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ThinkingBush

Knowledge for managing native vegetation in Australian landscapes

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Native Vegetation and Biodiversity R&D

BIODIVERSITY OUTCOMES FOR WATER POINT MANAGEMENT

SAVANNA BURNING AND THE CARBON ECONOMY

THE DECLINE OF WOODLAND BIRDS IN AGRICULTRUAL LANDSCAPES

TRACKING GENES IN FRAGMENTED LANDSCAPES

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Foreword

Jim Donaldson, Executive Manager, Sustainable Landscapes, Land & Water Australia

So this is it, the last *Thinking Bush*. As most of you will be aware, Land & Water Australia will be ceasing business over the next few months so we have been busy working out how to wrap up our various programs and projects.

As part of this, we thought it timely to take the opportunity to capture some reflections on the work we've been doing with researchers around the country through the Native Vegetation & Biodiversity R&D program and to thank people.

Thinking Bush started out in July 2002 as an occasional magazine designed to share insights being gained from science with people responsible for conserving and managing native vegetation in rural Australia.

Land & Water Australia first established a National Remnant Vegetation R&D Program in 1995 in partnership with the federal environment department. The findings from that first phase were well captured by Prof Jann Williams in her summary report 'Managing the Bush' published in 2000. Since then, there have been two more phases of the program, involving partnerships with the CSIRO, the then Murray Darling Basin Commission and Greening Australia.

Thinking Bush has provided a vehicle for sharing some of the knowledge gained from these projects.

Looking back over the last fifteen years, there has been an incredible amount of innovation in the vegetation management arena, with major changes occurring in policy and significantly higher levels of recognition within government programs of the importance of biodiversity conservation and wise land use and management. The programs at Land & Water Australia have played a vital role in fostering this innovation, through its landmark reports into areas such as: the ecology of remnants; the genetics of remnants; landscape thresholds and design; connectivity; the ecology of rangelands and tropical savannas; principles for classifying landscapes; and related investigations into economics, social values, policy instruments and incentives. You will see that many articles in this edition of the magazine continue to touch upon several of these topics.

The program has assisted thinking about vegetation and biodiversity management by policy makers, planners and managers to move from the patch to the landscape scale. Australia is now recognised around the world as a leader in the landscape ecology field.

As the only national R&D program in this area, the program has also provided a focal point for many of Australia's leading scientists to gather, debate and share ideas and insights about landscape ecology and vegetation and biodiversity management.

We have also tried to build the connections between scientists, policy advisers and managers by co-hosting major national events like the *Veg Futures* conferences in 2006 and 2008 and our semi-regular Science in the Paddock breakfast briefing sessions for Canberra based policy-makers. I extend a special thankyou to Greening Australia as our partner in many of these ventures, as well as the CSIRO, the Bureau of Rural Sciences, the Joint Venture Agroforestry Program, DAFF and DEWHA who have all worked with us in the national Partners in Vegetation group to improve our capacity to work together and coordinate our efforts to deliver better outcomes.

Our report from June 2008 into 'Restoring landscapes with confidence', where we explored the extent to which science was being used to inform regional natural resource management, revealed that while the science has come a long way there is much more that needs to be done. Critically, far more needs to be done to foster, facilitate and encourage greater connection between scientists and regional planners and managers as well as amongst the regions themselves so that knowledge, in all its forms, does indeed get to inform practice. While more resources are always needed, much of the demand is for more leadership and better coordination of programs and activities so that we drive the scarce resources available even further.

Finally, I would like to take this opportunity to thank all those who have been involved in the program and in helping to produce *Thinking Bush* over the years. In recent times within Land & Water Australia this has included Teresa Oppy, Nolani McColl, Nadeem Samnakay; our program coordinators over the years in Jann Williams, Jason Alexandra and Mick Quirk; and previous staff of Gill Whiting, Nick Schofield and Andrew Campbell. I also thank the various incarnations of the Board of Land & Water Australia for making all of this possible.

So this is it for now. To continue to access information about the program, its reports and publications, Land & Water Australia will maintain a legacy website at **www.lwa.gov.au** I wish you all well in your various roles and endeavours to protect, conserve and wisely manage Australia's bush.

This is the end
Beautiful friend
This is the end
My only friend, the end

Of our elaborate plans, the end
Of everything that stands, the end
No safety or surprise, the end
I'll never look into your eyes...again

[The End, The Doors]

Assessing biodiversity outcomes from waterpoint management: a case study in the gibber deserts of remote Australia

Anita Smyth

Domestic and feral herbivores need daily access to water during summer, and every few days during winter. The risk to biodiversity and ecosystem function depends on the type of herbivore activity, its intensity, and how long an area is exposed to grazing. We explore whether waterpoint manipulation is a useful management tool for achieving biodiversity and ecosystem outcomes in the arid grazing lands of remote Australia. We used the 'gibber gilgai' systems of the Stony Plains Bioregion in northern South Australia for our case study.

Waterpoint intensification (and therefore water-focussed grazing) is so widespread in our study area that it is rare to find waterpoints greater than 7 km apart (Figure 1). Many scientific studies have addressed grazing gradients and biodiversity responses to artificial waterpoints; some have recommended waterpoint closures to rest biodiversity from grazing pressure. No studies have investigated the place of waterpoint management in biodiversity planning and how biodiversity outcomes can be assessed. Correlative evidence indicates that rest from grazing pressure will result in beneficial biodiversity responses, but it is yet to be tested experimentally in the field.

What we did...

- developed a framework to guide assessment of biodiversity condition linked to desired management outcomes
- critically assessed the use of biodiversity metrics in reporting biodiversity condition and management outcomes
- examined the effect of rainfall seasonality on vegetation responses when assessing condition
- examined the response of biological attributes to controlled waterpoint closure
- assessed the capacity of remote sensing techniques to place vegetation site data into a broader spatial and temporal context.

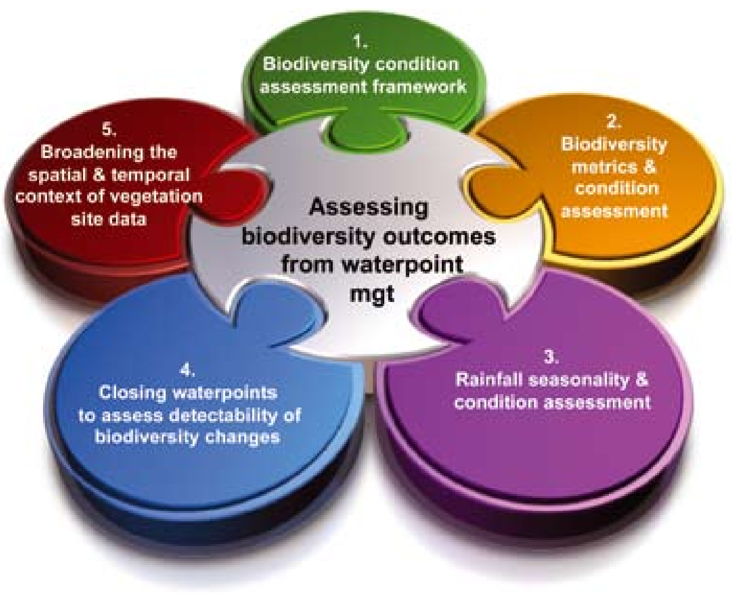
We achieved these objectives through five separate but interdependent activities, illustrated in Figure 1. Our methods were diverse involving technical workshops, desk-top studies, glasshouse experiments, and field studies. A full description of activities is in the final report, which will be uploaded onto a dedicated project website in CSIRO.

What we found...

Biodiversity Condition Assessment Framework

With no existing framework for assessing biodiversity in the study region, we developed an assessment framework that embraces biological diversity and its role in maintaining ecosystems. This does not replace other approaches but improves the transparency of the process.

Figure 1: Structure and interdependencies of our research.



The assessment has seven steps:

1. define biodiversity condition
2. prioritise the outcomes of a biodiversity condition assessment using priority setting related to management outcomes
3. identify biodiversity surrogates
4. select robust biodiversity indicators or measures
5. design and implement long-term monitoring
6. evaluate monitoring results
7. adapt biodiversity planning and management.

Biodiversity outcomes from waterpoint management cannot be understood without clear strategic planning and having a clear statement about what is meant by 'biodiversity condition'.

Use of biodiversity-related metrics

Indicators or measures are often expressed in terms of metrics, which are then combined to give a single score (or multimetric). Metrics are used to objectively classify and rank multi-attributed environmental data for a particular purpose, but their credibility in biodiversity conservation planning remains untested. Metrics can be misleading, as patterns are obscured and inherent errors are inflated by distilling field-based environmental details into a single score. Most alarmingly, biodiversity-related metrics are often accepted in the absence of upfront scientific data and transparent management decisions. As a result, we did not develop metrics for this project. Instead of using untested metrics, we recommend that all indicators be fully depicted, allowing planners to analyse and compare trends in biodiversity condition in a transparent fashion.

Seedlings from soil seedbank in glasshouse experiments. Photo by Rick Davies.

Study area with water point in the distance (white dot). Photo by Robert Brandle.

Robert Brandle and a volunteer (Raghu Palisetty) process a striped faced dunnart. Photo by Anita Smyth.

Effects of rainfall seasonality

Because rainfall seasonality drives biological processes, vegetation pulses and animal numbers in arid environments, we ran glasshouse experiments on germinable soil seed from gilgais.

The soil seed was germinated under 'winter' and 'summer' rainfall conditions to confirm species responses and to calibrate the seed bank plant characteristics with the standing herbage. We found the gilgais contained a diverse range of ephemeral-wetland plant species (see Thinking Bush 7, October 2008).

The plant community for the germinable seed bank and standing herbage were similar in composition, but different in life form dominance. The standing herbage cover (18.2%) is dominated by long-lived perennial and dwarf-shrubs (10.4%), grasses, perennial grasses and sedges (1.6%). In comparison, the soil seedbank was dominated by short-lived ephemeral forbs (83%), and relatively resistant to grazing pressure, with no evidence of significant decline in species richness even near long-established waterpoints.

Temperature seasonality drives plant diversity (69% and 31% in winter and summer respectively), with grasses germinating mainly in summer (81%), and short-lived ephemeral forbs, long-lived perennials and invasives in winter. When choosing vegetation measures to assess biodiversity outcomes from waterpoint management, species richness of 'highly palatable' and 'long lived perennial species' appear to be robust indicators under certain conditions.

Waterpoint closure experiments

Samples are still being processed, but preliminary indications suggest that rainfall and temperature seasonality have a greater influence on biodiversity than grazing relaxation. More details on the plant and animal composition were outlined in a previous Thinking Bush (October 2008), and will be available in the final report.

Remote sensing and upscaling of site-based data

To give our site-based gilgai data a broader landscape and temporal context, we used remote sensing imagery to understand the spatial characteristics of gilgais, and to build a profile of change in vegetation cover and seasonal conditions.

In the first study, Ikonos and Quickbird images (~1-m spatial resolution) were classified to map gilgai structures. Descriptive statistics (average gilgai size, nearest-neighbour distance, gilgai density) were then used to build a 'typology' of gilgais for each study site. Difficulties in precisely classifying gilgais and verifying results prevented accurate maps of gilgai shape and location, thus the spatial statistics are only indicative. Nevertheless, there were considerable differences in gilgai-type between sites, and this needs to be accounted for when interpreting field data.

Analysis of cover trends based on Landsat data (25-m pixel resolution) showed that cover remained relatively stable between 1974 and 1994 and was much more variable over the next ten years. It is likely that seasonal variation in rainfall accounted for most of the cover change. This historical pattern provides important context for interpreting vegetation data collected on the ground.

To sum up...

At this stage, we have been unable to detect an effect of grazing relaxation on biodiversity, but we still have significant analyses to complete. The most likely explanation is that rainfall and temperature seasonality mediate biological processes to a greater extent than grazing pressure present in the 'gibber gilgai' system. We suspect this may be unique to this biome, and that extensive gibber pavements, together with extreme temperatures most months of the year, restrict grazing to set numbers within threshold distances from waterpoints. With significant rain, cattle spread out into 'water remote areas', relaxing grazing pressure around waterpoints intermittently. Biodiversity responses from waterpoint management and grazing relaxation will be hard to detect in the 'gibber gilgai' grazing lands.

This project is undertaken with in-kind support from the Department for Environment and Heritage SA, the Department of Water, Land and Biodiversity Conservation SA, the South Australian Arid Lands NRM Boards, Kidman & Co. Ltd, Todmorden Cattle Co., and CSIRO. Special thanks to Gary Bastin (CSIRO), Kirrily Blaylock (DWLBCSA), Robert Brandle (DEHSA), Gary Cook (CSIRO), Rick Davies (Flinders University) and Tony Latz (DEHSA).

Anita Smyth marking a small lizard, Ctenotus olympicus. *Photo by Pam Keill*

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www.csiro.au/science/waterpointmanagement.html

Capturing the ecosystem service of pest control from native vegetation

Felix Bianchi

Natural pest regulation is an important ecosystem service that directly benefits growers and has an estimated value of several hundred billion dollars per year at a world-wide scale. Due to the activity of natural enemies, the vast majority of potential pest species are controlled and do not reach outbreak levels in crops. This natural pest regulation can, in turn, contribute to reduced pesticide use in agriculture and limit the associated negative impacts on the environment.

Ladybeetles are aphid predators that reproduce in grain crops and in native vegetation (photo: Anna Marcora).

Native vegetation in agricultural landscapes may affect populations of agricultural pests and their natural enemies in several ways. For instance, native vegetation may provide floral food resources, such as nectar and pollen, for herbivore insects and their natural enemies, as well as providing alternative prey or hosts for natural enemies when pest densities in crops are low. Native vegetation may also act as a refuge when crops are disturbed (e.g. by pesticide application, or harvest) and may provide a more moderate micro-climate than crops. However, as native vegetation can potentially stimulate both pests and their natural enemies, it is unclear whether native vegetation has a positive or negative impact on natural pest regulation in Australian agricultural landscapes.

In a study funded by Land & Water Australia and the Cotton Catchment Communities CRC, the role of native vegetation for sustaining and capturing the ecosystem service of pest control is being investigated in grain and cotton landscapes in South East Queensland's Darling Downs. The study revealed that native vegetation, in particular *Eucalyptus populnea, Acacia salicina,* and *Chenopodiaceae* spp. habitats had much higher predator to pest ratios than sorghum, cotton and chick pea crops. In addition, crops supported higher densities of immature pest species (including the major cotton pests *Helicoverpa* larvae and mirid nymphs) than native vegetation, indicating that crops function as sources of pest populations.

Native vegetation next to an arable field – a potential source for natural enemies that can suppress pest populations in crops. Photo by Felix Bianchi.

CSIRO research team: (standing, L-R) Norm Winters, Anna Marcora, Belinda Walters, Kylie Lukins, Saul Cunningham, Nancy Schellhorn, Karen Stafford and (kneeling) Felix Bianchi. Photo by Felix Bianchi.

Native vegetation can act as a source for natural enemies, but this depends on the species. Parasitism of whitefly – a pest in melons and cotton – was higher in native vegetation and fields adjacent to native vegetation than in crops that were 400 metres from native vegetation. However, the predation of *Helicoverpa* eggs was not influenced by the proximity to native vegetation. In this case, ants were the major predators of *Helicoverpa* eggs, and were distributed throughout the landscape. In Spring, native vegetation acts as an important green bridge by providing habitat for natural enemies at a time when autumn planted crops are being harvested and spring and summer crops have not yet been planted. This 'green bridge' function was shown to be particularly important during drought.

We found no evidence that native vegetation can enhance pest colonisation. That is, the number of *Helicoverpa*, aphids, thrips, leaf hoppers, and whiteflies in fields were not affected by the distance from native vegetation. This suggests that native vegetation is not a source for these pests, and that they can spread over large distances.

In conclusion, this study shows that native vegetation can improve the predator to pest ratio at the landscape scale, and can locally enhance the suppression of whitefly pests. These findings show that on-farm conservation of biodiversity can contribute to more sustainable crop production systems, which are less reliant on the use of chemical pesticides.

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CSIRO

Australian Government
Land & Water Australia

Cotton Catchment Communities CRC

The future of savanna burning and the carbon economy

Jeremy Russell-Smith

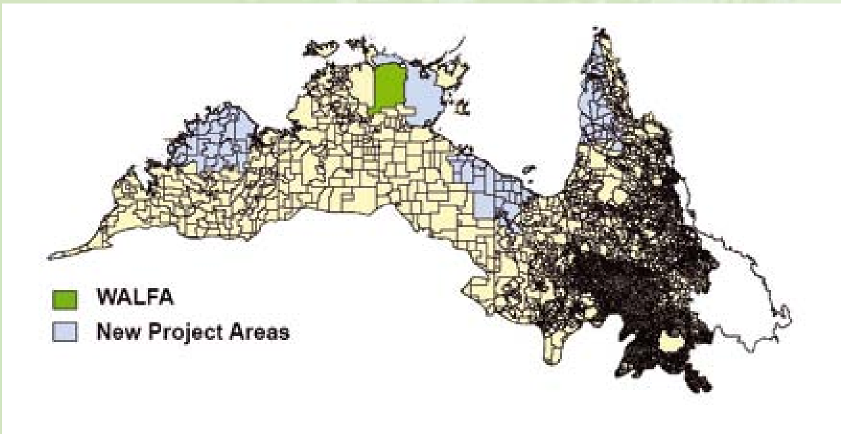
There is significant promise for developing new approaches to indigenous land management across the fire-prone northern savannas, especially with respect to economic greenhouse emissions abatement opportunities. The Western Arnhem Land Fire Abatement (WALFA) model, a decade of research and practical implementation, has demonstrated that substantial greenhouse emissions abatement, and associated biodiversity and regional indigenous employment benefits, can be achieved where appropriate fire management and associated funding support arrangements are put in place.

The WALFA model has potential application across fire-prone regions of northern Australia, but requires substantial development in different regional settings, particularly to establish regional savanna burning emissions baselines (i.e. develop the 'scientific base'), to build regional fire management capacity amongst practitioners, and to develop multi-tenure governance structures and business enterprises.

Exploring these issues has been at the heart of the Land & Water Australia-funded project, *Fire management in northern Australia: integrating ecological, economic and social outcomes*, which unfortunately will be prematurely truncated. To date, the project has delivered: a rigorous assessment of appropriate governance for implementing savanna burning projects, based on the WALFA experience, and necessary supportive national policy settings (Whitehead *et al.* 2008, 2009). An example of these include a soon-to-be completed assessment (Liedloff *et al.* in prep) of relationships between project-based emissions accounting methodologies, such as those developed for WALFA (Russell-Smith *et al.* 2009) and the National Carbon Accounting System; and ongoing development of training manuals (e.g. aerial burning approaches to fire management of biodiversity-rich sandstone regions) and information products (e.g. automated daily satellite-based fire mapping) which are aimed at building capacity and enhancing technical delivery of savanna burning.

While some challenges remain for developing the technical and governance aspects of regional savanna burning projects, these pale into significance beside the ongoing confusion surrounding the federal government's emissions trading scheme (ETS) agendas. The first issue is the reluctance to even acknowledge the possibility of substantial net offset benefits from ostensibly small contributors such as savanna burning (but see below) to major polluting sectors covered under the ETS—including not only benefits from reducing greenhouse emissions and associated sequestration, but equally importantly, to savanna biodiversity and regional indigenous economic development outcomes.

Additionally, as spelt out both in the ETS 'green' and 'white' papers, ETS policy makers labour under the misapprehension that "the complexity of property rights for Indigenous lands would make it difficult to identify single commercial entities that could take on scheme obligations for those emissions".



However, as WALFA demonstrates, effective governance arrangements can be established at landscape project scales. The issue raised by the Commonwealth is more relevant when applied to liability for savanna burning emissions from individual tenures across northern Australia.

From the perspective of regional northern Australian partners, the fundamental problem is that the issues surrounding, and broader benefits from, savanna burning have simply failed to raise a blip on the radar screen of ETS policy makers. If the intent of Commonwealth ETS policy is to seriously address greenhouse gas emissions, then some additional observations need to be kept in mind. Firstly, under the Kyoto Protocol Australia is required to account for only emissions of methane and nitrous oxide from savanna burning. Carbon dioxide itself is not accountable under the naive assumption that what gets emitted in one burning season will be fixed by vegetation in the next growing season. Regardless, carbon dioxide is present as a greenhouse gas for many months and, if accounted for, would constitute over 30% of national emissions in any one year (Russell-Smith *et al.*2007)! Secondly, significantly enhancing savanna burning practice would deliver carbon sequestration in living biomass many times greater than that achieved through emissions abatement alone (Murphy *et al.* 2009). Obviously, a lot more consideration needs to be given to developing a functional and demonstrably effective ETS. It is a significant pity that Land & Water Australia will not be around to help advance that debate.

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Landscapes under fire: the resilience of restored communities near Canberra to large scale disturbance by fire

David Freudenberger

The Canberra fires of 2003 provided a unique opportunity to study the long-term response of restored communities (direct seeding and tubestock revegetation) to disturbance by fire and compare this to the response of remnant vegetation and pasture and pine plantations.

Widespread landscape degradation and loss of habitat has led to the increasing need for ecological restoration and revegetation. In particular, revegetation is increasingly seen as an important means of improving biodiversity, providing vital ecosystem services, rehabilitating landscapes and for carbon sequestration to combat climate change. The primary goal of ecological restoration and revegetation is to create self-sustaining ecological communities that are resilient to periodic disturbance. This is particularly important for the disturbance prone Australian environment where events such as fire are a regular occurrence.

Although the response of native vegetation communities to fire is fairly well understood, currently little is known about the dynamics of restored communities, how they respond to disturbance events such as fire, and how this response compares to remnant vegetation and production systems such as pine plantations and pastures. In addition, for revegetation sites, there is little understanding of how the age or type of revegetation (e.g., direct seeding or tubestock) influences regeneration and recovery following fire.

Research overview

In this study, 10 burnt and 10 unburnt sites were chosen from each of five vegetation types in the Canberra region: direct seeding revegetation, tubestock revegetation, remnant woodland vegetation, pine plantation, and pastures. The 100 sampling sites across the five vegetation types were first surveyed six months after fire in 2003 and then again in 2006 and 2008 to quantify the survival, health and recovery of both native and exotic species in each community.

Resilient, self-sustaining ecological communities are characterised by the ability to recover and return to a similar condition following a disturbance event. In relation to fire, resilience and recovery can be measured by examining changes in three main components of vegetation following a fire event: (i) survival and recovery, (ii) vegetation structure and health, and (iii) ecological function.

Given that fire is a natural part of the Australian landscape, particularly around the urban-rural interface where native vegetation communities, revegetation, agriculture and forestry often co-exist, understanding what constitutes a resilient landscape is imperative for future planning and in the design of revegetation activities.

There are a number of variables that can influence the survival and growth of vegetation following fire. These include fire intensity, species identity (e.g. obligate seeding vs resprouting species), plant age, post fire soil surface condition, post-fire composition of the understorey, the density of trees and shrubs, and prevailing environmental conditions such as drought. Fire intensity can have an important influence on both the level of plant mortality and the speed of recovery after fire. In addition, older more established plants are more likely to survive and recover post-fire as well as withstand competition from colonising species after disturbance.

The aims of this study were to address the following questions:

1. Survival and recovery: Does survival and plant recovery following fire vary among the different vegetation types?
2. Vegetation structure and health: Does the recovery of vegetation structure and health vary between the different vegetation types?

3. Ecological function: Do the different vegetation types show different levels of recovery of ecosystem function as measured by Landscape Function Analysis?
4. Do revegetation plantings (both direct seeding and tubestock) show similar levels of recovery to remnant vegetation? How does their recovery compare to pine plantations?
5. Do the different vegetation types show different trajectories of recovery over time?

Results and key messages

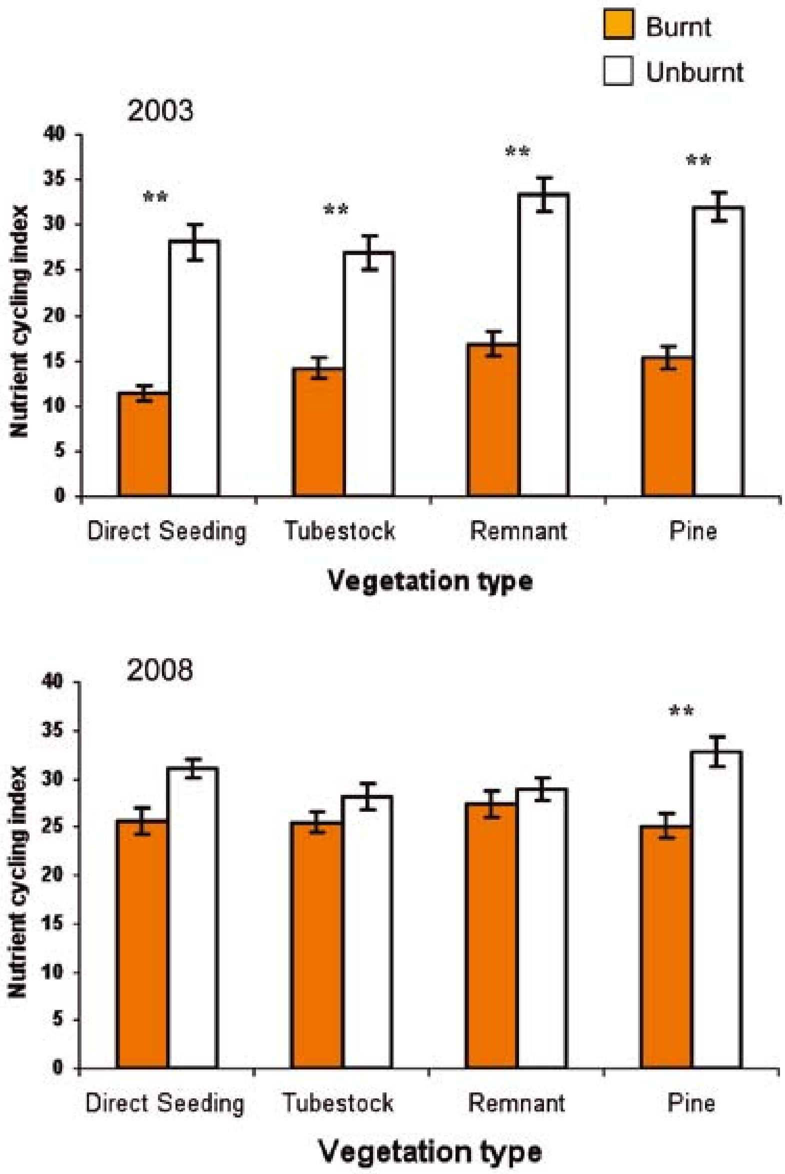
The main results of this study examining the resilience and recovery of native revegetation plantings following disturbance by fire were:

- Both direct seeing and tubestock revegetation sites (including young revegetation plantings less than 10 years old) showed high survival and recovery after fire. This suggests that both forms of revegetation plantings are resilient to fire and are able to recover from disturbance by fire, even under prevailing drought conditions. This is in contrast to the low resilient pine plantation sites where only one tree survived across all the burnt sites, compared to 99% survival in the unburnt control sites.
- Although overall survival was high in both revegetation plantings, survival rate varied among species, e.g. between species that survive fire and resprout from lignotubers or epicormic growth and obligate seeders which are killed by fire and recover through post-fire germination.
- The results from the study also suggest that differences between direct seeding and tubestock revegetation, in factors such as plant establishment and/or density, can influence a species recovery from fire.
- Exotic ground cover was higher in burnt sites in all vegetation types, while native ground cover was similar in burnt and unburnt sites. This increase in exotic cover is not surprising given the opportunistic nature of exotic weed species which tend to increase in dominance after disturbance. The study suggests native ground cover does recover after disturbance and after three years is approaching unburnt levels. This trend is illustrated in Figure 1, which is a photo comparison of the level of ground cover in a direct seeding site between 2003 and 2006. As ground cover is essential for the restoration and maintenance of soil function and health following disturbance, exotic cover in burnt sites may play a useful role in short-term soil stabilisation as more perennial native ground cover species re-establish over time.
- Plant health of the mid- and overstorey vegetation recovered to similar levels as vegetation within unburnt sites for both direct seeding and tubestock revegetation. The level of vegetation cover in the tree overstorey was similar in burnt and unburnt direct seeding and tubestock revegetation sites. In comparison, the level of overstorey cover in burnt remnant sites was much lower than unburnt sites, suggesting that a greater amount of time is required for the overstorey to recover to unburnt levels in remnant vegetation. In addition, the low resilience of pine plantations was highlighted by the very low recovery of the overstorey in burnt sites three years after fire.
- Vegetation cover in the shrub midstorey showed substantial recovery after fire for both direct seeding and tubestock revegetation sites. Interestingly, for tubestock sites, cover in the midstorey shrub layer was much higher in burnt sites three years after fire. This suggests fire-stimulated regeneration in these sites and may also reflect regeneration of tree species lost from the overstorey layer. This pattern was also mirrored in the remnant vegetation sites, where fire stimulated regeneration resulted in large differences in midstorey cover between burnt and unburnt sites. In contrast, there was no difference in midstorey shrub cover between burnt and unburnt pine sites, with both burnt and unburnt sites having low percent midstorey cover.
- Burnt direct seeding and tubestock revegetation sites showed substantial recovery of ecological function after disturbance by fire (as measured

Figure 1: Ground cover comparison of a direct seeding site between 2003 (left) and 2006 (right).

by the Landscape Function Analysis procedure developed by CSIRO which uses a range of soil surface assessments to create three indices that quantify overall soil health and function: (i) nutrient cycling, (ii) infiltration, and (iii) soil stability). All three indices, of nutrient cycling, infiltration and soil stability, showed very similar results in terms of recovery after fire across all vegetation types. For example, in 2003, six months after fire, there were large differences in the nutrient cycling index between burnt and unburnt sites for all vegetation types, see Figure 2. For direct seeding revegetation, nutrient cycling in burnt sites was approximately 40% of the nutrient cycling in unburnt sites, while in tubestock revegetation sites it was only 50%. Similar trends in nutrient cycling were observed for both remnant vegetation and pine sites six months after fire. This reduction in nutrient cycling reflects the loss of vegetation ground cover and leaf litter as well as reduced infiltration in recently burnt sites. However, by 2008 (five years after fire) nutrient cycling had recovered across all vegetation types such that there were only small differences in the nutrient cycling index. Only pine sites still showed a statistical difference in nutrient cycling between burnt and unburnt sites. These results indicate that by five years after fire there is little difference in soil health and function in burnt and unburnt sites for revegetation and remnant vegetation sites.

Figure 2: Nutrient cycling index in burnt (orange) and unburnt (control) (white) sites in 2003 (6 months after fire) and 2008 (5 years after fire) for all four vegetation types. ** statistically significant difference ($P < 0.05$) in nutrient cycling index between burnt and unburnt sites.



Conclusions

Revegetation plantings had high survival and rapidly recovered biomass, structure and ecological function following disturbance by fire, even in prevailing drought conditions. This suggests that revegetation can produce highly resilient vegetation communities and provide an important basis of landscape restoration in the fire-prone Australian environment.

The resilience and recovery of revegetation plantings was comparable to the high resilience observed in remnant vegetation sites, although remnant sites were often slower to recover to unburnt levels due to the more complex vegetation structure and biomass in these sites. These results are in stark contrast to the pine plantation sites, which showed very low resilience as demonstrated by the lower survival and recovery of vegetation structure and biomass as well as reduced soil function in these sites.

The high resilience of revegetation plantings also extends to young plantings (<10 years old), suggesting that even recently established revegetation plantings are resilient to disturbance by fire and show substantial recovery in the first few years following fire. This is particularly important given the growing demand for revegetation plantings for carbon sequestration to combat climate change. In this case, revegetation plantings represent a low risk and highly resilient vegetation community that can recover from disturbance by a severe fire event within a few years, even in drought conditions and when disturbance occurs within the first decade after establishment.

This study shows that revegetation with native plant species would appear to offer a resilient, cost-effective and efficient means of landscape restoration that provides an effective buffer for suburban and rural infrastructure, while presenting additional environmental benefits such as improved biodiversity, ecosystem services and carbon sequestration. This is in contrast to low resilient landscapes such as pine plantations, which show very minimal regeneration after large-scale disturbance events such as fire.

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New innovative and cost-efficient airborne technologies for natural resources management now available in Australia

Jorg Hacker

High-resolution airborne sensors can be used by natural resource managers and researchers to collect visible features of the landscape (for instance vegetation cover or the extent of water bodies), but also many invisible ones (such as canopy condition or the water use or health of plants). This data, often combined with further data, can then be used to derive estimates of carbon storage in vegetation, fire fuel load, biodiversity, plant growth rates, occurrence of invasive species, and many other measures relevant to land management.

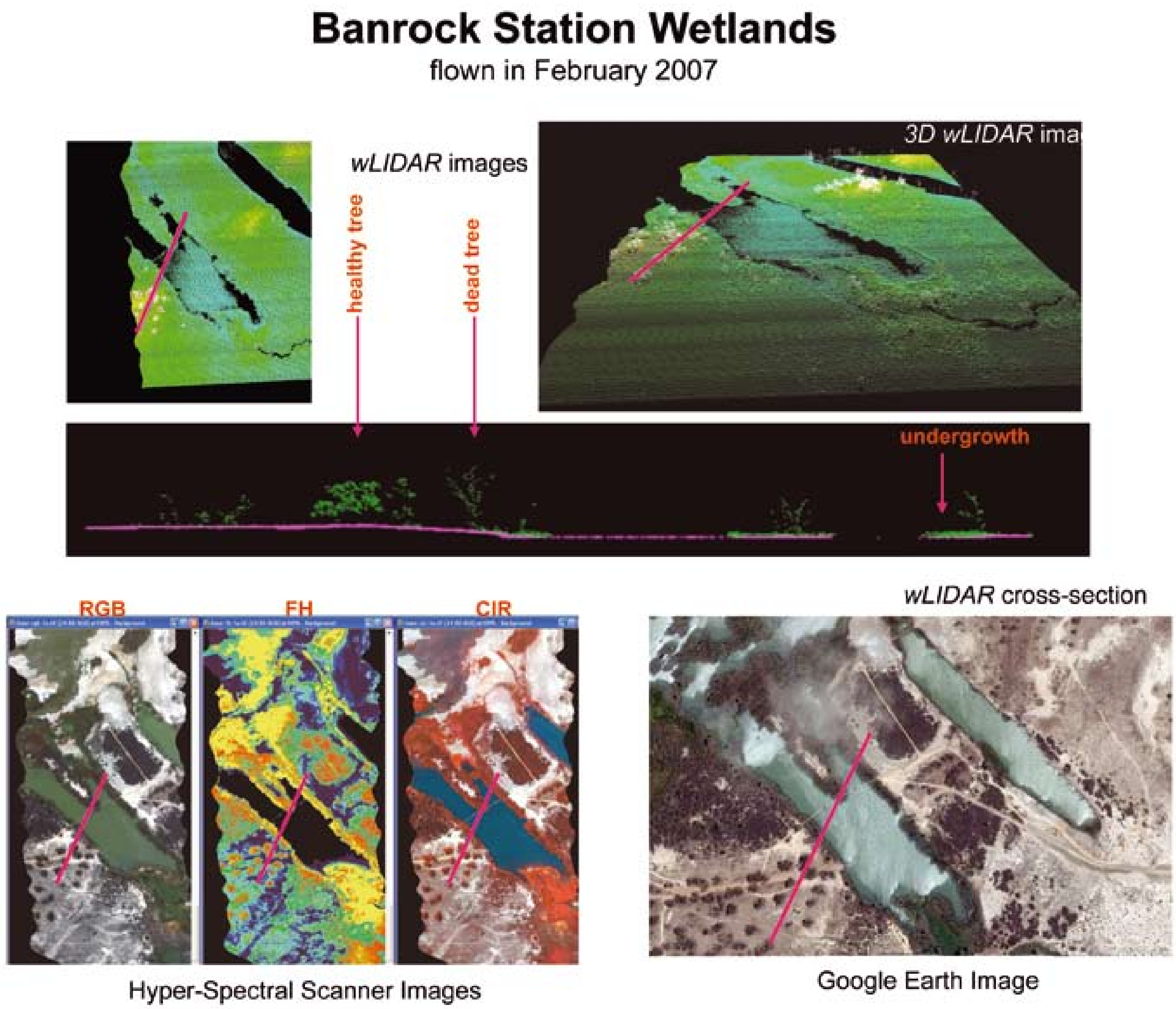
A/Professor Jorg Hacker of ARA – Airborne Research Australia, a research entity at Flinders University recently demonstrated the combination of a multitude of sensors in a proof-of-concept type project using full waveform resolving airborne Lidar combined with other airborne technologies (multi- and hyper-spectral scanners, digital video and still images) flown simultaneously on an environmentally friendly and cost-efficient small aircraft. This work, funded by Land & Water Australia, focused on instrumentation, calibration and airborne data acquisition and integration. The technology gave the best possible spatial resolution and information about the condition and structure of large areas of vegetation available today. "For this kind of data collection, there is no better combination of airborne instruments than these" said Prof. Hacker. "You can choose when and where, and even how close you fly to the vegetation, and are able to cover whole catchments in one day. It is also ideal for surveying difficult to access areas, or areas that are highly sensitive to pollution, such as Adelaide's coastal mangroves"

The ARA team (A/Prof. JM Hacker and assistant Ms. S Chakravarty) downloading data from one of the remote sensing pods of the aircraft in the field. Photo by Nico Hannemann.

During the trials the technology was used in a range of capacities all over South Australia. These included comparing the performance of vines under different irrigation strategies near Waikerie, mapping remnant and regenerating native vegetation near Monarto and in the Banrock Station wetland, and mapping vegetation and geological features around mound springs in the north of the state.

The technology has since been used further in many other research projects. Among them is a Land & Water Australia funded study of gully erosion in tropical Australia, which resource management groups in the region have identified as a high priority. Finding the extent and shapes of gullies and surrounding vegetation, previously done on foot with a global positioning system in hand, can now be done in half a day's flight.

As a direct result of this proof-of-concept project, this widely applicable technology will now be permanently available to Australian scientific and professional communities, after a successful application to the Australian Research Council for support to purchase and set up a complete and current system in Australia.



Results from he combined hyper-spectral and wLIDAR survey of the Banrock Station wetlands. The two top rows show images derived from the wLIDAR. At the bottom left, three hyper-spectral images are shown: RGB is a 'red-green-blue' visual image; FH is 'forest health'; CIR is 'composite infra-red'; FH and CIR can be used to assess the health and status of the vegetation. At the bottom right, the area is shown as a Google Earth image.

Further details are described in the ARA Tri-Annual Report **(www.airborneresearch.org.au/TriAnnualReport.pdf)**.

More information about Airborne Research Australia is available at their website **http://www.airborneresearch.org.au/**

Woodland birds in agricultural landscapes – have we paid the 'extinction' debt?

Jim Radford

Woodland birds in agricultural landscapes of north-central Victoria are declining faster than previously realised. The legacy of clearing large tracts of native vegetation and the ongoing degradation of remnant vegetation appear to have been compounded by a decade of very dry conditions, culminating in widespread population declines and the disappearance of many species from local landscapes. These are the alarming conclusions from a recently completed Land & Water Australia project (DUV 11: Improving landscape design guidelines by considering temporal trends in species richness and population sizes) that in 2006–07 re-surveyed 24 "land mosaics" that had originally been surveyed four years earlier in 2002–03.

Our research from 2002–03 concluded that species richness of the woodland bird community collapses when the amount of native vegetation in the landscape falls below 10%. However, the population size of many species begins to decrease well before this threshold is reached, with many species showing declines when native vegetation cover drops below 30% of the landscape. In mosaics with 10–20% cover, many species are in decline but this is enough habitat to support sustainable populations of some species. However, to support most species present in woodland regions in southern Australia, an average of at least 30–35% native vegetation cover is necessary.

An important question for land managers is whether there will be further loss of native species in modified landscapes, even if there is no further loss of habitat. Some species can persist in landscapes for some time following habitat loss but in ever-decreasing numbers before eventually disappearing. That is, landscapes carry an 'extinction debt' made up of species that are still present but destined for local extinction. If this is true, the threshold in species richness described above may shift to higher levels of habitat cover with time.

Theory predicts that the rate of population declines (and therefore species loss) will be faster in more extensively cleared and fragmented landscapes, at least at first. Then, as the sensitive species disappear, the rate of change will slow in the more modified landscapes as the bird community stabilizes with only tolerant and robust species remaining – that is, the extinction debt is paid. Over time, species progressively disappear from the most modified through to less modified landscapes, as the rate of population change slows in more intact landscapes. However, most of our knowledge about population declines is based on one-off or short-term surveys – they are 'snapshots' in time. In order to assess time-lags and rates of changes over time, we need repeated, long-term monitoring.

Where and how was the research done?

All the field work was completed in the dry forests and woodlands of north-central Victoria. In 2002–03, birds were surveyed four times (spring, autumn, winter and the following spring) at 10 sites in each of 24 study 'landscapes' (each 100 km2). The study landscapes sampled a gradient in remnant vegetation cover from 2% through to 60%, and were selected to sample landscapes with a similar amount but contrasting configuration (i.e. aggregated versus dispersed) of native vegetation. We re-surveyed all 240 sites in spring 2006 and autumn, winter and spring of 2007.

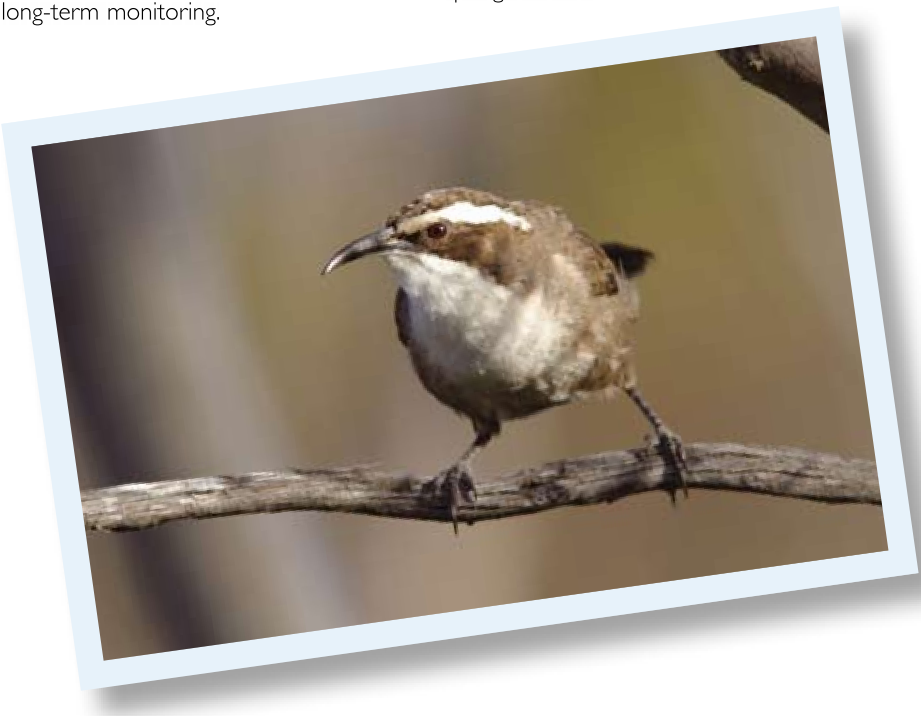
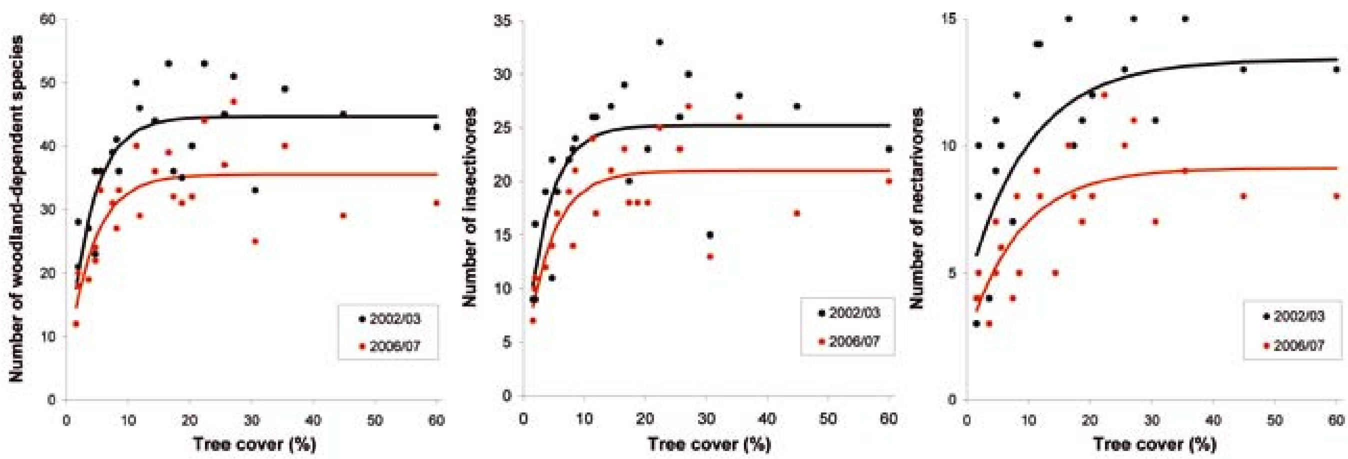


Figure 1: Species richness of woodland-dependent, insectivorous woodland-dependent and nectarivorous woodland-dependent species in each of the 24 study landscapes in 2002–03 (black) and 2006–07 (red).



Seasonal conditions in the region

This study occurred during an extended period of below-average rainfall in the study region, beginning around 1997 and continuing to 2007 and beyond. Between 1997 and 2007, annual rainfall in the region was more than 10% below the long-term average in six of eleven years, with only one year (2000) more than 10% above the long-term average. The 2002/03 sampling period began in the spring of an exceptionally dry year (2002: 47% below long-term average) and the entire 2006–07 sampling period occurred during years of severe rainfall deficit (2006: 44% below long-term average; 2007: 30% below long-term average). There was an almost complete absence of eucalypt flowering in the autumn and winter of 2007.

What happened to woodland birds between 2002–03 and 2006–07?

Species richness

There was a dramatic decline in the richness of woodland-dependent species, and also in the richness of both insectivorous and nectivorous species, in nearly all landscapes between 2002–03 and 2006–07 (Figure 1). There was a mean decrease between the sampling periods of 8.0 ± 0.9 (s.e.) woodland-dependent species per landscape.

Species loss was greater in landscapes with more native vegetation that was arranged in fewer and more aggregated patches. This is consistent with an extinction debt that has been fully realized in highly modified landscapes (low native vegetation cover) but is still being played out in less modified landscapes (medium to high cover and less fragmented) that continue to lose species. Therefore, remedial actions to increase landscape resilience to dampen the legacy of historical clearing should be directed towards medium to high cover landscapes (~10-30% extant tree cover) to stem losses in these landscapes.

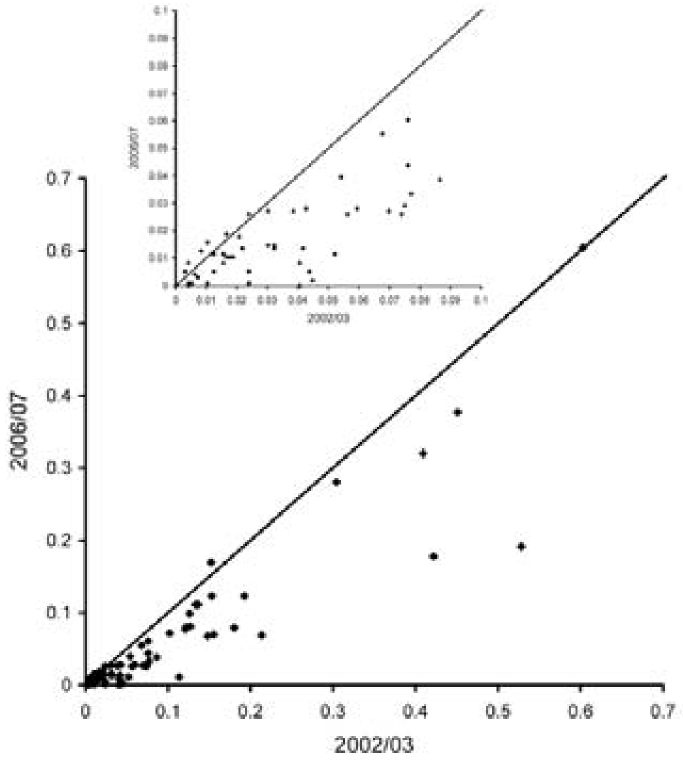
Landscapes with more riparian vegetation experienced smaller declines, suggesting riparian vegetation provides refuge for some woodland species in times of stress. Protection and restoration activities focusing on riparian vegetation should therefore be a priority in all landscapes.

Species abundance

There was a marked decline in the overall incidence (i.e., a measure of abundance) of nearly all species. Of 128 terrestrial species (excluding waterbirds) that were recorded at least four times in one of the sampling periods, 48 species (38%) declined by more than 50% and a further 41 species (32%) declined by 20–50%. Thus, fully 70% of all species were at least one fifth less common in 2006–07 than in 2002–03. Only 11 species (9%) increased by 20% or more over the same period. Of the 69 woodland-dependent species recorded four times or more in one of the sampling periods, 33 species (48%) declined in overall incidence by more than 50% and a further 19 species (28%) declined by 20–50% (Figure 2). A key finding was that the proportion of species that declined was very similar, irrespective of habitat preference, foraging or nesting guilds, mobility, biogeographic range or conservation status.

The decrease in mean species abundance averaged across all woodland-dependent species was greater in higher cover and less fragmented landscapes. However, the rate of decrease of individual species was not generally related to extent or pattern of native vegetation. These results suggest that the extinction debt may have largely run its course in the lower cover landscapes with only hardy species remaining. In high cover landscapes, there were more sensitive species remaining that declined during the course of the study. These results challenge the paradigm that relatively 'intact' landscapes are resistant to population declines and suggest that relatively intact landscapes may not be relied upon to sustain species under current conditions and management practices.

Figure 2: Incidence of woodland-dependent species, pooled across all 24 landscapes, in 2002/03 and 2006–07. All species below the diagonal line were less common in 2006–07 than in 2002–03. Inset is close-up of species with low (<0.1) incidence.



Threshold relationship between landscape-level tree cover and species richness

The threshold relationship between landscape-level tree cover and species richness of woodland-dependent birds detected in 2002–03 was re-affirmed in 2006–07. This indicates the threshold response is a robust and repeatable phenomenon. While the threshold has not shifted significantly, it did increase slightly in the interval between sampling periods, consistent with continued loss of species in moderate cover landscapes.

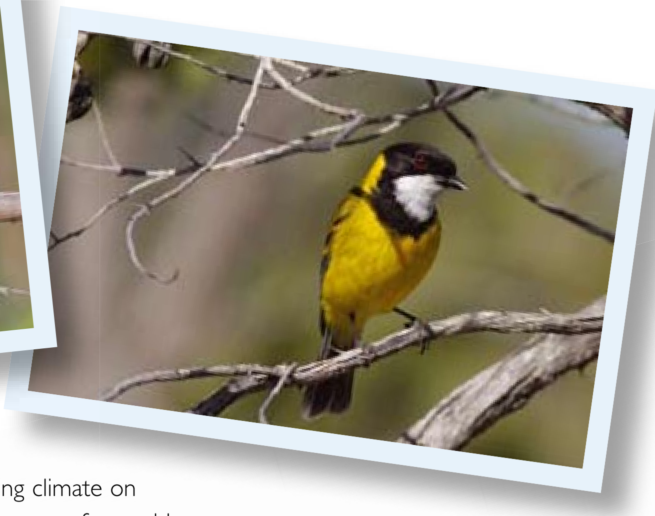
This has significant management and policy implications because it suggests there are particular landscapes where restoration activities could achieve substantially greater benefits for similar investment (i.e. in the steepest part of the response curve) and it provides a quantitative measure for setting minimum levels of native vegetation cover in agricultural landscapes.

We re-iterate our conclusions from the 2002–03 study that the threshold value of 10% tree cover is produced by multiple extinctions at the landscape level. Safe levels must be established well above the threshold: we recommend a goal of at least 30–35% tree cover.

Lessons for now

A call to arms

The substantial and rapid loss of species and population declines across all groups of woodland bird species in all study landscapes are alarming. The dire predictions of massive species extinctions across the temperate woodlands of southern Australia are not only ringing true but may be occurring even faster than predicted. These results should serve as a call to arms that unless dramatic remedial action is commenced immediately, and preventative measures are enacted to prevent further declines, we are likely to



see the disappearance of many relatively common and widespread woodland birds over the coming decades.

Evidence for an 'extinction debt'

The trend for faster species loss in higher cover and less fragmented landscapes is consistent with the expression of an 'extinction debt' in its later phases. That is, a time lag effect in which the consequences of historical clearing and landscape modification are continuing to be realised as species are lost progressively from the most modified landscapes to less modified landscapes. It is likely that the only species persisting in low cover landscapes in 2002/03 were relatively tolerant to landscape change because sensitive species had long since been eliminated from these landscapes. In contrast, high cover landscapes supported a host of species at low density that underwent substantial declines during the interval between sampling periods such that they were undetectable in 2006–07.

Overriding effect of extended dry conditions – a changing climate?

The magnitude and breadth of change detected in a relatively short interval was far greater than anticipated, suggesting a more pervasive driver than simply the legacy of historical clearing. It seems reasonable that population declines may have been compounded and accelerated by the added environmental stress imposed by the extended dry period during which this study was conducted. That is, much of the observed change reflects the impacts of a drying climate on landscapes that under more favourable climatic conditions had been able to support more diverse and abundant woodland bird assemblages.

What should be done?

Simply protecting remnant habitat and incremental increases in revegetation will not be sufficient to prevent widespread extinctions. The urgency and magnitude of remedial action required is several fold greater than current practice.

Three broad strategies are required. First, the protection of existing remnant vegetation is paramount, including small remnants, roadsides and creek lines. Once removed, the cost of replacement is far greater.

Second, extensive revegetation programs on more fertile land to induce accelerated growth must be instituted, with particular attention towards moderate cover landscapes (~10–25%) and riparian areas. Many bird species will breed in vigorous replantings from which recruits may disperse to other parts of the landscape. Multiple pathways for movement at multiple scales must be created through planned enhancement of existing habitat and revegetation. A program to buffer all riparian and wetland systems with native vegetation (e.g. buffer to 1-in-100 year flood line) could form the backbone for a network of local biolinks.

Third, a renewed focus on managing ecological processes, particularly in public estate forests, will re-focus governments, agencies and individuals towards a landscape perspective. This will improve habitat condition through an overhaul of current fire management practices, native and domestic herbivore control, weed control, feral predator control and eliminating extractive industries.

The instruments for implementing new strategies are largely politico-social: tax reform to encourage biodiversity-focused revegetation and remnant protection, participation in the carbon market with a premium for biodiversity-carbon plantings and restoration, government intervention to acquire high-productivity properties and manage them for biodiversity, and a mix of legislative requirements and incentives to promote revegetation and sustainable practices on freehold land. Without these reforms, I fear our forests will fall silent forever.

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or visit the research pages on **www.lwa.gov.au/nativevegetation** .
Project DUV6 has an informative brochure titled *How much habitat is enough?* and both DUV6 and DUV11 have final reports detailing research outcomes.

Are native forests on farms a blessing or a burden?

JVAP: 15 years research unlocking the secrets of forests on farms

Bruce Munday, JVAP Manager (Communications & Projects)

An important aspect of farm forestry involves sustainably managing the private land that remains forested after clearing for agriculture. How do we sustain its range of ecosystem services? Indeed, how do we even measure these? And does harvesting commercial timber from these forests enhance or diminish their ecological value? Can we improve our practices? Are there practical tools for monitoring?

These questions represent just part of the 15-year research agenda for the recently concluded Joint Venture Agroforestry Program (JVAP), a partnership of three R&D corporations to focus and coordinate national research on farm forestry. Those corporations involved were: Rural Industries Research and Development Corporation (RIRDC), Land & Water Australia (LWA) and Forest & Wood Products Australia (FWPA).

Since 1993 the JVAP partners, with support from the Natural Heritage Trust and the Murray-Darling Basin Commission, invested $29 million while leveraging an equivalent amount from research providers and industry.

The outcome of this extensive research effort on farm forestry have been distilled down in a report by John Powell (Optimal ICM) to ten key messages:

1. Except for short-rotation pulpwood, the profitability of 'traditional' farm forestry, including thinning private native forest (PNF), is generally marginal in higher rainfall areas and unprofitable elsewhere
2. Emerging markets (in carbon sequestration, bioenergy and biofuels) have the potential to profoundly change the profitability of farm forestry
3. Lack of early financial returns for 'traditional' farm forestry are being overcome by innovative processing technologies
4. The 38 million hectares of PNF can augment diminishing hardwood sawlog supplies from public native forests. Research into the biodiversity outcomes of good management, combined with metrics to underpin markets in environmental services, will assist
5. JVAP has greatly enhanced understanding of the water and salinity effects of tree and shrub plantings. This knowledge has much to offer the new, more complex challenge – how to achieve an optimal balance between recharge control and runoff
6. Market Based Instruments appear to have particular value for PNF management where there are commercial trade-offs associated with meeting community expectations and standards for biodiversity conservation
7. There appears to be significant potential for good returns on investment from research into farm forestry in the wet and dry tropics
8. JVAP has supported the Australian Master TreeGrower program and plain-English syntheses of its major R&D areas, however there is scope for improving communication and extension initiatives
9. Research into drivers and barriers that influence behaviour of target audiences can optimise time, resources and effort in developing the farm forestry sector
10. Key regional interests must be engaged in planning for Research, Development & Evaluation and on-ground action, particularly where large scale plantings are proposed.

What next?

Woody crops now have unprecedented potential to address many of the economic, environmental and social imperatives confronting Australian farmers and society at large. Farmers in particular seek credible strategies that collectively respond to the challenges of income diversification, carbon markets, climate variability, drought preparedness, sustainable farming and environmental stewardship.

Future broadacre agricultural landscapes can produce this mix of private and public benefits through integrating traditional farming systems with crops of trees and shrubs – a synergy between alternative land uses rather than competition.

The research and policy community increasingly recognise that woody crops are a vital part of future farming systems, and have signalled the need for change, underpinned by targeted and specialised research, development and extension.

Already several partners have committed to work together over a 12-month period to develop a prospective new program, *Woody Crops on Farms*. The developmental year will:

- bring partners and potential investors together to reach agreement on and commitment to a new program's scope, priorities, resourcing and management arrangements
- enable consultation processes that meet the requirements of individual organisations
- align with the strategic planning processes of partner organisations
- provide sufficient lead time for allocating funds
- maintain the momentum generated by 15-years of JVAP investment.

Fifteen years of the Joint Venture Agroforestry Program – Foundation research for Australia's tree crop revolution (by John Powell) and the co-investors prospectus *Woody Crops on Farms – integrating trees and shrubs in broadacre farms for multiple benefits* are available through the Farm Forestry link on the RIRDC website: **www.rirdc.gov.au**

Fifteen years of the Joint Venture Agroforestry Program

Foundation research for Australia's tree crop revolution

JVAP is celebrating fifteen years of its research on farm forestry by pulling together its key findings.

The result is a publication highlighting the broad scope of JVAP and its main achievements, and commenting on the timeliness of JVAP research and the significance of the knowledge generated. It synthesises what is currently known, mostly from JVAP research, about four main agroforestry topics:

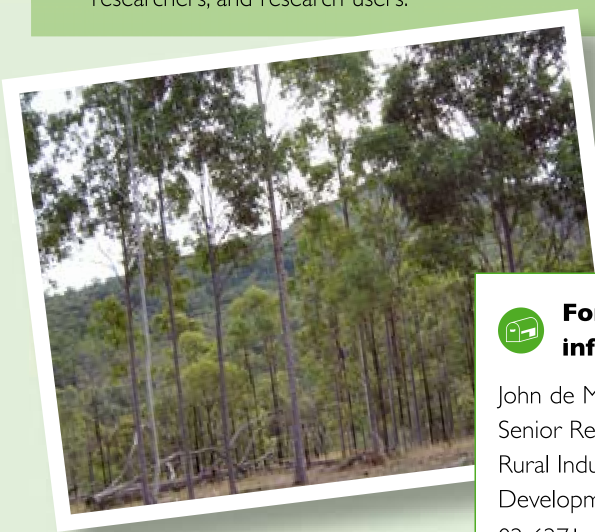
- farm forestry for multiple benefits
- products and markets
- public policy, investment options, grower initiatives
- socio-economic issues, training and extension.

Importantly, this publication interprets the relevance of the knowledge for today's issues. In writing the report, more than 200 research reports, papers, articles and websites were reviewed. For the most part, these were accessed from the RIRDC website.

Where are the gaps?

Six priority issues for a future Research, Development & Evaluation program on woody crops are highlighted in the comprehensive synthesis of JVAP research.

1. Tree crops for carbon sequestration and biomass-related industries
2. High-value, wood-based industries in the wet tropics, and timber products in the dry tropics
3. The social trajectories, and relevant knowledge, attitudes, skills and aspirations of communities who may become involved in growing tree crops
4. Integrating knowledge from 1, 2 and 3 in holistic assessments of the outcomes of industry scenarios and designs
5. Unlocking the potential of private native forests
6. Knowledge sharing between research program investors and managers, researchers, and research users.



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Tracking genes in fragmented landscapes

Linda Broadhurst

The clearing or modification of native vegetation across Australia has altered the way in which many natural processes take place. As remnants become smaller and more isolated a range of changes can occur, such as a loss of genetic diversity, increased levels of inbreeding, reduced opportunities for dispersal, and altered pollinator behaviour and abundance.

These changes can impact on the long term health and persistence of native vegetation. For example, genetic diversity is the raw material that evolution will act on as our environment changes, while inbreeding influences the viability and vigour of seed and seedlings. Managing remnant populations requires an understanding of how fragmentation is influencing these processes.

A recent collaborative study involving CSIRO Plant Industry, Department of Environment and Conservation Western Australia (DECWA) and Land & Water Australia showed that population size and isolation are critical influences on long term viability (Land & Water Australia CPI10 Genetic and Ecological Viability of Plant Populations in Remnant Vegetation). This research also indicated that pollen was moving among remnants over relatively large distances (more than 1 km) suggesting that patches of vegetation may be more connected than previously thought. It is important to understand how connected remnants are, as this may change the scale at which they need to be managed.

The research team has now tracked gene flow via pollen movement among fragmented remnants in two ecologically contrasting biomes – the Mallee woodlands of central western New South Wales and the Kwongan

Kwongan shrublands of Western Australia.

Mallee woodlands of central-west New South Wales.

heathlands and shrublands in south-western Western Australia. Both of these ecosystems have suffered from severe habitat loss and disturbance with the remaining native vegetation being highly variable in patch size and condition. In each biome a common long-lived and bird-pollinated shrub was chosen. *Eremophila glabra* var. *glabra* was targeted in the Mallee woodlands of central west NSW while *Banksia sphaerocarpa* var. *caesia* was selected from the Kwongan shrublands in Western Australia.

The study was primarily interested in tracking gene movement to understand:

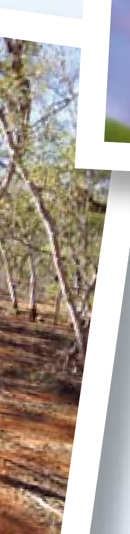
1. how far pollen is travelling across fragmented landscapes
2. whether this movement varies year-to-year
3. if gene flow influences seedling growth and vigour
4. if the arrangement of remnants in the landscape influences gene movement.

Study system

A reference grid was delineated in each biome and surveyed to locate all populations of the study species. Leaf samples were then taken from plants within the populations and genotyped. Seed were also collected from several focal sites within each grid, grown under glasshouse conditions and also genotyped. Each seed was then assessed to determine whether it was 1) pollinated by pollen from within the population and self-pollinated, 2) pollinated by pollen from within the population but from another plant, or, 3) the result of fertilisation by pollen from outside the population. When seed from this latter category was obtained, its genetic profile was compared with the population profiles to determine which was the most likely source of the pollen. This data could also be related to the growth of seedlings in the glasshouse to determine how important the pollen source was to seedling fitness.

Preliminary findings

This research is ongoing but several interesting findings have already come to light. Data from *Eremophila glabra* suggest that almost half of all of the seed set across the study grid is the result of pollen moving between populations and that pollen is regularly moving up to 5 km between these populations. The data also suggest populations do not contribute equally to the seed crop. For example, while the genetic profile of all populations was observed in the seed, approximately 50 % of this seed was pollinated by only four of the twenty populations surveyed. In contrast, another five of the populations contributed pollen to less than 5% of the total seed. These results are now being assessed to determine the importance of pollen source on seedling growth. Further research is being undertaken to determine how bird community structure within the focal sites might influence the way pollen moves between the populations. Other possible influences, including population size and distance between remnants, are also being investigated.



Eremophila glabra *from the highly fragmented Mallee woodlands of central west NSW.*

Banksia sphaerocarpa *from the highly fragmented Kwongan shrublands of WA.*

Data for *Banksia sphaerocarpa* var. *caesia* indicate that pollen movement across this study grid is not as widespread as seen in *E. glabra* but is still high with up to 30% of seed set in some populations due to pollen movement between populations. In some cases this pollen movement appears to be over at least 4 km and sometimes comes from large remnant populations while in other cases is moving from much smaller isolated road reserves. The data also clearly indicates that seedling growth in plants from small remnant patches or along road reserves is significantly slower than that observed in seedlings from larger remnant populations. However, not all small populations behave this way, with seedlings from some of these populations having growth rates similar to those found in large populations. This important finding is now been investigated to assess whether seedling growth is related to the proportion of pollen coming from outside the populations and its geographical location within the landscape.

Management implications

Although these data are still being investigated, the preliminary results support the view that remnant vegetation management must consider population interactions at the landscape level. In many fragmented landscapes this may require the co-operation of different management units such as across several farms or between farms and conservation agencies. The data also indicate that it is possible to improve remnant management by prioritising sites for conservation management based on their relative contribution to the landscape level genetic and demographic dynamics. Furthermore, this research will provide important information for restoring degraded landscapes by identifying where plantings should be placed to maximise interactions with existing remnants.

Research Team

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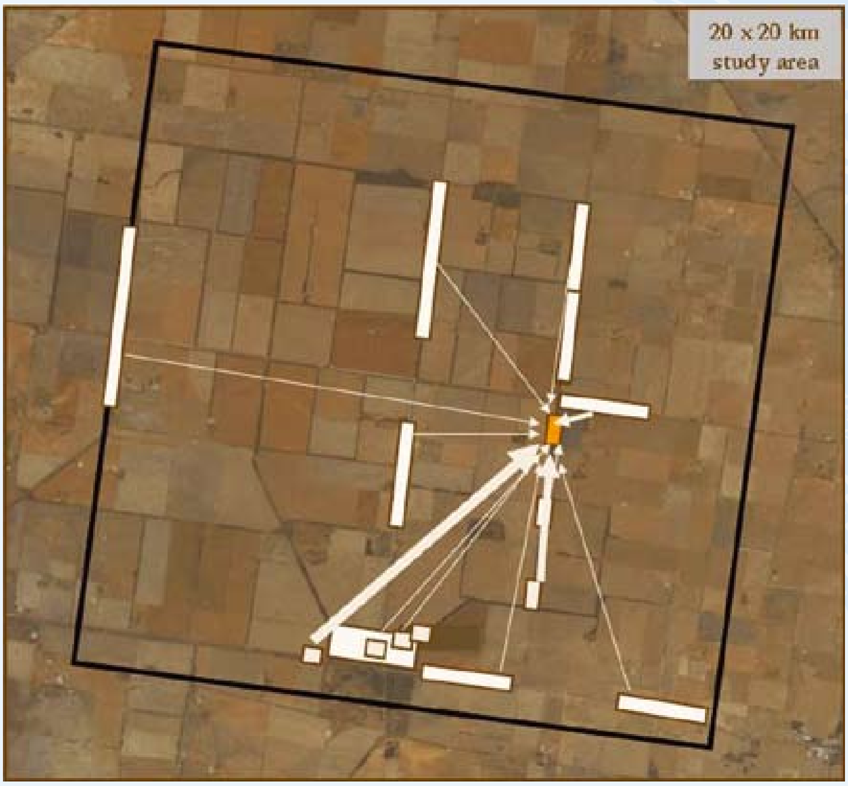
DECWA – Dr David Coates (Dave.Coates@dec.wa.gov.au, phone 08 9334 0490), Margaret Byrne, Colin Yates, Tanya Llorens & Heidi Nistelberger.



This figure shows the contribution of Eremophila glabra *remnants in the study grid (coloured cream) to the seed crop of one of the populations (coloured orange). The size of the arrow indicates the proportion of pollen contributed to the seed crop.*

Green roads out of trouble

Ted Lefroy

Environmental management in Australia is not short of problems. We've become so used to criticism of the way funds are allocated, failure to use the best available evidence and the inability to keep track of where we've been that we tend to miss signs of progress.

The recent Veg Futures conference (November 2008), in Toowoomba provided an opportunity for some optimism. Eighteen years earlier, Greening Australia, the convenor of Veg Futures along with Land & Water Australia, hosted the first national conference of landscape restoration researchers and practitioners in Adelaide. Three changes stood out in the Toowoomba conference.

The first was the quality of the research presentations. The theme of the Adelaide conference was direct seeding and the mantra was local provenance. This was the height of the Landcare movement and the prevailing assumption was that awareness, education and inspiration were all it would take to motivate people to "do the right thing". Public funds would only be required to prime the pump of good will and the paths to adoption were straight and paved.

Most of the presentations at Toowoomba went beyond mechanisms for change, dealing with more sophisticated social and biophysical conceptual models of the problems at hand and acknowledging the importance of the value proposition – why should anyone do this, what is the cost, who pays? They typically also involved more than one discipline, considered multiple spatial scales in their diagnosis and impact, and involved partnerships between government and community or the private sector.

The emphasis on cost effectiveness and the nature of the partnerships revealed the second difference – the emergence of a new social contract in science. It is no longer acceptable for research to be carried out in isolation of the people for whom it is ultimately intended, or to assume that it's someone else's job to promote or extend research findings.

The third big change was the growth of the private conservation sector. This reflects a global movement named the Sustainable Alternatives Networks by the UN Environment Program. Virtually every sector of the economy now has a shadow in the form of these loose affiliations of groups developing alternative ways of carrying out what has been until now the provenance of government and big business. These networks are evident in agriculture, food production, housing transport, energy and nature conservation. Many of these movements originated thirty years ago at the time of the last oil shock.

With the current intersection of concern over food, water, climate, oil and credit, these networks are coalescing and emerging as increasingly viable alternatives to the status quo. The private conservation sector in particular has shown itself to be a flexible, viable and well-organised manager and owner of conservation areas that now extend over hundreds of thousands of hectares in Australia and millions of hectares worldwide, complementing the public conservation estate.

The significance for environmental research is that both the public and private sectors are demanding evidence-based tools and techniques to guide managers and decision-makers and provide greater confidence for their investors.

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What should it cost to fix the environment?

Bruce Munday

In a well functioning market-place buyers and sellers are all satisfied. The willing sellers receive a satisfactory price for what they are good at providing; the buyers obtain a service or a good for a price that they consider reasonable – all driven by competition. Contrast this with the command economy where a central authority funds goods and services for which there might be no real demand and which might be produced by people not particularly well positioned or willing to do so.

The environment as a market place

Market based instruments (MBIs) have attracted considerable interest as a framework for purchasing environmental goods and services such as water quality, carbon sequestration, biodiversity and habitat. However, the perfect market doesn't exist, and this is particularly to be expected in the relatively immature market place of the environment. Nonetheless, even imperfect markets often have redeeming features compared with the difficulty and cost to governments of collecting information and delivering necessary incentives in complex environmental settings.

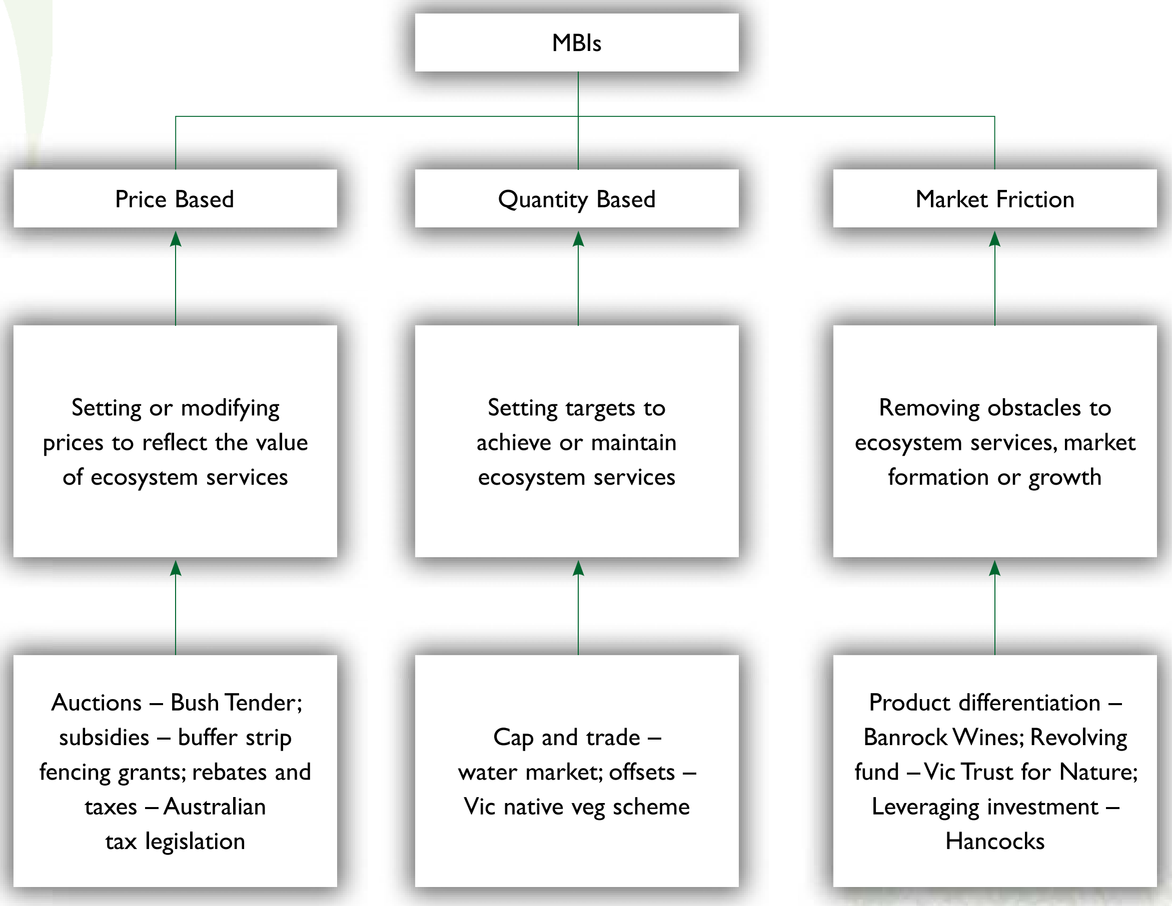
Dr Stuart Whitten's team at CSIRO Sustainable Ecosystems has recently completed a three year project which tackles some of the impediments to regional uptake of MBIs in pursuit of environmental outcomes.

The research by the Markets for Ecosystem Services team put MBI theory into practice, showing how to identify the need for an MBI, what general issues to consider and what principles to apply in designing it.

"This report is not and could not be a recipe book, because the actual design of an MBI should be strongly influenced

MBIs can combine local knowledge with flexible resource management. Photo by J. Powell.

Figure 1: Types of MBIs



by its regional and local context," says Dr Whitten.

"Every region has its unique environmental and socio-economic landscape which we ignore at our peril."

To support this message, the main report has two companion volumes: *'Case studies of Market Based Instruments for Six Ecosystem Services'* and *'Tools and Techniques to Design Market Based Instruments for Ecosystem Services'.*

Markets for ecosystem services can be created through government interventions, depending on whether there are pre-existing markets, the ecosystem services sought, how the service is to be provided, and who the potential market participants are.

Three common interventions to market creation are shown in Figure 1.

The case for MBIs runs on the premise that, in the right circumstances, they can offer a more efficient use of resources than conventional regulatory or broad-based incentive schemes.

So what are these circumstances?

The researchers have interrogated several innovative MBIs and identified key lessons (see Box, p28) that will be of great value to regional organisations choosing this option.

First and foremost they emphasise that MBIs will only achieve their potential benefits if there is strict attention to detail and to overcoming potential obstacles which will require:

- aligning instrument designs and policy objectives
- concurrent or prior removal of perverse incentives
- understanding complex natural resource management problems
- ensuring instruments are performance based rather than overly prescriptive.

Where to from here?

The six detailed case studies provide real-world applications of MBIs and show off the diversity of opportunities they present.

Nonetheless, Dr Whitten cautions that many aspects of MBI design, development, implementation, adoption and effectiveness are still not well understood by regional stakeholders.

"We have identified four key issues that, if addressed, could enhance the effectiveness of MBIs and may also be applicable to a wider range of instruments and settings:

- Designing instruments that encourage cooperative behaviour to achieve landscape outcomes
- Designing effective instruments in environments with biophysical thresholds and discontinuities
- Identifying key information requirements for effective markets
- Designing innovative approaches to support new markets – such as cheap and effective remote monitoring of environmental conditions.

"Most MBI research to date has treated MBIs as a largely isolated instrument that can simply be dropped fully formed among existing or new policy instruments. Our experience with MBIs, as with other instruments, is that this is the exception rather than the rule. Instead MBIs must be shaped to fit with existing institutions, should commence in either a trial or pilot form, and need to be part of a structured mix of policies in order to be effective."

This project was funded by the Joint Venture Agroforestry Program (a partnership of Rural Industries Research & Development Corporation (RIRDC), Land & Water Australia, and Forest & Wood Products Australia), CSIRO and RIRDC's Rangeland and Wildlife Systems Program.

All three reports are available on the Farm Forestry section of the RIRDC website: **www.rirdc.gov.au**

Key findings from CSIRO research, the details of which should make essential reading for organisations considering MBIs:

1. Seek specialist advice to support MBI development
2. MBI benefits rely on the gains from trade and should out-perform other instruments where:
   - there are large variations in the ability of potential participants to provide the desired outcome
   - there is flexibility in the responses that will deliver the desired outcome
   - regulatory approaches are difficult to design, implement and administer
   - there is scope for innovation in improving NRM management.
3. Comprehensive biophysical, community and policy context information is needed to design effective MBIs
4. Choice between the three commonly available forms of MBIs (Fig. 1) is guided by:
   - the presence of existing markets for the desired outcome
   - budget constraints or physical targets for ecosystem services
   - costs of incorrect price or quantity decisions
   - community acceptance of payments for the desired ecosystem service
   - the time to achieve the desired outcome
   - relative transaction costs of design, implementation and administration.
5. Multiple outcome MBIs should only be considered where many sites could produce multiple outcomes and available management actions can deliver
6. Market failure analysis should always underpin and frame MBI design
7. Ensure metric reflects the ecosystem outcome desired
8. Ensure metric considers principles for metric design
9. Identify and integrate necessary support measures
10. Consider benefits of nesting MBI to leverage off existing programs and structures
11. Seek specialist advice to ensure MBI suits local goals and objectives and addresses knowledge transfer requirements early in implementation.

A brown treecreeper. Photo by Megan Jones.

What is connectivity? A new synthesis reveals what works for native birds and mammals

Veronica Doerr

One potential solution to the widespread problem of habitat fragmentation is to protect and restore "structural connectivity" – elements of the landscape that physically link otherwise isolated patches of habitat. The aim is to help animals disperse between habitat patches and carry seeds and pollen to assist with plant dispersal. However, it is unclear what characteristics structural connectivity might need to provide for such dispersal – to provide "functional connectivity" in a landscape. While corridors (strips of native vegetation) have been a popular choice because they make a landscape look connected to human eyes, native animals do not necessarily view the landscape the same way. What features will they move through when dispersing in fragmented landscapes?

Fortunately, we are beginning to be able to answer this question. With support from Land & Water Australia and the Centre for Evidence-based Conservation in the United Kingdom, Dr Veronica Doerr, Dr Erik Doerr and Micah Davies at CSIRO Sustainable Ecosystems recently completed a new type of review to synthesise all existing evidence on connectivity in Australia and provide best-practice management recommendations. They used an approach called "systematic review", in which the search for evidence is exhaustive, and every effort is made to analyse data from all sources, rather than just summarise conclusions.

Below: A well-connected landscape includes multiple forms of connectivity, such as scattered paddock trees, not just continuous corridors. Photo by Veronica Doerr.

Photo by Megan Jones.

Evidence suggests that the eastern yellow robin (left), brown treecreepers (below) and striated pardalote (bottom) can move between habitat patches using stepping stones as well as corridors.

Photo by Orion Weldon.

Photo by Amy Wade.

While data were limited for plants, invertebrates and reptiles, and no data were available for grassland ecosystems, the researchers were able to derive new conclusions about what constitutes connectivity for birds and mammals in fragmented woodland and forest landscapes.

Stepping stones (scattered paddock trees) appeared to be at least as good as continuous corridors for facilitating movement of native species between habitat patches, if not better. The small amount of evidence on gap-crossing abilities suggested that these types of stepping stones need to be no more than 100m apart to ensure that a majority of species will be willing to move between them.

Corridors were also useful for helping species move between habitat patches, but width was unimportant. Both narrow (<10m) and wide corridors (>100m) were equally likely to facilitate species' movements.

However, results did suggest that the *length* of the connectivity was important – a variable rarely discussed in connectivity and landscape planning. Stepping stones or corridors should not extend for more than about 1km before connecting to another habitat patch (preferably at least 10ha in size). When corridors or stepping stones extend longer than 1km, many species may move into them but never travel all the way through to actually reach another habitat patch.

Why are these conclusions different from some of the conventional wisdom about connectivity? Conclusions about the types of structural connectivity we need to protect and restore need to be drawn largely from studies of its primary function as a movement conduit, rather than its secondary function as habitat. Yet many common perceptions were formed based on studies that investigated the value of structural connectivity as habitat for everyday living. Structural connectivity may provide a small amount of habitat for settlement and reproduction, but its primary function is to facilitate movement between larger, better habitat patches. The characteristics it needs to have to perform these two functions appear to be quite different.

Unfortunately, the review also revealed that for approximately half of all species studied, there was no evidence of movement between habitat patches regardless of whether or not corridors or stepping stones were provided. This suggests that a number of native species may not be able to persist in fragmented landscapes no matter what kind of structural connectivity we provide.

To summarise the main management recommendations from this systematic review:

- Protect and restore multiple types of structural connectivity, with a particular emphasis on stepping stones (paddock trees, ideally with associated shrubs and logs) in addition to corridors.
- Ensure that gaps between stepping stones or gaps in corridors are no wider than 100m.
- Concentrate on connecting habitat patches at least 10ha in size separated by no more than about 1km – longer stretches of connectivity are less likely to be effective.
- Remember that connectivity is designed to provide for movement, not necessarily habitat for everyday living, so don't evaluate the success of connectivity simply by the species found living there.
- Protect and manage large areas of continuous habitat as well, since not all species may be able to persist in fragmented landscapes even with structural connectivity.

Finally, the systematic review approach used in this study holds some promise for helping us make better, more evidence-based land management decisions. Systematic reviews are thorough and repeatable, and are specifically designed to answer questions posed by land managers. More widespread use of systematic reviews would greatly improve the cost-effectiveness of natural resource research and management in Australia by identifying the most critical research gaps and improving confidence that management decisions will achieve the desired results.

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Many birds and mammals can move between habitat patches using scattered paddock trees, but only if the trees are separated by less than 100m. These trees are at that limit. Photo by Veronica Doerr.

Landscape-scale reconnections on Victoria's Volcanic Plains – Conservation Volunteers give the Hopkins River a new head start

Patrick O'Callaghan

Victoria's Volcanic Plains stretch across almost the entire west of the state, but the extent of their grasslands and grassy woodlands has shrunk to a thin patchwork of very small reserves and privately retained remnants.

Amidst this landscape of large grazing and cropping farms, the Hopkins River winds its way south from Ararat to its estuary at Warrnambool. For years it has suffered from the all too common litany of land management abuses – extensive clearing, unfettered stock access, overgrazing of native seedlings by rabbits and loss of connection to surrounding native vegetation. The Hopkins River is currently listed as one of Victoria's worst-condition waterways.

Here today, not tomorrow – scenes of cattle pugging and damaging the Hopkins River are now a thing of the past on Jim Cochran's property. Photo by Patrick O'Callaghan/Conservation Enterprises Unlimited.

Whilst the effects of past land use will take many years to reverse, a project to combat soil erosion on private farmland north of Hexham, a small village mid-way along the river, has been helping the Hopkins to get back on its feet and once more find its place within the landscape.

Funding from the Australian Government has enabled Conservation Volunteers Australia and project partner Conservation Enterprises Unlimited to work with farmers in the region to install over 20kms of river-bank fencing and plant 20,000 local provenance grassy woodland plants along and adjacent to the Hopkins. The farmers involved in the project have contributed a considerable amount of their own time and resources to the project, making the funding dollars go even further.

Local farmer Jim Cochran, who owns "Cobra Killuc" at Hexham, has farmed sheep and cattle for years. Like many farmers across the Volcanic Plains, he is increasingly moving into cropping. Jim's involvement in the project grew from his increasing concern that the river's report card was so poor, and knowing that a substantial part of its length was surrounded by his farm. He also recognised that, as well as reducing erosion and helping improve the health of the Hopkins, the project would also help the productivity of his farm. "The trees planted by the project will give some extra protection to lambing ewes, and after a few years will also attract more birds to the farm, which of course will then help us with things like controlling insect pests for crops" he said. "I would like to think that by being part of this project, we'll see the river and the whole district landscape become that much healthier."

"Salt Creek", a property which adjoins Cobra Killuc, and "Bushy Creek", situated higher up in the Hopkins' catchment, will also contribute to the health of the river and soil protection with native trees, shrubs and grasses planted and direct seeded in fenced areas on the properties. At Salt Creek, near-extirpated populations of Manna

A Conservation Volunteers team puts finishing touches to stock-exclusion fencing along the Hopkins River near Hexham, Victoria. Photo by Patrick O'Callaghan/Conservation Enterprises Unlimited.

gums (*Eucalyptus viminalis*) are forming the basis of reconnections between the Hopkins and the Cobra Killuc Wildlife Reserve, one of only 3 small reserves in this region of the Plains.

Local Landcare secretary Jane Calvert considers the project, which involves volunteers from the local community working side by side with international students, to be a wonderful example of community support for farmers and for the health of important rivers such as the Hopkins. From her nearby property "Hopkins Hill", Jane has seen the slow and often difficult process of landscape restoration take place along the river. "Since our Landcare group was formed we have encouraged all the farmers along the Hopkins to fence and tree and grass it off from gazing. In those reaches where it has been completed for a few years now, the results are very pleasing. This new project represents an important new linkage along the river and across the landscape and will only continue to assist this improvement".

The project has made use of some innovative technology to ensure that the fencing and planting will deliver the best outcomes. Using software known as the Catchment Management Framework (CMF), developed by the Department of Sustainability and Environment, the project is able to make direct links between planting and fencing a specific location and the benefits this will provide to soils, water and biodiversity. Drawing on multiple NRM databases and relying on expert modelling of ecosystems, hydrology, soils behaviour and other relevant factors, the CMF acts as a decision support program to optimise the project's investments in fencing and revegetation, essentially giving the best landscape results possible with the funds available.

Conservation Volunteers has a strong history of working with farmers around Australia, including post-fire recovery works, tree-planting and weed control. Colin Jackson, who heads up the national non-profit group, said that volunteers on the Hopkins River project have come from as far away as Korea and Germany. These volunteers are integral part of the winning combination of community support, willing landowners and scientific guidance that is giving the Volcanic Plains along the Hopkins River a chance – reconnecting both the landscape and the people who continue to shape it.

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Status of Australia's revegetation information 2009

Richard Thackway and Christine Atyeo

Land managers are increasingly aware of the need for land protection and vegetation enhancement, and this has increased investment in revegetation activities. Currently, national information about location, size, type and success of revegetation activities is limited, inconsistent and largely anecdotal.

The Bureau of Rural Sciences has worked with key agencies in the Australian and State and Territory Governments, as well as CSIRO and Greening Australia, to develop and test a set of core attributes for consistently describing and mapping revegetation activities [September 2007, *Thinking Bush* Issue 5 page 26].

The newly-developed revegetation attribute framework provides land managers and NRM agencies with the opportunity to collect and compile revegetation data, as well as report on and evaluate the success of revegetation activities.

Testing of the core attribute framework included translating and compiling existing datasets and collecting new information about revegetation activities. The core attributes apply at a point or map unit in the landscape, at a particular time, and can include repeat visits. The core attributes were evaluated across different climatic regions and for a range of revegetation purposes including land and soil protection from erosion and the maintenance of water quality, establishing or improving wildlife habitat and the sequestration of carbon.

Data and information are stored in the Collaborative Australian Revegetation and Restoration Information System (CARRIS). CARRIS can be used to identify what revegetation data are available in an area of interest, how much revegetation was established at a point in time or what change has occurred over time. This information can be used to set priorities and to inform investment in NRM activities at the regional scale.

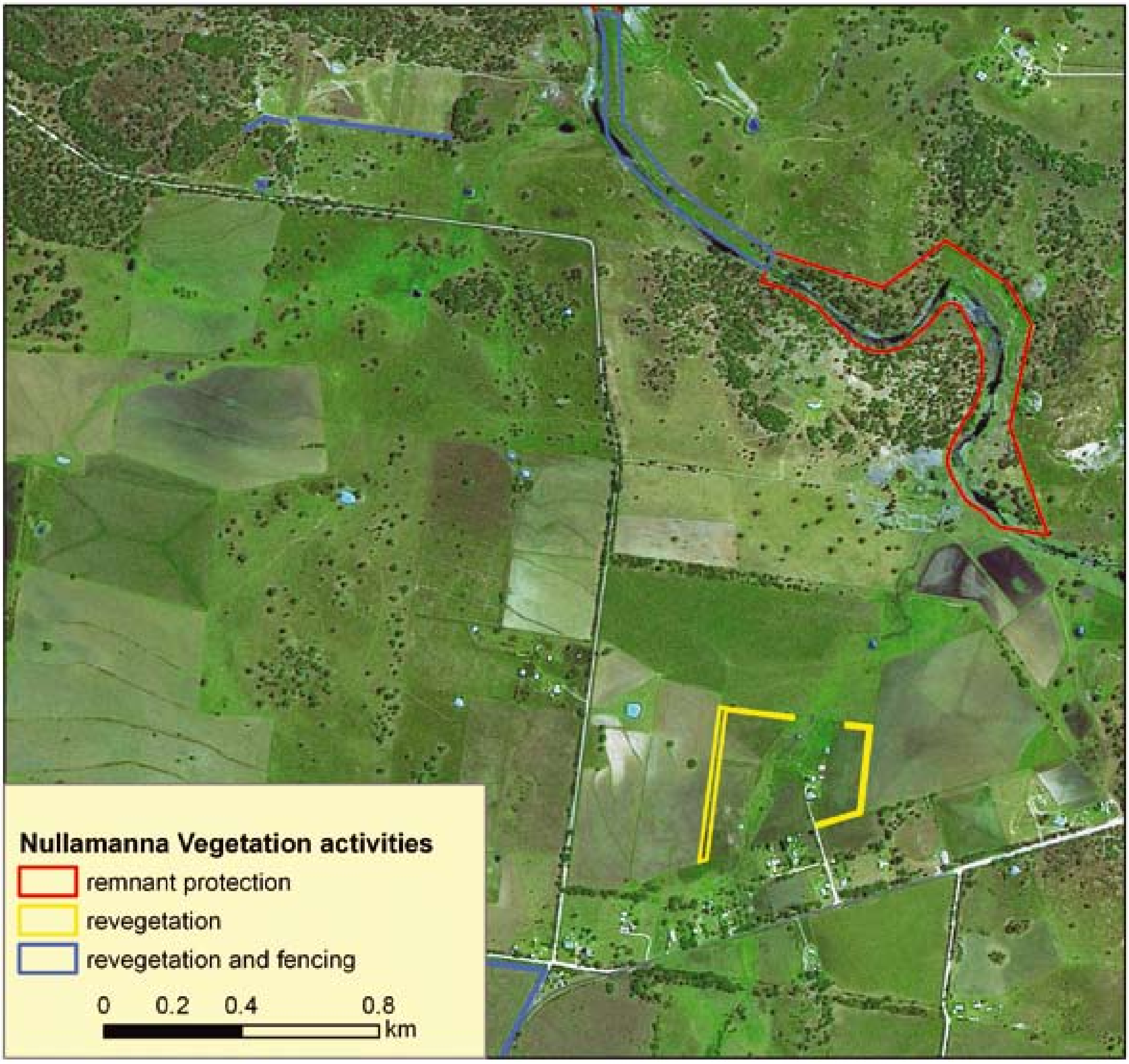
Online tools are also being developed as a component of CARRIS to assist land managers with data collection as well as monitoring and reporting. The core attributes have been developed as part of an online data collection tool, which is designed to guide what information should be collected by land managers to assess the success of revegetation methods and to gauge the effectiveness of public investment. The attributes also provide a framework for the collection of spatial information about revegetation.

The attribute framework and the information which is being compiled into CARRIS in partnership with Australian and state and territory agencies, as well as non-government agencies and regional bodies, could form the basis of a regular update on the status of Australia's revegetation activities.

Examples of the information from regional projects that is being compiled into CARRIS are shown opposite.

Above: Various tree species planted primarily for farm forestry and soil protection. Photo by Gregory Heath.

Right: Tube stock revegetation planted for farm forestry and biodiversity enhancement. Photo by Bob Schuster.



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Past revegetation and enhancement acitivities in the Nullamanna area of NSW. Data from the CARRIS database overlaid on SPOT imagery. Data source Andre Zerger – VegTrack, CSIRO.

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Bureau of Rural Sciences

The birds, the ants and the ungulates: biodiversity and primary productivity in the modified landscapes of the mulga lands

Teresa Eyre, Alan House, Giselle Whish, Rod Fensham, Jian Wang, Dan Ferguson and Michael Mathieson

The semi-arid environment of the mulga lands of Queensland is famous for many things; bilby breeding and clear skies for stargazing included. However, from a land management perspective, highly variable rainfall, a long history of domestic grazing by sheep, cattle and, increasingly, goats, and extensive consequent degradation have shaped the current environment of the mulga lands.

In other regions stock numbers fluctuate with prevailing market conditions and, importantly, with the incidence of drought. This helps preserve the land during adverse seasonal conditions. However, the unique characteristic of pastoralism in the mulga lands is that if ground forage is not available, then stock can eat the leaves from the mulga (*Acacia aneura*) trees. While this means that pastoralists can sustain stock numbers during drought, it also means that the cycle of land degradation associated with over-utilisation continues uninterrupted. As an added consequence of various approaches to pushing, pulling and selectively lopping mulga for fodder harvesting, landscape-scale patterns of cleared, regrowth and remnant mulga are distinct. It was these patterns of vegetation in the landscape, and the fact that knowledge of biodiversity in the mulga lands is extremely limited, that piqued our interest and led to this project, which was supported and funded by Land and Water Australia.

The primary objective of the project was to investigate how birds, reptiles, ants, flora and soil function varied across the various mulga states, at local and landscape scales, so that we could make recommendations on management to help sustain these values.

Surveying flora in the regrowth mulga, with remnant mulga in the background. Photo by T. Eyre, Department of Environment and Resource Management.

We detected 95 bird species at the 80 fauna sites we set up. However, bird abundance and composition varied considerably across the different mulga states within the landscape. Weebill, rufuous whistler, white-browed treecreeper, chestnut-rumped thornbill and red-capped robin were all identified as needing large intact tracts of remnant mulga. These species have all been identified as in decline, predominantly in response to increased habitat loss and fragmentation in the more southern and eastern parts of their range. Conversely, the yellow-throated miner, like its co-generic, more coastal cousin the noisy miner, appears to enjoy inhabiting modified landscapes, and the more extensively modified the better. We are still trying to work out if, like the noisy miner, the yellow-throated miner exerts a negative, bullying effect on the distribution of the smaller bird species.

We have not seen such clear patterns in the reptiles, although we have identified a number of species that appear to be very sensitive to fragmentation of remnant mulga, preferring to inhabit large intact patches of mulga. These include the arboreal skink *Cryptoblepharus pannosus*, and the arboreal gecko *Oedura marmorata* (pictured). These species also need to have a number of large, mature mulga trees.

Ants are "ecosystem engineers" and known to be sensitive to environmental change, responding quickly and predictably to changes in habitat conditions after disturbance. We looked at ant communities in remnant and regrowth patches to see what they could tell us about the way the ecosystem was coping with tree clearing. We sampled ants using pitfall traps in June 2007 and April 2008 to represent winter and late summer seasons. The 161 species we found show some preference (at community level) for either remnant or regrowth mulga, at least in warmer conditions, but this trend is not pronounced and many species are found in both habitats. The removal of trees in these landscapes alters ant habitat conditions, but not drastically. However, increased seeding of exotic forage grasses (such as buffel) and higher stock numbers may lead to a different and less acceptable outcome.

In the floristic data we are seeing geographic variation in species composition. Sites on properties in the north of the mulga lands are significantly different to those in the south. However, we still need to tease out the influence of rainfall and soil factors, as well as grazing management. The mulga lands are largely a non-weedy landscape, and there do not appear to be any fragmentation edge effects with regard to variation in floristic composition.

This project also contributed new knowledge on rare species. The botanists came across a rare plant, *Elacholoma hornii* (family: Scrophulariaceae), an annual and very small, cryptic herb. The Queensland Herbarium has only two specimens in its collection. The owners of the property where this plant was found were very proud. We also found a rare snake, *Furina barnardi*, a small, nocturnal species which has not previously been recorded from the mulga lands.

From a net primary production perspective, the conversion of remnant mulga to regrowth causes a reduction in organic matter inputs and/or a disruption to decomposition and nutrient cycling processes, resulting in lower organic carbon and nitrogen levels. Soft mulga soils have inherently low salinity and chloride contents; however, the removal of trees and their deeper root zones resulted in an increase in the accumulation of salts in regrowth soils.

Regrowth areas had about a third more bare ground; less overall ground cover; and a higher proportion of log bed patches, but less total patch area, than remnant sites. Bare ground is considered a 'runoff area' where vital resources (soil, nutrients and water) are moved by water or wind. These resources may be captured within 'patches' or may be lost from the system altogether. Soil condition was better in remnant areas with litter and cryptogam cover in the bare ground runoff areas, and slower movement of resources, contributing to a more stable soil surface that rainfall could infiltrate.

Odontomachus ruficeps, *an opportunist, predatory species found mainly in mulga regrowth. Photo by Belinda Walters, CSIRO.*

Grass production overall was low but consistently higher in regrowth areas, particularly grasses other than the perennial, productive and palatable grasses important for grazing land management. However, the short term benefit of increased grass in pushed or pulled mulga areas to grazing enterprises may be less significant if considered against potential costs of a disrupted grazing system on the production and profitability of the enterprise into the long term. These potential costs include reduced organic matter inputs, increased accumulation of salts at soil surface, increased runoff and loss of vital resources, disruption to nutrient cycling, and decreased resilience of the system to recover from stresses such as fire and droughts.

We would like to take this opportunity to acknowledge and thank all of our collaborating land managers, who allowed us access to their properties, showed us around, and shared their knowledge with us on mulga management. Also warm thanks to Land & Water Australia for supporting and funding this research. It would not have happened without you.

The arboreal gecko, Oedura marmorata, *prefers large tracts of remnant mulga with big, mature trees. Photo by Michael Mathieson, Department of Environment and Resource Management.*

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Australian Government
Land & Water Australia

Land & Water Australia commenced in 1990 as the Land & Water Resources Research and Development Corporation, one of 15 Rural Research and Development Corporations established by the then Minister for Agriculture, John Kerin. As a result of its recent abolition, this will be the last edition of Thinking Bush. We plan to maintain the website, and through it access to publications of LWA and the programs it has managed. We wish to thank you for your interest in native vegetation and biodiversity.

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