NATIONAL STANDARDS FOR THE PRACTICE OF ECOLOGICAL RESTORATION IN AUSTRALIA

Prepared by
Principles and Standards Reference Group,
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In consultation with key partners.

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Submissions invited
Submissions on any aspect of the draft National Standards for the Practice of Ecological Restoration in Australia are invited to be emailed to tein.mcdonald@seraustralasia.com by COB 15 February 2016.

The SERA board’s Principles and Standards Reference group acknowledges the close collaboration of the following Partners and Advisors in the preparation of these standards:

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Executive summary

The contemporary call for restoration and rehabilitation comes at a critical point in our planet’s history where human influence is all pervasive. Australia’s long and relatively uninterrupted evolutionary past mean the continent possesses ancient soils and exceptionally diverse biota—yet its terrestrial and marine ecosystems carry a legacy of extensive and continuing environmental degradation, particularly in urban, industrial and production landscapes and seascapes. Emerging anthropogenic climate change is superimposing further pressure on ecosystems, whose vulnerability to climate change is exacerbated by existing causal factors such as overclearing, overharvesting, fragmentation, inappropriate management and invasive species. Degradation is so severe in many cases that it will not be overcome without active and ecologically appropriate intervention including mitigation of these causal problems and reinstatement of indigenous biodiversity.

The practice of ecological restoration and rehabilitation seeks to transform humanity’s role from one where we act as 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 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. It identifies the principles underpinning restoration philosophies and methods, and outlines the steps required to plan, implement, monitor and evaluate a restoration project to increase its likelihood of 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 standards of restoration and rehabilitation practice across all sectors. The document provides the 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 within all land and water ecosystems of Australia.

1 SERA is the peak national body for ecological restoration and is an independent, non-profit organization 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).
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Section one  Introduction

Definitions

*Ecological restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed.*

(SER 2004)

These *National Standards for the Practice of Ecological Restoration in Australia* (the ‘Standards’) adopt the definition of ecological restoration articulated by the world’s peak ecological restoration body, the Society for Ecological Restoration (SER). The Standards recognise that ecological restoration is an activity or process while recognising that the term ‘ecological restoration’ is simultaneously used to describe the outcome sought (i.e. the restored state).

This dual meaning of the term—at times referring to the process and at times referring to the outcome—allows all projects that aim to ultimately achieve full recovery relative to an appropriate local indigenous reference ecosystem to be considered ecological restoration projects even though the restored state may entail long time frames for achievement. (See Glossary, Section 6.) The restored state can only be said to have been achieved when the ecosystem’s attributes are on a secure trajectory to match those of the reference community without further restoration-phase interventions being needed (i.e. after the completion of the restoration phase, ongoing management interventions would be considered ‘maintenance’) (SER Science & Policy Working Group 2004). The process 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, appropriate processes may lead to improved outcomes.

Projects based on a local indigenous reference ecosystem but unable to adopt the target of full restoration are considered rehabilitation which, as described in Appendix 1, is highly encouraged and valued where it (a) improves ecological condition or function and (b) is the highest standard that can be applied. These Standards can be applied to rehabilitation to optimise its outcomes. Projects that are not based on an appropriate local indigenous reference ecosystem are not covered by this Standard.
Why is ecological restoration practised globally?

Ecological restoration is a global pursuit. This is based on the following propositions:

1. The world's indigenous ecosystems are of high intrinsic, societal and economic value, are complex and are vulnerable to human-induced impacts that often results in degradation.
2. Indigenous ecosystems are diminishing in extent and condition at a global scale, exacerbated by climate change.
3. Active management is required, involving protection and repair, to both reduce further loss and to create a net gain in the extent and function of indigenous ecosystems.

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. Many government and non-government agencies, community groups, companies and private individuals choose to engage in the repair of damage inherited from previous generations (non-mandatory restoration); while others are required to undertake restoration as part of approvals and regulatory controls 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 (SERI Science & Policy Working Group 2004) and the IUCN (International Union for Conservation of Nature) guidelines (Keenlyside et al. 2012). These need supplementation, however, 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 with globally unique and remarkable species and ecosystems.

What are the Standards and who are they designed for?

The Standards list (a) principles that underpin current best practice ecological restoration and (b) steps considered necessary to plan, implement and monitor restoration projects if they are to have a reasonable chance of success. The Standards are applicable to any Australian ecosystem (whether terrestrial or aquatic) and any sector (whether private or public sector, mandatory or non-mandatory). They can be used by any person or organisation to help develop plans, contracts, consent conditions and closure criteria.
Section 2 Key principles underpinning practice

Principles have been developed to convey the main ecological, technical, social and ethical underpinnings of ecological restoration practice. Some of these can be drawn out as ‘Key’ principles, as below. The principles associated with the Standards are listed in Appendix 2.

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

A fundamental principle of ecological restoration is the identification of one or more ‘reference ecosystems’ that serve as a model for the project targets and provide a basis for monitoring and assessing outcomes. The reference ecosystem can be a real site (reference site) or a conceptual model derived from field indicators and historical and predictive records. It includes local indigenous taxa known to have occurred in the local area for very long timeframes as well as potentially any indigenous taxa from neighbouring localities that are recently migrating (See glossary). Where local evidence is lacking, regional information can help inform likely local indigenous ecosystems. Identifying a reference ecosystem involves understanding the composition (species), structure (complexity and configuration) and function (processes and dynamics) of the site to be restored. The model should also include descriptions of successional states that may be characteristic of the ecosystem.

Australia’s landmass and marine zones contain many intact or remnant indigenous ecosystems. These 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 reference ecosystems. This process can be assisted by regional species and ecosystem profiles, but not be replaced by them. Where irreversible altered topography, hydrology, or climatic conditions have occurred or are predicted (Box 1), a more viable local occurring ecosystem may be used as a guide. 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.

Function is important because recovery is achieved by the processes of growth, reproduction and recruitment of the organisms themselves over time—and because restoring the appropriate carbon cycling, soil biota, productivity levels and specific habitat niches can improve conditions for recovery. Continued monitoring of the recovery process is needed by the land manager to identify whether or not further (or different) interventions are needed to remove unexpected barriers and maintain an acceptable trajectory of recovery to result in a self-organising and functional ecosystem that can be considered local indigenous.
Box 1 Reference ecosystems in cases of irreversible environmental change

Many local sites, intact or degraded, are becoming increasingly threatened by human impacts including alteration of soil, water and topography as well as the pervasive impacts of climate change. Some of these are effectively irreversible. Reinstating local indigenous ecosystems in cases where irreversible environmental change has occurred requires us to anticipate and, if necessary, mimic natural adaptive processes.

1. Irreversible physical (soil, water and landform) changes. In cases where insurmountable environmental change has occurred to the site and the previously occurring ecosystem cannot be reinstated (e.g. where a hydrology has changed irreversibly from saline to freshwater or vice versa—or where quarrying has produced a rock platform), an appropriate solution would be to establish an alternative, local occurring ecosystem better suited to the changed conditions. This transformative approach is sometimes called ‘creation’ or ‘fabrication’ and can complement restoration where this is not used as a justification for further damage.

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 unflagging 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 if they are able. To assist potential adaptation, restoration 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 moisture levels are expected at an individual site, adaptability can be improved by ensuring the restoration includes at least some local occurring species suited to the anticipated conditions (e.g. more dry-adapted species if drying is expected). In cases where the climate envelope of the species is expected to shift as a result of climate forecasts (Appendix 3), introducing more diverse genetic material of the same species from other parts of a species’ range is often recommended—at least in fragmented landscapes where migration potential is lower than intact landscapes. 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 maximised where all threats affecting ecosystems (particularly fragmentation) are minimised.

In summary, the role of restoration is to ‘assist recovery’ not impose a human-design upon it—i.e. 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.
Principle 2 Restoration inputs will be dictated by level of degradation

Indigenous species have an intrinsic capacity to recover (after addressing causal factors) where degradation impacts are low or where sufficient populations and time frames exist. But where impacts are higher or insufficient recovery time is available, higher levels of restoration inputs and intervention are likely to be needed. The trajectory of recovery is rarely a smooth gradient, and amending the physical and chemical properties of the site or reintroducing missing species or ecological processes is often required, depending on level of damage (Figure 1). At highly damaged sites, or sites with complex abiotic or biotic characteristics, barriers to recovery may require active research to identify specific impediments to recovery and solutions for restoration.

The variation in the ability of sites to recover (and the higher cost of assisting recovery where the potential is lower) also shows us that strategic advantage can be gained by investing scarce resources into parts of a landscape or seascape where resilience and potential for connectivity is higher. This variability dictates that the ecological condition and resilience of a site must be skilfully assessed prior to prescribing whether regeneration-based or reconstruction-based approaches are needed (Box 2).

Figure 1 Conceptual model of ecosystem degradation and restoration. Rises represent thresholds and circles an ecosystem attribute. (Adapted from Keenleyside et al 2012, after Whisenant 1999, and Hobbs and Harris 2001).
Box 2 Identifying the appropriate ecological restoration approach

Correctly assessing the condition of various parts of a site facilitates the design of appropriate approaches and treatments—avoiding waste of natural resources or restoration inputs. A useful initial rule of thumb is to identify any potential for harnessing natural regeneration capacity—especially at scale—and to use ‘regeneration’ approaches in those areas. Introductions can then be focused on areas (or for species) where natural or assisted recovery is low or not possible.

Three approaches can be identified, that may be used alone or combined if appropriate. All such approaches will require ongoing adaptive management until recovery is secured.

1  **Natural regeneration** approach. Where damage is very low, pre-existing biota should be able to recover after ceasing cessation of the degrading practices alone (e.g. over-clearing, overgrazing, overharvesting, overburning etc.). Plant species can recover through resprouting or through germination from remnant soil seed banks or freshly dispersed propagules; while many faunal species can recolonise if sources are nearby.

2  **Assisted regeneration** approach. Species at sites that are somewhat more degraded need both the removal of causes of degradation and further active interventions to assist recovery (e.g. controlling invasive plants and animals, correcting resource levels and disturbance regimes, triggering activation of dormant propagules and /or installing habitat features such as hollow logs, debris piles, perch trees etc.).

3  **Reconstruction** approach. Where damage is high, such as in cases of long-term clearing and grazing, not only do all causes of degradation need to be managed (including removal of invasive species) but also desirable native species need to be reintroduced. In even higher-damage cases where the substrate has been altered (e.g. after livestock camping, cropping or mining), correction of the substrate’s physical and chemical conditions will be required before the reintroduction of missing species.

**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. Reintroductions in or near such areas might also be justified where genetic diversity requires supplementation.

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

**Responding to a site’s condition in this way will ensure optimal levels of similarity between the restoration outcome and the appropriately identified reference ecosystem.**
**Key principles underpinning practice**

**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 to measurable objectives.

Reference ecosystems 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. The Standards lists 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 to substantially approximating those in the reference ecosystem without further repair-phase interventions being needed other than ongoing protection and maintenance. At that stage the recovery can be considered ‘self-organising’ and resilient to natural disturbances.

Each attribute will comprise a range of more detailed component properties. These have different expressions in different biomes and different sites, which will dictate that each project will have site-specific targets, goals and objectives (Box 3)—with unique and specific indicators selected to help monitor and then evaluate whether these are being met as a result of the interventions (Figure 2 and Appendix 4).

**Progress assessment example**

*Figure 2* 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 1 year old reconstruction site on its way to a 4-star condition.)

A practitioner with a high level of familiarity with the goals and achievements of the project can shade the segments for each metric after formal or informal evaluation.
Box 3 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 organise planning so that proposed inputs are well matched to the desired ultimate outcomes.

While there is no universally accepted terminology, the Standards broadly adopt the terminology of the Open Standards for the Practice of Conservation (Conservation Measures Partnership 2013 cmp-openstandards.org/).

Note that goals and objectives need to be measurable, time-limited, specific and practical and should be directly connected to the target. This is achieved by the use of specific indicators.

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 Grassy Woodland’—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:
   
   i. To reinstate composition, structure and function in two remnants (relative to the target ecosystems) through assisted natural regeneration approach;
   
   ii. To improve habitat values, using reconstruction approaches, in three adjacent cleared areas totalling 20 ha by 2020 in configurations that will also connect the remnants; and,
   
   iii. To reduce landscape threats by running two impact reduction workshops with neighbours, attended by 20 people each by end of year.

3. **Objectives.** These are the changes and intermediate outcomes needed to attain the goal/s. For example, to achieve:
   
   i. Less than 1% cover of exotic plant species and recruitment of at least two obligate seeding shrub species in the remnants within 3 years; and,
   
   ii. A density of 300 stems/ha of trees and shrubs in the reconstructed linkages, comprising >80% of characteristic species and a coarse woody debris load of 10 m3/ha within 3 years.
   
   iii. Cessation of encroachments and weed dumping neighbours within a particular time frame e.g. 2 years.

(For other examples of objectives that use detailed indicators, see Appendix 4)
Principle 4  Full recovery is the goal of ecological restoration but outcomes may take long timeframes

Although full recovery of all the attributes in the reference ecosystem is, by definition, the ultimate goal of ecological restoration projects, this outcome is not always achievable within short time frames. This can be because sufficient time has not yet elapsed for vegetation maturation or successional processes to conclude or sufficient restoration resources or knowledge are not, as yet, available to enable recovery barriers to be overcome. In other cases, impacts from outside the site are beyond the control of the manager. To help managers track progress towards project goals over time, the Standards offer a tool (5-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, full recovery based on an appropriate local indigenous reference ecosystem—is the standard to which all ecological restoration projects aim. Projects that aim for substantially less than full 5-star recovery in the long-term, even if loosely based on an appropriate locally occurring reference ecosystem, are better referred to as rehabilitation (Appendix 1). Such rehabilitation projects can, nonetheless, employ the 5-star ranking system to identify the level to which their rehabilitation goals are being achieved and to encourage adoption of higher goals in the future. A weighting for scale should be included in rehabilitation reporting.

Table 1  Summary of generic standards for 1-5 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. Note 3: this system is applicable to both ecological restoration and rehabilitation where a reference ecosystem is used.)

<table>
<thead>
<tr>
<th>Number of stars</th>
<th>Recovery outcome (Note: modelled on an appropriate local indigenous reference ecosystem)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>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.</td>
</tr>
<tr>
<td>2</td>
<td>Adjacent threats starting to be managed or mitigated. Site has a small subset of characteristic indigenous species and there is little if any threat from undesirable species. Improved connectivity negotiated with adjacent landholders.</td>
</tr>
<tr>
<td>3</td>
<td>Adjacent threats being managed or mitigated. A subset of characteristic indigenous species are established and some evidence of ecosystem functionality commencing. Improved connectivity commencing.</td>
</tr>
<tr>
<td>4</td>
<td>A substantial subset of characteristic biota present (representing all species groupings), providing evidence of a developing community structure and commencement of ecosystem processes. Some improved connectivity established and surrounding threats being managed or mitigated.</td>
</tr>
<tr>
<td>5</td>
<td>Establishment of a characteristic assemblage of biota to a point where structural and trophic complexity is likely to develop without further intervention. 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.</td>
</tr>
</tbody>
</table>
Table 2  Generic 1-5 star recovery scale interpreted in the context of the six attributes used to measure progress towards a restored state. (Note: this 5-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.)

<table>
<thead>
<tr>
<th>Attribute</th>
<th>1-Star</th>
<th>2-Stars</th>
<th>3-Stars</th>
<th>4-Stars</th>
<th>5-Stars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absence of threats</td>
<td>Further deterioration discontinued and security arranged for the site.</td>
<td>Adjacent threats starting to be managed or mitigated. Site management secured.</td>
<td>All adjacent threats being managed or mitigated. Landscape-level threats starting to be managed or mitigated.</td>
<td>All threats managed or mitigated.</td>
<td>All threats managed or mitigated to high extent.</td>
</tr>
<tr>
<td>Physical conditions</td>
<td>Physical and chemical problems remediated and substrate stabilised.</td>
<td>Substrate chemical and physical properties within natural range.</td>
<td>Substrate maintaining conformity to chemical and physical criteria and supporting indigenous vegetation.</td>
<td>Substrate supporting increased growth and productivity of characteristic species highly similar to that of the reference ecosystem</td>
<td>Substrate exhibiting physical and chemical characteristics of species highly similar to that of the reference ecosystem</td>
</tr>
<tr>
<td>Species composition</td>
<td>Colonising indigenous species (e.g. ~2% of the species of reference ecosystem). No threat to regeneration. All biotic life forms/functional groups present, potentially representing diverse successional phases and with a capacity for further structural complexity to ‘self-organise’.</td>
<td>Climate-randomness of species arranged and a small subset of characteristic indigenous species establishing (e.g. ~10% of reference). Low threat from exotic invasive or undesirable species.</td>
<td>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. Intermediate 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.</td>
<td>High diversity of characteristic species (e.g. &gt;80% of reference) across the site, with high similarity to the reference ecosystem; improved potential for colonisation of most species over time.</td>
<td></td>
</tr>
<tr>
<td>Community Structure</td>
<td>Very low structural complexity relative to reference ecosystem.</td>
<td>Low structural complexity; some species represented in ratios not characteristic of reference ecosystem.</td>
<td>Medium structural complexity compared with reference site, Some trophic structure commencing. Community structure is developing and representing species from a range of functional groups, life forms and successional phases.</td>
<td>All biotic life forms/functional groups present, potentially representing diverse successional phases and with a capacity for further structural complexity to ‘self-organise’.</td>
<td></td>
</tr>
<tr>
<td>Ecosystem function</td>
<td>Foundational functions of substrates and hydrology similar to reference.</td>
<td>Increased potential for a wider range of functions including nutrient cycling, and provision of habitats/resources for other species.</td>
<td>Low level functions showing evidence of commencing - e.g. nutrient cycling, water filtration and provision of habitat resources for a range of species.</td>
<td>Substantial evidence of key functions and processes commencing including reproduction, dispersal and recruitment of many species.</td>
<td>Complexity of functions and processes increasing including some evidence of ecosystem resilience similar to reference model after reinstatement of appropriate disturbance regimes.</td>
</tr>
<tr>
<td>External exchanges</td>
<td>Potential for exchanges with surrounding landscape identified.</td>
<td>Potential exchanges with surrounding landscape being arranged through cooperation with adjacent landholders. Establishment of linkages between site and surrounding landscape commencing through partnerships with adjacent landholders.</td>
<td>Appropriate connectivity with other natural areas established to extent practicable, observing control of pest species Strategies for appropriate disturbance in place.</td>
<td>All possible gene flow reinstated and potential for migration optimised through permeable linkages. Potential flows for water and other elements (e.g. fire) optimised and controlled as appropriate. Long term management arrangements are in place and operative.</td>
<td></td>
</tr>
</tbody>
</table>
Notes for interpreting the 5-star evaluation system

1 SERA’s 5-star system represents a conceptual gradient, providing a qualitative framework that can be interpreted by managers, practitioners and regulators in more quantitative terms to suit a specific ecosystem. While the indicators described here are highly generic, the indicators or metrics used to interpret recovery at each ranking level for a specific project need to be developed specifically for each project and these will differ depending on the characteristics of the particular ecosystem.

2 Each restoration project does not necessarily start at a 1-star ranking. Sites that involve remnant biota and unaltered substrates may 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 5-star rated recovery.

3 It should be noted that the aim is to achieve a 5-star rating for all attributes, although full recovery of some attributes will be difficult to achieve at larger scales. Complete removal of all threats in a landscape, for example, is usually beyond the scope of the restoration project but mitigation of these threats may be possible and would be a suitable alternative (e.g. installation of runoff control structure, application of prescribed burning etc.) and levels of control must be in place at the restoration site to assess ongoing threat levels. If an attribute is not fully achievable, reports need to indicate whether this is the result of external constraints and to what extent these are intransigent.

4 Reporting on all evaluations needs to specify the level of detail and degree of formality of the monitoring from which the conclusions have been derived.
Principle 5  Science is essential to good practice but the two processes are synergistic

Ecological restoration is a rapidly emerging practice that fundamentally depends upon scientific inputs; while the results of scientifically monitored restoration can provide invaluable insights for the natural sciences. That is, formal field experiments can be incorporated into restoration practice, generating new findings that then become part of the available body of knowledge for adaptive management. Science is not the preserve of ‘scientists’—rather it celebrates an approach to thinking based on logical, well-planned steps and experiments to test a principle (hypothesis). To optimise our ability to gain knowledge from restoration practice, resources and science-practitioner partnerships should be encouraged to ensure that new approaches are installed and monitored in such a way as to provide reproducible data and robust guidance for future activities.

The levels of background knowledge needed for satisfactory ecological restoration planning, implementation and monitoring are high, 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 and is particularly needed with respect to 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 scenario (Appendix 3).

Science is also needed to overcome what can seem intransigent barriers to recovery. 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 ‘rehabilitation’ classification for that objective as soon as possible and seek alternative compensations to meet regulatory requirements.
Section 3 Standards for ecological restoration activity—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 standards outline a professional level of planning, implementation, monitoring and engagement required to optimise potential for achieving the outcome of ecological restoration. The size and complexity of the planning and implementation 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.

As relevant detailed national or state-based standards become available these will be linked to updates of the Standards document.

1. PLANNING AND DESIGN

1.1. Stakeholder engagement is meaningfully undertaken with all major stakeholders (including the land manager, neighbours and Traditional Owners as appropriate) at the planning stage, with plans for public lands or mandatory restoration including 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. Landscape 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 elements;

1.2.2. Identify ways habitats can be aligned at the restoration site to connect to each other and the surrounding landscape or seascape to optimise colonisation potential between sites; and,

1.2.3. Specify mechanisms for the project to interface optimally with nearby indigenous vegetation, production or residential areas.

1.3. Ecosystem assessment. Plans identify the site’s current or pre-existing ecosystem(s) including:

1.3.1. A list of the main ecological communities and component species native and non-native, and likely presence of any threatened species or communities;

1.3.2. The species’ natural resilience and any disturbance-dependence of the ecosystem;

1.3.3. Assessment of any habitat needs of important animal or plant species (including any minimum range areas for fauna, their responses to both degradation pressures and restoration interventions);
1.3.4. Description of any need for supplementing genetic diversity for species reduced to non-viable population sizes (to a standard described in Offord & Meagher 2009); and,

1.4. **Reference ecosystem identification.** Plans identify and describe (to the level needed to assist project design) the appropriate local native reference ecosystem(s), real or compiled from historical or predictive records, including:

1.4.1. Composition, structure and any notable functions (reflecting the six ecosystem attributes);

1.4.2. The major subset of characteristic species (representing all plant growth forms and functional groups of animals); and,

1.4.3. Any ecological mosaics reflecting multiple reference ecosystems on a site.

1.5. **Condition Assessment.** Plans identify:

1.5.1. Type and degree of threats that cause degradation, damage or destruction on the site and ways to mitigate (or in some cases adapt to) these. This includes:

   • Past, existing and anticipated overharvesting, fragmentation, pest plants and animals, hydrological impacts, pollution impacts, altered disturbance regimes and other threats;

   • Existing and anticipated effects of climate change (temperature, rainfall, sea level, marine acidity etc) on species and genotypes included. (For useful tools see: Appendix 3);

   • State and transition analysis where sufficient information exists.

1.5.2. Relative presence/absence of native and non-indigenous species including Threatened and Declared species;

1.5.3. Any areas of higher and/or lower condition, including priority resilient areas and any distinct spatial zones requiring different treatments.

1.6. **Restoration treatment prescription:** Plans contain clearly stated Treatment prescriptions for each zone, describing what, where and by whom treatments will be undertaken. These form the core of the plan and include:

1.6.1. Descriptions of actions to be taken for mitigation of or adaptation to causal problems;

1.6.2. Rationale for specific restoration approaches and descriptions of specific treatments for each zone and an indication of prioritization. Depending on the condition of the site, this includes identification of:

   • 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 plants and animals to be reintroduced. In the case of plant species sustainable seed supply strategies 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 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

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


- Identification of ecologically appropriate strategies (such as leaving gaps for filling next season) for addressing circumstances where the ideal species or genetic stock is not available within short-term timelines of a project.

1.7. Security of tenure and post treatment maintenance requirements. Plans identify:

1.7.1. Security of tenure for management to the highest extent possible;

1.7.2. 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. Logistics analysis: Plans address practical constraints and opportunities including:

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

1.8.2. Risk management and 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: Plans include a schedule and timeframe for:

1.9.1. 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 seascapes that are being conserved, including physical damage, chemical pollution or biological contamination (e.g. introduction of invasive species and pathogens, see http://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 including substrate and hydrological amendments, pest species control, application of recovery triggers and biotic reintroductions are carried out in a manner that fosters and protects ecosystem recovery;

2.3. Changes of direction in response to unexpected ecosystem responses are facilitated and ecologically informed and documented;
2.4. Adequate records of propagule provenance (i.e. source) are held by suppliers, with backup records held by the project managers. These records should include GPS location and description of donor and receiving sites, date of acquisition, identification procedures and collector name;

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, heritage, species and ecosystem conservation (including that all permits required are in place); and,

2.6. All project operatives regularly communicate 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 and regularly assess and analyse progress to adapt treatments 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 permits and ethical considerations are in place.

3.1. Monitoring begins at the planning stage with the development of a monitoring plan to identify success or otherwise of the treatments (See Box 3). This includes a clearly stated:

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

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

3.1.3. Restoration objectives—i.e. fine level achievements 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.

3.2. Monitoring and recording actions include:

3.2.1. Recording of work sessions, specific treatments and approximate costs; and,

3.2.2. Collection of data (prior to works and at regular intervals during the recovery phase) that can identify whether objectives, goals and targets are being reached. 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 the reference site.) Larger or professional projects additionally identify and monitor the performance of the site using pre-identified indicators consistent with the objectives, ideally through formal quantitative sampling methods supported by a condition assessment (taking account of any regionally appropriate benchmarking system). Note: Wherever possible, sampling units must be an appropriate size for the attributes measured and should be replicated sufficiently within the site.

3.3. Evaluation involves interpretation of the monitoring data against the targets, goals and objectives and assessment, documented in writing, of the degree to which these are being achieved.
3.4. **Reporting** involves preparation and dissemination progress reports to key stakeholders and broader interest groups (newsletters and journals) to convey outputs and outcomes as they become available. 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 land owner/manager is to ensure ongoing prevention of deleterious impacts and any required monitoring and maintenance of the site after completion of the project to ensure that the site does not regress into a degraded state.
Section 4 References


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

Abiotic non-living materials within a given ecosystem, including soil or substrate, the atmospheric or aqueous medium, weather and climate, topographic relief and aspect, the nutrient regime, hydrological regime, fire regime and salinity regime.

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

Assisted regeneration the practice of fostering natural regeneration and recolonization after deliberately removing ecological impediments and reinstating appropriate abiotic and biotic states. Interventions may be tailored to improve recruitment niches, trigger resprouting and germination and foster colonization. While this approach generally 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 physical conditions, species composition, community structure, ecosystem function, absence of threats and external exchanges).

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

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 climate in which a species currently exists. During climate change and where conditions become hotter, this envelope will move further poleward. (Movement due to changes in precipitation are more complex.)

Composition, of an ecosystem the array of component biological elements of an ecosystem biota.

Construction methods involved in engineering something permanent or temporary components that did not occur previously at that site—e.g. see ‘reconstruction’, ‘creation’ and ‘fabrication’.

Creation construction of a different ecosystem to that which previously occurred, due to permanently changed physical conditions. (See alternative terms ‘Fabrication’.)

Damage (to ecosystem) a level of deleterious impact that causes loss of structure or function.

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

Destruction (of an ecosystem) complete removal or depletion of an ecosystem.
Ecological restoration the intentional practice of assisting the recovery—towards a reference state—of ecosystems that have been degraded, damaged or destroyed.

Ecological trajectory a described pathway of development over time, which can be monitored by sequential measurements of biotic and abiotic ecological parameters.

Ecosystem small or large scale assemblage of biotic and abiotic components that 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. Single species restoration (such as translocation of a threatened species) can be considered complementary and an important component of ecological restoration.

Ecosystem change localised or broad scale change in ecosystem structure / composition / function including factors (such as climate, fire, flooding) and the responses of organisms to those factors. The term is also sometimes used to refer to more recent change caused by humans to the degree that these changes are now effectively irreversible.

Ecosystem services are the benefits to humans provided by ecosystems. These include clean air, water and soils; as well as products and opportunities for recreation and the satisfaction of other human values. Restoration targets may specifically refer to the reinstatement of particular ecosystem goods or services.

Five-star (5-star) recovery a semi-quantitative rating system based on biotic and abiotic factors that provides comparative assessment in the achievement of a restored/rehabilitated state.

Fabrication (also referred to as ‘creation’) a rehabilitation approach where the degree of degradation means current conditions are no longer suitable for the pre-existing ecosystem and a different, local occurring ecosystem is the best alternative. (Note: This refers to shifts in whole communities rather than in an individual species).

Framework species those dominant or sub-dominant species from the reference ecosystem that can facilitate recovery or establishment of other species from the reference ecosystem. These can be from any stratum or successional phase and can be significant contributors biomass, trophic support to other organisms e.g. pollinators, hydrological and edaphic processes.

Full recovery the state whereby all ecosystem attributes closely resemble those of the reference model. A state of 5-star recovery may not yet exhibit closely resemble but is on a trajectory to that state without further repair-phase intervention.

Functions, of an ecosystem the collective term for the roles and processes which arise from interactions between 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, reproduction, disturbance and resilience.

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).

Local indigenous reference ecosystem an ecosystem comprising taxa (excluding invasive non-indigenous species) that are either known to have existed in the local area for very long timeframes or, species from neighbouring localities that are recently migrating (or
being assisted in their migration as a result of sound science) due to changing climates. Where local evidence is lacking, regional or historical information can help inform the most probable local indigenous ecosystems.

**Maintenance (of an ecosystem)** activities intended to counteract processes of ecological degradation to sustain the attributes of an ecosystem. In a conservation management context this is directed to maintaining the attributes associated with its pre-impairment state, recognising the intrinsic values of natural systems, not merely their usefulness to humans. After the recovery phase, a ‘maintenance’ phase ensures continued desirable condition.

**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.

**Mitigation** the activity of reducing impacts upon the environment to the highest practicable extent, to maintain potential for conservation of biodiversity while pursuing ecologically sustainable production and ecologically sustainable lifestyles.

**Natural regeneration** recruitment of species on sites after removal of causes of damage (threats) alone. Natural regeneration can be intentionally adopted as a restoration approach.

**Non-mandatory restoration** restoration that is voluntarily carried out rather than required (mandated) by a government agency, court of law or statutory authority.

**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’.

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

**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. As this can occur in full or in part, this term can apply to both ecological restoration and rehabilitation.

**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, functions, processes and successional states that would have existed on the restoration site had degradation, damage or destruction not occurred—but must be adjusted to suit changed or predicted environmental conditions.

**Regeneration** see natural regeneration and assisted regeneration.

**Rehabilitation** the process of reinstating ecosystem functionality on degraded sites where ecological restoration is not the aspiration, to as a means to enable ongoing provision of ecosystem goods and services including support of biodiversity.
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.

Revegetation establishment of plants on sites/landscapes that may or may not utilise local or indigenous species.

Site discrete area/location. Can occur at different scales including patch and landscape.

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

Self-organising 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.

Self-referencing referring to circumstances where degraded remnant vegetation serves as its own reference ecosystem.

Sod transfer moving slabs or turves of herbaceous species and their substrate from a donor habitat to a receiving habitat (this practice can also be referred to as habitat transfer.)

Succession (Ecological) the process where species composition and abundances alter over time and space with later ‘seral’ stages dependent upon the composition and abundances of a prior state. Importantly for many of Australia’s most biodiverse ecosystems such as in the southwest Australian biodiversity hotspot, the climax community in terms of species composition is reflected in the immediate post-disturbance recruitment (under natural conditions this was usually after wildfire). Thus, restoration at the outset needs to reinstate as complete a species composition as is technically and practically feasible acknowledging that restoration may require ‘nurse species’ to amend soils or re-establish basic ecological processes (e.g. pollinators, hydrological processes etc).

Substrate the soil, sand, rock, debris or water medium on or in which habitats develop.

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

Threat a factor causing degradation, damage or destruction (e.g. clearing, hydrological change, presence of invasive species, altered disturbance regimes).

Threshold (ecological) a point at which external conditions cause a shift in an ecosystem property to a different state. Advancing that property over a threshold requires external assistance towards a higher ecological state.

Translocation the movement of organisms from a donor habitat to similar habitats in a different part of the landscape. Usually undertaken to secure conservation of the organisms.

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

(i) Creating protected areas to conserve intact or near-intact ecosystems;
(ii) Improving habitats for locally indigenous species in the broader production (e.g. rural, fisheries) or urban zones outside reserves; and,
(iii) Encouraging lower-impact lifestyles and industries in zones closest to human habitation.

Ecological restoration is the appropriate means of repairing damage wherever it is possible and desirable, irrespective of zone. In production and urban landscapes, 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 comprehensive ecological restoration undesirable or unachievable in these areas. In such cases the ‘best and highest’ level of environmental repair should be aspired to—termed here as rehabilitation.

Mitigation (improved environmental management) activities are critical to the success of all ecological restoration and rehabilitation. In the absence of ecologically sustainable activities or measures to reduce society’s impacts on biodiversity, soils, water, air quality and climate in urban and production zones, neither rehabilitation nor ecological restoration will be feasible in the longer term.

It can be helpful to align these three broad pursuits on a spectrum of broader environmental repair (Figure 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 mitigation and rehabilitation provide a supportive foundation for restoration (Figure 4).

Figure 3 Ecological restoration fits within a range of complementary activities undertaken by various sectors of society to repair damage to the broader environment.
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 including support of biodiversity.

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 to the highest possible recovery level (refer to 5-star system of recovery).

Further detail on current engagement of a range of industries in rehabilitation is outlined below.

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 require the highest standard of ecological restoration or a lower standard of rehabilitation. 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 on already modified lands, are asked to achieve a rehabilitation standard to bring the condition of the site to at least its prior, if not an improved condition. Other mines are asked to achieve full ecological restoration, many adopting and aspiring to this goal voluntarily. Ready-made, off-the-shelf post-mining solutions, however, are rarely available and companies will need to invest significantly in R&D if they are to achieve biodiverse, cost-effective and sustainable rehabilitation or restoration outcomes.

Critically, restoration and rehabilitation 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 and rehabilitation is integrated into the whole-of-mine planning. This includes linking engineering and production with environmental programs to ensure restoration and rehabilitation are part and parcel of the business of mining.

Regulatory authorities should seek evidence prior to ground disturbance that:

- Mining companies are integrating restoration and rehabilitation across their business.
• A full risk assessment 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 taxa, 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 is understood and mitigated where required.

• Corporate approvals and processes are in place to ensure that where restoration 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 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.)

Where mining is undertaken in natural areas, the highest standard of ecological restoration is expected by society. In sites with important or high biodiversity values, there is an expectation that post-mining rehabilitation achieves habitat recovery to the highest practicable extent, progressing the site to at least a +3-star recovery condition. In 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 to achieve ecosystems capable of long-term sustainability. Diverse local ecosystems have also been shown to provide high carbon stores.

Carbon farming adjacent to natural habitats should be encouraged to adopt a 5-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 or no appropriate local indigenous species model is used, the revegetation should be undertaken in a manner that provides ecosystem services and has no deleterious effect on the adjacent natural areas (e.g. does not pre-empt 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 the last 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.

Many smaller projects in agricultural lands are committed to ecological restoration and some have already achieved 4-star or 5-star recovery. Many others, particularly larger projects, however, have only achieved 3-star recovery and may or may not be able to progress further due to resource constraints. Whether the latter projects can
be considered ecological restoration or rehabilitation depends on whether or not the landholder (with or without support from an agency/organisation) can make the necessary commitment to comprehensive recovery (5-stars) in the medium to long-term.

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

**Marine**

Restoration and rehabilitation of marine, river (waterway) and estuarine habitats is underway in Australia, yet more is needed. Such activities protect marine and estuarine habitats and carbon stores (within seagrass, mudflats, saltmarsh and mangroves) and improve fish breeding for conservation, commercial and recreational fisheries; cultural and recreational values that highlight compatibility between these interests.

*Marine and estuarine ecosystems are naturally highly dynamic and interconnected and hence can have very high migratory resilience; potentially enabling full recovery (restoration). In others located in zones of high industry and public recreational activity, only a lower level of rehabilitation may be possible due to the limitations of managing degradation pressures.*

Marine, river and estuarine restoration and rehabilitation has specific needs that set these activities apart from terrestrial environments. A dialogue between terrestrial and marine/river/estuary restorationists will mean that the broader based restoration and rehabilitation principles from the terrestrial environment will have value in planning and implementing marine, river and estuary restoration programs.

**Utilities and infrastructure**

Revegetation after the construction of infrastructure such as highways and dams has provided opportunities for both ecological restoration and rehabilitation, including through programs designed to ‘offset’ the loss of biodiversity caused by the development. Some 5-star restoration has been achieved in water catchment areas and adjacent to utilities, while at other sites only rehabilitation is possible.

*5-star restoration is sought wherever possible in or adjacent to natural areas; with the fragmentation impacts of linear utilities corridors on fauna mitigated by increased installation of adequate, dedicated fauna crossings. At least 3-star recovery is to be sought in permanently modified areas.*

**Urban parks and gardens**

Urban landscapes including public parks can contain important natural areas and provide opportunities for ecological restoration and rehabilitation, particularly for improving indigenous habitat connectivity. 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. Importantly, if such areas are well designed with appropriate local indigenous or resource plants (e.g. nectar-producing plants and nesting sites) urban parks and gardens provide outstanding resource islands that also enhance genetic connectivity with remnant bushland.
Many urban bushland projects are committed to restoration and commonly achieve at least 4-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 to at least level 2 recovery is encouraged.

2 Mitigation

Mitigation is the activity of reducing impacts upon the environment to the highest practicable extent, to maintain potential for conservation of biodiversity while pursuing both production and lifestyles that are ecologically sustainable.

![Pyramid of environmental repair](image)

Figure 4 Pyramid of environmental repair. The degree of success or failure of ecological restoration will be effected by the degree of success or failure of rehabilitation and mitigation.

Society needs production, business and residential areas. However, a global groundswell of community support shows an increasing willingness to reduce impacts of the permanently converted zone upon the environment. The Standards seek to promote, within this movement, an increase in appreciation that biodiversity conservation is an important and substantial endpoint of their 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 clearing and 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 can engage in mitigation and rehabilitation. That is, the higher the consumer demand for ecological sustainability the higher the likelihood that industry sectors can viably adopt mitigation 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.

Private gardens 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 and include indigenous plant species in urban areas can not only complement restoration but also create a stronger appreciation of nature within society.
First order principles

Ecological restoration:

- **Supports existing indigenous ecosystems and does not predicate further harm.** Australia contains large tracts of relatively intact lands, which represent an invaluable natural heritage. Appreciation of the long periods 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 at increasingly larger scales. That is, it seeks to not only improve the condition of ecosystems but also to substantially expand the area available to nature conservation. This ethic informs and drives high quality restoration.

- **Is universally applicable and practiced locally with 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 recognises 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 manage ecosystems for their intrinsic value not just for the benefit of humans.

- **Relies upon rigorous, relevant and applicable knowledge drawn from 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 applied 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. Many projects that aspire to restoration fall short of reinstating reference ecosystem attributes for a range of reasons including scale and degree of damage and technical, ecological and resource limitations.
Second order principles

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 causes can include climate change, over-harvesting, clearing, pollution, inappropriate disturbance regimes, reduction and fragmentation of habitats and invasive species. The most pressing and overarching of these is climate change.

• **Recognizing that restoration initiates a process of natural recovery.** Re-assembling species and habitat features on a site invariably provides only the starting point for ecological recovery; the longer term process is carried out by the organisms themselves. The speed of this process can be increased with greater levels of resourcing.

• **Taking account of the landscape context and prioritising resilient areas.** 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 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 intervention, while highly damaged areas might need rebuilding from scratch. It is critical to first 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 include all groups of biota (invertebrates, fungi, lichens and micro-organisms) if functions such as nutrient cycling, soil disturbance, pollination and dispersal are to be reinstated. Faunal re-establishment may occur through natural dispersal or may require assistance.

• **Addressing genetic issues.** Where habitats and populations have been fragmented and reduced below a minimum size, the genetic diversity of plant and animal species may be compromised and inbreeding depression may occur unless more diverse genetic material is not reintroduced from more distance sources, gene flow reinstated and/or habitats expanded or connected.

Logistical

• **Knowing your ecosystems and being aware of 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, it must be agreed that the restored ecosystem will be the preferred long-term land use. This outcome is more secure when there are appreciable benefits or incentives available to the stakeholders and stakeholders are themselves engaged in the restoration effort.
• **Taking an adaptive approach.** Ecosystems are often highly dynamic, particularly at the early stages of recovery and each site is different, meaning that species, site and landscape-specific solutions will be necessary. 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.** In order to measure progress, it is helpful to identify at the outset how you will assess whether you have achieved your restoration outcomes (Box 3 and Appendix 4).

• **Adequate resourcing.** 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-frame 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, land 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 and rehabilitation of local indigenous vegetation communities

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

1. 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 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. As inbred seeds 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 may be necessary to capture sufficient genetic diversity to rebuild functional communities.

2. 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 when combined with high levels of fragmentation. Some habitats will be lost in some locations—e.g. some ecosystems on coastlines submerged by sea level rise and cold-adapted ecosystems at high elevations where there is nowhere higher to move. But under even conservative global warming scenarios, local environments to which species may have adapted will change dramatically. We cannot precisely predict the type and scale of risks that ecosystems face because only a small proportion of species has been individually studied. Some species may be lost from their traditional locations while others will colonise new areas, altering local species assemblages.

Species may have sufficient inherent ‘adaptive plasticity’ to persist as climates change, as has been demonstrated from 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.

Climate envelope
The climate 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. (Movement due to changes in precipitation are more complex.) 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.
Species that have large, connected landscapes, 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 may have a lower chance of adapting or migrating in response to climate change.

Implications for restoration and rehabilitation

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 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 may be 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, appropriate risk analysis should also be undertaken on a case-by-case basis to ensure that ad-mixing genetic material is undertaken only where there is sound scientific evidence to support this activity.

Tools for assessing climate-readiness

Some tools are available to help restoration planners undertake what could be called ‘climate readiness’ analysis at the planning stage. First, restoration 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. Genetic analysis can be undertaken by a range of research institutions and is becoming more and more affordable, with the cost reducing with increases in the numbers of species studied and with rapid improvements in the effectiveness and efficiency of genetic testing tools.

Proposed propagule sourcing strategies to build climate-readiness into restoration 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, Figure 1). Application of any such models should be undertaken within a risk management framework that considers the potential negative effects such as inbreeding and outbreeding depression. It should also include long-term monitoring to enable lessons learned to be captured for both restoration and climate science.

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.

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. A degree of caution will therefore always be required to ensure that the reference model used to guide a restoration project specifies strong local species and germplasm and, where based on sound scientific evidence, at least some germplasm with a wider genetic base, collected from larger populations. Such a combined approach—coupled with optimising connectivity to the extent possible—is likely to improved opportunities for natural adaptation should it be required.

References


### Appendix 4  Examples of detailed objectives (using quantifiable indicators)

<table>
<thead>
<tr>
<th>Attribute detail</th>
<th>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.)</th>
</tr>
</thead>
</table>
| **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 deposit 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 comp** | Herbaceous weeds reduced to <xx% cover and represented by only benign species  
>xx% canopy cover of native trees and camphor laurel reduced to rare seedlings  
Pittosporum reduced to <xx% cover and diversity of healthy shrubs maintained  
Kangaroo Grass cover between ~xx-xx% FTP 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 native fish species of reference site present |
| **Community structure** | Characteristic diversity of native 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  
Microbiological indicator genera xxx and yyy are present on zz zones |
| **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 |
Appendix 5 Progress assessment template (for practitioner use)
SERA gratefully acknowledges the following sponsors who have contributed funding to enable the preparation and production of the National Standards for the Practice of Ecological Restoration in Australia.

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