Emu Creek [N]	6	91%	$21.32	6	3880	$0.85
Sheepstation Creek [E]	5	100%	$15.70	19	870	$3.79
Average		85%	$21.03		2,365	$1.88

Site names followed by E were east of Melbourne (plants cost $15.70 each); site names followed by N were north of Melbourne (plants cost $19.40 each).

Table 2. Projected cost per hectare to plant tube–stock or direct seed riparian revegetation sites*.

Activity	Tube–stock	Seeding (spray only)	Seeding (hand weeded)
Site preparation	$3 400	$13 600	$13 600
Plant installation	$52 600	$4 700	$4 700
Maintenance	$12 000	$10 200	$35 700
Total	**$68 000**	**$28 500**	**$54 000**

*Assuming a target plant density of 2 500 sph, with a tube–stock plant costing $21.03 and a plant arising from direct seeding costing $1.88.

Discussion

The results of this study confirm that direct seeding is cheaper than planting tube–stock in riparian areas on a cost per plant and on a cost–effectiveness basis, incorporating weed management costs. However one limitation of this study, as for other recent studies of revegetation cost–effectiveness (Cole *et al.* 2011; Grose 2013; Palmerlee and Young 2010), is that plant survival was only monitored for a short period. Further evaluations of long term plant survival are required to determine cost–effectiveness of each technique in achieving revegetation outcomes.

The costs of revegetating riparian areas by either method are high. It should be noted that the data presented here do not include the costs of fencing, pest animal control or woody weed control, which may be significant at some sites, but which will be the same for both revegetation techniques. The most comprehensive analysis of revegetation costs in Australia was undertaken in the late 1990s and found that planting tube–stock cost about $11 000/ha (at 1999 values) (Schirmer and Field 2000). This included project management, monitoring and fencing costs, but no post–planting weed maintenance, and used a labour rate of $15/hour. A more recent analysis of rainforest replanting projects in northern Australia put the cost at $61 000/ha, which included $48 000 for post–planting weed maintenance (Hunt 2008). The requirement to intensively manage weeds in rainforest systems mirrors the situation in riparian areas in the study area. Hand weeding post–sowing is an expensive but potentially effective weed management option; further studies testing varying levels of hand weeding intensity may indicate that lower levels of hand weeding are equally as effective as those tested to date, which would reduce this cost.

From these results, we can conclude that at riparian sites where it is an appropriate revegetation option, direct seeding is likely to be more cost–effective than planting tube–stock, even if hand weeding is required.

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Managing Relictual Eucalypt Woodlands: Growth and Mortality Studies to Forecast Old Growth Habitat Feature Development and Resource Bottlenecks

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Abstract

We collected longitudinal data on 10 species of temperate woodland *Eucalyptus* to calculate recruitment, growth, mortality and canopy senescence rates, and measured allometric relationships, including hollow availability in relation to DBH. We are developing a stochastic model that integrates these relationships to predict future change in stand attributes, such as strata heights, stem density, canopy condition and hollow availability, of temperate woodlands dominated by the study species.

Introduction

Structure of individual trees and tree stands define habitats available to many species in a landscape. Loss of old-growth trees is linked to widespread species decline, particularly fauna reliant on tree hollows for breeding and survival. Australian temperate woodlands have suffered extensive losses of old-growth trees. While clearing continues, there is also increasing effort devoted to landscape restoration. Such work, starting with remnants of original woodlands or on greenfield sites, aims to restore some level of ecological function. However, predicting future changes in the availability of habitat features in temperate woodland trees and stands is complex and highly dependent on extensive data on the candidate species (*e.g.* Ross *et al*. 2008). Data describing the allometry of tree development and provision of habitat features are rare for *Eucalyptus* trees outside of silvicultural studies. This is particularly the case for woodland tree species, as opposed to forest tree species. Our aim was to determine the allometric relationships, including hollow availability, and temporal patterns of growth, canopy senescence and mortality of dominant and widespread tree species from the highly modified eucalypt woodlands of central NSW. These relationships are being incorporated into a tool to enable predictions of future states of trees and stands, whilst incorporating variability in all measured parameters.

Methods

We established 1-ha sites in the central NSW wheat-belt as part of an extensive study of fauna in relictual landscapes (Ellis and Taylor 2013). At 113 sites containing *Eucalyptus* trees, we collected morphometric and canopy condition (tree form) data on > 4000 eucalypt trees with trunk diameters (DBH) $\geq$ 15 cm (Taylor *et al.* 2016; Ellis *et al.* 2017) as measures of potential fauna habitat. We collected data on *Eucalyptus camaldulensis* (river red gum), *E. melliodora* (yellow box), *E. microcarpa* (grey box), *E. populnea* subsp. *bimbil* (poplar box), with smaller samples of *E. albens*, *E. conica*, *E. blakleyi*, *E. largiflorens* and *E. sideroxylon*. We estimated tree hollow abundance with surveys from the ground, and validated a subset of estimates by ascending trees (Rayner *et al.* 2011). We analysed hollow abundance data at the tree (Rayner *et al.* 2014) and plot scale (Ellis *et al*. 2015). We revisited trees after approximately 5 years to determine growth, mortality and recruitment (Taylor *et al.* 2014; Ellis *et al.* 2017) with the next resampling due in 2018 to determine the decadal growth rate for 1800 trees.

The tool we are developing is an individual-based stochastic temporal model in R (R Development Core Team 2015) to predict changes in individual tree characteristics and in the availability of habitat features of a stand. A tabular description of an initial state of a real stand or hypothetical revegetation site, giving details about each tree's species, DBH and canopy senescence, and the time period to simulate is required. The model applies growth, senescence, and mortality modules to individual trees at each time-step. The recruitment module uses the stand structure to estimate recruitment. Tree allometry and hollow characteristics can be estimated for each tree and summarised for the stand at each time-step. Replicate runs with the same starting conditions can be used to estimate the range of potential states at each time step and the range of potential outcomes.

Results

Relationships between trunk diameter and tree height, canopy size, growth rates, hollow abundance and the progression of canopy senescence were published for the study species (Rayner *et al*. 2014; Taylor *et al.* 2014, 2016). For *E. camaldulensis* these relationships varied between stands along the permanent Macquarie River and intermittent Bogan River (Ellis *et al.* 2017). The parameters, and their variances, describing growth rate, mortality, allometry and hollow abundance in relation to DBH for each species/form combination were extracted and tabulated in the relevant modules within the model. Equations for the probability of transition between forms at each time step for each species based on DBH, form and growth increment were derived for the senescence module. Similarly, recruitment probability and size equations were derived for the recruitment module.

Our tool is robust when dealing with complex interactions among factors impacting on the development of tree and stand characteristics. This has allowed us to start exploring the dynamics of individual species and the woodlands they form. For example, although *E. populnea* and *E. microcarpa* are superficially similar in their hollow abundance relative to DBH, across time the differences in their growth and canopy senescence rates can result in a four-fold difference in hollow abundances between stands of the two species after a century (Fig. 1), and a 25-year difference between species in the onset of hollows. Conversely, *E. camaldulensis* has to have a larger DBH than the previous two species to produce hollows, but a faster growth rate means that hollows are predicted to appear in *E. camaldulensis* at a similar age to *E. populnea* (Fig. 1). Similar comparisons have been made for development of tree height, trunk size, canopy condition and strata composition for monospecific and multi-species stands.

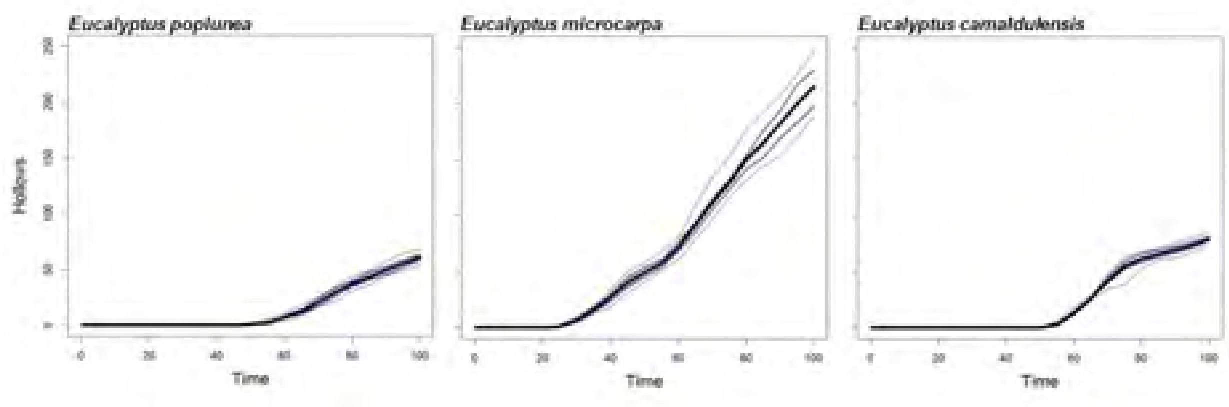

Fig. 1. The predicted number of hollows, showing the four quartiles, across a century for stands starting with 100 small trees (DBH 15 cm) for three species with differing growth and canopy senescence rates.

Discussion

We have demonstrated that woodland eucalypt species vary markedly in their allometric relationships (Taylor *et al.* 2016), with additional differences between populations of *E. camaldulensis* on perennial and intermittent rivers (Ellis *et al.* 2017), and significant differences in hollow abundance among species (Rayner *et al.* 2014). Temporal interpretations of these relationships need to incorporate variations in growth and senescence among individuals and species, with their rates being influenced by individual tree size and state of senescence (Taylor *et al.* 2014), if useful predictions are to be made about future states of tree stands and woodland landscapes.

The modular tool we are developing enables the integration of diverse and detailed field measurements into an individual-based stochastic temporal model that allows complex interactions and natural variation to play out across repeated simulations. Since results are recorded at each time-step, stand attributes can be plotted against time to forecast attributes of interest (*e.g*. Fig. 1). Such attributes may include tree density, basal area, canopy heights, stand composition, stand senescence structure, and the abundance of hollows of various types and sizes. Each of these attributes may be relevant to re-establishing different fauna species and restoring stand- or landscape-scale ecological functions. Furthermore, replicate runs (incorporating the variability within all parameters) from the same starting point not only can predict likely outcomes, but predicts the diversity of outcomes, including the worst-case scenario that may compromise a restoration project.

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Application of an eDNA detection framework for species monitoring

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Abstract
Environmental DNA (eDNA) is increasingly being used in surveys to establish the presence or absence of target species. Like any survey method, however, eDNA does not have perfect sensitivity, meaning there is some chance of failing to detect target DNA when it is present at a site. Failing to account for this imperfect detection can lead to biased estimates of species' distribution and abundance, and the analysis and interpretation of eDNA survey data needs to take this into account. We have developed a framework to estimate the sensitivity of both the field and laboratory components of an eDNA survey method, and show how these can be combined to estimate the overall sensitivity. We have applied this framework to species-specific eDNA surveys to estimate the sensitivity, or probability of detection. We present recent applications of eDNA to inform conservation management around i) endangered species reintroductions, ii) invasive species containment, iii) invasive species eradication, iv) identification of breeding events, and, v) remote biodiversity assessments. We demonstrate the broad utility of the eDNA technique, revealing its potential to transform species monitoring.

Introduction
Environmental DNA (eDNA) is gaining popularity as a detection tool because it can have advantages over traditional survey methods in difficult-to-survey locations, such as aquatic habitats, and for difficult-to-detect taxa, such as rare or cryptic species. The idea is that if a species is present at a site, individuals of that species will have released DNA into the environment through discharges such as faeces, skin cells, mucous and gametes. Collection of an environmental sample, such as a water sample, enables that DNA to be captured, isolated, extracted and amplified. eDNA surveys can be used to target a single species of interest or to detect broader biodiversity patterns across an entire taxonomic group.

eDNA is a highly sensitive tool that is capable of detecting DNA at low concentrations in the laboratory (Wilcox et al. 2013) and frequently provides greater detection rates than traditional survey methods (Hinlo et al. 2017; Dejean et al. 2012). A framework to estimate the overall sensitivity of eDNA surveys has been developed, enabling identification of spatial and temporal variation in eDNA concentrations (Fig. 1). This information can guide future sampling efforts to increase detection sensitivity as well as enable researchers to account for imperfect detection when interpreting results (Furlan et al. 2016).

Below, we review several applications of eDNA surveys, demonstrating how the technique can be used to inform conservation management.

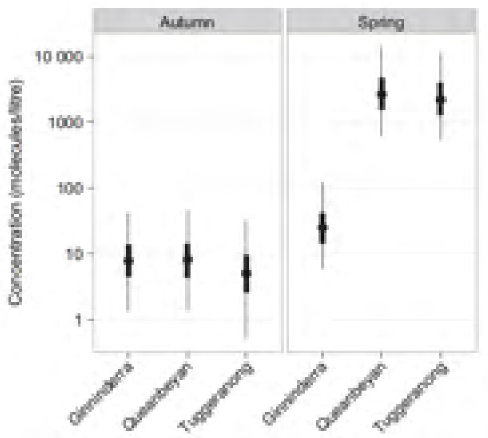

Fig. 1. The estimated concentration of Oriental weatherloach, *Misgurnus anguillicaudatus*, DNA in three streams (Ginninderra Creek, Queanbeyan River and Tuggeranong Creek) sampled during autumn and spring. Closed circles show the mean concentration and the thick and thin lines show the 50% and 95% credible intervals, respectively (Furlan et al. 2016).

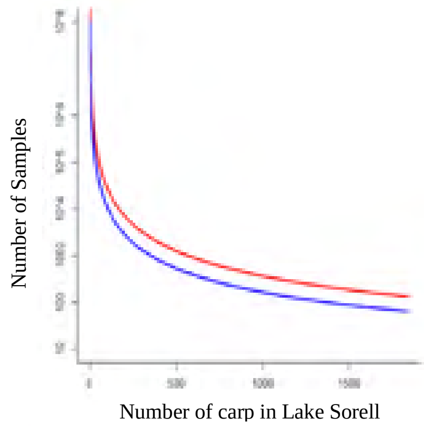

Fig. 2. eDNA detection in Lake Sorell. Number of samples required to achieve 95% detection probability for a given number of carp (assuming the current population size is 1140 or 1840 carp, red and blue lines respectively).

Applications
Reintroductions
Reintroductions can provide a valuable conservation tool, but for cryptic species, knowledge of their survival post-release can be difficult to determine. Species-specific eDNA surveys were able to demonstrate, for the first time, successful egg hatching and continued survival of the endangered Northern Corroboree Frog (*Pseudophryne pengilleyi*) in the wild following the reintroduction of captive bred eggs (Rojahn 2016).
Invasive species control and containment

Determining appropriate locations for the construction of containment barriers relies on detailed knowledge of species distributions. eDNA monitoring was able to determine the distribution of the invasive redfin perch, *Perca fluviatilis*, further upstream than traditional detection techniques (Bylemans et al. 2016b). Placement of a containment barrier beyond this distribution ensured redfin perch were excluded from critical breeding grounds of the endangered southern pygmy perch, *Nannoperca australis*.

Eradications

Confirming eradication success depends upon establishing species absence from an environment. eDNA surveys were conducted in an extremely low-density population of an intensively controlled population of European carp, *Cyprinus carpio*, in Lake Sorell, Tasmania (IFS 2016). The results were used to determine the survey effort required to confidently detect carp at their current density as well as the increased survey effort required to detect carp when their population drops to just several or a single individual (Fig. 2, Furlan et al. Unpub. data).

Reproductive events

Determining the timing and location of reproductive events is critical for effective species management. Many aquatic organisms breed through spawning, with males releasing a vast quantity of spermatozoa into the waterway. eDNA surveys were able to successfully detect a change in the relative abundance of nuclear and mitochondrial DNA (Fig. 3), enabling identification of spawning activity in endangered Macquarie perch, *Macquaria australasica* (Bylemans et al. 2016a).

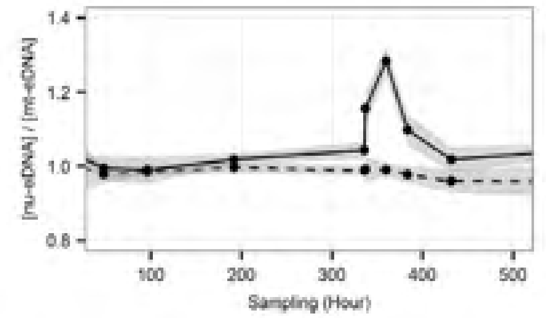

Fig. 3. The ratios between Macquarie perch nuclear and mitochondrial environmental DNA (eDNA) concentrations over time in treatment tanks. Solid lines represent Experimental Spawning Tanks (EST) while dashed lines represent Experimental Control Tanks (ECT). Ten millilitres of water (ECT) or a mixture of milt and water (EST) were added after 336 h (Bylemans et al. 2016a).

Remote biodiversity

Using a multi-species approach, eDNA metabarcoding can provide an extraordinarily powerful tool to conduct rapid biodiversity assessment (Taberlet et al. 2012). Recent eDNA surveys in remote waterholes in central Australia demonstrated the utility of the technique to detect a range of vertebrates including not only aquatic but semi-aquatic and terrestrial species (Furlan et al. Unpublished data).

Conclusion

eDNA is an extremely powerful detection technique capable of a broad range of applications to inform wildlife management. It is a highly sensitive technique but requires substantial investment to detect species at extremely low densities. The sensitivity and suitability of eDNA will vary according to the environment and species targeted. eDNA concentration estimates can provide critical information to guide future sampling schemes to improve confidence in detection and contribute to effective management action.

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Ecosystem Services and Profitability in Grazing Systems

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Abstract
Ecosystem services provide productive benefits for grazing systems. These include water and mineral cycling, habitat for beneficial organisms, shelter and protection for plants and animals, connectivity, climate modification and energy capture. Because these services are provided free of cost, economic theory postulates that the profitability of grazing systems cannot be maximised unless these benefits are maximised. This paper outlines the ways in which management can ensure that the providers of these ecosystem services are maintained. The science behind each of these ecosystem service providers will be explained and their role in grazing system productivity and profitability demonstrated. It will be shown that there are six key NRM criteria that ensure that the benefits of ecosystem services can be maximised. Data from our property, which has been using these NRM criteria for the past 7 years, will be used to demonstrate inherent inefficiencies in many grazing systems.

Introduction
Three basic inputs drive the productivity and, hence, profitability of grazing enterprises – energy, plant nutrients and water. In Australia, energy availability from solar radiation is never limiting to production. Rainfall Use Efficiency (RUE), the amount of rain required to produce 1 Megajoulles of Metabolisable Energy (MjME), is therefore a good measure of how well the grazing ecosystem is functioning. Any change in land management changes the interactions between and within plants and soil. These changes include soil and soil fertility loss, changed water and nutrient cycling, loss and change in plant species and the loss of other natural functions generally defined as ecosystem services. Loss of these free services either adds to the cost of production as free services are replaced by purchased inputs or the productivity of the system declines as, for example, soil fertility declines.

Rainfall is lost to the productive grazing system as run-off, deep drainage, evaporation from the soil and inefficiencies in water use by plants due to either changes to more inefficient species or inadequate plant nutrients in the soil. Pasture availability and other factors (heat, cold, distance to water, etc.) limit animal production and may reduce apparent RUE. The factors that minimise water loss from the system and maximise pasture utilisation by grazing animals are groundcover, litter, green leaf area, species diversity, shade and shelter and soil that has no physical, chemical or biological constraints. If maintained, these factors deliver such ecosystem services as erosion control, water and nutrient cycling, habitat and carbon sequestration to mention just a few.

The two key concepts for grazing managers are carrying capacity and stocking rate. Carrying capacity measures the ability of the natural resource base to indefinitely maintain an intensity of production. I define this as 30% of total MjME pasture production of the unstocked system. Because rainfall is part of the natural resource base, carrying capacity is inherently variable. Stocking rate is a measure of the intensity of production applied to the natural resource base by management (the number of MjME removed from the system). Viewed this way, stocking rate is independent of management practice. The two need not be, and commonly are not, the same. Stocking rate needs to change as the condition of the natural resource base (carrying capacity) changes. Although farming the driest inhabited continent, Australian farmers and graziers garner very little from the rain that falls. Based on Agsurf data from ABARES, rangeland graziers convert about 5% of the rain they receive into production (Gardiner, unpublished. Methodology available on request)

Method
There are six indicators of natural resource health that define a resilient system (Gardiner and Reid, 2010). These may be considered as the providers of ecosystem services in grazing systems, should be maintained 100% of the time and are a measure of the carrying capacity of the resource. Failure to maintain these conditions implies that the grazing enterprise is overstocked. They are:

- Sufficient groundcover to minimise runoff and wind and water erosion, generally more than 70%.
- Sufficient litter (dead detached plant material lying on the soil surface) to minimise water loss to evaporation, feed soil biology and insulate the soil against temperature fluctuations, generally more than 2 t/ha.
- Sufficient green leaf area (DGM) to maximise energy capture, help minimise evaporation through the shading effect, modify rainfall intensity, maintain relatively uniform soil temperature and provide sufficient feed for production, generally more than 1,500 kg/ha or a leaf area index greater than 5.
- Sufficient diversity of species to utilise rain when and where it falls. This would include C3 and C4 plants, annuals and perennials, grasses and legumes and trees and shrubs. Diversity minimises the risk of system loss to pathogens and/or pests.
- Sufficient shade and shelter to maximise plant and animal performance, mitigate temperature, provide connectivity, store carbon and maintain ecosystem integrity.

- Soil condition that is not being compromised by physical, chemical and/or biological deterioration or constraint. Highly fertile soil produces more MjME per mm of rain than soil that is nutrient constrained.

Our grazing operation has been designed with these principles in mind.

Results

On our own property, we have been managing the business to maintain the above criteria as a minimum standard for the past 7 years. We run a trading operation. We don't buy in until we have sufficient feed ahead of us to guarantee a profit and adjust numbers according to pasture availability throughout the season. We use rolling rainfall data to set initial stocking rate each year and actual rainfall in our 2 critical months (March and October) to fine tune numbers.

In part, the property is run as an experimental farm to help define the technical limits to plant and animal performance. With appropriate management, 800 mm of rainfall and 30% pasture utilisation, science shows that it should be possible to produce 1 kg of live weight gain/mm/ha/year in the Northern Tablelands environment. We are currently achieving about 0.8 kg/mm/ha while the district average is 0.1 to 0.2.

The property returns a profit of $500 - $700/ha despite expenditure of $150 - $250/ha on fertiliser every year. Despite contrary beliefs in some circles, this fertiliser program has increased pasture diversity from 23 species to 73 species. Most of the new species are either native or naturalised. We have planted 5,000 trees in windbreaks across the 40 ha block. Optimising the providers of ecosystem services allows us to achieve weight gains through the winter of at least 1 kg/head/day and 1.3 kg/head/day over our 10 month fattening cycle.

Our pastures produce an average of 30 kg GDM/mm/ha and we return about 12 t/ha of pasture residue to the soil each year. This compares to a tablelands average of 7 kg GDM/mm/ha (based on an average stocking rate of 5 DSE and pasture utilisation of 30%). Given the level of carbon sequestration in plants and soil, our grazing enterprise will be carbon negative for the next 60 years.

In combination, these six ecosystem services providers ensure maximum capture and utilisation of energy within the system and maximises water and nutrient cycling efficiency. If any of these conditions are not met, stocking rate exceeds carrying capacity and the natural resource base will decline. Each condition may be considered as a system threshold. As thresholds are crossed, the grazing system deteriorates to a worse state and is less likely to recover from disturbances. Most grazing systems in Australia do not meet the above criteria most of the time.

Conclusion

Management practices can enhance the ecological function of grazing systems, increasing both the number and effectiveness of ecosystem services provided and improving productivity, profitability and resilience. Failure to maintain at least the first 4 benchmarks listed above is a clear and consistent indicator that the enterprise is overstocked given the natural resource base and the management applied to it. We believe that the use of scientific principles in farming and grazing management is the key to developing regenerative agricultural systems.

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Limited Food Resources are affecting the Longevity of Diamond Firetails *Stagonopleura guttata* in the Mount Lofty Ranges, South Australia

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Abstract

Diamond Firetails *Stagonopleura guttata* (Shaw 1796) have been declining throughout their range in south-eastern Australia since at least the 1980s. In the Mount Lofty Ranges (MLR) South Australia, the population is fragmented and the range is contracting. At the broad-scale, habitat clearance is the main cause of this decline, but the specific processes affecting the ongoing survival of MLR Diamond Firetails (DFTs) are currently unknown. These finches are ground-foraging granivores, so they are susceptible to disturbances in the ground-layer. In the MLR, invasive weedy grasses have out-competed natives and now dominate the understorey, changing temporal patterns of seed production. Autumn rains trigger these weedy grass seeds on the surface layer to mass-germinate, reducing seed availability during winter. To determine whether DFTs are food limited during winter, a population was provided supplementary seed for one full year, and their use of this seed was monitored monthly. This population relied almost exclusively on supplementary seed during winter, but when natural resources were plentiful during spring and summer they took only half of their daily caloric requirements from supplementary seed. This highlights the importance of reinstating a sustainable year-round food supply for MLR DFTs. We recommend the restoration of both native perennial grass species and *Allocasuarina verticillata* – another important food source – that will provide a consistent supply of seed throughout the year, particularly during winter when resources are limited.

Introduction

The Diamond Firetail is among a suite of woodland bird species declining throughout their range in the Mount Lofty Ranges, South Australia. Their population has contracted significantly from the southern and central areas of the MLR and remaining sub-populations are fragmented and vulnerable (Paton *et al.* 1994). While habitat loss is the cause of these declines at the broadest scale, the specific processes affecting their ongoing survival in the region are unknown (Paton *et al.* 2004). DFTs are ground-foraging granivores, and are therefore susceptible to disturbances in the ground-layer. Invasive weeds, changed grazing regimes and changes in grass and forb communities can all impact their food supply. In the MLR, all three threats have occurred (Wilson and Bignall 2009). Introduced annual grasses have largely displaced native perennial grasses and they provide a rich supply of seeds during spring and summer (Ankor 2005). However, breaking autumn rains cause mass-germination of annual grass seeds (Lenz & Facelli 2005), leaving few seeds available for foraging birds through winter. These temporal changes in food abundances are likely impacting DFT survival (Houdet 2003; Ankor 2005).

In the MLR, DFTs breed predominantly during spring and summer and free-flying juveniles are prominent in post-breeding populations (Paton 2013, pers. comm.). This indicates successful breeding and fledging, but DFT numbers appear to diminish during winter (Paton *et al.* 2004; Ankor 2005). Therefore winter may be a critical period for the species, when food resources are scarce and fledglings from the spring-summer breeding season add to the strain on resources. Based on this evidence, our hypothesis is that a scarcity of food resources during winter affects the survival of MLR DFTs. Therefore, the objectives of this study are to a) identify periods of limited seed availability to DFTs in the MLR, b) determine whether the reliance of DFTs on supplementary seed changes temporally, and c) identify the most significant management issues for MLR DFTs.

Methods

Seed availability was sampled seasonally at three discrete study areas: Monarto, Rockleigh and Springton (each with three sites) in the eastern MLR. Grass and forb seeds were collected from seed heads and the soil surface from 25 x 25 cm plots (0.0625 m^2) where DFTs were observed foraging. We used a negative binomial generalised linear mixed model using packages '*lme4*' (Bates *et al.* 2015) and '*lsmeans*' (Lenth 2016) in R 3.3.1 to assess differences between study areas and seasons in seed availability.

Supplementary seed was provided for one full year at one of the discrete areas (Monarto). DFTs were trapped at the start of the year using mist-nets and colour-banded for individual identification. One feeder was surveyed from dawn to dusk once a month. Visitation, time spent foraging and foraging rates of colour-banded DFTs were recorded and used to calculate individual daily caloric intake from the supplied seed. Expected Daily Caloric Intake of a free-flying DFT (EDCI) was calculated using allometric scaling of Field Metabolic Rates (FMR) of birds, with the equation: $FMR=10.5M_b0.681$ (Nagy 2005), where $M_b = 19$ g (the body mass of an average free-flying DFT).

Results

The total forb and grass seed abundance per 25 x 25 cm plot is shown for the three areas for autumn, winter and spring (Fig. 1). A least squares means contrast of the model parameter estimates indicated that seed abundance was significantly lower in winter than in autumn for all three areas ($p < 0.05$). There was also evidence of reduced seed abundance during winter at other areas across the MLR as well as at those shown in Fig. 1. Fig. 2 shows the percentage of the EDCI (FMR = 77.99 kJ/day) that was taken from the supplement feeder by wild birds. During spring and summer this supplementary seed provided approximately 50% of the EDCI. During winter approximately 100% of the EDCI was taken from supplementary seed by colour-tagged individuals. DFT resighting rates after winter were significantly higher at the supplemented population compared with control populations.

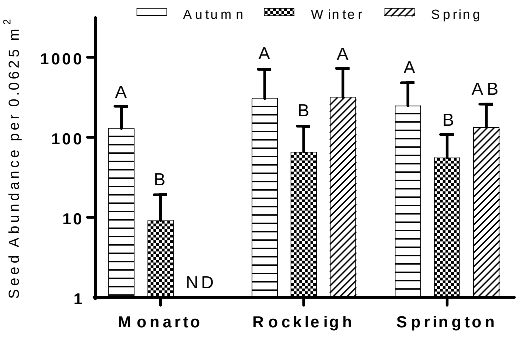

Fig. 1. Total grass and forb seed abundance in 0.0625m^2 plots during autumn, winter and spring 2015 at 3 study areas: Monarto, Rockleigh and Springton, MLR (log scale).

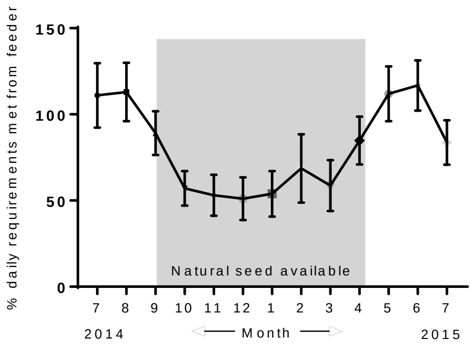

Fig. 2. Average percentage of Expected Total Daily Caloric Intake taken from supplemented seed by wild, colour-tagged DFTs at a Monarto feeder on one day per month from July 2014 to July 2015.

Discussion

The reduced seed availability at areas in the eastern MLR coincides with breaking autumn rains triggering mass-germination in annual exotic grasses. This supports the hypothesis that an understorey dominated by weedy annuals does not provide a consistent, year round food supply for ground-foraging granivores. The fact that wild DFTs at Monarto only used the feeder to meet approximately half of their daily caloric needs during spring and summer, when most exotic annual grasses were mass-seeding, indicates that they were able to forage naturally for at least part of the year, and were not wholly reliant upon the feeder. However, supplementing seed appeared to improve DFT survival at Monarto during winter, and birds took all of their daily caloric needs from supplement seed during this time (Fig. 2), when natural seed was scarce. Therefore, management of the MLR DFTs should focus on re-establishing reliable food species that provide sufficient seed, particularly during the winter months.

The MLR DFT population has been reported to eat predominantly grass seeds, mostly introduced species, and some forb seeds (Read 1994). However, 42% of foraging observations for DFTs away from feeders during winter 2014-16 were seeds from open Drooping Sheoak (*Allocasuarina verticillata)* cones (Hodder, unpublished). In the MLR, Drooping Sheoak populations have experienced fragmentation and contractions in range similar to those seen in DFTs (Bickford and Gell 2005). Drooping Sheoaks should be rehabilitated as a priority for DFTs, as they provide an important alternative food source to grasses and forbs during winter. Native perennial grasses are another important food resource as they produce seed for longer periods of the year compared to the exotic annuals that currently dominate DFT habitat (Hodder, unpublished). Perennial *Rytidosperma* spp and *Austrostipa* spp produce seed from the end of winter through to May, while native C4 grasses such as *Aristida behriana*, *Enneapogon nigricans* and *Setaria constricta* provide seed during autumn and winter (Hodder, unpublished). Restoring the understorey of grassy woodlands in the MLR with this suite of native perennials will improve the availability of reliable food resources for DFTs, and therefore aid their survival during the critical winter period.

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Differential use of remnant and revegetated woodland by Rufous Whistlers (*Pachycephala rufiventris*): implications for habitat restoration

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Abstract

The Rufous Whistler *Pachycephala rufiventris* (Latham, 1801) is one of many bird species declining due to woodland clearance in southern Australia. To reverse this, vegetation must be restored that incorporates the habitat attributes required by this species. To determine these requirements, habitat use by Rufous Whistlers was studied during the 2010/2011 breeding season at sites in remnant vegetation and revegetation in the Monarto region, South Australia. Radio-tracking of seven birds was used to establish home range size and vegetation use. Home ranges varied from 5.3 to 132.1 ha, and the ranges of some individuals were contained entirely within revegetation. The largest home ranges were recorded for birds using predominantly remnant vegetation. Birds used significantly more plant species in revegetation than they did in remnant, due to the high diversity of the plantings compared to the remnant habitat. Home range size is a function of resource availability and competition, so the small territories in revegetation suggest it is more productive than the remnant vegetation and can meet most of the habitat requirements of these birds. The mix of local, non-local and exotic species in the Monarto plantings and the more fertile land they were established on probably contribute to this. This suggests that to achieve successful, cost-effective conservation outcomes for Rufous Whistlers and other declining species, woodland restoration should be designed to create the most productive and biodiverse habitats, rather than just attempting to replicate remnant vegetation. Incorporating the specific habitat requirements of multiple species into revegetation schemes will reduce the amount of planting needed to support declining species, and improve the chances of halting their decline.

Introduction

Extensive vegetation clearance in southern Australia has resulted in declines in the diversity and abundance of woodland bird communities; to reverse this trend, large-scale, diverse and structurally complex habitat needs to be re-established across cleared landscapes (Ford 2011). The majority of current revegetation efforts in Australia fail to integrate these characteristics and consequently a number of declining bird species remain absent from typical revegetated sites (Cunningham *et al.* 2008). However, there are exceptions (e.g. Kavanagh *et al.* 2007), including in the Monarto region, South Australia, where plantings comprise over 250 species of local, WA and exotic trees and shrubs that were established on 1700 ha of retired agricultural land alongside remnant open woodland (Monarto Development Commission 1976). Because of this, these woodlands provide habitat for 92 of the region's bird species, 40 of which are declining and many of which also breed here (Paton and O'Connor 2010).

One species of conservation concern is the Rufous Whistler (RUW), an insectivorous passerine that defends discrete home ranges that serve both breeding and foraging needs (Higgins and Peter 2002). RUWs are known to respond positively to revegetation (e.g. Kavanagh *et al.* 2007, Cunningham *et al.* 2008). However, there is generally little known of the microhabitat features that woodland birds require, including RUWs, and how revegetation should be designed to meet these requirements (Ford 2011). The aim of this study was to determine these requirements for RUWs in the Monarto region. The objectives were to (1) tag and track RUWs in remnant vegetation and revegetation, (2) compare their home range size in each vegetation type, and (3) identify the plant species they use in each vegetation type.

Methods

Data on habitat use were collected at three locations in the Monarto region with varying degrees of remnant vegetation and revegetation. Seven RUWs were tagged with A2426 0.65 g radio transmitters (Advanced Telemetry Systems). These birds were tracked using an Australis 26k Scanning Receiver (Titley Electronics) and directional aerial. To map home range size, waypoints were successively marked with a Garmin 60 GPS unit at each tree or shrub the birds used, and the plant species was recorded. The home range area for each bird was determined using 100% Minimum Convex Polygons (MCP) with Hawth's Analysis Tools in ArcMap v9.3.1. Layers defining remnant vegetation and revegetation in the region were used to calculate percentage of each habitat type in these MCPs.

Results

Size of home ranges varied from relatively small at 5.3 ha to very large at 132.1 ha (Table 1). All birds used areas of both remnant vegetation and revegetation to varying degrees, except RVB-SM and RVB-CM/CF which were seen exclusively in revegetation. Differences in the extent of home ranges were not just the result of vegetation use but of territoriality, too; the home ranges of all pairs except RG-M and RV4-M/F were restricted by competition from two or more adjacent conspecifics. RV4-M/F were recorded nesting. Plant diversity in remnant vegetation was much lower than that in the revegetation, as highlighted by the number of plant species used in each habitat type (Table 1). Note that these data do not necessarily represent the absolute home range sizes of individuals, but the home ranges they occupied over the dates tracked.

Table 1. Extent and vegetation composition of RUW home ranges.

Bird ID	Dates tracked	No. days	*n*	Range (ha)	Area (ha)		Composition (%)		No. plant spp.	
					RV	REM	RV	REM	RV	REM
RG-M	17/02/11–17/03/11	9	1111	132.1	2.7	87.9	3.0	97.0	4	6
RV4-M	21/12/10–12/01/11	9	1139	63.2	33.6	12.8	72.6	27.4	31	5
RV4-F	20/12/10–14/01/11	7	904	48.5	26.9	9.6	73.7	26.3	32	5
RVB-SM	07/02/11–08/03/11	7	655	27.1	24.6	0.1	99.5	0.5	32	0
RVB-NM	23/11/10–09/12/10	5	594	23.3	12.9	7.2	63.8	36.2	21	4
RVB-CF	21/11/10–16/12/10	7	529	18.0	17.8	0.2	99.2	0.8	32	0
RVB-CM	21/11/10–16/12/10	4	327	5.3	5.3	0.0	100.0	0.0	30	0

GPS waypoint totals are listed under '*n*'. 'Range (ha)' is the total home range/MCP area in hectares over which birds were observed. 'RV' and 'REM' group revegetation and remnant vegetation data respectively, as follows: 'Area (ha)' indicates area in hectares of each vegetation type in each home range and 'Composition (%)' indicates these areas as a percentage of the total vegetation in each MCP; 'No. plant spp.' lists the number of plant species used by the birds in each vegetation type.

Discussion

Home range sizes of RUWs can be highly variable (Higgins and Peter 2002), but the 132.1 ha used by RG-M is unusually large (Table 1). Home range size is a function of resource availability and population size, where smaller ranges are indicative of a greater density of resources (higher quality habitat) and/or competition (Brown 1964). The smallest home ranges were recorded for RUWs exclusively occupying revegetation, and the RUW observed over the largest area predominantly used remnant vegetation (Table 1). This suggests the Monarto plantings not only have the capacity to meet the habitat requirements of RUWs but are also more productive, permitting smaller home range sizes despite having greater intraspecific competition than birds in remnant vegetation. Further study is needed to identify the drivers of habitat productivity and their effect on RUW home range size, but here we speculate on what these drivers might be and the implications for revegetation practices.

In the Monarto region, remnant vegetation is found predominantly on dune crests and rocky outcrops with shallow soil profiles, while most of the Monarto woodlands were planted on retired farmland on the more fertile, deeper swales between the dune systems (Chittleborough 1978). Vegetation on fertile soils is more productive, supports more plant growth and therefore – significantly for insectivorous birds – supports an increased invertebrate biomass (Watson 2011). In addition, RUWs in revegetation were observed using more plant species compared with the remnant vegetation, even in the smallest home ranges (Table 1), highlighting the diversity of these plantings. Though revegetation is strikingly different to the remnant in floristic composition and structure, its diversity and productivity creates a greater heterogeneity of spatial and structural resources. These attributes improve resource availability and may allow the habitat requirements of RUWs to be met in a smaller area.

Most restoration efforts for conservation aim to replicate remnant habitat as it is thought to be of greater value for local biodiversity, but these efforts often fall short of the complexity required for declining birds (Munro *et al.* 2007; Cunningham *et al.* 2008). Though the Monarto plantings incorporate non-local and exotic plants and were not originally designed for biodiversity gains, their complexity and significant scale have created excellent habitat for woodland birds. Given the imminent decline of many species, the expense of revegetation at adequate scales, and the difficulty in acquiring large areas of land for restoration (Vesk and Mac Nally 2006), it may not be cost-effective or efficient to restore landscapes to their pre-European state. To prevent extinctions, we need to employ innovative revegetation techniques to support the greatest diversity of wildlife in a given area. Productive land should be targeted in conservation acquisitions, and habitats created to make optimal use of land for biodiversity by understanding the requirements of declining species and prioritising their needs in restoration efforts.

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Resilience planning in restored landscapes

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Abstract

Under a changing climate, it is essential that habitat restoration planning to enhance ecological systems takes full account of modelled climate futures in Australia. Scenarios for climate-changed regions can lead to a myriad of restoration planning issues. Using a resilience planning framework can assist in marshalling thoughts and revealing the clarity that is critical to goal setting and shaping the methods to reach planned outcomes. Resilience planning identifies which ecosystems, or ecological characteristics are important, if these systems can be saved, or if active stewardship could transform these areas into systems that still provide ecologically important habitats. Resilience planning gives metapopulations in restored ecosystems the best chance to respond to a range of disturbances by minimising environmental damage and, through scientifically grounded restoration design, allowing a dynamic and rapid recovery. It identifies critical elements in the landscape that are ecologically important, and the disturbances that are likely to affect those landscape elements into the future. By predicting the impact of disturbances such as climate change on restored landscapes, and associated native communities, we can develop management interventions that ensure their ecological integrity. Here we provide on-ground examples of resilience planning at the landscape scale in a variety of agricultural landscapes in Victoria. These include significant widening of seed provenance to develop climate-adapted plant communities, flora and fauna distribution modelling to predict future dispersal, and connectivity modelling underpinned by species specific habitat requirements. In short, resilient landscapes will need to have the flexibility to self-organise and bounce back from both long-term change and short-term disturbances.

Introduction

Globally landscapes are increasingly degraded through habitat loss and fragmentation (Lindenmayer 2009). Habitat restoration has been proposed as a way to try and maintain biodiversity in the face of increasing habitat degradation, and disturbance effects such as climate change (Harris et al. 2006). In ecological systems, resilience planning may allow us manage landscapes so they can respond to and recover from disturbances (Desjardins et al. 2015; Millar et al. 2007; Newton and Cantarello 2015). Ecological resilience is the capacity of a natural system to absorb or tolerate change, as a result disturbance, before pushing past a threshold limit and moving to another state (Hobbs et al. 2009). This is related to engineering resilience, which is the time required for a system to return to an equilibrium point after a disturbance event (Desjardins et al. 2015; Newton and Cantarello 2015).

In order to undertake ecological resilience planning, some authors have suggested that appropriate resilience objectives need to be identified. These can be classified as: a) engineering resilience, by undertaking actions that increase the rate of an areas recovery following disturbance through activities such as revegetation; b) increasing the adaptive capacity of a system (a systems ability to adapt to a disturbance through reorganisation) by enabling areas to adapt to a changing environment through activities such as climate adapted plantings; c) ensuring natural areas are resistant to change (the degree to which a system remains unchanged despite a disturbance) by strengthening their ability to tolerate disturbance by implementing interventions such as fire breaks or planting fire/insect tolerant species (Newton and Cantarello 2015); and d) by making systems spatially resilient - through the development of connections through the landscape (Millar et al. 2007) and stepping stones - landscape scale processes can be facilitated. Finally, they highlight the importance of monitoring to evaluate the effectiveness of management interventions and to adaptively manage ecological systems (Newton and Cantarello 2015).

In this manuscript, we will (1) provide case-studies of ecological resilience planning undertaken by a non-government organisation in Victoria, Australia - Greening Australia, (2) illustrate how the above resilience objectives can be integrated into on-ground projects (Table 1) and (3) summarise how conservation planning tools can be used in resilience planning to meet conservation objectives. This information will be important for conservation practitioners who wish to integrate robust science into habitat restoration planning to ensure restored landscapes persist over the short and long-term.

Case-studies

Understanding Climate Impacts on Threatened Species - In the Wimmera, NW Victoria, Greening Australia are managing a large conservation reserve (1,000ha) to ensure that threatened species and carbon stocks are maintained in this landscape into the future, under a changing climate. Approximately 70% of this reserve is covered by remnant vegetation, while the remaining area was cleared for farming and more recently replanted with indigenous trees and shrubs. At present, 21 threatened plant and animal species have been recorded on the reserve. One of the more iconic species is the Red-Tailed Black Cockatoo (RTBC). Work is now underway to understand how best to restore parts of this landscape in ways that extend RTBC habitat needs.

Using Edgar's climate modelling for the RTBC, we were able to determine the current distribution of that species, and the likely areas that species could occupy by 2055 (Edgar 2016). This predicted that this species would be less likely to persist in this landscape into the future under current climate conditions, due to a lack of suitable food resources. To determine how best to restore and enhance key habitat areas for this species, such as Buloke

(*Allocasuarina luehmannii*) woodland communities, we used the Atlas of Living Australia. This allowed us to identify locations appropriate seed provenances in populations with similar climates to those predicted for the Wimmera in 2055. This would add a resilience capacity to the restored habitats, increasing the likelihood of their persistence in a hotter, drier climate (ALA 2017).

Mitigating Drying Landscapes/Critical Habitat - In central Victoria, east of Melbourne, we have planned and designed the conversion of an agricultural landscape at Haining Farm into fauna habitats by reinstating hydrological regimes (stream flows and wetlands) and associated vegetation communities through revegetation activities. This landscape will provide important habitat for two endangered species: Leadbeaters Possum (*Gymnobelideus leadbeateri*) and the Helmeted Honeyeater (*Lichenostomus melanops cassidix*). To do this, significant government and philanthropic funding will drive the reinstatement of a series of connected wetlands and associated fringing vegetation. Water, currently bypassing the site will be redirected into the reserve from roadside verges and the surrounding urban landscape. This sustainable use of water expected in a drying climate will ensure that the reinstated wetland communities persist over time. A detailed fire plan, developed at the start of the project, will ensure the property is resistant to the likely impacts of fire.

Increasing Landscape Permeability - In the Gippsland Lakes area, where wetlands are predicted to dry and get increasingly saline under climate change driven sea level rise, a project is underway to model how species might move through the landscape, and how best to make this landscape more permeable. By increasing landscape permeability, it is expected that dispersal will be facilitated via environmental flows; the removal of artificial barriers such as roads and weirs will allow plants and animals to disperse more freely; and by restoring key areas, by revegetating corridors or stepping stones, the distance between habitats could be reduced (Raulings et al. 2011).

Table 1. Resilience objectives used to plan on-ground activities in Greening Australia case studies.

	Engineering Resilience	Adaptive Capacity	Resistance	Spatial Resilience
Wimmera Conservation Reserve	X	X		
Haining Farm		X	X	
Gippsland Lakes				X

Conclusion

As discussed above, we believe that government and non-government organisations, as well as community groups undertaking landscape-scale habitat restoration need to actively consider how best to increase ecological resilience in practical ways that can be implemented on-ground. Under a changing climate scenario, the persistence of restored and remnant habitats is likely to be influenced by disturbance events. If organisations don’t try and mitigate these disturbance events, using some of the suggested resilience objectives, natural habitats and the species reliant upon them are likely to be negatively impacted.

This on-ground implementation of ecological resilience requires that organisations undertaking these activities to work closely with scientists and research bodies to monitor their actions and adaptively manage restored and remnant areas into the future. This is often a learning-by-doing process, and although mistakes may initially be made, the outcomes are likely to benefit biodiversity.

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Native seed produced under cultivation in the north-western United States

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Abstract

Ecological restoration in the semi-arid temperate Intermountain Region in the north-western United States is serviced by what is probably the most extensive and diverse native seed industry in the world. Seeds of multiple plant materials of numerous grass and, increasingly, forb species are produced in cultivated settings by a variety of growers and companies. Seed may be produced either under irrigation or in a dryland farming system. Grass and forb seed production is regarded as a specialised enterprise requires a high level of skill on the part of the seed grower, both as an agronomist and as a business person. It also involves elements of risk and reward, with most of the seed produced under speculation to service broadscale restoration. The ability of the seed industry to deliver large quantities of seeds can be complicated by unrealistic expectations on the part of customers. A nuanced understanding of natural selection and trade-offs associated with delivery of native plant materials and the biodiversity they provide may place expectations for native seeds on a more rational footing. Poor communication between customers and seed producers may impede restoration success, particularly when restoration is centrally planned.

Introduction

The Intermountain region of the western United States is located between the continental divide (Rocky Mountains) on the east and the Sierra Nevada (California) and Cascade (Oregon, Washington) ranges on the west. Most of the Intermountain Region is semi-arid or arid, with seedings being more successful in the semi-arid areas. Most native seeds of herbaceous species intended for these lands are produced under cultivation by a specialised seed-production industry. This industry has been successful in producing the quantities of seed needed for broadscale restoration in the region, e.g. fire rehabilitation, mineland reclamation, transportation corridors, wildlife habitat and revegetation by private landowners (Waters and Shaw 2003). The first objective of this paper is to familiarise readers with the diversity of businesses within the industry, the variety of strategies they employ to remain competitive and the niches they occupy to minimise competition. The second objective is to highlight some of the unrealistic expectations that seed buyers have of the seed industry. The third objective is to elucidate issues involving the nature and use of seeds that impact the seed industry. In order for the industry to function most efficiently, customers should have a clear understanding of what is technically and economically feasible for seed production. This is particularly true due to the large number of native species, an increasing number of which are coming into the marketplace. This article is based on 31 years of experience in Intermountain native plant material development and interfacing with the region's native seed industry and their customers.

The native seed industry

Several seed companies, as well as many individual growers, compete for a share of the native seed market. Companies made be owned by families, groups of families, individuals, or investors. They may encompass side enterprises in addition to seed, such as sale of erosion-control products or implementation of restoration projects. They may sell seed at the wholesale or retail levels and may or may not have strong marketing efforts. They may produce seed on land they own or rent, or they may contract with individual growers to produce for them. Companies may buy from one another to service their customers. They may be vertically integrated, i.e. attempting to capture all segments of the industry, or they may find a niche in a single segment. They most often produce seed under speculation, but small increases may be produced under a contract settled prior to production, as grower expense and seed price may be quite high. The industry is represented in Washington, DC by the American Seed Trade Association, a registered lobbyist group that services all crops.

Highest yields are produced in the Columbia Basin of eastern Washington state, which offers fertile soils, mild winters, and a plentiful irrigation supply. While land rents are high, the potential for late-summer planting means seed may be harvested the following summer, conferring a competitive advantage over areas that plant "dormant seedings" shortly before winter for spring germination. In contrast to herbaceous species, shrubs are slow to reach reproductive maturity. Thus, wildland collection by roaming field crews continues to be the source of seed for these species due to its superior cost effectiveness. This industry is centered in Sanpete Valley in central Utah.

Unrealistic expectations

Customers may have unrealistic expectations of the seed industry due to a lack of understanding of agriculture, options available to seed growers, and business principles (Dunne and Dunne 2002). Like agricultural commodities in general, growers have minimal control over prices, as seed is sold to the lowest bidder. Seed companies must make payroll even when business is slow, and turn a profit to secure loans. Much seed demand is related to wildfire rehabilitation, and profitable fire years may be separated by long periods of weak demand. Despite this, businesses must remain solvent until fires resume. Under such circumstances, promoting sales for non-fire uses is an advantage. Some customers believe that 'the customer is always right.' This attitude may lead to unreasonable demands placed on growers regarding which plant materials are grown (Johnson *et al.* 2010).

Issues surrounding the nature and use of native seeds

Many restoration biologists embrace the significance of global change yet are reluctant to incorporate the realities of such change in restoration planning. An example is the discomfort associated with assisted migration, as evidenced by insistence on the use of local plant populations (Vitt *et al.* 2010). Restoration biologists may profess a staunch belief in evolution, yet they typically fail to consider evolutionary processes in their planning (Jones and Monaco 2009). Mistaken notions concerning natural selection have led many to unquestioned acceptance of 'local is best' (Jones 2013b). Finally, local genotypes are often emphasised without consideration of the many other biotic and abiotic components of the ecosystem and how they may interact with plant genotype (Jones 2013a).

A fundamental conflict exists between the delivery of native plant materials and desired (large) levels of biodiversity. Some materials will be used more because they tend to be more successful in practice, because they are available in larger quantities or because they are less expensive. New native species are continually being introduced to the seed industry in the hope that they can be successfully increased, and new plant materials of established species can increase the array of genetic diversity that is available for such species. Nevertheless, the persistence of new items in the seed trade depends on their economic viability in commerce, particularly in light of their ability to compete in the marketplace with items for which they may substitute (Dunne and Dunne 2003).

Centralised planning (Plant Conservation Alliance 2015) can disappoint when it assumes that additional expenditures can solve all problems, that funds will continue to flow freely, and that restoration is a more pressing need than other national priorities. When such planning attempts to impose a solution that ignores market forces, unexpected outcomes may occur. Someone's desire for a seed increase of a novel item is unlikely to motivate a seed grower when the material does not biologically or economically lend itself to seed increase.

Clewell and Aronson (2006) discuss the technocratic rationale as one of several rationales for restoration. The aim of this rationale is to satisfy broad institutional missions and mandates that are typically supported by agency leadership and the public. The restoration practitioner is tasked with satisfying government stipulations for contract, permits, and orders, a technical role that can impinge on the creative content of restoration practice (Clewell and Aronson 2006). Furthermore, the metrics of project success may revolve around completion of tasks, hectareage treated and dollars spent, whether resulting in successful restoration or not (Svejcar *et al.* 2017). This becomes a problem, in particular, when promises of *accomplishment success* are made to politicians and the public. The Bureau of Land Management is responsible for management of federally owned rangelands in the western US, and its Emergency Stabilization & Rehabilitation (ESR) staff is responsible for seeding in response to wildfire at the local level. The ESR staff is familiar with the negative consequences of restoration failure, e.g. further spread of invasive annual grasses that perpetuate wildfire. Therefore, ESR seeks solutions to increase chances for success, while directives from Washington, DC may involve more esoteric concerns that may be less pragmatic at the local level.

Conclusions

In the future, closer collaboration between the restoration and seed industry sectors may reduce frustration and improve restoration outcomes in the US. Indeed, there are hopeful signs that this is already beginning to happen. The Intermountain experience is not directly applicable to Australia, as there are dramatic differences in soils, ecosystems, disturbances, climates, and population biologies of native plant species. Nevertheless, it may be useful for developing an effective model for Australia (Waters and Shaw 2003).

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Winners and losers over 17 years in response to large-scale eucalypt plantation establishment on farmland

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Abstract

Establishment of large-scale timber plantations can dramatically transform landscapes, however little is known about the response of more cryptic components of biodiversity. We highlight some of the diversity recorded during a 17 year longitudinal study on three large-scale plantations of locally indigenous eucalypts in northern NSW. The study began in a farmland mosaic and has continued to track occupancy after the establishment of eucalypt plantations within the paddock areas. Surveys were undertaken at focal trees located in different classes of remnant vegetation that became embedded within the plantations as well as in the plantation matrix itself. Reference sites were also located in adjacent blocks of forest. We recorded nine species of arboreal mammals, including threatened species such as squirrel glider *Petaurus norfolcensis*. The majority of these species were present, but uncommon, in farmland at the start of our study. The most dramatic change for mammals was a large increase in common brushtail possum *Trichosurus vulpecula,* a widespread generalist. Among diurnal birds, 47 % percent of species increased and 31 % of species declined. Notably the noisy miner, a hyper-aggressive species, decreased over time. Bird decreasers tended to be widespread species with generalist attributes, while increasers were more likely forest specialists. Our results confirm the importance of remnant vegetation and old growth elements within plantations because they function as a refuge for fauna, provide specialised resources such as tree hollows and facilitate the colonisation of plantations. The ecosystem implications of increasing populations of generalists such as *T. vulpecula* remain unclear.

Introduction

Large-scale plantations established on farmland for timber can dramatically transform landscapes and alter the habitat available for biodiversity. Plantations have great potential to soften the matrix and increase permeability.

Longitudinal studies of birds have demonstrated that open country species are typically disadvantaged by plantation establishment, whereas forest species and generalists may increase (Law et al. 2014; Lindenmayer et al., 2008). We present highlights and trends in biodiversity during a 17 year longitudinal study of eucalypt plantation establishment on farmland in northern NSW. These plantations are monoculture mosaics of locally native *Eucalyptus*. They are large-scale (> 500 ha), which means they far exceed many small scale Landcare and agroforestry plantings. The study began in a farmland mosaic of cleared paddocks, scattered trees and remnants in paddocks in 1997 and continued over time after the establishment of eucalypt plantations within the paddock areas. Initial surveys found that a moderately diverse, but uncommonly encountered, mammal and nocturnal bird fauna was present in the farmland mosaic, with arboreal marsupials emerging from hollows in 11% of trees (Law *et al*. 2000). Our overall aim has been to (1) track long-term changes in biodiversity and its trajectory in relation to nearby forest, (2) identify winners and losers as the plantations grew and (3) identify the role of plantations in improving biodiversity in embedded remnants (by altering matrix quality from paddock to trees).

Methods

We tracked changes in biodiversity at three large plantations (> 500 ha) in northern NSW (Law *et al*. 2017). Prior to plantation establishment, grassy paddocks with scattered isolated mature trees dominated all study areas. Remnant vegetation, often containing many mature hollow-bearing trees, occurred along creek-lines and in remnants within the paddock matrix (Law *et al*. 2000). We observed animals at focal trees using a tree-watching (25 m radius) and aural listening technique for birds in the morning (Law *et al*. 2014) and nocturnal animals (mammals and birds) at dusk. Focal trees were in remnant vegetation that became embedded within the plantations as well as in the plantation matrix itself. Reference sites were also sampled in adjacent forest. Surveys began at the pre-plantation farmland stage in 1997 (time 0) and were then repeated when plantations were one (1999), five (2003), 11 years old (2009) and 16 years old (2014), giving a temporal sequence of five time points. Results from additional survey methods (e.g. Anabats, Elliott and camera trapping) will be reported elsewhere.

Results

Focal tree watches and aural surveys recorded nine species of arboreal mammals, which possessed idiosyncratic occupancy rates across vegetation classes and over the study period, though no species was observed to decline. Gliders comprised feathertail gliders *Acrobates pygmaeus*, sugar gliders *Petaurus breviceps*, squirrel gliders *P. norfolcensis*, yellow-bellied gliders *P. australis* and greater gliders *Petauroides volans*. Both yellow-bellied glider and greater glider had highly restricted distributions (before and after plantation establishment), with *P. volans* observed in only one remnant close to forest, while *P. australis* was heard from a small number of remnants and adjacent forest, including two individuals exiting a tree hollow in a narrow riparian zone. *Petaurus breviceps* and *P. norfolcensis* were observed in a range of situations, including foraging on five year old flowering plantation blackbutt *Eucalyptus pilularis* (Fig. 1). *Phascolarctos cinereus* vocalisations typically originated from remnant vegetation initially surrounding paddocks, and later plantations. No koala scats were recorded at the base of survey trees (n=105 trees per survey year). Temporal trends from focal tree surveys revealed common brushtail possums as clear winners, increasing from ~ 10 % occupancy initially in farmland trees to 90 % occupancy on final surveys (Fig. 2). Trends for other mammal species were relatively constant.

Among diurnal birds, we recorded a large range of species in our plantations and embedded remnant vegetation. Analysis of the temporal trends indicated that we had more winners than losers (Law *et al*. 2014). 47 % percent of species increased over 11 years of plantation growth and 31 % of species declined.The winners tended to be small forest birds and the losers were larger, open country species (including noisy miners). At the start of the study noisy miners were most frequently observed at isolated trees and patches (50-60 % of trees), but by 2009 they were infrequently observed at these classes (~ 20 % of trees). Declines in the occurrence of noisy miners were not as steep at remnants and riparian trees as other classes. In the plantation matrix, noisy miners were virtually absent after five years, but they had increased at some plantation trees by 2009, particularly where there was recent thinning (Law *et al*. 2014).

Fig. 1. Squirrel glider *Petaurus norfolcensis* feeding on flowers of 5 year old plantation blackbutt *E. pilularis*.

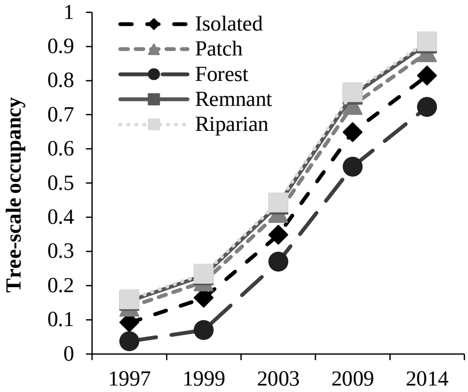

Fig. 2. Temporal trends in tree-level occupancy for common brushtail possum *Trichosurus vulpecula*.

Discussion

Longitudinal data on changes in biodiversity are scarce, particularly in relation to changing land-use (Lindenmayer *et al*. 2016). Our 17 year longitudinal study unexpectedly demonstrated that *Eucalyptus* plantations with embedded remnants supported a diverse mammal and bird community (Law *et al*. 2017). However, many of these species were present at the start of our study in the cleared farmland-remnant vegetation mosaic (Law *et al*. 2000). In contrast, Smith *et al.* (2015) found that 10 years of ecosystem restoration of degraded agricultural landscapes in Queensland provided habitat for a range of fauna species very different to that of the former agricultural state. In our study, establishing large-scale plantations on farmland rapidly transformed the landscape appearance, but it did not have a major effect on most mammals, except for the dramatic increase in *T. vulpecula* at vegetation classes with old-growth elements embedded within plantations and in adjacent native forest. The impact of increasing populations of *T. vulpecula* on other hollow-dependent species remains unclear. Mammal results contrasted with overall positive trends in diurnal bird species at these study locations, where there was a major effect on the local bird community (Law *et al.* 2014). We suggest that displacement of aggressive noisy miners in these large-scale plantations was an important contributor to increased bird diversity. Eucalypt plantations support unexpected species diversity and contribute to restoration, but restoration is limited to particular winners. Scattered remnant vegetation and their hollow trees within plantations were major contributors to species diversity and their continued sensitive management will be important.

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An Experimental Trial to Assess the Response of Biodiversity to Thinning of Regrowth

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Abstract

Cypress pine regrowth in western NSW often occurs as dense 'wheatfields' which 'lock-up' and remain unchanged for decades. While thinning to restore habitat values has been suggested for cypress forests, the science is lacking in identifying benefits for biodiversity. To provide an experimental assessment of the responses of biodiversity and habitat values to thinning, a trial was established in 2016, also in the Pilliga forests. The experimental thinning trial will measure the response of the same fauna groups and habitat values assessed in the chronosequence study. Experimental sites (12 ha) represent thinning undertaken at two different stages of cypress regeneration (early regeneration that is 'locked up' ('early thinning') and advanced regeneration ('second thinning'). Pre-thinning biodiversity and habitat surveys were completed (March 2016) at four replicates of each treatment and paired unthinned controls for each of the two thinning treatments as well as four long undisturbed reference sites. Thinning was undertaken between May and October 2016 with post-thinning surveys to commence in March 2017.

Introduction

Globally, forests support around 90% the world's terrestrial biodiversity (Brooks et al. 2006) but less than 8% is managed as conservation reserves. Achieving sustainable forest management requires balancing production with biodiversity conservation. Large-scale thinning is promoted as a tool to restore habitat as it can accelerate the development of habitat values such as hollow formation and increase spatial heterogeneity (Allen et al. 2002). Despite the extensive use of thinning as a silvicultural technique in Australia's production forests, few studies have assessed the effects of thinning on biodiversity.

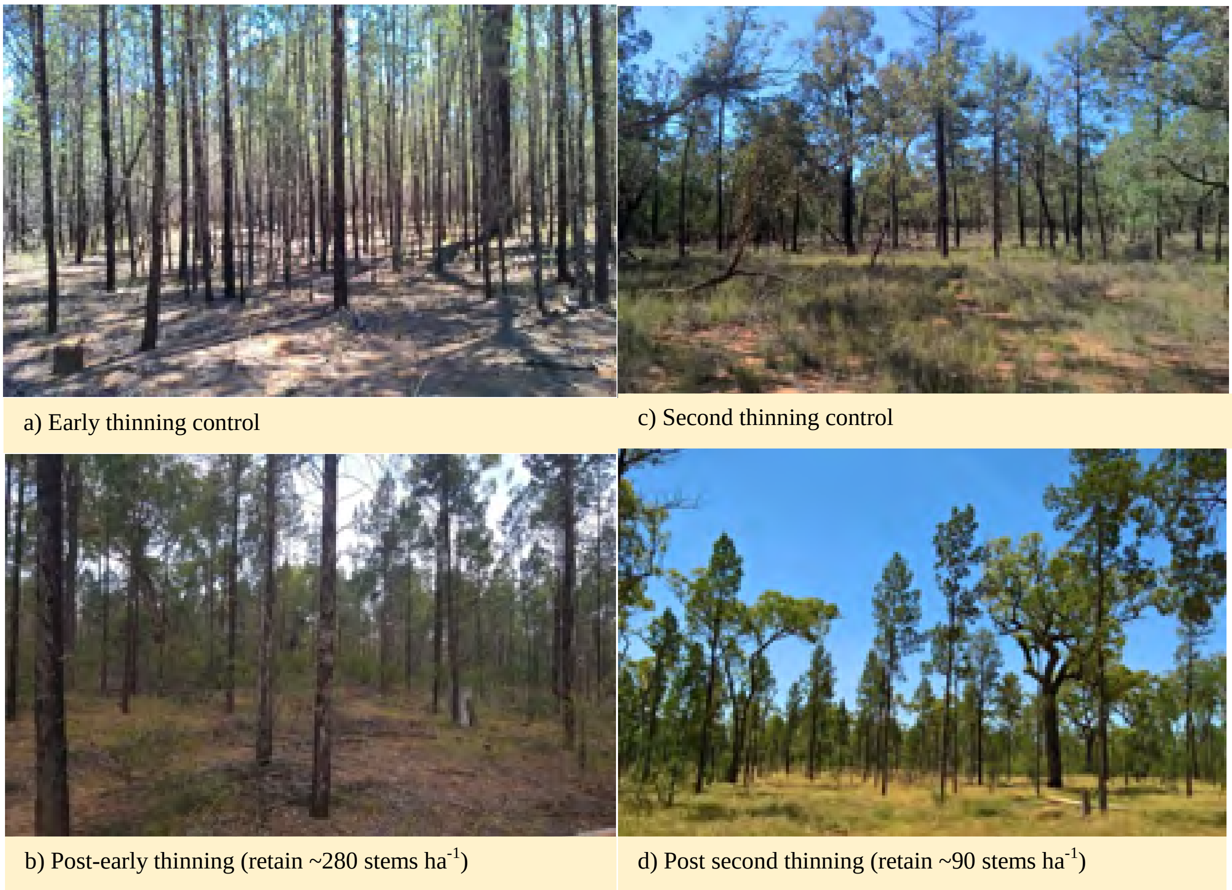
The Pilliga forests represent the largest inland woodland in Australia (535,000 ha, Thompson and Eldridge 2005). Much of the Pilliga is dominated by cypress pine (*Callitris* spp.) and is thought to have originally been open woodland with a similar plant species composition to today (Rolls 1981; van Kempen 1997), albeit with a different extent and density. Increasing tree density, particularly for *Callitris*, which is prone to 'lock-up' and limit growth (Whipp et al. 2012; Thompson and Eldridge 2005), has resulted in a long history of thinning for silvicultural purposes to maximise tree growth for timber production (Jurskis 2009). These historical thinning activities provided an opportunity to examine the impact of past thinning activities on biodiversity over the long (up to 40 years) and short-terms (<8 years). In 2015, a chronosequence study was undertaken to assess long-term temporal effects of thinning cypress regrowth on biodiversity in the Pilliga forests. In that study, biodiversity (bats, birds, ground mammals, reptiles, invertebrates and floristics) and habitat values (coarse woody debris and stem density) at sites 7-40 years post-thinning as well as sites that were long undisturbed and dense unthinned, regrowth were assessed. Results indicated that thinning restored habitat values for most fauna groups but also highlighted the an importance of unthinned regrowth to some fauna (Gonsalves, Law et al. unpublished data).

Here we describe an experimental assessment of the responses of biodiversity (bats, birds, reptiles, ground and arboreal mammals) and habitat values (living-, dead- and hollow-tree density, vegetation cover and coarse woody debris) to thinning, in a Before-After-Control-Impact (BACI) design thinning trial that was established in 2016, also in the Pilliga forests. This trial will control for variables that may not remain consistent in a chronosequence study (e.g., methods of thinning) and will be used to assess short-term responses to thinning, but can be monitored over time to track longer-term changes.

Methods

Twenty sites (12 ha) were established to test thinning undertaken at two different stages of cypress regeneration: 1) Early regeneration that is 'locked up' ('early thinning'); and 2) Advanced regeneration ('second thinning'), paired unthinned controls for each thinning treatment and long undisturbed references were selected (Fig. 1a-1d). The 'early thinning' treatment predominantly targeted small-sized stems (<10 cm dbh), although some larger stems were also thinned to meet the desired density (~280 stems ha^{-1}) of retained stems. The 'second thinning' treatment targeted larger stems (14-24 cm dbh) than early thinning and retained fewer stems (90 stems ha^{-1}). Long undisturbed reference sites were characterised by a lack of stumps and, the presence large cypress and/or ironbark trees. There were 4 replicate sites for each respective thinning treatment, paired control and long undisturbed reference.

Pre-thinning biodiversity surveys were undertaken in March 2016 and experimental sites were then thinned from May-October 2016. The first round of post-thinning biodiversity surveys were completed in March 2017 with results still being collated. Biodiversity surveys assessed diurnal birds, reptiles, ground mammals, bats, floristics and vegetation structure.



a) Early thinning control

c) Second thinning control

b) Post-early thinning (retain ~280 stems ha^{-1})

d) Post second thinning (retain ~90 stems ha^{-1})

Fig. 1. Post-thinning sites typical of: a) 'early thinning' control, b) 'early thinning', c) 'second thinning' control, and d) 'second thinning'. Long undisturbed reference sites (not pictured) were characterised by a lack of stumps and, the presence large cypress and/or ironbark trees.

Discussion

Variable environments and past land-use in the Pilliga forests can make ecological interpretation of subtle management effects difficult. Establishment of experimental field trials that manipulate one aspect of the environment provides a rigorous approach to testing management effects. We expect initial results from this trial will assess immediate on-site changes in biodiversity due to thinning disturbance. Longer-term monitoring of the trial will be required to identify whether thinning of regrowth can restore biodiversity and habitat values missing from young regrowth and guide how thinning may be used in the future.

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Creating Effective Institutional Arrangements for Governance of Public/Private Conservation Mosaics

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Abstract

Biodiversity in Australia has declined since European settlement, and continues to decline. Reasons include: grazing, invasive species, fire regimes, changed hydrology and the legacy of vegetation clearing, with climate change exacerbating all of these factors. Despite significant public investment and environmental laws, the evidence suggests that public action has been insufficient to change this trajectory. Threatened species continue to decline, with Australia's most endangered species being those most poorly protected in reserves. 13% of threatened species occur entirely outside protected areas and 21% of those critically endangered have the lowest level of protection. There are economic and institutional barriers to substantial increases in public investment, or more laws or stronger enforcement. Integrated knowledge systems and innovative, inter-disciplinary methodologies are required to overcome the current institutional impediments and to deliver effective connectivity conservation outcomes.

Introduction

Biodiversity in Australia has declined since European settlement, and continues to decline. Reasons include: unsympathetic grazing regimes, invasive species, fire regimes, changed hydrology and the legacy of vegetation clearing, with climate change exacerbating all of these factors (State of the Environment 2011 Committee). Despite significant public investment and environmental laws, the evidence suggests that public action has been insufficient to change the trajectory (State of the Environment 2011 Committee). Threatened species continue to decline, with Australia's most endangered species being those poorly protected in reserves. 13% of threatened species occur entirely outside protected areas and 21% of those critically endangered have the lowest level of protection (Watson, Evans et al. 2011). There are economic and institutional barriers to substantial increases in public investment, or to more laws or stronger enforcement (Martin, Williams et al. 2012). Effective conservation requires not only improved understanding of the underlying ecology, but also improved understanding of governance and the drivers of human-induced ecological degradation. Legal and governance research is essentially a social enquiry, but one that must pull together strands of knowledge from both the social spheres and the technical natural science spheres.

Connectivity Conservation as a Governance Challenge

Creating effective conservation mosaics that span both public and private estates is a concern of 'connectivity conservation', which aims to maintain and restore ecosystem integrity through landscape-scale conservation:
This can be achieved through systems of core protected areas that are functionally linked and buffered in ways that maintain ecosystem processes and allow species to survive and move, thus ensuring that populations are viable and that ecosystems and people are able to adapt to land transformation and climate change. (Papallacta Declaration, quoted in IUCN 2007).

To support the implementation of large, landscape-scale conservation connections, the Australian Government attempted to articulate a set of seven guiding principles in its 2012 National Wildlife Corridors Plan:

- Building wildlife corridors across Australian landscapes is a cooperative endeavour
- Corridors designed and implemented in ways that benefit local communities
- Healthy, functioning landscapes with connectivity at a variety of scales
- Effective corridors connected across a mosaic of land tenures and uses without affecting property rights
- Corridors designed using scientific research, Indigenous knowledge and practitioner experience
- Corridors designed to assist native species' adaptation to the impacts of climate change
- Recognising and managing potential risks such as those posed by invasive species and fire.

The institutional challenges to achieving such an ambition are daunting. There is an urgent need to overcome current institutional impediments for effective connectivity conservation governance in Australia, and to develop innovative, interdisciplinary methodologies and integrated knowledge systems to deliver effective connectivity conservation outcomes for application nationally and internationally (Campbell, 2006). These interconnected areas span landscapes, tenures and jurisdictions to link protected areas and significant remnant vegetation, creating a public/private conservation mosaic. There are many transactions in the creation, operation and monitoring of these institutionally complex arrangements, which involve diverse public and private actors. Numerous reviews of connectivity conservation in Australia have been undertaken highlighting similar legal and institutional issues (see for example Fitzsimons, Pulsford et al. 2013; Worboys and Pulsford 2011). A consistent message of 'lessons from practice' is a lack of suitable institutional arrangements and of governance capacity to implement strategies and plans (see submissions to National Wildlife Corridors Plan Advisory Group, 2012).

In 2012 six large-scale connectivity initiatives across the country were noted by the Australian Connectivity Council: Gondwana Link (WA), Great Eastern Ranges Initiative (Qld, NSW, Vic), Habitat 141 (SA and Vic), Nature Links (SA), Trans-Australia Eco Link (NT and SA), and Tasmanian Midlandscapes (Tas). Worboys and Pulsford (2011) described these wildlife corridors as ‘21st century large-scale land use management approaches undertaken as a response to the continued threats to biodiversity in Australia’. Even at this time, Worboys and Pulsford (2011) predicted that reliable resourcing and supportive planning, policies and instruments were required to consolidate the roles played by wildlife corridors in facilitating biodiversity conservation. These limitations are institutional matters, rather than limitations of our technical understanding of ecological processes, and by 2017, all six major initiatives had encountered the institutional challenges foreseen above, and some are struggling to endure (Wyborn, 2015). However, some have managed to weather the institutional impediments, including Gondwana Link (GL) and the Great Eastern Ranges Initiative (GERI). Such initiatives constitute important examples of institutional experimentation, attempting to enable collective action on a large scale. They are important ‘natural experiments’ to test theory and praxis for governance of conservation mosaics.

Governance Research

Future research on connectivity governance should address the following question, ‘What institutional arrangements will enable effective, efficient and fair governance of public/private approaches to biodiversity conservation and restoration mosaics?’ Creating and managing connected conservation arrangements in a Western Industrial setting is a complex collective action challenge. The significance of institutions for effective collective action is an established research topic, but the link between institutional arrangements for conservation mosaics in a modern industrialised society and the effectiveness of these arrangements have not been investigated. Institutional arrangements have a demonstrated impact on the effectiveness of natural resource governance, affecting issues such as funding, knowledge gathering and transfer, decision-making, coordination and resource allocation (Martin, Williams et al. 2012). Whilst there is a body of knowledge on the ecology, planning and ecological economics of conservation mosaics, there has been little investigation of the institutional arrangements needed to make these mosaics effective.

Conclusion

Further research on connectivity conservation governance is driven by three key needs. There is a need for a systematic understanding of the institutional arrangements required for effective governance of conservation mosaic arrangements, from both a theoretical and a practitioner perspective. This will assist in the establishment and operation of a larger set of mosaics, intended to help achieve national conservation goals. There is also a need for improved scholarly understanding of the institutional dimensions of large spatial scale collaborative arrangements for collective action on environmental issues. And finally, there is a need for refinement and demonstration of methods for the systematic analysis of legal and institutional issues which impact upon the effectiveness of natural resource governance. This has been identified as the major scholarly and practice challenge for environmental law and governance by international bodies.

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Managing a complex problem: Blakely's Red Gum dieback in the ACT

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Abstract

Dieback is a complex environmental problem observed in many of the world's forests and woodlands. It involves a protracted decline in the health and vigour of canopy trees which is typically evident through tree defoliation and mortality. Over the last decade in the ACT region, there has been increasing evidence of severe dieback in Blakely's Red gum (*Eucalyptus blakelyi*) and seven other *Eucalyptus* species. We provide an overview of dieback and some initiatives in the region developed with the aim of assessing, monitoring and managing the impacts of dieback. A forum was held to explore knowledge and expertise, software developed to record site information and observations of dieback, and site-based experimentation. Spatial and temporal assessment of dieback in *E. blakelyi* has been undertaken using satellite remote sensing as a cost-effective alternative to ground-based assessment of tree condition. Trends in tree condition over time are being analysed for correlations with parameters of climate, topography (e.g. drainage lines and soaks), soil types, land management (e.g. tenure, level of clearing), etc. Analysing the spatial extent and environmental factors correlating with development of dieback will improve our understanding of its etiology (i.e. causation) and effective approaches to managing impacts.

Introduction

Dieback is a complex environmental problem that has been observed in many of the world's forests and woodlands (Houston 1987; Mueller-Dombois 1992; Ciesla and Donaubauer 1994). Dieback involves the '"dying back" or death of meristem tissues of buds, branches, or stems, which, if continued or repeated, results in the decline and death of the [plant or] tree' (Houston 1987 p 349). In forests and woodlands, this manifests as a protracted decline in the health and vigour of canopy trees evident through leaf discoloration and necrosis, tree defoliation and, if the cause is not alleviated, tree mortality. In Australia, dieback has been of concern primarily in sclerophyll forests and woodlands (Old et al. 1981; Wardell-Johnson and Lynch 2005), but it has also occurred in other vegetation including chenopod and sandplain shrublands, freshwater wetlands and marine seagrass communities. *Eucalyptus* dieback was observed in the New England region of NSW as early as 1852-1857, when Norton (1887) attributed it to moisture stress from dry weather followed by rain deluges, exacerbated by ground compaction from overstocking of sheep. White (1986) also considered extensive *Eucalyptus* dieback in that region from the mid-1950s to early 1980s to be due to altered rainfall patterns, along with repeated insect defoliation. However, some scientists have highlighted agricultural and pastoral intensification as critical factors (Landsberg and Wylie 1988). In the ACT, *Eucalyptus* dieback occurred in small areas between 1935 and 1950, with more extensive and longer outbreaks between 1950 and 1972 (Clark and Dallwitz 1974) and in recent years.

The causes of dieback are complex and a broad range of natural and anthropogenic factors has been implicated. These factors include insects, fungi, vertebrate animals (e.g. koalas, possums, territorial birds), climatic perturbations, land degradation, parasitic plants, and repeated defoliation by insects. The specific causes and impacted species vary from place to place, but integrative researchers (e.g. Mueller-Dombois 1992; White 1986) have hypothesised a common mechanism for dieback. This consists of (i) natural predisposing factors (e.g. cohort aging, edaphically extreme or marginally favourable sites), (ii) precipitating or trigger factors (e.g. pulse or periodic climatic perturbations), and (iii) modifying factors (e.g. biotic agents) that accelerate or stall the decline process. For example, White (1986) posited climatic perturbations as the primary cause and pressures from biotic agents (e.g. plant pathogens, insect pests, leaf herbivores, wood borers) as tertiary. In some cases, large outbreaks of psyllids (i.e. insect; subfamily Hemiptera) on Eucalypts can result from feeding on the more nutritious (nitrogen-rich) leaves produced as a host plant senesces after water stress, or that occur in young, replacement leaves during seasons of low fruit production (Clark and Dallwitz 1974; White 1986).

Dieback in the ACT region

Over the last few years, there has been increasing evidence and extent in the ACT region of severe dieback in Blakely's Red gum (*Eucalyptus blakelyi*). The dieback affects all age classes, and occurs in trees in conservation reserves, rural properties and urban roadsides. In April 2015 and March 2016, severe browning and loss of leaves was observed in *E. blakelyi* dominated Box Gum Woodland and urban trees of Manna gum (*E. viminalis*). As Autumn progressed, leaf senescence increased to the point where some trees died and others lost most of their foliage, recovering slowly with flushes of epicormic regrowth. High population densities of psyllids were initially observed on some affected *E. viminalis* and *E. mannifera* trees (R Carne pers. comm.), and later also on *E. blakelyi*. The dieback appeared to intensify after the winter of 2016, the wettest for the region on record.

Preliminary research showed that the *E. blakelyi* dieback commenced much earlier and then spread in spatial extent and ecological impact. Satellite and infra-red imagery of the Woodstock Reserve and adjacent rural land in the northern ACT showed a marked decline in *E. blakelyi* canopy cover and photosynthetic activity during 2004-2015 (G Baines, unpubl. data). Also, dense thickets of *E. blakelyi* seedlings were not progressing to mature trees (G Baines, unpubl. data). Since October 2016, foliar dieback has been observed on the southern ACT – NSW border in seven other *Eucalyptus* species (*E. viminalis, E. bridgesiana, E. pauciflora, E. rubida, E. stellulata, E. dives, E. macrorhyncha*) with an undescribed Eucalyptus Weevil (*Gonipterus* sp. no. 1, R Oberprieler pers. comm.) and a gumleaf skeletoniser caterpillar (probably *Uraba lugens*) being the defoliating agents. The heaviest defoliation appeared to be associated with poorly drained soils (along drainage lines and open wet soaks). Extensive dieback (2000 km^2) of *E. viminalis* since about 2005 in the Monaro region of south-eastern NSW was also posited by Ross and Brack (2015) to be related to moisture availability (i.e. low rainfall). No evidence was found for the primary cause being land management, fire history, declining structural complexity or a defoliating weevil (*Gonipterus* sp. no. 2). This dieback recently spread north to Bredbo and north-east towards Numeralla (C Brack pers. comm.) and it is possible that the southern ACT dieback is a spatial extension of the Monaro dieback.

Local initiatives to assess, monitor and manage dieback

Dieback of *E. blakelyi* is an important conservation issue in the ACT. Firstly, the species is a canopy dominant of Box Gum Grassy Woodland; a vegetation type that is protected (Critically endangered) under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act; Cwlth) and in the ACT (*Nature Conservation Act 2014*). Secondly, the unexpected decline in the Red Gum species could have major consequences for areas of existing and future environmental offsets, where the ACT Government has committed under the EPBC Act to protect and enhance Box Gum Woodlands. Thirdly, there has been public concern about the dieback and requests for information about techniques to redress tree decline on public and private land. Fourthly, the increasing spatial extent and severity of dieback may affect long-term landscape-level ecosystem functioning and sustainability. Many mature and over-mature trees have died, with a consequent risk of loss of habitat trees and tree hollows.

In response to public concern, the ACT Government established a working group in May 2016 and Kosciuszko 2 Coast coordinated a forum in November 2016 to explore the issue. The discussions led to GPS (‘Collector’) and online (‘Canberra Nature Map’) software modifications to accommodate site records of dieback; experimentation to ameliorate dieback (stem-injected insecticides, fire, thinning, climate provenance restoration); and research on the spatio-temporal and environmental relationships of *E. blakelyi* dieback in the ACT. Remote sensing (SPOT 7 multispectral satellite imagery, LiDAR data, aerial photography) is being used with vegetation mapping and modelling as a cost-effective, rapid means to map dieback. A time series of SPOT 5 imagery (2004-2014) is used to assess changes in dieback extent and severity over time as the SPOT 5 sensor has band wavelengths sensitive to plant stress and vigour. SPOT 7 imagery enables mapping of dieback extent, while LiDAR data, aerial photography and vegetation mapping are used to map *E. blakelyi* communities. Trends in tree condition are being analysed against climatic variables, topography (e.g. drainage lines), soil types, land management (e.g. tenure, clearing). Analysing the spatial extent and environmental correlates with dieback will improve our understanding of its etiology (i.e. causation) and approaches to managing the impacts.

Conclusion

Vegetation dieback exemplifies the complexity of ecosystems and the difficulties of managing them sustainably. Often, dieback has been perceived as a local problem but the considerable similarities between different dieback events can be further explored. A cooperative, collaborative approach that makes good use of the range of multidisciplinary skills, knowledge, experience and research on the issue from the region and elsewhere is most likely to lead to a greater understanding of the causes of dieback and how best to manage its impacts in a particular region. In the ACT, cross-sectoral collaborations are enhancing our understanding of local dieback in *E. blakelyi*. Vegetation mapping, and environmental and climatic analyses, will assist in understanding the causes of dieback and guide efficient implementation of on-ground experimental trials and management actions. The repeated, widespread and ongoing incidence of dieback in Australia, and the potential implications for already threatened ecosystems and retention of habitat trees, means that it is important to Retain as well as to Restore, Regenerate, and Revegetate our landscape.

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Re-creating More Natural Plant Arrangements Can Improve Seed Production in Revegetated Woodlands

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Abstract

The spatial arrangement of individual plants play a central role in how ecosystems function and influence processes such as growth, competition, pollination, seed dispersal, and water and nutrient cycling. Consequently, the spatial arrangement of plants within revegetated sites is likely to influence the functional outcomes of restoration plantings. There have been calls to base revegetation designs on natural plant arrangements; however this seldom occurs, and the outcomes of failing to do so are poorly understood. The aims of our research were to (1) describe and compare plant arrangements in remnant and revegetated woodlands, and (2) assess how planting arrangement influences the ecological processes occurring in the revegetated site, specifically seed production. We found that aggregation was common in the remnant community and nearest neighbour pairs were often conspecific. While, revegetated sites were generally more dispersed and had greater spatial admixture of species. In revegetated areas, aggregated trees, or those with a neighbouring *Eucalyptus leucoxylon*, produced more seeds per fruit than dispersed trees. Therefore, we recommend that mimicking natural plant community spatial arrangements, where aggregation is common and nearest neighbours are often conspecific, as a guide to planting design, is likely to increase seed production in projects seeking to revegetate woodlands.

Introduction

Revegetation aims to return functional ecosystems to cleared land, but planting designs are often *ad hoc* and ecological outcomes can be highly variable (Hobbs 1993; Sluis 2002). Questions have therefore been raised about the effectiveness of many revegetation attempts. Revegetation success is often measured by the area restored or number of seedlings planted rather than ecological function (Miller *et al.* 2010). Consequently, further research is needed to determine if revegetation simply returns plants to the landscape or whether it creates functional ecosystems (Hobbs 1993). In natural systems, plant arrangements influence processes such as growth, competition, pollination, seed dispersal and herbivory (Miller *et al.* 2010). Therefore, more detailed consideration of plant arrangements may improve ecosystem function in revegetated sites and a potential way to achieve this is to mimic the spatial arrangements of natural plant communities (Miller *et al.* 2010; Sluis 2002).

At this stage, however, plant spatial arrangements are often overlooked as an important feature of revegetated sites and the role that arrangement plays in revegetation is not well understood (Miller *et al.* 2010). Our research aimed to close this gap, by (1) describing the spatial arrangement of remnant and revegetated *Eucalyptus leucoxylon* (F. Muell) woodlands in the Monarto area, South Australia; and (2) exploring the role of planting arrangement on seed production in revegetated *E. leucoxylon*.

Methods

1) Remnant *E. leucoxylon* woodland was surveyed (c.a. 4 ha) in the Monarto area, South Australia. GPS position, size and species of all reproductive *Eucalyptus* were recorded. In the revegetated woodlands (1850 ha, 250 local and introduced species, established in the 1970s), only the GPS position of *E. leucoxylon* individuals was recorded (c.a. 800 individuals over 85 ha). ArcGIS was used to map records and determine neighbour distances.
2) Fruit were collected from 75 *E. leucoxylon*, from four areas within revegetation. Approximately 40 fruit (2013 flowering season) were collected per tree and the average number of seeds per fruit (seed production) determined for each tree. Seed production was assessed in trees with and without a near neighbour and in dispersed (0 *E. leucoxylon* within 30 m) and aggregated trees (5 *E. leucoxylon* within 30 m), using unpaired t-tests.

Results

Conspecific aggregation and open space were common in the remnant *E. leucoxylon* woodland (Fig. 1). Approximately 90% of individuals had a neighbour of the same species and the fine-scale spatial admixture of the three different species was rare (Fig. 1). The distance between remnant *E. leucoxylon* ranged from < 1 to 24 m (mean 4.3 ± 4.7 m), with 95% of individuals having five conspecifics within 30 m. While, in the revegetated sites, *E. leucoxylon* occurred within a matrix of other species, with up to 50 different *Eucalyptus* species occurring together. *Eucalyptus leucoxylon* individuals were more dispersed in the revegetated area, with nearest neighbour distance ranging from 4 to 100 m, (average 18 ± 20 m). Furthermore, only 40% of individuals had an *E. leucoxylon* neighbour and only 50% had five *E. leucoxylon* within 30 m.

Planting arrangement influenced seed production in revegetated *E. leucoxylon*. Individuals with a conspecific neighbour (≤6 m) tended to produce more seeds per fruit than those without a conspecific neighbour (conspecific neighbour: 9.6 ± 1.7 (n = 30); no conspecific neighbour = 5.9 ± 1.1 (n = 45)) (Fig 2A; unpaired t-test: $t = 1.9$, $P = 0.06$). Aggregated *E. leucoxylon* (5 *E. leucoxylon* within 30 m) tended to produce more seeds per fruit than dispersed trees (0 *E. leucoxylon* within 30 m) (aggregated = 8.6 ± 1.4 (n=38); dispersed = 2.6 ± 1.0 (n = 11)) (Fig. 2B; unpaired t-test: $t = 2.3$, $P = 0.03$).

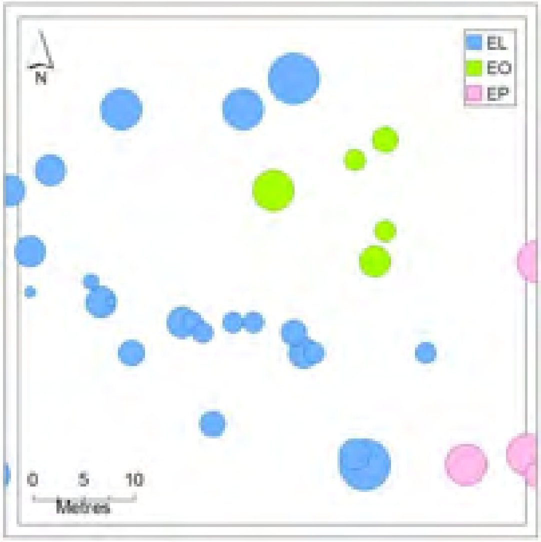

Fig. 1. A 50 m x 50 m survey area of remnant *E. leucoxylon* woodland at Monarto, South Australia. The GPS position of all reproductive *Eucalyptus* species are shown, with each colour representing a different species. Circle size is proportional to canopy width. EL = *E. leucoxylon*, EO = *E. odorata* and EP = *E. porosa*.

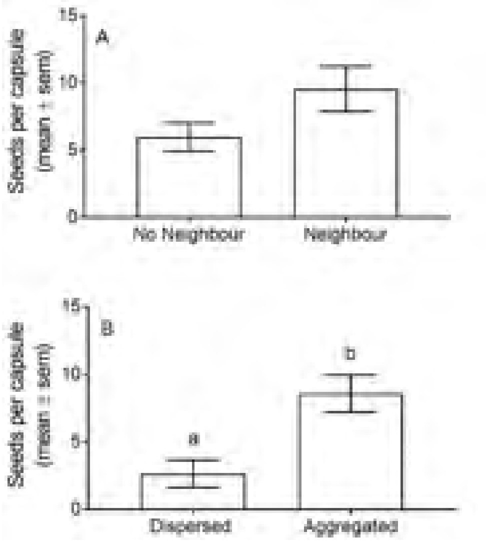

Fig. 2. Relationship between seed production and planting arrangement in revegetated *E. leucoxylon* in the Monarto woodlands, South Australia. Top - with and without a conspecific neighbour (another *E. leucoxylon* in the adjacent planting position) and bottom - dispersed (0 *E. leucoxylon* within 30 m) and aggregated (5 *E. leucoxylon* within 30 m).

Discussion

Conspecific aggregation was common and spatial mixing of different species was rare in the remnant woodland (Fig. 1). This contrasts to the random-to-dispersed arrangements observed in the revegetated sites. Revegetated *E. leucoxylon* were more dispersed than the nearby remnants, with the average distance between conspecifics 18 m compared to 4 m in the remnant. The revegetated sites also had greater spatial admixture of different species, with *E. leucoxylon* individuals occurring randomly throughout the matrix of other species. As a result, only 40% of nearest neighbours were conspecific in revegetated sites, compared to 90% in the remnant.

The spatial distribution of *E. leucoxylon* trees influenced seed production, with aggregated individuals and/or those with a neighbouring *E. leucoxylon* producing more seed than dispersed trees (Fig. 2A, B). Pollinators often move between neighbouring individuals (Hopper and Moran 1981). Therefore, it is likely that aggregated arrangements promoted pollinator movements (and pollen flow) between conspecifics. Greater numbers of pollinator visits tend to increase the amount and diversity of pollen received, which results in increased seed set (Breed *et al.* 2015; Ottewell *et al.* 2009). While, more dispersed or isolated trees often receive fewer pollinator visits and this can lower outcrossing rate. A reduction in seed set or seed quality as a result of lower outcrossing may limit natural regeneration in these dispersed individuals or populations (Ottewell *et al.* 2009).

Natural systems often have aggregated arrangements, with nearest neighbours of the same species and limited spatial admixture of different species (Fig. 1). The arrangements that were common in the remnant (conspecific neighbours, five neighbours within 30 m), were similar to those that improved seed production in the revegetated sites. Consequently, re-creating plant arrangements similar to those in natural systems can improve seed production in revegetated areas and in turn may help these sites to regenerate naturally and become self-sustaining. The position of individual plants can be easily controlled with tubestock plantings, but will be more difficult in broadcast seeded sites. Broadcast seeded sites may require additional hand seeding in patches or supplementary plantings over time to achieve aggregated arrangements (Jonson 2010).

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Overcoming Restoration Barriers in a Degraded Coastal Environment

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Abstract

Restoration techniques that naturally accelerate regeneration by removing ecological barriers, such as limited seed dispersal, could reduce the need for expensive and labour-intensive methods. One potential method to overcome this barrier is the strategic placement of artificial perches in degraded areas. These perches encourage frugivorous birds to fly out from remnant areas to rest and defaecate seed in degraded areas, thereby increasing seed dispersal. This technique has been extensively tested in tropical systems but is yet to be explored in coastal systems. We aimed to determine the success of artificial perches in a degraded coastal environment by investigating: (1) their ability to attract fruit-consuming birds from nearby remnant vegetation; (2) their potential to increase seed rain in comparison to the open landscape, and (3) the seasons in which they are most effective. In this study, nine bird species that consume fruit as part of their diet visited the perches. The most frequent of these visitors were *Gymnorhina tibicen* (Australian magpie), *Acanthagenys rufogularis* (spiny-cheeked honeyeater), *Sturnus vulgaris* (common starling) and *Corvus coronoides* (Australian raven), which are all greater than 20 cm in size. Smaller fruit-consumers may be less inclined to rest in open areas and risk predation. Artificial perches effectively increased the seed rain of several native fleshy-fruited species in degraded paddocks and were most effective in summer–autumn, when the majority of native species were fruiting. The restoration ability of perches was reduced in some months owing to the abundant defaecation of invasive species. Potential modifications to the restoration technique may overcome this limitation.

Introduction

There is increasing interest in the restoration of abandoned lands for the recovery of biodiversity and ecosystem function (Bradshaw 2002). For restoration of vegetation communities to occur, critical ecosystem processes such as seed dispersal, seed germination and plant recruitment must be present. Without these processes restoration is limited. Common strategies for overcoming recruitment limitations include direct seeding and planting seedlings. These methods, however, can be expensive and labour-intensive, restricting the scale of restoration and associated outcomes. These limitations have led to the development of novel restoration techniques that are both cost-effective and more natural means of restoration. Artificial perching structures are one such technique that has been developed for this purpose. Perches work by encouraging frugivorous birds to rest while flying between areas of remnant vegetation, where they may defaecate the seeds of fruit they have consumed and ideally increase seed dispersal and plant recruitment (Robinson and Handel 1993).

Currently, restoration using perching structures has been thoroughly trialled in inland tropical and temperate systems (Holl 1998; McDonnell and Stiles 1983), but has not been tested in coastal systems. Coastal systems are ideal for the use of artificial perches as many of the plant species are fleshy-fruited and require seed dispersal by frugivorous animals, as opposed to dispersal via wind or water (Castley *et al.* 2001). We aimed to determine the success of artificial perches in a degraded coastal environment by investigating: (1) the ability of perches to attract fruit-consuming birds from nearby remnant vegetation; (2) their potential to increase seed rain in comparison to the open landscape, and (3) the seasons in which they are most effective.

Methods

Field research was conducted in paddocks of Cantara Homestead (36.3393°S, 139.7378°E), located approximately 800 m inland from the ocean on the Younghusband Peninsula, South Australia. Twelve perches were erected in cleared paddocks at Cantara at distances between 50 to 250 m from remnant vegetation. Perches consisted of a dead branch wired to a metal stake, resulting in a structure approximately 2.5 m in height. A 1 × 1-m square-shaped seed trap constructed from fibreglass mesh was placed beneath each perch to collect seed rain. Twenty-five seed traps of the same design were also established at sites without perches in both the paddocks, as well as in open areas in the surrounding dunes, to measure the rates of seed rain in open areas. Traps were collected at the same time each month from September 2015 to August 2016. Collected seeds were then counted and identified.

Bird observations were made from dawn to dusk (total 108 hours) in October to December in 2015. Four perches were observed simultaneously for 2-hour periods. Bird observations were also carried out during December and January of 2016 using remote cameras aimed at the perches and set to trigger with detected motion. The two methods each recorded bird species and abundance at perches, allowing datasets to be combined for analysis.

Results

From the two bird observational methods a total of 302 observations were recorded with 697 bird visits to perches (Table 1). A total of 17 bird species visited the perches, where common visitors tended to be insectivorous birds. Although the most frequently observed perch visitor, *Acanthagenys rufogularis* (spiny-cheeked honeyeater), was a frugivore. Eight other species that consume fruit as part of their diet visited the perches. Over 12 months, a total of 25,919 seeds (mean 2160 seeds/m^2) were dispersed to sites with perches. During the same period 138 seeds were dispersed to traps in open dune areas (mean 6 seeds/m^2) and 22 seeds to traps in open paddock areas (<1 seed/m^2). Sites with perches accumulated more seeds than those without perches (Analysis of Variance, Tukey's Honestly Significant Difference test, $P < 0.05$). The numbers of seed counts in traps at open sites in dunes was also higher (but not significantly different; $P = 0.99$) than the numbers counted in traps placed in nearby open paddocks. Seasonal variation was observed in the abundance and species richness of seeds collected under artificial perches. The abundance of native seed dispersed to perches, as well as overall species richness, was greatest during summer and autumn (Fig. 1). Seeds of invasive plants, in particular *Lycium ferocissimum* (African Boxthorn), were abundant in traps under artificial perches in November–December and April–May (Fig. 1).

Table 1. Common perch visitors based on the number of observations and bird visitors determined by perch observations and remote camera photography.

Scientific Name	Diet	No. of obser-vations	No. of bird visits
Acanthagenys rufogularis	F, N, I	62	74
Anthus novaeseelandiae	I, G	41	46
Corvus coronoides	C, I, F	11	13
Cracticus tibicen	I, F	54	92
Hirundo neoxena	I	41	336
Falco berigora	C, I	11	11
Rhipidura leucophrys	I	29	30
Sturnus vulgaris+	I, G, F	11	47
Zosterops lateralis	F, N, I	9	11

Diet code: C = carnivore, F = frugivore; G = granivore; I = insectivore; N = nectarivore. Dietary preferences listed in order of presumed importance. + = invasive species.

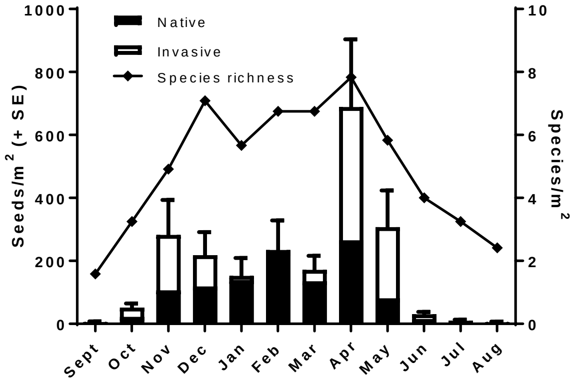

Fig. 1. Mean seed abundance and mean species richness of native and invasive species whose seeds were dispersed to artificial perches during the 12-month study.

Discussion

Fruit-consuming bird species that commonly visited the perches tended to be omnivores, which consume smaller proportions of fruit compared to frugivores. These bird species often frequent open areas and are all medium to large in size. Holl (1998) and Ferreira and Melo (2016) also found omnivorous birds to be common perch visitors in tropical systems. Smaller fruit-consumers such as *Zosterops lateralis* (silvereye), the most abundant bird during the fruiting season, may be less inclined to rest on simple-structured perches in open areas where predation risk is elevated. Perch of greater structural complexity that provide protection may be required to attract these species.

The provision of perches was successful at increasing the quantity of seed dispersal, and this is consistent with studies conducted in both tropical and temperate systems (Holl 1998; McDonnell and Stiles 1983). A substantial amount of seed was dispersed to perches; however, not all of this seed was suitable for restoration. A large proportion of the seed was from the invasive species, *L. ferocissimum*, which is able to fruit and germinate seed at any time of the year. Therefore removal of the perches at certain times of the year may not necessarily be a solution in reducing its dispersal. Rather, control of this species may be required particularly close to perches to minimise its dispersal and to improve the effectiveness of perches as a restoration technique.

Although artificial perches successfully attracted fruit-consuming birds and increased the dispersal of native seed to open areas, this does not necessarily mean that the perches were successful as a restoration technique. Rather success should be measured by the extent to which the dispersed native species seed germinates and establishes new recruits. Numerous factors including herbivory, seed predation and weed competition can prevent germination and seedling establishment. A recent study by Elgar *et* al. (2014) found enhanced recruitment under artificial perches when weed competition was suppressed by the use of herbicides. In future restoration, the use of supplementary techniques in association with artificial perches may be necessary to increase plant recruitment.

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Strategic revegetation: Applying eucalypt flowering phenologies to rebuild landscapes for nectarivorous birds

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Abstract

Nectar-feeding birds are prominent in the heavily-cleared Mount Lofty Ranges (MLR), with many species moving within the MLR to exploit seasonal flushes of flowering. However, most species are declining and three species are already lost from the region. The disproportionate clearance of good-quality eucalypt woodland, creating a shortage in nectar availability at certain times of the year, or in particular years, is likely contributing to these declines. Consequently, to arrest such declines, floral resources must be re-established.

Restoring region-wide floral resources to better sustain nectar-feeding birds requires knowledge of the flowering seasons of key nectar-producing plants, such as *Eucalyptus leucoxylon.* Populations of *E. leucoxylon* flower at different times of the year, such that there are plants in flower somewhere within the MLR in every month. In general, individuals within local populations flower at the same time each year, but the timing of flowering onset can differ between neighbouring plants. Assuming that flowering time is heritable, sourcing seeds for revegetation without knowledge of flowering phenologies of individuals or populations could profoundly influence when nectar is produced in new habitats. Two strategies should be considered for re-establishing floral resources in the MLR: (1) identifying periods of the year when nectar resources are limiting for birds and planting species or individuals to fill that gap; and (2) reconstructing new habitats that provide year-round supplies of nectar to reduce the need for nectarivorous birds to move. For heavily-fragmented systems such as the MLR, the latter approach is likely to be better.

Introduction

Eucalypts are dominant overstorey plants across many habitats in the Australian landscape and are frequently planted in restoration projects. Eucalypts play an important role in restoration, in particular, the nectar produced by eucalypts provides important food resources for nectarivorous birds with many species relying on this nectar to meet daily energy requirements (Paton 1982). However, birds (including honeyeaters) are in decline in the MLR and detailed information on the flowering phenology of common eucalypt species and how birds use those nectar resources are limited.

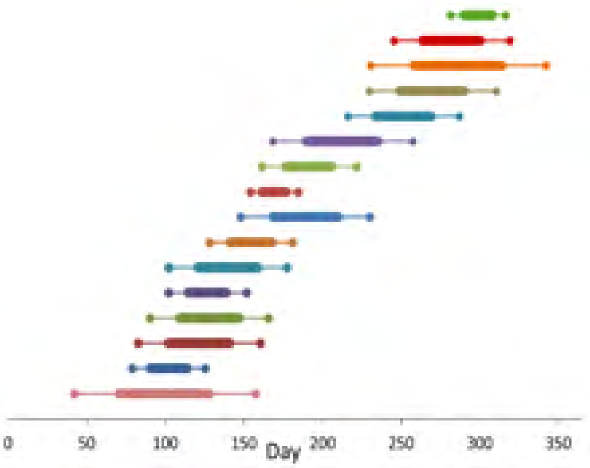
Woodland habitats need to be re-established over substantial areas to arrest declines of woodland birds in the MLR (Paton and O'Connor 2010). However, considerable amounts of land are currently unavailable for restoration and re-establishing functional habitat on cleared land takes decades. Given the limited land available, any revegetation needs to maximise the ecological benefits that accrues from those plantings. From a nectarivorous bird perspective, this means focusing on filling seasonal gaps in nectar resources or constructing new habitats that provide year round resources to reduce the need for birds to move to find food. Strategic planting for nectarivorous birds requires detailed knowledge of the flowering phenologies of the plants. In this paper we show that different populations of *E. leucoxylon* within the MLR flower at different times of the year and that individuals within populations also differ in the timing of flowering. If flowering time is inherited then knowledge of individual flowering times needs to be considered when sourcing seeds for revegetation.

Methods

Flowering times of individual plants were determined by estimating the percentages of a plant's floral production that were buds, flowers or recently finished flowers on several occasions across the flowering season. The percent of floral units that were flowers (FL) and recently finished (F) were used to estimate the extent to which each individual plant was through its flowering season, where percent through flowering was 0.5FL + F. To determine the flowering seasons of populations of *E. leucoxylon* we calculated the average percent through flowering of 25-50 individuals for different dates across a flowering season and where available pooled data collected over 2 or more years. We then extrapolated those data to estimate when the population was 10, 30, 70 and 90% through flowering. Differences among populations in flowering times were estimated by calculating the dates when populations were 10, 30, 70 and 90% through flowering. Data collected from 35 trees at Para Woodland in 2014 were used to illustrate individual variation in the time of flowering within a population.

Results

The flowering times of individual trees at Para Woodland in 2014 were staggered (Fig. 1). Eight plants flowered between days 70 and 200, while 14 flowered between days 200 and 300 and so did not overlap in flowering times. Thirteen individuals had flowering seasons that were intermediate. Early flowering and late flowering individuals were inter-dispersed within the population, with those trees maintaining early and late flowering, respectively, in other years (unpublished). Populations of *E. leucoxylon* also flowered at different times in the MLR to such an extent that there was some flowering somewhere in the MLR in all months of the year (Fig. 2).



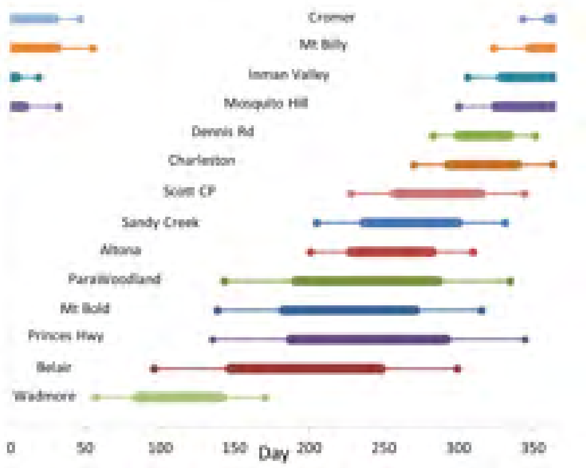


Fig. 1. Flowering times of 16 individual *E.leucoxylon* trees at Para Woodland in 2014. Dots represent 10 and 90% through flowering; thick line shows times when plants shifted from 30-70% through flowering. Day 1 is January 1.

Fig. 2. Average flowering seasons for 14 populations of *E. leucoxylon* in the MLR. Dots represent 10 and 90% through flowering; thick line shows average times for populations to shift from 30-70% through flowering. Day 1 is January 1.

Discussion

The flowering times of individuals within populations of *E. leucoxylon*, and between various populations within the MLR, differed. Those differences are likely to have a genetic basis, since early and late flowering individuals were interspersed within populations such that adjacent trees could have non-overlapping flowering times (pers. obs.), despite experiencing almost identical environmental conditions. Similarly, early and late flowering populations were interspersed across the MLR, with some populations having similar flowering times despite experiencing different environmental conditions (rainfall, temperatures, aspect, soils). These patterns all suggest a strong genetic component to flowering times. Provenance trials are now underway to confirm a genetic basis for flowering times for *E. leucoxylon* and other eucalypts; however, this will take more than 5 years for confirmation. In the interim, the collection of seeds for revegetation programs should take into account the flowering times of the plants used to source seeds so that the full range of early-, mid- and late-flowering individuals are sampled. The current method of haphazard collection of seeds from across a population may fail to capture the spread of flowering and result in truncating the flowering period in new plantings.

Individual variation in the time of flowering is also a characteristic of other gum and box eucalypts, although to varying levels, as well as other nectar-producing shrubs, like banksia (pers. obs.). However, none of these show the same breadth in flowering times that the different populations of *E. leucoxylon* show across the MLR. The adaptive reason for this breadth is not known.

Within the heavily cleared landscapes of the MLR many woodland birds are declining, including nectarivorous species. Three nectarivores have already been lost from the region (little lorikeet, swift parrot, regent honeyeater: Paton *et al.* 2004; Horton and Black 2006) and many others are in decline. Revegetation is often promoted as a panacea for reducing bird declines (e.g. Paton and O'Connor 2010). Knowledge of flowering times can be used to design habitats to better meet the requirements of nectarivorous birds, assuming flowering times are heritable. For example, honeyeaters regularly move within the MLR to exploit seasonal flushes of flowering with late summer and autumn regarded as periods of lower floral abundance (Paton *et al.* 2004). Revegetating with plants that provide nectar at those times will help fill a seasonal gap in flowering. Movements by birds across fragmented landscapes, however, are risky. Another strategy which may be better for birds, is to construct new habitats that provide year round supplies of nectar and so reduce the need for these birds to move across heavily cleared landscapes. With its breadth in flowering times, *Eucalyptus leucoxylon* could be particularly useful in delivering such habitats. Given the current deficiency of habitat, any new habitats that are re-established should be designed to maximise the ecological benefits for birds. For nectarivorous birds this should include accounting for flowering times.

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Planning for Effective Wildlife Habitat Restoration: a Wildlife Habitats and Corridors System Developed for Application at the Local Government Level in North East NSW

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Abstract

We developed a system of wildlife habitats and corridors to recover and conserve the most vulnerable terrestrial vertebrate species in the Lismore City Council LGA. The system grouped Threatened (*TSC Act 1995*) and conservation-priority species with core habitat in the LGA into assemblages on the basis of their zoogeographical origin, habitat preference, conservation status and dispersal capability. Assemblages were ranked on level of risk from landscape-scale threatening processes. The LGA's vegetation types were scored for their importance as habitat for the assemblages. Corridor selection focused on linking large blocks of habitat, considered refuges, by habitats of highest importance to assemblages while achieving the least fragmented links. Final corridor selection was informed by records of Threatened and conservation-priority species and links to important habitats in adjoining LGAs. Additional links were provided by buffering rivers and named streams. A system was derived that generally linked stands of wet forests, providing the greatest benefit to the most "at risk" species. The 26 identified blocks and corridors were ranked for importance to the assemblages and prioritised for restoration and revegetation action. This is currently being achieved through Lismore City Council's Rural Landholder Initiative scheme.

Introduction

In 2010 Lismore City Council engaged Landmark Ecological Services to develop a wildlife habitats and corridors system to aid environmental planning in the 1,292 km^2 Lismore Local Government Area (LGA). This paper describes the system of habitat selection and prioritisation adopted to maximise biodiversity conservation in the LGA, given the constraints of a limited budget and different vegetation mapping systems across the LGA.

The value of wildlife corridors for biodiversity conservation is well established (Saunders and Hobbs 1991) and their provision is particularly important in the Lismore LGA. This is due to the high refugial significance of the LGA for the Gondwanan-derived Tumbunan fauna (Schodde and Faith 1991), many of which are sedentary with poor dispersal capability, and the isolated nature of vegetation remnants in the LGA's centre and south.

Methodology

Previously, three existing corridor systems had been available for the LGA (Scotts 2003; DECC 2007; LCC 2010 LEP natural resources overlay) but these were unsuitable for use at the local level as they were developed at regional and sub-regional scales, were often truncated, did not provide connectivity across the central and southern LGA, excluded riparian corridors and one did not follow extant vegetation. This paper describes the four key steps in the process of deriving a system of habitats and corridors considered to most effectively cater for the most significant and sensitive vertebrate species in the Lismore LGA.

Most "at risk" species with core habitat in the Lismore LGA

Due to budgetary constraints, an expert model of vertebrate species regarded as most "at risk" from landscape-scale threatening processes was developed to drive the habitats and corridors selection. These were defined as Threatened (*TSC Act 1995*) and "conservation-priority" species (Scotts 1996) and a search of the NSW Bionet Atlas (accessed 11 November 2010) plus records from local observers revealed totals of 51 and 31 species respectively known from the LGA. Conservation-priority species have their stronghold in north east NSW and/or are severely affected by one or more threatening processes. Only terrestrial species dependent on woody vegetation were included. The pattern of records reflected biases in these data such as a very high reporting rate for the Koala *Phascolarctos cinereus* near Lismore, and results of past systematic surveys focused in the north.

The 82 Threatened and conservation-priority species were vetted to derive a subset of 50 species with core habitat in the LGA and thus most likely to benefit from a habitats and corridors system. Core habitat species had resident populations in the LGA or required habitats in the LGA for particular aspects of their lifecycles.

Derivation of species assemblages for ranking by level of risk from threatening processes

To inform habitat and corridor selection, the 50 core habitat species were grouped according to four criteria: i) zoogeographical origin; ii) habitat preference; iii) conservation status; and iv) dispersal capability. Thirty-five (70%) of the 50 species were of Tumbunan origin with 11 (22%) of Irian (New Guinean), three (6%) of Bassian (southern Australian) and one (2%) of Torresian (northern Australian) origins. Tumbunan or relictual species were considered most at risk, followed by Irian (rainforest associated), Bassian and then Torresian according to their decreasing vulnerability to landscape-scale threatening processes. Species' habitat preferences reflected their zoogeographic origin, with species considered most at risk associated with rainforest, followed by species associated with rainforest/wet sclerophyll forest, riparian forest, swamp forest and finally moist/dry sclerophyll forest. Conservation status followed listing under the *TSC Act 1995*, with endangered species regarded as most at risk followed by vulnerable and then non-listed (conservation-priority) species. The dispersal capability of species was assessed from known behaviour (author, unpublished) with species of low mobility considered more at risk than those with medium or high mobility. Grouping of species with similar criteria resulted in 12 species assemblages with similar levels of risk, which were ranked in decreasing order of risk.

Assignment of vegetation types to ranked assemblages
Vegetation types from the two mapping systems covering different areas of the LGA were listed for each assemblage according to the habitat preferences of the component species and scored for importance in supporting the assemblages according to their level of risk.

Corridor selection rationale and decision rules
Selection of habitats and corridors initially focused on connecting large habitat blocks identified by vegetation mapping in the Nightcap, Nimbin Rocks, Billen Cliffs and Mackellar Range areas in the north and the Tuckean Swamp area in the south of the LGA. These blocks, considered as refuges, were included in their entirety and linked by corridors enclosing the least fragmented and isolated patches of the highest scored habitats. Corridor width was limited by habitat extent or to a minimum of 500 m for regional and 300 m for sub-regional and local corridors (as adopted by Scotts 2003). Large gaps were mostly avoided but were included where it was necessary to link highly scored habitats, and areas of non-native vegetation, settlement, orchards and plantations were sometimes included to reduce fragmentation. Corridor selection was also informed by records of species from the highest ranked assemblages and by the need to connect to important habitat areas in adjoining LGAs. The system was enhanced by adding 100 m and 50 m wide buffers respectively to rivers and named streams.

Selection process outcome
The selection process produced a system that followed the distribution of the LGA's wet forests, providing greatest benefit to the assemblages considered most at risk. Additional potential corridors in the north of the LGA were not included in order to concentrate regeneration and revegetation actions where connectivity was most needed. The system comprised 26 sectors with five main habitat blocks and 21 corridors plus riparian corridors. Junctions between sectors were delineated at vegetation gaps or where watercourses cut corridors. The 26 sectors were ranked for importance in catering for the most at risk assemblages with blocks, and corridors directly linking blocks, rated as very high; corridors linking blocks via other corridors and with larger areas of the highest scored habitats rated as high; and corridors with smaller areas of such habitats rated as high-moderate. The system provided links to other important habitats in adjoining Kyogle, Byron, Ballina and Richmond Valley LGAs.

Prioritisation of sectors for restoration and revegetation
The 26 sectors were prioritised for restoration and revegetation based on their ranking plus whether they included conservation reserves and if they linked to important habitats in adjoining LGAs. Six levels of prioritisation were adopted, in decreasing order: i) sectors ranked as of very high importance and not included in reserves; ii) sectors of very high importance but mainly included in reserves; iii) sectors ranked as of high importance and/or linking important areas in adjoining LGAs, and riparian corridors along rivers; iv) sectors ranked as of high importance but including smaller areas of the highest scored habitats, and riparian corridors along streams; v) sectors ranked as of high-moderate importance including larger areas of the highest scored habitats; and vi) sectors of high-moderate importance including smaller areas of the highest scored habitats.

Application of the wildlife habitats and corridors system
Lismore City Council has now incorporated the habitats and corridors system into their Biodiversity Management Strategy and restoration and revegetation of the system is proceeding, guided by prioritisation, under the Rural Landholder Initiative scheme and funded by Council's special rate variation or biodiversity levy.

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Restoration: A Personal Journey

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Abstract

I was initially attracted to "Barn Gully" because, despite what appeared to be a history of overgrazing and limited productive capacity, it retained remarkable floristic diversity, abundant wildlife and areas of high quality native vegetation. My initial aims were to protect the intact vegetation, restore tree cover, and restore groundcover, expanding areas where the groundcover was dominated by original native tussock grasses. I was not seeking to run the property as a fully commercial entity. At first, I focussed on controlling potentially invasive weeds and building fences to better control grazing. Livestock were excluded altogether when I accepted a stewardship agreement with the Federal Government. My management priorities have changed over the years. For example, feral pig populations and my efforts to control them have increased. Natural regeneration of trees has exceeded my expectations, with tens of thousands of tree seedlings being established in repeated recruitment events during prolonged wet spells. In this paper, I describe my efforts over 14 years to restore and manage grassy woodland and open forest on a New England grazing property. I argue that effectively tackling climate change needs to include efforts to restore tree cover in a way that enhances landscape function and minimises climatic impacts. In this context, the re-establishment of trees on the property offers an example of what can be achieved.

Introduction

Over the last 14 years I have managed and attempted to restore grassy woodland and open forest on a New England grazing property, "Barn Gully", of approximately 1000 ha, located approximately 40 km north-west of Guyra. I was initially attracted to the property for conservation reasons. Despite what appeared to be a history of overgrazing and limited productive capacity, the property retained remarkable floristic diversity, abundant wildlife and areas of high quality native vegetation. The property overlies granite and acid volcanic rocks and is approximately 1000 m asl. Much of the granite country had originally been open woodland that was well suited for fine wool production, but the native pastures had generally declined from a production perspective. In areas where tree cover had been totally removed, swards were dominated by wire grasses (*Aristida* spp.), blady grass (*Imperata cylindrica*) or poverty grass (*Eremochloa bimaculata*), while most of the grazing occurred on relatively small, but fertile, sheep camp areas where swards were dominated by microlaena (*Microlaena stipoides*). The areas with soils derived from acid volcanic rocks tended to be more heavily wooded, except for areas with impeded drainage that were often covered in wet or dry heath. There had been failed attempts to clear much of this country, and at the time of purchase there was substantial regrowth of eucalypt saplings in many places and of *Kunzea* and *Leptospermum* in wetter areas.

My initial aims were to protect the intact vegetation, restore tree cover, and expand areas where the groundcover was dominated by original native tussock grasses. I was not seeking to run the property as a fully commercial entity, but I aimed to earn enough from the property to cover all expenses. At first, I continued with an existing agistment arrangement with a neighbouring landholder and focussed on controlling potentially invasive weeds and building fences to better control grazing. Livestock were removed in 2011 due to dry conditions, and the property was never re-stocked after I accepted a stewardship agreement with the Federal Government later that year. The stewardship agreement was aimed at restoring Box Gum Grassy Woodland, which generally occurred on the most productive parts of the property. So, the agreement was incompatible with continuing commercial grazing.

Restoring tree cover

In restoring tree cover, my long-term aim was, and still is, to re-establish a natural arrangement of trees with woodland or open forest cover over most of the property and to maintain the genetic integrity of the original trees. I initially observed that some natural regeneration of eucalypts was already occurring and, given that there were relatively few areas on the property that were more than about 50 metres from the nearest tree, I decided to see how effectively tree cover could be increased by natural regeneration before trying anything else. Between 2002 and 2010 the property was generally stocked with between 500 and 800 sheep. This stocking rate was insufficient to prevent substantial regeneration of eucalypts in open areas, mostly on the edges of stands of existing trees, although I did observe browsing damage to saplings from time to time. If anything, the rate of recruitment of new seedlings increased following the total cessation of grazing.

Natural regeneration of trees has exceeded my expectations, with tens of thousands of tree seedlings being established in repeated recruitment events during prolonged wet spells. In places, the regenerating eucalypts are far too dense, with the local density of regrowing eucalypts exceeding 2300 stems per hectare in at least one place. However, some trees are larger than others and it is likely that there will be self-thinning of suppressed trees, especially following events such as wildfires and droughts. In a worst-case scenario, thinning of trees (e.g. by poison axing) may be required in the future.

Other effects of destocking

The removal of livestock was a mixed blessing in terms of achieving other conservation goals. Destocking appeared to allow more recruitment of some grazing sensitive species, such as hickory (*Acacia implexa*) and wild sorghum (*Sorghum leiocladum*). I was also inspired by research that showed that excluding livestock may benefit the soil beneath trees, for example, resulting in increases in organic matter and improved infiltration, and possibly conferring some protection to trees against the impacts of droughts (Davidson et al. 2007). But destocking also meant that greater efforts were required to control some potentially invasive plants. In particular, blackberries (*Rubus fruiticosu*s Agg.) became difficult to control because there was greater survival of seedlings, which had previously been intensively browsed by sheep. My response, which appears to be enjoying some success, was to methodically destroy all large thickets of blackberries to minimise production of fruit. Also, invasive perennial grasses, such as whisky grass (*Andropogon virginicus*), Coolatai grass (*Hyparrhenia hirta*) and African lovegrass (*Eragrostis curvula*) appeared to set more seed in the absence of livestock, which meant that their control was more onerous. I have generally kept populations of Coolatai grass and African lovegrass low by repeatedly re-visiting the locations of infestations to eliminate new plants before they set seed, usually by spraying with glyphosate. Whisky grass, which is seldom, if ever, abundant in productive pastures, is proving more difficult to control. This grass is often not apparent until autumn when flowering and seed set occurs rapidly before infestations can be sprayed.

Other issues

Other management priorities have changed over the years. For example, feral pig populations have increased in the whole district including "Barn Gully", as have my efforts to control them. My approach changed from occasional reliance on amateur hunters, to trapping, to poisoning. I am still looking for more effective ways of controlling pigs. I am also still grappling with issues such as how to restore old sheep camp areas where excessive soil fertility favours weeds and the best way of using, and affording protection from, fire.

Lessons for the future

Tackling climate change has been a strong personal motive for increasing forest and woodland cover on my property. While I haven't tried to calculate the amount of carbon sequestered, given that there are large amounts of carbon stored in trees, roots and the soil beneath trees, it is likely to be high. However, taking a long-term perspective, growing trees is not a substitute for cutting emissions because the trees may not survive in a world affected by climate change. Forests and woodlands are affected by wild fires, more intense droughts and severe wind storms, all of which are expected to increase as a result of climate change. But establishing forests and woodlands also has other benefits that reduce the impact of climate change, providing habitat for wildlife and moderating the climate, at least at a local scale. Furthermore, evidence is accumulating that regional rainfall can be directly impacted by loss of forest cover (Sheil and Murdiyarso 2009).

Effectively tackling climate change needs to include efforts to restore tree cover in a way that enhances landscape function and minimises climatic impacts. In this context, the re-establishment of trees on "Barn Gully" offers an example of what can be achieved.

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Improved methods to measure and predict mine rehabilitation success and sustainability

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Abstract
Reinstatement of a 'self-sustaining native ecosystem' is an increasingly common revegetation goal for open-cut mines in Australia. For end-of-mine relinquishment, the environmental authority holder must demonstrate that rehabilitation outcomes are met and sustained, while the regulator must be satisfied that the likelihood of failure is low to avoid future site remediation liabilities being transferred to the State. There is a need for robust assessment methodologies for ecological restoration to provide the high degree of confidence needed to certify progressive rehabilitation or accept the surrender of lease at mine closure. The BioCondition Assessment method was applied to revegetation at Meandu mine, an open-cut coal mine in southeast Queensland. Sixty-two permanent sites established in revegetation ranging from one year to 26 years old, were assessed for 12 attributes. The scores for these attributes were compared to benchmark scores based on non-mined local remnant vegetation, which represented a self-sustaining eucalypt woodland. The BioCondition scores distinguished sites that were lacking in eucalypts, high in weed cover, low in lifeform diversity, and likely to require management intervention. The growth trajectory of the revegetation was modelled using the Ecosystem Dynamics Simulator (a calibrated tree-growth model) to project the likelihood of the revegetation meeting the benchmark height and cover within the life of the mine. No site was likely to meet the outcome within 60 years; however, some were developing as eucalypt woodlands.

Introduction
The aim of mine rehabilitation in Australia is to restore pre-mining land-use. For compliance, open-cut mines are to be back-filled using mine spoil, re-shaped, covered with top soil and restored to pre-mining land use. To progressively assess the development and success of rehabilitation sites against the restoration goal, monitoring is conducted by the mine manager and routinely evaluated by the government regulator. Though empirical research into restoration outcomes is clearly expanding (Wortley et al. 2013) and national standards devised (McDonald et al. 2016), there is currently no agreed methodology for this process. Ngugi and Neldner (2015) demonstrated the use of the BioCondition assessment framework (Eyre et al. 2015) for quantifying the current condition of vegetation rehabilitation, and the use of Ecosystem Dynamics Simulator (EDS) (Ngugi and Botkin 2011) to model the trajectory of mine rehabilitation using 25 monitoring sites sampled in 2012 and 2014. This paper integrates an additional 37 sites across the whole geographical and temporal range of vegetation rehabilitation on Meandu Mine.

Methods
Field assessment of 62 permanently marked plots in mine revegetation aged from 1-26 years was conducted at the Meandu coal mine, southeast Queensland, between 2012 and 2015. The plots were 50 m long and 4 m wide. The height and cover of the tree and shrub layers were measured. All trees and shrub species with diameter at breast height >2 cm had the species and diameter recorded. Five $1m^2$ quadrats were used for estimating ground cover and litter. The species richness of each lifeform, length of coarse woody debris (>50 cm length and >10 cm diameter) and recruitment of tree species was derived from an inventory of a larger 50 x 14 m plot. The EDS is a forest succession model that projects long-term growth dynamics of forests, that simulates tree and shrub establishment, growth and death in an uneven aged mixed species forest plot on an annual time step based on local growth conditions. These elements allow analyses of changes in species composition, tree age and tree size structures. Projection of each plot was initialised using tree data (species and dbh) collected in August 2012. Each plot was simulated 100 times for the period of years remaining for the stand to reach age of 70 years, to derive plot mean statistics.

Results
The data from the 62 plots were converted to BioCondition scores (maximum score of 65) using the scoring tables in Eyre et al. (2015) and the benchmark values in Neldner and Ngugi (2014). An example radar diagram for plot K2.4T3 which was sampled in 2012 and 2014 is shown as Fig. 1. Importantly the score for each assessment attribute is shown individually relative to the benchmark, to allow mine management and the regulator to clearly see attributes requiring improvement. It also shows BioCondition is sensitive to changes (increased weed cover, decrease in native grasses, and death of a canopy tree, i.e. reduced canopy cover) occurring in only two years. The mean BioCondition score for the 62 revegetation plots is shown in Fig. 2. The EDS projections for tree canopy height and cover, stand basal area and number of large trees (>47 cm DBH) are generated for individual plots and an example is shown in Fig. 3.

Discussion and Conclusions
The BioCondition 'scorecard' provides a visual, quantifiable tool for assessing vegetation rehabilitation relative to a benchmark. It demonstrates to both mine managers and regulators performance against 12 site attributes. Many plots were shown to be lacking in eucalypts, high in weed cover, and low in lifeform diversity, while frequently meeting canopy cover and litter cover benchmark values. The EDS modelling is able to predict the likely trajectories of the rehabilitation for tree height, cover, species and biomass attributes relative to a benchmark. This can provide stakeholders with some degree of confidence of the likelihood of rehabilitation meeting its

completion objectives, in this case a self-sustaining eucalypt woodland or open-forest. Together, these quantitative tools have the potential to allow robust assessment for both the mine managers and regulators, and drive sustainable rehabilitation outcomes.

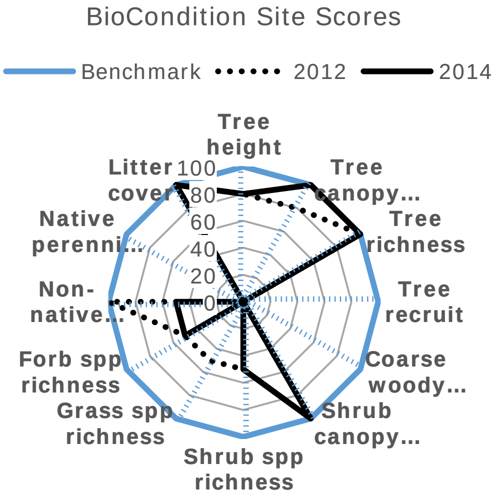

Fig. 1. Radar diagram of BioCondition site scores for site K2.4T3 for 2012 and 2014 (11 years old) relative to the benchmark.

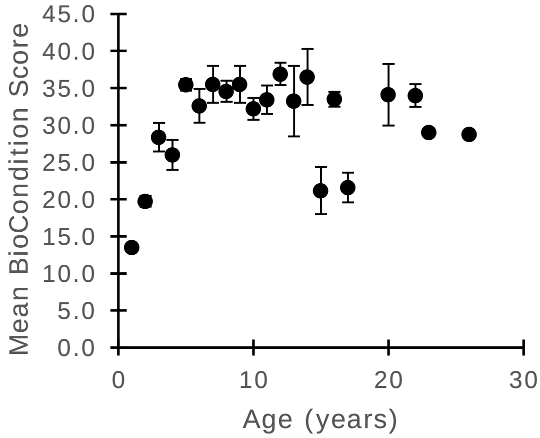

Fig. 2. Mean BioCondition site scores for 62 sites of varying ages at Meandu mine. The expected Benchmark score is 65.

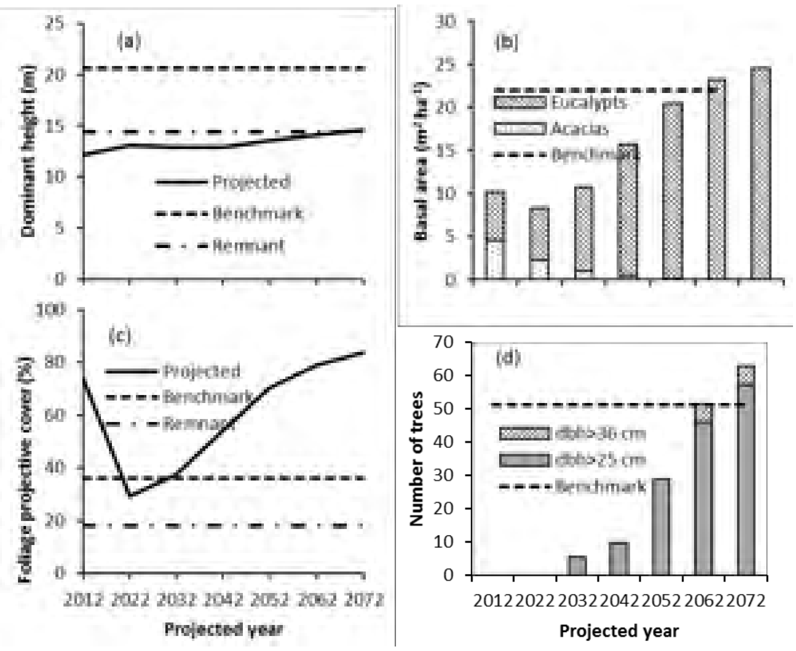

Fig. 3. EDS trajectories for site K2.4T3 against benchmark for (a) canopy height, (b) basal area, (c) canopy cover, and (d) number of large trees with DBH>47 cm.

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Translocation of *Ruppia tuberosa* to the Coorong, South Australia

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Abstract

Ruppia tuberosa was once abundant and widespread in the southern Coorong but, except for a greatly diminished seed bank, all but disappeared from the southern Coorong during the Millennium drought (2002–2010). When the River Murray flows returned in late 2010, *R. tuberosa* did not recover. Consequently, a translocation program was established to facilitate recovery. Although plants established at each of the five translocation sites, falling water levels in spring exposed plants before they had produced seeds, and seed banks declined. The issue of falling water levels in spring and early summer needs to be addressed to allow recovery. A shallow barrier across the middle of the Coorong may provide a solution, particularly because even after the Murray Darling Basin Plan has been implemented, the environmental flows will still be inadequate.

Introduction

The Coorong is a unique, protected, coastal lagoon system that stretches from the Murray Mouth SE for 110 km along the South Australian coastline. The region is a Wetland of International Importance listed under the Ramsar Convention in part because large numbers of waterbirds, including migratory shorebirds, use the region during the summer months. That listing places obligations on Australia to maintain the ecological character of the Coorong. A key feature of the Coorong is a longitudinal gradient in salinity. Estuarine conditions exist near the Murray Mouth but salinities progressively increase, becoming hypersaline further south, where they are typically between 60–100 gL^{-1}, about two to three times saltier than seawater (Paton 2010). This salinity gradient has a profound influence on the aquatic biota with a much higher diversity of fish and benthic invertebrates at the lower salinities. In the hypersaline southern Coorong, a simple but, nevertheless, highly productive aquatic ecosystem exists, with only one species of aquatic macrophyte, *Ruppia tuberosa*, one species of fish, the small-mouthed hardyhead (*Atherinosoma microstoma*), and one benthic macro-invertebrate, the chironomid *Tanytarsus barbitarsis*, prominent (Paton 2010). *Ruppia tuberosa* traps fine sediments, dampens wave action, and provides habitat for small fish and food resources (foliage, seeds and turions) for a wide variety of birds.

During the Millennium drought (2002–2010), River Murray flows to the Murray Mouth ceased for extended periods of time. Salinities rose sharply in the southern Coorong, exceeding 150 $g.L^{-1}$, above the salinity tolerances of fish and chironomids (Paton 2010). During this period, *R. tuberosa* all but vanished from the southern Coorong. In late 2010, substantial River flows returned to the region and salinities were quickly restored to pre-drought levels. Within 1–2 years, fish and chironomids re-colonised and re-established throughout the southern Coorong but *R. tuberosa* struggled to re-establish (Paton *et al.* 2016).

Ruppia tuberosa is an annual plant that grows in water 0.3 to 0.9 m deep on the ephemeral mud flats around the shorelines of the southern Coorong (Paton 2010). In winter and spring, these mudflats are covered with water but they become increasingly exposed as water levels drop with decreasing River flows and increasing evaporation over summer. In late autumn, as water returns to the ephemeral mudflats, the seeds germinate and the turions (asexual perennating structures) sprout. Salinities are typically under 100 $g.L^{-1}$ at these times. The plants continue to grow over winter and flower in late spring. By the end of the Millennium drought, the propagule banks (largely seeds) of *R. tuberosa* were minimal, with fewer than 200 $seeds.m^{-2}$ and with <1% viable (Paton 2010). Historically, seed densities were as high as 20,000 $seeds.m^{-2}$ in the 1980s (Paton 1986). Because the low density of viable seeds was likely to impede the recovery of *R. tuberosa*, a translocation program that involved transporting seeds from nearby Lake Cantara to sites within the Coorong was designed and implemented. This paper briefly describes those translocations and initial outcomes.

Methods

The translocation was undertaken in autumn 2013 and autumn 2014 by contractors engaged and managed by the South Australian Department of Environment, Water and Natural Resources. It consisted of scraping the upper 1.5 cm of surface sediment, containing seeds, from the dry Lake Cantara floor, using a small excavator. Scraped material was placed in 15–20 kg bags and transported by vehicle to the Coorong, where the sediment was spread by hand over areas where *R. tuberosa* was once abundant (i.e., on mud surfaces that were ~ 0 m to - 0.4 m AHD). The numbers of seeds translocated was estimated by sieving aliquots of bagged sediment through 250 µm Endecott sieves, counting the seeds and extrapolating, using number of aliquots per bag and numbers of bags translocated (Table 1). On average sites received from 700–800 $seeds.m^{-2}$ (Table 1).

A set of site-based criteria established to assess the recovery of *R. tuberosa* in the Coorong (Paton *et al.* 2015) were applied in assessing success of the translocations. This required a series of cores to be collected (75 mm diameter x 40 mm deep) and the numbers of shoots, seeds and turions present in those cores to be determined by sieving through a 250 µm sieve. A healthy, resilient population of *R. tuberosa* should have >30% of cores with shoots in winter, >50% of cores with seeds in summer and a mean of >8 seeds per core (2,000 $seeds.m^{-2}$).

Table 1. Quantities of sediment and seed transported from Lake Cantara to five sites in the Coorong in 2013 or 2014.

Site	Year of translocation	Area (ha)	#bags*	tonnes	#seeds (x10^6)	seeds.m^{-2}
Policeman Point	2013	10.0	7080	142	73.8	738
Woods Well	2013	10.0	7000	140	72.9	729
Fat Cattle Point	2014	11.5	8050	121	83.9	729
Jacks Point	2014	18.0	12800	192	133.4	741
Seagull Island	2014	9.5	7800	117	81.3	856

Results

Ruppia tuberosa germinated and grew at all translocation sites. By winter 2015, the two 2013 translocation sites had >30% of cores with shoots, while the three 2014 sites had <10% of cores with shoots (Table 2). By summer 2016, only one site had just in excess of the target 50% of cores with seeds. However, the quantity of seeds present at all sites by summer 2016 was around 1 seed per core and much less than the target 8 seeds per core (Table 2).

Table 2. Performance of *R. tuberosa* at five sites that received seed-containing sediment from Lake Cantara in 2013 or 2014.

Site	Year of translocation	% cores with shoots (30)	% cores with seeds (50)	Seeds/core (mean ± s.e.) (8)
Policeman Pt	2013	44	51	1.4 ± 0.2
Wood Well	2013	48	14	0.3 ± 0.1
Fat Cattle Pt	2014	7	44	1.4 ± 0.2
Jack Point	2014	8	31	0.6 ± 0.1
Seagull Island	2014	8	41	1.4 ± 0.2

Assessments of shoots was based on 400 to 1200 cores taken at each site in winter 2015, while assessments of seeds was based on 100 to 300 samples per site undertaken in summer 2016. The target is given in parentheses in the headings of each column.

Discussion

Despite good growth of *R. tuberosa* at some sites in the second year, the numbers of seeds produced and entering the propagule bank was poor. After 2–3 flowering seasons, the numbers of seeds present had dropped to around 1 seed per core or 225 seeds.m^{-2}. In the springs of 2013–2015, water levels in the Coorong dropped well below 0.2m AHD (Fig. 1), exposing plants to desiccation before they had completed flowering and set additional seeds.

The falling water levels in spring are associated with the premature closure of the barrages due to diminished flows to the Murray Mouth. Prior to over-extraction, water levels would have been maintained through spring (as illustrated for 2010 in Fig. 1, when there was an unregulated flow) allowing *R. tuberosa* to set seeds in most years, and so maintain a substantial seed bank.

Successful re-establishment of *R. tuberosa* in the Coorong, requires inadequate water levels during spring and early summer to be addressed. Modelling suggests that even returning 3200 GL, the maximum agreed under the Murray Darling Basin Plan, the flows will be inadequate. An alternative of using a shallow barrier across the Coorong to hold back water mid-way along its length has promise and should be considered as a possible solution. A 5-year experimental trial of a low, removable barrier, coupled with monitoring, should be undertaken.

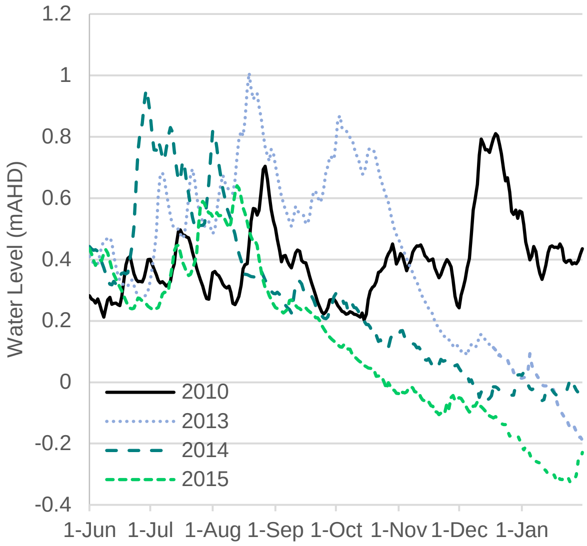

Fig. 1. Changes in average water levels (m AHD) for the South Lagoon between the 1st June and 31st January of the following year for 2010 and for the years 2013 to 2015.

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Bird Responses to Large-scale Revegetation at Cygnet Park, Kangaroo Island using Systematic Area Searches

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Abstract

From 2002 to 2014, 175 hectares were revegetated at Cygnet Park, a 310-ha former sheep-grazing property on Kangaroo Island, South Australia. Data on bird abundances and distributions were collected from 2009 onwards by systematic area searches of the whole property. Terrestrial bird abundance increased across the whole property since 2009, from < 1000 to ≈ 2500 birds. This increase is equivalent to 2.8 and 8.0 birds.ha^{-1}, respectively, with species density and area of occupation also increasing. Changes in bird populations were even greater when the 175-ha revegetated area was considered independently from the whole property. Generally, woodland bird species, and especially crescent honeyeaters and new holland honeyeaters, benefited from the revegetation, while the Australian magpie and Australian pipit, two largely grassland birds, were disadvantaged.

Introduction

Cygnet Park is a former sheep-grazing property of 310 ha on Kangaroo Island, South Australia, where hot, dry summers juxtapose mild, wet winters, and the average annual rainfall is 455mm (Bureau of Meteorology, 2017). Remnant vegetation covers about 30% of the property, consisting of gum woodland, predominantly along the Cygnet River corridor, and mallee strips between paddocks and around the property's boundary. Of the formerly-grazed paddocks, 175 ha were revegetated between 2002 and 2014, although the greater part was conducted in 2007 (22 ha), 2008 (24 ha), 2010 (54 ha) and 2011 (52 ha). Overall, some 200 species and 500 000 individual plants were planted at an average density of 1.8 plants.m^{-2} (excluding grasses). Planting on site occurred during July of each year, a few weeks after the top soil was scraped to remove accumulated seeds of weedy species.

The focus of the revegetation was to re-establish: (a) populations of rare and threatened plant species, (b) populations of drooping sheoak, which are a key seed source for the endangered glossy black cockatoo, and (c) the largely non-existent shrubby understorey of the critically endangered ecological community of *Eucalyptus cneorifolia* woodland. A secondary objective was to create better habitat for a diversity of birds and this is the focus of our research. The aim of this paper is to document initial changes in terrestrial bird populations using Cygnet Park, following revegetation. Further work will assist in managing birds at Cygnet Park and planning future large-scale revegetation programs to create bird habitat.

Methods

Systematic area searches for birds of the whole property (i.e., censuses) were conducted biannually from 2009 to 2012 and annually thereafter. Of the 12 censuses, five occurred in autumn, four in spring, two in winter and one in summer. Between one and three experienced ornithologists conducted each survey, taking between two and four consecutive days to complete, with differences in time owing to weather, the number of birds observed, the number of observers and density of vegetation (which changed considerably, as more paddocks were revegetated and the plants matured). Observers marked the location of every bird encountered during the search using a GPS by going to the place where the bird was detected. A record was made of the bird species; the number of individuals, their activity (e.g., foraging, perching), their height; the plant species and substrate that the birds were using (e.g., branch, foliage), whether the plant was dead or alive; and any additional relevant information, such as food or flight direction. Due to length restrictions of this paper, results from only four censuses are presented, including the first census in autumn 2009 (treated as a baseline, before much of the property was revegetated or revegetation was young), and three spring censuses (so as to limit seasonal differences between censuses) in 2010, 2012 and 2016. Changes in abundance, density, species diversity and area of occupation (AOO) are used to illustrate changes in the terrestrial bird population through time. AOO was determined by using ArcGIS to divide the property into 1-ha cells, and then expressing AOO as the percentage of cells the birds were observed in compared to the total number of cells. These criteria were calculated excluding records of birds flying over the property, as these birds were not necessarily using the property's habitat.

Results

The total number of terrestrial birds using Cygnet Park increased by more than 250% since autumn 2009, from less than 1000 birds (or 2.8 birds.ha^{-1}) to just shy of 2500 birds in spring 2012 and 2016 (about 8.0 birds.ha^{-1}) (Table 1). Birds in autumn 2009 were occupying 43% of the property, but this had almost doubled to 78% by spring 2016 (Table 1; Fig 1). Similarly, species diversity increased from the first census when 41 species were observed, with around 15 more species found using the property in the latter censuses (Table 1). When purely considering the area that was revegetated on the property, bird numbers increased by an order of magnitude from 145 birds in autumn 2009 to 1629 birds in spring 2016, or from less than 1 bird.ha^{-1} to 9.3 birds.ha^{-1} (Table 1). The species diversity also doubled in these areas over this time from 18 to 36 species, with 45 species observed in spring 2012 (Table 1), while there was a 7-fold increase in area of occupation from 10% to 70% (Table 1; Fig 1).

The greatest changes for individual species were observed for crescent honeyeaters and new holland honeyeaters, with only two birds of each species observed in autumn 2009 but over 300 individuals of each species observed in spring 2016. The abundances of a suite of small, insectivorous birds (namely brown thornbills, grey fantails and superb fairy-wrens) also increased, but to a lesser extent, ranging from 50-100 individuals for each species in autumn 2009 to 150-250 individuals in spring 2016. In contrast, Australian magpies and Australian pipits, both grassland birds, decreased from 80 to 28 individuals and 4 to 0 individuals from autumn 2009 to spring 2016, respectively.

Table 1. Criteria for assessing bird populations for the four censuses on Cygnet Park.

Census date	Whole Property				Revegetated Area			
	No. of birds	Birds.ha^{-1}	No. of species	Area of occupation	No. of birds	Birds.ha^{-1}	No. of species	Area of occupation
Aut 2009	871	2.8	41	43%	145	0.8	18	10%
Spr 2010	1217	3.9	47	55%	144	0.8	24	18%
Spr 2012	2488	8.0	57	74%	766	4.4	45	45%
Spr 2016	2459	7.9	55	78%	1629	9.3	36	70%

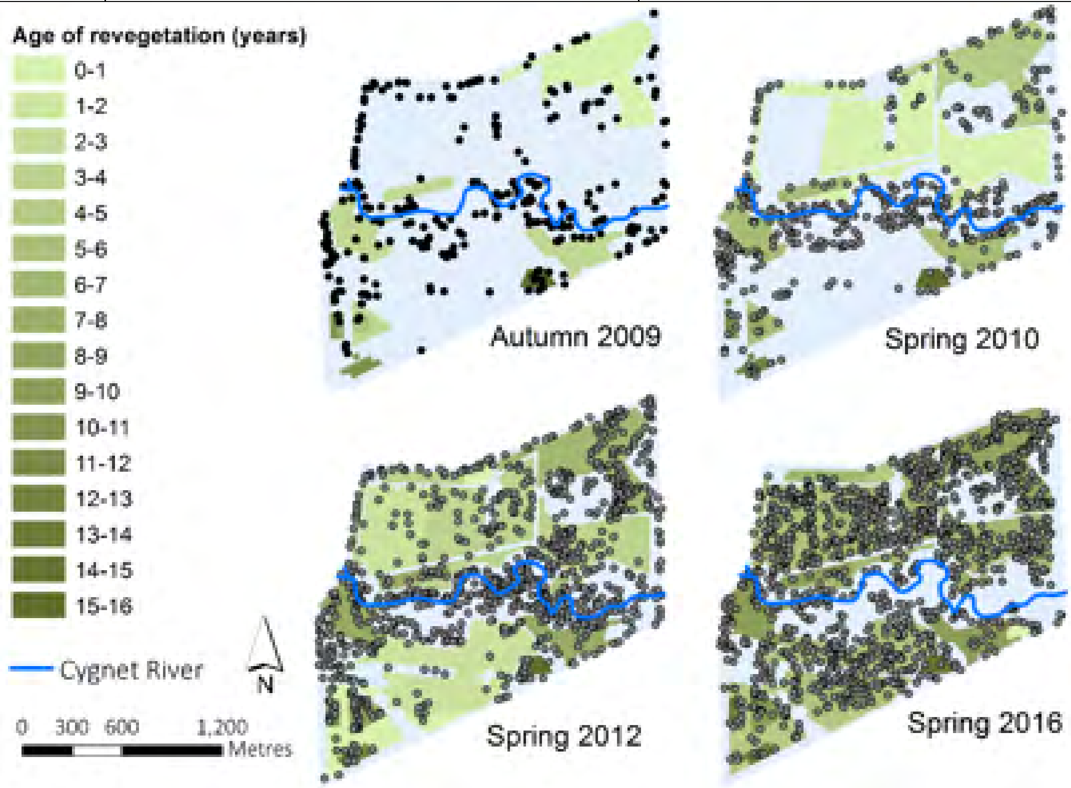

Fig. 1. Maps of Cygnet Park detailing the location of birds (not flying over) during four censuses with revegetation age.

Discussion

There was little difference in overall terrestrial bird abundance and density, diversity and area of occupation, in the initial years. However, as the vegetation aged, there was a marked increase in all parameters across spring surveys (Table 1; Fig. 1). This was even more evident when simply considering the area revegetated, as was to be expected, considering this was originally degraded, open farmland, while the remaining area was predominantly remnant vegetation. Not surprisingly, woodland bird species benefited from the establishment and ageing of the revegetation, while grassland birds were disadvantaged.

The benefits of using a systematic area search across the whole property, while energy intensive, are well illustrated in this study. First, locations of individual birds can be mapped and areas of occupation calculated, both effective tools in gaining an understanding of distribution and promptly identifying any unsuitable or unoccupied habitats within the area. Second, by sampling the entire area, any rare or patchily-distributed species are detected, while, thirdly, the data can still be assessed at smaller scales (e.g., 1-ha plots), if desired.

Future work will include annual censuses, and further analysis of the comprehensive dataset to better understand changes to the bird populations, and drivers of the changes (e.g., associations with particular plant species). Such findings will be useful in managing Cygnet Park and in planning future large-scale revegetation programs, for example, to highlight the habitat features that are important for birds and must be provided, if birds are to benefit.

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Integrating topographic, soil, ecohydrological and microclimatic systems for resilient landscape repair and revegetation

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Abstract
To increase the resilience of restored landscapes, revegetation should account for the complex feedbacks that modify landscape function. This particularly relates to changes in the flows and storages of water throughout a landscape and lower atmosphere when vegetation is removed or replanted. By strategically integrating the functional attributes of native and planted vegetation to match landscape position, resilience to climatic extremes can be enhanced. This paper outlines some threats facing production landscapes from increasing climatic extremes, and offers some conceptual approaches for resilient landscape repair that specifically integrates topographic, soil, ecohydrological and microclimate variability. Revegetation measures that aid in increasing water retention and recycling in landscapes and the lower atmosphere to increase their inherent resilience to climatic extremes are also discussed.

Introduction
Extended dry periods and drought, when coupled with high heat and strong winds, causes the desiccation of vegetation. As vegetation senesces, the land surface denudes and further increases the loss of vegetation. In such scenarios the retention of moisture becomes crucial to resilience. The stores and flows of water are vastly different between production and native landscapes, with each contributing towards either an amplified drying (positive feedback) or buffered (negative feedback) moisture retention regime (Ryan *et al*. 2007). For example, the broad-scale clearance of native vegetation over Australia during the past 200 years has seen water vapour flow drop by > 10% (340 km^3) (Gordon *et al*. 2003), leading to a 4–12% decline in rainfall and up to 2°C hotter droughts (McAlpine *et al*. 2007; 2009). At the same time, climate change is fuelling intense rainfall events that drive increases in peak catchment discharge with significant destructive power (e.g. Fig. 1a). The aim of this paper is to discuss revegetation measures that can be used in production landscapes to integrate the moisture retention and recycling mechanisms (e.g. Fig. 1b) of vegetation species from hillslope scales through to regional scales.

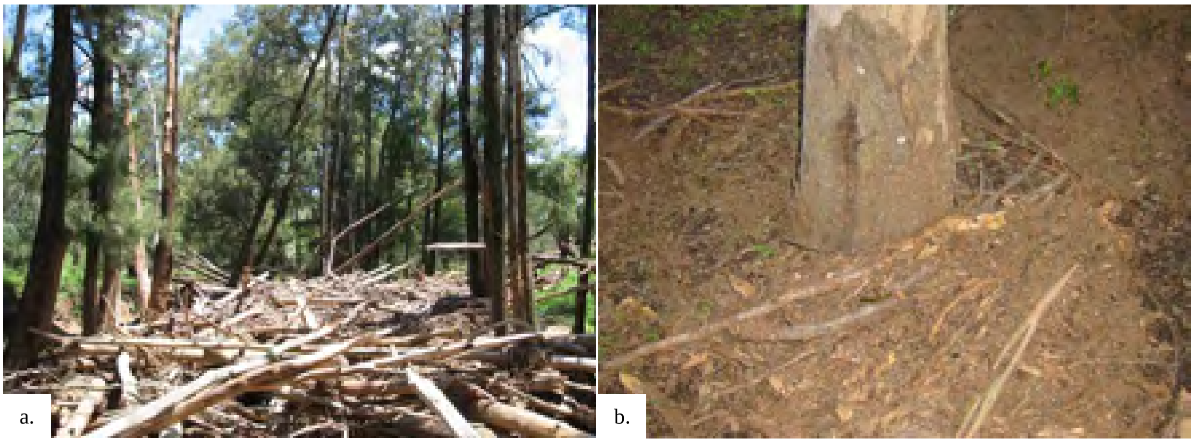

Fig. 1. a) Aftermath of flash flooding in the Warrumbungle Range, December 2007; b) Microtopography and vegetation roughness create micro-terraces that can enhance water spreading, infiltration and retention. Photos: Author.

Discussion
The location and spatial configuration of vegetation at the landscape scale can affect microclimatic and ecohydrological systems, soil erosion and above and below ground carbon sequestration processes (Ryan *et al.* 2010). Radiation partitioning between latent and sensible heat fluxes, wind field disruptions and turbulent exchange, albedo and roughness length are modified in production landscapes (McAlpine *et al*. 2007), and excess stormwater runoff has the potential to erode catchments (Ryan *et al*. 2015). To counter these effects, direct solar irradiation, wind speeds and stormwater peak runoff all need to be reduced using purposefully located groupings of different plant functional types to suit site characteristics (e.g. soil, climate) and topographic position.

Wind speed reductions can be achieved with tree vegetation bands/shelterbelts. Tree height is the main determinant of downwind extent of shelter provided by vegetation bands, as height directly affects how far downwind the turbulent layer re-establishes contact with the ground (Cleugh 2003). The greatest wind speed reductions occur at approx. two times (2H) and 10H the height of the tree downwind, but recover 80% of their speed by 20H (Judd *et al*. 1996). Multiple vegetation bands can reinforce the shelter effect across the landscape, but their effectiveness depends on their porosity, orientation and length (Judd *et al*. 1996; Cleugh 2003). Vegetation bands should be planted as dense, multi-layered species assemblages and oriented perpendicular to predominant wind directions, while considering the propensity of topography to modify and channel wind fields.

The interception and infiltration of precipitation along with the detention of overland flow is vital for enhancing moisture retention and reducing stormwater runoff, stream peak flows and flooding potential. Based on innovative concepts from Yeomans (1954) and Watkins (pers. comm. 2003) an adaptive form of revegetation termed *integrated vegetation bands* (IVB) was developed by Ryan *et al*. (2015) to test for the effects that they may have on runoff interception, soil moisture retention and stream peak/base flow in a small, steep rural catchment of Southeast Queensland. Using a distributed parameter hydrological simulation model to assess the effects of IVB on overland flow and catchment yield, the results showed that the main differences between a cleared grazing landscape versus IVB were soil water content at saturation (SAT), soil depth and compaction, and surface depression storage and roughness. Under simulated intense rainfall events the hillslope areas retaining more overland flow increased by 11% in the IVB model, as IVB held up to 25% greater water depth and had 10% greater infiltration than pasture only models. Due to these hillslope scale factors, catchment discharge decreased by 7%, infiltration increased by 23% and base flow was slightly extended.

Considering regional scales, improving moisture retention and recycling in any one landscape will not have an immediate impact on regional climate or precipitation patterns, although the accumulative effect from thousands of landscapes may (Pielke *et al*. 2007). In addition, the spatial pattern of cover (e.g. native forests/woodlands, pasture, crops) will matter as much as its extent because land surface discontinuities (e.g. dry and wet soil, different vegetation heights) affect patterns of wind and moisture convergence/divergence and the potential for convective rainfall to develop (Pal and Eltahir 2001; Osborne *et al*. 2004). For example, meso-scale circulations and areas of moist air convection can occur at scales as small as 10-20 km due to differences in heat and moisture between bare soil and vegetation (Mahfouf *et al.* 1987). Due to the scales involved however, improving water recycling for resilience is not something that can be implemented on a project basis but rather as a long-term integrated NRM planning objective.

Conclusion

The best location for vegetation of a particular type in production landscapes will vary depending upon landscape function and land use, and will likely vary considerably within a farm as much as between them. In addition, revegetation for resilience may not reflect the native state but rather a state that maximises natural systems functioning (integrated biomimicry) on the smallest land area possible. Generally, bands of vegetation integrated with land use and infrastructure offer a good ratio of land footprint versus gains in landscape functioning/moisture retention. The sustained build-up of litter beneath bands is crucial for increasing surface depression storage, soil infiltration and moisture retention, while large perennials aid deep drainage and cooling from evapotranspiration and shading. Planted vegetation bands or restored patches will also affect stormwater redistribution and detention. Infiltration excess precipitation will move into soil detention storage and subsequently aquifers the longer it resides within the landscape, so overland flow should ideally be intercepted by a litter layer as well as being encouraged to move from run-on to run-off areas (e.g. gully to ridge) to further enhance stormwater retention. At regional scales, long-term planning should aim to integrate the numerous landscape to catchment scale revegetation and native vegetation conservation projects to underpin the recycling of water vapour to the lower atmosphere. It is this reciprocal interaction (feedback) between vegetation cover, the soil surface and the lower atmosphere which can partially offset the most severe climatic extremes under a changing climate.

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Lessons Learned from Large Scale Mixed Native Tree Planting Projects

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Abstract

Large scale tree plantings to restore lands affected by degradation and to provide trees for government, local people and community needs, as well as for biodiversity conservation are increasingly being attempted. However, as well intentioned as these projects are, in many instances outcomes can be negatively affected when all aspects of the project are not fully thought through.

This paper presents the major lessons learned from one large-scale tree planting completed in Queensland, Australia, including planning issues; securing access to suitable lands; planting design project implementation, maintenance, community and stakeholder engagement risk management, contingency funding, governance and, evaluation and monitoring.

Introduction

People have been planting trees for eons. In Australia, Aborigines planted bunya pines (*Araucaria bidwillii*) for food and to mark routes to ceremonial sites. The 1982 Year of the Tree injected impetus to governments, groups and individuals to plant trees and other vegetation to address land degradation. Recently, landscape reforestation and conservation projects have commenced (e.g. Gondwana Link). There are a diversity of drivers, mechanisms, policies and legislation for large scale restoration plantings that differ from small-scale plantings.

The Two Million Tree Program ran between 2007 and 2012, covered 500 hectares and cost more than $20 million. Brisbane City Council embarked on this project to improve its green credentials and image, gain potential carbon credits, restore degraded lands and provide more wildlife habitats. We highlight some of the lessons learned in carrying out this Program.

Planning framework: Comprehensive planning should involve desk-top and field-based ecological data collection to map the range of factors that will influence the success of the planting. These factors include flood levels, heritage sites, any contamination of lands, existing infrastructure (e.g. powerline and water pipeline easements, fences and roads) and biosecurity concerns (e.g. fire ant occurrence). Field-based surveys may reveal the extent of influence of historical land use, highlight potential risks or locations of nearest remnant vegetation. ***Lesson 1***: Thorough planning is crucial to success due to unforeseen circumstances.

Securing land: The 2MT Program required access to more than 500 hectares of suitable land. Land owned or managed by Brisbane City Council was the primary land source but private, State and Federal Governments' lands were required to reach the target. Delicate negotiations about non-council lands took several months at upper levels of management threatening the program completion deadline. That is, less than optimal. ***Lesson2***: Securing lands suitable for planting should be undertaken many months prior to implementation of the project. ***Lesson3***: More land than is actually required will need to be secured to take into account factors such as area of existing infrastructure (e.g. roads) which have to be deducted from the total area available for planting.

Planting design Compared to small patch restoration, large scale reforestation requires detailed planting methodologies for the various land systems and zones occurring at each site and the uses of each site (Cole and Siepen 2014-16). For example, community park plantings require a different methodology than lands adjoining protected areas and plant density per zone should ideally be determined with reference to canopy structure and nearby reference ecosystem attributes. Likewise, one needs to consider row planting versus infill or haphazard planting design. Planting in rows allows access for water trucks, tractors, slashers and maintenance vehicles but haphazard design is often thought the ideal way of reproducing native forests. Since the completion of this Program in 2013 projects now being planned can be underpinned by the guidelines contained in the International Standards for Ecological Restoration developed by the Society for Ecological Restoration (McDonald et al. 2016) ***Lesson 4***: Planting design requires consideration of outcomes being sought, as well as economic and efficient maintenance systems to be applied.

Implementation: Before any plants are actually planted, a number of logistical issues need to be resolved (Cole and Siepen 2014-16). These include determining desired plant densities; procurement of plants and materials (e.g. fertilizers, fencing, stakes); establishment of storage areas, wash-down sites and holding nurseries on the various sites; identification and construction of access tracks; delimitation of exclusion zones (i.e. habitat areas, remnant vegetation); site preparation including weed control/removal; construction of planting rows using large machinery or motorized augers to prepare planting holes; and delineation of management zones on the ground. ***Lesson 5***: Implementation is more than just planting. It is a complex logistical exercise.

Maintenance: The major issues with maintenance relate to length of time required for maintenance of each site and accommodation for unforeseen factors. Some projects have short (i.e. two year) timeframes but a five-year maintenance program is preferred to ensure 'site capture', even though further interventions such as weed management, fire break maintenance and understorey enhancement planting may still be required.

The exact maintenance program specification will vary depending on the site characteristics, management zones and aims of the project (Cole and Siepen 2014-16). Maintenance programs may involve formative pruning, edge treatments, thinning, replanting and enhancement plantings in the later stages. ***Lesson 6***: The longer the maintenance period the more chance of site capture and long- term plant establishment.

Community engagement: Support from the broad community, corporate sector and neighbouring landholders for large-scale tree planting projects is essential to achieving the project goals. Hence, a detailed Communications Strategy is required for individual sites and for the duration of the project that includes ALL stakeholders. This strategy should commence during the land-securing stage to create widespread awareness about the project, thereby reducing the potential for disruptions due to a perceived lack of information. The program plantings provide remediation of degraded sites with ecological, educational, research, amenity and passive recreational benefits. ***Lesson 7***: Regular communication via newsletters, social media, websites, joint activities (e.g. community planting days) can greatly assist the implementation of the project.

Risk management: Risk assessment and management should be incorporated into the overall project planning phase to accommodate recognised and unforeseen risks. There must be a clear delineation of responsibilities and financial obligations between the client and contractors around plant mortality and damage which may result from fire, flood, drought, pests, vandalism and any other causes. Documentation of risk management processes needs to be included in contracts to reduce time delays in negotiating outcomes and to avoid creating negative attitudes between parties.

It is recognised that supplying the right plants at the right time in the required numbers involves huge risks, with long lead-times required for native seed collection and nursery production. Delays in plant supply can lead to extra costs if further site management (e.g. weed control) is required. Delays in site preparation can lead to increased nursery-holding-charges and possibly root-bound stock which may be unsuitable for planting. ***Lesson 8***: Flexibility and maintaining good relations between the client, contractor and nurseries can help overcome these risks.

Contingency funds should be incorporated into the overall budget to reduce potential conflicts and the development of bad relationships. Fortunately, in this Program extra funds were made available by the Council to replace plants, increase maintenance regimes and protect plants with tree guards after two flood episodes in 2011 and 2013 and herbivore damage caused by an unforeseen increase in kangaroo numbers. Approximately 20,000 replants occurred at one site alone.

Project governance: Project management is a complex 'beast' which typically requires establishing and maintaining relationships over several years with clients, contractors, community groups and other stakeholders. Effective project management requires continuous communication between all partners, including agreed, achievable goals, monitoring and assessment criteria, complemented with the ability to be flexible enough to implement adaptations to ensure the project goals are achieved. ***Lesson 10***: Good communication with all partners is essential throughout the whole project.

Evaluation & monitoring: This is an important aspect of every project which needs to be considered as part of the overall project plan, with funds provided accordingly. This Program was not formally evaluated due to the strong political will directing its completion within the deadline. Monitoring focused on measuring plant growth and survival (over 90% after a two-year maintenance period). ***Lesson 9***: It is recommended that formal and informal evaluation processes for biophysical and social parameters be implemented on all tree growing projects.

Summary

Large-scale tree planting for biodiversity outcomes is achievable with adequate budgets, thorough planning and a short (i.e. two-year) maintenance period. The Program was completed before the deadline. Plant survival was over 90%. Major lessons learned were that: thorough and adaptive planning is required; securing more land is needed for the plant design is required; and regular communication with all stakeholders is essential to complete the program and maintain good relationships.

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Approaching Local Eradication of Coral Tree *Erythrina* x *sykesii* Barneby & Krukoff at Wilsons Creek and Huonbrook, North-east New South Wales

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Abstract

Wilsons Creek Huonbrook Landcare Inc. is nearing the end of a three year project that aims to eradicate coral tree *Erythrina* x *sykesii* from the headwaters of two tributaries of the Richmond River, north-east NSW. Eradication is identified as a cost-effective management goal, generally referring to permanent removal of early incursions of weed species. Established and widespread weed species are more usually candidates for containment and asset protection approaches. A suite of species for which local eradication is feasible (no seed set and typically dispersed by floodwaters and machinery) has, however, been identified for the project area in the course of the development of a weed management strategy. Coral tree was prioritised for management. A widespread horticultural hybrid that does not set seed, Coral Tree spreads vegetatively from trunk and stem fragments. Inexpert management rarely kills the wood and typically produces sprouting debris. In waterways, fallen trunks grow into dense thickets, diverting watercourses and competing with high conservation value native vegetation. Our general approach has been to start at the top of the catchment and work downstream. The major dispersal corridors have now been treated and attention has extended to tributaries and other private land sites. We have raised awareness of coral tree and other weed management issues and provided landholders with advice about how to manage the remaining trees. Progress has been beyond expectations and the challenge will be to maintain momentum to complete eradication.

Introduction

Wilsons Creek Huonbrook Landcare Inc. (WCHL) operates in the headwaters of the Richmond River in north-east NSW, encompassing the extremities of Wilsons River (Wilsons Creek locality) and Coopers Creek (Huonbrook locality) (Fig. 1). In 2005, WCHL received funding to develop a weed management strategy, based on surveys of, and from, public land. We focussed on roads and creeks, which are easily accessible and are major weed dispersal corridors. We identified a suite of species for which local eradication is feasible (no seed is produced and dispersal by floodwaters and machinery is typical) (Landmark Ecological Services Pty Ltd 2006). If the weeds can be removed, they are very unlikely to be re-introduced from the surrounds, since the valleys are topographically isolated.

Coral tree *Erythrina* x *sykesii* was prioritised for local eradication. A horticultural hybrid, coral tree is naturalised in Australia in some coastal parts of Qld and NSW and around Perth in WA (Bean 2008). Coral tree does not set seed, but spreads vegetatively from trunk and stem fragments. Management by non-experienced practioners rarely kills the wood and typically results in the spread of sprouting debris. In waterways, fallen trunks grow into dense thickets while machinery smashes roadside trees, dropping and dragging fragments that spread downslope and sprout into expanding patches. Coral tree competes with native vegetation of high conservation value, primarily subtropical rainforest communities listed as threatened under both national and state legislation.

The Australian Weed Strategy Consultation Draft (Invasive Plants and Animals Committee 2016) identifies eradication as a cost-effective management goal, generally referring to permanent removal of early incursions of weed species or weed removal from oceanic islands. Established and widespread weed species are more usually candidates for containment and asset protection approaches. Circumstances in which local eradication of well-established weed species is feasible, can, however, be identified. Mainland environments may be functionally isolated, relative to the biology and dispersal vectors of the weed species, by topography or habitat configuration.

The aim of this paper is to document an approach, based on local and national weed management strategies, to the local eradication of coral tree. We demonstrate progress towards eradication through map-based records of weed occurrence and treatment.

Methods

Baseline information on coral tree locations from 2005-6 surveys (Fig. 1) provided a starting point for adaptive planning and for the design of an eradication strategy for the three year project period. Our general approach was to work downstream from the top of the catchment, but some early works were focussed on the lower reaches of the Wilsons River, in order to remove the bulk of the infestations and involve downstream landholders. Our preferred and most cost-effective technique was to inject trees with a glyphosate-based herbicide, leaving trees standing, achieving almost 100% kill rate. The dead wood broke down quickly in place or was removed during flood events. Natural regeneration and occasional plantings replaced the exotic vegetation. Occasional trees could not be left standing for safety reasons and required expensive felling, chipping and later stump injection. We mapped four treatment areas to track progress, calculating the percentage of streambank subjected to initial control and follow up.

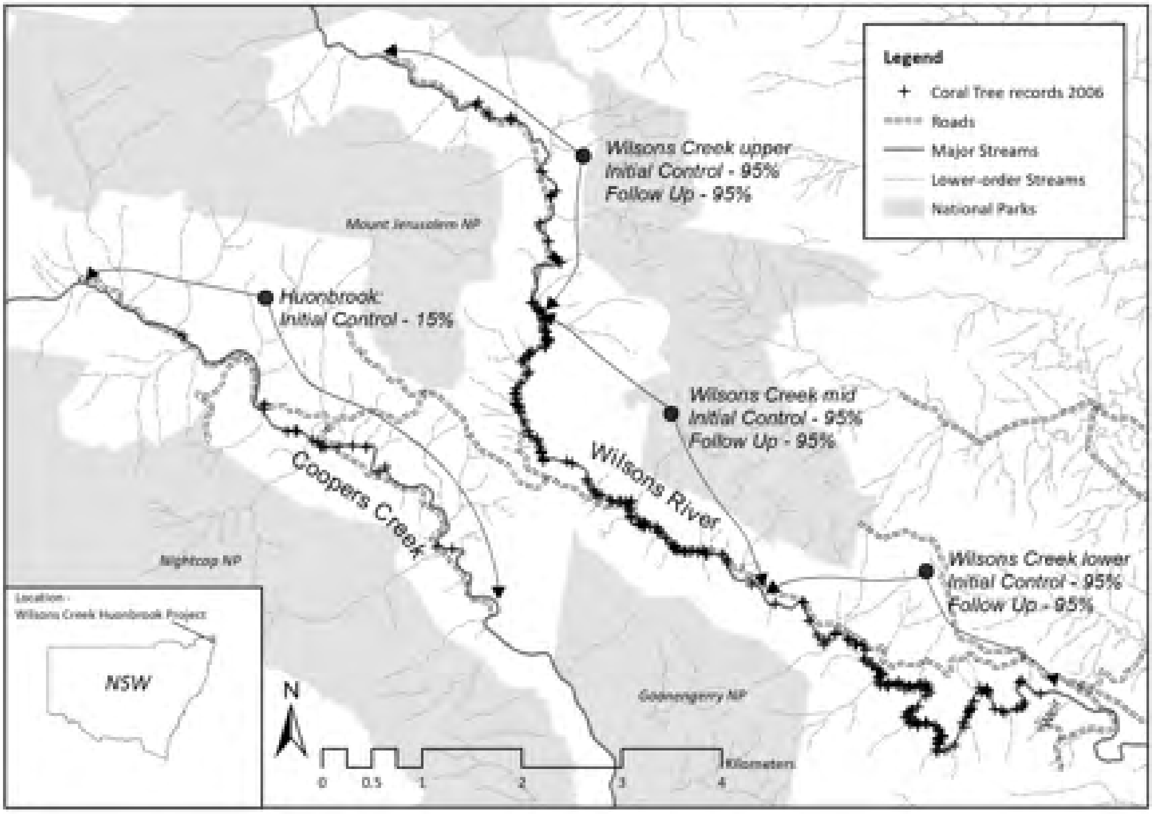

Fig. 1. Coral tree records (individuals and patches) and management to January 2017 for waterways of the project area.

Results

In 2005-6, 238 individual trees and forest patches were mapped in the Wilsons River, densest in lower reaches. Infestations were sparser in Coopers Creek. Trees also fringed the roadsides (not shown in Fig. 1) and in some very large patches (>1ha) in the headwaters, also in gullies and minor tributaries. The results of failed management (growth from half burnt fire piles, felled live tree material and machinery-smashed trees) were common around the project area. Awareness raising activities found landholders were receptive to ideas and demonstrations of techniques that produced successful results.

Eradication from the creek systems is now close to complete. Initial control in the four treatment areas was carried out along 95% and 15% of the Wilsons River and Coopers Creek streambanks respectively (Fig. 1). Follow-up control was carried out 6 – 12 months later along the Wilsons River. In addition, forest patches in the headwaters, minor tributaries and a large proportion of roadside trees have been treated, removing the major sources of dispersal material.

Conclusion

Prospects for the total local eradication of Coral Tree are good as a result of our three year program. Our successes are due to: (1) careful selection of a target weed taxon; (2) an appropriate sub-catchment scale; (3) excellent support from stakeholders, including local community, and (4) involvement of expert bush regenerators with experience with locally trialled management techniques. The danger is that small infestations have been missed and will provide re-infestation in years to come; hence ongoing vigilance and follow up will be essential. The challenge now will be to maintain the project momentum once major funding has ceased and the immediate nuisance and threats to biodiversity are no longer obvious.

Acknowledgements

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National core attributes for reporting changes in revegetation extent over time

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Abstract
National core or minimum attribute standards were developed in 2001 to routinely track changes and trends in revegetation type, extent and condition for reporting outcomes. In 2005 the attribute standards were endorsed by a national committee for Australian vegetation information. In 2009, the core attributes were used to compile a national revegetation dataset and report from a wide range of data sources including various scales; site, local, regional, state and national. Types of revegetation data included: site-based surveys, remote sensing, catchment-based reports and national farm-based surveys. An evaluation of the suitability of the data that was compiled for use in national reporting of the extent of revegetation extent was completed. The resulting national report documented changes and trends in the area and extent of revegetation within NRM regions and bioregions since 1990 using the National Carbon Accounting System dataset. That assessment highlighted major gaps and inconsistencies in national reporting on the changes and trends in the area and extent of revegetation. In 2017 the capacity to generate a consistent national report over time at regional, state and national levels, on restoration, regeneration and revegetation outcomes remains a critical challenge for decision makers requiring information on-ground outcomes.

Introduction

Revegetation is essential to meeting stated national and regional targets for biodiversity, natural resource management and sustainable agriculture. Over the past three decades in Australia we have seen the allocation of billions of dollars of public funding for national NRM priorities to improve the extent and condition of native vegetation, and to support NRM objectives such as habitat restoration, salinity mitigation, landscape connectivity initiatives and erosion control and the sequestration of carbon for multiple benefits. Little is known about the rates of change in the extent of revegetation, at the whole of landscape level, across Australia. An example of program-based monitoring outcomes is Australian Government's MERIT tool (http://www.nrm.gov.au/my-project/monitoring-and-reporting-plan/merit). Similar frameworks and tools have been developed with varying degrees of success at state, regional and local levels. Consequently, knowledge of the contribution that these on-ground public-private interventions have had on changes in vegetation type, extent and condition at across Australia is not available for national reporting (Cresswell and Murphy 2016).

In 2001 an agreed set of national core attributes for describing and mapping revegetation activities was developed (Atyeo and Thackway 2009, Table 1). The aim of these attributes was to describe, map and monitor revegetation and to complement the existing national forest and vegetation reporting including: National Forest Inventory; National Plantation Inventory and the National Vegetation Information System. The core attributes were designed for reporting baseline on-ground works and for monitoring changes in extent over time. This paper reports on a project that was completed in 2010, which provided an overview of the best available information for national reporting on revegetation extent and change over time.

Methods

In 2009 work commenced on compiling an Australia-wide geospatial dataset, comprising the core revegetation attributes (Atyeo and Thackway 2009, Table 1). Revegetation data were compiled into the GIS dataset from NRM groups, revegetation practitioners, researchers, private NRM investors, industry bodies, NGOs and government agencies. Data on the extent of revegetation was derived from a range of sources including: regional surveys, remote sensing, catchment-based data and detailed site-based mapping. These data included various scales; site, local and regional. A spatial and temporal coverage was compiled from discontinuous project level datasets, as well from discontinuous regional, state and national.

National changes and trends in extent of revegetation were derived from an analysis of the National Carbon Accounting System (NCAS) dataset. NCAS provided a 30 m resolution dataset derived from Landsat satellite imagery across Australia. A baseline of 1980 was selected for each pixel, where a 30 m pixel in 1980 was identified as non-woody i.e. not revegetated. That same 30 m pixel in 1980 was compared to the 1990 pixel and if it was recorded as woody, it was assumed that the change was the result of a deliberate land management action, the intent of which was to restore, regenerate or revegetate the area. The same approach was used in successive years. Thereafter, where each pixel remained woody, and had a lineage of originally non-woody, it was accounted as revegetated. Land use types were intersected with the NCAS dataset to ascertain which land use types were using revegetation to augment land cover and vegetation types. This assessment excluded areas managed for forest production. That method was used across the intensively managed agricultural zone to account and report on changes in the extent and trend in the area of revegetation with NRM and bioregions nationally. Each year the extent of new revegetation was recorded and counted. Losses in extent of revegetation due to drought and wildfire were noted.

An evaluation of the suitability of these data to be compiled and transformed and used for national reporting was completed.

To assist data custodians in the ongoing collection and supply of revegetation data into the national revegetation dataset, an attribute manual was developed (Atyeo and Thackway 2010).

Results

A national dataset was compiled comprising 11 datasets. That information was used to write a report on the extent of revegetation across Australia (Thackway et al. 2010, Unpublished). Only four of the 11 datasets were rated as highly suitable for national reporting including; ACT Landkeepers, NSW Land Management Practice (data compiled for only one NRM region), Vic Catchment Activity Management System and CSIRO's VegTrack (Zerger et al 2009). All these datasets were local and regional in coverage and did not have national extent. The other datasets had local/regional coverage and only partly or marginally met the core attributes requirement for national reporting. Of the 11 datasets, only two datasets had national coverage but did not have the required set of vegetation attributes (Atyeo and Thackway 2009, Table 1); NCAS woody extent and Australian Bureau of Statistics Agricultural Census. Changes in the area and extent of revegetation within NRM regions and bioregions between 1990-2008 relied on the NCAS dataset.

Figure 1 shows the suitability of the local/regional datasets that were compiled for use in national reporting. Most of the regional scale reporting on revegetation activities and outcomes were supplied as aggregate polygons and could not be disaggregated in a form relevant to the core attribute framework (Atyeo and Thackway 2009, Table 1).

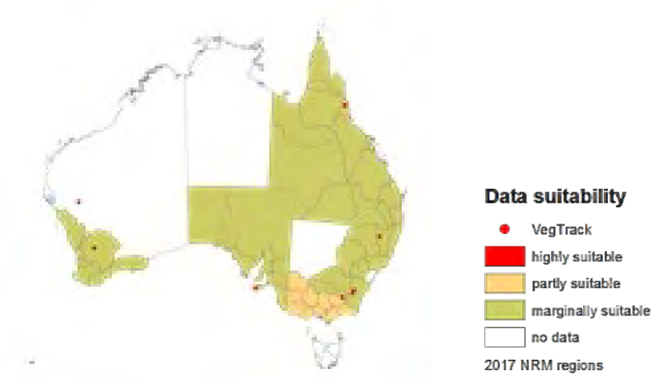

Fig. 1. Suitability of local/regional scale revegetation and restoration activity datasets for national reporting; compiled using the revegetation core attributes.

There are limitations in compiling data on revegetation activity and success from a diverse range of revegetation data suppliers across Australia. That report showed that most suppliers of revegetation data had their own attribute frameworks, which were either specific to a project, or program, or the spatial data were too coarse for national reporting (Fig.1). In should be noted that despite the development and endorsement of national attribute standards in 2001, at the time of writing this paper in 2017, the national standard had not been systematically or comprehensively implemented at regional, state and national levels.

Conclusions

A wide range of land managers, policy makers and planers have identified the need for information of the changes in the extent of revegetation at a range of scales. Access to consistent, comprehensive and up-to-date national data on the extent and change of revegetation in Australia are available however, data quality and coverage are limiting. Without information on the extent and change of revegetation, there is a major strategic national gap in information on changes and trends vegetation extent and condition. There is a still lack of leadership nationally to sponsor national standards for the collection and supply of data on revegetation extent and change, even though the infrastructure is now in place (*https://www.ala.org.au/biocollect/)*. Consistent application of the national set of core attributes by data collectors and suppliers would enable systematic and comprehensive monitoring and reporting of public-private revegetation outcomes over time.

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Vegetation recruitment in different aged rehabilitated patches in monsoonal vine forest in the Northern Territory, Australia.

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Abstract

Rehabilitation of coastal vine forest at East Point Recreational Reserve, Darwin, is ongoing. Rehabilitated stands ranging in age from 6 to 42 years were compared to a remnant community. Rehabilitation involved planting seedlings of pioneer species. Regeneration of climax species largely relies on dispersal from the nearby forest remnant. This study determined whether regeneration of climax species was dispersal limited and whether the rehabilitation strategy of using pioneers is likely to eventually restore remnant forest tree diversity. We predicted that if the advanced regeneration in these patches was dispersal limited the patches would be dominated by seedlings of planted pioneer species. We measured seed and seedling diversity and abundance in different aged stands for comparison with the remnant forest. In young stands pioneer species from different growth forms established easily and had achieved a closed canopy. Climax species established once canopy closure was achieved. However, even the oldest rehabilitated stand (42 years) had not begun to converge on the climax species diversity and abundance contained in the nearby remnant monsoonal vine forest.

Introduction

Rainforest in the Northern Territory, Australia, comprises many small (<5ha) patches of several different types (Russell-Smith, 1991). Coastal vine forest (CVT) is a dry monsoonal rainforest type because it establishes on a seasonally dry substrate which receives little rain from October to April.

CVF occurs at East Point Recreational Reserve (EPRR) in Darwin. Urban development and cyclones have removed the forest cover to 80% between 1932-1963 (Franklin *et al*., 2010). Rehabilitation of this vine forest has been ongoing since 1974 with rehabilitated stands of various ages (6, 7 24, 31, 42 years since planting). Stands were rehabilitated by planting seedlings of common pioneer trees and shrubs. Advanced regeneration in these stands is probably derived from climax species (Swaine and Whitmore 1988) growing in a nearby forest remnant. We investigated whether regeneration of climax species was dispersal limited in rehabilitated stands. We hypothesized that if the advanced regeneration in these patches was dispersal-limited the patches would be dominated by the original pioneer species that were planted. We further investigated the seedling density and composition of rehabilitated stands to determine whether rehabilitation using pioneer species eventually converges in composition with seedling patterns found in old growth forest.

Methodology

Twelve plots (10m x 20m) were established in the remnant forest and 6 similar-sized plots per site sampled in the 6, 7 24, 31, 42 year old rehabilitation patches in 2016. Four seed traps were established per plot and emptied monthly to assess the seed rain composition and density for a year period. Composition and species abundance (20 – 50 cm height) were assessed in 20 subplots (1m x 2m) per plot. The diversity, total density and climax species proportion of the seed rain and establishing seedlings were compared with that of the forest remnant.

Results

The proportion of dispersed seeds from climax trees compared to pioneer species is low in rehabilitation sites, just 0.5% in the youngest site compared to 54.7% in the remnant site (Table 1). The oldest rehabilitated patch (Site 1974; aged 42 Years) has about half the seedling density of climax tree species compared to the that recorded in the remnant. The total seedling density of climax species increased with the age of the stand but so did the seedling density of pioneer species until it reduced in the oldest stand. Species richness of seedlings of climax species increased with the age of the forest. However, certain climax species which occurred as seedlings in the remnant were not recorded in the oldest rehabilitated patches, which averaged half the species richness of seedlings found in the remnant.

Discussion

Our assessment of the seed rain and seedling recruitment that occurred in the revegetated sites determined that they are yet to achieve the climax species diversity found in the remnant patch. In young stands pioneer species from several different growth forms established easily and achieved a closed canopy within 6 years (personal observation). Seedlings of climax species appeared once canopy closure was achieved. However, even the oldest rehabilitated stand (Site 1974; age 42 years) had not begun to converge on the recruited climax species diversity and density contained in the nearby forest remnant. Tucker and Murphy (1997) report similar observations for their revegetated site in wet tropical rainforest in Northern Queensland. The lack of seedlings of climax species is likely to be due to limited dispersal and establishment success of climax species in the rehabilitated sites.

Limited dispersal of climax species into revegetated sites may be due to the lack of fleshy fruit producing trees and shrubs in rehabilitated forests to attract birds and mammals that would disperse seeds into the site (Nested 1989). Isolation may also be a factor (Tucker and Murphy, 1997), along with a small number of, established climax trees at reproductive maturity to shed seeds. Studies show limited recruitment of climax species may also arise due to unfavorable microsite conditions and herbivory of seeds and seedlings (Garcia-Orth and Martínez-Ramos, 2007). More studies are required to understand the causes for the paucity of the climax species dispersal and recruitment in these revegetated sites. This will help in implementing management practices to facilitate the establishment success of climax species in degraded CVF.

Table 1. Numbers of dispersed seeds, established seedlings number and densities of climax and pioneer species and the proportion of dispersed climax species in remnant and different aged revegetated sites.

Attribute	**Units**	**Site (year planted)**					
		2010	2009	1992	1985	1974	Remnant
Rehabilitation age	Years	6	7	24	31	42	na
Total seed rain	# m^{-2} $year^{-1}$	106.2 ± 29.6	105.1 ± 30.4	173.0 ± 24.7	244.4 ± 32.8	158.5 ± 28.2	72.0 ±7.7
Proportion of seeds that are climax species	%	0.5	2.4	3.5	7.2	9.5	54.7
Seedling density							
Climax spp.	# m^{-2}	0.05 ± 0.02	0.01 ± 0.05	0.4 ± 0.1	0.7 ± 0.1	0.9 ± 0.3	1.9 ± 0.4
Pioneer spp.	# m^{-2}	0.1 ± 0.0	0.3 ± 0.1	1.1 ± 0.3	2.3 ± 0.4	0.9 ± 0.1	0.7± 0.1
Species richness of seedlings							
Climax spp.	# $plot^{-1}$	0.7± 0.5	0 ± 0	2.3 ± 0.5	3.6 ± 0.4	3.3 ± 0.8	6.1± 0.4
Pioneer spp.	# $plot^{-1}$	2 ± 0.5	3 ± 0.9	8.3 ± 1.4	11 ± 1.2	7.2 ± 0.9	6.8 ± 0.7

na = not applicable

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Urban Ecosystem Function – Don't Forget the Fox

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Abstract

The European red fox (*Vulpes vulpes*) is known to predate upon domestic animals, livestock and native species, as well as spreading disease and also increasing the dispersal of weeds. Ecological restoration activities often neglect the impact of invasive fauna species due to a lack of knowledge of their presence at a site or a perceived inability to deal with the species. Fox densities in urban areas are known to be high but dealing with such a successful and elusive pest is difficult as the most effective methods of control are restricted in their availability for use. Camera traps are used for a wide variety of applications including monitoring both native and pest species but also to raise the awareness of landholders and land managers in what fauna is using their backyard, paddock or reserve. Camera traps have been placed across parts of western Sydney over the past four years. While the quality of camera deployment and duration has varied, more than 70 native and exotic species have been recorded. Monitoring using camera traps functions well as a landholder engagement tool, motivating some landholders to undertake restoration activities. One of the most common species recorded across western Sydney has been the fox. Highly coordinated approaches and more options for urban and peri-urban (private and public) control of foxes need to be considered for the successful long-term restoration of wildlife and ecosystem function.

Introduction

Ecological restoration aims to reduce causes of degradation and assist the recovery of locally occurring ecosystems. Ecosystem function is defined as the biological, geochemical and physical processes that take place in an ecosystem, including patterns and processes in relation to species interactions and the roles and functions these species play in the community or ecosystem in which they occur. Urban and peri-urban wildlife (flora and fauna) across Sydney, New South Wales, is under great pressure from factors such as habitat loss, predation, herbivory and weed invasion. Advances in the understanding of the complex networks and interactions of plants and animals in a system are leading the way to ensure restoration activities assess all parts of system structure to increase community stability (e.g. Sauve *et al*. 2016). Here we look briefly at one invasive species that impacts a number of components within the ecosystems that remain in western Sydney. It is these endangered ecosystems, such as the Cumberland Plain Woodland, that are targeted for restoration projects by community environment groups (e.g. landcare and bushcare), local councils and state government agencies.

The European red fox (*Vulpes vulpes*) causes significant damage to ecological and agricultural assets and is one of Australia's most important invasive species, with costs estimated to be over AU$200 million a year (Saunders and McLeod 2007). Many native mammals have become extinct, rare or vulnerable in Australia because of the fox (Short and Smith 1994). Experimental evidence demonstrates that native species can be successfully reintroduced to their former ranges (Short *et al*. 1992; Kinnear *et al*. 2010) and will increase in abundance or activity where foxes have been controlled (Banks *et al*. 2000; Salo *et al*. 2007). Camera traps have been widely used to identify native and introduced fauna, in particular foxes (Towerton *et al*. 2011) during control monitoring programs to assess presence and activity levels and thus provide information for management options.

Methods

Camera traps were loaned to landholders or deployed by Local Land Services officers at 108 sites across western Sydney between 2013 and 2016 to record native wildlife and pest species. The camera model, quality of setup, placement and the length of deployment varied across sites. Cameras were strategically deployed at a further 29 sites in a grid system as part of the Menangle fox campaign monitoring program during Spring 2016, where Reconyx HC600 cameras (Reconyx, Inc., Holmen, WI) were deployed to target foxes (e.g. along movement paths). Photos were checked and species tagged using ExifPro (http://www.exifpro.com) and extracted to a database using R (R Development Core Team 2006). Here we present the number of species observed (summarised to Class) and the proportion of sites recording foxes during these surveys. Trap rate, i.e. the total number of independent photo events ($\geq$ 60 minutes apart) per 100 camera trap-nights (Towerton *et al.* 2011) is presented for the five most common species recorded during the Menangle fox campaign monitoring program.

Results

More than 70 species (Table 1) were identified from more than 100,000 photos. Foxes were recorded at 64% of the 108 camera trap sites across western Sydney. During the Menangle fox campaign monitoring program, targeted specifically to record fox activity, foxes were recorded at 90% of sites with overall greater trap rates compared to other common species (Fig. 1), however not significantly greater.

Discussion

Urban areas have higher fox densities than other environments as increased human activity provides extra food and shelter for foxes (Saunders *et al*. 2010, Marks and Bloomfield 2006). The presence of foxes at 64% and 90% of camera-trap sites for non-targeted and targeted monitoring of foxes, respectively, reflecting the high levels of fox activity in western Sydney. In comparison, a similar targeted monitoring study in an agriculture and woodland area in central west NSW found foxes present at 43% of sites (n = 100; Towerton *et al*. 2011). The high trap rates

(Fig. 1) suggest that the presence of foxes increases the pressure on our remaining wildlife, the habitat in which they live, and the corridors they use to move throughout the landscape. Camera traps, when used as part of a targeted monitoring program, provide important information on the activity of species (Fig. 1, Table 1). Monitoring using camera traps functions well as a landholder engagement tool. Landholders have shown interest in the species identified on their properties, with some motivated and encouraged to take on ecological restoration and pest control activities (pers. obs. A Towerton, P Ridgeway).

The Menangle fox campaign covers a matrix of urban to rural landscapes including residential to agricultural production activities. Ecological restoration activities have been undertaken over the past decade. Partnerships with landholders and the Barragal Landcare group continue to protect remnants of Cumberland Plain Woodland in this area. Western Sydney would benefit from further highly coordinated control programs involving land managers across the urban and peri-urban landscape, where possible carrying out control operation at least twice a year, to increase the effectiveness of protecting both conservation and production interests. Control options in urban areas can be limited and need further investigation such as Canid Pest Ejectors and euthanasia bags when cage trapping (http://www.animalcontrol.com.au/news/2014/20140525-1.htm) Land managers and community groups are encouraged to consider including fox (and other invasive species where negative impacts are high) control methods when designing restoration programs.

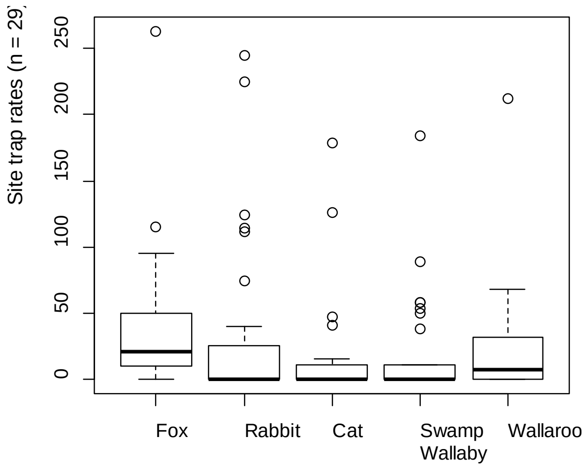

Fig. 1. Trap rates at each site were calculated for the Menangle fox campaign monitoring program using independent photo events (photos separated by at least 60 min for each species at each site) per 100 camera trap-nights.

Table 1. Number of species identified across western Sydney using camera traps.

Species	Native	Introduced
Birds	38	4
Mammals	14	14
Reptiles	3	-

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Drivers of riparian condition to prioritise restoration, regeneration and revegetation in the NSW North Coast Bioregion

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Abstract

Ecohealth is a comprehensive catchment-scale monitoring framework for ecosystem health in the NSW North Coast Bioregion. Riparian vegetation is a critical component of the Ecohealth program as it plays a geomorphic and biological role to support diverse habitats that contain high levels of biodiversity. The Ecohealth riparian vegetation condition is determined by a site-based rapid riparian assessment and spatial data for catchment scale condition. Indicators include cover, composition, structure, habitat and connectivity of vegetation, with a focus on mechanisms regulating vegetation condition such as fencing, clearing, animal impacts and regeneration. From upland tablelands to coastal floodplains and estuaries, declines in riparian communities from reference condition was found to be significantly affected by landuse across the Bioregion. We used riparian condition classes to highlight mechanisms that drive riparian condition and identify management priorities for investment. Key drivers of riparian condition in the Bioregion are weed control (restoration), riparian fencing and removal of stock (regeneration) and riparian plantings (revegetation). Regional scale assessments of riparian condition using site-based data are rare and are important for understanding spatial patterns and drivers of condition to inform management priorities.

Introduction

Riparian zones are the interface between terrestrial and aquatic ecosystems that play a critical role in aquatic health and ecological function by regulating nutrient flux, geomorphology, habitat, leaf litter inputs, temperature and light (Cummins, 1993; Boulton *et al.,* 2014). Riparian zones contain high biodiversity, but their nutrient-rich, deep alluvial soils and valuable timber and water resources have been heavily used for agricultural production (Jansen *et al.*, 2007). Ecohealth comprehensively assesses catchment-scale aquatic ecosystem health using physical, chemical and biological indicators, including riparian condition.

The Ecohealth Rapid Assessment of Riparian Condition (ERARC) measures pressure and response indicators to assess current condition and direct management investment. ERARC has been applied to approximately 400 sites in the NSW North Coast Bioregion and was specifically designed to assess a wide range of vegetation communities from tableland grassy woodlands to coastal mangroves and saltmarsh by comparisons with appropriate reference sites. Here we provide an example how ERARC is used to identify drivers of riparian condition across multiple vegetation communities and disturbance regimes in three catchments. By identifying and quantifying mechanisms of change to determine a condition score, the Ecohealth program helps prioritise and direct management actions at site, sub-catchment, catchment and bioregional scales.

Methods

The NSW North Coast Bioregion is a biodiversity hot spot, comprising 50,000km^2 across nine major catchments (Fig. 1). ERARC comprises 29 indicators combined into the five indices of Habitat, Native Species, Cover, Debris and Management (Ryder *et al.,* 2016). Indicators focus on mechanisms regulating vegetation condition such as fencing, clearing, animal impacts, regeneration and the structure and function of the vegetation community. We used four catchments (Coffs Harbour, Macleay, Hastings and Camden Haven) to use ERARC to identify the mechanisms driving riparian condition and their spatial relationships.

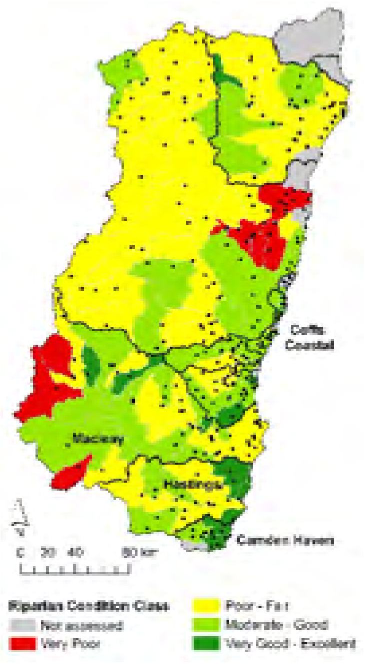

Fig. 2. The NSW North Coast Bioregion study area by catchment, with sub-catchments colour-coded by riparian condition. The four subset catchments used to explore the drivers of R.C. are indicated.

Results

Riparian condition differed with landuse; sites in conservation areas scored higher riparian condition than sites in grazing areas. Mean riparian condition was grouped into 1 of 4 riparian condition classes that best capture levels of decline from reference condition. This enabled more accurate assessments of the indices driving decline in each riparian condition class (Table 1). All 29 indicators contributed to riparian condition decline. However, some indices disproportionally contributed to the decline from reference riparian condition for each condition class, e.g. Management was either the primary or secondary index leading to decline in riparian condition in all four riparian condition classes, while Cover contributed the least (Table 1).

Table 1. Mean riparian declines (± standard deviation) from reference condition for the 5 indices across 89 sites in four condition classes.

	Riparian Condition Classes			
Indices	**Very Poor (<40)**	**Poor – Fair (40-60)**	**Moderate – Good (60-80)**	**Very Good – Excellent (80-100)**
Habitat	82% ± 8%	43% ± 11%	23% ± 10%	6% ± 7%
Native Species	65% ± 10%	49% ± 13%	35% ± 13%	13% ± 11%
Cover	46% ± 14%	33% ± 14%	19% ± 10%	5% ± 4%
Debris	76% ± 10%	50% ± 12%	39% ± 10%	24% ± 10%
Management	79% ± 13%	56% ± 11%	44% ± 13%	22% ± 12%

Table 2. Management goals and actions for each condition class can be classified into restoration, regeneration and revegetation.

Riparian Condition	Result	Maintain	Regenerate	Revegetate	Restore
80 - 100	Very Good - Excellent	✔	✓		
60 - 80	Moderate - Good	✓	✔	✓	
40 - 60	Poor - Fair		✓	✔	✓
0 - 40	Very Poor			✓	✔

Discussion

Management goals and actions for each condition class can be classified into restoration, regeneration and revegetation (Table 2). Sites in very poor condition (0-40 site scores) typically require a suite of restoration techniques. Sites in poor to fair condition (40-60 site scores) may be more responsive to revegetation techniques, while sites in moderate to good condition (60-80 site scores) may be appropriate candidates for regeneration techniques. Sites in very good to excellent condition (80-100 site scores) require current management practices to be maintained or may benefit from minor regeneration. The overlap amongst management principles, indicated by small ticks, signifies the potential for sites to improve over time and move into a different management phase.

While it may be practical to return sites in moderate to excellent condition to reference conditions using regeneration techniques, this is unlikely for sites in very poor to fair condition (Radford *et al.*, 2007). Depending on historical anthropogenic disturbance and subsequent ecosystem transformation, ecological trajectories at a site may be fundamentally changed, constraining the end point for ecological repair (Lunt and Spooner, 2005). Given that riparian zones support regional biodiversity and regulate energy and nutrient flows between terrestrial and aquatic systems (Naiman and Decamps, 1997), they are important determinants of catchment aquatic ecosystem health (Rapport *et al.*, 1998), and it is critical to manage them appropriately by reducing stressors and increasing connectivity. By using riparian condition classes to highlight indicators that drive riparian condition, we can identify the relevant management principle needed for improvement and set meaningful short, intermediate- and long-term management goals that encourage adaptive management and assist decision makers in making positive change at site, sub-catchment, catchment and bioregional scales.

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Grazing Animals as Tools for Grassland Management

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Abstract
Each grazing animal has a slasher out the front, four cultivators underneath and a fertiliser spreader out the back. This model comes from Tim Wright of 'Lana' Uralla, who has used these tools over the last 25 years or so to convert the grassy woodlands on his property from being *Aristida ramosa* R.Br. dominant to complex and productive pastures dominated by the more desirable and often grazing-sensitive native grasses. Tim's success contrasts with the conclusion of David Eldridge and co-workers' recent paper that grazing by domesticated livestock typically degrades rangelands. Greg Lodge and I were able to show that, by matching heavy grazing and rest with their different phenologies, it is possible to change the dominance of the undesirable *Aristida ramosa* to a pasture rich in *Rytidosperma bipartitum* (Gaudich.) Connor & Edgar. Unfortunately, this procedure resulted in low ground cover during the first few years of the treatment. Further studies found that rests from grazing at critical times of the year were effective in prolonging the life of native perennial grasses. There is now good evidence that grazing animals are effective tools for manipulating the species composition of grasslands towards perennial native grass dominance. However, to be effective, the stock density must be high with a long rest timed to the phenology of the preferred species. The duration of the graze period can be very short (say <1 day) in which case the stock density must be very high (say >5,000 dse/ha).

Introduction

There is a long history of the successful use of grazing animals as tools to manipulate the species composition of grasslands (Jones *et al*. 1933), but these results were ignored in Australia. John Wheeler from the CSIRO at Chiswick, came to the conclusion in the 1960's that there was no advantage of rotational grazing in terms of preferred pasture species survival, pasture productivity and animal performance compared with set stocking (Wheeler 1987). This became the advice from the advisory services in Australia for the next 30 years. Similarly, Eldridge *et al.* (2016), using an over-simplified estimate of grazing pressure, derived three ecosystem measures, structure, function and species composition, from a database of 7615 records of grazing studies in Australia. They reported that grazing significantly reduced all three measures in grazing lands. The use of set stocking throughout the temperate pastoral zone of Australia led to pasture degradation and loss of perennial pasture species as described by Moore and Biddiscombe (1964) (Fig. 1). A variant of this degradation model in the northern parts of NSW, was the increased dominance of the unpreferred warm season perennial native grass, *Aristida* ramosa R. Br. (Whalley 2001). The response by land managers was repeated re-sowing of introduced pasture species.

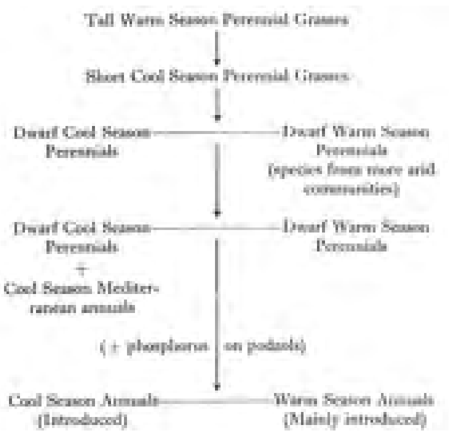

Fig. 1. Model of pasture degradation from Moore and Biddiscombe (1964).

Improving pastures using grazing animals as tools

We were able to show in the early 1980s that by matching heavy grazing and rest with the different phenologies of two native grass species, it is possible to change the dominance of the undesirable *Aristida ramosa* to a pasture rich in the grazing-sensitive *Danthonia linkii* Kunth (now *Rytidospermum bipartitum* (Gaudich.) Connor & Edgar) (Lodge and Whalley 1985). This was the reverse of the general degradation processes (Fig. 1) described by Moore and Biddiscombe (1964) and more recently by Eldridge *et al*. (2016). The downside of this procedure was that it left the grassland with very low ground cover during the first few years of the treatment.

By the late 1980s, there was widespread concern in the higher rainfall parts of temperate Australia that the introduced perennial pasture species died out after a few years and, with low rainfall during the 1980s, sown pastures either did not establish or lasted for a very short time before degradation occurred as described by Moore and Biddiscombe (1964), and in more detail by Whalley (2001). David Kemp, Greg Lodge and others designed a widespread project funded by the then Meat Research Council (MRC) to investigate the effectiveness of short periods of rest and grazing at different times of the year. This project involved research sites throughout the temperate, high rainfall zones in Australia. These rest and graze periods were timed according to the phenology of the preferred perennial species in the pastures, whether sown or native, and were designed to favour them and disadvantage the unpreferred species. This program was referred to as the Temperate Pasture Species Key Program TPSKP) and ran from 1992 until 1996. These treatments were applied t a wide range of pastures, including those dominated by preferred perennial native grasses and were effective in altering the species composition of the pastures in the desired direction (Fitzgerald and Lodge 1997). The MRC then funded a follow up program, the Sustainable Grazing Systems Key Program (SGSKP), which ran from 1996 to 2001. It was designed to further investigate aspects of perennial pasture maintenance by grazing management at three research locations and to demonstrate the value of effective rest periods on the pastures on commercial properties (over 100) throughout the temperate high rainfall zone. The general conclusions from this large number of investigations (each one usually un-replicated and with a set-stocked control) were (Fitzgerald 2003): (1) Rotational grazing increased desirable perennial species even in seriously degraded pastures dominated by weeds such as Chilean needle grass and African lovegrass; (2) In well-established sown pastures under a cell grazing regime, there was little invasion of the less vigorous weed species, and (3) In a native pasture subject to intermittent grazing there was an increase in the desirable palatable native legumes, glycine and desmodium. At continuously grazed sites, there was a decline in desired palatable species along with the invasion of weed species, irrespective of any fertiliser treatments. Declines were slow in newly-established sown pastures, but accelerated as the proportion of unpalatable species increased and plant selection by grazing animals became more influential (Fitzgerald 2003).

Further advances in short duration grazing methods since then (Norton and Reid 2013) have shown that the adoption of multi-paddock grazing rotations based on perennial grass recovery can regenerate perennial grasslands at a profit. Making grazing decisions based on a clearly defined goal and using adaptive management can produce significant improvements in perennial grassland regeneration, whether the preferred perennial species are introduced or native, sown or naturally occurring. An important aspect of these methods is the periodic removal of herbage mass and the incorporation of part of the organic material into the soil surface using trampling by domestic livestock. Further defoliation should be delayed until the preferred perennial grasses show some bleaching of the most mature leaves at the bases of the tussocks. The length of the rest period is critical for the success of this grazing method. The duration of the graze period can be very short (say <1 day) in which case the stock density must be very high (say >5,000 dse ha^{-1}) but generally should not be longer than 30 days (up to 100 dse ha^{-1}) (Jones 2003). If the use of livestock is not possible, then fire and/or slashing can be used to remove herbage mass but timing is critical and management can be more difficult than using grazing animals as tools (Morgan 2015). The incorporation of the organic matter into the soil surface is not as effective when there is no trampling by domestic livestock (Browns' Ranch 2017).

Conclusions

Grazing animals can be effective tools for manipulating the species composition of grasslands whether sown or naturally occurring. However, to be effective in maintaining the abundance of a successfully sown species, the stock density must be high and timed to the phenology of the preferred species as determined by rainfall events. Where the use of grazing animals is not practical, mechanical means and/or fire can be used to achieve the same purposes, but they are not as effective as using grazing animals.

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Australian Native Grass Breeding Systems in Relation to the Choice of Source Material for Revegetation

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Abstract

By far the majority of studies concerning the choice of source material for revegetation by either direct seed harvesting or for seed increase have come from North America. A feature of their native grasses is that most are cross-pollinated and mechanisms for the prevention of self-pollination are common. Recent publications now question whether local seed sources are always best. Artificial selection for specific functional traits important in revegetation are mooted in the recent literature. The aim is to produce restoration-ready seed supplies of native perennial grasses while still conserving genetic diversity. Species that are either self-pollinating (such as *Sporobolus airoides* Torr. or *Elymus multisetus* Burtt Davy) or apomictic (such as *Poa secunda* Zea ex Roem. & Schult.), are not considered to be good candidates for any recurrent selection and so some authors specifically exclude them for this reason. Studies of the breeding systems of Australian native grasses to date show that self-pollination is very common and that no specific mechanisms (except for a few dioecious species) preventing self-pollination have been recorded. Even *Spinifex sericeus* R.Br. (a dioecious species) reproduces vegetatively by rhizomes and stolons and seedling survival is very rare. The reproductive systems of many groups are complex resulting in a range of ploidy levels (such as in the *Rytidosperma caespitosum* (Gaudich.) Connor & Edgar complex). Some taxa are partly apomictic and partly selfed or cross-pollinated and with different ploidy levels, often with different reproductive mechanisms for the different levels. Simplistic principles such as 'local is best' are clearly inadequate for producing restoration-ready seed supplies of Australian native grasses.

Introduction

The native grass seed industry in North America has been stimulated by various Government initiatives both in the USA and Canada. These northern American grasslands have been subjected to repeated mass extinctions through several glaciations in recent geological time followed by re-colonisation of large areas following the retreat of the ice sheets (Richards 1997; Mithen 2003). Many native grasses in this region are open pollinated which confers advantages in terms of producing multiple genotypes. An advantage is that some of these multiple genotypes may be best suited to the new ecological niches becoming available as the ice sheets retreated. Some genera have specific genetic mechanisms preventing self-pollination such as the S-Z self-incompatibility mechanism (Baumann *et al*. 2000). Artificial selection for specific functional traits important in revegetation is mooted in the recent literature, and the aim is to produce restoration-ready seed supplies of native perennial grasses while still conserving genetic diversity. The result is that 'local is best' is often the principle used in the selection of material for native grass reseeding following land degradation (Mackay *et al.* 2005). Species that are either self-pollinating (such as *Sporobolus airoides* Torr. or *Elymus multisetus* Burtt Davy) or apomictic (such as *Poa secunda* Zea ex Roem. & Schult.) are not considered to be good candidates for any recurrent selection (Chivers *et al.* 2016) and so some authors specifically exclude them for this reason. Should the same principles be applied in the selection of suitable material for revegetation of native grasses for temperate Australia?

Breeding Systems of Australian Native Grasses

Studies of the breeding systems of Australian native grasses to date show that self-pollination is very common and that no specific mechanisms (except for a few dioecious species) preventing self-pollination have been recorded. At least one dioecious species (*Spinifex sericeus* RBr.) reproduces vegetatively by rhizomes and stolons and seedling survival is very rare (Maze and Whalley 1992). The reproductive systems of many groups are complex, mostly with high levels of self-pollination or apomixis (Groves and Whalley 2002). Some species such as *Microlaena stipoides* are mostly self-pollinated, whereas others may appear to be open pollinated such as species of *Danthonia* DC (later referred to as *Austrodanthonia* H.P.Linder and now *Rhytidosperma* Steud.). Closer examination showed that they are mostly self-pollinated (Brock and Brown 1961).

The spikelets of *M. stipoides* (Labill.) R.Br. are mostly cleistogamous and fertilisation occurs well before the spikelets are exserted above the flag leaf (Huxtable 1990). The anthers are very small and produce only several hundred pollen gains. In addition, a cleistogene is often produced in the lower node of a flowering stem when the inflorescence seed is mature. These cleistogenes are similar to but smaller than the cleistogamous flowers on the majority of the inflorescences (Groves and Whalley 2002). Periodically, some lines produce chasmogamous inflorescences with ~four large anthers which are exserted well after the spikelets emerge from the sheath of the flag leaf and provide the potential for cross pollination (Huxtable 1990; Whalley and Groves 2002). *Microlaena stipoides* plants appear to be tetraploids (4n = 48) operating as functional diploids (Parthasarathy 1939).

The breeding systems of *Rhytidosperma* spp. (or *Austrodanthonia* and the latter nomenclature will be used here) are even more complex. Waters *et al.* (2010) determined chromosome numbers for up to 100 individual plants of five different species collected in central western New South Wales (Fig.1). These plants represented 28 wild populations and the target species was originally *A. caespitosa* (Gaudich.) H.P.Linder but difficulties with field identification of vegetative material meant that up to five different species were collected at one site and all species collected were used in subsequent studies. Chromosome numbers for these plants were ascertained using flow cytometry and four or five ploidy races were found for all five species including two intermediate cytotypes (monoploid, 1x and triploid, 3x) for four of the species (Fig. 2). No monoploid cytotypes were recorded for *A. caespitosa*, but the majority were tetraploid, and triploid cytotypes occurred in the majority of plants assigned to *A. eriantha*, but only eight plants of this species were tested (Waters *et al.* 2010).

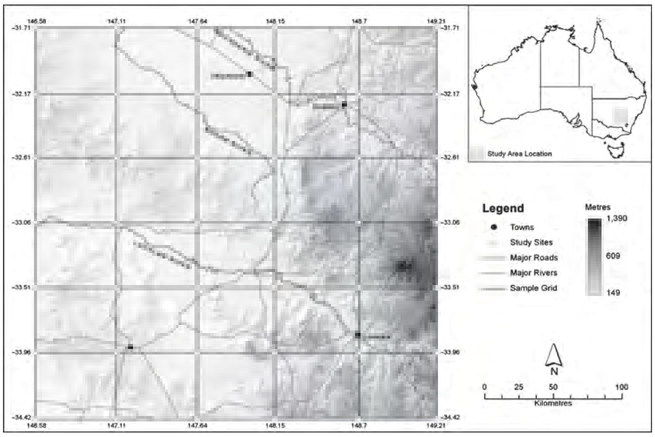

Fig. 1. Study area for *Austrodanthonia* collection. Annual rainfall is higher (600–800 mm) in the east, and lower (400 mm) in the west. Seasonality of rainfall also changes across the area, with southern localities representing more cool-season-dominant rainfall and northern localities typically aseasonal rainfall (from Waters *et al*. 2009).

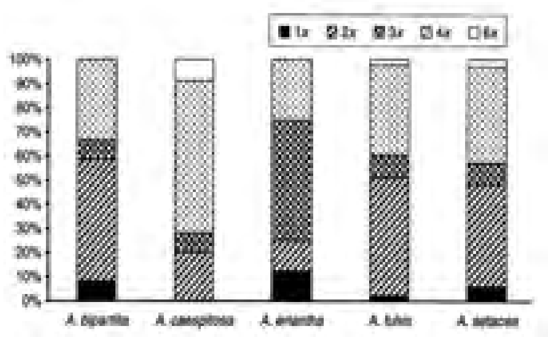

Fig. 2. Percentage of ploidy races (1x = monoploid, 2x = diploid, 3x = triploid, 4x = tetraploid and 6x = hexaploid) in five species of *Austrodanthonia* (from Waters *et al*. 2010).

Brock and Brown (1961) found that a few Australian *Danthonia* species were cleistogamous but that in most of the species, the florets opened for a short period in the early morning or late afternoon allowing open pollination to occur. The data presented above indicate widespread natural outcrossing both within and between cytotypes allowing members of this group to change rapidly in response to the changed ecological conditions that have occurred since the European invasion of Australia. A result is that selected 'varieties' of this genus often do not perform, in terms of survival and recruitment, as well as unselected 'wild' material from other areas (Waters *et al.* 2005).

Conclusions

The above are species of native Australian grasses that have coped well with the changed ecological conditions since the European invasion and others that have coped, have similarly complex breeding systems (Groves and Whalley 2002). As a result, simplistic principles such as 'local is best' are clearly inadequate for producing restoration-ready seed supplies of Australian native grasses.

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Metabolic Changes and Emotional Well-Being Responses After Temporary Reversion to a Traditional Hunting and Gathering Lifestyle in the Gibson Desert: a Project Outline

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Abstract

Modern lifestyles in 'consumer' societies are characterized by greatly reduced physical activity, substantial dietary changes, and marked physical and spiritual detachment from the natural world compared to traditional hunter-gatherer (HG) lifestyles. Previous research among Australian Aboriginal peoples has demonstrated that temporary reversion to a hunter-gatherer lifestyle greatly improves metabolic abnormalities associated with health conditions such as type 2 diabetes and obesity. However, whether temporary immersion in such a lifestyle can also impact psychological aspects of a person's well-being is unknown. This paper outlines an ambitious future study to be conducted with the Pintupi people of Australia's Gibson Desert to test the impacts of temporary reversion to an HG lifestyle on physiological, emotional and spiritual wellness responses. A complementary study to be conducted concurrently to the HG lifestyle project will examine the nutritional attributes of the desert diet consumed by project participants. Beyond providing fresh insights into the therapeutic implications and health benefits of hunter-gatherer diets and lifestyles, this project has the potential to deeply entrench in project participants traditional skills and knowledge relating to patch burning strategies, food procurement and processing, and management of traditional water resources.

Introduction

Lifestyle diseases such as type 2 diabetes, heart disease, metabolic syndrome and obesity are prevalent among both Aboriginal and non-Aboriginal populations in Australia (Chen et al. 2011). Though the etiology of these illnesses can sometimes be linked to genetic factors, their primary causes are believed to be lifestyle factors such as low exercise levels, high rates of alcohol and drug abuse, and poor diet (Egger and Dixon 2014). In a landmark study conducted among Australian Aboriginal people in the northern Kimberley region of Western Australia, temporary reversion over a 7-week period to a traditional hunter-gather lifestyle by urbanised participants resulted in marked improvement, and in some cases normalisation, of major metabolic abnormalities associated with type 2 diabetes (O'Dea 1984). The main reasons given by the study for these rapid health improvements included increased physical activity, loss of weight, and improved quality of diet of project participants. Despite Professor O'Dea's pioneering work providing many important insights into how chronic lifestyle diseases might be treated and prevented, the psychological impacts of O'Dea's work were never considered. This may be because during the 1980s there was less research emphasis and reduced understanding of the importance of psychological well-being than at present. As a result of this research short-fall, whether temporary immersion in an HG lifestyle can impact other facets of a person's well-being, such as emotional health, remains unclear.

This document outlines a proposed study to be conducted among the Pintupi people of the Gibson Desert on the impacts of temporary immersion in a hunter-gatherer lifestyle on physical and emotional well-being. A brief description will also be given of a complimentary study that will investigate the nutritional attributes of plant foods consumed by participants during the HG lifestyle project. Expected outcomes of these studies include: (1) empirical testing of theories and models relating to the impact of dietary modifications and lifestyle changes on human metabolism and emotional well-being; (2) improved understanding of the nutritional values of Australian native food plants; and (3) providing opportunities for project participants to strengthen their ecological and cultural knowledge.

Project outline and methodology

A group of up to 15 and not less than 10 project participants will live a traditional HG lifestyle in a remote region of the Gibson Desert for a period of 6-weeks. The only foods eaten by group members during the project will be those which can be hunted or gathered from surrounding desert landscapes. The participant group will comprise a mix of Aboriginal and non-Aboriginal Australians, with equal numbers of men and women. All project participants will be of relatively good health that will be sufficient to endure the arduous physical demands that the study will impose. Travel during the project will be on foot rather than vehicle. Immediately prior to the experimental period, baseline metabolic and emotional well-being examinations will be conducted in either the Alice Springs Regional Hospital or at the nearest Aboriginal community-based health clinic to the study site. At the conclusion of the experiment, participants will be transported back to the place of initial testing, and the metabolic and emotional well-being examinations repeated. Metabolic parameters to be monitored include oral glucose tolerance levels, fasting plasma insulin concentrations, and thyroid antibody counts. To assess the impacts of HG lifestyle immersion on emotional well-being, participants will be assessed using the World Health Organization Well-being Index (Topp et al. 2015). Several potential study sites for the project have been identified in the eastern and central regions of the Gibson Desert. Final selection of the site will take place subsequent to consultation with Aboriginal project participants and traditional land owners. A key decision in carrying out the project will be determining the seasonal timing of the experimental period. The two most favourable seasons in the Gibson Desert for hunting and gathering (and also in terms of general comfort) are the Autumn months of April and May and the spring months of September and October. During Autumn, plant foods such as grass seeds and the fruits of desert tomato plants (*Solanum* spp.) can be gathered, and animal foods such as cossid grubs and goanna are usually available (Cane 1987; Walsh 2008) (Table 1). During spring, plant foods such as the seeds of *Acacia* shrubs and edible tubers of the katjutarri vine (*Vigna lanceolate*) come into season, and larger game such as kangaroo and bush turkeys are common.

Table 1. Results of previous nutritional analyses of bush foods from Gibson and Great Sandy Desert bioregions, including protein and carbohydrate levels+, relative importance levels in daily diet of Aboriginal groups*, and calorific returns*.

Bush food species	Nutritional parameter			**Relative importance**	***K*cal/hr**
	Pintupi name	Protein (g/100g)	Carbohydrate (g/100g)		
Seeds					
Acacia aneura (mulga) seed	Kayurru	26.6	56.6	Moderate	-
Chenopdium rhadinostachyum (crumbweed)	Maturra	10.5	70.4	Major	661.1
Eragrostis eriopoda (woolybutt)	Wangunu	15.8	69.6	Moderate	-
Fruits					
Solanum centrale	Kumpurarrpa	8.4	53.9	Major	-
Solanum chippendalei	Pintalpa	1.5	17.4	Major	7504.6
Tubers					
Cyperus bulbosus	Yalka	4.0	71.9	-	-
Vigna lanceolata	Katjutarri	2.8	17.5	Major	254.8

+ Data from Latz (1995), results provided are mean values of multiple scores/species from previously published data.
* Data from Cane (1987).

An important factor in maximising the likelihood that adequate food reserves will be present during the study will be site preparation by burning. Several of the most important and easily gathered plant food species likely to be utilised as food by participants during the project are plants for which productivity is promoted by fire. These include various species of bush tomato and woolybutt grasses (Latz 1995). To ensure availability of these foods during the HG lifestyle project it will be essential to ensure that substantial tracts of country that are rich in these species are burnt during the year prior to the commencement of the project (Quamby M. pers. comm. 2017). Investigations on the chemical composition and nutritional value of selected plant foods that are consumed during the experimental period will be conducted by researchers at Latrobe University. Nutritional parameters to be analysed include gross energy and crude protein levels, antioxidant values, and key chemical compounds that are of interest from a nutritional perspective.

Conclusion

The success of the Gibson Desert HG lifestyle project will be contingent on numerous factors, including ensuring the project takes place following favourable fire and rainfall sequences for the growth of food plants, maintaining the health and safety requirements of participants during the study, and ensuring the ongoing participation of group members for the duration of the experimental period. Nevertheless, if all of these potential difficulties can be overcome, the project should provide important scientific insights into the role of hunter-gatherer diets and lifestyle in maintaining human health and preventing lifestyle diseases. Beyond scientific outcomes, the project has strong potential to bolster pre-existing cultural knowledge in project participants, and to deeply entrench skills and knowledge relating to patch burning strategies, and traditional food procurement and processing methods.

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