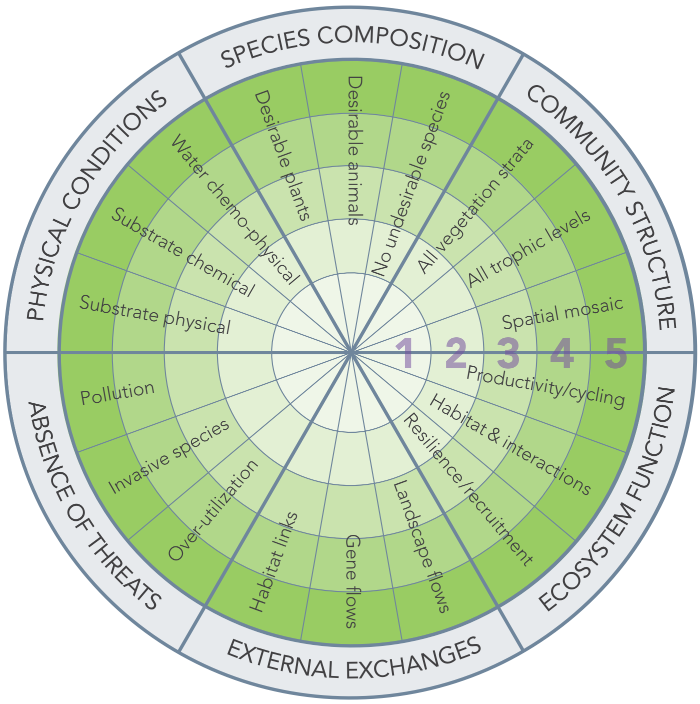
SER AUSTRALASIA
SOCIETY FOR ECOLOGICAL RESTORATION

National standards for the practice of ecological restoration in Australia



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In consultation with key partners.

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The Society for Ecological Restoration Australasia (SERA) is an independent, nonprofit ecological restoration organisation that connects the restoration community (industry, government, practitioners) across the Australasian region, and is a regional chapter of the peak international body for restoration, the Society for Ecological Restoration (SER). www.ser.org

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Notes to the Second Edition. The document is modified from (and supersedes) the First Edition of these standards which was the published paper: McDonald T., Jonson, J. and Dixon, K.W. (Eds) (2016a) National Standards for the Practice of Ecological Restoration in Australia. Restoration Ecology S1, 1-34. Most modifications consist of minor clarifications to the five-star evaluation tables and figures, as well as changes to the interpretation of what constitutes an ecological restoration activity to ensure consistency with the international document: McDonald, T., Gann, G.D., Jonson, J, and. Dixon, K.W. (2016b) International Standards for the Practice of Ecological Restoration—including principles and key concepts. First Edition. Society for Ecological Restoration, Washington DC.

Design: Little Gecko Media

Minister’s foreword

Australia is a country gifted with outstanding landscapes, unique and productive ecosystems, and thousands of species that occur nowhere else on earth. These places, plants, animals and systems are a core part of what it means to be Australian, they define us, and we all have a role to play in securing the future of our environment.

There are many parts of Australia that have become degraded and this has severe consequences for our quality of life and the natural values of this country. The Society for Ecological Restoration Australasia and its partners have taken a bold step to help ensure these areas, from urban bushland to the outback, can be restored using sound stewardship and the best possible science. The Society has produced the world’s first set of standards for restoration practice: *National Standards for the Practice of Ecological Restoration in Australia*.

Australian Government initiatives, such as the Green Army, 20 Million Trees and the National Landcare Programme, ensure we are working better with, and investing in, natural resource management groups, industry, farmers and local communities to support the protection, conservation and rehabilitation of Australia’s natural environment. Australia’s Threatened Species Strategy also sets out the Government’s commitment to reduce threats to our plants and animals, create and enhance safe havens and new habitat, improve the quality of existing habitat and improve recovery practices including through the use of national recovery plans and conservation advices. The Standards are a blueprint to ensure communities across Australia succeed in delivering sound environmental benefits.

The Society for Ecological Restoration Australasia and its partners are to be commended for delivering this world-first initiative that offers a way to change the face of ecological restoration in a positive and enduring way for all Australians. Supporting the recovery of our landscape requires a coordinated team approach and these Standards allow all Australians to contribute to rebuilding our wonderful natural heritage. This land is ours to protect and we all have a role to play.

The Hon Greg Hunt MP
Minister for the Environment,
Government of Australia

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Executive summary

The contemporary call for restoration comes at a critical point in our planet's history where human influence is all pervasive. Australia's long and relatively uninterrupted evolutionary past means the continent possesses ancient soils and exceptionally diverse and unique biota—yet its terrestrial and marine ecosystems carry a more recent legacy of extensive and continuing environmental degradation, particularly in urban, industrial and production landscapes and aquatic environments. Anthropogenic climate change is superimposing further pressure on ecosystems, whose vulnerability to climate change is exacerbated by other causal factors including land clearing, overharvesting, fragmentation, inappropriate management, disease and invasive species. Degradation is so severe in most cases that it will not be overcome without active and ecologically appropriate intervention including reduction of these causal factors and reinstatement of indigenous biodiversity.

The practice of ecological restoration seeks to transform humanity's role from one where we are the agents of degradation to one where we act as conservators and healers of indigenous ecosystems. It is in this context that the *National Standards for the Practice of Ecological Restoration in Australia* (the 'Standards') has been prepared by the Society for Ecological Restoration Australasia (SERA) in collaboration with its 12 not-for-profit Partner and advisor organisations; all of whom, like SERA, are dedicated to effective conservation management of Australia's indigenous ecological communities.

This document identifies the need and purpose of ecological restoration and explains its relationship with other forms of environmental repair. The Standards identifies the principles underpinning restoration philosophies and methods, and outlines the steps required to plan, implement, monitor and evaluate a restoration project to increase the likelihood of its success. The Standards are relevant to—and can be interpreted for—a wide spectrum of projects ranging from minimally resourced community projects to large-scale, well-funded industry or government projects.

SERA and its Partners have produced these Standards for adoption by community, industry, regulators/government and land managers (including private landholders and managers of public lands at all levels of government) to raise the standard of restoration and rehabilitation practice across all sectors. The document provides a blueprint of principles and standards that will aid voluntary as well as regulatory organisations in their efforts to encourage, measure and audit ecologically appropriate environmental repair in all land and water ecosystems of Australia.

Section 1 Introduction

Definitions

Ecological restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed. *(SER 2004[1])*

These *National Standards for the Practice of Ecological Restoration in Australia* (the 'Standards') adopt the above definition of **ecological restoration**—as articulated by the world's leading ecological restoration body, the Society for Ecological Restoration (SER 2004).

The Standards recognise that the same term 'ecological restoration' is commonly used to describe not only a process (i.e. the activity undertaken) but also the outcome sought (i.e. the restored state). These Standards favour the term **restoration** for the activity undertaken and **recovery** for the *outcome* sought or achieved. Thus the Standards define as a restoration activity any project that aims to progress an ecosystem as far as possible towards full recovery, relative to an appropriate local indigenous reference ecosystem - regardless of the period of time required to achieve that state. **Full recovery** is defined as the state whereby all ecosystem attributes closely resemble those of the reference ecosystem. Where only lower levels of recovery are possible despite best efforts, the recovery would be referred to as being in a state of partial recovery; although all such activities need to aspire to substantial recovery of native biota of the reference ecosystem to qualify as ecological restoration. (For definitions of all terms, see Glossary, Section 6.)

The fully restored state can only be considered achieved when the ecosystem's **attributes** are on a secure trajectory (pathway) to highly resemble those of the reference ecosystem without further restoration-phase interventions being needed. After full recovery has been attained, ongoing management interventions would be viewed as a form of ecosystem maintenance.

The *activity* and the *outcome* of ecological restoration are therefore inextricably linked. If the desired restoration *outcomes* are identified from the outset then these outcomes can direct the optimal restoration *process*. Similarly, where outcomes are uncertain, applying appropriate processes can help us to arrive at satisfactory outcomes.

Projects that focus solely on reinstating some form of ecosystem functionality without seeking to also recover a substantial proportion of the native biota found in an appropriate native reference ecosystem would be best described as **rehabilitation**. Such rehabilitation, as described in Appendix 1, is especially encouraged and valued where it: (i) improves ecological condition or function and (ii) is the highest standard that can be applied.

The ethic of ecological restoration

The ethic of ecological restoration is one of conservation, repair and renewal. There is global recognition that local indigenous ecosystems are of high intrinsic biological, societal and economic value but are diminishing in extent and condition. While protecting remaining ecosystems is vital to conserving our natural heritage, protection alone is not

[1] While the Standards draw on extensive expert input and a large body of knowledge available in the literature, the policy style and need for independence of the Standards require that citations are minimized.

sufficient. Human societies are increasingly recognising that we to need to achieve a net gain in the extent and function of indigenous ecosystems through supplementing conservation with environmental repair.

Ecological restoration therefore seeks the highest and best conservation outcomes for all ecosystems at increasingly larger scales. That is, ecosystem restoration seeks to not only compensate for damage and improve the condition of ecosystems but also to substantially expand the area available to nature conservation. This ethic informs and drives a process of scaling-up restoration efforts.

Ecological restoration in Australia—the need for Standards

The practice of ecological restoration is widespread in Australia and the demand for this activity is increasing across terrestrial, freshwater and marine biomes. Many government and non-government agencies, community groups, companies and private individuals choose to engage in the repair of damage, often inherited from previous generations, (**non-mandatory** restoration); while others are required to undertake restoration as part of consent conditions for current developments (**mandatory** restoration). While successes have occurred, often the outcomes from both pursuits fall short of their objectives due to a lack of appropriate effort, resources or insufficient or inappropriate knowledge or skill. Substantial progress could be made, however, with improved focus and greater resourcing.

Important foundation documents exist that inform and guide ecological restoration, namely the SER International Primer on Ecological Restoration (SER 2004)—expanded upon in Clewell & Aronson (2013)—and the IUCN (International Union for Conservation of Nature) guidelines (Keenleyside et. al. 2012). However this document (and its international adaptation McDonald et al. 2016b) are considered necessary to supplement these foundation documents. This is particularly to clarify the guiding principles and minimum standards expected if a project is to be described as an ecological restoration *activity*; and to clarify the degree to which *outcomes* are to be evaluated as ecological restoration. Australian Standards are also needed to more specifically tailor information to Australian planners and practitioners; drawing lessons from ecological restoration practice around the world but especially from Australia, a continent rich in unique species and ecosystems of extraordinary diversity and ecological complexity.

What are the Standards and for whom are they designed?

The Standards list (i) the principles that underpin current best practice ecological restoration and (ii) the steps required to plan, implement and monitor restoration projects to increase their chance of success. The Standards are applicable to any Australian ecosystem (whether terrestrial or aquatic) and any sector (whether private or public, mandatory or non-mandatory). They can be used by any person or organisation to help develop plans, contracts, consent conditions and closure criteria.

The Standards will be updated periodically or on a five-year cycle as required. They are designed to be generic in nature and thereby compatible with more detailed guidelines and standards that may already exist or which are yet to be prepared for a specific aspect of restoration, or geographically distinct biome.

Section 2 Six key principles of ecological restoration practice

Six 'key principles' are used here to provide a framework for conceptualizing, defining and measuring ecological restoration, particularly at a time of rapid environmental change.

Principle 1 Ecological restoration practice is based on an appropriate local indigenous reference ecosystem

A fundamental principle of ecological restoration is the identification of an appropriate **reference ecosystem** to guide project targets and provide a basis for monitoring and assessing outcomes. The **reference ecosystem** can be an actual site (**reference site**) or a conceptual model synthesized from numerous reference sites, field indicators and historical and predictive records. It includes local indigenous plants, animals and other biota characteristic of the pre-degradation ecosystem. (For exceptions see Box 1). The reference ecosystem may also include species from neighbouring localities that have recently naturally migrated e.g. due to a changing climate (See definition of 'local indigenous ecosystem' in Glossary). Where local evidence is lacking, regional information can help inform identification of likely local indigenous ecosystems. Identifying a reference ecosystem involves analysis of the **composition** (species), **structure** (complexity and configuration) and **function** (processes and dynamics) of the ecosystem to be restored on the site. The model should also include descriptions of successional states that may be characteristic of the ecosystem's decline or recovery.

A reference ecosystem is a model adopted to identify the particular ecosystem that is the **target** of the restoration project. This involves describing the specific compositional, structural and functional ecosystem attributes requiring reinstatement before the desired outcome (the restored state) can be said to have been achieved.

Australia's landmass, waterways and marine areas contain many intact or remnant indigenous ecosystems. The site's pre-degradation ecosystems are used as starting points for identifying restoration targets—taking into account natural variation and acknowledging the fact that ecosystems are dynamic and adapt and evolve over time, including in response to changing environmental conditions. That is, we use existing and recent assemblages, coupled with sound scientific and practical knowledge of current and future environmental conditions, to help identify suitable reference ecosystems. Where irreversible altered topography, hydrology, or climatic conditions have occurred or are predicted; a local indigenous ecosystem more ecologically appropriate to the changed conditions may be used as a guide (see caveats in Box 1). Adopting a reference ecosystem is therefore not an attempt to immobilize an ecosystem at some point in time but to optimise potential for local species to recover and continue to evolve and reassemble over subsequent millennia.

Identifying functional components of a reference ecosystem is important to goal setting; but returning functions also facilitates restoration. That is, recovery is achieved by the processes of growth, reproduction and recruitment of the organisms themselves over time, facilitated by the return of appropriate cycles, flows, productivity levels and specific habitat structures or niches. Monitoring of the recovery process is required to identify whether acceptable trajectories of recovery are likely to result in a self-organizing and functional ecosystem or whether further (or different) interventions are needed to remove barriers to recovery.

Box 1 Reference ecosystems in cases of irreversible environmental change

Many local sites, intact or degraded, are becoming increasingly threatened by human activities and some of these result in effectively irreversible impacts. Reinstating local indigenous ecosystems in cases where irreversible environmental change has occurred requires anticipation and, if necessary, mimicry of natural adaptive processes.

1 **Irreversible physical (soil and water) and biological changes.** In cases where insurmountable environmental change has occurred to the site and the pre-degradation ecosystem cannot be reinstated, an appropriate solution would be to establish an alternative, locally occurring ecosystem that would be expected to naturally occur under the changed conditions. (Examples include sites where hydrology has changed irreversibly from saline to freshwater or vice versa, traditional fire regimes cannot be reinstated, or where erosion has produced a rocky platform). *Examples of conversion.*

Whether such activities function as ecological restoration, a complementary restorative activity or simply a **reallocation** to another land use other than conservation (e.g. the creation of a designer ecosystem) will be highly dependent on the local historic occurrence of such shifts due to natural dynamic processes, the strength of the case for irreversibility, and the degree to which the project is primarily focused on establishing the full complement of key ecosystem attributes as distinct from ecosystem services alone.

Where biological degradation cannot be reversed, the next best alternative would be rehabilitation to the highest practicable ecological functionality, with as high as possible similarity to the reference ecosystem.

2 **Accelerated and irreversible climate change.** A changing climate means that all local ecosystems are likely to be changing at faster rates than in the past; in ways that are difficult to anticipate. Some entire ecosystems will be destroyed (e.g. many marine, coastal, alpine and cool temperate communities) where no suitable migration habitats exist; while in other ecosystems, species may have a capacity to adapt by genetic selection or migration, options that are less likely under conditions of fragmentation (Appendix 3).

Climate change is recognised as an anthropogenic degradation pressure that requires urgent and unfaltering mitigation of its causes, mitigation that needs to be embraced by the whole of society. Even with optimal mitigation, however, much of this change is irreversible and therefore becomes part of the environmental background conditions to which species need to adapt or be lost. To assist potential adaptation, target-setting needs to be informed by research into the anticipated effects of climate change on species and ecosystems so that reference ecosystems and restoration targets can be modified as required (Appendix 3).

> Where fine scale changes in temperature or moisture levels are expected to affect only some species at an individual site, adaptability can be improved by ensuring the restoration includes a high diversity of the site's other pre-existing species, some of which may be suited to the changed conditions. In cases where the climate envelope of the species is expected to shift as a result of climate forecasts, introducing more diverse genetic material of the same species from other parts of a species' range is often recommended; at least in fragmented landscapes or aquatic environments where migration potential is lower than intact areas (Refer to Appendix 3). As a rule of thumb, managers need to optimise potential for adaptation by retaining and enhancing genetically diverse representatives of the current local species in configurations that increase linkages and optimise gene flow. Such adaptation is maximized where all threats affecting ecosystems (particularly fragmentation) are minimized.

In the final analysis, however, the role of restoration is to 'assist recovery' not impose a human-design upon it—that is, to reinstate ecosystems on their trajectory of recovery so that their constituent species may continue to adapt and evolve. The Standards recommend practitioners continue with restoration aspirations based on local reference ecosystems, but be ready to adapt these in the light of observable or likely changes occurring within these local ecosystems, as informed by sound science and practice. Examples of renewing linkages in landscapes.

Principle 2 Restoration inputs will be dictated by level of resilience and degradation

All species (and ecosystems) possess an evolved but variable level of resilience: that is, a capacity to recover naturally from external stresses or shocks as long as those stresses are similar in type and degree to those previously experienced during the evolution of the species. This means that where human-induced impacts are low (or where sufficient time frames and nearby populations exist for effective recolonisation) recovery may be able to occur without assistance, but in sites of somewhat higher impact, at least some intervention is likely to be needed to initiate recovery. Where impacts are substantially higher or sufficient recovery time or populations are not available, correspondingly higher levels of restoration inputs and interventions are likely to be needed (see Figure 1). These may include remediation of the physical and chemical properties of the site, supplementing populations or reintroducing missing species or ecological processes. At extremely damaged sites, intransigent barriers to recovery may occur, in which case adaptive management and/or active research will be needed to identify specific solutions for restoration.

Skillful assessment of capacity for natural recovery should be done prior to prescribing whether **regeneration-based** or **reconstruction-based** approaches are needed (Box 2). This is essential to optimise success but is also important to assist prioritisation. That is, variation in the resilience of sites (and the higher cost of assisting recovery where the potential is lower) highlights the strategic advantage that can be gained by investing scarce resources into areas where resilience and potential for connectivity is higher.

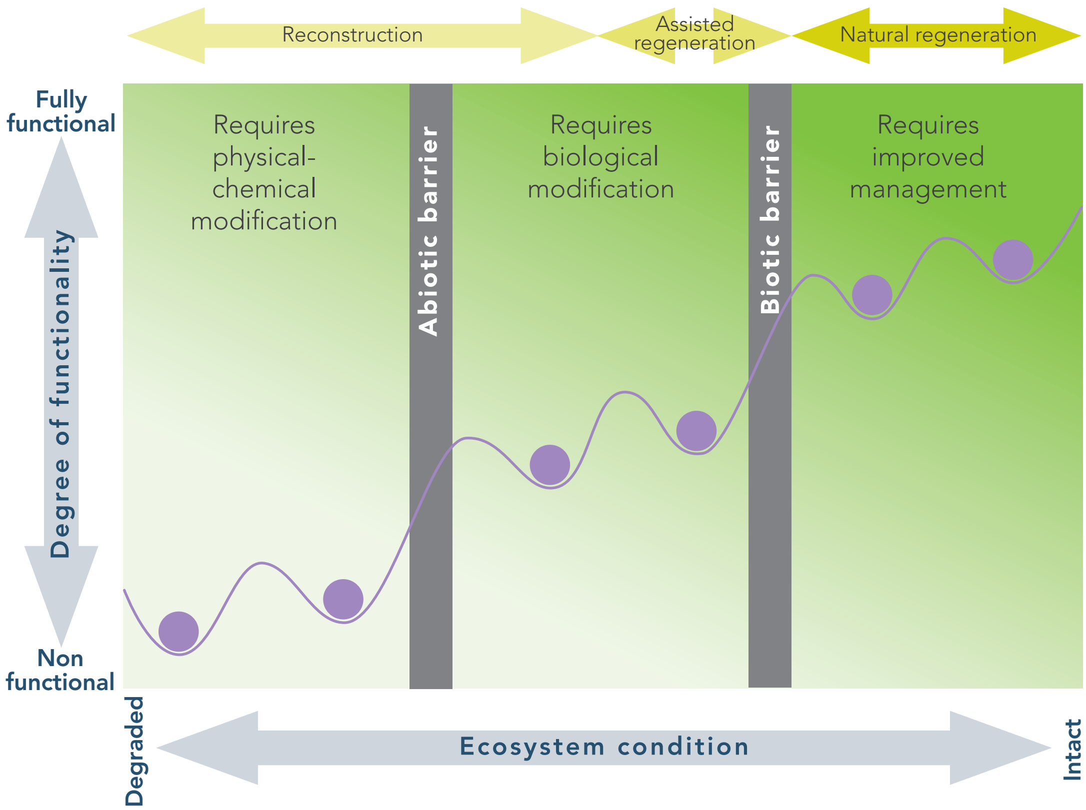

Figure 1 Conceptual model of ecosystem degradation and restoration. (Adapted from Keenleyside et al 2012, after Whisenant 1999, and Hobbs & Harris 2001). The troughs in the diagram represent basins of stability in which an ecosystem can remain in a steady state prior to being shifted by a restoration or a degradation event past a threshold (represented by peaks in the diagram) towards a higher functioning state or a lower functioning state. [Note: Not all sites in need of physical/chemical amendment depend upon reintroduction for the return of biota—e.g. if colonisation potential in that ecosystem is high.]

Box 2 Identifying the appropriate ecological restoration approach

Correctly assessing the capacity of various parts of a site to recover facilitates the selection of appropriate approaches and treatments—avoiding inefficient use of natural resources or restoration inputs. A useful initial rule of thumb is to identify any potential for harnessing the natural regeneration capacity of plants, animals or other biota and to use one of the 'regeneration' approaches outlined below where such potential exists. Introductions can then be focused on areas (or for species) where natural or assisted recovery is low or not possible.

Three approaches are usually used alone or combined if appropriate. All will require ongoing adaptive management until recovery is secured.

1 **Natural regeneration** approach. Where damage is relatively low, pre-existing biota should be able to recover after cessation of the degrading practices. Examples of degrading practices include removal of native vegetation, over-grazing, over-fishing, restriction of water flows or inappropriate fire regimes etc. Animal species may be able to migrate back to the site if connectivity is in place. Plant species may recover through resprouting or germination from remnant soil seed banks or seeds that naturally disperse from nearby sites. *Examples of natural regeneration.*

2 **Assisted regeneration** approach. Recovery at sites of intermediate (or even high) degradation need both the removal of causes of degradation and further active interventions to correct biotic or abiotic damage. Examples of biotic interventions include controlling invasive plants and animals and reintroducing dispersal attracting species. Lower level abiotic interventions include e.g. reinstating environmental flows and fish passage (in aquatic sites), and (in terrestrial sites) applying disturbances such as fire to break seed dormancy or installing habitat features such as hollow logs, rocks, woody debris piles and perch trees. Higher level abiotic interventions include remediating contamination or substrate chemistry, reshaping watercourses and landforms and building habitat features such as shell reefs. *Examples of assisted regeneration.*

3 **Reconstruction** approach. Where damage is high, not only may all causes of degradation need to be removed or reversed and all biotic and abiotic damage corrected to suit the identified local indigenous ecosystem, but also all or a major proportion of its desirable biota need to be reintroduced. *Examples of reconstruction.*

Combined approaches are sometimes warranted. Varying responses by individual species to the same impact type can mean that some species drop out of an ecosystem earlier than others. In such cases less resilient species may require reintroduction in an area where a natural or assisted regeneration approach is generally applicable. In addition, plant species may require reintroduction, while all or some animal species may recover without the need for reintroduction (or vice versa). Reintroductions of plants or animals may also be justified where genetic diversity requires supplementation. *Examples of fauna reintroduction.*

A mosaic of approaches can be warranted where there is a diversity of different condition across a site. That is, some parts of a site may require a regeneration approach, while others require a reconstruction approach or combinations as appropriate.

Responding to site conditions in this way will ensure optimal levels of similarity between the restoration outcome and conditions observed in the appropriately identified reference ecosystem.

Principle 3 Recovery of ecosystem attributes is facilitated by identifying clear targets, goals and objectives

A restoration project will have greater transparency, manageability and improved chances of success if the restoration targets and goals are clearly defined and translated into measurable objectives. These can then be used to monitor progress over time, applying adaptive management approaches (Box 3).

Ecological references identify the particular terrestrial or aquatic ecosystem that is the **target** of the restoration project. This involves describing the specific compositional, structural and functional **ecosystem attributes** requiring reinstatement before the desired outcome (the restored state) can be said to have been achieved. The Standards list the ecosystem attributes (rationalised from those of the SER Primer) as: *absence of threats, physical conditions, species composition, community structure, ecosystem function, and external exchanges* (Figure 2). These attributes in combination can then be used to derive a five-star rating system (see Principle 4) that enable practitioners, regulators and industry to track restoration progress over time and between sites.

That is, a restored state is considered to have been achieved when the ecosystem's attributes are on a secure trajectory approximating those in the ecological reference without further repair-phase interventions being needed other than ongoing protection and maintenance. At that stage the ecosystem under recovery would be considered 'self-organising' and increasingly resilient to natural disturbances.

Each ecosystem attribute will comprise a range of more detailed component properties, that in turn inform **goals** and **objectives** needed to achieve the target. These component properties have different expressions in different biomes and different sites, which will mean that each project will have site-specific targets, goals and objectives aligned with specific attributes (Box 4). Specific **indicators** are selected to help evaluate whether these targets, goals and objectives are being met as a result of the interventions (Boxes 3 and 4, Appendix 4).

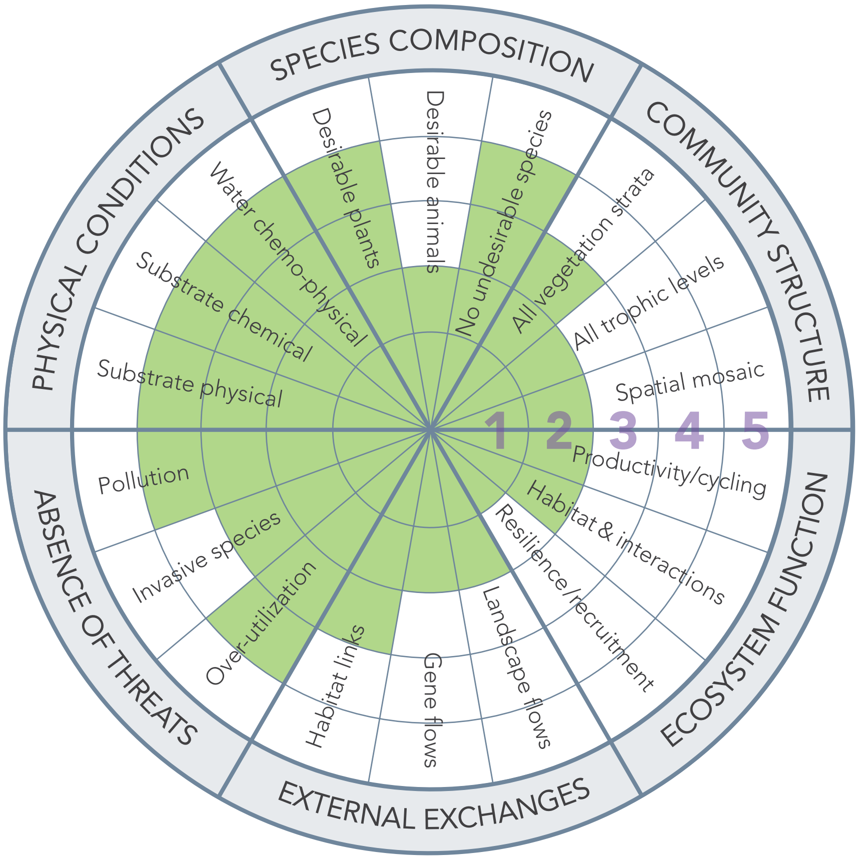

Figure 2 Progress evaluation 'recovery wheel'. This template allows a manager to illustrate the degree to which the project is achieving its ecosystem goals over time. (In this case a hypothetical one-year old reconstruction site on its way to a four-star condition.) A practitioner with a high level of familiarity with the goals and achievements of the project can shade the segments for each sub-attribute after formal or informal evaluation. (Blank templates for the diagram and its accompanying proforma are available in Appendix 5.) Notes: Sub-attribute labels can be adjusted or more added to better represent a particular ecosystem. The scores must be based on informal or formal monitoring indicators for the project, and reflect the rigour and reliability of that monitoring. These should be identified at the outset of the project to provide ecologically meaningful information about the sub-attributes and attributes being finally evaluated.

Box 3 Restoration monitoring and adaptive management

Monitoring the responses of an ecosystem to restoration actions is essential to:

- identify whether the actions are working as expected or need to be modified (i.e. adaptive management);
- provide evidence to stakeholders that specific goals are being achieved (Box 4); and,
- answer specific questions—e.g. to evaluate particular treatments or what organisms or processes are returning to the ecosystem.

Adaptive management is a form of 'trial and error'. Using the best available knowledge, skills and technology, an action is implemented and records are made of success, failures and potential for improvement. These learnings then form the basis of the next round of 'improvements'. An adaptive management can and should be a standard approach for any ecological restoration project irrespective of how well-funded that project may be.

1 The most direct and critical form of monitoring for adaptive management is routinely inspecting the site to **identify whether restoration actions are working or need to be modified**. Such monitoring is undertaken by the project supervisor to identify any need for a rapid response and to ensure appropriate treatments can be scheduled before problems become entrenched. Additional inspections are also needed after episodic events such as storms, floods, fire, severe frost and droughts.

2 The minimum formal monitoring required for adaptive management—and to provide **evidence to stakeholders and regulators that goals are being achieved**—is to maintain a photo monitoring record of the site being treated, using a fixed photopoint. All monitoring—even time series photos—needs to have evidence of 'before' condition. This is because, once the whole site is treated, a photo may be the only evidence that change has occurred. Photo monitoring at control (untreated) sites is also recommended, where possible. For larger sites, aerial photography may also provide useful before and after imagery.

Well-funded projects (or projects under regulatory controls e.g. mine site restoration) are expected to undertake formal comprehensive monitoring for adaptive management and reporting to stakeholders. This usually involves professionals or skilled advisors and is based on a monitoring plan that identifies, among other things, monitoring design, timeframes, who is responsible, the planned analysis, and frameworks for response and communication to regulators, funding bodies or other stakeholders.

The monitoring design of projects may involve development or adaptation of a condition assessment system or formal sampling system to track the progress of specific indicators, whether they be abiotic or biotic. In some cases individual species or groups of species can function as surrogates for suitable abiotic conditions. For soil microorganisms, one or more quantitative determinants are used consistently throughout the life of the restoration project to ensure that the functional diversity of the microbial communities is restored in soils. Formal sampling of plant and animal populations can involve a range of faunal trapping and tracking methods or vegetation sampling using randomly located quadrats or transects. Design of such monitoring schemes should occur at the planning stage of the project to ensure that the project's goals, objectives and their selected indicators are measurable and that the monitoring aligns with these goals. Care should be taken to ensure that the sampling commences prior to the commencement of restoration treatments, and where possible, control sites should be included in the design. If the necessary skills are not available in-house, advice should be sought from relevant professionals with experience in designing site-appropriate monitoring, documenting and storing data, and carrying out appropriate analysis.

3 Monitoring can be used **to answer questions** (hypotheses) about new treatments or the return of organisms or processes—but only if the data collected are well matched to the particular question and an appropriate experimental design is employed. A restoration project that is comparing or trialling techniques needs to observe the conventions of replication and include untreated controls in order to interpret the results with any certainty. Rigorous recording is also needed of specific restoration treatments and any other conditions that might affect the results. A standard practice in such a situation would be for the practitioner to partner with an ecologist or relevant scientist to ensure the project receives the appropriate level of advice and assistance. Where new treatments are being considered or where the nature of the site is uncertain, treatments are first trialled in smaller areas prior to application over larger areas.

Example of integrating research and practice.

Box 4 Targets, goals and objectives—what terms should we use?

It is useful to have a hierarchy of terms such as 'target', 'goals' and 'objectives', to better organize planning so that proposed inputs are well matched to the desired ultimate outcomes.

While there is no universally accepted terminology and many groups will prefer to use their traditional terms, the Standards broadly adopt the terminology of the Open Standards for the Practice of Conservation (Conservation Measures Partnership 2013 cmp-openstandards.org/).

It helps to think of objectives needing to be S.M.A.R.T.(i.e. specific, measurable, achievable, reasonable and time-bound). They should be directly connected to key attributes of the target ecosystem. This is achieved by the use of specific **indicators**.

Hypothetical example:

1 **Target**. The target of a project can be interpreted as the specific reference community to which the restoration project is being directed—e.g. 'Box-Ironbark Forest'—and will include a description of the ecosystem attributes.

2 **Goal/s.** The goal or goals provide a finer level of focus in the planning hierarchy compared to the target. They describe the status of the target that you are aiming to achieve and, broadly, how it will be achieved. For example, goals in this hypothetical project may be to achieve:

- i An intact and recovering composition, structure and function of remnants A and B within five years;
- ii 20 ha of revegetated linkages between the remnants within 10 years; and,
- iii 100% support of all stakeholders and neighbours within five years.

3 **Objectives.** These are the changes and intermediate outcomes needed to attain the goal/s. For example preliminary objectives may be to achieve:

- ii Less than 1% cover of exotic plant species and recruitment of at least two obligate seeding native shrub species in the remnants within two years; and,
- ii A density of 300 stems /ha of native trees and shrubs, at least three native herb species / 10 m^2 and a coarse woody debris load of 10 m^3/ha in the reconstructed linkages within three years.
- iii Cessation of all livestock encroachment and weed dumping within one year and formation of a 'friends' group representing neighbours within two years.

(For other examples of some detailed indicators, see Appendix 4)

Principle 4 Full recovery is the goal of ecological restoration wherever possible, even if outcomes take long timeframes or involve high inputs

Qualification of a project as an ecological restoration activity is not determined by the duration of the project but by the intent to achieve the highest and best level of recovery possible. It is important to bear in mind that the desired outcome may take long timeframes. This can be because sufficient time has not yet elapsed for recovery processes to run their course; sufficient restoration resources or knowledge are not yet available to overcome recovery barriers; or mitigating impacts originating from outside the site require lengthy negotiation. While success can be achieved ultimately by continuous improvement over time in many cases (e.g. non-mandatory cases), the achievement of full recovery would require more substantial human and financial investment including in-depth research where only relatively short timeframes are available (e.g. many mandatory restoration cases).

To help managers track progress towards project goals over time, the Standards offer a tool (five-levels or 'stars') for progressively assessing and ranking degree of recovery over time. This tool is summarised in Table 1 and more fully described, relative to the six attributes of ecological restoration, in Table 2.

Five-star recovery—that is, where the ecosystem is on a self-organising trajectory to full recovery based on an appropriate local indigenous reference ecosystem—is the standard to which ecological restoration projects ideally aim. However, in some cases, constraints may limit potential to less than full level of recovery. Such cases can still be referred to as ecological restoration projects as long as the aim is for substantial recovery relative to the appropriate local indigenous reference ecosystem. However, projects that aim for low levels of recovery—or solely recovery of ecosystem functions without including the appropriate local biota—are better referred to as rehabilitation (Appendix 1).

Table 1 Summary of generic standards for one to five star recovery levels. [Note 1: Each level is cumulative. Note 2: The different attributes will progress at different rates—see Table 2 that shows more detailed generic standards for each of the six attributes.

Number of stars	**Recovery outcome** (Note: modeled on an appropriate local indigenous ecological reference)
1	Ongoing deterioration prevented. Substrates remediated (physically and chemically). Some level of indigenous biota present; future recruitment niches not negated by biotic or abiotic characteristics. Future improvements for all attributes planned and future site management secured.
2	Threats from adjacent areas starting to be managed or mitigated. Site has a small subset of characteristic indigenous species and there is low threat from undesirable species on site. Improved connectivity arranged with adjacent property holders.
3	Adjacent threats being managed or mitigated and very low threat from undesirable species on site. A moderate subset of characteristic indigenous species are established and evidence of ecosystem functionality commencing. Improved connectivity in evidence.
4	A substantial subset of characteristic biota present (representing all species groupings), providing evidence of a developing community structure and commencement of ecosystem processes. Improved connectivity established and surrounding threats being managed or mitigated.
5	Establishment of a characteristic assemblage of biota to a point where structural and trophic complexity is likely to develop without further intervention other than maintenance. Appropriate ecosystem exchanges are enabled and commencing and high levels of resilience is likely with return of appropriate disturbance regimes. Long term management arrangements in place.

Notes for interpreting the five-star evaluation system

1 The five-star system has been designed to evaluate the progression of an ecosystem along its recovery trajectory. It is not a tool for evaluating the practitioner.

2 The five-star system represents a conceptual gradient, providing a framework that can be interpreted by managers, practitioners and regulators in more quantitative terms to suit a specific ecosystem. The indicators described here are generic and provided as a guide only. This means that the indicators or metrics used to specifically describe and interpret recovery at each ranking level for a specific ecosystem need to be interpreted for each project.

3 Evaluation can only be as rigorous (and therefore as reliable) as the monitoring that informs it. As some projects can only provide informal monitoring, evaluation needs to transparently specify the level of detail and degree of formality of the monitoring from which the conclusions have been drawn. This means that Figure 2 or an evaluation table cannot be used as evidence of restoration success without the monitoring report on which it is based.

4 Each restoration project does not necessarily start at a one-star ranking. Sites that involve remnant biota and unaltered substrates will start at a higher ranking—while sites where substrates are impaired and/or biota are absent will start at a lower ranking. Whatever the entry point of a project, the aim will be to progress the ecosystem along the trajectory of recovery towards a five-star rated recovery.

5 Although the ideal aim is to achieve a five-star rating for all attributes in a restored system, full recovery of some attributes will be difficult to achieve at larger scales. Complete removal of external threats in a fragmented landscape or aquatic environment, for example, is usually beyond the scope of site-specific restoration project but reduction of these threats may be possible (e.g. pollution regulation, 'no take' zoning, installation of nutrient filters, ongoing control of pest species etc). Assessment of ongoing threat levels should be in place at the restoration site. If removal or reduction of external threats is not fully achievable, monitoring and reporting needs to indicate whether this is the result of external constraints and to what extent these are resolvable.

6 Evaluation using the five-star system and Figure 2 must be site- and scale-specific. An evaluation will provide more detail when applied at the scale of an individual project or site. However multiple evaluations can be aggregated to inform degree of recovery in larger programs. Where larger scale projects retain substantial areas of permanently converted industrial activity or urban development, scores will necessarily be lower. Nonetheless, in such situations additional detail in supplementary reporting can capture even low level gains at larger scales where these are important for some species or ecological processes. Similarly, in social-ecological systems, progress with important social outcomes of the project (such as increasing level of capacity and stewardship commitment by stakeholders) can be reported separately to capture social elements.

Table 2 Generic one-to-five-star recovery scale interpreted in the context of the six attributes used to measure progress towards a restored state. (Note: this five-star scale represents a gradient from very low to very high similarity to the reference ecosystem. It provides a generic framework only; requiring users to develop indicators and a metric specific to their system and ecosystem type.)

Attribute	One-star	Two-star	Three-star	Four-star	Five-star
Absence of threats	Further deterioration discontinued and site has tenure and management secured.	Threats from adjacent areas beginning to be managed or mitigated.	All adjacent threats being managed or mitigated to a low extent.	All adjacent threats starting to be managed or mitigated to an intermediate extent.	All threats managed or mitigated to high extent.
Physical conditions	Gross physical and chemical problems remediated (e.g. contamination, erosion, compaction).	Substrate chemical and physical properties (e.g. pH, salinity) on track to stabilise within natural range.	Substrate stabilised within natural range and supporting growth of characteristic biota.	Substrate maintaining conditions suitable for ongoing growth and recruitment of characteristic biota.	Substrate exhibiting physical and chemical characteristics highly similar to that of the reference ecosystem with evidence they can indefinitely sustain species and processes.
Species composition	Colonising indigenous species (e.g. ~2% of the species of reference ecosystem). No threat to regeneration niches or future successions.	Genetic diversity of stock arranged and a small subset of characteristic indigenous species establishing (e.g. ~10% of reference). Low threat from exotic invasive or undesirable species.	A subset of key indigenous species (e.g.~25% of reference) establishing over substantial proportions of the site, with nil to low threat from undesirable species	Substantial diversity of characteristic biota (e.g. ~60% of reference) present on the site and representing a wide diversity of species groups. No inhibition by undesirable species	High diversity of characteristic species (e.g. >80% of reference) across the site, with high similarity to the reference ecosystem; improved potential for colonisation of more species over time
Structural diversity	One or fewer strata present and no spatial patterning or trophic complexity relative to reference ecosystem.	More strata present but low spatial patterning and trophic complexity, relative to reference ecosystem.	Most strata present and some spatial patterning and trophic complexity relative to reference site.	All strata present. Spatial patterning evident and substantial trophic complexity developing, relative to the reference ecosystem	All strata present and spatial patterning and trophic complexity high. Further complexity and spatial patterning able to self-organise to highly resemble reference ecosystem.
Ecosystem functionality	Substrates and hydrology are at a foundational stage only, capable of future development of functions similar to the reference.	Substrates and hydrology show increased potential for a wider range of functions including nutrient cycling, and provision of habitats/ resources for other species.	Evidence of functions commencing—e.g. nutrient cycling, water filtration and provision of habitat resources for a range of species.	Substantial evidence of key functions and processes commencing including reproduction, dispersal and recruitment of a species.	Considerable evidence of functions and processes on a secure trajectory towards reference and evidence of ecosystem resilience likely after reinstatement of appropriate disturbance regimes.
External exchanges	Potential identified for reinstating exchanges (e.g. of species, genes, water, fire) with surrounding landscape or aquatic environment.	Connectivity for enhanced positive (and minimised negative) exchanges arranged through cooperation with stakeholders and configuration of site.	Connectivity increasing and exchanges between site and external environment starting to be evident (e.g. more species, flows etc)	High level of connectivity with other natural areas established, observing control of pest species and undesirable disturbances.	Evidence that potential for external exchanges is highly similar to reference and long term integrated management arrangements with broader landscape in place and operative.

Principle 5 Restoration science and practice are synergistic

Practitioner and stakeholder knowledge and experience, particularly where arising from local sources, is important to restoration practice, This knowledge however should, wherever possible, be supported by knowledge drawn from informal and formal science

Ecological restoration is a rapidly emerging practice that often relies upon processes of trial and error, with monitoring increasingly being informed by scientific approaches (Box 3). Formal field experiments can also be incorporated into restoration practice, generating new findings to both inform adaptive management and provide valuable insights for the natural sciences.

Science is not the preserve of professional scientists—rather it is a logical approach to thinking based on systematic, repeatable observations and, ideally, controlled experiments to test a prediction (hypothesis). To optimise our ability to gain knowledge from restoration practice and be informed by science-practice partnerships should be encouraged. Such partnerships will help optimise potential for innovative restoration approaches to provide reproducible data and robust guidance for future activities.

Substantial background knowledge of both restoration practice and underpinning ecology is needed for professional ecological restoration planning, implementation and monitoring, requiring the planner and practitioner to draw as fully as possible from all learnings to date. Further applied and basic science is needed in a range of scenarios to support the ongoing development of the discipline of ecological restoration. This is particularly needed with respect to understanding how an ecosystem is assembled and what may be the critical minimum conditions needed to enable an ecosystem to continue its own recovery processes unaided (complete with characteristic resistance and resilience to stresses). There is also an emerging need for science to assist with assessing the potential adaptability of a plant or animal population to climate change. If little is known about a population, research may be needed to determine the degree of assistance required to improve climate-readiness, i.e. improve the potential adaptability of a population to anticipated climate scenarios (Appendix 3).

Formal research can help practitioners overcome what can seem intransigent barriers to recovery, particularly for larger scale projects where cost-effectiveness becomes paramount. These barriers might include hostile substrate conditions, problematic reproductive attributes of species and inadequate supply and quality of germplasm. In cases of mandatory restoration, transparency regarding the availability of scientific knowledge to support a restoration outcome would be expected at the development proposal stage. Where reasonable or unanticipated technical challenges arise during a mandatory restoration project, targeted research should be undertaken to identify solutions. If such research is appropriate and adequate but still fails to provide the technical solutions to meet performance criteria in relation to a restoration objective, it would be appropriate to redefine the restoration end-point to a lower classification for that objective as soon as possible and seek alternative compensations to meet regulatory requirements.

Principle 6 Social aspects are critical to successful ecological restoration

Restoration is carried out to satisfy not only conservation values but also socioeconomic values, including cultural ones. Without considering these values, particularly relationships between a site and its stakeholders, a restoration project may not gain the social support needed for success and may fail to deliver important benefits to ecosystems and to society. Few ecosystems are without human influence—whether positive or negative. Some human-induced disturbance regimes are intrinsic to the structure and function of a local indigenous ecosystem (e.g. Indigenous fire management regimes that have long exposed sites to fire or protected them from it); while others can progressively erode ecosystems or shift them to cultural ecosystems. This means that values and behaviors of humans (whether positive or negative) will dictate the future of ecosystems. Conserving and restoring ecosystems therefore depends upon appreciation by society of the negative and positive effects of different behaviors; and involvement by all stakeholders in finding solutions to ensure that ecosystems and society mutually prosper.

The practical implications for restoration are that restoration planners and project managers need to genuinely and actively engage with those who live or work within or near a site to be restored, as well as with others who have a stake in the area's goods, services or values. This needs to occur at the outset of and throughout a restoration project. Not only will a restoration project be more secure if genuine dialogue occurs between managers and stakeholders, but also this dialogue—coupled with education about the ecosystem—can increase the level of practical collaboration, facilitating solutions best suited to local ecosystems and cultures.

Education and engagement is often best achieved by actively involving adequately supervised stakeholders in paid or voluntary work—both having a positive effect in stakeholder communities. Restoration work has demonstrated a potential to generate direct and indirect employment opportunities in many regions. This is particularly beneficial in rural or remote regions where other industries and gainful employment are declining or are marginal—including in remote areas owned and managed by Indigenous groups who are employed to provide ecosystem services (e.g. carbon abatement or habitat restoration) for which society is prepared to pay. Where projects involve community volunteers, restoration activity can serve to educate participants and create improved social outcomes including community cohesion and individual welfare.

Social engagement, interpretation and education regarding the benefits of restoration to stakeholders are therefore essential components of a restoration project and need to be planned and resourced alongside the physical or biological project components. This investment is likely to be rewarded manyfold with increased awareness and understanding of problems and potential solutions by members of society who may have the strongest 'say' in the future of an area when funding programs and individual champions have come and gone.

Section 3 Standards for ecological restoration activities—planning, implementation, monitoring and evaluation

Restoration projects need to adopt appropriate processes of planning, implementation, monitoring and evaluation to improve the chances of achieving the desired restoration outcomes.

The following activities and their performance levels are those required for professional level ecological restoration planning, implementation, monitoring and evaluation. The size and complexity of the work carried out (as well as qualifications and experience of staff) should correspond to the size, complexity, degree of damage, regulatory status and budgets of the project. Non-professional practitioners, using a similar process of adjusting performance levels to project size, are encouraged to adopt this guide to optimise success.

As complementary interpretations, guidelines or specific industry sector standards become available these will be linked to updates of this Standards document.

1 PLANNING AND DESIGN

1.1 Stakeholder engagement. Stakeholder engagement is essential to the sustained success of any project. Meaningful engagement must be undertaken at the planning stage of a restoration project, with all key stakeholders (including the land or water manager, industry interests, neighbours and Indigenous stakeholders). Plans for public areas or mandatory restoration include a strategy for stakeholder engagement throughout and upon completion of the project. (See tool: *The Open Standards for the Practice of Conservation* (cmp-openstandards.org/).

1.2 External context assessment. Plans are informed by regional conservation goals and priorities and:

1.2.1 Contain a diagram or map of the project in relation to its surrounding landscape or aquatic elements;

2.2.2 Identify ways to align habitats at the restoration site to improve external ecological connectivity with the surrounding landscape or aquatic environment to optimise colonisation and gene flow potential between sites; and,

1.2.3 Specify mechanisms for the project to interface optimally with nearby indigenous ecosystems or land or water use areas.

1.3 Ecosystem baseline inventory. Plans identify the site's current ecosystem and its condition—including:

1.3.1 A list of all native and non-native species evidently persisting on the site, particularly noting any threatened species or communities;

1.3.2 Status of current abiotic conditions—including the dimensions, configuration and physical and chemical condition of streams, waterbodies, land surfaces, water column or any other material elements relative to prior conditions;

1.3.3 Relative capacity of the biota on site or external to the site to commence and continue recovery with or without assistance (i.e. degree of resilience). This includes undertaking an inventory of:

- Indigenous and non-indigenous species presumed absent and those potentially persisting as propagules or occurring within colonisation distance;
- Any areas of higher and/or lower condition, including priority resilient areas and any distinct spatial zones requiring different treatments;

1.3.4 Type and degree of threats that have caused degradation, damage or destruction on the site and ways to eliminate, mitigate or (in some cases) adapt to them; depending on degree of reversibility. This includes assessment of:

- Historical, existing and anticipated impacts within and external to the site—e.g. over-utilisation, sedimentation, fragmentation, pest plants and animals, hydrological impacts, pollution impacts, altered disturbance regimes and other threats—and ways to manage, remove or adapt to them;
- Description of the need for supplementing genetic diversity for species reduced to non-viable population sizes due to fragmentation [to a standard described in Offord & Meagher 2009 (for flora); and IUCN/SSC 2013 (for fauna)].
- Existing and anticipated effects of climate change (temperature, rainfall, sea level, marine acidity etc.) on species and genotypes with respect to likely future viability. (For useful tools see: Appendix 3).

1.4 Reference ecosystem identification. Plans identify and describe (to the level needed to assist project design) the appropriate local native reference ecosystem(s), actual or compiled from historical or predictive records. (Generic information on benchmark characteristics and functions for the ecosystems may be available in state-based guidelines. These should be used to assist, not replace, reference ecosystem identification.) The reference ecosystem will represent the composition and any notable structure or functions (reflecting the six ecosystem attributes) including:

1.4.1 Substrate characteristics (biotic or abiotic, aquatic or terrestrial),

1.4.2 The ecosystem's functional attributes including nutrient cycles, characteristic disturbance and flow regimes, animal-plant interactions, ecosystem exchanges and any disturbance-dependence of component species;

1.4.3 The major characteristic species (representing all plant growth forms and functional groups of micro and macro fauna);

1.4.4 Any ecological mosaics, requiring the use of multiple reference ecosystems on a site. (In cases where intact ecosystems are being disturbed and then restored, the pre-existing intact ecosystems must be mapped in detail prior to site disturbance);

1.4.5 Assessment of habitat needs of important biota (including any minimum range areas for fauna and their responses to both degradation pressures and restoration interventions).

1.5 Targets, goals and objectives. To produce well-targeted works and measure whether success has been achieved (see also Monitoring, below), plans identify a clearly stated:

1.5.1 Restoration **target**—i.e. reference ecosystem (including description of ecosystem attributes);

1.5.2 Restoration **goal**(s)—i.e. the condition or state of that ecosystem and attributes that you are aiming to achieve;

1.5.3 Restoration **objectives**—i.e. changes and immediate outcomes needed to achieve the target and goals relative to any distinct spatial zones within the site. Such objectives are stated in terms of measurable and quantifiable indicators to identify whether or not the project is reaching its objectives within identified timeframes.

1.6 Restoration treatment prescription: Plans contain clearly stated treatment prescriptions for each zone, describing what, where and by whom treatments will be undertaken and their order or priority. Where knowledge or experience is lacking, adaptive management or targeted research that informs what an appropriate prescription is, will be necessary.

Plans should include:

1.6.1 Descriptions of actions to be undertaken for elimination or reduction/ mitigation of causal problems;

1.6.2 Identification of (and brief rationale for) (i) specific restoration approaches (ii); descriptions of specific treatments for each zone; and (iii) prioritisation of actions. Depending on the condition of the site, this includes identification of:

- Amendments to the shape, configuration, chemistry or other physical condition of abiotic elements to render them amenable to the recovery of target biota and ecosystem structure and function;
- Effective and ecologically appropriate strategies and techniques for the control of undesirable species to protect desirable species, their habitats and the sensitivities of the site.
- Ecologically appropriate methods for triggering regeneration or achieving reintroduction of any missing species.
- Specifications for appropriate species selection and genetic sourcing of biota to be reintroduced. In the case of fauna, a strategy for sourcing and re-introduction should comply with IUCN/SSC (2013). In the case of plant species a strategy for sustainable seed supply and a timetable for collection and supply of seed should be prepared that complies with guidelines in 'Plant germplasm conservation in Australia' (Offord & Meagher 2009) and the 2016 or later revision of the Florabank guidelines and codes of practice www.florabank.org.au/. Useful standards for seed-related practice can be found in Australian Seeds, Sweedman & Merritt (2006) and Revegetation Industry Association of Western Australia's (RIAWA) Seed Industry Standards riawa.com.au/wordpress/wp-content/uploads/2015/05/01-RIAWA-Seed-Standards-1505201.pdf
- Identification of ecologically appropriate strategies (such as leaving gaps for in-fill plantings in subsequent seasons) for addressing circumstances where the ideal species or genetic stock is not immediately available.

1.7 Assessing security of site tenure and of post treatment maintenance scheduling. Some indication of potential for long term conservation management of the site is required before undertaking a restoration plan. Plans identify:

1.7.1 Security of tenure of the site to enable long term restoration commitment and allow appropriate ongoing access and management;

1.7.2 Potential for adequate arrangements for ongoing prevention of impacts and maintenance on the site after completion of the project to ensure that the site does not regress into a degraded state.

1.8 Analyzing logistics: Some indication of potential for resourcing the project and of likely risks is required before undertaking a restoration plan. Plans address practical constraints and opportunities including:

1.8.1 Identifying funding, labor (including appropriate skill level) and other resourcing arrangements that will enable appropriate treatments (including follow up treatments) until the site reaches a stabilized condition.

1.8.2 Undertaking a full risk assessment and identifying a risk management strategy for the project, particularly including contingency arrangements for unexpected changes in environmental conditions or resourcing;

1.8.3 A rationale for the duration of the project and means to maintain commitment to its aim, objectives and targets over that period; and,

1.8.4 Permissions, permits and legal constraints applying to the site and the project.

1.9 Review process scheduling: Plans include a schedule and timeframe for:

1.9.1 Stakeholder and independent peer review as required; and,

1.9.2 Review of the plan in the light of new knowledge, changing environmental conditions and lessons learned from the project.

2 IMPLEMENTATION

During the implementation phase, restoration projects are managed in such a way that:

2.1 No further and lasting damage is caused by the restoration works to any natural resources or elements of the landscape or waterscape that are being conserved, including physical damage (e.g. clearing, burying topsoil, trampling), chemical pollution (e.g. over-fertilizing, pesticide spills) or biological contamination (e.g. introduction of invasive species and pathogens, e.g. see www.environment.gov.au/biodiversity/threatened/publications/threat-abatement-plan-disease-natural-ecosystems-caused-phytophthora-cinnamomi);

2.2 Treatments are interpreted and carried out responsibly, effectively and efficiently by suitably qualified, skilled and experienced people or under the supervision of a suitably qualified, skilled and experienced person;

2.3 All treatments are undertaken in a manner that is responsive to natural processes and fosters and protects natural recovery. Primary treatments including substrate and hydrological amendments, pest species control, application of recovery triggers and biotic reintroductions are adequately followed up by secondary treatments as required and appropriate aftercare is provided to any planted stock;

2.4 Corrective changes of direction in response to unexpected ecosystem responses are facilitated in a timely manner and are ecologically informed and documented;

2.5 All projects exercise full compliance with occupational work, health and safety legislation and all other legislation including that relating to soil, air, water, oceans, heritage, species and ecosystem conservation (including that all permits required are in place) ; and,

2.6 All project operatives communicate regularly with key stakeholders (or as required by funding bodies) to keep them appraised of progress.

3 MONITORING, DOCUMENTATION, EVALUATION AND REPORTING

Ecological restoration projects adopt the principle of observing, recording and monitoring treatments and responses to the treatments in order to inform changes and different approaches for future work. They regularly assess and analyse progress to adapt treatments (adaptive management) as required. Partnerships with research bodies are sought in cases where innovative treatments or treatments applied at a large scale are being trialled and to ensure all necessary research permits and ethical considerations are in place.

3.1 Monitoring to evaluate progressive restoration outcomes begins at the planning stage with the development of a monitoring plan to identify success or otherwise of the treatments (See also Boxes 3 and 4).

3.1.1 Monitoring is geared to specific targets and measurable goals and objectives identified at the start of the project and include:

- Collection of data prior to works and at appropriate intervals (e.g. at higher frequency early in the recovery phase) to identify whether objectives, goals and targets are being attained; and
- Collecting data on work sessions, specific treatments and approximate costs.

3.1.2 A minimum standard of monitoring for small, volunteer projects is the use of photo points, along with species lists and condition descriptions. (Note that photographic and formal quantitative 'before and after' monitoring is ideally undertaken not only at the restored site but also at untreated areas and any actual reference site.)

3.1.3 Projects also monitor the performance of the recovery using pre-identified indicators consistent with the objectives. In professional or larger projects this is ideally carried out through formal quantitative sampling methods supported by a condition assessment (taking account of any regionally appropriate benchmarking system).

3.1.4 Sampling units must be an appropriate size for the attributes measured and should be replicated sufficiently within the site.

3.2 Adequate records of treatments (inputs) and all monitoring are maintained to enable future evaluation.

3.2.1 Consideration should be given to lodging data with open access databases such as the Atlas of Living Australia www.ala.org.au and the Terrestrial Ecosystem Research Network (TERN) portal.tern.org.au/.

3.2.2 Secure records of the provenance (i.e. source) of any re-introduced plants or animals are held by the project managers. These records should include location (preferably GPS-derived) and description of donor and receiving sites, reference to collection protocols, date of acquisition, identification procedures and collector/breeder's name;

3.3 Evaluation and documentation of the outcomes of the works is carried out, with progress assessed against the targets, goals and objectives of the project (i.e. reference conditions).

3.3.1 Evaluation can use any system that adequately assesses results from the monitoring.

3.3.2 Results are used to inform ongoing management.

3.4 Reporting involves preparation and dissemination of progress reports to key stakeholders and broader interest groups (newsletters and journals) to convey outputs and outcomes as they become available.

3.4.1 Reporting can use any system that conveys the information in an accurate and accessible way, customized to the audience.

3.4.2 Reporting must clarify the level and details of monitoring upon which any evaluation of success or otherwise has been based.

4 POST-IMPLEMENTATION MAINTENANCE

4.1 The management body is responsible for ongoing maintenance to prevent deleterious impacts and carries out any required monitoring of the site after completion of the project to ensure that the site does not regress into a degraded state. Comparison with an appropriate reference ecosystem will be ongoing.

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Section 4 Glossary of terms

The terms defined here are specific to the National Standards and pertain to Australian conditions and species

Abiotic non-living materials and conditions within a given ecosystem, including soil, rock, dead wood, litter or aqueous substrate, the atmosphere, weather and climate, topographic relief and aspect, the nutrient regime, hydrological regime, fire regime and salinity regime.

Adaptive management a sophisticated form of 'trial and error'. Using the currently best available knowledge, skills and technology an action is implemented and outcomes recorded including success, failures and potential for improvement. These learnings form the basis of the next round of decision making and trialling in a process of continuous improvement.

Approach, (to restoration) the category of treatment (i.e. natural regeneration, assisted regeneration or reconstruction).

Assisted regeneration the practice of fostering natural regeneration and recolonisation after actively removing ecological impediments (e.g. invasive species, fish barriers) and reinstating appropriate abiotic and biotic states (e.g. environmental flows, fire regimes). While generally this approach is typical of sites of low to intermediate degradation, even some very highly degraded sites have proven capable of natural recovery given appropriate treatment and sufficient time frames.

Attributes, of an ecosystem the biotic and abiotic properties and functions of an ecosystem (In this document referred to as including absence of threats, physical conditions, species composition, community structure, ecosystem function and external exchanges).

Barriers (to recovery) factors impeding recovery of an ecosystem attribute.

Biotic, biota the living components of an ecosystem, including living animals and plants, fungi, bacteria and other forms of life (microscopic to large).

Carbon sequestration the capture and long-term storage of atmospheric carbon dioxide (typically in biomass by way of photosynthesis and tree growth) to reduce the impacts of climate change.

Climate envelope the climatic range in which a species currently exists. With climate change, such envelopes are likely to shift towards the poles or higher elevations. However, as precipitation is likely to change in less predictable ways, it is likely that the displacement of climate envelopes will be more complex.

Community structure the physical organisation of biotic and abiotic elements in a community. This refers to the degree of layering and spatial patchiness in an ecosystem; whether of substrates (e.g. rocks, coral or shell reefs, woody debris) or organisms (e.g. trees, shrubs, ground layer vegetation). This enables the development of complexity of habitats and functions

Composition (of an ecosystem) the array and relative proportion of organisms within an ecosystem.

Construction methods involved in engineering permanent or temporary components that did not occur previously at that site—as distinct from 'reconstruction'.

Cultural ecosystem some ecosystems (e.g. agro-ecosystems) in which local indigenous species have been substantially transformed by humans well beyond natural analogues (e.g. agro-ecosystems). These may become the subject of ecological restoration or may be conserved as cultural ecosystems.

Cycling ecological cycles include the movement of resources such as water, carbon, nitrogen, and other elements that are fundamental to all other ecosystem functions.

Damage (to ecosystem) a substantial level of impact, generally from a single disturbance event.

Degradation (of an ecosystem) a persistent decline in the structure, function and composition of an ecosystem compared to its former state, generally from frequent or persistent impacts.

Destruction (of an ecosystem) complete removal or depletion of an ecosystem.

Ecological maintenance ongoing activities intended to counteract processes of ecological degradation to sustain the attributes of an ecosystem. This maintenance phase is distinguished from the restoration phase that precedes it. Higher ongoing maintenance is likely to be required at restored sites where higher levels of threats continue, compared to sites where threats have been controlled.

Ecological restoration the process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed. (Note: Single species restoration can be considered complementary and an important component of ecological restoration.)

Ecosystem small or large scale assemblage of biotic and abiotic components in oceans, rivers and on land in which the components interact to form complex food webs, nutrient cycles and energy flows. The term 'ecosystem' is used in the Standards to describe an ecological community of any size or scale.

Ecosystem attributes (see Attributes)

Ecosystem services are the benefits to humans provided by ecosystems. They include the production of clean soil, water and air, the moderation of climate and disease, nutrient cycling and pollination, the provisioning of a range of goods useful to humans and potential for the satisfaction of aesthetic, recreation and other human values. Restoration targets may specifically refer to the reinstatement of particular ecosystem services.

Environmental repair any intentional activity—including reduction of impacts, rehabilitation and ecological restoration—that improves ecosystem functionality, ecosystem services, or biodiversity.

External exchanges the 2-way flows that occur between elements in the landscape or aquatic environment including flows of energy, water, fire, genetic material, animals and seeds. Exchanges are facilitated by habitat linkages.

Five-star (5-star) recovery A semi-quantitative rating system based on biotic and abiotic factors that provides comparative assessment of how well the attributes of an ecosystem are recovering after treatment. (Note, it is not a rating of the restoration works but of the recovery outcomes.)

Full recovery the state whereby all ecosystem attributes closely resemble those of the reference ecosystem.

Functions, of an ecosystem the collective term for the roles and processes that arise from interactions among living and non-living components of ecosystems. Examples include nutrient cycling and sequestration (through biomass accumulation, food production, herbivory, predation and decomposition), water filtration and cycling, soil formation, succession, disturbance regimes (fire, flooding and drying), water filtration and storage, provision of habitat, predation, dispersal, pollination, reproduction, disturbance and resilience.

Gene flows flows of seed or pollen between individual organisms that maintains the genetic diversity of a species' population. In nature, gene flow can be limited by dispersal distances of vectors and by topographic barriers such as mountains and rivers. In fragmented habitats it can be limited by the separation of remnants caused by clearing.

Germplasm the various regenerative materials (e.g. seeds, vegetative materials) that provide a source of genetic material for future populations.

Indicators of recovery characteristics of an ecosystem that a manager identifies as being suitable for measuring the progress of restoration goals or objectives at a particular site (e.g. measures of biotic or abiotic components of the ecosystem).

Landscape flows external exchanges that occur at a level larger than the site (including marine and freshwater areas) and including flows of energy, water, fire, genetic material, animals and seeds. Exchanges are facilitated by habitat linkages.

Local indigenous ecosystem an ecosystem comprising species or subspecies (excluding invasive non-indigenous species) that are either known to have evolved locally or have recently migrated from neighbouring localities due to changing climates. Where local evidence is lacking, regional or historical information can help inform the most probable local indigenous ecosystems. While many ecosystems we consider natural have been modified in extent and configuration (e.g. through burning by Indigenous peoples), the term used to describe ecosystems in which local indigenous species have been substantially transformed by humans well beyond natural analogues (e.g. agro-ecosystems) is 'cultural ecosystem'.

Management (of an ecosystem) a broad categorisation that can include maintenance *and* repair of ecosystems (including restoration).

Mandatory restoration restoration that is required (mandated) by government, court of law or statutory authority.

Natural regeneration recovery or recruitment of species from a germination or resprouting event. A 'natural regeneration' approach to restoration relies on spontaneous or unassisted natural regeneration as distinct from an 'assisted natural regeneration' approach that depends upon active intervention.

Non-mandatory restoration restoration that is voluntary rather than required (mandated) by a government, regulatory authority or court of law.

Over utilisation any form of harvesting or exploitation of an ecosystem beyond its capacity to regenerate those resources (including over-fishing, over-clearing, over-grazing, over-burning etc.).

Primary treatment the first treatment of a site (e.g. removal of standing weed biomass), after which there will be subsequent follow-up treatments referred to as 'secondary treatments'.

Productivity the rate of generation of biomass in an ecosystem, contributed to by the growth and reproduction of plants and animals.

Provenance source (location) from which seed or other germplasm is derived.

Reallocation transformation to another land use other than conservation.

Reconstruction a restoration approach where the appropriate biota need to be entirely or almost entirely reintroduced as they cannot regenerate or recolonise within feasible timeframes, even after expert assisted regeneration interventions.

Recovery the process of an ecosystem regaining its composition, structure and function relative to the levels identified for the reference ecosystem. In restoration, recovery is assisted by restoration activity—and recovery can be described as partial or full.

Recruitment production of a subsequent generation of organisms. This is measured not by numbers of new organisms alone (e.g. germinants of plants) but by the number that establish to adulthood in the population.

Reference ecosystem a real or notional community of organisms able to act as a model or benchmark for restoration. A reference ecosystem usually represents a non-degraded version of the ecosystem complete with its flora, fauna (and other biota), functions, processes and successional states that would have existed on the restoration site had degradation, damage or destruction not occurred—but should be adjusted to accommodate changed or predicted environmental conditions.

Regeneration see natural regeneration and assisted regeneration.

Rehabilitation the process of reinstating a level of ecosystem functionality on degraded sites where ecological restoration is not the aspiration, as a means of enabling ongoing provision of ecosystem goods and services.

Resilience the degree, manner and pace of recovery of species after a disturbance or stress, or the potential or capacity for such recovery. This property is developed by natural selection under conditions of exposure of the species to disturbance over evolutionary time scales—and enables a species or population to persist despite disturbance.

Resilience (of an ecosystem) the capacity of a system to absorb disturbance and reorganize while still retaining similar function, structure, and feedbacks. Highly dependent on the long adapted resilience of the species within the ecosystem. Capacity of a system to absorb disturbance and reorganize while still retaining similar function, structure, and feedbacks. Highly dependent on the long adapted resilience of the species within the ecosystem.

Restoration see also ecological restoration. The term 'restoration' is in common usage and can be used singly and in combination with other words to convey an intent to return something to a prior condition (e.g. restoring a species, a population or a particular ecosystem function such as carbon sequestration). Single species restoration can be considered complementary and an important component of ecological restoration.

Restoration project all works undertaken to achieve recovery of an ecosystem, from the planning stage, through implementation, to the point of full recovery. The term 'project' is not used in this document to refer to a specific limited set of works confined to a contract or funding round.

Revegetation establishment, by any means, of plants on sites (including terrestrial, freshwater and marine areas) that may or may not involve local or indigenous species.

Secondary treatment repeated follow-up treatments, e.g. to control weed, required during the restoration phase after primary treatment has triggered an ecological response.

Seed production area (SPA) a site used for the production of bulk quantities of high quality seed of known origin, quality, free of any undesirable hybridity and with appropriate genetic diversity for replanting or direct seeding onto restoration and rehabilitation sites.

Self-organizing a state whereby all the necessary elements are present and the ecosystem's attributes can continue to develop towards the reference state without outside assistance. Self organisation is evidenced by factors such as growth, reproduction, ratios between producers, herbivores, and predators and niche differentiation—relative to characteristics of the identified reference ecosystem.

Site discrete area/location. Can occur at different scales including patch and larger scales (e.g. landscapes or aquatic environments).

Spatial mosaic patchiness in assemblages of species often reflecting spatial patterning (in vertical and/or horizontal plane) due to differences in substrate, topography, hydrology disturbance regimes.

Spatial patterning see spatial mosaic.

Succession (ecological) patterns of change and replacement occurring within and between ecosystems over time in response to disturbance or its absence. Some Australian ecosystems (including higher diversity heath communities) respond to disturbance with all species regenerating together from the outset, whereas others can assemble gradually over time.

Stratum, strata layer or layers in an ecosystem; often referring to vertical layering such as trees, shrubs and herbaceous layers.

Substrate the soil, sand, rock, debris or water medium where ecosystems develop.

Structure (of an ecosystem) the physical organisation of an ecological system both within communities and at a larger scale (e.g. density, stratification, and distribution of species-populations, habitat size and complexity, canopy structure, pattern of habitat patches).

Threat a factor potentially or already causing degradation, damage or destruction.

Threshold (ecological) a point at which a small change in environmental conditions causes a shift in an ecosystem property to a different ecological state. Once crossed, an ecosystem may not easily return to its previous state.

Trajectory (ecological) a pathway of development over time, which can be defined and monitored using sequential measurements of biotic and abiotic ecological parameters.

Transform shift to a different ecosystem. In this Standard, specifically referring to an agro-ecosystem or urban ecosystem.

Translocation the movement of organisms to a different part of the landscape or aquatic environment.

Treatment interventions r actions undertaken to achieve restoration, such as substrate amendment, exotics control, habitat conditioning, reintroductions.

Trophic levels levels in food webs (e.g., producers, herbivores, predators, and decomposers).

Appendix 1 Relationship of ecological restoration to other environmental repair activities

As terrestrial and aquatic ecosystem degradation continues to expand across the globe, many countries and communities have been adopting policies and measures designed to conserve biodiversity and improve the way societies integrate with nature in a healing and sustainable way.

This is largely done in three ways; corresponding with three zones of the biosphere:

1. Creating protected areas to conserve intact or near-intact ecosystems;
2. Improving habitats for locally indigenous species in broader production (e.g. rural, fisheries) or urban zones outside reserves; and,
3. Reducing impacts in already transformed zones closest to human habitation.

Ecological restoration is the appropriate means of repairing damage in natural areas wherever it is attainable and desirable, irrespective of zone where they occur. For this to avoid net loss this needs to be accompanied by avoidance of degradation, damage or destruction of intact ecosystems in the first instance and there should be complete avoidance of damage to rare or irreplaceable ecosystems or ecosystem elements that take a long time to develop (such as old growth). Any offsetting for unavoidable damage in natural areas should aspire to a restoration standard of full recovery.

In production and urban areas however, many areas have undergone extreme and extensive past modification and the lands and waters within them may be of high economic or cultural value. This can make ecological restoration undesirable or unattainable in such cases. Here the next 'highest and best' level of repair should be aspired to.

Improved environmental management activities in already transformed production and urban areas are needed to reduce impacts. Such improvements are critical to the success of all ecological restoration as even intact ecosystems are affected by how we live and work. That is, substantial improvements in the ecological sustainability of urban and production zones are needed to reduce society's impacts on biodiversity, soils, water, air quality and climate—thereby securing longer term rehabilitation and ecological restoration.

It can be helpful to align these three broad pursuits on a spectrum of broader environmental repair (Fig 3). The point along that spectrum where the label 'ecological restoration' is applied is the point where an appropriate local indigenous ecosystem is adopted as a model and there is an aspiration for the site to be comprehensively restored in the long-term. Sound reduction of impacts and rehabilitation provide a supportive foundation for restoration.

Cross disciplinary skills in project design and implementation (including but not restricted to the fields of landscape architecture, engineering, agronomy and horticulture) are highly valued in the improved management of ecosystems, whether the goal is restoration, rehabilitation or reduction of impacts.

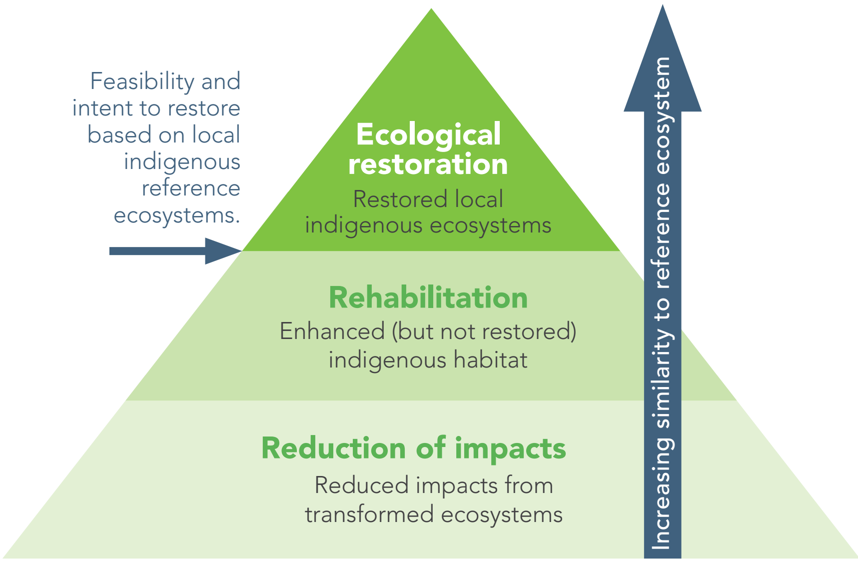

Figure 3 Broader context of 'environmental repair'. Ecological restoration fits within a range of complementary activities undertaken by various sectors of society to repair damage to the broader environment, with the broader context referred to in the Standards as 'environmental repair'. The pyramid arrangement depicted here applies only to transformed urban or production landscapes where the degree of success or failure of ecological restoration will be greatly influenced by the degree of success or failure of rehabilitation and reduction of impacts.

1 Rehabilitation

Rehabilitation is the process of reinstating degrees of ecosystem functionality on degraded sites where restoration is not the aspiration, to permit ongoing provision of ecosystem goods and services.

Where rehabilitation is the highest and best outcome possible at a site and represents an improvement in condition to the prior state, it can expand and buffer available habitats for indigenous species. At larger scales, rehabilitation can play an ecologically highly significant role in improving the resilience of ecosystems and individual species to rapid environmental change particularly in the transitional zones between natural areas and altered/degraded areas. As such, rehabilitation can be highly complementary to ecological restoration.

Current best practice in rehabilitation (indeed, in ecological restoration) has largely arisen from professional or voluntary efforts made within a range of industry, government and community sectors, the mining industry, forestry, agriculture, fisheries, utilities corridors, urban bushland and urban parks and gardens sectors.

The Standards seek to encourage all industry, government and community sectors to continue to adopt the practice of ecological restoration wherever appropriate; and where not appropriate, to undertake rehabilitation of ecosystem function to the highest possible recovery level (refer to five-star system of recovery for functional elements).

Further detail on current engagement of a range of industries in rehabilitation is outlined below, with comments included on the degree to which ecological restoration is also practiced (or could be increasingly practiced) in the particular industry sector.

Examples of rehabilitation.

Appropriate standards for both restoration and rehabilitation in various management sectors in Australia

Mining

A regulator (government) consent authority will determine the level of repair and restitution required under law for a project—i.e. whether proponents will be required to undertake restoration (whether full or some lower level of recovery) or the lower standard of rehabilitation, as appropriate. The decision is usually based on a number of factors, particularly the condition of the site prior to the commencement of ground-disturbing activities. That is, some mines are asked to achieve what would be defined here as ecological restoration, with many adopting and aspiring to this goal voluntarily. Other mines (e.g. mines on already modified land) are asked to achieve what would be defined here as a rehabilitation standard to bring the condition of the site to at least a useful condition or an agreed land use through consultation with stakeholders such as local communities.

Ready-made, off-the-shelf post-mining restoration or rehabilitation solutions are rarely available and companies will need to invest significantly in R&D if they are to achieve biodiverse, cost-effective and sustainable outcomes on remade substrates and landscapes. Critically, programs that have been successful in the mining industry are those that have been planned well in advance of the disturbance activities and where restoration or rehabilitation is integrated into the whole-of-mine planning process. This includes linking engineering and production with environmental programs to ensure restoration or rehabilitation are is an integral part of the business of mining, from concept to closure. Regulatory authorities should seek evidence of the following prior to ground disturbance.

- Mining companies are integrating the appropriate standard of restoration or rehabilitation across their business.
- For restoration a full risk assessment is provided of the capacity of the company to deliver timely restoration that includes understanding landform, soil creation (where topsoil is limited), topsoil protection (to enhance biological and seed preservation), propagation needs, recalcitrant biota, seed supply and storage requirements, seed dormancy alleviation and 'germination on demand', precision seeding, hydrological support for establishment plants, weed and feral animal controls, nutritional and pollination needs of plants. (Cost alone would not be an acceptable excuse for avoiding reinstating representative biota or achieving other restoration objectives.)
- Corporate approvals and processes are in place to ensure that where restoration or rehabilitation knowledge is lacking, appropriate targeted investment in R&D occurs well ahead of ground disturbance. The five-star rating system of the Standards provides an internal and external measure of restoration success for the mining industry and regulators. [Note: in Australia, generous tax concessions are provided to mining companies engaging with research bodies in mining restoration research, plus the Australian Research Council provides funding for industry to undertake such research through the various Centre and Linkage Grant schemes.]
- Safeguards are in place to ensure that economic down-turns or defaults by development companies do not result in a failure to restore a site to the agreed closure standard.

Examples of a reconstruction approach – rebuilding from 'scratch'

***Precis.** Where mining is undertaken in natural areas, the highest standard of ecological restoration is expected by society as exemplified in the regulatory process. This means that a five-star recovery should be the goal of any restoration project involving a natural area. In semi- natural sites with important or high biodiversity values, there is*

an expectation that post-mining repatriation achieves habitat recovery to the highest practicable extent, progressing the site to at least a three-star recovery condition. Where mining occurs on converted landscapes, there is an expectation that mine site rehabilitation achieves a safe, stable and ecologically sustainable utilitarian condition which provides ecosystem services and lowers rather than raises impacts on natural systems (i.e. rehabilitation as defined in this document).

Reforestation for timber production or carbon storage

Reforestation for timber production and especially carbon farming can provide substantial co-benefits for the conservation of biodiversity if ecological restoration models are adopted to the greatest extent practicable; thus achieving ecosystems capable of long-term sustainability. Diverse local ecosystems have also been shown to provide high carbon stores. Maintenance of high genetic diversity, as opposed to excessive selection of preferred forms, will help to maintain adaptability of forest areas to climate change.

Precis. Silviculture, Carbon farming or agroforestry projects should be encouraged to at least use local native species and adopt local native reference ecosystems to the extent practicable. Such projects, where adjacent to natural habitats, should be encouraged to adopt a five-star recovery goal, using the natural habitat as a reference ecosystem. Where this is not possible, as high a recovery ranking as practicable should be the goal. If lower goals are applied for good reason, the revegetation should be undertaken in a manner that enhances ecosystem services (rehabilitation) and has no deleterious effect on the adjacent natural areas and does not preempt potential for further recovery if it is possible in the future.

Agricultural lands

Agricultural lands occupy large areas of Australia with many farms and rangelands containing substantial indigenous habitats. Over recent decades, many landholders have been restoring and rehabilitating remnant habitats on farmlands and in rangelands, particularly through Landcare and often with co-investment from governments through regional natural resource management (NRM) organisations. The goal of much of this work is to provide extensions or linkages to other indigenous habitats or carbon sequestration.

Precis. Many smaller projects in agricultural lands are committed to ecological restoration and some have already achieved four-star or five-star recovery on a range of attributes. Many others, particularly larger projects, however, have only achieved three-star recovery and may or may not be able to progress further due to resource constraints and the irreversibility of some causal factors including fragmentation. Degree of recovery depends on whether or not the land or water manager (with or without support from an agency/organisation) can make the necessary commitment to contribute land for linkages in the medium to long-term.

Whether aiming for restoration or rehabilitation, landholders, Landcare groups, regional NRM organisations and funding bodies are encouraged to use the ecological restoration Standards to progressively improve outcomes at all sites to the greatest extent practicable, particularly through improved knowledge dissemination and prioritisation of more resilient and strategically important areas.

Examples from agricultural areas.

Aquatic ecosystem management

Restoration and rehabilitation of freshwater, estuarine and marine habitats is underway in Australia, yet more is needed. Ecological restoration, and in some cases rehabilitation, protects aquatic species, habitats and carbon stores (e.g. within rivers, lakes wetlands, kelp forests, seagrass meadows, mudflats, saltmarsh and mangroves); improves fish breeding for conservation, commercial and recreational fisheries; and provides cultural and recreational values that highlight compatibility between these interests.

Aquatic ecosystem restoration and rehabilitation has specific needs including the need to reduce impacts from terrestrial zones to the extent possible. A dialogue between terrestrial and aquatic professionals will ensure that the broader based restoration principles from the terrestrial environment can be adapted to planning and implementing marine, freshwater and estuary restoration programs.

Precis. Many but not all aquatic ecosystems are naturally highly dynamic and interconnected and hence many aquatic species and ecosystems can have very high migratory resilience. This can potentially enable full or substantial recovery (restoration) if combined with reintroduction of some ecologically important species that have very limited dispersal capacity due to their reproductive biology. In areas located in zones of high industry and public recreational activity, only recovery of some ecosystem function (i.e. rehabilitation) may be possible due to the limitations of managing degradation pressures.

Examples of freshwater restoration. Examples of marine restoration.

Utilities and infrastructure

Revegetation after the construction of infrastructure such as highways and dams has provided opportunities for both ecological restoration and rehabilitation. Some restoration is attained through programs designed to 'offset' the loss of biodiversity caused by the development. Some five-star restoration has been achieved in water catchment areas and adjacent to utilities, while at other sites only rehabilitation is possible.

Precis. Five-star restoration is sought wherever possible in or adjacent to natural areas; with the fragmentation impacts of linear utilities corridors on fauna mitigated by installation of adequate, dedicated fauna crossings. In permanently modified areas,a three star recovery) should be sought where possible. Where no substantial recovery level can be attained, at least rehabilitation of ecosystem function such as provision of habitat connectivity should be sought.

Urban green space

Urban landscapes including public parks can contain important natural and semi-natural areas and provide opportunities for ecological restoration , particularly for improving indigenous habitat connectivity at the urban/natural area interface. Local and state governments, statutory bodies and NGOs—and many thousands of community Bushcare and Coastcare volunteers across Australia—are involved in controlling the causes of degradation and actively applying ecological restoration to these areas, supported by rehabilitation of adjacent lands and waterways.

Urban parks, streetscapes and private gardens (including non-indigenous plants) can also provide important supplementary habitat and resources for native fauna and can be modified to incorporate local indigenous plant species to enhance the genetic diversity of remnant bushland fragments. (Such enhancement or rehabilitation would require advice from ecologists or restoration professionals.) In urban areas, however, it is important that such work is done while maintaining design values and amenity—as design qualities of a site may be a deciding factor in enhancing support from individuals and communities for improvements at both the local site and in relation to broader issues of environmental concern.

Precis.* *Many urban bushland projects are committed to restoration and commonly achieve at least four-star or higher outcomes. Where this is not possible (but where parks and gardens can include indigenous plantings that enhance conservation genetics and provide faunal habitats) rehabilitation consisting of professionally advised genetic supplementation and the enhancement of habitat, connectivity is encouraged.

Example of ecological restoration in a city.

2 Reduction of impacts

Reduction of impacts in utilized areas of the environment is needed to the highest practicable extent, particularly in transformed zones,to maintain potential for conservation of biodiversity while pursuing both production and lifestyles that are ecologically sustainable.

Society needs production, business and residential areas. However, a global groundswell of community support shows an increasing willingness to reduce impacts of this permanently converted zone upon the environment. The Standards seek to promote, within this movement, an increase in appreciation that biodiversity conservation and enhancement is an important and substantial endpoint of these efforts. Particularly important to the conservation of biodiversity is reduction of the impact of industry and lifestyles on air pollution by reducing carbon emissions and storing carbon.

(a) Ecologically sustainable production

Substantial and increasing efforts have been made over recent decades by agencies, industry groups and producers to reduce the impact of agriculture, horticulture, aquaculture and fisheries upon the quality of Australia's biodiversity, land, water and air. These efforts are partly due to consumer trends and recognition that ongoing impact is both ecologically and economically unsustainable in the long term.

The most valuable contributions to nature conservation have come from minimising natural area over-harvesting, clearing, fragmentation, reducing the impacts of pest plants and animals, reducing erosion, sedimentation and nutrient enrichment of waterways, minimising methane emissions in agriculture and sequestering carbon through revegetation and improved soil management.

(b) Ecologically sustainable lifestyles

The lifestyle and purchasing choices made by all Australians dictate the degree to which our industries can be sustainable and engage in reduction of impacts and rehabilitation. That is, the higher the consumer demand for ecological sustainability the higher the likelihood that industry sectors can viably adopt reduction of impacts and rehabilitation strategies. Consumers can directly assist the conservation of natural areas by adopting renewable energy solutions for transport and powering the home, purchasing goods whose production has a lower ecological impact, and reducing waste.

Domestic lifestyles in cities, suburbs and rural towns can also have a direct negative or positive impact upon indigenous ecosystems through ways we manage, among other things, our nutrient runoff, disposal of garden debris, pets and invasive exotic plants. Positive engagement with natural areas to improve these practices can not only complement restoration but also create a stronger appreciation of nature within society.

Examples of reduction of impacts.

Appendix 2 Values and principles underpinning ecological restoration

First order

Ecological restoration:

- **Supports and is modelled on indigenous ecosystems and does not cause further harm.** Australia contains large tracts of relatively intact land and water ecosystems, which represent an invaluable natural heritage. Appreciation of the long history of evolution of organisms interacting with their natural environments underlies the ethic of ecological restoration within the Australian context.
- **Is aspirational.** The ethic of ecological restoration is to seek the highest and best conservation outcomes for all ecosystems. Even if it takes long timeframes, full ecological restoration should be the goal wherever it may be ultimately attainable and desirable. Where full ecological restoration is clearly not attainable or desirable, continuous improvement in the condition of ecosystems and substantial expansion of the area available to nature conservation is encouraged.
- **Is universally applicable and practiced locally with positive regional and global implications.** It is inclusive of aquatic and terrestrial ecosystems, with local actions having regional and global benefits for nature and people.
- **Reflects human values but also recognizes nature's intrinsic values.** Ecological restoration is undertaken for many reasons including our economic, ecological, cultural and spiritual values. Our values also drive us to seek to repair and manage ecosystems for their intrinsic value, rather than for the benefit of humans alone. In practising ecological restoration, we seek a more ethical and satisfying relationship between humans and the rest of nature.
- **Is improved by rigorous, relevant and applicable knowledge drawn from a dynamic interaction between science and practice.** All forms of knowledge, including knowledge gained from science, nature-based cultures and restoration practice are important for designing, implementing and monitoring restoration projects and programs. Results of practice can be used to refine science; and science used to refine practice. Primary investment in practice-applicable research and development increases the chance of restoration success and underpins regulatory confidence that a desired restoration outcome can be achieved.
- **Is not a substitute for sustainably managing and protecting ecosystems in the first instance.** The promise of restoration cannot be invoked as a justification for destroying or damaging existing ecosystems because functional natural ecosystems are not transportable or easily rebuilt once damaged and the success of ecological restoration cannot be assured.

Second order

Successful ecological restoration depends upon:

Ecological

- **Addressing causes at multiple scales to the extent possible**. Degradation will continue to undermine restoration inputs unless the causes of degradation are addressed or mitigated. The range of anthropogenic threats include over-utilisation, clearing, erosion and sedimentation, pollution, altered disturbance regimes, reduction and fragmentation of habitats and invasive species. All these threats are capable of causing ecosystem decline in their own right, and can be exacerbated when combined, particularly over long time frames. Habitat loss and fragmentation, in particular, exacerbates the threats to biodiversity from climate change.
- **Recognizing that restoration initiates a process of natural recovery.** Re-assembling species and habitat features on a site invariably provides just the starting point for ecological recovery; the longer term process is performed by the organisms themselves. The speed of this process can sometimes be increased with greater levels of resourcing.
- **Recognizing that undesirable species can also be highly resilient to the disturbances that accompany restoration,** with sometimes unpredictable results as competition and predator-prey relationships change. Invasive species, for example, can intensify or be replaced with other invasives without comprehensive, consistent and repeated treatment.
- **Taking account of the landscape/aquatic context and prioritising resilient areas.** Sites must be assessed in their broader context to adequately assess complex threats and opportunities. Greatest ecological and economic efficiency arises from improving and coalescing larger and better condition patches and progressively doing this at increasingly larger scales. Position in the landscape/aquatic environment and degree of degradation will influence the scale of investment required.
- **Applying approaches best suited to the degree of impairment.** Many areas may still have some capacity to naturally regenerate, at least given appropriate interventions; while highly damaged areas might need rebuilding 'from scratch'. It is critical to consider the inherent resilience of a site (and trial interventions that trigger and harness this resilience) prior to assuming full reconstruction is needed (Box 2).
- **Addressing all biotic components.** Terrestrial restoration commonly starts with re-establishing plant communities but must integrate all important groups of biota including plants and animals (particularly those that are habitat-forming) and other biota at all levels from micro—to macro-organisms. This is particularly important considering the role of plant-animal interactions and trophic complexity required to achieve the reinstatement of functions such as nutrient cycling, soil disturbance, pollination and dispersal. Collaboration between fauna and plant specialists is required to identify appropriate scales for on-ground works and to ensure the appropriate level of assistance is applied to achieve recovery.
- **Addressing genetic issues.** Where habitats and populations have been fragmented and reduced below a threshold/minimum size, the genetic diversity of plant and animal species may be compromised and inbreeding depression may occur unless more diverse genetic material is reintroduced from larger populations, gene flow reinstated and /or habitats expanded or connected.

Logistical

- **Knowing your ecosystems and avoiding past mistakes.** Success can increase with increased working knowledge of (i) the target ecosystem's biota and abiotic conditions and how they establish, function, interact and reproduce under various conditions including anticipated climate change; and (ii) responses of these species to specific restoration interventions tried elsewhere.
- **Gaining the support of stakeholders**. Successful restoration projects have strong engagement with stakeholders including local communities, particularly if they are involved from the planning stage. Prior to expending limited restoration resources, potential benefits of the restored ecosystem to the whole of society must be explicitly examined and recognised and it must be previously agreed that the restored ecosystem will be the preferred long-term use. This outcome is more secure when there are appreciable benefits or incentives available to the stakeholders; and where stakeholders are themselves engaged in the restoration effort.
- **Taking an adaptive (management) approach.** Ecosystems are often highly dynamic, particularly at the early stages of recovery and each site is different. This not only means that specific solutions will be necessary for specific ecosystems and sites; but also that solutions may need to be arrived at after trial and error. It is therefore useful to plan and undertake restoration in a series of focused and monitored steps, guided by initial prescriptions that are capable of adaptation as the project develops.
- **Identifying clear and measurable targets, goals and objectives.** In order to measure progress, it is necessary to identify at the outset how you will assess whether you have achieved your restoration outcomes. This will note only ensure a project collects the right information but it can also better attune the planning process to devise strategies and actions more likely to end in success (Box 3 and Appendix 4).
- **Adequate resourcing.** Budgeting strategies need to be identified at the outset of a project and budgets secured. When larger budgets exist (e.g. as part of mitigation associated with a development) restoration activities can be carried out over shorter time frames. Smaller budgets applied over long time-frames can be highly effective if works are limited to areas that can be adequately followed-up within available budgets before expanding into new areas. Well-supported community volunteers can play a valuable role in improving outcomes when budgets are limited.
- **Adequate long-term management arrangements.** Secured tenure, property owner commitment and long-term management will be required for most restored ecosystems, particularly where the causes of degradation cannot be fully addressed. Continued restoration interventions aid and support this process as interactions between species and their environment change over time. It can be helpful to identify likely changes in species, structure and function over the short, medium and longer term duration of the recovery process.

Appendix 3 Genetics, fragmentation and climate change—implications for restoration of local indigenous vegetation communities

Two primary threats and their interactions need to be recognised by revegetation practitioners. These are fragmentation and climate change.

Effect of fragmentation on genetic diversity

The concept of confining seed collection to a 'local provenance' area (to ensure local adaptation is maintained) has been widely adopted by plant-based restoration practitioners. However, the paradigm of collecting very close to the restoration site is no longer considered useful. Firstly, scientists agree that plant local adaptation is not as common as many believe. Secondly, many practitioners now understand that a 'local' genotype may occur over wider areas (i.e. from 10s to 100s of km) depending on the species and its biology. However, in a largely cleared landscape, small fragments are at risk of elevated inbreeding when populations of a species drop below threshold numbers, which can be different for every species. As inbred seed may fail to reinstate functional and adaptable plant populations, in general it is best to collect seed from larger, higher density stands. This means that in fragmented landscapes where vegetation stands are smaller, less dense and more isolated, collecting seed from wider distances and multiple sources will be necessary to capture sufficient genetic diversity to rebuild functional communities. This seed should be multiplied in regional seed production areas, however, to avoid overharvesting from remnants.

Examples of seed production areas.

Box 5 Climate envelope

The climate range in which a species currently exists can be referred to as its 'climate envelope'.

During climate change this climate envelope is likely to uncouple from the current location in which the species exists and, where conditions become hotter, move further poleward or to higher elevations. This means that the species may be lost from the more equatorial extreme of the range and need more help to adapt as it, or its genotypes, move poleward or to higher elevations.

However, as precipitation is likely to change in less predictable ways, it is likely that the displacement of climate envelopes will be more complex.

Climate change

Examination of Australian ecosystems shows that many indigenous species have endured ancestral extremes of climate well beyond predicted climate change scenarios. However, *accelerated* climate change is a serious emerging problem. Some species will be impaired by increasing ocean temperatures, acidity and marine, freshwater and terrestrial habitats will be lost in some locations due to sea level rise. Many river channels, lakes and wetlands may also be affected by drying or its consequences such as increase salinity—and cold-adapted species will be lost at colder, higher elevations where there is nowhere higher for them to migrate as climate warms. Indeed, even conservative global warming scenarios suggest that a wide range of local environments to which species may have adapted will change dramatically.

Although we cannot precisely predict the type and scale of risks that ecosystems face because only a small proportion of species has been individually studied, we know that some species may be lost from their current locations while others will colonise new areas, altering local species assemblages. We also know that the effect of climate change will be particularly strong when combined with high levels of fragmentation.

Some species may have sufficient inherent 'adaptive plasticity' to persist as climates change, as has been demonstrated from translocation experiments and detailed pollen analysis of past environments. That is, an *individual* plant may be able to adjust its form by mechanisms such as reducing its leaf size, increasing leaf thickness or altering flowering and emergence times. But in many cases, persistence may depend on a species' capacity for genetic selection or adaptation, which in turn depends on population size and the diversity of the genes available.

Species that have large, connected populations, a wide climatic range, naturally high dispersal characteristics and whose populations have many genes in common are likely to have a higher chance of genetically adapting to the new environments or migrating as their climate envelope moves. Conversely, species with low pollen and seed dispersal characteristics, that occur naturally in 'islands' or 'outliers' or that have been isolated through land clearing or river regulation, for example, may be less able to adapt or migrate in response to climate change.

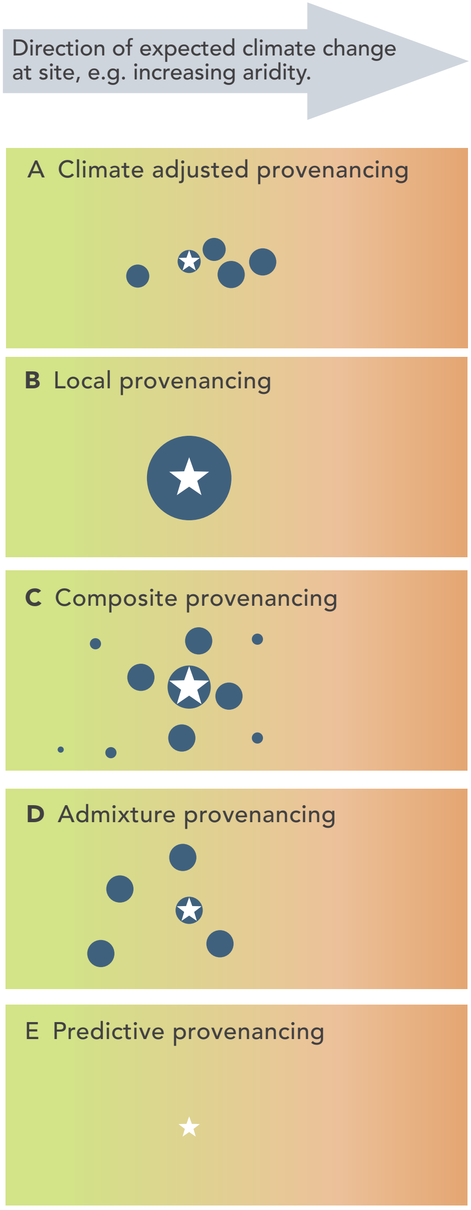

Figure 4 Provenancing strategies for revegetation, (Reproduced here from Prober et al 2015) The star indicates the site to be revegetated, and the circles represent native populations used as germplasm sources. The size of the circles indicates the relative quantities of germplasm included from each population for use at the revegetation site. In the case of the climate-adjusted provenancing the relative quantities of the germplasm from the various populations will depend upon factors such as genetic risks, and the rate and reliability of climate change projections. For simplicity this represents the major direction of climate change in a single dimension (e.g. aridity, to combine influences of increasing temperature and decreasing rainfall), but multiple dimensions could be considered as required.

Implications for restoration

Techniques and protocols are emerging to guide the collection of genetically diverse material to use in revegetation to enhance a species' adaptive potential. In extensive, intact indigenous habitats where species and populations are likely to have a greater capacity to adapt unaided because of high connectivity, interventions to enhance adaptive potential are unlikely to be needed. But where landscapes or waterscapes remain largely fragmented, interventions to assist genetic adaptation are expected to be beneficial. This means that, while the local gene pool still has potential to play a major role in adaptation, it is prudent to consider including at least a small amount of germplasm of the same species from a 'future climate'—that is, a region with a climate similar to that which is predicted for the area being restored. Research is underway to test some of these new approaches and it is hoped that 'rules of thumb', will eventually be developed. Meanwhile, researchers are designing protocols and proformas for appropriately documented and registered 'citizen science' trials integrated into low risk restoration settings. Participation in such trials will enable groups to actively test a range of recommendations on their sites while also optimising opportunities for improved science and practice.

Tools for assessing climate-readiness in relation to genetics

Some tools are available to help restoration planners undertake what could be called 'climate readiness' analysis at the planning stage. Firstly, restoration practitioners are encouraged to seek out predictions of locations where ecosystems are likely to be affected by climate change. Secondly, practitioners are encouraged to liaise with researchers to gain a better understanding of predicted responses of species to both fragmentation and climate change and to identify the relative risks of a range of options relating to the deliberately movement of genetic material in restoration projects. (Genetic analysis can be undertaken by a range of research institutions and is increasingly affordable for practitioners. This cost reduction is increasing numbers of species being studied while rapid improvements in the effectiveness and efficiency of genetic testing tools is also occurring.)

Web-based tools are also readily accessible for identifying whether the species currently occurring in the vicinity of your site will still be suited to climates predicted to occur at your site in the future. One of the most important of these is the Atlas of Living Australia website (www.ala.org.au) which can help practitioners identify the natural geographic range of a species and whether it may have potential to tolerate the conditions predicted to occur under climate change scenarios which themselves are mapped on the website www.climatechangeinaustralia.gov.au. An explanation of how these tools can be combined is found in Booth et al. (2012).

Proposed propagule sourcing strategies to build climate-readiness into restoration through ensuring genetic diversity include: *composite provenancing* (Broadhurst *et al.* 2008), *admixture provenancing* (Breed et al. 2013), *predictive provenancing* (e.g. Crowe & Parker 2008), and *climate adjusted provenancing* (Prober et al. 2015, Fig 4). Application of any such models should be undertaken within a risk management framework that considers the potential negative effects of inbreeding and outbreeding depression, interpreted in a manner clearly understood by practitioners. It should also include long-term monitoring (i.e. at least a decade) to enable lessons learned to be captured for both restoration and climate science.

Practitioners designing planting lists need to bear in mind, however, that it is impossible to be certain of the changes that will occur. Different species will respond to climate change in different ways and at the moment there is no easy way to predict this. Furthermore, temperature and rainfall are not the only important predictors. A range of physical (e.g. soils) and biological factors (e.g. dispersal)—which themselves may or may not be affected by a changing climate—can also have important roles in influencing the distribution of a species. While some caution will always be required, a balanced approach in fragmented areas would see the restoration plan specify the use of locally occurring species (preferring germplasm from larger populations, even if somewhat more distant) and where advised, formally trialling the inclusion of some germplasm from 'future climate' locations. Such a combined approach—coupled with optimising connectivity to the extent possible—is likely to improved opportunities for natural adaptation should it be required.

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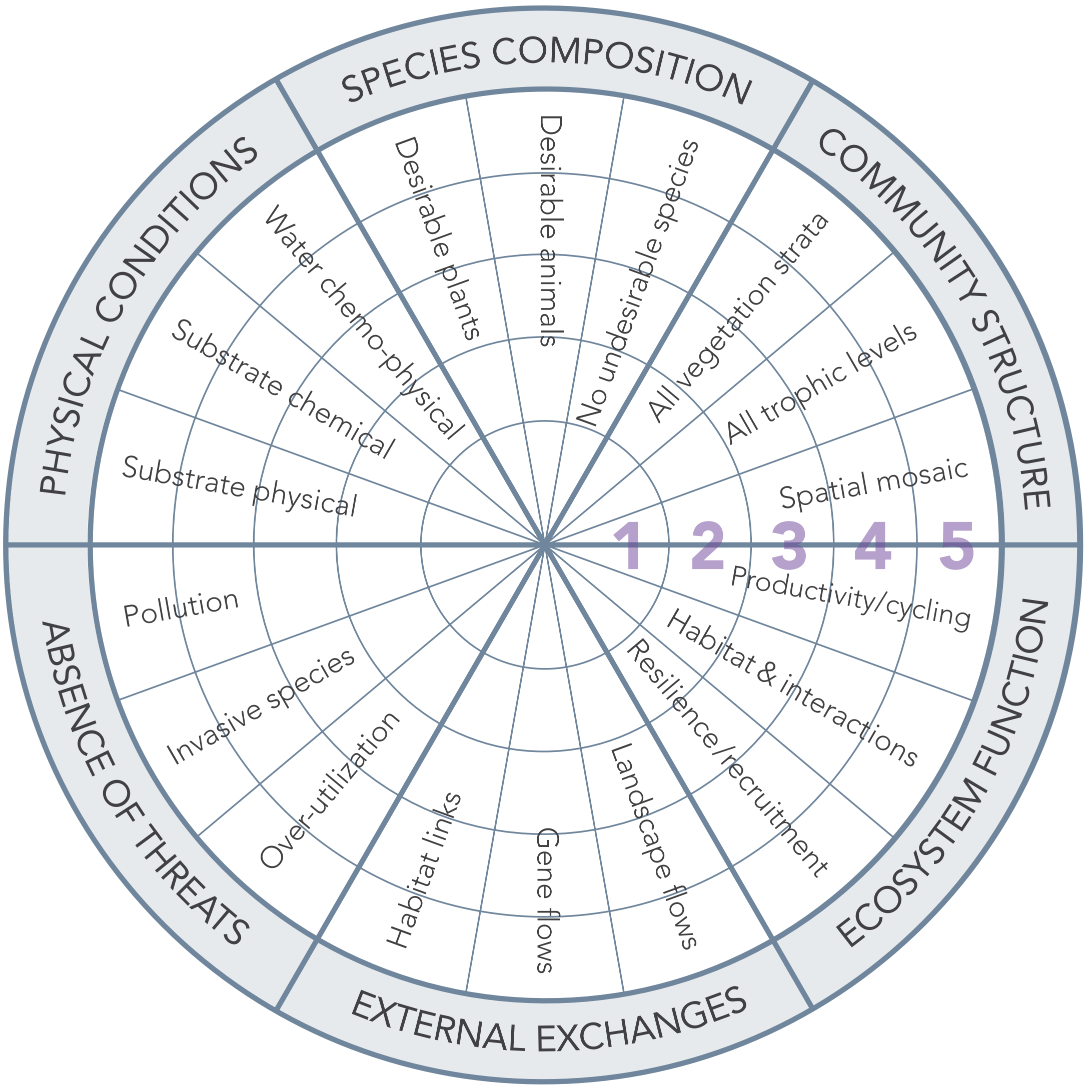
Appendix 4 Some examples of detailed objectives (using quantifiable indicators)

Attribute detail	Examples
Controlling threats	Nil incidence of undesirable livestock incursions
	Climate-readiness of xx species considered and appropriate propagules arranged
	Invasive plant threats under management in surrounding landscape
	Fox and cat populations reduced to xxha and xxha respectively in surrounding landscape
	Overharvesting regulated in surrounding marine area
	Anti-fouling pollutants prohibited in surrounding waters
Physical conditions	pH of substrate is between e.g. xx.xx and xx.xx (Raupach test)
	A minimum of XX mm of top soil (A horizon) and yy mm of subsoil (B horizon) is installed at establishment.
	Topsoil and subsoil are returned within 2 months of initial clearing
	Soil compaction reduced to <xx psi across site
	Nil sediment deposition in stream
	Site topography and hydrological flow lines reinstated
	Salinity level of substrate < EC Units
	Turbidity level = xxx
	Rocky outcrops cover xx% of site and remain without vegetation cover
Species composition	Herbaceous exotics reduced to <xx% cover and represented by only benign species
	>xx% canopy cover of indigenous trees and exotic trees reduced to rare seedlings
	mesic shrubs reduced to <xx% cover and diversity of heathy shrubs maintained
	Kangaroo Grass cover between ~xx-xx% FPC and diversity of forbs and grasses maintained.
	Crown of Thorns Starfish reduced to >xx% cover and coral mortality < xx%
	Carp reduced to <xx% of fish population and xx% of indigenous fish species of reference present
Community structure	Characteristic diversity of indigenous plant species from each stratum established
	Mosaic of vegetation patches reinstated
	All ant functional groups present
	All frog species present
	Size of area sufficient to support populations of species 'x'
	Species 'y' present at a density of x stems per ha
Ecosystem function	All plant species regenerating after natural disturbance event
	A diversity of genera of saprophytic insects found in all fallen timber
	'xx' number of tree hollows per hectare
	Owl pair breeding in area and feeding on site
	Litter decomposition rate = xx
	Filtration rate = x% of tide residence time
	Appropriate fire regime reinstated for the target ecosystem
	Carbon sequestered at a rate of xx tonnes per year
	Positive change in the microbial functionality parameter 'xx'
External exchanges	Ground dwelling faunal species can readily disperse into and out of site
	Site is connected to surrounding floodplain and river to enable periodic flooding
	Fish passage reinstated
	Tidal flushing reinstated
	Pollinators can readily connect with site

Note: The 'indicator' is the measure used – while the 'objective' is the quantification adopted for the particular project. (Examples drawn from a range of different biomes.)

Appendix 5 Blank progress assessment templates (for practitioner use)

Download the separate recovery wheel (256 kb) and the evaluation of ecosystem recovery proforma (16k b) in Word format—or an editable version where both are combined in Excel format



Evaluation of ecosystem recovery

Site ....

Attribute category	Recovery level (1-5)	Evidence for recovery level
Attribute 1 Absence of threats		
Over-utilization		
Invasive species		
Pollution		
Attribute 2 Physical conditions		
Substrate physical		
Substrate chemical		
Water chemo-physical		
Attribute 3 Species composition		
Desirable plants		
Desirable animals		
No undesirable species		
Attribute 4 Community structure		
All vegetation strata		
All trophic levels		
Spatial mosaic		
Attribute 5 Ecosystem function		
Productivity, cycling etc		
Habitat & plant-animal interactions		
Resilience, recruitment etc		
Attribute 6 External exchanges		
Landscape flows		
Gene flows		
Habitat links		

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Australian Institute of Landscape Architects (AILA)
Australian Network for Plant Conservation (ANPC)
Australian Seed Bank Partnership (ASBP)
Bush Heritage Australia (BHA)
Gondwana Link
Greening Australia (GA)
Indigenous Flora and Fauna Association (IFFA)
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Trees For Life (TFL)
Trust for Nature Vic (TFN Vic)
WetlandCare Australia (WCA).

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Hanson Construction Materials
ARC Centre for Mine Site Restoration
Little Gecko Media.