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Restoring Landscapes with Confidence

State of Knowledge Discussion Paper on Landscape Restoration Science in Australia

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Executive Summary

The field of landscape ecology/restoration is around two decades old in Australia. A number of key publications and landscape-scale experiments mark the beginnings of the topic as a research focus in the late 1980s, with interest gaining pace over the last decade.

Landscape restoration science has focussed on a number of 'themes', including connectivity and corridors, buffers and edge effects, vegetation patterns in the landscape, ecological processes and disturbance, resilience and recovery. The focus varies geographically in Australia and includes both increasing the extent of native vegetation in highly cleared areas and maintaining and enhancing vegetation condition across all landscapes. Research has largely focused on animals, less on plants (apart from vegetation as habitat), and even less on soils, although these areas are starting to gain more attention. The context where landscape restoration research is undertaken and applied is critical, as is setting clear restoration goals. While conservation planning approaches and tools are not usually included in the ambit of landscape restoration science, they have an important role to play and are of keen interest to policy and on-ground practitioners.

The main restoration approaches used by groups and organisations at the regional level in the intensive land-use zone include 'focal' species, thresholds, improving vegetation condition, managing for structural and floristic diversity, and connectivity/corridors. The concept of ecosystem services is also being increasingly adopted, but there is limited quantitative information available that is relevant to regional decision-making. Emerging trends see an increasing number of large-scale 'biolink' style projects to combat threats such as climate change and continuing fragmentation. These 'biolink' style approaches currently have a limited scientific basis, however, this is starting to be addressed.

The choice and application of these approaches by policy and on-ground practitioners spans the intuitive to the systematic. One of the reasons why the application of landscape restoration science is not as systematic as it could be, is related to the extensive range of landscape restoration approaches, tools and guidelines currently available. This diversity means that it is difficult for practitioners to work out which approach or technique best applies to them and the

work they are doing. It was largely felt amongst those involved in a recent study on landscape restoration theory and practice (see Lovett *et al* 2008) that there were already enough landscape 'principles' available, and the challenge was providing guidance on how to select the most appropriate set of guidelines and tools for the landscape restoration goal at hand. Landscape restoration theories and approaches needed to be demonstrated in action, with the 'real life' challenges and opportunities they bring, clearly communicated.

A number of trends and influences on landscape restoration science and its application exist. These can be summarised as 'from pattern to process', 'from patch to continent', 'from static to dynamic (space and time)', 'managing the matrix' (in intensively managed landscapes)', 'the direct and indirect impacts of climate change' (including the 'carbon economy'), 'intensification of land use', 'increased use of technology' and a suite of policy tools such as market-based instruments and offsets. It is important that these factors are kept in mind when undertaking, implementing and evaluating landscape restoration science.

It has been acknowledged that much of the significant body of knowledge gained over the last twenty years has had limited bearing on the on-ground management of landscapes, and that there is a need for more effective knowledge transfer and deeper exploration of this process. Some of the areas identified in trying to enhance the uptake of research include building relations, using cultural translators (knowledge brokers), user-friendly publications, building capacity (e.g. on-ground, institutional, students, supervision) and developing research agendas with end-users.

As well as paying more attention to the way science is translated into practice, there is a need for disciplines such as ecologists, economists and social scientists to work more closely together, in partnership with end-users. A number of research gaps have been identified, such as examining the transferability of results between regions, gaining a better understanding of the long-term impacts of restoration and 'bio-link' projects on biodiversity outcomes, and the need to undertake a series of large-scale experimental trials of different landscape restoration approaches in an adaptive management framework. Until stronger links are made between research and adoption, such investment will not maximise the potential to influence policies and on-ground programs.

1. Defining landscape restoration

Restoration ecology is a relatively young science, particularly at the landscape level. Even so, over the two decades that research has been undertaken in this area in Australia, there has been a large amount written and spoken about this topic. The definition of landscape restoration used in this project has been adapted from the definition of ecological restoration developed by the Society for Ecological Restoration International, as follows:

> *"Landscape restoration is the process of assisting the recovery of a landscape that has been degraded, damaged or destroyed. It is an intentional activity that initiates or accelerates landscape recovery with respect to its health (functional processes), integrity (species composition and community structure) and sustainability (resistance to disturbance and resilience)."*

Restoration overtly attempts to recover a pre-existing condition close to the original state, although this will rarely be possible in practice. The related practice of *rehabilitation* also seeks to improve the condition of degraded areas to resilient, self-supporting ecosystems, but not necessarily in the direction of the pre-existing state (Bradshaw 1997). Many research and on-ground projects in Australia do not explicitly differentiate between restoration and rehabilitation, so in this discussion paper the term landscape restoration is used to cover both of these activities. Consequently, it includes science and on-ground practice that aims to improve the condition of degraded areas, but not necessarily to the original state. Landscape restoration can encompass many factors such as biodiversity, water quality and quantity and nutrient cycling. For the purposes of this review, the focus is on the retention and restoration (via improved condition and/or extent) of native vegetation for biodiversity values.

Also of importance when defining landscape restoration, is identifying the scale at which one works. Intuitively, there is general agreement that landscapes are areas covering tens of square kilometers or more. Radford *et al*. (2007) describe landscape restoration as an approach that explicitly recognises and is concerned with maintaining or restoring interactions and flows across adjacent ecosystems or elements of the landscape. Others argue that the size of landscapes differ depending on which organism is being studied. For example, a landscape for an organism like a bug may only be a few square meters, whereas for a flying fox it could be several kilometers. In reality, research undertaken at a number of scales can inform patterns and processes at the landscape scale. As on-ground activities to meet landscape restoration goals are undertaken at the site scale, the importance of addressing landscape restoration at a number of scales becomes more important.

Given the diversity of ways terms like landscapes and restoration are used, it is critical that precise definitions are given in any project, policy or on-ground program that claims to be addressing landscape restoration.

2. Background and approach used

This discussion paper is part of a larger project that examined how well the science of landscape restoration is embedded in day-to-day practical approaches at the regional level (Lovett *et al*. 2008). It investigated what makes some research relevant, meaningful and easily integrated. Land & Water Australia (LWA), who supported this project, were particularly interested in how landscape restoration science was used by the NRM regions that had been funded through the second phase of the Natural Heritage Trust. It was apparent, however, that many other organizations, particularly in the non-government sector, were involved in restoration projects at the landscape scale. Indeed in many cases they were driving some of the more ambitious 'biolink' style projects.

All landscapes of Australia are covered by the larger project and this discussion paper, from the relatively intact regions in the north, to the highly fragmented regions in southern and eastern Australia. The scope of the project was ambitious for the resources and time available, putting some tight boundaries on what could be covered in this discussion paper. Originally it was intended to undertake a 'state of knowledge' review of landscape restoration science. However, it soon became apparent that it would take several months of concerted effort to systematically review the volume of the literature that has been generated on landscape restoration and related topics. Consequently, this ‘state of knowledge’ discussion paper presents a number of perspectives on landscape restoration science and its application, as described below.

The Discussion Paper draws on three main elements that address landscape restoration science from different perspectives:

1. a survey of some of the leading landscape ecologists in Australia;
2. a desk-top review of the major Australian literature on landscape restoration science; and
3. the workshops and desktop studies undertaken as part of the larger project.

1. A survey of some of the leading landscape ecologists in Australia.

A list of landscape ecologists was drawn together with input from the project steering committee. Scientists were sent an invitation by email in early January inviting them to answer four questions (Box 1). Many people were on holidays at this time, so subsequent reminders were sent over the proceeding weeks. Some additional scientists were also invited to contribute at this stage. The scientists were able to respond either in writing or over the phone, with most taking the former option.

Box 1: The four questions on landscape restoration that ecologists were invited to answer.

1. What currently available landscape restoration research/principles are relevant to achieving on-ground outcomes for native vegetation and biodiversity?
2. How successfully is this research being applied by regional NRM agencies?
3. What, in your experience, are the key factors influencing the uptake of landscape restoration research by regional NRM agencies?
4. Are there major research gaps on landscape restoration that need addressing?

The intent of these questions were to help ensure the review covered the most recent research undertaken on landscape restoration, identified what new research was considered important, and captured the views of scientists on what they thought were the barriers to the uptake of their research by regional organisations and groups. Over 20 scientists responded to the invitation. The level and depth of response was encouraging and added another dimension to the discussion paper, which was originally only intended as a desk-top review.

2 Desk-top review of the major Australian literature on landscape restoration science.

To ensure that the main themes and issues were covered, a number of synthesis publications were used as sources of information. These included Lindenmayer *et al*. (2008), Lindenmayer and Hobbs (2007a), Radford *et al*. (2007), Huggett (2007) and Williams (2005). The focus of landscape restoration has been on the highly cleared areas of southern and eastern Australia, so these publications tend to focus on these regions. The exception is Williams (2005), which assessed a range of research and resources on native vegetation management across Australia, several of which are relevant to landscape restoration. A useful addition to the literature on landscape restoration would be a synthesis of research and principles from the more intact landscapes of the arid zone and tropical savannas.

These publications were chosen because they provided an entry point to a large amount of relevant material, were recently published and were relevant to work being undertaken on the ground by catchment management authorities and equivalents across Australia. Several researchers contacted through phone interviews also pointed to the book (and associated paper) by Lindenmayer and Hobbs (2007a), as being a key document on the latest thinking about landscape restoration. A number of other references have been used in the review to complement these documents. Where possible, these were also papers or books that synthesised current thinking and acted as a point of reference to further work. To add to this information, the lessons learnt from projects underway or recently completed, but not yet published, were also included.

3: Workshops and desktop studies undertaken as part of the larger project.

The Discussion Paper has drawn on the four regional workshops and four desktop studies that were undertaken as part of the larger project on the application of landscape restoration science at the regional level (Lovett *et al*. 2008). The workshops were held between the end of February and mid-April in Nagambie (Victoria), Cowra (NSW), Albany (WA) and Emerald (Queensland), with comprehensive reports written on each to capture the key learnings. To provide national coverage, desktop studies were undertaken for the ACT, NT, Tasmania and South Australia. Both the workshops and desk-top studies drew on questionnaires that had been sent to people to explore issues related to the application of landscape restoration science. A summary version of the Discussion Paper was tailored for each of the regional workshops. This was sent to participants in advance of the workshops to act as a background document and conversation starter.

The workshops and desk-top studies provided a wealth of information on the type of research that was being applied at the regional level, as well as identifying the issues of importance to practitioners (both on-ground and policy). The interests of workshop participants have been reflected in the Discussion Paper, for example, the emphasis placed by different groups on prioritization/planning tools that are applicable at the landscape scale, resulted in a separate section on landscape/conservation planning tools being included in the final document. Another key theme that arose was the increasing use of technologies such as remote sensing and GIS, and the range of issues that surround their use.

While the terms of reference for the Discussion Paper focus on the biophysical aspects of landscape restoration, the workshop reports and desk-top studies placed strong emphasis on the importance of the human elements of landscape restoration, and the impacts of costs, other constraints and the role of interactions among people. These topics are beyond the scope of the Discussion Paper, but are briefly covered in Section 10 of the document.

3. The beginnings of landscape restoration science

Restoration ecology is a relatively new sub-discipline of ecology that developed from mine-site rehabilitation, post-logging recovery and habitat manipulation for the management of game species (Radford *et al.* 2007). Early restoration efforts concentrated on site-specific processes, such as re-establishment of vegetation and re-introduction of species of interest in damaged sites. The emergence of landscape ecology – the study of spatially heterogeneous land mosaics and the interactions between landscape structure and function as they change over time (Forman and Godron 1986) – complemented the need for a broader spatial perspective in restoration ecology.

In Australia, the ‘Nature Conservation’ series of books raised awareness about native vegetation management in highly cleared landscapes, with the first book being published in 1987 (Saunders *et al*. 1987). This series of books identified a range of issues that are still being explored, including a seminal work on corridors (Saunders and Hobbs 1991) and the reconstruction of fragmented ecosystems (Saunders *et al.* 1993). The wealth of information in these books perhaps does not always get the recognition (and citations) they warrant, with a tendency for researchers and practitioners alike to refer to the most recent work on a topic. Partly this is related to challenges keeping up with the large volume of literature on landscape restoration and related topics. While it is important to keep up to date with the latest thinking, it is also important to acknowledge the earlier work and draw out the key learnings.

One of the first large-scale experiments in fragmented systems, called the ‘Wog-Wog Habitat Fragmentation Experiment’, was established twenty years ago (Margules 1992). In northern Australia, the Kapalga fire experiment (Andersen *et al*. 2003), the first landscape-scale fire experiment in the country, was being developed at the same time. This initial ground-breaking work set the scene for the explosion – relatively speaking – of landscape scale experiments and literature that took place in the last decade.

Programs that focused more attention on managing natural resources and biodiversity on private land, such as Landcare and Community Management Networks have also helped pave the way for a greater appreciation of conservation values on private land. They have also provided a mechanism for translating science into practical on-ground information. The Land for Wildlife newsletters and technical notes, which started in Victoria around 1990 (Platt and Ahern 1995), are seen as a very successful avenue for translating science into practice (Andrew Bennett, personal communication). This model has been adopted elsewhere in Australia with varying levels of uptake, but other programs have played a similar role elsewhere.

4. Gaining pace

The science and application of landscape ecology has gained considerable pace in recent years. Some of the key influencers in raising awareness about landscape restoration over this period include:

1. Land & Water Australia's Native Vegetation and Biodiversity Program started in 1998 and invested a range of projects focusing on the topic of landscape restoration.
2. *Ecological Management and Restoration* journal – started in 2000 providing a reference point for researchers on topics relating to landscape restoration.
3. The Norman Wettenhall Foundation ran a workshop in October 2007 called *Landscape restoration – creating long-term resilience*. The Australian Landscape Trust has also started using the term and investing accordingly.
4. Non-government organisations such as Greening Australia and Bush Heritage Australia are adopting a landscape-scale approach to managing native vegetation and biodiversity.
5. New research groups began emerging in academic and other institutions that had a focus on landscape ecology/restoration. Examples include: Landscape Logic (University of Tasmania); Applied Environmental Decision Analysis (University of Queensland); Landscape Futures Alliance (Monash University); a loose group in Victoria around ecological processes (linked to the Victoria Naturally initiative); the Ecosystem Restoration Laboratory, Murdoch University (Hobbs and others); and Australian Research Council Research Networks such as the one on vegetation function run out of Mark Westoby's group at Macquarie University.
6. In particular, the last ten years has seen a major growth in landscape-scale projects – both in the research sector and on-ground projects (Table 1). Examples include:
    - the six major landscape-scale projects in south-eastern Australia overseen by David Lindenmayer at ANU (http://fennerschool-research.anu.edu.au/cle/);
    - The BioAssess project around Holbrook (or 'Return of the dawn chorus to NSW farmland') (http://www.csiro.au/science/ps1vq.html);

- the Mallee Fire and Biodiversity project (a relatively new fire regime project in the NSW/SA/Victorian mallee) (http://www.zoo.latrobe.edu.au/Staff/mfc/Mallee/);
- the research on thresholds by Andrew Bennett and Jim Radford in northern and central Victoria (Radford *et al*. 2004, 2005) and
- research in south-east Queensland by Neil McLeod and other on applying landscape-scale principles to agricultural and peri-urban landscapes (McIntyre *et al*. 2002, http://www.csiro.au/science/LandscapesInTransition.html).

A number of large-scale on-ground restoration projects are also underway (Table 1). These can both apply landscape restoration research and undertake research as part of their activities. The primary goal however is to improve the condition of native vegetation and biodiversity at the landscape scale, rather than undertake research *per se*. 'Biolink'-style, large-scale connectivity projects such as Gondwana Link in south-western WA (http://www.gondwanalink.org/) and Alps to Atherton (DEC NSW 2007) in NSW epitomise these sorts of approaches. Because of the rapid growth of 'biolink' style projects, they are dealt with in greater detail in Section 9 of the discussion paper.

Table 1: Examples of restoration projects (research and on-ground) at the landscape scale undertaken in the last decade or thereabouts.

Landscape scale research projects	Landscape-scale on-ground projects
- David Lindenmayer's 6 projects, SE Australia: *Victorian Central Highlands Forest Management Study; Tumut Fragmentation Study; Nanagroe Natural Experiment; Riverina Restoration Study; Jervis Bay Fire Response Study and Goorooyaroo Study.* - BIO-ASSESS, southern NSW - Andrew Bennett's work on thresholds – northern Victoria - Mallee Fire and Biodiversity Project, NW Victoria - Heartlands, NSW - SE Queensland work in agricultural and peri-urban landscapes - Better Knowledge, Better Bush (NSW)	- Biolink style projects such as Gondwana Link – see list in Section 9 on 'Trends and influences' - Big Scrub Rainforest Restoration Program - Red Gum Plains Landscape Restoration project, East Gippsland (Australian Landscape Trust) - Hindmarsh Biolink, Victoria - Living Landscapes, SW WA - Mount Lofty Ranges Integrated Landscape Restoration Project, SA - Cumberland Plain Woodlands, NSW - Ecosystem Management Unit (EMU) Project, Gascoyne region, WA

5. Landscape restoration themes

Drawing on a range of literature, different policies and programs relevant to native vegetation and biodiversity management, as well as findings from the workshops and desk-top studies, a number of landscape restoration/ecology themes can be identified. These include themes such as patch geometry, corridors and connectivity, indicators, vegetation condition, ecological processes, thresholds, state and transition models and resilience. Lindenmayer *et al*. (2008) identified six major themes in the ecology and conservation of landscapes (Box 2). This list collapses some of the themes addressed in Lindenmayer and Hobbs (2007a), including ecosystem processes, aquatic systems and individual species management.

It is interesting to compare these themes with the ones identified in Ludwig *et al*. (1997) for the rangelands, which focus on landscape function and dysfunction, ecological processes and the conservation of water and nutrients within landscapes.

Box 2: The six major landscape restoration themes addressed in Lindenmayer *et al*. (2008)

1. Landscape classification
2. Habitat amount, amount of land cover, patch sizes and mosaics
3. Connectivity
4. The significance of edges
5. Structure and condition
6. Disturbance, resilience and recovery

The theme of landscape classification is an important one to start with, although is not always recognised explicitly by practitioners when planning and undertaking landscape restoration projects. Many workers remain unaware that there is a range of models that can be used to classify landscapes (Lindenmayer and Hobbs 2007b). The island biogeography model has therefore typically been the default classification used by researchers and land managers, particularly in landscapes subject to broad-scale clearing of native vegetation (Table 2). This was certainly the case in the workshops, case studies and questionnaires that were undertaken as part of the larger project this discussion paper is a part of (Lovett *et al*. 2008). When asked what theories and principles underpinned their work, most of the regions in southern and eastern Australia identified island biogeography and species-areas curves as one of the key influences.

Table 2: Similarities between island biogeography theory and 'current' design principles

Island biogeography theory and reserve design (Diamond 1975)	**Design principles from 'How to plan wildlife landscapes' (Platt 2002)**
Larger reserves are better than smaller ones	The bigger, the better
Given a homogenous habitat, the reserves should be divided into as few disjointed pieces as possible	The more consolidated, the better
Reserves should be as close as possible	The more connected, the better
Reserves should be grouped equidistant rather than linearly	The more consolidated, the better
Disjoined reserves should be connected by habitat strips	Include corridors Provide stepping stones
The optimal reserve shape should be circular	Consider edge effects

As Lindenmayer and Hobbs (2007b) note, it is important to be aware of the existence of a range of models for perceiving and classifying landscapes other than the island model and its derivatives like the patch-corridor-matrix model. The island model is based on islands in the ocean, so when translated to terrestrial systems the modified landscapes ('ocean') in-between the patches of vegetation ('islands') has often been viewed as 'hostile' to native plants and animals. As our understanding of these systems increase, it is clear that the 'matrix' that native vegetation patches are found in can provide a range of resources and linkages for native biota (Craig *et al*. 2000). Different models will be relevant to different parts of the landscape to achieve particular management outcomes.

In Australia, much of the research on landscape restoration has concentrated on the woodlands and grasslands of southern and eastern Australia. As a consequence, there has been a focus on managing and restoring remnant patches of vegetation and increasing the area and connectivity of patches through revegetation. This is reflected in three of the themes in Lindenmayer *et al*. (2008), which focus on the amount of habitat, the connectivity between it (e.g. by corridors and stepping stones) and the edge effects that are created by patches. Connectivity was a common theme running through the workshop and desk-top study reports, as were the concepts of thresholds and following the trifecta of 'protect, enhance and restore'.

In areas where rainforest has been cleared in northern Australia the focus, to date, has been on patch level dynamics, but the need to put this in a landscape context has been recognised (John Kanowski, personal communication). In the extensive land use zone (the savannas, rangelands and desert country) that covers over 85% of the country, landscape restoration is about improving the condition of vegetation rather than its extent. The term does not resonate in these landscapes as much as in the highly cleared areas in the south and east of the country, because landscape restoration is often associated with increasing the quality and extent of fragmented native vegetation.

The landscape restoration theme of 'disturbance, resilience and recovery' is one that more closely links the intensive land use zones in Australia with the more extensive landscapes in arid and tropical Australia. Ecological restoration strives to restore natural disturbance regimes, as these have a major impact on the structure, function and composition of ecological systems. It is, therefore, important to identify intrinsic variability in resources arising from natural disturbances and distinguish this from external disturbances.

Pervasive issues such as weeds and inappropriate fire and grazing regimes are the key drivers that landscape-scale research addresses in northern and central Australia (Allan and Southgate 2002, Russell-Smith *et al*. 2003, Fisher *et al*. 2005). Fire regimes have also received considerable attention in the south, with a particular focus on forests and national parks/conservation reserves (Bradstock *et al*. 2002, Abbott and Burrows 2003). The understanding of fire regimes and their use as a management tool still requires further attention, however, in the grasslands and woodlands on private land in southern and eastern Australia (Hobbs 2002, Lunt and Morgan

2002). The major focus of landscape restoration in agricultural landscapes has been on restoring native vegetation as habitat for birds and mammals, with some work on other fauna and plants. This is changing, especially with the change in perception that grazing by domestic animals may be a useful management tool in landscape restoration (Lunt *et al*. 2007, Kirkpatrick and Bridle 2007). Understanding and managing the flow of water in the landscape, or 'hydroecology' as it is sometimes called, is also an area of growing interest in landscape restoration.

The concept of resilience is used widely in restoration ecology and amongst practitioners although, like the term landscape restoration, it is loosely applied. The Resilience Alliance, which has been working on this approach for over 15 years, have published a book to try and demystify the concept (Walker and Salt 2006). 'Resilience thinking' is being promoted as offering a new way of understanding the world, and a new approach to managing resources. The approach embraces human and natural systems as complex entities, continually adapting through cycles of change, and seeks to understand the qualities of a system that must be maintained or enhanced in order to achieve sustainability. It is based on the concept of thresholds in human and ecological systems, and presents an alternative to the optimisation approach used in much of conservation planning (see Section 7). Fischer *et al*. (2007) identified resilience as a key concept in their paper on guiding principles for commodity production landscapes, arguing that biodiversity enhances resilience, or a systems capacity to recover from external pressures such as droughts or management errors.

The resilience model is well suited to the arid rangelands because of the highly variable climate and diversity of responses to rainfall in different kinds of country (http://www.cazr.csiro.au/resilience.htm). Rain can be patchily distributed in storms and the land itself is often organised into patches of richer and poorer soils. These patches can be on a scale from centimetres to hundreds of metres. Understanding the complexities of ecosystems like these is an essential part of knowing just how resilient they are. The response of systems after rainfall is a key measure of how far they can be pushed before they are unable to recover to their former state.

It is not possible within the scope of this discussion paper to write in detail about each of the landscape restoration themes, and their sub-components, that have been identified across research, policies and on-ground programs. Readers are referred to Lindenmayer and Hobbs (2007a), Radford *et al*. (2007) and Williams (2005) as entry points to the literature on these topics. Table 3 also provides some of the key themes and sub-themes that were identified as part of the larger project on landscape restoration, and provides some useful references for them.

Table 3: Some of the key landscape restoration themes identified in the project

Landscape restoration theme	**Relevant reference**
Thresholds	McIntyre *et al*. (2002), Radford *et al*. (2004, 2005)
State and transition	Westoby *et al*. (1989), Freudenberger (2003), Cale (2007)
Connectivity (e.g. corridors, stepping stones)	
Patch geometry	
Buffers, edge effects	
Structural and floristic diversity	
Vegetation condition	Special issue of *Ecological Management and Restoration* (McDonald 2006)
Disturbance regimes	See references in text
Landscape function	Ludwig *et al*. (1997)
Ecological processes	Soulé *et al*. (2004)
Resilience	Walker and Salt (2006)
Revegetation, natural regeneration	Munro *et al*. (2007), Dorrough and Moxham (2005), Vesk and MacNally (2006)

6. In search of principles

The search for general and transferable principles that can guide landscape restoration is one of the ‘holy grails’ of landscape ecology. Despite the production of a large body of literature over two decades, there is little consensus on the applicability of such principles. The book edited by Lindenmayer and Hobbs (2007a) is the most recent attempt, with each of the chapters developing a list of principles for that specific topic. The synthesis paper by Lindenmayer *et al*. (2008) provides a useful overview of the key findings from the book. It identifies 13 important issues to consider when developing approaches to landscape conservation (Box **). These issues are presented as a checklist to follow, and are influenced by landscape context, species assemblages and management goals. Two crucial over-arching issues identified in the synthesis paper were firstly, the need for a clearly articulated vision for landscape conservation and, secondly, quantifiable objectives that offer unambiguous signposts for measuring progress.

Importantly, the authors concluded that these considerations in Box 3 (see over page) do not translate directly into the on-ground management guidelines, but recommend that they should be recognised by both resource managers and researchers when developing guidelines for specific cases. Lindenmayer *et al*. (2008) felt that interpreting principles or broad considerations in the context of local examples can be a valuable step in making them more accessible and relevant to managers. This can be achieved by conducting the relevant research in landscapes at a variety of spatial scales appropriate to the hypotheses being tested. The principles should not however be transferred uncritically and directly into on-ground action, as there is no one set of rules that applies universally. Rather they provide a key set of issues to be considered by agencies and resource managers when developing practical plans and guidelines.

Many other attempts have been made to develop general principles or broad considerations, with one of the earlier papers trying to link the general to the specific published by Hobbs and Yates in 1997. This paper deals with more specific restoration issues, as does the book by McIntyre *et al*. (2002) on principles and thresholds for managing grassy woodland systems in south-eastern Australia. McCullough and Musso (2004) draw on a number of principles underpinning the management of healthy rangelands in Northern Queensland. More recently, Radford *et al*. (2007)

examined strategies for restoration planning (including some commonly advocated ‘rules’) in a northern Victorian context. This paper formulated a set of guiding principles for restoration at the property level that were relevant to individual landholders, as well as guidelines for landscape linkages. The first of these was to clearly define the biological purpose of the linkage in terms of target species or faunal groups, spatial (i.e., extend over what distance) and temporal (i.e., used over what timeframe) scale and ecological function (e.g., seasonal migration, access to irregular resources, natal dispersal).

Box 3: Issues to be considered when developing approaches to landscape conservation (Lindenmayer *et al*. 2008)

1. Develop long-term shared visions and quantifiable objectives
2. Manage the entire mosaic, not just the pieces
3. Consider both the amount and configuration of habitat and particular land cover types
4. Identify disproportionately important species, processes and landscape elements
5. Integrate aquatic and terrestrial environments
6. Use a landscape classification and conceptual models appropriate to objectives
7. Maintain the capability of landscapes to recover from disturbances
8. Manage for change
9. Time lags between events and consequences are inevitable
10. Manage in an experimental framework
11. Manage both species and ecosystems
12. Manage at multiple scales
13. Allow for contingency

A common theme across the workshops and desk-top studies was that there are probably enough ‘principles’ already available. One participant felt that because of the relative plethora of principles, it was possible to go ‘principle shopping’ and select the principles that suited your purpose. It was felt that if goals are clearly identified then the next step should be to articulate which principles have been used and why, and to be willing to use an adaptive approach based on reflection and review over time. The challenge to policy and on-ground practitioners is knowing which principles are most suited to the issue at hand.

7. Landscape/conservation planning and prioritisation tools

Landscape planning tools have been designed to help prioritise areas for protection, restoration or rehabilitation. Some of the early work in this area, which is now deeply embedded in Australian conservation policy, is the concept of comprehensive, adequate and representative reserve (CAR) systems. While reserve design is not strictly classified as landscape restoration (Radford *et al.* 2007), it is an allied area and is essential for identifying the core areas for the conservation estate. By identifying core conservation areas, managing the rest of the landscape in a complementary manner can be enhanced. As also pointed out in Section 5, reserve design science undertaken in the mid 1970s has had a major impact on the design principles that are commonly used in landscape restoration today.

Conservation planning tools, and especially those that could help prioritise where on-ground actions should be focused, were of particular interest to participants at the workshops associated with this project. Wintle (2008) has recently undertaken a review of the commonly used prioritisation and decision tools that may assist natural resource managers achieve systematic and defensible biodiversity investment decisions. These included the Biodiversity Benefits Index (Oliver and Parkes 2003), MARXAN (Ball and Possingham 2000, http://ecology.uq.edu.au/marxan.htm), C-Plan (Pressey 2005) and Bio-forecasting (Ferrier 2005, DEC NSW 2006). The bulk of the tools have been developed for static allocation of lands between reserve and non-reserve land tenures. More recent extensions (e.g. MARZONE and OPRAH), which are planned to be formally released in 2008, enable allocation of lands between multiple tenures or land-uses.

Wintle (2008), in the draft paper, concluded that the array of tools, resources and decision frameworks available is confusing. I would add that they can also be difficult to use and access unless one is familiar with (and even part of) the conservation planning world and has some mathematical/computational nouce. Wintle (2008) believed that no new tools were required, but that the existing set needed careful examination and trialling to clarify which are most appropriate. Existing tools were found to give limited consideration to public versus private benefit and strategies for ensuring successful adoption and implementation. Very little attention has also been given to methods for estimating the probability and magnitude of threat reduction that can be achieved through management actions, although some of the tools could be adapted to do so (Wintle 2008). In another review of biodiversity conservation planning tools, Sarkar *et al*. (2006) concluded that that such tools will likely be quite different in the future as they will be based on dynamic rather than static models of ecosystem change.

Two of the planning tools reviewed by Wintle (2008) were described more as frameworks or shells within which other planning tools could fit. These tools were the Biodiversity Action Planning (BAP) approach used principally in Victoria (Platt and Lowe 2002) and the Conservation Action Planning (CAP) tool developed by The Nature Conservancy in the United States (http://conserveonline.org/workspaces/cbdgateway/cap/index_html). The latter is being increasingly used in Australia to guide landscape scale activities, having been adopted and modified by Greening Australia and Bush Heritage Australia to suit their needs. This is one of the reasons why the CAP received considerable prominence in the feedback the project received from workshop participants and people involved in the desktop studies and questionnaires. Many participants at the Victorian workshop also referred to the BAP, and its use in NSW was becoming more common. Both of these tools help set priorities and identify clear goals for managing and restoring landscapes. In the United States of America, the Wildlands Project has developed an alternative approach to landscape design based on MARXAN.

Wintle's (2008) draft review was not able to cover all the available conservation planning approaches. One of the newer approaches, which aims to consider multiple objectives in a planning context, has been developed by Neville Crossman and colleagues at CSIRO Land & Water in Adelaide. This approach to systematic regional planning utilises integer programming within a structured multi-criteria decision analysis framework to identify geographic priorities for revegetation and/or restoration (Crossman and Bryan 2006, Bryan and Crossman in press, Crossman *et al*. 2007). Physical and environmental spatial data is used to describe a region's ecosystems, which in turn act as surrogates for biodiversity in highly fragmented landscapes. The use of a Geographic Information System is an important component of this tool.

A 2006 workshop on conservation planning held in Perth, which was convened by the Southwest Australia Ecoregion Initiative (http://swaecoregion.org/news.asp), is one example of how science is being used to help make informed decisions in developing a large-scale biodiversity conservation planning strategy. In the rangelands, there have been concerns that approaches to identifying areas of high conservation value used in other regions in Australia may not be the most appropriate, and a workshop was held in 2005 to address this concern. It concluded that while priority setting for 'focal areas' in the rangelands can be handled by systematic conservation planning, the diffuse processes that are so important to biodiversity conservation in the rangelands require a different approach (Stafford Smith and Ash 2006). Recent work, which tries to integrate process and threat-based models with conservation planning tools (e.g. Pressey *et al*. 2007), may help address some of these concerns.

Feedback from researchers, who had input into this discussion paper, was that it would be valuable to write some papers on the application of conservation planning tools that made them more accessible. It was also felt that some of the more recent research in conservation planning had gone off on a technical side track in developing more and more complex algorithms to do spatially driven planning, largely to meet the original aims of identifying reserve networks. On the one hand it was acknowledged that it is important to make the work accessible to end-users, and on the other that the approaches seemed to be getting more complex. This highlights some of the challenges of dealing with complex systems in a way that can be utilised by policy and on-ground practitioners.

The perspectives on, and experiences with, conservation planning and prioritisation tools gained in this project were somewhat unexpected, but very useful. Initially it was not intended to include this area in the discussion paper, but it became very clear that this is an important area for landscape restoration science and its application. This was evident from both the workshops and feedback from researchers. For example, one scientist felt that the primary area of research that was relevant to landscape restoration, and that was not taking hold in on-ground restoration efforts, were the systematic conservation and prioritisation approaches. Although the bulk of the literature on conservation planning and prioritisation focuses on spatial prioritisation for reserve design, it was felt that there were some general principles arising out of that literature that could be valuably applied in restoration planning at the CMA or landscape level.

As a vegetation ecologist, it seems that currently the science of conservation planning is running almost, but not quite, in parallel with the research on the themes identified in Section 5. There is a lot to be said however for greater integration of both the science and application of conservation planning and work on the ecology of the systems that the planning tools are prioritising. As noted by Sarkar *et al*. (2006), advances in our understanding of factors influencing the persistence of biodiversity must be incorporated into planning tools. There is also much to be potentially gained by ecologists giving greater thought to how the science of conservation planning could aid their work, especially when there appears to be considerable interest in planning tools at the practitioner level.

8. Setting restoration goals

Landscape restoration actively seeks to restore pre-existing conditions, which introduces the fundamental issue of setting restoration goals. Defining restoration (or rehabilitation) goals and constructing a 'landscape vision' are fundamental to the planning, implementation and success of restoration programs (Radford *et al*. 2007). This is supported by Lindenmayer *et al*. (2008) who identified two crucial over-arching issues to address when developing approaches to landscape conservation. Firstly, there is the need for a clearly articulated vision and, secondly, quantifiable objectives that offer unambiguous signposts for measuring progress. The importance of goal setting at all scales was also raised frequently in the workshops, desk-top studies and in responses to the questionnaires.

Once a vision for the landscape has been agreed, there are two questions that need to be answered:

1. what is a desirable end-point for restoration?, and
2. when has the restoration been successful?

In order to address question one, a reference site(s) or condition must be selected, and indicators for that condition must be developed to address question two. The two most common sources of reference information for goal setting are historical data from the same site, or contemporary data from reference sites that are assumed to match the environmental and biotic attributes of the restoration site prior to degradation (White and Walker 1997). As noted in Section 1 of this paper, if the goal is to reach something close to the original state, then this is considered restoration. If the goal is to improve the condition of degraded areas to resilient, self-supporting ecosystems, but not necessarily in the direction of the pre-existing state, then this is related practice of *rehabilitation*. In reality, complete restoration is often not technically or financially feasible, so rehabilitation is the more commonly practiced.

In Australia, reference sites and/or conditions are frequently referred to as benchmarks, with native vegetation often the unit that is compared between sites. In Australia, references have included the extent and structure of vegetation as it was in 1788 or some other fixed date, a nominated reference site (if this exists for the vegetation type in question), or an 'ideal' state. At the national level, the discussion paper on native vegetation condition for the national Matters for Targets, states that reference points will be expressed as a benchmark that represents:

> '*the average characteristics of a mature and apparently long-undisturbed stand of the same vegetation type*.'

When using benchmarks, individual attributes are compared against the value of the same attributes in the benchmark, providing an indication of the direction and magnitude of change. At the regional and catchment level, they are mostly used to assess the extent and condition of vegetation types across their distribution, compared to the benchmark or reference area. As each vegetation type is different, a number of reference areas are needed in any one region.

In some circumstances, the current focus on ‘pre-1750 vegetation’, ‘pre-agricultural vegetation’ and ‘naturalness’ as a benchmark, may limit efforts to restore landscapes. Three principal reasons have been put forward as to why using these benchmarks can be an issue when site-based methods are used (Oliver *et al.* 2002, Williams 2005). These are also broadly applicable at the regional and catchment scale and are as follows:

1. The nature of disturbance in Australia makes it difficult to define a single meaningful benchmark, even for a single vegetation type.
2. In a context of natural disturbance such as fire or flood, the properties of a system such as structure and floristic composition, will change over time.
3. Vegetation is dynamic and likely to have varied in composition and structure over time, even in it’s ‘natural’ state.

Where possible, it is recommended that benchmark areas should be of sufficient size to support large-scale processes that sustain native vegetation and its associated biodiversity. This goal may be more challenging in the intensive land-use zone than the rangelands, but is a worthwhile aim. The key message is that reference areas are a relative benchmark of the ‘good’ current status and condition of biodiversity or native vegetation. Their greatest value is to represent standards for evaluating differences between areas under more or less pressure, in order to identify changes over time.

In rangeland systems, two important criteria identified for selecting a reference area are that they must be representative of the characteristic landscapes and habitats of the region to be monitored and, have minimal influence from all the major pressures acting on the country type they represent (Smyth *et al.* 2003). In areas where entire landscapes are under pressure, such as those that are highly productive and/or restricted in extent, it is recommended that reference areas should be located to represent the ‘best-on-offer’ state of that vegetation type.

9. Trends and influences

A number of trends and influences on landscape restoration science and its application were identified through the three Elements outlined in Section 2. These are captured in Box 4, with supporting text following where they have not been covered elsewhere in the paper.

Box 4: Trends in, and influences on, landscape restoration science

- From pattern to process
- From patch to continent
- From static to dynamic (space & time)
- Managing the matrix (in intensively managed landscapes)
- Ecosystem services
- Climate change – direct impacts
- Increased use of technology
- Market-based instruments, offsets
- Whole property/farm business focus
- The 'carbon economy'Optimisation cf resilience approaches
- Prioritising restoration activities
- Land sparing (intensification) cf 'wildlife friendly' farming
- Other forms of knowledge
- People as part of the landscape

Over the last decade, much of the focus of landscape scale research and on-ground programs in south-eastern Australia has been on identifying and managing patches of native vegetation to provide habitat for native animals. Identifying, protecting and enhancing the conservation status of species and communities has also been an important driver for policies and programs. Concepts such as corridors and vegetation thresholds have been widely adopted by groups such as regional organisations, state governments and to some extent the wider community.

One of the major shifts that has recently occurred in the intensively managed landscapes, has been from a focus on pattern (e.g. corridors, patch geometry, thresholds) to fundamental ecological processes that support viable populations of plants and animals (Soulé *et al*. 2004, Schroder and Seppelt 2006, Broadhurst 2007). It should be noted that understanding ecological processes has been a focus of research in the arid and savanna landscapes of Australia for some time (e.g. Ludwig *et al*. 1997). As noted in the Section on research directions below, these processes include pollination, dispersal, predation, mating behaviour, competition and recruitment. Understanding the processes that underpin biodiversity in the landscape such as nutrient and water cycles and fire and grazing regimes is also gaining greater attention. Remotely sensed time series estimates of gross primary productivity, which is now available for all of Australia, is a potential tool to examine some of the processes driving the dispersal of animals, particularly bird species with large scale and irregular patterns of movement (Berry *et al*. 2007).

There has also been a shift in thinking in Australia over the last decade or so from the patch and local scales to continental scale conservation (e.g. Soulé *et al.* 2004). This has been driven to some extent by work in the United States on large species such as elks and moose that migrate hundreds of kilometres each year (Hudson 1991, Soulé and Terborgh 1999). In order for these migrations to continue, there is a need to maintain or restore suitable habitat along their migration paths. With the coming of the new millennium, there has been a number of regional-scale connectivity ('biolink') projects in Australia that are being implemented on-ground or are in the planning stage (Box 5). A number of them have developed a form of alliteration, potentially to make them more memorable.

Box 5: Examples of 'biolink'-style landscape scale projects – planned and underway in the last decade. The names in italics represent components that fall under the umbrella project.

- Gondwana Link, SW WA
- Hindmarsh Biolink, Victoria
- Habitat 141 (Outback to Ocean, O2O), Victorian/South Australian border
- Alps to Atherton (A2A), NSW: *Kosciusko to Coast, Slopes to Summit* (S2S)
- Western Woodland Way (WWW), NSW
- Broome to Bamaga (B2B), northern Australia
- Naturelinks Program, South Australia: *East meets West, Flinders and Olary Ranges Bounceback, Cape Borda to Barossa, River Murray Forest*
- Birdsville to (Hervey) Bay, Queensland
- Landscape Linkages, NE Tasmania

One of the best known and most established of the 'connectivity' projects developed in the last ten years is 'Gondwana Link' in south-western Australia (http://www.gondwanalink.org/). The

Alps to Atherton (A2A) project, which spans 2800 km up the east coast of Australia, is a particularly ambitious project that has recently started (http://www.environment.nsw.gov.au/a2a/index.htm). The World Conservation Union (IUCN) has also developed a program called 'Connectivity Conservation', where landscape-scale conservation is achieved through systems of core protected areas that are functionally linked and buffered in ways that maintain ecosystem processes and allow species to survive and move.

The science underpinning this trend to 'biolink' projects is currently sketchy in the Australian context. This is partly due to the recent nature of most of the initiatives and the subsequent lack of scientific publications. Programs on landscape scale science such as those run by the Living Laboratories in South Australia, which is linked in with Habitat 141, should help address these gaps. The Gondwana Link program has also recently developed a Functional Landscape Plan for the area between the Stirling Ranges and Fitzgerald River National Park, which sets out the objectives and actions for landscape restoration into the future.

The concept of increasing connectivity in the landscape, primarily to provide continuous habitat for fauna, is sometimes given as a rationale for biolink style projects. This is intuitively very appealing. Connectivity is a primary process influencing ecosystem function and the distribution, abundance and persistence of all biota (Lindenmayer *et al.* 2008). There are circumstances, however, where the mantra that 'the more connectivity the better' does not apply, like, for example, when connectivity promotes the spread of invasive taxa. In the face of a changing climate, it has also been noted that connectivity may both help and hinder (Dunlop and Brown 2008). There is little doubt that better approaches are needed to determine when, where and why more connectivity is desirable and when it is not. Unlike North America, Australia does not have the large migrating herbivores that require continuous habitat over hundreds of kilometres.

Other reasons given to support large scale projects is to provide resilience to ecological systems, to buffer systems against climate change (e.g. Habitat 141), and to maintain or restore ecological processes that underpin the long-term maintenance of biodiversity. For example, the ecological processes identified as part of the Wildcountry program (Soulé *et al*. 2004) are put forward to justify large-scale ‘biolink’ style projects. Currently however, the links between these processes and their on-ground application need to be strengthened. The NSW component of the Alps to Atherton initiative focuses on the role these large-scale projects have in engaging people with nature (DEC NSW 2007). It will certainly be interesting to see how this increasing focus on regional and continental scale connectivity will shape landscape restoration science, policy and programs in the future.

The scale and nature of landscape restoration science lends itself to the use of technologies such as Geographic Information Systems and remote sensing, as well as modelling approaches. Several issues about the quality and accuracy of data associated with these techniques were raised in various workshops and desk-top studies associated with the larger project (Lovett *et al*. 2008). Easy access to data was also raised as an issue. A classic example of how the interpretation of remotely sensed data can affect landscape restoration outcomes was given at the Cowra workshop. The project that was described used a variety of information sources, and highlighted the problem of maps or aerial photos that classify a site as being ‘native vegetation’ on the basis of tree density. Habitats that actually have good recovery potential such as open grasslands or woodlands, while being mapped as highly disturbed or cleared as a result of low tree density, may be quite representative of their original condition. It is beyond the scope of this paper to address these valid concerns, but important to acknowledge that they exist and need to be addressed.

In addition to paying greater attention to (very) large-scale projects, there is an increasing focus on the spatial prioritisation of restoration works (see Section 7) and how patterns and processes may change over time. Issues such as time lags (Vesk *et al*. 2008), hysteresis (Mac Nally 2007) and future landscape scenarios are being addressed by groups such as CSIRO and the Landscape Futures Alliance in Victoria - and no doubt others. Incorporating spatial and temporal dynamics into landscape restoration research, policies and programs is likely to be a key future direction, especially with the complexities associated with climate change (Dunlop and Brown 2008).
Principles associated with climate change and its impact on landscape restoration were explicitly referred to in only one of the eight regional/state reports that were written as part of the larger

project this paper is part of (Lovett *et al*. 2008). This is likely to change quite quickly with the political focus now fairly and squarely on this issue. While this is an encouraging development, climate change has been identified as a major issue for some time (Pearman 1988, Williams *et al*. 1994) and ground has been lost with the delays in responding to the threats posed. On-ground practitioners are already asking questions about whether local provenances should be included in restoration projects, or they should be planting species from the climate that is predicted to be in a region in the future. Given the uncertainty of regional climate scale predictions, the best advice is probably to plant a mix of species with a range of tolerances. Policies developed to mitigate climate change, such as the introduction of a 'carbon economy', could also have a major impact on landscape restoration. The increasing focus on 'biodiverse carbon' through programs such as Greening Australia's '*Breathe Easy*' could see the scale of revegetation increase significantly that meets both carbon and biodiversity outcomes.

In parallel with work in the research community, a number of farmers have been developing management approaches (e.g. Natural Sequence Farming (Andrews 2006) and pasture cropping) that when applied across a landscape could have a major impact on ecological patterns and processes that underpin biodiversity conservation. These approaches are now being evaluated scientifically (e.g. Howden *et al*. 2005). Lessons can also be learnt from approaches to managing farming landscapes such as holistic resource management, which focuses on managing fundamental ecological processes. Indigenous knowledge and world views on the landscapes they live in is a whole other area that has largely been untapped or understood, but is beyond the scope of this paper.

Other emerging themes in landscape-scale research, policy and programs are bio-banking and offsets (e.g. the offsets policy introduced in Queensland in the second half of 2007), focusing on the whole property scale, intensification of land use (Dorrough *et a*l. 2007, Fischer *et al*. in press), restoring landscapes for multiple benefits, an increasing focus on peri-urban areas (Crossman *et al*. 2007, Landscape in Transition program (http://www.csiro.au/science/LandscapesInTransition.html)).

It is worth dedicating a few paragraphs to some recent policy tools and programs that influence landscape restoration science and practice. Ecosystem services have been receiving some attention as a policy tool to encourage landscape-scale changes on private land. Examples include CSIRO-led projects in Victoria (the Goulburn-Broken and Wimmera regions), projects undertaken in the Namoi region in northern NSW and the 'Farming in the landscape' project funded by GRDC in Queensland that examine landscape function and services provided by agro-ecosystems. There is further potential for using this approach in guiding and informing landscape restoration, as well as the potential for payment for ecosystem services provided by vegetation (both native and exotic) across the landscape.

Payment of private landholders for the range of services they provide has become an increasingly used policy tool through various market-based instrument (MBIS) programs. These are relevant to landscape restoration in at least two ways. Firstly, they influence where on-ground actions are taken by landholders and secondly the metrics used that underpin the instruments draw on landscape restoration science. MBIs are still in their embryonic stage in Australia and there is considerable debate and discussion about their application (e.g. Whitten *et al*. 2006). Land & Water Australia is funding a project titled '*Achieving coordinated landscape scale outcomes with auction mechanisms*' that is addressing the issue of assessing the contribution of multiple sites in MBI schemes rather than individual properties. Getting the right metric that represents the desired landscape outcomes will be a major challenge, not just design of the auction process *per se*.

Offsets are another policy tool (linked to goals such as 'No net loss' and 'Net gain' of vegetation) that can have an impact on landscape restoration outcomes by compensating for losses of existing native vegetation. Gibbons and Lindenmayer (2007) believe that offsets can be useful policy instrument if five recommendations are followed. These include the type of vegetation that is cleared, the time the offsets are in place and compliance to the policy.

As noted elsewhere in this paper, the focus of much of the landscape restoration work in southern and eastern Australia has been on fragmented native vegetation and the habitat that it provides fauna. This is a conservation-oriented approach, which has not always engaged with private landholders where much of the native vegetation is found. In order to address this, and acknowledge that farmers manage their property as a whole and are running a business, many projects and programs are starting to focus on the whole property/farm business scale. This makes sense from several angles, including the need to work on areas larger than remnant patches to achieve landscape restoration outcomes. Programs such as Land, Water & Wool (www.landwaterwool.gov.au) and Evergraze (http://www.evergraze.com.au/) have been taking whole farm approach that aims to integrate production and conservation, building on earlier work such as that undertaken by Jim Crosthwaite and Neil McLeod. This work introduces some of the realities and costs associated with undertaking restoration in the context of a farm business (e.g. Dorrough *et al*. 2008).

10. Socio-economic dimensions

The lack of information and knowledge about social and economic factors in landscape restoration was commented on several times in the workshops and desk-top studies. For example, people wanted to know which incentive mechanisms and social engagement strategies are the best for undertaking large-scale restoration project. The point was made that there is often a tension between science and community values, and this was a consistent theme to emerge. A comment made by one of the people interviewed in the Northern Territory is reflected across all of the country:

> *"While the biophysical research is very important, harnessing the appropriate social, cultural and economic knowledge also plays a key role in north Australia".*

It is important to understand the social community within which any landscape restoration efforts are to be undertaken, as it is this community that will have a direct bearing on whether or not efforts are successful.

A comprehensive review of the social-economic literature relevant to landscape restoration is well beyond the scope of this project and paper. This Section will point readers in the direction of relevant material, and they can take it from there. Two excellent places to start looking for relevant research is Land & Water Australia's Social and Institutional Research Program (http://sirp.gov.au/) and the Cooperative Venture for Capacity Building (http://www.rirdc.gov.au/capacitybuilding/index.html). We know through these Programs that there has been a lot of research into what motivates people to act (e.g. Panell *et al*. 2006). Having said that, Fenton (2008) argues that the infusion of social science knowledge and expertise into NRM is limited and often narrowly focused when compared to the infusion and knowledge and expertise from the natural sciences. Lovett *et al*. (2008) have recommended that rather than commission new research immediately, a review should be undertaken of what has already been done and tailor it for this particular audience. At that stage it can be determined whether new research is required.

The reason why social and economic issues were raised so frequently during this project is that ecological and social systems are complex and entwined. This is the environment that ‘resilience thinking’ (See Section 5) is designed to address (Walker and Salt 2006). Complex social-ecological systems interact in a multitude of ways at many spatial scales across time. Brunckhorst (2005) also uses the concept of resilience in a paper that discusses the local interactions of human communities with the ecological systems of a landscape and the “place” that is created to give rise to its social identity. The author acknowledges that identifying ‘Turning Points’ is a crucial step in changing resource management practices. The ‘Turning Point’ refers to a window of opportunity, when it is easier to alter course towards more ecologically sustainable resource use, communities, institutions, and policies. Examples of turning points given in Brunckhorst (2005) are Tilbuster Commons and New South Wales Eco-Civic Regionalisation.

Like many of the issues and themes addressed in this paper, the Nature Conservation series of books (edited by Saunders and others) recognised that conservation involves everyone, not just scientists and academics. Hence a book on the role of networks was published (Saunders et al. 1996). This comprehensive book covered networks formed by the broad range of people involved in nature conservation, from the local to landscape scale. The included indigenous people, Landcare groups and property owners, mining and environmental consultants, agency and community networks and conservation education and extension networks. It provides a useful snapshot for the thinking on the relationship between people and nature in the mid 1990s and a context for what we've learnt since. More recently, the edited book by Kirkpatrick and Bridle (2007) use qualitative and quantitative research to describe the complex relationships between people, sheep and nature conservation.

Several other have dipped their fingers into the socio-economic component of landscape restoration and management. For example, Possingham and Nicholson (2007) argue strongly that costs should be considered up-front in any landscape restoration program and that much of the current efforts in landscape restoration research are misguided. Briggs (2001, 2003, 2006) has tackled the challenging issue of some of the changes needed in institutional and policy settings to achieve better landscape restoration.

Collaborative projects between ecologists and social scientists, which happen from time to time, are to be encouraged. Groups such as the Alcoa Research Centre for Stronger Communities, which was represented at our project workshop in Albany, have much to offer the field of landscape restoration science and practice. There are other examples of groups and programs that bring together different disciplines to address questions of landscape restoration and management. This snapshot of socio-economic research and practice draws on a few of the examples I have come across and identifies two major Programs as a starting point for further information. Readers are encouraged to delve into the socio-economic literature in a systematic way to discover the wealth of material out there.

11 Translating science into practice – researcher's perspectives

Lindenmayer *et al*. (2008) suggest that much of the significant body of knowledge that has been generated from landscape ecology, conservation biology and restoration ecology has had limited bearing on the on-ground management of landscapes. The authors identify the need for more effective knowledge transfer and deeper exploration of this process. If more effective transfer can occur, Lindenmayer *et al.* (2008) believe that it will be important to increase the number of scientifically-based landscape planning and management examples that encompass true adaptive management experiments.

One of the questions posed to researchers as part of this review, explored their perspectives on the key factors influencing the uptake of the research. Consistent themes in the responses included the importance of building and maintaining relationships with agency staff (through one to one interactions), having an active presence in an area and translating the research into an accessible form that can be understood (e.g. producing user-friendly publications such as newsletters, brochures, books and posters), giving presentations in the region and practical demonstrations. Examples of 'user-friendly' publications that were seen to engage regional managers, based on either personal feedback or high demand for publications, were the Birds on Farms brochure and the publication 'How much habitat is enough?' (Andrew Bennett, personal communication). These and other 'user-friendly' publications can be found in Box (see over). Programs such the National Riparian Lands R&D Program, managed by Land & Water Australia, have also been very successful in translating science into practices (see www.rivers.gov.au).

Most of these recommendations relate to effective and diverse forms of communication. In this context, the role of Knowledge Brokers and having project staff living in local communities were seen as important ways to bridge the gap between science and practice. Getting the work or principles to the right person at the right time, or to an agency at the time when it is specifically dealing with the issues, was also thought to increase the chances of successful uptake.

The need to increase capacity across a number of areas was another consistent theme – this included the capacity of regional staff to understand and use the research, the capacity of organisations to implement the research, having the supervisory capacity to expand the research effort through student projects, and attracting good students to work in the regions. Some researchers considered that the ecological education of regional staff was quite variable, which affected their ability to understand and implement the relevant research.

Box 6: Some of the 'user-friendly' publications available on landscape restoration across different regions of Australia

- How to plan wildlife landscapes (Platt 2002)
- How much habitat is enough? (Radford *et al*. 2004)

- Wildlife on farms (Lindenmayer *et al*. 2003)
- Birds on farms: ecological management for agricultural sustainability (Barrett 2000)
- Wildlife in Box-Iron bark forests (Bennett 1999)
- Revegetation and wildlife (Bennett *et al*. 2000)
- Bats and paddock trees (Lumsden and Bennett 2003)
- Managing genetic diversity in remnant vegetation (Broadhurst 2007)
- Using natural regeneration to establish shelter on wool properties (Land & Water Australia 2006.)
- Management of total grazing pressure: Managing for biodiversity in the rangelands (Fisher *et al*. 2005)
- Biograze (Biograze 2000)
- Talking fire – Desert Uplands, Queensland (Fensham and Fairfax 2007)

One researcher strongly felt that regional staff should be allocated time in their work-plans to keep up with current landscape restoration research at the national and international level and that there be consistent standards developed for educating natural resources management professionals. Another idea was to engage on-ground staff prior to undertaking projects and involving them in the research so that they get a 'hands-on' appreciation and understanding of findings and how they relate to their work. This kind of an approach builds ownership and engagement of end-users in the research, a model that has been used in the Land Water & Wool and National Riparian Lands Research & Development Program to great effect.

Having the appropriate human and financial resources, both for the regional agencies and to undertake the research, are two key factors that will influence the adoption of research findings. Developing a collaborative research agenda with regional agencies was also identified as an important element of success, as was relatively long-term funding to allow time for relationships to be built and for cultural change/adaptation to occur both within the natural resources management organisation and within the research team. Finally, a high level of commitment to applied research from the researchers is needed, regardless of the lack of formal recognition for this type of research in some aspects of the academic world.

12. Translating science into practice – on-ground application

A consistently raised issue at the workshops and in the desk-top studies was the gap between the concept of landscape restoration and the practical realities of implementing it on-the-ground. Practitioners agreed with research scientists about the key areas to be addressed to improve knowledge exchange (Section 11, Box 6). Implementing these in practice can however be challenging, especially given the time and financial pressures on both scientists and practitioners.

> Box 7: The key areas identified by research scientists to build more effective knowledge exchange.
>
> - Importance of building and maintaining relationships
> - Having an active presence in an area
> - Developing a collaborative research agenda
> - Translating research into accessible forms
> - Increased capacity (regional staff, organisations, researchers)
> - Appropriate human and financial resources.

Policy and on-ground practitioners identified a range of approaches/concepts derived from landscape restoration science they were using in their day to day work. Common themes were connectivity and corridors, thresholds, focal species, conservation significance, island biogeography, vegetation condition and maintaining structural and floristic diversity. While some of these reflect the current thinking and practice in landscape restoration science, there was the sense that concepts that intuitively make sense were widely adopted, sometimes despite a lack of scientific evidence to support them. Corridors are a classic example. This is one of the most commonly adopted approaches to landscape restoration in southern and eastern Australia, even though there is minimal scientific evidence to support their use. The systematic review of corridors and connectivity outlined in Section 13 should help address this.

The focal species approach is also a good example to demonstrate some of the issues of implementing landscape restoration science, as it has gained some currency in on-ground programs. The focal species approach was developed by Lambeck (1977) to develop a systematic approach to landscape restoration. It has been adopted and/or promoted by a number of programs in south-western and eastern Australia (eg. Platt 2002, Freudenberger 2001, 2003, Huggett 2004). The usefulness (or otherwise) of the technique has generated strong debate amongst the scientific community (Lindenmayer *et al.* 2002, Lambeck 2002, Lindenmayer and Fischer 2003). One of the strong points of the focal species approach is that it provides a pragmatic and explicit approach to landscape design that managers can use now. This highlights the value of using birds as a 'social hook' as part of the focal species approach, a role that should not be understated.

A recent review of the approach by Huggett in 2007, attempted to move the debate about the focal species approach forward. Huggett concluded that it can provide quantitative and spatial advice for strategically restoring landscapes for the most sensitive species to given threats or threatening processes. However, a word of caution was provided about applying the focal species approach as a conservation tool. This is because threats often interact, and there is usually limited data available on the more sensitive species. Huggett (2007) recommends that care, knowledge and forethought are needed when considering this approach.

At the operational level, it has been observed that the implemented recommendations arising from the focal species approach have not been tested, and that this is a major potential knowledge gap in the application of focal species approach-based landscape designs (Gavan Mullan, personal communication). This observation echoes the call of scientists to undertake a series of landscape scale experiments that systematically examines the on-ground impact of implementing landscape restoration science, including the focal species approach.

One of the reasons why the application of landscape restoration science is not as systematic as it could be is related to the extensive range of landscape restoration approaches, tools and guidelines currently available. This diversity means that it is difficult for practitioners to work out which approach or technique best applies to them and the work they are doing. The range of approaches, tools and guidelines are scattered amongst websites, publications, guidelines and in 'people's heads', making it hard for people to know if they are accessing the most up to date, or relevant work for their region. Landscape restoration theories and approaches need to be demonstrated in action, with the 'real life' challenges and opportunities they bring, clearly communicated. Changes to the policy and funding environments are also needed to achieve long-term sustainable landscape restoration outcomes (Lovett *et al*. 2008).

13. Emerging and new research directions

As noted earlier, landscape restoration is a relatively new science in Australia. It is, therefore, not surprising that a number of new research directions/gaps have been identified by scientists. The recent book on managing and designing landscapes by Lindenmayer and Hobbs (2007a) provides some directions on where future efforts could be directed. A recent workshop on the 'Better Bush: Better Knowledge' program in NSW also identified some further research to increase our understanding of how complex landscapes function. This program was a major investment in ecological research in agricultural landscapes by the Environmental Trust of NSW.

Andrew Young was invited to synthesise the key messages coming out of the Better Bush workshop and draw on his own work. He identified two key areas for future examination. Firstly, he felt there was a need to better understand the spatial and temporal dynamics of key processes such as mating behaviour, dispersal, recruitment, pollination, competition, succession and nutrient cycling. The other key area he identified was developing a better understanding of the response of these processes to landscape structure and management. The challenges he identified for the future were: translating emerging knowledge about ecological processes at landscape level into better land management, extrapolating from single to multi-species responses, and learning more about cryptic but important groups such as fungi and soil rhizobia for which we currently have very limited knowledge.

At the Better Bush workshop, Veronica Doerr of CSIRO identified three key areas where additional research funds could be spent on corridors and connectivity, a key concept in landscape restoration that has been widely adopted. Overall, her observation was that there was very little research testing the effectiveness of corridors in Australia, with her focus being on birds and mammals. She felt that this could be addressed by:

- A systematic synthesis of current knowledge to identify best management practice (BMP).
- Testing the general applicability of the BMP; and
- Examining whether traditional corridors act as habitat sinks.

The first of these projects has recently been funded by Land & Water Australia and will focus on the effectiveness of different landscape elements in providing functional connectivity for a range of taxa in Australian ecosystems. The project is using the relatively new approach to systematic reviews developed by the Centre for Evidence-based Conservation (http://www.cebc.bangor.ac.uk/). I would add to the list above that there needs to be research on the importance of corridors and connectivity for elements other than fauna, as this skews the focus of the research to one set of organisms. This comment is particularly relevant to gaining a better understanding of what connectivity means in terms of ecological processes such as water flowing through the landscape, and disturbance regimes at the landscape scale.

As noted in the introduction to the review, a number of researchers were asked what they saw as major research gaps in landscape restoration in Australia. This engendered a diversity of responses, which were influenced by the discipline of the ecologist (plant versus animal ecologists), and the region of Australia they worked in (e.g. landscape restoration research is more common in temperate regions than in sub-tropical regions that have been cleared; researchers in savanna and rangeland regions have different perspectives). One scientist responded by saying that no more biophysical research was needed, and that the way forward was to encourage and support more Knowledge Brokers who understand and can transmit the "Science and Practice of NRM". The recent book edited by Lindenmayer and Hobbs (2007a) also recognised the need for more effective knowledge transfer and deeper exploration of this process. Another scientist felt that a major area of new research was needed in the socio-economic realm, including the cost of revegetation work (noting the recent work of Josh Dorrough and others in this area).

A list of eleven key areas for future research was derived from the input from researchers and workshop/desk-top study participants and research that is currently being funded by the Native Vegetation and Biodiversity Program of Land & Water Australia (Box 8). These are the areas that were raised a number of times, with some further details provided on some of the topics in the text that follows.

Box 8: Current and new research directions identified from input from researchers and workshop/desk-top study participants.

1. Clarifying corridors and connectivity.
2. Spatial and temporal dynamics of key processes (pollination, dispersal, fire, nutrient cycling etc.)Transferability between species (e.g. single to multiple) & regions.The role of cryptic biota in restoration (fungi, rhizobia etc.).Ecosystem services - *pest control, tropical ag, farmers*.Conservation & production synergies (managing the matrix).Native vegetation – design, restoration – site & large-scale.Develop a framework based on nutrient management.Examining the biodiversity outcomes of 'biolinks'.Experimentally trialling large-scale restoration approaches.Socio-economic research *e.g. costs of restoration activities; coordinated landscape scale outcomes with auctions; policy instruments to promote land-use change.*

In relation to biophysical science, there was general consensus that there is a need to gain a better understanding of the long-term impacts of restoration and 'bio-link'/large-scale connectivity projects on biodiversity outcomes (function, structure and composition) and the need to undertake a series of large-scale experimental trials of different landscape restoration approaches in an adaptive management framework. Examining the transferability of results between regions was another area of research that was raised as requiring further investment.

Using nutrient management as a unifying framework for vegetation and many other biota in the intensive land use zone, at catchment and patch scales, was proposed by Ian Lunt at Charles Sturt University. The rationale was that increasing nutrient levels lead to depleted vegetation diversity and weed responses, with impacts on soil biota, tree health, catchment nutrient leakage, river health, etc. A prime direction for vegetation restoration identified therefore was practical methods to reduce available nutrients, both in remnants and pastures. Given that increasing eutrophication is widely seen as one of the key global issues for biodiversity conservation, Ian believed that there is a vital need to get nutrient management on the restoration agenda in the highly modified landscapes of southern and eastern Australia.

Recent work by Suzanne Prober and Sue McIntyre have also focused on the role of nutrients in landscape restoration, with suggestions that farmers could be paid not to apply fertilisers in areas that were identified as having conservation significance (Sue McIntyre, personal communication). Nutrient management is also likely to be important for fauna. Research in forested landscapes has demonstrated the importance of foliar nutrients for breeding behaviour in arboreal mammals. It is likely that similar interactions occur in woodland ecosystems. The fluxes of nutrients and water in the landscape have also been identified as fundamental processes to manage in the rangelands (Ludwig *et al*. 1997) and when trying to maintain or enhance resilience (Walker and Salt 2006). Considering the importance given to nutrient and water cycles across a range of landscapes, further exploration of their value as an overarching framework seems warranted, building on the work that has already been done in the rangelands.

Better coupling of research with NRM on-ground investments was identified as an important element of future research activity, so that we learn from the restoration we undertake, and deal explicitly with our lack of knowledge, rather than pretend that the ‘feel-good’ actions currently funded will make the difference that is needed. This means strongly involving scientists in the design of NRM investments, and in monitoring outcomes.

14. Summary and conclusions

The field of landscape ecology/restoration is around two decades old in Australia. A number of key publications and landscape-scale experiments mark the beginnings of the topic as a research focus in the late 1980s, with interest gaining pace over the last decade. The use and application of the terms ‘landscape’ and ‘restoration’ are quite broad in both the research and on-ground worlds. It is critical therefore that precise definitions are given in any project, policy or on-ground program that claims to be addressing landscape restoration.

Landscape restoration science is grouped around number of ‘themes’, including connectivity and corridors, buffers and edge effects, vegetation patterns in the landscape, ecological processes and disturbance, resilience and recovery. The focus varies geographically in Australia and includes both increasing the extent of native vegetation in highly cleared areas and maintaining and enhancing vegetation condition across all landscapes. Research has largely focused on animals, less on plants (apart from it’s role as habitat), and even less on soils, although these areas are starting to gain more attention. The context where landscape restoration research is undertaken and applied is critical, as is setting clear restoration goals.

While conservation planning and prioritisation science and tools are not usually included in the ambit of landscape restoration science, they have an important role to play and are of keen interest to policy and on-ground practitioners. It would be valuable therefore to see greater integration of both the science and application of conservation planning and the work on the ecology of the systems that the planning tools are prioritising. Although the bulk of the literature on conservation planning and prioritisation focuses on spatial prioritisation for reserve design, there are some general principles arising out of that literature that could be valuably applied in restoration planning at the regional or landscape level.

The main restoration approaches used by groups and organisations at the regional level in the intensive land-use zone include focal species, thresholds, improving vegetation condition, managing for structural and floristic diversity and connectivity/corridors. The concept of ecosystem services is also being increasingly adopted, but there is limited quantitative information available that is relevant to regional decision-making. Emerging trends see an increasing number of large-scale 'biolink' style projects being implemented on-ground to combat threats such as climate change and continuing fragmentation. These 'biolink' style approaches currently have a limited scientific basis, which is starting to be addressed.

The choice and application of these approaches by policy and on-ground practitioners spans the intuitive to the systematic. One of the reasons why the application of landscape restoration science is not as systematic as it could be is related to the extensive range of landscape restoration approaches, tools and guidelines currently available. This diversity means that it is difficult for practitioners to work out which approach or technique best applies to them and the work they are doing. It was largely felt that there were already enough landscape principles available, the challenge was providing guidance on how to select the most appropriate set of principles for the landscape restoration goal at hand. Landscape restoration theories and approaches need to be demonstrated in action, with the 'real life' challenges and opportunities they bring, clearly communicated.

A number of trends and influences on landscape restoration science and its application were identified. These were summarised as 'from pattern to process', 'from patch to continent', from static to dynamic (space and time)', 'managing the matrix' (in intensively managed landscapes)', 'the direct and indirect impacts of climate change' (including the 'carbon economy'), 'intensification of land use', 'increased use of technology' and a suite of policy tools such as market-based instruments and offsets. It is important that these factors are kept in mind when undertaking, implementing and evaluating landscape restoration science.

No one recipe for landscape restoration exists, even though this is what practitioners may be looking for. As Mencken (a writer in the 1920s) said – there are no simple answers to complex problems. There is a need for a diversity of approaches in social, economic and ecological systems to reflect the diversity of these systems in the real world. This means taking a holistic approach to landscape management.

It has been acknowledged that much of the enormous body of knowledge gained over the last twenty years has had little bearing on the on-ground management of landscapes and that there is a need for more effective knowledge transfer and deeper exploration of this process. Some of the areas identified in trying to enhance the uptake of research include building relations, using cultural translators (knowledge brokers), user-friendly publications, building capacity (e.g. on-ground, institutional, students, supervision) and developing research agendas with end-users.

As well as paying more attention to the way science is translated into practice, there is a need for disciplines such as ecologists, economists and social scientists to work more closely together, in partnership with regional groups. A number of research gaps have been identified such as examining the transferability of results between regions, gaining a better understanding of the long-term impacts of restoration and 'bio-link' projects on biodiversity outcomes and the need to undertake a series of large-scale experimental trials of different landscape restoration approaches in an adaptive management framework. Until stronger links are made between research and it's adoption, such research will not meet it's full potential to influence policies and on-ground programs.

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Some URLs

- the focus here has been on sites that take you to a broad range of projects and resources.

http://www.greeningaustralia.org.au/resources/index.html - This will take you to Greening Australia's Exchange resource website, which includes the link to the Native Vegetation Resource Directories (which are national in scope), amongst other things.

http://www.ser.org/ - the website of the Society for Ecological Restoration International. This includes a link to the Global Restoration Network, for which an Australian section is currently being developed.

http://www.aeda.edu.au/ - this URL links to the Applied Environmental Decision Analysis (AEDA) research hub, funded through the Commonwealth Environment Research Facilities (CERF) programme. AEDA is planning to produce a series of informaiton sheets summarising their research as it comes to fruition.

http://www.lwa.gov.au/ - the URL for Land & Water Australia where you can gain access to all copies of Thinking Bush, as well as reports and fact sheets on the wide range of research across Australia. In particular, see the:

- The products from the Native Vegetation R&D Program of Land & Water Australia and the Native Vegetation and Biodiversity Sub-program of Land, Water & Wool; and
- The products from the Riparian Lands R&D Program of Land & Water Australia and the River and Water Quality Sub-program of Land, Water & Wool.

http://www.nrmtoolbar.net.au/ - The NRM Toolbar is a set of online tools and databases that make it easier for NRM professionals to find and share information.

http://www.betterbush.org.au/ - takes you to the Better Knowledge Better Bush website, which is providing the science to underpin landscape restoration initiatives in NSW (with relevance to other states in south-eastern Australia) and address gaps in our understanding of native vegetation and its management in agricultural landscapes.

http://savanna.cdu.edu.au/ - the website for the Tropical Savanna CRC, which has a wealth of information on research undertaken across northern Australia.

Appendix 1:

Scientists who responded to the invitation to answer the four questions; others expressed interest but didn't have the time to respond.

- Dr Joern Fischer, ANU
- Dr Suzanne Prober, CSIRO
- Associate Professor Andrew Bennett, Deakin University
- Dr Sue Briggs, Department of Conservation, NSW
- Dr Neville Crossman, CSIRO Land & Water
- Dr Veronica Doerr, CSIRO Sustainable Ecosystems
- Dr David Freudenberger, Greening Australia
- Dr Peter Jacklyn, Charles Darwin University
- Dr John Kanowksi, Griffith University
- Professor Jamie Kirkpatrick, University of Tasmania
- Associate Professor Ian Lunt, Charles Sturt University
- Professor David Lindenmayer, ANU
- Dr John Ludwig, CSIRO Sustainable Ecosystems
- Dr Sue McIntyre, CSIRO Sustainable Ecosystems
- Dr David Paton, University of Adelaide
- Professor Hugh Possingham, University of Queensland
- Dr Anita Smyth, CSIRO Sustainable Ecosystems
- Dr David Tongway, CSIRO Sustainable Ecosystems
- Dr Peter Vesk, Monash University
- Dr Brendan Wintle, University of Melbourne
- Dr Dick Williams, CSIRO Sustainable Ecosystems